Environmental Impact Assessment

September 2017

Sri Lanka: Wind Power Generation Project
Appendices 1–5

Prepared by Ceylon Electricity Board, Ministry of Power and Renewable Energy, Democratic Socialist Republic of Sri Lanka for the Asian Development Bank. This is an updated version of the draft originally posted in May 2017 on https://www.adb.org/projects/documents/sri-49345-002-eia

APPENDICES

APPENDIX 1

Temporary Pier Construction

SRI: 100 MW Mannar Wind Power Project

PERMIT FOR A DEVELOPMENT ACTIVITY ISSUED UNDER PART III - SECTION 14 OF THE COAST CONSERVATION & COASTAL RESOURCE MANAGEMENT ACT No. 57 OF 1981

Permit No. : P/17/471

Name of Permit Holder : Project Director, Mannar Wind Power Project, Ceylon Electricity Board

(*Surname*) (*Other Names*)

Postal Address : Ceylon Electricity Board, No 12, Udumulla Rd, Battaramulla.

Nature of Development Activity : Construction of a Temporary Pier for 100Mw Wind Power Park project

Location of Development Activity : Nadukuda, Southern Coast of Mannar Island

Province : Nothern

District : Mannar

Local Authority : Mannar

Particulars of Survey Plan submitted by Applicant :

Duration of Permit : 04.05.2017 to 03.05.2018

Conditions Attached : (1) All proposed construction should be carried out in accordance with the proposal and design submitted by the developer to this department.

Director General
Coast Conservation &
Coastal Resource Management.

Date : 04/05/2017

CM 20705 – 25,000 (2015/09) Dept. of Govt. Printing, Sri Lanka

(2) This approval is only valid for construction of Temporary Pier to facilitate the unloading of heavy and lengthy equipment during the construction period of proposed 100MW wind park project as indicated in the condition no.03 of the permit no. P/16/985 issued by this department.

(3) All construction of the proposed temporary pier should be carried out in accordance with the proposal and design submitted by the developer to the Coast Conservation & Coastal Resource Management Department.

(4) This approval is valid for construction of 50m length; 6m wide temporary pier with deck level is 3m above from the Mean Sea Level.

(5) Any alterations / extensions of the proposed activities should not be carried out without a prior approval of the Coast Conservation & Coastal Resource Management Department.

(6) All proposed construction activities should be carried out under the supervision of the Coast Conservation & Coastal Resource Management Department.

(7) The Developer should inform to the Coast Conservation & Coastal Resource Management Department the commencement of the construction activities of the proposed construction.

(8) Dredged sand / material should be dumped only the area approved by Coast Conservation & Coastal Resource Management department and dredge sand / material should not be used for commercial and any other purpose.

(9) All precautionary measures (such as silt screens) should be used around the area of proposed activity to minimize siltation / sedimentation.

(10) All mitigation measures should be taken to avoid damage to the marine and coastal environment during the construction period.

(11) Necessary clearance should be obtained from the Department of Fisheries & Aquatic Resources, Geological Survey & Mines Bureau, Marine Environment Protection Authority, Pradeshiya Sabhawa – Mannar and other relevant government agencies prior commencement of the proposed activity.

(12) Existing fishing activities in the area should not be disturbed by any means of proposed construction activities and proposed alterative options to the existing fishing activities should be carried out with assistance of the Department of Fisheries & Aquatic Resources during the construction period.

(13) Developer should coordinate with the Department of Fisheries and Aquatic Resource Development on fishing activities in the area in order to avoid user conflicts during construction period of the proposed construction activities.

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(14) Fishing community should be awarded on proposed construction activities in collaboration with the Department of Fisheries & Aquatic Resources prior to commence the proposed project activities.

(15) Beach access in the area should not be obstructed and damaged by any means of project activities.

(16) The temporary pier should be removed after completion of the construction activities of the wind power project and remove any form of wreckage, rubbish and derbies in the project area and reinstate the site area back to its natural state.

(17) All mitigatory measures should be implemented to mitigate the environmental and socio economic impacts due to the proposed project activity as included in the IEE project.

(18) The developer should pay compensation for the person or parties to be affected due to the proposed project activities.

(19) The developer should take all responsibilities to mitigate the negative impacts due to the proposed project activities.

(20) The developer will be bound to adhere to any additional conditions given by the Coast Conservation & Coastal Resource Management Department.

(21) This permit will be invalid if violation of any of the above conditions. In such a case this Department will consider relevant activities as unauthorized and will take legal action according to the Coast Conservation & Coastal Resource Management Act No. 57 of 1981.

A.H. Gamini Hewage
Actg.Director (Coastal Resource Management.)
For Director General / Coast Conservation &
Coastal Resource Management.

Copies to :

(1) Divisional Secretary, Divisional Secretariat, Mannar
(2) Secretary, Pradeshiya Sabhawa, Mannar.
(3) Director General, Department of Fisheries & Aquatic Resources, Colombo 10.
(4) Director General, Geological Survey and Mines Bureau, Colombo 07.
(5) General Manager, Marine Environment Protection Authority, Colombo
(6) Mr. J.A. Daniel, Planning Assistant, Divisional Secretariat, Mannar.

CEYLON ELECTRICITY BOARD

MANNAR WIND POWER PROJECT

Construction of Proposed Temporary Pier in Nadukuda

April 11, 2017

Mannar Wind Power Project
Ceylon Electricity Board
No. 12, Udumulla Road
Battaramulla. 10120
Tel: +94 11 288 96 40
Fax: +94 11 286 96 31

Contents

1. Background

The Ceylon Electricity Board is now in the process of implementing a 100 MW Semi Dispatchable Wind Farm in the southern coast of Mannar Island. The novel operational strategy of "Semi Dispatchability" enables to capture the promising wind resource in a large scale, at a substantially lower cost while minimizing the operational impact to the national grid. The project expects to deliver 395 GWh of annual energy, contributing and complying with the renewable energy obligations set forth by the Government of Sri Lanka.

In a nutshell, the project scope comprises of the following major components.

a. Installation of Wind Turbine Generators to cater the installed capacity of 100 MW
b. Construction of infrastructure for grid interconnection, operational and control strategies for the wind farm.
c. Supporting infrastructure which includes construction of the pier, Corporate Social Responsibility (CSR) activities and construction of office and accommodation facilities for the operational staff etc.

Adhering to the statutory obligations, CEB had carried out an Initial Environmental Examination (IEE) as recommended by the scoping committee that was chaired by the Coast Conservation and Coastal Resource Management Department (CCD) and obtained the development permit, on July 08, 2016, under reference No. P/16/985.

However, according to the Clause 3.0 of the aforementioned permit, CEB requires to obtain a separate approval from the CCD for the construction of the proposed temporary pier which will be utilized for unloading the heavy and lengthy equipment during the wind farm construction stage.

Consequently, CEB submitted an application (Ref. No. PA/11/MS/17/90) on February 18, 2017 to obtain the clearance from the CCD to construct the temporary pier.

2. Baseline Data Analysis

There were four locations identified as potential sites for the proposed pier and these locations were thoroughly investigated by performing underwater studies and a detailed bathymetric survey, as part of IEE requirements, in screening out the optimum site.

The underwater studies revealed that, all potential sites suggested for the construction of pier, consist of identical uniform sandy bottom. It was found out that none of these locations are inhabited with sensitive ecosystems or any threatened/conservation needed organisms and these observations were reported in detail in the IEE report.

Further, after scrutinizing the outcomes of bathymetric survey carried out by NARA, the optimum location was selected which is about 350 meters towards Thaleimannar from Nadukuda beach. The coordinates of the potential site are *Lat.* 9.051590^0, *Lon.* 79.784450^0.

3. Description of Proposed Pier Design and Layout

A column and deck type pier will be constructed where the construction will be extended up to 50 meters towards the sea, from the shoreline. In addition, the pier will be 6 meters wide which could adequately cater the specific purpose of unloading heavy and long equipment. The deck level will be 3 meters above the Mean Sea Level (MSL). A complete design layout of the proposed pier is attached as ***Annex 1*** of this report.

4. Pier Construction and Site Clearance Methodology

The development of Mannar Wind Power Project will be awarded to an EPC contractor to design, supply and install the wind farm and associated facilities while complying to the specifications and requirements impose by the CEB. Therefore, more detail environmental studies such as, underwater profile surveys along the proposed pier line will be done prior to commencing the construction work as well, to minimize the impact to the environment while optimizing the design solution.

4.1 Pier Construction

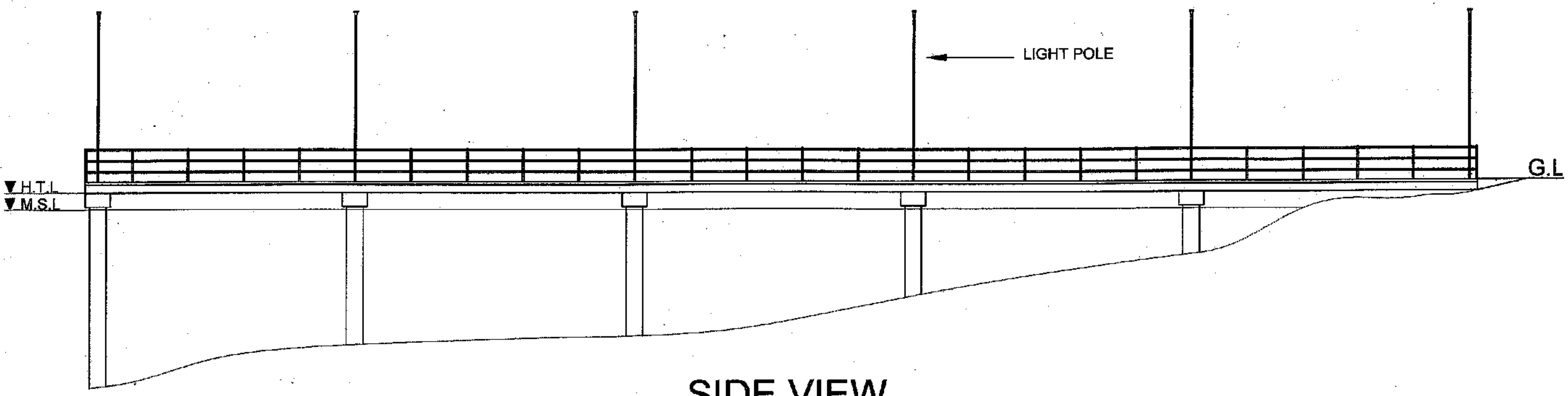
The proposed pier will be constructed during the inter-monsoon period especially after the south-west monsoon period. Tentatively, the construction could be started in the early weeks of November, 2018 as per the current project scheduling. The steel “I” beams are driven into the seabed by a pile driving hammer up to the design specifications. The implementation schedule of the pier is attached as ***Annex 2*** of this report.

After completion of the wind turbine erection and at the initial commissioning phases of the wind farm, the pier would be removed, particularly during the inter-monsoon seasons to avoid technical difficulties which may arise due to rough sea conditions.

4.2 Pier Removal and Site Clearance

The removal process will be done, section by section starting from the cantilevers extending towards the sea. The installed piles will be cut off from the seabed while minimizing the impact to the seabed and surrounding ecology. During the pile removal process, a water retaining wall will be formed by utilizing sheet piles, so that the installed piles could be cut off below the existing seabed. The pier removal will be done as per the standard procedures adhering to the environmental concerns. Further, the CEB strictly enforces the contractor on site clearance work as per the conditions laid out during contractual formulation. The contractor will be responsible for the removal of wreckage, rubbish and debris of any form, from the site and also be responsible to reinstate the site back to its natural state after the completion of the proposed tasks.

Annex 01: Plan View and Side View Drawings of the Proposed Temporary Steel Pier



SIDE VIEW

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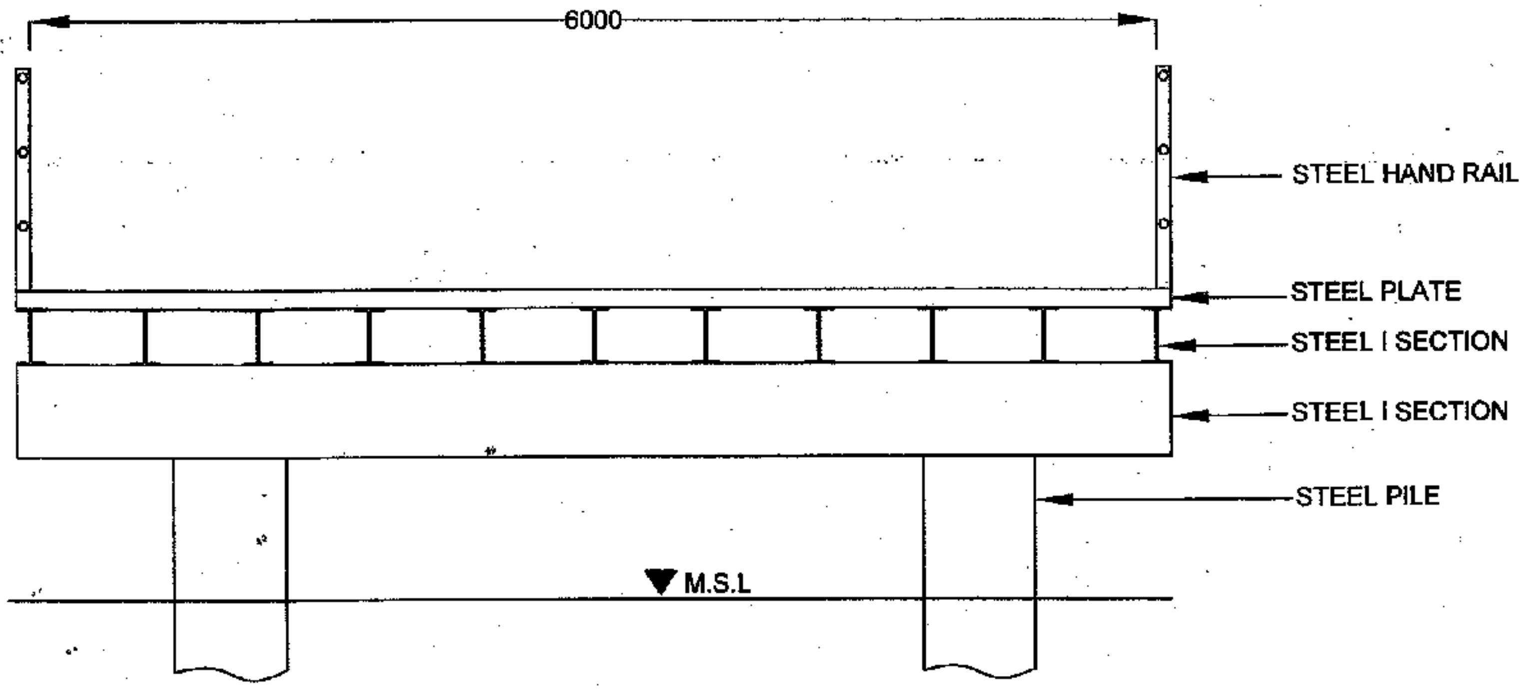

CROSS SECTIONAL VIEW

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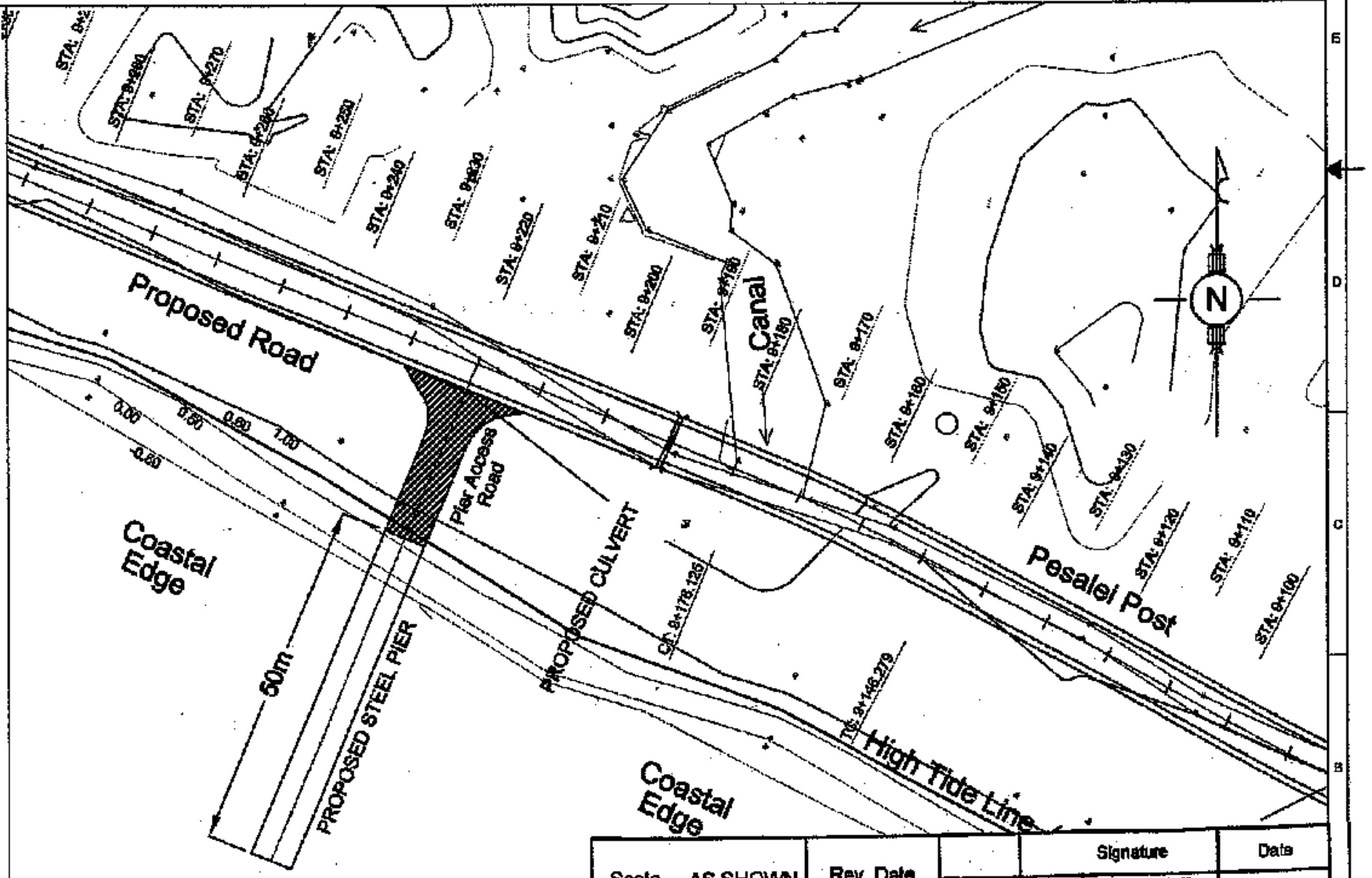

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Dwg. No.
CEB/MWPP/T/E/06

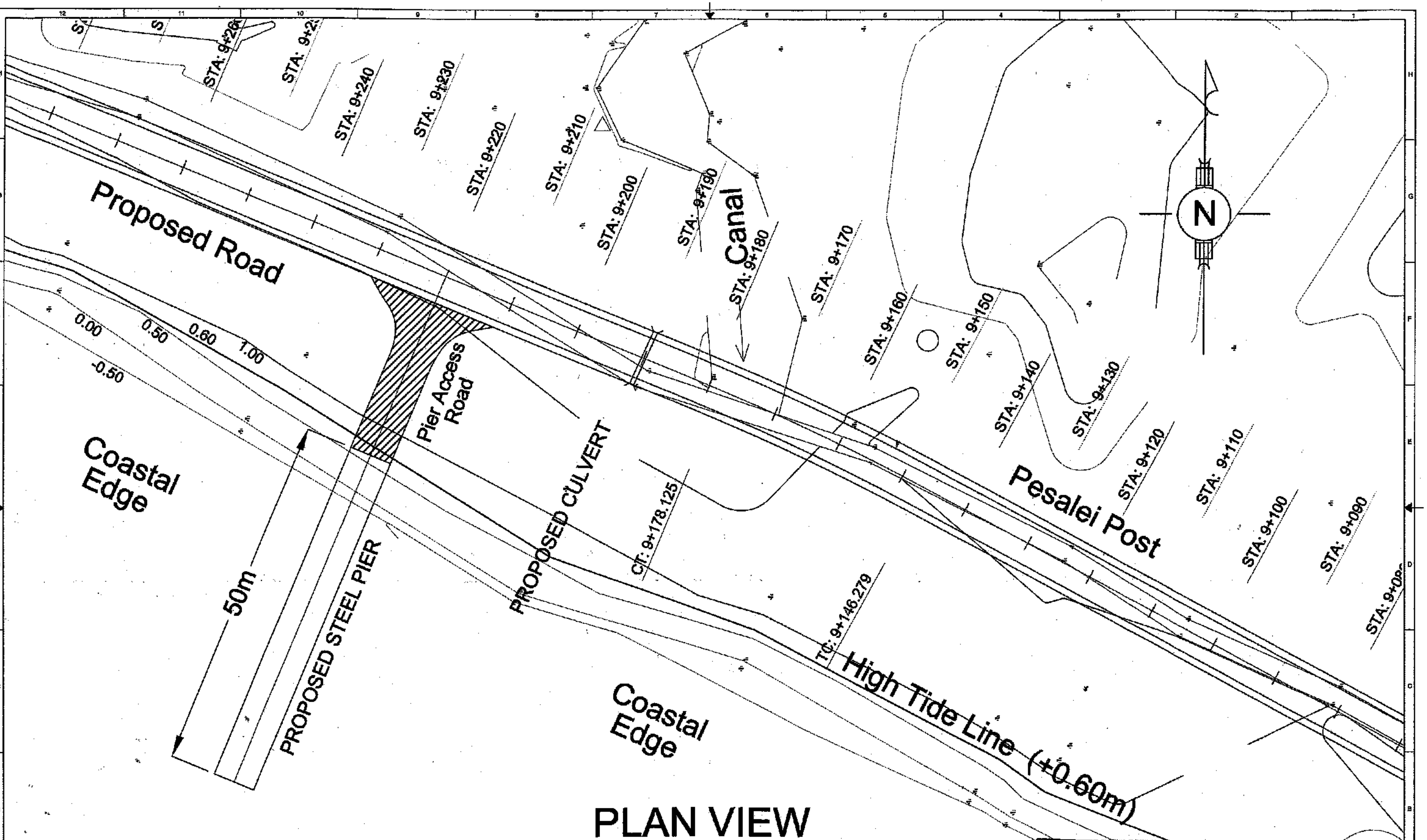
Project Director
Mannar Wind Power Project

Rev. No	Date	Description	Drawn	Checked	Approved

CEYLON ELECTRICITY BOARD
MANNAR WIND POWER PROJECT - PHASE 1

Project Title
MANNAR WIND POWER PROJECT - PHASE1
CONSTRUCTION OF 100W SEMI DISPATCHABLE WIND FARM

DESCRIPTION
STEEL PIER



PLAN VIEW

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Rev. No	Date	Description

CEYLON ELECTRICITY BOARD
MANNAR WIND POWER PROJECT - PHASE 1

Project Title
MANNAR WIND POWER PROJECT - PHASE1
CONSTRUCTION OF 100W SEMI DISPATCHABLE WIND FARM

DESCRIPTION
STEEL PIER

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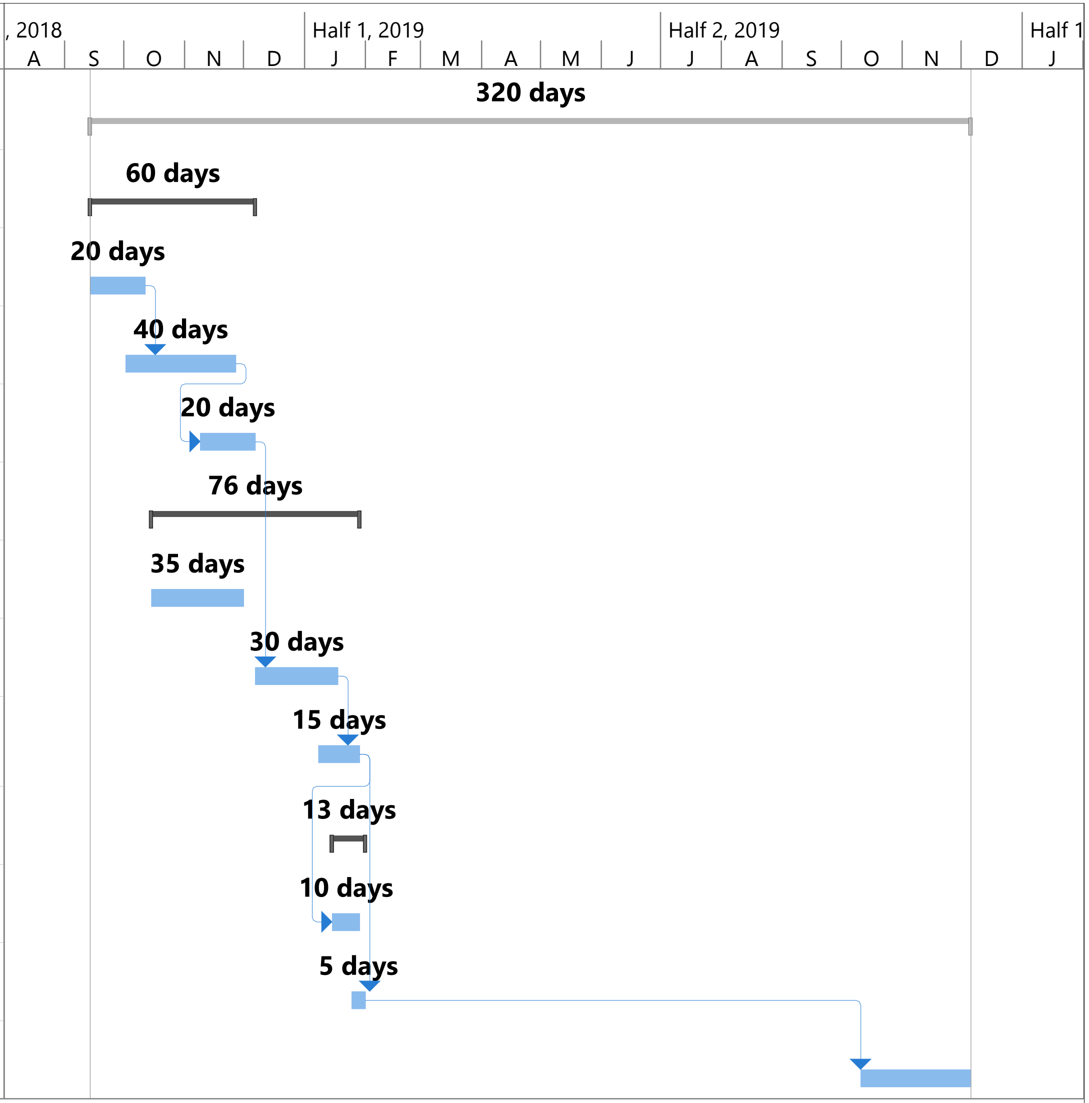
CEB/MWPP/T/E/07

Project Director
Mannar Wind Power Project

Annex 02: Implementation Schedule of the Pier

ID	Task Name	Duration	Start	Finish
0	**Pier Implementation Schedule**	**320 days**	**14-09-18**	**05-12-19**
1	**Sub-structure Construction**	**60 days**	**14-09-18**	**06-12-18**
2	Fabrication of Steel Piling and Deliver to site	20 days	14-09-18	11-10-18
3	Pile Placement & Driving	40 days	02-10-18	26-11-18
4	Welding and Finishing Works on Substructure	20 days	09-11-18	06-12-18
5	**Super Structure Construction**	**76 days**	**15-10-18**	**28-01-19**
6	Fabrication of Steel Sections and deliver to site	35 days	15-10-18	30-11-18
7	Placement of Steel Sections	30 days	07-12-18	17-01-19
8	Construction of Deck and Completion of Super Structure	15 days	08-01-19	28-01-19
9	**Finishing Works**	**13 days**	**15-01-19**	**31-01-19**
10	Electrification Jobs and Hand Rail Installation	10 days	15-01-19	28-01-19
11	Environment Facilities as Required by CEB	5 days	25-01-19	31-01-19
12	Removal of Pier	2 mons	11-10-19	05-12-19



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COAST CONSERVATION AND COASTAL RESOURCE MANAGEMENT DEPARTMENT

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Ministry of Mahaweli Development and Environment

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த. பெ. இல. 556, புதிய செயலகம் மாளிகாவத்தை, கொழும்பு 10.
P.O. Box. 556, New Secretariat, Maligawatta, Colombo 10.
Web : www.coastal.gov.lk E-mail: info@coastal.gov.lk

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04.04.2017

Project Director,
Mannar Wind Power Project,
Ceylon Electricity Board,
No.12 Udumulla Road,
Battaramulla.

Dear Sir / Madam,

<u>Permit Application under the Coast Conservation & Coastal Resource Management Act No. 57 of 1981 – Construction of Temporary Pier (50m) – Nadukuda, Southern Coast of Mannar Island</u>

This has reference to the application No. PA/11/MS/17/90 dated 18.02.2017 regarding the above subject.

You are kindly inform to submit the original certified design with details of the proposed pier including time period, removing methodology to consider granting approval for proposed project.

Yours faithfully,

A.H. Gamini Hewage
Actg. Director (Coastal Resource Management)
For Director General / Coast Conservation & Coastal Resource Management.

Letters - Mannar

දුරකථන / தொலைபேசி / Telephone

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කාර්යාලය / அலுவலகம் / Office } 011 2449754

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இல. 72, ஆனந்த குமாரசுவாமி மாவத்தை, கொழும்பு 07.
No. 72, Ananda Coomaraswamy Mawatha, Colombo 07.

SCANNED

Received
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22 MAR 2017
AGM (Projects)
Ceylon Electricity Board

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දිනය / திகதி / Date .03.2017

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22 MAR 2017
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Director General
Department of External Resources

Aide Memoire of the Loan Fact - Finding Mission for Mannar Wind Power Project (14 – 24 February 2017)
– Request for Comments

PM(WPP).
M. Dayan pls

This refers your letter dated 01.03.2017 on the above.

I wish to inform you that we are in the agreement of the content of the Aide Memoire of the Mission held during the period of 14th – 24th February 2017 subject to the following comment received from Ceylon Electricity Board.

Item 44, sub item (IV)

> "As the project implementation team, we are concerned on item 44, sub item (iv) which envisage on restricting construction work of temporary pier and equipment unloading during low wind season. This must have been recommended in order to avoid disturbances to the fishing community.
>
> As per the present work program, it has been planned to carry out the construction activities of temporary Pier and equipment unloading during low wind season which occur from October to April. It may not be possible to undertake any maritime activities during the balance period (May to September) due to rough sea. Therefor restricting construction work and equipment unloading during low wind season cannot be accepted. The impact (Financial) on fishing community during low wind season can be mitigated by compensating them for the loss of income. In view of this CEB has been maintaining constant dialogue with the fishing community and relevant officials of the Fisheries Department since the inception of environmental approval process which dates back to 2015.
>
> The officers attached to Assistant Director Fisheries of Mannar are collecting and maintain the detailed records on fish harvest and details pertaining to fishing community (Beach siene owners/laborers and fishermen and areas of fishing). These historical data would no doubt enable us to propose a very effective compensation scheme for the affected parties.

AGM(PP)
17/3
Eng. A. K. Samarasinghe
General Manager, CEB

DGM(AWP)

Eng. W. D. W. Gunawardana
AGM (P) CEB

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ෆැක්ස් / தொலைநகல் / Fax 2574880 2574743 2574741

I wish to inform you that CEB is determine to pay required compensations to the fishing community in accordance with the recommendations of Assistant Director Fisheries- Mannar"

Dr. B.M.S. Batagoda
Secretary
Ministry of Power & Renewable Energy

Copies:	Country Director Sri Lanka Resident Mission Asian Development Bank	- F.I. Pls.
	General Manager Ceylon Electricity Board	- F.I. Pls.

MANNAR WIND FARM, NORTHERN PROVINCE, SRI LANKA: AVIAN COLLISION RISK ASSESSMENT

REPORT TO THE ASIAN DEVELOPMENT BANK

PROJECT TA-9085 SRI: WIND POWER GENERATION PROJECT

Dr Steve Percival

Ecology Consulting

Swallow Ridge Barn, Old Cassop, Durham DH6 4QB, UK.

Email: steve.percival@ecologyconsult.co.uk

July 2017

MANNAR WIND FARM: AVIAN COLLISION RISK ASSESSMENT

EXECUTIVE SUMMARY

This report supports the Ceylon Electricity Board (CEB) in undertaking the ornithological assessment for a proposed large-scale wind power development (Mannar Wind Farm) and its associated power evacuation infrastructure. The wind farm itself could result in bird collisions and/or displacement through disturbance. The proposed overhead powerline that will connect the wind farm to the grid will pose a collision risk to birds, particularly where it will cross the Vanaklai Sanctuary Ramsar site, a site of international importance for its waterbird populations.

Baseline bird surveys have been conducted at the site over a three-year period and over a wide survey area. Grid Count line transects have successfully characterised the bird communities over the large survey area, and Block Counts have provided very useful data on the Vankalai Sanctuary Ramsar site populations and on other wetland sites. Initial Vantage Point surveys were undertaken, but were enhanced from June 2016 onwards to focus on quantifying collision risk.

It is clear that the survey area supports a range of internationally important bird populations. The highest conservation importance are those species associated with the Vankalai Sanctuary Ramsar site and the Adam's Bridge National Park, though the survey data show that several of these are not restricted to the designated sites but range more widely (and hence could be affected by the wind farm as well as the overhead transmission line).

Collision modelling was undertaken for the wind farm, using the Band et al. (2007) model. The wind turbine collision risk modelling highlighted the three Critical Habitat species at particular risk; Spot-billed Pelican, Indian Cormorant and Gull-billed Tern. The collision risk to all of these species could be significant.

Previous collision modelling for the 7.5km section of the transmission line that passes through the Vankalai Sanctuary Ramsar site (an associated facility of the wind farm) highlighted the following Critical Habitat species at risk of collision with the transmission line; Indian Spot-billed Duck, Northern Pintail, Greater Flamingo, Painted Stork, Black-headed Ibis, Spot-billed Pelican, Indian Cormorant and Caspian Tern. The collision risk to all of these species could also be significant, so a package of mitigation measures has been agreed and is being implemented to ensure no net loss.

The wind farm also has the potential to disturb birds from a zone around the wind turbines. Specific targeted counts of this area have shown that seven Critical Habitat species could be at risk, including Little Egret, Indian Cormorant, Red-wattled Lapwing, Brown-headed Gull, Caspian Tern, Gull-billed Tern and Lesser Crested Tern. However, the numbers at risk were generally low, many of the birds there are habituated to presence of people (reducing their vulnerability to disturbance) and evidence from existing wind farms has shown similar species to be little-affected by such disturbance. The likelihood of disturbance is therefore considered to be low, though some minor disturbance effects cannot be completely ruled out. As a result, it will be necessary to implement mitigation measures to avoid any net loss of habitat to any Critical Habitat species.

A package of mitigation measures will be required to satisfy the ADB Critical Habitat requirements, including design mitigation, mitigation to reduce impacts during the construction (and decommissioning) phase of the development (through the production and implementation of a Construction Method Statement following industry best practice), and measures to mitigate the operational phase impacts.

A Biodiversity Management Plan will need to be developed for the project to ensure no net loss of biodiversity and implementation of a program to promote and enhance the conservation aims of the sanctuary in accordance with ADB's SPS's requirements for Legally Protected Areas. It is proposed that this should include the funding of the development of a management plan for the Ramsar site and for the Adam's Bridge National Park, and of the implementation of the first five years of those plans.

SPECIALIST DETAILS

Professional experience

Dr Steve Percival has a B.Sc. (Hons) degree in Biological Sciences from the University of Durham, UK (awarded in 1984) and a Ph.D. in Zoology from the University of Glasgow, UK (awarded in 1988).

As principal of his own private practice, Ecology Consulting, he has a wide experience of nature conservation and wind energy issues. His clients have included Natural England, the Wildfowl and Wetlands Trust, Scottish Natural Heritage, the Countryside Agency, the Department of Trade and Industry's Energy Technology Support Unit, the European Bank for Reconstruction and Development and the New Zealand Department of Conservation and numerous wind energy companies. He has been involved in over 350 wind energy projects, including carrying out ecological assessments, preparation of ecological material for environmental statements and giving evidence at public inquiries. As well as sites in the UK he has also worked on sites in New Zealand, Poland, Bulgaria, Mongolia, Sweden, India, South Africa and Australia. He has published papers on the interactions between birds and wind farms and on assessing the potential effects, and given conference papers both within the UK and internationally (including as an invited guest speaker).

He has been studying the conservation ecology of bird populations since 1983. This has included work on population changes of waders in the Outer Hebrides and detailed ecological studies of barnacle geese (including a long-term project extending over 32 years), brent geese, wigeon, golden plover and curlew. His work has been published in major international scientific journals including the Journal of Applied Ecology, Biological Conservation, Ecography and Ibis.

Professional registration

Dr Percival is a member of the Chartered Institute for Ecology and Environmental Management (UK), the British Ecological Society and the British Ornithologists' Union.

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Terms of Reference of the Avian Collision Risk Assessment

1. At the request of the Government of Sri Lanka and Ceylon Electricity Board (CEB), Asian Development Bank (ADB) agreed to provide a technical assistance (TA) to prepare a feasibility study and preliminary design and to conduct due diligence for a Wind Power Generation Project. CEB is an implementing agency for the TA and has initiated initial assessments including an Environmental Impact Assessment (EIA) for the construction of the power evacuation line and grid substation and a relevant associated facility (a wind park of 100 megawatt [MW] in Mannar Island of the Northern Province) as part of another transaction (Tranche 2 of the Green Power and Energy Efficiency Improvement Investment Program). The potential estimated capacity of the proposed Wind Park Zone is about 375 MW (between 125 to 188 turbines) of wind power generation parks. The wind turbines could be developed in a series of blocks on Mannar Island (about 300 MW) and the mainland (about 75 MW). The CEB's 100 MW wind park will be the first stage of the development.

2. The proposed wind farm will be located on land in proximity to the Vankalai Sanctuary Ramsar site (an internationally important wetland), Adam's Bridge National Park and an Important Bird Area (IBA) (which overlaps with the Sanctuary). Given that the proposed wind park is along a migratory flyway between India and Sri Lanka, CEB will need to demonstrate to ADB that the Critical Habitat requirements in paragraph 28 of Appendix 1 of ADB's SPS 2009 can be met by the project.

3. At ADB's request, CEB conducted bird surveys in the Mannar Island and sanctuary area from January 2013 to April 2016, with further work focusing on the wind farm site itself from June 2016 - March 2017. Species noted as being supported by the sanctuary include those at potential risk of collision with wind turbines. The work of the international ornithological consultant includes a review the available bird survey data, production of a survey design and coordination of any additional survey work that would be required for robust assessment of the project alone and the cumulative impact on Critical Habitat - the survey area to include Mannar Island and the Ramsar sanctuary, undertake relevant cumulative collision risk modeling for the project and assist CEB in preparing the EIA's ornithological assessment including an ornithological Critical Habitat assessment.

Scope of Work

4. This report sets out to support CEB in undertaking the ornithological assessment for the proposed wind farm. This includes analysis of the collected CEB survey results and preparation of bird flight activity data for input to a collision risk model. Collision risk modelling has been carried out where sufficient baseline data are available, and written input has been provided to the EIA's ornithological assessment including discussion on the methodology, results, assumptions and limitations of collision risk modelling undertaken.

Detailed Tasks and/or Expected Output

5. The tasks to be conducted included:

   I. In conjunction with CEB's bird migration survey, review the results of the bird distribution and vantage point surveys to:

      a. confirm the ornithological value of the habitats impacted by the project alone an in terms of cumulative impact,

      b. assess the potential adverse impacts of the project alone and cumulatively on the bird species supported,

      c. identify those bird species supported which are at potential risk of collision;

      d. identify data gaps if any;

      e. produce a survey design for any additional survey work needed to inform robust assessment of the project alone and cumulatively on Critical Habitat, the survey design will need to take into account timing constraints for survey work and the project processing timeline;

      f. coordinate/guide a national ornithologist in gathering the missing survey data and producing survey maps to inform the assessment; and

   g. obtain/prepare bird flight activity data in a format for input into the collision risk model;

II. Liaise with CEB to obtain the wind turbine layouts for each block and details of the anticipated wind turbine model for input into the collision risk model;

III. For each species at risk of collision, using the Band Model (Band et al. 2007) as promoted by SNH (http://www.snh.gov.uk/docs/C205425. pdf) (or an equivalent model agreed with ADB) estimate the annual number of collisions for each wind turbine block (and any associated power lines):

   a. Assessing the probability of a bird colliding with the rotating turbine blades if it flies through an operational turbine,

   b. Estimating the number of birds passing through the zone swept by the rotating turbine blades of each wind turbine block using the available bird flight activity data,

   c. Applying an avoidance factor to the estimates to reflect that birds may avoid the rotating turbine blades (http://www.snh.gov. uk/docs/B721137.pdf).

IV. For each species at risk of collision, using a suitable model to be agreed with ADB estimate the annual number of collisions with the wind turbines and associated overhead lines;

V. For each species at risk of collision, obtain an estimate of cumulative bird mortality per annum,

VI. For species that are Critical Habitat triggers (internationally or nationally endangered or critically endangered birds, globally restricted range or endemic birds, birds that are listed on the Ramsar or Important Bird Area citations, birds where >1% of the global population is supported by the project area) determine if the potential impacts of the wind park including any increase in bird mortality will lead to a reduction in the species population,

VII. Determine if the project will adversely impact on the globally significant numbers of individuals of congregatory species supported by the sanctuary or impair its ability to act as a migratory flyway,

VIII. Propose appropriate mitigation measures to mitigate the adverse impacts of the project including potential deletion of any wind turbine blocks, revisions to wind turbine layouts, selection of wind turbine model, active turbine management, marking of transmission lines to avoid collision risk, and timing of measures, to ensure there is no net loss of biodiversity;

IX. Provide input to the development of a biodiversity management plan including compensatory measures if needed to ensure no net loss of biodiversity and implementation of a program to promote and enhance the conservation aims of the Ramsar sanctuary and Adam's Bridge National Park in accordance with ADB's SPS's requirements for Legally Protected Areas,

X. Rerun the collision risk model and update the assessment as necessary taking into account mitigation measures agreed with CEB.

XI. Work together with the environmental team of the TA in completing the EIA for the wind park, considering the project alone and cumulative impacts;

XII. Provide written inputs to the EIA's ornithological assessment including discussion on the survey and assessment methodology, results and baseline situation including evaluation of the ecological and conservation value of habitats present, assumptions and limitations of collision risk modelling and assessment undertaken, and assist CEB/team in reporting the bird distribution and vantage point surveys results, the ornithological value of the habitats impacted, the potential adverse impacts of the project and demonstrating if the Critical Habitat requirements in paragraph 28 of Appendix 1 of ADB's Safeguard Policy Statement can be met.

The Proposed Development

6. The main aspect of the development being assessed at this stage is the first phase of the Mannar Island Wind Farm, and its associated facilities. This comprises the following elements:

   - The first phase of the wind farm would be for a 100MW wind farm of up to 39 turbines. The turbines would have a rated capacity of 2.5-3.5 MW, a hub height of between 80 and 100m, and a rotor diameter of up to 130m.

- Crane hardstandings;
- Wind monitoring masts (anemometers);
- Underground electrical cables within the site;
- Internal access roads;
- Construction compound; and
- Operations building.

Associated facilities

- Overhead grid connection cabling that will the wind farm to the grid. This runs for a length of 29km SE from the proposed wind farm across from Mannar Island to the mainland (about 7.5km of which is through the Vankalai Sanctuary Ramsar site). The transmission line will comprise four overhead wires at about 15-45m above ground level, with supporting poles at approximately 300-400m intervals; and a
- Substation.

7. The locations of the proposed wind turbine locations and the transmission line route are shown in Figure 1.

Review of the results of the bird distribution and vantage point surveys

Ornithological value of the habitats potentially impacted by the project

Ramsar Site

8. The Vankalai Sanctuary lies 5.5km to the south-east of the nearest proposed wind turbine location. It is an internationally important wetland, designated as a Ramsar site. It covers a total area of 4,839 ha. It is described on its Ramsar Information Sheet (RIS) as follows:

> *"This site consists of several habitats and vegetation types: arid-zone thorn scrubland, arid-zone pastures and maritime grasslands, sand dunes, mangroves, waterholes and tanks, salt marshes, lagoons, tidal flats and sea-grass beds. It also includes part of the shallow marine region. The site provides excellent feeding and living habitats for a large number of waterbird species, including annual migrants, which use this area also for landfall (on arrival in Sri Lanka) in the Mannar region, and a last staging point (during their exit from Sri Lanka). A total of 149 species of birds have been recorded from this region. According to the annual waterbird census carried out by the Ceylon Bird Club, the site harbours much more than 20,000 waterbirds during a migration season. The recent civil war has managed to keep away detrimental human activities from this area, which in turn has contributed to a high bird diversity. A breeding colony of the Indian Spot-billed Duck, which was known as a rare migrant in Sri Lanka, was recently found in this site."*

9. Its key ornithological interest features (for which it qualified for designation as a Ramsar site) include:

- Indian Spot-billed Duck – the site supports a small breeding population of this nationally endangered species.
- Greater Flamingo – up to 5,000 have been recorded in winter, 2.1% of the international flyway population.
- Eurasian Wigeon – up to 56,000 have been recorded in winter, 22% of the international flyway population.
- Northern Pintail - up to 95,000 have been recorded in winter, 4.8% of the international flyway population.
- Black-tailed Godwit - up to 3,000 have been recorded in winter, 2.0% of the international flyway population.
- Wintering waterfowl assemblage >20,000 individuals – the wintering waterfowl population has exceeded 120,000 individuals in recent years.

10. Numbers of all waterfowl species have been highly variable between years.
11. Two species of rare migratory waterfowl are also mentioned on the Ramsar Information Sheet (RIS), Gadwall and Comb Duck. Additionally, bird species noted on the RIS include Red Knot (common here but rare elsewhere in Sri Lanka), and Pied Avocet (regular here but very rare elsewhere in Sri Lanka).

Important Bird Areas (IBA)

12. The Periyakalapuwa mouth IBA includes 800 ha of saltmarsh and other wetland habitat. Its key IBA trigger species is also its wintering Curlew Sandpiper population (Birdlife International 2016b). It lies within the Vankalai Sanctuary Ramsar site.
13. The Amaipaddukkai IBA and the Giant's Tank IBAs, which support internationally important populations of winter curlew sandpiper, and of Eurasian Wigeon and Black-necked Ibis respectively, lie sufficient distance from the development that they would be unaffected by it.

Adam's Bridge National Park

14. The proposed wind farm site lies adjacent to the north-eastern edge of the Adam's Bridge/Gulf of Mannar National Park, which has recently been established at the western end of Mannar Island. It has been designated primarily for its breeding seabird population (it is one of only a small number of seabird breeding colonies in Sri Lanka) and other marine features, though does also include the western end of Mannar Island. This National Park has only recently been designated, but the proposed extent of the wind farm has been updated from its original indicative layout, so that no development would take place within that National Park.

Designated Areas and Critical Habitat

15. For the purposes of this assessment, therefore, the Vankalai Sanctuary Ramsar site (including the Periyakalapuwa mouth IBA) and the Adam's Bridge/Gulf of Mannar National Park have been considered as Critical Habitat.

Potential Effects of the Development on Birds

Effects on birds

16. The main potential effects of wind farms on birds are collision risk with the wind turbines, direct loss of breeding or feeding habitat, and indirect loss of habitat from disturbance (either temporary during construction or more permanent from operating turbines) (Percival 2005, Drewitt and Langston 2006). This report focusses on the collision risk posed by both the wind turbines, but consideration is also given to the potential disturbance and habitat loss that could occur.
17. The collision risk that the overhead transmission line may cause to birds from the Vankalai Sanctuary Ramsar site was assessed previously (Percival and Weerakoon 2016), but the current report draws on that assessment for the transmission line as an associated facility of the wind farm, and for the cumulative assessment in combination with the wind farm.

Direct effects (1): wind turbine collision risk

18. Wind farms have caused significant bird mortalities through collision but their characteristics are different to those at the proposed Mannar site. Most notably, at Altamont Pass in California and Tarifa in southern Spain, large numbers of raptors have been killed (Orloff and Flannery 1992, Janss 1998, Thelander *et al.*

2003). Such problems have occurred where large numbers of sensitive species occur in close proximity to very large numbers (hundreds/thousands) of turbines, and usually also where the wind farm site itself provides a particularly attractive feeding resource. At Altamont, for example, the wind turbine bases provided an attractive shelter for ground squirrels which themselves provided an attractive raptor foraging resource (Thelander *et al.* 2003).

