









TOTAL E&P PNG LIMITED

PAPUA LNG

Upstream Environmental Impact Statement

Volume 2: Environmental and Social Baseline

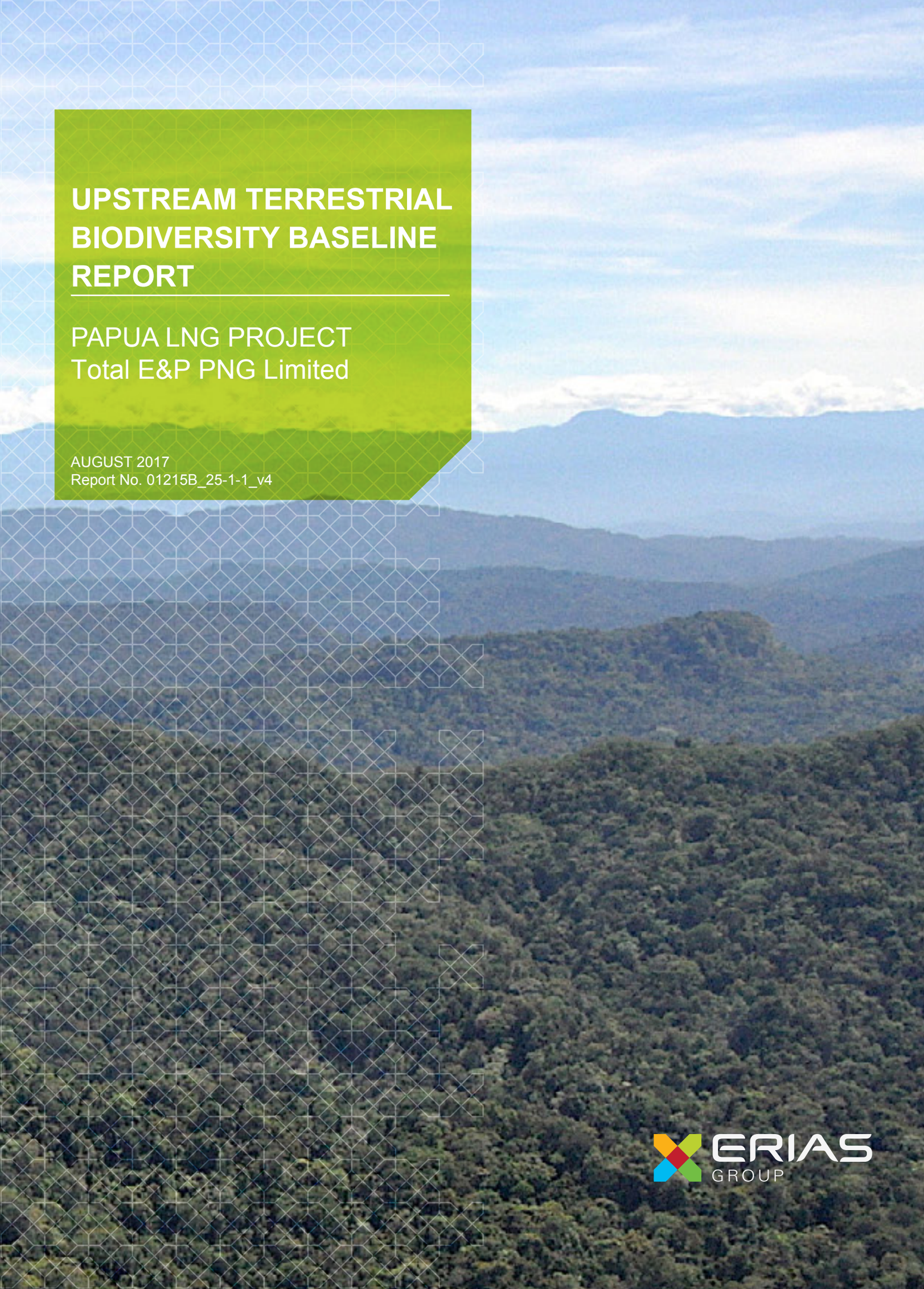
Part 6
Upstream Terrestrial Biodiversity Baseline Report

TOTAL
TOTAL E&P PNG LIMITED

UPSTREAM TERRESTRIAL BIODIVERSITY BASELINE REPORT

PAPUA LNG PROJECT
Total E&P PNG Limited

AUGUST 2017
Report No. 01215B_25-1-1_v4



ERIAS GROUP

ERIAS Group Pty Ltd
ACN 155 087 362

Table of Contents

Executive Summary **1**

1. Introduction **1–1**

1.1 Project Overview 1–1

1.2 Study and Objectives 1–2

2. Regulatory Framework and Standards **2–1**

2.1 Papua New Guinean Authorities and Legislation 2–1

2.2 International Standards and Guidelines 2–2

2.2.1 Equator Principles and International Finance Corporation Performance Standards 2–2

2.2.2 International Union for the Conservation of Nature 2–2

2.2.3 Other International Standards and Agreements 2–3

2.3 TOTAL's Company Standards and Commitments 2–3

3. Study Area **3–1**

3.1 Study Area 3–1

3.1.1 Upstream Project Area of Influence 3–1

3.1.2 Upstream Terrestrial Biodiversity Study Area 3–1

3.1.3 Ecological Zones 3–4

3.2 Climate 3–9

3.2.1 Annual Patterns 3–9

3.2.2 Influence of Elevation 3–9

3.2.3 Other Climatic Phenomena 3–9

3.3 Anthropogenic Setting 3–10

3.3.1 Local Population 3–10

3.3.2 Industry Ventures 3–11

4. Existing Information **4–1**

4.1 Prior Studies within the Study Area 4–1

4.1.1 1970s Environmental Studies 4–1

4.1.2 Prior Studies Elk-Antelope Environmental Studies....4–1
4.1.3 2011 to 2012 Purari Hydropower Project Surveys....4–1
4.2 Prior Studies in Neighboring Regions....4–2
4.2.1 Kikori Basin....4–2
4.2.2 Lakekamu Basin....4–2
4.2.3 Crater Mountain Wildlife Management Area....4–2
4.3 Other Data Sources....4–3
4.4 Summary....4–4
5. Methods....5–1
5.1 General Approach....5–1
5.1.1 Biodiversity Values....5–1
5.1.2 Supporting Studies....5–2
5.2 Field Surveys....5–5
5.2.1 Flora and Fauna Surveys....5–5
5.2.2 Other Vegetation Related Surveys....5–10
5.3 Assessing Vegetation....5–10
5.3.1 Vegetation Mapping....5–10
5.3.2 Terminology....5–11
5.4 Protocols Used....5–12
5.4.1 Conservation Listed Species....5–12
5.4.2 Endemic and Restricted-Range Species....5–13
5.4.3 Taxonomy and Nomenclature....5–14
5.4.4 Mapping and Spatial Conventions....5–14
5.5 Assigning Sensitivity....5–16
5.5.1 Overview....5–16
5.5.2 Sensitivity of Ecosystems and Focal Sites....5–16
5.5.3 Species Level Sensitivities....5–16
5.6 Permits Obtained....5–18

6. Baseline Characterization 6–1

6.1 Regional Biodiversity Setting 6–1

6.2 Vegetation 6–2

6.2.1 Ecoregional Setting 6–2

6.2.2 Natural Vegetation Within the Study Area 6–2

6.2.3 Anthropogenic Disturbance 6–4

6.2.4 Vegetation Types 6–12

6.3 Flora and Fauna 6–35

6.3.1 Biogeographic Setting 6–36

6.3.2 IUCN Listed and Nationally Protected Species 6–40

6.3.3 New-to-Science and Undescribed Species 6–74

6.3.4 Endemic and Restricted-range Species 6–88

6.3.5 Migratory and Congregatory Species 6–100

6.3.6 Invasive Alien Species 6–103

6.4 Protected Areas 6–113

6.4.1 Crater Mountain WMA 6–113

6.4.2 Protected Areas Near the Study Area 6–115

6.4.3 Proposed World Heritage Sites 6–115

6.5 Priority Ecosystems 6–115

6.5.1 Terrestrial Ecosystems 6–116

6.5.2 Freshwater Aquatic Ecosystems 6–130

6.5.3 Marine Aquatic Ecosystems 6–141

6.6 Focal Sites 6–143

6.6.1 Caves and Other Rock Shelters 6–143

6.6.2 Large Trees 6–145

6.6.3 *Bruguiera hainesii* Site 6–146

6.6.4 IUCN Vulnerable Freshwater Turtle Nesting Sites 6–146

6.6.5 Crocodile Nesting Sites 6–150

6.6.6 Hill Forest Pools 6–151

6.7 Conservation Value of the Study Area Landscape 6–151

6.8 Study Limitations 6–152

6.8.1 Coverage of Major Environments 6–153

6.8.2 Knowledge of Sensitive Species 6–153

7. Conclusions 7–1

8. Study Team 8–1

9. Glossary and Abbreviations 9–1

10. References 10–1

Appendix 1. Example Sensitivity Criteria for Ecosystems and Focal Sites/Habitats 1

Appendix 2. Example Sensitivity Criteria for New-to-science, Other Scientifically Undescribed and Restricted-range Species 10–1

Appendix 3. FIMS Vegetation Descriptions and Terms 10–1

Appendix 4. IUCN listed, Nationally Protected and Scientifically Named Restricted-range Species Recorded or Potentially Occurring in the Study Area 10–1

Appendix 5. New-to-science and Other Scientifically Undescribed Species Recorded in the Study Area 10–1

Tables

Table 3.1 – Ecological Zones Defined Within the Study Area 3–5

Table 5.1 – Location, Timing and Elevations Covered at Flora and Fauna Survey Sites 5–5

Table 5.2 – Natural Vegetation Types Accessed During Flora and Fauna Surveys 5–9

Table 5.3 – Biodiversity Survey Methods 5–9

Table 5.4 – IUCN and CITES Listed Categories 5–12

Table 5.5 – Regional Endemism Categories 5–13

Table 5.6 – Criteria Used to Assess the Sensitivity of Conservation Listed, New-to-Science, Undescribed and Restricted-range Species Present in the Study Area 5–19

Table 6.1 – Example Global Biodiversity Priority Areas Within Which the Study Area is Located 6–1

Table 6.2 – Terrestrial Ecoregions Underlying Major Project Components 6–2

Table 6.3 – Vegetation Types Within Broad Vegetation Groups and their Extent Within the Study Area 6–3

Table 6.3 – Vegetation Types Within Broad Vegetation Groups and their Extent Within the Study Area (cont'd) 6–4

Table 6.4 – Logging Concessions Overlapping the Study Area and Proportion of Forest Logged 6–5

Table 6.5 – The Number of Species Recorded During Project Flora and Fauna Surveys 6–36

Table 6.6 – The Number of Species From Each Conservation Category Recorded (X/–) and Potentially Occurring (–/Y) in the Study Area 6–42

Table 6.7 – Very Sensitive and Extremely Sensitive Conservation Listed Flora Recorded or Potentially Occurring in the Study Area[A] 6–43

Table 6.7 – Very Sensitive and Extremely Sensitive Conservation Listed Flora Recorded or Potentially Occurring in the Study Area[A] (cont'd) 6–44

Table 6.7 – Very Sensitive and Extremely Sensitive Conservation Listed Flora Recorded or Potentially Occurring in the Study Area[A](cont'd) 6–45

Table 6.7 – Very Sensitive and Extremely Sensitive Conservation Listed Flora Recorded or Potentially Occurring in the Study Area[A](cont'd) 6–46

Table 6.8 – Very Sensitive and Extremely Sensitive Conservation Listed Non-volant Mammals Recorded or Potentially Occurring in the Study Area 6–52

Table 6.8 – Very Sensitive and Extremely Sensitive Conservation Listed Non-volant Mammals Recorded or Potentially Occurring in the Study Area (cont'd) 6–53

Table 6.8 – Very Sensitive and Extremely Sensitive Conservation Listed Non-volant Mammals Recorded or Potentially Occurring in the Study Area (cont'd) 6–54

Table 6.8 – Very Sensitive and Extremely Sensitive Conservation Listed Non-volant Mammals Recorded or Potentially Occurring in the Study Area (cont'd) 6–55

Table 6.9 – Very Sensitive and Extremely Sensitive Conservation Listed Bats Recorded or Potentially Occurring in the Study Area. 6–60

Table 6.10 – Very Sensitive and Extremely Sensitive Conservation Listed Birds Recorded or Potentially Occurring in the Study Area 6–61

Table 6.10 – Very Sensitive and Extremely Sensitive Conservation Listed Birds Recorded or Potentially Occurring in the Study Area (cont'd) 6–62

Table 6.10 – Very Sensitive and Extremely Sensitive Conservation Listed Birds Recorded or Potentially Occurring in the Study Area (cont'd) 6–63

Table 6.10 – Very Sensitive and Extremely Sensitive Conservation Listed Birds Recorded or Potentially Occurring in the Study Area (cont'd) 6–64

Table 6.11 – Extremely Sensitive and Very Sensitive Conservation Listed Herpetofauna Recorded or Potentially Occurring in the Study Area 6–68

Table 6.12 – Very Sensitive and Extremely Sensitive Conservation Listed Invertebrates Recorded or Potentially Occurring in the Study Area 6–73

Table 6.13 – The Number of New-to-science and Undescribed Species from Each Surveyed Taxonomic Group 6–75

Table 6.14 – Very Sensitive and Extremely Sensitive New-to-science Species Recorded in the Study Area 6–76

Table 6.14 – Very Sensitive and Extremely Sensitive New-to-science Species Recorded in the Study Area (cont'd) 6–77

Table 6.14 – Very Sensitive and Extremely Sensitive New-to-science Species Recorded in the Study Area (cont'd) 6–78

Table 6.14 – Very Sensitive and Extremely Sensitive New-to-science Species Recorded in the Study Area (cont'd) 6–79

Table 6.15 – Restricted-range Species Recorded or Potentially Occurring in the Study Area .. 6–89

Table 6.16 – Very Sensitive Restricted-range Species (Scientifically Named and not Conservation Listed) 6–91

Table 6.16 – Very Sensitive Restricted-range Species (Scientifically Named and not Conservation Listed (cont'd) 6–92

Table 6.17 – 'Priority 1' Alien Weeds Recorded from the Study Area 6–104

Table 6.18 – The Sensitivity of Ecosystems Present Within the Study Area 6–115

Table 6.18 – The Sensitivity of Ecosystems Present Within the Study Area (cont'd) 6–116

Table 6.19 – Oxbow Lakes Within the Study Area 6–136

Table 6.20 – Pig-nosed Turtle Nesting Sites on the Purari River in the South of PRL-15 6–147

Table 7.1 – Species of Conservation Significance Recorded or Potentially Occurring in the Study Area 7–1

Table 8.1 – Study Team 8–1

Figures

Figure 1.1 – Project Schematic 1–3

Figure 3.1 – Regional Setting of the Study Area 3–2

Figure 3.2 – Study Area, Component Ecological Zones and Major Catchments 3–3

Figure 4.1 – Southern Scarp Wet Zone 'Major Terrestrial Unknown' 4–6

Figure 5.1 – Flora and Fauna Survey Coverage of the PRL-15 Area 5–7

Figure 5.2 – Flora and Fauna Survey Coverage of the Export Pipeline Corridor Area 5–8

Figure 5.3 – Map of Regional Endemism Categories 5–15

Figure 6.1 – Vegetation Types within the Study Area 6–7

Figure 6.2 – Vegetation and Anthropogenic Disturbance in the PRL-15 Area 6–8

Figure 6.3 – Vegetation and Anthropogenic Disturbance in the Export Pipeline Corridor 6–9

Figure 6.4 – The Proportion of the Study Area and Ecological Zones Covered by the Five Broad Vegetation Groups and Converted Lands 6–10

Figure 6.5 – Logging Concessions and Post-logging Secondary Forest within Broad Vegetation Groups 6–11

Figure 6.6 – Select High Sensitivity Species Locations at Flora and Fauna Survey Sites 1 and 2 in PRL-15 6–37

Figure 6.7 – Select High Sensitivity Species Locations at Flora and Fauna Survey Sites 4, 5 and 6B in PRL-15 6–38

Figure 6.8 – Select High Sensitivity Species Locations at Flora and Fauna Survey Site 7, Export Pipeline Corridor 6–39

Figure 6.9 – IUCN Listed and Nationally Protected Species Potentially Occurring in Ecological Zones and Major Natural Environments 6–41

Figure 6.10 – New-to-science and Undescribed Species Recorded in Ecological Zones and Major Environments 6–74

Figure 6.11 – Patterns of Regional Endemism Among Major Faunal Groups 6–89

Figure 6.12 – Restricted-range Species Recorded (Scientifically Undescribed Species and Named Species Known Only from the Type Locality) or Potentially Occurring (Other Named Species) in Ecological Zones and Major Environments 6–90

Figure 6.13 – Protected Areas and Proposed World Heritage Sites 6–114

Figure 6.14 – Sensitivity Map of Ecosystems and Select Focal Sites, PRL-15 Area 6–123

Figure 6.15 – Sensitivity Map of Ecosystems and Select Focal Sites, Export Pipeline Corridor ... 6–124

Figure 6.16 – Sensitivity Map of Ecosystems and Select Focal Sites, Coastal Approach of Export Pipeline Corridor 6–125

Figure 6.17 – Gulf Province Limestones 6–126

Figure 6.18 – Gulf Province Alluvial Forests and Logged Areas 6–127

Figure 6.19 – Off-river Waterbodies Within the Study Area 6–135

Figure 6.20 – The PRL-15 Oxbow Wetlands 6–137

Figure 6.21 – Coastal Freshwater Lakes 6–140

Figure 6.22 – Turtle and Crocodile Nesting Sites Documented in Southern PRL-15 6–148

Plates

Plate 6.1 – Well Structured Hill Forest (Hm) on Aure Bed Sediments of the Mena Basin, Elk-Antelope Gas Field 6–14

Plate 6.2 – Very Large-boled Tree in Hill Forest (Hm) at Site 6B 6–15

Plate 6.3 – Variable Forest Structure on Highly Erodible and Slump-prone Orubadi Beds Sediments, near Site 2 6–15

Plate 6.4 – Interior of Small Statured Hill Forest (Hm) at Site 2 6–16

Plate 6.5 – Logged Hill Forest (Hm) at Site 3 6–16

Plate 6.6 – Logged Small Crowned Hill Forest (Hs) at Site 7 6–17

Plate 6.7 – Remnant Primary Small Crowned Hill Forest (Hs) at Site 7 6–18

Plate 6.8 – Recently Logged Alluvial Forest (Pl) Southeast of Kilavi Village, Southern Export Pipeline Corridor 6–20

Plate 6.9 – Garden Development in Alluvial Forest (Pl) in Hinterland of Orokolo Bay, North of Site 9 Fly Camp, Southeast Coast 6–20

Plate 6.10 – Alluvial Forest (Pl) Orokolo Bay Hinterland, Southeast Coast 6–21

Plate 6.11 – Open Alluvial Forest (Po) at Site 4 6–22

Plate 6.12 – Open Alluvial Forest (Po) Interior at Site 4 6–23

Plate 6.13 – Interior of Logged Open Alluvial Forest (Po) near the Logging Road at Site 7, Northern Export Pipeline Corridor, Eastern Delta Swamps and Plains 6–23

Plate 6.14 – Interior of Primary Open Alluvial Forest (Po) at Site 7, Showing the More Open Understorey of a Mature Forest Structure 6–24

Plate 6.15 – Herbaceous Swamp (Hsw) with Sago Swamp Woodland (Wsw) in the Background, PRL-15 Oxbow Wetlands Area, Southwest PRL-15 6–26

Plate 6.16 – Swamp Woodland/Swamp Grassland (Wsw/Gsw) Complex, Eastern Delta Swamps and Plains, near Aivai Village between the Purari Distributary Channel and the Export Pipeline Corridor 6–27

Plate 6.17 – Intermittently Dry Swamp Grassland (Gsw) Amid Swamp Woodland/Swamp Grassland (Wsw/Gsw) Complex at Site 7, Western Export Pipeline Corridor 6–27

Plate 6.18 – Riverine Successional Grassland (Gri) Along the Purari River 6–28

Plate 6.19 – An Area of Swamp Woodland/Swamp Forest (Wsw/Fsw) Dominated by Sago Palms (*Metroxylon sagu*), Delta Swamps and Plains, Southwest PRL-15 6–29

Plate 6.20 – Interior of Sago Swamp Woodland (Wsw) Near Site 7, Eastern Delta Swamps and Plains, Western Export Pipeline Corridor 6–30

Plate 6.21 – Swamp Forest (Fsw), Southeast Delta Swamps and Plains, West of the Purari Distributary Channel 6–31

Plate 6.22 – Variable Patterns of Zonation in Mangrove (M) Along the Purari Distributary Channel—Parallel to the Estuary Front at Right Foreground, Mosaic Interior in the Background. 6–33

Plate 6.23 – Fringing Mangrove Along Oeha Creek, Western Export Pipeline Corridor, with Fringing *Sonneratia/Avicennia*Backed by Nipa Palm *Nypa fruticans* 6–33

Plate 6.24 – Nipa Palm *Nypa fruticans* Forest Along Oeha Creek, Western Export Pipeline Corridor 6–34

Plate 6.25 – Transitional Mangrove Forest North of Harevavo Village, Border Mangroves and Southeast Coast Ecological Zones, Southwest Export Pipeline Corridor. Trees on the Left are the IUCN Critically Endangered *Bruguiera hainesii* 6–34

Plate 6.26 – Littoral Beach Vegetation on Accreting Sand Dunes in the Southeast Corner of the Export Pipeline Corridor, Coastward of Coconut Plantations (in Background) 6–35

Plate 6.27 – Seed Pods of the Timber Tree Maple Silkwood (*Flindersia pimenteliana*) (EN) ... 6–47

Plate 6.28 – *Archidendron forbesii* (VU) 6–47

Plate 6.29 – Flowers of the Timber Tree Kwila/Merbau (*Intsia bijuga*) (VU) 6–48

Plate 6.30 – *Mammea grandifolia* (VU) 6–48

Plate 6.31 – *Cycas scratchleyana* (NT) 6–49

Plate 6.32 – Fruit of *Myristica globosa* (NT) 6–49

Plate 6.33 – *Aglaia euryanthera* (NT) 6–50

Plate 6.34 – *Mammea novoguineensis* (DD) 6–50

Plate 6.35 – Giant Bandicoot *Peroryctes broadbenti* (EN) Camera Trapped at Site 7 6–56

Plate 6.36 – Grey Dorcopsis *Dorcopsis luctuosa* (VU) Camera Trapped at Site 5 6–56

Plate 6.37 – False Water Rat *Xeromys myiodes* (VU) Camera Trapped at Site 8 6–57

Plate 6.38 – Wolloey's Three-striped Dasyure *Myoictis leucura* (DD) Camera Trapped at Site 2.6–57

Plate 6.39 – Teeth of Juvenile Bulmer's Fruit Bat (*Aproteles bulmerae*) (CR) (the Six Teeth at Right; Unerupted Teeth of Juvenile Dobsonia Shown at Left for Comparison) Collected from Owl Pellet Deposit at the Wi'i Creek Cave Site 6–58

Plate 6.40 – New Guinea Sheath-tailed Bat (*Emballonura furax*) (DD) 6–59

Plate 6.41 – Southern Cassowary (*Casuarius casuarius*) (VU) and Chicks Camera Trapped at Site 4 6–65

Plate 6.42 – Scheepmaker's Crowned Pigeons (*Goura scheepmakeri*) (VU) Camera Trapped at Site 4 6–65

Plate 6.43 – Starry Owlet-nightjar (*Aegotheles tatei*) (DD) 6–65

Plate 6.44 – Palm Cockatoo (*Probosciger aterrimus*) (P) Camera Trapped at Site 4 6–66

Plate 6.45 – Glossy-mantled Manucode (*Manucodia ater*) (P) 6–66

Plate 6.46 – Pig-nosed Turtle (*Carettochelys insculpta*) (VU) 6–67

Plate 6.47 – Striped New Guinea Soft-shelled Turtle (*Pelochelys bibroni*) (VU) 6–69

Plate 6.48 – New Guinea Freshwater Crocodile (*Crocodylus novaeguineae*) 6–70

Plate 6.49 – Estuarine Crocodile (*Crocodylus porosus*) 6–70

Plate 6.50 – *Callulops marmoratus* (DD) 6–71

Plate 6.51 – *Diplacina cyrene* (DD) 6–72

Plate 6.52 – Nososticta nigrifrons (DD) 6–72

Plate 6.53 – *Begonia* sp. 3 6–80

Plate 6.54 – *Begonia* sp. 5 6–80

Plate 6.55 – *Archidendron* sp. 1 6–80

Plate 6.56 – *Medinilla* sp. 1 6–81

Plate 6.57 – *Glochidion* sp. 1 6–81

Plate 6.58 – Rubiaceae, Genus 1 sp. 2 6–81

Plate 6.59 – *Hydromys* sp. 1 (Scale Bar = 5 mm) 6–82

Plate 6.60 – *Pseudohydromys* sp. 1 (Scale Bar = 5 mm) 6–82

Plate 6.61 – *Nyctophilus* sp. 1 6–83

Plate 6.62 – *Gehyra* sp. 1 6–83

Plate 6.63 – *Sphenomorphus* sp. 1 6–83
Plate 6.64 – *Stegonotus* sp. 1 6–84
Plate 6.65 – *Litoria* sp. 1 6–84
Plate 6.66 – *Austrochaperina* sp. 1 6–84
Plate 6.67 – *Cophixalus* sp. 3 6–85
Plate 6.68 – *Oreophryne* sp. 1 6–85
Plate 6.69 – *Oreophryne* sp. 2 6–85
Plate 6.70 – *Hylarana* sp. 2 6–86
Plate 6.71 – *Metagrion* sp. 1 6–86
Plate 6.72 – *Teinobasis* sp. 1 6–86
Plate 6.73 – *Nososticta* sp. 1 6–87
Plate 6.74 – *Rhyacocnemis* sp. 1 6–87
Plate 6.75 – *Palaeosynthemis* sp. 1 6–87
Plate 6.76 – *Pseuduvaria filipes* 6–93
Plate 6.77 – *Psychotria purariensis* 6–94
Plate 6.78 – Oriomo Bandicoot (*Echymipera oriomo*) Camera Trapped at Site 5 6–94
Plate 6.79 – *Curtodactylus serratus* 6–95
Plate 6.80 – *Lepidodactylus* cf. *orientalis* 6–95
Plate 6.81 – *Carlia aenigma* 6–95
Plate 6.82 – *Cryptoblepharus litoralis vicinus* 6–96
Plate 6.83 – *Emoia physicae purari* 6–96
Plate 6.84 – *Litoria chloristona* 6–96
Plate 6.85 – *Litoria exophthalmia* 6–97
Plate 6.86 – *Copiula guttate* 6–97
Plate 6.87 – *Metamagnusia slateri* 6–97
Plate 6.88 – *Pyrrhargiolestes angulatus* 6–98
Plate 6.89 – *Teinobasis buwaldai* 6–98
Plate 6.90 – *Nososticta chrismulleri* 6–98

Plate 6.91 – *Nososticta paraconifera* 6–99

Plate 6.92 – *Nososticta smilodon* 6–99

Plate 6.93 – *Drepanosticta taurulus* 6–99

Plate 6.94 – Monkey Face (*Angelonia angustifolia*) Infestation at Elk-1 Wellpad 6–106

Plate 6.95 – Water Hyacinth (*Eichhornia crassipes*) Along Nea Creek, Southwest PRL-15 ... 6–106

Plate 6.96 – Anglestem Willow (*Ludwigia leptocarpa*) Infestation at Dieback Site in a Logged Area Along the Export Pipeline Corridor 6–107

Plate 6.97 – Bamboo Daka (*Piper aduncum*) Infestation Along a Logging Road 6–107

Plate 6.98 – African Tulip Tree (*Spathodea campanulate*) at Muro Mission 6–108

Plate 6.99 – Coconut Palms (*Cocus nucifera*) Established in Mangrove (M) Along Oeha Creek, Southwest Export Pipeline Corridor (Site 8M) 6–109

Plate 6.100 – Black Rat (*Ratus rattus*) Trapped at Antelope-3 Operations Camp 6–110

Plate 6.101 – Feral Pig (*Sus scrofa*) Sow and Piglets Camera Trapped at Site 4 6–111

Plate 6.102 – Cane Toad (*Rhinella marina*) in a Coastal Village at Orokolo Bay 6–112

Plate 6.103 – Hill Forest Stream Near the Antelope-3 Operations Camp, Middle Purari Hills 6–131

Plate 6.104 – Hill Forest Stream in Logged Forest at Site 2, with Increased Silt Loads from Stream Bank and Hill Slope Erosion, and Grass Growing on Muddy Banks Beneath Disturbed Open Canopies 6–132

Plate 6.105 – Boa Creek Upstream of the Antelope-3 Operations Camp, Middle Purari Hills 6–133

Plate 6.106 – The Purari River Flowing Through the Middle Purari Hills 6–134

Plate 6.107 – The Large, Eastern Oxbow Lake in the PRL-15 Oxbow Wetlands 6–138

Plate 6.108 – One of the Smaller, Western Oxbow Lakes in the PRL-15 Oxbow Wetlands, with Flock of Egrets in Upper Left of Picture 6–138

Plate 6.109 – Coastal Freshwater Lake, Southeast Export Pipeline Corridor 6–139

Plate 6.110 – Coastal Freshwater Lake, Southeast Export Pipeline Corridor 6–141

Plate 6.111 – Tidal Habitats at the Mouth of '*Wara Are'ape*', West of Harevavo Village, Western Export Pipeline Corridor 6–143

Plate 6.112 – Sheer Cliffs of the Mena Basin Aure Beds Formation, near Antelope-3 Operations Camp, Elk-Antelope Gas Field 6–145

Plate 6.113 – Pig-nosed Turtle Nesting Bank, South Bank of Purari River, Upstream from Herd Base (Site 11 in Table 6.20 and Figure 6.16) 6–149

Plate 6.114 – Pig-nosed Turtle Nesting Bank, South Bank of Purari River, Downstream from Herd Base (Site 5 in Table 6.20 and Figure 6.16).....6–150

Plate 6.115 – Aerial View of the Vegetated Swamp Along the Purari River, South PRL-15, Said to be an Important Nesting Site for New Guinea Freshwater Crocodile 6–151

Appendices

Apppendix 1 – Example Sensitivity Criteria for Ecosystems and Focal Sites/Habitats

Apppendix 2 – Example Sensitivity Criteria for New-to-science, Other Scientifically Undescribed and Restricted-range Species

Apppendix 3 – FIMS Vegetation Descriptions and Terms

Apppendix 4 – IUCN listed, Nationally Protected and Scientifically Named Restricted-range Species Recorded or Potentially Occurring in the Study Area

Apppendix 5 – New-to-science and Other Scientifically Undescribed Species Recorded in the Study Area

Annexes

Annex 1A – Upstream Flora Baseline Report, Papua LNG Project

Annex 1B – Upstream Vegetation Mapping and Forest Condition Baseline, Papua LNG Project

Annex 1C – Upstream Weeds Baseline Report, Papua LNG Project

Annex 1D – Upstream Forestry Baseline Report, Papua LNG Project

Annex 2 – Upstream Non-volant Mammals Baseline Report, Papua LNG Project

Annex 3 – Papua LNG Project Upstream Bats (Chiroptera) Baseline Report

Annex 4 – Avifauna of the Papua LNG Project upstream terrestrial biodiversity baseline study

Annex 5 – Upstream Herpetofauna Baseline Report, Papua LNG Project

Annex 6 – Upstream Dragonflies and Damselflies (Odonata) Baseline Report, Papua LNG Project

Executive Summary

This report presents the results of a terrestrial biodiversity baseline study conducted as part of an environmental, social and health impact assessment (ESHIA) undertaken for the Papua LNG Project (the 'Project'). It describes terrestrial biodiversity values present within an upstream project area of influence (upstream PAOI) and broader upstream terrestrial biodiversity study area (hereafter 'study area'), as defined for the Project, such that key biodiversity values may be identified for subsequent impact assessment and monitoring of the efficacy of the Project's biodiversity program.

The upstream PAOI covers approximately 2,765 km^2 of the Gulf Province lowlands. It incorporates: (1) Petroleum Retention Licence 15 (PRL-15) and nearby Pawaian villages; (2) a proposed export pipeline corridor extending more than 50 km south from PRL-15 to the Gulf Province coast, and; (3) the Purari River and its distributaries, providing river transport routes linking the Gulf of Papua with PRL-15 ('Riverways').

The upstream PAOI is contained within a c. 7,290 km^2 study area. The study area covers more than 21% of the land surface of Gulf Province, spanning more than 70 km of coastline and extending nearly 120 km north to the foothills of New Guinea's central cordillera. It spans an elevational range of 600 m and overlaps five major catchments, including the middle and lower reaches of the Purari River basin. The study area is divided into five 'ecological zones' defined primarily according to landform and vegetation—the Middle Purari Hills, Southeast Hills, Delta Swamps and Plains, Mangroves and Southeast Coast.

A bibliographic study revealed a limited availability of recent and/or reliable biodiversity data, including a lack of information on the arrangement and condition of natural vegetation types and on sensitive species potentially occurring within the study area. A series of supporting desk and field studies was undertaken to provide additional baseline information, including studies of flora and fauna communities, vegetation mapping, forestry activities and vegetation loss within the study area.

The baseline 'sensitivity' of biodiversity values is here determined based on existing disturbances and threats to facilitate subsequent impact assessment. Species and the ecosystems and 'focal sites' (localized habitat features of importance) that they occupy were each assigned to one of five sensitivity categories (Not Sensitive, Low Sensitivity, Moderately Sensitive, Very Sensitive, Extremely Sensitive).

Vegetation

Vegetation mapping is based on the PNG Forest Inventory Mapping System (FIMS) dataset. The FIMS mapping units were updated based on recent aerial/satellite imagery and field observations, and overlay maps of post-logging secondary forest were prepared.

The study area land surface is covered almost entirely in natural vegetation (98.9%; including regenerating logged forest). Its 32 FIMS-coded natural vegetation types are arranged into five broad vegetation groups—hill forest, alluvial forest, freshwater swamp vegetation, mangroves and littoral forest. Hill forest is the most widespread broad vegetation group, covering more than 3,400 km^2 and nearly half of the study area land surface in the Middle Purari Hills and Southeast Hills ecological zones. Freshwater swamp vegetation covers nearly 1,800 km^2, predominantly as

Swamp forest (Fsw) and Swamp woodland (Wsw) on the Delta Swamps and Plains. Alluvial forest covers c. 1,160 km^2, mostly on the Delta Swamps and Plains, and Mangrove vegetation covers more than 600 km^2 along the study area coast.

Approximately 1,300 km^2 of forest have been logged within the study area, most of it hill and alluvial forest in the southeast quarter. In terms of key Project areas, more than 50 km^2 have been harvested from within the southeast corner of PRL-15 and approximately 116 km^2 from along nearly the entire length of the export pipeline corridor.

Species Level Values

A multi-disciplinary series of flora and fauna technical studies was undertaken by species specialists. Seven major taxonomic groups were investigated—vascular plants, non-volant (non-flying) mammals, bats, birds, reptiles and amphibians (herpetofauna) and odonates (dragonflies and damselflies). Project field surveys were conducted at 14 sites across all ecological zones within the upstream PAOI with supplementary aerial surveys and visits to village communities. Surveys were conducted in two phases to provide seasonal sampling of major environments.

A total of 1,272 plant and animal species was recorded during Project field surveys. Taxonomic inventories were comparable to or exceed those of other well-documented regions of lowland Papua New Guinea.

Sixty-four IUCN listed and nationally Protected species have been recorded within the study area. Three IUCN Critically Endangered species are confirmed present—the timber tree *Diospyros lolinopsis* in primary alluvial forest within the export pipeline corridor, the mangrove tree *Bruguiera hainesii* within the export pipeline corridor, and Bulmer's Fruit Bat (*Aproteles bulmerae*) via remains collected from a limestone cave outside of key Project areas (northeast of PRL-15). Additional high value taxa include six IUCN Endangered species (the timber trees *Diospyros insularis* and *Flindersia pimenteliana*, two tree kangaroo (*Dendrolagus*) species, Giant Bandicoot (*Peroryctes broadbenti*) and Far Eastern Curlew (*Numenius madagascariensis*)), 17 IUCN Vulnerable species and one Data Deficient species assigned Very Sensitive status—Starry Owlet-nightjar (*Aegotheles tatei*).

A further 32 IUCN listed and nationally Protected species, including seven IUCN Threatened species, may occur in the study area based on current knowledge of distribution and habitat preferences.

Forty-nine new-to-science species were discovered for the first time during Project surveys—34 plants, two small non-volant mammals, two reptiles, three frogs and eight odonates. Sixteen species discovered previously remain scientifically undescribed. Based on habitat associations and recorded distribution and abundance, one new-to-science species is ranked as Extremely Sensitive—the terrestrial herb *Begonia* sp. 5, currently known only from a few individuals at two sites within and near the proposed CPF area. Another 26 new-to-science and undescribed species are ranked as Very Sensitive.

At least 114 restricted-range species (area of occurrence less than 50,000 km^2) have been recorded or may occur in the study area. Many of these are also conservation listed (12 species) or new-to-science/undescribed (61 species). Ten additional species not in these categories are ranked as Very Sensitive—six plants known only from the type material collected previously from within the study area, and four habitat-specialist damselflies known from outside the study area only in neighboring regions.

Ninety-seven invasive alien plant species were recorded in the study area, including seven 'Priority 1' weed species that have the potential to invade undisturbed natural habitats—Angelonia (*Angelonia angustifolia*), Water Hyacinth (*Eichhornia crassipes*) Anglestem Willow (*Ludwigia leptocarpa*), Mile-a-Minute Vine (*Mikania micrantha*), Bamboo Daka (*Piper aduncum*), African Tulip Tree (*Spathodea campanulate*) and Coconut Palm (*Cocus nucifera*, commercial cultivar). Among invasive alien fauna, four rodent species, feral pigs and dogs, the Eurasian Tree Sparrow (*Passer montanus*) and the Cane Toad (*Rhinella marina*) are all confirmed present. Despite the invasive potential of some of these species, with the exception of feral pigs, alien species were virtually absent from intact natural environments, including extensive areas of relatively remote and little-disturbed forest habitat. They are well-established in areas where the natural vegetation has been removed or heavily degraded, such as in villages and gardens, existing facility sites and along logging roads. These sites are widespread and often isolated within natural forest landscapes, demonstrating the potential for infestation of newly developed areas.

Protected Areas

The Crater Mountain Wildlife Management Area overlaps c. 445 km^2 of the northern margin of the study area in the Middle Purari Hills ecological zone, including 11.9 km^2 of PRL-15. No Project facilities are present or are planned to be developed within this WMA.

Priority Ecosystems

Hill and alluvial forests support the highest species richness within the study area, including the highest diversity and abundance of species of conservation significance. Of these forest types, primary alluvial forest has the highest conservation value due to: (1) its more restricted local and regional availability; (2) relatively limited connectivity with similar habitat outside of the study area, and; (3) its high commercial value to the logging industry. The study area supports the largest remaining primary formations of Alluvial forest (Pl) and Open alluvial forest (Po) remaining anywhere within the Kikori-Purari biogeographic region. The study area's alluvial forests are considered to be Very Sensitive.

Mangrove ecosystems are sensitive to disturbance, provide a variety of important ecosystem services and support a diverse terrestrial biota that includes a high proportion of habitat-specialist taxa. The study area's mangrove forests support the IUCN Critically Endangered tree *Bruguiera hainesii* and are the only known area of occurrence for three additional plant species. The extensive formations present in the Mangroves ecological zone are largely undisturbed and form part of one of the most extensive pristine mangrove areas in the world. The mangrove ecosystem is considered to be Very Sensitive.

Among aquatic ecosystems, oxbow lakes within the study area are ranked Very Sensitive as they are essentially unmodified systems that support multiple habitat-specialist taxa, provide important breeding habitat for a variety of birds and herpetofauna (including crocodiles), and are sensitive to a variety of impacts, notably including the establishment and spread of invasive alien species. The most extensive lake system, located in the southwest of PRL-15, includes five oxbow lakes linked by an extensive area of vegetated swamps; the 'PRL-15 oxbow wetlands' overlap the 'CPF, logistics base and airstrip area'.

Tidal wetlands of the Purari delta are considered Very Sensitive as they provide important habitat for migratory shorebirds. Most migratory shorebird species occurring in the study area congregate in coastal areas, more than one quarter of which (8/23) are listed by the IUCN as Threatened or Near Threatened. Based on a prior assessment of the nearby Kikori delta, tidal wetlands of the

Purari delta may qualify as an internationally important site (under the RAMSAR Convention) for one or more migratory shorebird species.

Additional intact natural ecosystems supporting species of conservation significance include various forms of freshwater swamp vegetation, watercourses and coastal (dune system) freshwater lakes. These ecosystems are assigned Moderately Sensitive status.

Priority Focal Sites

Focal sites include localized terrain and habitat features upon which multiple species and/or multiple individuals of one or more species are ecologically dependent.

The area supporting the IUCN Critically Endangered mangrove tree *Bruguiera hainesii* is ranked as Extremely Sensitive.

Caves are Very Sensitive for their potential to play a regionally significant role in supporting (*inter alia*) bat populations, for their limited availability and for their sensitivity to disturbance. The Wi'i Creek area in the northeast of the study area is judged to be Extremely Sensitive for potentially harboring a maternity roost of the IUCN Critically Endangered Bulmer's Fruit Bat. Large cave systems are probably confined to major areas of surface limestone in the north of the study area—in the hills north of the Purari River between Subu and Uraru villages, along the western slopes of the Aure Scarp and in the Kereru Range. No large cave systems are present in PRL-15, the export pipeline corridor or along the Riverways.

The IUCN Vulnerable Pig-nosed Turtle (*Carettochelys insculpta*) and Striped New Guinea Soft-shelled Turtle (*Pelochelys bibroni*) nest on the sandy banks of larger watercourses in the study area. In the south of PRL-15, 12 Pig-nosed Turtle nesting sites were located along c. 18 km of the Purari River, and six tributary watercourses were identified that harbor nesting sites of one or both species. Tributaries used by both species for nesting include Djo'boh Creek and Oyomo Creek, both of which drain the 'CPF, logistics base and airstrip area'. Nesting by both species occurs more widely in the study area, and in the case of Pig-nosed Turtle may occur as far south as the coast in the Mangroves ecological zone. Nesting sites for both species are considered to be Very Sensitive.

The Estuarine Crocodile (*Crocodylus porosus*) and the New Guinea Freshwater Crocodile (*Crocodylus novaeguineae*) nest in vegetated swamps near watercourses and off-river waterbodies. Crocodile nesting sites are ranked as Very Sensitive. Site identified within PRL-15 include the PRL-15 oxbow wetlands and a small vegetated swamp adjacent to the main Purari River channel. Nesting by both species occurs more widely in the study area.

Additional Moderately Sensitive focal sites include large trees, hill forest pools and rock shelters other than caves supporting roosting bat or swiftlet colonies.

Conservation Value of the Study Area Landscape

The study area is set in one of the world's most biologically diverse and endemically rich terrestrial regions, where it comprises almost the entire eastern half of the 'Kikori-Purari' biogeographic region. It is of high conservation value due to its large size, remoteness, low human population and high degree of connectivity among a variety of intact and biodiversity-rich habitats that support numerous species of conservation significance. These values have been repeatedly recognized in national biodiversity priority assessments.

Conclusion

Investigations undertaken for the present study provide the most detailed terrestrial biodiversity dataset heretofore available for the study area. Information provided on sensitive species, ecosystems and focal sites is considered sufficient to progress terrestrial biodiversity impact assessment.

1. Introduction

1.1 Project Overview

The following Project description is focused on the upstream components of the Papua LNG Project and aims at providing minimal but appropriate context for the baseline reports.

Joint venture partners are currently planning the development of the Elk-Antelope gas field, which is located within Petroleum Retention License 15 (PRL-15) in the Gulf Province, Papua New Guinea. Total E&P PNG Limited (TEP PNG), a wholly owned subsidiary of TOTAL S.A (TOTAL) has the largest interest in the Elk-Antelope gas field and is the operator of the Papua LNG Project (the Project) on behalf of the other joint venture partners.

The Elk-Antelope gas field is a significant gas discovery in Papua New Guinea consisting of a gas reservoir with several trillion cubic feet of gas reserves located approximately 120 km inland from the township of Kerema, and 340 km northwest of Port Moresby (Figure 1.1)

The Project will comprise upstream production well development and associated infrastructure at the gas field within PRL-15, construction of an upstream central processing facility (CPF) and delivery of gas and condensate via onshore and offshore export pipelines to a LNG Plant site at Caution Bay, Central Province, 20 km northwest of Port Moresby. The design life for the Project will be 25 years.

The Project area comprises the physical footprint of the various Project components and associated infrastructure as detailed below.

- Production, processing and related facilities (within PRL-15):
  - Wellpads and the associated gathering system (including flowlines and trunkline).
  - An upstream central processing facility (CPF) to separate condition gas and condensate streams, including an acid gas removal unit (AGRU).
  - Logistics base and river offloading facilities, accommodation camps, airstrip, roads and bridges.
  - Quarries and communications infrastructure.
- Onshore pipeline (outside PRL-15):
  - Onshore export pipeline system comprising separate single gas and condensate pipelines, from the CPF to landfall on the gulf coast including valve stations.
  - Temporary laydown areas and camps.
  - Quarries and communications infrastructure.
- Transport (river) corridor:
  - River transport routes— the Purari, Urika-Ivo and Wame-Varoi rivers.
- Onshore pipeline (outside PRL-15):

– Offshore section of the export pipeline to a LNG Plant site, Caution Bay.

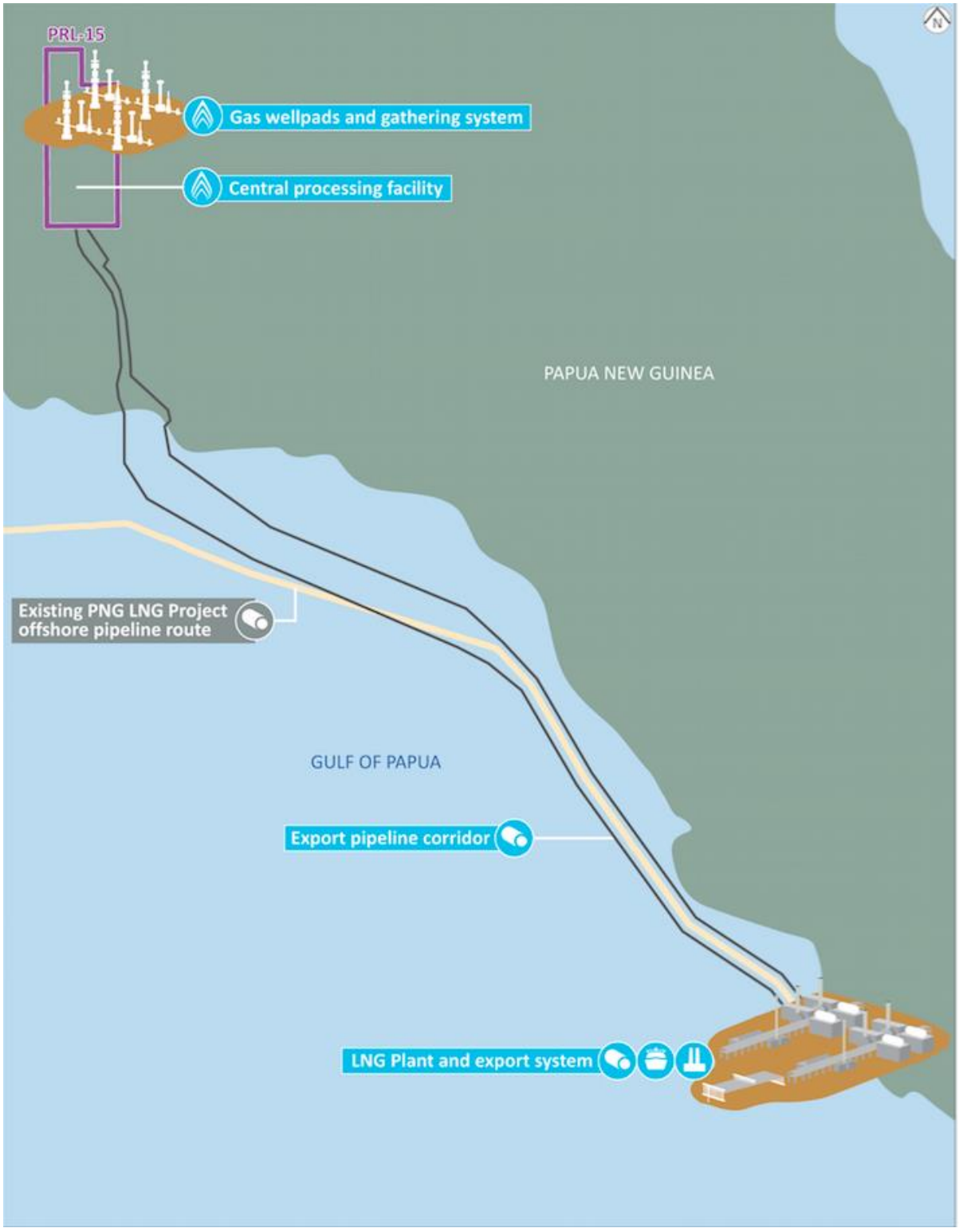
1.2 Study and Objectives

A terrestrial biodiversity baseline study has been commissioned as part of the Project environmental, social and health impact assessment (EIS/ESHIA). The overall objective of the upstream component of the terrestrial biodiversity baseline study program (this 'Study') is to describe the terrestrial biodiversity and related conservation features present in the 'upstream terrestrial biodiversity study area' (as defined for the Project: Section 3.1) such that key biodiversity values may be identified for subsequent impact assessment and monitoring of the efficacy of the Project's biodiversity program.

The specific objectives of the terrestrial biodiversity baseline study are to:

- Characterize terrestrial biodiversity values present in the study area at varying levels of biological organization, including at ecosystem and species scales.
- Collate and assess existing information relevant to biodiversity values present within the study area.
- Map the distribution and condition of major vegetation types present within the study area.
- Determine the presence and (where practicable) status of species of conservation significance recorded or potentially present within the study area.
- Assess the distribution and status of invasive alien species present within the study area.
- Plan and execute baseline studies, including field surveys to supplement existing information, to collect sufficient data to underpin assessment of potential Project-related impacts to satisfy International Finance Corporation (IFC) (2012) environment and social performance standards and to meet Papua New Guinea (PNG) requirements under the *Environment Act 2000*.

Figure 1.1 – Project Schematic



2. Regulatory Framework and Standards

Regulatory frameworks relevant to terrestrial biodiversity baseline and impact assessments are outlined below. They include:

- Papua New Guinean legislative and regulatory requirements (Section 2.1).
- International standards and guidelines (Section 2.2).
- TOTAL's corporate standards and guiding principles (Section 2.3).

2.1 Papua New Guinean Authorities and Legislation

In accordance with TOTAL's Code of Conduct (Section 2.3), the Project respects 'all applicable national and international laws and norms'.

The Conservation and Environment Protection Authority (CEPA), formerly the Department of Environment and Conservation (DEC), is the Government department responsible for protecting PNG's environment. Its two key functions, to conserve environmental values and to regulate development projects, are performed through a variety of legislative mechanisms.

The *Environment Act 2000* and supporting Environment (Prescribed Activities) Regulation 2002 provide the legal framework for regulating the Project's environmental effects. Under these regulations, the Project has been classified as a Level 3 Activity, and in accordance with Section 50 of the Environment Act must submit an environmental impact statement (EIS). The terrestrial biodiversity baseline study has been undertaken with deference to the requirements of the Environment Act, and to its key objectives (outlined in Part 2, Section 4 of the Act), including:

- Avoid, remedy or mitigate any adverse effects of activities on the environment by regulating…activities, products, substances and services that cause environmental harm.
- Apply a precautionary approach to the assessment of risk of environmental harm.

The *Fauna (Protection and Control) Act 1966* (hereafter Fauna Act) governs the protection, control, harvesting and destruction of native fauna. Fauna 'Protected' under the Fauna Act cannot be taken, killed, bought, sold or possessed without a permit. The list of nationally Protected fauna was consulted when screening for sensitivities in this report (Section 5.4.1.2). The Fauna Act also provides for the declaration of sanctuaries, Protected Areas and Wildlife Management Areas (WMAs), which was reviewed regarding the Crater Mountain WMA that overlaps the study area.

The *International (Fauna and Flora) Trade Act 1978* (hereafter International Trade Act) promotes the sustainable use of fauna and flora and implements the State's obligations as a party to the Convention on International Trade in Endangered Species (CITES; Section 2.2.3). Both CEPA and the PNG Customs Department have power under this Act. CITES listings (under Appendix I and II) are presented in this report for all species recorded in the study area (see Section 5.4.1.3).

2.2 International Standards and Guidelines

The following international standards and guidelines are relevant to terrestrial biodiversity under Project activities.

2.2.1 Equator Principles and International Finance Corporation Performance Standards

The Equator Principles are a voluntary standard for managing social and environmental risk in project financing transactions. The signatory Equator Principles Financial Institutions (EPFIs) are committed to following the ten Equator Principles, which in turn require adherence to (inter alia) the screening criteria of the International Finance Corporation's (IFC's) Performance Standards on Environmental and Social Sustainability (IFC 2012; hereafter 'IFC Performance Standards'). The IFC Performance Standards and their supporting Guidance Notes define client roles and responsibilities for managing development projects and the requirements for receiving IFC support.

TEP PNG is seeking Project alignment with the IFC Performance Standards.

Performance Standard 1 (IFC PS1) – Assessment and Management of Environmental and Social Risks and Impacts, requires that clients undertake a detailed assessment of the environmental and social risks associated with project development, and introduces the 'mitigation hierarchy' (avoid before minimize before compensate/offset) as the key approach for risk management.

Performance Standard 6 (IFC PS6) – Biodiversity Conservation and Sustainable Management of Living Natural Resources, whose requirements are guided by the Convention on Biological Diversity (Section 2.2.3), requires that environmental assessment focus on threats to key biodiversity values with an emphasis on habitat loss. Under IFC PS6 habitats are classified as modified habitat, natural habitat or critical habitat, with each habitat class triggering compliance with operational standards that differ in level of stringency. IFC PS6 also places emphasis on legally protected and internationally recognized areas, on the importance of controlling invasive alien species and on the management of ecosystem services.

2.2.2 International Union for the Conservation of Nature

The International Union for Conservation of Nature (IUCN) Species Programme plays a key role in biodiversity assessment by maintaining the widely-endorsed IUCN Red List of Threatened Species (www.iucnredlist.org; hereafter 'IUCN Red List'). Together with species Protected in PNG under the Fauna Act (Section 2.1), the IUCN Red List provides a core set of high value species considered in the terrestrial biodiversity baseline study (Section 5.4.1.1). Additionally, IUCN threatened categories underpin a key criterion for critical habitat assessment under IFC PS6.

At the ecosystem scale, the IUCN Global Ecosystem Management Programme is developing the IUCN Red List of Threatened Ecosystems (www.iucnrle.org) using an assessment protocol similar to that employed by the IUCN Red List (IUCN 2016). No New Guinea ecosystems have had their status evaluated.

2.2.3 Other International Standards and Agreements

PNG is signatory to multiple additional international agreements related to the preservation of biodiversity and natural resources. The following are relevant to the terrestrial biodiversity baseline study through their support of landscape- and/or species-level sensitivities, including coastal and tidal terrestrial communities:

- Convention on Biological Diversity (1992), ratified by PNG in 1993.
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat (The Ramsar Convention, 1971).
- Convention on the Protection of Natural Resources and Environment of the South Pacific Region and related Protocols (Noumea, 1986).
- Convention Concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972).
- Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Washington, 1973). CITES is an international treaty drawn up in 1973 to protect wildlife against over-exploitation and works by subjecting international trade in specimens of selected species to certain controls.
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention, 1979) and associated Memorandum of Understanding for the Conservation of Cetaceans and their Habitats in the Pacific Island Region (2006).
- Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (Bonn, 2001, signed by PNG in 2010).
- International Plant Protection Convention (Rome, 1952) with associated Plant Protection Agreement for the Asia and Pacific Region (Rome, 1956) as amended.
- International Tropical Timber Agreement (ITTA) (Geneva, ITTA2 1994, ITTA3 2006).
- London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention, 1972), and International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (Fund Convention, 1992).

TOTAL is a signatory to the International Petroleum Industry Environmental Conservation Association (IPIECA) and further adheres to the environmental principles set out in the United Nations Global Compact and in the Organisation for Economic Co-operation and Development (OECD) Guidelines for Multinational Enterprises. Relevant directives include environmentally sustainable development in accordance with applicable laws and ethical business practices, a precautionary approach to environmental risk management, and the development of management systems that cover baseline data collection, impact assessment, the establishment of conservation initiatives and monitoring of their outcomes.

2.3 TOTAL's Company Standards and Commitments

TEP PNG is guided by TOTAL's Code of Conduct (TOTAL, 2014), a 'Priority Principle' of which is its commitment to 'the highest Safety, Health, Security and Environmental standards wherever we operate'. Total's biodiversity policy (outlined at www.total.com) centers on a 'very clear

objective…to avoid impacting biodiversity as much as possible…throughout the entire life cycle of our facilities and products'. This is achieved by 'taking tangible measures to avoid, reduce, mitigate and, when necessary, compensate for any loss of biodiversity'.

Company guidelines relevant to conducting baseline and impact assessment studies are outlined in the following General Specification documents:

- GS EP ENV 111: Environmental baseline and monitoring studies: onshore sites.
- GS EP ENV 120: Environmental impact assessment of E&P activities.

These guidelines have been considered in the development of the terrestrial biodiversity baseline study.

3. Study Area

3.1 Study Area

The regional setting of the upstream terrestrial biodiversity baseline study area is shown in Figure 3.1. The upstream Project area of influence (upstream PAOI) and the arrangement of ecological zones and major catchments within the study area are shown in Figure 3.2.

3.1.1 Upstream Project Area of Influence

The upstream PAOI includes the area within which the Project may potentially and measurably impact biodiversity through direct, indirect and/or cumulative impact processes.

The upstream PAOI is delineated according to Project information provided by TEP PNG at the time of writing this report. It incorporates, at a minimum:

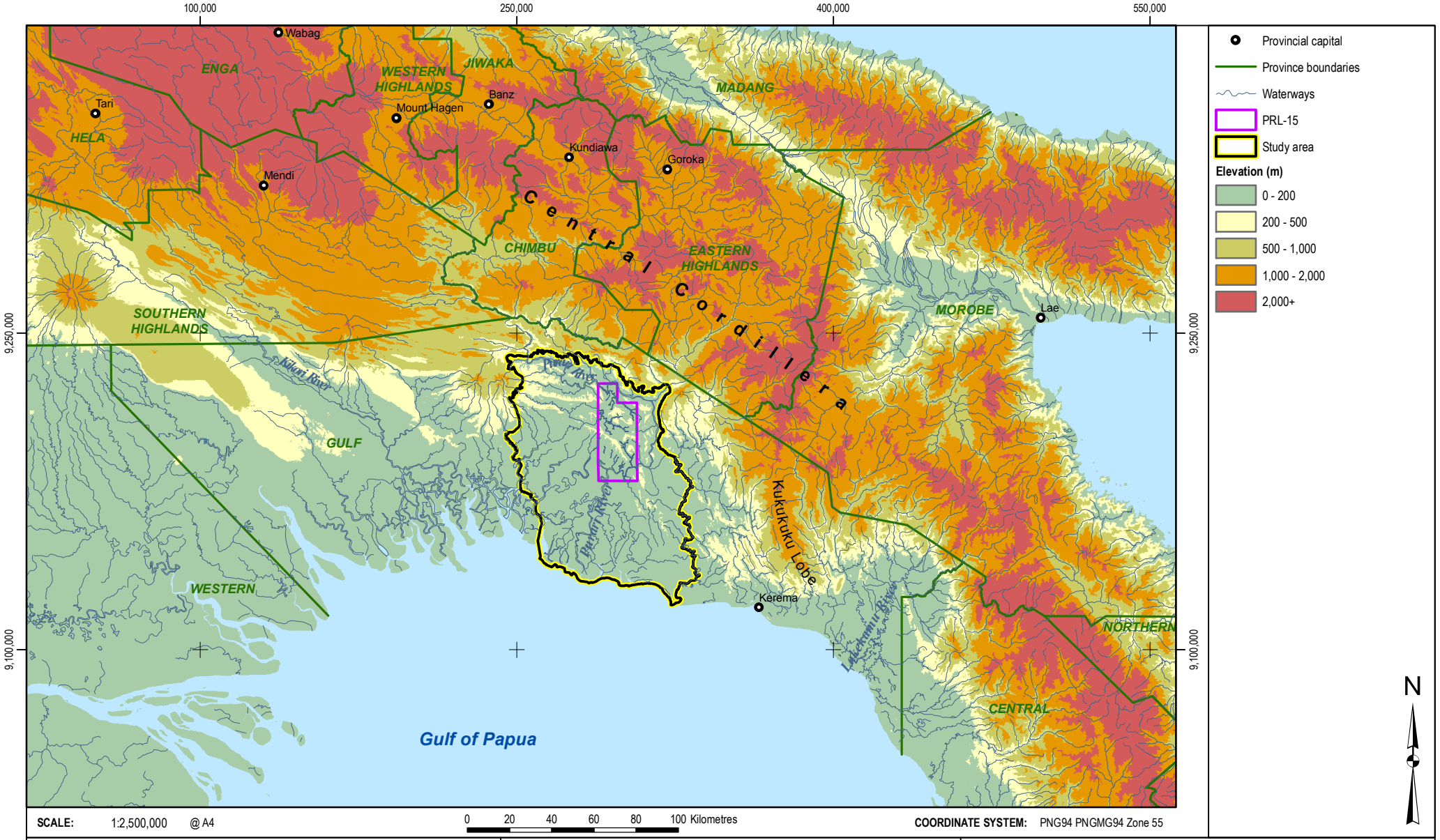
- Within PRL-15, 5 km buffers around existing or proposed facility sites and infrastructure routes, including Project roads, existing and future wellpads, pipelines upstream of the proposed CPF (injection, trunkline and flowline) and the 'CPF, logistics base and airstrip area' located near the Purari River in the south of PRL-15.
- South of PRL-15, a 5 km buffer around the proposed export pipeline corridor, and a 1 km buffer into vegetation surrounding the 'Riverways' potential river transport routes along the Purari River and each of its three main delta distributaries—the Purari, Urika-Ivo and Wame-Varoi rivers. River transport routes south of PRL-15 are collectively termed the 'Riverways'.

The upstream PAOI expands on these minimum requirements north and east of PRL-15 to incorporate Pawaian villages located on the Purari River, and west of PRL-15 to incorporate the confluence of the Mena and Era rivers.

The upstream PAOI covers 2,768.4 km^2, including parts of all five ecological zones defined for the broader study area (Section 3.1.3). For the ESHIA, the environmental and social baseline field surveys have been undertaken within the upstream PAOI. Therefore, for all intents and purposes, the PAOI where referred to in this report largely compares to the terrestrial biodiversity baseline survey area.

3.1.2 Upstream Terrestrial Biodiversity Study Area

In accordance with recent good practice guidelines (Gullison et al., 2015) an upstream terrestrial biodiversity study area (hereafter 'study area') is also defined that encompasses and expands on the upstream PAOI. The study area contains continuous extensions of those ecosystems and habitats present within the upstream PAOI and is considered likely to support viable populations of most or all resident species whose distributions overlap with Project components. The study area boundaries are based on the arrangement of physical landscape features that influence the composition and distribution of terrestrial biotic communities such as landform, substrate, elevation and watersheds.



TITLE: Regional Setting of the Study Area

FIGURE: 3.1

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R117_79669 **REVISION:** C

DATE: 12/04/2017

DATA SOURCES:

Provincial capitals (TOTAL and ERIAS Group 2015-2017). Study area (ERIAS Group 2017). PRL-15, waterways (TOTAL 2016). Elevation (GMTED2010 USGS 2011). Province boundaries derived by Mipela GeoSolutions (2016-2017).

CLIENT:

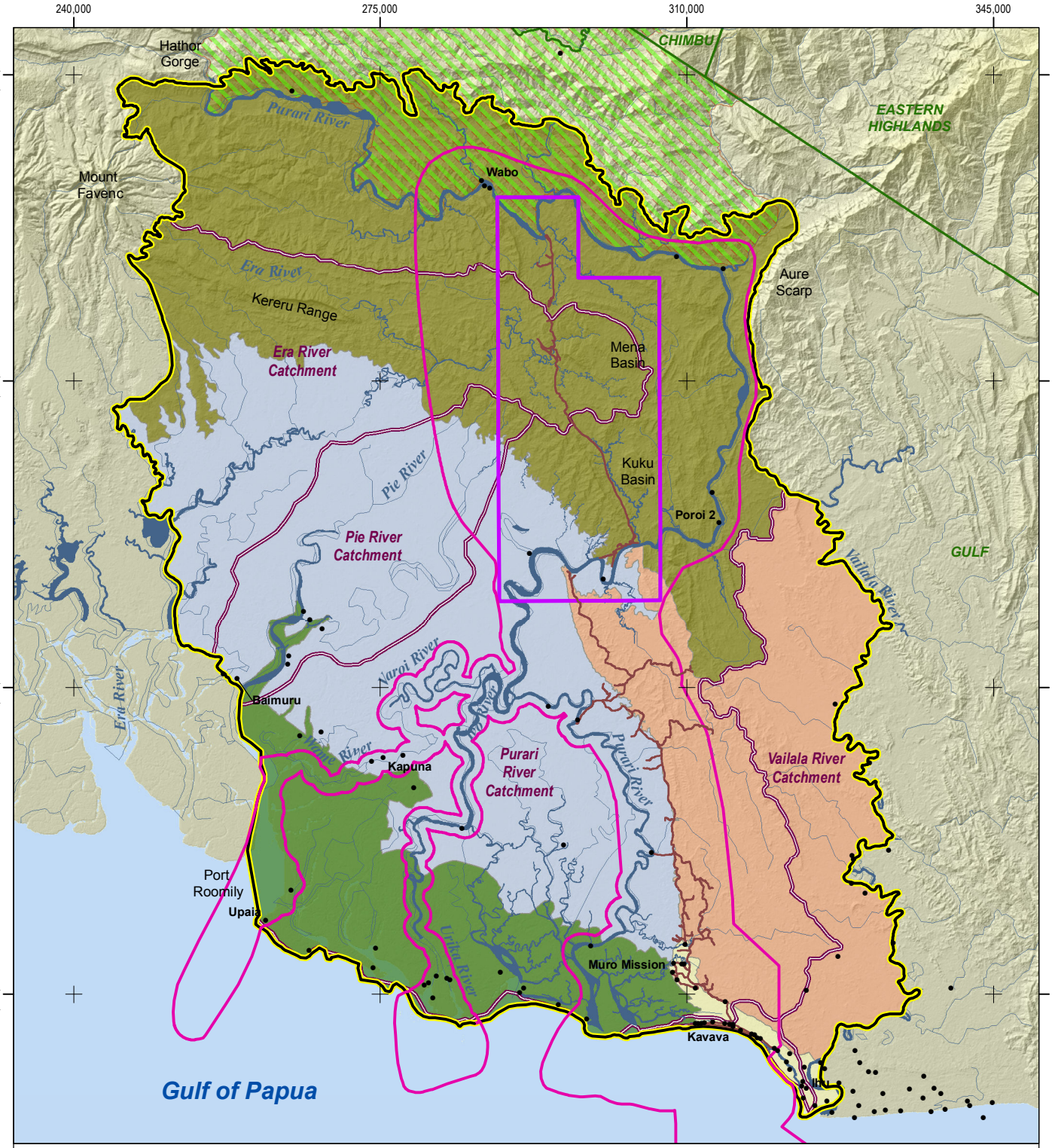
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ER1002 Elk Antelope LNG Project EIS-ESHIA\Work Request\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79669-Figure 3.1-C.mxd



SCALE: 1:650,000 @ A4

0 5 10 15 20 25 Kilometres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Province boundaries
- Tracks
- Waterways
- Waterbodies
- Catchment boundaries
- PRL-15
- Study area
- Upstream project area of influence*
- Crater Mountain Wildlife Management Area

Ecological Zones

- Delta Swamps and Plains
- Mangroves
- Middle Purari Hills
- South East Coast
- Southeast Hills

N

** Largely represents the terrestrial biodiversity baseline survey area*

Note: Not all communities have been verified in the field. Only Government administrative centres and notable locations have been labelled for context.

TITLE: Study Area, Component Ecological Zones, and Major Catchments

FIGURE: 3.2

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79670 **REVISION:** C

DATE: 12/04/2017

DATA SOURCES:

Towns and villages, study area (ERIAS Group 2017). Upstream project area of influence digitised by Mipela GeoSolutions based on data supplied by ERIAS Group (2017). PRL-15, waterways, tracks (TOTAL 2016). Crater Mountain Wildlife Management Area (IUCN and UNEP-WCMC (2016), The World Database on Protected Areas (WDPA), Cambridge, UK: UNEPWCMC. Available at: www.protectedplanet.net). DEM (Planet Observer 2015). Province boundaries derived by Mipela GeoSolutions (2016). Catchments downloaded from World Resources Institute (2017) and aligned with data from Iain Woxvold (2016). Ecological zones (Iain Woxvold 2016).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79670-Figure 3.2-C.mxd

The study area covers 7,292.8 km^2 and is bounded:

- In the north by the 500 m contour.
- In the west by (from north to south) the volcanic landforms of Mount Favenc (PNG Resource Information system (PNGRIS) data: Bryan and Shearman 2008), the Era and Pie rivers and Port Romilly.
- In the east by (from north to south) the Aure Scarp and the Vailala River.
- In the south by the Gulf Province coast, extended offshore to include intertidal habitats (e.g., mudflats) as determined by recent aerial and satellite imagery.

