ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROVISION OF RO PLANT AND STORAGE TANK IN

L.GAN, K.GAAFARU & B.KENDHOO

DECEMBER 2017

Prepared for: Ministry of Environment and Energy

MEECO
MALDIVES ENERGY AND ENVIRONMENTAL COMPANY

PROJECT SYNOPSIS

Name of the Project: Construction of RO Plant in K. Gaafaru, L. Gan and B. Kendhoo
Project Proponent: Ministry of Environment and Energy
Project Value: -
Expected Duration: 7 months per island
EIA Consultant: Ahmed Saleem (MEECO)
EIA Date: November 2017

WEIGHTS AND MEASURES CONVERSIONS

1 metric tonne = 2,204 pounds (lbs.)
1 kilogramme (kg) = 2.2 pounds (lbs.)
1 metre (m) = 3.28 feet (ft.)
1 millimetre (mm) = 0.03937 inches (")
1 kilometre (km) = 0.62 mile
1 hectare (ha) = 2.471 acres

LIST OF ABBREVIATIONS

CBD	Convention on Biological Diversity
CO_2-e	Carbon dioxide equivalent
DA	Decentralisation Act
DDRPM	Development of Disaster Risk Management Profile Maldives
DIRAM	Detailed Island Risk Assessment in Maldives
DNP	Department of National Planning
DO	Dissolved Oxygen
EIA	Environment Impact Assessment
EMP	Environmental Monitoring Plan
EPA	Environmental Protection Agency
EPPA	Environmental Protection and Preservation Act
ES	Environmental Score
EPZ	Environmental Protection Zone
RO	Reverse Osmosis
GHG	Green House Gas
GPP	Gross Primary Production
GoM	Government of Maldives
HIES	Household income and expenditure survey
HIA	Hanimaadhoo International Airport
Hs	Peak Height
HPA	Health Protection Agency
IWM	Island Waste Management
IWMC	Island Waste Management Center
IWMF	Island Waste Management Facility
LUP	Land Use Plan
MCA	Multi Criteria Analysis
MEE	Ministry of Environment and Energy
MHI	Ministry of Housing and Infrastructure
MSDS	Material Safety Data Sheet
MMS	Maldives Meteorological Service
MOFA	Ministry of Fisheries and Agriculture
MPA	Marine Protected Area
MSL	Mean Sea Level
MoT	Ministry of Tourism
NBSAP	National Biodiversity Strategy and Action Plan

NBSAP	National Biodiversity Strategy and Action Plan
MNSSD	Maldives National Strategy for Sustainable Development
NAPA	National Adaptation Programme of Action
PPG	Personnel Protective Gear
PPE	Personnel Protective Equipment
RWM	Regional Waste Management
RWMC	Regional Waste Management Centre
RWMS	Regional Waste Management System
WMP	Waste Management Plan
RWMP	Regional Waste Management Plan
IWMP	Island Waste Management Plan
WSS	Water Supply System

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

DECLARATION OF THE CONSULTANT AND PROPONENT

Consultant
I certify that the statements made in this Environmental Impact Assessment are true, complete and correct to the best of my knowledge and available information at the time of writing this report.

Ahmed Saleem (EIA 03/13)
Signature:

Proponent
The Proponent's declaration and commitment to undertake the mitigation and monitoring is given in **Annex 1**.

ސާރާ ހުލާސާ:

ތައާރަފު

މިއީ ކ.ގާފަރު، ލ.ގަން އަދި ބ.ކެންދޫގައި ފެންފޯރުކުރުމުގެ ނިޒާމު ގާއިމްކުރުމަށް ހިންގޭ މަޝްރޫއަށް ތައްޔާރު ކުރެވިފައިވާ ތިމާވެއްޓަށް އަސަރު ކުރާ މިންވަރު ބަޔާންކުރާ ރިޕޯޓެވެ.

މަޝްރޫއުގެ ލީޑް ފަރާތަކީ މިނިސްޓްރީ އޮފް ހައުސިންގ އެންޑް އިންފްރާސްޓްރަކްޗަރ އެވެ. މަޝްރޫއު ފުރިހަމަ ކުރުމަށް ކަނޑައަޅާފައިވާ ބޭފުޅާއީ ކޮންމެ ރަށެއްގައި މަސައްކަތް ފެށުމަށް 7 މަސްދުވަސް ނަގާނެއެވެ.