19. A specific problem has been identified for old world vultures, which have much the highest numbers of reported raptor collisions (Hotker *et al.* 2004, Illner 2011). Martin *et al.* (2012) reported that these species have large blind areas in their field of vision above, below and behind the head, such that with the head positions typically adopted by foraging vultures, they will often be blind in the direction of travel. This would make them particularly vulnerable to collision with wind turbines and the studies that have been undertaken bare out this conclusion (Janss 1998, Lucas *et al.* 2012). Vultures also have a high wind loading, reducing their maneuverability which also increases their vulnerability to collision (Janss 2000, Barrios and Rodríguez, 2004; Lucas *et al.,* 2008). In addition to this wind farms have been located in areas of high vulture food resource and several of their populations are vulnerable to additional mortality (Carrete *et al.* 2009).

20. Another species clearly more vulnerable to collision with wind turbines is the White-tailed Eagle. Small numbers of collisions have been reported at several wind farms including in Germany and Poland, but at one particular site rather more fatalities have occurred, Smøla in NW Norway (an average of 8 collisions per year, May *et al.* 2010). In Australia White-Bellied Sea Eagle and Wedge-Tailed Eagle have also both been demonstrated to be vulnerable to collision (Hull and Muir 2013).

21. Sites where higher numbers of bird collisions have occurred generally have supported a high density of flight activity that has been maintained post-construction, often associated with attractive ecological resource within the wind farm site, resulting in attraction into the wind farm rather than avoidance. The key risk features can be summarised as:

    - High turbine numbers
    - Turbine design – older design lattice towers can provide a perching resource
    - High bird density within the wind farm – particularly where there is a rich food resource within the wind farm, or attractive breeding sites
    - Source of distraction in close proximity to turbines, e.g. food resource in turbine bases, breeding displays.
    - Vultures have a specific issue with their limited field of vision, and a high wing loading that reduces their maneuverability
    - Particular vulnerability of populations to additional mortality (e.g. Egyptian vulture – where wind farms have been implicated in population decline often where acting in combination with other factors, Carrete *et al.* 2009).

22. Studies of waterbird behaviour at existing wind farms has generally shown that these birds exhibit very high avoidance rates from wind turbines, usually well in excess of 99% (e.g. Desholm and Kahlert 2005; Fernley *et al.* 2006). The latter publication has suggested that goose avoidance rates are actually in the order of 99.93%, based on the available empirical data. More recent post-construction monitoring of pink-footed geese in the UK (Percival *et al.* 2008, Percival *et al.* 2015) shows that this higher rate provides a more realistic measure of the actual risk to geese. Waders too have only very occasionally been reported as collision victims (Hotker *et al.* 2004, Percival 2005, Illner 2011, Gove *et al.* 2013). However, even with high avoidance rates, if the numbers at risk of collision are very high there can still be a potential for a significant collision impact.

23. The mitigation of collision risk has been recently reviewed by Marques *et al.* (2014). This publication outlined a range of measures that have been implemented at existing wind farms in order to reduce collision risk. It includes details of several highly successful schemes, including:

    - Turbine shutdown on demand - Lucas *et al.* (2012) showed that wind turbine shutdown on demand halved Griffon Vulture fatalities in Andalusia, Spain, with only a marginal (0.07%) reduction in energy production. This study used human observers but automated (radar and video-based) systems are also now becoming available (Collier *et al.* 2011; Desholm *et al.* 2006).

- Restriction of turbine operation – this involves avoiding operation of the turbines at key risk times. This has been very effective for bats (Arnett *et al.* 2010), where reducing turbine operation during periods of low wind speeds reduced bat mortality by 44% - 93%, with marginal annual power loss (<1% of total annual output). For birds it is generally less likely to be such a useful tool, as defining the higher risk periods is usually more difficult, so it is unlikely that such a large reduction would be achievable without a much greater loss in power output.
- Habitat management – these schemes are usually implemented to reduce the attractiveness of the wind farm site for foraging (e.g. removal of carcasses for carrion feeding species) whilst at the same time increasing food availability elsewhere (to draw birds away from the wind farm and at the same time offset lost foraging opportunity) (Walker *et al.* 2005).
- Increasing turbine visibility – laboratory experiments have shown this to be a potentially effective tool but there have not yet been any field trials that have demonstrated a major benefit of such measures. Its applicability remains to be proven.
- Deterrents – bioacoustic or other scaring devices might have the potential to deter birds from flying in close proximity to wind turbines. Smith *et al.* (2011) showed that use of an acoustic deterrent (Long Range Acoustic Device) elicited strong reactions from 60% of Griffon Vultures but its efficacy depended on the distance from the bird, altitude and flock size. Deterrents also have the potential to be activated by automated real-time surveillance systems as an initial mitigation step and prior to blade curtailment (May *et al.,* 2012; Smith *et al.,* 2011). A possible problem with this mitigation though, as noted by Marques *et al.* (2014), is that the deterrent may have an unpredictable effect on the flight path and may not always deflect the bird in the desired direction.
- Compensation – these include measures to deliver a wider benefit to the populations that could be affected by the wind farm, including habitat expansion, creation or restoration, predator control and supplementary feeding.

Direct effects (2): loss of habitat

24. This should be an effect of low/negligible magnitude, with only a small area taken up by the powerline towers and by the wind turbine bases and access tracks. Use of existing tracks and the careful selection of routes for the access tracks and turbine locations, alongside use of proven construction techniques should be implemented to ensure that such effects on birds would be of low/negligible magnitude (even in a local context), and would not be significant. A Construction Method Statement should be produced and agreed with relevant stakeholders, before construction commences, to follow industry best practice.

Indirect effects: disturbance

25. Disturbance could potentially affect a rather greater area than direct habitat loss. Disturbance itself can result from several factors associated with the wind farm, including operational noise, the visibility of tall structures and increased human presence through maintenance activities, as well as the construction works prior to operation. Published studies have only been able to look at all of these factors acting together, so it is not possible to separate out the different aspects of disturbance when assessing the potential effects.

26. The maximum distance that wind turbines have been shown to affect birds is 800m (Percival 2005; Pearce-Higgins *et al.* 2009), though most reliable studies have not reported effects further than 600m from turbines (Drewitt and Langston 2006) and displacement is usually partial rather than complete (i.e. a reduction in use not complete exclusion). Displacement has generally been more widely reported and over a greater distance outside the breeding season.

27. Experience from existing wind farms has shown that many species, including many waterbirds, are tolerant of the presence of wind turbines and not unduly disturbed by them. A study of wintering golden plover, lapwing and pink-footed geese in the UK found no evidence of displacement of any of these species (Percival *et al.* 2008). All three species were observed feeding within 300m of wind turbines in years when their preferred crop was present in that zone. Some short-term displacement of species such as curlew may occur following construction but populations have been found to subsequently re-establish themselves (Bullen Consultants 2002). Most species that have been studied have not been significantly affected (Meek *et al.* 1993, Phillips 1994, Dulas 1995, Thomas 1999, Gill 2004, Percival 2005, Percival *et al.* 2008, Devereux *et al.*

2008). A recent RSPB study has reported partial displacement of breeding upland birds around wind turbines up to 800m (Pearce-Higgins *et al.* 2009). This scale and pattern of displacement is similar to that reported for breeding waders in general by Hotker *et al.* (2004), with most studies reporting only small scale (0-200m) displacement distances and a smaller number over a greater distance.

28. Studies of disturbance to wintering geese at existing wind farms have reported a range of results. Work on pink-footed geese by Larsen and Madsen (2000) found birds displaced from only 1-200m around wind turbines, an effect comparable to their displacement from hedgerows and farm buildings. A further study at the same site 10 years later found a displacement distance of only 40-100m (Madsen and Boertmann 2008). In Germany a study of barnacle geese (Kowallik and Borbach-Jaene 2001) recorded lower numbers than expected up to 600m from turbines, whilst a study on the same goose population in Sweden (Percival 1998) recorded no significant displacement effect at all, with the geese even feeding within 50m of turbines. The most likely explanation for these variable results is that these birds will avoid the close vicinity of wind turbines (up to 600m) where there is alternative feeding habitat in the area, but will move closer to them when alternative resources are more scarce. In terms of the ecological consequences of potential disturbance effects, these results would therefore suggest that either birds would just move to nearby alternative food sources (if available) or be more tolerant of the presence of the wind turbines.

29. Several of the studies referred to above relating to collision risk (e.g. Walker *et al.* 2005, Percival *et al.* 2009a, Percival *et al.* 2009b, Whitfield *et al.* 2006) have noted some displacement of raptors from a zone around wind turbines. This has typically been reported over a distance of 1-200m of turbines, though Fielding and Haworth (2013) found evidence of displacement of golden eagle up to 500m. Displacement effects have also been reported for White-tailed Eagles at Smøla, in Norway (May *et al.* 2013). Campedelli *et al.* (2013) found significant reductions in a range of raptor species at a wind farm in Italy. Though disturbance would reduce collision risk it does mean that the development of a wind farm could result in effective loss of habitat if birds are dissuaded from using the area in proximity to turbines. Any impact on the population would be dependent on importance of that area from which displaced and the availability of alternative areas, but any assessment should take into account the possibility of such small-scale displacement.

30. The most effective way to mitigate any such losses would be through the provision of alternative resources nearby (but outside the potential impact zone of the wind farm). Such measures have been successfully implemented at several wind farms, including for waterbirds (Percival *et al.* 2015) and raptors (Walker *et al.* 2005).

31. Disturbance is likely to be highest during construction owing to the activities being carried out. Pearce-Higgins *et al.* (2012) found that Red Grouse, Snipe and Curlew densities all declined on wind farms during construction, whilst densities of skylark and stonechat increased. Construction also involves the presence of work personnel on site which itself can be an important source of potential disturbance. Even at this time displacement from a zone around the wind turbines is likely to be only partial. Pearce-Higgins *et al.* (2012) for example reported decreases in curlew density during construction of 40% and snipe by 53%.

32. A further potential disturbance effect could be disruption to important flight lines (barrier effect; Percival 2005, Drewitt and Langston 2006). Birds may see the wind farm and change their route to fly around (rather than through) it. This would reduce the risk of collision but could possibly have other effects, for example potentially making important feeding areas less attractive (by acting as a barrier to the birds reaching them) and (if diversions were of a sufficient scale) resulting in increased energy consumption. Such a barrier effect needs to be assessed in the context of the location of any important local bird flight routes through the wind farm site.

Baseline Data Available

33. Baseline bird survey work is being led by Prof Devaka Weerakoon, of Colombo University Department of Zoology, with the specific objectives of the following:

    - Compile all available sources of existing background information on the bird populations reported in the areas identified for the proposed wind parks in the Mannar Island and provide an ornithological assessment of the potential impacts and level of risk to the bird population associated with the proposed wind park.

- Establish and follow internationally acceptable survey methodologies, survey locations and data collection formats to inform an ornithological assessment of the wind park development in the Mannar Island
- Prepare an inventory of birds that inhabit the areas identified for the wind park development in the Mannar Island and identify the presence of any endangered or restricted range species
- Document the baseline conditions that exist in the Mannar Island that can be used for future monitoring to assess the real impact arising due to the proposed development.
- Identify diurnal, and seasonal patterns of avifaunal behaviour and the factors that govern these behaviours such as wind, rain, etc.,
- Identify the potential impacts that may arise as well as to provide recommendations towards minimizing potential harmful impacts that may arise due to the proposed development
- Consult relevant stakeholders regarding the proposed wind power development in Mannar Island

34. The work reported here was undertaken to inform the wind farm development and the transmission line route to the substation on the mainland. The surveys undertaken for this work included the following survey methods:

    - **Line Transect surveys (Grid Counts)**: these surveys covered a high proportion of the study area, to determine temporal changes in bird composition, abundance and movement patterns within the study area. The study area was divided in to 1x1 km grids and a line transect was carried out in each square by slowly walking through the grid for a period of 20 min (the average distance that was covered during the timed transect was around 1 km), recording the birds observed, together with the height of flying birds and their direction of flight. Each grid was usually surveyed twice each year, once within and once outside the migration season, to determine the usage of each grid by migrants as well as resident bird species.
    - **Block counts**: these surveys set out to determine the densities of water birds and waders. Six main sites were covered (see Figure 3); Kora Kulam, the northern beaches and southern beaches and Kralls of Mannar Island, the salt pans, the Erukkalampiddy lagoon, and the Vankalai Sanctuary (including both sides of the causeway, Periya Kalapuwa, Mantai Kulam and other water bodies in the Sanctuary). Of these count areas though, it is only the Mannar Island south shore that is particularly relevant to the wind farm assessment, as all of the other areas lie outside the potential impact zone of the wind farm.

      Each site was divided into blocks and the birds in each block were counted using a spotting scope. The method was used to count birds that inhabit the main water bodies present within the study area. These counts were carried out during the migration season (three counts, made during January/February 2014, 2015 and 2016) and non-migration season (two counts in May/June 2014 and 2015) to determine different usage of these water bodies by aquatic birds. The Erukkalampiddy lagoon was only counted in 2015 and 2016, as it was dry in 2014 so held very few waterbirds. These counts were undertaken over a single day in each count area, but with repeat counts made during each sampling period. The mean of these repeat counts in each sampling period were the only data provided and hence were the data used in this assessment.
    - **Initial Vantage Point surveys**: these surveys were undertaken to quantify bird flight activity through the study area, and identify any important flight routes. The surveys were designed to primarily focus on visible migration through the survey area. Six vantage points were established along the long axis of the study area, three (VP1, 2 and 3) in the Vankalai Sanctuary on the route of the grid connection powerline, and three (VP4, 5 and 6) on Mannar Island within/in proximity to the areas identified for the wind farm. The locations of the vantage points are shown in Figure 2. The vantage point surveys were undertaken by scanning the area from each point by eye and with binoculars, to a distance of approximately 250m (where all species could be identified). Two observers sat and recorded back-to-back, giving 360° coverage. The surveys excluded small-scale local movements within the observation area.

      These surveys were very limited with regard to the wind farm proposal. They were primarily designed to provide sample data on visible bird migration over the study area and were located outside the current proposed wind farm site. They also only covered a short time period (February-April 2014 and October-November 2015). These surveys have therefore been superseded by an alternative vantage point survey methodology that is described below in order to improve the data on flight activity through the proposed wind farm site.

- **Enhanced Vantage Point Surveys (2016-17)**: following a review of the above data, further specific surveys have been carried out during June 2016 - March 2017, focused more on the specific wind farm site and on quantifying more precisely how many birds could be affected by the wind farm. These new surveys were undertaken from four Vantage Points (VP) along the southern Mannar Island shore, giving a view over the proposed wind farm site. The observation time at each VP varied between 24 and 60 hours, with a total observation time of 156 hours. Observations were made through the whole daylight period, and all bird flights observed were logged (to a distance of 2km from each VP). The following data were recorded for each observation:
    - Date and time
    - Species
    - Flock size
    - Flight direction
    - Flight height above the ground (estimated by eye) - to estimate flight height as accurately as possible available reference features (e.g. existing power lines, radio masts) were used. Flight heights was estimated to the nearest 1m below 10m, to 2m between 10 and 20m, to 5m between 20m and 50m, and to the nearest 10m above 50m. When birds were observed over an extended period, estimates of flight height were recorded every 30 seconds. The activity during each flight (e.g. striking prey, displaying, food passing) was also recorded. Particular attention was paid to any observations of birds at rotor height crossing the proposed wind farm site that would be at risk of collision.
    - Distance from beach at the time of observation using five distance categories:
        - 1 = Flying over the sea or the beach up to the high wave mark
        - 2= 0-50 m band inland from the high wave mark
        - 3= 50-100 m band inland from the high wave mark
        - 4= 100-150 m band inland from the high wave mark
        - 5 = land beyond 150 m from the high wave mark

    The survey methodology was updated from January 2017 to include mapping of flight lines of key species from each vantage point, to provide more detail on the movements of key (Critical Habitat) species through the wind farm site. A further 24-36 hours' data were collected from each of the four VPs over this period, with a total observation time of 120 hours. Key species comprised all of those that could be considered to be Critical Habitat species. All flight lines of key species were mapped, and the flight height of each flock recorded. Observations were carried out throughout daylight hours (planning to cover as wide a time range as possible on each visit) but not in periods of severely reduced visibility (<3km).

    The positions of the vantage points and the viewsheds (viewing to 2km) from those VPs are shown in Figure 2, in relation to current proposed layout. These vantage points gave a clear view across the wind farm site, with the large majority of the wind turbine envelope within 2km of the VP. The area in which the turbines will be located plus a 500m buffer could be observed by looking in a 180° arc forward from the vantage point, or for a wider arc two observers were used (i.e. there was no need for an observer to look behind to cover the site). Surveys were undertaken for a maximum of three-hour individual sessions to reduce observer fatigue.

- **Enhanced Block Counts (2016-17):** the objective of these additional surveys was to obtain data to sufficient spatial accuracy to enable key species numbers within the potential disturbance zone of the wind farm to be more accurately calculated. They were carried out during January-March 2017. They comprised regular counts on a sector-by-sector basis of all habitats that could hold Critical Habitat species (primarily open coastal and any other wetland), within 1km of the proposed wind turbine locations (to include all of the area that could possibly be affected by the wind farm). This survey area was divided into small (approximately 25 ha.) count sectors, but excluded habitat where Critical Habitat species would not be likely to occur (dry scrub/woodland). The extent of the survey area is shown in Figure 2. A total of six of these surveys was undertaken through this survey period. Though not covering the full year they do cover the period when bird numbers using this area are likely to be high.

The counts were carried out as instantaneous counts, recording a snapshot of the birds present in each sector at the time it is surveyed. Each sector was surveyed from an observation point over-looking it. One such count of each sector was made for each survey, recording the numbers of all the key species present. The same key species were recorded as for the VP surveys, i.e. all those that could be considered as Critical Habitat trigger species.

Review of Baseline Data Currently Available

35. The surveys carried out between January 2014 and April 2016 included a range of survey types, as described above, and have covered a wide survey area. These baseline data were not specifically collected for the purpose of collision risk modelling, so further more detailed observations of flight activity in proximity to the wind farm have also been carried out more recently.

36. The Grid Count line transects have successfully characterised the bird communities over the large survey area.

37. The Block Counts have provided very useful data on the Vankalai Sanctuary Ramsar site populations and on other wetland sites (and hence the ecological links with the Ramsar site). They are less useful though in understanding the populations at risk from the proposed development, as they did not record data in smaller sectors that would have given better understanding of the birds' spatial distribution (including the numbers in proximity to the proposed development).

38. The initial Vantage Point surveys were limited, as they were primarily designed to provide sample data on visible bird migration over the study area. They covered only a small proportion of the survey area (and of the potential impact zone of the development, for both the wind farm and the power line). They also only covered a short period (February-April 2014 and October-November 2015). These surveys have therefore been superseded by an alternative vantage point survey methodology that is described below, to improve the data on flight activity through the proposed wind farm site.

39. The VP surveys carried out during June 2016 -March 2017 have provided much-improved data on bird flight rates through the wind farm site, and have therefore enabled a much-improved collision risk modelling to be undertaken.

Summary of Survey Results

40. All of the survey results presented in this report focus on the main bird groups at risk of significant effect from the wind farm, i.e. waterbirds (including seabirds) and raptors (SNH 2014). This includes all species that are considered as Critical Habitat species.

Block Counts

41. The results available from the block count surveys of the South Shore count area (i.e. the area adjacent to the proposed wind farm site) are summarised in Table 1. These gives the count block peaks for the South Shore count area for each season (migrant/non-migrant). It should be noted that this count sector includes extensive areas outside the potential impact zone of the wind farm, so should only be used to give an indicative view of the baseline bird populations that could be affected by the wind farm.

Table 1. Waterbird and raptor counts seasonal peak counts recorded in the 'South Shore' count area during the Block Count Surveys, migrant (Sep-Apr) and non-migrant (Apr-Aug) seasons 2014-2016.

Species	**South Shore** **Non-migrant**	**Migrant**
Garganey	0	2000
White-breasted Waterhen	0	10
Purple Swamphen	0	16
Common Moorhen	0	12
Painted Stork	0	200
Asian Openbill	6	25
Eurasian Spoonbill	0	75
Black-headed Ibis	0	25
Indian Pond-heron	5	25
Eastern Cattle Egret	0	100
Grey Heron	11	50
Purple Heron	6	10
Great Egret	12	25
Intermediate Egret	30	60
Little Egret	34	350
Spot-billed Pelican	0	13
Little Cormorant	45	350
Indian Cormorant	10	250
Indian Stone-curlew	0	3
Great Thick-knee	12	8
Black-winged Stilt	10	45
Pacific Golden Plover	0	6
Common Ringed Plover	0	4
Little Ringed Plover	0	120
Kentish Plover	42	50
Lesser Sand Plover	40	100
Red-wattled Lapwing	10	15
Whimbrel	21	4
Eurasian Curlew	1	25
Black-tailed Godwit	0	10
Ruddy Turnstone	5	32
Curlew Sandpiper	0	75
Sanderling	0	32
Little Stint	0	180
Terek Sandpiper	11	56
Common Sandpiper	1	3
Common Greenshank	2	12
Common Redshank	2	25
Wood Sandpiper	0	12
Marsh Sandpiper	0	275
Brown-headed Gull	0	5000
Heuglin's Gull	0	3000
Little Tern	45	150
Saunders's Tern	8	20

Species	**South Shore** **Non-migrant**	**Migrant**
Gull-billed Tern	5	110
Caspian Tern	300	400
Whiskered Tern	2	150
Common Tern	100	0
Lesser Crested Tern	4	250
Sandwich Tern	0	2
Greater Crested Tern	1	100
Oriental Honey-buzzard	0	2
Changeable Hawk-eagle	2	2
Booted Eagle	0	4
White-bellied Sea-Eagle	2	2
Brahminy Kite	3	15
Black Kite	1	5
Common Kestrel	0	1

Grid Counts

42. The results of the grid count line transect surveys for grid squares that overlapped the potential impact zone of the wind farm (taken as the wind turbines plus a 600m buffer) are summarised in Table 2. This Table gives the peak monthly count made across all of the surveyed grid squares within this zone in the migrant (September-April) and non-migrant (May-August) seasons over the two survey years. The results of these surveys are again only indicative as only a small number of survey visits were made to each grid square (1-5 over the two survey years).

Table 2. Peak monthly bird counts of waterbirds and raptors recorded during the Grid Line Transect Surveys, during the migrant (Sep-Apr) and non-migrant (May-Aug) seasons, 2014-15 and 2015-16.

Species	**Migrant peak**	**Non-migrant peak**
White-breasted Waterhen	0	1
Asian Openbill	10	7
Indian Pond-heron	2	0
Eastern Cattle Egret	20	0
Purple Heron	0	1
Great Egret	4	1
Intermediate Egret	5	0
Little Egret	40	3
Little Cormorant	3	0
Great Thick-knee	5	2
Black-winged Stilt	1	0
Grey Plover	1	0
Kentish Plover	4	0
Lesser Sand Plover	13	3
Red-wattled Lapwing	25	13
Whimbrel	2	0
Ruddy Turnstone	9	2

Species	Migrant peak	Non-migrant peak
Sanderling	87	1
Common Sandpiper	13	1
Brown-headed Gull	136	3
Black-headed Gull	5	0
Heuglin's Gull	65	0
Little Tern	0	12
Gull-billed Tern	27	9
Caspian Tern	6	22
Whiskered Tern	7	0
Common Tern	2	0
Lesser Crested Tern	2	6
Greater Crested Tern	3	87
Booted eagle	1	0
White-bellied Sea-eagle	1	2
Brahminy Kite	33	10
Black Kite	2	0

Enhanced Vantage Point Surveys (June-December 2016)

43. The waterbird and raptor over-flying rates at rotor height (i.e. those at risk of collision) recorded during the June-December 2016 enhanced VP surveys are summarised in Table 3. This Table gives the mean over-flying rate recorded through the proposed wind farm site from each of the four vantage points.

Table 3. Waterbird and raptor flight rates (number of birds per hour) recorded through the proposed wind farm site, June-December 2016, from each of four vantage points.

Species	Migratory season (Sep-Dec) flight rate (birds/hour)				Non-migratory season (Jun-Aug) flight rate (birds/hour)			
	VP 1	VP 2	VP 3	VP 4	VP 1	VP 2	VP 3	VP 4
Northern Pintail	1.47	0	0	1.25	0	0	0	0
Indian Pond-heron	0.09	0.13	0.78	0	0	0	0	0
Eastern Cattle Egret	0	0.08	0	0	0	0	0	0
Purple Heron	0	0	0.06	0.04	0	0	0	0
Great Egret	0.03	0	0	0.04	0	0	0	0
Intermediate Egret	0.27	0	0.72	0	0.02	0	0	0
Little Egret	0.09	0.50	1.55	0.08	0.01	0.07	0	0
Spot-billed Pelican	1.50	0.42	0	0	0	0	0	0
Little Cormorant	0.03	0.38	0	0	0.05	0	0	0
Indian Cormorant	1.18	0	0	0	0.02	0	0	0
Heuglin's Gull	0.21	0	0	0	0	0	0	0
Gull-billed Tern	0.15	0.08	0.12	0	0	0	0	0
Caspian Tern	0.03	0	0	0	0	0	0	0
Little Tern	0	0	0	0	0.001	0	0.005	0.02
Lesser Crested Tern	0	0	0	0	0.001	0	0	0
Greater Crested Tern	0	0.13	0	0	0.02	0.004	0.04	0
Booted Eagle	0.06	0	0.06	0.04	0	0	0	0

Species	**Migratory season (Sep-Dec) flight rate (birds/hour)**				**Non-migratory season (Jun-Aug) flight rate (birds/hour)**			
	VP 1	**VP 2**	**VP 3**	**VP 4**	**VP 1**	**VP 2**	**VP 3**	**VP 4**
White-bellied Sea-eagle	0.29	0	0.48	0.13	0.02	0.04	0	0
Brahminy Kite	1.59	2.96	0.84	1.38	0.30	0.18	0.77	0.23
Common Kestrel	0	0	0	0.04	0	0	0	0

44. The flight rates in Table 3 relate to those birds passing through the wind farm itself. These rates were generally low, with most birds observed concentrated over the sea or along the long rather than coming further inland where the wind turbines would be located. Table 4 provides further information on this flight distribution. It gives the percentage of flights of each species that were recorded more frequently (>10 flights) in each of the five distance categories from the shore. By locating the VPs looking along the shore, it has been possible to more accurately determine which flights remained along the shore and which came further inland and through the wind farm site. All flights inland from the beach have been considered as potentially at risk of collision.

Table 4. Distribution of flights recorded during the VP surveys in relation to distance from the shore (Jun-Dec 2016, when data recorded to these distance classes).

Species	**Number of flocks recorded**	**Sea/beach**	**0-50m from beach**	**50-100m from beach**	**100-150m from beach**	**>150m from beach**
Indian Pond-heron	47	4%	40%	30%	17%	9%
Eastern Cattle Egret	52	40%	19%	29%	6%	6%
Purple Heron	10	0%	20%	30%	10%	40%
Great Egret	21	57%	10%	19%	5%	10%
Intermediate Egret	53	51%	21%	19%	8%	2%
Little Egret	298	72%	16%	8%	3%	1%
Spot-billed Pelican	5	0%	40%	20%	0%	40%
Little Cormorant	11	36%	18%	18%	18%	9%
Indian Cormorant	17	41%	18%	24%	12%	6%
Great Thick-knee	25	68%	24%	4%	4%	0%
Lesser Sand Plover	34	91%	9%	0%	0%	0%
Red-wattled Lapwing	18	0%	50%	44%	6%	0%
Ruddy Turnstone	16	88%	13%	0%	0%	0%
Sanderling	15	100%	0%	0%	0%	0%
Brown-headed Gull	187	100%	0%	0%	0%	0%
Heuglin's Gull	397	96%	3%	1%	0%	0%
Sooty Tern	11	100%	0%	0%	0%	0%
Little Tern	186	96%	2%	1%	1%	0%
Gull-billed Tern	1133	85%	12%	2%	0%	0%
Caspian Tern	35	94%	0%	3%	3%	0%
Whiskered Tern	24	92%	8%	0%	0%	0%
Lesser Crested Tern	185	99%	1%	0%	0%	0%
Greater Crested Tern	400	96%	3%	1%	0%	0%
White-bellied Sea-eagle	63	51%	16%	11%	10%	13%
Brahminy Kite	458	30%	20%	17%	19%	15%
Black Kite	12	50%	25%	17%	8%	0%

Enhanced Vantage Point Surveys (January-March 2017)

45. The waterbird and raptor over-flying rates at rotor height (i.e. those at risk of collision) recorded during the January-March 2017 VP surveys (surveys further enhanced with more detailed flight mapping) are summarised in Table 5. This Table gives the mean over-flying rate recorded through the proposed wind farm site at rotor height from each of the four vantage points.

Table 5. Waterbird and raptor flight rates (birds per hour) recorded through the proposed wind farm site, January-March 2017, from each of four vantage points.

Species	**Flight rate/hour (VP 1)**	**Flight rate/hour (VP 2)**	**Flight rate/hour (VP 3)**	**Flight rate/hour (VP 4)**
Painted Stork	0	0	0.042	0
Intermediate Egret	0.028	0	0	0
Spot-billed Pelican	0	0	0.167	0
Indian Cormorant	0	0	0	0.208
Great Black-headed Gull	0	0	0.042	0
Heuglin's Gull	0.115	0	0.208	0
Gull-billed Tern	0.119	0	0	0.250
Caspian Tern	0	0.083	0	0
Greater Crested Tern	0	0.111	0	0
White-bellied Sea-eagle	0	0.028	0	0
Brahminy Kite	0.338	0.489	0.637	11.780
Black Kite	0	0.028	0	0
Common Kestrel	0.028	0	0	0

Enhanced Block Counts (January-March 2017)

46. The waterbird and raptor counts made during the enhanced block counts in January-March 2017 are summarised in Table 6. These surveys covered all of the potential disturbance zone around the wind farm, so show the bird populations that could be at risk of disturbance over the survey period. This Table gives the count totals for each of the six survey days, and the overall peak count. Seven Critical Habitat species were recorded during these surveys; little egret, Indian cormorant, red-wattled lapwing, brown-headed gull, gull-billed tern, Caspian tern and lesser crested tern. Their distributions are shown in Figures 4a-g. Most were restricted to the beach/coastal habitat and were uniformly distributed along the coast. Only little egret, Indian cormorant, red-wattled lapwing were found on the inland sectors (on thonas/water channels).

Table 6. Waterbird and raptor block counts from in/around the the proposed wind farm site, January-March 2017 (daily count totals). Critical Habitat species are indicated in bold.

Species	**17-Jan**	**18-Jan**	**16-Feb**	**18-Feb**	**21-Mar**	**23-Mar**	**Peak**
Indian Pond-heron	4	9	7	18	18	26	**26**
Eastern cattle egret	35	31	29	63	39	88	**88**
Great egret	40	41	25	53	44	78	**78**
Intermediate egret	40	20	30	34	57	98	**98**
Little egret	**124**	**83**	**78**	**98**	**80**	**124**	**124**
Little cormorant	2	2	5	14	11	29	29

Species	**17-Jan**	**18-Jan**	**16-Feb**	**18-Feb**	**21-Mar**	**23-Mar**	**Peak**
Indian Cormorant	**0**	**4**	**20**	**17**	**22**	**48**	**48**
Red-wattled lapwing	**7**	**4**	**4**	**7**	**6**	**9**	**9**
Whimbrel	9	6	4	2	2	3	**9**
Sanderling	4	5	3	3	1	4	**5**
Terek sandpiper	6	3	6	2	2	2	**6**
Common sandpiper	18	19	13	8	11	23	**23**
Brown-headed gull	**166**	**178**	**195**	**169**	**282**	**345**	**345**
Black-headed gull	27	20	30	22	41	27	**41**
Heuglin's gull	161	164	165	171	245	316	**316**
Little tern	41	44	52	60	54	75	**75**
Gull-billed tern	**97**	**78**	**70**	**86**	**64**	**81**	**97**
Caspian tern	**18**	**29**	**17**	**13**	**7**	**8**	**29**
Whiskered tern	104	128	135	180	177	218	**218**
Lesser crested tern	**14**	**53**	**68**	**61**	**92**	**83**	**92**
Greater crested tern	17	13	13	25	17	23	**25**
White-bellied sea-eagle	8	2	3	2	3	1	**8**
Brahminy kite	43	34	40	35	29	33	**43**
Black kite	2	5	4	6	6	0	**6**

Evaluation of Conservation Importance

Critical Habitat Criteria

47. The highest ornithological sensitivity category relates to the ADB tests for Critical Habitat. Critical habitat is defined ADB (2012) as follows:

> *"Critical Habitat is an area that has high biodiversity value and may include sites that are legally protected or officially proposed for protection (e.g. areas that meet the International Union for Conservation of Nature (IUCN) classification criteria, the Ramsar List of Wetlands of International Importance, and United Nations Educational, Scientific, and Cultural Organization (UNESCO) world natural heritage sites. Critical habitat includes:*
>
> - *habitat required for the survival of critically endangered or endangered species*
> - *areas with special significance for endemic or restricted-range species*
> - *sites that are critical for the survival of migratory species*
> - *areas supporting globally significant concentrations or numbers of individuals of congregatory species*
> - *areas with unique assemblages of species that are associated with key evolutionary processes or provide key ecosystem services*
> - *areas with biodiversity that has significant social, cultural or economic importance to local communities*

48. Further, ADB's Good Practice Sourcebook (2012) states that " *In accordance with the SPS, no project activity is permitted in areas of critical habitat unless: (i) there are no measurable adverse impacts, or likelihood of such, on the critical habitat that could impair its high biodiversity value or ability to function; (ii) the project is not anticipated to lead to a reduction in the population of any recognized endangered or critically endangered species, or a loss in the area of the habitat concerned such that the persistence of a viable and representative host ecosystem will be compromised; and (iii) any lesser impacts are mitigated to achieve at*

least no net loss of biodiversity.”

49. A Critical Habitat Assessment has been undertaken following this guidance. The first step was to identify the internationally/nationally important designated areas that could qualify as Critical Habitat.

50. After that the species/populations of importance that triggered this Critical Habitat were identified through reference to the protected area designations and using the baseline survey data collected for the project EIA. This part of the assessment was done primarily using the 1% criterion (Wetlands International 2012)[1], with an area considered Critical Habitat if it supported more than 1% of the relevant flyway population (though with reference also to the global and national populations). As the baseline data and historic data were sparse, a precautionary approach was adopted utilizing the overall peak count as the key population indicator. Flyway and global populations were taken from the most recently-published Wetlands International report (Wetlands International 2012).

51. As the Vankalai Sanctuary Ramsar site is also internationally important for its wintering bird assemblage, and given the high between-year variability in numbers recorded, all populations with more than 0.5% of the flyway population, and species occurring in higher numbers (>500 individuals) have also been considered as potential Critical Habitat triggers (as contributing to the overall assemblage in numeric terms).

52. Nationally important species listed as Critically Endangered and/or Endangered in the Sri Lanka Red Data Book, endemics and range-restricted species have also been additionally considered, to determine whether there are any areas that could qualify as Critical Habitat on that basis (where nationally important numbers are present).

53. For the purposes of this assessment, therefore, the **Vankalai Sanctuary Ramsar site** (including the Periyakalapuwa mouth IBA) and the **Adam’s Bridge/Gulf of Mannar National Park** have been considered as **Critical Habitat**. The following section considers all of the species/populations that trigger this Critical Habitat definition from all of the baseline surveys, then focusses on which of these would be specifically affected by the proposed wind farm.

Critical Habitat Triggers: IUCN Red-listed Species

54. The species recorded during the baseline surveys that are listed on the IUCN red data list are given in Table 7. This gives their IUCN global and Sri Lanka red data status, and their status in the Mannar area (from the Ramsar Information Sheet). Only one, great knot, is globally endangered so is considered further in the Critical Habitat assessment on this basis.

Table 7. IUCN red-listed species recorded during the Mannar wind farm baseline surveys, 2014-17.

Species	IUCN Global Red List	Sri Lanka National Red List	Status (source: Ramsar Information Sheet)
Painted Stork	NT	LC	Common breeding resident
Asian Woollyneck	VU	NT	
Black-headed Ibis	NT	LC	Very common breeding resident
Spot-billed Pelican	NT	LC	Common breeding resident
Oriental Darter	NT	LC	Common breeding resident
Great Thick-knee	NT	LC	Common breeding resident
Eurasian Oystercatcher	NT		Migrant, regular here, very rare
Eurasian Curlew	NT		Migrant, common in the Mannar
Bar-tailed Godwit	NT		Migrant, common in the Mannar

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[1] Wetlands International, 2012. Waterbird Population Estimates, Fifth Edition. Summary Report. Wetlands International, Wageningen, The Netherlands

Species	**IUCN Global Red List**	**Sri Lanka National Red List**	**Status (source: Ramsar Information Sheet)**
‘Western’ Black-tailed Godwit	NT		*limosa* Very common migrant
‘Eastern’ Black-tailed Godwit	NT		[*limosa*] *melanuroides* Migrant, very rare
Great Knot	EN		Migrant, common
Red Knot	NT		Migrant, common here, rare elsewhere
Curlew Sandpiper	NT		Very common migrant
Pallid Harrier	NT		Migrant, common here, uncommon elsewhere

Note: Red Data Stats: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern.

Critical Habitat Triggers: Additional Sri Lanka RDB Red-listed Species

55. Additional species of Sri Lankan national conservation concern (red-listed) include Indian Spot-billed Duck, Black-winged Kite, Oriental Honey-buzzard, Black-crowned Night Heron, Kentish Plover, Little Ringed Plover, Eurasian Collard Dove, Crab-plover, Peregrine Falcon, Common Kestrel, Little Tern, Great Crested Tern, Saunders’s Tern, Gull-billed Tern, Caspian Tern, Common Tern, and Grey Francolin, though it should be noted that this listing is based on breeding rather than migratory populations. Of these four species, Spot-billed Duck, Gull-billed Tern, Caspian Tern, Common Tern are listed as nationally Critically Endangered/Endangered Species, so are considered further in the Critical Habitat assessment. Further consideration is also given to the following species with restricted range in Sri Lanka; Long-tailed Shrike, Eurasian Collared-dove, Grey Francolin and Black Kite; and to two Sri Lankan endemics; Common Woodshrike and Pompadour Green Pigeon.

Critical Habitat Triggers: Migratory/congregatory Populations

56. All species with qualifying populations for the Ramsar/IBA sites were considered as Critical Habitat triggers. The baseline data showed that there was a range of additional species that also had internationally important populations in the survey area, based on their peak population counts. This used the same criterion as applied to the designation of Ramsar sites to identify such populations, i.e. >1% of the global/flyway population. Consideration was also given to other populations that contributed to the overall waterbird assemblage.

57. Table 8 gives the details of the Ramsar species totals from the systematic block counts of the key wetland habitats across the survey area, including the Vankalai Sanctuary and the other important wetlands. All of these species are considered to contribute to the wintering waterfowl assemblage, and therefore have been considered further in the Critical Habitat Assessment.

Table 8. Ramsar listed species (in bold) and other species recorded in internationally important (>1% flyway) numbers (in red) and contributing to the internationally important wintering bird assemblage.

Species	**Migrant overall peak**	**Non-migrant overall peak**	**1% threshold**	**% flyway population at peak**
Lesser Whistling-duck	1321	4034	10000	0.4%
Garganey	5423	23	3500	1.5%
Northern Shoveler	1120	0	7100	0.2%
Eurasian Wigeon	2500	0	2500	1.0%
Northern Pintail	9410	12	20000	0.5%
Greater Flamingo	1800	0	2400	0.8%
Painted Stork	621	277	250	2.5%

Species	Migrant overall peak	Non-migrant overall peak	1% threshold	% flyway population at peak
Eurasian Spoonbill	589	112	230	2.6%
Black-headed Ibis	423	77	250	1.7%
Eastern Cattle Egret	612	2	20000	0.03%
Grey Heron	343	39	1000	0.3%
Great Egret	191	221	1000	0.2%
Intermediate Egret	333	134	1000	0.3%
Little Egret	2079	256	1400	1.5%
Spot-billed Pelican	188	72	100	1.9%
Little Cormorant	1530	340	2500	0.6%
Indian Cormorant	624	209	300	2.1%
Black-winged Stilt	1060	480	1700	0.6%
Pacific Golden Plover	355	0	710	0.5%
Kentish Plover	4033	588	710	5.7%
Lesser Sand Plover	13175	5008	1200	11.0%
Yellow-wattled Lapwing	18	75	70	1.1%
Red-wattled Lapwing	151	66	100	1.5%
Eurasian Curlew	376	11	1000	0.4%
Black-tailed Godwit	6344	104	1500	4.2%
Great Knot	88	1	30	2.9%
Curlew Sandpiper	15200	5010	2400	6.3%
Little Stint	17700	634	2400	7.4%
Common Greenshank	405	13	710	0.6%
Common Redshank	2377	952	1000	2.4%
Marsh Sandpiper	3073	5	1000	3.1%
Brown-headed Gull	10610	100	1400	7.6%
Heuglin's Gull	4330	2	10000	0.4%
Little Tern	376	595	710	0.8%
Gull-billed Tern	380	21	770	0.5%
Caspian Tern	3810	343	710	5.4%
Whiskered Tern	780	51	1000	0.8%
Common Tern	152	100	10000	0.02%
Lesser Crested Tern	3830	154	1600	2.4%
Greater Crested Tern	2632	26	10000	0.3%

58. Additionally, Indian Spot-billed Duck, though present in only small numbers in terms of the international flyway population, is very important from a national perspective (and on that basis has been cited on the Ramsar designation).

59. A Critical Habitat Assessment has assessed each of these species/populations, and its conclusions regarding the species that do trigger Critical Habitat are summarised in Table 9.

Table 9. Summary of Species for which Critical Habitat Supported

Species	Reason for Critical Habitat	Extent of Critical Habitat
Globally CR/EN		
Great Knot	>1% flyway population	Erukkalampiddy Lagoon
Nationally CR/EN		
Spot Billed Duck	Nationally important concentration of nationally critically endangered species	Korakulam and Vankalai sanctuary – transmission line corridor used as a feeding

Species	**Reason for Critical Habitat**	**Extent of Critical Habitat**
		area
Caspian Tern	Nationally important concentration of nationally critically endangered species	Vankalai Sanctuary, Erukkalampiddy Lagoon and the north shore of Mannar Island.
Common Tern	Nationally important concentration of nationally critically endangered species	Vankalai Sanctuary, Erukkalampiddy Lagoon and the north and south shores of Mannar Island
Gull-billed Tern	Nationally important concentration of nationally critically endangered species	Vankalai Sanctuary, Korakulam, Erukkalampiddy Lagoon and the north and south shores of Mannar Island
Migratory and Congregatory Species		
Spot billed pelican	>1% global population of a migratory or congregatory species	Vankalai Sanctuary
Curlew Sandpiper	BirdLife International’s Criterion A4 for congregations	Vankalai Sanctuary, Saltern and the north shore of Mannar Island
Northern pintail	Ramsar site Criterion 5	Vankalai sanctuary
Greater flamingo	Ramsar site Criterion 5 and 6	Vankalai sanctuary
Eurasian wigeon	Ramsar site Criterion 5 and 6	Vankalai sanctuary
Garganey	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary, Korakulam and the south shore of Mannar Island
Black-tailed godwit	Ramsar site Criterion 5 and 6	Vankalai sanctuary and Korakulam
Painted stork	>1% global population of a migratory or congregatory species	Vankalai sanctuary and Korakulam
Eurasian Spoonbill	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary
Black-headed Ibis	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary
Little Egret	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary
Indian Cormorant	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary, Korakulam and the north and south shore of Mannar Island
Yellow-wattled Lapwing	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary and Erukkalampiddy Lagoon
Red-wattled Lapwing	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary and the north shore of Mannar Island
Kentish plover	> 1% of the flyway population of a migratory/congregatory species	Vankalai sanctuary and Erukkalampiddy Lagoon
Lesser sand plover	>1% global population of a migratory or congregatory species	Vankalai Sanctuary, Saltern and north shore of Mannar Island
Little stint	>1% global population of a migratory or congregatory species	Vankalai Sanctuary, Saltern and north shore of Mannar Island
Common Redshank	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary
Marsh sandpiper	>1% global population of a migratory or congregatory species	Vankalai sanctuary, Saltern
Brown headed gull	> 1% of the flyway population of a migratory/congregatory species	North and south shores of Mannar Island
Lesser Crested Tern	>1% flyway population of a migratory or congregatory species	North shore of Mannar Island
Restricted range		
None		
Endemic		
None		

60. The key Critical Habitat Species present at the proposed Wind Farm site and hence at risk of being affected by the development were as follows:

- Species flying through the wind farm site at risk of collision/barrier effect:
    - Northern Pintail

  - Little Egret
  - Spot-billed Pelican
  - Indian Cormorant
  - Gull-billed Tern
  - Caspian Tern
  - Lesser Crested Tern
- Species at risk of disturbance - those that use habitats within the potential disturbance zone:
  - Little Egret
  - Indian Cormorant
  - Red-wattled Lapwing
  - Brown-headed Gull
  - Gull-billed Tern
  - Caspian Tern
  - Lesser Crested Tern

Proposed wind turbine layout and details of the anticipated wind turbine model for input into the collision risk model

61. RMA Energy Consultants have developed a Master Plan for wind power development in the Mannar District on behalf of the ADB. The project assessed in this report represents the first phase in the implementation of that plan, with consideration also given to possible future phases. The location of the proposed wind farm site is shown in Figure 1. This is located within the site boundary identified in the RMA Master Plan, though with the western edge of the scheme slightly reduced to avoid any development with the Adam's Bridge National Park. That National Park was designated after the RMA study had been completed.

62. The proposed overhead powerline that will connect the wind farm to the grid (assessed here as an associated facility) will also pose a collision risk to birds, particularly as it will cross the Vanaklai Sanctuary Ramsar site, a site of international importance for its waterbird populations. The proposed route of the powerline is shown in Figure 1.

Ornithological Assessment Methods

Assessment Methodology

63. The key test for this assessment is whether the ADB Critical Habitat requirements in paragraph 28 of Appendix 1 of ADB's Safeguard Policy Statement (SPS) 2009 can be met by the project. That paragraph states that:

> *"No project activity will be implemented in areas of critical habitat[2] unless the following requirements*

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[2] *Critical habitat is a subset of both natural and modified habitat that deserves particular attention. Critical habitat includes areas with high biodiversity value, including habitat required for the survival of critically endangered or endangered species; areas having special significance for endemic or restricted-range species; sites that are critical for the survival of migratory species; areas supporting globally significant concentrations or numbers of individuals of congregatory species; areas with unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services; and areas having biodiversity of significant social, economic, or cultural importance to local communities. Critical habitats include those areas either legally protected or officially proposed for protection, such as areas that meet the criteria of the World*

> *are met:*
>
> *(i) There are no measurable adverse impacts, or likelihood of such, on the critical habitat which could impair its high biodiversity value or the ability to function.*
>
> *(ii) The project is not anticipated to lead to a reduction in the population of any recognized endangered or critically endangered species[3] or a loss in area of the habitat concerned such that the persistence of a viable and representative host ecosystem be compromised.*
>
> *(iii) Any lesser impacts are mitigated in accordance with para. 27."*

64. Paragraph 27 of the SPS Appendix 1 referred to above states that:

> "*Mitigation measures will be designed to achieve at least no net loss of biodiversity. They may include a combination of actions, such as post project restoration of habitats, offset of losses through the creation or effective conservation of ecologically comparable areas that are managed for biodiversity while respecting the ongoing use of such biodiversity by Indigenous Peoples or traditional communities, and compensation to direct users of biodiversity."*

65. This assessment is also being informed by reference to the other international assessment methodologies produced by Scottish Natural Heritage (2006) for the wider countryside, the UK Institute for Ecological and Environmental Management (2006) and Percival (2007) – an assessment methodology widely used in the wind industry. This includes evaluation of the conservation importance (as defined in Table 10) of the bird populations present in the study area, and the magnitude of the likely effects on those receptors (as described in Table 11).

66. The conservation importance of the bird populations in the study area was assessed by reference to Table 8 and by using the standard 1% criterion method (Holt *et al.* 2015); >1% national population = nationally important, >1% international population = internationally important. A further category of 'local importance' was used for species that did not reach regional importance but were still of some ecological value.

Table 10. Conservation importance of bird species

Conservation Importance	**Definitions**
VERY HIGH	Cited interest of an internationally or nationally important statutory protected sites. Cited means mentioned in the citation text for those protected sites as a species for which the site is designated. Includes all ADB Critical Habitat trigger species/populations.
HIGH	Other species that contribute to the integrity of an internationally or nationally important statutory protected sites species for which the site is designated. A local population of more than 1% of the national population of a species. Any ecologically sensitive species, e.g. large birds of prey or rare birds (usually taken as <300 breeding pairs in the UK). Species recognised as requiring special conservation measures or otherwise specially protected (in a UK context this includes EU Birds Directive Annex 1, EU Habitats Directive priority habitat/species and/or W&C Act Schedule 1 species).

Conservation Union classification, the Ramsar List of Wetlands of International Importance, and the United Nations Educational, Scientific, and Cultural Organization's world natural heritage sites.

[3] *As defined by the Word Conservation Union's Red List of Threatened Species or as defined in any national legislation.*

Conservation Importance	Definitions
MEDIUM	Regionally important population of a species, either because of population size or distributional context.
LOW	Any other species of conservation interest.