The study area covers more than 21% of the land surface of Gulf Province. It spans an elevational range of 600 m (from sea level to the Kereru Range) and includes a diverse array of landforms and substrates (Bryan and Shearman, 2008). This variation in physical parameters forms the basis for a diverse set of biological environments. The study area encompasses a wide variety of terrestrial vegetation types as well as marine and freshwater ecosystems—it includes extensive areas of hill forest, alluvial forest, freshwater swamp forest and mangroves, tidal flats and estuaries, freshwater swamps and lakes and hundreds of river kilometers. These features occur across five major catchments (Figure 3.2), notably including the middle and lower reaches of the Purari River, PNG's third largest watercourse (Petr, 1983a).

3.1.3 Ecological Zones

To accommodate this heterogeneity the study area is divided into five ecological zones. The ecological zones are defined primarily according to landform and vegetation, with further division based on catchment boundaries or areas of marine tidal influence (Figure 3.2; Table 3.1). These physiographic parameters in turn influence the distribution of overlying biota, with each ecological zone expected to support a distinct assemblage of terrestrial flora and fauna. The ecological zones have notional boundaries, with populations of most species spanning zonal borders. Nevertheless, they represent a useful ecological division of the large study area landscape.

The ecological zones are described below. Descriptions include a summary of the various physiographic features that are important in shaping the component biological environments (ecosystems, communities), including geomorphology, terrain and soils.

Table 3.1 – Ecological Zones Defined Within the Study Area

Ecological Zone	Description	Area (km2)			
		Study Area Total	Upstream PAOI	PRL-15	Export Pipeline Corridor A
Middle Purari Hills	Uplifted erosional landforms north of the Southeast Hills and the Delta Swamps and Plains ecological zones	2,655.99	596.34	595.55	–
Southeast Hills	Uplifted erosional landforms east of the Purari River that drain: (1) onto the Delta Swamps and Plains (Purari River catchment), or; (2) into the Vailala River (Vailala River catchment)	1,291.80	397.33	20.58	89.34
Delta Swamps and Plains	Recent alluvial landform supporting a variety of freshwater swamp and alluvial forest habitats	2,411.81	571.50	157.40	52.30
Mangroves	Recent alluvial landform under marine tidal influence	855.57	170.72	–	17.16
Southeast Coast	Beach ridges and plains	77.62	61.59	–	44.70
Total		7,292.79	1,797.48	773.53	203.50

3.1.3.1 Middle Purari Hills

The Middle Purari Hills ecological zone covers 36.4% of the study area. It underlies the northern three quarters (76.7%) of PRL-15 including the entire Elk-Antelope gas field, the Herd Base—Gas Field Road, the eastern boundary of the trunkline route corridor and the northern half and parts of the southern half of the eastern boundary. The eastern quarter (15.6 km^2; 24.2%) of the CPF, logistics base and airstrip area is also within this ecological zone (though most facilities are planned for construction on alluvial terrain; Section 3.1.3.3).

The Middle Purari Hills comprise an extensive area of low relief, even-peak foothills that extend north across a 30 to 40 km expanse from the head of the Purari delta to the 500 m contour of New Guinea's central cordillera[1]. It is bounded to the west by the volcanic landforms of Mount Favenc (not included within the study area), to the east by the Aure Scarp, and to the south by the Southeast Hills and the Delta Swamps and Plains ecological zones. The northern rim of the Middle Purari Hills is contained within the Crater Mountain Wildlife Management Area (WMA), covering an area of approximately 445 km^2 north of the Purari River (Figure 3.2).

The Middle Purari Hills overlap three major catchments—the Purari, Era and Pie River (Figure 3.2). The Purari River catchment covers the largest area, including some 140-river kilometers of PNG's third largest watercourse. The Era River catchment extends east from the foot-slopes of Mount Favenc into the northern half of PRL-15 including the Elk-Antelope gas field.

[1] Lands north of the study area rise much more abruptly, attaining heights of 1,000 m asl within a distance of 5 km.

The Middle Purari Hills form part of the 'Aure fold area' geomorphic region, located at the eastern end of the Southern Fold Mountains (Löffler, 1977). Folding and faulting of Tertiary sediments has resulted in a topography characterized by closely spaced sub-parallel ridge systems, trending west-northwest across most of the area and north-south in the extreme east (Löffler, 1977; Pain, 1983; Figure 3.2). The steep escarpments face south/west and the gentler corresponding dip slopes (in most areas less than 25°: Bryan and Shearman, 2008) face north/east. Elevation ranges from c. 40 m above sea level (asl) at the boundary with the Delta Swamps and Plains to more than 600 m asl on the Kereru Range. Most of the land, however, is below 300 m, including many of the larger ridge systems and all proposed Project development areas.

Geology of the Middle Purari Hills is dominated by Tertiary (Miocene to Pliocene) sandstones and mudstones. Major topographic features including the Pide Syncline, Mena and Kuku basins are formed of the sandstone-dominant Era Beds (Pieters, 1980). These are interspersed with extensive areas of Orubadi Beds mudstones and siltstones and, in the north and east of this ecological zone, greywacke sandstones of the Aure Beds. The Orubadi Beds are inherently unstable and susceptible to rapid erosion with slumping common.

Surface limestone occurs in limited areas in the west along the Kereru Range and in the extreme northwest where it contacts the Purari River at Hathor Gorge and around Mua Creek (Bain and MacKenzie, 1974; Pieters, 1980). Representing the eastern limit of the Darai Limestone megasequence (Hill and Gleadow, 1989), these are the only major limestone formations present in the study area and the only areas where large cave formations are likely to occur. No surface limestone is present in PRL-15.

Soils of the Middle Purari Hills are characterized broadly as 'acid brown soils' (Wood, 1983). Dystropept and eutropept inceptisols are the most widespread soil types (Bryan and Shearman, 2008). These moderately weathered, moderately fertile soils are among the most widespread soil types in New Guinea (Bleeker, 1983; Hope and Hartemink, 2007). They occur locally as yellowish to red or brown clays. Distinctive minor occurrences include rendoll mollisols (shallow limestone soils) on surface limestones (e.g., Kereru Range) and fluvaquent entisols (recent alluvial soils) in poorly drained areas alongside major watercourses (Bryan and Shearman, 2008).

3.1.3.2 Southeast Hills

The Southeast Hills ecological zone covers 17.7% of the study area between the Purari and Vailala Rivers. It extends c. 65 km south from the Middle Purari Hills to the Southeast Coast ecological zone and 20 to 35 km east from the Delta Swamps and Plains to the Vailala River. The Southeast Hills underlie the eastern 43.9% of the export pipeline corridor south of PRL-15, and 2.7% of PRL-15 in its extreme southeast.

This ecological zone includes all uplifted landforms east of the Purari River that drain onto the Delta Swamps and Plains (Purari catchment) or into the Vailala River. Elevation ranges from below 10 m asl on the meander floodplains alongside the lower reaches of the Vailala River to more than 350 m asl in the north of this ecological zone on the ridge separating the Vailala River and Purari River catchments. Most of this zone lies below 200 m, including many of the prominent ridge systems and all areas within the proposed export pipeline corridor.

The Southeast Hills comprise part of the 'Aure fold area' geomorphic region; topographical features that characterize the Middle Purari Hills continue southward throughout this ecological zone, with Tertiary sediments of the Orubadi, Era and (to a lesser extent) Aure Beds folded to produce a north-northwest trending series of sub-parallel homoclinal ridges (Ruxton, 1969a;

Löffler, 1977; Pieters, 1980; Bryan and Shearman, 2008). Similarly, dystropept inceptisols are among the dominant soils. By contrast, troporthent entisols replace the eutropept inceptisols as the co-dominant soil type atop these ridge systems in the north and centre of this ecological zone (Bryan and Shearman, 2008); these are typically very young, shallow soils of moderate to high fertility (Bleeker, 1983; Hope and Hartemink, 2007). In the extreme south the dystropepts occur as a minor associate to tropudult ultisols—strongly weathered acid soils of low fertility.

The landform character of the Southeast Hills differs most markedly from the Middle Purari Hills in having large areas of alluvial plains and back swamps interspersed among the ridge system matrix. These are most extensive in the east in the Vailala River catchment and in the southern half of the Purari River catchment (e.g., Orovoi Basin). The soils in these systems are characterized by recent alluvial deposits of high to moderate fertility: tropofluvent, fluvaquent and hydraquent entisols are the most widespread, respectively occurring in moderately well drained, poorly drained and permanently inundated environments (Bleeker, 1983; Bryan and Shearman, 2008). Peaty soils—tropohemist and tropofibrist histosols—occur in some very poorly drained areas, predominantly in the Vailala River catchment.

3.1.3.3 Delta Swamps and Plains

The Delta Swamps and Plains ecological zone covers 33.1% of the study area. It extends 30 to 40 km southwest from the base of the Middle Purari Hills to the marine tidally influenced Mangroves ecological zone at the deltaic front, and 70 to 80 km northwest from the Southeast Coast ecological zone to the Era River and the southeast edge of the volcanic foothill slopes of Mount Favenc.

The central east of the Delta Swamps and Plains, around the point at which the Purari River flows from the Middle Purari Hills, underlies 20.6% of PRL-15 in its southwest corner, including most of the CPF, logistics base and airstrip area (75.8%). South of PRL-15, the southeast rim of this ecological zone underlies the western half of the proposed export pipeline corridor. The Delta Swamps and Plains also include the freshwater sections (inland from the Mangroves) of the river transport routes along each of the Purari River's three distributaries.

The Delta Swamps and Plains span the Purari, Era and Pie River catchments (Figure 3.2). The Purari River catchment covers the largest area. Near the head of the deltaic system, c. 15 km coastward from the hill zone boundary, the Purari River splits into three major distributaries—from west to east, the Wame-Varoi, Urika-Ivo and Purari channels. The Pie River catchment is contained almost entirely within this ecological zone, its headwaters extending less than 5 km inland to the southernmost ridge of the Middle Purari Hills. At the distal end of this ecological zone the catchments merge via complicated networks of multiple distributaries and interconnecting channels.

The Delta Swamps and Plains is a recent alluvial landform composed of sediments (mud, silt, sand and gravel) deposited primarily by the Purari and Era Rivers (Pieters, 1980; Thom and Wright, 1983). Together with the Mangroves ecological zone it comprises the easternmost component of a much larger depositional system that stretches west and south along the Gulf of Papua to include the Kikori, Turama and Fly River deltaic systems (Thom and Wright, 1983).

Elevation ranges from below 5 m asl to above 60 m asl on a few isolated foothills near the base of the Middle Purari Hills. However, most of the land is below 25 m asl, with areas above 30 m restricted to levee banks along the main Purari distributaries (present and former) and on older

sediment accumulations at the base of the Middle Purari Hills and Southeast Hills ecological zones.

The Delta Swamps and Plains form a transitional series of freshwater swamp and alluvial plain systems, from newly formed deep-water swamps through shallower swamps in various stages of infill to better-drained alluvial plains subject to only intermediate inundation (Ruxton, 1969a). Levee banks produced by regular flood deposits border the main distributaries and slope gently away into the backwater swamps (Bryan and Shearman, 2008). The sequential stages of development are readily recognized in the distribution of overlying vegetation types (Section 6.2.4.3). The region is underlain by heavy fine-textured clays (recent alluvial entisols, mollisols) with occasional peat layers (tropofibrist and tropohemist histosols) (Bleeker, 1983; Bryan and Shearman, 2008).

3.1.3.4 Mangroves

The Mangroves ecological zone consists of the coastal section of the aggrading delta landform that is under marine tidal influence. It is delineated by a combination of three mangrove mapping datasets—FIMS, PNGRIS and the USGS Global Distribution of Mangroves (Giri et al., 2011)—trimmed to exclude minor dendritic inland incursions. Covering 11.7% of the study area, it extends up to 25 km inland and spans a coastal front of more than 50 km between Port Romilly and the Southeast Coast ecological zone.

The Mangroves ecological zone underlies the coastal approach of the western part of the export pipeline corridor and the near-coastal sections of the river transport routes along each of the Purari River's three distributaries.

The deltaic front is morphologically dynamic, prograding in some areas and eroding in others in response to active river dynamics, tidal flows, wave action and sediment deposition (Ruxton, 1969a; Thom and Wright, 1983; Shearman et al., 2013). The sediments are composed of lagoonal muds, silts and sands (recent alluvial entisols) with regular peat occurrences (tropofibrist and tropohemist histosols, sulfaquent entisols) (Bleeker, 1983; Bryan and Shearman, 2008). Acid sulfate soils (sulfaquents) are widespread, comprising more than 25% of the soil area mapped for this ecological zone (Bryan and Shearman, 2008). At low tide, extensive areas of tidal mud and sand flats are exposed along the coast and at estuary mouths. These are morphologically very dynamic, their arrangement and area of exposure changing rapidly with the tides and between seasons and years.

In a regional context, the Mangroves ecological zone forms the eastern part of the largest area of mangroves in PNG, stretching west along the coast for approximately 150 km to the mouth of the Omati River (Percival and Womersley, 1975; Saulei and Beehler, 1993). This region is characterized by the broadest coastal band of mangroves found anywhere in PNG, at their widest point extending inland nearly 50 km from the deltaic front at the mouth of the Kikori River (west of the study area).

3.1.3.5 Southeast Coast

The Southeast Coast ecological zone comprises just 1.1% of the study area. It spans approximately 18 km of the coastline east from the Mangroves ecological zone to the mouth of the Vailala River, and extends inland approximately 10 km to the border of the Delta Swamps and Plains. This ecological zone encompasses the eastern three quarters of the coastal approach of the export pipeline corridor south from Kilave village.

The Southeast Coast ecological zone is centred on 'beach ridges and plains' landform units (Bryan and Shearman, 2008), expanded in the east to include some minor mangrove and swamp areas near the mouth of the Vailala River, and in the northwest to include all of the Alluvial forest vegetation unit (FIMS code Pl) that overlaps strongly with the central defining landform. The beach ridges and plains landform is composed of recent littoral sands, originally deposited near the mouth of the Vailala and other rivers further east along the coast, and moved northwest by longshore currents (driven by the southeast trade winds) to form an aggrading series of sub-parallel beach ridges with intervening swales and plains (Ruxton, 1969b; Ruxton et al., 1969a; Bryan and Shearman, 2008). The sand ridges are most prominent near the coast, with relict features gradually decreasing in height inland to form a level or gently undulating sandy plain. Sandy soils occur on beach ridges, while intervening swampy swales and relict flats support recent alluvial soils (hapludoll mollisols, tropofluvent, psammaquent, fluvaquent and hydraquent entisols) (Bleeker, 1969; Bryan and Shearman, 2008). Areas permanently inundated (or nearly so) have peaty (tropofibrists histosols) or mangrove acid sulfate soils (sulfaquent entisols).

3.2 Climate

Climatic conditions within the study area are described in the upstream Environmental and Social Baseline (ESBS) Report. Briefly, the study area is subject to a tropical perhumid climate, characterized by high rainfall and hot and humid conditions throughout the year.

3.2.1 Annual Patterns

Seasonal changes in rainfall, temperature and humidity are generally low (Evesson, 1983; Bryan and Shearman, 2008). Rainfall is heaviest, and temperatures slightly lower, during the 'southeast (trade wind) season' of May to October, when the hills of the study area, and the mountainous region directly to its north, present a topographical barrier to moist air flowing from the southeast across the Gulf of Papua. Rainfall trends lower during the 'northwest season' of December to March.

Within the study area the amount and seasonality of rainfall varies from north to south. The northern half receives very high rainfall with annual totals averaging more than 5 m in most areas and annual falls at Wabo averaging more than 8 m (Evesson, 1983; McAlpine et al., 1983). Rainfall seasonality is low in this area with high monthly falls received throughout the year (> 500 mm in all months at Wabo; Evesson, 1983). Slightly less rain falls in the south of the study area, with annual totals averaging 3,200 to 3,400 mm per year at Ihu and Baimuru (McAlpine, 1969; Evesson, 1983). Seasonality is reported to be higher ('moderate': McAlpine et al. 1983), with average monthly falls dropping below 200 to 300 mm for at least some months during the northwest season (Evesson, 1983; McAlpine et al., 1983; Bryan and Shearman, 2008).

3.2.2 Influence of Elevation

Climate is strongly influenced by elevation (McAlpine et al., 1983). Despite the large scale of the study area, its elevational range is limited—only one small isolate (Kereru Range peak) lies above 600 m asl and all areas of PRL-15 and the export pipeline corridor are below 450 m asl. The influence of elevation on temperature and rainfall within the study area is accordingly low, being well within the range of diurnal variations (Evesson, 1983; Bryan and Shearman, 2008).

3.2.3 Other Climatic Phenomena

El Niño-Southern Oscillation (ENSO) climatic events occur every few years, causing a shift in rainfall away from the western Pacific and the eastern Australasian region during the austral (southern hemisphere) winter to spring periods (BOM, 2016). ENSO events vary in their intensity.

In PNG 'extreme' events, such as occurred in 1982–83 and 1997–98, have resulted in severe droughts in some areas with major fires resulting in the loss of large areas of forest (Haberle et al., 2001; McVicar and Bierwirth, 2001; Johns et al., 2007a). A strong ENSO event occurred during the 2015/2016 season. Its effects on climate parameters within the study area are unknown (data unavailable), though based on prior survey experience in the lowlands of southern mainland PNG this event is not expected to have hindered data collection for the current Project.

Tropical storm regimes can influence the structure of tropical forests (de Gouvenain and Silander 2003). Cyclones have minimal influence on this part of PNG, with tropical storm genesis and cyclonic tracks in the Gulf of Papua discouraged by prevailing northwesterly winds during the November to April cyclone season, and by flanking land masses of the Fly Platform, Southeast Peninsula and Cape York Peninsula (Evesson, 1983; McAlpine et al., 1983; Evans and Allan, 1992).

3.3 Anthropogenic Setting

The following sections provide a broad summary of the patterns of settlement and industrial activities that exist at the time of this study and that influence ecosystems and biotic communities within the study area. Detailed assessments of various local and regional socio-economic parameters are the subject of separate studies.

3.3.1 Local Population

Gulf Province has the lowest population of all mainland PNG provinces and the lowest national growth rate (1.1% in the decade to the 2011; NSO 2012, 2014)[2]. Figures from the 2011 National Population and Housing Census give an average population density within the study area of less than 3.2 PNG residents per square kilometer (NSO, 2014)[3].

More than half (51.1%) of the study area's census population live on or near the coast. The Southeast Coast is the most densely populated ecological zone with 38.3% of the study area population found within approximately 1% of its land surface. Almost the entire coastal strip and the sub-coastal section of the Vailala River support a dense array of settlements, gardens and coconut plantations. Inland sectors are less densely populated, though settlements and gardens occur along most of the relict beach plain that extends into the northwest of this ecological zone. Another 12.8% of the census population lives along the coastal fringe of the Mangroves ecological zone, where most settlements are situated at estuary mouths.

More than one third (35.9%) of the study area's census population live on recent alluvial landforms further inland. Most settlements here are located on the Era River along the western edge of the study area (Delta Swamps and Plains) or on navigable waterways near the border of the Delta Swamps and Plains and the Mangroves ecological zones, including the lower reaches of the Pie, Wame, Varoi, Urika, Ivo and Purari rivers.

The interior hills of the study area are very sparsely populated. The Middle Purari Hills and the Southeast Hills ecological zones together support 13.0% of the study area population over more than half (53.9%) of its area. Some 6.4% live in the Southeast Hills along the Vailala River east of

[2] Summary statistics presented in this section are based on results of the 2011 National Population and Housing Census (NSO 2012, 2014) with information on the location of settlements taken from mapping provided by TEP PNG and their arrangement within LLG Wards taken from Bryan and Shearman (2008).
[3] Based on a count of 23,133 for all LLG Area Wards located within the study area.

the upstream PAOI. Pawaian communities make up the remainder, residing in the Middle Purari Hills in a small number of permanent settlements and satellite subsistence gardens scattered along the banks of the Purari River and its major tributaries.

Large parts of the study area support no permanent local resident settlements. They include:

- The interior of the Mangroves ecological zone, between the coast and its northern border with the Delta Swamps and Plains.
- Most of the Delta Swamps and Plains, including its northern rim and the vast interior expanse between the Era and Purari rivers and upstream of the margin near the Mangroves ecological zone.
- Most of the Southeast Hills, including all areas west of the Vailala River and north of the Southeast Coast ecological zone.
- Most of the Middle Purari Hills away from the Purari River, including all areas off of the Purari River.

3.3.2 Industry Ventures

3.3.2.1 Industrial Logging

The most extensive anthropogenic influence on local ecosystems is that associated with industrial logging. Forestry activities within the study area are described in the Annex 1D. These are summarized, and areas of logged forest are mapped, in Section 6.2.3 of this baseline report.

3.3.2.2 Gas Exploration

The only other large-scale venture presently operating within the study area is that associated with the exploration and development of natural gas reserves. Activities and components of the current Project are described in the upstream ESBS Report. Major developments existing at the time of this study include:

- Exploration wellpads and an operations camp in the Elk-Antelope gas field in the northern half of PRL-15.
- Logistic bases and associated wharf facilities on the Purari River at Herd Base and Hou Creek Base, in the south and north of PRL-15 respectively.
- Approximately 40 km of road running north-south through PRL-15, including the Hou Creek Road from decommissioned Hou Creek Base to the Elk-Antelope gas field, and the Herd Base-Gas Field Road linking Herd Base with the gas field at the Antelope-3 Operations Camp.

Beyond the Elk-Antelope gas field, gas exploration not associated with this Project is ongoing in the Triceratops gas field in the northwest of the Middle Purari Hills ecological zone.

3.3.2.3 Hydro-electric Scheme Feasibility Studies

Feasibility studies investigating the potential for development of a hydro-electric dam in the middle Purari basin upstream of Wabo were undertaken in the 1970s (Petr, 1983b) and again during 2011 to 2013. The project was not developed, though a logistic camp (‘Staging Camp’) on the Purari River c. 30 km downstream of Wabo was in use and geotechnical studies were undertaken at the proposed site of a dam wall.

3.3.2.4 Other Industry Ventures

In the early 20th century extensive coconut plantations were established in the Southeast Coast ecological zone from the shorefront inland to the Muro Mission area. Though no longer commercially owned, the coconut groves remain a notable feature of the vegetation in this populated sector of the study area.

4. Existing Information

A detailed review of existing information on biodiversity and conservation values present in the vicinity of the study area was undertaken during a bibliographic review (Section 5.2.1). The following sections provide a summary of relevant data sources, including terrestrial flora and fauna surveys conducted within the study area (Section 4.1) or in neighboring regions (Section 4.2), and other sources (Section 4.3) relevant to understanding the status and distribution of potentially sensitive species and/or the presence and arrangement of communities and ecosystems within the study area. More detailed summaries of the prior survey coverage of specific taxonomic groups are presented in Annexes 1A, 2 to 6.

4.1 Prior Studies within the Study Area

Prior to the 1970s, ground-based biological research within the study area was limited primarily to broad-scale vegetation studies of the Purari delta (Lane-Poole, 1925) and the southeast sector of the study area (Paijmans, 1969).

4.1.1 1970s Environmental Studies

PNG Wildlife Division Surveys

In 1975 to 1977 a series of wildlife surveys was conducted in the Purari delta and Wabo areas by the Wildlife Division of the PNG Department of Natural Resources (Liem, 1983). Survey techniques included community interviews, direct observation of wildlife, mist netting, trapping, spotlighting and selective shooting. Though not intended as an exhaustive biodiversity survey, some specimens were collected (fauna and flora) and deposited in the Wildlife Division Museum and the PNG National Museum and Art Gallery (NMAG) in Port Moresby. The results of these surveys have not been published.

Wabo Hydro-electric Scheme Environmental Studies

In the late 1970s a series of environmental studies was initiated to examine the potential impacts of developing a hydro-electric project in the study area upstream of Wabo (Middle Purari Hills). Some 45 research projects were conducted, the results of which were written up in 21 technical reports and a publicly available monograph (Petr, 1983b). Flora and fauna studies were not a major focus; although a variety of taxa were investigated, most reports relied heavily on the few data collected previously from within or outside of the study area (Pernetta, 1983); most terrestrial groups were scarcely covered (e.g., herpetofauna, mammals, plants) or were not surveyed (terrestrial invertebrates).

4.1.2 Prior Studies Elk-Antelope Environmental Studies

Following discovery of the Elk-Antelope gas field in 2006, in 2008 Douglas Environmental Services (DES) acknowledged that '[t]here have been no detailed biological studies carried out within the project area' (DES, 2008). Consequently, in order to support approvals for petroleum development proposals contemplated by the previous operator (InterOil), a number of biological assessments were conducted within and southeast of PRL-15 by DES (2008, 2010), Worley Parsons (2009) and GHD (2011). The adequacy of these data is summarized below (Section 4.4).

4.1.3 2011 to 2012 Purari Hydropower Project Surveys

In 2011, development of a hydro-electric dam in the northern study area upstream of Wabo (Middle Purari Hills) was again considered. A series of multi-disciplinary biodiversity surveys was

undertaken for the Purari Hydropower Project (PHP) by a team of regionally experienced species specialists. Survey effort focussed largely on areas north of PRL-15 with some sampling of habitats within the Project export pipeline corridor south of PRL-15. Relevant data from the PHP studies are held under confidentiality embargo and no further reference can be made to the results of those surveys.

4.2 Prior Studies in Neighboring Regions

4.2.1 Kikori Basin

West of the study area, in partnership with industry leaders[4], in 1994 WWF initiated the Kikori Integrated Conservation and Development Project (KICDP), later named the Kikori Basin Conservation Program, aimed at preserving biodiversity within the Kikori River drainage (Leary et al., 1996; McCall and Flemming, 2000). Under the program WWF and its partners have carried out multiple biodiversity surveys covering a broad range of taxa at elevations from sea level to over 2,500 m asl. Studies most relevant to the present purpose are those conducted between Lake Kutubu (c. 800 m asl) in Southern Highlands Province and the Kikori delta in western Gulf Province (e.g., Hartshorn et al., 1995). Surveyed taxa include flora, mammals, birds and herpetofauna. The findings of the WWF Kikori basin surveys have been previously reported in the PNG LNG Project Environmental Impact Statement (EIS) (Coffey, 2009).

4.2.2 Lakekamu Basin

East of the study area, Bruce Beehler and colleagues have conducted a long-term study (nearly 20 years) of bird communities present in the Lakekamu Basin lowlands (below 100 m asl) (e.g., Beehler et al., 1994, 1995; Beehler and Mack, 1999). In 1996 Conservation International surveyed the Lakekamu Basin as part of their Rapid Assessment Program (RAP) for assessing biodiversity and conservation values in remote and poorly studied landscapes (Mack, 1998; Alonso et al., 2011). All vertebrate groups, plants and a variety of invertebrate taxa were surveyed. Between 35 and 47 new species, including some new genera, were discovered during this single-visit month-long survey, highlighting the extensive gap in our current knowledge of the region's biota.

4.2.3 Crater Mountain Wildlife Management Area

The northern rim of the study area (c. 445 km^2), including part of PRL-15, lies within the Crater Mountain Wildlife Management Area (WMA) (Figure 3.2). Established jointly in 1994 by the Research and Conservation Foundation (RCF) of PNG and the Wildlife Conservation Society (WCS), the Crater Mountain WMA covers 2,700 km^2 across three provinces (Eastern Highlands, Chimbu and Gulf Provinces) at elevations that range from over 3,000 m asl down to c. 50 m asl at the Purari River (Sekhran and Miller, 1995; Mack and West, 2005).

Much research has been conducted within the Crater Mountain WMA, including studies of flora, terrestrial vertebrates and invertebrates. Most of this work was conducted above 800 m asl; of more than 50 publications[5], few include results from below 750 m (e.g., Mack and Wright, 1998; Takeuchi, 1999; Watson and Asoyama, 2001; Marsden et al., 2006; Symes et al., 2006) and most of these report on only one or a few species (cf. Takeuchi, 1999). Elevation exerts a marked influence on the structure and composition of tropical forest communities (Whitmore, 1998;

[4] A joint venture currently led by Esso Highlands Limited as operator of the PNG LNG Project.

[5] Including postgraduate theses and studies published in peer-reviewed scientific journals.

Diamond, 1972; Takeuchi, 2007), and the results of most research conducted in the Crater Mountain WMA are of limited relevance to flora and fauna communities across the study area lowlands.

4.3 Other Data Sources

Other relevant data sources are described below. These have been used collectively to inform the arrangement of ecosystems within the study area, including the delineation of ecological zones and major vegetation types, and they provide insight into the distribution of biodiversity values both within the study area and in a broader regional context. They include:

- Published scientific literature, such as peer-reviewed journals, books, and private sector, government and non-governmental organization (NGO) reports.
- Unpublished scientific reports and data, including masters/doctoral theses, museum records and various NGO and private sector sources.
- National assessments and planning documents, including the PNG Conservation Needs Assessment (Beehler, 1993a; Swartzendruber, 1993), the results of which subsequently informed the PNG Country Study on Biological Diversity (Sekhran and Miller, 1995) and the PNG National Biodiversity Strategy and Action Plan (Government of Papua New Guinea 2007, 2010).
- Information on PNG protected areas and other high conservation value areas, including RAMSAR sites (wetlands of international importance), areas proposed for World Heritage status, WWF proposed conservation areas (Leary, 1996), Endemic Bird Areas (Stattersfield et al., 1998) and Important Bird Areas.
- Spatial data and landscape/regional mapping assessments, including:
  - Topographic, geological, hydrological and watershed mapping.
  - Vegetation, land classification and land use mapping, including the PNG Resources Information System (PNGRIS, Third Edition; Bryan and Shearman, 2008), the PNG Forest Inventory Mapping System (FIMS) (Hammermaster and Saunders, 1995a,b), the United Nations Environment Programme (UNEP) World Conservation Monitoring Centre (WCMC) World Atlas of Mangroves (Spalding et al., 2010) and the United States Geological Survey (USGS) Global Distribution of Mangroves (Giri et al., 2011). In 2005 FIMS was endorsed by the National Forest Board and the PNG Forest Authority as the official National Forest Inventory.
  - Regional ecosystem mapping, in the form of terrestrial ecoregions, biomes and bioregions (e.g., Wikramanayake et al., 2002).
  - Satellite and aerial imagery available for the study area.
  - On-line resources mapping recent change in forest cover, including the Global Forest Change (Hansen et al., 2013; earthenginepartners.appspot.com/science-2013-global-forest) and PNG Forest Observatory (forest.pngsdf.com) websites.
- Other web-based data sources:
  - The IUCN Red List (IUCN, 2016) and CITES listings.

– The Integrated Biodiversity Assessment Tool (IBAT), Alliance for Zero Extinction (AZE) and Proteus (United Nations Environment Programme World Conservation Monitoring Centre) were also checked also for applicability to the study area.

4.4 Summary

In 1993 the PNG Conservation Needs Assessment included much of the lowlands of western Gulf Province, including the northern part of the study area (most of the Middle Purari Hills and the northern half of PRL-15), within an area defined as one of the country's 'major terrestrial unknowns' (Figure 4.1)—specifically, one of '16 major geographic areas…for which the present lack of scientific information is particularly serious' (Swartzendruber, 1993).

In the southern part of study area, aside from a few studies on vegetation of the Purari delta and adjacent outlets ,Lane-Poole 1925; Paijmans, 1969; Womersley, 1975; Floyd, 1977), little additional biological work had been conducted at the time of publication of the PNG Conservation Needs Assessment.

From the years following that assessment, accessible data on species level values within the study area are restricted largely to those collected during prior Elk-Antelope environmental studies (Section 4.1.2). These are of limited value to the current baseline study program because:

- Flora and vertebrate inventories were low, largely unvouchered and included a number of errors in identification, inviting doubt as to the veracity of unvouchered listings (e.g., without photographs).
- Invertebrates were not systematically sampled.
- Coverage of conservation listed species (Section 5.4.1) was incomplete, scientifically undescribed taxa were under-investigated and no information was provided on restricted-range species.

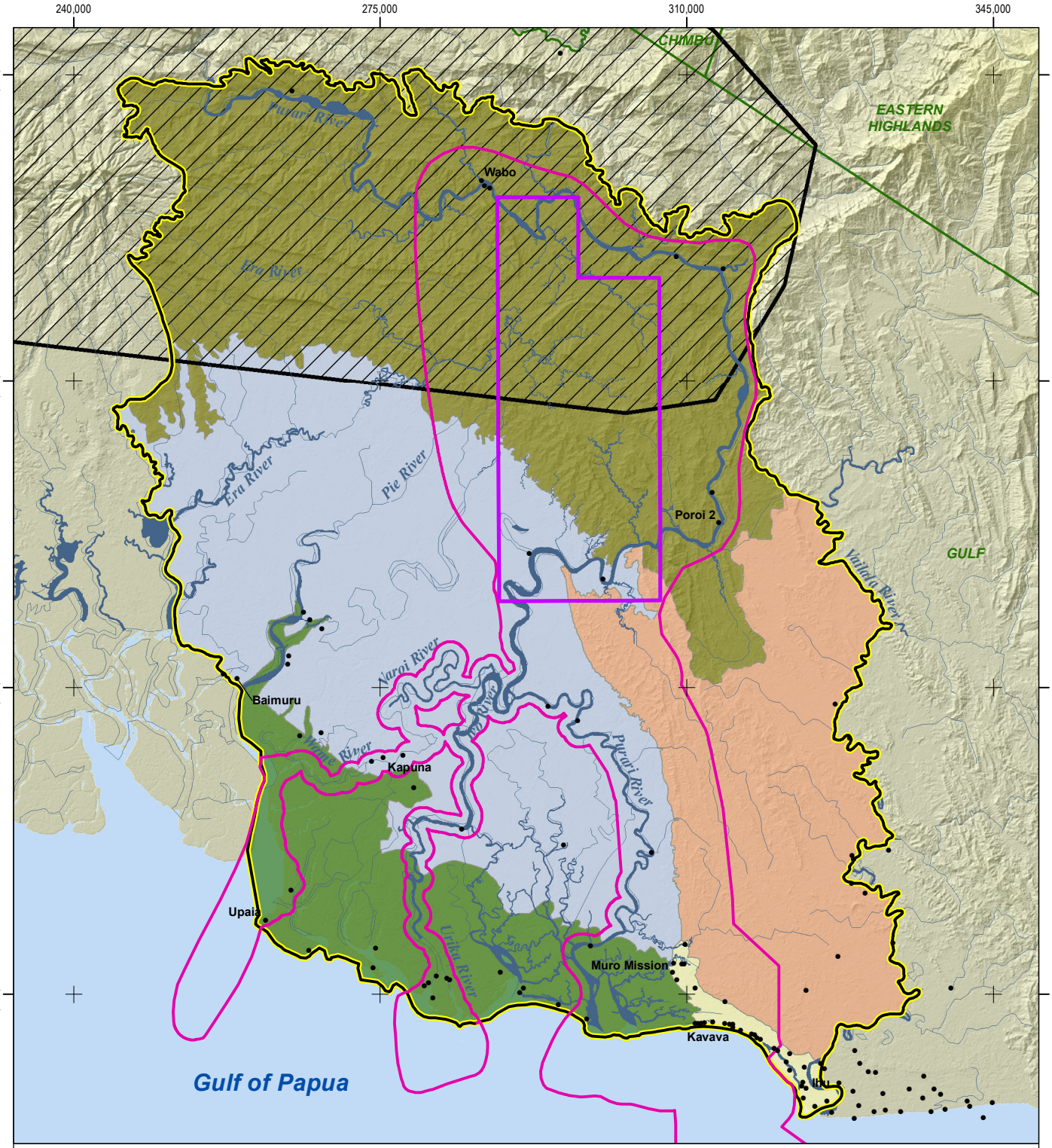
While more detailed research has focused on neighboring regions—in the lowlands of the Kikori and Lakekamu basins, and in adjacent uplands of the Crater Mountain WMA—information on the status and distribution of potentially sensitive species within the upstream PAOI and broader study area is currently lacking.

At the landscape level, national mapping resources (the finest scale available) rely mostly on historical data, often lack ground truthing and are generally too broad in scale to accurately map ecosystems at the site level.

The FIMS dataset serves as the official National Forest Inventory for all of PNG and is the most detailed (1:100,000) vegetation mapping available for the study area. However, surveys regularly reveal inaccuracies in the assignation of vegetation class, and with the latest updates now 20 years old and limited to previously logged over areas, the assessment of vegetation condition is in many places outdated. Vegetation assessments from prior Elk-Antelope environmental studies did not improve on the national mapping resources.

The arrangement of some physical landscape features also requires updating. With topographic maps (1:100,000) based on 1970s aerial photography and some PNGRIS datasets (up to 1:500,000) more than 20 years old, the dynamics of floodplain and coastal environments mean that many rivers, wetlands and shorelines are now inaccurately mapped.

To address the gaps described above, a series of field surveys was undertaken (Section 5.2) and LIDAR and aerial imagery datasets were commissioned to supplement existing information in support of the terrestrial biodiversity baseline studies. To the extent possible, prior available data have been incorporated into the results of the terrestrial biodiversity baseline study.



SCALE: 1:650,000 @ A4

0 5 10 15 20 25 Kilometres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Province boundaries
- Waterways
- Waterbodies
- PRL-15
- Upstream project area of influence*
- Study area
- Major Terrestrial Unknown

Ecological Zones

- Delta Swamps and Plains
- Mangroves
- Middle Purari Hills
- South East Coast
- Southeast Hills

N

** Largely represents the terrestrial biodiversity baseline survey area*

TITLE: Southern Scarp Wet Zone 'Major Terrestrial Unknown'

FIGURE: 4.1

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79671 **REVISION:** C

DATE: 13/04/2017

DATA SOURCES:

Towns and villages, study area (ERIAS Group 2017). Upstream project area of influence digitised by Mipela GeoSolutions based on data supplied by ERIAS Group (2017). PRL-15, waterways (TOTAL 2016). DEM (Planet Observer 2015). Province boundaries derived by Mipela GeoSolutions (2016). Ecological zones (Iain Woxvold 2016). Kukukuku Lobe (Iain Woxvold 2017). Major Terrestrial Unknown (Iain Woxvold 2017 derived from Swartzendruber, 1993).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79671-Figure 4.1-C.mxd

5. Methods

5.1 General Approach

This baseline assessment draws on a combination of sources, including review of existing data (Section 4), field surveys, stakeholder consultation and expert opinion. Results of these assessment methods are presented in a series of supporting studies and/or contribute directly to this report.

5.1.1 Biodiversity Values

Biodiversity features presented in this report are characterized at the following scales of biological organization.

5.1.1.1 Regional Values

Values associated with the national and broader regional biodiversity setting. These values occur at a scale larger than that of the study area landscape. While they do not allow comparison of the risks associated with Project development options, they do illustrate the high value setting in which the Project will operate, and provide context on the national and international recognition of biodiversity and conservation values present in the local region. Values at this scale are summarized in Section 6.1.

5.1.1.2 Ecosystems, Habitats and Focal Sites

These include the composition and conservation value of the study area and its component landscape features, including ecosystems, protected areas, and 'focal sites'—various localized terrain and habitat features upon which multiple species and/or multiple individuals of one or more species are ecologically dependent. Assessment at this scale includes detailed vegetation mapping of the study area (Section 6.2).

5.1.1.3 Species Level Values

Species level values include the results of the flora and fauna technical studies conducted for the Project (Section 5.2.1; Annex 1A, 2 to 6), with summaries for conservation listed species, scientifically undescribed species, endemic and restricted-range species, migratory and congregatory species and invasive alien species. Seven major taxonomic groups (in italics below) have been selected for focus at this level:

- *Vascular plants* (higher plants; Tracheophyta)—including ferns, gymnosperms (including conifers) and angiosperms (flowering plants).
- Mammals (Mammalia). For the purposes of this assessment mammals are divided into two groups:
  - *Non-volant (non-flying) mammals*—monotremes (Prototheria), marsupials (Marsupialia) and all placental mammals (Placentalia) other than bats.
  - *Bats* (Chiroptera).
- *Birds* (Aves).
- Herpetofauna—including *reptiles* (Reptilia) and *amphibians* (Amphibia).

- *Odonates*—Dragonflies and damselflies (Odonata).

Other terrestrial fauna that are conservation listed, including IUCN listed and nationally Protected species (e.g., butterflies), are assessed at a desktop level.

This taxonomic coverage is considered sufficiently broad so as to inform a set of avoidance, mitigation and management recommendations that are applicable to most terrestrial biota. This concept mirrors an expanded 'focal species' approach, in which a suite of taxa is selected whose management is expected to confer an ecosystem-wide conservation advantage (Lambeck, 1997; Nicholson et al., 2013).

5.1.1.4 Information Relevant to Critical Habitat Assessment

The collection and presentation of baseline information is tailored to align with the IFC Performance Standards (Section 2.2.1), most specifically with Performance Standard 6 (PS6) Biodiversity Conservation and Sustainable Management of Living Natural Resources. A key component of IFC PS6 is the classification of potentially impacted habitats as modified, natural or critical habitat, each category triggering different levels of compliance in order to meet lender expectations. Critical habitat assessment is important to understanding Project-related risks and impacts to biodiversity, implementing appropriate avoidance and mitigation measures and designating suitable biodiversity offsets. Accordingly, this report provides information on those biodiversity values that may trigger the designation of critical habitat within the study area, as determined against the criteria outlined in IFC PS6.

5.1.2 Supporting Studies

The following sections outline those studies commissioned to support the terrestrial biodiversity baseline study, and other relevant studies conducted under the broader ESHIA program of work.

5.1.2.1 Bibliographic Study

A bibliographic study, including a literature review and desktop study of available data, was conducted to assess the existing level of biological knowledge and to identify those species, ecosystems and areas of conservation significance confirmed or potentially present within the study area that may be sensitive to Project development and/or require further investigation through other assessment methods (e.g., field surveys). Section 4 describes the data sources that were reviewed.

The results of the bibliographic review are incorporated into various sections of this report and in the technical study annexes. Physical landscape and climatic features relevant to the distribution of species and to the arrangement of ecosystems and ecological zones are presented in Section 3. The adequacy of existing data for the characterization of species level values is discussed in Section 4 and in the flora and fauna technical studies (Annexes 1A, 2 to 6). Section 6.3 and the individual flora and fauna technical studies include information on species of conservation significance recorded or potentially occurring in the study area. Information on priority landscape level values is included in Sections 6.4 to 6.8.

In addition, information from the bibliographic review on the distribution of vegetation types, faunal habitats, catchment boundaries, ecological zones, accessibility and prior disturbed areas was incorporated with information on Project layout to inform field survey design (Section 5.2).

5.1.2.2 Vegetation, Flora and Fauna Technical Studies

A full list of supporting technical studies are listed below along with their authors:

- Vegetation and flora:
  - Annex 1A – Upstream Flora Baseline Report, authored by F. Venter and F. Bewang.
  - Annex 1B – Upstream Vegetation Mapping and Forest Condition Baseline, authored by Booyong Forest Science.
  - Annex 1C – Upstream Weeds Baseline Report, authored by Booyong Forest Science.
  - Annex 1D – Upstream Forestry Baseline Report, authored by Booyong Forest Science.
- Fauna:
  - Annex 2 – Upstream Non-volant Mammals Baseline Report, authored by K. Aplin, J. Novera and I. Woxvold.
  - Annex 3 – Upstream Bats (Chiroptera) Baseline Report, authored by K. Armstrong, K. Aplin and P. Amick.
  - Annex 4 – Upstream Avifauna Baseline Report, authored by I. Woxvold, P. Amick and J. Novera
  - Annex 5 – Upstream Herpetofauna Baseline Report, authored by S. Richards, E. Nagombi and C. Dahl.
  - Annex 6 – Upstream Dragonflies and Damselflies (Odonata) Baseline Report, authored by S. Richards and P. Toko.

A brief description of each study is provided in the following sections.

Flora and Fauna Taxonomic Studies

A multi-disciplinary series of technical studies was commissioned to provide information on the seven major taxonomic groups listed in Section 5.1.1.3. These technical studies were conducted by external (independent) experts engaged specifically for their knowledge of the region's flora and fauna (Section 8). The flora and fauna technical studies draw on the results of field surveys conducted at various sites in the upstream PAOI in 2016 (Section 5.2.1), on the review of existing data sources and on expert opinion. These forms of assessment were supplemented with information provided by local PNG residents, a number of whom were assigned to assist with the terrestrial biodiversity field surveys.

The flora and fauna taxanomic study reports are appended to this report as Annexes 1A and 2 to 6.

Vegetation Mapping Study of PRL-15 and the Export Pipeline Corridor

The existing FIMS vegetation mapping units were revised for part of PRL-15 and export pipeline corridor areas based on:

- 2016 LIDAR imagery—using aerial imagery and 1 m contour datasets.

- Ground truthing from field surveys conducted for the flora technical study (Annex 1A) and other vegetation related surveys (Section 5.2.2).
- Aerial reconnaissance and photography.
- PNGRIS datasets.

The report is appended to this report as Annex 1B.

Weeds Study

In addition to the more general flora technical study (Annex 1A), the presence of weeds in the study area was assessed focusing on areas of anthropogenic disturbance within the upstream PAOI. Results are presented in Annex 1C.

Forestry, Deforestation and Vegetation Regeneration Studies

Information on forestry activities and the condition of forested ecosystems was assessed and relevant results are incorporated into the study area vegetation assessment (Section 5.3). The study examined marketable forest resources and associated harvesting activities across the study area using a combination of desktop review, aerial survey and stakeholder consultation, including interviews with key forestry sector organizations and with selected village communities. The study is appended to this report as Annex 1D.

In addition to these studies annexed to this report:

- The Upstream Deforestation Study (Booyong Forest Science, 2017c; Part 17 of ESBS Dossier) assessed recent (post-2000) forest loss and degradation within the deforestation study area (eastern c. 63% of the study area) via analysis of satellite imagery supported by ground truthing and aerial survey.
- The Upstream Vegetation Regeneration Study (Booyong Forest Science, 2017d; Part 8 of ESBS Dossier) assessed the natural regeneration potential and assisted rehabilitation capacity of natural vegetation types present within PRL-15 and the export pipeline corridor via literature review and field survey.

5.2 Field Surveys

Due to a lack of existing and recent data (Section 4), a series of multi-disciplinary field surveys was undertaken to provide baseline information on the composition, condition and conservation significance of terrestrial biotic communities and habitats present within the study area.

5.2.1 Flora and Fauna Surveys

Flora and fauna field surveys were conducted by four taxon-specialist scientists and supported by five specialist field assistants including three staff from the Binatang Research Centre (BRC). Survey personnel are listed in Section 8.

5.2.1.1 Survey Sites and Timing

Flora and fauna were surveyed at 13 sites within, and one site (Wi'i Creek) outside of, the upstream PAOI. Surveys were conducted in two 'phases' to provide a seasonal sampling perspective (Phase 1—northwest season, Phase 2—southeast season; Section 3.2.1). Table 5.1 lists the location, timing and elevations covered at each site. Team survey coverage at each site is shown in Figures 5.1 and 5.2. Information on the survey coverage of individual disciplines is provided in the flora and fauna technical study reports (Annexes 1A and 2 to 6).

Table 5.1 – Location, Timing and Elevations Covered at Flora and Fauna Survey Sites

Survey Phase/Site	Camp Position (PNG94)[A]	Survey Period (2016)	Camp Elevation (m asl)	Surveyed Elevations (m asl)
Phase 1 Surveys (Northwest Season)				
Site 1	294689 9209644	19 to 27 January	100	50 to 380
Site 2	291894 9202769	27 January to 2 February	95	55 to 295
Site 3	303459 9171560	2 to 9 February	130	40 to 170
Site 4	300251 9186944	9 to16 February	30	25 to 90
Phase 2 Surveys (Southeast Season)				
Site 5	294432 9191260	21 June to 2 July	20	15 to 45
Site 6A	—	27 and 28 June	—	30 to 75
Site 6B	—	25 June	—	5 to 30
Site 6C	—	30 June	—	(aerial)
Site 6D	—	26 June	—	185 to 310
Wi'i Creek	—	30 June	—	75 to 320
Site 7	308305 9153930	2 to 9 July	15	5 to 120
Site 8	308835 9138610	9 to 15 July	5	0 to 70
Site 8M	—	11 to 13 July	—	0 to 5
Site 9	315970 9131180	15 to 19 July	0	0 to 70

[A] Camp positions are shown only for the eight 'principal' survey sites.

The main survey program was based on sampling over multiple days (range: 4 to 12 days) at eight 'principal' survey sites provided with field-based accommodation (Sites 1 to 5, 7, 8 and 9). Accommodation at most principal sites (n = 7) was provided at temporary 'fly camps' constructed specifically for the purpose of the present study. Accommodation at Site 1 was provided at an existing Project facility (Antelope 3 Operations Camp). While based at the principal survey sites, shorter expeditionary visits were made to five additional sites of interest (Sites 6A, 6B, 6D, 8M and Wi'i Creek), an aerial survey of all oxbow lakes and adjacent swamp habitats in the southwest of PRL-15 (Site 6C; 'PRL-15 oxbow wetlands'; see Section 6.5.2.2) was undertaken, and two members of the non-volant mammal team (K. Aplin and J. Novera) visited ten villages in

the PRL-15 area (Wabo, Ura, Poroi 1, Subu 2, Mapaio Fish Camp) and the export pipeline corridor area (Evara, Aivai, Oru/Hururu, Kavava/Mareke, Harevavo/Marea).

Additional to the main survey program, in November 2015, I. Woxvold undertook an aerial reconnaissance of the PRL-15 and export pipeline corridor areas (Figures 5.1 and 5.2).

5.2.1.2 Site Selection

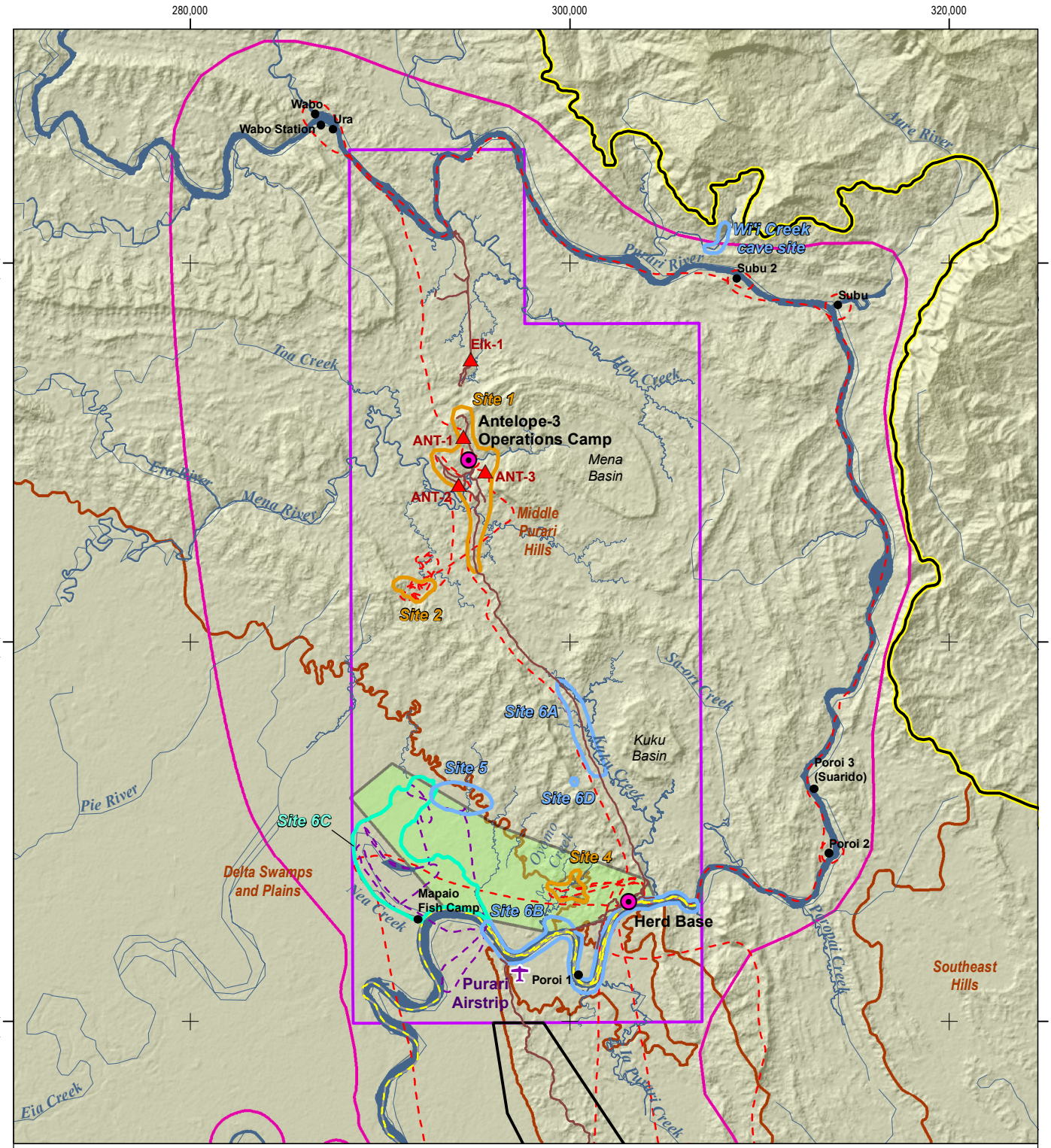
Surveys were conducted in all ecological zones. Based on review of existing data, mapping analysis and aerial reconnaissance, fly camps and short-visit sites were positioned to:

- Maximize coverage of vegetation types occurring in areas potentially affected by Project development. Vegetation within the study area (Section 6.2) occurs as structural variants and combinations of 13 natural vegetation types, 12 of which were accessed by flora and fauna specialists (Table 5.2). The one unsurveyed type—Small crowned alluvial forest (Ps)—covers 781 ha in the extreme north of the upstream PAOI, north of PRL-15 and nearly 5 km from the nearest proposed Project development site.
- Provide seasonal coverage of key vegetation types, particularly in light of the Phase 1 surveys being conducted during the 2015/2016 ENSO event. Seasonal sampling was achieved for all three vegetation types surveyed during Phase 1—Hill forest (Hm), Open alluvial forest (Po) and Swamp forest (Fsw). Social constraints prevented access to coastal vegetation types during the Phase 1 surveys.
- Provide access to specific microhabitat and local landscape features of interest to various species specialists (potentially supporting species-level sensitivities).
- In sparsely populated sectors of the upstream PAOI (north of the Southeast Coast ecological zone), provide access to habitats distant from major settlements and associated hunting activity.

While no terrestrial biodiversity surveys were conducted along the Wame-Varoi River or the Urika-Ivo River in the river transport route sectors of the upstream PAOI, the vegetation types mapped along these watercourses occur in other surveyed areas.

5.2.1.3 Survey Methods

Field surveys followed a rapid assessment protocol (RAP), combining a number of techniques to maximize the completeness of species inventories and the likelihood of locating ecologically sensitive features, including rare and threatened taxa, in the time available at each site. Table 5.3 shows the sampling methods applied to each of the major taxonomic groups under investigation. Further detail on survey methods and the effort expended on each taxonomic group is provided in the flora and fauna technical study reports (Annexes 1A, 2 to 6).



SCALE: 1:300,000 @ A4

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Tracks
- Waterways
- Waterbodies
- PRL-15
- Upstream project area of influence*
- Export pipeline corridor
- Study area
- CPF, logistics base and airstrip area
- Oxbow wetlands
- Ecological zone boundary

Facilities
- Base camp
- Wellpad
- Airstrip

Survey routes
- 2015 aerial reconnaissance
- Site C aerial survey
- Boat survey route

Terrestrial Biodiversity Survey Sites
- Phase 1
- Phase 2

** Largely represents the terrestrial biodiversity baseline survey area*

Note: Not all communities have been verified in the field. Only Government administrative centres and notable locations have been labelled for context.

TITLE: Flora and Fauna Survey Coverage of the PRL-15 Area

FIGURE: 5.1

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-81609 **REVISION:** D

DATE: 21/07/2017

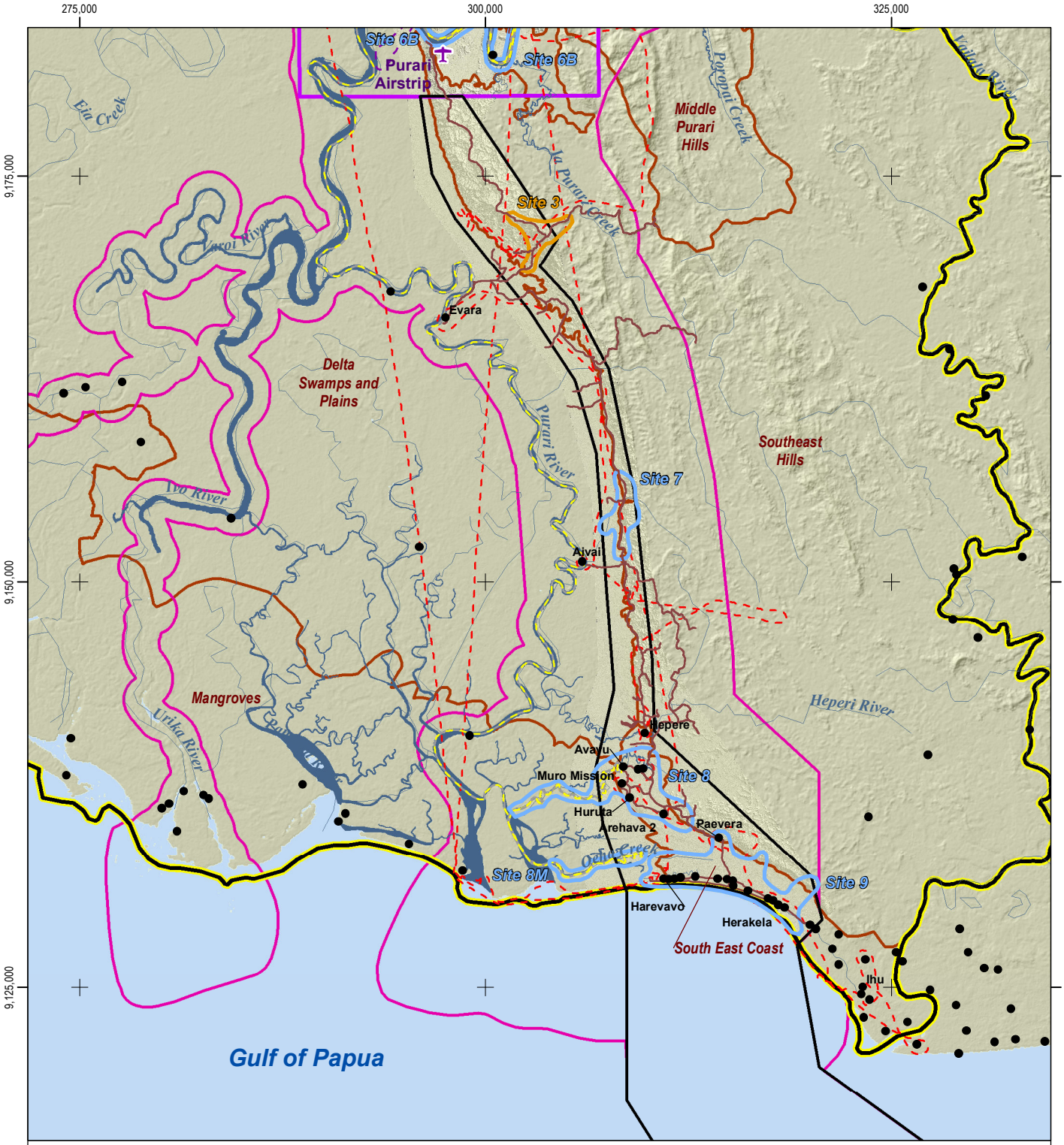
DATA SOURCES:
Facilities, CPF logistics base and airstrip area, towns and villages, waterways, wellpads, tracks, airstrip, export pipeline corridor, PRL-15, hillshade supplied by ERIAS Group and TOTAL (2015-2016). Study area (ERIAS Group 2017). DEM (Planet Observer 2015). Upstream project area of influence digitised by Mipela GeoSolutions based on data supplied by ERIAS Group (2017). Oxbow wetlands, ecological zones (Iain Woxvold 2016). Terrestrial biodiversity survey sites, survey routes, Mena and Kuku basins (Iain Woxvold 2017).

CLIENT:
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:
Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-81609-Figure 5.1-D.mxd



SCALE: 1:350,000 @ A4

0 2 4 6 8 10 Kilometres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Airstrip
- Tracks

Survey routes

- 2015 aerial reconnaissance
- Site C aerial survey
- Boat survey route
- Waterways
- Waterbodies
- PRL-15
- Upstream project area of influence*
- Export pipeline corridor
- Study area
- Ecological zone boundary

Terrestrial Biodiversity Survey Sites

- Phase 1
- Phase 2

N

*Largely represents the terrestrial biodiversity baseline survey area

Note: Not all communities have been verified in the field. Only Government administrative centres and notable locations have been labelled for context.

TITLE: Flora and Fauna Survey Coverage of the Export Pipeline Corridor area

FIGURE: 5.2

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79673 **REVISION:** C

DATE: 13/04/2017

DATA SOURCES:

CPF, logistics base and airstrip area, town and villages, waterways, wellpads, tracks, airstrip, export pipeline corridor, PRL-15, hillshade supplied by ERIAS Group and TOTAL (2015-2016). Study area (ERIAS Group 2017). Upstream project area of influence digitised by Mipela GeoSolutions based on data supplied by ERIAS Group (2017). Oxbow wetlands, ecological zones (Iain Woxvold 2016). Terrestrial biodiversity survey sites, survey routes (Iain Woxvold 2017).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79673-Figure 5.2-C.mxd

Table 5.2 – Natural Vegetation Types Accessed During Flora and Fauna Surveys

Broad Vegetation Group/Vegetation Type	FIMS Code	Phase 1	Phase 2[A]
Hill Forest			
Hill forest	Hm	X	X
Small crowned hill forest	Hs		X
Alluvial Forest			
Alluvial forest	Pl		X
Open alluvial forest	Po	X	X
Small crowned alluvial forest	Ps		
Riverine seral forest	Fri		Xb
Freshwater Swamp Vegetation			
Swamp forest	Fsw	X	X
Swamp woodland	Wsw		X
Herbaceous swamp	Hsw		X
Swamp grassland	Gsw		X
Riverine successional grassland	Gri		Xb
Mangroves			
Mangrove	M		X
Littoral Forest			
Littoral forest	B		X

Xb = accessed by boat only.

Table 5.3 – Biodiversity Survey Methods

Survey Method	Vascular Plants	Non-volant Mammals	Bats	Birds	Herpetofauna	Odonates
Visual searches	X	X	X	X	X	X
Audial detection		X	X	X	X	
Mist-nets			X	X		
Harp traps			X			
Camera traps		X		X		
Snap-traps		X				
Elliot traps		X				
Hand nets			X			X
Sound recording				X	X	
Sound playback				X		
Ultrasonic call recording			X			
Specimen collection	X	X	X	X	X	X
Informal interviews with local landowners		X	X	X	X	X

5.2.2 Other Vegetation Related Surveys

Additional field surveys were undertaken by Booyong Forest Science to support various vegetation related studies. These include:

- Vegetation Mapping Study—aerial survey to verify vegetation types and potential mapping anomalies within the PRL-15 and export pipeline corridor areas.
- Forestry Study—aerial survey to obtain an overview of commercial forestry and associated infrastructure, to verify the location of current operations, and to confirm the commercial forest types where logging has occurred. Interviews were conducted with industry representatives at Evara logging camp.
- Weeds Study—weeds were assessed at a range of disturbed and natural sites, including Project infrastructure sites, along logging roads, at a sample of villages and at each of the principal flora and fauna survey sites.
- Deforestation Study—aerial survey, aerial photography and ground-truthing to refine results of the Deforestation Study undertaken separately to the terrestrial biodiversity baseline study

Further details are provided in the relevant reports.

5.3 Assessing Vegetation

5.3.1 Vegetation Mapping

Vegetation mapping and descriptions presented in this report are based on the FIMS dataset (Hammermaster and Saunders, 1995a, b). FIMS provides broad-scale (1:100,000) national vegetation mapping based on 1970s aerial photography with limited ground-truthing and limited areas subject to logging updated in the 1990s. As such, ground surveys regularly reveal inaccuracies in broad-scale mapping, mapping of the condition and distribution of vegetation in developed or dynamic landscapes is often outdated, and small-scale variations relevant to management decisions are often not apparent. Accordingly, in key Project areas (within the upstream PAOI) the FIMS vegetation maps have been revised through examination of recent aerial/satellite imagery, LIDAR digital elevation modelling (DEM) and ground and aerial surveys.

Vegetation mapping in parts of PRL-15 and the export pipeline corridor was updated under the Vegetation Mapping Study (Annex 1B). In other areas, recent aerial/satellite imagery revealed notable changes (since the time of the original FIMS mapping) within Purari delta environments to the study area shoreline and to the routes of the Purari River and its distributary courses. Accordingly, where recognizable from the imagery, the FIMS mapping in areas within the upstream PAOI and along the study area coast was further revised by I. Woxvold and Mipela GeoSolutions:

- To align with the current shoreline and courses of the Purari, Ivo-Urika, Wame-Varoi and Vailala rivers.
- To map areas of successional vegetation (e.g., Riverine successional grassland (Gri)) on recently aggraded riverine scroll arches.
- To more accurately map areas of freshwater swamp vegetation (e.g., Swamp woodland (Wsw) and Swamp forest (Fsw) as indicated by the presence of Sago *Metroxylon sagu*).

- In the southeast of the study area, to extend those mapping units revised within the export pipeline corridor under the Vegetation Mapping Study.
- To map the modern boundaries of settlements and surrounding areas of anthropogenic converted lands.

Outside of the upstream PAOI and away from the coast, the arrangement of natural vegetation types within the study area is based on the original FIMS mapping.

As a final step, recent logging disturbance and loss of natural vegetation across the study area were assessed in the following ways:

- Overlay maps of post-logging secondary forest were prepared by combining 'harvested areas' mapped under the Deforestation Study and areas of secondary forest digitized from the PNG Forest Observatory website (http://forest.pngsdf.com/). Logged areas within PRL-15 and the export pipeline corridor were verified, and adjusted as required, based on visual assessment of aerial/satellite imagery and ground truthing from the flora and fauna surveys.
- Recent vegetation losses, additional to those mapped under FIMS (original and revised) as converted lands, were identified based on areas of non-vegetation mapped as 'roads' and 'bare ground' under the Deforestation Study. These were generally too small or too narrow to map separately at the scale of vegetation mapping adopted in this study.

5.3.2 Terminology

Vegetation types are referred to using FIMS codes and a set of FIMS-equivalent terms developed specifically for this study. The vegetation terms are based on the founding FIMS descriptors (Paijmans, 1976; Hammermaster and Saunders, 1995a) but are generally less cumbersome. A list of the FIMS descriptor terms applicable to study area vegetation is presented in Appendix 3.

Where a specific vegetation type is referred to in the text it is capitalized and followed in brackets by its FIMS code, for example 'Hill forest (Hm)' and 'Open alluvial forest (Po)'. In other cases, more general terms are used that apply to multiple possible variants within the study area (and more widely in PNG). These appear without capitals or a FIMS code, for example 'hill forest' and 'alluvial forest'. These generic descriptors follow the broad vegetation groupings (see Section 6.2.2), in these examples coded 'H' and 'P' respectively.

Logging disturbance is distinguished from forest loss for the purposes of this study. Regenerating logged forest is here classified as a natural vegetation type, following IFC principles.

5.4 Protocols Used

5.4.1 Conservation Listed Species

Conservation listed species fall into the following three categories.

5.4.1.1 IUCN Listed Species

'IUCN listed' species are here defined as those species listed in the IUCN Red List (IUCN 2016) as Threatened, Near Threatened (NT) or Data Deficient (DD). Threatened species are further divided into three categories: in descending order of conservation priority—Critically Endangered (CR), Endangered (EN) and Vulnerable (VU). IUCN categories rank the relative risk of individual taxa becoming extinct based on a set of standardized criteria. Definitions for each IUCN listed category are presented in Table 5.4.

Most species appearing in this report are classified as 'Least Concern' (LC) by the IUCN. These taxa are not considered to be of conservation priority. Species whose conservation status has not been evaluated by the IUCN (e.g., undescribed species, most reptiles and invertebrates) are listed as Not Evaluated (NE). Although not considered to be of conservation priority by virtue of this category, a number of Not Evaluated species are of conservation significance by virtue of one or more additional criteria considered in this baseline assessment (e.g., restricted-range status).

Table 5.4 – IUCN and CITES Listed Categories

Category		Definition[A]
IUCN		
Threatened	Critically Endangered (CR)	A taxon is Critically Endangered when the best available evidence indicates that it is facing an extremely high risk of extinction in the wild
	Endangered (EN)	A taxon is Endangered when the best available evidence indicates that it is facing a very high risk of extinction in the wild
	Vulnerable (VU)	A taxon is Vulnerable when the best available evidence indicates that it is facing a high risk of extinction in the wild
Near Threatened (NT)		A taxon is Near Threatened when it is close to qualifying for or is likely to qualify for a threatened category in the near future
Data Deficient (DD)		A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that listing under a threatened category is appropriate
CITES		
Appendix I		Appendix I includes [but is not limited to] species threatened with extinction. Trade in specimens of these species is permitted only in exceptional circumstances
Appendix II		Appendix II includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival

[A] Definitions sourced from www.iucnredlist.org and www.cites.org. Contextual text added in square brackets.

5.4.1.2 Nationally Protected Species

Nationally Protected (P) species are those species listed as Protected under the Fauna Act. The list of nationally Protected species was obtained from Kula and George (1996).

5.4.1.3 CITES Listed Species

'CITES listed' species are here defined as those species listed under CITES Appendix I or Appendix II. These categories are defined in Table 5.4.

All CITES Appendix I species potentially occurring in the study area are also listed under an IUCN Threatened or Near Threatened category or are nationally Protected.