Table 11. Definition of terms relating to the magnitude of ornithological impacts

Magnitude	Definition
VERY HIGH	Total loss or very major alteration to key elements/ features of the baseline conditions such that post development character/ composition/ attributes will be fundamentally changed and may be lost from the site altogether. Guide: >80% of population/habitat lost
HIGH	Major alteration to key elements/ features of the baseline (pre-development) conditions such that post development character/composition/attributes will be fundamentally changed. Guide: 20-80% of population/habitat lost
MEDIUM	Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/ composition/ attributes of baseline will be partially changed. Guide: 5-20% of population/habitat lost
LOW	Minor shift away from baseline conditions. Change arising from the loss/ alteration will be discernible but underlying character/ composition/ attributes of baseline condition will be similar to pre-development circumstances/patterns. Guide: 1-5% of population/habitat lost
NEGLIGIBLE	Very slight change from baseline condition. Change barely distinguishable, approximating to the "no change" situation. Guide: <1% of population/habitat lost

Collision Risk Modelling Methodology (Wind Turbines)

67. One of the main potential ornithological impacts of concern for the Mannar wind farm is collision with the operational turbines. Collision risk modelling (CRM) has therefore be undertaken following the method of Band *et al.* (2007), as extensively used in the UK and elsewhere. Details of the original SNH guidance on this model (Band 2000) are available from the SNH web site at <www.snh.gov.uk/docs/C205425.pdf>. The model runs as a two-stage process. Firstly, the risk is calculated making the assumption that flight patterns are unaffected by the presence of the wind turbines, i.e. that no avoidance action is taken. This is essentially a mechanistic calculation, with the collision risk calculated as the product of (i) the probability of a bird flying through the rotor swept area, and (ii) the probability of a bird colliding if it does so. This probability is then multiplied by the estimated numbers of bird movements through the wind farm rotors at the risk height (i.e. the height of the rotating rotor blades) in order to estimate the theoretical numbers at risk of collision if they take no avoiding action.

68. The second stage then incorporates the probability that the birds, rather than flying blindly into the turbines, will actually take a degree of avoiding action, as has been shown to occur in all studies of birds at existing wind farms (Urquhart 2010[4]). Discussion as to the most appropriate avoidance rates to apply is included in the following section.

69. The CRM has been carried out on the key species of concern (i.e. those listed in Tables 6 and 7) that were

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[4] See SNH web site: www.snh.gov.uk/docs/B721137.pdf

observed flying within the collision risk zone at risk height, for both the wind turbines and for the overhead power line. Whilst other species were also recorded flying through the collision risk zone, collision risks were only considered to be potentially significant to those that were modelled (as a result of a combination of the numbers observed, their flight behaviour and their population status in the area).

70. The collision modelling requires a range of input data on the wind turbine specifications, which have been provided by the CEB (Table 12). This modelling has taken a conservative approach, running the model for the turbine likely to give the highest collision risk of the options being considered. The model has been run for the current proposed 39-turbine layout being assessed (the first phase of the Mannar wind farm). A conservative approach has been taken that all 39 of these turbines would be built, though it is likely that a reduced number of turbines would actually be constructed.

Table 12. Wind turbine data to be used in the collision risk modelling.

Specification	**Turbine input data**
Number of turbines	39
Hub height	80-100m
Rotor diameter	130m
Height to blade tip (max)	155m
Minimum height of blade above ground	25m
Rotational speed (variable – mean of range used)	5-20rpm (mean 12.5rpm)
Blade maximum chord	4.5m
Blade pitch (variable – mean value used)	6°
Turbine operation time (when not constrained by high/low wind speed or maintenance activity)	90%

71. The collision model also requires data on bird body size and flight speed. Body sizes and baseline mortality rates were taken from Robinson (2005) and Grimmet et al. (2012) and flight speeds from Alerstam et al. (2007).

72. The results of any collision risk modelling using the Band *et al.* (2007) approach is highly sensitive to the avoidance rate used (Chamberlain *et al.* 2006). Application of an appropriate rate is therefore of fundamental importance in undertaking such modelling. However, there are very few studies at existing wind farms where avoidance rates have been fully determined, comparing pre-construction flight activity with the actual numbers of collisions post-construction (Urquhart 2010). The approach generally used to address this is to apply a precautionary rate based on the available data, such that any collision prediction is unlikely to be exceeded (i.e. represents a conservative estimate of the number of collisions). Where data on actual avoidance rates of particular species/groups have been established, then this has usually enabled a higher rate to be safely applied. For example, SNH has recently recommended a move from a 99% rate to 99.8% for geese based on recent research (Douse 2013). SNH now recommends using a value of 99.8% as an avoidance rate for geese (Douse 2013), 99% for several birds of prey (including Golden Eagle and Hen Harrier), and 98% for most other species (Urquhart 2010).

73. There is a lack of specific avoidance rate data from Sri Lanka and on the species of concern at Mannar. As collision avoidance rates are not yet known for the species of concern, suitable overseas species have been used as proxies. The selection of appropriate rates followed SNH guidance and with reference to the bird-wind farm literature. As recommended in SNH guidance, a precautionary 98% was adopted as the default value (Urquhart 2010) but the work has also explored whether particular species exhibit similar behaviour to more vulnerable species such as White-tailed Sea Eagle and Kestrel, or such behaviour that would reduce risk (and hence allow higher rates to be used as is recommended by SNH for Golden Eagle and Hen Harrier for example). The collision risk modelling results is presented for each layout for a range of avoidance rates to inform the assessment but the most appropriate rate to apply in each specific case will be indicated.

Collision Risk Modelling Methodology (Transmission Line)

74. The primary ornithological concern regarding the associated facilities of the proposed development is the collision risk posed by the overhead transmission line, where it passes through the Vankalai Sanctuary Ramsar site.

75. A similar approach to the wind farm collision risk modelling was adopted for modelling the collision risk posed by the overhead power line that will connect the wind farm to the grid. This has involved the calculation of the percentage of flight paths through the transmission line that would result in a collision, then the application of an appropriate avoidance rate. The transmission line wires would be between 15m and 45m above the ground, and would run for 7.5km through the Vankalai Sanctuary (the key area of concern). The risk zone around each wire was calculated for each species dependent on its size (wingspan), assuming a conservative position that any flight within a wing-length of a wire could result in collision.

76. Predicting collision risk of overhead lines requires information on both the vulnerability of species to collision and the exposure of those species to the risk (i.e. the numbers of flights across the transmission line). Whilst vulnerability of different species has been widely studied (e.g. Bevanger 1998), there are few studies that have quantified the exposure to risk and documented the numbers of collisions that have occurred, both of which are needed in order to produce robust measures of avoidance rates (and hence quantify the risk).

77. Janss and Ferrer (2000) is one of the few studies that have quantified the exposure to risk and documented the numbers of collisions that have occurred, and this was done for two species considered particularly vulnerable to collision, great bustard and common crane. Using the data from that study and the collision risk model used here generated estimates of avoidance rate of 99.5% for the bustards and 99.98% for the cranes, so these values have been used to inform the assessment of the Mannar transmission line.

78. The transmission line modelling was limited by the amount of baseline data available, from only three vantage points (covering approximately 1.5km of the 7.5km route through the Ramsar site) and for surveys over only a short period of time (Feb-Apr 2014 and Oct-Nov 2015). The paucity of baseline data has meant that a series of precautionary assumptions had to be made, so the figures produced should be treated as conservative estimates rather than estimates of the most likely outcome. It was, however, possible to use this analysis of the bird collision risk to determine the key species at risk and inform the mitigation measures required.

79. Finally, the cumulative collision risk of the wind farm and the overhead transmission line in combination has been considered.

Collision Modelling Interpretation

80. Whilst the Band wind turbine collision model and the transmission line risk modelling produce a quantitative estimate of the numbers of birds that might collide with the wind turbines, those numbers need to be put into the context of the existing mortality to enable their significance to be assessed. The same level of additional mortality on a population that has a low level of background mortality could potentially have a much more important effect than on a population with a higher level of existing mortality. The collision mortality needs to be assessed in the context of each species population dynamics. In the UK a 1% increase over the baseline mortality is now frequently used as an initial filter threshold above which there may be a concern with the predicted collision mortality (and hence requiring further investigation). The ‘baseline mortality’ is the mortality that would occur in the absence of the wind farm (calculated from the population sizes and published mortality rates). The % increase over baseline mortality therefore sets the predicted wind farm mortality as a percentage of the mortality that would occur in the absence of the development. Collision risks below a 1% increase are usually considered not to be significant.

81. In the context of the Mannar site, the predicted collision mortality has been set against the Ramsar population background mortality for each of the key species at risk of collision (as set out in the Ramsar Information Sheet, and also using the block count data from the wind farm baseline surveys).

Collision Risk Modelling Results: Wind Farm

82. The results of the collision risk modelling are summarised in Table 13. The results are presented for a range of avoidance rates, with 98% adopted as a conservative position used to inform the further assessment (following SNH guidance, Urquhart 2010). The percentage increase over the baseline mortality is also given, for that 98% avoidance, together with the magnitude of effect that could represent.

Table 13. Predicted annual number of collisions of key species with the proposed first 100MW phase of the Mannar Island wind farm.

Species	**Predicted number of collisions by avoidance rate:**				**% increase over baseline mortality (98% avoidance)**	**Indicative magnitude of effect**
	98%	**99%**	**99.8%**	**99.9%**		
Critical Habitat Species:						
Northern Pintail	2.1	1.1	0.5	0.2	0.02%	Negligible
Little Egret	2.7	1.3	0.7	0.3	0.5%	Negligible
Painted Stork	0.1	0.03	0.01	0.005	0.04%	Negligible
Spot-billed Pelican	1.5	0.7	0.4	0.1	9.7%	Medium
Indian Cormorant	0.8	0.4	0.2	0.1	1.7%	Low
Gull-billed Tern	0.46	0.23	0.12	0.05	1.0%	Low
Caspian Tern	0.2	0.08	0.04	0.02	0.2%	Negligible
Lesser Crested Tern	0.01	0.003	0.002	0.001	0.002%	Negligible
Other Important Species:						
Little Cormorant	0.51	0.3	0.1	0.1	0.4%	Negligible
Heuglin's Gull	0.35	0.2	0.1	0.0	0.07%	Negligible
Little Tern	0.33	0.2	0.1	0.0	0.1%	Negligible

83. This modelling has highlighted three Critical Habitat trigger species that could be at significant risk of collision with the wind turbines; (i.e. a non-negligible magnitude collision risk) Spot-billed Pelican, Indian Cormorant and Gull-billed Tern. Though only low numbers of collisions were predicted, their populations are also low and hence more vulnerable to any additional mortality. The collision risk to other Critical Habitat species - and all other bird species - would not be significant.

Collision Risk Modelling Results: Transmission Line (associated facility)

84. The results of the collision risk modelling for the transmission line within the Ramsar site are summarised in Table 14. As for the transmission line modelling, the results are presented for a range of avoidance rates, with 99.5% adopted as a conservative position used to inform the further assessment (given the results of the modelling with the Janss and Ferrer 2000 data, for a species highly vulnerable to collision with power lines, great bustard), and 99.98% as an estimate of the more likely outcome (derived from the same study for common crane). The percentage increase over the baseline mortality is also given, for that conservative position 99.5% avoidance (the ‘conservative position’ being the highest value that could reasonably be expected to occur given the available information).

Table 14 Predicted annual number of collisions of key species with the proposed transmission line through the Vankalai Sanctuary Ramsar site.

	Conservative case (99.5% avoidance rate)			**Likely outcome (99.98% avoidance rate)**		
Species	**Collision risk (unmitigated)**	**Collision risk (with markers)**	**% increase over baseline mortality (residual)**	**Collision risk (unmitigated)**	**Collision risk (with markers)**	**% increase over baseline mortality (residual)**
Critical Habitat Species:						
Garganey	76.0	15.2	0.35%	3.0	0.61	0.01%
Eurasian Wigeon	13.6	2.7	0.01%	0.5	0.11	0.0004%
Indian Spot-billed Duck	2.9	0.6	4.87%	0.1	0.02	0.19%
Northern Pintail	257.6	51.5	0.51%	10.3	2.06	0.02%
Greater Flamingo	12.8	2.6	3.57%	0.5	0.10	0.14%
Painted Stork	16.7	3.3	2.50%	0.7	0.13	0.10%
Eurasian Spoonbill	2.2	0.4	0.42%	0.1	0.02	0.02%
Black-headed Ibis	4.1	0.8	1.29%	0.2	0.03	0.05%
Little Egret	4.6	0.9	0.18%	0.2	0.04	0.01%
Spot-billed Pelican	61.7	12.3	81.7%	2.5	0.49	3.27%
Indian Cormorant	2.6	0.5	1.18%	0.1	0.02	0.05%
Lesser Sand Plover	8.5	1.7	0.08%	0.3	0.07	0.003%
Curlew Sandpiper	7.7	1.5	0.08%	0.3	0.06	0.003%
Brown-headed Gull	6.9	1.4	0.12%	0.3	0.06	0.005%
Caspian Tern	20.5	4.1	1.13%	0.8	0.16	0.05%
Gull-billed Tern	6.4	1.3	1.88%	0.3	0.05	0.07%
Other Important Species:						
Lesser Whistling-duck	2.5	0.5	0.06%	0.1	0.02	0.002%
Northern Shoveler	1.3	0.3	0.08%	0.1	0.01	0.003%
Little Cormorant	21.2	4.2	3.27%	0.8	0.17	0.13%
Black-winged Stilt	4.8	1.0	0.36%	0.2	0.04	0.01%
Heuglin's Gull	0.3	0.1	0.01%	0.01	0.002	0.0005%
Little Tern	0.4	0.1	0.20%	0.02	0.003	0.01%
Whiskered Tern	3.8	0.8	1.12%	0.2	0.03	0.04%
Peregrine Falcon	0.1	0.0	0.08%	0.004	0.001	0.003%

85. These results for the transmission line collision modelling should be considered carefully in light of the issues with the baseline data. They should be viewed as an index of relative risk rather than accurate predictions of the numbers of collisions that are likely to occur. The low total amount of survey time at each transmission line VP over only a small number of survey days, means that even a single observation can skew the results, and makes the results less reliable. The results for Spot-billed Pelican, for example, likely over-estimate the actual risk to this species. Similarly, less frequent events of importance may have been missed as a result of the sampling strategy. This was highlighted by the observation of three additional very large duck flocks of note during the VP surveys of the powerline within the Vankalai Ramsar site. These were all recorded on 29/11/15; 60,000 Eurasian Wigeon, 30,000 Northern Pintail and 10,000 Garganey. These illustrate the large numbers present in the area, and reinforce the need for mitigation measures to be applied.

86. Whilst these predicted number of collisions do need to be treated with considerable caution, this modelling has still highlighted the key species at risk of collision with the transmission line; Indian Spot-billed Duck, Northern Pintail, Greater Flamingo, Painted Stork, Black-headed Ibis, Spot-billed Pelican, Indian Cormorant

and Caspian Tern (as well as Little Cormorant and Whiskered Tern, though neither of these are Critical Habitat species). Significant collision risks to these species could not be excluded given the information available, so a package of appropriate mitigation measures has been agreed and is beingimplemented.

Collision Risk: Cumulative Effects

87. The cumulative collision risks from the wind farm and the transmission line would be additive, and they have been set out in Table 15. As the transmission line has now been approved and mitigation measures agreed, only the residual effects with that mitigation implemented have been considered here. A conservative assumption has been made applying a 98% avoidance for the wind farm and 99.5% for the transmission line.

Table 15. Cumulative annual collision risk of the Mannar Island wind farm in combination with the transmission line.

Species	**Wind farm Phase 1 collision risk**	**Transmission line collision risk (mitigated)**	**Cumulative collision risk (transmission line + Phase 1 wind farm)**	**% increase of cumulative risk over baseline mortality**	**Magnitude**
Critical Habitat Species:					
Garganey	0	15.2	15.2	0.4%	Negligible
Eurasian Wigeon	0	2.7	2.7	0.01%	Negligible
Indian Spot-billed Duck	0	0.6	0.6	4.9%	Low
Northern Pintail	2.1	51.5	53.6	0.5%	Negligible
Greater Flamingo	0	2.6	2.6	3.6%	Low
Little Egret	2.7	0.9	3.6	0.7%	Negligible
Painted Stork	0	3.3	3.3	2.5%	Low
Eurasian Spoonbill	0	0.4	0.4	0.4%	Negligible
Black-headed Ibis	0	0.8	0.8	1.3%	Low
Spot-billed Pelican	1.5	12.3	13.8	91.3%	Very high
Indian Cormorant	0.8	0.5	1.3	2.9%	Low
Lesser Sand Plover	0	1.7	1.7	0.1%	Negligible
Curlew Sandpiper	0	1.5	1.5	0.1%	Negligible
Brown-headed Gull	0	1.4	1.4	0.1%	Negligible
Caspian Tern	0.1	4.1	4.3	1.2%	Low
Gull-billed Tern	0.5	1.3	1.7	3.8%	Low
Lesser Crested Tern	0.01	0.0	0.01	0.002%	Negligible
Other Important Species:					
Lesser Whistling-duck	0	0.5	0.5	0.1%	Negligible
Northern Shoveler	0	0.3	0.3	0.1%	Negligible
Little Cormorant	0.5	4.2	4.8	3.7%	Low
Black-winged Stilt	0	1.0	1.0	0.4%	Negligible
Heuglin's Gull	0.4	0.1	0.4	0.1%	Negligible
Little Tern	0.3	0.1	0.4	1.0%	Low
Whiskered Tern	0	0.8	0.8	1.1%	Low
Peregrine Falcon	0	0.02	0.02	0.1%	Negligible

Barrier Effects

88. Both the wind farm and the associated transmission line have the potential to act as a barrier to bird flights, which could be important if they were located on routes that were used by large numbers of birds and there were no alternative routes around the barriers (or if any alternative route involved significantly greater energy expenditure). However, the baseline surveys of bird flight activity at the site have shown that the more important flight routes are broadly parallel to the transmission line and to the longer axis of the wind farm, so it is not considered that any barrier effects of either the transmission line or the wind farm would be significant.

Disturbance Effects

89. The January-March 2017 block counts of the wind farm site and its surrounds have shown that the potential disturbance zone around the wind farm is used by a range of species that could be affected by disturbance, including seven Critical Habitat species; little egret, Indian cormorant, red-wattled lapwing, brown-headed gull, gull-billed tern, Caspian tern and lesser crested tern. Table 16 summarises the peak counts made in the potential disturbance zone around the wind farm (from these block counts) and compares them with the peak counts from the whole survey area (including the Vankalai Sanctuary and the whole of Mannar Island), to make an assessment of the local importance of the numbers at risk of disturbance. The Table also shows the species that have been identified as Critical Habitat species.

Table 16. Peak counts at risk of disturbance and the local importance of those numbers.

Species	Wind farm peak count	Critical Habitat species	Survey area peak population	% peak at wind farm
Indian Pond-heron	26		144	18%
Eastern cattle egret	88		612	14%
Great egret	78		221	35%
Intermediate egret	98		333	29%
Little egret	124	✓	2079	6%
Little cormorant	29		1530	2%
Indian Cormorant	48	✓	624	8%
Red-wattled lapwing	9	✓	151	6%
Whimbrel	9		32	28%
Sanderling	5		358	1%
Terek sandpiper	6		337	2%
Common sandpiper	23		73	32%
Brown-headed gull	345	✓	10610	3%
Black-headed gull	41		41	100%
Heuglin's gull	316		4330	7%
Little tern	75		595	13%
Gull-billed tern	97	✓	380	26%
Caspian tern	29	✓	3810	1%
Whiskered tern	218		780	28%
Lesser crested tern	92	✓	3830	2%
Greater crested tern	25		2632	1%
White-bellied sea-eagle	8		8	100%
Brahminy kite	43		60	72%
Black kite	6		14	43%

90. Of the seven Critical Habitat species, the numbers within the disturbance zone are generally low in

comparison with those elsewhere in the survey area, with the peak in this zone representing only 6% of the local little egret population, 8% of the Indian cormorants, 6% of the red-wattled lapwing, 3% of the brown-headed gulls, 1% of the Caspian terns and 2% of the lesser crested terns. This zone did though hold a peak count of 97 gull-billed terns, which is equivalent to 26% of the peak count recorded over the whole survey area, indicative that this zone is relatively more important for that species. It also held relatively high populations of several other non-Critical Habitat species, notably Indian pond-heron, Eastern cattle egret, great egret, intermediate egret, little tern and whiskered tern.

91. The birds at risk of disturbance are predominantly fish-eating species, that are using the beach to rest between fishing trips (cormorants and terns) or are opportunistically associating with fishermen - scavenging their discards or following their nets during hauling to capture escaping fish (egrets and gulls). Their presence in this area is therefore likely to be strongly influenced by the fishing activity - this largely switches to the north shore in May through to October, so numbers in the wind farm would be likely to be much lower at that time. Many of these birds are highly habituated to presence of people, reducing their vulnerability to disturbance.

92. Published studies of similar species at existing wind farms have generally shown little evidence of any biologically significant disturbance effects, including for cormorants, gulls and terns (Furness and Wade 2012, Percival 2013, Krijgsveld 2014, Percival *et al*. 2016). The likelihood of disturbance to these species at the Mannar wind farm is therefore considered to be low, though given the proximity between the wind turbines and the beach/wetland habitats, some minor disturbance effects cannot be completely ruled out. As a result, it will still be necessary to implement mitigation measures to avoid any net loss of habitat to any Critical Habitat species as a result of disturbance from the wind farm. The proposed Biodiversity Management Plan for the Vankalai Sanctuary and the Adam's Bridge National Park should enable this requirement of no net loss to be achieved.

Mitigation

93. It is clear from this assessment that there are important bird populations that could be affected by the proposed development, and a package of mitigation measures will therefore be required to satisfy the ADB Critical Habitat requirements. These are set out in the following section.

Wind Farm Mitigation

94. Several potentially significant collision risks have been identified in the assessment, for three Critical Habitat species; Spot-billed Pelican, Indian Cormorant and Gull-billed Tern. Mitigation measures will therefore be needed to reduce collision risk.

95. A range of possible mitigation options have been considered, including (a) specific turbine shutdown on demand when risk of collision is imminent, (b) wider restriction of turbine operation in certain seasons/times of days associated with higher risks, (c) habitat management, (d) increasing turbine visibility, (e) use of deterrents and (f) compensation.

96. Of these, (b), (d) and (e) are considered unlikely to provide a deliverable solution at Mannar. With regards to (b), there are not any specific periods/seasons to which risk is restricted, so an economically viable scheme would be unlikely. Options (d) and (e) are not widely proven techniques and still in the developmental phase, so could not currently be relied upon. Each of the other three are discussed below:

- *Turbine shutdown on demand*

97. Curtailment of the operation of wind turbines could potentially be a useful mitigation measure to reduce collision risk, but is often uneconomic. Recent developments of schemes that have very limited shutdown over short periods has made the implementation of such schemes more viable, and there are now several in operation globally (mainly in southern Europe). These rely either on direct human observers at key risk periods and/or automated detection systems based on radar or video monitoring. CEB are proposing to install a bird radar with the wind farm, which could provide the basis for delivery of this mitigation. A system should be implemented at Mannar to provide a back-up response should the number of collisions approach levels that could be significant (i.e. non-negligible magnitude), informed by the post-construction monitoring programme.

- *Habitat Management (on-site)*

98. The key bird species at risk are just over-flying the wind farm site rather than using any of its particularly habitats, so on-site habitat management would not be able to deliver any reduction in collision risk.

- *Habitat management (off-site)*

99. Habitat management measures implemented off-site have the potential to deliver a benefit that could outweigh the risk of any negative effect from the wind farm. A Biodiversity Management Plan for the Vankalai Sanctuary has already been agreed as part of the mitigation measures for the transmission line, and this could be extended to deliver a further benefit to the Critical Habitat species at risk from the wind farm itself. This should include measures to enhance the conservation value of the Adam's Bridge National Park as well as the Vankalai Sanctuary.

100. Additionally, mitigation will also be required to reduce impacts during the construction (and decommissioning) phase of the development (through the production and implementation of a Construction Method Statement following industry best practice).

Transmission Line Mitigation

101. A package of mitigation measures has been agreed for the transmission line, including the fitting of bird diverters to the line to reduce the risk of collision. The transmission line ornithological assessment identified residual impacts that still required mitigation in order to meet the ADB SPS no net loss requirement, so further mitigation is being implemented to ensure no net loss.The Ramsar site currently has no specific targeted management plan, so part of a mitigation package will provide the resources to address this gap through a Biodiversity Management Plan. The transmission line mitigation will include funding for the development of a management plan for the Ramsar site, and funding to finance the implementation of that plan for a period of five years after the completion of construction of the line.

Residual Effects

102. The residual effects on these key species are summarised in Table 17. In order to satisfy the ADB Critical Habitat Requirement of no net loss, the Biodiversity Management Plan will need to deliver benefits to all of the Critical Habitat species where the potential effects are non-negligible, for both the wind farm (in relation to both the Vankalai Sanctuary and the Adam's Bridge National Park).

Table 17. Summary of predicted effects of the wind farm and transmission line on Critical Habitat and other important bird species.

Species	**IUCN Global Red List**	**Ramsar citation species**	**Ramsar >1% flyway population**	**Ramsar additional assemblage species**	**Wind farm collision risk**	**Trans-mission line collision risk**	**Cumulative collision risk**	**Wind farm disturbance**
Critical Habitat Species:								
Garganey	LC			✓		N	N	
Eurasian Wigeon	LC	✓				N	N	
Indian Spot-billed Duck	LC	✓				L	L	
Northern Pintail	LC	✓			N	N	N	
Greater Flamingo	LC	✓				L	L	
Painted Stork	NT		✓			L	L	
Eurasian Spoonbill	LC		✓			N	N	
Black-headed Ibis	NT			✓		L	L	
Little Egret	LC			✓	N	N	M	N
Spot-billed Pelican	NT		✓		M	VH	VH	

Species	**IUCN Global Red List**	**Ramsar citation species**	**Ramsar >1% flyway population**	**Ramsar additional assemblage species**	**Wind farm collision risk**	**Trans-mission line collision risk**	**Cumulative collision risk**	**Wind farm disturbance**
Indian Cormorant	LC			✓	L	L	H	N
Kentish Plover	LC		✓					
Lesser Sand Plover	LC		✓			N	N	
Yellow-wattled Lapwing	LC			✓				
Red-wattled Lapwing	LC			✓				N
Black-tailed Godwit	NT		✓					
Great Knot	EN		✓					
Curlew Sandpiper	NT		✓			N	N	
Little Stint	LC		✓					
Marsh Sandpiper	LC		✓					
Brown-headed Gull	LC		✓			N	N	N
Caspian Tern	LC		✓		N	L	L	N
Gull-billed Tern	LC			✓	L	L	L	L
Lesser Crested Tern	LC			✓	N			N
Other Important Species:								
Lesser Whistling-duck	LC			✓		N	N	
Northern Shoveler	LC			✓		N	N	
Eastern Cattle Egret	LC			✓				N
Little Cormorant	LC			✓	N	M	M	N
Black-winged Stilt	LC			✓		N	N	
Common Greenshank	LC		✓					
Heuglin's Gull	NR			✓	N	N	N	N
Little Tern	LC			✓	N	N	N	L
Whiskered Tern	LC			✓		L	L	L

Note: VH = very high magnitude effect, H = high, M = medium, L = Low, N = Negligible, blank = no exposure to risk from baseline surveys.

Proposed Ornithological Monitoring Programme

Pre-Construction Monitoring

103. It is strongly recommended that the bird monitoring programme for the development should include continuation of pre-construction baseline surveys (vantage point surveys and block counts) for a further year to provide more detailed information about bird activity (including flight activity) within the wind farm site (and to complement similar pre-construction surveys being undertaken for the transmission line). This work should include:

- VP surveys with flight line mapping for key species, with at least 36 hours' surveys from each VP and VPs covering a range of 2km maximum, including both the wind farm and the power line, with sufficient VPs to cover all of the development site;
- Block counts of key species within and in proximity to (within 2km) of the whole development footprint, with the survey area sub-divided into count sectors to enable spatial analysis of the data set, and with counts made twice-monthly through the key seasons (Sep-April).

104. These data will, as well as providing further baseline information for a post-construction monitoring

programme, provide more detailed input to the site design process and identify where mitigation measures will be required (and inform how they would best be implemented, particularly any turbine shutdown).

Post-Construction Monitoring

105. Post-construction bird monitoring should be undertaken to better understand the impacts that actually occur and ensure that significant impacts are avoided (through feedback into the mitigation process).

106. The post-construction bird monitoring should include continuation, for an initial period of three years, of the key species block surveys and enhanced vantage point surveys, to compare bird distribution, abundance and flight behaviour before and after construction, and a programme to monitor the actual collisions that occur (with both the wind turbines and the overhead line where this is practical), from a sufficient sample of turbines and lengths of power line. These results should then be reviewed by an independent international ornithological expert to determine whether any further monitoring would be required (if significant impacts were identified and if mitigation measures had not been effective).

107. The operational phase collision monitoring should follow the standard methodology developed for this purpose in the United States (Morrison 1998). A core area of 100m radius around the turbines and sample lengths of the power line should be carefully searched on foot. The 100m distance has been set conservatively as bird fatalities have rarely been documented over 70m from turbines at other wind farms (Johnson *et al.* 2000). Sectors around the turbine/powerline should be slowly searched, taking particular care to search any taller clumps of vegetation, rocks and openings of animal burrows. In addition, a further area 250m around each turbine should be checked for larger bird carcasses by scanning the ground with binoculars. The precise location of any dead birds found should be recorded and mapped (by reference to the distance and direction to the nearest wind turbine, and using a GPS). All carcasses should be photographed as found then placed in a plastic bag, labelled as to the location and date (turbine number, distance and direction from turbine base), and preserved (refrigerated or frozen) until identified. Feather spots (e.g., a group of feathers attached to skin) and body parts should also be collected. For all casualties found, data recorded should include species, sex, age, date and time collected, location, distance and direction (degrees) to nearest turbine, condition, and any comments regarding possible causes of death. The condition of each carcass found should be recorded using the following condition categories:

    - Intact - carcass that is completely intact, is not badly decomposed, and shows no sign of being fed upon by a predator or scavenger.
    - Scavenged - entire carcass that shows signs of being fed upon by a predator or scavenger or a portion(s) of a carcass in one location (e.g., wings, skeletal remains, legs, pieces of skin, etc.).
    - Feather Spot - 10 or more feathers at one location indicating predation or scavenging.

108. A sample of 50 dead birds (e.g. dark-feathered chickens) should be obtained in order to study the rate of carcass removal and to test observer search efficiency. These should be placed within the search area at intervals through the study by someone independent of the carcass searcher, at precise recorded locations (mapped in relation to distance and direction from the wind turbines), and marked appropriately (e.g. with coloured tape) to identify them as experimental birds. They should then be recorded by the observer on all subsequent visits, noting their precise location (distance and direction from nearest wind turbine) and condition, and left in place on site until they disappear. The amount of scavenger activity should inform the survey frequency, but an initial programme of weekly visits is recommended as a starting point.

Conclusions

109. Baseline bird surveys have been conducted at the site over a three-year period and over a wide survey area. Some issues have been identified with regard to the detail of those surveys, particularly their spatial and temporal coverage in relation to the proposed development. Enhanced surveys during June 2016 - March 2017 have addressed these issues and provided an improved baseline data for the wind farm assessment, including collision risk modelling.

110. It is clear that the survey area supports a range of internationally important bird populations. The highest conservation importance are those species associated with the Ramsar site, though the survey data show

that several of these are not restricted to the designated site but range more widely (and hence could be affected by the wind farm as well as the overhead transmission line).

111. A package of mitigation measures will be required to satisfy the ADB Critical Habitat requirements, including design mitigation, mitigation to reduce impacts during the construction (and decommissioning) phase of the development (through the production and implementation of a Construction Method Statement following industry best practice), and measures to mitigate the operational phase impacts (particularly measures to reduce collisions with the overhead line passing through the Vankalai Sanctuary Ramsar site by using appropriate markers to increase line visibility to birds).

112. A biodiversity management plan will need to be developed for the project to ensure no net loss of biodiversity and implementation of a program to promote and enhance the conservation aims of the sanctuary in accordance with ADB's SPS's requirements for Legally Protected Areas. It is proposed that this should include the funding for the development of a management plan for the Ramsar site, for the Adam's Bridge National Park and for the implementation of the first five years of that plan.

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Mannar, NW Sri Lanka:
100 MW CEB
Wind Power Project

FIGURE 1

Proposed Wind Farm Site and Transmission Line Route

KEY:

Wind turbines:

- ◆ 31T layout
- ⌽ Additional Ts for 37T
- ● Additional Ts for 39T
- ━ Proposed Transmission Line
- Ⓢ Proposed Substation
- ▨ Vankalai Sanctuary

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Mannar, NW Sri Lanka:
100 MW CEB
Wind Power Project

FIGURE 2

Proposed Wind Farm Site and Vantage Point and Block Count Survey Areas

KEY:

Wind turbines:

- ◆ 31T layout
- ◇ Additional Ts for 37T
- • Additional Ts for 39T
- ● VP Locations 2016
- — Proposed Transmission Line
- ▨ Block Count Survey Area
- ⬚ VP 2km buffer (main viewing area)

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N/A N/A

MWF-SL 2017

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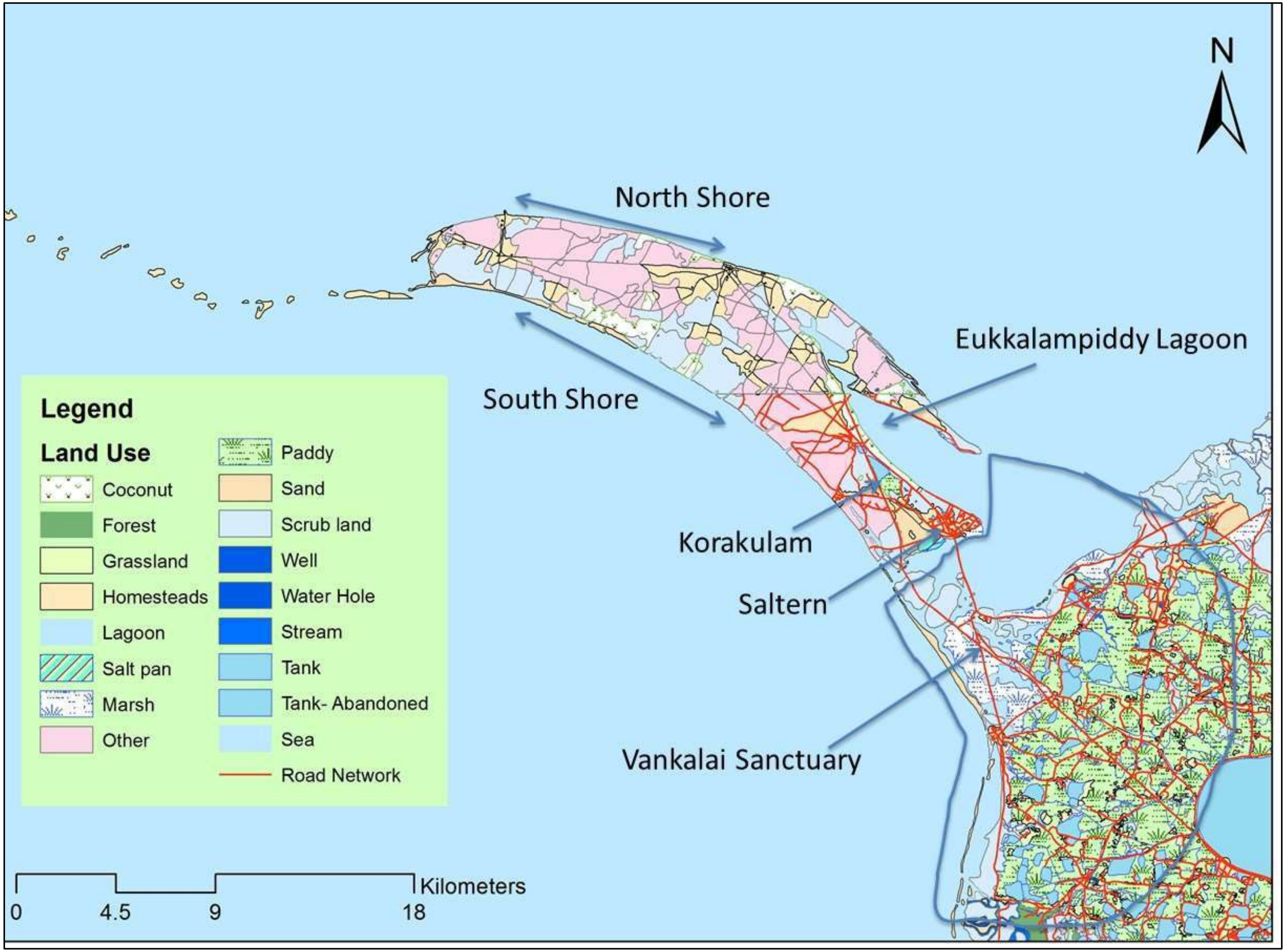
Figure 3. Block Count Areas (Figure supplied by Prof Devaka Weerakoon).



Mannar, NW Sri Lanka:
100 MW CEB
Wind Power Project

FIGURE 4a

Block Count Survey
Critical Habitat Species:
Little Egret

KEY:

▨ Block Count Survey Area

Count

- ● 1
- ● 5
- ● 10

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N/A

N/A

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FIGURE 4b

Block Count Survey
Critical Habitat Species:
Indian Cormorant

KEY:

▨ Block Count Survey Area

Count

- ● 1
- ● 5
- ● 10

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Mannar, NW Sri Lanka:
100 MW CEB
Wind Power Project

FIGURE 4c

Block Count Survey
Critical Habitat Species:
Red-wattled Lapwing

KEY:

▨ Block Count Survey Area

Count

- ● 1
- ● 5
- ● 10

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Mannar, NW Sri Lanka: 100 MW CEB Wind Power Project

FIGURE 4d

Block Count Survey Critical Habitat Species: Brown-headed Gull

KEY:

▨ Block Count Survey Area

Count

- ● 1
- ● 5
- ● 10

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Mannar, NW Sri Lanka:
100 MW CEB
Wind Power Project

FIGURE 4e

Block Count Survey
Critical Habitat Species:
Gull-billed Tern

KEY:

▨ Block Count Survey Area

Count

● 1
● 5
● 10

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N/A

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Mannar, NW Sri Lanka:
100 MW CEB
Wind Power Project

FIGURE 4f

Block Count Survey
Critical Habitat Species:
Caspian Tern

KEY:

▨ Block Count Survey Area

Count

- • 1
- ● 5
- ● 10

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N/A	N/A

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Mannar, NW Sri Lanka:
100 MW CEB
Wind Power Project

FIGURE 4g

Block Count Survey Critical Habitat Species: Greater Crested Tern

KEY:

▨ Block Count Survey Area

Count

- • 1
- ● 5
- ● 10

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N/A

N/A

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Appendix 3

Critical Habitat Assessment of the Proposed Mannar Windfarm

1. Critical habitat is defined in the IFC Guidance Note 6: Biodiversity Conservation and the Sustainable Management of Ecosystem Services and Living Resources (GN6)[1] as follows:

> *"Critical habitat is a subset of both natural and modified habitat that deserves particular attention. Critical habitat includes areas with high biodiversity value, including areas with the following criteria:*
>
> *(i) habitat of significant importance to Critically Endangered and/or Endangered species, endemic and/or restricted-range species, and globally significant concentrations of migratory species, and/or congregatory species;*
>
> *(ii) areas with regionally unique and/or highly threatened ecosystems; and*
>
> *(iii) areas which are associated with key evolutionary processes."*

2. The Critical Habitat Assessment has been undertaken following this guideline. The first step was to identify those species that are present in the area that would qualify under the above criteria.

3. After that based on their habitat use patterns the critical habitats within the Mannar Island and Vankalai Sanctuary was defined.

4. The primary sources of data for this assessment were the block counts undertaken during the baseline survey of the birds in the Mannar Island and Vankalai Sanctuary that have been undertaken during 2014-16. In addition for the proposed wind farm Vantage point surveys were conducted by establishing four permanent vantage points along the identified windfarm corridor and monitoring bird movement in the windfarm corridor using these vantage points once every month from June 2016 to March 2017.

5. Based on the baseline data collected a critical habitat assessment was carried out for the entire Mannar Island and Vankalai Sanctuary using three critical habitat triggers, habitats used by species that are listed as **Globally** Critically Endangered/ Endangered, habitats used by species that are listed as **Nationally** Critically Endangered/ Endangered and migratory/ congregatory species/ habitats occupied by more than 1% of the flyway population[2].

6. Based on this analysis species that qualify under one or more of the above three critical habitat trigger is shown in table 1 below

Table 1. Species that were selected for critical habitat assessment based on global/ national conservation status and presence of more than 1% of the flyway population.

Scientific Name	Common Name	IUCN Global Red List[3]	SL National Red List[4]	More than 1% of the flyway population
Calidris tenuirostris	Great Knot	EN	NE	>1% flyway Population
Anas poecilorhyncha	Spot Billed Duck	LC	CR	
Sterna caspia	Caspian Tern	LC	CR	
Sterna hirundo	Common Tern	LC	CR	
Sterna nilotica	Gull-billed Tern	LC	CR	
Pelecanus philippensis	Spot billed pelican	LC	NT	>1% of global population

---

[1] http://www.ifc.org/wps/wcm/connect/c2815b0049800a9fab72fb336b93d75f/Phase2_GN6_English_clean.pdf?MOD=AJPERES

[2] Wetlands International, 2012. Waterbird Population Estimates, Fifth Edition. Summary Report. Wetlands International, Wageningen, The Netherlands

[3] IUCN (2016) IUCN list of threatened species. www. Iucnredlist.org

[4] MOE (2012) The National Red List 2012 of Sri Lanka; Conservation Status of the Fauna and Flora. Ministry of Environment, Colombo, Sri Lanka. viii + 476pp.

Scientific Name	Common Name	IUCN Global Red List[3]	SL National Red List[4]	More than 1% of the flyway population
Calidris ferruginea	Curlew Sandpiper	LC	NE	IBA listed species
Anas acuta	Northern pintail	LC	NE	Ramsar Criterion 5
Phoenicopterus roseus	Greater flamingo	LC	NE	Ramsar Criterion 5 and 6
Anas Penelope	Eurasian wigeon	LC	NE	Ramsar Criterion 5 and 6
Anas querquedula	Garganey	LC	NE	>1% flyway Population
Limosa lapponica	Black-tailed godwit	LC	NE	>1% of global population
Mycteria leucocephala	Painted stork	LC	NT	>1% of global population
Platalea leucorodia	Eurasian Spoonbill	LC	LC	>1% flyway Population
Threskiornis melanocephalus	Black-headed Ibis	LC	NT	>1% flyway Population
Charadrius alexandrinus	Kentish plover	VU	LC	>1% flyway Population
Charadrius mongolus	Lesser sand plover	LC	NE	>1% of global population
Calidris minuta	Little stint	LC	NE	>1% of global population
Tringa tetanus	Common Redshank	LC	NE	>1% flyway Population
Tringa stagnatilis	Marsh sandpiper	LC	NE	>1% of global population
Larus brunnicephalus	Brown headed gull	LC	NE	>1% flyway Population
Tringa tetanus	Lesser Crested Tern	LC	NE	>1% flyway Population

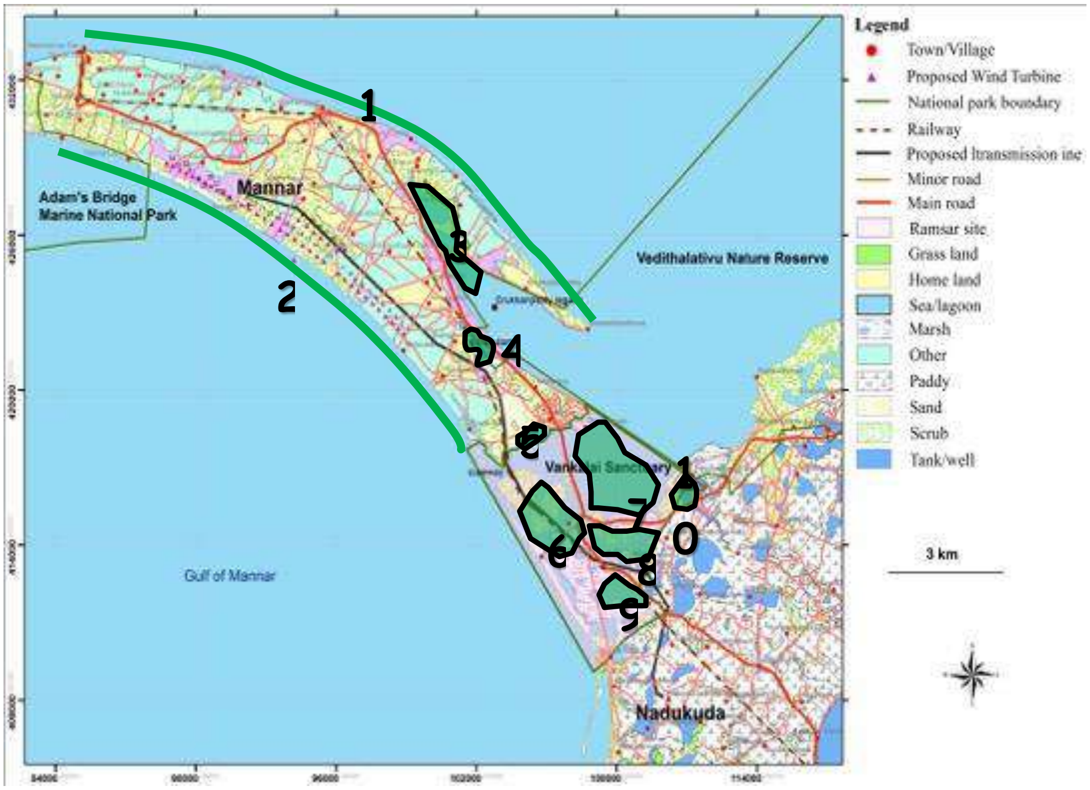
7. Based on the block counts carried out during the baseline survey the critical habitats of these species have been identified and these critical habitats are listed in table 2 below.

Table 2. Critical Habitats that Supported species that triggered the critical habitat criterion in the Mannar Island and Vankalai Sanctuary.

Species	Reason for Critical Habitat	Extent of Critical Habitat
Globally CR/EN		
Great Knot	>1% flyway population	Erukkalampiddy Lagoon
Nationally CR/EN		
Spot Billed Duck	Nationally important concentration of nationally critically endangered species	Korakulam and Vankalai sanctuary – transmission line corridor used as a feeding area
Caspian Tern	Nationally important concentration of nationally critically endangered species	Vankalai Sanctuary, Erukkalampiddy Lagoon and the north shore of Mannar Island.
Common Tern	Nationally important concentration of nationally critically endangered species	Vankalai Sanctuary, Erukkalampiddy Lagoon and the north and south shores of Mannar Island
Gull-billed Tern	Nationally important concentration of nationally critically endangered species	Vankalai Sanctuary, Korakulam, Erukkalampiddy Lagoon and the north and south shores of Mannar Island
Migratory and Congregatory Species		
Spot billed pelican	>1% global population of a migratory or congregatory species	Vankalai Sanctuary
Curlew Sandpiper	BirdLife International's Criterion A4 for congregations	Vankalai Sanctuary, Saltern and the north shore of Mannar Island
Northern pintail	Ramsar site Criterion 5	Vankalai sanctuary
Greater flamingo	Ramsar site Criterion 5 and 6	Vankalai sanctuary
Eurasian wigeon	Ramsar site Criterion 5 and 6	Vankalai sanctuary
Garganey	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary, Korakulam and the south shore of Mannar Island
Black-tailed godwit	Ramsar site Criterion 5 and 6	Vankalai sanctuary and Korakulam
Painted stork	>1% global population of a migratory or congregatory species	Vankalai sanctuary and Korakulam
Eurasian Spoonbill	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary

Species	Reason for Critical Habitat	Extent of Critical Habitat
Black-headed Ibis	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary
Kentish plover	> 1% of the flyway population of a migratory/congregatory species	Vankalai sanctuary and Erukkalampiddy Lagoon
Lesser sand plover	>1% global population of a migratory or congregatory species	Vankalai Sanctuary, Saltern and north shore of Mannar Island
Little stint	>1% global population of a migratory or congregatory species	Vankalai Sanctuary, Saltern and north shore of Mannar Island
Common Redshank	>1% flyway population of a migratory or congregatory species	Vankalai Sanctuary
Marsh sandpiper	>1% global population of a migratory or congregatory species	Vankalai sanctuary, Saltern
Brown headed gull	> 1% of the flyway population of a migratory/congregatory species	North and south shores of Mannar Island
Lesser Crested Tern	>1% flyway population of a migratory or congregatory species	North shore of Mannar Island
Restricted range		
None		
Endemic		
None		

Figure 1. Distribution of the habitats listed in table 2 within Mannar island and Vankalai Sanctuary 1 - North Shore of Mannar Island, 2 - South shore of Mannar island; 3 - Erukkalampiddy Lagoon; 4 - Korakulam; 5 - Saltern; 6 - Wetlands on either side of the railway line; 7 - Wetlands on either side of the Causeway; 8 - Periya Kalapuwa in the Vankalai Sanctuary; 9 - Wetlands in the southwestern end of Vankalai Sanctuary; 10 - Wetlands in the northwestern edge of the Vankalai Sanctuary.

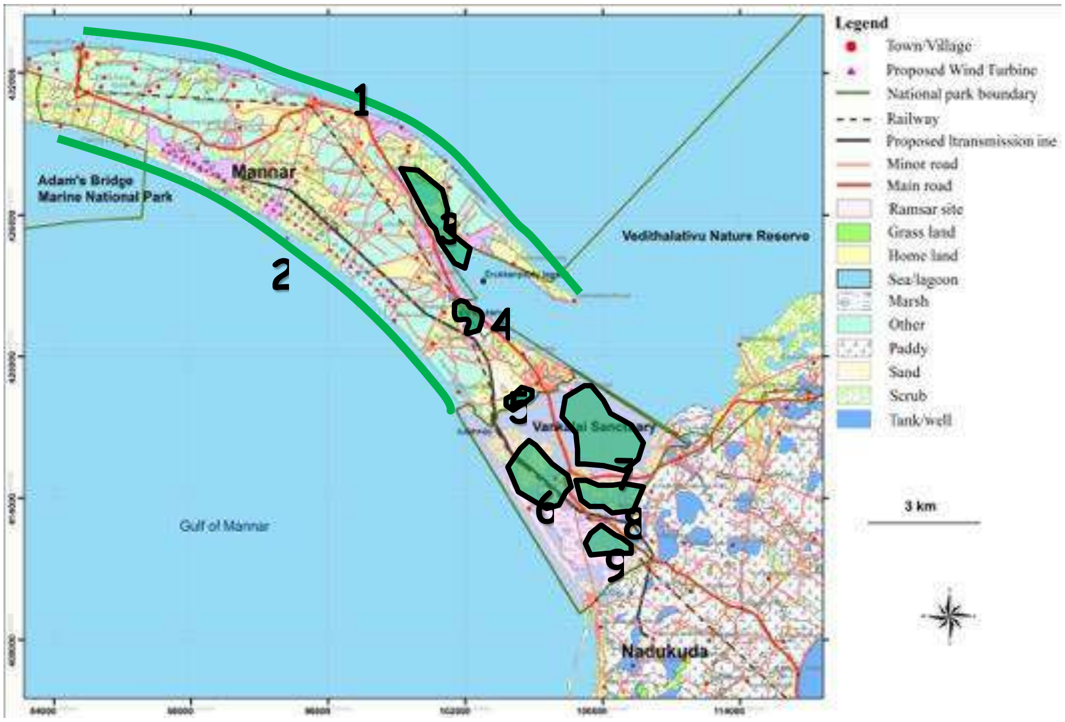


8. Out of the species listed in table 2 only eight species were recorded in the windfarm block during the vantage point surveys that were carried out during June 2016 to March 2017. These eight species include Caspian tern, Common tern, Gull-billed tern, Spot Billed Pelican, Kentish Plover, Lesser Sand Plover, Brown-headed Gull and Lesser Crested Tern. Out of these two species, Spot Billed Pelican and Kentish Plover were only recorded few times. Further, the number of birds observed during the non migratory season was much less compared to the migratory season. Further, the wind farm site does not have any aquatic habitats and therefore all these species were observed either flying along the cost, feeding in off shore waters or resting on the beach. Therefore, even though the critical species habitat is triggered for the windfarm based on the presence of these species, the windfarm site is not directly used by any of these birds as a habitat. Details regarding the eight species observed along the windfarm corridor is given below

Species observed in the Mannar Windfarm block for whom the region is considered as a critical habitat

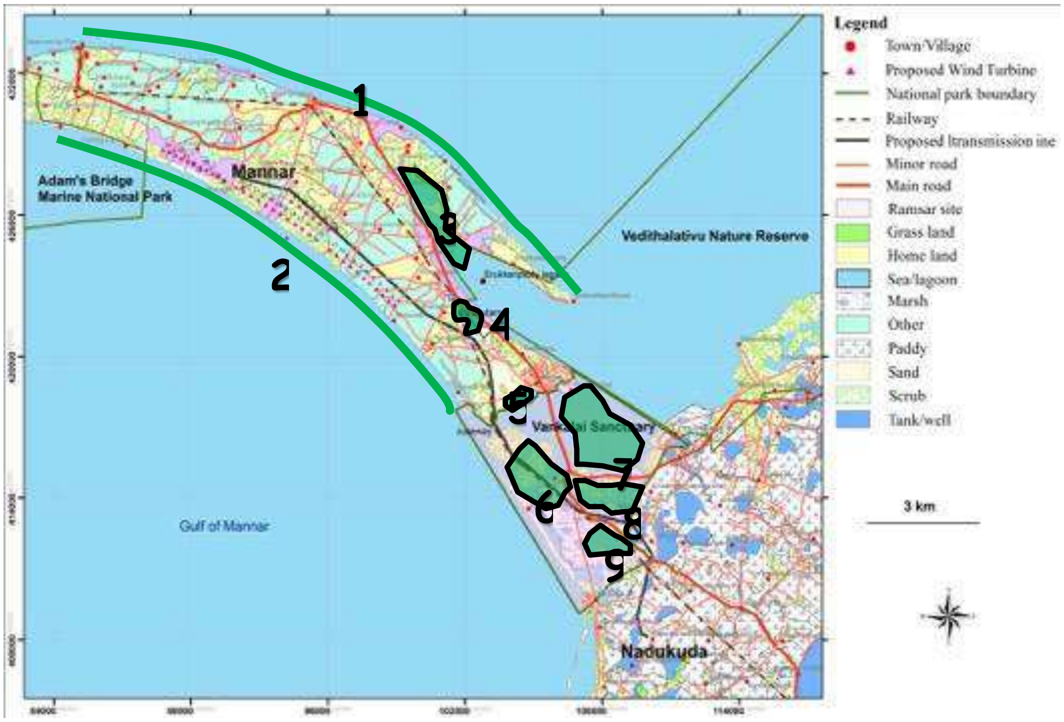
9. **Caspian tern**: This species has an extremely wide range. The global population is estimated to be around 240,000-420,000 individuals (IUCN Red List database) and therefore it is listed as globally not threatened. Further, its population is increasing. In Sri Lanka it is listed as a common winter visitor with a small breeding population present in the third island of the Adams Bridge National Park, which is listed as Critically endangered. It is also a migratory/congregatory species. The maximum number recorded in the project area (Mannar Island and Vankalai Sanctuary) was 343 during the non-migrant season and 3,810 during the migrant season. Both Mannar Island and Vankalai Sanctuary lie within the feeding ground of the breeding and migrant population. The total peak population found in survey area represents 1.6% of the global population, and 5.4% of the flyway population. The survey area supports a nationally important concentration of this nationally critically endangered species, it is considered as a Critical Habitat for Caspian tern, with areas of Critical Habitat comprising the Vankalai Sanctuary, Erukkalampiddy Lagoon and the north shore (see figure 2) of Mannar Island.

Figure 2. Habitats where Caspian Terns are frequently observed (1 - North Shore of Mannar Island, 2 - South shore of Mannar island; 3 - Erukkalampiddy Lagoon; 4 - Korakulam; 5 - Saltern; 6 - Wetlands on either side of the railway line; 7 - Wetlands on either side of the Causeway; 8 - Periya Kalapuwa in the Vankalai Sancturay; 9 - Wetlands in the southwestern end of Vankalai Sanctuary).



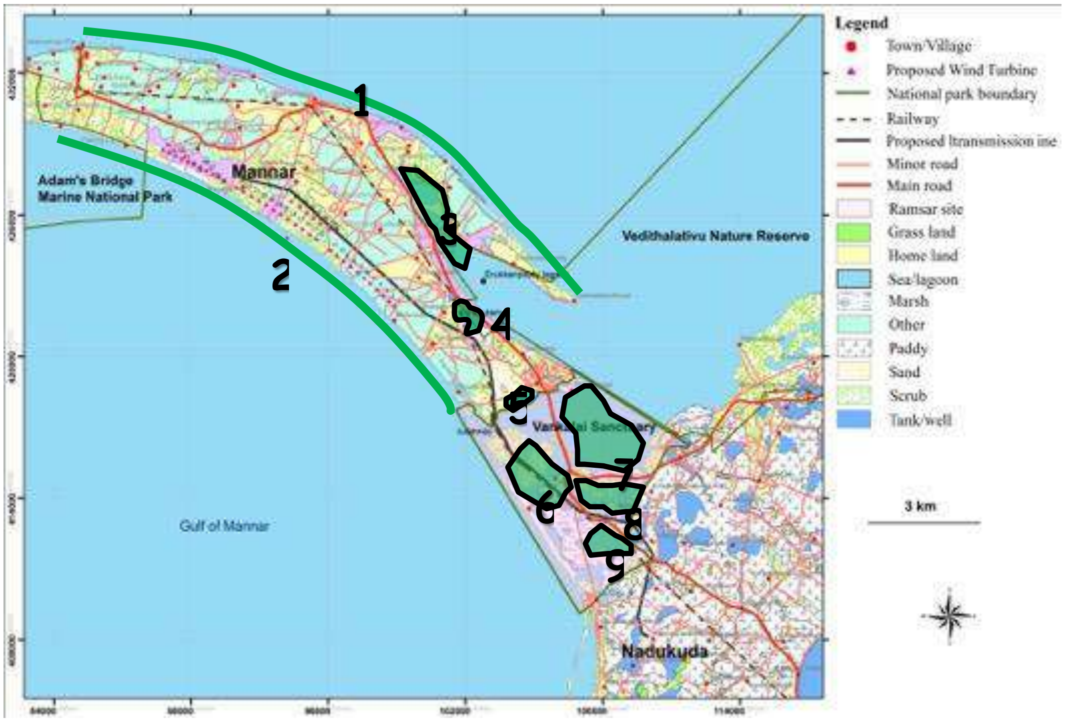
10. **Common Tern**: This species has an extremely wide range. The population size is estimated to be around 1,600,000 to 4,600,000 (IUCN Red List database) and therefore it is listed as globally not threatened even though its population is declining slowly, but not rapid enough to be listed under vulnerable status. In Sri Lanka it is listed as a winter visitor with a small breeding population present in the third island of the Adams Bridge National Park, which is listed as Critically endangered. It is also a migratory/congregatory species. The maximum number recorded in the survey area was 100 during the non-migrant season and 152 during the migrant season. Both Mannar Island and Vankalai Sanctuary lie within the feeding ground of the breeding and migrant populations. The total population found in the project area is 0.01% of the global population and only 0.02% of the flyway population. However, as the survey area supports a nationally important concentration of this nationally critically endangered species, it is considered the main areas used by this species do still constitute Critical Habitat; Vankalai Sanctuary, Erukkalampiddy Lagoon and the north and south shores of Mannar Island (see Figure 3).

Figure 3. Habitats where Common Terns are frequently observed (1 - North Shore of Mannar Island, 2 - South shore of Mannar island; 3 - Erukkalampiddy Lagoon; 4 - Korakulam; 5 - Saltern; 6 - Wetlands on either side of the railway line; 7 - Wetlands on either side of the Causeway; 8 - Periya Kalapuwa in the Vankalai Sanctuary; 9 - Wetlands in the southwestern end of Vankalai Sanctuary).



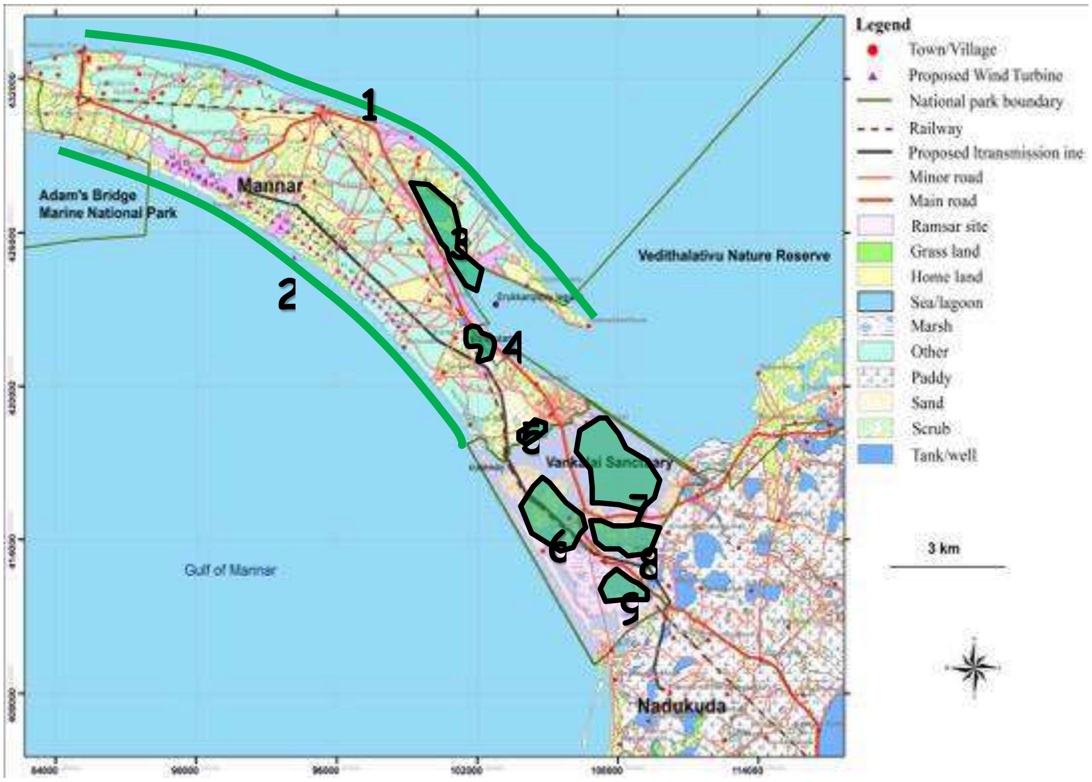
11. **Gull-billed tern**: This species has an extremely wide range. The global population is estimated to be around 150,000-420,000 individuals (IUCN Red List database) and therefore it is listed as globally not threatened even though its population is declining slowly, but not rapid enough to be listed under vulnerable status. In Sri Lanka it is listed as a winter visitor with a small breeding population present in the third island of the Adams Bridge National Park, which is listed as Critically Endangered. It is also a migratory/congregatory species. The maximum number recorded in the survey area was 21 during the non migrant season and 380 during the migrant season. Both Mannar Island and Vankalai Sanctuary lie within the feeding ground of the breeding and migrant population. The total population found in Mannar region is 0.25% of the global population and 0.5% of the flyway population. As the survey area supports a nationally important concentration of this nationally critically endangered species, it is considered the main areas used by this species do still constitute Critical Habitat; Vankalai Sanctuary, Korakulam, Erukkalampiddy Lagoon and the north and south shores of Mannar Island (see Figure 4).

Figure 4. Habitats where Gull-billed Terns are frequently observed (1 - North Shore of Mannar Island, 2 - South shore of Mannar island; 3 - Erukkalampiddy Lagoon; 4 - Korakulam; 5 - Saltern; 6 - Wetlands on either side of the railway line; 7 - Wetlands on either side of the Causeway; 8 - Periya Kalapuwa in the Vankalai Sanctuary; 9 - Wetlands in the southwestern end of Vankalai Sanctuary)



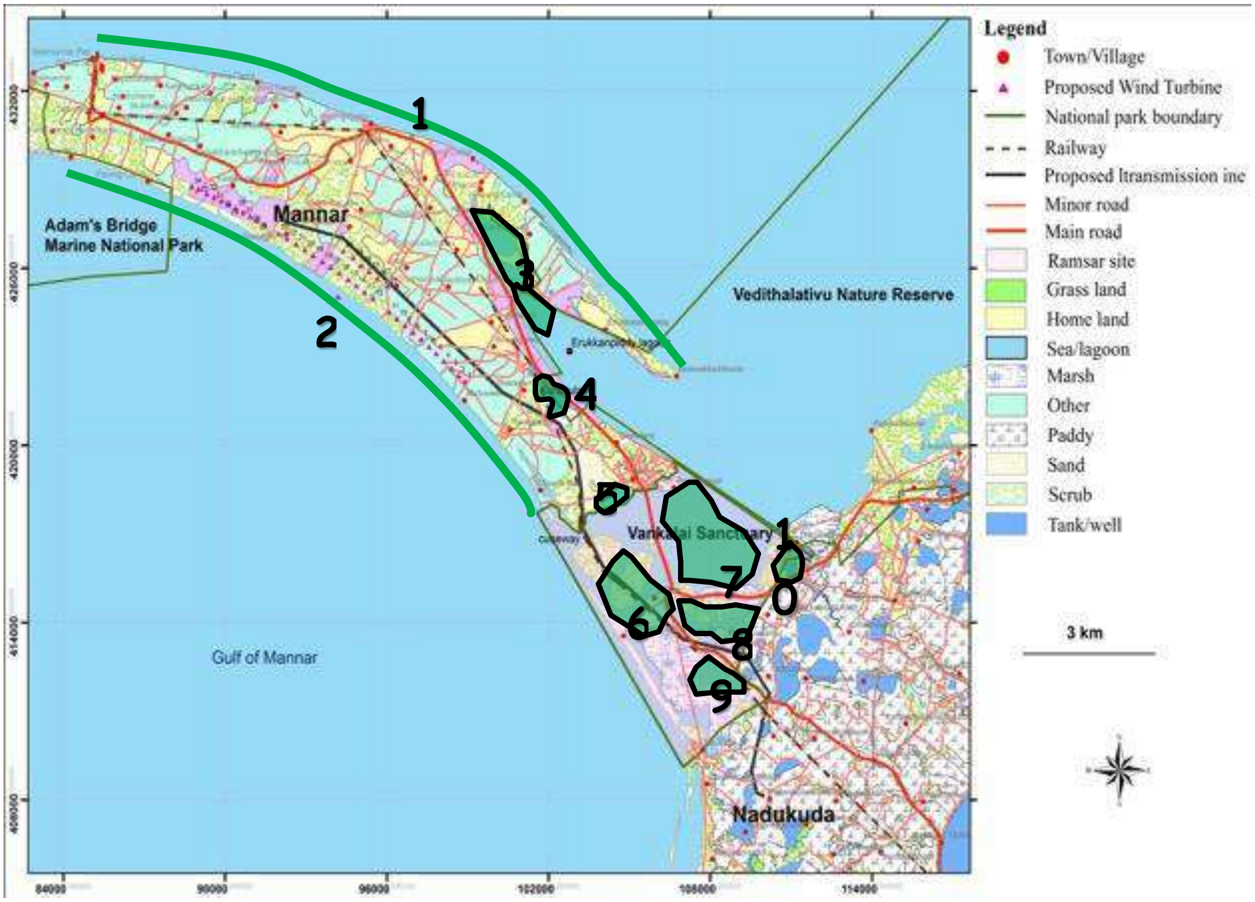
12. **Spot-billed pelican**: Spot-billed Pelican is native to Cambodia, India, Indonesia, Lao, Myanmar, Nepal, Sri Lanka, Thailand and Vietnam. Known breeding populations are now confined to India, Sri Lanka and Cambodia, with probable small breeding populations in Sumatra and Indonesia. It has been listed as Globally Vulnerable until 2007 where it was down listed due to improvement in population size due to increased protection. The global population size is estimated to be around 13,000 to 18,000 birds (IUCN Red List database). In Sri Lanka Spot-billed Pelican is recorded from at least 25 locations mostly in the dry zone except a breeding population of around 100 individuals in the greater Colombo area. The estimated population is around 1500 individuals where the largest breeding populations being reported from Kumana and Lunugamvehera in the South-eastern part of Sri Lanka. The highest number of Spot-billed Pelicans recorded at Vankalai region is 188 birds during 2015 migrant season which is 1.5% of the global population, and 1.9% of the flyway population. Even though the collision risk model places this bird at a high risk it is unlikely to result in a total extinction of the Mannar population due to bulk of the population in Mannar region was recorded in the areas outside the proposed transmission line corridor. Further, this bird is found in several wetlands that are used as transmission line corridors including Colombo and not a single death due to collision with transmission line has been reported in Sri Lanka. As the total population found in project area exceeds 1% of both the global (1.5%) and flyway (1.9%) populations, of a congregatory species the Vankalai Sanctuary is Critical Habitat for the Spot-billed Pelican (see Figure 5).

Figure 5. Habitats where Spot-billed pelicans are frequently observed (1 - North Shore of Mannar Island, 2 - South shore of Mannar island; 3 - Erukkalampiddy Lagoon; 4 - Korakulam; 5 - Saltern; 6 - Wetlands on either side of the railway line; 7 - Wetlands on either side of the Causeway; 8 - Periya Kalapuwa in the Vankalai Sanctuary; 9 - Wetlands in the southwestern end of Vankalai Sanctuary).



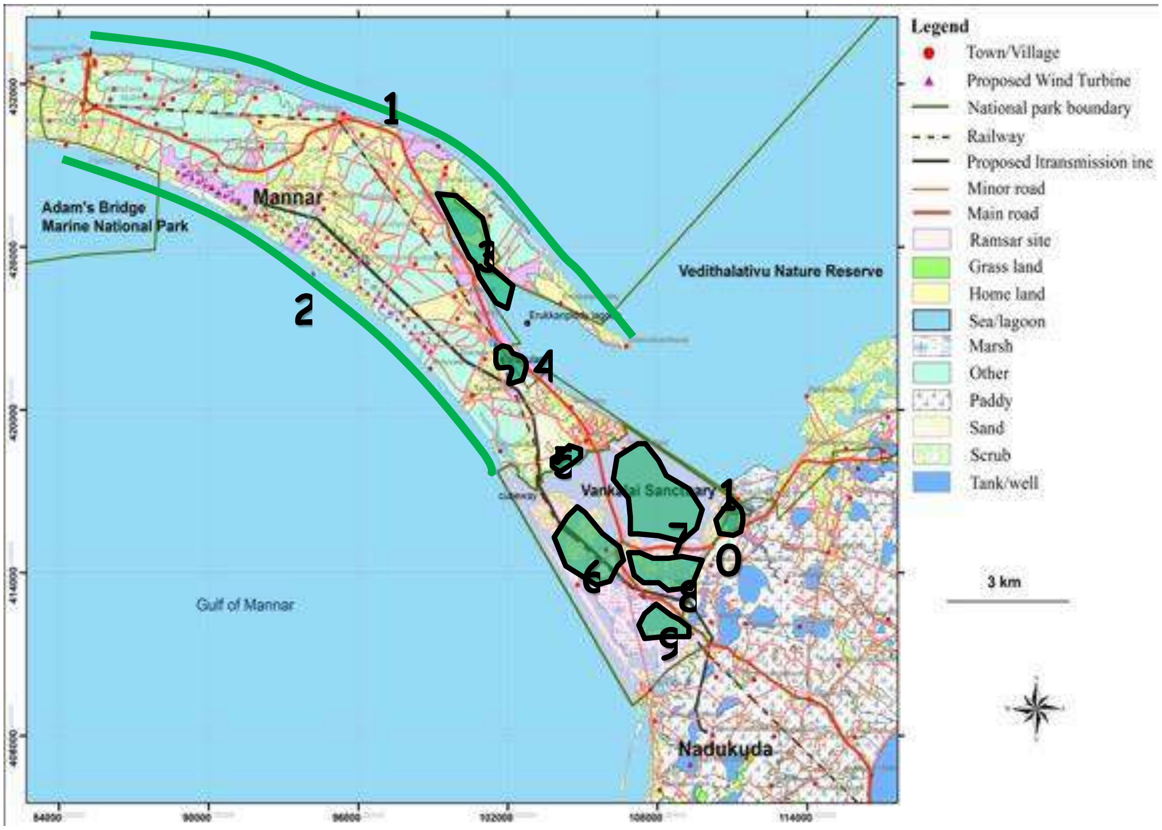
13. **Kentish Plover**: This species has an extremely wide range. The global population is not known due to recent changes in taxonomy of the species. The flyway population is estimated to be around 71,000 (Wetlands International). However, the species is listed as globally not threatened. In Sri Lanka it is listed as a breeding resident as well as a winter visitor. The species has been observed to breed in the Northern section of the Vankalai Sanctuary and Korakulam within the Island. The maximum number recorded in the survey area is 4,033 individuals, which is 5.7% of the flyway population. The species was recorded in the transmission line corridor passing through the Vankalai sanctuary and the site selected for the windfarm. Therefore, as it supports more than 1% of the flyway population of a migratory/ congregatory species the Vankalai Sanctuary and Erukkalampiddy Lagoon are critical habitat (see Figure 6) for the Kentish Plover.

Figure 6. Habitats where Kentish Plovers are frequently observed (1 - North Shore of Mannar Island, 2 - South shore of Mannar island; 3 - Erukkalampiddy Lagoon; 4 – Korakulam (breeding); 5 - Saltern; 6 - Wetlands on either side of the railway line; 7 - Wetlands on either side of the Causeway; 8 - Periya Kalapuwa in the Vankalai Sanctuary; 9 - Wetlands in the southwestern end of Vankalai Sanctuary; 10 - Wetlands in the northwestern edge of the Vankalai Sanctuary (breeding).



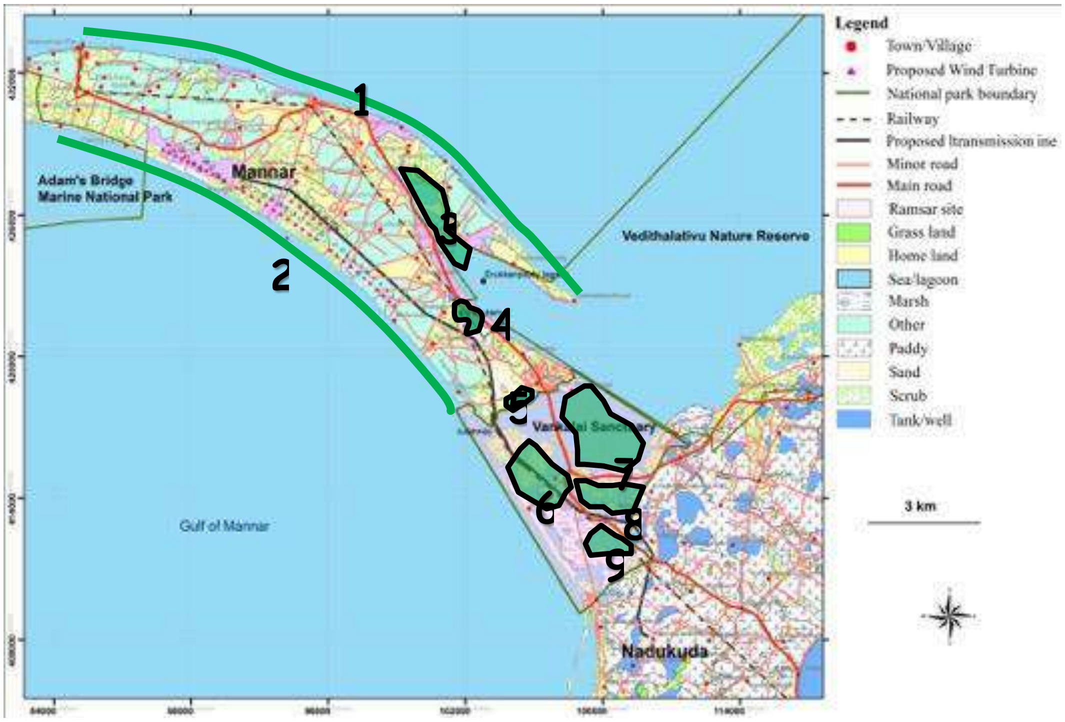
14. **Lesser Sand Plover**: This species has an extremely wide range. The global population is estimated to be around 310,000-390,000 individuals and therefore it is listed as a globally not threatened species. In Sri Lanka it is listed as a winter visitor. The maximum number recorded in the survey area is 13,175 individuals of which more than 68% was recorded from the Vankalai Sanctuary. The species was recorded in the transmission line corridor passing through the Vankalai sanctuary. The total population found in the survey area is 4.3% of the global population and 11% of the flyway population. Therefore, as it supports more than 1% of the global and flyway populations of a migratory/congregatory species the Vankalai Sanctuary, Saltern and north shore of Mannar Island are a Critical Habitat (see Figure 7) for Lesser Sand Plover.

Figure 7. Habitats where Lesser Sand Plovers are frequently observed (1 - North Shore of Mannar Island, 2 - South shore of Mannar island; 3 - Erukkalampiddy Lagoon; 4 – Korakulam; 5 - Saltern; 6 - Wetlands on either side of the railway line; 7 - Wetlands on either side of the Causeway; 8 - Periya Kalapuwa in the Vankalai Sanctuary; 9 - Wetlands in the southwestern end of Vankalai Sanctuary; 10 - Wetlands in the northwestern edge of the Vankalai Sanctuary).



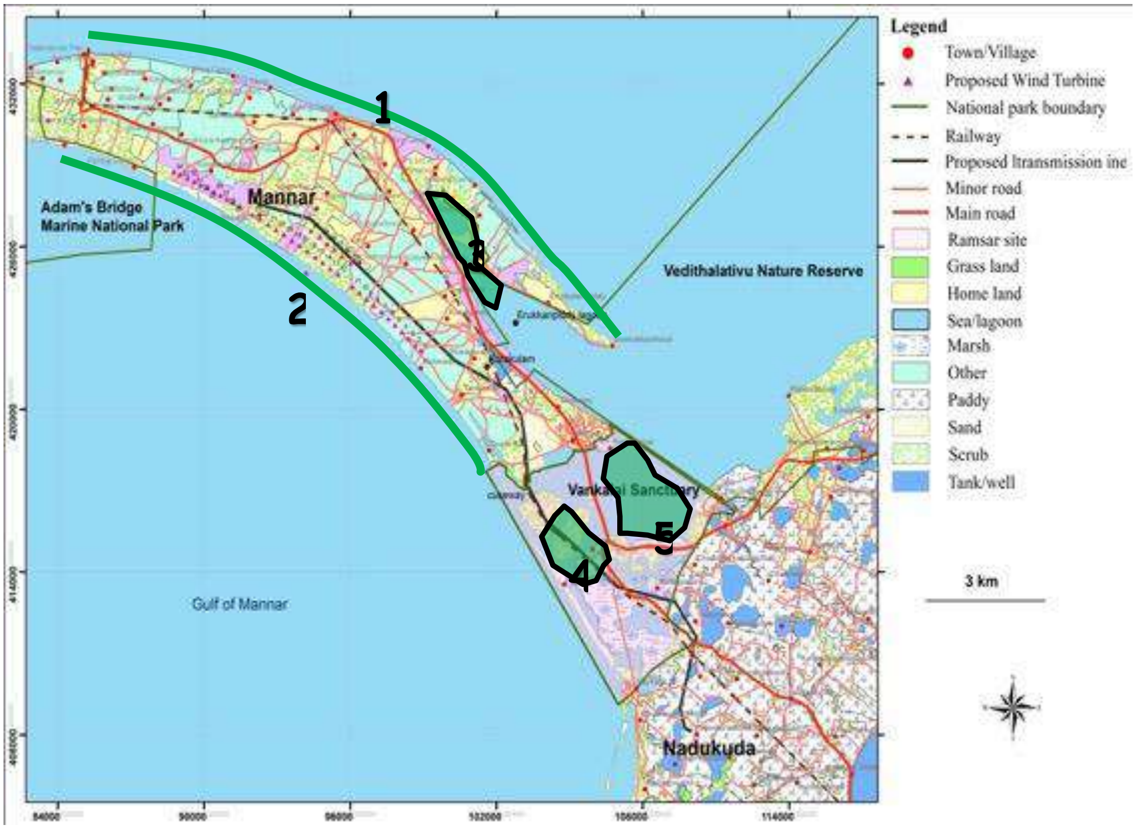
15. **Brown-headed Gull** - This species has an extremely wide range. The global population is not known but considered to be stable and therefore it is listed as a globally not threatened species. The flyway population is estimated to be 140,000 (Wetlands International). In Sri Lanka it is listed as a winter visitor. The maximum number recorded in the survey area is 10,600 individuals. The species was recorded in the transmission line corridor passing through the Vankalai sanctuary and the site selected for the windfarm. The peak population found in the survey area was 7.6% of the flyway population. Therefore, as it supports more than 1% of the global and flyway populations of a migratory/congregatory species the north and south shores of Mannar Island are Critical Habitat (see Figure 8) for Brown-headed Gull.

Figure 8. Habitats where Brown-headed Gulls are frequently observed (1 - North Shore of Mannar Island, 2 - South shore of Mannar island; 3 - Erukkalampiddy Lagoon; 4 - Korakulam; 5 - Saltern; 6 - Wetlands on either side of the railway line; 7 - Wetlands on either side of the Causeway; 8 - Periya Kalapuwa in the Vankalai Sanctuary; 9 - Wetlands in the southwestern end of Vankalai Sanctuary).

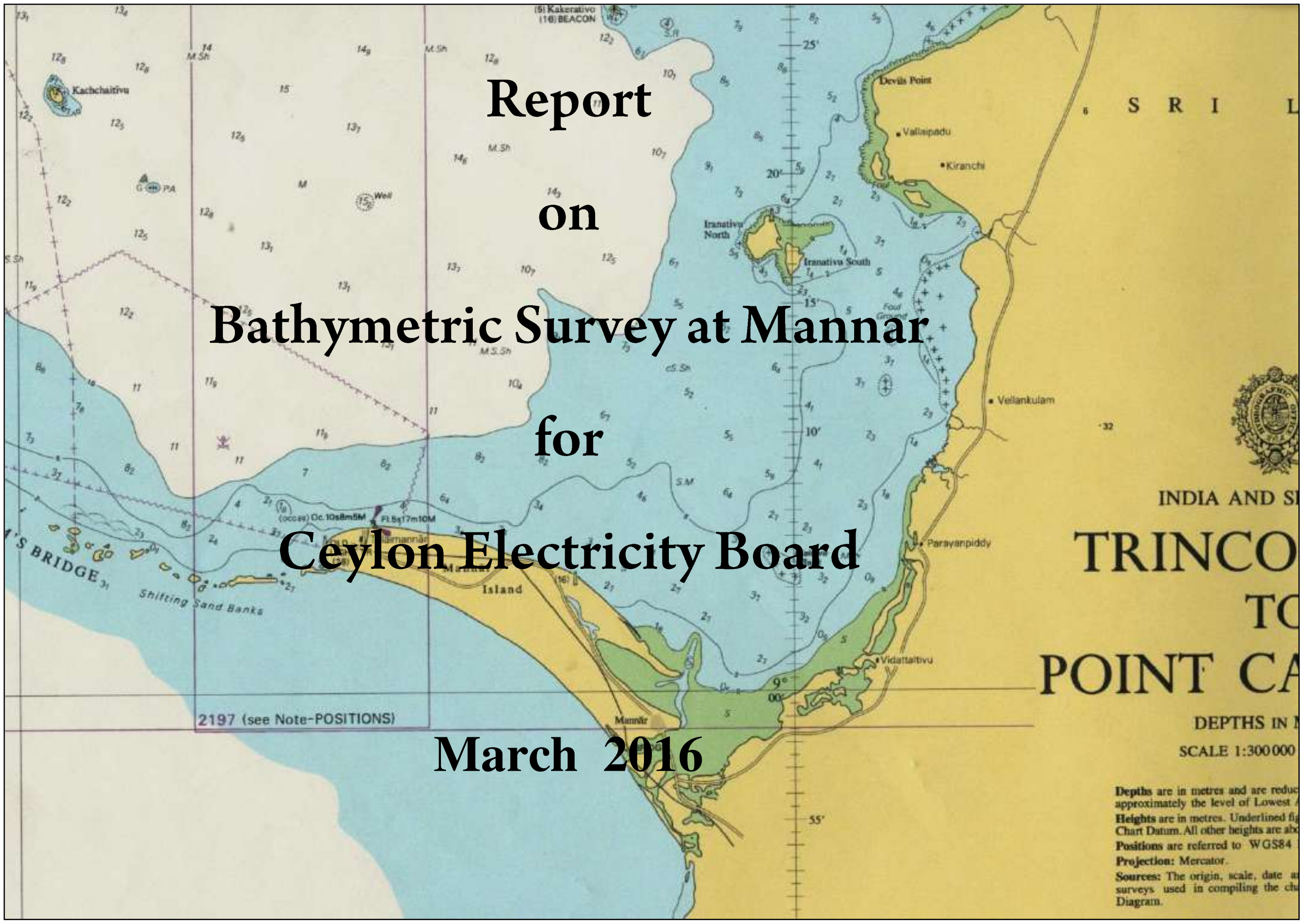


16. **Lesser Crested Tern** - This species has an extremely wide global range. The global population size is not known but considered to be stable and therefore listed as globally not threatened. In Sri Lanka it is listed as a common winter visitor with a small breeding population present in the third island of the Adams Bridge National Park, which is listed as Critically endangered. The maximum number recorded in the survey area is 3,830 individuals. The species was recorded in the transmission line corridor passing through the Vankalai sanctuary. The peak population found in the survey area was 2.4% of the flyway population. Therefore, as it supports more than 1% of the flyway populations of a migratory/congregatory species the north shore of Mannar Island (see Figure 9) is Critical Habitat for Lesser Crested Tern.

Figure 9. Habitats where Lesser Crested Terns are frequently observed (1 - North Shore of Mannar Island, 2 - South shore of Mannar island; 3 - Erukkalampiddy Lagoon; 4 - Wetlands on either side of the railway line; 5 - Wetlands on either side of the Causeway)


1
2
3
4
5
Mannar
Adam's Bridge
Marine National Park
Vedithalativu Nature Reserve
Erukkalampiddy
Vankalai Sanctuary
Nadukuda
Gulf of Mannar
Legend
Town/Village
Proposed Wind Turbine
National park boundary
Railway
Proposed ltransmission ine
Minor road
Main road
Ramsar site
Grass land
Home land
Sea/lagoon
Marsh
Other
Paddy
Sand
Scrub
Tank/well
3 km
84000
90000
96000
102000
108000
114000
432000
426000
420000
414000
408000

National Hydrographic Office
of
National Aquatic Resource Research & Development Agency (NARA)



Report

on

Bathymetric Survey at Mannar

for

Ceylon Electricity Board

March 2016

National Hydrographic Office
National Aquatic Resources Research & Development Agency(NARA)
Crow Island, Colombo 15
Sri Lanka

Tel: +94 (0) 112521705
Fax: +94 (0) 112521699

For and on behalf of the
National Hydrographic Office/NARA

Approved by: A. N. D. Perera

Signed:

Position: Chief Hydrographer

Date: December 2015

This report has been prepared by the National Hydrographic Office/NARA, with all reasonable care, skill and attention to detail as set within the terms of the Contract with the client.

We disclaim any responsibility to the client and others in respect of any matters outside the scope of the above.

This is a confidential report to the client and we accept no responsibility of whatsoever nature to third parties to whom this report, or any part thereof, is made known. Any such parties rely on the report at their own risk.

Table of Contents

1.0 Introduction

Ceylon Electricity Board (CEB) has taken a decision to develop the first large scale wind farm of 100MW at Mannar Island which would be owned and operated by the CEB. Transportation of the Wind turbine Blades which are to be installed under this project is impossible by land since they are very long. The CEB suggests to transport those from barges at least with 5m draft and then there arises a requirement to construct a pier for unloading.

The CEB has requested National Hydrographic Office (NHO) to carry out Bathymetric Survey at the Southern Coast of Mannar to identify the navigation route for above barges.

2.0 Bathymetric Survey - Phase 1

2.1 Methodology

2.1.1 Area Surveyed

Following figure shows the area requested by CEB to be surveyed.

Figure 1. Requested Survey Area

NHO has suggested to carry out this bathymetric survey in two phases. First phase was a reconnaissance survey with the line spacing of 100m and then to find out the 200 m wide suitable navigation route from those data. In second phase it was suggested to do the bathymetric survey with 10 m smaller line space for more details.

This suggestion was approved by CEB who offered NHO to carry out the project.

2.1.2 Survey Boat, Survey Equipments and Software

NHO Survey team mobilised Mannar on 04th February 2016 and hired a dingi boat which could navigate in very shallow water. The equipment used for this survey included a Deso 30 Single Beam Echo Sounder, SVP 100 Sound Velocity Probe and positioning system SxBlue II- B. The Hypack Max software installed in a ruggedized laptop was used to design the entire survey for data acquisition and data processing (Figure 2).

Figure 2 Survey Boat & Instruments

2.1.3 Bathymetric Survey

The survey area (5km long coastal stretch and 15 km seawards) covered 100m interval bathymetric lines using data acquisition system (echo Sounder with the Differential GPS) in a low draft small boat which could navigate in shallow waters.

The survey continued until 16th March 2016. Weather at sea in Mannar was favourable in the morning and unfavourable in the evening for bathymetric survey. Hence the survey speed reduced to 2-3 knots and it took more time than expected.

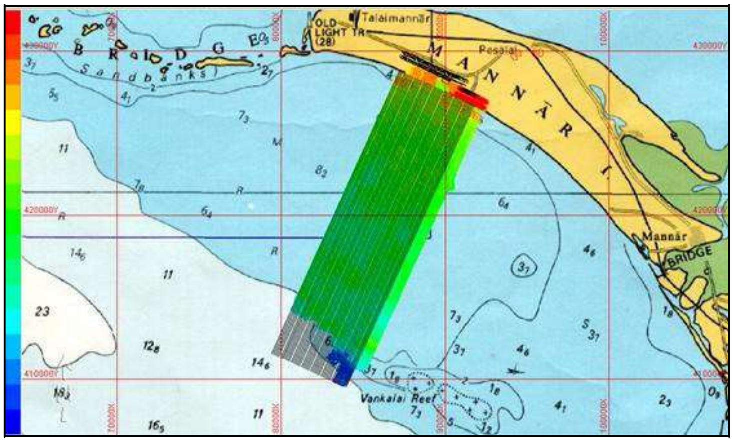


Figure 3 Bathymetric data covering the proposed area

2.1.4 Water Level Observation

The depths obtained from the DESO 30 respect to the water level are required to reduced to the proper vertical datum. Water level was observed in 15 m interval throughout the survey period of the day. The vertical datum used here is Lowest Astronomical Tide (LAT) datum since this data is used for navigation. Temporary Bench Mark (TBM) was established by NHO and was connected with the permanent Bench mark which was established by CEB and was already connected to the Survey Department Bench Mark. All the observed water levels are reduced to LAT.

2.1.5 Horizontal Control

SXBlue II GPS receiver was verified on the Survey Department control point at Mannar. Depths are associated with the Kandawala Datum.

2.1.6 Vertical Control

The measured depths were reduced to Lowest Astronomical Tide (LAT) datum using observed tide observations.

2.1.7 Bathymetric Data Processing

The depth profiles acquired digitally were compared with analogue echo profiles to eliminate digital signal interpretation errors.

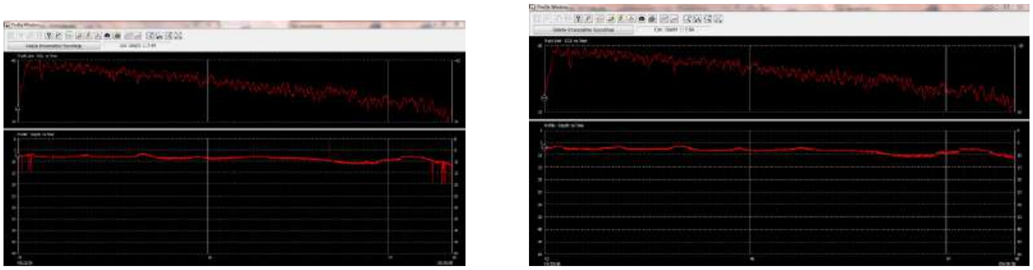


Figure 4 Bathymetric data processing

2.1.8 Quality Control

Cross lines were run appropriately (2 cross lines) across the survey lines to maintain quality of the data.

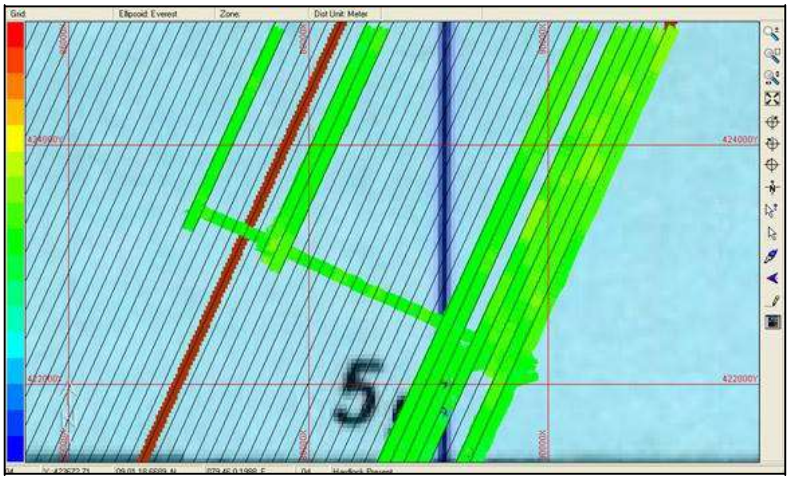


Figure 5 Cross Lines across the Main Scheme

3.0 Contouring and Mapping

All sound data(X,Y, Z) and land detailed data were imported in to Caris GIS 4.5 software and new caris digital file was created for both bathymetry and land data. Later Triangulated Irregular Network (TIN) was created to generate contours. Contour interval is 1.0m. Final maps were produced in AutoCad 2007 (dwg format) using SLD99 coordinate system and Kandawala coordinate system. Geographical grids which are shown in both maps, are referred to WGS 84.

4.0 Accuracy

It can be concluded that after the rigorous checks carried out in plotting and transmitting of information to sheets, the results carry a high degree of accuracy.

5.0 Deliverables

5.1 Documents and Plans

The maps submitted for work in connection with the bathymetric survey are listed below

1. Bathymetry Survey For Navigation Route at Mannar - CEB 2016

   NHO Metric Sheet No. MISC.00116 (Scale 1 : 10000).

2. Bathymetry Survey For Navigation Route at Mannar - CEB 2016

   (SLD99 coordinate system)

   NHO Metric Sheet No. MISC.002/16 (Scale 1 : 10000).