Numerous species from multiple broad taxonomic groups are blanket-listed under CITES Appendix II—for example all orchids, tree ferns, birds of prey and parrots. Given that most are neither IUCN listed nor nationally Protected and are not considered to be of conservation priority, and that the Project will not be involved in wildlife trade, the CITES database was not screened for a full list of potentially occurring CITES Appendix II species.

CITES listings are noted for species presented in this report and in the flora and fauna technical study reports (Annex 1A, 2 to 6). However, for the reasons described above they do not independently influence the assessment of species level sensitivities in this study, and they do not feature in summaries of conservation listed species appearing below (Section 6.3.2).

5.4.2 Endemic and Restricted-Range Species

Regional patterns of endemism were summarized for fauna using a five-part classification scheme shown in Table 5.5 and Figure 5.3. This scheme was developed for this study and has been modified from that used in environmental impact assessments prepared recently for other projects in PNG. Endemism among locally occurring flora was not examined due to the cumbersome dataset (high species richness) and insufficient knowledge regarding the distribution of many taxa.

In discussing patterns of regional endemism, the term ‘New Guinea region’ refers to mainland New Guinea together with its major ‘satellite island’ groups (the Raja Ampat Islands, the islands of Geelvink Bay and the Aru Islands in Indonesia, and the Louisiade and d’Entrecasteaux archipelagos in PNG) and closer offshore islands. This definition follows that used in other regional assessments (Mayr, 1941; Beehler and Pratt, 2016).

Table 5.5 – Regional Endemism Categories

Code	Region of occurrence
1	Occur more widely in the Indo-Pacific
2	Endemic to the ‘New Guinea region’, the Bismarck Archipelago and Maluku Islands
3	Endemic to the New Guinea region
4	Endemic to mainland New Guinea
5	Endemic to the southern watershed of mainland New Guinea and the northern watershed of the southeast peninsula (not west of Huon Gulf)

At a finer geographic scale, ‘restricted-range’ species are here defined as those with an extent of occurrence of less than 50,000 km^2. This threshold is applied under IFC PS6 to all faunal groups investigated in this study. All faunal groups investigated in the technical studies were screened for restricted-range species potentially occurring in the study area.

A more limited screening approach was applied to flora, including all species recorded in the study area and those potentially occurring but known only from Gulf Province or from adjacent provinces in areas below 500 m asl within catchments that overlap the study area. Local floristic communities are too species rich, and the relevant data too incomplete, to permit a more comprehensive analysis. While this approach yields an incomplete set of potentially occurring restricted-range plant species, it is biased towards those species that have a more limited geographic range and are therefore of relatively high conservation value.

5.4.3 Taxonomy and Nomenclature

For plants and mammals, taxonomic arrangements and nomenclature (scientific and English common names) generally follow those contained within the current IUCN Red List. Avian taxonomy follows the International Ornithological Congress (IOC) World Bird List (version 6.1) (Gill and Donsker, 2016). Taxonomy and nomenclature for frogs follows Amphibiaweb[6] and for reptiles follows the Papuan Herpetofauna website[7]. Where the usage departs from these listings, it is because recent studies indicate an alternative arrangement.

In many cases it is not possible to assign an established name to a species encountered during survey. Taxonomic research on New Guinean flora and fauna is ongoing, and the taxonomic framework of many major groups remains incomplete. Insufficient data may be available for confident assignation, or the species may be scientifically undescribed. To account for various levels of uncertainty the following system of nomenclatural tags and abbreviations is applied in this report and in the flora and fauna technical studies.

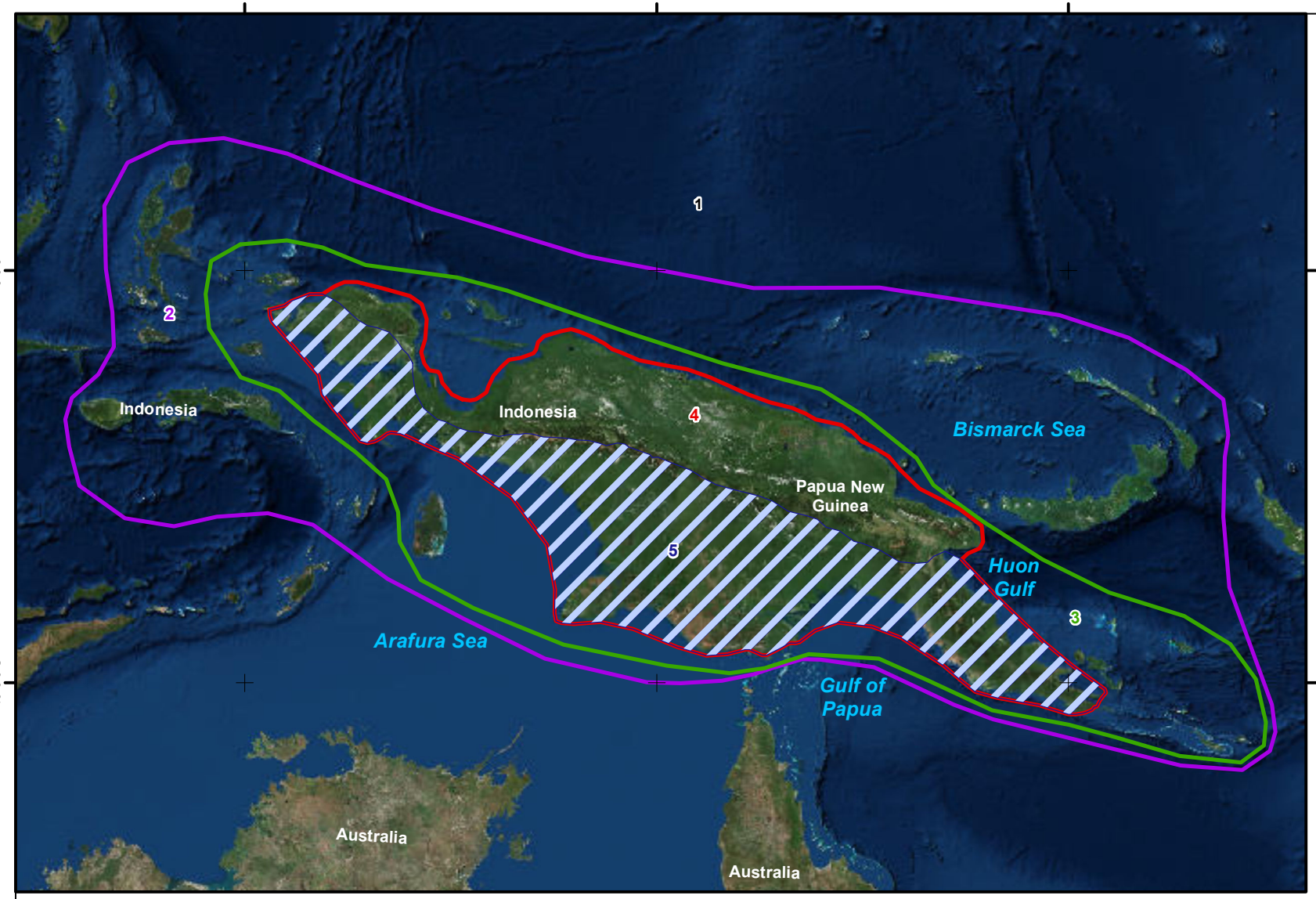
- '**sp**.' (singular) or '**spp**.' (plural). These abbreviations are used in cases where one or more taxa were not able to be identified to species level, for example if a frog is seen insufficiently to identify to species level (*Litoria* sp.), or where reference is made to multiple species within a genus, for example where referring to fig trees (*Ficus* spp.).
- '**cf**.'—for example: *Paramelomys* cf*. levipes*. This abbreviation is used to refer to species that are similar to a named taxon, but for which insufficient data are available to confidently assign specimens to any particular species. The taxon may be part of a known species complex, and/or may be scientifically undescribed (i.e., unnamed), though further work would be required to determine its identity.
- '**sp. 1**', '**sp. 2**', etc.—for example: *Begonia* sp. 1, *Begonia* sp. 2, *Begonia* sp. 3. The numeric system is used where taxonomic identity is confidently resolved and the species is scientifically undescribed. Distinction is made between: (a) 'new-to-science' species discovered for the first time during Project surveys, and; (b) other 'undescribed' species previously discovered but yet to be scientifically described.

Where species are mentioned in the text the scientific name appears with the capitalized English name on first mention and only the common name is used thereafter. The scientific name is used exclusively for species that lack a commonly applied English name.

5.4.4 Mapping and Spatial Conventions

All maps and coordinates appearing in this report use the PNG94 geographic coordinate system (datum). All elevations are given as meters above sea level (m asl).

6 Available at http://amphibiaweb.org/
7 Available at http://pbs.bishopmuseum.org/papuanherps/



TITLE: Map of Regional Endemism Categories

FIGURE: 5.3

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-81812 **REVISION:** B

DATE: 31/07/2017

DATA SOURCES:

Regional endemism (ERIAS 2017). Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ER\002 Elk Antelope LNG Project EIS-ESHIA\Work Request\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-81812-Figure 5.3-B.mxd

5.5 Assigning Sensitivity

5.5.1 Overview

The 'sensitivity' of biodiversity values is here determined for this baseline study to facilitate the subsequent assessment of potential Project-related impacts and the development of appropriate avoidance, mitigation and management measures. The baseline sensitivity of biodiversity values is evaluated on existing conditions and threats at the species, ecosystem (major environments) and focal site/habitat (e.g., caves) scales.

Each biodiversity value is assigned a sensitivity ranking based on its inherent value and sensitivity to change. These qualities are aligned with the key concepts of 'irreplaceability' and 'vulnerability' outlined in IFC PS6. Relevant sensitivity attributes include:

- Intrinsic worth—including the feature's importance to supporting sensitive communities and/or species, and conservation status as applied by governments and other authorities.
- Intactness—the degree to which the biodiversity value under consideration remains unchanged by anthropogenic impact processes.
- Replacement potential—a measure of the value's abundance and distribution within and beyond the study area and biogeographic region, incorporating the potential for a representative or equivalent example to be found to replace or buffer any losses.
- Recovery potential—a measure of the value's ability to buffer (ecosystems/focal sites) or adapt to (species) changing conditions without affecting its inherent value (e.g., a habitat's potential to support species/communities) and/or other sensitivity attributes (e.g., a species' conservation status, abundance/rarity).

5.5.2 Sensitivity of Ecosystems and Focal Sites

The sensitivity of each ecosystem (major environment) and focal site/habitat was determined according to a numeric score applied to each of the sensitivity attributes listed above. Example criteria used to score each attribute are presented in Appendix 1. The sum of all attribute scores was then used to determine sensitivity according to the following system:

- Score less than 8: Not Sensitive.
- Score 8–10: Low Sensitivity.
- Score 11–13: Moderately Sensitive.
- Score 14–16: Very Sensitive.
- Score 17–20: Extremely Sensitive.

5.5.3 Species Level Sensitivities

At the species level, to some degree the attributes listed in Section 5.5.1 are already considered in the designation of formal conservation categories such as IUCN listings. These designations are among the key criteria used to rank species sensitivity in this baseline characterization (Table 5.6). However, formal status categories are often an inexact measure of a species' true conservation status. This is particularly relevant in the New Guinean context, since:

- The list of nationally Protected species reflects a legislative focus on culturally significant wildlife rather than on species that are of conservation concern.
- Many species have not been evaluated by the IUCN or are listed as Data Deficient on the grounds that insufficient data are available to make a reliable assessment.
- Regional biodiversity knowledge is lacking; the discovery of species new-to-science is commonplace (Thompson, 2011), and among named species the standard of information normally required for IUCN assessment (e.g., population sizes and trends) is rarely met.

IUCN Data Deficient and Not Evaluated species often receive limited focus in conservation assessments. In reality, species in these categories vary in their 'true' conservation status, from widespread and secure but poorly known, through to those that are genuinely rare or declining. To account for this variation, in this assessment the sensitivity of nationally Protected, IUCN Data Deficient, Least Concern and Not Evaluated species is assigned on a case-by-case basis and according to the expert opinion of species specialists (Table 5.6).

The sensitivity of new-to-science, other scientifically undescribed and restricted-range species was determined using a system similar to that described above for ecosystems and focal sites. It is based on four principal factors:

- Degree of habitat specialization.
- Dispersal ability (flora only).
- Geographic spread of recorded occurrence.
- Abundance/rarity at recorded sites.

Each species was scored according to a numeric ranking applied to each factor and the summed total used to rank sensitivity (Table 5.6). Example criteria used to rank scores within each factor are presented in Appendix 2.

The acute lack of available data for many New Guinean species presents a particular challenge in conservation assessments. While some taxa, such as herpetofauna and birds, have been well sampled in neighboring landscapes (Kikori and Lakekamu basins, Purari catchment uplands), others have been well covered in only some or in none of these areas. This results in a mixed ability to form conclusions about the potential for new-to-science or undescribed species, and for many named restricted-range species, to occur in adjacent regions. To account for this variation, criteria applied to the 'spread of occurrence' varied according to prior survey effort in surrounding areas (examples in Appendix 2). Many species are known only from within the study area. Until further information about the wider occurrence of these species becomes available, all are treated as Moderately Sensitive or higher, the final ranking of each species depending in part upon the availability and condition of suitable habitat within the study area, and on connectivity with comparable environments in adjacent areas.

For the purposes of this study, the term 'species of conservation significance' is defined as those species ascribed a sensitivity ranking of Moderately Sensitive or higher.

5.6 Permits Obtained

Flora and fauna surveys were conducted in accordance with permitting procedures of the Government of PNG as administered by CEPA. The relevant permits are presented in Annex 3 and 4.

Table 5.6 – Criteria Used to Assess the Sensitivity of Conservation Listed, New-to-Science, Undescribed and Restricted-range Species Present in the Study Area

Sensitivity	Not Sensitive (NS)	Low Sensitivity (LS)	Moderately Sensitive (MS)	Very Sensitive (VS)	Extremely Sensitive (ES)
Conservation listed species	♦ Invasive species ♦ Native species well adapted to habitat loss/degradation	♦ CITES Appendix II ♦ IUCN LC ♦ UCN DD or NE species considered to be common and/or widespread according to expert opinion	♦ Protected under the Fauna Act ♦ CITES Appendix I ♦ IUCN NT ♦ IUCN DD, NE or LC species whose true conservation status is likely to be equivalent to IUCN NT at the national or global scale, according to expert opinion	♦ IUCN VU and EN ♦ IUCN non-Threatened (DD, NT, NE or LC) species whose true conservation status is likely to be equivalent to IUCN VU or EN at the national or global scale, according to expert opinion	♦ IUCN CR ♦ IUCN non-CR species whose true conservation status is likely to be equivalent to IUCN CR at the national or global scale, according to expert opinion
New-to-science, undescribed and restricted-range species	Undescribed species common and/or widespread beyond the study area, that are not restricted-range and are well adapted to habitat loss/degradation	Sensitivity score <6 and known from outside the study area	♦ Species known only from the study area and sensitivity score flora 1–9 or fauna 1–7 ♦ Fauna score 6–7 and known from outside the study area but restricted-range	Species known only from the study area and sensitivity score flora 10–13 or fauna 8–10	Species known only from the study area and sensitivity score flora 14–15 or fauna 11–12

6. Baseline Characterization

6.1 Regional Biodiversity Setting

New Guinea is among the most biologically diverse and endemically rich regions on Earth (Olson and Dinerstein, 1998; Brooks et al., 2006; Jenkins et al., 2013). The world's second largest island, it supports the third largest block of unbroken tropical rainforest (behind the Amazon and the Congo) and the largest tract of primary rainforest remaining in the Asia-Pacific region (Beehler, 2007; Bryan and Shearman, 2015). New Guinea's forests support more than 5% of the world's plant and animal species on less than 1% of its land surface (Faith et al., 2001).

In a national context, PNG ranks within the top ten countries for endemism and/or diversity of all terrestrial vertebrate groups, and fourth overall in the diversity and endemism of terrestrial vertebrates per unit area (Mittermeier et al., 1997).

Accordingly, that part of New Guinea in which the study area is situated has figured heavily among global biodiversity priority assessments. Examples are listed in Table 6.1. Most assessments have highlighted the intact values present in this region of PNG and across New Guinea in general. In a synthesis involving many of these assessments, Brooks et al. (2006) showed that New Guinea ranks among the world's most irreplaceable and presently relatively intact biodiversity regions.

Table 6.1 – Example Global Biodiversity Priority Areas Within Which the Study Area is Located

Source	Region (e.g., Country, Ecoregion, Ecosystem)	Value/Risk
Value Assessments		
Mittermeier et al. (1997)	Papua New Guinea	Megadiverse nation
Mittermeier et al. (2003)	New Guinea	High biodiversity wilderness area
Jenkins et al. 2013	New Guinea	Priority area—high density of 'small-ranged vertebrates'
Olson and Dinerstein (1998, 2002)	New Guinea lowland forests	Global 200: Earth's most biologically valuable ecosystems
	New Guinea rivers and streams	
Sanderson et al. (2002)	Southern New Guinea Freshwater Swamp Forests	'Last of the Wild'—biome's 10% wildest areas
	Southern New Guinea Lowland Rain Forests	
Wikramanayake et al. (2002)	Southern New Guinea Lowland Rain Forests	Ecoregions globally outstanding for endemism and biological distinctiveness. Rank highest in plant species richness
Stattersfield et al. (1998)	South Papuan Lowlands (<1,000 m asl)	Endemic Bird Area
Risk Assessments		
Bryant et al. (1997)	Western and Gulf Province forests	Threatened 'Last Frontier' forest
Hoekstra et al. (2005)	Southern New Guinea Freshwater Swamp Forests	Vulnerable ecoregions
	Southern New Guinea Lowland Rain Forests	

6.2 Vegetation

The study area supports a diverse array of tropical lowland vegetation communities. In the following sections, the broader regional phytogeographic setting is first outlined (Section 6.2.1), followed by summaries of the distribution of natural vegetation types (Section 6.2.2) and overlying patterns of anthropogenic disturbance (Section 6.2.3) within the study area. This is followed by descriptions of the structure, floristics and condition of the vegetation types, with a focus on vegetation present in key Project areas (Section 6.2.4).

6.2.1 Ecoregional Setting

In the broadest attempt at mapping vegetation communities, Olson, Wikramanayake and colleagues (Olson et al., 2001; Wikramanayake et al., 2002) delineated global forest environments into a series of 'terrestrial ecoregions'. Three ecoregions overlap the study area. Their distribution follows closely the arrangement of ecological zones:

- Southern New Guinea Lowland Rain Forests—includes all non-swamp forest habitats present below 1,000 m asl in New Guinea's southern watershed. It comprises the Middle Purari Hills, Southeast Hills and Southeast Coast ecological zones.
- Southern New Guinea Freshwater Swamp Forests—coincides with the Delta Swamps and Plains ecological zone.
- New Guinea Mangroves—coincides with the Mangroves ecological zone.

The arrangement of terrestrial ecoregions with respect to major Project components is listed in Table 6.2.

Table 6.2 – Terrestrial Ecoregions Underlying Major Project Components

Terrestrial Ecoregion	Upstream PAOI	PRL-15			Export Pipeline Corridor	River Transport Corridors
		Entire PRL-15 Area	Gas Field	CPF, Logistics Base and Airstrip Area		
Southern New Guinea Lowland Rain Forests	X	X	X	X	X	
Southern New Guinea Freshwater Swamp Forests	X	X		X	X	X
New Guinea Mangroves	X				X	X

6.2.2 Natural Vegetation Within the Study Area

Thirty-two FIMS-coded natural vegetation types are mapped within the study area[8], plus two FIMS types denoting areas where the original vegetation has been converted for anthropogenic land use ('converted lands'). The natural vegetation types occur as structural variants and combinations ('complexes' of more than one base type) of 13 'base' vegetation types (Table 5.2), and are further arranged into five broad vegetation groups based on vegetation structure and floristics and on landform affiliations (following Paijmans, 1976; Hammermaster and Saunders, 1995a)—hill forest, alluvial forest, freshwater swamp vegetation, mangroves and

[8] Excluding the degree of habitat/canopy disturbance mapped within vegetation types.

littoral forest. Table 6.3 lists the vegetation types within each broad vegetation group, their FIMS codes and areal extent within the study area.

Vegetation is mapped for the study area in Figure 6.1. More detailed vegetation maps are provided for key Project areas in Figures 6.2 and 6.3.

Table 6.3 – Vegetation Types Within Broad Vegetation Groups and their Extent Within the Study Area

Broad Vegetation Group/Vegetation Type	FIMS Code	Study Area	
		Area (km^2)	% Cover
Hill forest		**3,409.79**	**48.70**
Hill forest	Hm	3,013.61	43.04
Hill forest, *Araucaria* noted	Hm.Ar	19.24	0.27
Hill forest/Small crowned hill forest	Hm/Hs	55.86	0.80
Small crowned hill forest	Hs	321.08	4.59
Alluvial forest		**1,161.94**	**16.59**
Alluvial forest	Pl	113.05	1.61
Alluvial forest/Swamp forest	Pl/Fsw	35.40	0.51
Open alluvial forest	Po	334.46	4.78
Open alluvial forest/Swamp forest	Po/Fsw	441.24	6.30
Open alluvial forest/Swamp forest/Hill forest	Po/Fsw/Hm	78.77	1.12
Open alluvial forest/Swamp forest/Mangrove	Po/Fsw/M	101.38	1.45
Open alluvial forest/Herbaceous swamp	Po/Hsw	0.85	0.01
Open alluvial forest/Swamp woodland	Po/Wsw	8.64	0.12
Small crowned alluvial forest	Ps	39.61	0.57
Riverine seral forest	Fri	8.54	0.12
Freshwater swamp vegetation		**1,792.43**	**25.60**
Swamp forest	Fsw	642.83	9.18
Swamp forest with *Campnosperma*	FswC	89.10	1.27
Swamp forest/Swamp grassland	Fsw/Gsw	0.33	0.01
Swamp forest/Mangrove	Fsw/M	121.75	1.74
Swamp forest/Swamp woodland	Fsw/Wsw	260.60	3.72
Swamp woodland	Wsw	423.07	6.04
Swamp woodland/Swamp forest	Wsw/Fsw	34.57	0.49
Swamp woodland/Swamp grassland	Wsw/Gsw	67.20	0.96
Swamp woodland/Herbaceous swamp	Wsw/Hsw	77.83	1.11
Swamp grassland/Swamp forest	Gsw/Fsw	3.38	0.05
Swamp grassland/Swamp woodland	Gsw/Wsw	3.82	0.06
Riverine successional grassland	Gri	2.05	0.03
Herbaceous swamp	Hsw	47.67	0.68
Herbaceous swamp/Swamp grassland	Hsw/Gsw	0.75	0.01
Herbaceous swamp/Swamp forest	Hsw/Fsw	0.53	0.01
Herbaceous swamp/Swamp woodland	Hsw/Wsw	16.95	0.24
Littoral forest		**1.78**	**0.03**
Littoral forest	B	1.78	0.03
Mangroves		**603.63**	**8.62**
Mangrove	M	603.63	8.62

Table 6.3 – Vegetation Types Within Broad Vegetation Groups and their Extent Within the Study Area (cont'd)

Broad Vegetation Group/Vegetation Type	FIMS Code	Study Area	
		Area (km^2)	% Cover
Converted lands		**32.17**	**0.46**
Land use	O	30.07	0.43
Urban areas	U	2.10	0.03
Other losses*	**n/a**	**44.23**	
Total land area		**7,001.74**	**100.00**
Total natural vegetation cover		**6,924.99**	**98.90**

* Areas of non-vegetation mapped as 'roads' and 'bare ground' under the Deforestation Study (see Section 5.3.1). Mapped separately to the vegetation mapping, they are subtracted independently from total natural vegetation cover (but not total land area) to calculate the proportion of the study area supporting natural vegetation.

Including both primary and secondary forest types (Section 6.2.3), the study area land surface is covered almost entirely in natural vegetation (98.9%; Table 6.3; Figure 6.1).

Within the study area landscape, landform, topography and geology are the principal determinants of vegetation community structure[9]. Each broad vegetation group occupies a distinct physical environment, and as the ecological zones are defined principally according to landform and vegetation (Section 3.1.3), each in turn supports a distinct composition of broad vegetation groups (Figure 6.4). Uplifted landforms of the Middle Purari Hills and Southeast Hills support large expanses of hill forest. Recent depositional landforms of the Delta Swamps and Plains support a complex mosaic of alluvial forest and freshwater swamp vegetation, while those under marine tidal influence in the Mangroves ecological zone are covered mostly by mangrove ecosystems. The beach ridges and plains of the Southeast Coast support the only mapped occurrences of Littoral forest (B), as well as a complex array of other broad vegetation groups and the largest area of converted lands present within the study area. Within these environments, further variations in terrain, soils, flooding and tidal regimes influence the distribution, structure and floristics of the component natural vegetation types (Section 6.2.4).

6.2.3 Anthropogenic Disturbance

Two types of anthropogenic disturbance to natural vegetation are here distinguished—degradation and loss. Degraded vegetation retains a natural species composition, albeit altered in structure and/or proportional floristic composition. It is mapped as natural vegetation in this report, and includes areas of post-logging secondary forest. Habitat loss results from the removal of natural vegetation or its replacement with predominantly non-native plant communities, including gardens and agroforestry.

6.2.3.1 Industrial Logging

Commercial forestry is the largest industrial land use activity to have operated within the study area. Seven logging concessions overlap 76.3% of the study area (Table 6.4; Figure 6.5), of which 71.1% (3,954.2 km^2) is considered commercially viable 'production forest' (Annex 1D). Four concessions are currently licensed (Table 6.4), two of which are active:

- Vailala Blk 3, covering 26.9% of the study area in the southeast, including all of the export pipeline corridor and the southern margins of PRL-15 (all land south of the Purari River). Current activities are focused in the north of this concession, with logs barged out along the Purari distributary from the Evara Logging Camp near Evara village.

[9] Climate and elevation having limited effect at the study area scale.

- East Kikori, covering 1.5% of the study area in the northwest, outside of the upstream PAOI and including parts of the Middle Purari Hills and the Delta Swamps and Plains ecological zones.

Other licensed concessions include Vailala and Baimuru Blk 3. Vailala has been logged out, and Baimuru Blk 3 is yet to be developed. In the west of the study area, portions of all three expired concessions have been logged (Table 6.4).

To date, approximately 1,300 km^2 of forest have been logged within the study area, nearly one quarter of the total area under concession (Table 6.4; Figure 6.5).

Harvesting has been most extensive in the Vailala and Vailala Blk 3 concessions. Approximately 1,125 km^2 of hill and alluvial forest have been logged, including most of the forest in the Southeast Hills ecological zone and parts of the Middle Purari Hills and Delta Swamps and Plains. In terms of key Project areas, some 50.4 km^2 of forest have been harvested from within the southeast corner of PRL-15 and approximately 116.3 km^2 from along nearly the entire length of the export pipeline corridor (Figure 6.5). The regenerating forest is variable in age. Forest in the southeast and northwest of this area, including areas within the export pipeline corridor north of the active Evara Logging Camp, was logged at least 15 years ago (before 2002). By contrast, some areas of forest in the northeast, between Poroi 1 and Poroi 2 villages, and in the southeast between Kilavi and Arehava 2 villages, have been logged within the last two to three years.

Elsewhere in the study area:

- More than 100 km^2 of alluvial forest were logged in the Baimuru area prior to 2002, from within the Pie Era, Eia River and parts of the Baimuru Blk 3 concessions.
- Nearly 70 km^2 of hill and alluvial forest have been logged in the East Kikori and Iowa River concessions.

Table 6.4 – Logging Concessions Overlapping the Study Area and Proportion of Forest Logged

Concession Name	Overlap with Study Area (km^2)[A]	Area Logged (km^2)[B]	% Logged	Concession Status
Vailala	52.53	41.12	78.28	Current, logged out
Vailala Blk 3	1,963.53	1,083.82	55.2	Current
Baimuru Blk 3	2,936.00	16.40	0.56	Current, no logging yet
East Kikori	109.00	57.89	53.11	Current
Iowa River	48.35	11.85	24.51	Expired
Pie-Era	374.43	56.59	15.11	Expired
Eia River	80.63	31.37	38.91	Expired
Total	5,564.47	1,299.04	23.35	

[A] Figures from Annex 1D.
[B] Figures from this study (see Section 5.3.1).

Hill forest and alluvial forest are the main production forest types within the study area. Typical logging operations in PNG harvest all the accessible commercial species >50 cm diameter at breast height (DBH) where free of defects. Compared with forests in other parts of PNG, local production forests contain relatively low merchantable timber volumes (Annex 1D).

Nevertheless, numerous high value (Group 1; PNGFA 1996) timber species were reported as common and/or widespread (recorded at three or more sites) in the study area during Project surveys, including*Pometia*, *Terminalia*, *Calophyllum*, *Dillenia papuana*, *Octomeles sumatrana*, *Intsia bijuga*, *Homalium foetidum*, *Anisoptera thurifera* and *Dracontomelon dao* (Annex 1A).

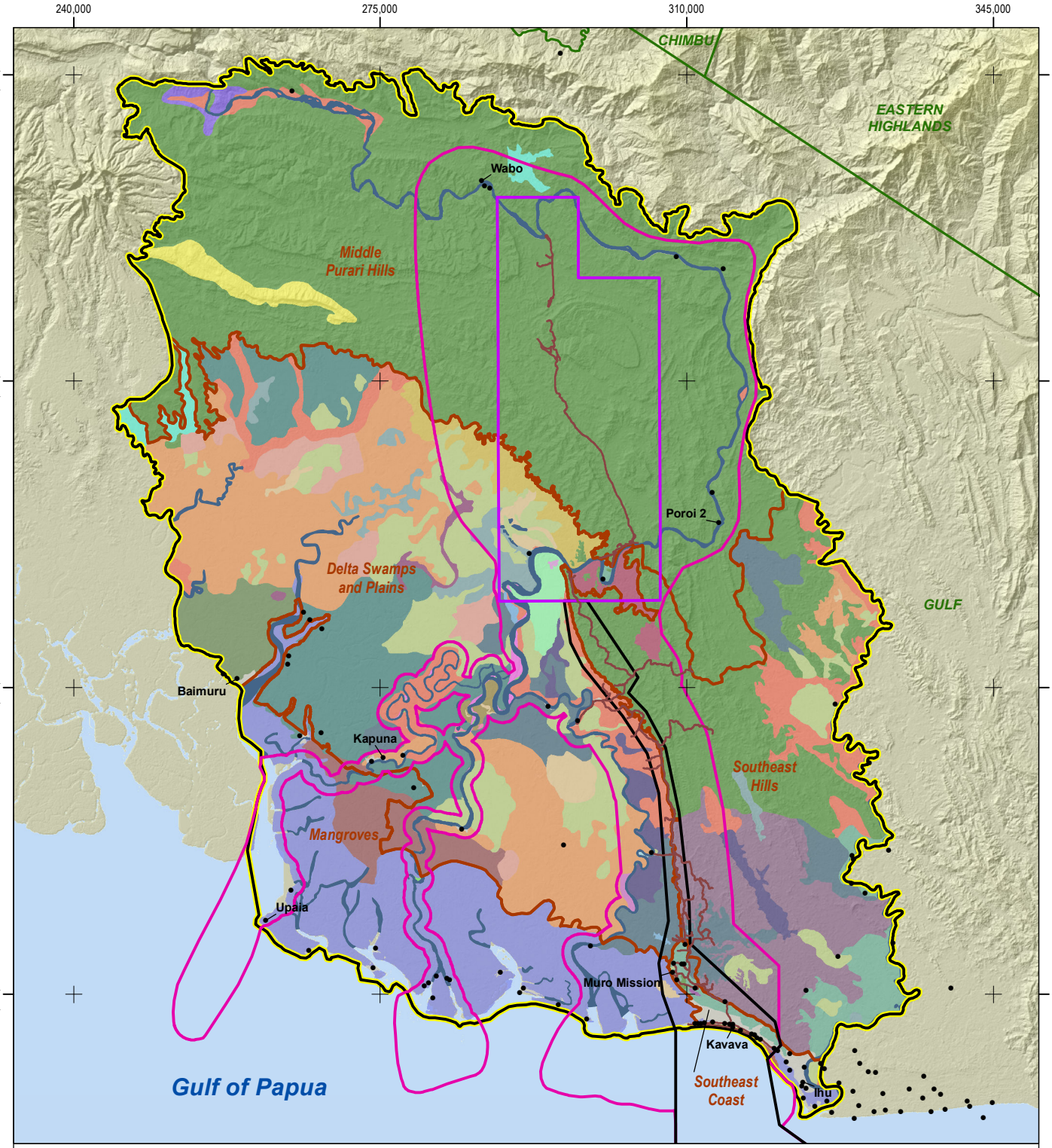
Nearly 3,370 km^2 of unlogged hill forest (2,509.8 km^2) and alluvial forest (858.5 km^2) remain within the study area. More than two-thirds of this (66.9%) occurs within the Baimuru Blk 3 concession as hill forest in the Middle Purari Hills (1,824.7 km^2) or alluvial forest on the Delta Swamps and Plains (428.9 km^2) (Figure 6.5).

In addition to forestry concessions, Special Agricultural and Business Leases (SABLs) provide a mechanism for the conversion of forest to agricultural land use. Some SABLs have been used to log production forest without proceeding to agricultural development. The Purari SABL, gazetted in 2011 with a 99-year leasehold, covers more than three quarters (77.7%) of the study area (Annex 1D; Numapo, 2013). Logs harvested from an SABL require an export permit from the National Forest Board. The legality of the Purari SABL is under question following the Commission of Inquiry into SABLs, making legalized log exports unlikely.

6.2.3.2 Local Resource Extraction

In addition to industrial operations, small-scale timber harvesting is practised throughout PNG to meet local community requirements. Among its many uses, timber provides the raw material for houses, fencing, canoes and firewood. Of the forests observed during biodiversity baseline surveys, those most affected by local timber extraction were the alluvial forests in the densely settled Southeast Coast ecological zone. The only portable sawmill observed during biodiversity baseline surveys was operated in this area (out of Paevera village: Annex 1D). However, while degradation was everywhere apparent (all observed remnant examples), amid widespread land conversion in this area patches of remnant alluvial forest were retained by local landowners, sometimes to the exclusion of industrial logging interests, in order to provide a continuing supply of natural resources.

The Eaglewood species *Gyrinops caudata* and *Aquilaria filaria* are present in the study area (recorded in logged hill forest at Site 3; Annex 1A). However, there is no evidence of local harvesting of this commercially valuable non-timber forest product (Annex 1D).



SCALE: 1:650,000 @ A4

0 10 20 30 40 Kilometres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Province boundaries
- Tracks
- Waterbodies
- Upstream project area of influence
- PRL-15
- Export pipeline corridor
- Ecological zone boundary
- Study area

Vegetation Type

B, Fri, Fsw, Fsw/Gsw, Fsw/M, Fsw/Wsw, FswC, Gri, Gsw/Fsw, Gsw/Wsw, Hm, Hm.Ar, Hm/Hs, Hs, Hsw, Hsw/Fsw, Hsw/Gsw, Hsw/Wsw, M, O, Pl, Pl/Fsw, Po, Po/Fsw, Po/Fsw/Hm, Po/Fsw/M, Po/Hsw, Po/Wsw, Ps, U, Wsw, Wsw/Fsw, Wsw/Gsw, Wsw/Hsw

N

Note: Not all communities have been verified in the field. Only Government administrative centres and notable locations have been labelled for context.

TITLE: Vegetation Types within the Study Area

FIGURE: 6.1

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-81656 **REVISION:** D

DATE: 21/07/2017

DATA SOURCES:

Towns and villages, export pipeline corridor, study area (ERIAS Group 2017). Upstream project area of influence digitised by Mipela GeoSolutions based on data supplied by ERIAS Group (2017). PRL-15, tracks (TOTAL 2016). DEM (Planet Observer 2015). Province boundaries derived by Mipela GeoSolutions (2016). Ecological zones (Iain Woxvold 2016). Upstream vegetation and waterbodies modified by Mipela GeoSolutions based on data supplied by Iain Woxvold (2017).

CLIENT:

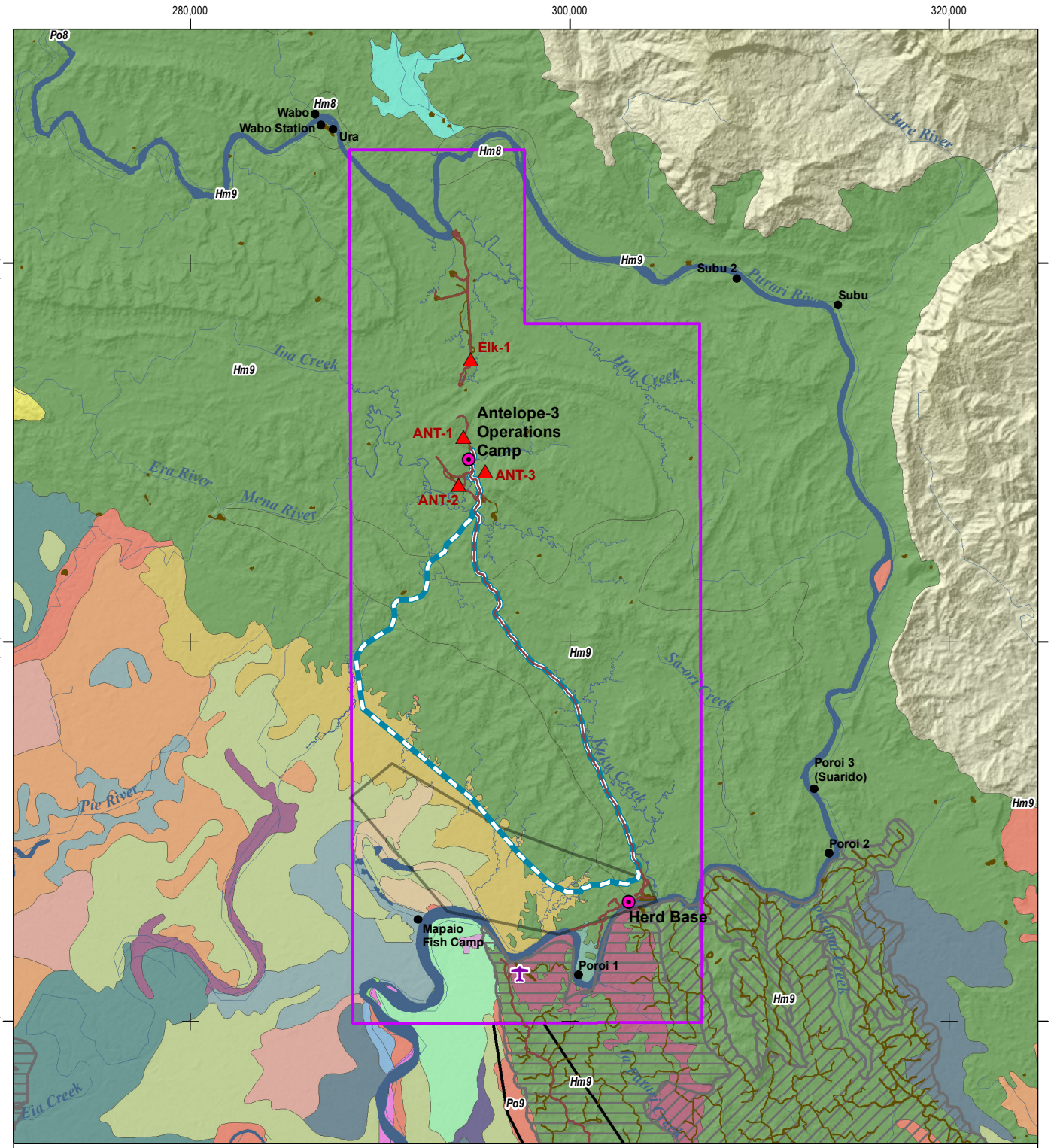
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-81656-Figure 6.1-D.mxd

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.



SCALE: 1:300,000 @ A4

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Base camp
- Wellpad
- Airstrip
- Tracks
- Waterways
- Waterbodies
- Trunkline corridor
- CPF, logistics base and airstrip area
- Logging roads and cleared land
- PRL-15
- Export pipeline corridor

Post-logging Secondary Forest
- 2002
- 2015
- 2015+

Vegetation type
- Fri
- Fsw
- Fsw/Wsw
- FswC
- Gri
- Gsw/Wsw
- Hm
- Hm/Hs
- Hsw
- Hsw/Gsw
- Hsw/Wsw
- Pl
- Pl/Fsw
- Po
- Po/Fsw
- Po/Fsw/Hm
- Ps
- Wsw
- Wsw/Fsw
- Wsw/Gsw
- Wsw/Hsw

N

TITLE: Vegetation and Anthropogenic Disturbance in the PRL-15 Area

FIGURE: 6.2

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-81381 **REVISION:** D

DATE: 14/07/2017

DATA SOURCES:
Facilities, town and villages, CPF, logistics base and airstrip area, pipeline routes, waterways, tracks, airstrip, export pipeline corridor, PRL-15, hillshade supplied by ERIAS Group and TOTAL (2015-2016). DEM (Planet Observer 2015). Upstream vegetation, post-logging secondary forest, logging roads and cleared land supplied by Iain Woxvold (2016-2017).

CLIENT:

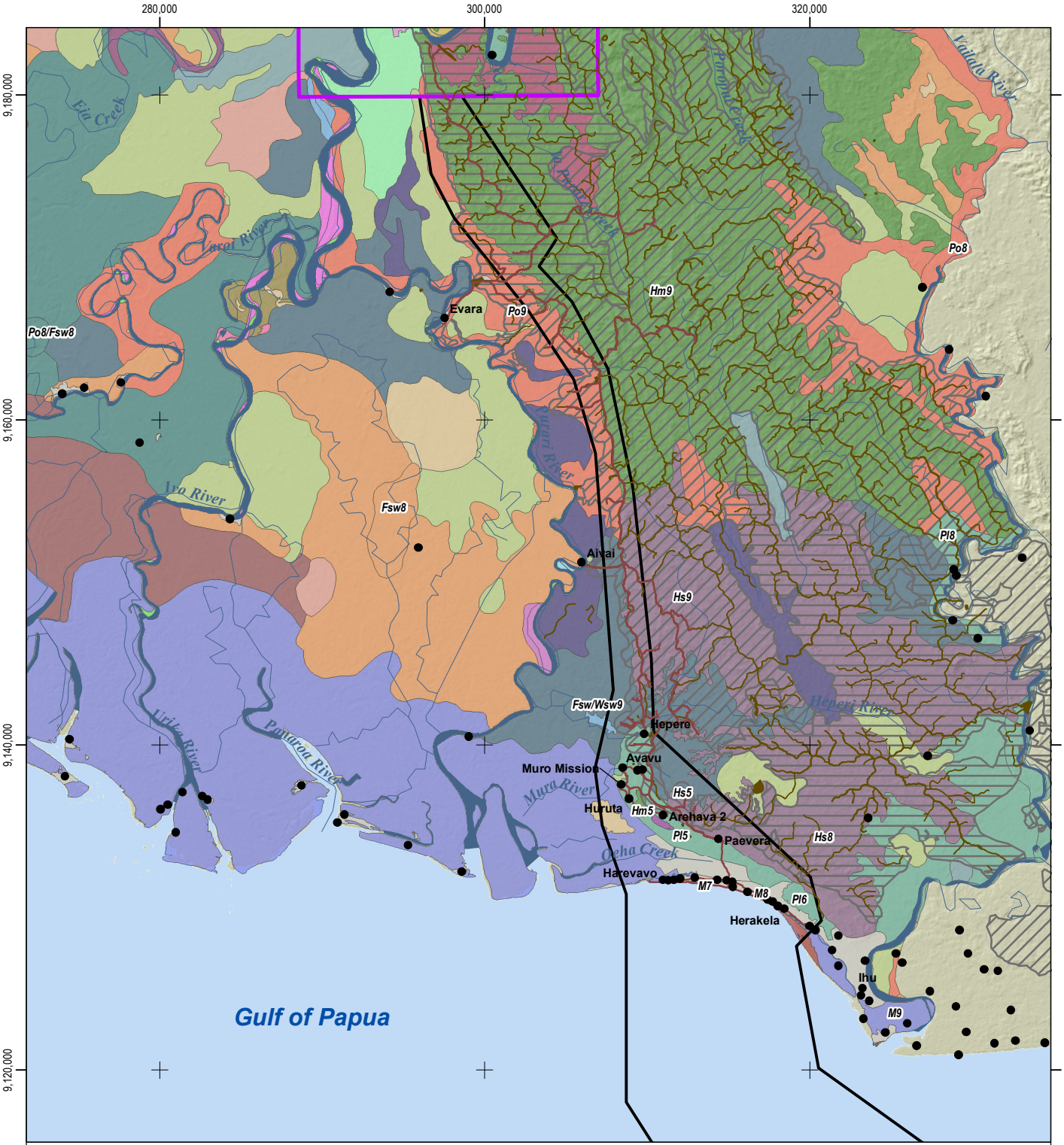
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI\002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-81381-Figure 6.2-D.mxd



SCALE: 1:350,000 @ A4

0 2 4 6 8 10 Kilometres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Tracks
- Waterways
- Waterbodies
- PRL-15
- Export pipeline corridor
- Logging roads and cleared land

Post-logging secondary forest

- 2002
- 2015
- 2015+

Vegetation type

B	Fsw/Wsw	Hs	O	Po/Hsw
Fri	FswC	Hsw	Pl	Po/Wsw
Fsw	Gri	Hsw/Fsw	Pl/Fsw	Wsw
Fsw/Gsw	Gsw/Fsw	Hsw/Gsw	Po	Wsw/Fsw
Fsw/M	Gsw/Wsw	Hsw/Wsw	Po/Fsw	Wsw/Gsw
	Hm	M	Po/Fsw/Hm	Wsw/Hsw

N

Note: Not all communities have been verified in the field. Only Government administrative centres and notable locations have been labelled for context.

TITLE: Vegetation and Anthropogenic Disturbance in the Export Pipeline Corridor

FIGURE: 6.3

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-81382 **REVISION:** D

DATE: 14/07/2017

DATA SOURCES:
Town and villages, waterways, tracks, export pipeline corridor, PRL-15, hillshade supplied by ERIAS Group and TOTAL (2015-2016). DEM (Planet Observer 2015). Upstream vegetation, waterbodies, post-logging secondary forest, logging roads and cleared land supplied by Iain Woxvold (2016-2017).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

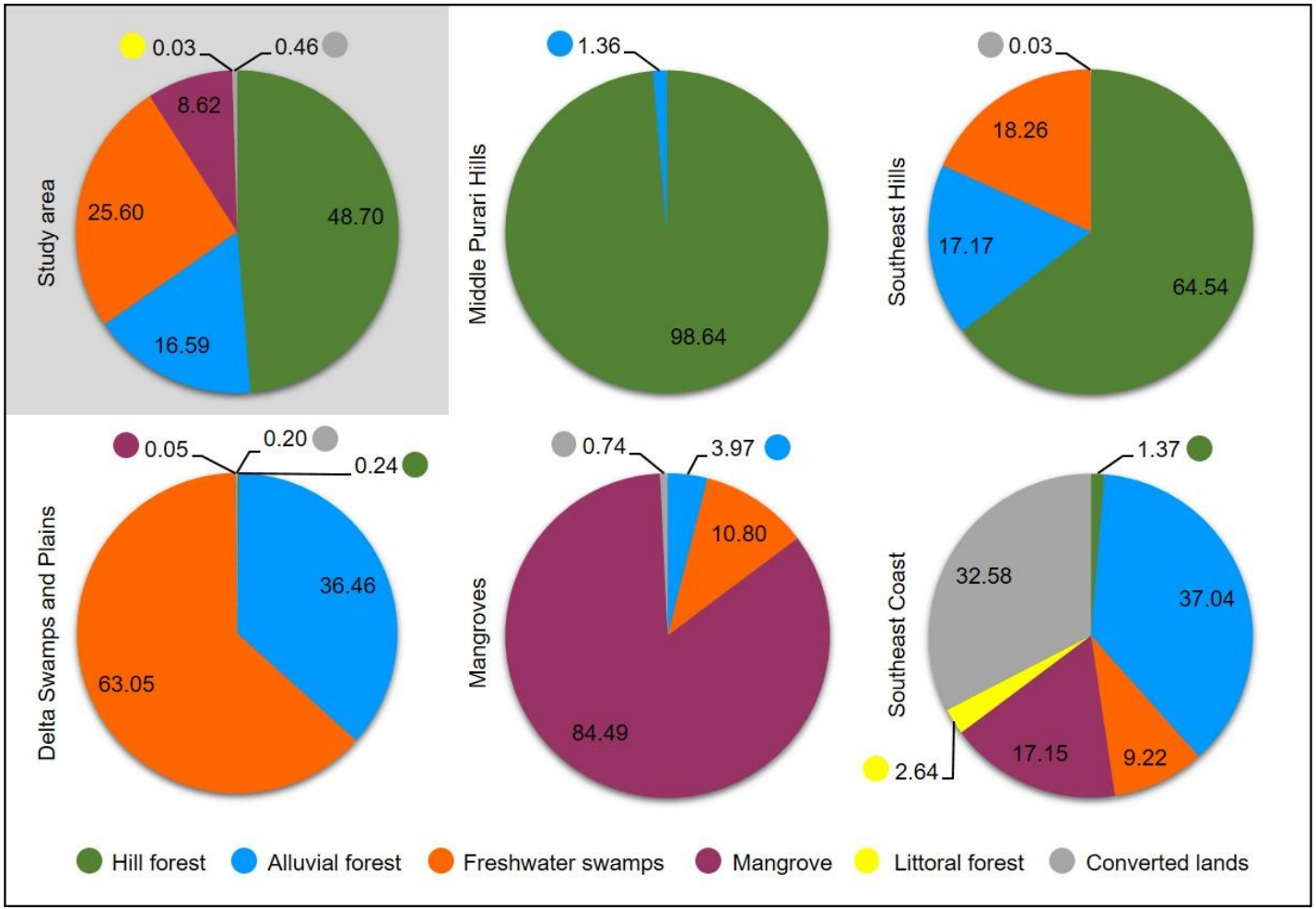
PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

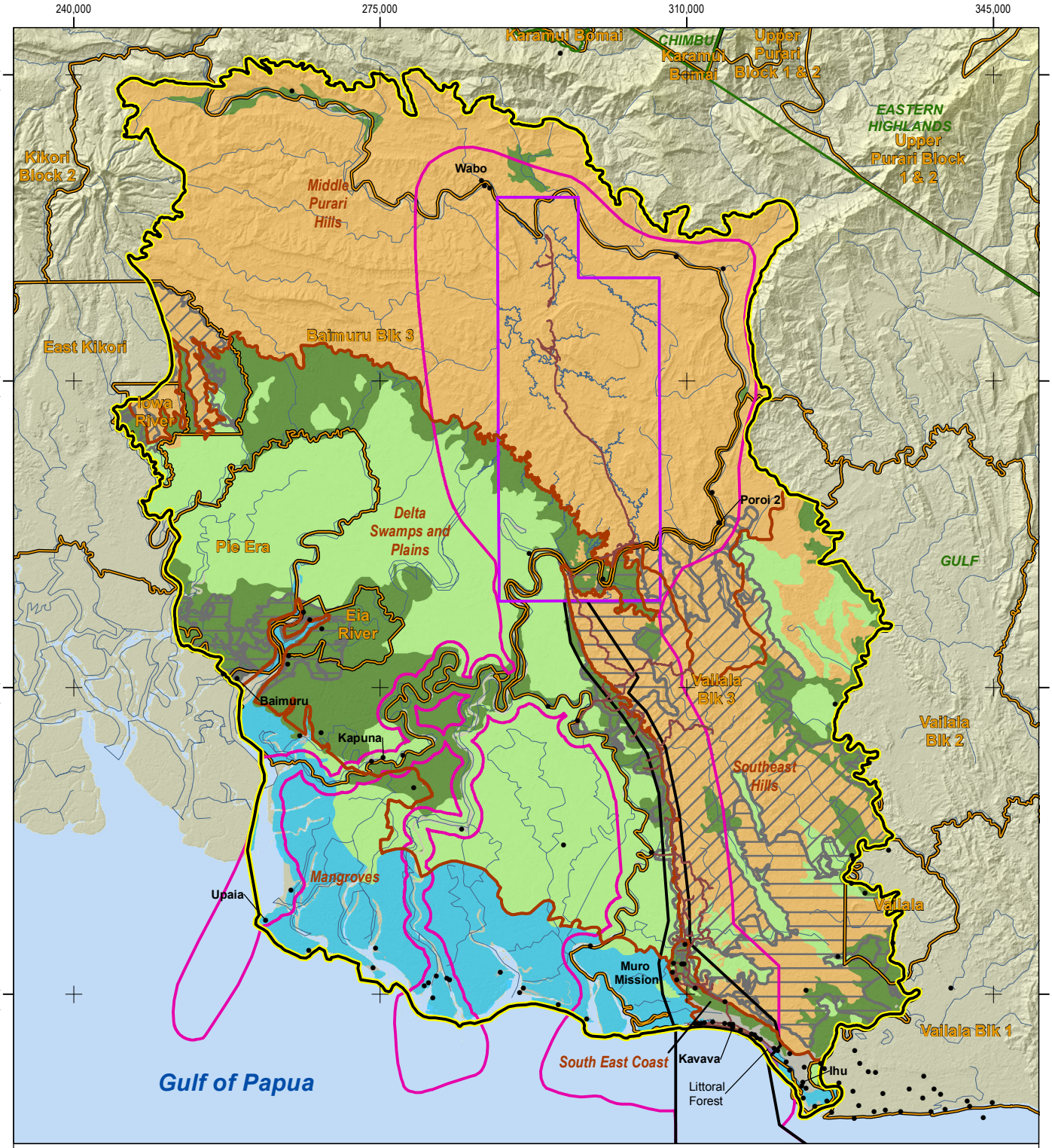
Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-81382-Figure 6.3-D.mxd

Figure 6.4 – The Proportion of the Study Area and Ecological Zones Covered by the Five Broad Vegetation Groups and Converted Lands



Numbers indicate percentage of land surface cover.



SCALE: 1:650,000 @ A4 — 0 10 20 30 40 Kilometres — **COORDINATE SYSTEM:** PNG94 PNGMG94 Zone 55

- Towns and villages
- Waterways
- Tracks
- Province boundaries
- Upstream project area of influence*
- PRL-15
- Export pipeline corridor
- Study area
- Ecological zones
- Logging concessions

Post-logging Secondary Forest

- 2002
- 2015
- 2015+

Broad Vegetation Groups

- Littoral forest
- Converted lands
- Freshwater swamp vegetation
- Hill forest
- Mangrove
- Alluvial forest

N

** Largely represents the terrestrial biodiversity baseline survey area.*

Note: Not all communities have been verified in the field. Only Government administrative centres and notable locations have been labelled for context.

TITLE: Logging Concessions and Post-Logging Secondary Forest within Broad Vegetation Groups

FIGURE: 6.5

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79675 **REVISION:** C

DATE: 13/04/2017

DATA SOURCES:

Towns and villages, waterways, tracks, PRL-15, export pipeline corridor, hillshade supplied by ERIAS Group and TOTAL (2015-2016). Upstream project area of influence digitised by Mipela GeoSolutions based on data supplied by ERIAS Group (2017). DEM (Planet Observer 2015). Province boundaries derived by Mipela GeoSolutions (2016). Study area (ERIAS Group 2017). Broad vegetation types, post-logging secondary forest, ecological zones logging concessions (Iain Woxvold 2016-2017).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

T:\Projects\ERI\002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79675-Figure 6.5-C.mxd

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

6.2.3.3 Habitat Loss

Mapped areas of habitat loss amount to 1.1% (76.4 km^2) of the study area land surface.

Approximately 32.2 km^2 of converted lands are identified in the vegetation mapping (Land use (O) and Urban areas (U)). The largest area occurs along the densely settled coastal strip of the Southeast Coast ecological zone. Other areas are identified around villages along the coast in the Mangroves ecological zone and along major waterways on the Delta Swamps and Plains.

An additional 44.2 km^2 of cleared land were identified under the deforestation study. Most of this loss (96%) is attributed to clearance for logging roads and associated infrastructure, the largest affected area being in the Vailala Blk 3 concession in the southeast study area. Additional minor contributions are associated with subsistence agriculture (1.9%) and petroleum sector activities (1.5%), the latter contained mostly within PRL-15. Non-anthropogenic causes such as landslides account for less than 1% of vegetation loss (Booyong Forest Science, 2017c).

Most areas of forest loss identified under the Deforestation Study are too small or too narrow to map separately at the scale of vegetation mapping adopted in this study. They are overlain on the vegetation maps in Figures 6.1, 6.2 and 6.3.

The total calculated area of habitat loss is an underestimate of the actual amount of natural vegetation that has been removed from within the study area. In many instances this is because converted land occurs in mosaic form with areas of natural vegetation, and/or due to the inability of remote sensing methodologies to detect differences between natural and non-natural vegetation types. While the areal extent of such areas has not been calculated, in most cases their presence is registered in a numeric disturbance code appended to the relevant vegetation mapping units: from four (40% intact) to nine (90% intact). Disturbance codes are displayed in the detailed vegetation maps shown in Figures 6.2 and 6.3, and are summarized in relation to specific vegetation types in the following sections.

6.2.4 Vegetation Types

Key aspects of the various vegetation types are described in the following sections. Unless otherwise stated, characterizations are summarized from Paijmans (1976), Hammermaster and Saunders (1995) and Johns et al. (2007b), with local context provided by Paijmans (1969, 1983), Cragg (1983) and baseline biodiversity studies including the vegetation mapping and forest condition (Annex 1B), the Upstream Deforestation Study (Booyong Forest Science, 2017a), the Upstream Land and Natural Resources Study (Booyong Forest Science, 2017b; Part 18 of ESBS Dossier), the Upstream Vegetation Regeneration Study (Booyong Forest Science, 2017d) and the flora field surveys (Annex 1A). More detailed descriptions of the vegetation types present at flora and fauna survey sites are provided in Annex 1A.

Detailed vegetation maps for key Project areas are shown in Figures 6.2 and 6.3.

6.2.4.1 Hill Forest

Hill forest is the natural vegetation occurring on all areas of hill terrain in the study area. It is the most widespread broad vegetation group, in its various forms covering more than 3,400 km^2 and nearly half (48.7%) of the study area land surface.

Hill Forest (Hm)

The medium crowned form of Hill forest (Hm) is the most extensive vegetation type in the study area—it covers more than 3,000 km^2, including more than 95% of the Middle Purari Hills and

much of the northern half of the Southeast Hills. In terms of Project components, Hill forest (Hm) covers:

- 81.1% of PRL-15, including all of the gas field, 26.0% of the CPF, logistics base and airstrip area.
- 25.5% of the export pipeline corridor, mostly in the northeast (Southeast Hills), but with an isolated occurrence in the south, on Heve Hill east of Huruta village (Southeast Coast).

Hill forest (Hm) is widespread throughout mainland PNG. Typically, it has a canopy of medium crowned trees (8 to15 m diameter), 25 to 30 m high with 60 to 80% closure and emergents up to 40 m high. It is species rich, with frequent canopy taxa including those of the families Anacardiaceae, Burseraceae, Cannabaceae, Combretaceae, Dipterocarpaceae, Lauraceae, Meliaceae, Moraceae, Myrtaceae and Sapindaceae. Floristic composition varies with altitude, with assemblages below 500 m asl normally resembling those of alluvial forest. In the extreme northwest of the Middle Purari Hills, outside of the upstream PAOI, a localized occurrence of Hill forest, *Araucaria* noted (Hm.Ar) is identified under FIMS mapping at elevations between c. 100 and 500 m asl. Distinguished by the presence of *Araucaria* emergents to 70 m tall, this forest type is normally found above 500 m asl and has closer floristic affinities with higher elevation hill forest.

The structure and floristics of hill forest varies markedly at the local scale, often changing with terrain and substrate parameters. Forest on steep terrain with shallow, unstable soils supports a more open, uneven canopy with smaller crowns. By contrast, relatively shallow slopes, sheltered gullies, terraces and broad ridges or plateaux generally support a taller forest type. Understorey communities vary accordingly, with marked changes in species composition from moist, shaded stream gullies to the warmer, drier conditions on steep slopes and narrow ridges.

Most of the Hill forest (Hm) in PRL-15 remains in its natural state. The expansive forests north of Herd Base have not been commercially logged and support no villages. While Pawaian residents do pass through the area, associated disturbance is low, and most forest loss/degradation is attributable to the Project through the construction and operation of roads, wellpads and camp facilities. The disturbance code Hm9 is appropriately applied.

At the landscape level, geology and soils are among the principal determinants of hill forest structure and condition in this area. Mature forest structures were observed on the relatively stable Era Bed sediments, associated with major topographic features such as the Mena and Kuku Basins (Plate 6.1) and on the hills sloping southwest towards the Delta Swamps and Plains. At surveyed sites, the largest statures were observed on gentle foothill terrain above the transition to alluvial forest (Sites 4, 5 and 6B). Canopies here reach 30 to 40 m tall, with a notable frequency very large trees of 1 to 2 m DBH in the eastern half of the proposed wharf area at Site 6B (Plate 6.2).

In contrast, the soft mudstones and siltstones of the Orubadi Beds are prone to rapid soil erosion and slumping. Much of the overlying vegetation is poorly structured, characterized by regenerating forest with a low, open canopy and a high frequency of climbing rattan palms (*Calamus, Korthalsia* spp.) (Plates 6.3 and 6.4). More mature forest structures are present in areas of relatively stable terrain such as alluvial valley terraces and on broad ridges. The high natural disturbance rate within this structural mosaic was recognized in the original FIMS mapping by the assignment of Scrub (Sc) in complex form (Hm/Sc). This was reclassified (to Hm) in the vegetation mapping study (Annex 1B) as the regenerating forest does not conform to Scrub (Sc) floristics.

South of the Purari River, most of the Hill forest (Hm) has been intensively logged, including all examples in the southeast of PRL-15 and the northeast export pipeline corridor. The most mature secondary forests are present in the north of this area—those surveyed at Site 3 showed a heavily altered canopy structure (Plate 6.5), under-developed sub-canopy and a well-developed shrub layer in response to high light conditions (Annex 1A). Small areas of primary forest remain along some drainage lines and in areas of steep terrain unsuitable for logging.

Hill forest (Hm) regenerates well where the vegetation is cut without exposing the topsoil, and moderately where exposed topsoil occurs on gentle hill slopes, including on sidecast surfaces. Regenerative capacity is generally poor where topsoil is exposed on steep hill slopes and in areas where the topsoil is removed.

Plate 6.1 – Well Structured Hill Forest (Hm) on Aure Bed Sediments of the Mena Basin, Elk-Antelope Gas Field



Photo source: I. Woxvold.

Plate 6.2 – Very Large-boled Tree in Hill Forest (Hm) at Site 6B



Photo source: I. Woxvold.

Plate 6.3 – Variable Forest Structure on Highly Erodible and Slump-prone Orubadi Beds Sediments, near Site 2



Photo source: I. Woxvold.

Plate 6.4 – Interior of Small Statured Hill Forest (Hm) at Site 2



Photo source: I. Woxvold.

Plate 6.5 – Logged Hill Forest (Hm) at Site 3



Photo source: I. Woxvold.

Small Crowned Hill Forest (Hs)

Small crowned hill forest (Hs) covers more than 320 km^2 in the southern half of the Southeast Hills ecological zone, including 30.1 km^2 within the export pipeline corridor. Characteristic of low hilly terrain with poor, strongly weathered acid clay soils, it overlies the tropudult ultisol soils found in this area (Section 3.1.3.2). In its undisturbed form, it typically has an uneven canopy of small crowned trees (4 to 8 m diameter) 20 to 30 m high with 60 to 80% closure and few emergent. However, almost all of the Small crowned hill forest (Hs) in the study area has been intensively logged, including most of that in the export pipeline corridor between 2002 and 2015 (Figure 6.5; Plate 6.6). The structural damage is widespread and similar to that observed in Hill forest (Hm), with remnant pockets of primary forest remaining in some areas (Plate 6.7).

Structural Complex: Hill Forest/Small Crowned Hill Forest (Hm/Hs)

In the extreme west of the Middle Purari Hills, outside of the upstream PAOI, 55.9 km^2 of the structural combination Hill forest/Small crowned hill forest (Hm/Hs) occurs on the limestone soils of the Kereru Range. In this vegetation complex, the Small crowned hill forest (Hs) component typically occurs on ridge crests and upper slopes, while Hill forest (Hm) occupies the middle and lower slopes.

Plate 6.6 – Logged Small Crowned Hill Forest (Hs) at Site 7



Photo source: I. Woxvold.

Plate 6.7 – Remnant Primary Small Crowned Hill Forest (Hs) at Site 7



Photo source: I. Woxvold.

6.2.4.2 Alluvial Forest

Alluvial forest occurs on recent depositional 'plains' landforms in areas well drained or subject to periodic inundation. It is tall and floristically rich. Forest structure is variable, with drainage and soils among the dominant abiotic factors. Canopies are often open with numerous gaps and with a dense understorey rich in saplings, palms, pandans, gingers, lianes and epiphytes.

Alluvial forest often occurs as a dominant type (50 to 80% of the mapping unit) in complexes with other broad vegetation groups, most commonly freshwater swamp vegetation types (Section 6.2.4.3). In its various forms (including complexes), it covers more than 1,160 km^2 (16.6%) of the study area.

Alluvial Forest (Pl) and Complexes

The large crowned form of Alluvial forest (Pl) is the climax form of this vegetation group. Average canopy height is 30 to 35 m with emergents to more than 50 m high. Tree species composition is similar to that of low elevation hill forest, though often in different proportions. Flooding is infrequent and of short duration.

Alluvial forest (Pl) covers 113.1 km^2 of the study area. Where accessible, it is among the first forest types to be harvested by commercial logging operations. The largest local occurrences, in the lower Vailala River catchment (Southeast Hills), have mostly been logged.

Within the export pipeline corridor, nearly 24 km^2 of Alluvial forest (Pl) occur on the interior plains of the Southeast Coast ecological zone. Most of this mapping unit has not been commercially logged. However, this area is densely settled and much of the non-swamp vegetation has been converted for shifting agriculture, agroforestry or village developments; this is reflected in a high disturbance code (Pl5). Conversions are most prevalent in the north of this area between Hepere

and Paevera villages, with some of the remaining forest heavily logged in recent years (Plate 6.8). Some forest patches have been retained by local landowners to provide a continuing supply of forest resources. Remnant forest canopies are fragmented, uneven and varied in height from 20 to 30 m (Annex 1A). Southeast of Paevera village, in the eastern half of the export pipeline corridor coastal approach, the forest is in better condition. Garden developments and resource harvesting were apparent (Plate 6.9), but the mature forest matrix was characterized by tall canopies (averaging 35 m) with many trees of >1 m DBH, floristically rich sub-canopy and understoreys and an open forest floor (Plate 6.10).

Further north, 35.4 km^2 of Alluvial forest/Swamp forest (Pl/Fsw) complex abuts of the southern banks of the Purari River along approximately 12 river kilometers at the head of the Purari delta downstream from Herd Base. The Swamp forest (Fsw) component occurs patchily in poorly drained sites. Some 62.2% of this mapping unit lies within southeast PRL-15, mostly between Herd Base and Purari airstrip. Located within the Vailala Blk 3 concession, almost all of this forest has been logged. Outside of this concession, a smaller area (2.1 km^2) of unlogged Alluvial forest (Pl) is present on the opposite (northern) bank of the Purari River around Poroi 1 village. While the canopy is largely intact, some conversion and resource harvesting is expected from the local residents.

Open Alluvial Forest (Po) and Complexes

Open alluvial forest (Po) is floristically similar to Alluvial forest (Pl) but occurs on sites more frequently flooded or subject to longer-term inundation through impeded drainage. Undisturbed canopies consist of small and medium crowned trees with large crowned emergents, often figs and *Octomeles sumatrana*, to 40 m. The canopy profile is uneven with large gaps often colonized by thorny rattan palms (*Calamus* and *Korthalsia* spp.).

Open alluvial forest (Po) occurs alone or as a dominant feature in complexes with a variety of freshwater and tidal swamp vegetation types (Table 6.3), the latter types patchily present on poorly drained or frequently flooded sites within the alluvial forest matrix. Together they cover more than 965 km^2 of the study area, predominantly on the margins of the Delta Swamps and Plains (landward along the rim of the Middle Purari Hills and the Southeast Hills, and downstream near the border with the Mangroves ecological zone) and on the Vailala River plains in the Southeast Hills. Lesser occurrences of Open alluvial forest (Po) occur at the northern end of the Orovoi Basin in the Southeast Hills, and along the Purari River in the northwest Middle Purari Hills.

Logging disturbance is widespread. More than 105 km^2 have been harvested from the western study area (outside of the upstream PAOI), most of it Open alluvial forest/Swamp forest/Mangrove complexes (Po/Fsw and Po/Fsw/M) from the now expired Pie Era and Eia River concessions. In the east, extensive areas of Open alluvial forest (Po) have been logged from Vailala Blk 3, including within the export pipeline corridor (see below).

Plate 6.8 – Recently Logged Alluvial Forest (Pl) Southeast of Kilavi Village, Southern Export Pipeline Corridor



Photo source: I. Woxvold.

Plate 6.9 – Garden Development in Alluvial Forest (Pl) in Hinterland of Orokolo Bay, North of Site 9 Fly Camp, Southeast Coast



Photo source: I. Woxvold.

Plate 6.10 – Alluvial Forest (Pl) Orokolo Bay Hinterland, Southeast Coast



Photo source: I. Woxvold.