5.2 Digital Files

AutoCad Files :

1. MannarNavigationRoute_CEB_2016.dwg
2. MannarNavigationRoute_CEB_2016-SLD99.dwg

ASCII Files for soundings :

1. Bathymetricdata_KandawalaSystem.TXT
2. Bathymetricdata_WGS84.TXT

6.0 PERSONNEL

6.1 Bathymetric Survey

S.R.C.Ranaweera	-	Senior Hydrographic Surveyor
R. K. Anura Ariyaratne	-	Hydrographic Surveyor
D.L.P.Hewage	-	Hydrographic Surveyor
L.S.C.Siriwardana	-	Hydrographic Surveyor
R. M. D. I. Rathnayaka	-	Hydrographic Surveyor

6.2 Data Processing and Mapping

S.W.S. Weerasinghe	-	Chief Systems Analyst
S.R.C.Ranaweera	-	Senior Hydrographic Surveyor
Y. M. R. Nilupa Kumari	-	Hydrographic Surveyor
R. K. Anura Ariyaratne	-	Hydrographic Surveyor
S.R.T.P. Sinhabahu	-	Cartographer
J. De Silva	-	Cartographer
W.A.K. Prabath	-	Cartographer

6.3 Co-ordination & Report Writing

A. N. D. Perara	-	Chief Hydrographer
S.W.S.Weerasinghe	-	Chief Systems Analyst
Y. M. R. Nilupa Kumari	-	Hydrographic Surveyor

Appendix

Technical Specification

Atlas DESO 30 Single Beam Echo Sounder

SPECIFICATION AND PERFORMANCE DATA

OPERATING FREQUENCIES

- Low: 3.5 – 50 kHz
- High: 100 – 1000 kHz
- Manual tuning in 1 kHz steps

DEPTH RANGE

- 1.0 – 6000 m @ 12 kHz
- 0.5 – 1500 m @ 33 kHz
- 0.2 – 200 m @ 210 kHz

OUTPUT POWER

- Low: 2000 W_{RMS}
- High: 900 – 1000 W_{RMS}

ACCURACY

- 0.18 m ± 0.1% depth @ 12 kHz
- 0.10 m ± 0.1% depth @ 33 kHz
- 0.01 m ± 0.1% depth @ 210 kHz

RESOLUTION

- 0.01 m

PHASING

- Automatic or manual change of measurement range 30%, 20%, 10% overlap

PING RATE

- Up to 25 Hz

OPERATING CONTROLS

- Reception gain
- Chart on/off and advance
- Event marker

PAPER RECORDER

- 216 mm, fax paper or film
- 8 dots/mm, 16 grey scales
- Paper speed control from 1cm/min to 22 cm/min

LCD DISPLAY

- 240 x 64 pixels transflective LCD with backlight 8 lines

ANNOTATION

- Internal: date, time, position
- External: from RS232 port

INTERFACES

- 1x RS232 or RS422, 3x RS232
- Input: DGPS, heave
- Output: depth data as NMEA 0183, ATLAS DESO 25, Odom, echogram output on LAN

OPERATION AND STORAGE

- Operation on front panel
- Operation and storage on optional external standard PC

SOFTWARE

- ATLAS DESO CONTROL software supplied for ATLAS DESO 30 operation and echogram storage
- Hydrographic software package on request

HELP

- The function of each parameter and its maximum and minimum value is shown in the help file of the software or could be printed onto paper chart

POWER REQUIREMENTS

- 11–28 VDC or 115/230 VAC

OPERATING CONDITIONS

- 0° – 50°C
- 5 – 90% relative humidity, non-condensing

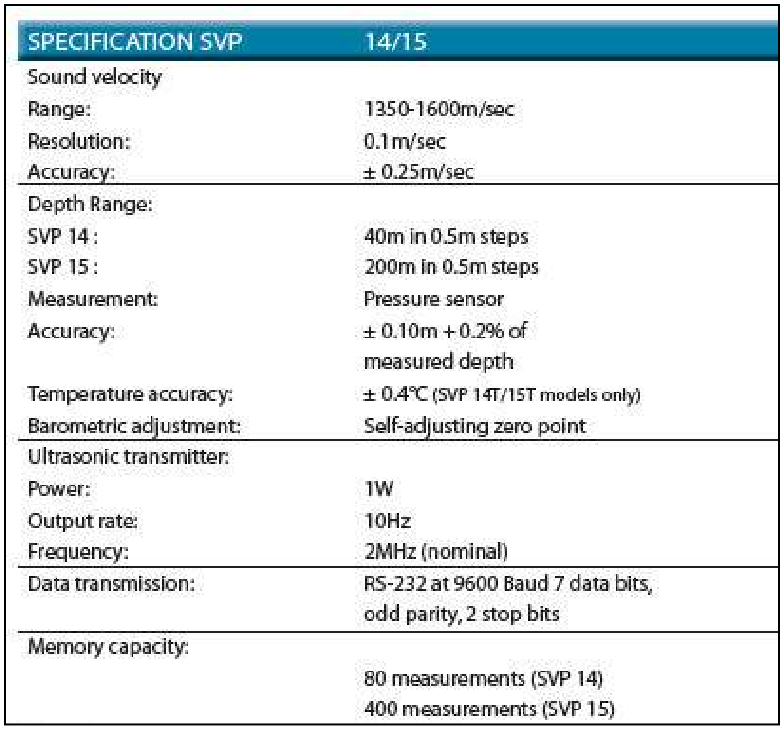
DIMENSIONS AND WEIGHT

- H: 444 mm x W: 443 mm x D: 275 mm
- 15.9 kg

SXBlue II - B DGPS System

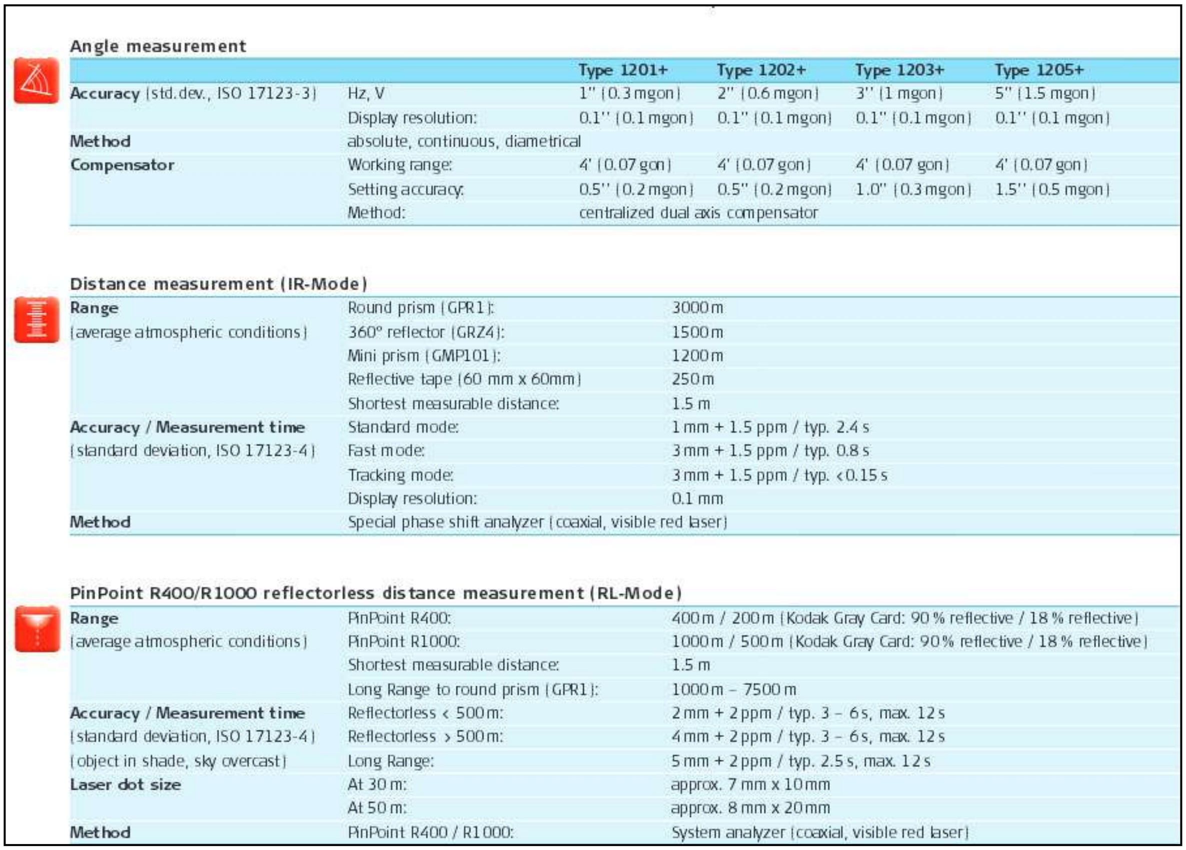
- Horizontal DGPS accuracy < 60 cm 2dRMS (95% confidence)
- Horizontal RTK accuracy < 5 cm
- Horizontal Post-processed accuracy with carrier phase 1 cm (varies with baseline and length of observation)
- Max Position update rate Up to 20 Hz (selected messages)

SVPD 10 Sound Velocity Probe



SPECIFICATION SVP	14/15
Sound velocity	
Range:	1350-1600m/sec
Resolution:	0.1m/sec
Accuracy:	± 0.25m/sec
Depth Range:	
SVP 14 :	40m in 0.5m steps
SVP 15 :	200m in 0.5m steps
Measurement:	Pressure sensor
Accuracy:	± 0.10m + 0.2% of measured depth
Temperature accuracy:	± 0.4°C (SVP 14T/15T models only)
Barometric adjustment:	Self-adjusting zero point
Ultrasonic transmitter:	
Power:	1W
Output rate:	10Hz
Frequency:	2MHz (nominal)
Data transmission:	RS-232 at 9600 Baud 7 data bits, odd parity, 2 stop bits
Memory capacity:	
	80 measurements (SVP 14)
	400 measurements (SVP 15)

Leica TCRP1202 Robotic Total Station



Angle measurement

		Type 1201+	Type 1202+	Type 1203+	Type 1205+
Accuracy (std.dev., ISO 17123-3)	Hz, V	1" (0.3 mgon)	2" (0.6 mgon)	3" (1 mgon)	5" (1.5 mgon)
	Display resolution:	0.1" (0.1 mgon)	0.1" (0.1 mgon)	0.1" (0.1 mgon)	0.1" (0.1 mgon)
Method	absolute, continuous, diametrical				
Compensator	Working range:	4' (0.07 gon)	4' (0.07 gon)	4' (0.07 gon)	4' (0.07 gon)
	Setting accuracy:	0.5" (0.2 mgon)	0.5" (0.2 mgon)	1.0" (0.3 mgon)	1.5" (0.5 mgon)
	Method:	centralized dual axis compensator			

Distance measurement (IR-Mode)

Range	Round prism (GPR1):	3000 m
(average atmospheric conditions)	360° reflector (GRZ4):	1500 m
	Mini prism (GMP101):	1200 m
	Reflective tape (60 mm x 60mm)	250 m
	Shortest measurable distance:	1.5 m
Accuracy / Measurement time	Standard mode:	1 mm + 1.5 ppm / typ. 2.4 s
(standard deviation, ISO 17123-4)	Fast mode:	3 mm + 1.5 ppm / typ. 0.8 s
	Tracking mode:	3 mm + 1.5 ppm / typ. < 0.15 s
	Display resolution:	0.1 mm
Method	Special phase shift analyzer (coaxial, visible red laser)	

PinPoint R400/R1000 reflectorless distance measurement (RL-Mode)

Range	PinPoint R400:	400 m / 200 m (Kodak Gray Card: 90 % reflective / 18 % reflective)
(average atmospheric conditions)	PinPoint R1000:	1000 m / 500 m (Kodak Gray Card: 90 % reflective / 18 % reflective)
	Shortest measurable distance:	1.5 m
	Long Range to round prism (GPR1):	1000 m – 7500 m
Accuracy / Measurement time	Reflectorless < 500 m:	2 mm + 2 ppm / typ. 3 – 6 s, max. 12 s
(standard deviation, ISO 17123-4)	Reflectorless > 500 m:	4 mm + 2 ppm / typ. 3 – 6 s, max. 12 s
(object in shade, sky overcast)	Long Range:	5 mm + 2 ppm / typ. 2.5 s, max. 12 s
Laser dot size	At 30 m:	approx. 7 mm x 10 mm
	At 50 m:	approx. 8 mm x 20 mm
Method	PinPoint R400 / R1000:	System analyzer (coaxial, visible red laser)

entura
Hydro Tasmania
The power of
natural thinking

MANNAR WIND POWER PROJECT
Noise assessment

E305674
25 August 2017

Prepared by Hydro-Electric Corporation
ABN48 072 377 158

t/a Entura 89 Cambridge Park Drive,
Cambridge TAS 7170 Australia

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Document information

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Client organisation	Asian Development Bank
Client contact	Mukhtor Khamudkhanov
ConsultDM number	E305674
Project Manager	Ranjith Perera
Project number	511697

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Revision 4

Revision description	Updated comments on receptors and background noise measurements		
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Reviewed by	Brendon Bateman		25/08/2017
Approved by	Seth Langford		25/08/2017
	(name)	(signature)	(date)
Distributed to	Mukhtor Khamudkhanov (name)	Asian Development Bank (organisation)	25/08/2017 (date)

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Document History and Status

Revision	Prepared by	Reviewed by	Approved by	Date approved	Revision type
0	BB	AW	SL	31/01/2017	First release
1	AW	BB	SL	31/03/2017	Updated receiver locations and scenarios
2	AW	BB	SL	05/05/2017	Updated comments
3	AW	BB	SL	11/05/2017	Updated with Industrial re-zone
4	AW	BB	SL	25/08/2017	Updated comments on receptors and noise measurements

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Executive summary

A noise assessment of the proposed 100 MW Mannar Wind Farm has been completed, as a component of the feasibility study, and as an input to the Asian Development Bank (ADB) and Ceylon Electricity Board (CEB) Environmental Impact Assessment.

The wind turbine model will be selected through a tender process, so the noise characteristics and number of wind turbine locations are not decided. As such, the noise impact has been assessed by modelling a selection of illustrative scenarios, with the maximum impact defined by noise limits that are prescribed at sensitive locations in the vicinity of the wind farm.

In consultation with ADB and CEB, sensitive locations, or ‘receptors’, have been classified as follows:

- Residential: permanent dwellings and community facilities in surrounding villages, Shell Coast Resort and two new tourist hotels (Cabanas) currently under construction (potentially to be acquired by CEB, which would negate their status as receptors), and sleeping quarters where migrant workers are living (and are not provided alternative accomodation)
- Institutional (sleeping): Naval camps (potentially to be classified as Institutional based on CEB agreement with the Navy)
- Institutional: Naval outpost and churches
- Industrial: Industrial facilities including the fish meal processing factory, and the proposed cucumber hatchery
- Commercial: Fisher camps

Noise limits have been defined in accordance with ADB requirements, referencing IFC World Bank Environmental Health and Safety Guidelines. Based on this guideline and in consultation with ADB, the proposed maximum allowable total noise levels at the identified receptors :

- At residential locations: 50 dB (LA_{eq} 1 hour) during day-time hours of 0600-1800, and 45 dB (LA_{eq} 1 hour) during night-time hours of 1800-0600
- At institutional locations (where people are sleeping): 55 dB (LA_{eq} 1 hour) during day-time hours of 0600-1800, and 45 dB (LA_{eq} 1 hour) during night-time hours of 1800-0600
- At institutional locations: 55 dB (LA_{eq} 1 hour) during day-time and night-time hours
- At industrial and commercial locations: 70 dB (LA_{eq} 1 hour) during day-time hours of 0600-1800, and 60 dB (LA_{eq} 1 hour) during night-time hours of 1800-0600

Wind farm noise level is typically modelled at receptors without consideration of any potential additive effects of ambient background noise. As such, a 1 dB allowance for the additive effect of wind farm noise plus background noise has been assumed in this assessment, to estimate the total noise level.

Where background noise exceeds noise limits, an allowance of measured background noise +3 dB (LAeq 1hour) is permitted by the IFC World Bank Environmental Health and Safety Guidelines. Background noise measurements have been made during the south-west wind season, and additional measurements will be made during the north-east wind season, in order to define allowable wind turbine noise output during high background noise periods. For the interim, modelling in this report is compared against only the fixed limits.

Scenarios A1, A2 and A3 outline the potential noise impact of all 39 wind turbine locations for a range of wind turbine noise power curves. During unconstrained operation of the wind farm under these scenarios, predicted noise levels exceed the night-time limits (and in some cases day-time limits) at receptors in close proximity to wind turbines, including the Shell Coast Resort, two ‘Investment Cabanas’, and naval camps grouped along the coastline.

Scenarios B and C have been developed as realistic scenarios that illustrate a wind turbine layout of 31 x 3.3 MW wind turbines that is compliant with specified noise limits, through use of operational constraints on wind turbine noise output settings, which can be varied based on time of day and season (and potentially wind speed and direction). There is an estimated 8.5% and 4.3% reduction respectively in annual energy output based on the constrained operation modelled under these scenarios. Scenario C assumes migrant labourers residing near WT31 can be relocated and thus fewer wind turbines operate in a noise constrained mode.

As a consequence of this assessment, Entura provides the following recommendations:

1. Wind turbines supplied for the project must be able to operate in a noise constrained mode, in order to meet the seasonal day/night noise limit requirements defined by this report. The noise constrained operation will be implemented automatically as wind speed increases, with the specific noise mode selected to ensure the project is in compliance with the relevant seasonal day/night noise limits, based on outputs from noise modelling.
2. Wind turbine noise should have no tonal component unless incorporated into the assessment as a penalty.
3. During the tender process, the wind turbine supplier must propose a wind turbine model and wind farm layout (subset of 39 locations) that complies with the prescribed limits at relevant receptors. Any requirements for reduced noise output (and hence reduced power output) must be quantified, and a specific operational regime will be determine from the outputs of noise modelling.
4. Background noise measurements completed in June 2017 during the shouth-west wind season have facilitated noise limits to be further refined, and for details the reader should refer to the report on those background noise measurements [14]. ADB has further indicated that additional background noise measurements are to be undertaken during the north-east wind season.
5. CEB should obtain further information on the use of naval camps and migrant labour quarters used for sleeping, and continue to pursue the possibility of acquiring or relocating facilities and/or compensating to facilitate the lifting of some of the noise constraints at these locations.
6. Compliance with noise limits defined in the Environmental Impact Assessment will require CEB to commit to implementing operational constraints on the wind farm, which will reduce noise and energy output of the wind farm.

Contents

Appendices

List of figures

List of tables

1. Introduction

1.1 Objectives

Entura has been engaged by the Asian Development Bank (ADB) to model the noise output of the Mannar Wind Farm. Modelling of the following scenarios is required to achieve the objectives of the project proponent (Ceylon Electricity Board - CEB) and ADB:

1. For the Environmental Impact Assessment (EIA)
2. For the feasibility study and energy production estimates

This report describes the noise limits, based on relevant standards and guidelines, that constitute the maximum permissible noise impact from the project, consisting of up to 39 wind turbine locations. Because of the nature of the tender process, the final wind turbine model and final wind turbine layout are not decided. As such, this report also provides a typical 100 MW project design using only 31 wind turbine locations, that is provided to demonstrate compliance with the maximum permissible noise impact.

1.2 Noise assessment methodology

The wind farm noise assessment consists of the following key stages:

- Identification of noise sensitive locations within the vicinity of the wind farm, typically by first considering where noise levels exceed 35 dB LA_{90}. [4]
- Identification of a limited number of selected locations where background noise monitoring should be undertaken, that are deemed to be representative of noise receptor locations around the wind farm.
- Derive noise limits at noise receptor locations, based on fixed limits
- Predict wind farm noise output and assess wind farm compliance (this report)
- Acquire background noise monitoring

1.3 Background noise measurements

Background noise measurements were obtained at locations in the vicinity of the wind farm during two initial separate measurement programs:

1. As an input to the project's Initial Environmental Examination (IEE) report. The Industrial Technology Institute of Sri Lanka was engaged by CEB to acquire background noise measurements at the following 8 locations, for a period of 24 hours at each location, from 5-8 October 2015:
    a. Thoddaveli Water Board Office
    b. Mr Mariyadas
    c. Shell Coast Resort
    d. Julian Dias, Pesale
    e. House, Nadukudda

   f. Bishop house, Mannar
   g. Old pier (Navy camp), Thalimannar
   h. House, Tahlimannar

2. The National Engineering Research Development Centre of Sri Lanka was engaged by ADB to acquire background noise measurements at 6 locations, for a period of 48 hours at each location, from 6-12 March 2017:
   a. Sea cucumber drying compound near WT1
   b. Kalutota Cabanas between WT7&8
   c. Fishing camp near WT7&8, sea cucumber hatchery is 135 m east from this point
   d. Shell Coast Resort between WT10&11
   e. Kalutota Cabanas between WT17&18
   f. Fishing camp near WT30&31

The duration of each of these measurement programs is relatively short in comparison to the minimum 2-3 week duration required by international standards for wind farm background noise monitoring. A longer duration of measurements is necessary because measurements are heavily influence by factors such as wind speed and direction and the specific social and environmental conditions found outside during the measurement period. Further, quality documentation for the second program of measurements has not been made available, and the uncertainty associated with these measurements cannot be determined.

Given the above factors, these measurements provide a preliminary indication of ambient background noise at measurement locations, but are insufficient for setting noise limits based on background noise. Results from the 6-12 March 2017 measurement program are presented in Table 1.1**Error! Reference source not found.**.

Table 1.1: March 2017 background noise measurement results (dB)

	L $_{Aeq}$			**L$_{90}$**		
	Ave	Min	Max	Ave	Min	Max
Sea cucumber drying compound near WT1	48.8	43.1	55.1	45.3	40.2	50.0
Kalutota Cabanas between WT7&8	46.7	41.5	55.8	39.3	33.0	42.8
Fishing camp near WT7&8	46.1	39.1	54.8	40.3	31.7	52.6
Shell Coast Resort between WT10&11	42.2	32.5	49.7	38.6	25.1	45.4
Kalutota Cabanas between WT17&18	41.7	35.9	51.7	36.9	30.8	46.3
Fishing camp near WT30&31	49.4	42.9	59.1	44.7	40.0	52.7

High quality measurement for a duration of 2-3 weeks were obtained in June 2017 at these same 6 locations, and are reported separately [14]. These measurements were acquired by a specialised acoustic consultant, experienced in the application of international guidelines on wind farm noise measurements. Wind farm noise requirements based on these most recent measurements are a combination of fixed limits at lower wind speeds as defined in this report, and variable, generally increasing noise allowance at higher wind speeds as background noise increases. However for the purposes of this report comparison is made against the fixed limits until such time the full complement of background noise measurements is available including during the north-east wind season (and the wind turbine model selected for the project is known.

1.4 Compliance requirements – Sri Lankan regulations

The Sri Lankan Urban Development Authority has confirmed in a letter [1] to the Sri Lankan Sustainable Energy Authority that the project site is to be classified an 'Industrial Area' for application of the National Environmental (Noise Control) Regulations [1]. These regulations require the noise output from the wind farm to be within the greater of the following, at the "*boundary of the land in which any source of noise is located*":

- 70 dB (LA_{eq}) during the day defined as between 0600 and 1800, 60 dB (LA_{eq}) during the night defined as between 1800 and 0600
- Measured Background Noise Level +5 dB

Noise limits are expressed as LA_{eq} over an unspecified time period.

Background noise level is defined as LA_{90}, and measurement time intervals are not specifically defined.

CEB is seeking clarification on the definition of the 'boundary' at which these noise limits should be applied, the overall site boundary or the boundary of each individual parcel of land on which a wind turbine is located.

1.5 Compliance requirements – Asian Development Bank

ADB has indicated the following guidelines are to be followed for noise assessment:

1. Local regulatory requirements (to be adhered to where they are more stringent) [2]
2. IFC General EHS Guidelines [3]
3. World Bank Group, Environmental, Health and Safety Guidelines for Wind Energy, August 7, 2015 [4] (and reference documents below for some aspects of the assessment)
    (a) The Assessment and Rating of Noise from Wind Farms, ETSU-R-97, September 1996 [5]
    (b) A Good Practice Guide to the Application of ETSU-R-07 for the Assessment and Rating of Wind Turbine Noise, IAO, May 2013 (and supplementary guidance) [6]

With the site classified as an 'industrial area', compliance with local regulatory requirements is achievable for even a relatively small boundary around each individual wind turbine, such as the 150 m x 150 m land parcels CEB are acquiring.

In addition to local regulatory requirements, fixed noise limits defined by the IFC General EHS Guidelines [3] are applicable to the project, with limits at receptors as follows, with day defined as between 0700 and 2200, and night defined as between 2200 and 0700:

- for residential, institutional and educational facilities, 55 dB (LA_{eq} 1 hour) during the day, 45 dB (LA_{eq} 1hour) during the night; or
- for industrial and commercial facilities, 70 dB (LA_{eq} 1 hour) day and night; or
- measured background noise +3 dB (LA_{eq} 1hour)

The following clarifications are offered on how these limits will be applied to the Mannar wind project:

- Background noise suitable for deriving noise limits at sensitive locations has only just been acquired for the south-west wind season. ADB has indicated that additional noise measurements will be required to define maximum allowable wind turbine noise levels during the north-east wind season. As such, the noise predictions presented in this report are compared with the IFC General EHS Guideline fixed limits as defined above, until such time the full complement of background noise measurements is available (and the wind turbine model selected for the project is known).
- Higher daytime limits shall apply between the hours of 0600 and 1800, consistent with Sri Lankan regulations, and more stringent than IFC General EHS guidelines [3].
- The IFC General EHS Guideline noise limits refer to the total noise level at sensitive locations, considering the combined ambient background noise and wind farm noise. For the purpose of modelling wind farm noise output, the typical assumption is that wind farm noise is the dominant noise source, and that ambient background noise at a similar or lower level than wind farm noise output does not materially add to the total noise level. That said, there is a potential increase due to the summation of the sound pressure levels, which in theory is a maximum of 3dB for similar sound pressure levels, but in practice typically adds very little to the total noise level when wind farm noise output is high. For this assessment, Entura will assume that ambient background noise adds 1 dB to the modelled wind farm noise level. CEB will ultimately need to confirm total noise level at receptors through post-construction measurements.
- Fisher camps and tea kiosks along the coast are only occupied from October through to March, and will only be considered receptors for that period.
- Naval outposts are locations where it is assumed that naval personnel are stationed but are not sleeping. Therefore, it can be considered an Institutional location, but with day-time limits applicable at night-time.
- ADB's social safeguard consultant has noted the church at Nadukudda is a small church, which is used by fishermen to conduct their prayers for a few minutes before they set out for fishing. Except for occasional masses conducted by a priest coming from outside which would last for 1-2 hours, the church is rarely used for any mass gatherings or regular religious activities. Therefore, it can be considered an Institutional location, but with day-time limits applicable at night-time.
- Receptors will be classified as follows:
    - Residential: permanent dwellings and community facilities in surrounding villages, Shell Coast Resort and two new tourist hotels (Cabanas) currently under construction (potentially to be acquired by CEB, which would negate their status as receptors), and sleeping quarters where migrant workers are living (and are not provided alternative accomodation)
    - Institutional (sleeping): Naval camps (potentially to be classified as Institutional based on CEB agreement with the Navy)
    - Institutional: Naval outpost and churches
    - Industrial: Industrial facilities including the fish meal processing factory, and the proposed cucumber hatchery
    - Commercial: Fisher camps

ADB has further specified that for reasons of daytime amenity, the day-time limit shall be adjusted to 50 dB for the local villages, homes, churches, tourist facilities and sleeping quarters where migrant workers are living.

Consequently, the proposed allowable total noise levels for the Mannar wind project at receptors, for this assessment are as follows (with the maximum allowable wind farm noise level 1 dB lower):

- At residential locations: 50 dB (LA_{eq} 1 hour) during day-time hours of 0600-1800, and 45 dB (LA_{eq} 1 hour) during night-time hours of 1800-0600
- At institutional locations (sleeping): 55 dB (LA_{eq} 1 hour) during day-time hours of 0600-1800, and 45 dB (LA_{eq} 1 hour) during night-time hours of 1800-0600
- At institutional locations: 55 dB (LA_{eq} 1 hour) during day-time and night-time hours
- At industrial and commercial locations: 70 dB (LA_{eq} 1 hour) during day-time hours of 0600-1800, and 60 dB (LA_{eq} 1 hour) during night-time hours of 1800-0600

Further detail on these noise limits and the impact of background noise is provided by the background noise measurements report [14].

ADB has indicated that wind turbine noise should have no tonal component unless incorporated into the assessment as a penalty. It is unusual for wind turbines noise output to have a tonal component, and it is not typically considered during modelling.

Compliance with limits will be verified through:

- Pre-construction modelling of wind farm noise output – this report
- Post-construction measurement of ambient noise with the wind farm operating

1.6 Wind turbine noise constrained operation

The noise output of a wind farm can be controlled by several means:

- Design features: The wind turbines supplied for the project may contain design features, such as aerodynamic modifications to the blade to permanently reduce the noise output of a wind turbine model. There may be an associated cost to include such additional features, and there may or may not be an impact on the power curve / energy output.
- Operational modes: Modern wind turbines are equipped with programmable operational modes that can reduce the noise output of the wind turbine on-demand. There is typically an associated reduction in power output, which increases as the noise output decreases. These operational modes of reduced noise ouput are triggered automatically as wind speed, power output (and consequently noise output) increase. The operational modes are programmed for each wind turbine based on time of day and season.
- Shut down: In extreme cases, wind turbines might be shut down (turned off) under certain conditions to eliminate noise output. This can also be programmed, based on wind speed and time of day/season.

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2. Noise model inputs

2.1 Wind turbine layout

The following scenarios are considered in this report:

A. The 39 wind turbine layout developed by CEB and provided to Entura on 30 November 2016, with the following wind turbine characteristics:

    1. Wind turbine noise level of 108.5 dB (a typical 3MW wind turbine)
    2. Wind turbine noise level of 106.5 dB (a typical 3 MW wind turbine)
    3. Wind turbine noise level of 101.0 dB (a typical noise constrained 3 MW wind turbine)

B. A subset of 31 wind turbines for a 102.3 MW wind farm consisting of 3.3 MW wind turbines with a 117 m rotor diameter, as per the energy production report [12].

    - For this layout, WT 27 and WT 28 have been removed, as instructed by CEB.
    - The following five (5) locations have been removed due to their potential to generate relatively high noise levels at nearby receptors: WTs 4, 7, 8, 17, 22, 31.
    - The remaining 31 locations are operating in noise modes ranging from the standard unconstrained 105.7 dB version, to the noise constrained 101.0 dB version of the wind turbine.

C. An example alternate subset of 31 wind turbines, assuming that migrant worker sleeping quarters located between WT30 and WT31 can be relocated. Relative to Scenario B, WT31 is reinstated, WT5 disregarded, and noise constraints on WT29, 30, 32 and 33 can be lifted.

Wind turbine location coordinates are listed in Appendix A.1, and displayed in Figure 2.1.

Due to ongoing land acquisition and micro-siting, there are likely to be changes to these wind turbine locations. The impact of such changes may require an update of this noise assessment. Further, CEB has reached preliminary agreement with the Navy to move nearby sleeping quarters, and CEB has initiated an acquisition process for the two ‘Investment Cabanas’. Depending on the outcome of these processes, the sensitivity of receptors will reduce and the applicable noise limits will change.

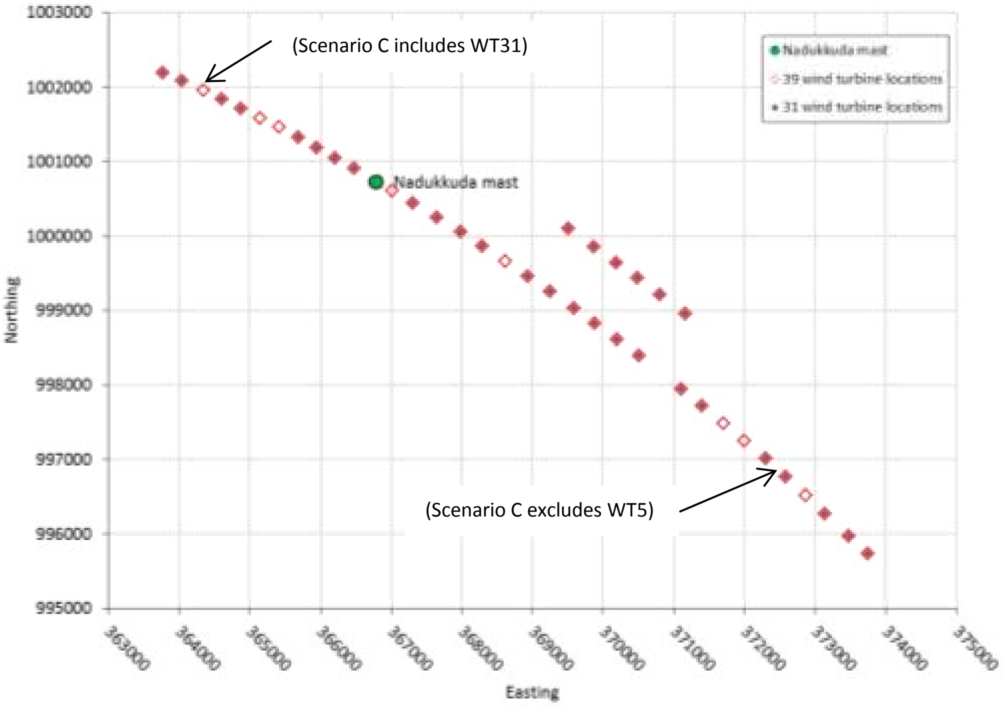

Figure 2.1: Wind turbine layout

2.2 Wind turbine noise output

The noise model based on ISO 9613-2 requires the wind turbine noise output to be represented by Octave Band data. For the generic wind turbine examples, Entura has used octave band data from a reputed manufacturer's [11] wind turbine, scaled to achieve the maximum broadband sound power levels detailed in Table 2.1.

Table 2.1: Reference octave band spectrum

Octave band centre frequency (Hz)	**Sound power level at hub height (dBA)**			
	Generic wind turbine 108.5 dB	**Generic wind turbine 106.5 dB**	**Generic wind turbine 101.0 dB**	**Generic wind turbine 105.7 dB**
31.5	77. 4	74.7	69.2	73.9
63	87.4	85.2	79.7	84.4
125	94.8	92.1	86.6	91.3
250	99.8	98.5	93.0	97.7
500	104.5	101.5	96.0	100.7
1000	103.0	101.8	96.3	101.0
2000	98.4	97.3	91.8	96.5
4000	94.0	90.0	84.5	89.2
8000	70.9	70.1	64.6	69.3
Broadband Noise	**108.5**	**106.5**	**101.0**	**105.7**

Noise output vs. wind speed data for a selection of typical wind turbines that might be employed for this project are shown in Table 2.2. Different manufacturers have different methods for specifying noise constrained modes, but typically it is presented as a reduced noise output (and hence reduced power output) as wind speed increases, such as shown in Table A.3 for the generic 105.7 dB wind turbine.

Table 2.2: Example noise output curves

Hub height wind speed (m/s)	**Vestas V117 3.3 MW**	**Vestas V117 3.3 MW (blades with serrated training edge)**	**Siemens SWT-3.2-113**	**GE 3.4-130**	**Senvion 3.2M122NES**
3	92.5	91.3			
4	93.0	91.6		95.7	95
5	95.5	93.5		96.3	97.2
6	99.0	96.5	106	98.7	99.8
7	102.4	99.8	106	102	103.2
8	105.5	102.8	106	104.7	105.5
9	107.6	105.0	106	106.4	105.5
10	108.3	105.7	106	106.5	105.3

2.3 Receptor locations

The study area can be defined as the area around the wind farm where preliminary modelling suggests LA90 noise level will exceed 35 dB(A) at up to 10 m/s wind speed from the proposed wind turbines [4][6]. For the Mannar Wind Power Project, this is equivalent to a distance of approximately 2 km from the wind turbines.

Within this area a list of 115 ‘receptor’ locations has been prepared, and is provided in Appendix A.3. This list has been prepared by ADB’s environmental and social safeguard consultants, with some additional building locations that Entura has identified through observations of Google Earth aerial imagery.

2.4 Model parameters

Wind farm noise predictions have been derived using the software package *DNG-GL Windfarmer 5.2.11.0*, which is based on the ISO 9613-2 standard, with input parameters set as required by relevant guidelines [5][6] for this assessment. Model parameters are listed in Table 2.3.

Table 2.3: Noise model parameters

<table>
<tr><th>Parameter</th><th colspan="9">Setting</th></tr>
<tr><td>Noise model</td><td colspan="9">Complex (ISO9613) General</td></tr>
<tr><td>Ground effect</td><td colspan="9">Ground factor of G=0.5</td></tr>
<tr><td>Atmospheric attenuation</td><td colspan="9">Octave spreading</td></tr>
<tr><td>Calculation grid spacing</td><td colspan="9">10 m</td></tr>
<tr><td>Height above ground level for noise mapping</td><td colspan="9">4 m</td></tr>
<tr><td>Atmosphere</td><td colspan="9">10°C temperature, 70% humidity, 101.325 kPA atmospheric pressure</td></tr>
<tr><td>Topographic corrections</td><td colspan="9">None</td></tr>
<tr><td rowspan="3">Air absorption parameters</td><td colspan="9">Octave band mid frequency (Hz)</td></tr>
<tr><td>31.5</td><td>63</td><td>125</td><td>250</td><td>500</td><td>1k</td><td>2k</td><td>4k</td><td>8k</td></tr>
<tr><td>0</td><td>0.1</td><td>0.4</td><td>1.0</td><td>1.9</td><td>3.7</td><td>9.7</td><td>32.8</td><td>117</td></tr>
</table>

Ground effect factor of G=0.5 is selected as a conservative model input. The IOA guideline [6] notes that a soft ground factor (G=1.0) should not be used, and a ground factor of G=0.0 is commonly used, and provides robust predictions in most situations, however can overpredict noise levels. Therefore, G=0.5 is recommended.

A receiver height of 4 m is recommended, as it has the effect of reducing the potential over-sensitivity of the calculation to ground factor compared to lower receiver heights, and the selected atmospheric conditions represent a reasonably low level of air absorption.

International studies show this prediction model with the selected input parameters provides a reliable representation of the upper noise levels expected in practice.

3. Predicted noise levels

The predicted maximum noise levels for the different scenarios are presented in Appendix A.3. A discussion of the results is presented below.

Scenarios A and B are compared against noise limits that include residential classification for fisher camps where migrant workers are living. Scenario C assumes these workers are to be provided with accommodation elsewhere.

3.1 Scenario A1: 39 x generic wind turbines at 108.5 dB

Scenario A1 is for illustrative purposes, showing the predicted noise levels from a 108.5 dB wind turbine model, using all 39 wind turbine locations. Noise limits are exceeded at many receptor locations, and significant operational controls would be required to reduce noise levels at receptors below the limits specified in Table A.4.

3.2 Scenario A2: 39 x generic wind turbines at 106.5 dB

Scenario A2 is similar to Scenario A1, but with predicted noise levels at receptor locations reduced by slightly less than 2 dB relative to Scenario A1. As with Scenario A1, significant operational controls would be required to reduce noise levels at all receptors below the limits specified in Table A.1.

This scenario complies with noise limits at nearby villages without operational constraints. In Entura's opinion, 106.5 dB is an appropriate maximum noise level for the wind turbines, and this specification permits a good range of wind turbine models (with noise control) that can be considered for the project.

3.3 Scenario A3: 39 x generic wind turbines at 101.0 dB

Scenario A3 is representative of a wind turbine operating in a highly constrained mode at low noise level. Scenario A3 is significantly closer to achieving full compliance with the specified noise limits than either Scenarios A1 or A2. However maximum noise level exceeds noise limits at the following locations:

- The naval camp between WT4 and WT5. It is recommended that CEB investigate the use of these buildings at the naval camp, to confirm whether or not the 45 dB night-time limit is appropriate.
- The migrant labour quarters between WT7 and WT8. It is recommended that CEB confirm when these buildings will be occupied and when the occupants will be sleeping, to confirm whether or not the 45 dB night-time limit is appropriate. CEB should investigate possible alternative accommodation arrangements.
- The Kaluthota Finance Hotel (under construction), adjacent WT8.
- The Kaluthota Finance Hotel (under construction) St Jude Road, adjacent WT17

- Vadi between WT30 and 31. It is recommended that CEB investigates the use of these buildings by migrant labourers, and possible alternative accommodation arrangements (as assumed for Scenario C).

3.4 Scenarios B and C: 31x 105.7 dB wind turbines in noise constrained mode

Scenario B is a layout of 31 wind turbines, with some wind turbines operating in a constrained mode (which differs from day to night) as listed in Table A.2, in order to meet the prescribed noise limits.

The results are within the prescribed day-time and night-time limits at all locations.

It is noted that to comply with night-time limits in Scenario B, the following locations are only compliant when wind turbine shut-down at night is assumed:

- The naval camp between WT4 and WT5. It is recommended that CEB investigates the use of these buildings at the naval camp, to confirm whether or not the 45 dB night-time limit is appropriate.
- Vadi and naval observation unit between WT30 and 31. It is recommended that CEB investigates that use of these buildings by migrant labourers, and possible alternative accommodation arrangements.

Scenario C assumes such relocation of migrant labourers is achievable, and therefore location WT31 is used instead of WT5.

Background measurements to be completed in June 2017 may result in increased noise limits that facilitate compliance.

Scenarios B and C demonstrate that a 100 MW wind farm is feasible using a likely wind turbine model and a subset of 31 of the 39 available locations – provided the impacts on receptors are managed by CEB through appropriate operational constraints.

Entura has modelled the impact on energy output of the constrained operation that generates the maximum noise levels listed in Table A.1, and the results are displayed in Table 3.1. (A 2% loss is included for night-time shutdown of WT5 and WT 30 (during October to April) to make Scenario B fully compliant with noise limits.)

Table 3.1: Annual energy loss as a percentage of annual energy output for Scenarios B and C (from draft energy report)

Scenario	May to September		October to April		Total
	Day	Night	Day	Night	
B	0.3%	6.4%	0.1%	1.7%	**8.5%***
C	0.1%	3.2%	0.0%	1.0%	**4.3%**

* Including night-time shutdown of WT5 and WT30 equal to 2% on annual energy output

It is noted that reduced sensitivity of naval camps and Investment Cabanas based on CEB’s current activities would allow contraints on output to be relaxed.

4. Summary and recommendations

The number of wind turbine locations and specific wind turbine model for the proposed 100 MW project will only be known after the conclusion of the tender process. As such, the noise impact of the proposed wind farm can only be modelled using likely scenarios, and is ultimately defined by the maximum noise limits defined in this report.

Scenarios A1, A2 and A3 presented in this report are illustrative, but do not represent likely wind farm configurations as they exceed 100 MW installed capacity. Scenarios B and C consisting of 31 x 3.3 MW wind turbines and including constrained operation, are realistic examples of a 100 MW wind farm.

During unconstrained operation of the wind farm with all wind turbine locations (represented by Scenarios A1 and A2), predicted noise levels exceed the night-time limits (and in some cases day-time limits) at receptors in close proximity to wind turbines, including the Shell Coast Resort, two ‘Investment Cabanas’, sea cucumber hatchery, and many of the naval observations units (and naval camps) and Vadi (fisher camps, and fishermen’s restrooms) grouped along the coastline.

For Scenarios B and C, constrained output results in compliance with noise limits, and estimated losses in annual energy output of 8.5% and 4.3% respectively, compared to operating unconstrained by noise limits. The significantly reduced loss of Scenario C results from assuming migrant labourers residing near WT31 can be relocated.

As a consequence of this assessment, Entura provides the following recommendations:

- Wind turbines supplied for the project must be able to operate in a noise constrained mode, in order to meet the seasonal day/night noise limit requirements defined by this report. The noise constrained operation will be implemented automatically as wind speed increases, with the specific noise mode selected to ensure the project is in compliance with the relevant seasonal day/night noise limits, based on outputs from noise modelling.
- Wind turbine noise should have no tonal component unless incorporated into the assessment as a penalty.
- During the tender process, the wind turbine supplier must propose a wind turbine model and wind farm layout (subset of 39 locations) that complies with the prescribed limits at relevant receptors. Any requirements for reduced noise output (and hence reduced power output) must be quantified, and a specific operational regime will be determine from the outputs of noise modelling.
- Background noise measurements to be completed in June 2017 during the south-west wind season have facilitated noise limits to be further refined, and for details the reader should refer to the report on those background noise measurements [14]. ADB has further indicated that additional background noise measurements are to be undertaken during the north-east wind season.
- CEB should continue to pursue the possibility of acquiring or relocating facilities and/or compensating to facilitate the lifting of some of the noise constraints at these locations.

- Compliance with noise limits defined in the Environmental Impact Assessment will require CEB to commit to implementing operational constraints on the wind farm, which will reduce noise and energy output of the wind farm.