Open alluvial forest/Swamp forest/Hill forest (Po/Fsw/Hm) covers 5.8% of PRL-15, in the southwest along the interior rim of the Delta Swamps and Plains, including 37.0% of the CPF, logistics base and airstrip area. This vegetation type was surveyed at Sites 4, 5 and 6B. Forest structure and floristics vary with minor changes in elevation and associated shifts in drainage pattern. The tallest Open alluvial forest (Po) was observed on better drained sites along the slightly elevated alluvial rim adjacent to the foothill zone (Plate 6.11); canopies here reach 30 to 35 m with some emergents higher than 40 m. Treefall is more common in poorly drained sites further away from the foothills, where lower (20 to 30 m) and more open canopies with a denser understorey were common (Plate 6.12). Within this complex, the Hill forest (Hm) component occurs on isolated raised sites present mostly near the hill zone, and the Swamp forest (Fsw) component is more prevalent on lower ground further onto the Delta Swamps and Plains landform. Poorly drained areas with associated swamp vegetation were most prominent at Sites 5 and 6B. Figs (*Ficus* spp.) were notably common at Site 4 (Annex 1A).

In the northern half of the export pipeline corridor, 32.0 km^2 of Open alluvial forest (Po) occur along a c. 30 km length of the eastern rim of the Delta Swamps and Plains. All accessible areas of merchantable forest appear to have been logged here between 2002 and 2015. Surveyed at Site 7, post-logging secondary forest close to the logging road was low with an uneven and often open canopy with dense understoreys (Plate 6.13). Examples of primary Open alluvial forest (Po) were present a few hundred meters west of the logging road at Site 7 (Plate 6.14). It is not possible to accurately map the boundary of logged and primary alluvial forest in this region. The

coverage of logged forest shown in Figure 6.5 is taken from the Deforestation Study, applying a 500 m buffer around observed logging trails. Actual logged areas will be more extensive in some sites, and more limited in others.

Elsewhere within the upstream PAOI, along the river transport routes downstream of PRL-15, Open alluvial forest (Po) and a variety of swamp vegetation complexes (Po/Fsw, Po/Wsw and Po/Hsw) line much of the Purari River and its distributaries upstream of the Mangroves ecological zone. This area is sparsely populated, and apart from a few localized sites where logging of Open alluvial forest (Po) is mapped along the eastern banks of the Purari River distributary between Evara and Aivai villages, these vegetation types remain essentially intact and no disturbance codes are applied.

Plate 6.11 – Open Alluvial Forest (Po) at Site 4



Photo source: S. Richards.

Plate 6.12 – Open Alluvial Forest (Po) Interior at Site 4



Photo source: S. Richards.

Plate 6.13 – Interior of Logged Open Alluvial Forest (Po) near the Logging Road at Site 7, Northern Export Pipeline Corridor, Eastern Delta Swamps and Plains



Photo source: I. Woxvold.

Plate 6.14 – Interior of Primary Open Alluvial Forest (Po) at Site 7, Showing the More Open Understorey of a Mature Forest Structure



Photo source: I. Woxvold.

Small Crowned Alluvial Forest (Ps)

Small crowned alluvial forest (Ps) occurs on gravelly and/or poorly drained soils. It typically has a dense even canopy of small crowns, 25 to 30 m high with no emergents. Species present may be broadly similar to those of Open alluvial forest (Po), but the canopy is often dominated by single species such as *Intsia* sp. or dipterocarps (Dipterocarpaceae).

Small crowned alluvial forest (Ps) occurs in two discrete areas:

- 12.9 km^2 in the central north Middle Purari Hills, within the upstream PAOI but north of PRL-15, in the Eri River valley, a tributary flowing south into the Purari River downstream from Wabo. This area is little disturbed.
- 26.7 km^2 in the extreme northwest of the Delta Swamps and Plains, outside of the upstream PAOI. These formations are inside the East Kikori and Iowa River logging concessions but have been largely circumvented by recent harvesting.

Riverine Seral Forest (Fri)

Riverine seral forest (Fri) occurs on aggrading scroll arches next to meandering rivers. It comprises a heterogeneous association of forest in different stages of development following change in river course, often appearing as distinct bands of low to mature forest increasing in height with distance from the river edge. Species composition varies between successional stages, with Octomoeles sumatrana and Artocarpus often present among the early pioneers. Mature stages have an irregular canopy to 30 m high.

Riverine seral forest (Fri) occurs in numerous discrete areas along the river transport routes on the Delta Swamps and Plains, along the Purari River at the head of the delta (upstream of the

distributary divisions) and along the Wame-Varoi and Urika-Ivo distributaries. This area is sparsely populated—these vegetation types remain essentially intact and no anthropogenic disturbance codes are applied.

6.2.4.3 Freshwater Swamp Vegetation

Freshwater swamp vegetation occurs in areas subject to frequent or permanent flooding. It is the second most widespread broad vegetation group within the study area, in its various forms covering nearly 1,800 km^2 and more than one quarter (25.6%) of its land surface. It is most widespread on the composite levee plains of the Delta Swamps and Plains and interior margins of the Mangroves ecological zone, predominantly on the poorly drained back plains spanning the vast interfluvial areas behind riverine levee banks. Other major occurrences are found on the alluvial plains and back swamps of the Vailala River and parts of the Purari River catchment in the Southeast Hills, and to a lesser extent the Southeast Coast ecological zone. No freshwater swamp vegetation is mapped for the Middle Purari Hills.

Freshwater swamp vegetation within the study area presents a sequence of five distinct base vegetation types, each occupying a discrete environment defined by variation in the depth, movement and/or periodicity of inundation. These grade into one another, and into adjacent alluvial forest and mangrove vegetation, through a variety of complex forms (Fsw/Gsw, Wsw/Hsw, Po/Wsw, etc.) as relatively minor changes in topography influence local hydrological and overlying vegetation patterns in a low relief environment. The freshwater swamps are a dynamic ecosystem complex—meandering rivers regularly change course, and progressive sediment input to former river channels and flooded back plains creates a transitional series of environments as water depths change and new environments are created.

The vegetation types are described below. Unless otherwise stated they are not a logging target and remain predominantly undisturbed by local residents.

Herbaceous Swamp (Hsw)

Herbaceous swamp (Hsw) occurs in relatively deep and permanently inundated stagnant water environments. The flora comprises sedges, herbs and ferns, in places reaching 2.5 m above the water surface.

Herbaceous swamp (Hsw) is a minor component of the local vegetation. As a dominant form it covers less than 1% of the study area land surface, mostly as an unaccompanied vegetation type, but in some places in complex with Swamp woodland (Hsw/Wsw), Swamp grassland (Hsw/Gsw) and Swamp forest (Hsw/Fsw). It is slightly more widespread as the minor component in complex with Swamp woodland (Wsw/Hsw: 1.1% of the study area).

Herbaceous swamp (Hsw) occurs across 28.3 km^2 of southwest PRL-15, mostly as an unaccompanied vegetation type around the oxbow wetlands north of the Purari River (12.7 km^2; Plate 6.15), and forming part of the ‘PRL-15 oxbow wetlands’ ecosystem complex (see Section 6.5.2.2). This Herbaceous swamp (Hsw) system extends north from the oxbow wetland to cover 10.5% (6.8 km^2) of the CPF, logistics base and airstrip area. It was accessed on foot from Site 5, where the sedge *Mapania sumatrana* and the herb *Hanguana malayana* were conspicuous elements.

There are two discrete occurrences at the southern end of the export pipeline corridor near the coast—3.0 km^2 of Herbaceous swamp (Hsw) at the western edge of the corridor, at the eastern end of the Mangroves ecological zone c. 4 km inland, and 0.5 km^2 of Herbaceous swamp/Swamp

forest (Hsw/Fsw) in the centre of corridor, a few hundred meters south of Arehava 2 village in the Southeast Coast ecological zone. Along the river transport routes there are minor occurrences (less than 1 km^2) along the Urika-Ivo distributary channel.

Plate 6.15 – Herbaceous Swamp (Hsw) with Sago Swamp Woodland (Wsw) in the Background, PRL-15 Oxbow Wetlands Area, Southwest PRL-15



Photo source: I. Woxvold.

Swamp Grassland (Gsw)

Swamp grassland (Gsw) occurs in permanently inundated to intermittently dry swamps. Compared to the Herbaceous swamp (Hsw) flora, grasses dominate in areas with flowing water.

Swamp grassland (Gsw) is a minor component of the local vegetation. It occurs as the dominant type in complex with Swamp woodland (Gsw/Wsw) and Swamp forest (Gsw/Fsw) across just 0.1% of the study area land surface. In key Project areas this includes minor occurrences: (1) along river transport routes, and; (2) in the southern export pipeline corridor north of the Southeast Coast ecological zone, within or adjacent to logged areas near Hepere village.

Swamp grassland (Gsw) is most widespread as the minor component in complex with Swamp woodland (Wsw/Gsw: 1.0% of the study area; Plate 6.16). This vegetation type covers 0.9 km^2 of the western edge of the export pipeline corridor along the eastern rim of the Delta Swamps and Plains. Examples surveyed at Site 7 comprised dense stands of the native sugarcane *Saccharum spontanaeum* with various sedges (Cyperaceae) and grasses (Poaceae) (Plate 6.17) (Annex 1B).

Swamp grassland (Gsw) readily regenerates following disturbance.

Plate 6.16 – Swamp Woodland/Swamp Grassland (Wsw/Gsw) Complex, Eastern Delta Swamps and Plains, near Aivai Village between the Purari Distributary Channel and the Export Pipeline Corridor



Photo source: I. Woxvold.

Plate 6.17 – Intermittently Dry Swamp Grassland (Gsw) Amid Swamp Woodland/Swamp Grassland (Wsw/Gsw) Complex at Site 7, Western Export Pipeline Corridor



Photo source: I. Woxvold.

Riverine Successional Grassland (Gri)

Riverine successional grassland (Gri) is a tall grassland community found at the edge of meandering rivers and on sand bars in braided rivers. Site conditions vary from frequently flooded to permanently swampy.

Mapped occurrences cover just 2.1 km^2 (less than 0.1%) of the study area. They occur at numerous discrete sites, exclusively on aggrading scroll arches of the Purari River and its three distributary channels along the river transport routes (Plate 6.18).

Plate 6.18 – Riverine Successional Grassland (Gri) Along the Purari River



Photo source: I. Woxvold.

Swamp Woodland (Wsw)

Swamp woodland (Wsw) consists of an open to fairly dense layer of sago palms (*Metroxylon sagu*; Plate 6.19) or pandans (*Pandanus* spp.), with or without scattered trees floristically similar to those of Swamp forest (Fsw). The ground layer may be bare (e.g., under dense sago formations; Plate 6.20) or comprise tall sedges, ferns and/or grasses. Where the waterlogged soils are little disturbed, Swamp Woodland (Wsw), especially sago woodland, typically regenerates well following disturbance or clearing.

Swamp woodland (Wsw) occurs on permanent to near permanent shallow swamp. As water depth increases the vegetation grades into complex forms with Swamp grassland (Gsw) (Plates 6.16 and 6.17) or Herbaceous swamp (Hsw), with fewer trees separated by areas of flooded grassland or herbland. In better-drained areas, Swamp woodland/Swamp forest (Wsw/Fsw) (Plate 6.19) occurs on sub-permanently or periodically inundated sites. Tree densities (other than palms) are higher than in Swamp woodland (Wsw), regularly forming an even canopy of medium to very small crowns.

Swamp woodland (Wsw) is widespread in the study area, occurring as an unaccompanied type (423.1 km^2) or as a complex dominant (Wsw/Fsw, Wsw/Gsw, Wsw/Hsw: 179.6 km^2) across 8.6% of its land surface area, and as a subordinate component with Open alluvial forest (Po/Wsw: 8.6 km^2) or with other freshwater swamp vegetation types (Fsw/Wsw, Gsw/Wsw, Hsw/Wsw: 281.4 km^2) across a further 4.1%. It is most prevalent on the Delta Swamps and Plains (84.5% of total Wsw dominant types area), where it is concentrated in the interior (northern and eastern) half.

Swamp woodland (Wsw) and associated vegetation complexes overlap all key Project areas. They cover 7.8% of southwest PRL-15, including 24.2% of the CPF, logistics base and airstrip area in its western half (15.6 km^2 of sago Swamp woodland (Wsw)). They also line much of the river transport routes. In most places their mapped occurrence extending unbroken for at least 3 km, and in places to nearly 20 km, across the adjacent interfluvial expanse. These areas are remote from human disturbance and no anthropogenic disturbance code is applied.

In the northern half of the export pipeline corridor, there are a number of minor incursions of Swamp woodland (Wsw: 1.3 km^2) and Swamp woodland/Swamp grassland (Wsw/Gsw: 0.9 km^2) from wetter areas further west on the Delta Swamps and Plains (Plates 6.16 and 6.17). In the southern half of the export pipeline corridor, it is widespread as the minor component in complex with Swamp forest (Fsw/Wsw: 29.4 km^2). This mapping unit extends south for approximately 16 km from near Aivai village to the northern part of the densely populated Southeast Coast ecological zone. While much of it is mapped as logged, sago has no commercial value as a timber species and any extensive stands are likely to remain intact. At the local scale, sago present near villages is often harvested by landowners. In addition to mapped occurrences, coastal areas mapped as Land use (O) within the export pipeline corridor support a number of linear, sub-parallel sago swamps occupying the poorly drained swales between relict parallel beach ridges behind the densely populated coastal front.

Plate 6.19 – An Area of Swamp Woodland/Swamp Forest (Wsw/Fsw) Dominated by Sago Palms (*Metroxylon sagu*), Delta Swamps and Plains, Southwest PRL-15



Photo source: I. Woxvold.

Plate 6.20 – Interior of Sago Swamp Woodland (Wsw) Near Site 7, Eastern Delta Swamps and Plains, Western Export Pipeline Corridor



Photo source: I. Woxvold.

Swamp Forest (Fsw)

Swamp forest (Fsw) has an irregular open, almost even canopy of small crowned trees 20 to 30 m high (Plate 6.21). It has a mixed species composition, with common canopy taxa including Lauraceae, Myristicaceae, Campnosperma, Calophyllum, Syzygium, Garcinia, Diospyros, Intsia bijuga and Sapium indicum. Tree diameters are typically small reflecting slow growth in the poor drainage. Lower storeys may be open or dominated by sago or Pandanus. In some areas, flat-topped Campnosperma form pure canopy stands, recognized under FIMS mapping as Swamp forest with Campnosperma (FswC).

The Swamp forest (Fsw) water table fluctuates strongly, mostly seasonally but in some places daily. Where drainage is more impeded and anaeration conditions more prevalent, the vegetation grades into complex forms with Swamp woodland (Wsw) (Plate 6.19), Swamp grassland (Gsw) or Herbaceous swamp (Hsw).

Swamp forest (Fsw) is the most widespread swamp vegetation type present in the study area. It occurs as an unaccompanied type (642.8 km^2), a floristic variant (FswC: 89.1 km^2) and a complex dominant (Fsw/Wsw, Fsw/Gsw, Fsw/M: 382.7 km^2) across 15.9% of the study area land surface, and as a subordinate component with alluvial forest (Pl/Fsw, Po/Fsw, Po/Fsw/Hm, Po/Fsw/M: 656.8 km^2) or with other freshwater swamp vegetation types (Wsw/Fsw, Gsw/Fsw, Hsw/Fsw: 38.5 km^2) across a further 9.9%. These vegetation types cover two-thirds (66.4%) of the vast Delta Swamps and Plains ecological zone, 14.3% of the Mangroves and 11.9% of the Southeast Hills.

Swamp forest (Fsw) and associated vegetation complexes overlap all key Project areas. They span 84.0 km^2 of southwest PRL-15, mostly (99.0%) as a subordinate in complexes with alluvial

forest (Po/Fsw/Hm, Pl/Fsw; described in Section 6.2.4.2) and Swamp woodland (Wsw/Fsw; described above), but with minor occurrences (0.8 km^2) in the extreme southwest of PRL-15, downstream of proposed facility sites.

In the southern half of the export pipeline corridor, Swamp forest (Fsw) covers 29.4 km^2 in complex with Swamp woodland (Fsw/Wsw; described above). Much of this area is mapped as logged. While Swamp forest (Fsw) is not considered a commercial 'production forest' type (Annex 1D), typical communities do include desirable timber species such as Intsia bijuga. The northern end of this mapping unit was surveyed near Site 7, where the forest floor was notably dry and canopy elements included additional Group 1 timber species in Dracontomelon dao and Terminalia (Annex 1A). Unlogged examples occur in other parts of the export pipeline corridor and extend west on to the Delta Swamps and Plains.

Swamp forest (Fsw) and swamp forest complexes line much of the river transport corridors.

Plate 6.21 – Swamp Forest (Fsw), Southeast Delta Swamps and Plains, West of the Purari Distributary Channel



Photo source: I. Woxvold.

6.2.4.4 Mangroves

The mangrove ecosystem (mangal) is a community of salt tolerant plant species growing in coastal, estuarine and riverine areas that are subject to periodic tidal inundation and protected from heavy wave action (Giri et al. 2011). Mangrove (M) covers 603.6 km^2 of the study area, nearly all (97.9%) within the Mangroves ecological zone, with minor occurrences in the Southeast Coast (11.6 km^2) and the Delta Swamps and Plains (1.1 km^2).

Plant diversity in mangrove forest is low compared to non-saline lowland rainforest ecosystems (Swamp forest (Fsw), alluvial and hill forest). Cragg (1983) lists 29 trees and shrubs of the Purari delta mangrove forests, to which the IUCN Critically Endangered Bruguiera hainesii can be added, along with taxa of other growth habit including the terrestrial mangrove fern Acrostichum

speciosum and a suite of epiphytic orchids, ferns and members of the Apocynaceae and Fabaceae families (Annex 1A). Total plant diversity within the mapped area of Mangrove (M) is notably higher, as some non-mangrove environments are present in fringing areas at sites too small to be mapped at the FIMS scale, including Littoral forest (B) and associated beach scrub communities, freshwater swamp vegetation, and alluvial forest and agroforestry elements (e.g., Coconut Palm Cocos nucifera) on more elevated sites.

Mangrove vegetation is characterized by a distinct pattern of floristic zonation, determined by abiotic factors such as tidal regime, salinity, wave action and substrate. Zonation patterns are variably arranged parallel to the shoreline or as a mosaic in interior environments (Plate 6.22). Cragg (1983) identified three major zones of mangrove vegetation in the Purari delta—'fringing', 'main' and 'transitional'.

'Fringing' mangrove (Plate 6.23) occurs on aggrading lands at the water's edge along the coast, estuary or tidal rivers. It consists of shrubs and small trees less than one to ten meters high, important taxa including Avicennia, Sonneratia and Aegiceras. The Nipa Palm (*Nypa fruticans*) is present along low salinity river reaches.

The 'main' mangrove associations are found on longer established sediments, such as occur behind fringing systems and along eroded river banks. Canopy heights range from less than 10 to 30 m, with important genera including Rhizophora and Bruguiera. Pure stands of Nipa Palm cover vast areas (totalling hundreds of square kilometers) where substantial freshwater influence is present (Plate 6.24).

'Transitional' mangrove forest occurs in the zone of transition to swamp and alluvial forest forms. It is found at the landward edge of the Mangrove (M) mapping units. These are floristically the most species rich mangrove communities, due both to a diverse mangrove flora and to the presence of flora characteristic of neighboring swamp and alluvial forest communities. An example surveyed at Site 9 north of Harevavo village included numerous shrubs, herbs, vines and epiphytes as well as a stand of *Bruguiera hainesii* (Plate 6.25). Further west there are extensive transitional complexes mapped across the western half of the study area as Swamp forest/Mangrove (Fsw/M: 121.8 km^2) and Open alluvial forest/Swamp forest/Mangrove (Po/Fsw/M: 101.4 km^2).

Mangrove (M) vegetation of the Mangroves ecological zone is largely undisturbed. Areas of Land use (O) associated with permanent settlements are mapped along the coast. Natural resources including construction timber, firewood, medicinal plants and other small-scale items (e.g., stilt roots used for pounding sago) are harvested from adjacent forest areas, and gardens are planted within mangrove forest on some areas of raised ground. However, given the vast scale of the mangrove ecosystem in this deltaic zone these disturbances do not register as a FIMS disturbance code.

Local habitat pressure is greater in the Southeast Coast, where settlements are more widespread and the mangrove vegetation more limited. Mangrove-lined creeks traversing village areas within the export pipeline corridor are assigned disturbance code 7, and larger areas of Mangrove (O) to the southeast near the Vailala River mouth are assigned disturbance code 9.

In the northwest transition zone, some 57.8 km^2 of Open alluvial forest/Swamp forest/Mangrove (Po/Fsw/M) have been logged from the Pie Era concession (outside of the upstream PAOI). Commercial logging of mangroves is prohibited in PNG, and it is assumed that the subordinate mangrove components of this vegetation complex were not targeted for harvesting.

Mangrove (M) is sensitive to disturbance and active rehabilitation is likely to be required where vegetation is removed and soil disturbed across large areas.

Plate 6.22 – Variable Patterns of Zonation in Mangrove (M) Along the Purari Distributary Channel—Parallel to the Estuary Front at Right Foreground, Mosaic Interior in the Background



Photo source: I. Woxvold.

Plate 6.23 – Fringing Mangrove Along Oeha Creek, Western Export Pipeline Corridor, with Fringing *Sonneratia/Avicennia*Backed by Nipa Palm *Nypa fruticans*



Photo source: I. Woxvold.

Plate 6.24 – Nipa Palm *Nypa fruticans* Forest Along Oeha Creek, Western Export Pipeline Corridor



Photo source: I. Woxvold.

Plate 6.25 – Transitional Mangrove Forest North of Harevavo Village, Border Mangroves and Southeast Coast Ecological Zones, Southwest Export Pipeline Corridor. Trees on the Left are the IUCN Critically Endangered *Bruguiera hainesii*



Photo source: S. Venter.

6.2.4.5 Littoral Forest

Littoral vegetation grows on dry sandy beach plains and ridges. It comprises a succession of vegetation types from pioneering herbaceous ground covers to tall mixed forest inland with irregular canopies 20–30 m high. The FIMS type Littoral forest (B) is here applied to all successional stages. Mapped occurrences are restricted to 1.8 km^2 of coastal habitats in the Southeast Coast ecological zone, 1.0 km^2 of which covers accreting sand bars in the southeast corner of the export pipeline corridor (Plate 6.26). Surveyed at Site 9, the vegetation had not reached mature littoral forest statures but included early successional stage woody species of *Hibiscus tiliaceous, Desmodium umbellatum, Barringtonia asiatica* and *Premna serrata* to 4 m height. Herbaceous beach vegetation included the beach vine *Ipomea pes-carpae*, the parasitic vine *Cassytha filiformis* and the grass *Ischaemum muticum*.

Apart from the pioneer herbaceous vegetation, Littoral forest (B) is considered to have poor regenerative capacity due to the relatively thin layer of topsoil being sensitive to disturbance.

Plate 6.26 – Littoral Beach Vegetation on Accreting Sand Dunes in the Southeast Corner of the Export Pipeline Corridor, Coastward of Coconut Plantations (in Background)



Photo source: I. Woxvold.

6.3 Flora and Fauna

Some 1,272 terrestrial plant and animal species were recorded during the 2016 biodiversity baseline surveys (Table 6.5), providing the most detailed flora and fauna dataset available for the study area. Taxonomic inventories were comparable to or exceed those of other well-documented regions of lowland PNG. This is attributed to the wide variety of environments covered during biodiversity baseline surveys, to the low human population densities present across most of the study area, and to the accordingly low levels of disturbance to large tracts of hill, alluvial, swamp and mangrove forest habitats.

Together with the results of prior studies, the findings are discussed in detail in the flora and fauna technical study reports (Annex 1A, 2 to 6). Key themes relating to biogeographic affinities (Section 6.3.1) and species of conservation significance (Sections 6.3.2 to 6.3.6) are summarized in the following sections. Where references are provided in the flora and technical annex reports (1A, 2 to 6) they are not repeated here.

Locations of select Very Sensitive and Extremely Sensitive flora and habitat-specialist fauna known from one or few specific localities are shown in Figures 6.6 to 6.8. Other specific locations relevant to high sensitivity taxa (e.g., Wi'i Creek cave site and *Bruguiera hainesii* site) are shown below in sensitive area maps (Figures 6.14 to 6.16). Relatively widespread high sensitivity taxa (including plants recorded from multiple sites and rarely recorded fauna that are not habitat specialists) are not mapped; the habitats that they occupy are identified and in most cases the relevant ecosystems are mapped elsewhere (e.g., Figures 6.2 and 6.3).

Table 6.5 – The Number of Species Recorded During Project Flora and Fauna Surveys

Taxonomic Group	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6A	Site 6B	Site 6C	Site 6D	Site 7	Site 8	Site 8M	Site 9	Wi'i Ck cave	Totals[A]
Flora	348	282	200	318	323	179	163	–	146	301	267	21	294	–	812
Non-volant mammals	12	7	10	16	12	5	–	–	–	13	14	3	14	23	42
Bats	26	23	25	23	23	11	–	–	–	24	25	15	21	2	39
Birds	90	81	102	106	109	62	39	11	32	113	96	39	92	–	183
Reptiles	19	22	22	21	18	4	4	1	5	18	21	1	15	–	57
Frogs	32	26	26	25	18	3	0	–	3	24	17	0	13	–	42
Odonates	46	27	30	31	44	21	4	–	6	44	28	0	30	–	97

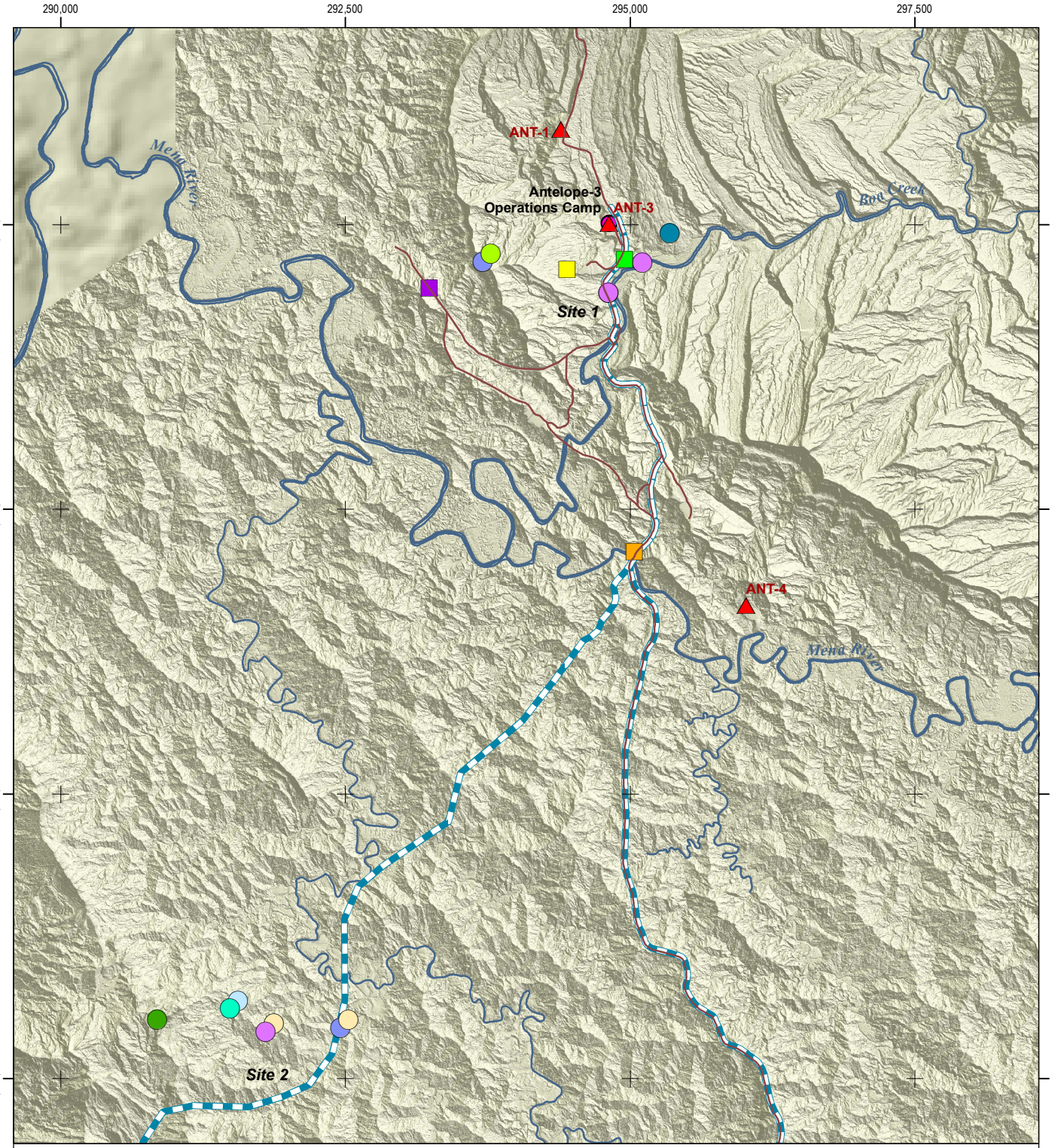
[A] In addition to species recorded at survey sites: totals for non-volant mammals include five species confirmed present from Middle Purari Hills based on local landowner information, plus one invasive rodent species observed only at Herd Base; totals for birds include three additional bird species seen only at Herd Base or Purari airstrip. Totals for non-volant mammals and reptiles exclude five marine species – Dugong (*Dugong dugon*), Australian Snubfin Dolphin (*Orcaella heinsohni*), Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*), Loggerhead Turtle (*Caretta caretta*) and Green Turtle (*Chelonia mydas*); though reported in Annex 2 and Annex 5, information on these species is summarized in the Marine Ecology Baseline Report (BMT WBM, 2017a).

6.3.1 Biogeographic Setting

Various attempts have been made to define biogeographic 'areas of endemism' within New Guinea; to delineate regions within which biotic communities are more similar to one another (in terms of species composition) than they are to communities of surrounding areas.

In a broad regional sense, the study area is located at the eastern end of New Guinea's 'Southern Lowlands' region[10], an area that spans more than 1,200 km from the base of the southeast peninsula in PNG west to the 'Bird's Neck' isthmus of Indonesian New Guinea, and that is separated from the northern lowlands by the central cordillera. While authorities differ on the precise borders, there is consensus that biotic communities within this 'area of endemism' are distinct from those of the neighboring uplands and southeast peninsula (e.g., Stattersfield et al., 1998; Wikramanayake et al., 2002; Duffels and de Boer, 2007; Takeuchi, 2007; Pratt and Beehler, 2015).

[10] Various terms are applied to this biogeographic region, this taken from Pratt and Beehler (2015).



SCALE: 1:50,000 @ A4

0 500 1,000 1,500 2,000 2,500 Meters

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

Existing Facilities
- Base camp

Proposed Facilities
- Wellpad

Sensitive Fauna
- Argiolestes tuberculiferus
- Oreophryne sp. 2
- Palaeosynthemis sp. 1
- Teinobasis sp. 1

Sensitive Flora
- Archidendron forbesii
- Begonia sp. 2
- Begonia sp. 3
- Begonia sp. 4
- Genus 1 sp. 2
- Glochidion sp. 1
- Lasianthus sp. 1
- Medinilla sp. 1

- Tracks
- Waterways
- Waterbodies
- Trunkline corridor

N

TITLE: Select High Sensitivity Species Locations at Flora and Fauna Survey Sites 1 and 2 in PRL-15

FIGURE: 6.6

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79678 **REVISION:** C

DATE: 12/04/2017

DATA SOURCES:
Waterways, tracks, wellpads, proposed logistics base, trunklines, hillshade supplied by ERIAS Group and TOTAL (2015-2016). DEM (Planet Observer 2015 and TOTAL 2016). Terrestrial biodiversity survey sites, sensitive flora and fauna supplied by Iain Woxvold (2017)

CLIENT:

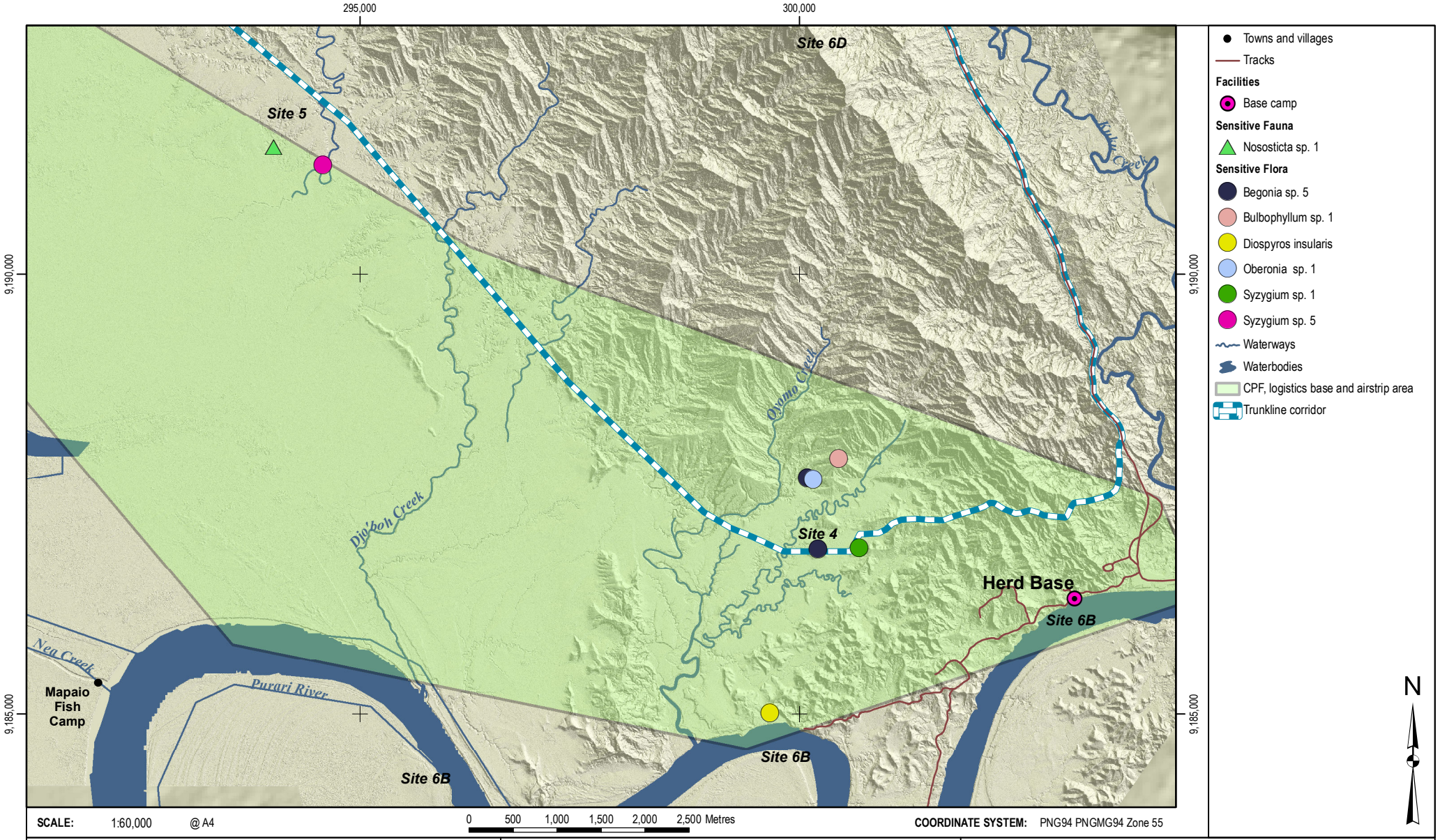
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI\002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79678-Figure 6.6-C.mxd



TITLE: Select High Sensitivity Species Locations at Flora and Fauna Survey Sites 4, 5 and 6B in PRL-15

FIGURE: 6.7

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-81956 **REVISION:** D

DATE: 8/08/2017

DATA SOURCES:

Towns and villages, waterways, tracks, CPF, logistics base and airstrip area, trunklines, hillshade supplied by ERIAS Group and TOTAL (2015-2016). DEM (Planet Observer 2015 and TOTAL 2016). Terrestrial biodiversity survey sites, sensitive flora and fauna supplied by Iain Woxvold (2017).

CLIENT:

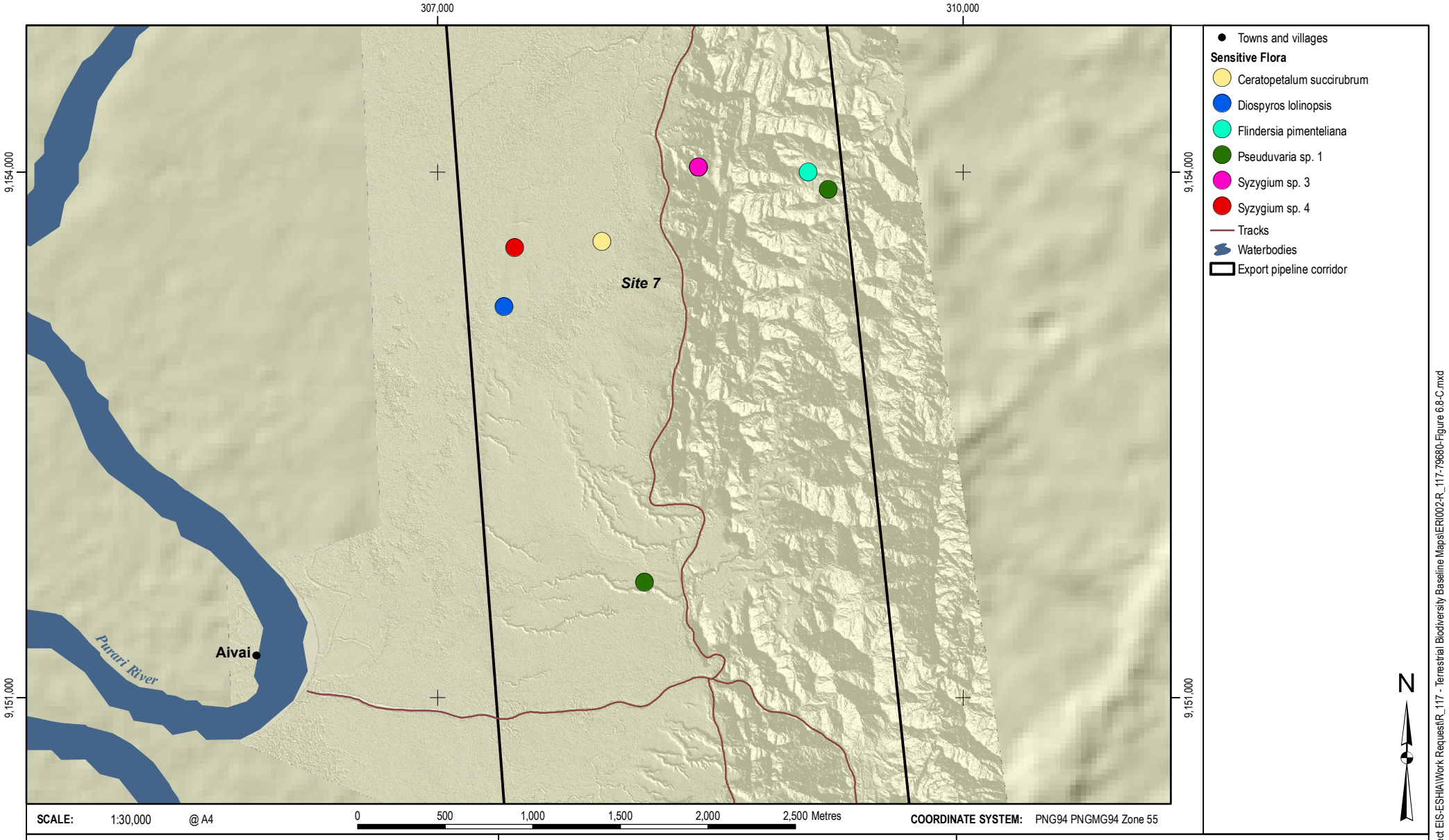
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ER1002 Elk Antelope LNG Project EIS-ESHIA\Work Request\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-81956-Figure 6.7-D.mxd



TITLE: Select High Sensitivity Species Locations at Flora and Fauna Survey Site 7, Export Pipeline Corridor

FIGURE: 6.8

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79680 **REVISION:** C

DATE: 12/04/2017

DATA SOURCES:

Towns and villages, waterways, tracks, export pipeline corridor supplied by ERIAS Group and TOTAL (2015-2016). DEM (Planet Observer 2015 and TOTAL 2016). Terrestrial biodiversity survey sites, ensitive flora and fauna supplied by Iain Woxvold (2017).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

T:\Projects\ER1002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79680-Figure 6.8-C.mxd

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

At a finer scale, various authorities recognize within the Southern Lowlands a number of smaller biogeographic regions. The arrangement of these regions both within and beyond the study area differs among major taxonomic groups.

As identified by Beehler (1993b) for warm-blooded vertebrates (mammals and birds), the study area is contained entirely within the 'Kikori-Purari' biogeographic region. This region is contained within the Gulf Province lowlands (not above 500 m asl) and extends from the Turama River east to the Vailala River. Under this arrangement the study area is located in a biogeographic region separate to which includes the Lakekamu basin to the east.

By contrast, the study area spans two biogeographic regions identified for lower vertebrates (fish and herpetofauna: Allison, 1993) and terrestrial insects (Miller et al., 1993)—the 'Gulf Lowlands' and the 'Eastern Highlands'. The boundary between these regions was not clearly defined, but follows approximately the southern boundary of the Middle Purari Hills ecological zone. The Gulf Lowlands biogeographic region includes the southern part of the study area and extends west to the Fly River and east to near Hall Sound to include the Lakekamu basin. The Eastern Highlands biogeographic region extends north from the Middle Purari Hills to montane environments above 3,000 m asl.

Polhemus et al., (2004) identified a similar division based on the distribution of aquatic insects[11], though their biogeographic regions are more limited in extent outside of the study area. Their 'Papuan Gulf Coastal Lowlands' biogeographic region includes the southern coastal lowlands below 50 m asl from the Kikori River delta east to Kerema. It includes the Delta Swamps and Plains, Mangroves and Southeast Coast ecological zones and parts of the Southeast Hills ecological zone. The 'Papuan Gulf Foreland' biogeographic region comprises the basins of the Kikori, Purari, Vailala and Lakekamu rivers at elevations between 50 and 1,200 m asl.

Consistent with the above arrangements, recorded plant and animal communities are generally a subset of those found in comparable lowland environments that extend across much of southern PNG, most notably the Kikori River and Lakekamu River basins, insofar as prior surveys within those regions permit comparison. Strong affinities were also found between communities of the Middle Purari Hills and the Purari catchment uplands (below 1,000 m asl) to the immediate north of the study area.

6.3.2 IUCN Listed and Nationally Protected Species

6.3.2.1 Patterns of Occurrence

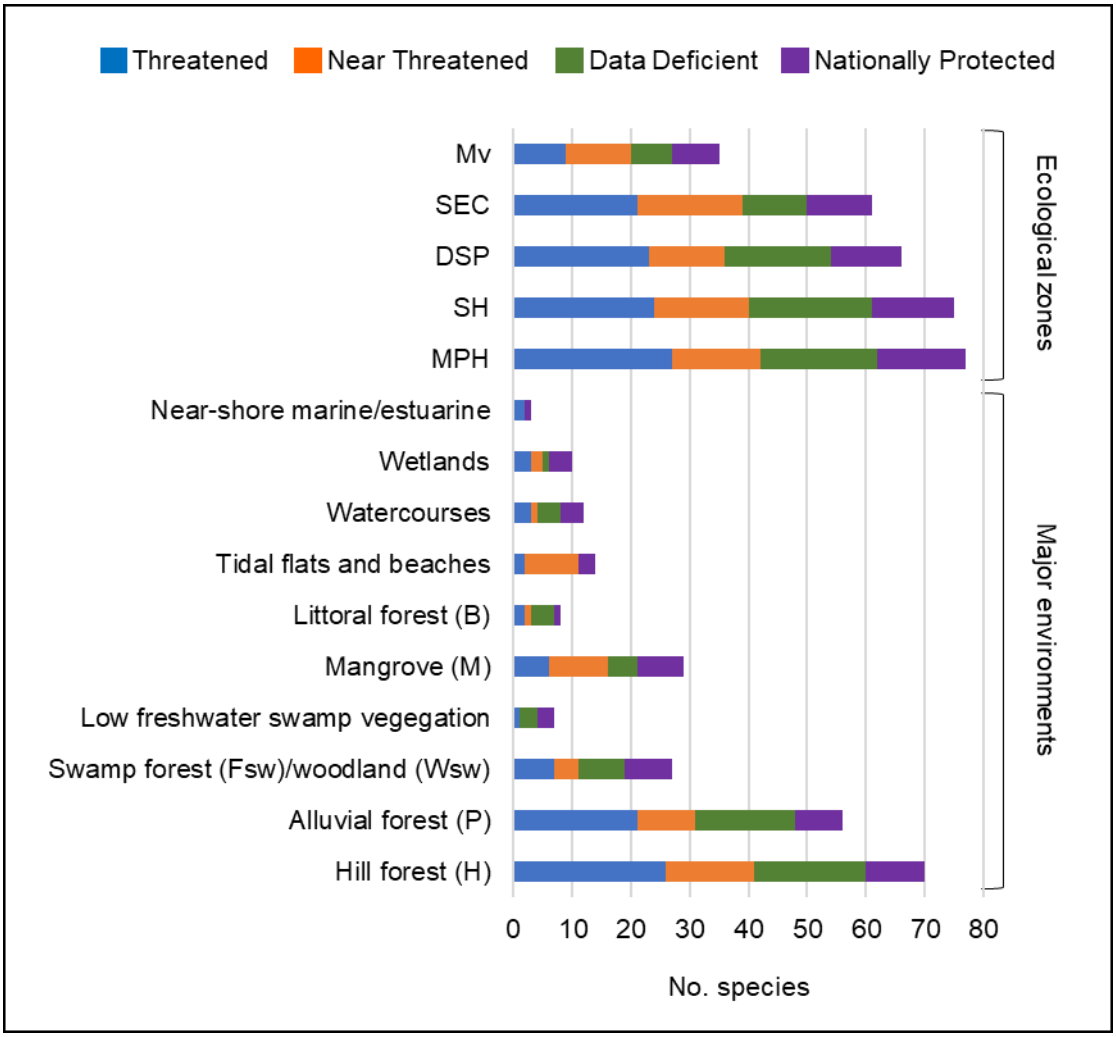
A total of 96 IUCN listed and nationally Protected species has been recorded within the study area (64 species) or may occur based on known distribution and habitat preferences (32 species). These are listed in Appendix 4 together with their conservation status, sensitivity ranking, study area records and the presence of suitable habitat in various ecological zones and major environments identified within the study area.

Figure 6.9 shows the number of IUCN listed and nationally Protected species potentially occurring in each ecological zone, and in each of 10 major natural environments identified within the study area. Most species occupy dry-floor forest (hill and alluvial forest) and/or wooded swamp (swamp forest/woodland) environments. Diversity is highest in hill and alluvial forest, where most

[11] Including odonates (dragonflies and damselflies), an insect group with both an aquatic (larva) and a terrestrial (adult) life stage and included here in the terrestrial biodiversity baseline study (Annex 6).

conservation listed species are permanent residents. Marine environments, littoral forest and low statured freshwater swamp vegetation (FIMS types Hsw, Gsw) support the fewest conservation listed species. Wetlands, watercourses and tidal flats and beaches each support multiple conservation listed species, many of which are migratory or transient non-breeding visitors.

Figure 6.9 – IUCN Listed and Nationally Protected Species Potentially Occurring in Ecological Zones and Major Natural Environments



Protected species tallies exclude those also listed under a displayed IUCN category.

For each major taxonomic group, Table 6.6 lists the number of species from each conservation category recorded or potentially occurring in the study area. Of greatest significance are those species assigned Extremely Sensitive or Very Sensitive status. They include:

- Four IUCN Critically Endangered species (Extremely Sensitive), three of which are confirmed present—the timber tree *Diospyros lolinopsis*, the mangrove tree *Bruguiera hainesii*, and Bulmer's Fruit Bat (*Aproteles bulmerae*).
- Eight IUCN Endangered species (Very Sensitive), six of which are confirmed present—the timber trees *Diospyros insularis* and *Flindersia pimenteliana*, two tree kangaroo species (*Dendrolagus* spp.), the Giant Bandicoot (*Peroryctes broadbenti*) and the migratory Far Eastern Curlew (*Numenius madagascariensis*).
- Twenty-one IUCN Vulnerable species (Very Sensitive), 17 of which are confirmed present—six tree species, five non-volant mammals, four resident forest bird species and two freshwater turtle species.
- One IUCN Data Deficient species assigned Very Sensitive status—Starry Owlet-nightjar (*Aegotheles tatei*).

Table 6.6 – The Number of Species From Each Conservation Category Recorded (X/–) and Potentially Occurring (–/Y) in the Study Area

Taxonomic group	IUCN					PNG
	CR	EN	VU	NT	DD	P
Flora	2/3	2/2	6/9	6/8	5/5	–
Non-volant mammals	–	3/3	5/5	1/1	1/2	4/4
Bats	1/1	–	–	–	4/5	1/1
Birds	–	1/2	4/5	3/15	2/6	14/18
Reptiles	–	–	2/2	–	–	–
Frogs	–	–	–	–	1/1	–
Odonates	–	–	–	–	4/4	–
Butterflies[A]	–	–/1	–	–	–	–/3
Total	3/4	6/8	17/21	10/24	17/23	19/26

[A] Butterflies were not subject to field survey. No other potentially occurring terrestrial flora or fauna are conservation listed.

The following sections further summarize the occurrence of conservation-listed species according to major taxonomic groupings. Brief accounts are provided for species ranked Very Sensitive or Extremely Sensitive. Accounts include a summary of the range, status, study area distribution and threats/susceptibilities of each species. For all taxa, where a species' sensitivity is promoted above that inherent to its conservation listing (see Table 5.6) the reasoning is provided. Additional information on listed species is found in Appendix 4 and in the flora and fauna technical study reports (Annex 1A, 2 to 6).

6.3.2.2 Flora

Twenty-one IUCN listed plants have been recorded in the study area, and another six may occur. No plant species are Protected under PNG law. Fourteen locally occurring IUCN Threatened plants are ranked as Very Sensitive or higher (Table 6.7). All Near Threatened species are Moderately Sensitive, and all Data Deficient species are assigned Low Sensitivity. A selection of IUCN listed plant species are shown in Plates 6.27 to 6.34.

Table 6.7 – Very Sensitive and Extremely Sensitive Conservation Listed Flora Recorded or Potentially Occurring in the Study Area[A]

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Diospyros lolinopsis	CR/-/-/-	ES	Timber tree to 25 m. A rare PNG endemic previously known only from Bigei River area in Madang Province	Several in primary alluvial forest at Site 7, western edge export pipeline corridor in DSP (at 307379 9153234). Potentially alluvial, swamp and hill forest in DSP, MPH and SH. May be more widespread though not yet recorded in suitable habitat in PRL-15	Logging and habitat degradation. Primarily a subcanopy species dependent on shaded conditions, habitat degradation may negatively impact on recruitment and survival of mature specimens
Bruguiera hainesii	CR/-/-/-	ES	Mangrove tree to 12 m. Rare (250 mature individuals known) but widely distributed from mainland Southeast Asia to PNG. Occupies the high intertidal zone of mangrove forest ecosystems. While a recent genetic study (Ono et al. 2016) has found it to be a hybrid of *B. cylindrica* and *B. gymnorrhiza*, it is conservatively treated here as a separate species based on its high-value IUCN status	Recorded at eastern edge of mangroves at Site 9, western export pipeline corridor in Mv (at 310910 9132280): 32 mature specimens with many young plants and germinating hypocotyls. Suitable habitat occurs across the landward margin of mangrove forest in Mv, and to a lesser degree in the subcoastal mangrove strip parallel to the shorefront along Orokolo Bay in SEC	Globally threatened by habitat loss and sea level rise. Local threats include harvesting for firewood and building material. The study area population was found on a well-used path c. 600 m north of Harevavo village
Guioa hospita	CR/-/-/-	ES	Likely a tree (unknown; van Welzen 1994). Known only from the type material collected in Mt Yule, Gulf Province in 1890, east of the study area	Not recorded. Potentially hill forest in MPH and SH	Ecology poorly known. Most vulnerable to habitat conversion

Table 6.7 – Very Sensitive and Extremely Sensitive Conservation Listed Flora Recorded or Potentially Occurring in the Study Area[A] (cont'd)

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Diospyros insularis	EN/-/-/-	VS	Timber tree to 15 m. An insular species known previously from a few localities in the Solomon Islands, New Britain, and Kiriwina Island in Milne Bay Province	One tree in hill forest at Site 6B (MPH), within the southeast corner of the proposed Logistics Base area (at 299660 9185012). Potentially hill and alluvial forest in DSP, MPH and SH. Seeds dispersed by pigeons and bats, so likely to be more widespread, but possibly locally rare and/or patchy given lack of records from other potentially suitable sites	Overexploitation and logging threaten prior known populations. Susceptible also to habitat degradation
Maple Silkwood (*Flindersia pimenteliana*)	EN/-/-/-	VS	Timber tree to 40 m. Widespread across New Guinea from foothills to 2,700 m asl. Also northeast Australia. Serious declines from logging in Bulolo/Wau districts of PNG (Eddowes 1998). Some populations are secure due to topographic constraints	Five in hill forest at Site 7 (SH) within the export pipeline corridor (at 309115 9153999). Potentially hill forest in MPH and SH	Logging is the major threat
Gluta papuana	VU/-/-/-	VS	Tree. Endemic to PNG, known from Western and Gulf Provinces where it occurs in seasonally inundated freshwater swamp and alluvial forest habitats below 50 m asl	Not recorded during Project surveys. First collected in 1953 from the Romilly Sawmill Logging Area, probably in the southwest study area within Pie Era or Eia River concession (Section 6.2.3.1). Alluvial and/or swamp forest in DSP, potentially also SH, SEC and Mv	Logging is the major threat, with its area of occurrence previously subject to extensive harvesting. Changes to hydrology would impact local populations

Table 6.7 – Very Sensitive and Extremely Sensitive Conservation Listed Flora Recorded or Potentially Occurring in the Study Area[A](cont'd)

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Avicennia rumphiana	VU/-/-/-	VS	Mangrove tree to 20 m, across the tropical Indo-Pacific from Malaysia and the Philippines to PNG. A fast growing species colonizing newly formed mudflats and tolerant of hypersaline conditions	Not recorded. Potentially suitable mangrove habitat widespread in Mv	Globally threatened by habitat loss and sea level rise. Local threats include harvesting for firewood and building material
Mammea grandifolia	VU/-/-/RR	VS	Small tree to 6 m. A rare PNG endemic, previously known only from the type locality at Pinini Creek in the Kikori basin, Gulf Province	Widespread in alluvial forest and foothill forest near the border of alluvial plains, PRL-15 and export pipeline corridor. Some specimens within proposed CPF fencing and Logistics Base areas	Habitat loss is the major threat; extensive logging operations are underway across most of its known range. Somewhat tolerant of disturbance as recorded in logged hill forest at Site 3
Ceratopetalum succirubrum	VU/-/-/-	VS	Timber tree to 35 m. Northeast Queensland (Australia) and New Guinea from Papua Province (Indonesia) to Morobe Province in PNG. Project records are first for southern mainland PNG	Recorded at Site 7, in logged hill forest and in alluvial forest within the export pipeline corridor (at 308488 9154030; 307939 9153603). Potentially hill forest in SH and MPH, well drained alluvial forest in DSP	Logging and habitat loss; targeted by loggers, though at Site 7 it persists in logged areas
Archidendron forbesii	VU/-/-/-	VS	Tree to 24 m. A rare PNG endemic previously known from Central Province and Oro Province, as a late secondary species in forest below 500 m asl	One specimen in hill forest at Site 2 (MPH) (at 290848 9203022). Potentially in hill and alluvial forest in all ecological zones except Mv, possibly most numerous in MPH	Logging and habitat loss are the major threats
Kwila/Merbau (*Intsia bijuga*)	VU/-/-/-	VS	Timber tree to 40 m. Widespread from Africa through Asia to New Guinea, where often a canopy dominant in lowland forests below 500 m asl	Widespread and fairly common. Suitable hill, alluvial and littoral forest in all ecological zones	Logging is the major threat. In some regions it has been eliminated as a timber resource, though it is still secure across much of New Guinea

Table 6.7 – Very Sensitive and Extremely Sensitive Conservation Listed Flora Recorded or Potentially Occurring in the Study Area[A](cont'd)

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Koompassia grandiflora	VU/-/-/-	VS	Timber tree to 50 m. Endemic to New Guinea, widespread from the Vogelkop Peninsula, Indonesia, to the southeast peninsula of PNG, in primary forest up to c. 840 m asl (Verdcourt 1979; Eddowes 1998)	Not recorded. Potentially hill and alluvial forest in all ecological zones except Mv	Logging, habitat loss and degradation. A primary forest species targeted by loggers
Burmese Rosewood (*Pterocarpus indicus*)	VU/-/-/-	VS	Timber tree to 50 m. Widespread from Asia to South Pacific islands in a variety of forest types up to >1,000 m asl. The largest remaining populations are in New Guinea where it is heavily exploited but still widespread and fairly common in many parts of PNG	Widespread and fairly common; recorded in all ecological zones in hill, alluvial, swamp and littoral forest and mangroves. Occurs in primary and logged forest	Logging is the major threat, with regional extinctions across parts of mainland and insular Southeast Asia
Myristica brachypoda	VU/-/-/RR	VS	Tree to 10 m. A rare PNG endemic known only from the type specimens collected in 1955 from a logging area at Sirebi River in the Kikori basin, Gulf Province	Not recorded. Ecology poorly known, but potentially suitable habitat may include hill, alluvial and/or swamp forest in all ecological zones except Mv	Logging, habitat loss and degradation are presumed the major threats; extensive logging operations are underway in its known area of occurrence

[A] Where available, positional data are provided for species that are known from single sites.

Plate 6.27 – Seed Pods of the Timber Tree Maple Silkwood (*Flindersia pimenteliana*) (EN)



Photo source: S. Venter.

Plate 6.28 – *Archidendron forbesii* (VU)



Photo source: S. Venter.

Plate 6.29 – Flowers of the Timber Tree Kwila/Merbau (*Intsia bijuga*) (VU)



Photo source: S. Venter

Plate 6.30 – *Mammea grandifolia* (VU)



Photo source: S. Venter

Plate 6.31 – *Cycas scratchleyana* (NT)



Photo source: S. Venter

Plate 6.32 – Fruit of *Myristica globosa* (NT)



Photo source: S. Venter

Plate 6.33 – *Aglaia euryanthera* (NT)



Photo source: S. Venter

Plate 6.34 – *Mammea novoguineensis* (DD)



Photo source: S. Venter

6.3.2.3 Non-volant Mammals

Eleven IUCN listed non-volant mammals may occur in the study area, 10 of which are confirmed present (nine species) or are considered likely present (Dusky Pademelon (*Thylogale brunii*)) based on evidence collected during biodiversity baseline surveys. Five non-volant mammals are nationally Protected or listed under CITES Appendix I, all of which are also listed under an IUCN Threatened category. A selection of listed non-volant mammals is shown in Plates 6.35 to 6.38.

Eight IUCN Threatened non-volant mammals are assigned Very Sensitive status (Table 6.8). One IUCN Near Threatened species is Moderately Sensitive, and one IUCN Data Deficient species is assigned Low Sensitivity. The Data Deficient Woolley's Three-striped Dasyure (*Myoictis leucura*) (Plate 6.38) is here considered Moderately Sensitive as it is a restricted-range, habitat specialist species with one of few known populations overlapping the study area.

Table 6.8 – Very Sensitive and Extremely Sensitive Conservation Listed Non-volant Mammals Recorded or Potentially Occurring in the Study Area

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Giant Bandicoot (*Peroryctes broadbenti*)	EN/-/-/RR	VS	The largest bandicoot, males up to 5 kg. Endemic to PNG where peviously known from two discrete areas on the southeast peninsula: (1) south coast between Port Moresby area and Vanapa River (Central Province); (2) north coast in Oro and Milne Bay Provinces. Most records predate 1970, including all southern records, and the species appears to be in serious decline or extinct across much of its former range; it is probably one of New Guinea's most endangered vertebrates	Camera trapped in alluvial forest at Sites 7, 8 and 9. Potential in alluvial and low elevation hill forest in DSP, SEC and SH. Within upstream PAOI may be confined to southern half of export pipeline corridor	Behavior and ecology poorly known. Decline elsewhere probably due to hunting pressure and forest conversion. Locally it appears moderately tolerant of forest disturbance as it was photographed in areas logged or subject to frequent visitation (e.g., next to gardens). Susceptible also to feral dogs and collisions with traffic, and as an omnivorous species potentially poisining by alien invasive Cane Toad
Goodfellow's Tree Kangaroo (*Dendrolagus goodfellowi*)	EN/P/-/-	VS	A large (9 to 10 kg) arboreal kangaroo with reddish brown fur and cream-yellow markings. Endemic to eastern New Guinea, from near sea level to lower montane elevations but probably restricted to hill and lower montane forest in areas where Lowland Tree Kangaroo also occurs. Population density moderately high in some remote areas, but now rare or locally extinct across much of its former range	Not recorded directly. Based on landowner testimony: almost certainly present in hill forest of MPH, including remote areas north of the Purari River, the eastern footslopes of Mt Favenc and possibly the Kereru Range; possibly also PRL-15; likely absent south of there	Threatened by a combination of hunting (especially with dogs) and forest loss and degradation. Susceptible also to feral dogs and collisions with traffic. Tree kangaroos are sensitive to disturbance and are rarely observed close to areas of human activity

Table 6.8 – Very Sensitive and Extremely Sensitive Conservation Listed Non-volant Mammals Recorded or Potentially Occurring in the Study Area (cont'd)

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Western Montane Tree Kangaroo (*Dendrolagus notatus*)	EN/P/-/-	VS	A large (>10 kg) arboreal kangaroo with dark brown fur and a cream spot at the base of the tail. Endemic to eastern New Guinea, usually above 1,500 m asl but recorded also at hill elevations (below 1,000 m asl) in areas of high rainfall. Population density moderately high in some remote areas, but rare or locally extinct near settled areas	Not recorded directly. Based on landowner testimony: restricted occurrence in study area in rugged and remote areas of hill forest in northern MPH, north of the Purari River and on the eastern slopes of Mt Favenc	As for Goodfellow's Tree Kangaroo
Eastern Long-beaked Echidna (*Zaglossus bartoni*)	VU/P/II/-	VS	A heavy (to 10 kg), slow-moving mammal of the forest floor with a long snout and harsh spines concealed within dark fur. Endemic to New Guinea. Recorded from sea level to the highest mountains in a variety of habitats. Population densities are highest in remote montane localities, naturally low in hill forest, even in remote areas, very low or absent from alluvial plains subject to inundation. Generally extirpated from areas near human settlement	Not recorded directly. Based on landowner testimony: present but confined to remote forest of northern study area, including hill forest in MPH and potentially well drained alluvial forest on northern rim DSP; recent landowner sightings from north of Purari River, eastern slopes of Mt Favenc and slopes of Aure Scarp. Presence in PRL-15 uncertain	Long-lived and slow maturing, thus highly susceptible to overhunting. Echidnas are prized as game and easy to locate with dogs. Susceptible to habitat disturbance where this reduces food availability (worms and grubs) via effects on surface soil

Table 6.8 – Very Sensitive and Extremely Sensitive Conservation Listed Non-volant Mammals Recorded or Potentially Occurring in the Study Area (cont'd)

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Lowland Tree Kangaroo (*Dendrolagus spadix*)	VU/P/-/RR	VS	A large (9 to 10 kg) arboreal kangaroo, reddish brown with yellow or black marks on the tail. Endemic to PNG, Gulf of Papua hinterland up to c. 650 m asl. Probably restricted to mature forest habitats and absent from low-lying areas that are subject to periodic inundation. The least known of all tree kangaroos, the population density is probably everywhere low	Not recorded directly. Based on landowner testimony: present in hill forest of MPH, including within PRL-15, areas north of the Purari River, the eastern footslopes of Mt Favenc and possibly the Kereru Range. Also, possibly alluvial forest along northern rim DSP. Although suitable habitat occurs in SH and SEC (marginal), probably no longer present there due to over-exploitation	Ecology poorly known. As for Goodfellow's Tree Kangaroo
Grey Dorcopsis (*Dorcopsis luctuosa*)	VU/-/-/-	VS	A medium-sized grey-brown wallaby. Endemic to lowland and hill forest of southern New Guinea and the southeastern peninsula. Two subspecies recognized: D. l. luctuousa in the east and D. l. phyllis in the west (geographic limits unknown). Appear similar but are genetically divergent and may represent distinct species. Populations around the southeast peninsula have been severely impacted; D. l. phyllis still locally common in remote areas of Gulf and Western provinces	Records widespread in hill and alluvial forest in all ecological zones except Mv, including throughout PRL-15 and export pipeline corridor. Camera trap rates indicate preference for alluvial forest over hill forest, and for primary forest over disturbed areas. The taxonomic identity of the local population is uncertain	Susceptible to hunting (especially with dogs) and forest loss and degradation. Susceptible also to feral dogs and collisions with traffic. The study area population is less impacted by existing pressures than tree kangaroos and echidnas—it is widespread and persists in logged forest and in areas near human settlements

Table 6.8 – Very Sensitive and Extremely Sensitive Conservation Listed Non-volant Mammals Recorded or Potentially Occurring in the Study Area (cont'd)

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Dusky Pademelon (*Thylogale brunii*)	VU/-/-/-	VS	A medium-sized brown wallaby with short face. Endemic to New Guinea region, known from Aru Islands, the Trans-Fly, the southeast peninsula west to Port Moresby area and from the Gulf of Papua hinterland. There are no recent records from the southeast peninsula or Gulf Province (1980s most recent). Trans-Fly and Aru populations are probably secure	Not recorded; considered likely present based on records to the north (Purari catchment uplands) and on landowner accounts at Wabo village. Potentially in hill forest of MPH, perhaps also SH. Likely to occupy forest edge providing access to grassy foraging areas. Local populations likely to be fragmented and restricted to areas away from human settlement	Susceptible to hunting (especially with dogs) and forest loss and degradation. Susceptible also to feral dogs and collisions with traffic
False Water Rat (*Xeromys myoides*)	VU/-/I/-	VS	A small grey and white rodent. Widespread but patchy in coastal and riverine swamp and mangrove habitats of Queensland and the Northern Territory, Australia. Only one prior record from New Guinea, from the Trans-Fly region of Western Province. Large areas of potentially suitable habitat occur in southern New Guinea but its status in these areas has not been evaluated	Camera trapped in low elevation hill forest at Site 5 (MPH), and in disturbed alluvial forest at Site 8 (SEC). Potentially in alluvial forest, freshwater swamp vegetation and mangroves in DSP, SEC and Mv, and in hill forest at MPH base near border with DSP	Declining in parts of Australia due to urban development, predation by invasive alien species (foxes and pigs) and chemical pollution. The newly discovered Gulf of Papua population is likely to be secure as deltaic habitats are extensive and relatively undisturbed

Plate 6.35 – Giant Bandicoot *Peroryctes broadbenti* (EN) Camera Trapped at Site 7



Photo source: I. Woxvold.

Plate 6.36 – Grey Dorcopsis *Dorcopsis luctuosa* (VU) Camera Trapped at Site 5



Photo source: I. Woxvold.

Plate 6.37 – False Water Rat *Xeromys myiodes* (VU) Camera Trapped at Site 8



Photo source: I. Woxvold.

Plate 6.38 – Wolloey's Three-striped Dasyure *Myoictis leucura* (DD) Camera Trapped at Site 2



Photo source: I. Woxvold.

6.3.2.4 Bats

Six IUCN listed bats may occur in the study area, four of which are confirmed present and one of which (Semon's Leaf-nosed Bat (*Hipposideros semoni*)) is provisionally recorded due to uncertainty in assigning echolocation call types for that taxon. A selection of listed bats is shown in Plates 6.39 and 6.40.

The IUCN Critically Endangered Bulmer's Fruit Bat (*Aproteles bulmerae*) (Plate 6.39) is the only bat species Protected in PNG. It is assigned Extremely Sensitive status (Table 6.9).

Four IUCN Data Deficient species are assigned Low Sensitivity. The Data Deficient Papuan Free-tailed Bat (*Otomops papuensis*), recorded at Site 8, is here considered Moderately Sensitive as it is a restricted-range, habitat specialist species with one of few known populations overlapping the study area (Table 5.6).

Plate 6.39 – Teeth of Juvenile Bulmer's Fruit Bat (*Aproteles bulmerae*) (CR) (the Six Teeth at Right; Unerupted Teeth of Juvenile Dobsonia Shown at Left for Comparison) Collected from Owl Pellet Deposit at the Wi'i Creek Cave Site



Photo source: K. Aplin.

Plate 6.40 – New Guinea Sheath-tailed Bat (*Emballonura furax*) (DD)



Photo source: S. Richards

6.3.2.5 Birds

Forty-two IUCN listed and nationally Protected bird species may occur in the study area, 21 of which are confirmed present. A selection of listed birds is shown in Plates 6.41 to 6.45.

Seven IUCN Threatened bird species are assigned Very Sensitive status (Table 6.10). In addition, the Starry Owlet-nightjar is here considered Very Sensitive as it is a restricted-range, habitat specialist species with one of few known populations overlapping the study area and with its preferred habitat under significant pressure (e.g., from industrial logging) across much of its range.

Another 29 IUCN Near Threatened and nationally Protected bird species are Moderately Sensitive, and five IUCN Data Deficient species are assigned Low Sensitivity.

.

Table 6.9 – Very Sensitive and Extremely Sensitive Conservation Listed Bats Recorded or Potentially Occurring in the Study Area.