5. References

[1] Letter from Urban Development Authority to Sustainable Enercon Authority, 2/5/2017, Request to Declare the Energy Development Area of Mannar Wind Power Project as an Industrial Zone, File No: J/PR/SED/60

[2] National Environmental (Noise Control) Regulations No.1 1996,The National Environment Act, No. 47 of 1980,

[3] IFC General EHS Guidelines

[4] World Bank Group, Environmental, Health and Safety Guidelines for Wind Energy, August 7, 2015. (and reference documents below for some aspects of the assessment)

[5] The Assessment and Rating of Noise from Wind Farms, ETSU-R-97, September 1996

[6] A Good Practice Guide to the Application of ETSU-R-07 for the Assessment and Rating of Wind Turbine Noise, IAO, May 2013 (and supplementary guidance)

[7] Proposed 100 MW Mannar Wind Power Project Initial Environmental Examination Report, CEB, April 2016

[8] Report on Feasibility Study on 100 MW Semi-Dispatchable Wind Farm in Mannar Island, Sri Lanka, CEB, May 2016

[9] Monitoring of Background Noise Levels and Existing Noise Levels, Existing Vibration levels Report No:CP – 1515188, ITI, October 2015

[10] General Specification, V117-3.3/3.45 MW 50/60 Hz, 0035-1209 V10, 10/7/2015

[11] V126-3.3/3.45MW Third Octaves according to General Specification, 0048-2151_V03

[12] Mannar wind power project, wind resource, wind turbine suitability and energy production report, Entura, E305674 TR-01

[13] Guidelines for Community Noise, World Health Organisation, 1999

[14] Mannar Wind Power Project Backgrounf Noise Measurements, M17244RP2, Revision B, 24/8/2017

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Appendices

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A Locations and results

A.1 Wind turbine locations

Table A.1: WTG layout

Turbine number	X coordinate	Y coordinate	Scenario B noise mode (dB)		Scenario C noise mode (dB)	
			Day	Night	Day	Night
WT 1	373,744	995,733	105.7	105.7	105.7	105.7
WT 2	373,477	995,973	105.7	105.7	105.7	105.7
WT 3	373,136	996,277	105.7	101.0	105.7	105.7
WT 4	372,859	996,524	-	-	-	-
WT 5	372,582	996,767	102.5	101.0	-	-
WT 6	372,294	997,017	105.7	101.0	105.7	105.7
WT 7	371,999	997,250	-	-	-	-
WT 8	371,695	997,487	-	-	-	-
WT 9	371,398	997,717	105.7	101.0	105.7	101.0
WT 10	371,105	997,950	105.7	101.0	105.7	101.0
WT 11	370,507	998,397	105.7	101.0	105.7	101.0
WT 12	370,200	998,612	105.7	101.0	105.7	101.0
WT 13	369,882	998,832	104.3	104.3	105.7	104.3
WT 14	369,586	999,033	105.7	105.7	105.7	105.7
WT 15	369,246	999,257	105.7	101.0	105.7	101.0
WT 16	368,935	999,462	105.7	101.0	105.7	101.0
WT 17	368,614	999,667	-	-	-	-
WT 18	368,285	999,867	105.7	101.0	105.7	101.0
WT 19	367,979	1,000,059	105.7	101.0	105.7	101.0
WT 20	367,649	1,000,250	105.7	105.7	105.7	105.7
WT 21	367,309	1,000,444	105.7	102.5	105.7	102.5
WT 22	367,006	1,000,609	-	-	-	-
WT 23	366,476	1,000,904	105.7	101.0	105.7	101.0
WT 24	366,211	1,001,046	104.3	102.5	102.5	104.3
WT 25	365,953	1,001,183	105.7	105.7	105.7	105.7
WT 26	365,684	1,001,324	105.7	105.7	105.7	105.7
WT 27	365,415	1,001,463	-	-	-	-
WT 28	365,144	1,001,588	-	-	-	-
WT 29	364,873	1,001,714	105.7	101.0	105.7	105.7
WT 30	364,605	1,001,843	104.3	101.0	105.7	105.7
WT 31	364,343	1,001,963	-	-	105.3	105.3
WT 32	364,043	1,002,092	105.7	101.0	105.7	105.7
WT 33	363,772	1,002,196	105.7	101.0	105.7	105.7

Turbine number	X coordinate	Y coordinate	Scenario B noise mode (dB)		Scenario C noise mode (dB)	
			Day	Night	Day	Night
WT 34	371,158	998,958	105.7	101.0	105.7	101.0
WT 35	370,797	999,215	105.7	102.5	105.7	102.5
WT 36	370,484	999,434	105.7	105.7	105.7	105.7
WT 37	370,184	999,641	105.7	105.7	105.7	105.7
WT 38	369,868	999,852	105.7	104.3	105.7	104.3
WT 39	369,503	1,000,099	105.7	101.0	105.7	101.0

Note: Scenarios A1, A2, A3 are fixed at 108.5, 106.5 and 101.0 dB
Coordinate reference: WGS84 / UTM zone 44P

A.2 Wind turbine noise curve

Table A.2: Wind turbine annual energy loss as a percentage of wind turbine annual energy output for the different operational modes

105.7dB wind turbine noise mode	Annual Energy Loss
0 – 105.7 dB	-
1 – 105.3 dB	0.6%
2 – 104.3 dB	4.4%
3 – 102.5 dB	10.6%
4 – 101.0 dB	18.1%

Table A.3: Example wind turbine noise curve, 105.7 dB wind turbine

Wind speed at hub height (m/s)	Frequency	Energy generation distribution	Sound power level at hub height (dBA)				
			0 – 105.7	1 – 105.3	2 – 104.5	3 – 102.5	4 – 101.0
3	3.8%	0.0%	91.3	91.3	91.3	91.3	91.3
4	6.0%	0.4%	91.6	91.6	91.6	91.6	91.6
5	8.8%	1.5%	93.5	93.5	93.5	93.4	92.1
6	11.3%	3.5%	96.5	96.5	96.5	96.4	94.6
7	12.9%	6.5%	99.8	99.8	99.7	99.2	98.0
8	11.7%	8.9%	102.8	102.7	101.9	100.6	99.3
9	9.0%	9.8%	105.0	104.7	102.8	100.9	99.5
10	6.5%	9.7%	105.7	105.3	103.2	101.1	99.6
11	6.1%	11.8%	105.7	105.3	103.6	101.4	99.9
12	6.5%	14.1%	105.7	105.3	104.1	101.8	100.1
13	5.5%	12.4%	105.7	105.3	104.1	102.1	100.4
14	4.2%	9.4%	105.7	105.3	104.1	102.3	100.8

15-20	5.2%	11.8%	105.7	105.3	104.1	102.5	101.0

A.3 Receptors

Table A.4: Receptor list and noise predictions, Scenarios A and B

Nearby WT	ID	Receptor name	Easting (m)	Northing (m)	Distance to nearest wind turbine (m)	Limit		Receptor noise (night), including +1dB assumed background contribution (LA_{eq} dB) Scenario			
						Day	Night	A1	A2	A3	B
	1	Thalvupadu	374870	994562	1625	50	45	35.1	33.8	28.3	31.3
	2	Thottavelly-Thalvupadu Rd	374475	996332	945	50	45	41.7	40.1	34.6	37.8
	3	N1 Thoddaveli Water Board Office	374610	996618	1238	70	60	39.8	38.3	32.8	35.5
	4	N2 Mr Mariyadas	372979	997738	995	50	45	43.9	42.4	36.8	36
	5	Konniankuduiruppu village and church	373383	997683	1217	50	45	42.2	40.7	35.2	35
	6	Konniankuduiruppu	374340	996759	1167	50	45	41.1	39.6	34.1	36.5
	7	Konniankuduiruppu	373894	997101	1119	50	45	42.3	40.8	35.3	36.5
	8	Konniankuduiruppu	373544	997385	1103	50	45	42.9	41.3	35.8	36
	9	Konniankuduiruppu	372959	997586	875	50	45	44.9	43.3	37.8	37
WT 1	10	Naval observation unit	373853	995455	299	55	55	49.9	48.1	42.5	47
WT 1	11	Vadi	373809	995533	210	70	60	52.6	50.7	45.2	49.7
	12	Vadi	373829	995556	196	70	60	53.1	51.2	45.6	50.2
	13	Vadi	373817	995564	184	70	60	53.5	51.7	46.1	50.6
	14	Vadi	373824	995573	179	70	60	53.7	51.9	46.3	50.8
	15	Vadi	373837	995574	185	70	60	53.5	51.7	46.1	50.6
	16	Vadi	373800	995576	167	70	60	54.2	52.4	46.8	51.3
	17	Vadi	373815	995578	171	70	60	54.1	52.2	46.6	51.2
	18	Vadi	373809	995578	168	70	60	54.2	52.3	46.7	51.3
WT 1 and 2	19	Industrial unit (fish meal manufacturing company) boundary	373496	995860	115	-	-	57.3	55.4	49.8	54.3
	20	Industrial unit (fish meal manufacturing company) boundary	373639	996013	166	-	-	55.3	53.4	47.8	52.2
	21	Industrial unit (fish meal manufacturing company) boundary	373733	995954	221	-	-	54.2	52.3	46.8	51.2
	22	Industrial unit (fish meal manufacturing company) boundary	373661	995697	90	-	-	58.1	56.2	50.5	55.1
	23	Industrial unit (fish meal manufacturing	373568	995816	182	70	60	56	54.1	48.6	53.1

		company) estimated location										
WT 4 and 5	24	Naval Camp - boundary	372741	996424	179	-	-	55.7	53.8	48.3	43.6
	25	Naval Camp - boundary	372880	996603	124	-	-	58.8	56.9	51.2	44
	26	Naval Camp - boundary	372550	996609	161	-	-	55.6	53.8	48.2	47.4
	27	Naval Camp - boundary	372687	996766	106	-	-	57.8	56	50.3	49.7
	28	Naval Camp (building)	372692	996656	156	55	45[1]	56.6	54.8	49.2	45.0
	29	Naval Camp (building)	372773	996494	138	55	45[1]	58.4	56.5	50.8	44.1
WT 7 and 8	30	Vadi	371800	997235	199	70	60	54.9	53.1	47.6	40.3
	31	Vadi	371843	997235	156	70	60	56	54.1	48.5	40.5
	32	Vadi	371801	997250	198	70	60	55.1	53.3	47.7	40.3
	33	Vadi	371845	997254	154	70	60	56.1	54.3	48.7	40.5
	34	Vadi	371760	997262	235	70	60	54.7	52.9	47.3	40.3
	35	Naval observation unit	371757	997279	217	55	55	54.9	53.1	47.5	40.3
	36	Vadi	371774	997281	221	70	60	55.1	53.3	47.7	40.3
	37	Vadi	371706	997292	196	70	60	54.9	53	47.5	40.4
	38	Sea cucumber hatchery	371797	997312	203	70	60	55.7	53.8	48.3	40.4
	39	Vadi	371764	997314	186	70	60	55.6	53.7	48.2	40.4
	40	Vadi	371739	997314	178	70	60	55.5	53.7	48.1	40.4
	41	Vadi	371770	997322	182	70	60	55.7	53.9	48.3	40.4
	42	Vadi	371771	997324	180	70	60	55.8	53.9	48.3	40.4
	43	Fishermen’s rest room	371768	997333	170	55	45	55.9	54.1	48.5	40.5
	44	Tea kiosk	371783	997336	175	70	60	56	54.1	48.5	40.5
	45	Vadi	371646	997348	148	70	60	56	54.1	48.5	40.9
	46	Vadi	371677	997382	108	70	60	57.6	55.8	50.1	41.1
	47	Residential unit - Konniankuduiruppu	372959	997594	880	50	45	44.9	43.3	37.8	36.9
	48	Residential unit - Konniankuduiruppu	372936	997607	872	50	45	44.9	43.3	37.8	36.9
	49	Residential unit - Konniankuduiruppu	372907	997617	858	50	45	45	43.4	37.9	37
	50	Residential unit - Konniankuduiruppu	372790	997705	848	50	45	45.1	43.5	38	36.9
WT 8 and 9	51[2]	Kaluthota Finance Hotel (under construction) - boundary	371824	997619	183	50	45	54.7	52.9	47.3	41
	52[2]	Kaluthota Finance Hotel (under construction) - boundary	371707	997679	192	50	45	54.8	53	47.4	42.9
	53[2]	Kaluthota Finance Hotel (under construction) - boundary	371811	997726	265	50	45	52.7	50.9	45.4	41.3
	54[2]	Kaluthota Finance Hotel (under construction) - boundary	371751	997764	282	50	45	52.7	50.9	45.4	42.2
WT 9 and 10	55	Vadi	371140	997761	192	70	60	55	53.2	47.7	47.5

WT 10 and 11	56	Vadi	370907	997982	201	70	60	53.7	51.9	46.3	46.4
	57	Vadi	370888	997999	223	70	60	53.1	51.3	45.7	45.9
	58	Vadi	370873	998007	239	70	60	52.7	50.9	45.4	45.5
WT 10 and 11	59	Shell Coast Hotel - boundary	370770	998142	366	50	45	51.4	49.7	44.2	44.5
	60	Shell Coast Hotel - boundary	370723	998172	312	50	45	51.7	50	44.5	44.9
	61	Shell Coast Hotel - boundary	370947	998404	440	50	45	50.7	49	43.5	44.1
	62	Shell Coast Hotel - boundary	370905	998436	400	50	45	50.9	49.2	43.7	44.3
	63	Shell coast resort B	370881	998362	375	50	45	51.2	49.4	43.9	44.4
WT 12	64	Naval observation unit	370171	998500	116	55	55	57.3	55.5	49.8	50.4
WT 13	65	Vadi	369853	998753	84	70	60	58.8	56.9	51.2	54.3
WT 17	66	Naval observation unit	368425	999674	190	55	55	55.6	53.8	48.3	45.8
	67	Olaiththoduvai	372627	998956	1469	50	45	40.6	39.2	33.7	34.1
	68	Olaiththoduvai Church	372637	998802	1487	55	55	41	39.5	34	34.3
	69	Olaiththoduvai School	372650	999016	1493	50	45	40.3	38.9	33.4	33.9
	70	Residential unit - Uvary village and church	371517	999660	789	50	45	45.0	43.4	37.9	39.8
	71	Residential unit - Uvary village and church	371572	999697	847	50	45	44.4	42.9	37.3	39.2
	72	Residential unit - Uvary village and church	371525	999728	853	50	45	44.6	43	37.5	39.4
WT 17	73[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368920	999781	320	50	45	52.9	51.2	45.7	44.9
	74[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368931	999793	331	50	45	52.7	51	45.4	44.8
	75[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368688	999852	199	50	45	54.5	52.7	47.1	44
	76[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368822	999864	286	50	45	52.7	50.9	45.4	43.9
	77[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368716	999918	270	50	45	52.8	51.1	45.5	43.7
WT 22 and 23	78	Naval Camp - Nadukuda - boundary	366705	1000673	308	55	45[1]	52.6	50.9	45.3	44.4
	79	Naval Camp - Nadukuda - boundary	366806	1000608	200	55	45[1]	54	52.2	46.6	43.5
	80	Naval Camp - Nadukuda - boundary	366839	1000657	173	55	45[1]	54.8	53	47.4	43.6
	81	Naval Camp - Nadukuda - boundary	366748	1000717	280	55	45[1]	53	51.2	45.6	44.4
	82	Naval Camp - Nadukuda - boundary	366738	1000700	283	55	45[1]	52.9	51.1	45.6	44.3
	83	Naval Camp - Nadukuda - boundary	366725	1000705	297	55	45[1]	52.8	51.1	45.5	44.5

WT 22 and 23	84	Tea kiosk	366663	1000680	292	70	60	52.6	50.9	45.3	44.9
	85	Tea kiosk	366681	1000705	286	70	60	52.8	51	45.5	45
	86	Fishermen's rest room	366735	1000715	291	70	60	52.9	51.1	45.6	44.5
	87	Church	366752	1000818	288	55	55	52.9	51.1	45.5	44.9
WT 24	88	Naval observation unit	366162	1000961	98	55	55	58.4	56.5	50.9	52.7
	89	Nadukudda	367265	1001684	1106	50	45	43.6	42	36.5	37.6
	90	N5 House, Naddukkuda	367682	1001397	1023	50	45	44	42.4	36.9	38.1
	91	Residential unit - Nadukuda	367670	1001365	989	50	45	44.2	42.7	37.2	38.3
WT 30 and 31	92	Vadi	364358	1001787	176	55	45	56	54.1	48.6	45.0
	93	Vadi	364393	1001824	147	55	45	57.1	55.3	49.7	45.0
	94	Vadi	364379	1001827	140	55	45	57.2	55.3	49.7	45.0
	95	Vadi	364388	1001846	125	55	45	57.8	55.9	50.3	45.0
	96	Naval observation unit	364314	1001859	107	55	55	58	56.1	50.5	45.0
WT 32 and 33	97	Vadi	363921	1001969	173	70	60	55.6	53.8	48.2	47.8
	98	Vadi	363938	1001997	141	70	60	56.7	54.8	49.2	48.8
	99	Vadi	363950	1001999	132	70	60	57	55.1	49.5	49.1
	100	Vadi	363948	1002005	129	70	60	57.1	55.3	49.7	49.3
	101	Vadi	363938	1002011	133	70	60	57.1	55.2	49.6	49.2
WT 33	102	Vadi	363431	1002204	341	70	60	49.2	47.5	41.9	41.7
	103	Vadi	363424	1002209	348	70	60	49.1	47.3	41.8	41.5
	104	Vadi	363428	1002221	345	70	60	49.1	47.4	41.8	41.6
	105	Vadi	363412	1002222	361	70	60	48.8	47	41.5	41.2
	106	Residential unit - KeelaiyanKuduiruppu	365518	1002322	823	50	45	46.1	44.5	39	38.8
	107	Residential unit - KeelaiyanKuduiruppu	365484	1002328	814	50	45	46.2	44.6	39.1	38.8
	108	Residential unit - KeelaiyanKuduiruppu	365519	1002351	850	50	45	45.9	44.3	38.7	38.6
	109	Residential unit - KeelaiyanKuduiruppu	365476	1002359	839	50	45	46	44.3	38.8	38.6
	110	Navy Camp - Selvary	364797	1003133	1255	55	45	41.9	40.3	34.8	34.2
WT 33	111	Vadi	363098	1002427	712	70	60	43.2	41.6	36.1	35.7
	112	N4 Julian Dias, Pesale	370200	1003437	3410	50	45	32.6	31.6	26	27.6
	113	N6 Bishop House	362710	1003504	1685	50	45	35.7	34.4	28.8	28.5
	114	N7 Old pier (Navy camp)Thalimannar	360523	1003453	3484	50	45	28.2	27.2	21.7	21.6
	115	N8 House Thalimannar	360075	1004468	4340	50	45	25.8	25	19.4	19.5

Notes:
1-Limit increased to 55 dB if naval sleeping quarters are relocated
2-Noise limits removed if acquired by CEB

Coordinate reference: WGS84 / UTM zone 44P

Yellow shading: dB > lower night limit, red shading: dB > upper day/night limit

Table A.5: Noise predictions, Scenario C

Nearby WT	ID	Receptor name	Easting (m)	Northing (m)	Distance to nearest wind turbine (m)	Limit		Receptor noise, including +1dB assumed background contribution (LA_{eq} dB) Scenario	
						Day	Night	Day	Night
	1	Thalvupadu	374870	994562	1625	50	45	32.1	31.8
	2	Thottavelly-Thalvupadu Rd	374475	996332	945	50	45	38.5	38.4
	3	N1 Thoddaveli Water Board Office	374610	996618	1238	70	60	36.4	36.2
	4	N2 Mr Mariyadas	372979	997738	995	50	45	38.5	37.5
	5	Konniankuduiruppu village and church	373383	997683	1217	50	45	37.1	36.2
	6	Konniankuduiruppu	374340	996759	1167	50	45	37.5	37.3
	7	Konniankuduiruppu	373894	997101	1119	50	45	38.0	37.7
	8	Konniankuduiruppu	373544	997385	1103	50	45	37.8	37.3
	9	Konniankuduiruppu	372959	997586	875	50	45	39.3	38.5
WT 1	10	Naval observation unit	373853	995455	299	55	55	47.1	47.1
WT 1	11	Vadi	373809	995533	210	70	60	49.8	49.8
	12	Vadi	373829	995556	196	70	60	50.3	50.2
	13	Vadi	373817	995564	184	70	60	50.7	50.7
	14	Vadi	373824	995573	179	70	60	50.9	50.9
	15	Vadi	373837	995574	185	70	60	50.7	50.7
	16	Vadi	373800	995576	167	70	60	51.4	51.4
	17	Vadi	373815	995578	171	70	60	51.2	51.2
	18	Vadi	373809	995578	168	70	60	51.3	51.3
WT 1 and 2	19	Industrial unit (fish meal manufacturing company) boundary	373496	995860	115	-	-	54.4	54.4
	20	Industrial unit (fish meal manufacturing company) boundary	373639	996013	166	-	-	52.4	52.4
	21	Industrial unit (fish meal manufacturing company) boundary	373733	995954	221	-	-	51.4	51.3
	22	Industrial unit (fish meal manufacturing company) boundary	373661	995697	90	-	-	55.1	55.1
	23	Industrial unit (fish meal manufacturing company) estimated location	373568	995816	182	70	60	53.2	53.2
WT 4 and 5	24	Naval Camp - boundary	372741	996424	179	-	-	45.0	44.9
	25	Naval Camp - boundary	372880	996603	124	-	-	45.2	45.1
	26	Naval Camp - boundary	372550	996609	161	-	-	44.2	44.0

	27	Naval Camp - boundary	372687	996766	106	-	-	44.4	44.2
	28	Naval Camp (building)	372692	996656	156	55	45[1]	44.2	44.0
	29	Naval Camp (building)	372773	996494	138	55	45[1]	45.1	45.0
WT 7 and 8	30	Vadi	371800	997235	199	70	60	44.1	42.5
	31	Vadi	371843	997235	156	70	60	44.3	42.9
	32	Vadi	371801	997250	198	70	60	44.2	42.4
	33	Vadi	371845	997254	154	70	60	44.3	42.8
	34	Vadi	371760	997262	235	70	60	44.1	42.1
	35	Naval observation unit	371757	997279	217	55	55	44.2	42.1
	36	Vadi	371774	997281	221	70	60	44.2	42.2
	37	Vadi	371706	997292	196	70	60	44.3	41.9
	38	Sea cucumber hatchery	371797	997312	203	70	60	44.3	42.3
	39	Vadi	371764	997314	186	70	60	44.3	42.1
	40	Vadi	371739	997314	178	70	60	44.4	42.0
	41	Vadi	371770	997322	182	70	60	44.4	42.1
	42	Vadi	371771	997324	180	70	60	44.4	42.1
	43	Fishermen’s rest room	371768	997333	170	70	60	44.4	42.1
	44	Tea kiosk	371783	997336	175	70	60	44.4	42.2
	45	Vadi	371646	997348	148	70	60	45.1	42.0
	46	Vadi	371677	997382	108	70	60	45.2	42.1
	47	Residential unit - Konniankuduiruppu	372959	997594	880	50	45	39.3	38.4
	48	Residential unit - Konniankuduiruppu	372936	997607	872	50	45	39.3	38.5
	49	Residential unit - Konniankuduiruppu	372907	997617	858	50	45	39.4	38.5
	50	Residential unit - Konniankuduiruppu	372790	997705	848	50	45	39.6	38.5
WT 8 and 9	51[2]	Kaluthota Finance Hotel (under construction) - boundary	371824	997619	183	50	45	45.2	42.0
	52[2]	Kaluthota Finance Hotel (under construction) - boundary	371707	997679	192	50	45	47.3	43.4
	53[2]	Kaluthota Finance Hotel (under construction) - boundary	371811	997726	265	50	45	45.5	42.0
	54[2]	Kaluthota Finance Hotel (under construction) - boundary	371751	997764	282	50	45	46.4	42.6
WT 9 and 10	55	Vadi	371140	997761	192	70	60	52.0	47.5
WT 10 and 11	56	Vadi	370907	997982	201	70	60	50.8	46.4
	57	Vadi	370888	997999	223	70	60	50.3	45.9
	58	Vadi	370873	998007	239	70	60	49.9	45.6
WT 10 and 11	59	Shell Coast Hotel - boundary	370770	998142	366	50	45	48.7	44.6

	60	Shell Coast Hotel - boundary	370723	998172	312	50	45	49.0	44.9
	61	Shell Coast Hotel - boundary	370947	998404	440	50	45	48.0	44.1
	62	Shell Coast Hotel - boundary	370905	998436	400	50	45	48.2	44.4
	63	Shell coast resort B	370881	998362	375	50	45	48.4	44.5
WT 12	64	Naval observation unit	370171	998500	116	55	55	54.5	50.4
WT 13	65	Vadi	369853	998753	84	70	60	55.9	54.3
WT 17	66	Naval observation unit	368425	999674	190	55	55	49.9	45.8
	67	Olaiththoduvai	372627	998956	1469	50	45	37.1	34.6
	68	Olaiththoduvai Church	372637	998802	1487	55	55	37.3	34.8
	69	Olaiththoduvai School	372650	999016	1493	50	45	36.9	34.4
	70	Residential unit - Uvary village and church	371517	999660	789	50	45	42.4	39.9
	71	Residential unit - Uvary village and church	371572	999697	847	50	45	41.8	39.3
	72	Residential unit - Uvary village and church	371525	999728	853	50	45	41.9	39.5
WT 17	73[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368920	999781	320	50	45	48.7	44.9
	74[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368931	999793	331	50	45	48.5	44.8
	75[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368688	999852	199	50	45	47.9	44.1
	76[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368822	999864	286	50	45	47.6	43.9
	77[2]	Kaluthota Finance Hotel (under construction) St Jude Road - boundary	368716	999918	270	50	45	47.4	43.7
WT 22 and 23	78	Naval Camp - Nadukuda - boundary	366705	1000673	308	55	45[1]	47.5	44.8
	79	Naval Camp - Nadukuda - boundary	366806	1000608	200	55	45[1]	46.3	43.9
	80	Naval Camp - Nadukuda - boundary	366839	1000657	173	55	45[1]	46.4	44.0
	81	Naval Camp - Nadukuda - boundary	366748	1000717	280	55	45[1]	47.5	44.8
	82	Naval Camp - Nadukuda - boundary	366738	1000700	283	55	45[1]	47.4	44.7
	83	Naval Camp - Nadukuda - boundary	366725	1000705	297	55	45[1]	47.6	44.9
WT 22 and 23	84	Tea kiosk	366663	1000680	292	70	60	48.1	45.3
	85	Tea kiosk	366681	1000705	286	70	60	48.2	45.4
	86	Fishermen’s rest room	366735	1000715	291	70	60	47.6	44.9
	87	Church	366752	1000818	288	55	55	48.2	45.3

WT 24	88	Naval observation unit	366162	1000961	98	55	55	53.3	54.1
	89	Nadukudda	367265	1001684	1106	50	45	39.7	38.3
	90	N5 House, Naddukkuda	367682	1001397	1023	50	45	40.3	38.4
	91	Residential unit - Nadukuda	367670	1001365	989	50	45	40.5	38.6
WT 30 and 31	92	Vadi	364358	1001787	176	70	60	52.9	52.9
	93	Vadi	364393	1001824	147	70	60	54.1	54.1
	94	Vadi	364379	1001827	140	70	60	54.1	54.1
	95	Vadi	364388	1001846	125	70	60	54.6	54.6
	96	Naval observation unit	364314	1001859	107	55	55	54.8	54.8
WT 32 and 33	97	Vadi	363921	1001969	173	70	60	52.8	52.8
	98	Vadi	363938	1001997	141	70	60	53.9	53.9
	99	Vadi	363950	1001999	132	70	60	54.2	54.2
	100	Vadi	363948	1002005	129	70	60	54.3	54.3
	101	Vadi	363938	1002011	133	70	60	54.2	54.2
WT 33	102	Vadi	363431	1002204	341	70	60	46.5	46.5
	103	Vadi	363424	1002209	348	70	60	46.4	46.3
	104	Vadi	363428	1002221	345	70	60	46.4	46.4
	105	Vadi	363412	1002222	361	70	60	46.1	46.1
	106	Residential unit - KeelaiyanKuduiruppu	365518	1002322	823	50	45	41.6	41.5
	107	Residential unit - KeelaiyanKuduiruppu	365484	1002328	814	50	45	41.7	41.6
	108	Residential unit - KeelaiyanKuduiruppu	365519	1002351	850	50	45	41.4	41.3
	109	Residential unit - KeelaiyanKuduiruppu	365476	1002359	839	50	45	41.6	41.4
	110	Navy Camp - Selvary	364797	1003133	1255	55	45	38.6	38.5
WT 33	111	Vadi	363098	1002427	712	70	60	40.5	40.5
	112	N4 Julian Dias, Pesale	370200	1003437	3410	50	45	29.9	28.0
	113	N6 Bishop House	362710	1003504	1685	50	45	33.0	32.8
	114	N7 Old pier (Navy camp)Thalimannar	360523	1003453	3484	50	45	25.6	25.2
	115	N8 House Thalimannar	360075	1004468	4340	50	45	23.3	22.8

Notes:
1-Limit increased to 55 dB if naval sleeping quarters are relocated
2-Noise limits removed if acquired by CEB

B Noise contour maps

Attached:

E305674-P511697-GIS04-1 - Scenario B - 31 WTGs - 1 of 2 Rev 1

E305674-P511697-GIS04-1 - Scenario B - 31 WTGs - 2 of 2 Rev 1

E305674-P511697-GIS04-2 - Scenario A1 - 39 WTGs - 1 of 2

E305674-P511697-GIS04-2 - Scenario A1 - 39 WTGs - 2 of 2

E305674-P511697-GIS04-3 - Scenario A2 - 39 WTGs - 1 of 2

E305674-P511697-GIS04-3 - Scenario A2 - 39 WTGs - 2 of 2

E305674-P511697-GIS04-4 - Scenario A3 - 39 WTGs - 1 of 2

E305674-P511697-GIS04-4 - Scenario A3 - 39 WTGs - 2 of 2

E305674-P511697-GIS04-5 - Scenario C - 31 WTGs - 1 of 2

E305674-P511697-GIS04-5 - Scenario C - 31 WTGs - 2 of 2

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Mannar Wind Power Project
Mannar Island, Sri Lanka
Background Noise Measurements

Report Date: Friday, 15 September 2017
Reference: M17244RP2, Revision B

Document Information

Project	Mannar Wind Power Project – Mannar Island, Sri Lanka	
Client	Entura Hydro Tasmania	
Report title	Background Noise Measurements	
Project Number	M17244	
Author	Jon Cooper Associate Director p+61 8 8155 5888 m+61 407 605 692 jon.cooper@resonateacoustics.com	
Reviewed by	Tom Evans	

Revision Table

Report revision	Date	Comments
0	19 July 2017	Draft for review
A	22 August 2017	For issue
B	24 August 2017	Minor amendments

Glossary

A-weighting	A spectrum adaption that is applied to measured noise levels to represent human hearing. A-weighted levels are used as human hearing does not respond equally at all frequencies.
Day	Period defined by Sri Lankan regulations to be 6 am to 6 pm.
dB	Decibel—a unit of measurement used to express sound level. It is based on a logarithmic scale which means a sound that is 3 dB higher has twice as much energy. We typically perceive a 10 dB increase in sound as a doubling of that sound level.
dB(A)	Units of the A-weighted sound level.
Frequency (Hz)	The number of times a vibrating object oscillates (moves back and forth) in one second. Fast movements produce high frequency sound (high pitch/tone), but slow movements mean the frequency (pitch/tone) is low. 1 Hz is equal to 1 cycle per second.
L_{A90}	Noise level exceeded for 90% of the measurement time. The L_{90} level is commonly referred to as the background noise level.
L_{Aeq}	Equivalent Noise Level—Energy averaged noise level over the measurement time.
Night	Period defined by Sri Lankan regulations to be 6 pm to 6 am.

Table of Contents

1 Introduction

The Ceylon Electricity Board is proposing to develop the Mannar Wind Power Project, which will be located on Mannar Island, in northern Sri Lanka. The wind farm will consist of up to 39 wind turbine generators (WTGs) with a hub height of nominally 81.5 m above ground level (AGL).

This report presents the results of approximately three weeks of background noise measurements at receivers in the vicinity of the proposed wind farm. The background noise measurements have been conducted in general accordance with the requirements of the UK Institute of Acoustics guidance document *A Good Practice Guide to the Application of ETSU-R-07 for the Assessment and Rating of Wind Turbine Noise*.

The background noise measurements are used to establish environmental noise limits, which have been based on the Asian Development Bank (ADB) requirements for this project.

In presenting the assessment, this report:

- Presents the results of pre-construction background noise monitoring conducted at six representative noise-sensitive receiver locations around the site.
- Establishes applicable operational noise limits for the project to achieve the ADB requirements.

2 Project description

The Mannar Wind Power Project will be located on Mannar Island, in northern Sri Lanka. The wind farm will consist of up to 39 wind turbine generators (WTGs) with a nominal hub height of 81.5 m above ground level (AGL).

Entura have undertaken an assessment of noise emissions from the wind turbines at the site (document E305674 dated 11 May 2017) and identified 115 noise-sensitive receiver locations around the site. These include existing residences, temporary accommodation, naval facilities, hotels and industrial facilities.

The wind turbines are to be arranged in a line along the southern coast of Mannar Island, on low costal dunes.

The current proposed location of the WTGs and the locations of the nearest residences are shown on Figure 1.

Figure 1 Mannar site map

3 Guidelines

3.1 Noise limits

The noise limits for the Mannar Wind Power Project have been determined considering the requirements of local Sri Lankan Regulations and the ADB requirements, which refer to the World Bank Group International Finance Corporation *Environmental, Health, and Safety (EHS) Guidelines* and other relevant documentation. A full discussion of the derivation of the noise limits is included in the Entura Report (document E305674 dated 11 May 2017).

The noise limit at each of the receivers around the project is defined as the existing background noise level + 3 dB, or the base limit for each receiver type, whichever is the greater.

The base limits for each of the receiver types vary with time of day and are defined in Table 1. The existing background noise levels are defined separately for the day time (6 am to 6 pm) and night time (6 pm to 6 am) periods, and are determined in Section 4 of this report.

Table 1 Base noise limits for various receiver types

Location	Base noise limit (dB $L_{Aeq,1\ hour}$)	
	Day time (6 am to 6 pm)	Night time (6 pm to 6 am)
Residential locations	50	45
Institutional locations (sleeping)	55	45
Institutional locations	55	55
Industrial and commercial locations	70	60

The ADB has indicated that the total noise level (background + wind turbine noise) should achieve compliance with these limits. Therefore, a project wind turbine noise limit has been set for each receiver and for each integer wind speed, that defines the allowable level of wind turbine noise from the Project based on the measured background noise levels documented within this report. The procedure for determining the turbine noise limit is described in Section 5.

The establishment of the project limits for wind turbine noise are considered to set a requirement for the Project that is consistent with the ADB requirements and the current level of background noise around the site. However, it is noted that it may be difficult to achieve compliance with the overall project limit in practice due to the uncertainty associated with changes in background noise levels over time. Two factors that contribute to this uncertainty are:

- The L_{Aeq} level of background noise alone may exceed the L_{A90} background noise level, which was used to set the noise limits, by more than 3 dB, resulting in exceedance of the noise limits without any wind turbine noise being present.

- The background noise level can vary over time such that it may increase following construction of the Project and result in an apparent exceedance of the noise limits even if the wind turbine noise level achieves compliance with the wind turbine limits.

The above factors would need to be considered as part of any post-construction compliance assessment.

3.2 Noise target for lower wind speeds

The above methodology for determining project-specific wind turbine noise limits results in noise limits that decrease with increasing wind speed at the point where the background noise level approaches within 3 dB of the base limit. At the wind speed at which the background noise level is exactly 3 dB below the background noise level, the wind turbine noise limit will be at its minimum.

The ADB has expressed a preference for the wind turbine noise to also comply with the minimum applicable project noise-limit at lower wind speeds, to reduce the difference between background noise levels and wind turbine noise levels where the background level is low. This has therefore been adopted as a noise target for the project.

4 Background noise measurements

In order to quantify the existing noise environment, pre-construction noise monitoring was conducted for three weeks at six locations around the site from 31 May to 20 June 2017. The background noise measurements were taken in general accordance with the recommendations provided in the UK Institute of Acoustics *Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise* (the IOA GPG), with the analysis of data adapted to meet the ADB requirements where necessary.

4.1 Monitoring locations

The background noise monitoring locations used for this assessment are presented in Table 2. The location of the local weather station, used to record periods of rainfall, is also provided. A map showing the location of each of the background noise monitoring sites is included as Figure A1 and Appendix A. Photographs showing the monitoring equipment at each of the locations are included in Appendix B.

Table 2 Monitoring locations

Location	Coordinates in UTM WGS84 Zone 44N		Description of location
	Easting	Northing	
BG#1	373746	995617	Adjacent to land with new building under construction. Logger located approximately 85 m back from the surf, with low vegetation and dunes providing partial shielding from beach. Noise levels at this location controlled by noise from the surf, with some influence from Palmyra palms in the vicinity.
BG#2	371689	997364	Near Fishermen's rest room / sea cucumber hatchery. Location approximately 60 m from surf and partially shielded from surf by low dunes / vegetation. Background noise levels controlled by noise from the surf.
BG#3	371920	997603	On side of road adjacent Kalthota Finance Hotel (under construction). Noise monitor located approximately 360 m from the surf, and background noise levels controlled by distant vegetation in the vicinity of the hotel.
BG#4	370792	998259	South west entry to Shell coast resort. Approximately 230 m from the surf and shielded by low dunes and vegetation. Background noise levels controlled by surf / distant vegetation.

Location	Coordinates in UTM WGS84 Zone 44N		Description of location
	Easting	Northing	
BG#5	368540	999970	Near entry to Kalthota Finance Hotel (under construction), on St Jude Road. Noise logger 400 m from surf and noise levels controlled by more wind exposed vegetation in the distance towards the surf. Location of logger relatively sheltered, so that localised vegetation noise did not significantly contribute.
BG#6	364382	1001818	Vadi (fisher camp) near western end of project. Exposed location 75 m from surf between two huts at top of beach, with direct line of sight to surf.
Local weather station	368540	999970	Located near BG#5 noise monitor.

In all cases the monitoring equipment was positioned at least 5 m away from any vertical reflecting surfaces, and as far away as practical from significant vegetation, as required by the IOA GPG.

4.2 Noise monitoring equipment

Details of the sound level meters and calibrator used for the noise monitoring are provided in Table 3.

Table 3 Sound level meter and calibrator details

Location	Make	Serial number	Laboratory calibration valid until
BG#1	Rion NL-52	820995	25 July 2018
BG#2	Casella CEL-633	1057051	9 December 2017
BG#3	Rion NL-52	820994	9 December 2017
BG#4	Rion NL-31	772983	19 November 2017
BG#5	Rion NL-32	451254	17 August 2018
BG#6	Casella CEL-633	2145425	6 December 2018
Calibrator	Casella CEL-120/1	0254977	16 January 2018

All of the above sound level meters are Class 1 instruments with low noise floors, suitable for wind farm noise measurements in accordance with the IOA GPG.

A multi-layer windshield was installed around the microphones in accordance with the requirements of the IOA GPG. The multi-layer windshield consisted of a 90 mm internal windshield around the microphone with a 250 mm diameter external layer of acoustically transparent fabric. Testing of this windshield configuration by Resonate Acoustics has confirmed that it provides suitable attenuation of wind-induced noise and does not attenuate environmental noise.

The sound level meter calibration was field checked at the start and finish of the measurement periods, and no significant drift in calibration was observed. All items of equipment used carry a current calibration certificate from a NATA accredited laboratory. Copies of the certificates are provided in Appendix C.

4.3 Wind speed and direction data

During the background monitoring campaign, the wind speed was measured on the Nadukuda wind mast by the Sri Lanka Sustainable Energy Authority (SLEA). The wind mast is equipped with anemometers at 81.5 m, 80 m, 60 m, 40 m and 20 m, however during the noise measurement period the SLEA data logger was not functioning. Instead, the mast was equipped with temporary anemometers at 10 m and 15 m, and wind direction sensor at 15 m.

The data was recorded in 10-minute intervals at a height of 10 and 15 m above ground, and this data was converted by Entura to provide the average wind speed at a nominal hub height of 81.5 m. The conversion applied an extrapolation based on a power law method, as set out in Section 2.4.2 of the IOA GPG Supplementary Guidance Note 4: Wind shear.

The IAO GPG describes the derivation of noise limits based on a 'standardised' wind speed at a 10 m height, and wind turbine sound power levels in the past have been reported with reference to 'standardised' wind speed at 10 m height. However, the 2012 edition 3 of IEC61400-11 mainly requires sound power levels to be stated in relation to the hub height wind speed, and recent standards and guidelines worldwide have eliminated the procedure of standardising wind speeds to a 10 m height. As such, wind speed at a nominal hub-height of 81.5 m has been selected as the preferred reference wind speed for this analysis. This method simplifies any post-construction compliance measurements that are analysed using data from the 81.5 m Nadukuda mast.

4.4 Background noise analysis

Data exclusion

Collected noise data was excluded in cases that rain fall was recorded at the logging rain gauge which was positioned at the BG#5 monitoring location. There was limited rainfall during the 3 week monitoring period and so only 6 or 7 data points were excluded at each of the monitoring locations.

The noise levels at all of the monitoring locations were dominated by noise from the surf or vegetation, with very little other extraneous noise from sources such as birds, insects or traffic, and so no other data points were excluded from the analysis at any of the monitoring locations. Construction noise was not observed to influence the measurement results at any of the locations, as can be seen from the strong correlation between wind speed and background noise level at all sites.

Number of data points

Table 4 summarises the total, excluded, remaining valid, day, and night data points for each location.

A memory card write error at BG#4 resulted in the noise monitor stopping on 9 June at approximately 2 pm. This noise monitor was manually restarted again on 15 June at 1:30 pm, but no noise data was available at that location between those times. This has not significantly affected the results at that monitoring location, as data for a good range of wind speeds was still achieved at this site consistent with the requirements of the IOA GPG.

Table 4 Data points for each residence

Location	Number of data points				
	Total	Excluded[1]	Remaining valid	Day time	Night time
BG#1	2858	7	2851	1416	1435
BG#2	2850	7	2843	1408	1435
BG#3	2853	7	2846	1411	1435
BG#4	1986	6	1980	977	1003
BG#5	2843	7	2836	1401	1435
BG#6	2832	7	2825	1390	1435

(1) Excluded due to rain at local weather station.

Wind speeds during the monitoring period ranged from 4 m/s to 16 m/s during the daytime, and 3 m/s to 16 m/s during the night time. Wind-induced background noise (e.g. noise generated by wind through vegetation) continues to increase as speed increases, while modern wind turbine sound power levels remain stable at wind speeds above the rated power of the WTG (typically 10 to 14 m/s depending on the WTG make). Compliance with the noise limit at 16 m/s therefore results in compliance at all higher wind speeds.

The wind direction during the monitoring period was limited to only the southwest (210˚ to 250˚), which we understand is typical for the season.

Data analysis

Analysis of the data was carried out in general accordance with the IOA GPG. The primary deviation from the IOA GPG was the adoption of day and night time periods that were consistent with Sri Lankan Regulations, namely 6 am to 6 pm for day and 6 pm to 6 am for night. The IOA GPG recommends different daytime amenity and night time periods that would not be consistent with these requirements.

The IOA GPG states that the background noise level with wind speed for each location should be determined by regression analysis (using a linear to fourth order polynomial), but notes that in many cases a third order polynomial is likely to be most suitable. A third order polynomial provided a sensible fit of the data gathered in all cases during our measurements and so has been used to determine the relationship between wind speed and background noise level at all of the monitoring locations.

The analysed day and night time datasets, trend lines used and the coefficients of determination (R^2) for each location are shown in the Figures in Appendix D. Also plotted on the figures for information are the data points excluded from the analysis due to rainfall. A high degree of correlation between wind speed and noise level has been achieved at all of the monitoring locations.

4.5 Existing background noise levels

The measured existing background noise levels based on the trend lines fitted to the data included in Appendix D are provided in Table 5.

Table 5 Background noise levels at the six monitoring locations for 81.5 m wind speeds

Location	Time period	Background noise level in dB L_{A90} at 81.5 m height wind speed in m/s													
ID		3	4	5	6	7	8	9	10	11	12	13	14	15	16
BG#1	Day 6 am–6 pm	-	40	43	46	48	50	51	52	53	53	54	55	56	58
	Night 6 pm–6 am	42	43	45	46	47	48	50	51	52	53	54	55	55	56
BG#2	Day 6 am–6 pm	-	41	44	47	49	51	52	53	53	54	55	55	56	58
	Night 6 pm–6 am	42	44	46	48	49	50	52	53	54	54	55	55	55	55
BG#3	Day 6 am–6 pm	-	35	37	40	42	44	45	47	48	49	50	52	53	55
	Night 6 pm–6 am	40	40	40	41	42	43	44	46	47	49	50	51	52	53
BG#4	Day 6 am–6 pm	-	35	39	41	44	45	46	47	48	48	49	50	51	52
	Night 6 pm–6 am	37	39	40	42	43	45	46	47	48	49	50	50	50	50
BG#5	Day 6 am–6 pm	-	31	35	37	40	42	43	44	45	46	47	49	50	51
	Night 6 pm–6 am	38	38	38	39	40	41	42	43	45	46	47	48	49	49

Location	**Time period**	**Background noise level in dB L_{A90} at 81.5 m height wind speed in m/s**													
ID		**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
BG#6	Day 6 am–6 pm	-	46	48	50	51	53	54	55	56	56	57	58	59	60
	Night 6 pm–6 am	49	49	50	51	52	53	54	55	56	56	57	58	58	58

5 Applicable noise limits

The background noise levels measured at the six representative locations at the site were primarily dependent on the distance to the surf and shielding from the surf, with the highest measured levels being measured in close proximity to the beach in exposed locations. Therefore, the background noise monitoring results from the six representative noise monitoring locations have been assigned to each of the 115 receiver locations in the vicinity of the Mannar Wind Power Project based on the similarity of surf distance, shielding, and surrounding vegetation.

A site plan which is colour coded to show the background noise monitoring location that has been assigned to represent each of the receiver locations is provided in Appendix A.

5.1 Overall noise limits

Overall noise limits have been established for each of the 115 receiver locations using the assigned background noise levels and classification of receiver type as per Table 1 in Section 3. The overall noise limit at each of the receivers around the project is defined as the existing background noise level + 3 dB, or the base limit for each receiver type, whichever is the greater. The overall day time noise limit with wind speed at each of the 115 receiver locations is provided as Table E1 in Appendix E, and overall night time noise limit included in Table E2 in Appendix E.

5.2 Turbine noise limits

Procedure for determining limits

As noted in Section 3, the ADB has advised that the above limits should apply to the overall noise level at the site (background noise + wind turbine noise). The limit for wind turbine noise alone must therefore be set lower than this level, to allow for the contribution of background noise. The procedure applied to determine the turbine noise limits is summarised in Table 6.

Table 6 Procedure for determining turbine noise limit at each integer wind speed

Situation for integer wind speed	Applicable turbine noise limit (dB L_{Aeq})
Background level + 10 ≤ Base limit	Base limit
Background level + 6 ≤ Base limit ≤ Background level + 9	Base limit – 1
Background level + 4 ≤ Base limit ≤ Background level + 5	Base limit – 2
Base limit = Background level + 3	Base limit – 3(1)
Base limit ≤ Background level + 2	Background level

(1) This condition is the wind speed at which minimum applicable turbine noise limit applies and the ADB has indicated that this should be a noise target for lower wind speeds.

Turbine noise limits

The required noise limit for wind turbine noise alone has been calculated for each of the receivers based on the measured levels of background noise and is included in Table F1 in Appendix F for day time, and as Table F2 in Appendix F for the night time.

The noise limits, including the ADB low background noise level noise target, are shown graphically for each of the monitoring locations in Appendix G for both day and night time.

We note that compliance with overall noise limit at the site is likely to be difficult to demonstrate once the site is constructed, as variation and changes in background noise alone may be sufficient for the overall noise limits to be exceeded. This will need to be considered as part of any post-construction monitoring conducted for the Project.

6 Conclusion

This report presents the results of background noise measurements undertaken for the proposed Mannar Wind Power Project, to be located on Mannar Island in northern Sri Lanka. The assessment has been undertaken in accordance with the requirements of the UK Institute of Acoustics guidance document *A Good Practice Guide to the Application of ETSU-R-07 for the Assessment and Rating of Wind Turbine Noise*, except were modified as required by the Asian Development Bank.

Background noise measurements were undertaken at six representative monitoring locations in the vicinity of the Mannar Wind Power Project, and the results of those measurements assigned to the remaining receivers in the vicinity of the project.

Environmental noise limits have been established for each of the receivers in the vicinity of the project based on the measured background noise level and a base noise limit which depends on the type of usage which occurs at each receiver. The noise limits are provided in Appendix E and Appendix F, with an overall noise limit established along with a noise limit for emissions from the wind farm alone. Limits are defined separately for the day and night time periods, as per the requirements of the Asian Development Bank.

Appendix A—Site plan showing receiver assignment to monitoring location

Appendix B—Noise monitoring locations

BG#1

Figure B1 Plan view of BG#1 monitoring location

Figure B2 Photograph of BG#1 monitoring location looking south west to coast

Figure B3 Photograph of BG#1 monitoring location looking north east (inland)

BG#2

Figure B4 Plan view of BG#2 monitoring location

Figure B5 Photograph of BG#2 monitoring location looking south west to coast

Figure B6 Photograph of BG#2 monitoring location looking north east (inland)

BG#3

Figure B7 Plan view of BG#3 monitoring location

Figure B8 Photograph of BG#3 monitoring location looking south west towards coast

Figure B9 Photograph of BG#3 monitoring location looking north east (inland)

BG#4

Figure B10 Plan view of BG#4 monitoring location

Figure B11 Photograph of BG#4 monitoring location looking south to coast

Figure B12 Photograph of BG#4 monitoring location looking north east towards Shell Coast Resort (inland)

BG#5

Figure B13 Plan view of BG#5 monitoring location

Figure B14 Photograph of BG#5 monitoring location looking south west towards coast

Figure B15 Photograph of BG#5 monitoring location looking north

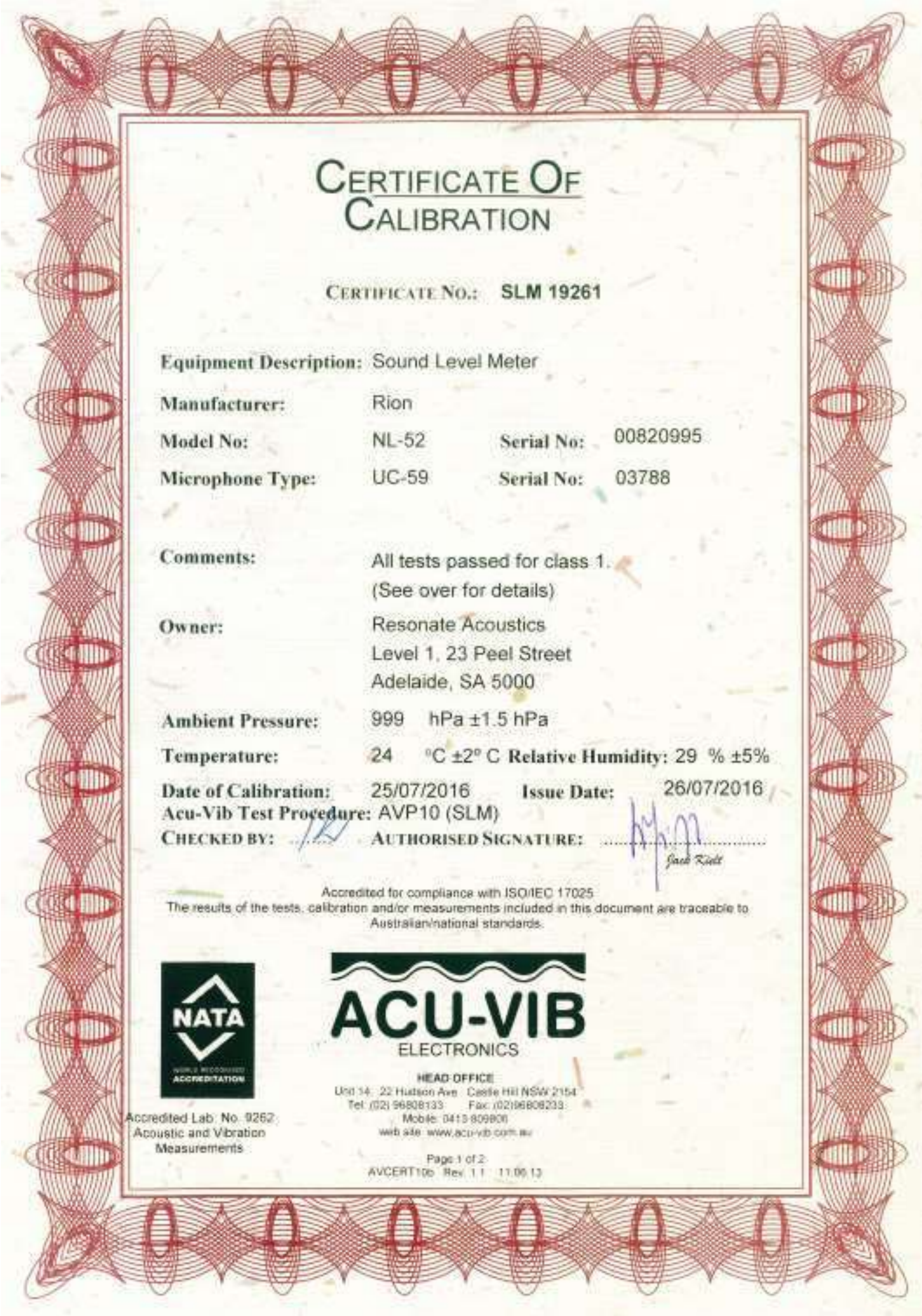
BG#6

Figure B16 Plan view of BG#6 monitoring location

Figure B17 Photograph of BG#6 monitoring location looking south west towards coast

Figure B18 Photograph of BG#6 monitoring location looking north east

Appendix C—Calibration certificates



CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: **SLM 19261**

Equipment Description: Sound Level Meter

Manufacturer: Rion

Model No: NL-52 **Serial No:** 00820995

Microphone Type: UC-59 **Serial No:** 03788

Comments: All tests passed for class 1.
(See over for details)

Owner: Resonate Acoustics
Level 1, 23 Peel Street
Adelaide, SA 5000

Ambient Pressure: 999 hPa ±1.5 hPa

Temperature: 24 °C ±2° C **Relative Humidity:** 29 % ±5%

Date of Calibration: 25/07/2016 **Issue Date:** 26/07/2016

Acu-Vib Test Procedure: AVP10 (SLM)

CHECKED BY: ...... **AUTHORISED SIGNATURE:** ....
Jack Kielt

Accredited for compliance with ISO/IEC 17025
The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.