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/ Susceptibilities
Bulmer's Fruit Bat (*Aproteles bulmerae*) (Plate 6.39)	CR/P/-/RR	ES	A large, cave-roosting fruit bat (c. 600 g). Known only from PNG, as a living animal (two sites) and recent skeletal remains from two regions with forested limestone at c. 500 to 2,400 m asl: Western Province uplands and Purari basin uplands (including Crater Mountain WMA) (Aplin et al., 2016). Ecology poorly known, presumed similar to the closely related Moluccan Naked-backed Fruit Bat Dobsonia moluccensis	Modern skeletal remains were found in a limestone cave above Wi'i Creek (Plate 6.39), north of Purari River in the northeast study area (MPH) and within the Crater Mountain WMA. Remains of juveniles indicate proximity of a maternity roost, potentially located in the Wi'i Creek cave itself, and/or in other caves present in this limestone area. Elsewhere within the study area, large cave systems potentially suitable for this species are likely to be restricted to other areas of surface limestone associated with the Darai formation (all in MPH): in other areas, north of the Purari River and northwest of Subu village, on the Aure Scarp and the Kereru Range (see Figure 6.17). Foraging individuals may utilize forest habitats anywhere within the MPH, including within PRL-15	Hunting represents the major threat to known populations. Also, vulnerable to damage/destruction of roost sites, disturbance of roosting colonies and to large scale clearing of forest habitat that would deny them adequate foraging territory

Table 6.10 – Very Sensitive and Extremely Sensitive Conservation Listed Birds Recorded or Potentially Occurring in the Study Area

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Far Eastern Curlew (*Numenius madagascariensis*)	EN/-/-/-	VS	A large migratory shorebird. Breeds in northeast Asia, migrates south to spend the austral summer in Australia and New Zealand. In New Guinea, predominantly near-coastal on tidal mudflats on the shoreline and in sheltered bays, estuaries and lagoons	Not recorded during Project surveys. Previously listed for Purari delta with no information on number of birds. Suitable habitat occurs along the shorefront and tidal estuaries of the Purari delta in Mv, and to a lesser extent SEC. Likely to be most common in transit (during migration) during August to November and March/April	Currently undergoing major population decline. Globally threatened by loss of habitat along migratory route and at wintering grounds. Hunting presents additional localized threat
Great Knot (*Calidris tenuirostris*)	EN/-/-/-	VS	A medium-sized migratory shorebird of tidal flats, lagoons and estuaries. Breeds in northeast Asia, migrates south to spend the austral summer in Australia and New Zealand	Not recorded in study area, but known to visit nearby Kikori delta. May occur seasonally along the shorefront and tidal estuaries of the Purari delta in Mv, and to a lesser extent SEC. Likely to be most common in transit (during migration) during September to November and February to April	As for Far Eastern Curlew

Table 6.10 – Very Sensitive and Extremely Sensitive Conservation Listed Birds Recorded or Potentially Occurring in the Study Area (cont'd)

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Southern Cassowary (*Casuarius casuarius*) (Plate 6.41)	VU/-/-/-	VS	A large flightless bird. The world's largest avian frugivore, as a seed disperser it plays a critical role in forest ecosystem dynamics. Widespread southern New Guinea, where stil fairly common in some regions, and in northeast Australia, in lowland and foothill forest normally below 300 m asl. Prefers gentle terrain	Widespread and fairly common in many areas. The most frequently camera trapped bird species. Recorded all sites ground surveyed except Site 8M. Present PRL-15, including throughout gas field and CPF, logistics base and airstrip area, and throughout export pipeline corridor. Primary and logged hill, alluvial and swamp forest in all ecological zones except Mv. Prefers alluvial forest over hill forest, and primary forest over disturbed areas	Forest loss and hunting present the major threats. Other threats include habitat degradation, dogs, pigs and, in areas with roads, collisions with traffic
Salvadori's Teal (*Salvadorina waigiuensis*)	VU/P/-/-	VS	A medium-sized duck (to 0.5 kg) of cool streams and lakes. Endemic to New Guinea uplands along the central cordillera and on Huon and Vogelkop peninsulas, normally above 600 m asl, occasionally in foothills	Not recorded. Potentially only in watercourses at the base of the cordillera proper, northern rim MPH	Hunting and habitat degradation via loss/damage to riparian forest habitat or siltation of waterways. Also, predation by dogs

Table 6.10 – Very Sensitive and Extremely Sensitive Conservation Listed Birds Recorded or Potentially Occurring in the Study Area (cont'd)

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Papuan Eagle (*Harpyopsis novaeguineae*)	VU/P/II/-	VS	New Guinea's largest bird of prey, up to 90 cm in length. Endemic to New Guinea in forest throughout, from sea-level to over 3,000 m asl. Does not soar; hunts mammals and birds on the ground, in trees or from tree hollows. Actively hunted in some areas, now rare or extirpated from some areas near human settlement	Present. Widespread though sparsely distributed (large territories), with highest densities likely in primary hill and alluvial forest in MPH, SH and DSP	Forest loss, hunting, and forest degradation where this results in reduction of prey availability. Secure within local region, with no evidence of targeted hunting and large expanses of suitable forest remaining. However, given very low population density any losses through hunting or accident would represent a disproportionate loss to the local population
Scheepmaker's Crowned Pigeon (*Goura scheepmakeri*) (Plate 6.42)	VU/P/II/RR	VS	The world's largest pigeon; a terrestrial-foraging species up to 80 cm long, blue-grey with maroon underparts, white shoulder patch and large filmy crest. Endemic to lowland forests (<500 m asl) of southern PNG, from southeast peninsula west at least to the Purari basin. One of PNG's rarest birds (Beehler 1993b), now rare or extirpated from much of its former range around Port Moresby and the southeast peninsula	Widespread and fairly common in some areas. Recorded most sites. Present PRL-15, including throughout gas field and CPF, logistics base and airstrip area, and throughout export pipeline corridor. Prefers primary forest on alluvial terrain. Suitable habitat: alluvial and nearby swamp forest on rim DSP and in SEC, and alongside watercourses amid hilly terrain in MPH and SH; hill forest, especially at the hill base near alluvial forest, in MPH and SH. The study area supports the largest remaining expanse of undisturbed suitable habitat within its currently known range	Forest loss/degradation and hunting. Tolerant of some forest disturbance where hunting pressure remains low, but likely to be scarce in recently logged forest. Other threats include habitat fragmentation, dogs and collisions with traffic

Table 6.10 – Very Sensitive and Extremely Sensitive Conservation Listed Birds Recorded or Potentially Occurring in the Study Area (cont'd)

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Pesquet's Parrot (*Psittrichas fulgidus*)	VU/P/II/-	VS	A large (to 46 cm long) black and red parrot. Endemic to New Guinea in hill and lower montane forest to 1,200 m asl, occasionally higher. A nomadic fig specialist. Listed as one of PNG's rarest birds (Beehler 1993b), though within PNG more secure in extensive areas of remaining intact forest than this would imply	Widespread in suitable forest habitat of the north and central east study area, preferring hill forest (primary and logged) in MPH and northern SH, but also in alluvial forest along rim of DSP bordering hill zones. Recorded throughout PRL-15 and export pipeline corridor in areas north of SEC	Forest loss and hunting. In some areas hunted for its plumes; now rare or extirpated from many settled areas. No evidence of large scale hunting within the study area, though local residents occasionally sell birds to logging company employees and in Port Moresby. Other threats include loss of food trees (Ficus spp.) and nest trees. Logged forest still provides suitable foraging habitat
Starry Owlet-nightjar (*Aegotheles tatei*) (Plate 6.43)	DD/-/-/RR	VS	Relatively large (25 cm long, 50 g) among a group of diminutives, insectivorous frogmouth-like night-birds. Endemic to southern New Guinea; rare and poorly known from four areas spanning c. 1,000 km, from near Kiunga (Western Province) east to near Milne Bay. Recorded in primary and 'selectively logged' alluvial forest below 150 m asl	One mist netted in alluvial forest at Site 5 (DSP), northwest CPF, logistics base and airstrip area. Habitat requirements poorly known. Potential in primary and logged alluvial and adjacent foothill forest, DSP, MPH and SH	Forest loss and degradation. Its preferred alluvial forest habitat is under pressure from industrial logging across southern mainland PNG, including within the study area, and the degree of tolerance to forest disturbance is unknown. May be susceptible to the loss of large trees with nest hollows and to predation by invasive mammals. Not a hunting target

Plate 6.41 – Southern Cassowary (*Casuarius casuarius*) (VU) and Chicks Camera Trapped at Site 4



Photo source: I. Woxvold.

Plate 6.42 – Scheepmaker's Crowned Pigeons (*Goura scheepmakeri*) (VU) Camera Trapped at Site 4



Photo source: I. Woxvold.

Plate 6.43 – Starry Owlet-nightjar (*Aegotheles tatei*) (DD)



Photo source: I Woxvold.

Plate 6.44 – Palm Cockatoo (*Probosciger aterrimus*) (P) Camera Trapped at Site 4



Photo source: I. Woxvold.

Plate 6.45 – Glossy-mantled Manucode (*Manucodia ater*) (P)



Photo source: I Woxvold.

6.3.2.6 Herpetofauna

Three IUCN listed or nationally Protected herpetofauna species may occur in the study area, all of which were recorded during Project surveys. A selection of listed herpetofauna is shown in Plates 6.46 to 6.50.

No conservation listed herpetofauna are ranked as Extremely Sensitive. Two IUCN Vulnerable freshwater turtle species are ranked as Very Sensitive—the Pig-nosed Turtle (*Carettochelys insculpta*) and Striped New Guinea Soft-shelled Turtle (*Pelochelys bibroni*) (Table 6.11).

One IUCN listed frog species occurs in the study area—the Data Deficient *Callulops marmoratus*. It is here considered Moderately Sensitive as it is a restricted-range species with one of few known populations overlapping the study area. No frogs are Protected under PNG law.

In addition to these IUCN listed species, two IUCN Least Concern species – the New Guinea Freshwater Crocodile (*Crocodylus novaeguineae*) (Plate 6.48) and the Estuarine Crocodile (*Crocodylus porosus*) (Plate 6.49) – are here considered Moderately Sensitive as they are of importance to local communities and have localized, habitat-specific breeding sites.

Plate 6.46 – Pig-nosed Turtle (*Carettochelys insculpta*) (VU)



Photo source: S. Richards

Table 6.11 – Extremely Sensitive and Very Sensitive Conservation Listed Herpetofauna Recorded or Potentially Occurring in the Study Area

Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/Susceptibilities
Pig-nosed Turtle (*Carettochelys insculpta*) (Plate 6.46)	VU/-/II/-	VS	A large (carapace to >55 cm, weight to 22 kg) freshwater turtle with a 'pig-like' snout and limbs modified as flippers. Southern New Guinea (Indonesia and PNG) and Northern Territory, Australia. Occupies most major drainages of southern New Guinea, though eastern and western distributional limits are poorly known. In the Gulf of Papua deltaic zone, nests in sandy banks in coastal areas and upstream along major rivers. Juveniles congregate in the lower delta (Georges et al. 2008). In New Guinea nests during September–February	Widespread. Nesting sites recorded along the Purari River and tributaries in the south of PRL-15 (see Section 6.6.4) and upstream to areas above Wabo. Previously reported from the Purari delta mangroves by Liem and Haines (1977). May also nest on coastal beaches. Suitable habitat: rivers, swamps, lagoons, estuaries and beaches in all ecological zones	Unsustainable harvesting of nests and adults are the major threats. Adults and eggs are widely consumed in the Purari catchment; potentially unsustainable in Pawaian territory. Vulnerable also to boat strike and egg loss through feral pig predation
Striped New Guinea Soft-shelled Turtle (*Pelochelys bibroni*) (Plate 6.47)	VU/-/II/-	VS	A very large (carapace to >1 m) soft-shelled freshwater turtle with a patterned carapace. Endemic to the southern drainages of New Guinea (Indonesia and PNG), primarily in rivers and streams, with some coastal records. Nests during June–August/September. In the Kikori basin co-occurs with Pig-nosed Turtle but is much less common	Known to occur in the Purari River system (Liem and Haines 1977; Rhodin et al. 1993) though status and distribution poorly known. Based on landowner testimony: nesting sites reported for five Purari River tributaries in the south of PRL-15 (see Section 6.6.4) where it appears not to nest on the main Purari channel. Suitable habitat: rivers, swamps, lagoons and estuaries, potentially in all ecological zones. Compared to Pig-nosed turtle, nesting sites are fewer and this species is expected to be much scarcer	Unsustainable harvesting of nests and adults are the major threats. Considered 'probably locally endangered' in the Kikori basin by Georges et al. (2008a). Adults and eggs are widely consumed in the Purari catchment; potentially unsustainable in Pawaian territory. Vulnerable also to boat strike and egg loss through feral pig predation

Plate 6.47 – Striped New Guinea Soft-shelled Turtle (*Pelochelys bibroni*) (VU)



Photo source: S. Richards

Plate 6.48 – New Guinea Freshwater Crocodile (*Crocodylus novaeguineae*)



Photo source: S. Richards

Plate 6.49 – Estuarine Crocodile (*Crocodylus porosus*)



Photo source: S. Richards

Plate 6.50 – *Callulops marmoratus* (DD)



Photo source: S. Richards

6.3.2.7 Invertebrates

Seven IUCN listed and nationally Protected terrestrial invertebrate species may occur in the study area. A selection of listed invertebrates is shown in Plates 6.51 and 6.52.

Four IUCN Data Deficient odonates are confirmed present. Two are assigned Low Sensitivity. *Selysioneura rhaphia* is here considered Moderately Sensitive as it is a habitat specialist species with one of few known populations overlapping the study area. Diplacina cyrene is here considered Moderately Sensitive as it is a restricted-range, habitat specialist species with one of few known populations overlapping the study area.

Three nationally Protected birdwing butterflies (*Ornithoptera* spp.) may occur in the study area. One of these – the IUCN Endangered Ornithoptère Méridional (*Ornithjoptera meridionalis*) – is assigned Very Sensitive status (Table 6.1.2).

Plate 6.51 – *Diplacina cyrene* (DD)



Photo source: S. Richards

Plate 6.52 – Nososticta nigrifrons (DD)



Photo source: S. Richards

Table 6.12 – Very Sensitive and Extremely Sensitive Conservation Listed Invertebrates Recorded or Potentially Occurring in the Study Area

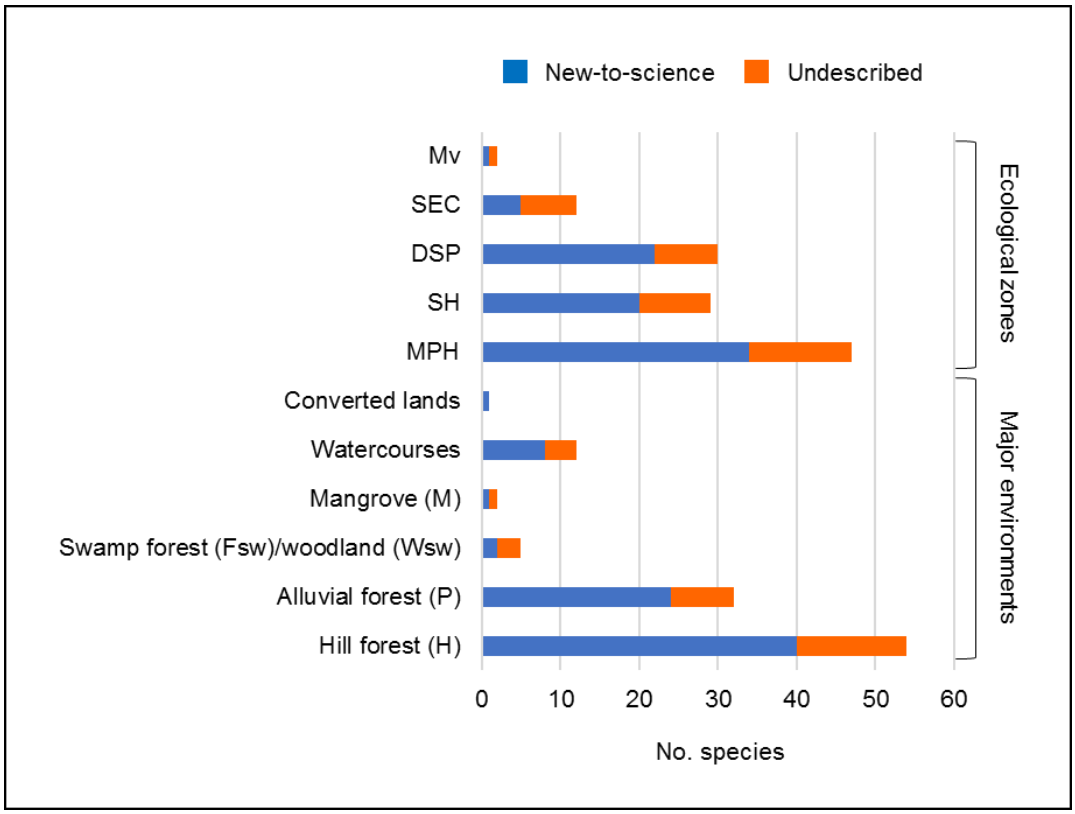
Species	Conservation Listing (IUCN/PNG/ CITES/RR)	Sensitivity	Description, Range and Status in New Guinea	Occurrence in Study Area	Threats/ Susceptibilities
Ornithoptère Méridional Ornithoptera meridionalis	EN/P/II/-	VS	A large birdwing butterfly, wingspan to 124 mm. Endemic to mainland New Guinea, mainly south of the central cordillera, from Indonesian Papua east to Milne Bay. 'Reasonably common' at the margins of advanced secondary and primary lowland forest (up to 700 m asl at Lake Kutubu, Southern Highlands Province) (Parsons 1999). Larvae feed exclusively on the vine Pararistolochia meridionaliana	Not recorded. Suitable habitat: hill and alluvial forest in all ecological zones except Mv	Large-scale forest loss and alien invasive species, including weeds that may replace Aristolochia food plants and rats and Cane Toads that may feed on the larvae and pupae

6.3.3 New-to-Science and Undescribed Species

Sixty-five species recorded within the study area are scientifically undescribed. These are listed in Appendix 5 together with their restricted-range status, sensitivity ranking and study area records. Forty-nine species are new-to-science, being discovered for the first time during Project surveys. Sixteen species were discovered previously but remain scientifically undescribed. Most of these are known to occur beyond the study area in other parts of southern New Guinea, though two undescribed frog species – *Litoria* sp. 1 and *Hylarana* sp. 2 – are previously known only from the Wabo area. A total of 51 species is thus so far known only from within the study area in the upstream PAOI.

Figure 6.10 shows the number of new-to-science and undescribed species recorded in each ecological zone and in various major environments identified within the study area. Rates of discovery were highest in hill forest within the Middle Purari Hills ecological zone, followed by alluvial forest on the Delta Swamps and Plains. Fewer discoveries in mangroves (two species), freshwater swamp vegetation types (five species) and littoral forest (no species) reflect lower species richness, higher previous survey efforts and more widespread distributions of these lowland community components. Undescribed terrestrial species closely associated with watercourses include a number of frogs, odonates and the water rat *Hydromys* sp. 1; additional novelties in these environments may be expected among aquatic taxa.

Figure 6.10 – New-to-science and Undescribed Species Recorded in Ecological Zones and Major Environments



Major environments yielding no undescribed species are not shown.

Patterns of discovery among surveyed taxonomic groups are shown in Table 6.13. Plants yielded the highest number of new-to-science species, all but one being found in hill and/or alluvial forest; the orchid *Bulbophyllum* sp. 2 was discovered in mangrove forest. Rates of discovery were also high among odonates, despite relevant survey effort in the nearby Lakekamu basin (Richards et

al. 1998), and to a lesser degree the Kikori basin (see Annex 6), reflecting the relatively high rate of limited-range endemics[12] reported within this group, and damselflies in particular (Section 6.3.4). Limited-range endemism is also frequently observed in New Guinean frogs; five frog species are known only from hill, alluvial and/or swamp forest environments within the study area, though a larger number of scientifically undescribed species are known also from adjacent regions. Among reptiles, one new gecko (*Gehyra* sp. 1) was discovered in logged hill forest within the export pipeline corridor, and a distinctive new species of snake (*Stegonotus* sp. 1) is closely associated with alluvial forest, found in both PRL-15 and the export pipeline corridor but not in the adjacent Lakekamu or Kikori basins despite extensive survey effort in those areas. Among non-volant mammals, two new-to-science species of small rodent were identified among skeletal remains from an owl pellet deposit collected at the Wi'i Creek cave site.

Table 6.13 – The Number of New-to-science and Undescribed Species from Each Surveyed Taxonomic Group

Taxonomic Group	New-to-science	Undescribed	Study Area Only
Flora	34	1	34
Non-volant mammals	2	0	2
Bats	0	1	0
Birds	0	0	0
Reptiles	2	1	2
Frogs	3	12	5
Odonates	8	1	8
Total	49	16	51

Twenty-seven new-to-science and undescribed species are ranked as Very Sensitive (26 species) or Extremely Sensitive (one species). Brief accounts are provided in Table 6.14. More detailed accounts are presented in the flora and fauna study technical report annexes. A selection of new-to-science flora and fauna is shown in Plates 6.53 to 6.75.

[12] Distinguished from restricted-range distributions, limited-range endemism here refers to species with small distributions of an indeterminate size; in the groups discussed here this is often significantly less than the 50,000 km^2 cut-off used to define restricted-range species.

Table 6.14 – Very Sensitive and Extremely Sensitive New-to-science Species Recorded in the Study Area

Taxon	Sensitivity	Description, Habitat and Occurrence in the Study Area	Threats/Susceptibilities
Flora			
Pseuduvaria sp. 1	VS	A shrub/small tree to 4 m tall. Known only as a few (<10) scattered individuals in well shaded, closed canopy hill and alluvial forest at Site 7 in the export pipeline corridor. Fruit is bird/mammal dispersed	Habitat loss and degradation
Begonia sp. 2	VS	A terrestrial herb of permanently moist shaded stream banks in hill forest. Known only from Sites 1 and 2 in the Era River catchment, PRL-15, where localized and uncommon. Fruit water dispersed	Habitat loss and degradation where this affects understorey microclimate. Contamination of waterways
Begonia sp. 3	VS	A terrestrial herb found in closed canopy hill forest with thick leaf litter layer. Known only from two isolated populations (30+ individuals) at Site 2 in Era River catchment, PRL-15. Fruit wind dispersed	Habitat loss and degradation where this affects understorey microclimate
Begonia sp. 4	VS	A terrestrial herb found in closed canopy hill forest with thick leaf litter layer. Known from a single specimen at Site 2 in Era River catchment, PRL-15	Habitat loss and degradation where this affects understorey microclimate
Begonia sp. 5	ES	A tall (50 cm) terrestrial herb of permanently moist shaded stream banks in foothill and well drained alluvial forest. Known from only five specimens in two isolated populations at Site 4 within the CPF, logistics base and airstrip area, one within the proposed CPF fenceline and the other c. 150 m to the north. Fruit water dispersed	Habitat loss and degradation where this affects understorey microclimate. Contamination of waterways
Archidendron sp. 1	VS	Shrub 3 m tall. Locally rare, known only as three scattered fruiting plants in alluvial forest at Site 4 within the CPF, logistics base and airstrip area; primarily bird dispersed, so likely to be more widespread	Habitat loss and degradation
Medinilla sp. 1	VS	A small, low level epiphyte of permanently moist creek-side forest on alluvial terrain amid hill forest, known from scattered populations on two watercourses at Sites 1 and 2 in the Era River catchment, PRL-15. Fruit bird dispersed	Habitat loss and degradation where this affects understorey microclimate
Syzygium sp. 1	VS	Small tree (3 m). Known from a single specimen collected from a shaded stream bank in well drained alluvial forest near hill-foot boundary at Site 4 within the within the CPF, logistics base and airstrip area, and in the vicinity of proposed CPF footprint. Likely bird/mammal dispersed and more widespread, but difficult to identify sterile plants (without fruits or flowers)	Habitat loss and degradation

Table 6.14 – Very Sensitive and Extremely Sensitive New-to-science Species Recorded in the Study Area (cont'd)

Taxon	Sensitivity	Description, Habitat and Occurrence in the Study Area	Threats/Susceptibilities
Syzygium sp. 3	VS	Shrub 2–3 m tall. Known from seven specimens in undisturbed hill forest near streams at Site 7 within the export pipeline corridor. Likely bird/mammal dispersed and more widespread, but not yet recorded in apparently suitable habitat in PRL-15. Known area of occurrence has been heavily logged	Habitat loss and degradation
Syzygium sp. 4	VS	Tree 8 m tall. Known from a single specimen in unlogged alluvial forest at Site 7 within the export pipeline corridor. Likely bird/mammal dispersed and more widespread, but locally rare	Habitat loss and degradation
Syzygium sp. 5	VS	Tree 18 m tall. Known from a single specimen in unlogged alluvial forest at Site 5, northern CPF, logistics base and airstrip area; fruit bird/mammal dispersed and seen to be eaten by local residents, likely more widespread	Habitat loss and degradation
Bulbophyllum sp. 1	VS	Epiphytic forest canopy orchid, known from one locality at Site 4 but only detected on fallen trees/branches and potentially more widespread. Wind dispersed	Habitat loss and degradation
Bulbophyllum sp. 2	VS	Epiphytic mid-level orchid, one of few Bulbophyllum species associated with mangroves. Known only from Site 8M in the subcoastal southwest of the export pipeline corridor. Wind dispersed. Likely more widespread though there has been a history of sampling in Purari delta mangrove environments	Habitat loss and degradation
Oberonia sp. 1	VS	Epiphytic forest canopy orchid, known from one locality at Site 4 but only detected on fallen trees/branches and potentially more widespread. Wind dispersed	Habitat loss and degradation
Glochidion sp. 1	VS	Tree. Known from only three specimens growing on deep soil along the shady bank of a stream in hill forest at Site 1, within the gas field in the Era River catchment. Likely bird/mammal dispersed and more widespread, though locally rare and not observed in other apparently suitable sites	Habitat loss and degradation
Lasianthus sp. 1	VS	Shrub 1 m tall. Known from a single locality in tall, closed canopy hill forest at Site 1, within the gas field in the Era River catchment. Bird dispersed and likely more widespread, though locally rare and not observed in other apparently suitable sites	Habitat loss and degradation
Rubiaceae, Genus 1 sp. 2	VS	Shrub. Known from a single small population in hill forest at Site 2 in the Era River catchment, PRL-15, growing on a ridge in moist conditions under closed canopy. Probably bird dispersed and more widespread, though locally rare and not observed in other apparently suitable sites	Habitat loss and degradation

Table 6.14 – Very Sensitive and Extremely Sensitive New-to-science Species Recorded in the Study Area (cont'd)

Taxon	Sensitivity	Description, Habitat and Occurrence in the Study Area	Threats/Susceptibilities
Mammals			
Hydromys sp. 1	VS	A small 'water rat'. Known only from a few isolated teeth found in an owl pellet deposit collected at the Wi'i Creek cave site northeast of PRL-15 and north of the Purari River. Known relatives associated with fast-flowing hill forest streams. Difficult to detect during field surveys, but apparently uncommon based on frequency of occurrence in the bone deposit	Habitat loss and degradation. Contamination of waterways
Pseudohydromys sp. 1	VS	A small 'shrew mouse'. Known only from a single lower jaw found in an owl pellet deposit collected at the Wi'i Creek cave site northeast of PRL-15 and north of the Purari River. Known relatives primarily terrestrial and montane. Difficult to detect during field surveys, but apparently uncommon based on frequency of occurrence in the bone deposit	Habitat loss and degradation
Reptiles			
Gehyra sp. 1	VS	A small gecko with large adhesive pads on the fingers and toes. Known from two individuals in the canopy of logged hill forest at Site 3 within the export pipeline corridor. Tolerant of habitat disturbance and likely more widespread, but not recorded in adjacent Lakekamu or Kikori basins despite extensive survey effort in those areas.	Habitat loss
Stegonotus sp. 1	VS	A moderately large (to c. 1.2 m) strikingly patterned white and brown snake. Known from seven individuals encountered in well drained alluvial forest at Sites 4, 5, 8 and 9. Potentially more widespread, but not recorded in adjacent hill forest or in Lakekamu or Kikori basins despite extensive survey effort in those areas	Habitat loss
Amphibians			
Cophixalus sp. 3	VS	A tiny (males 12 to 14.5 mm) terrestrial microhylid frog apparently confined to moist stream banks in hill forest and adjacent well drained alluvial forest rim. Locally widespread (seven sites in three ecological zones), but not recorded in adjacent Lakekamu or Kikori basins despite extensive survey effort in those areas	Habitat loss and degradation
Oreophryne sp. 2	VS	A very small (<20 mm) microhylid frog. Known only from a single specimen found in low foliage next to a stream in hill forest at Site 1, within the gas field in PRL-15. Habitat requirements poorly known. Not recorded in adjacent Lakekamu or Kikori basins despite extensive survey effort in those areas	Habitat loss and degradation

Table 6.14 – Very Sensitive and Extremely Sensitive New-to-science Species Recorded in the Study Area (cont'd)

Taxon	Sensitivity	Description, Habitat and Occurrence in the Study Area	Threats/Susceptibilities
Odonates			
Teinobasis sp. 1	VS	Moderately large damselfly with blue markings. Known only from small forest pools at Site 1	Habitat loss and degradation. Contamination of forest pools and streams
Nosoticta sp. 1	VS	A slender black damselfly with yellow markings. Known only from swampy pools in undisturbed alluvial and swamp forest complex at Site 5, northern CPF, logistics base and airstrip area	Habitat loss and degradation. Contamination of forest pools and streams
Rhyacocnemis sp. 1	VS	A small, nondescript damselfly, not closely resembling any other known species (generic status uncertain). Known only from near clear-flowing hill forest streams at Sites 2 and 3, PRL-15 and export pipeline corridor, where uncommon. Patchily distributed but remains in suitable remnant closed canopy sites within logged forest	Habitat loss and degradation. Contamination of waterways
Palaeosynthemis sp. 1	VS	A moderately large, slender dragonfly with yellow spot on the abdomen. Known only from a single individual found at night along a hill forest stream at Site 1. Ecology poorly known, potentially dependent on primary hill forest streams. Locally rare	Habitat loss and degradation. Contamination of waterways

Plate 6.53 – *Begonia* sp. 3



Photo source: S. Venter.

Plate 6.54 – *Begonia* sp. 5



Photo source: S. Venter.

Plate 6.55 – *Archidendron* sp. 1



Photo source: S. Venter.

Plate 6.56 – *Medinilla* sp. 1



Photo source: S. Venter.

Plate 6.57 – *Glochidion* sp. 1



Photo source: S. Venter.

Plate 6.58 – Rubiaceae, Genus 1 sp. 2



Photo source: S. Venter.

Plate 6.59 – *Hydromys* sp. 1 (Scale Bar = 5 mm)



Photo source: K. Aplin.

Plate 6.60 – *Pseudohydromys* sp. 1 (Scale Bar = 5 mm)



Photo source: K. Aplin.

Plate 6.61 – *Nyctophilus* sp. 1



Photo source: S. Richards

Plate 6.62 – *Gehyra* sp. 1



Photo source: S. Richards.

Plate 6.63 – *Sphenomorphus* sp. 1



Photo source: S. Richards.

Plate 6.64 – *Stegonotus* sp. 1



Photo source: S. Richards.

Plate 6.65 – *Litoria* sp. 1



Photo source: S. Richards.

Plate 6.66 – *Austrochaperina* sp. 1



Photo source: S. Richards.

Plate 6.67 – *Cophixalus* sp. 3



Photo source: S. Richards.

Plate 6.68 – *Oreophryne* sp. 1



Photo source: S. Richards.

Plate 6.69 – *Oreophryne* sp. 2



Photo source: S. Richards.

Plate 6.70 – *Hylarana* sp. 2



Photo source: S. Richards.

Plate 6.71 – *Metagrion* sp. 1



Photo source: S. Richards.

Plate 6.72 – *Teinobasis* sp. 1



Photo source: S. Richards.

Plate 6.73 – *Nososticta* sp. 1



Photo source: S. Richards.

Plate 6.74 – *Rhyacocnemis* sp. 1



Photo source: S. Richards.

Plate 6.75 – *Palaeosynthemis* sp. 1



Photo source: S. Richards.

6.3.4 Endemic and Restricted-range Species

6.3.4.1 Patterns of Regional Endemism

New Guinea is among the most endemically rich regions on Earth (Mittermeier et al., 1997; Wikramanayake et al., 2002). High rates of floristic endemism are reported at both the species (estimated at 60 to 70%) and genus levels (Johns 1993, 1995; Balgooy et al., 1996). Among fauna, more than two-thirds of New Guinea's non-marine vertebrates are endemic, with estimates for frogs reaching over 90% (Allison, 2007). Rates of endemism are highest in New Guinea's montane environments, its lowland biotas having stronger affinities with those of neighboring regions. The southern lowlands of New Guinea form part of the northern rim of the Australo-Papuan continental shelf, and accordingly support a comparatively high proportion of Australian taxa (Gressitt,1982; Allison, 2007). In general, these affinities are strongest at higher taxonomic levels (genera and above) and within the seasonally dry and coastal environments that characterize much of northern Australia and parts of southern New Guinea. By contrast, the lowland rainforests of southern New Guinea support a comparatively high proportion of regional endemic species. However, the tendency towards regional endemism varies among major taxonomic groups.

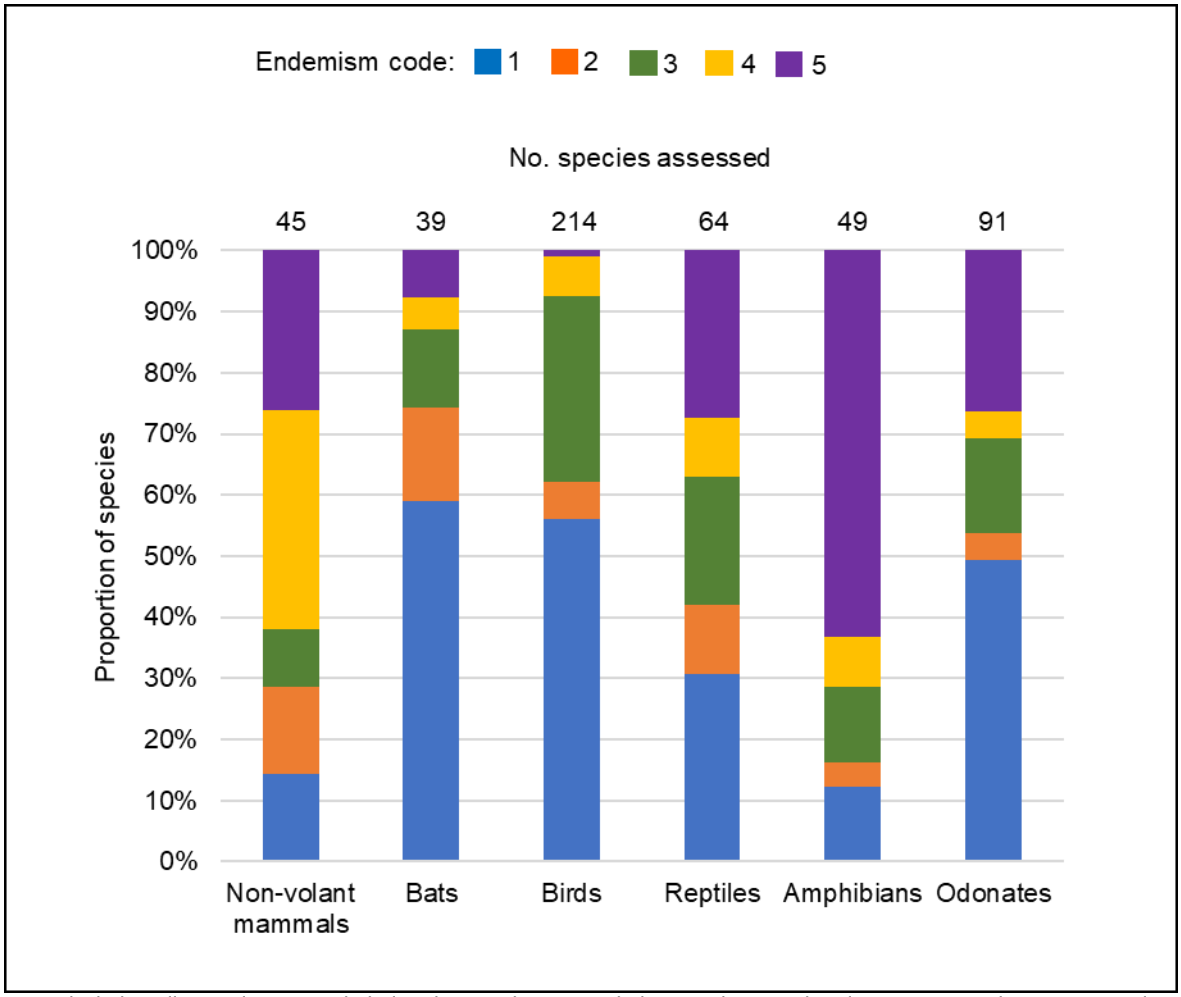
Figure 6.11 shows patterns of regional endemism among fauna recorded within the study area. Regional endemism is highest among non-volant mammals and herpetofauna. Frogs have the highest rate of endemism, with 83.7% of species known only from the 'New Guinea region' (endemism code 3; see Section 5.4.2) and the highest proportion of species (63.3%; more than double any other group) restricted more locally to southern mainland New Guinea (endemism code 5). Compared to reptiles, a higher proportion of non-volant mammals are restricted to the New Guinea region, although similar proportions are restricted to southern New Guinea.

Flight-capable fauna are generally more wide ranging (Figure 6.11). Fewer than half of bats, birds and odonates are found only in the New Guinea region (range 25.6 to 46.2%), and only 7.7% and 0.9% of bats and birds respectively are restricted to southern New Guinea. Among odonates, regional endemism is highest among the damselflies (sub-order Zygoptera), with nearly half (47.7%) of all recorded species restricted to southern New Guinea compared to only 6.4% of dragonflies (sub-order Anisoptera).

6.3.4.2 Restricted-Range Species

At a finer geographic scale, 115 restricted-range species have been recorded or may occur in the study area. They include 12 conservation listed species, 61 new-to-science and undescribed species and a further 42 named species (Table 6.15). All restricted-range species are listed in Appendix 4 (scientifically named species) or in Appendix 5 (scientifically undescribed species) together with their sensitivity ranking, study area records and suitable habitat in ecological zones and major environments. Detailed accounts for all restricted-range species are presented in the flora and fauna technical reports (Annex 1A, 2 to 6). A selection of restricted-range flora and fauna is shown in Plates 6.76 to 6.93.

Figure 6.11 – Patterns of Regional Endemism Among Major Faunal Groups



Data include all species recorded in the study area during Project and prior surveys where taxonomic identity is sufficiently known. Includes non-native species.

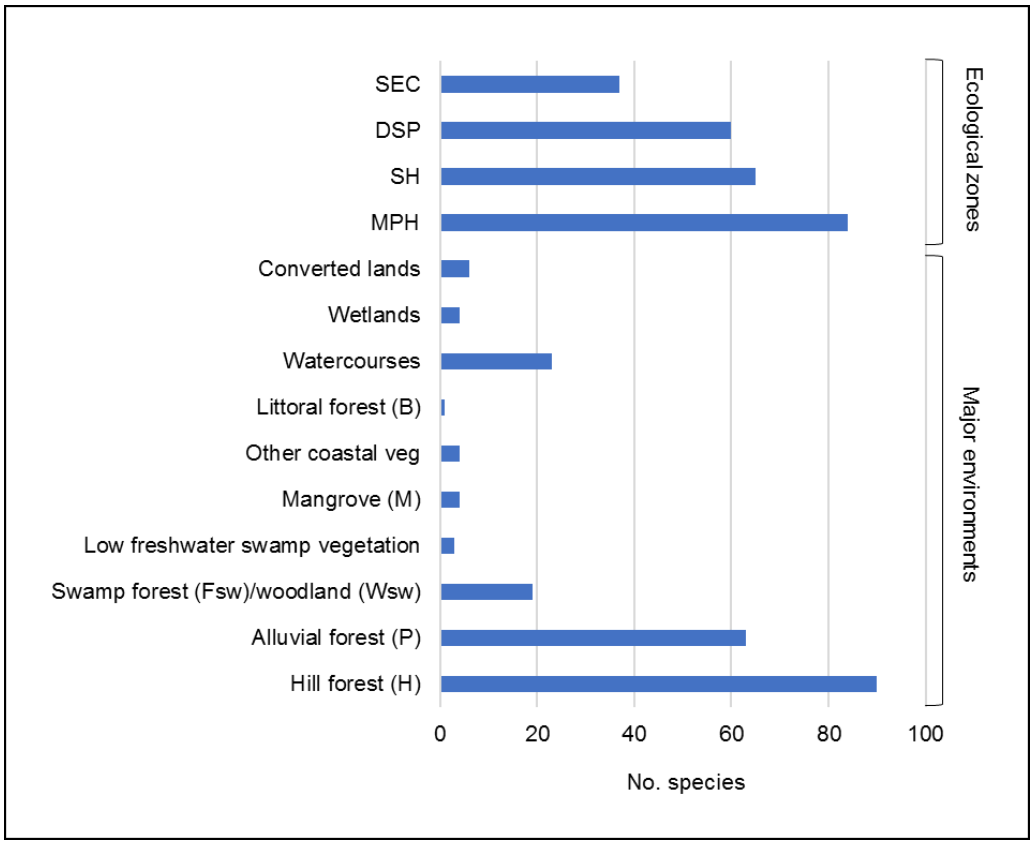
Table 6.15 – Restricted-range Species Recorded or Potentially Occurring in the Study Area

Taxonomic Group	IUCN					PNG[A]	New-to-science	Undescribed	Other Named RR	Total
	CR	EN	VU	NT	DD	P				
Flora	–	–	2	–	–	–	34	1	9	46
Non-volant mammals	–	1	1	–	1	1	2	–	3	8
Bats	1	–	–	–	1	1	–	–	1	3
Birds	–	–	1	1	1	1	–	–	–	3
Reptiles	–	–	–	–	–	–	2	–	7	9
Frogs	–	–	–	–	1	–	3	10	9	23
Odonates	–	–	–	–	1	–	8	1	13	23
Total	1	1	4	1	5	3	49	12	42	115

[A] Restricted-range species Protected under PNG law are also listed under an IUCN listed category.

Figure 6.12 shows the number of restricted-range species recorded or potentially occurring in each ecological zone and in various major environments identified within the study area. Hill and alluvial forest support the highest diversity of restricted-range species. Watercourses within forest environments provide important habitat for a suite of restricted-range odonates (18 species), frogs (four species) and the new-to-science small water rat *Hydromys* sp. 1.

Figure 6.12 – Restricted-range Species Recorded (Scientifically Undescribed Species and Named Species Known Only from the Type Locality) or Potentially Occurring (Other Named Species) in Ecological Zones and Major Environments



Major environments yielding no restricted-range species are not shown.

Forty-four restricted-range species are ranked as Very Sensitive (42 species) or Extremely Sensitive (2 species). Most are either conservation listed (seven species) or new-to-science (27 species), and are described in previous sections (Sections 6.3.3 and 6.3.4). Another ten restricted-range species are here considered Very Sensitive. They include:

- Six plants known only from the type material collected previously from the southeast sector of the study area. Precise type localities are not provided. However, none of these species is known from PRL-15, and all but *Cyrtandra externata* are expected to have been found outside of the export pipeline corridor. None were 'rediscovered' during Project surveys.
- Four damselflies, all habitat specialists of clear-flowing primary forest streams, previously known only from the type localities either north of the study area, in the Purari River catchment uplands in the Crater Mountain WMA (three species), or west of the study area in the lower Kikori River basin (one species). Each of these species was recorded during Project surveys.

Brief accounts of these species are provided in Table 6.16.

Table 6.16 – Very Sensitive Restricted-range Species (Scientifically Named and not Conservation Listed)

Taxon	Sensitivity	Description, Habitat and Occurrence in the Study Area	Threats/Susceptibilities
Flora			
Cyathocalyx lucidus	VS	Tree (height unknown). Known only from the original collection near 'Hewa' (presumably = Heawa) village near the Vailala River, presumed to be within the study area in the Southeast Hills ecological zone, east of the export pipeline corridor. The area is now heavily logged. Birds and fruit bats disperse the seeds of Cyathocalyx	Habitat loss and degradation
Marsdenia venusta	VS	A liane known only from the type material collected near Ihu, from 'primary lowland rainforest at 40 m altitude' (Forster 1995, p. 740). The precise locality and vegetation type are unknown, but here presumed to be within the study area and probably east of the export pipeline corridor. Much of the region has been heavily logged. Marsdenia seeds are wind dispersed	Habitat loss and degradation
Cyrtandra externata	VS	Known only from the type material collected in 1926 near Hohoro, presumed to be within the study area in the Southeast Coast ecological zone, potentially within the southeast corner of the export pipeline corridor. Habit unknown. The vegetation type is unspecified, but Cyrtandra is adapted to germinate in permanently moist substrates. Much of the region is heavily logged or otherwise disturbed. The genus in general is sensitive to logging (Cronk et al. 1995). Bird dispersed, though the group includes a high frequency of localized endemic species	Habitat loss and degradation
Glochidion delticola	VS	Tree to 18 m. Known only from the type material collected c. 24 km inland from the mouth of the Purari River, near sea level in an alluvial-freshwater tidal forest ecotone. Precise locality unknown, but presumed within the study area in the Delta Swamps and Plains ecological zone, west of the export pipeline corridor. Bird dispersed	Habitat loss and degradation. Changes to hydrology, contamination of waterways
Ixora whitei	VS	Bird dispersed shrub or small tree. Known only from 'between Ihu and Vailala' at 10 to 15 m asl, here presumed within the Southeast Coast ecological zone and southeast of the export pipeline corridor. Habitat unknown, but the area includes littoral vegetation, mangroves, alluvial forest and swamp forest/woodland types. Known area of occurrence is densely populated with extensive converted lands	Habitat loss and degradation. Potentially also changes to hydrology and contamination of waterways
Psychotria heterophylla	VS	Known only from the type material collected in 1926 near Ihu along the Vailala River at 10 m asl in mangroves. Precise locality unknown but here presumed within the Southeast Coast ecological zone and southeast of the export pipeline corridor	Habitat loss and degradation. Changes to hydrology, contamination of waterways

Table 6.16 – Very Sensitive Restricted-range Species (Scientifically Named and not Conservation Listed (cont'd)

Taxon	Sensitivity	Description, Habitat and Occurrence in the Study Area	Threats/Susceptibilities
Odonates			
Argiolestes tuberculiferus	VS	A moderately large and robust damselfly. Previously known only from the type locality at 900 m asl in the Crater Mountain WMA, upper Purari River catchment. A habitat specialist of cool, clear streams in closed canopy hill forest. One specimen found along a forested stream at Site 1 in the gas field, PRL-15	Habitat loss and degradation where this affects understorey microclimate. Contamination of waterways
Pyrrhargiolestes angulatus	VS	A moderately large and robust red-and-black damselfly. Previously known only from the type locality at 1,500 m asl in the Crater Mountain WMA, upper Purari River catchment. A habitat specialist of cool, clear streams in closed canopy hill and lower montane forest. In the study area found only along streams at Sites 1 and 6D in PRL-15	Habitat loss and degradation where this affects understorey microclimate. Contamination of waterways
Nososticta smilodon	VS	A small, slender, black, blue and orange damselfly. Previously known only from the type locality in the lower Kikori basin. Found along streams in primary low elevation hill forest and well-drained alluvial forest, Sites 2 and 4 in PRL-15	Habitat loss and degradation where this affects understorey microclimate. Contamination of waterways
Drepanosticta taurulus	VS	A moderately large, dark damselfly with bright blue terminal abdomen segments. Previously known only from a single specimen collected at 1,400 m asl in the Crater Mountain WMA, upper Purari River catchment. A habitat specialist of cool, clear streams in closed canopy hill forest. Common at Sites 1–3 in PRL-15 and the northern export pipeline corridor	Habitat loss and degradation where this affects understorey microclimate. Contamination of waterways

Plate 6.76 – *Pseuduvaria filipes*



Photo source: S. Venter.

Plate 6.77 – *Psychotria purariensis*



Photo source: S. Venter.

Plate 6.78 – Oriomo Bandicoot (*Echymipera oriomo*) Camera Trapped at Site 5



Photo source: I. Woxvold.

Plate 6.79 – *Curtodactylus serratus*



Photo source: S. Richards.

Plate 6.80 – *Lepidodactylus* cf. *orientalis*



Photo source: S. Richards.

Plate 6.81 – *Carlia aenigma*



Photo source: S. Richards.

Plate 6.82 – *Cryptoblepharus litoralis vicinus*



Photo source: S. Richards.

Plate 6.83 – *Emoia physicae purari*



Photo source: S. Richards.

Plate 6.84 – *Litoria chloristona*



Photo source: S. Richards.

Plate 6.85 – *Litoria exophthalmia*



Photo source: S. Richards.

Plate 6.86 – *Copiula guttate*



Photo source: S. Richards.

Plate 6.87 – *Metamagnusia slateri*



Photo source: S. Richards.

Plate 6.88 – *Pyrrhargiolestes angulatus*



Photo source: S. Richards.

Plate 6.89 – *Teinobasis buwaldai*



Photo source: S. Richards.

Plate 6.90 – *Nososticta chrismulleri*



Photo source: S. Richards.

Plate 6.91 – *Nososticta paraconifera*



Photo source: S. Richards.

Plate 6.92 – *Nososticta smilodon*



Photo source: S. Richards.

Plate 6.93 – *Drepanosticta taurulus*



Photo source: S. Richards.

6.3.4.3 Note on Species Known Only from the Study Area

Species known only from the study area include 49 new-to-science species discovered for the first time during Project surveys, two additional scientifically undescribed frogs previously known only from the Wabo area, and the six restricted-range plant species listed in Table 6.16.

In most cases the habitats known to support these species extend beyond the study area into the adjacent Kikori, Vailala and Lakekamu River catchments without apparent geographic barrier. Habitat continuity is less available for alluvial forest, with discontinuous and relatively minor occurrences, some of which have been logged, located to the immediate west and east of the study area. Seven new-to-science species are currently documented only from alluvial forest environments within the study area (Section 6.5.1.4). Whether these species are truly restricted to non-swamp forest on alluvial terrain is yet to be determined. Most plant and animal species occupying alluvial forest also occur in foothill forest and/or swamp forest (Paijmans, 1976; Hammermaster and Saunders, 1995a; Coates, 1985, 1990; Flannery, 1995; Menzies, 2006), though often at different densities, and it is possible that the absence of records from other vegetation types is an artefact of under-sampling in these recently discovered taxa.

Most or all species presently known only from the study area are expected to occur more widely in Gulf Province, at least in other sectors of the local biogeographic regions of which the study area forms a part (Section 6.3.1). Extensive survey effort would be required to confidently predict that a species does not occur in adjacent areas of suitable habitat. However, until such records exist, the possibility that one or more species is restricted to the study area cannot be ruled out. Candidate taxa include (but may not be limited to) those belonging to groups that include a high proportion of limited range endemics – including frogs, damselflies and some understorey rainforest plant groups – and/or those that to date are known only from alluvial forest environments.

6.3.5 Migratory and Congregatory Species

Due to widespread global declines, migratory species are the subject of targeted conservation focus (see, for example, the Convention on the Conservation of Migratory Species of Wild Animals[13]). Species that congregate at a particular site, whether for the purpose of breeding, feeding or shelter, present an elevated conservation concern due to the disproportionate effect that a single impacting event may have on the status of a local population. IFC PS6 makes specific provision for the consideration of migratory and congregatory species in critical habitat assessment. Migratory and congregatory species are discussed in detail in the fauna technical reports (Annex 2 to 6).

No terrestrial mammals or herpetofauna occurring in the study area engage in long-distance migration, and no terrestrial non-volant mammals or herpetofauna are known to congregate in large groups. More significant congregatory behaviors and localized landscape-level movements are observed among bats, birds and two large freshwater turtle species.

6.3.5.1 Bats

Movements Across the Study Area Landscape

The seasonal and daily movements of New Guinean bats are poorly documented. However, many are probably capable of long-distance flights and some may travel many kilometers between regular roosting and feeding sites. For frugivorous species, destination feeding sites may shift across the landscape in response to seasonal changes in fruit availability. Insectivorous species reliant on limited-availability roosting sites (such as caves) may also undergo regular

[13] http://www.cms.int/index.html

landscape level movements to access favorite feeding areas. It is not possible to identify regular bat movement corridors within the study area. They may be numerous and widespread, are expected to vary between taxa and potentially across seasons within taxa. The most permanent and well defined flight corridors (with the greatest number of individuals travelling through the narrowest aerial channel) are expected to occur on approach to caves that support large colonies of one or more bat species (see below: Congregatory behavior).

Congregatory Behavior

Many New Guinean bat species roost together in large groups, either habitually or seasonally for breeding. Flying-foxes of the genus *Pteropus* congregate seasonally in large 'maternity camps', often located in mangroves, riparian forest or freshwater swamp vegetation. While no flying-fox camps were observed directly during Project surveys, a number were reported by local residents. Among these, the large oxbow wetland system in the southwest of PRL-15 ('PRL-15 oxbow wetlands'; see Section 6.5.2.2) may represent a regular seasonal camp with females carrying dependent young there during May–June. Other camps were reported near the coast, including in mangroves, but were said to change position from year to year.

Caves and rock overhangs provide important habitat for a variety of bats that shelter there to roost and breed in colonies. Several species of large Pteropodidae and many small insectivorous bats belonging to the families Emballonuridae, Hipposideridae, Rhinolophidae, Miniopteridae and Vespertilionidae roost and breed in caves. Among those recorded in the study area are the IUCN listed Bulmer's Fruit Bat (CR), New Guinea Sheath-tailed Bat (*Emballonura furax*) (DD), Papuan Sheath-tailed Bat (*Saccolaimus mixtus*) (DD) and Semon's Leaf-nosed Bat (*Hipposideros semoni*) (DD). Aggregate numbers depend on the species present and chamber size. The large Moluccan Naked-backed Fruit Bat (*Dobsonia moluccensis*) is known to congregate in groups of up to many thousands of individuals inside large caves, while colonies of bent-winged bats (*Miniopterus*) are reported to reach tens of thousands (Bonaccorso, 1998). Sizeable caves often include bats of multiple species. The potential location and importance of caves and rock overhangs is discussed further in Section 6.6.1.

6.3.5.2 Birds

The study area includes habitats that support trans-oceanic migrant birds both from the northern hemisphere and from Australia, and a number of migratory and resident taxa that congregate together at various sites within the study area landscape.

Coastal Migratory and Congregatory Species

Of all the migratory bird groups that visit New Guinea, the northern Palaearctic 'shorebirds' ('waders'; Scolopacidae, Charadriidae) are of the highest conservation concern, since many species are in serious decline and continue to be threatened by a wide range of environmental changes and human-related activities (Gosbell and Clemens, 2006; Wilson et al., 2011; Aharon-Rotman, 2015; Szabo et al., 2016). At least 31 migratory shorebird species may occur in the study area. Most of these (23 species) congregate on or near the coast, more than one third of which (8/23) of these are listed by the IUCN as Threatened or Near Threatened with extinction. Numerous additional migratory and resident bird taxa may join these coastal aggregations. Within the study area the largest aggregations of coastal bird species are expected to occur along the tidal flats, lagoons and estuaries of the Mangroves ecological zone, and to a lesser degree the Southeast Coast.

Based on numbers of migratory shorebirds recorded previously in the nearby Kikori delta (Jaensch and Watkins, undated; Bamford et al., 2008), the tidal wetlands of the Purari delta may qualify as an internationally important wetland site (under Criterion 6 of the RAMSAR Convention) for Greater Sand Plover (*Charadrius leschenaultia*) and Terek Sandpiper (*Xenus cinereus*) and as an internationally important staging site for the IUCN Endangered Far Eastern Curlew. These habitats are discussed further in Section 6.5.3.2.

Freshwater Wetland Migratory and Congregatory Species

At least 36 bird species may occur in freshwater environments within the study area. These include the majority of Australian breeding migrants that visit the region, as well as a number of northern hemisphere migrants and locally resident bird species. Waterbirds may occur singly, together in small numbers or in large flocks. Within the study area the largest aggregations of wetland bird species are expected to occur in off-river freshwater wetlands such as oxbow lakes and swamps of the Purari and Vailala River basins, respectively in the Delta Swamps and Plains and Southeast Hills ecological zones. The location and potential importance of these habitats is discussed further in Section 6.5.2.2.

Terrestrial Migratory Species

Most avian migrants to terrestrial habitats breed in Australia. All occur widely across southern New Guinea and most either predominantly occupy or are tolerant of open and disturbed environments. Most occur singly or in small groups and are not known to form large aggregations. The study area does not include habitat for these species requiring specific conservation action.

Cave Roosting Swiftlets

Swiftlets (*Aerodramus* spp., *Collocalia esculenta*) are among the most common and widespread bird species observed in the study area. At least two and possibly as many as five species occur locally, all of which nest and roost colonially in caves. Colony sizes are poorly documented, but range from a few individuals to 100s of birds, depending on the dimensions of the shelter site. The potential location and importance of caves is discussed in Section 6.6.1.

Colonial Starlings

Other congregatory bird species include the Metallic Starling (*Aplonis metallica*), Singing Starling (*A. cantoroides*) and Yellow-eyed Starling (*A. mystacea*) (NT). The latter is a little known and sparsely distributed species restricted mostly to riparian habitats in New Guinea's southern lowlands and north of the Trans-Fly. Metallic and Yellow-eyed Starlings are the most gregarious, nesting in colonies of up to 100+ nests packed into one or two trees. Favored nesting trees may be used repeatedly over multiple years. Suitable nesting trees are widespread within and beyond the study area's forest environments.

Lekking Birds-of-Paradise

Male Raggiana birds-of-paradise (*Paradisaea raggiana*) congregate daily in groups of up to ten or more individuals to display simultaneously at traditional display sites termed 'leks' (Frith and Beehler, 1998). Leks are usually formed in the upper branches of a canopy tree and may be temporary or used continuously for many years. Both the Raggiana Bird-of-paradise and suitable lekking trees are widespread within and beyond the study area's forest environments.

6.3.5.3 Large 'Freshwater' Turtles

The Pig-nosed Turtle and Striped New Guinea Soft-shelled Turtle nest on sandy river banks, and the Pig-nosed Turtle additionally (at least in the Kikori delta) at the mouths of major rivers, on islands in river deltas and on coastal beaches. Both of these IUCN Vulnerable species nest along the Purari River and/or its tributaries in the south of PRL-15, and probably more widely in the study area. The nesting sites are used year after year and each is visited by multiple laying females. The location and significance of the PRL-15 nesting sites is discussed in Section 6.6.4.

The behavioral ecology and life history requirements of these species in New Guinea is still poorly known (Georges et al., 2008; Eisemberg et al., 2015). While neither is known to be socially gregarious, both can be said to be congregatory in that multiple females typically use the same nesting site and may be encountered there together when laying. The harvesting risks posed by this behavior are similar to these endured by other congregatory species. Patterns of movement within the Gulf Province drainages are still poorly known (A. Georges, pers. comm. to S. Richards, 2016) but may involve 'migrations' between nesting and feeding areas (Eisemberg et al., 2014, 2015). For example, in the Purari and Kikori catchments hatchlings move to the lower delta to feed on mangrove fruit and other vegetation.

6.3.6 Invasive Alien Species

Alien species include any taxa that are introduced beyond their original geographic range. They include species not native to New Guinea, and species originally present only in other parts of New Guinea.

6.3.6.1 Weeds

The status and distribution of weeds in the study area is described in detail in Annex 1C.

Ninety-seven alien plant species were identified within the study area at widespread infestation sites. Notable infestations were reported:

- In village and garden areas—some weeds were present in all villages visited, though infestations were most diverse and widespread in the densely populated Southeast Coast ecological zone.
- At Purari airstrip, in logging camps, along the extensive network of logging roads and in associated dieback areas.
- At Project facility and infrastructure sites, including Herd Base, Antelope 3 Operations Camp, wellpads, as well as along the Herd Base—Gas Field Road.

Despite this widespread occurrence, most alien species have a low potential to invade natural ecosystems. Weeds are classified into three groups based on their potential to cause ecological harm by establishing in unmodified natural environments (Booyong Forest Science, Annex 1C):

- Priority 1 species can persist in unmodified native ecosystems. They have the potential to cause ecosystem degradation by displacing native species and/or negatively impact on regeneration/rehabilitation measures.
- Priority 2 species persist in disturbed areas and are unlikely to persist without some anthropogenic influence.
- Priority 3 species require ongoing disturbance and are unable to out-compete native species without regular human interference. These species are not considered an ecological threat.

Seven plant species recorded in the study area are Priority 1 weeds. Priority 1 species and their occurrences in the study area are described in Table 6.17, and examples are shown in Plates 6.94 to 6.99. Another 34 species are Priority 2 weeds, and nearly 60% of alien plants are Priority 3 weed species.

Table 6.17 – 'Priority 1' Alien Weeds Recorded from the Study Area

Species	Description and Occurrence in Study Area
Angelonia/Monkey Face (*Angelonia angustifolia*)	Erect herb to 1 m high. Forms dense stands on poorly drained sites. Widespread: in PRL-15 infesting wellpads and associated landslips, Antelope 3 Operations Camp, the Herd Base—Gas Field Road at Site 6A and Purari airstrip and nearby logging roads; in the export pipeline corridor present at Paevera village and coastal villages
Water Hyacinth (*Eichhornia crassipes*)	An erect perennial aquatic herb, free-floating or occasionally rooted in shallow water. Noted in Nea Creek, the PR-15 oxbow wetlands (Section 6.5.2.2) and at Purari airstrip
Anglestem Willow (*Ludwigia leptocarpa*)	Annual herb. Infests wet sites where exposed topsoil. Infestations were reported: in PRL-15 at the Elk 2 wellpad and Purari airstrip; in the export pipeline corridor in waterlogged sites adjacent to logging roads and in a logged area with dieback

Species	Description and Occurrence in Study Area
Mile-a-Minute Vine (*Mikania micrantha*)	A fast-growing vine that tolerates partially shaded environments, commonly invading low to moderately disturbed, poorly drained sites. Highly invasive and can smother the canopy of large trees. Widespread in disturbed and open sites: in PRL-15 present at Herd Base, along the Herd Base—Gas Field Road at Site 6A, at Purari airstrip and nearby logging roads; in the export pipeline corridor present along logging roads and in a logged area with dieback, in undisturbed Swamp grassland (Gsw) west of Site 7 and in coastal villages; a problem in food gardens at Evara village on the Purari River
Bamboo Daka (*Piper aduncum*)	Shrub/small tree to 6 m. Tolerates a range of climatic conditions and will grow in shade and full sun. Highly invasive and can establish in natural gaps and stream banks in primary forest. Widespread, particularly along roads: in PRL-15 present at Herd Base, along the Herd Base—Gas Field Road at Site 6A, at Purari airstrip and nearby logging roads and along watercourses; in the export pipeline corridor present along logging roads and in a logged area with dieback; also in Pawaian villages and along the banks of the Purari River
African Tulip Tree (*Spathodea campanulate*)	The only Priority 1 large tree (to 20 m high) identified within the study area. Along with *Piper aduncum* this is the most successful woody invader of disturbed forest environments in New Guinea. Invades post-logging secondary forest and outc-competes regenerating native species. Recorded at Muro Mission, southern export pipeline corridor
Coconut Palm (*Cocus nucifera*)	A tall palm to 20 m. A naturally occurring species, but with a commercial cultivar planted extensively in the Southeast Coast ecological zone since the early 1900s. Forms localized infestations on areas of raised ground in Mangrove (M). Causes structural change in mangrove forest and has the potential to out-compete native species. Recorded in mangrove forest in the southwest export pipeline corridor, Site 8M

In contrast to the infestations observed at heavily disturbed sites, few weeds were observed in intact natural environments. Records include three Priority 1 species—Coconut Palm (*Cocus nucifera*) in Mangrove (M) at Site 8M, Mile-a-Minute Vine (*Mikania micrantha*) in Swamp grassland (Gsw) at Site 7, Water Hyacinth (*Eichhornia crassipes*) in the PRL-15 oxbow wetlands (Section 6.5.2.2)—and the Priority 2 Bilimbi Tree (*Averrhoea bilimbi*) which had established along footpaths in little-disturbed forest at Sites 7 and 9.

Consequently, expansive areas of natural forest habitat are essentially weed free. Within PRL-15, no weeds were reported from forest at Sites 2, 4, 5, 6B and 6D, or from areas of forest away from Project roads and facilities at Sites 1 and 6A. Even in logged areas, at Sites 3 and 7 along the export pipeline corridor, few weeds were present in logged forest and none recorded in primary forest away from logging roads. This circumstance reflects the relatively pristine and undisturbed quality of the forests that cover much of the upstream PAOI and broader study area.

Plate 6.94 – Monkey Face (*Angelonia angustifolia*) Infestation at Elk-1 Wellpad



Photo source: H. Rogers.

Plate 6.95 – Water Hyacinth (*Eichhornia crassipes*) Along Nea Creek, Southwest PRL-15



Photo source: H. Rogers.

Plate 6.96 – Anglestem Willow (*Ludwigia leptocarpa*) Infestation at Dieback Site in a Logged Area Along the Export Pipeline Corridor



Photo source: H. Rogers.

Plate 6.97 – Bamboo Daka (*Piper aduncum*) Infestation Along a Logging Road



Photo source: H. Rogers.

Plate 6.98 – African Tulip Tree (*Spathodea campanulate*) at Muro Mission



Photo source: H. Rogers.

Plate 6.99 – Coconut Palms (*Cocus nucifera*) Established in Mangrove (M) Along Oeha Creek, Southwest Export Pipeline Corridor (Site 8M)



Photo source: I. Woxvold.

6.3.6.2 Mammals

Invasive alien mammals present in the study area (feral or domestic) include various rodents (Muridae), the cat (*Felis catus*), the dog (*Canis familaris*), and the pig (*Sus scrofa*). They are described in detail in Annex 2. No invasive alien bats were recorded or are likely to occur in the study area (Annex 3).

Rodents

Four alien rodent species were detected during the survey—Pacific Rat (*Rattus exulans*), Black Rat (*R. rattus*), Small Spiny Rat (R*. steini*) and House Mouse (*Mus musculus*). Each of these species is currently restricted to anthropogenic habitats, including active Project facility sites, active logging roads and villages. The Black and Pacific Rats are the most widespread alien rodents, the Small Spiny Rat and House Mouse being recorded at single sites.

Infestation histories vary across the study area. A long-term resident Black Rat population (pre-1970s) is reported for the densely populated Southeast Coast. By contrast, recent infestations are reported by local landowners residing near transport infrastructure sites—Black and Polynesian Rats in Evara village (Delta Swamps and Plains) shortly after the construction of a nearby logging camp in 2000, and Black Rats at Wabo village (Middle Purari Hills) within the last one to two years.

Native rodent populations are presumed thus far to have kept alien species from invading natural habitats. Moreover, trapping results suggest that disturbance-tolerant native species such as Southern Lowland Rat (*Rattus leucopus*) and White-bellied Melomys (*Melomys leucogaster*) are out-competing alien rodents in at least some post-disturbance regrowth habitats. These observations suggest that alien rodent populations are currently patchily distributed in heavily disturbed sites within the study area. Alien Rattus species are capable of invading natural forest environments in the absence of native competitors, and preventing the further spread of established alien populations depends in part on the continuing health of native rodent populations. Within the mosaic of suitable disturbed environments, dispersal of alien rodents to novel sites occurs primarily by human transport vectors (road and/or air).

Plate 6.100 – Black Rat (*Ratus rattus*) Trapped at Antelope-3 Operations Camp



Photo source: K. Aplin.

Feral pigs

Pigs were introduced into New Guinea approximately 2,500 years ago. Feral populations are now widespread and occupy a variety of habitats.

Feral pigs are widespread in the study area, where they were recorded at all flora and fauna survey sites except in mangroves at Site 8M. The highest densities were recorded in undisturbed alluvial forest; camera trapping rates suggest they are less abundant in hill forest and wherever they are subject to hunting by local communities.

Plate 6.101 – Feral Pig (*Sus scrofa*) Sow and Piglets Camera Trapped at Site 4



Photo source: I. Woxvold.

Dogs

Dogs (*Canis familiaris*) have been present in New Guinea since prehistoric times. They occur both as domestic and feral populations, with a regular interchange of individuals in some areas. Where present, feral dogs are the apex predator in New Guinea's terrestrial ecosystems.

Domestic dogs are kept by local residents throughout the study area. The status of local feral populations is uncertain. At least one feral population is likely to be present north of the Purari River in PRL-15—unaccompanied dog prints seen at Site 6A were attributed to feral dogs by local residents who stated they were common in the area.

Cats

Feral Cat (*Felis catus*) populations are rarely reported in New Guinea's rainforest environments, and may be largely restricted to human settlements and nearby disturbed areas (Flannery, 1995)

Within the study area cats are kept as pets in most villages and at some Project facility sites. No evidence of a feral population was obtained.

6.3.6.3 Birds

One alien bird species was recorded, the Eurasian Tree Sparrow (*Passer montanus*) having established colonies at Herd Base, the Antelope-3 Operations Camp and in coastal villages of Orokolo Bay. The Eurasian Tree Sparrow is strongly commensal New Guinea, being restricted to open and disturbed habitats around human settlements.

6.3.6.4 Herpetofauna

The Cane Toad (*Rhinella marina*) is a rapidly spreading and highly toxic amphibian introduced to Australia and New Guinea from South America. It has a patchy distribution in PNG where it is restricted predominantly to open savanna habitats, urban areas, and disturbed forest environments. They are rare in closed canopy rainforest.

Cane Toads are widespread but patchily distributed in anthropogenic habitats across the study area. They were present in PRL-15 at the Antelope 3 Operations Camp and at Herd Base. Within the export pipeline corridor, they were common in densely settled areas of the Southeast Coast (Sites 8 and 9) and were present along the logging road at Site 3, but were not found within adjacent logged forest habitats. They are easily introduced to novel, isolated disturbed sites via human transport vectors (road and/or air).

Plate 6.102 – Cane Toad (*Rhinella marina*) in a Coastal Village at Orokolo Bay



Photo source: S. Richards.

6.3.6.5 Invertebrates

No alien odonates were recorded in the study area, and terrestrial invertebrates were not otherwise systematically surveyed. However, a severe infestation of the Giant East African Snail (*Lissachatina fulica*) was observed at Site 8. Local residents indicated that it had arrived within the last few years and that it was a very serious agricultural pest. It was also common in adjacent

alluvial forest, with multiple individuals photographed on 80% (4/5) of camera traps deployed in this vegetation type south of the Muro River. Local residents stated that the Muro River was acting as a dispersal barrier and that snails were yet to be found north of there.

A number of other alien pest invertebrates may be present in the study area or become established in the future. Alien ant species present among the most serious threats via their impacts on local fauna populations. Invasive alien ant species now established in PNG include the Yellow Crazy Ant (*Anoplolepis gracilipes*), the Fire Ant (*Solenopsis geminata*), the Longhorn Crazy Ant (*Paratrechina longicornis*), the African Big-headed Ant (*Pheidole megacephala*), the Pharaoh Ant (*Monomorium pharaonis*), the White-footed Ant (*Technomyrmex albipes*), the Ghost Ant (*Tapinoma melanocephalum*) and *Tetramorium bicarinatum* (www.newguineants.org, accessed 6 July 2017). Each is defined as a 'tramp' species in that it is easily dispersed via human commerce and trade activities; ants may be spread by the movement of equipment, food, logs and other vegetation such as leaves and flowers that are infested (ISSG, 2017). Of these species, the Yellow Crazy Ant is potentially the most destructive and is known to occupy natural forest habitats as well as disturbed environments (ISSG, 2017).

No invasive alien ant species were recorded in the study area, but their presence cannot be ruled out.

6.4 Protected Areas

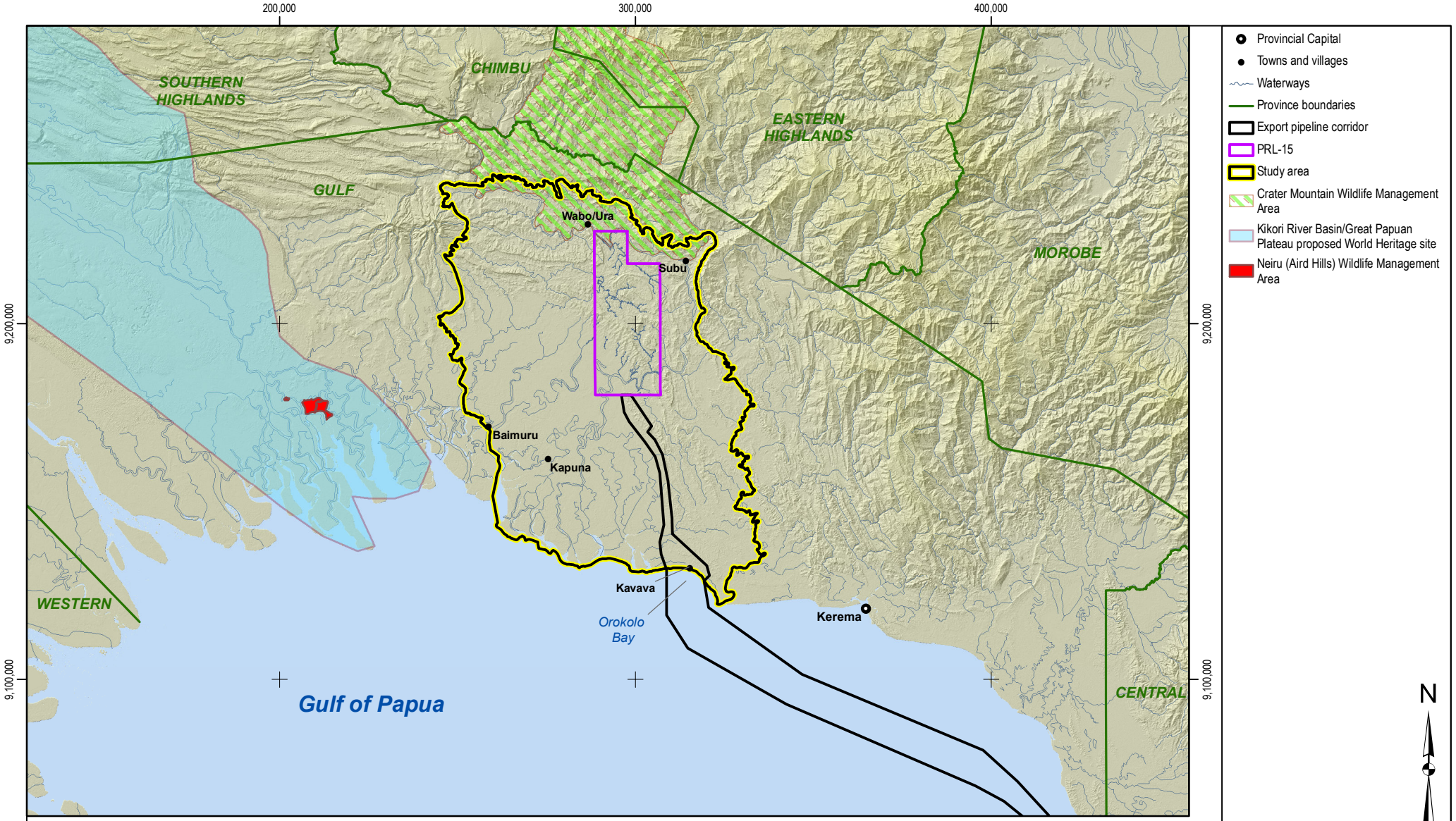
6.4.1 Crater Mountain WMA

Approximately 445 km^2 of the Crater Mountain WMA overlaps the study area at the northern margin of the Middle Purari Hills ecological zone in areas north of the Purari River (Figure 6.13). North of the study area, this 2,700 km^2 WMA extends into Chimbu and Eastern Highlands Provinces to elevations over 3,100 m asl.

The northern extremities of PRL-15 (11.9 km^2) and the upstream PAOI (140.0 km^2) overlap this WMA. No Project facilities are present or are planned to be developed within this WMA. Hou Creek Base is located on the opposite (southern) side of the Purari River, approximately 300 m from the WMA boundary at its closest point. The next closest facilities are the Elk 2 and Elk 3 wellpads, respectively located approximately 2.1 km and 3.0 km south of this WMA at its closest point.

WMAs are community-based conservation initiatives provided for under the Fauna Act. Rules for the use of natural resources within a WMA are established by a Wildlife Management Committee comprised of local community leaders. The Crater Mountain WMA was established in cooperation with conservation NGOs and was gazetted as a national WMA in 1994 (Johnson, 1997). NGO involvement was downgraded in 2006 with the discontinuation of a major biological research program (Mack, 2014; West and Kale, 2015). The current status and activities of the Wildlife Management Committee are unknown.

Regardless of its functional status, due to its ongoing recognition as part of the New Guinean protected areas network the Crater Mountain WMA is here considered to be Very Sensitive.



SCALE: 1:1,500,000 @ A4

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

TITLE: Protected Areas and Proposed World Heritage Sites

FIGURE: 6.13

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79681 **REVISION:** C

DATE: 12/04/2017

DATA SOURCES:

Towns and villages, export pipeline corridor, study area (ERIAS Group 2017). PRL-15, waterways (TOTAL 2016). Province boundaries derived by Mipela GeoSolutions (2016). Crater Mountain Wildlife Management Area, Neiru (Aird Hills) Wildlife Management Area (IUCN and UNEP-WCMC (2016), The World Database on Protected Areas (WDPA), Cambridge, UK: UNEPWCMC. Available at: www.protectedplanet.net). Kikori River Basin/Great Papuan Plateau proposed World Heritage Site (Iain Woxvold (2017). DEM (Planet Observer 2015).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

T:\Projects\ER1002 Elk Antelope LNG Project EIS-ESHIA\Work Request\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79681-Figure 6.13-C.mxd

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

6.4.2 Protected Areas Near the Study Area

The Neiru (Aird Hills) WMA is the only other currently gazetted protected area within Gulf Province, and the only other protected area located within 50 km of the study area (Figure 6.13). It comprises 24.6 km^2 of low elevation hills (below 300 m asl) and surrounding mangrove and freshwater swamp forest in the Kikori delta, approximately 37 km west of the study area at its closest point (southwest Delta Swamps and Plains).

6.4.3 Proposed World Heritage Sites

West of the study area, the 'Kikori River Basin/Great Papuan Plateau' proposed World Heritage site covers more than 20,000 km^2 and over 6% of PNG's land mass, extending northwest from the Purari delta more than 300 km to encompass Mount Bosavi, the Great Papuan Plateau and parts of the Southern Fold Mountains (Figure 6.13). It lies just 15 km from the study area at its closest point in the Purari delta.

This area was included in the PNG Government's 'Tentative List' of seven potential World Heritage sites submitted in 2006 on the basis of their outstanding natural features. In a subsequent assessment of Tentative List sites, the IUCN (2008) noted that the Kikori River Basin/Great Papuan Plateau may have the potential to attain World Heritage status based on the combined presence of karst terrain and globally outstanding biodiversity values.

> The Kikori Basin/Great Papuan Plateau contains one of the largest remaining tracts of undisturbed forest in the Southern Hemisphere. The catchment spans across nearly all forest types found in PNG (UNESCO, 2012).

The current status of this application is unknown.

6.5 Priority Ecosystems

Major environments are divided into 20 ecosystems to which a baseline sensitivity value has been assigned. The sensitivity ranking of the various ecosystems is shown in Table 6.18. The features underpinning these assessments are described below for ecosystems considered to be Moderately Sensitive or higher. Sensitivity maps of terrestrial ecosystems and select focal sites are shown in Figures 6.14 to 6.16.

Table 6.18 – The Sensitivity of Ecosystems Present Within the Study Area

Feature	Sensitivity[A]
Terrestrial Ecosystems	
Hill forest (H) - primary	MS
Hill forest (H) - logged	LS
Hill forest (H) on limestone (MPH)	VS
Alluvial forest (P) - primary	VS
Alluvial forest (P) - logged	MS
Riverine seral forest (Fri)	MS
Swamp forest (Fsw)	MS
Swamp woodland (Wsw)	MS
Low freshwater swamp vegetation (Hsw, Gsw, Gri)	MS
Mangrove (M)	VS

Table 6.18 – The Sensitivity of Ecosystems Present Within the Study Area (cont'd)

Feature	Sensitivity[A]
Littoral forest (B)	LS
Converted land	NS
Freshwater Aquatic Ecosystems	
Forest streams	MS
Open-canopy watercourses	MS
Oxbow lakes	VS
PRL-15 oxbow wetlands	VS
Coastal freshwater lakes	MS
Marine Aquatic Ecosystems	
Near-shore marine/estuarine waters	LS
Tidal wetlands - Purari delta	VS
Tidal wetlands - export pipeline corridor	MS

[A] NS—Not Sensitive; LS—Low Sensitivity; MS—Moderately Sensitive; VS—Very Sensitive; ES—Extremely Sensitive.

6.5.1 Terrestrial Ecosystems

In addition to the priority ecosystems described below:

- Littoral forest (B), including beach scrub vegetation, is judged to have Low Sensitivity due to its high regenerative potential (as a colonizing vegetation type), frequent rate of human visitation (in the densely populated Southeast Coast), small statures (mature developmental stages not observed in Orokolo Bay environments), and low diversity of species of conservation significance.

- Converted land (O), including Urban areas (U), is considered to be Not Sensitive due to the general absence or poor representation of natural ecosystem components.

6.5.1.1 Overview of Forest Environments

Tropical lowland rainforests, be they on alluvial or hill terrain, are among the most biodiversity-rich ecosystems on Earth (Whitmore, 1999; Corlett and Primack, 2011). In terms of supporting local biodiversity values, forest is the most important landscape feature present in the study area. In their various forms[14] forest ecosystems cover 89.8% of the study area land surface and support the vast majority of species that permanently reside or regularly occur there. For example, New Guinea has among the world's highest diversity of forest-dependent birds (Buchanan et al., 2011)—of 214 bird species recorded in the study area, nearly three-quarters (72.4%) occur in forest environments, most of which are forest-dependent (cannot persist in converted or secondary habitats alone) (Annex 4). Most species of conservation significance are dependent on forest habitats, including:

- More than three quarters (76.2%) of IUCN listed and nationally Protected species recorded or potentially occurring in the study area, including nearly three quarters (73.4%) of IUCN Threatened and Near Threatened species[15].

[14] Here including hill and alluvial forest in their various forms, Swamp forest (Fsw) and Mangrove (M), and all vegetation complexes in which these types form the dominant component.
[15] Excluding seven Threatened marine and/or river-dwelling turtle species, two marine mammals and ten migratory or resident shorebird species.

- Almost all restricted-range taxa (excluding two frogs and the coastal skink *Cryptoblepharus litoralis vicinus*).
- All new-to-science and undescribed taxa recorded in the study area.

In addition, many of the priority sites/habitats identified within the study area occur within forest environments, including large trees, forest streams and stream banks, many caves and rock overhangs.

Within the overall forest matrix, a number of priority forest ecosystems are identified. Described in the Section 6.5.1.3 to 6.5.1.5, these are distinguished for a combination of:

- Their importance to flora and fauna of conservation significance.
- Their importance to habitat-specialist taxa.
- Their recognition as important environments in prior national assessments.
- Their condition and availability within the study area and surrounding areas.

6.5.1.2 The Influence of Logging

The influence of forest loss and degradation on New Guinean flora and fauna communities has been little studied (Gardner et al., 2010; Munks and Watling, 2013). Based on the work that has been conducted in New Guinea (reviewed for PNG by Munks and Watling, 2013), and in other tropical regions (e.g., Meijaard et al., 2005), it is evident that logging-related impacts on species and their habitats are complex and varied. Impacts include changes to forest structure and floristics, reduced capacity for forest regeneration, altered microclimate below canopy level, changes in faunal community structure, and increased susceptibility to invasion by alien species and to anthropogenic fires. The degree of impact depends on a variety of factors, including the taxa investigated, the intensity of logging, time since logging, substrate type, degree of fragmentation, proximity to other forested areas, and susceptibility to (or remoteness from) secondary (post-logging) anthropogenic influences.

Approximately 1,300 km^2 of forest have been logged within the study area, most of it (86.6%) hill and alluvial forest (Section 6.2.3.1). Structural impacts are notable across the more than 1,080 km^2 of forest logged in the southeast study area (Vailala Blk 3 concession: Table 6.4; Figure 6.5). Among the highest impacted forests are the recently (within the last few years) and intensively logged Alluvial forest (Pl) formations in the densely populated Southeast Coast ecological zone, where some sites have subsequently been converted to gardens. However, heavily altered canopy structures and under-developed sub-canopies are also widespread in the more remote hill forests further inland, where regenerative capacities may be low due to 'low growth rates associated with high rainfall, shallow and heavily leached infertile sedimentary soils' (Annex 1D). Ameliorating these impacts, the regenerating forest is typically not fragmented and retains local patches of primary forest, often in areas inaccessible to loggers (including slopes of $>30^0$ in hill forest and poorly drained areas on alluvial plains). Except for the densely populated Southeast Coast, most of the logged forest further inland is remote from human settlements and subject to limited secondary conversion processes (e.g., secondary logging or conversion to gardens). Logged hill forest is contiguous with extensive areas of primary hill forest to the north in the Middle Purari Hills and to the east beyond the study area boundary. Logged alluvial forest has more limited connectivity with primary exemplars (see below), although, as noted above (Section

6.3.4.3), most plant and animal species occupying alluvial forest also occur in foothill and/or swamp forest.

Logged tropical forests are widely recognized as capable of supporting high biodiversity values (Chazdon et al., 2009; Edwards et al., 2009; Berry et al., 2010). Within the study area, multiple species of conservation significance were reported from areas subject to logging, including:

- The IUCN Threatened timber trees Diospyros lolinopsis (CR), Maple Silkwood (EN), *Pterocarpus indicus* (VU) and *Intsia bijuga* (VU), and non-timber plant species *Mammea grandifolia* (VU) and *Ceratopetalum succirubrum* (VU).
- IUCN Threatened fauna: Giant Bandicoot (EN), Grey Dorcopsis (VU), False Water Rat (VU), Southern Cassowary (VU), Scheepmaker's Crowned Pigeon (VU) and Pesquet's Parrot (VU).
- Multiple new-to-science species, including 13 plants (*Pseuduvaria* sp. 1, *Cyrtandra* sp. 1, *Cyrtandra* sp. 2, *Barringtonia* sp. 2, *Ficus* sp. 1, *Syzygium* sp. 2, *Syzygium* sp. 3, *Syzygium* sp. 4, *Discocalyx* sp. 1, *Ixora* sp. 1, *Ixora* sp. 3, (Rubiaceae) Genus 1 sp. 1 and (Rubiaceae) Genus 1 sp. 3), the gecko *Gehyra* sp. 1, the frogs *Cophixalus* sp. 1 and *Oreophryne* sp. 1, and the odonates *Metagrion* sp. 1, *Rhyacocnemis* sp. 1, *Agyrtacantha* sp. 1 and *Bironides* sp. 1.
- Numerous additional restricted-range species.

Many of these species were recorded in remnant primary or relatively little-disturbed forest habitats, while for others there is some evidence (e.g., from camera trapping: Annex 2) that population densities are lower than those occurring in primary forest. However, examples of primary forest appear to be widespread at the patch scale within the logged forest matrix, and are additionally available in surrounding areas. Moreover, apart from a few weed species recorded in logged forest, and feral pigs, which are widespread also in primary habitats, infestations of invasive alien species, including rodents, appear still to be low in regenerating secondary environments.

In summary, logging has no doubt impacted upon the biodiversity values originally present in the study area's hill and alluvial forests. However, post-logging secondary forest still retains high value taxa, and in the absence of further conversion processes presents opportunity for future recolonization from adjoining source populations, or for increased population densities among remnant resident populations, as forest regeneration progresses.

In the following sections, the reduced sensitivity of logged forest environments is recognized variously through the influence of logging on intrinsic worth, intactness and potential for recovery to an already disturbed baseline state.

6.5.1.3 Hill Forest

Hill Forest on Non-calcareous Sediments

Geology of the study area's hill terrain landforms is dominated by non-calcareous sediments (Section 3.1.3).

Hill forest supports the highest number of conservation listed (Figure 6.6), new-to-science and other scientifically undescribed species (Figure 6.7) and restricted-range species (Figure 6.9)

recorded and potentially occurring in the study area. It provides foraging habitat for the IUCN Critically Endangered Bulmer's Fruit Bat, supports localized occurrences of up to three tree kangaroo species (*Dendrolagus* spp.) and the Eastern Long-beaked Echidna (VU), widespread occurrences of multiple IUCN Vulnerable mammals and birds (Grey Dorcopsis, Southern Cassowary, Papuan Eagle, Scheepmaker's Crowned Pigeon, Pesquet's Parrot) and IUCN Threatened plants, and is the only vegetation type known to support 25 new-to-science species.

The highest value hill forests are unlogged. Expansive areas of primary hill forest remain in the northern study area, spanning most of the sparsely populated Middle Purari Hills ecological zone and most of PRL-15. The Middle Purari Hills landscape lies with multiple areas of biological importance recognized under the PNG Conservation Needs Assessment (Beehler, 1993a), including an area of biological importance to herpetofauna (Allison, 1993) and major wilderness areas (Allison, 1993; Beehler, 1993b).

Hill forest is the most widespread vegetation type locally, regionally and nationally. Hill forest in the extensively logged Southeast Hills ecological zone is well connected with primary examples of comparable altitude (below 500 m asl) to the north in the Middle Purari Hills and to the east outside of the study area. Connectivity is more limited for unlogged forest of the Middle Purari Hills, being bordered by high elevation environments to the east (Aure Scarp), north (central cordillera) and west (Mount Fanvec). Moreover, much of the comparable low elevation habitat across the footslopes of Mount Favenc has been logged. Some connectivity with primary low elevation exemplars does remain, however, and most or all species present in the study area's hill forests are expected to occur more widely (Section 6.3.4.3).

Hill forest regenerates well where the vegetation is removed without exposure of topsoil, or in areas of relatively gentle terrain where the exposed topsoil remains intact. Regenerative capacity in poorer on steep slopes and/or where the topsoil has been disturbed or removed.

Unlogged hill forest on sedimentary substrates is considered to be Moderately Sensitive because:

- It supports a high diversity of IUCN Threatened and other Very Sensitive species.
- It is largely unmodified by human activity and has recognized wilderness values.
- It is moderately well connected with comparable habitats widespread elsewhere in the region.

Logged hill forest (all of it on sedimentary substrates) is assigned Low Sensitivity. However, it should be noted that the Low Sensitivity logged hill forest matrix is permeated by areas of Moderately Sensitive primary forest that are too small to be mapped.

Hill Forest on Limestone

Mapped areas of surface limestone[16] cover 112.4 km^2 in discrete occurrences in the Middle Purari Hills—in the west along the Kereru Range and in the extreme northwest where it contacts the Purari River at Hathor Gorge and around Mua Creek (Bain and MacKenzie, 1974; Pieters, 1980; Figure 6.17). One notable unmapped occurrence of surface limestone was observed—a locally

[16] Primary areas of limestone mapped from Tmd and Te Darai limestone formations as per Bain and MacKenzie 1974 and Pieters 1980 and transcribed under PNGRIS. Excludes areas where calcareous sediments are mapped as a subordinate element to other sediments (sandstones, mudstones, etc.).

extensive area of karst topography (limits unknown, but extending at least c. 500 m into surrounding forest; K. P. Aplin, in litt. 2017) at the Wi'i Creek site in the northeast Middle Purari Hills. Mapping of surface limestone is thus incomplete, and additional areas of similar lithology may occur elsewhere. No known areas of limestone overlap PRL-15, and none other than the minor Heve Hill site[17] is known to occur within the export pipeline corridor.

Limestone has a strong influence on the composition of overlying biotic communities by virtue of its chemistry and weathering pattern. Limestone topography (including karst formations) provides unique structural habitat for fauna and supports plant communities that are uniquely suited to alkaline and nutrient-poor soil conditions. Limestone topography is thus associated with high levels of rarity and endemism among flora and fauna throughout the Asia-Pacific region (Whitmore, 1984; Vermeulen and Whitten, 1999; Clements et al., 2006), including in New Guinea (Miller et al., 1994; Takeuchi, 2003, 2011; Richards and Gamui, 2011).

Ecosystem fragility is pronounced in limestone forests. Limestone-derived soils are often shallow, typically nutrient-poor and the overlying forest often exhibits lowered resilience to major disturbance events. For example, on the limestone mountains of western Malesia, forests destroyed by fire remain bare for many years, followed by a slow recovery to a depauperated scrub (Anderson 1965). Slow recoveries are also characteristic in New Guinean montane karst environments (I. Woxvold, unpublished data).

The Wi'I Creek site was visited once by the non-volant mammal team. No limestone forest within the study area has been surveyed for flora or other faunal groups.

Limestones in the Middle Purari Hills represent the eastern limit of the Darai Limestone megasequence, which extends west and north from the study area across Western Province and into Indonesian Papua Province (Hill and Gleadow, 1989). Hill forest on the Darai limestones in the Middle Purari Hills is considered to be Very Sensitive because:

- It potentially supports a high diversity of Very Sensitive (including IUCN Threatened) and habitat-specialist species.
- It is largely unmodified by human activity and is located in an area with recognized wilderness values.
- It has a poor recovery potential.

6.5.1.4 Alluvial Forest

In its various forms (including complexes), alluvial forest covers 16.6% of the study area (Section 6.2.4.2), predominantly in discrete areas at the northern, southern and eastern margins of the Delta Swamps and Plains ecological zone, and as more minor occurrences (often too small to be mapped) along major watercourses in the Middle Purari Hills and the Southeast Hills ecological zones and at the base of the foothills in the Southeast Coast ecological zone.

[17] Limestones at Heve Hill in the Southeast Coast are very minor amid predominant calcareous mudstone (K. P. Aplin, *in litt.* 2017). These formations are considered too minor to support 'hill forest on limestone' as discussed here.

Alluvial forest supports the second highest (behind hill forest) number of conservation listed species, new-to-science and undescribed species and restricted-range species recorded or potentially occurring in the study area. While there is extensive overlap in the composition of flora and fauna communities occupying New Guinean alluvial and hill forest environments, a number of distinctive features relating to high value taxa were observed in the study area's alluvial forests. In addition to a broader range of high value taxa occurring in both hill and alluvial forests:

- Alluvial forest supports one of few known populations of the IUCN Critically Endangered timber tree *Diospyros lolinopsis* and the IUCN Endangered Giant Bandicoot.
- Based on camera trapping results, a variety of terrestrial birds and mammals show a strong preference for alluvial forest over hill forest habitats, notably including the IUCN Vulnerable Grey Dorcopsis (VU), Southern Cassowary (VU) and Scheepmaker's Crowned Pigeon (VU).
- Seven new-to-science species are currently documented only from alluvial forest environments within the study area—the plants *Barringtonia* sp. 2, *Medinilla* sp. 1, *Syzygium* sp. 1, *Syzygium* sp. 4, *Syzygium* sp. 5 and *Oberonia* sp. 1, and the snake *Stegonotus* sp. 1.

Compared to hill forest, alluvial forest has a much more restricted distribution both within the study area and more broadly across Gulf Province. As presented under FIMS mapping, the study area's alluvial forests are separated from those of the Kikori River basin to the west by unbroken blocks of hill forest, swamp forest and mangroves, and from those of the Lakekamu basin to the east by the hills of the Kukukuku Lobe that extend south to the coast. Moreover, much of the alluvial forest originally present in these adjacent sectors has been logged (Figure 6.18).

Alluvial forest, particularly the better drained Alluvial forest (Pl) and Open alluvial forest (Po) formations, is a favored source of commercial timber, and where accessible is among the first forest types to be harvested by logging operations. Within the study area, 26.1% (303.4 km^2) of alluvial forest has been logged. The most heavily impacted formations are the areas of Alluvial forest (Pl) recently logged (since 2015) in the northwest of the Southeast Coast ecological zone, areas of which have since been converted to gardens.

Beyond the study area, the vast majority of Pl and Po formations present elsewhere within the Kikori-Purari biogeographic region (sensu Beehler 1993b) have been logged—the larger areas of unlogged alluvial forest remaining in the Kikori basin (Figure 6.18) are Small crowned alluvial forest (Ps), much of it disturbed by local resident activities (based on FIMS disturbance codes). The study area thus supports the largest remaining primary formations of Alluvial forest (Pl) and Open alluvial forest (Po) remaining anywhere within the Kikori-Purari biogeographic region.

Alluvial forest of the Delta Swamps and Plains overlaps multiple areas of biological importance identified under the PNG Conservation Needs Assessment (Beehler, 1993a), including areas of botanical importance (Johns, 1993) and of biological importance to herpetofauna (Allison, 1993) and a major wilderness area (Allison, 1993).

Rehabilitation of alluvial forest may present challenges due to the potential for damage to poorly drained soils if disturbed (for example, compaction/damage to soil structure and the associated soil seed bank) and/or changes to hydrology arising from minor alterations to the topography of the almost flat alluvial terrain. The impact of prolonged waterlogging on alluvial forest was evident in a dieback site observed along the export pipeline corridor (Booyong Forest Science, 2017d).

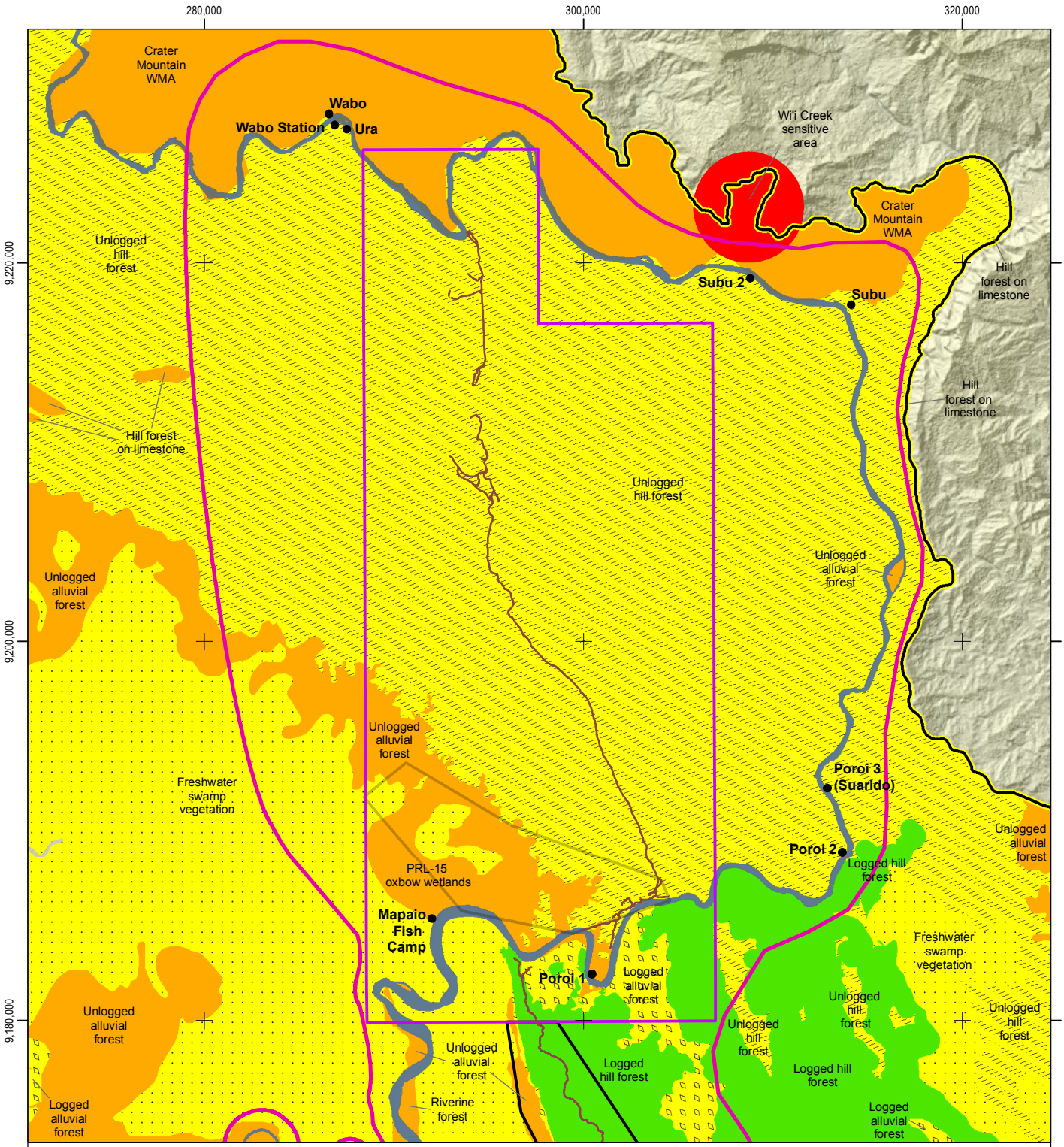
Unlogged alluvial forest is considered to be Very Sensitive because:

- It supports the IUCN Critically Endangered *Diospyros lolinopsis*.
- It may be critical to the survival of a suite of new-to-science species not recorded in other forest environments.
- Regional equivalents have been extensively harvested and are under continuing pressure from logging operations.

Logged alluvial forest is judged to be Moderately Sensitive. While recently logged formations (since 2015) are currently very heavily impacted, their moderate sensitivity status is maintained for their connectivity with relatively undisturbed exemplars and for their potential to regenerate and support a variety of species of conservation significance.

At the southern end of the export pipeline corridor, areas of Alluvial forest (Pl) that have not been commercially logged have been heavily disturbed by local residents. In essence these comprise a patchwork of remnant natural forest and converted habitats in varying stages of regeneration. As it was not possible to accurately map the often fine-scale patchwork of natural and converted environments, high anthropogenic disturbance codes (Pl5 and Pl6) were applied to these mapping units. In the map of ecosystem sensitivities shown in Figure 6.16, these are displayed as a hatched mix of Very Sensitive and Not Sensitive areas. In general, however, the proportion of remnant Very Sensitive Alluvial forest (Pl) increases towards the southeast (based on ground survey from Sites 8 and 9).

Riverine seral forest (Fri), here included within the alluvial forest broad vegetation group, considered to be Moderately Sensitive. As a pioneer successional vegetation type on aggrading river scroll arches, it is prone to regular flooding disturbance, has a high regenerative capacity and its occurrences are too small to support regionally important concentrations of species of conservation significance.



SCALE: 1:300,000 @ A4

0 2 4 6 8 10 Kilometres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and Villages
- Tracks
- Waterways
- PRL-15
- Export pipeline corridor
- Upstream project area of influence*
- Study area
- CPF, logistics base and airstrip area

Sensitivity areas

- Wi'i Creek sensitive area
- Crater Mountain WMA
- Hill forest on limestone
- PRL-15 oxbow wetlands

- Unlogged alluvial forest
- Riverine forest
- Logged alluvial forest
- Freshwater swamp vegetation
- Unlogged hill forest
- Logged hill forest

Sensitivity rankings

- EXTREMELY SENSITIVE
- VERY SENSITIVE
- MODERATELY SENSITIVE
- LOW SENSITIVITY

N

* Largely represents the terrestrial biodiversity baseline survey area

TITLE: Sensitivity Map of Ecosystems and Select Focal Sites, PRL-15 Area

FIGURE: 6.14

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79682 **REVISION:** C

DATE: 12/04/2017

DATA SOURCES:

Towns and villages, export pipeline corridor, study area (ERIAS Group 2017). Upstream project area of influence digitised by Mipela GeoSolutions based on data supplied by ERIAS Group (2017). PRL-15, waterways, tracks (TOTAL 2016). Crater Mountain Wildlife Management Area (IUCN and UNEP-WCMC (2016), The World Database on Protected Areas (WDPA), Cambridge, UK: UNEPWCMC. Available at: www.protectedplanet.net). DEM (Planet Observer 2015). Sensitivity areas, sensitivity rankings (Iain Woxvold 2017).

CLIENT:

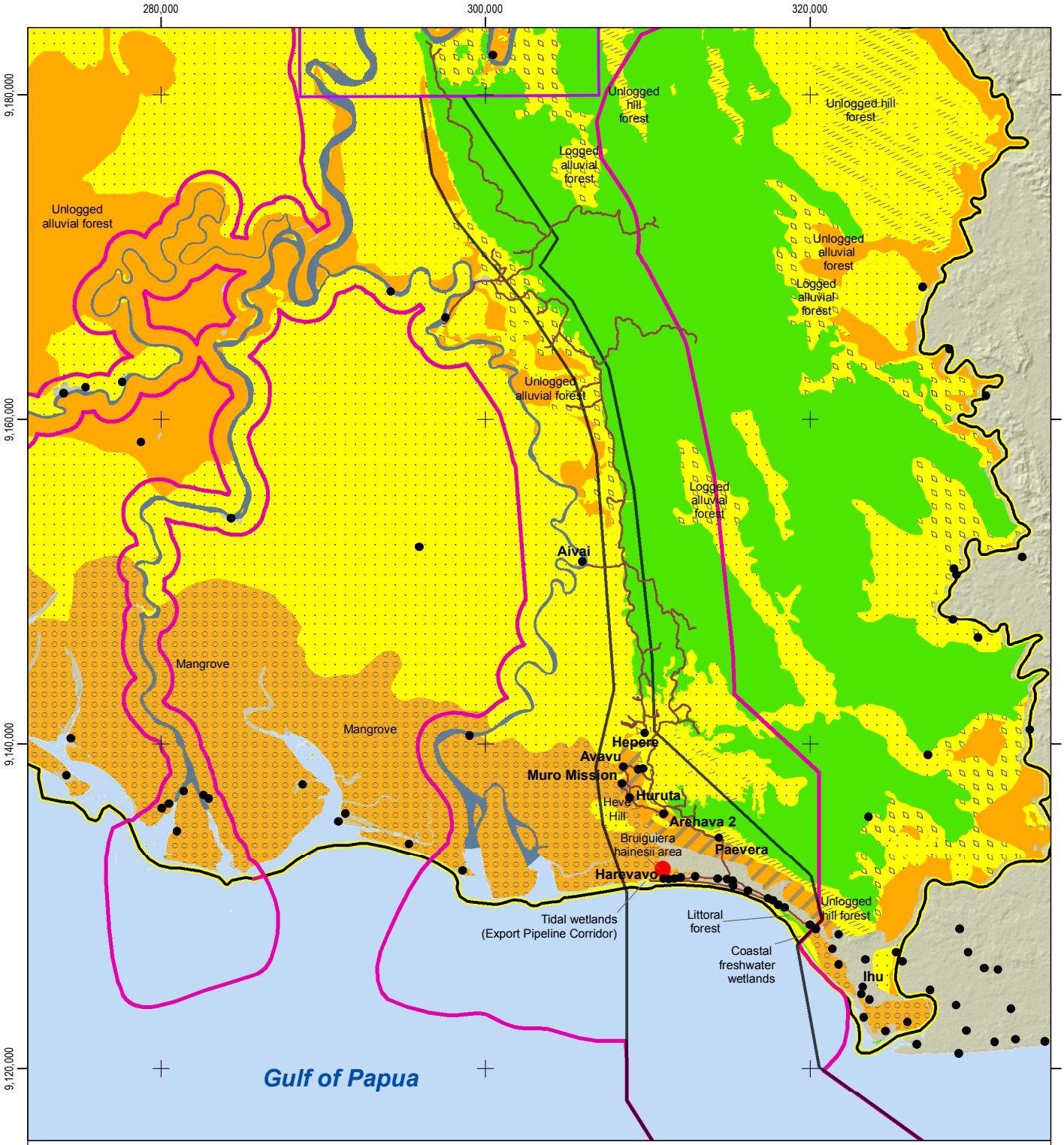
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79682-Figure 6.14-C.mxd



SCALE: 1:350,000 @ A4

0 2 4 6 8 10 Kilometres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Tracks
- Waterways
- PRL-15
- Export pipeline corridor
- Upstream project area of influence*
- Study area

Sensitivity areas

- Bruiguiera hainesii zone
- Heve Hill
- Mangrove
- Unlogged alluvial forest
- Coast PI5, PI6
- Logged alluvial forest
- Coastal freshwater wetlands
- Tidal wetlands (Export Pipeline Corridor)
- Freshwater swamp vegetation
- Unlogged hill forest
- Logged hill forest
- Littoral forest

Sensitivity rankings

- EXTREMELY SENSITIVE
- VERY SENSITIVE
- MODERATELY SENSITIVE
- LOW SENSITIVITY

N

** Largely represents the terrestrial biodiversity baseline survey area*

Note: Not all communities have been verified in the field. Only Government administrative centres and notable locations have been labelled for context.

TITLE: Sensitivity Map of Ecosystems and Select Focal Sites, Export Pipeline Corridor

FIGURE: 6.15

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79683 **REVISION:** C

DATE: 12/04/2017

DATA SOURCES:

Towns and villages, export pipeline corridor, study area (ERIAS Group 2017). Upstream project area of influence digitised by Mipela GeoSolutions based on data supplied by ERIAS Group (2017). PRL-15, waterways, tracks (TOTAL 2016). DEM (Planet Observer 2015). Sensitivity areas, sensitivity rankings (Iain Woxvold 2017).

CLIENT:

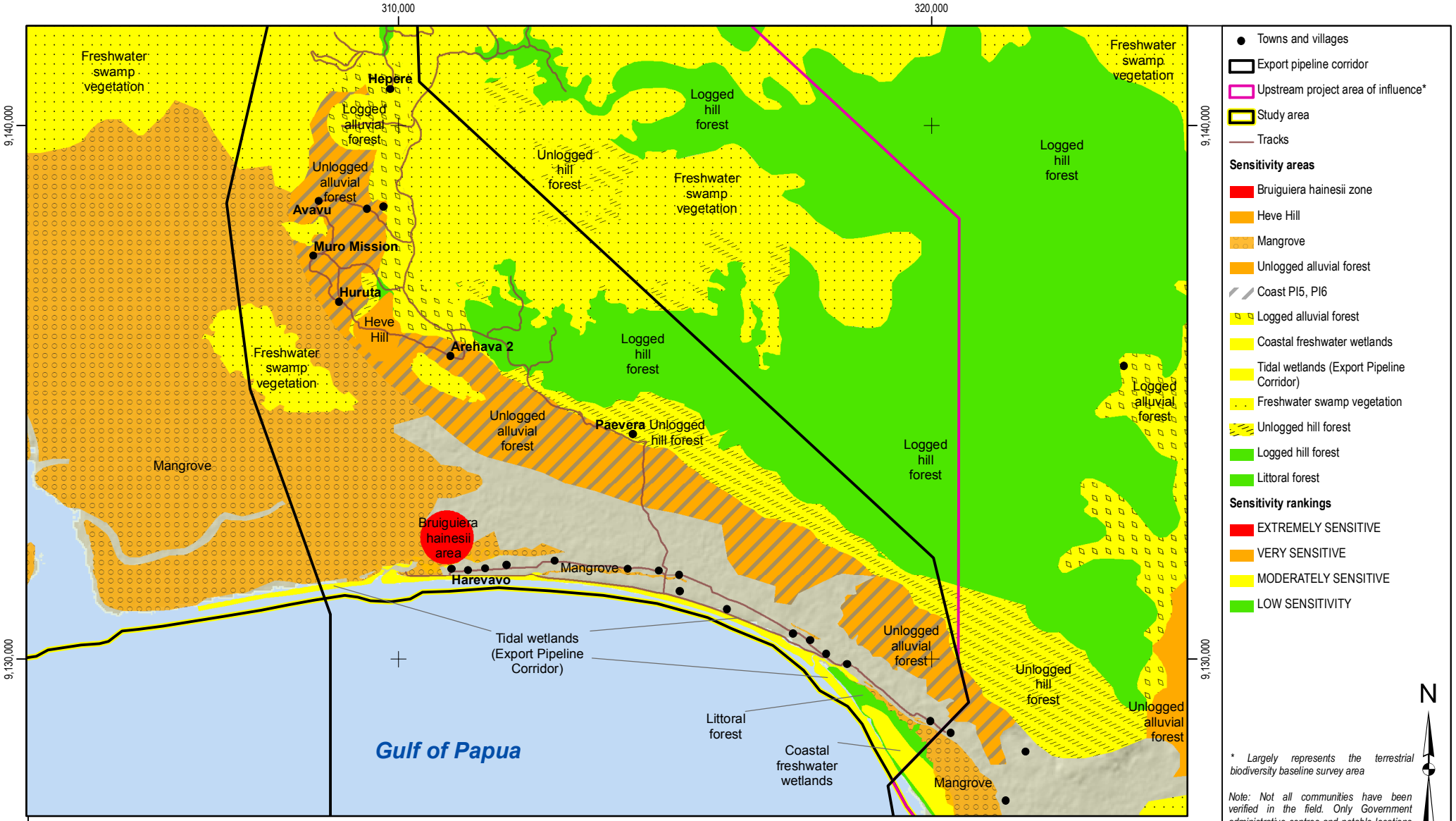
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

T:\Projects\ERI\002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79683-Figure 6.15-C.mxd

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.



TITLE: Sensitivity Map of Ecosystems and Select Focal Sites, Coastal Approach of Export Pipeline Corridor

FIGURE: 6.16

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79684 **REVISION:** C

DATE: 12/04/2017

DATA SOURCES:

Towns and villages, export pipeline corridor, study area (ERIAS Group 2017). Tracks (TOTAL 2016). Upstream project area of influence digitised by Mipela GeoSolutions based on data supplied by ERIAS Group (2017). DEM (Planet Observer 2015). Sensitivity areas, sensitivity rankings (Iain Woxvold 2017).

CLIENT:

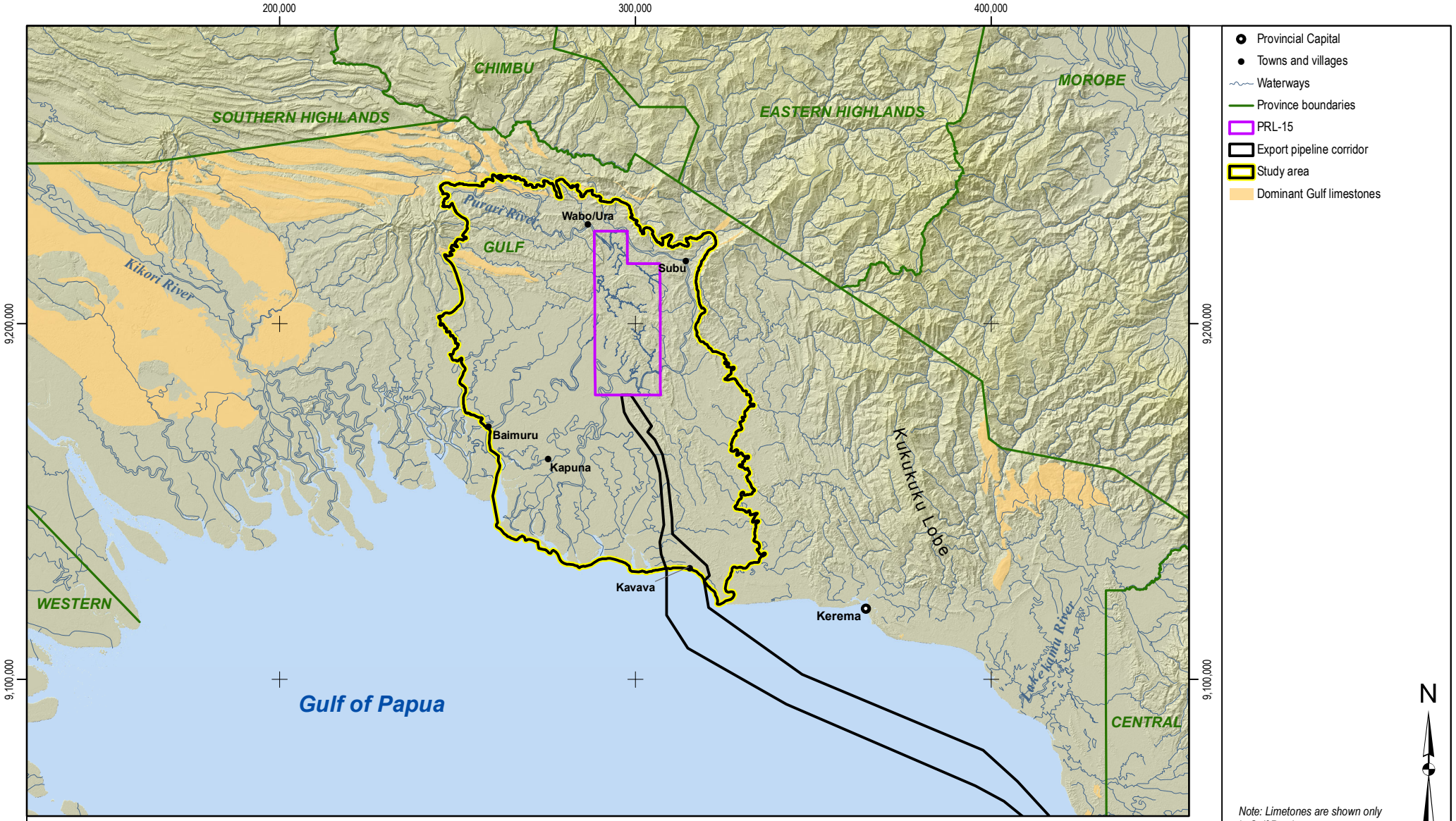
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ER1002 Elk Antelope LNG Project EIS-ESHIA\Work Request\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79684-Figure 6.16-C.mxd



TITLE: Gulf Province Limestones

FIGURE: 6.17

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79685 **REVISION:** C

DATE: 13/04/2017

DATA SOURCES:

Export pipeline corridor, upstream study area (ERIAS Group 2017). Towns and villages, provincial captials (TOTAL and ERIAS Group 2015-2017). PRL-15, waterways (TOTAL 2016). DEM (Planet Observer 2015). Province boundaries derived by Mipela GeoSolutions (2016). Dominant Gulf limestones (Iain Woxvold 2017) from Bryan and Shearman 2008: lithological symbols Te, Tmd1, Tms, Tmg2, Tou-m2, Tpwh.

CLIENT:

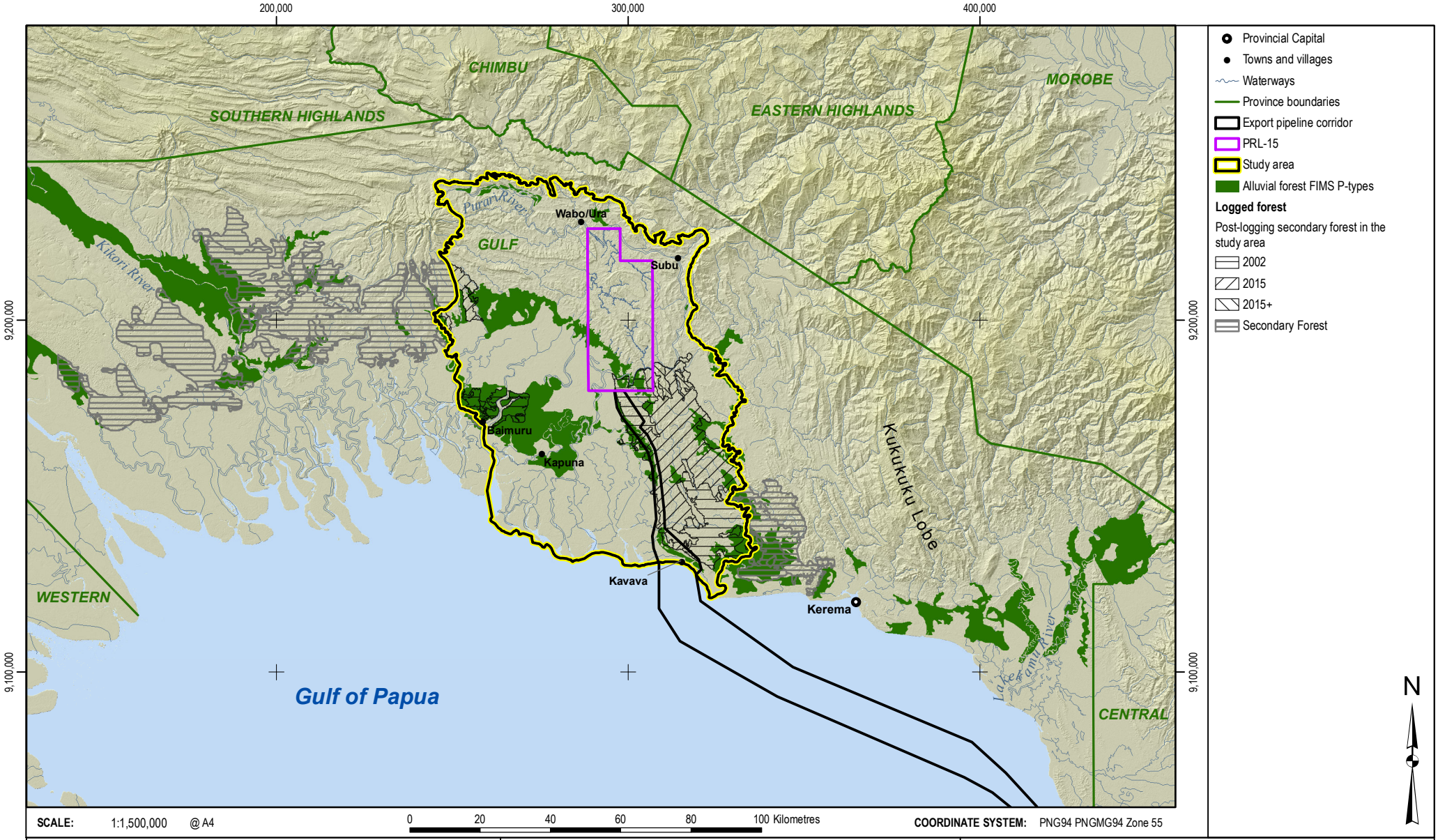
ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ER1002 Elk Antelope LNG Project EIS-ESHIA\Work Request\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79685-Figure 6.17-C.mxd



TITLE: Gulf Province Alluvial Forests and Logged Areas

FIGURE: 6.18

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79286 **REVISION:** C

DATE: 13/04/2017

DATA SOURCES:

Export pipeline corridor, study area (ERIAS Group 2017). Towns and villages, provincial captials (TOTAL and ERIAS Group 2015-2017). PRL-15, waterways (TOTAL 2016). DEM (Planet Observer 2015). Province boundaries derived by Mipela GeoSolutions (2016). Broad vegetation groups, FIMS, logged forest digitised by Mipela GeoSolutions based on data from Iain Woxvold (2016-2017).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ER1002 Elk Antelope LNG Project EIS-ESHIA\Work Request\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79686-Figure 6.18-C.mxd

6.5.1.5 Mangrove

Mangrove ecosystem covers more than 600 km^2 of the study area, forming the eastern part of the largest area of mangroves in PNG. The Kikori–Purari region includes the broadest band of mangroves in PNG, extending inland within the study area approximately 30 km from the mouth of Port Romilly to the brackish waters of the Pie River.

Mangrove ecosystems support a diverse terrestrial biota that includes a high proportion of habitat-specialist taxa. New Guinea supports among the world's most species-rich mangrove ecosystems (Johnstone and Frodin, 1982). Habitat endemicity is particularly high among plants and birds (Kusmana, 2014; Rajpar and Zakaria, 2014). The unique composition of mangrove plant communities is well known (e.g., Hogarth, 2015) and for the Kikori-Purari region has been relatively well documented (e.g., Percival and Womersley, 1975; Cragg, 1983; Ellison, 1997). Among birds, locally resident mangrove specialists include Mangrove Robin (*Peneoenanthe pulverulenta*), Red-headed Myzomela (*Myzomela erythrocephala*), Mangrove Gerygone (*Gerygone levigaster*), Mangrove Fantail (*Rhipidura phasiana*), Arafura Fantail (*R. dryas streptophora*), Mangrove Golden Whistler (*Pachycephala melanura*) and Broad-billed Flycatcher (*Myiagra ruficollis*). Most fauna species, however, are 'mangrove associates', occurring also in any of a number of adjacent habitats, including tidal flats and beaches, freshwater swamp forest, alluvial forest or littoral vegetation. Although the transition between these habitats is often very abrupt, more than half of the faunal species that may be present in mangrove forest may also occur in adjacent plant communities.

Mangrove forest within the study area provides habitat for numerous species of conservation significance. Its landward 'transitional zone' supports at least one population of the IUCN Critically Endangered tree Bruguiera hainesii (Figure 6.16), and is the only recorded area of occurrence for the tree Glochidion delticola (IUCN Not Evaluated; one known locality at ecotone with Swamp forest (Fsw)). Local mangrove ecosystems are also the only known sites of occurrence for the plants *Psychotria heterophylla* and the new-to-science orchid *Bulbophyllum* sp. 2. They provide important habitat for the False Water Rat (VU), a nursery habitat for Pig-nosed Turtles (VU), and foraging and roosting habitat for a suite of migratory shorebirds (Rajpar and Zakaria, 2014), including some Very Sensitive species (Far Eastern Curlew (EN), Great Knot (EN)).

Among other major taxonomic groups, the Gulf of Papua mangroves are internationally significant as spawning grounds for commercial fisheries (Sekhran and Miller, 1995).

Mangrove ecosystems provide important physical and chemical regulating services vital to maintaining ecosystem health. They are vital for coastal protection, water purification and have a high carbon storage capacity (Donato et al., 2011). Mangroves play an important role in trapping sediments, and protecting the shore-line from wave action. The fine, anoxic sediments that accumulate at the base of mangrove forest often act as a sink for a variety of heavy (trace) metals which are removed from the overlying seawater by colloidal particles in the sediments (Hogarth, 2015). In places where mangroves have been cleared for development, the disturbance of these underlying sediments may result in trace metal contamination of seawater and associated biota. Healthy mangrove forest may also prevent muds from becoming acidic on exposure to air and rainwater, which then have the potential to affect surrounding habitats.

Logging of mangroves is prohibited in PNG. Resource use by local residents has impacted the relatively limited mangrove occurrences in the densely populated Southeast Coast ecological zone, but in the expansive deltaic system remains localized in discrete areas along the shorefront

and landward 'transitional zone', so that the vast majority of the deltaic mangrove system remains undisturbed. Elsewhere, global mangrove forest cover has declined by up to 50% in the last half century (Donato et al., 2011; Ellison, 2014). The Kikori–Purari mangroves are regarded as one of the most extensive pristine mangrove areas in the world (Percival and Womersley, 1975; Liem and Haines, 1977; Agardy and Pernetta, 1993; Saulei and Beehler, 1993).

Mangrove forest within the study area was included in two areas of biological importance identified in the PNG Conservation Needs Assessment—the 'Papuan Gulf Mangroves' important forest environment (Saulei and Beehler, 1993) and the 'Gulf-Ihu' botanically important area (Johns, 1993).

As marginal ecosystems mangroves regularly experience sudden and drastic changes in the environment. Nevertheless, alterations of hydrography and substrate have considerable impact; mangroves are susceptible to pollution, particularly oil and other petroleum compounds. Mangroves do not recover spontaneously after the impact of natural or man-made catastrophic events such as cyclones or clearing, and changes in siltation, leading to altered levels of forest floor muds and soils, can seriously affect regeneration capabilities, requiring significant intervention for successful rehabilitation (Hogarth, 2015). Mangrove ecosystems are vulnerable to climate change, particularly sea-level rise (Ellison, 2014).

The study area's mangrove ecosystem is considered to be Very Sensitive because:

- It supports the IUCN Critically Endangered tree *Bruguiera hainesii*.
- It may be critical to the survival of a number of plant species known only from single sites.
- It is sensitive to disturbance and rehabilitation may require extensive intervention.
- It provides important physical and chemical regulating services necessary for supporting nearshore environments that act as nurseries for a range of aquatic (fish, invertebrate) species.

6.5.1.6 Freshwater Swamp Vegetation

Freshwater swamp vegetation is the second most widespread broad vegetation group within the study area (behind hill forest), in its various forms covering nearly 1,800 km^2 of its land surface. The majority of this area comprises Swamp forest (Fsw) (62.2%) and Swamp woodland (Wsw) (34.0%) and associated complexes. The component vegetation types of this broad vegetation group together form a diverse and interconnected ecosystem complex that is largely remote from human disturbance. They form part of the 'Gulf-Ihu' botanically important area (Johns 1993), and part of this system (northwest) is located within the 'Mount Bosavi/Gulf lowlands' major wilderness area (Allison 1993) as recognized in the PNG Conservation Needs Assessment. The broad vegetation group is regionally well represented and forms part of a continuous freshwater swamp system that extends unbroken west across the Gulf Province lowlands and into Western Province.

Compared to the forest environments discussed above, freshwater swamp vegetation types support relatively few species of conservation significance (Figures 6.6, 6.7 and 6.9). Of the various forms, Swamp forest (Fsw) supports the highest diversity of conservation listed, new-to-science and undescribed species and restricted-range species, though most of these species occur at relatively low densities compared to their presence in adjacent alluvial forest, hill forest and/or mangroves. Some notable conservation listed bird species do prefer Swamp forest (Fsw)

and/or Swamp woodland (Wsw), including the New Guinea Flightless Rail (*Megacrex inepta*) (NT), Blue-black Kingfisher (*Todirhamphus nigrocyaneus*) (DD) and Twelve-wired bird-of-paradise (*Seleucidis melanoleuca*) (P). Swamp forest (Fsw) within the study area is also among the preferred habitat of two rare plant species—*Glochidion delticola*, known from a single locality along the Purari distributary at the ecotone with the Mangrove (M) transitional zone, and Gluta papuana (VU) which may also occur in alluvial forest. The new-to-science damselfly *Nososticta sp. 1* is currently known only from Site 5 where it was found at forest pools in Open alluvial forest/Swamp forest (Po/Fsw).

Herbaceous swamp (Hsw), Swamp grassland (Gsw) and Riverine successional grassland (Gri) provide habitat for a variety of habitat-specialist fauna, particularly where these vegetation types are connected with open water environments (watercourses and off-river waterbodies). Relevant taxa include a variety of migratory bird species including three nationally Protected egret species. Vegetated swamps fringing waterbodies also provide breeding sites for a variety of resident waterbirds and both locally occurring crocodile species.

As intact natural systems that support some species of conservation significance, Swamp forest (Fsw), Swamp woodland (Wsw) and the low statured forms of freshwater swamp vegetation (Hsw, Gsw, Gri) are all considered to be Moderately Sensitive.

6.5.2 Freshwater Aquatic Ecosystems

This section describes briefly those 'open-water' aquatic ecosystems present within the study area. Well vegetated lowland swamps and marshes, many of which are daily or permanently inundated, are considered among freshwater swamp vegetation types assessed in Section 6.5.1.6.

Aquatic ecosystems provide important habitat for a wide range of terrestrial biota, including multiple species from all major tetrapod groups (mammals, birds, reptiles and amphibians) and a wide variety of invertebrates. Additional information on freshwater aquatic fauna is reported in the Upstream Freshwater and Estuarine Baseline Report (MBT WBM, 2017b).

The study area spans five catchments that flow separately to the Gulf Province coast (Figure 6.4). The largest, making up more than 60% of the study area, comprises the lower and parts of the middle sections of the Purari River catchment. The Purari River catchment is flanked to the west by the Era and Pie River catchments and to the east by the Vailala River catchment. A small 'Coastal' catchment drains discrete near-coastal environments in the extreme southeast of the study area.

The following sections assess the sensitivity of various terrestrial aquatic environments only from the perspective of those faunal communities considered in this study. It is acknowledged that other study disciplines (for example, freshwater aquatic and/or marine studies) may ascribe different sensitivity values to these environments.

6.5.2.1 Freshwater Rivers and Streams

Watercourses in the study area vary in character from minor intermittent and perennial headwater streams to extensive midreach and terminal reach river sections[18].

[18] Terminology from Polhemus and Allen (2007).

Forest Streams

Minor forest streams and creeks flow beneath a closed forest canopy across much of the Middle Purari Hills and Southeast Hills landscapes and in more limited areas of well drained alluvial forest, predominantly at the northern and eastern rims of the Delta Swamps and Plains near the hill-foot boundary.

Fauna associated with these watercourses are sometimes classified as forest-dwelling species. Forest streams provide important habitat for a variety of species of conservation significance, including the elusive Forest Bittern (*Zonerodius heliosylus*) (NT), a number of new-to-science and restricted-range frog and odonate species that rely on these environments for reproduction, and the new-to-science Small Water Rat. Stream-specialist odonates are sensitive to changes in forest understorey microclimate associated with disturbance to the forest canopy (Annex 6) and are at higher risk of localized extinctions compared to more widely ranging habitat generalist species (Korkeamäki and Suhonen, 2002). Forest streams in unlogged forest of the Middle Purari Hills (Plate 6.103), and in remnant closed canopy sites within logged areas in the Southeast Hills, are thus considered to be particularly important habitat for a diverse assemblage of new-to-science and restricted-range odonate species (Annex 6).

These watercourses and their associated biota are well represented elsewhere in the local region wherever closed canopy lowland hill forest persists.

Forest streams are collectively considered to be Moderately Sensitive as important habitat for a variety of new-to-science and other restricted-range habitat-specialist species. However, the sensitivity of particular streams varies on a case-by-case basis in response to variables including condition of the waterway and surrounding vegetation. In general, intrinsic worth and intactness average lower in logged forest environments, where increased silt loads and open canopies are frequent along even relatively minor watercourses (Plate 6.104).

Plate 6.103 – Hill Forest Stream Near the Antelope-3 Operations Camp, Middle Purari Hills



Photo source: S. Richards.

Plate 6.104 – Hill Forest Stream in Logged Forest at Site 2, with Increased Silt Loads from Stream Bank and Hill Slope Erosion, and Grass Growing on Muddy Banks Beneath Disturbed Open Canopies



Photo source: S. Richards.

Open-canopy Watercourses

Larger watercourses too wide for canopy closure vary in width from c.10 m across to more than 500 m wide in places along the Purari River, PNG's third largest river draining one of the highest rainfall regions in the world. Midreach sections flow across rocky substrates in hilly terrain (Plate 6.105), while terminal reach sections with fine sediment bases flow for hundreds of river kilometers across gentle gradients through foothill environments (Plate 6.106) and on the Delta Swamps and Plains.

These largely unmodified river systems support populations of two crocodile species and a variety of freshwater turtles. Two large IUCN Vulnerable freshwater turtles – the Pig-nosed Turtle and Striped New Guinea Soft-shell Turtle – use these rivers and their banks for feeding and nesting respectively (see Section 6.6.4). These larger watercourses also provide habitat for a suite of waterbirds not found along minor forest streams. However, despite its size, surveys conducted thus far indicate that these lower sections of the Purari River do not provide important habitat for resident or migratory waterbird species (Annex 4).

Watercourses comparable in size and character to the Pie, Era and Vailala rivers and the Purari River's major tributaries are well represented regionally in PNG's southern watershed. By contrast, being PNG's third largest river the Purari River is less well replicated in a regional context.

Open canopy watercourses are collectively considered to be Moderately Sensitive as essentially unmodified systems that provide important habitat for two IUCN Vulnerable freshwater turtle species and for two crocodile species.

Plate 6.105 – Boa Creek Upstream of the Antelope-3 Operations Camp, Middle Purari Hills



Photo source: B. de Vals.

Plate 6.106 – The Purari River Flowing Through the Middle Purari Hills



Photo source: I. Woxvold.

6.5.2.2 Off-river Waterbodies

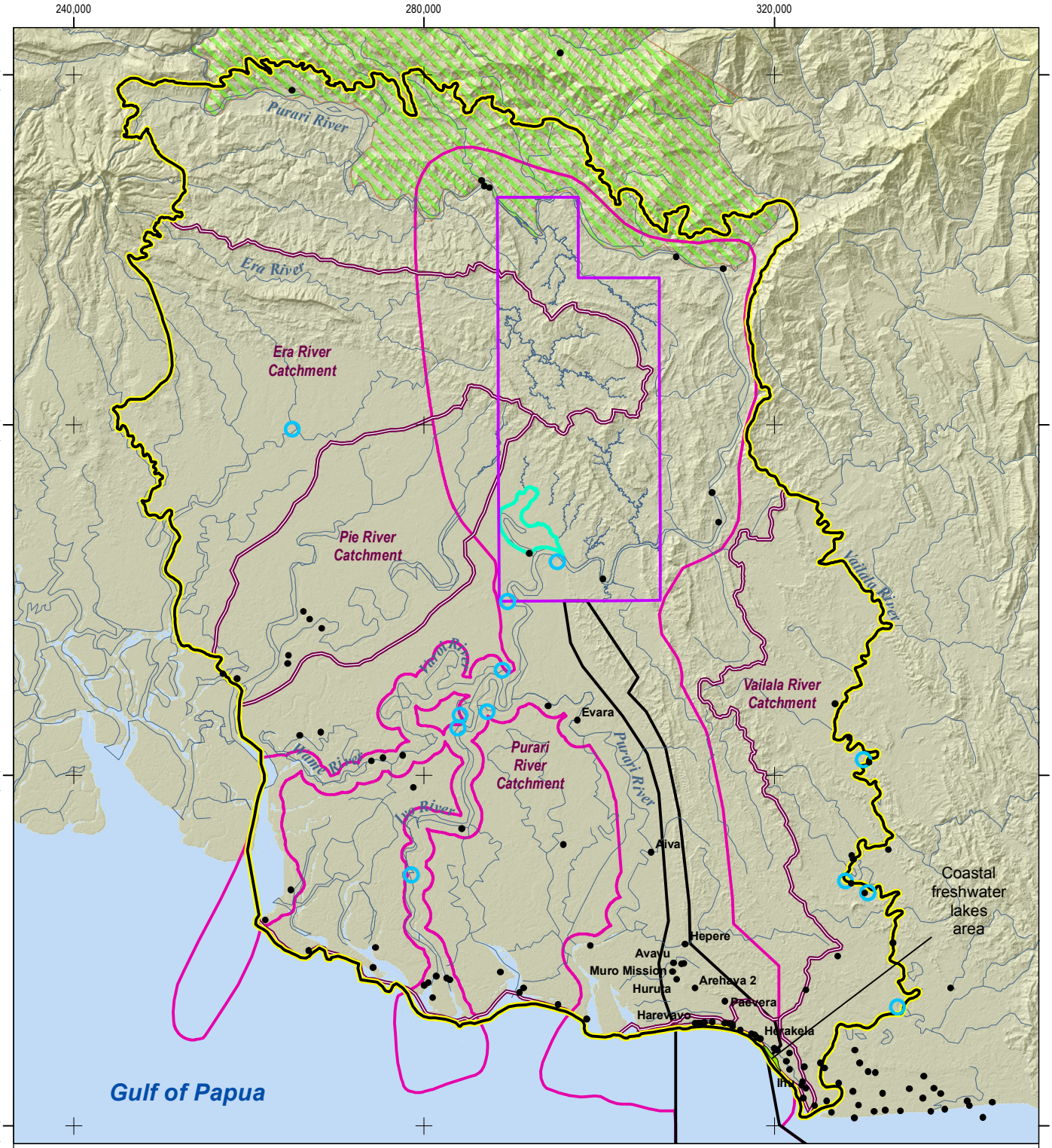
The location of off-river waterbodies was assessed via desktop study (topographic mapping and aerial and satellite imagery) and aerial survey. Twenty-nine waterbodies were located, their arrangement shown in Figure 6.19. They are of two general types—oxbow lakes and coastal freshwater lakes.

All off-river waterbodies are sensitive to a range of degradational processes, including the introduction of alien flora and fauna, loss or degradation of surrounding vegetation, changes to hydrology, increased sedimentation and contamination with pollutants (Polhemus and Allen, 2007). The resilience of these standing water systems to such impacts is generally lower than that of flowing watercourses.