NATA
WORLD RECOGNISED ACCREDITATION

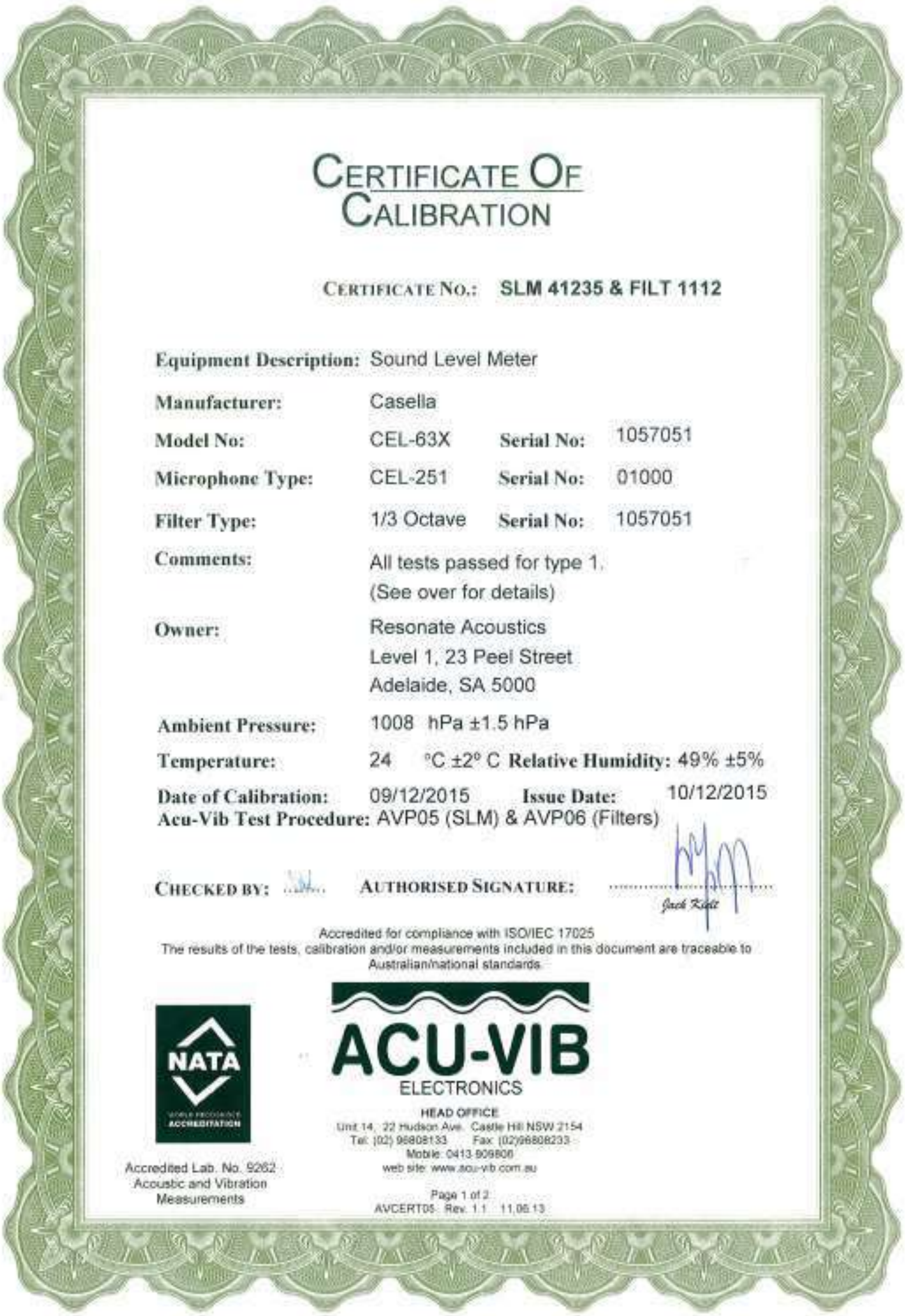
Accredited Lab. No. 9262
Acoustic and Vibration Measurements

ACU-VIB
ELECTRONICS

HEAD OFFICE
Unit 14, 22 Hudson Ave. Castle Hill NSW 2154
Tel: (02) 96808133 Fax: (02)96808233
Mobile: 0413 809806
web site: www.acu-vib.com.au

Page 1 of 2
AVCERT10b Rev. 1.1 11.06.13

Figure C1 Calibration certificate for sound level meter at BG#1



CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: SLM 41235 & FILT 1112

Equipment Description: Sound Level Meter
Manufacturer: Casella
Model No: CEL-63X **Serial No:** 1057051
Microphone Type: CEL-251 **Serial No:** 01000
Filter Type: 1/3 Octave **Serial No:** 1057051
Comments: All tests passed for type 1.
(See over for details)

Owner:
Resonate Acoustics
Level 1, 23 Peel Street
Adelaide, SA 5000

Ambient Pressure: 1008 hPa ±1.5 hPa
Temperature: 24 °C ±2° C **Relative Humidity:** 49% ±5%
Date of Calibration: 09/12/2015 **Issue Date:** 10/12/2015
Acu-Vib Test Procedure: AVP05 (SLM) & AVP06 (Filters)

CHECKED BY: .... **AUTHORISED SIGNATURE:** ....
Jack Kielt

Accredited for compliance with ISO/IEC 17025
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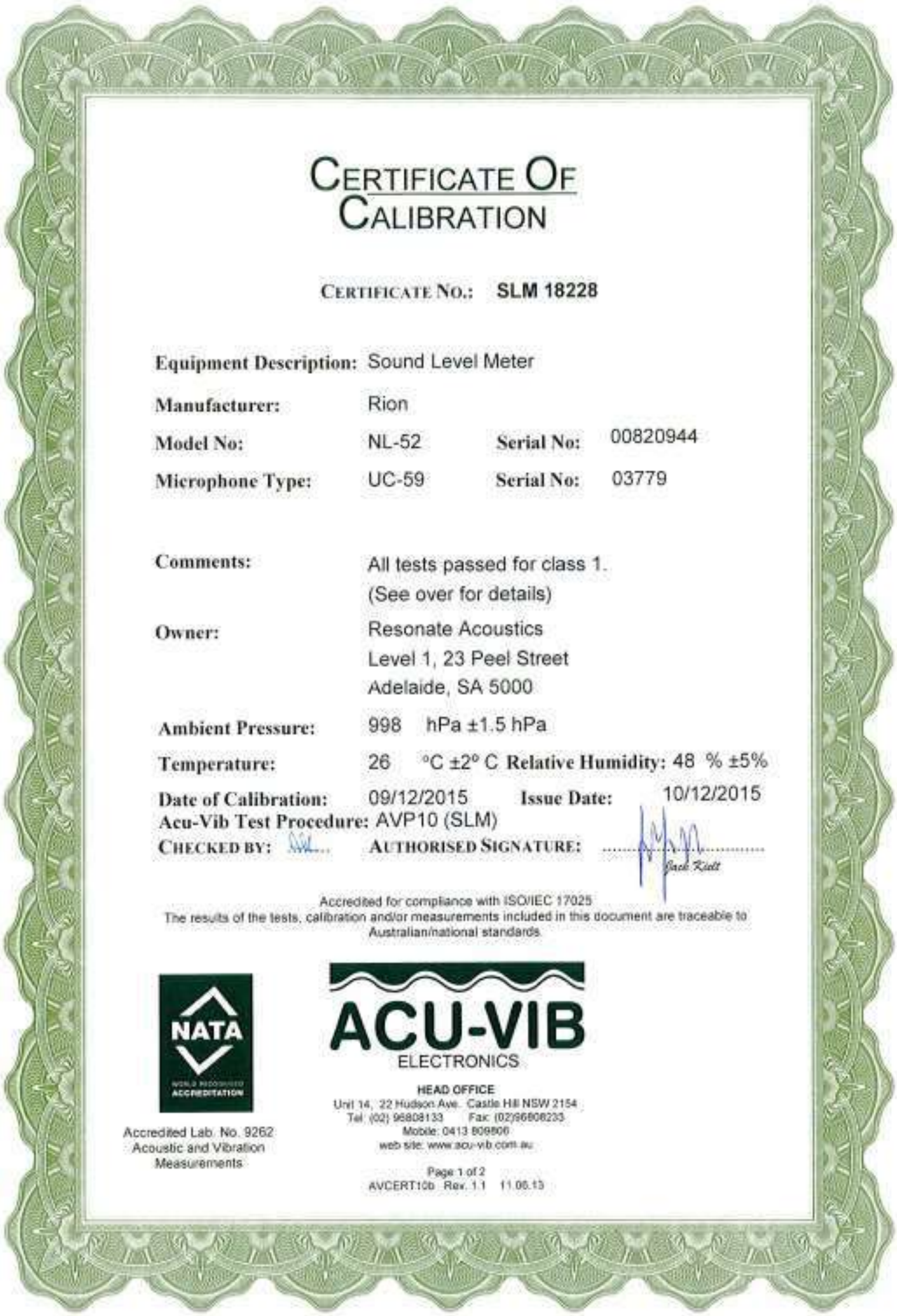
Figure C2 Calibration certificate for sound level meter at BG#2



CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: **SLM 18228**

Equipment Description: Sound Level Meter

Manufacturer: Rion

Model No: NL-52 **Serial No:** 00820944

Microphone Type: UC-59 **Serial No:** 03779

Comments: All tests passed for class 1.
(See over for details)

Owner: Resonate Acoustics
Level 1, 23 Peel Street
Adelaide, SA 5000

Ambient Pressure: 998 hPa ±1.5 hPa

Temperature: 26 °C ±2° C **Relative Humidity:** 48 % ±5%

Date of Calibration: 09/12/2015 **Issue Date:** 10/12/2015

Acu-Vib Test Procedure: AVP10 (SLM)

CHECKED BY: ...... **AUTHORISED SIGNATURE:** ....
Jack Kielt

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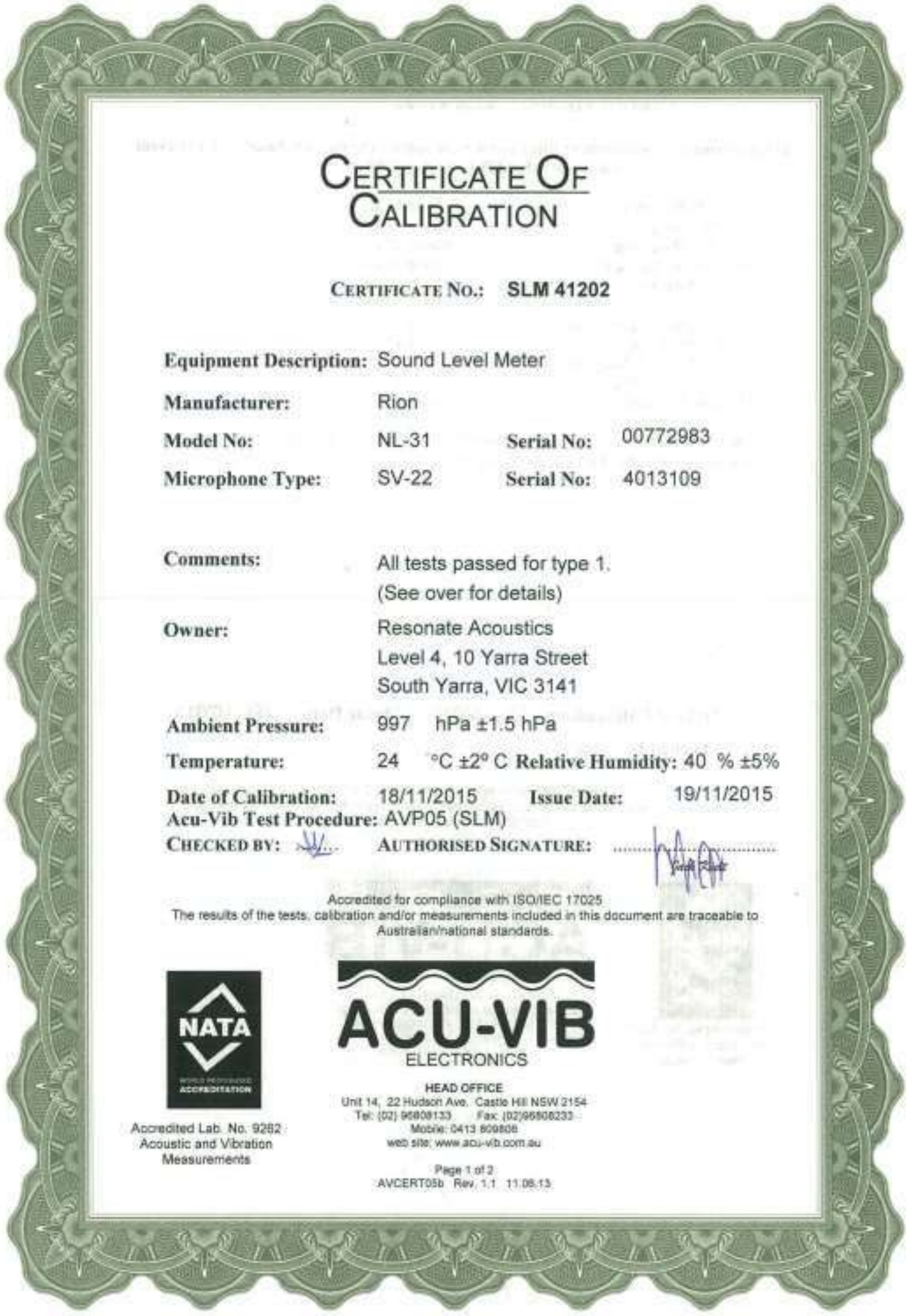
Figure C3 Calibration certificate for sound level meter at BG#3



CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: **SLM 41202**

Equipment Description:	Sound Level Meter		
Manufacturer:	Rion		
Model No:	NL-31	**Serial No:**	00772983
Microphone Type:	SV-22	**Serial No:**	4013109

Comments: All tests passed for type 1.
(See over for details)

Owner:
Resonate Acoustics
Level 4, 10 Yarra Street
South Yarra, VIC 3141

Ambient Pressure: 997 hPa ±1.5 hPa

Temperature: 24 °C ±2° C **Relative Humidity:** 40 % ±5%

Date of Calibration: 18/11/2015 **Issue Date:** 19/11/2015

Acu-Vib Test Procedure: AVP05 (SLM)

CHECKED BY: ...... **AUTHORISED SIGNATURE:** ......

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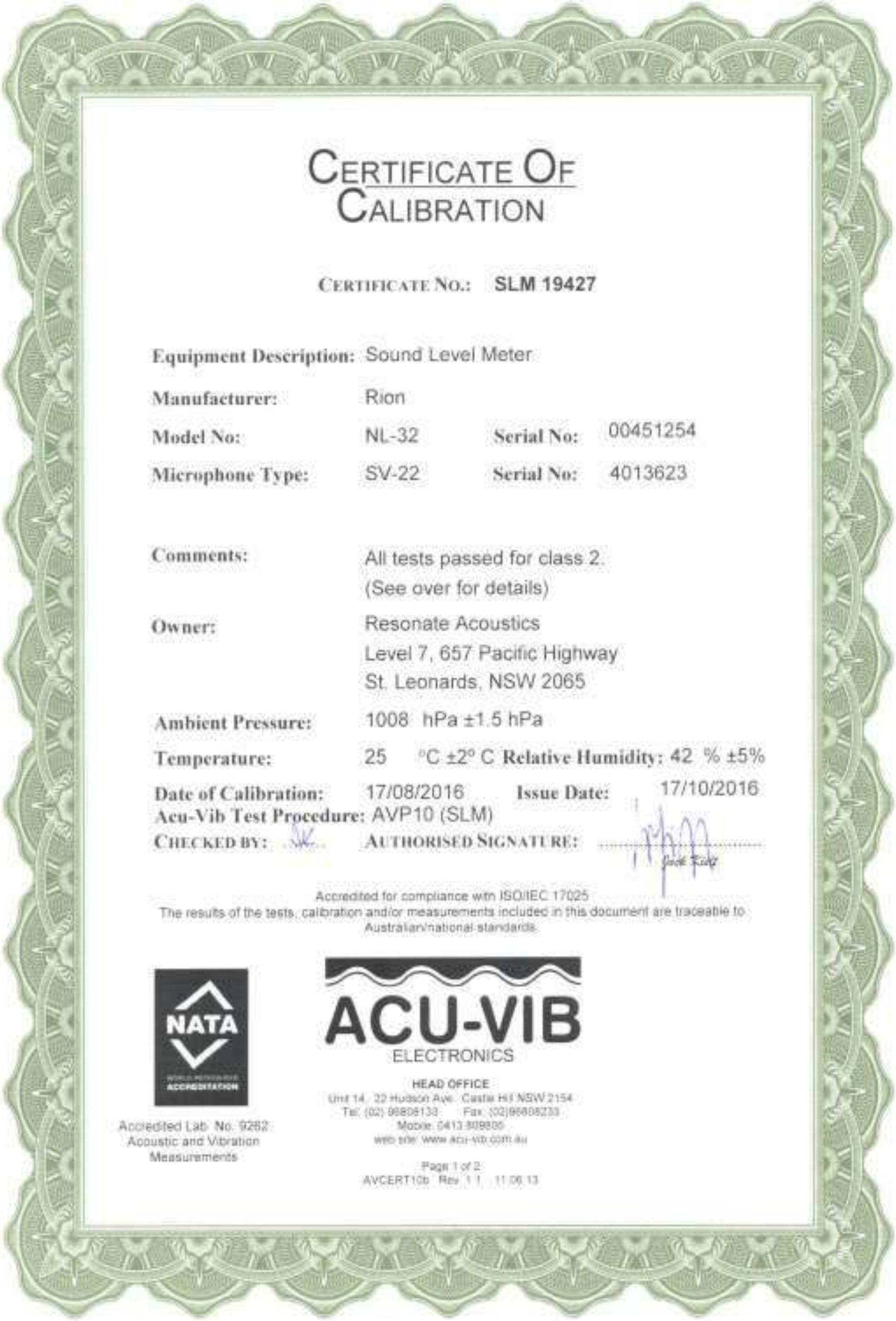
Figure C4 Calibration certificate for sound level meter at BG#4



CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: SLM 19427

Equipment Description: Sound Level Meter

Manufacturer: Rion

Model No: NL-32 **Serial No:** 00451254

Microphone Type: SV-22 **Serial No:** 4013623

Comments: All tests passed for class 2.
(See over for details)

Owner: Resonate Acoustics
Level 7, 657 Pacific Highway
St. Leonards, NSW 2065

Ambient Pressure: 1008 hPa ±1.5 hPa

Temperature: 25 °C ±2° C **Relative Humidity:** 42 % ±5%

Date of Calibration: 17/08/2016 **Issue Date:** 17/10/2016

Acu-Vib Test Procedure: AVP10 (SLM)

CHECKED BY: SK **AUTHORISED SIGNATURE:** Jack Kielt

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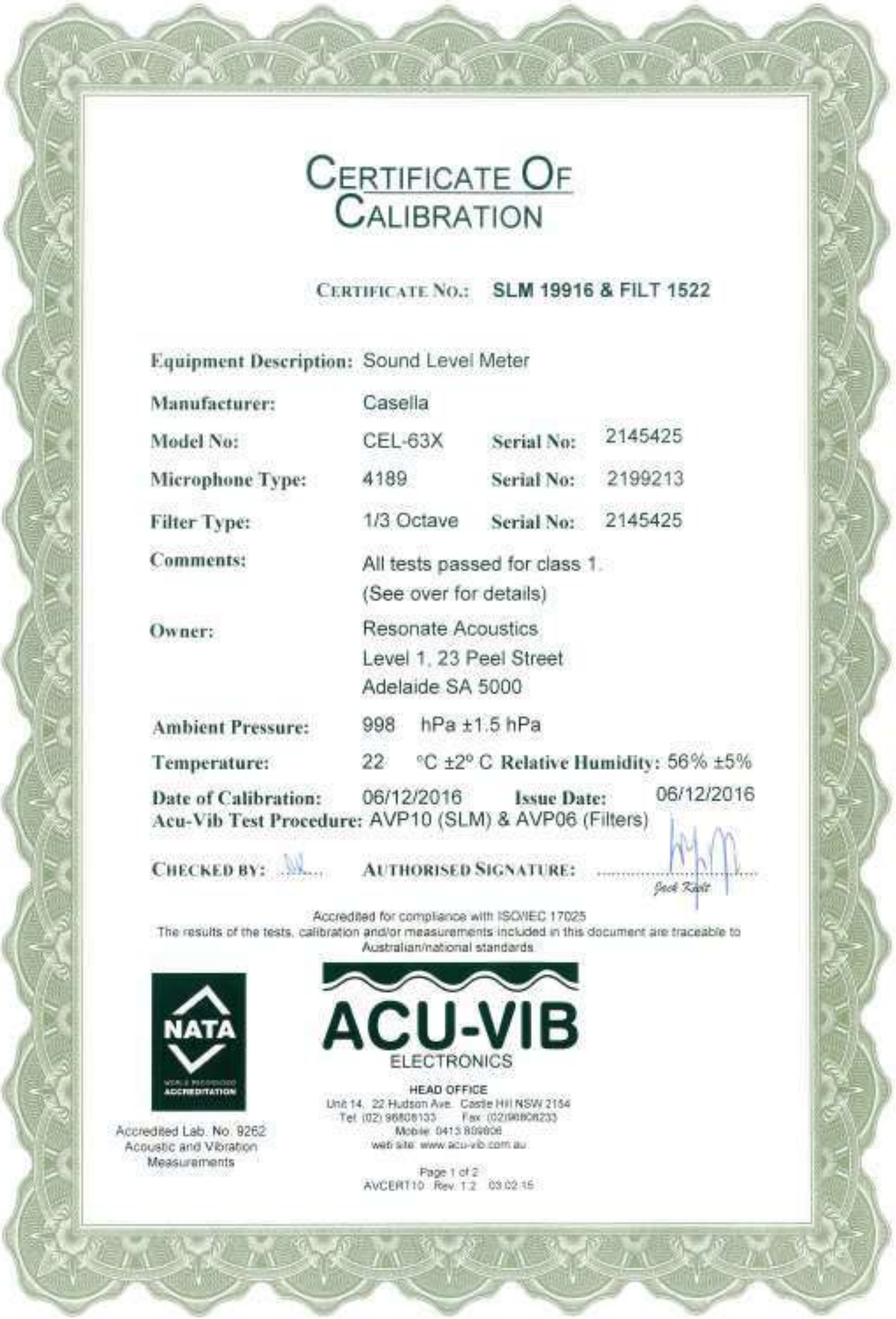
Figure C5 Calibration certificate for sound level meter at BG#5



CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: SLM 19916 & FILT 1522

Equipment Description: Sound Level Meter
Manufacturer: Casella
Model No: CEL-63X **Serial No:** 2145425
Microphone Type: 4189 **Serial No:** 2199213
Filter Type: 1/3 Octave **Serial No:** 2145425
Comments: All tests passed for class 1.
(See over for details)
Owner: Resonate Acoustics
Level 1, 23 Peel Street
Adelaide SA 5000
Ambient Pressure: 998 hPa ±1.5 hPa
Temperature: 22 °C ±2° C **Relative Humidity:** 56% ±5%
Date of Calibration: 06/12/2016 **Issue Date:** 06/12/2016
Acu-Vib Test Procedure: AVP10 (SLM) & AVP06 (Filters)

CHECKED BY: .... **AUTHORISED SIGNATURE:** ....
Jack Kielt

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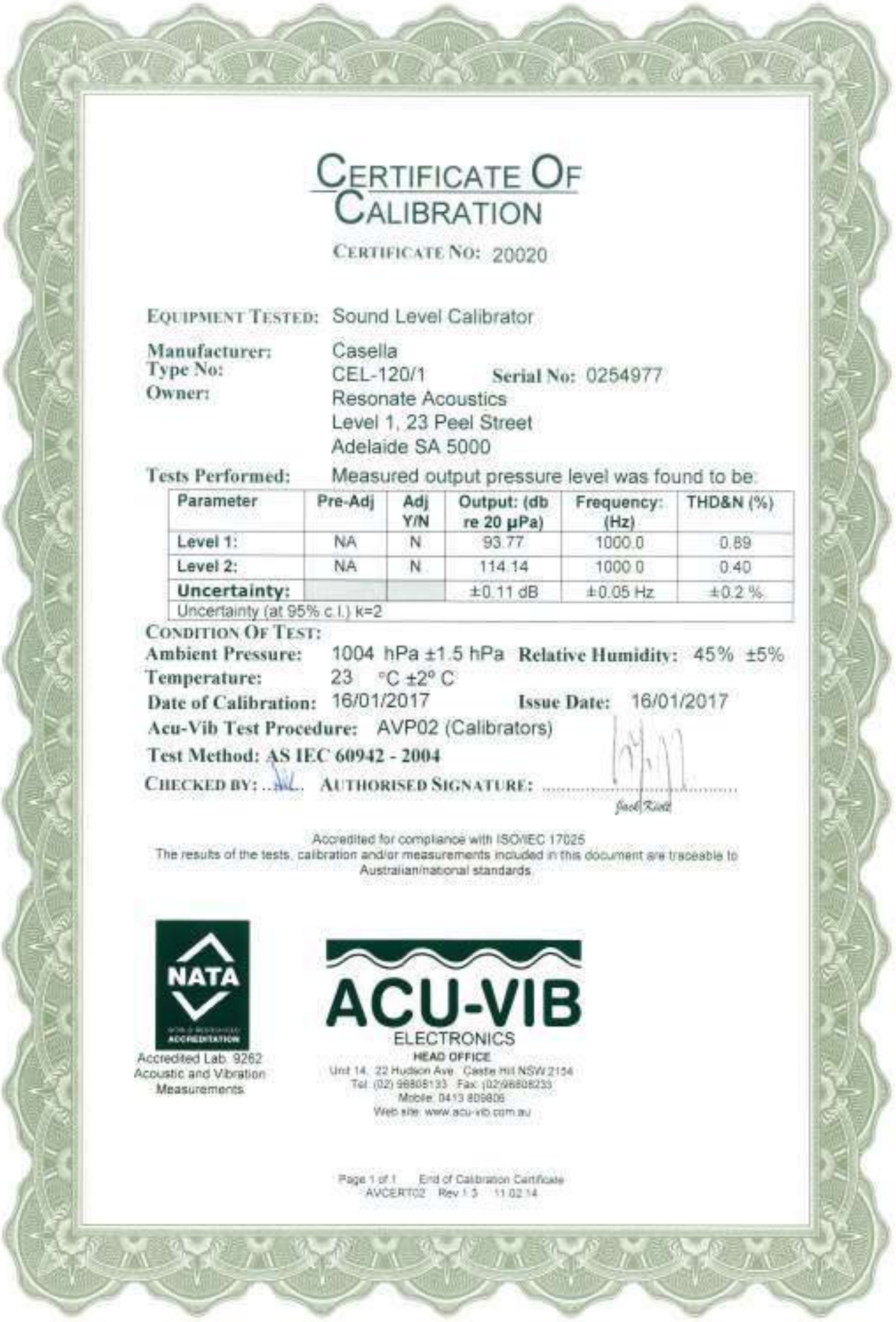
Figure C6 Calibration certificate for sound level meter at BG#6



CERTIFICATE OF CALIBRATION

CERTIFICATE NO: 20020

EQUIPMENT TESTED: Sound Level Calibrator

Manufacturer: Casella
Type No: CEL-120/1 **Serial No:** 0254977
Owner: Resonate Acoustics
Level 1, 23 Peel Street
Adelaide SA 5000

Tests Performed: Measured output pressure level was found to be:

Parameter	Pre-Adj	Adj Y/N	Output: (db re 20 µPa)	Frequency: (Hz)	THD&N (%)
Level 1:	NA	N	93.77	1000.0	0.89
Level 2:	NA	N	114.14	1000.0	0.40
Uncertainty:			±0.11 dB	±0.05 Hz	±0.2 %
Uncertainty (at 95% c.l.) k=2					

CONDITION OF TEST:
Ambient Pressure: 1004 hPa ±1.5 hPa **Relative Humidity:** 45% ±5%
Temperature: 23 °C ±2° C
Date of Calibration: 16/01/2017 **Issue Date:** 16/01/2017
Acu-Vib Test Procedure: AVP02 (Calibrators)
Test Method: AS IEC 60942 - 2004
CHECKED BY: .... **AUTHORISED SIGNATURE:** ....

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AVCERT02 Rev 1.3 11.02.14

Figure C7 Calibration certificate for field calibrator used at all locations

Appendix D—Background noise plots for 81.5 m AGL wind speed

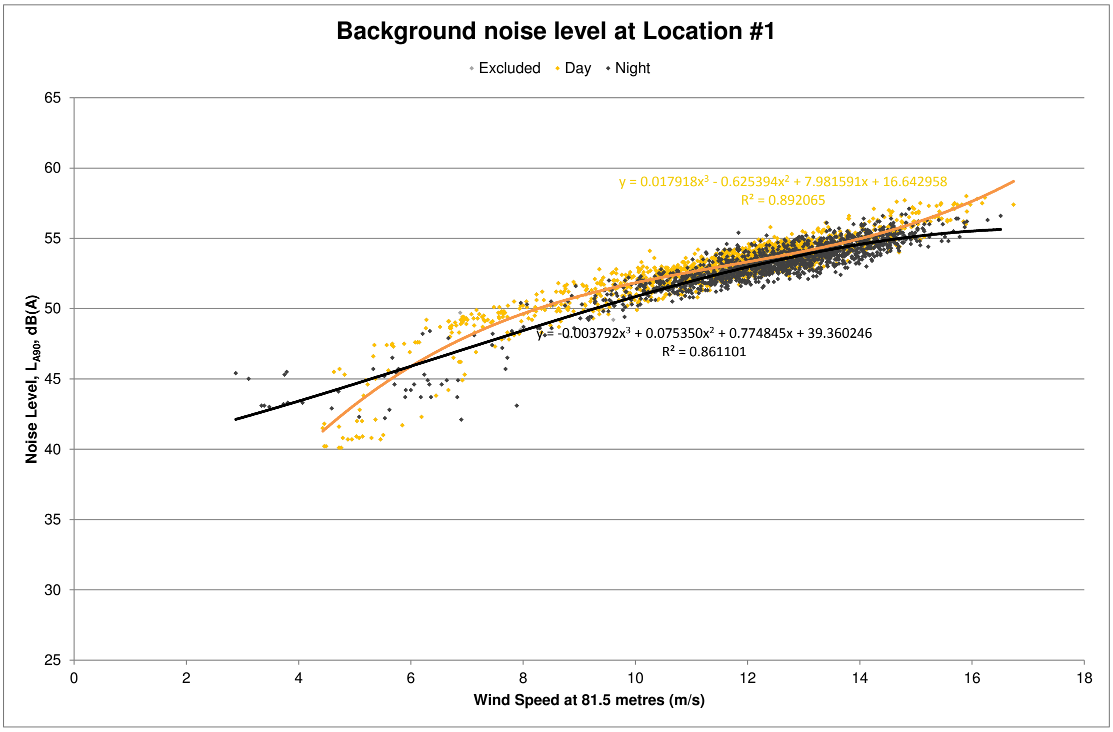

Figure D1 Noise level graphed against wind speed for BG#1

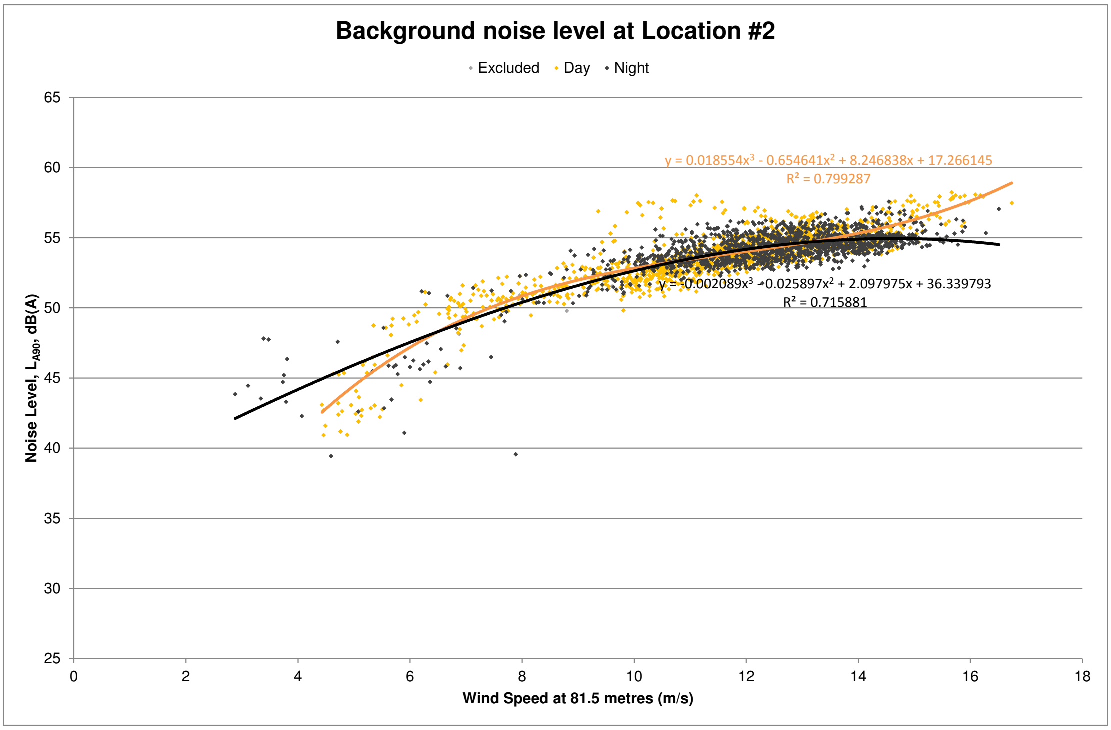

Figure D2 Noise level graphed against wind speed for BG#2

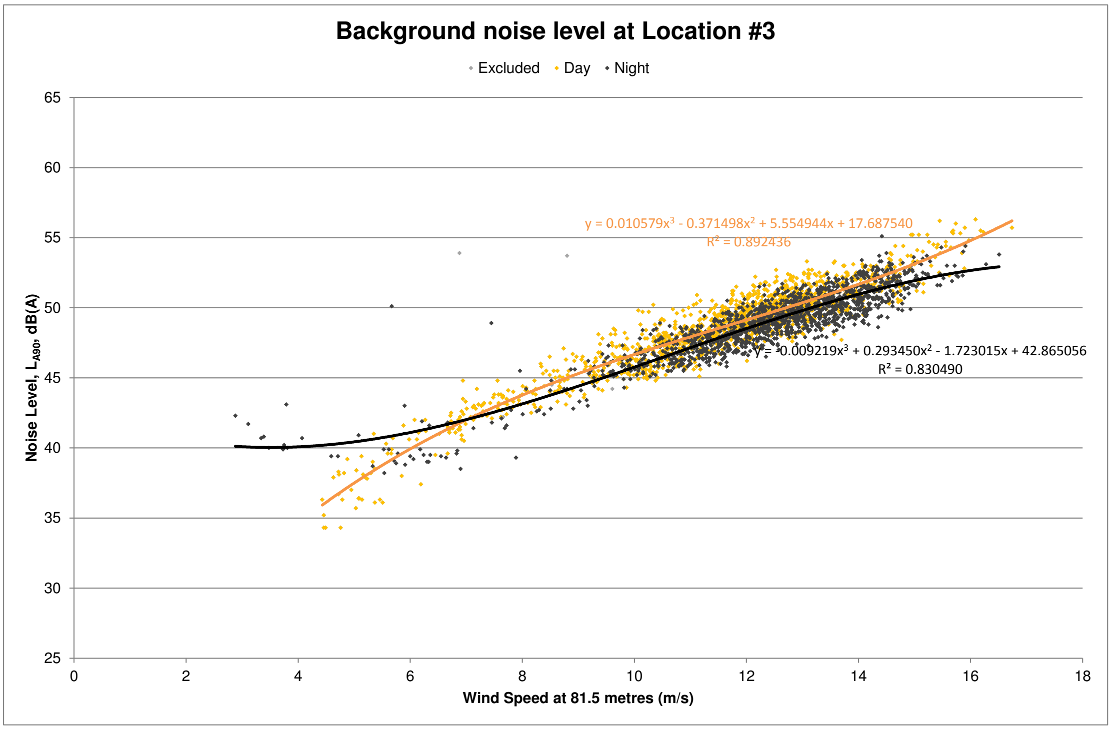

Figure D3 Noise level graphed against wind speed for BG#3

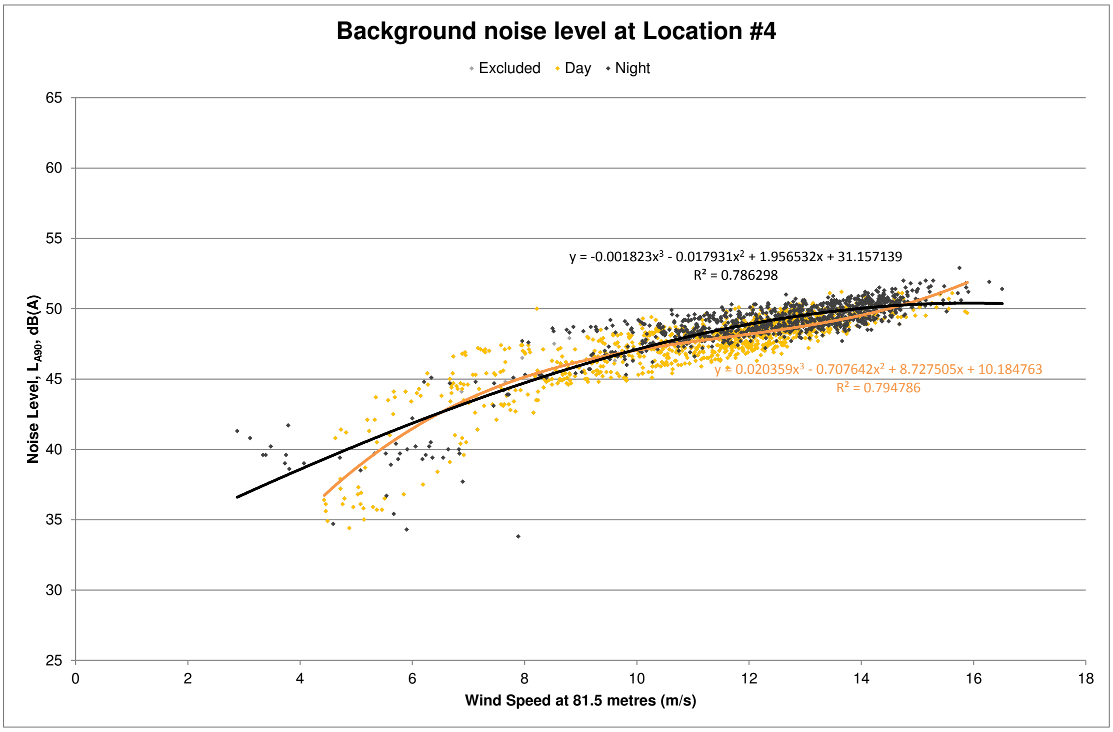

Figure D4 Noise level graphed against wind speed for BG#4

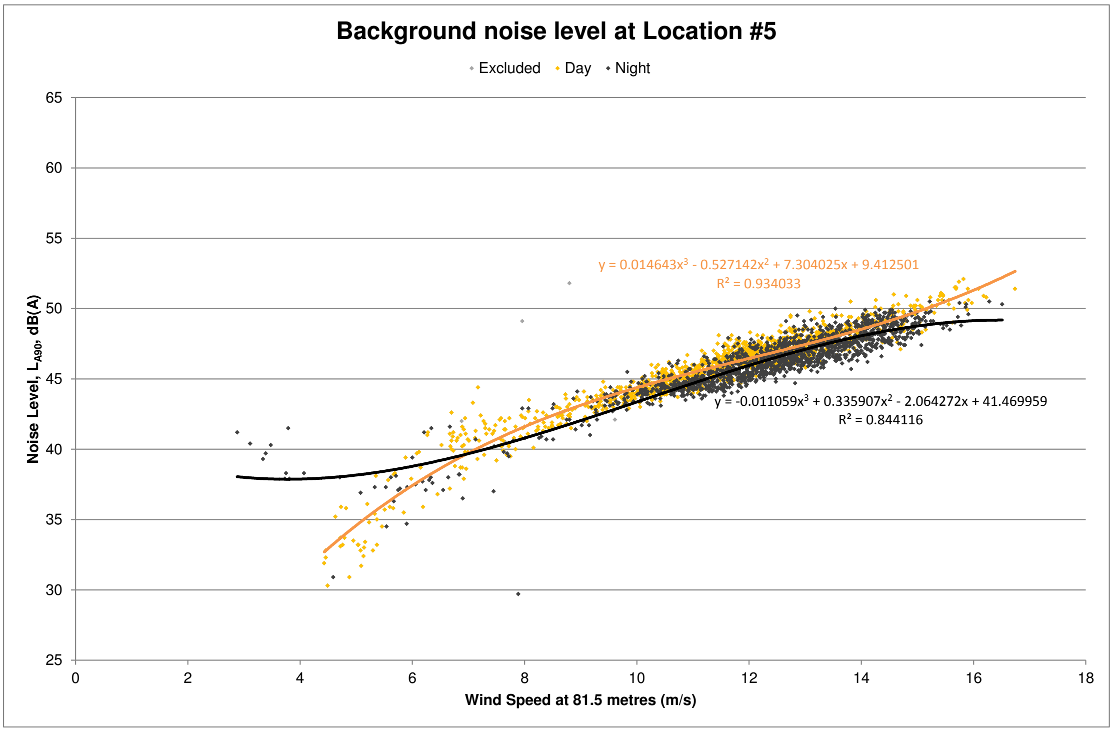

Figure D5 Noise level graphed against wind speed for BG#5

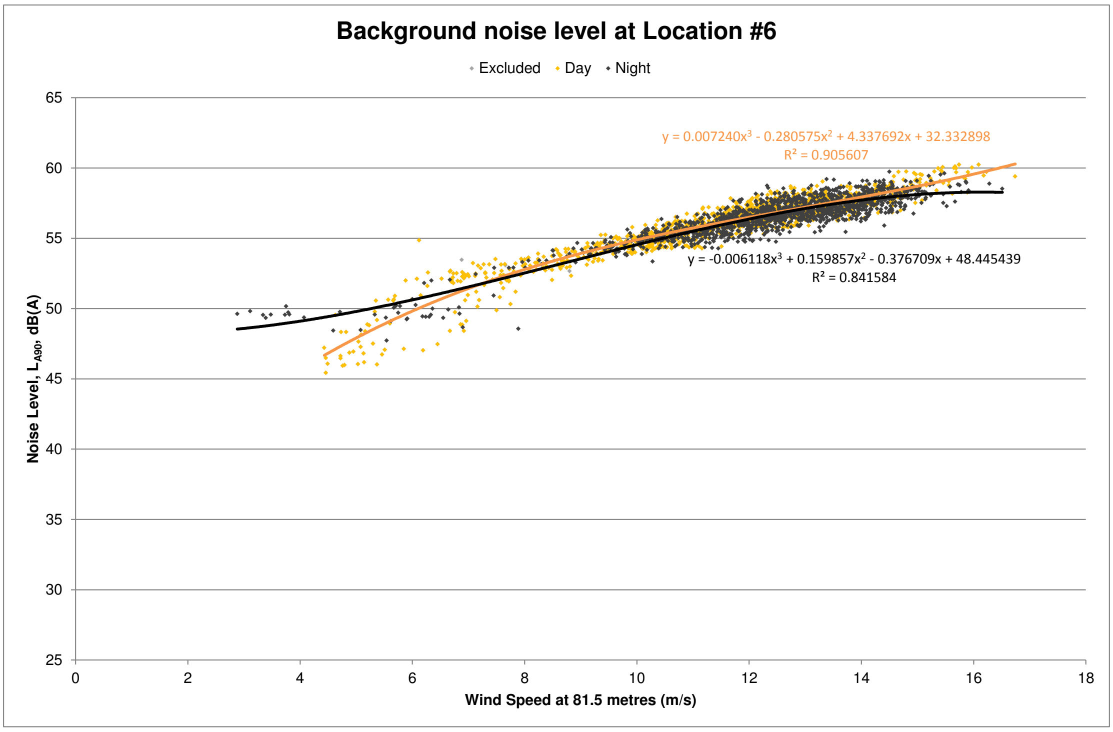

Figure D6 Noise level graphed against wind speed for BG#6

Appendix E—Overall noise limits for 81.5 m AGL wind speed

Table E1 Overall (Background + turbine) noise limits at receiver locations during the day time, for 81.5 m wind speeds

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	374870	994562	Residential	50	BG#1	50	50	50	50	51	53	54	55	56	56	57	58	59	61
2	374475	996332	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
3	374610	996618	Commercial	70	BG#5	70	70	70	70	70	70	70	70	70	70	70	70	70	70
4	372979	997738	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
5	373383	997683	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
6	374340	996759	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
7	373894	997101	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
8	373544	997385	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
9	372959	997586	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
10	373853	995455	Institutional	55	BG#1	55	55	55	55	55	55	55	55	56	56	57	58	59	61
11	373809	995533	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
12	373829	995556	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
13	373817	995564	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
14	373824	995573	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
15	373837	995574	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
16	373800	995576	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
17	373815	995578	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	373809	995578	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
19	373496	995860	n/a	n/a	BG#1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	373639	996013	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	373733	995954	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	373661	995697	n/a	n/a	BG#1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	373568	995816	Industrial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
24	372741	996424	n/a	n/a	BG#6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	372880	996603	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	372550	996609	n/a	n/a	BG#6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	372687	996766	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	372692	996656	Institutional	55	BG#4	55	55	55	55	55	55	55	55	55	55	55	55	55	55
29	372773	996494	Institutional	55	BG#1	55	55	55	55	55	55	55	55	56	56	57	58	59	61
30	371800	997235	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
31	371843	997235	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
32	371801	997250	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
33	371845	997254	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
34	371760	997262	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
35	371757	997279	Institutional	55	BG#2	55	55	55	55	55	55	55	56	56	57	58	58	59	61

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
36	371774	997281	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
37	371706	997292	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
38	371797	997312	Industrial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
39	371764	997314	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
40	371739	997314	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
41	371770	997322	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
42	371771	997324	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
43	371768	997333	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
44	371783	997336	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
45	371646	997348	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
46	371677	997382	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
47	372959	997594	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
48	372936	997607	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
49	372907	997617	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
50	372790	997705	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
51*	371824	997619	Residential	50	BG#3	50	50	50	50	50	50	50	50	51	52	53	55	56	58
52*	371707	997679	Residential	50	BG#3	50	50	50	50	50	50	50	50	51	52	53	55	56	58
53*	371811	997726	Residential	50	BG#3	50	50	50	50	50	50	50	50	51	52	53	55	56	58

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
54*	371751	997764	Residential	50	BG#3	50	50	50	50	50	50	50	50	51	52	53	55	56	58
55	371140	997761	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
56	370907	997982	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
57	370888	997999	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
58	370873	998007	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
59	370770	998142	Residential	50	BG#4	50	50	50	50	50	50	50	50	51	51	52	53	54	55
60	370723	998172	Residential	50	BG#4	50	50	50	50	50	50	50	50	51	51	52	53	54	55
61	370947	998404	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
62	370905	998436	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
63	370881	998362	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
64	370171	998500	Institutional	55	BG#2	55	55	55	55	55	55	55	56	56	57	58	58	59	61
65	369853	998753	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
66	368425	999674	Institutional	55	BG#2	55	55	55	55	55	55	55	56	56	57	58	58	59	61
67	372627	998956	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
68	372637	998802	Institutional	55	BG#5	55	55	55	55	55	55	55	55	55	55	55	55	55	55
69	372650	999016	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
70	371517	999660	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
71	371572	999697	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54

Location number	**Coordinates (WGS84 UTM 44P)**		**Classification**	**Base limit**	**Representative location**	**Overall (background + turbine) day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s**													
	Easting	**Northing**				**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
72	371525	999728	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
73*	368920	999781	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
74*	368931	999793	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
75*	368688	999852	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
76*	368822	999864	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
77*	368716	999918	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
78	366705	1000673	Institutional	55	BG#6	55	55	55	55	55	56	57	58	59	59	60	61	62	63
79	366806	1000608	Institutional	55	BG#6	55	55	55	55	55	56	57	58	59	59	60	61	62	63
80	366839	1000657	Institutional	55	BG#2	55	55	55	55	55	55	55	56	56	57	58	58	59	61
81	366748	1000717	Institutional	55	BG#2	55	55	55	55	55	55	55	56	56	57	58	58	59	61
82	366738	1000700	Institutional	55	BG#2	55	55	55	55	55	55	55	56	56	57	58	58	59	61
83	366725	1000705	Institutional	55	BG#2	55	55	55	55	55	55	55	56	56	57	58	58	59	61
84	366663	1000680	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
85	366681	1000705	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
86	366735	1000715	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
87	366752	1000818	Institutional	55	BG#2	55	55	55	55	55	55	55	56	56	57	58	58	59	61
88	366162	1000961	Institutional	55	BG#6	55	55	55	55	55	56	57	58	59	59	60	61	62	63
89	367265	1001684	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
90	367682	1001397	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
91	367670	1001365	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
92	364358	1001787	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
93	364393	1001824	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
94	364379	1001827	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
95	364388	1001846	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
96	364314	1001859	Institutional	55	BG#6	55	55	55	55	55	56	57	58	59	59	60	61	62	63
97	363921	1001969	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
98	363938	1001997	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
99	363950	1001999	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
100	363948	1002005	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
101	363938	1002011	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
102	363431	1002204	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
103	363424	1002209	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
104	363428	1002221	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
105	363412	1002222	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
106	365518	1002322	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
107	365484	1002328	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	**Northing**				**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
108	365519	1002351	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
109	365476	1002359	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
110	364797	1003133	Institutional - sleeping	55	BG#5	55	55	55	55	55	55	55	55	55	55	55	55	55	55
111	363098	1002427	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
112	370200	1003437	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
113	362710	1003504	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
114	360523	1003453	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54
115	360075	1004468	Residential	50	BG#5	50	50	50	50	50	50	50	50	50	50	50	52	53	54

* CEB is considering acquisition of these properties, which would remove these locations as sensitive receivers.