Oxbow Lakes

The largest open-water wetlands occur as oxbow lakes in former meander channels of the larger rivers. These lake systems are dynamic environments, being infilled with clay and transported by river flows (Ruxton, 1969a); many former oxbow lakes now support well vegetated swamp habitats (not shown in Figure 6.19). Lakes associated with large river systems are the most common form of lacustrine environment present in PNG (Miller et al., 1994).

Seventeen oxbow lakes were identified within the study area (Table 6.19), 12 of them within the Purari River catchment. Six oxbow lakes are present in the southwest of PRL-15, five of them associated with a single wetland system of lakes and vegetated swamps, here termed the 'PRL-15 oxbow wetlands' and described below. Another six oxbow lakes are located downstream within the Riverways sector of the upstream PAOI, along the Purari River and the Urika-Ivo distributary. Outside of the upstream PAOI, one oxbow lake was identified along the Era River, and four on the western side of the Vailala River (additional examples being present to the east of the Vailala River and immediately outside of the study area).



SCALE: 1:650,000 @ A4

0 5,000 10,000 15,000 20,000 25,000 Metres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Oxbow lakes
- Waterways
- Oxbow wetlands
- PRL-15
- Catchment boundaries
- Export pipeline corridor
- Upstream project area of influence
- Study area
- Coastal freshwater lakes area
- Crater Mountain Wildlife Management Area

N

Note: Not all communities have been verified in the field. Only Government administrative centres and notable locations have been labelled for context.

TITLE: Off-river Waterbodies Within the Study Area

FIGURE: 6.19

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-81383 **REVISION:** D

DATE: 14/07/2017

DATA SOURCES:
Waterways, PRL-15, supplied by TOTAL (2015-2016). Towns and villages, study area, export pipeline corridor (ERIAS Group 2017). Upstream project area of influence digitised by Mipela GeoSolutions based on data provided by ERIAS (2017). Crater Mountain Wildlife Management Area (IUCN and UNEP-WCMC (2016), The World Database on Protected Areas (WDPA), Cambridge, UK: UNEP-WCMC. Available at: www.protectedplanet.net). DEM (Planet Observer 2015). Coastal freshwater lakes, oxbow lakes, oxbow wetlands (Iain Woxvold 2017). Catchments downloaded from World Resources Institute (2017) and aligned with data from Iain Woxvold (2016).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-81383-Figure 6.19-D.mxd

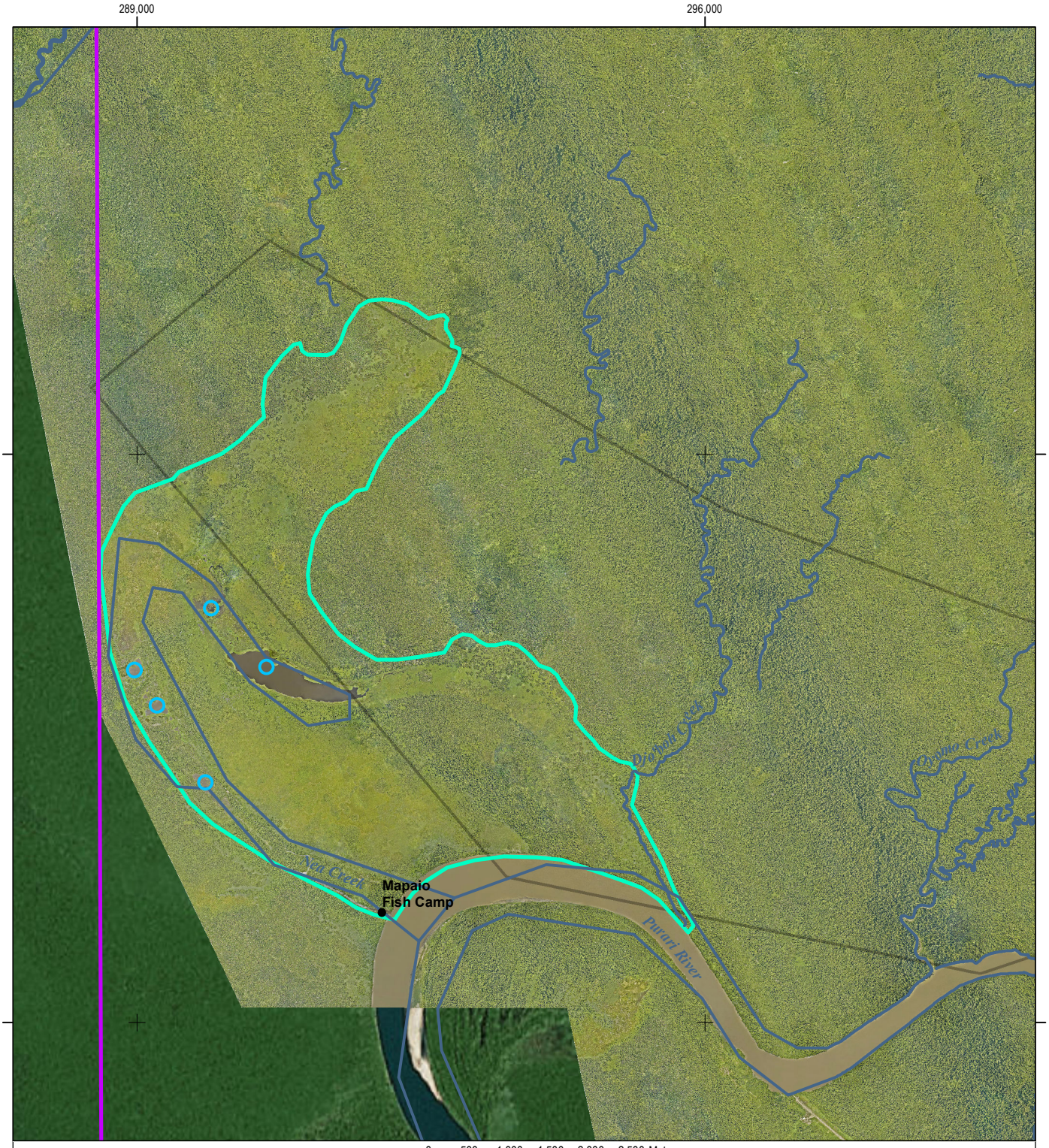
Table 6.19 – Oxbow Lakes Within the Study Area

Parent Watercourse/Location	Easting	Northing	Ecological Zone	Project Sector
PRL-15 oxbow wetlands (Purari River)	289920	9189100	DSP	PRL-15
	290600	9188375		
	288975	9188340		
	289250	9187900		
	289850	9186950		
Purari River	295220	9184330	DSP	PRL-15
	289570	9179800		Riverways
Urika-Ivo distributary	288950	9171950	DSP	Riverways
	287250	9167200		
	284150	9166840		
	283900	9165400		
	278600	9148600	Mangroves	Riverways
Era River	265000	9199500	DSP	–
Vailala River	330180	9161800	Southeast Hills	–
	328170	9147920		
	330700	9146600		
	334100	9133525		

The ‘PRL-15 oxbow wetlands’ system covers approximately 25 km^2 and contains the largest off-river waterbodies present in the study area (Figure 6.20; Plates 6.107 to 6.108). It includes multiple lakes of varying size, surrounding areas of permanently (or almost so) inundated vegetation (including Herbaceous swamp (Hsw)), and two minor watercourses (Nea Creek and Djo’boh Creek) that link the oxbow lake system with the Purari River to the south. Interconnecting vegetated swamps also have significant water exchange with the open water lake environments. The PRL-15 oxbow wetlands system overlaps the ‘CPF, logistics base and airstrip area’.

Oxbow lakes and associated vegetated swamps provide important habitat for a variety of resident, migratory and congregatory bird species (Annex 4) and are important breeding habitats for both New Guinea Freshwater and Estuarine Crocodiles and for small freshwater turtle species (Annex 5). The PRL-15 oxbow wetlands supported the largest congregations of waterbirds observed in the study area (including more than 250 egrets; Annex 4) and provide important local habitat for nesting crocodiles (information from landowners; Annex 5).

Oxbow lakes and the PRL-15 oxbow wetlands system are considered Very Sensitive as they are essentially unmodified systems that support a wide variety of habitat-specialist taxa, provide important breeding habitat for a variety of birds and herpetofauna, and are sensitive to a variety of impacts, notably including establishment and spread of invasive alien species.



SCALE: 1:70,000 @ A4

0 500 1,000 1,500 2,000 2,500 Metres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Oxbow lakes
- Waterways
- Oxbow wetlands
- PRL-15
- CPF, logistics base and airstrip area

N

TITLE: The PRL-15 Oxbow Wetlands

FIGURE: 6.20

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79688 **REVISION:** C

DATE: 13/04/2017

DATA SOURCES:
CPF, logistics base and airstrip area, towns and villages, waterways, PRL-15, imagery supplied by ERIAS Group and TOTAL (2015-2016). Oxbow lakes, oxbow wetlands supplied by Iain Woxvold (2016-2017). ESRI imagery service layer credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79688-Figure 6.20-C.mxd

Plate 6.107 – The Large, Eastern Oxbow Lake in the PRL-15 Oxbow Wetlands



Photo source: A. Pym.

Plate 6.108 – One of the Smaller, Western Oxbow Lakes in the PRL-15 Oxbow Wetlands, with Flock of Egrets in Upper Left of Picture



Photo source: I. Woxvold.

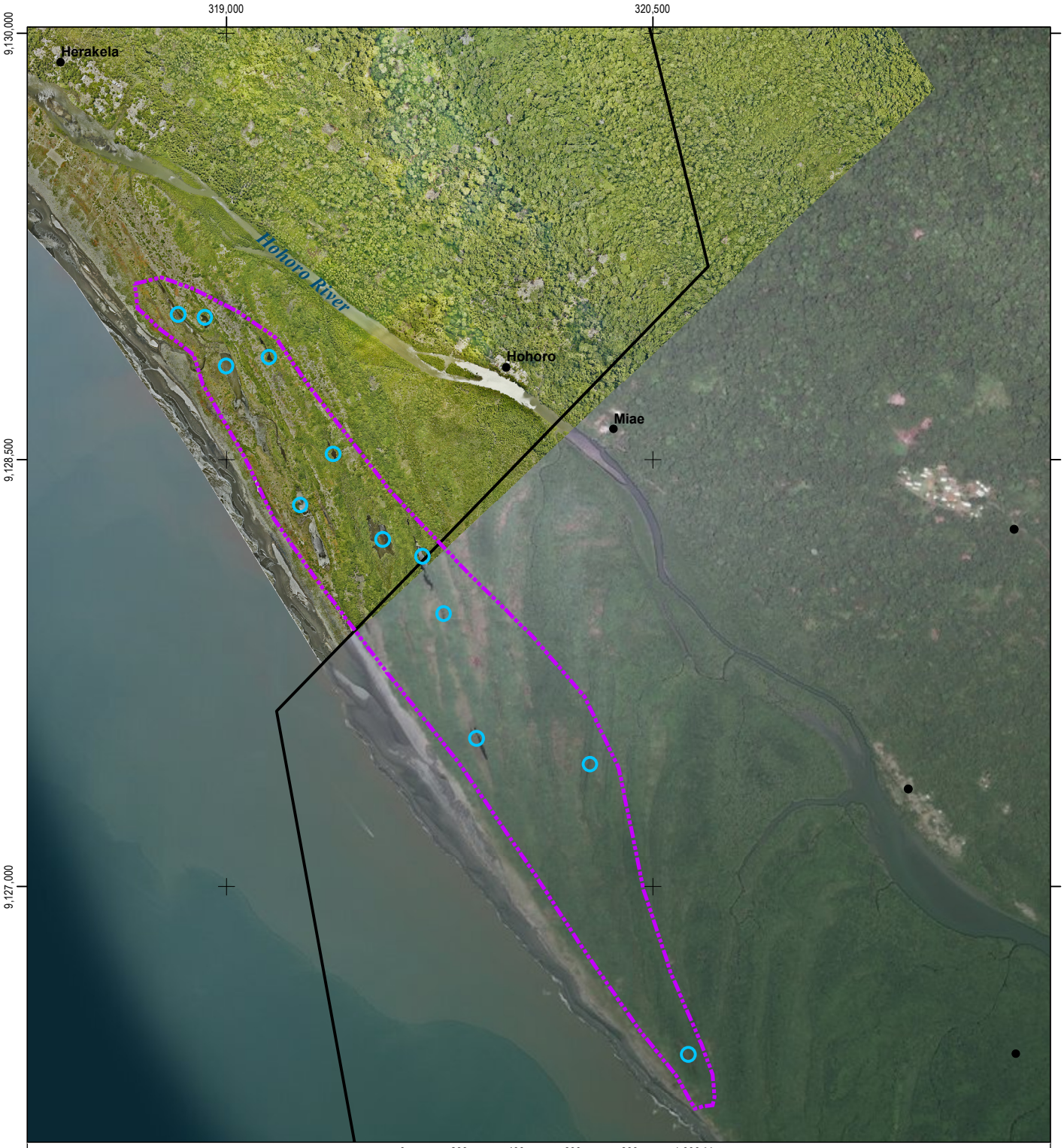
Coastal Freshwater Lakes

In the Southeast Coast ecological zone, the recently aggraded shorefront southeast of Herakela village includes at least 12 small freshwater lakes located within the vegetated (Littoral forest (B)) dune system, eight of which are located within the southeast corner of the export pipeline corridor (Figure 6.21; Plates 6.109 and 6.110). These support a variety of resident and migratory habitat-specialist species, including nationally Protected egret species, various frogs, odonates and other wetland flora and fauna. This lake system has developed in recent decades, is visited regularly by local residents, and is not expected to be of particular importance to any Very Sensitive or Extremely Sensitive species. However, it does represent a locally restricted habitat feature that may not recover easily from disturbance. Coastal freshwater lakes are considered to be Moderately Sensitive.

Plate 6.109 – Coastal Freshwater Lake, Southeast Export Pipeline Corridor



Photo source: I. Woxvold.



SCALE: 1:20,000 @ A4

0 200 400 600 800 1,000 Metres

COORDINATE SYSTEM: PNG94 PNGMG94 Zone 55

- Towns and villages
- Lakes
- Coastal freshwater lakes area
- Export pipeline corridor

N

Note: Not all communities have been verified in the field. Only Government administrative centres and notable locations have been labelled for context.

TITLE: Coastal Freshwater Lakes

FIGURE: 6.21

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-79689 **REVISION:** C

DATE: 12/04/2017

DATA SOURCES:
Towns and villages, export pipeline corridor (ERIAS Group 2017). Lakes, coastal freshwater lakes area (Iain Woxvold 2017).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ERI002 Elk Antelope LNG Project EIS-ESHIA\Work Requests\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-79689-Figure 6.21-C.mxd

Plate 6.110 – Coastal Freshwater Lake, Southeast Export Pipeline Corridor



Photo source: I. Woxvold.

6.5.3 Marine Aquatic Ecosystems

6.5.3.1 Estuaries and Near-Shore Marine Waters

Estuaries form at the seaward end of the terminal reaches of perennial watercourses. They are saline environments, freshwater flows mixing with marine tidal waters to produce a salinity gradient that increases coastward. The Mangroves ecological zone includes more than 100 km^2 of funnel-shaped estuaries interconnected by a complex network of sub-coastal channels.

Estuaries and near-shore marine waters within the study area provide habitat for the Estuarine Crocodile, the Pig-nosed Turtle (VU), and a variety of coastal and seabirds. Among Very Sensitive and Extremely Sensitive species, the study area appears to support a resident population only of the Pig-nosed Turtle, which may breed along coastal and estuarine beaches

Estuarine and marine waters providing similar habitat extend west across the Gulf of Papua coast. They are resilient to moderate forms of disturbance due to the regular replacement of large water volumes. They are here considered to have Low Sensitivity from a terrestrial biodiversity perspective.

Additional information on estuarine and near-shore marine ecosystems is reported in the Marine Ecology Baseline Report (BMT WMB, 2017).

6.5.3.2 Tidal Wetlands

Tidal flats, lagoons and estuaries of the Mangroves and Southeast Coast ecological zones, both along the shorefront and in subcoastal zones, provide focal habitat for a variety of migratory and resident bird species that congregate in these environments. Notable among these are at least 23 species of migratory Palaearctic shorebirds (Charadriidae, Scolopacidae) that fly south along the East Asian–Australasian Flyway (EAAF) from their northern hemisphere breeding grounds to

wintering stations in Australasia. The conservation of migratory shorebirds and their habitats is the focus of elevated international concern, since a large proportion of species has experienced sustained population declines, some more than 50%, resulting in a disproportionate number of taxa being listed by the IUCN as Threatened or Near Threatened (Annex 4).

The Study Area's Mangroves and Southeast Coast ecological zones include large areas of suitable migratory shorebird foraging habitat in the form of exposed tidal sand and mudflats along the coast, estuaries and tidally flooded subcoastal lagoon systems. The conservation value of the study area's tidal wetlands varies with factors such as the area of available foraging habitat and the frequency of visitation/disturbance by local residents.

The highest value tidal systems sites are located along the c. 65 km shorefront of the lower Purari delta within the Mangroves ecological zone. This region includes extensive tidal flats fringing the outlets of the major Purari River distributaries and Port Romilly. The eastern-most example is located at the mouth of the Alele Passage approximately 4 km west of the export pipeline corridor. These areas are known to support congregations of migratory shorebirds, though the number of birds involved is unknown. Based on shorebird counts conducted immediately west of the study area, the Kikori delta is recognized as an internationally important wetland site for three migratory shorebird species under RAMSAR Convention threshold criteria (Bamford et al., 2008). The Purari delta includes a similar area of tidal habitats, and these are considered to be Very Sensitive.

By contrast, tidal wetlands along the densely settled shorefront of the export pipeline corridor (Figure 6.16; Plate 6.111) are more limited in extent and more frequently visited by local landowners, particularly along the shorefront but also in areas along the mangrove watercourses which are visited regularly by local hunters and fishermen. Compared to the Purari delta tidal wetlands, these areas are of relatively low conservation value for migratory shorebirds, and are considered to be Moderately Sensitive.

Most migratory shorebirds visit New Guinea during the northern hemisphere winter, with the highest numbers reported during periods of transit (to and from more southerly wintering grounds) in September to November and March to May (Coates, 1985; Bishop, 2006). The sensitivity of their host environments is highest at these times.

Plate 6.111 – Tidal Habitats at the Mouth of '*Wara Are'ape*', West of Harevavo Village, Western Export Pipeline Corridor



Photo source: I. Woxvold.

6.6 Focal Sites

Focal sites include various localized terrain and habitat features upon which multiple species and/or multiple individuals of one or more species are ecologically dependent. There is a heightened risk that the loss or degradation of such features, singly or otherwise, may disproportionately affect the activities and/or survivability of multiple individuals within a local population, and in some cases jeopardize the viability of local populations.

6.6.1 Caves and Other Rock Shelters

Caves and rock overhangs provide important habitat for a variety of fauna. Shelters of various size and configuration are known to harbor breeding and roosting aggregations of many different bats, including multiple species of large Pteropodidae (fruit bats) and various small insectivorous bats belonging to the families Emballonuridae, Hipposideridae, Rhinolophidae, Miniopteridae and Vespertilionidae. Cave-roosting bats recorded in the study area include (among others) the IUCN Critically Endangered Bulmer's Fruit Bat and the IUCN Data Deficient Semon's Leaf-nosed Bat (*Hipposideros semoni*), New Guinea Sheath-tailed Bat (*Emballonura furax*) and Papuan Sheath-tailed Bat (*Saccolaimus mixtus*). Among birds, swiftlets (*Collocalia* and *Aerodramus* spp.) and Sooty Owl (*Tyto tenebrosa*) also roost and/or breed in rock shelters.

6.6.1.1 Caves

Caves are the most important rock shelter features present within the study area. Where large cave systems are present, bat diversity and abundance can be especially high (Section 6.3.5.1), since such systems offer a range of microenvironments to suit the specific breeding requirements of many different species. In addition to the fauna described above, large caves may also support a variety of obligate cave-dwelling terrestrial invertebrates (troglobitic fauna). Limited range

endemics are common in this group, with many species known from single cave systems (Christman and Culver, 2001; Wynne and Pleytez, 2005).

Most caves form in limestone (Deharveng et al., 2007), and large cave systems present within the study area are probably confined to major areas of surface limestone such as those mapped in Figure 6.17. The location of large caves has not been assessed in detail, but the mapped areas of limestone correspond well with information provided by local Pawaian residents that a number of caves are present (Annex 3):

> …in the hills to the north of the Purari River between Subu and Uraru villages, along the western slopes of the Aure Scarp in the northeast corner of the study area, and in the Kereru Range, to the west of PRL-15.

The geological mapping units do not account for all potential cave-forming areas of surface limestone, as evidenced by the presence of the Wi'i Creek cave (Annex 3). The Wi'i Creek site is of particular importance since recent remains of juvenile Bulmer's Fruit Bat (CR) found at a cave entrance indicate that a maternity roost may be present in the area (Annex 3). Large limestone bluffs were observed on both sides of Wi'i Creek—multiple caves may be present in the area, and the exact location of the Bulmer's Fruit Bat roosting/breeding colony remains unknown.

> Large limestone bluffs are present on both sides of Wi'i Creek and there is much scope for other substantial cave systems to be present in this area.

Based on this description and its location, this may be an unmapped area of the Darai limestone formation.

Smaller caves also not mapped include Heve Hill located between Huruta and Arehava 2 villages in the Southeast Coast ecological zone at the southern end of the export pipeline corridor. While only minor limestone outcrops were observed here (K. Aplin, in litt., 2017), other calcareous sediments were present and underground chambers were evident and may be a locally important site for the cave-roosting bat the Common Rousette (*Rousettus amplexicaudatus*) (Annex 3).

Caves in general are considered to be Very Sensitive for their potential to play a regionally significant, and in some cases potentially globally significant (e.g., troglobitic fauna), role in supporting populations of multiple habitat-specialist species, for their somewhat limited regional availability and their sensitivity to disturbance. Other than the Heve Hill site (Fig 6.16), the location of these features has not been mapped.

The Wi'i Creek area is judged to be Extremely Sensitive for potentially harboring a maternity roost of the IUCN Critically Endangered Bulmer's Fruit Bat. Any other caves found to support this species would be considered to be similarly sensitive.

6.6.1.2 Other Rock Shelters

Shallow rocky overhangs and fissures are often mentioned as secondary roost sites for cave-roosting bat species (Flannery, 1995; Bonaccorso, 1998). Based on the high capture and detection rates of numerous 'obligate' cave-roosting bat species at multiple sites located a considerable distance from major limestone outcrops, it is considered likely that these species are also using rock overhangs and fissures that are more widely available within the study area landscape than limestone caves (Annex 3). Suitable terrain is particularly evident in the Middle Purari Hills as sheer-walled topographic features associated with the sandstone-dominant Aure Beds gelological formation; examples include the Mena and Kuku Basins within PRL-15

(Plate 6.112). These and similar features are likely to be localized but may occur anywhere in hilly terrain within the study area.

Rock overhangs and fissures used by bats are considered to be Moderately Sensitive.

Plate 6.112 – Sheer Cliffs of the Mena Basin Aure Beds Formation, near Antelope-3 Operations Camp, Elk-Antelope Gas Field



Photo source: I. Woxvold.

6.6.2 Large Trees

6.6.2.1 General

Large trees provide a concentrated source of natural resources that are important for maintaining the diversity of local wildlife populations. Tree hollows, for example, are larger and more numerous in large, old trees (Bennett et al., 1994; Gibbons and Lindenmayer, 2003). Large trees are thus essential for maintaining local populations of a wide variety of mammals, birds, reptiles and amphibians that use hollows for shelter and/or reproduction, and those species (e.g., owls, diurnal raptors) that prey on them. Large trees are also the preferred breeding sites for diurnal birds-of-prey and large Pteropus flying-foxes, the preferred lekking sites for Raggiana Bird-of-paradise (*Paradisaea raggiana*), and support heavier epiphyte loads which provide additional habitat for fauna.

The conservation value of large trees depends on their local availability. Tree size and longevity are determined by numerous factors including soil type, drainage, terrain and disturbance history. Large tree densities are lowest on landforms with poor soils, steep unstable terrain and/or that experience regular prolonged flooding (Whitmore 1984). They are also relatively rare in logged forest, where all accessible commercial species free of defects and >50 cm DBH are typically removed.

For the purposes of this assessment:

- In areas of unlogged hill forest (all types), Alluvial forest (Pl) and Open alluvial forest (Po), large trees are defined as those with >1 m DBH.
- In areas of logged hill and alluvial forest, and in vegetation types other than those mentioned above, large trees are defined as those with >75 cm DBH.
- In these contexts, these features are considered Moderately Sensitive.

6.6.2.2 Large Fig Trees

Figs (*Ficus spp*.) are among the most important food source for tropical frugivores the world over (O'Brien et al., 1998; Shanahan et al., 2001), a fact attributed to their nutrient-rich, unprotected fruits, their production of large crops that ripen synchronously within a tree, consistent production between years, and asynchronous fruiting between trees resulting in a year-round supply of fruit. New Guinea's wildlife includes a high proportion of frugivorous birds (Pearson ,1977; Mack and Dumbacher, 2007) and mammals, many of which rely heavily on figs. Among birds, Fig-parrots (*Cyclopsitta/Psittaculirostris spp*.), Pesquet's Parrot (VU), the manucode birds-of-paradise (P) and some cuckooshrikes (*Coracina spp.)* have all evolved to become fig specialists. Among other frugivores, a number of keystone species that play an important ecological role in dispersing the seeds of rainforest trees (e.g., cassowaries, Blyth's Hornbill, pigeons; Mack and Wright, 2005) and a number of birds-of-paradise (Paradisaeidae, in addition to the manucodes; Frith and Beehler, 1988) include figs as a major component of their diet.

Large fig trees are here defined as those with >50 cm dbh. They are considered Moderately Sensitive.

6.6.3 *Bruguiera hainesii* Site

A stand of this IUCN Critically Endangered mangrove tree was found in the southwest corner of the export pipeline corridor, at the eastern edge of the Mangroves ecological zone approximately 550 m north of Harevavo village, in an area regularly used as a pathway by local residents. An area with 500 m radius around the reported site is here categorized as Extremely Sensitive (Figure 6.16).

Given the confirmed presence of this species within the study area, and the incomplete botanical coverage of potentially suitable habitat, the species must be considered as potentially occurring along the interior landward margin of the mangrove ecosystem anywhere in the Mangrove ecological zone, as well as potentially in isolated stands of mangroves outside and to the east of this ecological zone.

6.6.4 IUCN Vulnerable Freshwater Turtle Nesting Sites

Two large IUCN Vulnerable freshwater turtle species – the Pig-nosed Turtle and the Striped New Guinea Soft-shelled Turtle – nest on the banks of larger watercourses in the study area. Information on the location of nesting sites along the Purari River and its tributaries in the southern portion of PRL-15 (upstream from Djo'boh Creek) was collected from local Pawaian residents during a boat trip in June 2016.

Twelve Pig-nosed Turtle nesting sites were located along nearly 18 km of river surveyed (Table 6.20; Figure 6.22; Plates 6.113 and 6.114). Only the Pig-nosed Turtle was reported to nest on the banks of the main Purari River channel in this area (although Striped New Guinea Soft-shelled Turtles are known to nest along the banks of major rivers elsewhere in southern New Guinea).

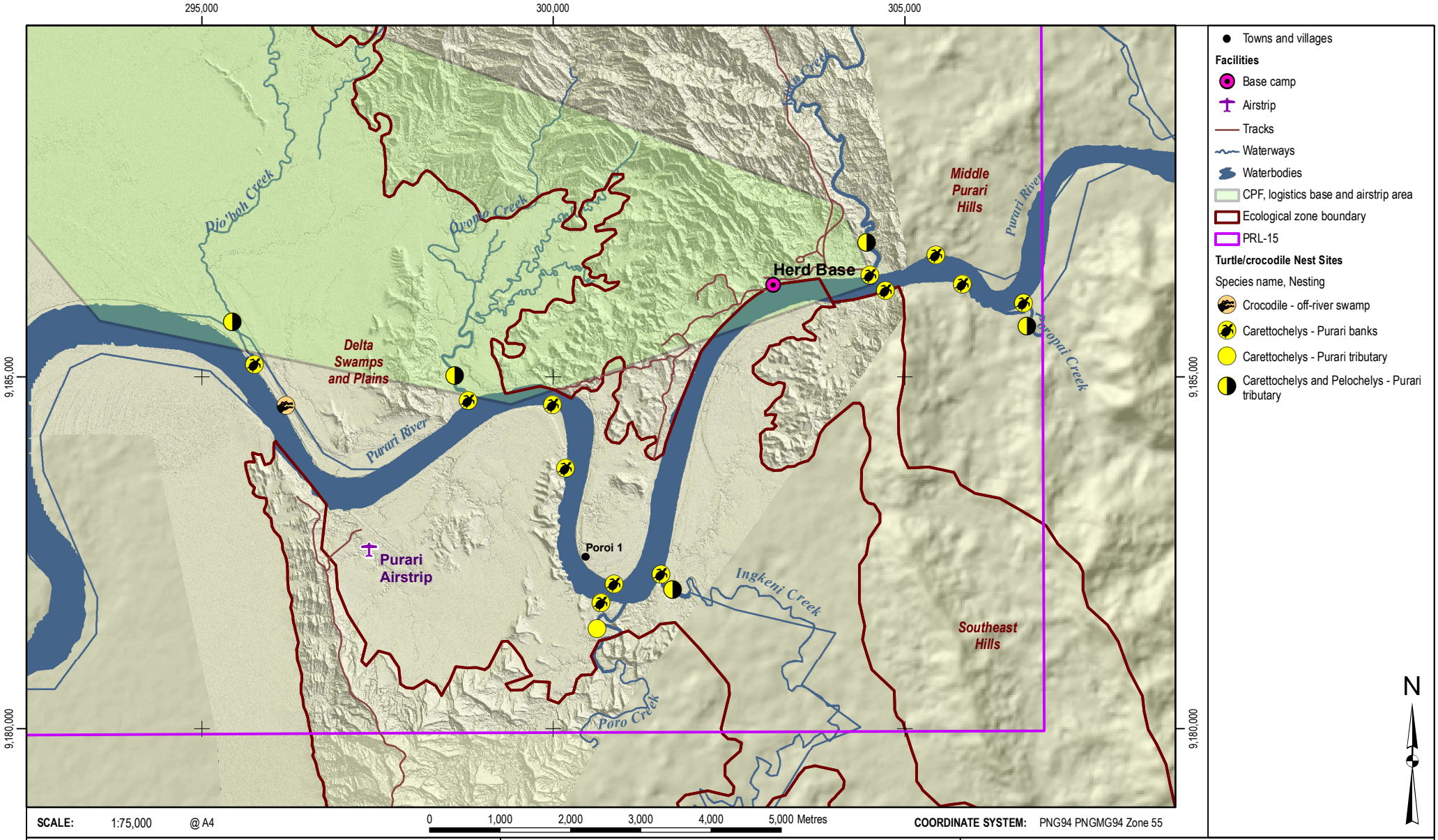
Table 6.20 – Pig-nosed Turtle Nesting Sites on the Purari River in the South of PRL-15

Site	Easting	Northing	Description
1	295750	9185170	Mouth of Djo'boh Creek, north bank Purari River.
2	298790	9184660	Mouth of Oyomo Creek, north bank Purari River.
3	299990	9184600	South bank Purari River.
4	300175	9183700	West bank Purari River.
5	300685	9181790	South bank Purari River, c. 300 m downstream from Poro Creek mouth.
6	300865	9182050	North bank Purari River, opposite site no. 5.
7	301535	9182190	South bank Purari River, mouth of Ingkeni Creek.
8	304500	9186445	North bank Purari River, mouth of Kuku Creek; within 50 m of Herd Base development, and this nest site is still in use.
9	304720	9186220	South bank Purari River, opposite site no. 8.
10	305435	9186730	North bank Purari River.
11	305830	9186320	South bank Purari River.
12	306680	9186040	South bank Purari River, near mouth of Poropai Creek.

Both IUCN Vulnerable turtle species nest on the banks of tributary streams in the south of PRL-15. Six tributary watercourses were identified that harbor nesting sites of one or more of these species (Figure 6.22). Among the identified tributaries, both Djo'boh Creek and Oyomo Creek were said to harbor nest sites for both turtle species. Both of these creeks drain the 'CPF, logistics base and airstrip area', and parts of two tributaries of the Oyomo Creek system are located within the proposed CPF fence line. The boat provided for survey was not able to navigate these smaller tributaries, and the number and location of nesting sites along them remains unknown.

The Phase 1 flora and fauna surveys covered those parts of the two Oyomo Creek tributary streams that lie within CPF fence line. During that survey, local residents informed[19] that: (1) neither of these turtle species nest that high up the stream system, and; (2) juvenile turtles are sometimes seen in that area, but they are not common and the Pig-nosed Turtle has been observed there. Thus, current evidence suggests that these smaller mid-reach stream areas are not of ecological importance for any life-history stage of these Threatened turtles.

[19] S. Richards, team herpetologist



TITLE: Turtle and Crocodile Nesting Sites Documented in Southern PRL-15

FIGURE: 6.22

PROJECT: Papua LNG Project

DOCUMENT NUMBER: R_117-81957 **REVISION:** D

DATE: 8/08/2017

DATA SOURCES:

Facilities, CPF, logistics base and airstrip area, waterways, tracks, airstrip (ERIAS Group and TOTAL 2016). DEM (Planet Observer 2015 and TOTAL 2016). Ecological zones (Iain Woxvold 2016). Turtle and crocodile nesting sites (Iain Woxvold 2017).

CLIENT:

ERIAS Group
13-25 Church Street
Hawthorn VIC 3122
Australia

PREPARED BY:

Phone: 1300 807 770
Phone: +61 7 3252 5589
Web: www.mipela.com.au
Email: support@mipela.com.au

Mipela GeoSolutions does not guarantee the accuracy or completeness of the map and does not make any warranty about the data. Mipela GeoSolutions is not under any liability to the user for any loss or damage (including consequential loss or damage) which the user may suffer resulting from the use of this map.

T:\Projects\ER1002 Elk Antelope LNG Project EIS-ESHIA\Work Request\R_117 - Terrestrial Biodiversity Baseline Maps\ERI002-R_117-81957-Figure 6.22-D.mxd

The Striped New Guinea Soft-shelled Turtle is of higher conservation concern than the Pig-nosed Turtle. Both species are harvested locally and both are listed as globally Threatened by the IUCN. However, the Striped New Guinea Soft-shelled Turtle is considerably rarer than the Pig-nosed Turtle, there are fewer suitable nesting sites, and they nest less frequently. In a study of turtles in the nearby Kikori drainage, Georges et al. (2008, p. 708) noted that the Striped New Guinea Soft-shelled Turtle is 'probably critically endangered locally'.

Consequently, while Djo'boh Creek and Oyomo Creek are considered to harbor important nesting areas for both species, their importance is notably higher for the Striped New Guinea Soft-shelled Turtle.

Nesting by both species occurs more widely in the study area, and in the case of Pig-nosed Turtle may occur as far south as the coast in the Mangroves ecological zone.

Nesting sites for both IUCN Vulnerable freshwater turtle species are considered to be Very Sensitive.

Plate 6.113 – Pig-nosed Turtle Nesting Bank, South Bank of Purari River, Upstream from Herd Base (Site 11 in Table 6.20 and Figure 6.16)



Photo source: I. Woxvold.

Plate 6.114 – Pig-nosed Turtle Nesting Bank, South Bank of Purari River, Downstream from Herd Base (Site 5 in Table 6.20 and Figure 6.16)



Photo source: I. Woxvold.

6.6.5 Crocodile Nesting Sites

The Estuarine Crocodile (*Crocodylus porosus*) and the New Guinea Freshwater Crocodile (*Crocodylus novaeguineae*) nest in vegetated swamps near watercourses and off-river waterbodies. During the June 2016 Purari boat survey (Section 6.6.4), a swamp adjacent to the main Purari River channel in the southern portion of PRL-15 (at 296200 9184580) was identified as an important breeding habitat for New Guinea Freshwater Crocodile and small freshwater turtles (*Emydura subglobosa*). The area is shown in Plate 6.115, and its location in Figure 6.22.

The PRL-15 oxbow wetlands were also reported by local residents to be an important crocodile breeding area.

Nesting by both the Estuarine Crocodile and the New Guinea Freshwater Crocodile occurs more widely in the study area.

Nesting sites for both crocodile species are considered to be Very Sensitive.

Plate 6.115 – Aerial View of the Vegetated Swamp Along the Purari River, South PRL-15, Said to be an Important Nesting Site for New Guinea Freshwater Crocodile



6.6.6 Hill Forest Pools

Small pools in hill forest provide important breeding habitat for a variety of frogs and odonates, including two undescribed species of treefrog – *Litoria* sp. 1 and *Litoria* sp. 2 – and the new-to-science damselfly *Teinobasis* sp. 1. Both *Litoria* sp. 1 and *Teinobasis* sp. 1 are currently known only from the study area.

Hill forest pools occur as small (normally one to ten meters across) permanent or semi-permanent (not ephemeral) waterbodies in areas of impeded drainage in forested hill terrain. They occur in small-scale landform depressions on hill slopes or terraces, in flooded depressions left by the uplifted root-mass of a fallen tree, and as stagnant pools along ephemeral drainage lines during relatively dry periods. They are widespread but sparsely distributed in steep terrain of the Middle Purari Hills and Southeast Hills ecological zone. Their recovery from various forms of contamination and disturbance is expected to be low in many cases. They are considered to be Moderately Sensitive.

6.7 Conservation Value of the Study Area Landscape

At the landscape level, the study area as a whole is of high conservation value due to its large size, remoteness, low human population and high degree of connectivity among a variety of intact and biodiversity-rich habitats that span at least three terrestrial eco-regions (‘Southern New Guinea lowland rain forests’, ‘Southern New Guinea freshwater swamp forests’, ‘Southern New Guinea mangroves’; Wikramanayake et al., 2002). It covers a diverse ecosystem complex on a variety of topographies and substrates, extending north from coastal mangroves and intertidal mudflats for some 120 km through swamp and alluvial forest systems to include broad expanses of hill forest at the base of New Guinea’s central cordillera.

To its north, the study area overlaps with intact hill and montane forest ecosystems that reach over 3,100 m asl and that are protected within the Crater Mountain WMA. The Crater Mountain WMA extends south to the Purari River, overlapping with approximately 445 km^2 of the study area including parts of PRL-15. The study area thus covers a major portion of a complete and partially protected ecosystem complex that extends from upper montane to coastal habitats, thus providing for vital evolutionary processes, ecosystem services and opportunity for climate change adaptation among local biotic communities (Opdam and Wascher, 2004).

In terms of flora and fauna, the study area is set in one of the world's most biologically diverse and endemically rich terrestrial regions (Olson and Dinerstein, 1998; Brooks et al., 2006), where it comprises almost the entire eastern half of the 'Kikori-Purari' biogeographic region (Beehler, 1993b). Numerous species of conservation significance are confirmed present, including 29 IUCN Threatened species (three of them Critically Endangered), 51 species presently known only from within the study area (including 49 species newly discovered during Project surveys), and a suite of additional restricted-range, rare and poorly known taxa. Based on the importance of local environments to flora and fauna communities, the study area comprises most of the 'Purari Basin' Biologically Important and Very Important Areas, as recognized in the PNG Conservation Needs Assessment (Beehler, 1993a; Swartzendruber, 1993) for the overlap of multiple areas of importance to terrestrial biodiversity independently identified by biodiversity scientists, including areas of botanical importance (Johns, 1993), important forest environments (Saulei and Beehler, 1993), areas of importance to herpetofauna (Allison, 1993) and major wilderness areas (Allison, 1993; Beehler, 1993b).

Component features of the study area are, for the most part, remarkably intact, in most places preserving the wilderness values recognized previously under the PNG Conservation Needs Assessment. By contrast, long-term high population densities in the Southeast Coast ecological zone, and logging of some 18.6% of the study area's land surface, have resulted in the conversion or degradation of expansive areas of original forest habitat. Most of these pressures have been concentrated in the southeast of the study area, and for the most part, vast expanses of hill and alluvial forest, freshwater swamp vegetation and mangroves remain essentially undisturbed. Notably, the study area supports the largest expanses of well-structured alluvial forest (Pl and Po formations) remaining anywhere within the Kikori-Purari biogeographic region.

Considering all assets, from a terrestrial biodiversity perspective the study area is of very high conservation value.

6.8 Study Limitations

Investigations undertaken for the present study provide the most detailed terrestrial biodiversity dataset heretofore available for the study area. However, given the inadequacy of prior existing information (Section 4), and the high diversity of species and environments present within the study area, existing data are subject to a number of limitations. No landscape is completely understood in terms of its component biotic communities, and data gaps are naturally widest in species-rich tropical environments. Different data vary in their importance to the management of potential Project-related impacts. Accordingly, data acquisition was managed in the present study by prioritizing the collection of key information.

Coverage of environments and species-level sensitivities achieved in the present study is briefly summarized here. Remaining gaps are identified, and strategies for managing them proposed.

6.8.1 Coverage of Major Environments

Field surveys were conducted in all ecological zones, with survey sites positioned to maximize coverage of vegetation types occurring in areas potentially affected by Project development, and to provide seasonal coverage as far as logistically possible. Of 13 natural vegetation types identified within the study area (Section 6.2), 12 were accessed by flora and fauna specialists (Table 5.2), the one unsurveyed type (Small crowned alluvial forest (Ps)) being a structural variant of a well surveyed broad vegetation group (alluvial forest) that does not overlap any key Project areas (PRL-15, export pipeline corridor, Riverways). All major environments identified within the study area were subject to ground and/or aerial survey.

Most of the information collected during Project surveys was gathered from PRL-15 and the export pipeline corridor. Additional data were collected from other parts of the upstream PAOI by a more limited ground survey effort (for example, Wi'i Creek), during village visits and by aerial survey. Additional information from prior surveys was sourced mainly from PRL-15, the Purari delta environments and the Vailala River catchment (Section 4). Across the broader study area, data are most lacking for areas west of PRL-15—in the western half of the Middle Purari Hills ecological zone, and in the Era River and Pie-Eia River catchments of the Delta Swamps and Plains. Information from these sectors is limited mostly to the original FIMS vegetation mapping, to the mapping of recently logged areas, and to the testimonies of local Pawaian residents as to the occurrence of a few high value mammal taxa in remote hill forest regions (for example, tree kangaroos and Eastern Long-beaked Echidna). Given that these areas are outside of the upstream PAOI and contain no vegetation types or other major environments additional to those present in surveyed areas, the lack of more specific data from these sectors should not impede the assessment of Project-related impacts.

6.8.2 Knowledge of Sensitive Species

A major objective of the flora and fauna studies is to document the presence and status of species of conservation significance. These include conservation listed species, new-to-science and undescribed species, restricted-range and other species ascribed a sensitivity ranking of Moderately Sensitive or higher (Section 5.5.3).

More species of conservation significance certainly occur within the study area than have been directly documented during Project or prior surveys. In terms of conservation listed species, screening by species specialists has produced a reliably complete list of potential additional occurrences for all terrestrial groups. Similar lists were compiled for restricted-range species among focal faunal groups (mammals, birds, herpetofauna and odonates; Annex 2 to 6). Among plants, a general scarcity of data (Takeuchi, 2007) means that many named species are known from only one or very few localities and that large range extensions (often in the order of hundreds of kilometers) are frequently documented (e.g., Takeuchi, 2009, 2010, 2012; Venter 2015; this study). Given these limitations, and the large floristic datasets involved, screening for potential additional restricted-range plants was limited primarily to species known only from Gulf Province. While this results in an incomplete dataset, it is biased towards species with the smallest known geographic range, and thus those that are potentially at greatest risk. For all of the above species, relevant information on their ecology, status and susceptibilities is provided where known.

Additional potentially sensitive taxa that fall outside of this screening approach include restricted-range plants with a wider area of occurrence, restricted-range fauna from non-focal groups (invertebrates other than odonates), and potentially sensitive species that remain unknown to

science. Given the high rate of discovery in New Guinean environments (Thompson, 2011), including within the study area (49 species during Project surveys), additional new-to-science species, even among the groups here investigated, no doubt remain undocumented. It is not possible to predict the distribution, ecological requirements or sensitivities of as yet undiscovered species.

Despite these uncertainties, the taxonomic coverage of sensitive species achieved in this study is considered sufficiently broad so as to inform a set of avoidance, mitigation and management recommendations that is applicable to most terrestrial biota, known or unknown. Specifically, in cases where a sensitive species remains undetected within the upstream PAOI, other species with similar ecological requirements have already been considered and/or the habitats that they occupy have been identified, providing the basis for recommendations aimed at preserving the viability of these ecosystems and their component biota. This concept represents an expanded 'focal species' approach, in which a suite of taxa is selected whose management is expected to confer an ecosystem-wide conservation advantage (Lambeck, 1997; Nicholson et al., 2013).

Troglobitic (terrestrial obligate cave-dwelling) fauna represent notable case. Limited range endemics are common in this group, with many species known from single cave systems (Christman and Culver, 2001; Wynne and Pleytez, 2005). Cave environments are among the most poorly known and sensitive environments on Earth (Wynne and Pleytez, 2005), and their obligate inhabitants are susceptible to threatening processes distinct from those affecting most surface-dwelling taxa (e.g., Biota, 2009). Given the specialist techniques required to survey troglobitic fauna, and the fact that no major limestone outcrops are expected to occur in key Project areas, their assessment is considered beyond the scope of this study. Yet until evidence is available to prove otherwise, large limestone caves are conservatively considered capable of harboring locally endemic forms. However, even in the absence of specific knowledge regarding troglobitic fauna, the sensitivity of their host environment is here acknowledged (Section 6.6.1.1).

Despite the coverage provided, a number of knowledge gaps remain in relation to key species of conservation significance potentially affected by Project development. These include:

- Uncertainty as to the wider occurrence of Very Sensitive and Extremely Sensitive plant species known from the study area only within or near to currently planned Project footprint areas including the proposed CPF fence line and logistics base areas. Relevant taxa include the IUCN Endangered timber tree *Diospyros insularis*, and the new-to-science plants *Begonia* sp. 5, *Archidendron* sp. 1 and *Syzygium* sp. 1.
- The location of nesting sites of IUCN Vulnerable Pig-nosed Turtle and Striped New Guinea Soft-shelled Turtle along Purari River tributary watercourses potentially affected by Project development, including the Oyomo Creek and Djo'boh Creek drainages (Section 6.6.4).
- The location of crocodile nesting sites in potentially affected areas, additional to those already identified in Section 6.6.5.

These gaps will not interfere with ESHIA development.

Two additional notable gaps regard high value mammal species:

- Uncertainty as to the identity of the Peroryctes bandicoot recorded in the southern half of the export pipeline corridor. Based on available evidence, this species is assumed to involve the IUCN Endangered Giant Bandicoot, one of New Guinea's most threatened mammal species.

- Uncertainty as to the location of caves harboring colonies of the IUCN Critically Endangered Bulmer's Fruit Bat. No Project activities are currently planned for major limestone areas. Should this situation change with development in Project design, this issue will be managed in future Project stages.

Neither of these gaps will interfere with progressing the ESHIA.

7. Conclusions

Previous sections characterize terrestrial biodiversity values present in the study area at varying levels of biological organization. Focus is given to the presence, status and distribution of flora and fauna of conservation significance and to the ecosystems and 'focal sites' that they occupy. Combining information from the current biodiversity surveys and prior studies, the baseline presented here represents the most detailed terrestrial biodiversity dataset heretofore available for the study area.

To facilitate the impact assessment and the development of appropriate biodiversity management strategies, each key biodiversity asset has been ascribed a baseline sensitivity value using criteria developed specifically for this study. To some degree, assigning sensitivity to biodiversity values is inherently subjective, as acknowledged in IFC PS6, and in TOTAL's General Specifications (GS EP ENV 120), by an emphasis on the requirement for expert specialist opinion. In this study, the expert opinion of species specialists was used to inform criteria relating to various sensitivities, and a numeric scoring system was developed to introduce some level of repeatability in assessment across related values (Section 5.5).

A total of 162 species of conservation significance was recorded or may occur within the study area, including 92 Moderately Sensitive, 65 Very Sensitive and five Extremely Sensitive species (Table 7.1). Extremely Sensitive taxa include four IUCN Critically Endangered species confirmed present (Bulmer's Fruit Bat, *Diospyros lolinopsis*, *Bruguiera hainesii*) or potentially occurring (*Guioa hospita*) in the study area, and one new-to-science plant species (*Begonia* sp. 5) currently known only from a few individuals within or near the proposed CPF area. Very Sensitive species are reported from most taxonomic groups investigated and include a high proportion of IUCN Threatened taxa (29 species; 44.6%) and new-to-science species known only from the study area (25 species; 38.5%). For all species of conservation significance, the major environments and ecological zones that they occupy are identified.

Table 7.1 – Species of Conservation Significance Recorded or Potentially Occurring in the Study Area

Taxonomic Group	Sensitivity[A]		
	MS	VS	ES
Flora	8/20/18/(29)	11/24/15/(32)	3/1/1/(4)
Non-volant mammals	2/3/–/(4)	8/4/2/(10)	–/–/–/(0)
Bats	1/1/–/(1)	–/–/–/(0)	1/1/–/(1)
Birds	29/1/–/(29)	8/2/–/(8)	–/–/–/(0)
Reptiles	–/–/–/2/(2)[B]	2/2/2/(4)	–/–/–/(0)
Frogs	1/10/8/(10)	–/2/2/(2)	–/–/–/(0)
Odonates	2/14/5/(15)	–/8/4/(8)	–/–/–/(0)
Butterflies	2/–/–/(2)	1/–/–/(1)	–/–/–/(0)
Total	92	65	5

[A] Sensitivity: MS—Moderately Sensitive; VS—Very Sensitive; ES—Extremely Sensitive. Numbers indicate: conservation listed/restricted-range/new-to-science and undescribed/(total). Within each cell the total is not a sum of all figures since many species occupy more than one category (e.g., conservation listed and restricted-range).
[B] The fourth category for Moderately Sensitive reptiles refers to the two locally occurring crocodile species, neither of which is conservation listed, restricted-range or scientifically undescribed.

The study area includes a diverse array of major environments, including five broad vegetation groups (hill forest, alluvial forest, freshwater swamp vegetation, mangroves and littoral forest), anthropogenic converted lands, tidal wetlands and freshwater aquatic environments. The major environments are divided into 20 ecosystems (Table 6.18), within which focal sites were identified by species specialists that represent localized habitat features of importance to one or more sensitive species and/or to local/regional faunal populations. Focal sites include caves, large trees, crocodile nesting sites, large freshwater turtle nesting sites, hill forest pools and an area occupied by the IUCN Critically Endangered mangrove tree *Bruguiera hainesii*.

The sensitivity of ecosystems and focal sites is determined in part by their support of sensitive species, as well as by their condition, their availability within the local (study area) and regional (biogeographic region/Gulf Province) landscape, and/or their susceptibility to disturbance.

The study area land surface is covered almost entirely in natural vegetation (98.9%), with hill and alluvial forests supporting the highest species richness, including the highest diversity and abundance of species of conservation significance. Of these forest types, alluvial forest is of the highest conservation value due to: (1) its more restricted local and regional availability; (2) relatively limited connectivity with similar habitat outside of the study area, and; (3) its high commercial value to the logging industry. The study area supports the largest primary formations of Alluvial forest (Pl) and Open alluvial forest (Po) remaining anywhere within the Kikori-Purari biogeographic region.

Logging has adversely impacted more than 28% of the study area's hill and alluvial forests, predominantly in the southeast and including most of the forest habitat within the export pipeline corridor. However, secondary (post-logging) impacts are minimal in most areas, and the large expanses of regenerating secondary forest retain a suite of natural biodiversity values and support numerous species of conservation significance.

Although not as species rich as the dry-floor forest environments, other habitats such as mangrove forest, off-river waterbodies and tidal wetlands support distinct communities with a suite of habitat-specialist species, including a variety of rare, endemic and/or migratory taxa.

The distribution of ecosystem-level sensitivities is mapped for the study area, and the location of Very Sensitive and Extremely Sensitive focal sites is mapped for the PRL-15 and export pipeline corridor (Figures 6.14 to 6.16) insofar as this is known.

8. Study Team

The terrestrial biodiversity baseline study team are listed in Table 8.1 along with their institutional affiliation and role in the study.

Table 8.1 – Study Team

Consultant Scientist	Affiliation	Study	Role
Peter Amick	Binatang Research Centre	Flora and fauna	Specialist field assistant - bats
Dr Ken Aplin	Ammerican Museum of Natural History; Western Australian Museum; United States National Museum (Smithsonian Institution); independent consultant	Flora and fauna	Lead scientist - non-volant mammals, bats
Dr Kyle Armstrong	University of Auatraia; South Australian Museum; Australasian Bat Society (president); independent consultant	Flora and fauna	Lead scientist - bats
Fufuse Bewang	Booyong Forest Science	Flora and fauna	Specialist field assistant - botany
Chris Dahl	Binatang Research Centre	Flora and fauna	Specialist field assistant - herpetofauna
Elizah Nagombi	Binatang Research Centre	Flora and fauna	Specialist field assistant - herpetofauna
Junior Novera	PNG Institue of Biological Research	Flora and fauna	Specialist field assistant - mammals
Stephen Richards	South Australian Museum; independent consultant	Flora and fauna	Lead scientist - herpetofauna, odonates
Pagi Toko	Binatang Research Centre	Flora and fauna	Specialist field assistant - odonates
Howard Rogers	Booyong Forest Science	Vegetation, weeds, forestry and deforestation	Technical lead
Benjamin Kelimbua	Booyong Forest Science	Vegetation, weeds and forestry	Specialist field assistant
Amos Ona	Booyong Forest Science	Vegetation, weeds and forestry	Specialist field assistant
Dr Stephanus (Fanie) Venter	James Cook University; independent consultant	Flora and fauna	Lead scientist - flora
Dr Iain Woxvold	Museum Victoria; independent consultant	Terrestrial biodiversity study	Technical lead - Terrestrial biodiversity study; lead scientist - avifauna.

9. Glossary and Abbreviations

Anthropogenic	Originating from human activity
asl	above sea level
Biogeographic zone	An area that is characterized by a specific geographical distribution of plants and/or animals.
c.	Abbrev. ‘circa’; approximately
Central cordillera	Refers to the central mountainous spine of New Guinea that runs from the eastern edge of the Vogelkop Peninsula in Indonesian New Guinea to the eastern tip of mainland Papua New Guinea
CEPA	Conservation and Environment Protection Authority
Community structure	The taxonomic composition of a community; species assemblage.
Conservation listed species	Includes: (1) species listed under the IUCN Red List as Threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened or Data Deficient; (2) species listed as Protected under the PNG *Fauna (Protection and Control) Act 1966*; (3) species listed under CITES Appendix I or II
CPF	Central Processing Facility
DBH	Diameter at breast height
DD	Data Deficient (IUCN threat category)
EIS	Environmental impact statement
EN	Endangered (IUCN threat category)
Endemic	Belonging exclusively or confined to a particular place.
Endemism	Describes the proportion of endemic taxa occurring in a place; e.g., a high level of endemism
ERIAS Group	ERIAS Group Pty Ltd
ESBS	Environment and Social Baseline Study
ESHIA	Environmental, social and health impact assessment

FIMS	PNG Forest Inventory Mapping System
Frugivore	A species that includes fruit as a significant component of its diet
GPS	Global Positioning System
Habit (plants)	A plant's characteristic growth form or appearance; for example: tree, climbing plant, shrub, herb
IFC	International Finance Corporation
IOC	International Ornithological Congress
IUCN	International Union for the Conservation of Nature
km	Kilometers
km^2	Square kilometers
LC	Least Concern (IUCN threat category)
LIDAR	Light Detection and Ranging; a light-based remote detection method
LNG	Liquefied Natural Gas
m	Meters
mm	Millimeters
NT	Near Threatened (IUCN threat category)
Oxbow lake	A lake next to a winding river; originally a river meander section, it is formed when the river adjusts course.
P	Abbrev. Protected (see Protected)
pers. comm.	Abbrev. 'personal communication'
PGK	Papua New Guinea Kina
PNG	Papua New Guinea
PRL-15	Petroleum Retention Licence-15
Project	Papua LNG Project
Protected	Species listed as Protected under the Papua New Guinea *Fauna (Protection*

	and Control) Act 1966; abbrev. 'P'
Raptor	A bird of prey. Includes diurnal (eagles, hawks, falcons, etc.) and nocturnal species (owls)
Restricted-range	Species which have a total historical breeding range of less than 50,000 km^2
sp.	Abbrev. ‘species’ (singular)
spp.	Abbrev. ‘species’ (plural)
study area	Upstream terrestrial biodiversity study area
Taxa	Plural of taxon; a systematic division (i.e., more than one species, genera, etc.)
Taxonomic	Taxonomy is the science of identifying, naming and classifying living organisms
Terrestrial biodiversity study	Project terrestrial biodiversity study
TEP PNG	Total E&P PNG Limited
Upstream PAOI	Upstream project area of influence
WMA	Wildlife Management Area
WWF	World Wide Fund for Nature

10. References

Agardy, M. T. & Pernetta, J. 1993. A preliminary assessment of biodiversity and conservation for coastal and marine ecosystems in Papua New Guinea. Pp. 381–421 in Beehler, B. M. (ed.) *Papua New Guinea Conservation Needs Assessment* (Volume 2). Biodiversity Support Program, Washington, D. C.

Aharon-Rotman, Y., Bauer, S. & Klaassen, M. 2015. A chain is as strong as its weakest link–assessing the consequences of habitat loss in long-distance migratory shorebirds. Chapter 4 in Aharon-Rotman, Y. *Challenges within the annual cycle of long-distance migratory waders*. PhD Thesis, Deakin University.

Allison, A. 1993. Biodiversity and conservation of the fishes, amphibians, and reptiles of Papua New Guinea. pp. 157–225 in Beehler, B. M. (ed.) *Papua New Guinea Conservation Needs Assessment* (Volume 2). Biodiversity Support Program, Washington, D. C.

Alonso, L. E., Deichmann, J. L., McKenna, S. E., Naskrecki, P. & Richards, S. J. (eds.) 2011. *Still counting… Biodiversity exploration for conservation – the first 20 years of the Rapid Assessment Program*. Conservation International, Arlington, Virginia.

Anderson, J. A. R. 1965. The limestone habitat in Sarawak. Pp. 49–57 *in Proceedings of the Symposium on Ecological Research into Humid Tropics Vegetation*. UNESCO, Kuching.

Aplin, K. P. & Kale, E. 2011. Non-volant mammals of the Muller Range, Papua New Guinea. *In* Richards, S. J. & Gamui, B. G. (eds) *Rapid Biological Assessments of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments*. RAP Bulletin of Biological Assessment 60. Conservation International, Arlington, VA.

Bain, J. H. C. & MacKenzie, D. E. 1974. *Explanatory notes on the Karimui geological sheet*. Record 1974/58. Bureau of Mineral Resources, Geology and Geophysics, Canberra.

Bamford, M., Watkins, D., Bancroft, W., Tischler, G. and Wahl, J. 2008. *Migratory Shorebirds of the East Asian - Australasian Flyway; Population Estimates and Internationally Important Sites*. Wetlands International - Oceania. Canberra, Australia.

Beehler, B. M. (ed.) 1993a. *Papua New Guinea Conservation Needs Assessment* (Volume 2). Biodiversity Support Program, Washington, D. C.

Beehler, B. M. 1993b. Biodiversity and conservation of the warm-blooded vertebrates of Papua New Guinea. Pp. 77–155 *in* Beehler, B. M. (ed.) *Papua New Guinea Conservation Needs Assessment* (Volume 2). Biodiversity Support Program, Washington, D. C.

Beehler, B. M. 2007. Introduction to Papua. Pp. 3–13 *in* Marshall, A. J. and Beehler, B. M. (eds.) *The ecology of Papua* (Part One). Periplus Editions, Hong Kong.

Beehler, B. M., Burg, C. G., Filardi, C. & Merg, K. 1994. Birds of the Lakekamu–Kunamaipa basin. *Muruk* 6: 1–8.

Beehler, B. M. & Mack, A. L. 1999. Constraints to characterising spatial heterogeneity in a lowland forest avifauna in New Guinea Pp. 2,569–2,579 *in* Adams, N. J. and Slotow, R. H.

(eds) *Proceedings of the 22nd International Ornithological Congress, Durban*. BirdLife South Africa, Johannesburg.

Beehler, B. M. & Pratt, T. K. 2016. *Birds of New Guinea: Distribution, Taxonomy, and Systematics*. Princeton University Press, Princeton, New Jersey.

Beehler, B. M., Sengo, J. B., Filardi, C. & Merg, K. 1995. Documenting the lowland rainforest avifauna in Papua New Guinea – effects of patchy distributions, survey effort and methodology. *Emu* 95: 149–161.

Bellamy, J. A. (ed.) 1986. *Inventory of natural resources, population distribution and land use*. Natural Resource Series No. 6, Division of Water and Land Resources. Institute of Biological Resources, CSIRO.

Bennett, A. F., Lumsden, L. F. & Nicholls, A. O. 1994. Tree Hollows as a Resource for Wildlife in Remnant Woodlands: Spatial and Temporal Patterns across the Northern Plains of Victoria, Australia. *Pacific Conservation Biology* 1 (3): 222–235.

Berry, N. J., Phillips, O. L., Lewis, S. L., Hill, J. K., Edwards, D. P., Tawatao, N. B., Ahmad, N., Magintan, DD., Khen, C. V., Maryati, M., Ong, R. C. & Hamer, K. C. 2010. The high value of logged tropical forests: lessons from northern Borneo. *Biodiversity and Conservation* 19: 985–997.

Biota, 2009. *Mesa A Troglofauna Management Plan*. Biota Environmental Sciences, prepared for Rio Tinto Iron Ore, November 2009.

Bishop, K. D. 2006. Shorebirds in New Guinea: their status, conservation and distribution *Stilt* 50: 103–134.

Bleeker, P. 1969. Soils of the Kerema-Vailala area. Pp. 77–94 *in* Ruxton, B. P., Bleeker, P., Leach, B. J., McAlpine, J. R., Paijmans, K. & Pullen, R. *Lands of the Kerema–Vailala Area, Territory of Papua New Guinea*. Land Research series No. 23. CSIRO, Melbourne.

Bleeker, P. 1983. *The soils of Papua New Guinea*. Australian National University Press, Canberra.

BMT WBM. 2017a. Papua LNG Project ESBS Technical Report: Marine Biodiversity Baseline Report. Report prepared by BMT WBM Pty Ltd for ERIAS Group, Hawthorn, Victoria.

BMT WBM. 2017b. Papua LNG Project ESBS Technical Report: Upstream Freshwater and Estuarine Biodiversity Baseline Report. Report prepared by BMT WBM Pty Ltd for ERIAS Group, Hawthorn, Victoria.

Booyong Forest Science. 2017a. Upstream Land and Natural Resources Use (Ecosystem Services – Provisioning) Baseline Report. Report prepared for for ERIAS Group, Hawthorn, Victoria.

Booyong Forest Science. 2017b. Upstream Land and Natural Resources Use (Ecosystem Services – Provisioning) Baseline Report. Report prepared for ERIAS Group, Hawthorn, Victoria.

Booyong Forest Science. 2017c. Upstream Deforestation Baseline Study Report. Report prepared for for ERIAS Group, Hawthorn, Victoria.

Booyong Forest Science 2017d. Upstream Vegetation Regeneration Baseline Study Report. Report prepared for for ERIAS Group, Hawthorn, Victoria.

BOM 2016. Australian Government Bureau of Meteorology. http://www.bom.gov.au/climate/updates/articles/a008-el-nino-and-australia.shtml, accessed 17 March 2016.

Bonaccorso, F. J. 1998. *Bats of Papua New Guinea.* Conservation International, Washington, D. C.

Brooks, T. M., Mittermeier, R. A., da Fonseca, G.A.B., Gerlach, J., Hoffmann, M., Lamoreux, J. F., Mittermeier, C. G., Pilgrim, J. D. & Rodrigues, A. S. L. 2006. Global biodiversity conservation priorities. *Science* 313: 58–61.

Bryan, J. E. & Shearman, P. L. (comps) 2008. *Papua New Guinea Resource Information System Handbook*. 3rd edition. University of Papua New Guinea, Port Moresby.

Bryan, J. E. & Shearman, P. L. (eds) 2015. *The State of the Forests of Papua New Guinea 2014: Measuring change over the period 2002-2014*. University of Papua New Guinea, Port Moresby.

Bryant, D., Nielsen, D. & Tangley, L. 1997. *The Last Frontier Forests: ecosystems and economies on the edge.* World Resources Institute, Washington, DC.

Buchanan, G. M., Donald, P. F. & Butchart, S. H. M. 2011. Identifying priority areas for conservation: a global assessment for forest-dependent birds. *PLoS ONE* 6(12): e29080. doi:10.1371/journal.pone.0029080

Chazdon, R. L., Peres, C. A., Dent, D., Sheil, D., Lugo, A. E., Lamb, D., Stork, N. E. & Miller, S. E. 2009. The potential for species conservation in tropical secondary forests. *Conservation Biology* 23: 1,406–1,417.

Christman, M. C. & Culver, D. C. 2001. The relationship between cave biodiversity and available habitat. *Journal of Biogeography* 28: 367–380.

Clements, R., Sodhi, N. S., Schilthuizen, M. & Ng, P. K. L. 2006. Limestone karsts of Southeast Asia: imperiled arks of biodiversity. *BioScience* 56: 733–742.

Coates, B. J. 1985. *The Birds of Papua New Guinea, Including the Bismarck Archipelago and Bougainville.* Volume I, Non–Passerines. Dove Publications, Alderley, Queensland.

Coates, B. J. 1990. *The Birds of Papua New Guinea, Including the Bismarck Archipelago and Bougainville*. Volume II, Passerines. Dove Publications, Alderley, Queensland.

Coffey. 2009. PNG LNG Project: Environmental Impact Statement. Prepared by Coffey Natural Systems for Esso Highlands Limited, Port Moresby, Papua New Guinea.

Corlett, R. T. & Primack, R. B. 2011. *Tropical rain forests: an ecological and biogeographical comparison* (second edition). Wiley-Blackwell, West Sussex, UK

Cragg, S. 1983. The mangrove ecosystem of the Purari delta. Pp. 295–324 *in* Petr, T. (ed.) *The Purari: tropical environment of a high rainfall river basin*. Monographiae Biologicae, Vol. 51. Dr W. Junk Publishers, The Hague.

Cronk, Q. C. B., Kiehn, M., Wagner, W. L. & Smith, J. F. 2005. Evolution of Cyrtandra (Gesneriaceae) in the Pacific Ocean: the origin of a supertramp clade. *American Journal of Botany* 92(6): 1,017-1,024.

De Gouvenain, R. C. & Silander, J. A. Jr. 2003. Do tropical storm regimes influence the structure of tropical lowland rain forests? *Biotropica* 35: 166–180.

Deharveng, L., Whitten, T. & Leclerc, P. 2007. Caves of Papua. Pp. 1,064–1,083 *in* Marshall, A. J. and Beehler, B. M. (eds) *The ecology of Papua* (Part Two). Periplus Editions, Hong Kong.

DES 2008. *Elk/Antelope Gasfield Project Environmental Impact Statement*. Douglas Environmental Services, December 2008. Document no. PG_ELK_02_9700_004408

DES 2010. Appendix 2. *Terrestrial Biodiversity Studies Report. A Rapid Assessment of the Terrestrial Biological Environment Of Elk/Antelope Gasfield PDL Extension Area*. Douglas Environmental Services. Document no. PG_ELK_02_9700_004405

Diamond, J. M. 1972. *Avifauna of the Eastern Highlands of New Guinea*. Nuttall Ornithological Club, Cambridge, Massachusetts.

Donato, D. C., Kauffman, J. B., Murdiyarso, D., Kurnianto, S., Stidham, M. & Kanninen, M. 2011. Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience* 4: 293–297.

Duffels, H. & de Boer, A. J. 2007. Cicada endemism in Papia. Pp. 532–538 *in* Marshall, A. J. and Beehler, B. M. (eds.) *The ecology of Papua* (Part One). Periplus Editions, Hong Kong.

Eddowes, P. J. 1998. Multiple species accounts. *The IUCN Red List of Threatened Species*. Accessed February 2017.

Edwards, D. P., Ansell, F. A., Ahmad, A. H., Nilus, R. & Hamer, K. C. 2009. The value of rehabilitating logged rainforest for birds. *Conservation Biology* 23: 1,628–1,633.

Eisemberg, C., Rose, M., Yaru, B., Amepou, Y. & Georges, A. 2014. Salinity of the coastal nesting environment and its association with body size in the estuarine pig-nosed turtle. *Oryx* 49: 659–668.

Eisemberg, C., Rose, M., Yaru, B. & Georges, A. 2015. Spatial and temporal patterns of harvesting of the Vulnerable pig-nosed turtle *Carettochelys insculpta* in the Kikori region, Papua New Guinea. *Journal of Zoology* 295: 65–74.

Ellison, J. C. 1997. Mangrove ecosystems of the Western and Gulf Provinces of Papua New Guinea: a review. *Science in New Guinea* 23(1): 3.

Ellison, J. C. 2014. Vulnerability of mangroves to climate change. Pp. 213–232 *in* Faridah-Hanum, I. et al. (eds.) *Mangrove ecosystems of Asia*. Springer, New York.

Evans, J. L. and Allan, R. J. 1992. El Nino/Southern Oscillation modification to the structure of the monsoon and tropical cyclone activity in the Australasian region. *International Journal of Climatology* 12: 611–623.

Evesson, D. T. 1983. The climate of the Purari River basin. Pp. 9–26 *in* Petr T (ed.) *The Purari: tropical environment of a high rainfall river basin*. Monographiae Biologicae, Vol. 51. Dr W. Junk Publishers, The Hague.