Table E2 Overall (Background + turbine) noise limits at receiver locations during the night time, for 81.5 m wind speeds

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) night time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	374870	994562	Residential	45	BG#1	45	46	48	49	50	51	53	54	55	56	57	58	58	59
2	374475	996332	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
3	374610	996618	Commercial	60	BG#5	60	60	60	60	60	60	60	60	60	60	60	60	60	60
4	372979	997738	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
5	373383	997683	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
6	374340	996759	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
7	373894	997101	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
8	373544	997385	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
9	372959	997586	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
10	373853	995455	Institutional	55	BG#1	55	55	55	55	55	55	55	55	55	56	57	58	58	59
11	373809	995533	Commercial	60	BG#1	60	60	60	60	60	60	60	60	60	60	60	60	60	60
12	373829	995556	Commercial	60	BG#1	60	60	60	60	60	60	60	60	60	60	60	60	60	60
13	373817	995564	Commercial	60	BG#1	60	60	60	60	60	60	60	60	60	60	60	60	60	60
14	373824	995573	Commercial	60	BG#1	60	60	60	60	60	60	60	60	60	60	60	60	60	60
15	373837	995574	Commercial	60	BG#1	60	60	60	60	60	60	60	60	60	60	60	60	60	60
16	373800	995576	Commercial	60	BG#1	60	60	60	60	60	60	60	60	60	60	60	60	60	60
17	373815	995578	Commercial	60	BG#1	60	60	60	60	60	60	60	60	60	60	60	60	60	60

Location number	**Coordinates (WGS84 UTM 44P)**		**Classification**	**Base limit**	**Representative location**	**Overall (background + turbine) night time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s**													
	Easting	**Northing**				**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
18	373809	995578	Commercial	60	BG#1	60	60	60	60	60	60	60	60	60	60	60	60	60	60
19	373496	995860	n/a	n/a	BG#1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	373639	996013	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	373733	995954	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	373661	995697	n/a	n/a	BG#1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	373568	995816	Industrial	60	BG#1	60	60	60	60	60	60	60	60	60	60	60	60	60	60
24	372741	996424	n/a	n/a	BG#6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	372880	996603	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	372550	996609	n/a	n/a	BG#6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	372687	996766	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	372692	996656	Institutional	55	BG#4	55	55	55	55	55	55	55	55	55	55	55	55	55	55
29	372773	996494	Institutional	55	BG#1	55	55	55	55	55	55	55	55	55	56	57	58	58	59
30	371800	997235	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
31	371843	997235	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
32	371801	997250	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
33	371845	997254	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
34	371760	997262	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
35	371757	997279	Institutional	55	BG#2	55	55	55	55	55	55	55	56	57	57	58	58	58	58

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) night time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
36	371774	997281	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
37	371706	997292	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
38	371797	997312	Industrial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
39	371764	997314	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
40	371739	997314	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
41	371770	997322	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
42	371771	997324	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
43	371768	997333	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
44	371783	997336	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
45	371646	997348	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
46	371677	997382	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
47	372959	997594	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
48	372936	997607	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
49	372907	997617	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
50	372790	997705	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
51*	371824	997619	Residential	45	BG#3	45	45	45	45	45	46	47	49	50	52	53	54	55	56
52*	371707	997679	Residential	45	BG#3	45	45	45	45	45	46	47	49	50	52	53	54	55	56
53*	371811	997726	Residential	45	BG#3	45	45	45	45	45	46	47	49	50	52	53	54	55	56

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) night time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
54*	371751	997764	Residential	45	BG#3	45	45	45	45	45	46	47	49	50	52	53	54	55	56
55	371140	997761	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
56	370907	997982	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
57	370888	997999	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
58	370873	998007	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
59	370770	998142	Residential	45	BG#4	45	45	45	45	46	48	49	50	51	52	53	53	53	53
60	370723	998172	Residential	45	BG#4	45	45	45	45	46	48	49	50	51	52	53	53	53	53
61	370947	998404	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
62	370905	998436	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
63	370881	998362	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
64	370171	998500	Institutional	55	BG#2	55	55	55	55	55	55	55	56	57	57	58	58	58	58
65	369853	998753	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
66	368425	999674	Institutional	55	BG#2	55	55	55	55	55	55	55	56	57	57	58	58	58	58
67	372627	998956	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
68	372637	998802	Institutional	55	BG#5	55	55	55	55	55	55	55	55	55	55	55	55	55	55
69	372650	999016	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
70	371517	999660	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
71	371572	999697	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) night time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
72	371525	999728	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
73*	368920	999781	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
74*	368931	999793	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
75*	368688	999852	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
76*	368822	999864	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
77*	368716	999918	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
78	366705	1000673	Institutional	55	BG#6	55	55	55	55	55	56	57	58	59	59	60	61	61	61
79	366806	1000608	Institutional	55	BG#6	55	55	55	55	55	56	57	58	59	59	60	61	61	61
80	366839	1000657	Institutional	55	BG#2	55	55	55	55	55	55	55	56	57	57	58	58	58	58
81	366748	1000717	Institutional	55	BG#2	55	55	55	55	55	55	55	56	57	57	58	58	58	58
82	366738	1000700	Institutional	55	BG#2	55	55	55	55	55	55	55	56	57	57	58	58	58	58
83	366725	1000705	Institutional	55	BG#2	55	55	55	55	55	55	55	56	57	57	58	58	58	58
84	366663	1000680	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
85	366681	1000705	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
86	366735	1000715	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
87	366752	1000818	Institutional	55	BG#2	55	55	55	55	55	55	55	56	57	57	58	58	58	58
88	366162	1000961	Institutional	55	BG#6	55	55	55	55	55	56	57	58	59	59	60	61	61	61
89	367265	1001684	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Overall (background + turbine) night time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
90	367682	1001397	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
91	367670	1001365	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
92	364358	1001787	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
93	364393	1001824	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
94	364379	1001827	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
95	364388	1001846	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
96	364314	1001859	Institutional	55	BG#6	55	55	55	55	55	56	57	58	59	59	60	61	61	61
97	363921	1001969	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
98	363938	1001997	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
99	363950	1001999	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
100	363948	1002005	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
101	363938	1002011	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
102	363431	1002204	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
103	363424	1002209	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
104	363428	1002221	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
105	363412	1002222	Commercial	60	BG#6	60	60	60	60	60	60	60	60	60	60	60	61	61	61
106	365518	1002322	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
107	365484	1002328	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52

Location number	**Coordinates (WGS84 UTM 44P)**		**Classification**	**Base limit**	**Representative location**	**Overall (background + turbine) night time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s**													
	Easting	**Northing**				**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
108	365519	1002351	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
109	365476	1002359	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
110	364797	1003133	Institutional - sleeping	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
111	363098	1002427	Commercial	60	BG#2	60	60	60	60	60	60	60	60	60	60	60	60	60	60
112	370200	1003437	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
113	362710	1003504	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
114	360523	1003453	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52
115	360075	1004468	Residential	45	BG#5	45	45	45	45	45	45	45	46	48	49	50	51	52	52

* CEB is considering acquisition of these properties, which would remove these locations as sensitive receivers.

Appendix F—Turbine noise limits for 81.5 m AGL wind speed

Table F1 Turbine noise limits at receiver locations during the day time, for 81.5 m wind speeds

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	374870	994562	Residential	50	BG#1	50	50	49	48	48	50	51	52	53	53	54	55	56	58
2	374475	996332	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
3	374610	996618	Commercial	70	BG#5	70	70	70	70	70	70	70	70	70	70	70	70	70	70
4	372979	997738	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
5	373383	997683	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
6	374340	996759	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
7	373894	997101	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
8	373544	997385	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
9	372959	997586	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
10	373853	995455	Institutional	55	BG#1	55	55	55	54	54	53	53	52	53	53	54	55	56	58
11	373809	995533	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
12	373829	995556	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
13	373817	995564	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
14	373824	995573	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
15	373837	995574	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
16	373800	995576	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
17	373815	995578	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
18	373809	995578	Commercial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
19	373496	995860	n/a	n/a	BG#1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	373639	996013	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	373733	995954	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	373661	995697	n/a	n/a	BG#1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	373568	995816	Industrial	70	BG#1	70	70	70	70	70	70	70	70	70	70	70	70	70	70
24	372741	996424	n/a	n/a	BG#6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	372880	996603	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	372550	996609	n/a	n/a	BG#6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	372687	996766	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	372692	996656	Institutional	55	BG#4	55	55	55	55	55	55	54	54	54	54	54	53	53	52
29	372773	996494	Institutional	55	BG#1	55	55	55	54	54	53	53	52	53	53	54	55	56	58
30	371800	997235	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
31	371843	997235	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
32	371801	997250	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
33	371845	997254	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
34	371760	997262	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
35	371757	997279	Institutional	55	BG#2	55	55	55	54	54	53	52	53	53	54	55	55	56	58

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
36	371774	997281	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
37	371706	997292	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
38	371797	997312	Industrial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
39	371764	997314	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
40	371739	997314	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
41	371770	997322	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
42	371771	997324	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
43	371768	997333	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
44	371783	997336	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
45	371646	997348	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
46	371677	997382	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
47	372959	997594	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
48	372936	997607	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
49	372907	997617	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
50	372790	997705	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
51*	371824	997619	Residential	50	BG#3	50	50	50	50	49	49	48	47	48	49	50	52	53	55
52*	371707	997679	Residential	50	BG#3	50	50	50	50	49	49	48	47	48	49	50	52	53	55
53*	371811	997726	Residential	50	BG#3	50	50	50	50	49	49	48	47	48	49	50	52	53	55

Location number	**Coordinates (WGS84 UTM 44P)**		**Classification**	**Base limit**	**Representative location**	**Turbine day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s**													
	Easting	**Northing**				**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
54*	371751	997764	Residential	50	BG#3	50	50	50	50	49	49	48	47	48	49	50	52	53	55
55	371140	997761	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
56	370907	997982	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
57	370888	997999	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
58	370873	998007	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
59	370770	998142	Residential	50	BG#4	50	50	50	49	49	48	48	47	48	48	49	50	51	52
60	370723	998172	Residential	50	BG#4	50	50	50	49	49	48	48	47	48	48	49	50	51	52
61	370947	998404	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
62	370905	998436	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
63	370881	998362	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
64	370171	998500	Institutional	55	BG#2	55	55	55	54	54	53	52	53	53	54	55	55	56	58
65	369853	998753	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
66	368425	999674	Institutional	55	BG#2	55	55	55	54	54	53	52	53	53	54	55	55	56	58
67	372627	998956	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
68	372637	998802	Institutional	55	BG#5	55	55	55	55	55	55	55	55	55	54	54	54	53	53
69	372650	999016	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
70	371517	999660	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
71	371572	999697	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
72	371525	999728	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
73*	368920	999781	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
74*	368931	999793	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
75*	368688	999852	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
76*	368822	999864	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
77*	368716	999918	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
78	366705	1000673	Institutional	55	BG#6	54	54	54	53	53	53	54	55	56	56	57	58	59	60
79	366806	1000608	Institutional	55	BG#6	54	54	54	53	53	53	54	55	56	56	57	58	59	60
80	366839	1000657	Institutional	55	BG#2	55	55	55	54	54	53	52	53	53	54	55	55	56	58
81	366748	1000717	Institutional	55	BG#2	55	55	55	54	54	53	52	53	53	54	55	55	56	58
82	366738	1000700	Institutional	55	BG#2	55	55	55	54	54	53	52	53	53	54	55	55	56	58
83	366725	1000705	Institutional	55	BG#2	55	55	55	54	54	53	52	53	53	54	55	55	56	58
84	366663	1000680	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
85	366681	1000705	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
86	366735	1000715	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
87	366752	1000818	Institutional	55	BG#2	55	55	55	54	54	53	52	53	53	54	55	55	56	58
88	366162	1000961	Institutional	55	BG#6	54	54	54	53	53	53	54	55	56	56	57	58	59	60
89	367265	1001684	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
90	367682	1001397	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
91	367670	1001365	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
92	364358	1001787	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
93	364393	1001824	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
94	364379	1001827	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
95	364388	1001846	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
96	364314	1001859	Institutional	55	BG#6	54	54	54	53	53	53	54	55	56	56	57	58	59	60
97	363921	1001969	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
98	363938	1001997	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
99	363950	1001999	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
100	363948	1002005	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
101	363938	1002011	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
102	363431	1002204	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
103	363424	1002209	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
104	363428	1002221	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
105	363412	1002222	Commercial	70	BG#6	70	70	70	70	70	70	70	70	70	70	70	70	70	70
106	365518	1002322	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
107	365484	1002328	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51

Location number	**Coordinates (WGS84 UTM 44P)**		**Classification**	**Base limit**	**Representative location**	**Turbine day time noise limit in dB L_{Arq}, for 81.5 m height wind speed in m/s**													
	Easting	**Northing**				**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
108	365519	1002351	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
109	365476	1002359	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
110	364797	1003133	Institutional - sleeping	55	BG#5	55	55	55	55	55	55	55	55	55	54	54	54	53	53
111	363098	1002427	Commercial	70	BG#2	70	70	70	70	70	70	70	70	70	70	70	70	70	70
112	370200	1003437	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
113	362710	1003504	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
114	360523	1003453	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51
115	360075	1004468	Residential	50	BG#5	50	50	50	50	50	49	49	49	48	48	47	49	50	51

* CEB is considering acquisition of these properties, which would remove these locations as sensitive receivers.

Table F2 Turbine noise limits at receiver locations during the night time, for 81.5 m wind speeds

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine night time noise limit in dB L_{Aeq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	374870	994562	Residential	45	BG#1	42	43	45	46	47	48	50	51	52	53	54	55	55	56
2	374475	996332	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
3	374610	996618	Commercial	60	BG#5	60	60	60	60	60	60	60	60	60	60	60	60	60	60
4	372979	997738	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
5	373383	997683	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
6	374340	996759	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
7	373894	997101	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
8	373544	997385	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
9	372959	997586	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
10	373853	995455	Institutional	55	BG#1	55	55	55	54	54	54	53	53	52	53	54	55	55	56
11	373809	995533	Commercial	60	BG#1	60	60	60	60	60	60	60	59	59	59	59	58	58	58
12	373829	995556	Commercial	60	BG#1	60	60	60	60	60	60	60	59	59	59	59	58	58	58
13	373817	995564	Commercial	60	BG#1	60	60	60	60	60	60	60	59	59	59	59	58	58	58
14	373824	995573	Commercial	60	BG#1	60	60	60	60	60	60	60	59	59	59	59	58	58	58
15	373837	995574	Commercial	60	BG#1	60	60	60	60	60	60	60	59	59	59	59	58	58	58
16	373800	995576	Commercial	60	BG#1	60	60	60	60	60	60	60	59	59	59	59	58	58	58
17	373815	995578	Commercial	60	BG#1	60	60	60	60	60	60	60	59	59	59	59	58	58	58

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine night time noise limit in dB L_{Aeq}, for 81.5 m height wind speed in m/s													
	Easting	**Northing**				**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
18	373809	995578	Commercial	60	BG#1	60	60	60	60	60	60	60	59	59	59	59	58	58	58
19	373496	995860	n/a	n/a	BG#1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	373639	996013	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	373733	995954	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	373661	995697	n/a	n/a	BG#1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	373568	995816	Industrial	60	BG#1	60	60	60	60	60	60	60	59	59	59	59	58	58	58
24	372741	996424	n/a	n/a	BG#6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	372880	996603	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	372550	996609	n/a	n/a	BG#6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	372687	996766	n/a	n/a	BG#4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	372692	996656	Institutional	55	BG#4	55	55	55	55	55	55	54	54	54	54	53	53	53	53
29	372773	996494	Institutional	55	BG#1	55	55	55	54	54	54	53	53	52	53	54	55	55	56
30	371800	997235	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
31	371843	997235	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
32	371801	997250	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
33	371845	997254	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
34	371760	997262	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
35	371757	997279	Institutional	55	BG#2	55	55	54	54	54	53	52	53	54	54	55	55	55	55

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine night time noise limit in dB L_{Aeq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
36	371774	997281	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
37	371706	997292	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
38	371797	997312	Industrial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
39	371764	997314	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
40	371739	997314	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
41	371770	997322	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
42	371771	997324	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
43	371768	997333	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
44	371783	997336	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
45	371646	997348	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
46	371677	997382	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
47	372959	997594	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
48	372936	997607	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
49	372907	997617	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
50	372790	997705	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
51*	371824	997619	Residential	45	BG#3	43	43	43	43	42	43	44	46	47	49	50	51	52	53
52*	371707	997679	Residential	45	BG#3	43	43	43	43	42	43	44	46	47	49	50	51	52	53
53*	371811	997726	Residential	45	BG#3	43	43	43	43	42	43	44	46	47	49	50	51	52	53

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine night time noise limit in dB L_{Aeq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
54*	371751	997764	Residential	45	BG#3	43	43	43	43	42	43	44	46	47	49	50	51	52	53
55	371140	997761	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
56	370907	997982	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
57	370888	997999	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
58	370873	998007	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
59	370770	998142	Residential	45	BG#4	44	44	43	42	43	45	46	47	48	49	50	50	50	50
60	370723	998172	Residential	45	BG#4	44	44	43	42	43	45	46	47	48	49	50	50	50	50
61	370947	998404	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
62	370905	998436	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
63	370881	998362	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
64	370171	998500	Institutional	55	BG#2	55	55	54	54	54	53	52	53	54	54	55	55	55	55
65	369853	998753	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
66	368425	999674	Institutional	55	BG#2	55	55	54	54	54	53	52	53	54	54	55	55	55	55
67	372627	998956	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
68	372637	998802	Institutional	55	BG#5	55	55	55	55	55	55	55	55	55	54	54	54	54	54
69	372650	999016	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
70	371517	999660	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
71	371572	999697	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49

Location number	**Coordinates (WGS84 UTM 44P)**		**Classification**	**Base limit**	**Representative location**	**Turbine night time noise limit in dB L_{Aeq}, for 81.5 m height wind speed in m/s**													
	Easting	**Northing**				**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
72	371525	999728	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
73*	368920	999781	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
74*	368931	999793	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
75*	368688	999852	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
76*	368822	999864	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
77*	368716	999918	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
78	366705	1000673	Institutional	55	BG#6	54	54	53	53	52	53	54	55	56	56	57	58	58	58
79	366806	1000608	Institutional	55	BG#6	54	54	53	53	52	53	54	55	56	56	57	58	58	58
80	366839	1000657	Institutional	55	BG#2	55	55	54	54	54	53	52	53	54	54	55	55	55	55
81	366748	1000717	Institutional	55	BG#2	55	55	54	54	54	53	52	53	54	54	55	55	55	55
82	366738	1000700	Institutional	55	BG#2	55	55	54	54	54	53	52	53	54	54	55	55	55	55
83	366725	1000705	Institutional	55	BG#2	55	55	54	54	54	53	52	53	54	54	55	55	55	55
84	366663	1000680	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
85	366681	1000705	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
86	366735	1000715	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
87	366752	1000818	Institutional	55	BG#2	55	55	54	54	54	53	52	53	54	54	55	55	55	55
88	366162	1000961	Institutional	55	BG#6	54	54	53	53	52	53	54	55	56	56	57	58	58	58
89	367265	1001684	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49

Location number	Coordinates (WGS84 UTM 44P)		Classification	Base limit	Representative location	Turbine night time noise limit in dB L_{Aeq}, for 81.5 m height wind speed in m/s													
	Easting	Northing				3	4	5	6	7	8	9	10	11	12	13	14	15	16
90	367682	1001397	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
91	367670	1001365	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
92	364358	1001787	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
93	364393	1001824	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
94	364379	1001827	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
95	364388	1001846	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
96	364314	1001859	Institutional	55	BG#6	54	54	53	53	52	53	54	55	56	56	57	58	58	58
97	363921	1001969	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
98	363938	1001997	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
99	363950	1001999	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
100	363948	1002005	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
101	363938	1002011	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
102	363431	1002204	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
103	363424	1002209	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
104	363428	1002221	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
105	363412	1002222	Commercial	60	BG#6	60	60	60	59	59	59	59	58	58	58	57	58	58	58
106	365518	1002322	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
107	365484	1002328	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49

Location number	**Coordinates (WGS84 UTM 44P)**		**Classification**	**Base limit**	**Representative location**	**Turbine night time noise limit in dB L_{Aeq}, for 81.5 m height wind speed in m/s**													
	Easting	**Northing**				**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
108	365519	1002351	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
109	365476	1002359	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
110	364797	1003133	Institutional - sleeping	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
111	363098	1002427	Commercial	60	BG#2	60	60	60	60	60	60	59	59	59	59	58	58	58	58
112	370200	1003437	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
113	362710	1003504	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
114	360523	1003453	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49
115	360075	1004468	Residential	45	BG#5	44	44	44	44	43	43	42	43	45	46	47	48	49	49

* CEB is considering acquisition of these properties, which would remove these locations as sensitive receivers.

Appendix G—Graphical presentation of turbine noise limits

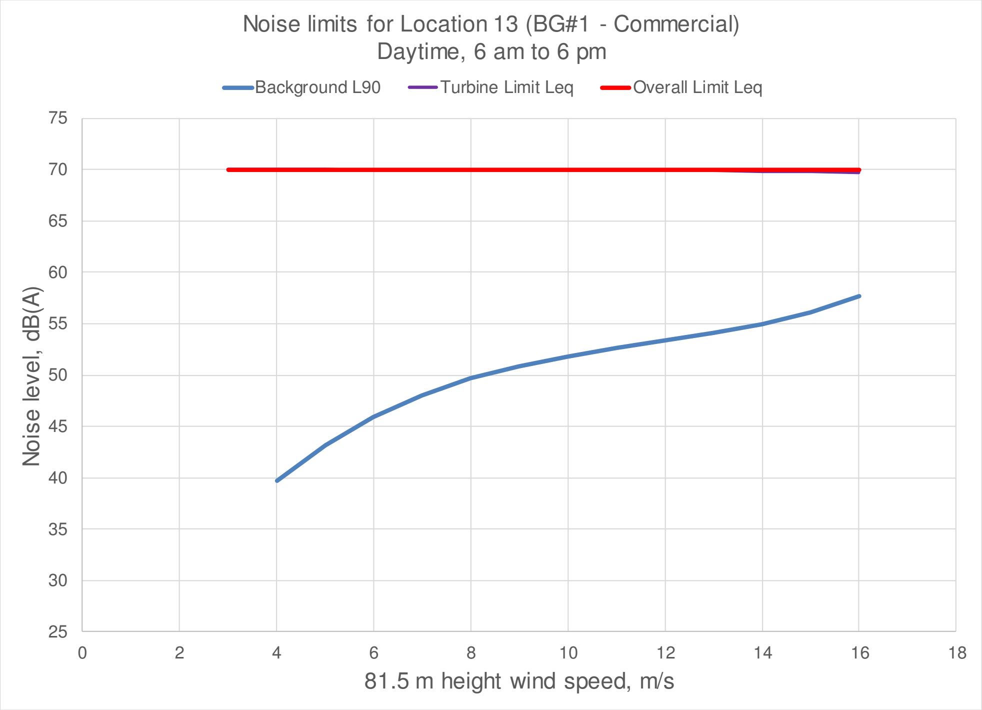

Figure G1 Daytime noise limit graphed against wind speed for BG#1

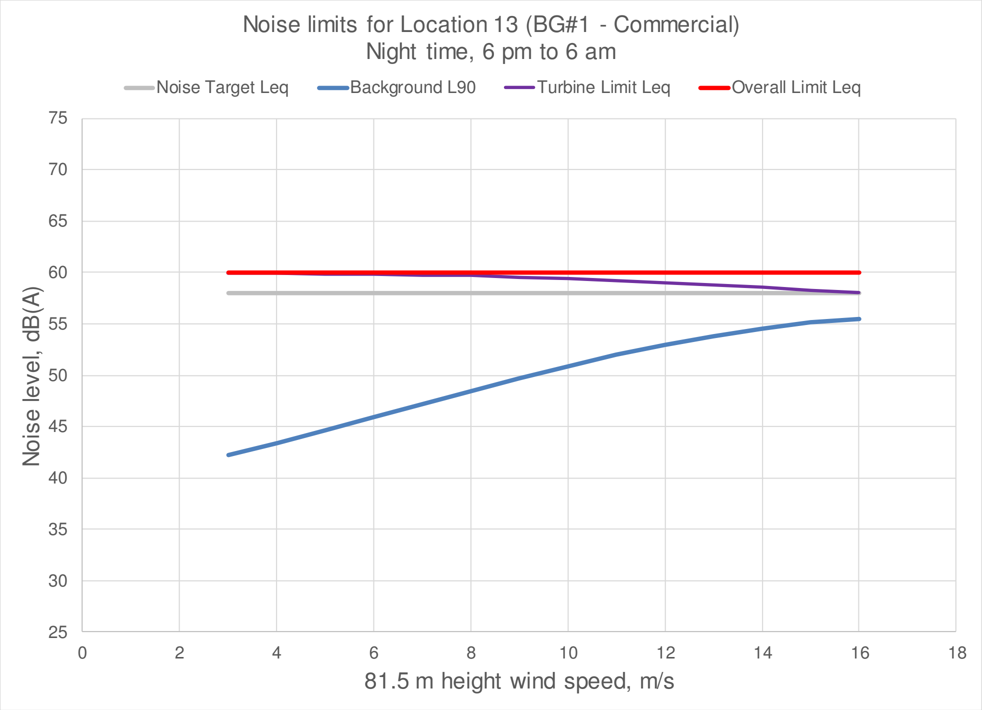

Figure G2 Night time noise limit graphed against wind speed for BG#1

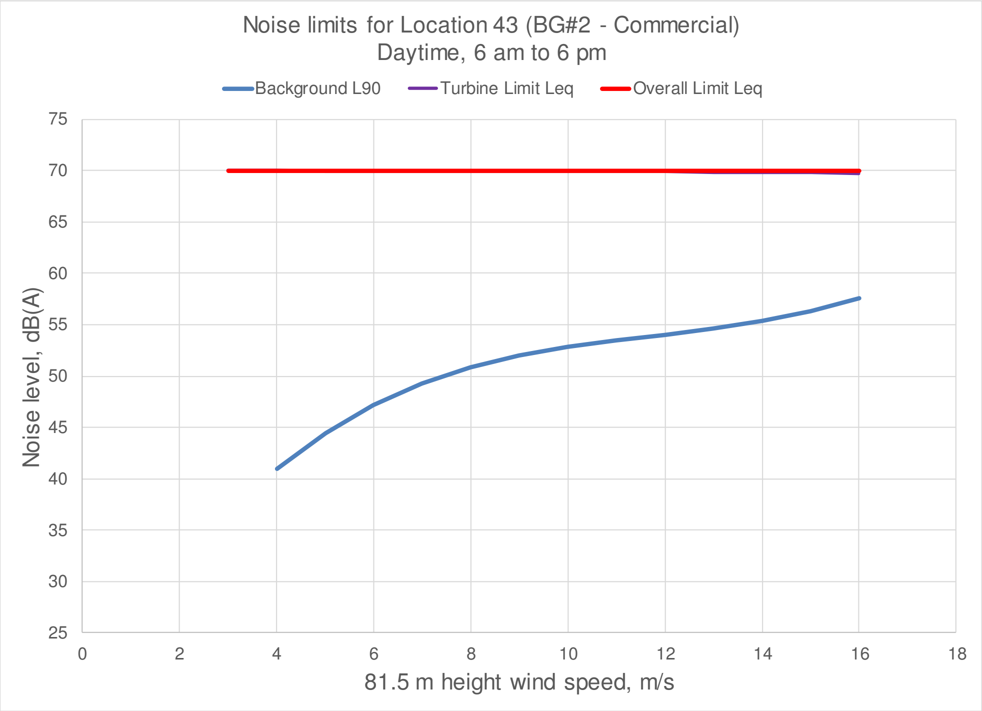

Figure G3 Daytime noise limit graphed against wind speed for BG#2

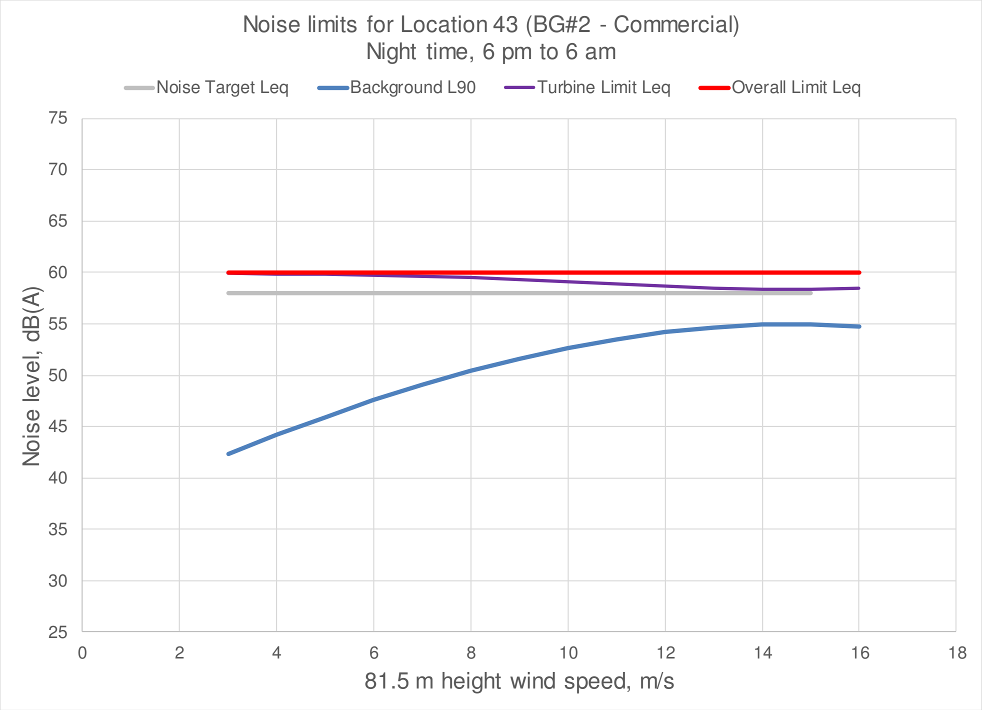

Figure G4 Night time noise limit graphed against wind speed for BG#2

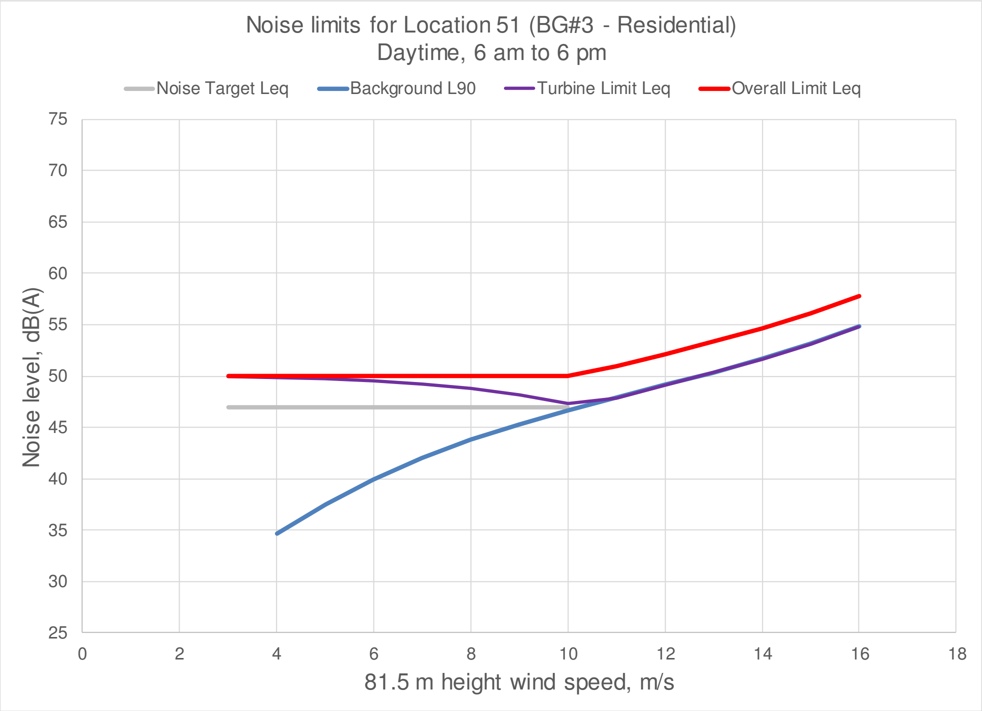

Figure G5 Daytime noise limit graphed against wind speed for BG#3

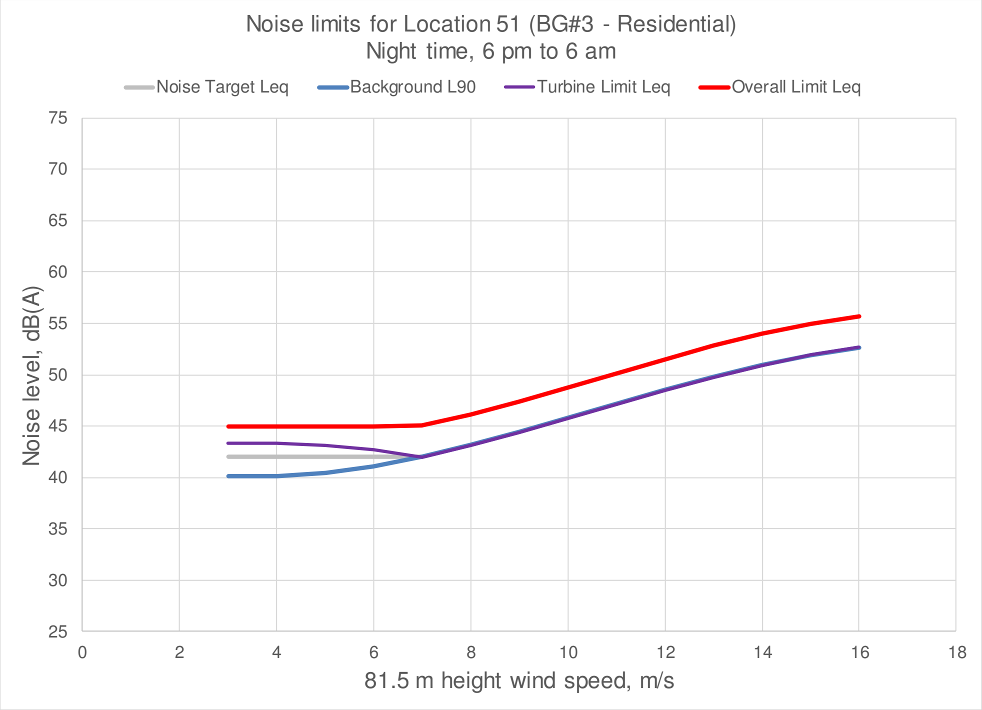

Figure G6 Night time noise limit graphed against wind speed for BG#2

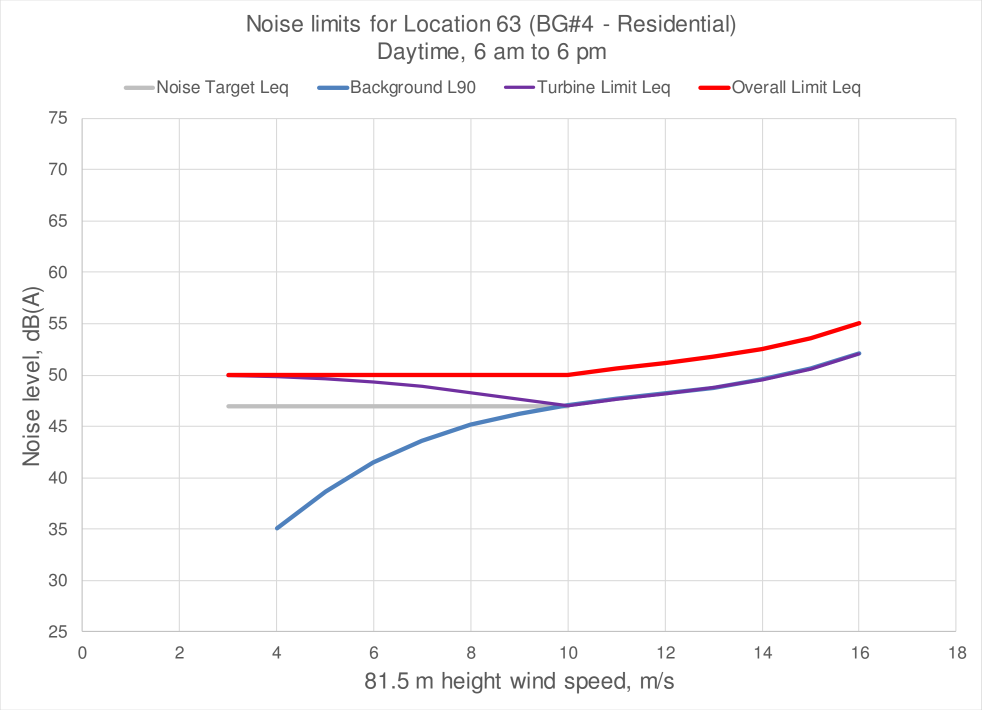

Figure G7 Daytime noise limit graphed against wind speed for BG#4

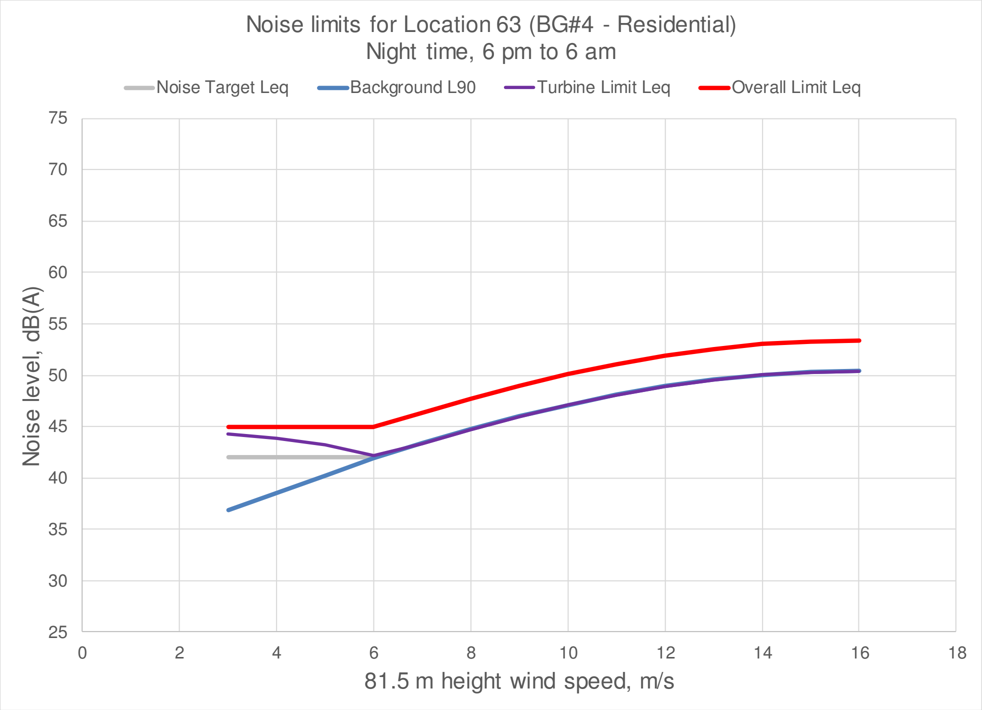

Figure G8 Night time noise limit graphed against wind speed for BG#4

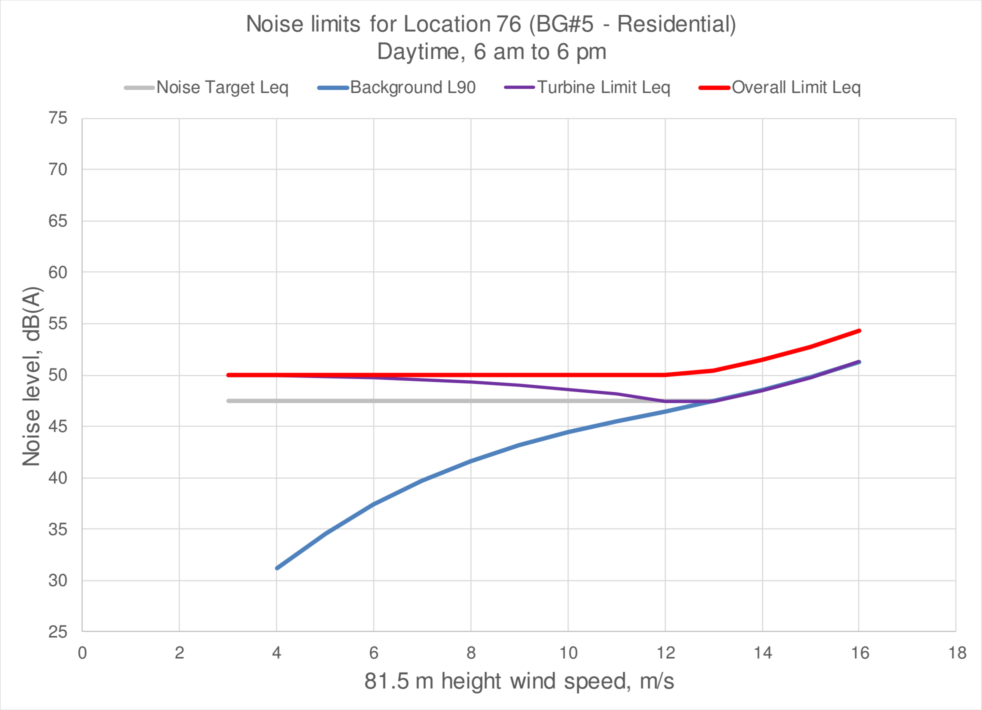

Figure G9 Daytime noise limit graphed against wind speed for BG#5

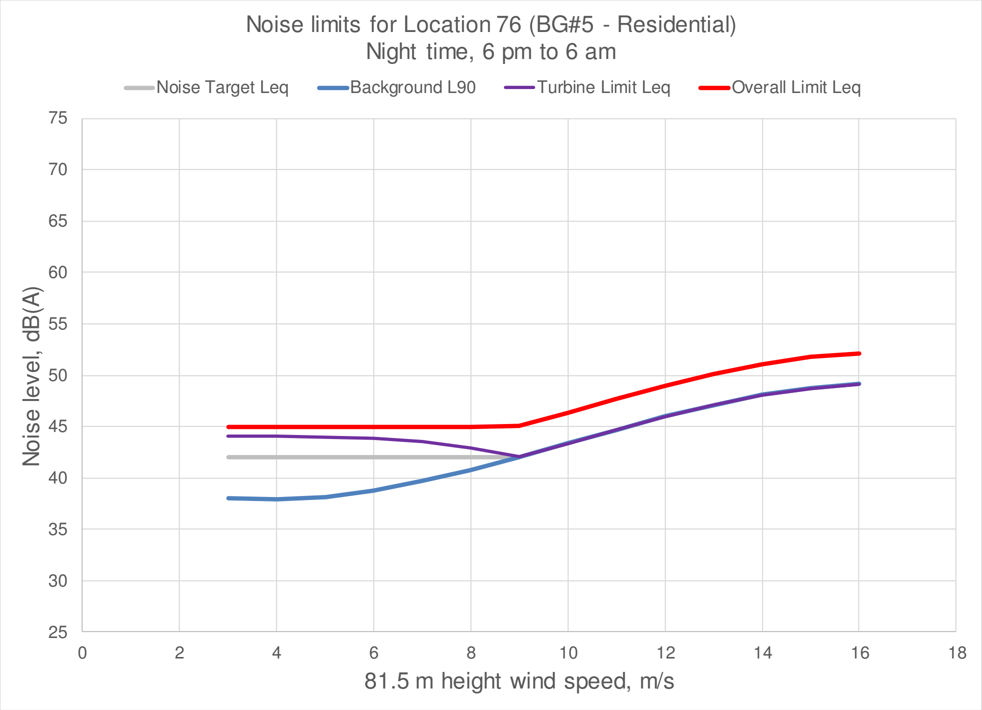

Figure G10 Night time noise limit graphed against wind speed for BG#5

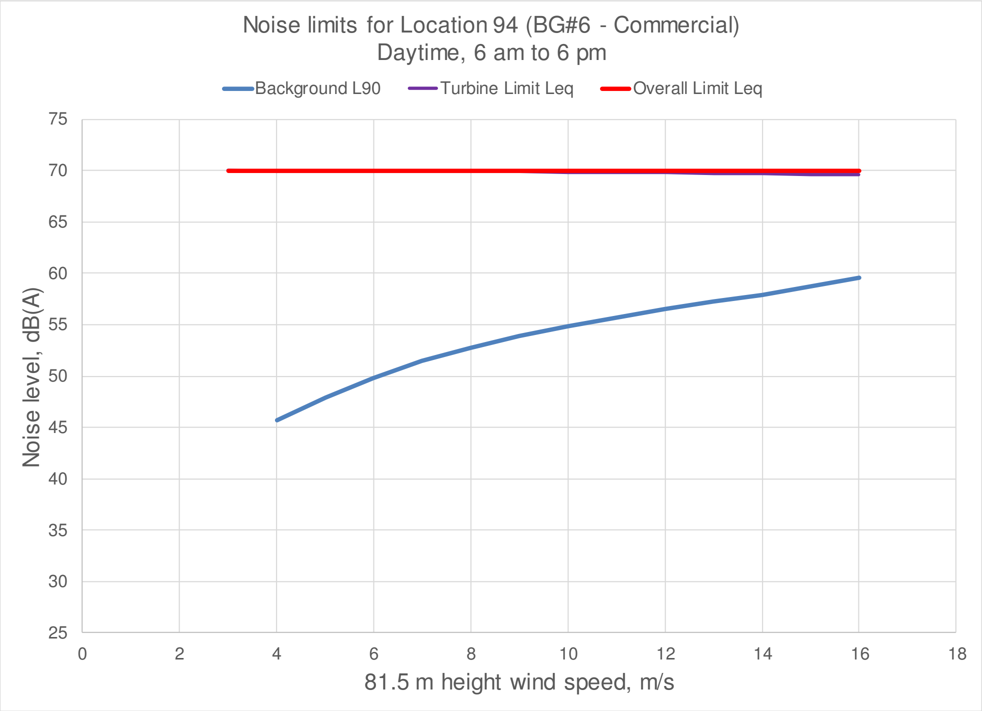

Figure G11 Daytime noise limit graphed against wind speed for BG#6

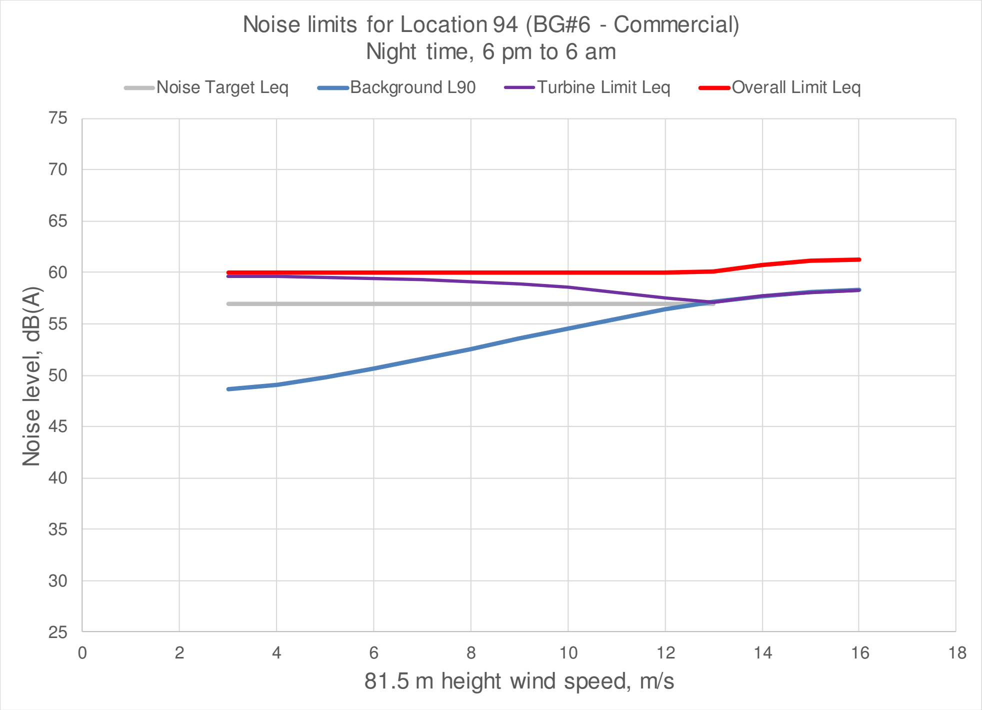

Figure G12 Night time noise limit graphed against wind speed for BG#6