Faith, D. P., Nix, H. A., Margules, C. R., Hutchinson, M. F., Walker, P. A., West, J., Stein, J. L., Kesteven, J. L., Allison, A. & Natera, G. 2001. The BioRap biodiversity assessment and planning study for Papua New Guinea. *Pacific Conservation Biology* 6: 279–288.

Flannery, T. F. 1995. *The Mammals of New Guinea*. Chatswood, NSW: Reed Books.

Floyd, A. G. 1977. *Ecology of the tidal forests in the Kikori–Romilly Sound area Gulf of Papua*. Ecology Report No. 4, Division of Botany, Office of Forests, Lae, 59 pp.

Forster, P. I. 1995. Circumscription of *Marsdenia* (Asclepiadaceae: Marsdenieae) with a revision of the genus in Australia and Papuasia. *Australian Systematic Botany* 8: 703–933.

FRA 2000. *Global Forest Resources Assessment*. Main Paper. FAO Forestry Paper 140. Food and Agriculture Organisation of the United Nations, Rome.

FRA 2005. *Global Forest Resources Assessment country report. Papua New Guinea*. Food and Agriculture Organisation of the United Nations, Rome.

FRA 2010. *Global Forest Resources Assessment country report. Papua New Guinea*. Food and Agriculture Organisation of the United Nations, Rome.

Frith, C. B. & Beehler, B. M. 1998. *The Birds of Paradise: Paradisaeidae*. Oxford University Press, Oxford.

Frodin, D. G. 2007. Biological exploration of New Guinea. Pp. 14–107 *in* Marshall, A. J. and Beehler, B. M. (eds) *The ecology of Papua* (Part One). Periplus Editions, Hong Kong.

Georges, A., Doody, S., Eisemberg, C., Alacs, E. & Rose, M. 2008. *Carettochelys insculpta* Ramsay 1886 – Pig-Nosed Turtle, Fly River Turtle. *In* Rhodin, A. G. J., Pritchard, P. C. H., van Dijk, P. P., Saumure, R. A., Buhlmann, K. A. & Iverson, J. B. (eds) *Conservation biology of freshwater tortoises and turtles*. Chelonian Research Monographs.

GHD 2011. Appendix 3. *Report for Pre-Construction Surveys. Native Flora and Fauna*. GHD, April 2011. Document no. PG_ELK_02_9700_004414

Gibbons, P. & Lindenmayer, D. 2003. *Tree hollows and wildlife conservation in Australia.* CSIRO Publishing, Collingwood, Australia.

Gill, F. & Donsker, D. (eds) 2016. IOC World Bird List (v 6.1). http://www.worldbirdnames.org/

Giri, C., Ochieng, E., Tieszen, L. L., Zhu, Z., Singh, A., Loveland, T., Masek, J. & Duke, N. 2011. Status and distribution of mangrove forests of the world using earth observation satellite data (version 1.3, updated by UNEP-WCMC). *Global Ecology and Biogeography* 20: 154–159.

Gosbell, K. & Clemens, R. 2006. Population monitoring in Australia: some insights after 25 years and future directions. *Stilt* 50: 162–175.

Green, E. P. & Short, F. T. 2003. *World atlas of seagrasses*. Prepared by UNEP World Conservation Monitoring Centre. University of California, Berkeley, 332 pp. URL: https://archive.org/details/worldatlasofseag03gree.

Gressitt, J. L. 1982. Zoogeographical summary. Pp. 897–918 *in* Gressitt, J. L. (ed.) *Biogeography and ecology of New Guinea* (Volume Two). Dr W. Junk Publishers, The Hague.

Gullison, T., Hardner, J., Anstee, S. & Meyer, M. 2015. *Good practices for the collection of biodiversity baseline data*. Prepared for the Multilateral Financing Institutions Biodiversity Working Group & Cross-Sector Biodiversity Initiative. Available at https://www.icmm.com/document/9454

Haberle, S. G., Hope, G. S. & van der Kaars, S. 2001. Biomass burning in Indonesia and Papua New Guinea: natural and human induced fire events in the fossil record. *Palaeogeography, Palaeoclimatology, Palaeoecology* 171: 259–268.

Hammermaster, E. T. & Saunders, J. C. 1995a. *Forest Resources and Vegetation Mapping of Papua New Guinea*. PNGRIS Publ. 4. CSIRO and AIDAB, Canberra.

Hammermaster, E. T. & Saunders, J. C. 1995b. *Forest Resources and Vegetation Mapping of Papua New Guinea*. 1: 250,000 vegetation map overlays separately issued as working copies to PNGRIS Publ. 4. CSIRO and AIDAB, Canberra.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O. & Townshend, J. R. G. 2013. High-resolution global maps of 21st century global forest cover change. *Science* 342: 850–853.

Hartshorn, G. S., Burrows, I., Leary, T., Seri, L., Allen, G., Polhemus, D., Balun, L., Orsak, L., Bigilale, E., Kinbag, F., Kinibel, A., Dahl, C., Wasel, H., Ellis, G. & Forney, M. 1995. *Field survey of biodiversity in the Kikori River Basin, Papua New Guinea*. WWF KICDP area Report.

Hill, K. C. & Gleadow, A. J. W. 1989. Uplift and thermal history of the Papuan fold belt, Papua New Guinea: apatite fission track analysis. *Australian Journal of Earth Sciences* 36: 515–539.

Hoekstra, J. M., Boucher, T. M., Ricketts, T. H. & Roberts, C. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. *Ecology Letters* 8: 23–29.

Hogarth, P. J. 2015. *The biology of mangroves and seagrasses.* Third edition. Oxford University Press, Oxford, UK.

Hope, G. S. & Hartemink, A. E. (2007) Soils of Papua. Pp. 165–176 *in* Marshall, A. J. & Beehler, B. M. (eds.) *The ecology of Papua* (Part One). Periplus Editions, Hong Kong.

IFC 2012. *Performance Standards on environmental and social sustainability*. International Finance Corporation, World Bank Group, January 1, 2012. Available at: www.ifc.org/policyreview

Invasive Species Specialist Group (ISSG). ISSG Global Invasive Species Database. Accessed July 2017. http://www.issg.org/database/.

IUCN 2008. *World Heritage karst and caves. A global review of karst World Heritage properties: present situation, future prospects and management requirements.* IUCN Protected Areas Programme, Gland, Switzerland.

IUCN 2016. IUCN Red List of Threatened Species. Version 2016.3. Available at: www.iucnredlist.org

Jaensch, R. & Watkins, D., undated. *Birds recorded in the Lower Kikori River and Kikori delta areas Papua New Guinea (first draft).* Wetlands International Report.

Jenkins, C. J., Pimm, S. L. & Joppa, L. N. 2013. Global patterns of terrestrial vertebrate diversity and conservation. PNAS 110: E2602–E2610, doi: 10.1073/pnas.1302251110

Johns, R. J. 1993. Biodiversity and conservation of the native flora of Papua New Guinea. Pp. 15–75 *in* Beehler, B.M. (ed.) *Papua New Guinea Conservation Needs Assessment* (Volume 2). Biodiversity Support Program, Washington, D. C.

Johns, R. J., Shea, G. A., Vink, M. & Puradyatmika, P. 2007a. Montane vegetation of Papua. Pp. 977–1,024 *in* Marshall, A. J. and Beehler, B. M. (eds) The ecology of Papua (Part Two). Periplus Editions, Hong Kong.

Johns, R. J., Shea, G. A. & Puradyatmika, P. 2007b. Lowland vegetation of Papua. In: Marshall, A. J. and Beehler, B. M. (eds.) *The ecology of Papua* (Part Two), pp. 945–961. Hong Kong: Periplus Editions.

Johnson, A. 1997. Processes for effecting community participation in conservation drives: a case study of the Crater Mountain Wildlife Management Area. Pp. 44–77 *in* Miller, S. & Sim, J. (comps.) *Sixth South Pacific conference on nature conservation and protected areas*, volume 3, conference papers.

Johnstone, I. M. & Frodin, D. G. 1982. Mangroves of the Papuan seubregion. Pp. 513–528 *in* Gressitt, J. L. (ed.) *Biogeography and ecology of New Guinea* (Volume One). Dr W. Junk Publishers, The Hague.

Kusmana, C. 2014. Distribution and current status of mangrove forests in Indonesia. Pp. 37–65 *in* Faridah-Hanum, I., Latiff, A., Hakeem, K. R. & Ozturk. M. (eds) *Mangrove ecosystems of Asia: Status, challenges and management strategies*. Springer, New York.

Lambeck, R. J. 1997. Focal Species: A Multi-Species Umbrella for Nature Conservation. *Conservation Biology* 11: 849–56.

Lane-Poole, C. E. 1925. *The forest resources of the Territories of Papua and New Guinea*. Printed and published for the Government of the Commonwealth of Australia by H. J. Green, government printer for the State of Victoria, Melbourne.

Leary, T. 1996. *Areas of known exceptional biodiversity or conservation significance in the Kikori Integrated Conservation and Development project area, Papua New Guinea*. WWF Report, Port Moresby, Papua New Guinea.

Leary, T., Naug, R. and Price, J. 1996. Kikori Integrated Conservation and Development Project. Pp. 805–814 *in* Buchanan, P. G. (ed.) *Petroleum exploration, development and production in Papua New Guinea.* Proceedings of the third PNG Petroleum Convention, Port Moresby, 9–11 September 1996.

Liem, D. S. 1983. Survey and management of wildlife resources along the Purari River. Pp. 269–282 *in* Petr, T. (ed.) *The Purari: tropical environment of a high rainfall river basin*. Monographiae Biologicae, Vol. 51. Dr W. Junk Publishers, The Hague.

Liem, D. S. & Haines, A. K. 1977. *The ecological significance and economic importance of the mangrove and estuarine communities of the Gulf Province, Papua New Guinea*. Purari River (Wabo) Hydroelectric Scheme Environmental Studies, Vol. 3. Office of Environment and Conservation, Central Government Offices, Waigani, and Department of Minerals and Energy, Konedobu, 35 pp.

Löffler, E. 1977. *Geomorphology of Papua New Guinea*. CSIRO and Australian National University Press, Canberra.

Mack, A. L. (ed.) 1998. *A biological assessment of the Lakekamu Basin, Papua New Guinea*. Conservation International, Washington, D. C.

Mack, A. L. 2014. *Searching for pekpek: cassowaries and conservation in the New Guinea rainforest*. Cassowary Conservation and Publishing, New Florence, PA, USA.

Mack, A. L. & Dumbacher, J. 2007. Birds of Papua. Pp. 654–688 *in* Marshall, A. J. and Beehler, B. M. (eds.) *The ecology of Papua* (Part One). Periplus Editions, Hong Kong.

Mack, A. L. & West, P. 2005. *Ten thousand tonnes of small animals: wildlife consumption in Papua New Guinea, a vital resource in need of management*. Resource Management in Asia-Pacific Working Paper No. 61.

Mack, A. L. & Wright, D. D. 1998. The Vulturine Parrot, Psittrichas fulgidus, a threatened New Guinea endemic: notes on its biology and conservation. *Bird Conservation International* 8: 185–194.

Mack, A. L. & Wright, D. D. 2005. The Frugivore Community and the Fruiting Plant Flora in a New Guinea Rainforest: Identifying Keystone Frugivores. Pp. 184–203 *in* Dew, L. J., and Boubli, J. P. (eds) *Tropical Fruits and Frugivores: The Search for Strong Interactors*. Springer, The Netherlands.

Marsden, S. J., Symes, C. T. & Mack, A. L. 2006. The response of a New Guinean avifauna to conversion of forest to small-scale agriculture. *Ibis* 148: 629–640.

Mayr, E. 1941. *List of New Guinea birds*. American Museum of Natural History, New York.

McAlpine, J. 1969. Climate of the Kerema–Vailala area. Pp. 50–57 *in* Ruxton, B. P., Bleeker, P., Leach, B. J., McAlpine, J. R., Paijmans, K. & Pullen, R. *Lands of the Kerema–Vailala Area, Territory of Papua New Guinea*. Land Research series No. 23. CSIRO, Melbourne.

McAlpine, J., Keig, G. & Falls, R. 1983. *Climate of Papua New Guinea*. Canberra: Australian National University.

McCall, D. & Flemming, D. 2000. *Chevron and WWF: Lessons learned from six years of collaboration in biodiversity protection*. WWF/Chevron Niugini Report.

McVicar, T. R. & Bierwirth, P. N. 2001. Rapidly assessing the 1997 drought in Papua New Guinea using composite AVHRR imagery. *International Journal of Remote Sensing* 22: 2,109–2,108.

Meijaard, E., Sheil, D., Nasi, R., Augeri, D., Rosenbaum, B., Iskandar, D., Setyawati, T., Lammertink, M., Rachmatika, I., Wong, A., Soehartono, T., Stanley, S. & O'Brien, T. 2005. *Life After Logging: Reconciling Wildlife Conservation and Production Forestry in Indonesian Borneo.* CIFOR, WCS and UNESCO, Bogor, Indonesia.

Menzies, J. I. 2006 *The frogs of New Guinea and the Solomon Islands*. Pensoft, Bulgaria.

Miller, S. E. 1993. Biodiversity and conservation of the nonmarine invertebrate fauna of Papua New Guinea. Pp. 227–325 *in* Beehler, B.M. (ed.) *Papua New Guinea Conservation Needs Assessment* (Volume 2). Biodiversity Support Program Washington, D. C.

Miller, S. E., Osborne, P., Asigau, W. & Mungkage, A. J. 1994. Environments of Papua New Guinea. Pp. 97–124 *in* Sekhran, N. & Miller, S. (eds.) 1995. *Papua New Guinea Country Study on Biological Diversity*. Colorcraft Ltd, Hong Kong.

Mittermeier, R. A., Robles-Gil, P. & Mittermeier, C. G. (eds.) 1997. *Megadiversity. Earth's biologically wealthiest nations*. CEMEX, Mexico City.

Mittermeier, R. A., Mittermeier, C. G., Brooks, T. M., Pilgrim, J. D., Konstant, W. R., da Fonseca, G. A. B. & Kormos, C. 2003. Wilderness and biodiversity conservation. *Proceedings of the National Academy of Sciences U.S.A*. 100: 10309–10313.

Munks, S. A. & Watling, D. 2013. *A review of information on the impact of forestry operations on the biodiversity of PNG's forests*. A report under Project GCP/PNG/003/AUL for the PNG Forest Authority, the Food and Agricultural Organisation of the United Nations and the Australian Government Department of Agriculture, Fisheries and Forestry, May 2013, 67 pp.

Nicholson, E., Lindenmayer, D. B., Frank, K. & Possingham, H. G. 2013. Testing the focal species approach to making conservation decisions for species persistence. *Diversity and Distributions* 19: 530–40.

NSO 2012. *Preliminary figures: Papua New Guinea Census 2011*. National Statistical Office, Port Moresby.

NSO 2014. 2011 *National Population and Housing Census: Ward population profile, Southern Region*. National Statistical Office, Port Moresby.

Numapo, J. 2013. *Commission of Inquiry into the Special Agricultural and Business Lease (SABL).* Final Report. Government of PNG, Port Moresby, 24 June 2013.

O'Brien, T. G., Kinnaird, M. F., Dierenfeld, E. S., Conklin-Brittain, N. L., Wrangham, R. W. & Silver, S. C. 1998. What's so special about figs? *Nature* 392: 668.

Olson, D. M. & Dinerstein, E. 1998. The Global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions. *Conservation Biology* 12: 502–515.

Olson, D. M. & Dinerstein, E. 2002. The Global 200: priority ecosystems for global conservation. *Conservation Biology* 12: 502–515.

Olson, D. M. Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'amico, J. A., Itoua, I., Strand, H. E. Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P. and Kassem, K. R.

2001. Terrestrial ecoregions of the world: a new map of life on Earth. *BioScience* 51(11): 933–938.

Ono, J., Yong, J. W. H., Takayama, K., bin Saleh, M. N., Wee, A. K. S., Asakawa, T., Yllano, O. B., Salmo, S. G. III, Suleiman, M., Tung, N. X., Soe, K. K., Meenakshisundaram, S. H., Watano, Y., Webb, E. L. & Kajita, T. 2016. *Bruguiera hainesii*, a critically endangered mangrove species, is a hybrid between *B. cylindrica* and *B. gymnorhiza* (Rhizophoraceae). *Conservation Genetics*, published online 20 May 2016.

Opdam, P. & Wascher, D. 2004. Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation* 117.3: 285–297.

Paijmans, K. 1969. Vegetation and ecology of the Kerema–Vailala area. Pp. 95–116 *in* Ruxton, B. P., Bleeker, P., Leach, B. J., McAlpine, J. R., Paijmans, K. & Pullen, R. *Lands of the Kerema–Vailala Area, Territory of Papua New Guinea*. Land Research series No. 23. CSIRO, Melbourne.

Paijmans, K. (ed.) 1976. *New Guinea vegetation*. CSIRO and Australian National University Press, Canberra.

Paijmans, K. 1983. The vegetation of the Purari catchment. Pp. 227–252 *in* Petr, T. (ed.) *The Purari: tropical environment of a high rainfall river basin*. Monographiae Biologicae, Vol. 51. Dr W. Junk Publishers, The Hague.

Pain, C. F. 1983. Introduction to the Purari River catchment. Pp. 1–7 *in* Petr, T. (ed.) *The Purari: tropical environment of a high rainfall river basin*. Monographiae Biologicae, Vol. 51. Dr W. Junk Publishers, The Hague.

Parsons, M. 1999. *The butterflies of Papua New Guinea: their systematics and biology.* Academic Press, London.

Pearson, D. L. 1977. A pantropical comparison of bird community structure on six lowland rain forest sites. *Condor* 79: 232–244.

Percival, M. & Womersley, J. S. 1975. *Floristics and ecology of the mangrove vegetation of Papua New Guinea*. Botany Bulletin No. 8. Papua New Guinea National Herbarium, Department of Forests, Lae.

Pernetta, J. C. 1983. The wildlife of the Purari catchment. Pp. 253–268 *in* Petr, T. (ed.) *The Purari: tropical environment of a high rainfall river basin*. Monographiae Biologicae, Vol. 51. Dr W. Junk Publishers, The Hague.

Petr, T. (ed.) 1983a. Introduction. Pp. XIII–XVI *in* Petr, T. (ed.) *The Purari: tropical environment of a high rainfall river basin. Monographiae Biologicae*, Vol. 51. Dr W. Junk Publishers, The Hague.

Petr, T. (ed.) 1983b. *The Purari: tropical environment of a high rainfall river basin*. Monographiae Biologicae, Vol. 51. Dr W. Junk Publishers, The Hague.

Pieters, P. E. 1980. *The geology of the Kikori 1:250 000 Sheet area, PNG*. Record 1980/79, Bureau of Mineral Resources, Geology and Geophysics, Canberra.

PNG 2007. *Papua New Guinea national Biodiversity Strategy and Action Plan*. Government of the Independent State of Papua New Guinea.

PNG 2010. *Papua New Guinea's Fourth National Report to the Convention on Biological Diversity*. United Nations Environment Programme (UNEP), Global Environment Facility (GEF), Government of the Independent State of Papua New Guinea.

Polhemus, D. A. & Allen, G. R. 2007. Inland water ecosystems in Papua: classification, biota and threats. Pp. 858–900 *in* Marshall, A. J. and Beehler, B. M. (eds.) *The ecology of Papua* (Part Two). Periplus Editions, Hong Kong.

Polhemus, D. A., Englund, R. A. & Allen, G. R. 2004. *Freshwater biotas of New Guinea and nearby islands: analysis of endemism, riches, and threats*. Bishop Museum Technical Report No. 31, Contribution No. 2004-004 to the Pacific Biological Survey. Report to Conservation International, Washington, D. C.

Pratt, T. K. & Beehler, B. M. 2015. *Birds of New Guinea*. 2nd edition. Princeton University Press, Princeton.

Rajpar, M. N. & Zakaria, M. 2014. Mangrove fauna of Asia. Pp. 153–197 *in* Faridah-Hanum, I. et al. (eds.) *Mangrove ecosystems of Asia*. Springer, New York.

Richards, S. J. and Gamui, B. G. (eds.) 2011. *Rapid Biological Assessments of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments*. RAP Bulletin of Biological Assessment 60. Arlington, VA: Conservation International.

Richards, S. J., Kawanamo, M. & Torr, G. 1998. Odonata (dragonflies and damselflies) Pp. 47–49 and 144–148 *in* Mack. A. (ed.) *A Biological assessment of the Lakekamu Basin, Papua New Guinea*. Rapid Assessment Program Working Paper Number 9. Conservation International, Washington.

Ruxton, B. P. 1969a. Regional description of the Kerema–Vailala area. Pp. 9–16 *in* Ruxton, B. P., Bleeker, P., Leach, B. J., McAlpine, J. R., Paijmans, K. & Pullen, R. *Lands of the Kerema–Vailala Area, Territory of Papua New Guinea*. Land Research Series No. 23. CSIRO, Melbourne.

Ruxton, B. P. 1969b. Geomorphology of the Kerema–Vailala area. Pp. 65–76 *in* Ruxton, B. P., Bleeker, P., Leach, B. J., McAlpine, J. R., Paijmans, K. & Pullen, R. *Lands of the Kerema–Vailala Area, Territory of Papua New Guinea*. Land Research series No. 23. CSIRO, Melbourne.

Ruxton, B. P., Paijmans, K., Bleeker, P. & Leach, B. J. 1969a. Land systems of the Kerema–Vailala area. Pp. 17–49 *in* Ruxton, B. P., Bleeker, P., Leach, B. J., McAlpine, J. R., Paijmans, K. & Pullen, R. *Lands of the Kerema–Vailala Area, Territory of Papua New Guinea*. Land Research series No. 23. CSIRO, Melbourne.

Ruxton, B. P., Bleeker, P., Leach, B. J., McAlpine, J. R., Paijmans, K. & Pullen, R. 1969b. *Lands of the Kerema–Vailala Area, Territory of Papua New Guinea*. Land Research series No. 23. CSIRO, Melbourne.

Sanderson, E. W., Jaiteh, M., Levy, M. A., Redford, K. H., Wannebo, A. V. & Woolmer, G. 2002. The human footprint and the last of the wild. *Bioscience* 52: 891–904.

Saulei, S. M. & Beehler, B. M. 1993. Biodiversity and conservation of humid forest environments in Papua New Guinea. Pp. 423–433 *in* Beehler, B. M. (ed.) *Papua New Guinea Conservation Needs Assessment* (Volume 2). Biodiversity Support Program Washington, D. C.

Sekhran, N. & Miller, S. (eds.) 1995. *Papua New Guinea Country Study on Biological Diversity*. Colorcraft Ltd, Hong Kong.

Shanahan, M., So, S., Compton, S. G. & Corlett, R. 2001. Fig-eating by vertebrate frugivores: A global review." *Biological Review* 76: 529–572.

Shearman, P. L., Bryan, J. E. & Walsh, J. P. 2013. Trends in deltaic change over three decades in the Asia-Pacific region. *Journal of Coastal Research* 29: 1,169–1,183.

Spalding, M., Kainuma, M., Collins, L. 2010. *World Atlas of Mangroves*. A collaborative project of ITTO, ISME, FAO, UNEP-WCMC, UNESCO-MAB, UNU-INWEH and TNC. Earthscan, London. 319 pp. URL: http://www.routledge.com/books/details/9781844076574; http://data.unepwcmc.org/datasets/5

Stattersfield, A. J., Crosby, M. J., Long, A. J. & Wege, D. C. 1998. *Endemic Bird Areas of the World*. BirdLife International, Cambridge, UK.

Swartzendruber, J. F. 1993. *Papua New Guinea conservation needs assessment: synopsis report*. Washington, D.C. & Boroko, Papua New Guinea: Biodiversity Support Program & Govt. of Papua New Guinea, Dept. of Environment and Conservation.

Symes, C. T., Hughes, J. C., Mack, A. L. & Marsden, S. J. 2006. Geophagy in birds of Crater Mountain Wildlife Management Area, Papua New Guinea. *Journal of Zoology* 268: 87–96.

Szabo, J. K., Choi, C.-Y., Clemens, R. S. & Hansen, B. 2016. Conservation without borders – solutions to declines of migratory shorebirds in the East Asian–Australasian Flyway. *Emu* 116: published online 5 April 2016.

Takeuchi, W. N. 1999. New plants from Crater Mt., Papua New Guinea, and an annotated checklist of the species. SIDA Contributions to Botany 18: 941–986.

Takeuchi, W. N. 2003. A community-level floristic reconnaissance of the Raja Ampat Islands in New Guinea. *Saia* 20: 1093–1144.

Takeuchi, W. N. 2007. Introduction to the flora of Papua. Pp. 269–302 *in* Marshall, A. J. & Beehler, B. M. (eds.) *The ecology of Papua* (Part One). Periplus Editions, Hong Kong.

Takeuchi, W. N. 2011. Vascular plants of the Strickland Basin, Papua New Guinea: taxonomic and vegetation survey. In: Richards, S. J. and Gamui, B. G. (eds.) 2011. *Rapid Biological Assessments of the Nakanai Mountains and the upper Strickland Basin: surveying the biodiversity of Papua New Guinea's sublime karst environments*, pp. 119–157. RAP Bulletin of Biological Assessment 60. Arlington, VA: Conservation International.

Takeuchi, W. N. 2012. Floristic discoveries from the LNG Pipeline in Papua New Guinea: *Macaranga esseriana* sp. nov. (Euphorbiaceae), and noteworthy records for twelve taxa from the southern provinces. *Phytotaxa* 56: 35–58.

Theim, T. J., Shirk, R. Y. & Givnish, T. J. 2014. Spatial genetic structure in four understory *Psychotria* species (Rubiaceae) and implications for tropical forest diversity. *American Journal of Botany* 101: 1,189–1,199.

TOTAL 2014. *Code of Conduct.* Available at www.total.com

Thom, B. G. & Wright, L. D. 1983. Geomorphology of the Purari delta. Pp. 47–65 *in* Petr, T. (ed.) *The Purari: tropical environment of a high rainfall river basin*. Monographiae Biologicae, Vol. 51. Dr W. Junk Publishers, The Hague.

Thompson, C. 2011. *Final Frontier: Newly Discovered Species of New Guinea (1998–2008)*. WWF Report. WWF Western Melanesia Programme Office.

UNESCO 2012. *Kikori River Basin/Great Papuan Plateau*. Available at: http://whc.unesco.org/en/tentativelists/5060/

van Welzen, P. C. 1994. Guioa Cav. (Sapindaceae): taxonomy, phylogeny, and historical biogeography. Rijksherbarium, Leiden, The Netherlands, 314 pp.

Verdcourt, B. 1979. *A manual of New Guinea legumes*. Kristen Pres, Madang, PNG.

Vermeulen, J. & Whitten, T. 1999. *Biodiversity and cultural property in the management of limestone resources – lessons from east Asia*. Washington, DC: World Bank.

Watson, M. & Asoyama, S. 2001. Dispersion, habitat use, hunting behaviour, vocalizations, and conservation status of the New Guinea Harpy Eagle (Harpyopsis novaeguineae). *Journal of Raptor Research* 35: 235–239.

West, P. & Kale, E. 2015. Ch. 7: The Fate of Crater Mountain: Forest Conservation in the Eastern Highlands of Papua New Guinea. Pp. 155–178 *in* Bell J. A., West, P. & Filer, C. (eds) *Tropical forests of Oceania*. ANU Press, The Australian National University, Canberra, Australia.

Whitmore, T. C. 1984. *Tropical rain forests of the Far East* (2nd edition). Clarendon Press, Oxford.

Whitmore, T. C. 1998. *An introduction to tropical rain forests*. Second Edition. Oxford University Press, New York.

Wikramanayake, E., Dinerstein, E., Loucks, C. J., Olson, D. M., Morrison, J., Lamoreux, J., McKnight, M. & Hedao, P. 2002. *Terrestrial eco-regions of the Indo-Pacific: a conservation assessment*. Island Press, Washington, D. C.

Wilson, H. B., Kendall, B. E., Fuller, R. A., Milton, D. A. & Possingham, H. P. 2011. Analyzing variability and the rate of decline of migratory shorebirds in Moreton Bay, Australia.

Womersley, J. S. 1975. Management of mangrove forests. Utilisation versus conservation, with special reference to the forest of the Papuan Gulf. Pp. 732–741 *in* Walsh, G. S., Sneddaker, S. C. & Teas, H. J. (eds.) *Proceedings of the international symposium and management of mangrove*. Institute of Food and Agricultural Science, University of Florida, Gainesville, Florida.

Wood, A. W. 1983. Soil types and traditional soil management in the Purari catchment. Pp. 67–85 *in* Petr, T. (ed.) *The Purari: tropical environment of a high rainfall river basin. Monographiae Biologicae*, Vol. 51. Dr W. Junk Publishers, The Hague.

Worley Parsons 2009. *Liquid Niugini Gas Pipeline Terrestrial Fauna Assessment*. Worley Parsons, 16 June 2009. Document no. 301001-00033 – 00-EN-REP-0001

Wynne, J. J. & Pleytez, W. 2005. Sensitive ecological areas and species inventory of Actun Chapat Cave, Vaca Plateau, Belize. *Journal of Cave and Karst Studies* 67: 148–157.

Appendix 1.

Example Sensitivity Criteria for Ecosystems and Focal Sites/Habitats

Appendix 1

Example criteria used to score the sensitivity of ecosystems and focal sites/habitats. The criteria were developed specifically for this study based on systems applied in other PNG projects. 'Local' and 'regional' availability refers to study area and broader biogeographic region respectively.

Score	Intrinsic Worth	Intactness	Replacement Potential	Recovery Potential
Ecosystems				
1	Ecosystem supports few or no native species and/or invasive species are prevalent	Areas with little or no remnant vegetation and/or areas are highly degraded	The ecosystem is common and widespread locally, regionally and nationally, with high connectivity to comparable environments outside the study area	Recolonization by and/or revegetation with native/endemic species to restore ecosystem structure and function occurs without intervention and is expected to be successful in all cases
2	Ecosystem supports viable assemblages of some native species, but plant and/or animal communities are significantly altered from original composition found elsewhere locally in intact habitats. Invasive species may be present	Converted land retaining some native vegetation cover, or natural vegetation extensively/heavily degraded by human activity	The ecosystem is common locally and regionally, with moderately high connectivity to comparable environments outside the study area	Recolonization by and/or revegetation with native/endemic species to restore ecosystem structure and function occurs is expected to be successful in most of cases without intervention
3	A natural ecosystem/habitat area supporting viable assemblages of native plant and animal species that are largely unaltered from original composition. Conservation listed species may be present	An area of natural habitat where human activity has not significantly modified the area's primary ecological functions, species composition or forest structure	The ecosystem has a moderate number of local and regional equivalents, with some connectivity to comparable environments outside the study area	Recolonization by and/or revegetation with native/endemic species to restore ecosystem structure and function is slow and/or partially successful without intervention
4	A natural ecosystem/habitat area that: ♦ Supports high/regionally important concentrations of IUCN Threatened and/or other Very Sensitive species ♦ Supports >5% of the entire known population of an endemic, restricted-range or congregatory species ♦ Supports a unique species assemblage and/or a high proportion of habitat-specialist species in a small area	The ecosystem is essentially unmodified by human activity and its primary ecological functions and species composition are intact. Wilderness values recognized	The ecosystem is rare locally and regionally, or has a moderate number of regional equivalents that have been extensively harvested, with limited connectivity to comparable environments outside the study area	Recolonization by and/or revegetation with native/endemic species to restore ecosystem structure and function requires significant intervention and/or is only successful in a minority of cases

Score	Intrinsic Worth	Intactness	Replacement Potential	Recovery Potential
	♦ Is of local/regional importance to migratory species ♦ Is a protected area ♦ Is Tier 2 Critical Habitat			
5	A natural ecosystem/habitat area that: ♦ Supports IUCN Critically Endangered or other Extremely Sensitive species where that area is one of five or fewer known sites ♦ Is critical to the survival of a species or ecological community ♦ Is Tier 1 Critical Habitat	The ecosystem is unmodified by human activity; ecological functions and species composition are unmodified. Wilderness values recognized	The ecosystem is unique or very rare locally and regionally	Recolonization by and/or revegetation with native/endemic species to restore ecosystem structure and function is problematic with success unlikely
Focal Sites				
1	A local landscape (terrain/habitat) feature which is likely to only be used by a limited number of species and/or limited number of individuals of one or more species that are not sensitive or low sensitivity	Converted or highly modified by human activity; rarely used	♦ The feature is common and widespread locally, regionally and nationally ♦ Numerous replacements exist within the territory/home range of the species	The feature is robust and will recover from disturbance in a short time
2	A local landscape (terrain/habitat) feature which multiple species and/or multiple individuals of one or more species will opportunistically use	Largely modified by human activity; may be used opportunistically	♦ The feature is common and widespread locally and regionally ♦ The feature can be replaced/relocated with minimum effort	The feature is relatively robust and will recover from disturbance in a moderate time
3	A local landscape (terrain/habitat) feature upon which multiple species and/or multiple individuals of one or more species (excluding not sensitive species) are ecologically dependent	Modified by human activity and/or subject to some disturbance but has evidence of use	♦ The feature is not common but is widespread locally and regionally ♦ The feature can be replaced/relocated with moderate effort	The feature is likely to recover from disturbance over a long time
4	A local landscape (terrain/habitat) feature upon which one or more IUCN Threatened or other Very Sensitive species is ecologically dependent	Unmodified and undisturbed by human activity and has evidence of recent and/or regular use	♦ The feature has restricted regional distribution and limited local availability ♦ The feature is difficult to replace/relocate	The feature is relatively fragile and may not recover from disturbance

Score	Intrinsic Worth	Intactness	Replacement Potential	Recovery Potential
5	A local landscape (terrain/habitat) feature upon which one or more IUCN Critically Endangered or other Extremely Sensitive species is ecologically dependent	Unmodified and undisturbed by human activity and has evidence of recent, frequent use	♦ The feature has very limited local availability ♦ The feature is extremely difficult to replace/relocate	The feature is fragile and is unlikely to recover from disturbance

Appendix 2.

Example Sensitivity Criteria for New-to-science, Other Scientifically Undescribed and Restricted-range Species

Appendix 2

Example criteria used to score the sensitivity of new-to-science, other scientifically undescribed and restricted-range species. The criteria were developed specifically for this study based on systems applied in other PNG projects. For each species, the scores for each factor were summed to provide an overall sensitivity ranking according to the numeric system described in Section 5.5.3, Table 5.6.

Factor/Score	Criteria
Habitat Specialization	
1	Multiple or widespread vegetation types, tolerant of habitat disturbance
2	Primary forest; shaded environments within a forest type, potentially susceptible to canopy disturbance; fauna—microhabitat (e.g., streams) required at some life history stage within a widespread forest type
3	Single restricted and/or exploited vegetation type, or restricted areas at interface; strong microhabitat preference; fauna—specific microhabitat requirement at some life history stage within a restricted or primary vegetation type
4	Specialist occupant of microhabitat within primary vegetation type
Dispersal (Flora Only)	
1	High dispersal potential (e.g., bird/mammal dispersed canopy species; wind dispersed in open/disturbed enviroments)
2	Moderate dispersal potential (e.g., wind dispersed in forest; bird/mammal dispersed understorey species (Theim et al. 2014)); dispersal ecology not known
3	Low dispersal potential (e.g., water dispersed on drainage lines in steep forested terrain)
Geographic Spread of Recorded Occurrence	
1	New-to-science and regionally poorly sampled: recorded at 4+ sites and/or 3+ ecological zones. Undescribed but regionally well sampled: widespread, not restricted-range. Restricted-range: not applicable
2	New-to-science and regionally poorly sampled: recorded at 2-3 sites in 2+ ecological zones and/or multiple catchments. Undescribed but regionally well sampled/restricted-range: potentially restricted-range, but extends beyond Gulf Province into Western Province or southeast peninsula
3	New-to-science and regionally poorly sampled: recorded at 2 sites in a limited area within one ecological zone/catchment. Undescribed but regionally well sampled/restricted-range: extends beyond study area into adjacent Kikori and Lakekamu catchments
4	New-to-science and regionally poorly sampled: recorded at a single site. Regionally well sampled/restricted-range: not known from adjacent Kikori and Lakekamu catchments despite relevant survey effort
Rarity/Abundance	
1	Locally fairly common to common
2	Locally uncommon to fairly common
3	Uncommon to rare, few examples in few populations (plants) difficult to detect (fauna)
4	Rare to very rare, <10 examples of plants, fauna reasonably easy to detect with sufficient survey effort

Appendix 3.

FIMS Vegetation Descriptions and Terms

Appendix 3

FIMS vegetation descriptions and equivalent terms used in the terrestrial biodiversity baseline study.

Broad Vegetation Group/ FIMS Code	FIMS Group/Description	Biodiversity Study Term
Natural Vegetation Types		
Hill forest		
H	***Low altitude forest on uplands (below 1,000 m)***	***Hill forest***
Hm	Medium crowned forest	Hill forest
Hm.Ar	Medium crowned forest - Presence of *Araucaria* noted	Hill forest, *Araucaria* noted
Hm/Hs	Complex: Medium/Small crowned forest	Hill forest/small crowned hill forest
Hs	Small crowned forest	Small crowned hill forest
Alluvial forest		
P	***Low altitude forest on plains and fans (below 1,000 m)***	***Alluvial forest***
Pl	Large to medium crowned forest	Alluvial forest
Pl/Fsw	Complex: Large to medium crowned forest/Mixed swamp forest	Alluvial forest/Swamp forest
Po	Open forest	Open alluvial forest
Po/Fsw	Complex: Open forest/Mixed swamp forest	Open alluvial forest/Swamp forest
Po/Fsw/Hm	Complex: Open forest/Mixed swamp forest/Medium crowned low altitude forest on uplands	Open alluvial forest/Swamp forest/Hill forest
Po/Fsw/M	Complex: Open forest/Mixed swamp forest/Mangrove	Open alluvial forest/Swamp forest/Mangrove
Po/Hsw	Complex: Open forest/Herbaceous swamp	Open alluvial forest/Herbaceous Swamp
Po/Wsw	Complex: Open forest/Swamp woodland	Open alluvial forest/Swamp woodland
Ps	Small crowned forest	Small crowned alluvial forest
Fri	***Seral forest***	
Fri	Riverine mixed successions	Riverine seral forest
Freshwater swamp vegetation		
Fsw	***Swamp forest***	
Fsw	Mixed swamp forest	Swamp forest

Broad Vegetation Group/ FIMS Code	FIMS Group/Description	Biodiversity Study Term
FswC	Swamp forest with Campnosperma	Swamp forest with Campnosperma
Fsw/Gsw	Complex: Mixed swamp forest/Swamp grassland	Swamp forest/Swamp grassland
Fsw/M	Complex: Mixed swamp forest/Mangrove	Swamp forest/Mangrove
Fsw/Wsw	Complex: Mixed swamp forest/Swamp woodland	Swamp forest/Swamp woodland
W	***Woodland***	
Wsw	Swamp woodland	Swamp woodland
Wsw/Fsw	Complex: Swamp woodland/Mixed swamp forest	Swamp woodland/Swamp forest
Wsw/Gsw	Complex: Swamp woodland/Swamp grassland	Swamp woodland/Swamp grassland
Wsw/Hsw	Complex: Swamp woodland/Herbaceous swamp	Swamp woodland/Herbaceous swamp
G/Hsw	***Grassland and herbland***	
Gsw/Fsw	Complex: Swamp grassland/Mixed swamp forest	Swamp grassland/Swamp forest
Gsw/Wsw	Complex: Swamp grassland/Swamp woodland	Swamp grassland/Swamp woodland
Gri	Riverine successions dominated by grass	Riverine successional grassland
Hsw	Herbaceous swamp	Herbaceous swamp
Hsw/Fsw	Complex: Herbaceous swamp/Mixed swamp forest	Herbaceous swamp/Swamp forest
Hsw/Gsw	Complex: Herbaceous swamp/Swamp grassland	Herbaceous swamp/Swamp grassland
Hsw/Wsw	Complex: Herbaceous swamp/Swamp woodland	Herbaceous swamp/Swamp woodland
Littoral forest		
B	***Littoral forest***	
B	Mixed forest	Littoral forest
Mangroves		
M	***Estuarine Communities***	
M	Mangrove	Mangrove
Non-vegetation and Land Use Areas		
Converted lands		
O	Non-forest areas dominated by land use	Land use
U	Larger urban areas	Urban areas
Open water		

Broad Vegetation Group/ FIMS Code	FIMS Group/Description	Biodiversity Study Term
E	Lakes and large rivers	Rivers and lakes

Appendix 4.

IUCN listed, Nationally Protected and Scientifically Named Restricted-range Species Recorded or Potentially Occurring in the Study Area

Appendix 4

IUCN listed, nationally Protected and scientifically named restricted-range species recorded or potentially occurring in the study area. 'Conservation listing' displayed as: IUCN/PNG Protected (P)/CITES (Appendix I or II)/Restricted-range (RR). IUCN codes are explained in Section 5.4.1.1. IUCN Least Concern or Not Evaluated species listed only under CITES Appendix II are not shown unless their sensitivity is ranked as Moderate or higher. Sensitivity: ES—Extremely Sensitive; VS—Very Sensitive; MS—Moderately Sensitive; LS—Low Sensitivity. 'Project surveys' show records from: survey sites in numerical order (1, 2, 3, 4, 5, 6A, 6B, 6C, 6D, 7, 8, 8M, 9); local landowner testimony (L); Wi'i Creek cave bone deposits (WC); the Purari River area in south of PRL-15 (PR); blank cells indicate no records from Project surveys. Provisional (probable but uncertain) records are shown in square brackets. 'Major environments' indicates suitability (recorded and potential) of 10 major natural habitats and of converted lands; '?' indicates uncertain whether the species occupies this habitat; species known only from the type collection (six restricted-range plants, see Section 6.3.4.2) show only the recorded habitat (where known). 'Ecological zones': MPH—Middle Purari Hills; SH—Southeast Hills; DSP—Delta Swamps and Plains; SEC—Southeast Coast; Mv—Mangroves; X—confirmed record in ecological zone; A—possible occurrence in suitable habitat within ecological zone; species known only from the type collection show only the recorded ecological zone.

English Name	Scientific Name	Conservation Status	Sensitivity	Project Sites	Prior Surveys	Major Environments											Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Low Freshwater Swamp Vegetation (Hsw, Gsw, Gri)	Mangrove (M)	Littoral Forest (B)	Tidal Wetlands	Watercourses	Off-river Waterbodies	Near-shore Marine/Estuarnewaters	Converted Lands	MPH	SH	DSP	SEC	Mv
Flora																					
	Gluta papuana	VU/-/-/-	VS		X		X	X										A	X	A	A
	Pentaspadon motleyi	DD/-/-/-	LS		X		X	X										A	X	A	A
	Cyathocalyx lucidus	NE/-/-/RR	VS		X	X												X			
	Pseuduvaria filipes	NE/-/-/RR	MS	3,7		X											A	X			
	Marsdenia venusta	NE/-/-/RR	VS		X ?	X ?	X ?											X ?		X ?	
	Avicennia rumphiana	VU/-/-/-	VS							X											A

English Name	Scientific Name	Conservation Status	Sensitivity	Project Sites	Prior Surveys	Major Environments										Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Low Freshwater Swamp Vegetation (Hsw, Gsw, Gri)	Mangrove (M)	Littoral Forest (B)	Tidal Wetlands	Watercourses	Off-river Waterbodies	Near-shore Marine/Estuarnewaters	Converted Lands	MPH	SH	DSP	SEC	Mv
	Mammea grandifolia	VU/-/-/RR	VS	3–5,6B,7		X	X										X	X	X	A	
	Mammea novoguineensis	DD/-/-/-	LS	4,5,7,8,9		X	X										X	X	X	X	
	Ceratopetalum succirubrum	VU/-/-/-	VS	7		X	X										A	X	X		
	Cycas scratchleyana	NT/-/II/-	MS	1–6B,6D,7		X	X										X	X	X	A	
	Diospyros insularis	EN/-/-/-	VS	6B		X	X										X	A	A		
	Diospyros lolinopsis	CR/-/-/-	ES	7		X	X	X									A	A	X		
	Archidendron forbesii	VU/-/-/-	VS	2		X	X										X	A	A	A	
Kwila/Merbau	*Intsia bijuga*	VU/-/-/-	VS	4–6B,7,8,9		X	X				X						X	A	X	X	
	Koompassia grandiflora	VU/-/-/-	VS			X	X										A	A	A	A	
Burmese Rosewood	*Pterocarpus indicus*	VU/-/-/-	VS	1–6A,7–9		X	X	X		X	X						X	X	X	X	X
	Cyrtandra externata	NE/-/-/RR	VS		X		X ?	X?												X	
	Magnolia tsiampacca	DD/-/-/-	LS	1,8		X											X	X			
	Brownlowia argentata	DD/-/-/-	LS		X			X		X									X		A
Pacific Maple	*Aglaia cucullata*	DD/-/-/-	LS	6B,7			X	X		X								A	X	A	A
	Aglaia euryanthera	NT/-/-/-	MS	1–6A		X	X										X	X	X	A	
	Aglaia rimosa	NT/-/-/-	MS	7		X											A	X			
	Myristica brachypoda	VU/-/-/RR	VS			X	X	X									A	A	A	A	
	Myristica globosa	NT/-/-/-	MS	2,5,6B		X	X										X	A	X	A	
	Glochidion delticola	NE/-/-/RR	VS		X		X	X		X									X		

English Name	Scientific Name	Conservation Status	Sensitivity	Project Sites	Prior Surveys	Major Environments										Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Low Freshwater Swamp Vegetation (Hsw, Gsw, Gri)	Mangrove (M)	Littoral Forest (B)	Tidal Wetlands	Watercourses	Off-river Waterbodies	Near-shore Marine/Estuarnewaters	Converted Lands	MPH	SH	DSP	SEC	Mv
	Helicia amplifolia	NT/-/-/-	MS	2		X											X	A			
	Helicia latifolia	NT/-/-/-	MS	2		X											X	A			
	Bruguiera hainesii	CR/-/-/-	ES	9						X										A	X
	Ixora whitei	NE/-/-/RR	VS		X		X	X												X	
	Psychotria diplococca var. *tauriensis*	NE/-/-/RR	MS		X	X	X	X		X							A	X ?	X ?	X ?	A
	Psychotria heterophylla	NE/-/-/RR	VS		X					X										X	
	Psychotria purariensis	NE/-/-/RR	MS		X		X	X									X	A	A	A	
	Flindersia amboinensis	NT/-/-/-	MS			X	X										A	A	A	A	
Maple Silkwood	*Flindersia pimenteliana*	EN/-/-/-	VS	7		X											A	X			
	Flindersia schottiana	NT/-/-/-	MS			X	X										A	A	A	A	
	Guioa hospita	CR/-/-/-	ES			X											A	A			
Non-volant Mammals																					
Eastern Long-beaked Echidna	*Zaglossus bartoni*	VU/P/II/-	VS	L		X	X										X	A	A	A	
New Guinea Quoll	*Dasyurus albopunctatus*	NT/-/-/-	MS	L		X	X										X	A	A	A	
Woolley's Three-striped Dasyure	*Myoictis leucura*	DD/-/-/RR	MS	2,4		X	X										X	A	X	A	
Goodfellow's Tree Kangaroo	*Dendrolagus goodfellowi*	EN/P/-/-	VS	L		X											X				
Western Montane Tree Kangaroo	*Dendrolagus notatus*	EN/P/-/-	VS	L		X											X				
Lowland Tree Kangaroo	*Dendrolagus spadix*	VU/P/-/RR	VS	L		X	X										X		A		

English Name	Scientific Name	Conservation Status	Sensitivity	Project Sites	Prior Surveys	Major Environments										Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Low Freshwater Swamp Vegetation (Hsw, Gsw, Gri)	Mangrove (M)	Littoral Forest (B)	Tidal Wetlands	Watercourses	Off-river Waterbodies	Near-shore Marine/Estuarnewaters	Converted Lands	MPH	SH	DSP	SEC	Mv
Grey Dorcopsis	*Dorcopsis luctuosa*	VU/-/-/-	VS	1–6A,7,8,9		X	X										X	X	X	X	
Dusky Pademelon	*Thylogale brunii*	VU/-/-/-	VS	[L]		X											[X]	[X]			
Oriomo Bandicoot	*Echymipera oriomo*	NE/-/-/RR	MS	4,5,8,9,L		X	X										X	A	X	X	
Purari Long-nosed Bandicoot	*Echymipera rufescens* subsp.	NE/-/-/RR	MS	1,3–5,7,8,9,WC,L		X	X										X	X	X	X	
Giant Bandicoot	*Peroryctes broadbenti*	EN/-/-/RR	VS	7,8,9		X	X											A	X	X	
Long-footed Paramelomys	*Paramelomys levipes*	LC/-/-/RR	LS	1,2,4,7,8,9, WC		X	X										X	X	X	X	
False Water Rat	*Xeromys myoides*	VU/-/I/-	VS	5,8,[8M(L)]		X	X	X	X	X				X			X		A	X	A
Southern Groove-toothed Shrew Mouse	*Microhydromys argenteus*	DD/-/-/-	LS			X	X										A	A	A	A	
Bats																					
Bulmer's Fruit Bat	*Aproteles bulmerae*	CR/P/-/RR	ES	WC		X	X									?	X	A	A		
Papuan Free-tailed Bat	*Otomops papuensis*	DD/-/-/RR	MS	8	X	X	X	X	?	?	X					?	X	X	A	X	A
Semon's Leaf-nosed Bat	*Hipposideros semoni*	DD/-/-/-	LS	[1,3–5,7,8]		X	X	?		?	X					?	[X]	[X]	[X]	[X]	?
New Guinea Sheath-tailed Bat	*Emballonura furax*	DD/-/-/-	LS	7	X	X	X	?	?	?						?	A	X	X	A	?
Papuan Sheath-tailed Bat	*Saccolaimus mixtus*	DD/-/-/-	LS	1–5,7–9		X	X	X	X	X	X					?	X	X	X	X	X
Small Melanesian Bent-winged Bat	*Miniopterus macrocneme*	DD/-/-/-	LS			X	X	X	X	X	X					?	A	A	A	A	A
Watts's Pipistrelle	*Pipistrellus wattsi*	LC/-/-/RR	LS			?	?	?	?	?	?					?	A	A	A	A	A
Birds																					

English Name	Scientific Name	Conservation Status	Sensitivity	Project Sites	Prior Surveys	Major Environments											Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Low Freshwater Swamp Vegetation (Hsw, Gsw, Gri)	Mangrove (M)	Littoral Forest (B)	Tidal Wetlands	Watercourses	Off-river Waterbodies	Near-shore Marine/Estuarnewaters	Converted Lands	MPH	SH	DSP	SEC	Mv
Southern Cassowary	*Casuarius casuarius*	VU/-/-/-	VS	1–6B,6D–8,9	X	X	X	X									X	X	X	X	
Salvadori's Teal	*Salvadorina waigiuensis*	VU/P/-/-	VS			X							X				A				
Forest Bittern	*Zonerodius heliosylus*	NT/-/-/-	MS			X	X	X					X				A	A	A	A	
Great Egret	*Ardea alba*	LC/P/-/-	MS	4,5,6C,8–9,PR	X				X	X		X	X	X		X	X	A	X	X	X
Intermediate Egret	*Egretta intermedia*	LC/P/-/-	MS	6C,7,9,PR	X				X	X		X	X	X		X	X	X	X	X	A
Little Egret	*Egretta garzetta*	LC/P/-/-	MS	5,6C,8,9,PR	X				X	X		X	X	X		X	X	A	X	X	X
Eastern Osprey	*Pandion cristatus*	LC/P/II/-	MS							X	X		X	X	X		A	A	A	A	A
Papuan Eagle	*Harpyopsis novaeguineae*	VU/P/II/-	VS	2,7	X	X	X										X	X	X	A	
Gurney's Eagle	*Aquila gurneyi*	NT/-/II/-	MS	6A,PR		X	X	X									X	A	X	A	A
Chestnut-shouldered Goshawk	*Erythrotriorchis buergersi*	DD/-/II/-	LS			X											A				
Doria's Goshawk	*Megatriorchis doriae*	NT/-/II/-	MS			X	X	X		X							A	A	A	A	A
New Guinea Flightless Rail	*Megacrex inepta*	NT/-/-/-	MS	8(L),9(L)				X		X								A	A	X	A
Beach Stone-curlew	*Esacus magnirostris*	NT/-/-/-	MS							X	X	X								A	A
Asian Dowitcher	*Limnodromus semipalmatus*	NT/-/-/-	MS							X		X								A	A
Black-tailed Godwit	*Limosa limosa*	NT/-/-/-	MS		X					X		X								A	X
Bar-tailed Godwit	*Limosa lapponica*	NT/-/-/-	MS							X		X								A	A
Far Eastern Curlew	*Numenius madagascariensis*	EN/-/-/-	VS		X					X		X								A	X
Grey-tailed Tattler	*Tringa brevipes*	NT/-/-/-	MS							X		X								A	A

English Name	Scientific Name	Conservation Status	Sensitivity	Project Sites	Prior Surveys	Major Environments											Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Low Freshwater Swamp Vegetation (Hsw, Gsw, Gri)	Mangrove (M)	Littoral Forest (B)	Tidal Wetlands	Watercourses	Off-river Waterbodies	Near-shore Marine/Estuarnewaters	Converted Lands	MPH	SH	DSP	SEC	Mv
Great Knot	*Calidris tenuirostris*	EN/-/-/-	VS							X		X								A	A
Red Knot	*Calidris canutus*	NT/-/-/-	MS							X		X								A	A
Red-necked Stint	*Calidris ruficollis*	NT/-/-/-	MS							X		X		X				A	A	A	A
Curlew Sandpiper	*Calidris ferruginea*	NT/-/-/-	MS							X		X		X				A	A	A	A
Scheepmaker's Crowned Pigeon	*Goura scheepmakeri*	VU/P/II/RR	VS	1,2,3–6B,7,8,9	X	X	X	X									X	A	X	X	
Papuan Hawk-Owl	*Uroglaux dimorpha*	DD/-/II/-	LS			X	X										A	A	A	A	
Starry Owlet-nightjar	*Aegotheles tatei*	DD/-/-/RR	VS	5		X	X										A	A	X		
Wallace's Owlet-nightjar	*Aegotheles wallacii*	DD/-/-/-	LS			X											A	A			
Three-toed Swiftlet	*Aerodramus papuensis*	DD/-/-/-	LS			X	X	X	X					X			A	A	A		
Blue-black Kingfisher	*Todirhamphus nigrocyaneus*	DD/-/-/-	LS	8M			X	X		X							A	A	A		X
Blyth's Hornbill	*Rhyticeros plicatus*	LC/P/II/-	MS	1-6B,6D–9,PR	X	X	X	X		X							X	X	X	X	X
Palm Cockatoo	*Probosciger aterrimus*	LC/P/I/-	MS	1–6A,6D–8	X	X	X	X									X	X	X	X	
Pesquet's Parrot	*Psittrichas fulgidus*	VU/P/II/-	VS	1–6A	X	X	X										X	X	X	A	
Striated Lorikeet	*Charmosyna multistriata*	NT/-/II/-	MS			X											A				
Glossy-mantled Manucode	*Manucodia ater*	LC/P/II/-	MS	1–6A,7–9	X	X	X	X		X						X	X	X	X	X	X
Crinkle-collared Manucode	*Manucodia chalybatus*	LC/P/II/-	MS			X											A	A			
Trumpet Manucode	*Phonygammus keraudrenii*	LC/P/II/-	MS	1,2,5–6B,7,8,9		X	X	X		X							X	X	X	X	A
Magnificent Riflebird	*Ptiloris magnificus*	LC/P/II/-	MS	3,7		X	X	X									A	X	X		

English Name	Scientific Name	Conservation Status	Sensitivity	Project Sites	Prior Surveys	Major Environments											Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Low Freshwater Swamp Vegetation (Hsw, Gsw, Gri)	Mangrove (M)	Littoral Forest (B)	Tidal Wetlands	Watercourses	Off-river Waterbodies	Near-shore Marine/Estuarnewaters	Converted Lands	MPH	SH	DSP	SEC	Mv
Magnificent Bird-of-paradise	*Diphyllodes magnificus*	LC/P/II/-	MS			X											A	A			
King Bird-of-paradise	*Cicinnurus regius*	LC/P/II/-	MS	1–6A,7,8,9	X	X	X	X		X							X	X	X	X	A
Twelve-wired Bird-of-paradise	*Seleucidis melanoleuca*	LC/P/II/-	MS	4,5,7	X		X	X									A	A	X	A	
Raggiana Bird-of-paradise	*Paradisaea raggiana*	LC/P/II/-	MS	1,3–6B,6D,7,8,9	X	X	X	X								X	X	X	X	X	
Banded Yellow Robin	*Poecilodryas placens*	NT/-/-/RR	MS			X											A				
Yellow-eyed Starling	*Aplonis mystacea*	NT/-/-/-	MS			X	X										A	A	A		
Reptiles																					
Pig-nosed Turtle	*Carettochelys insculpta*	VU/-/II/-	VS	PR(L)	X								X	X	X		X	A	X	A	A
Striped New Guinea Soft-shelled Turtle	*Pelochelys bibroni*	VU/-/II/-	VS	PR(L)	X								X	X	X		X	A	X	A	A
	Cyrtodactylus serratus	LC/-/-/RR	LS	5		X	X										A	A	X		
	Lepidodactylus cf. *orientalis*	NE/-/-/RR	LS	2		X											X	A			
	Gehyra membranacruralis	LC/-/-/RR	LS	8			X									X				X	
	Carlia aenigma	LC/-/-/RR	LS	1–3,5,6A,7,8,9		X	X	X			X					X	X	X	X	X	
	Carlia cf. *luctuosa*	NE/-/-/RR	LS	2–4,6D		X	X									X	X	X	X		
	Cryptoblepharus litoralis vicinus	NE/-/-/RR	LS	9							X	X								X	
	Emoia physicae purari	LC/-/-/RR	LS	1–6B,6D,7		X	X	X									X	X	X		
New Guinea Freshwater Crocodile	*Crocodylus novaeguineae*	LC-/-II/-	MS	5,[6A],PR(L)	X								X	X			X	A	X	A	
Estuarine Crocodile	*Crocodylus porosus*	LC-/-II/-	MS	6C(L),8,8M,9	X								X	X	X		A	A	A	X	X

English Name	Scientific Name	Conservation Status	Sensitivity	Project Sites	Prior Surveys	Major Environments										Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Low Freshwater Swamp Vegetation (Hsw, Gsw, Gri)	Mangrove (M)	Littoral Forest (B)	Tidal Wetlands	Watercourses	Off-river Waterbodies	Near-shore Marine/Estuarnewaters	Converted Lands	MPH	SH	DSP	SEC	Mv
Amphibians																				
	Litoria chloristona	NE/-/-/RR	LS	1,3,5,7,8				X	X					X		X	X	X	X	X	
	Litoria congenita	LC/-/-/RR	LS	9							X			X		X				X	
	Litoria dorsalis	LC/-/-/RR	LS					X	X					X					A	A	
	Litoria exophthalmia	LC/-/-/RR	MS	1,2,7		X							X				X	X			
	Litoria sauroni	NE/-/-/RR	MS	1–4,7		X	X										X	X	X	A	
	Litoria vocivincens	LC/-/-/RR	LS						X					X				A		A	
	Callulops marmoratus	DD/-/-/RR	MS	1–4,7		X	X										X	X	X		
	Copiula guttata	LC/-/-/RR	LS	1–5,7,8,9		X	X										X	X	X	X	
	Metamagnusia slateri	LC/-/-/RR	LS	1–6A,6D–8,9		X	X	X									X	X	X	X	
	Oreophryne pseudunicolor	NE/-/-/RR	LS	1–5,7,8,9		X	X	X									X	X	X	X	
Odonates																				
	Selysioneura rhaphia	DD/-/-/-	MS	1,3		X							X				X	X			
	Nososticta finisterrae	DD/-/-/-	LS	1–4,6A,6B		X	X						X				X	X	X		
	Nososticta nigrifrons	DD/-/-/-	LS	1,2,5,6A		X	X						X				X	A	X		
	Diplacina cyrene	DD/-/-/RR	MS	2		X							X				X	A			
	Argiolestes tuberculiferus	NE/-/-/RR	VS	1		X							X				X				
	Metagrion trigonale	NE/-/-/RR	MS	1,2		X							X				X				
	Pyrrhargiolestes angulatus	NE/-/-/RR	VS	1,6D		X							X				X				
	Teinobasis buwaldai	NE/-/-/RR	MS	7		X							X				A	X			

English Name	Scientific Name	Conservation Status	Sensitivity	Project Sites	Prior Surveys	Major Environments										Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Low Freshwater Swamp Vegetation (Hsw, Gsw, Gri)	Mangrove (M)	Littoral Forest (B)	Tidal Wetlands	Watercourses	Off-river Waterbodies	Near-shore Marine/Estuarnewaters	Converted Lands	MPH	SH	DSP	SEC	Mv
	Teinobasis debeauxi	NE/-/-/RR	MS	1–3		X											X	X			
	Indolestes linsleyi	NE/-/-/RR	MS	5			X	X											X		
	Idiocnemis patriciae	NE/-/-/RR	MS	1,7		X							X				X	X			
	Nososticta chrismulleri	NE/-/-/RR	MS	1,2,4–6A,7		X	X						X				X	X	X		
	Nososticta makrodon	NE/-/-/RR	LS	1,4,7,8		X	X						X				X	A	X	X	
	Nososticta paraconifera	NE/-/-/RR	MS	4		X	X						X				A	A	X		
	Nososticta smilodon	NE/-/-/RR	VS	2,4		X	X						X				X	A	X		
	Nososticta truncata	NE/-/-/RR	MS	1,2,4		X	X						X				X	A	X		
	Drepanosticta taurulus	NE/-/-/RR	VS	1–3		X							X				X	X			
Butterflies																					
Goliath Birdwing	*Ornithoptera goliath*	NE/P/II/-	MS			X											A				
Butterfly of Paradise	*Ornithoptera paradisea*	LC/P/II/-	MS			X											A				
Ornithoptère Méridional	*Ornithoptera meridionalis*	EN/P/II/-	VS			X	X										A	A	A	A	

Appendix 5.

New-to-science and Other Scientifically Undescribed Species Recorded in the Study Area

Appendix 5

New-to-science (NTS) and other scientifically undescribed (UN) species recorded in the study area. Restricted-range (RR) status and species known only from the study area are indicated. Sensitivity: ES—Extremely Sensitive; VS—Very Sensitive; MS—Moderately Sensitive; LS—Low Sensitivity. 'Project surveys' show records from: survey sites in numerical order (1, 2, 3, 4, 5, 6A, 6B, 6C, 6D, 7, 8, 8M, 9); Wi'i Creek cave bone deposits (WC). 'Major environments' indicates occurrence in various major natural habitats and in converted lands; only those environments in which undescribed species were recorded are shown. 'Ecological zones': MPH—Middle Purari Hills; SH—Southeast Hills; DSP—Delta Swamps and Plains; SEC—Southeast Coast; Mv—Mangroves. Only recorded occurrences in major environments and ecological zones are indicated; knowledge of distribution and habitat preferences is insufficiently known to predict potential occurrences in other habitats/zones.

Scientific Name	Status	Study Area Only	Restricted-range	Sensitivity	Project Sites	Major Environments						Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Mangrove (M)	Watercourses	Converted Lands	MPH	SH	DSP	SEC	Mv
Flora																
Orophaea sp. 1	NTS	X	RR	MS	2,6B	X						X				
Pseuduvaria sp. 1	NTS	X	RR	MS	7	X	X						X	X		
Livistona sp. 1	NTS	X	RR	MS	4,5,6B,6D	X						X				
Begonia sp. 1	NTS	X	RR	MS	1,2,4	X	X					X		X		
Begonia sp. 2	NTS	X	RR	VS	1,2	X						X				
Begonia sp. 3	NTS	X	RR	VS	2	X						X				
Begonia sp. 4	NTS	X	RR	VS	2	X						X				
Begonia sp. 5	NTS	X	RR	ES	4	X						X		X		
Archidendron sp. 1	NTS	X	RR	VS	4		X							X		

Scientific Name	Status	Study Area Only	Restricted-range	Sensitivity	Project Sites	Major Environments						Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Mangrove (M)	Watercourses	Converted Lands	MPH	SH	DSP	SEC	Mv
Cyrtandra sp.1	NTS	X	RR	MS	2,3	X						X	X			
Cyrtandra sp.2	NTS	X	RR	MS	1–3,5,6B	X						X	X			
Cyrtandra sp. 3	NTS	X	RR	MS	1,2,4,5	X	X					X		X		
Barringtonia sp. 1	NTS	X	RR	MS	1,2,5	X						X				
Barringtonia sp. 2	NTS	X	RR	MS	2,4,5,6B,7		X					X		X		
Medinilla sp. 1	NTS	X	RR	VS	1,2		X					X				
Memecylon sp. 1	UN		RR	LS	1,5,6B	X						X				
Ficus sp.1	NTS	X	RR	MS	3	X							X			
Syzygium sp. 1	NTS	X	RR	VS	4		X							X		
Syzygium sp. 2	NTS	X	RR	MS	5,6B,6D,7	X	X					X	X	X		
Syzygium sp. 3	NTS	X	RR	VS	7	X							X			
Syzygium sp. 4	NTS	X	RR	VS	7		X							X		
Syzygium sp. 5	NTS	X	RR	VS	5		X							X		
Bulbophyllum sp. 1	NTS	X	RR	VS	4	X						X				
Bulbophyllum sp. 2	NTS	X	RR	VS	8M				X							X
Oberonia sp. 1	NTS	X	RR	VS	4		X							X		
Glochidion sp. 1	NTS	X	RR	VS	1	X						X				
Discocalyx sp. 1	NTS	X	RR	MS	2,3	X						X	X			
Ixora sp. 1	NTS	X	RR	MS	1–5,7	X	X					X	X	X		

Scientific Name	Status	Study Area Only	Restricted-range	Sensitivity	Project Sites	Major Environments						Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Mangrove (M)	Watercourses	Converted Lands	MPH	SH	DSP	SEC	Mv
Ixora sp. 2	NTS	X	RR	MS	1,2,4,6D	X						X				
Ixora sp. 3	NTS	X	RR	MS	1–3,5,7,9	X	X					X	X		X	
Lasianthus sp. 1	NTS	X	RR	VS	1	X						X				
Maschalodesme sp. 1	NTS	X	RR	MS	2,4,5	X	X					X		X		
Genus 1 sp. 1	NTS	X	RR	MS	1,2,4,5,7,8	X	X					X	X	X		
Genus 1 sp. 2	NTS	X	RR	VS	2	X						X				
Genus 1 sp. 3	NTS	X	RR	MS	4,5,6B,6D,7,9	X	X					X	X	X	X	
Mammals																
Hydromys sp. 1	NTS	X	RR	VS	WC	X				X		X				
Pseudohydromys sp. 1	NTS	X	RR	VS	WC	X						X				
Nyctophilus sp. 1	UN			LS	1–6A,7–9	X	X		X			X	X	X	X	X
Reptiles																
Gehyra sp. 1	NTS	X	RR	VS	3	X							X			
Sphenomorphus sp. 1	UN			LS	2	X						X	A			
Stegonotus sp. 1	NTS	X	RR	VS	4,5,8,9		X							X	X	
Amphibians																
Litoria sp. 1	UN	X	RR	MS	2,3	X				X		X	X			
Litoria sp. 2	UN			LS	1,2	X				X		X				
Austrochaperina sp. 1	UN		RR	MS	1	X						X				

Scientific Name	Status	Study Area Only	Restricted-range	Sensitivity	Project Sites	Major Environments						Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Mangrove (M)	Watercourses	Converted Lands	MPH	SH	DSP	SEC	Mv
Choerophryne sp.1	UN		RR	MS	1	X						X				
Cophixalus sp. 1	UN		RR	LS	1–3	X						X	X			
Cophixalus sp. 2	UN		RR	MS	1,2,5,7,8	X	X	X				X	X	X	X	
Cophixalus sp. 3	NTS	X	RR	VS	1–4,6A,6D,7	X	X					X	X	X		
Copiula sp. 1	UN		RR	MS	1–5,7,8	X	X					X	X	X	X	
Hylophorbus sp. 1	UN		RR	LS	1,7,8,9	X	X	X				X	X	X	X	
Oreophryne sp. 1	NTS	X	RR	MS	4,7,8	X	X	X					X	X	X	
Oreophryne sp. 2	NTS	X	RR	VS	1	X						X				
Xenorhina sp. 1	UN		RR	LS	1–5,6D–8	X	X					X	X	X	X	
Hylarana sp. 1	UN		RR	MS	1,2,4	X	X			X		X		X		
Hylarana sp. 2	UN	X	RR	MS	1–4,7	X	X			X		X	X	X		
Hylarana sp. 3	UN			LS	3–5,7,8,9	X	X	X		X			X	X	X	
Odonates																
Metagrion sp. 1	NTS	X	RR	MS	3,7	X				X			X			
Papuagrion sp. 1	NTS	X	RR	MS	8		X				X				X	
Teinobasis sp. 1	NTS	X	RR	VS	1	X						X				
Idiocnemis sp. 1	UN		RR	VS	1,4,5,6B,7,8	X	X			X		X	X	X	X	
Nososticta sp. 1	NTS	X	RR	VS	5		X	X		X				X		
Rhyacocnemis sp. 1	NTS	X	RR	VS	2,3	X				X		X	X			

Scientific Name	Status	Study Area Only	Restricted-range	Sensitivity	Project Sites	Major Environments						Ecological Zones				
						Hill Forest (H)	Alluvial Forest (P)	Swamp Forest (Fsw)/ Swamp Woodland (Wsw)	Mangrove (M)	Watercourses	Converted Lands	MPH	SH	DSP	SEC	Mv
Agyrtacantha sp. 1	NTS	X	RR	MS	4,5,7	X	X						X	X		
Bironides sp. 1	NTS	X	RR	MS	3,4,7	X	X			X			X	X		
Palaeosynthemis sp. 1	NTS	X	RR	VS	1	X				X		X				