އީ.އައި.އޭ ރިޕޯޓުގެ މަގުސަދު

މި ރިޕޯޓު ތައްޔާރުކޮށްފައިވަނީ ދިރިއުޅުއްޖޭގެ ތިމާވެށީ އަސަރުތަކަށް މިންވަރު ބަލާން ކުރާ ރިޕޯޓު ހުށަހަޅަންވާނެ ގޮތުގެ ޤަވާއިދު 4 ގެ ދަށުން ދިރިއުޅުއްޖޭގައި ހިންގާ ފެންފޯރު މިކުރާ މަޝްރޫއުތަކުގެ އަމަލީ މަސައްކަތްތަކުގެ ސަބަބުން ތިމާވެށީގެ ކޮންމެ ނުބައި އަސަރުތަކެއް ހުރިކަން ބެލުމަށް ރިޕޯޓު ތައްޔާރު ކުރުމަށް ބާރުއަޅާފައިވާ ގޮތުގެ މަތިން އެވެ. އެކަން ފުރިހަމަ ކުރުމަށް މަގުސަދުވީ ދެ ގޮތަކަށް އެއް ތިމާވެއްޓަށް އަސަރު ކުރާ މިންވަރު ބެލުމުގެ އިތުރުން ނުބައި އަސަރުތަކުގެ ބޮޑުމިން ވަޒަން ކުރުމާއި، ކުރަހާލާ ގޮތްތަކާ މަޝްރޫއުގެ ކަންކަން ހުށަހެޅުމާއި އެކަށީގެން ވާ ބަދަލުތައް ގެނައުމާއި ތިމާވެށީގެ ދިރިއުޅުމާއި ވާލާ ގޮތުން ފާހަގަކުރެވޭ ކަންކަމާ ގުޅޭ މަޝްރޫއުތަކަށް ހުއްދަ ދިނުމާއި ތިމާވެށީގެ ހާލަތު ނަގާ މަޝްރޫއުގެ ތިމާވެއްޓަށް ކުރާ އަސަރުތަކާ ގުޅިގެން މަޝްރޫއާ ގުޅިގެން ތިމާވެށީގެ ބަދަލުތަކަށް ފާހަގަކުރާ ތިމާވެށީ ނިޒާމުގެ ޙިމާޔަތް ކުރުމެވެ.

މަޝްރޫއުގެ މުހިންމުކަން

ދިވެހި ރާއްޖެއަކީ ދިރިއުޅުމުގެ ބޭނުމަށް ޖަހާ ފަސޭހަތަކާއި ވަސީލަތް މަދު ގައުމެކެވެ. މިގޮތުން ދިވެހިން ޖަމާކުރާ ފެނުގެ މުހިންމު ބައެއް ބޭނުން ކުރާ އަދި ގިނަ ބައެއް ލިބިގަންނަން ބޭނުން ކުރަނީ ވާރޭފެނާއި ގްރައުންޑް ވޯޓަރެވެ. ނަމަވެސް އާބާދީ އިތުރުވުމުގެ ސަބަބުން ގްރައުންޑް ވޯޓަރގެ ކޮލިޓީ ދަށްވެ، ގޮތް ގޮތުގެ ދުއްތުރާ ގްރައުންޑް ވޯޓަރ އެކަނި ތަރައްޤީ ކުރުމަށް ބާރުލިބޭ ގޮތުން ދިރިއުޅެން ނުކެރޭ ހަމަ ވެއްޖެއެވެ. މިކަމުގެ ސަބަބުން ރަށްރަށުގެ ފެނުގެ ހާލަތު ހުރީ ތަފާތު ތަފާތު ގޮތްގޮތަށެވެ. މިސާލަކަށް ބޯފެން، ފިނިފެން، މީރުފެން ހަމަ ކަމަށް ބޭނުންކުރާ ފެނަށް ވާރޭފެން އަދި ގްރައުންޑް ވޯޓަރުގެ މިންވަރު ދަށްވެ، ވަޔަށް ނުވެގެން ބޭނުން ކުރާ ފެނަށް ގެއްލުން ލިބޭ ހާލަތު ދިމާވެއްޖެއެވެ. އަދި ފެނުގައި ބެކްޓީރިއާ ފެން ބޯން ނުކެރޭ ގޮތަށް ގިނަވުމުން ނުރައްކާތެރި ނަތީޖާތައް ދިމާވެފައިވެއެވެ. ބޯފެނުގެ ގޮތުގައި ބޭނުންކުރާ ފެނުގެ ތެރެއިން ވާރޭފެން، ފިނިފެން، މީރުފެން އަދި ގްރައުންޑް ވޯޓަރު އަދި ދިރިއުޅުމުގެ ހާލަތާއި ގުޅުން ހުރި ގޮތަށް ބޭނުން ކުރާ މިންވަރު މަދުވުމުން ފެނަށް ލިބޭ ގެއްލުން ކުރިމަތިވާ އުނދަގޫތަކާ ހުރި ކުރިމަތިލާން ޖެހިއްޖެއެވެ.

ހާލަތުގައި ފެނުގެ ޖާގަ ދިރިއުޅެން ނުކުޅަދުވާ ފެނުގެ ފެންނަށް ދުވަހަކު ނިކަމެތިކަމުން ކުރުމުގެ ދަތިތަކުގައި ދިރިއުޅެނީ ފެނާއި ބޭނުންކުރުމަށް ފެނުގެ ބޭނުމަށް އެއްވެސް ގޮތެއްގައި ފެންޖަހާފައިވާ ފެނެކެވެ. ފެންފޯރުކުރުމުގެ ނިޒާމު ރަނގަޅު ނުވުމުން ސާފުތާހިރު އެކަށީގެންވާ ފެނެއް ނުލިބެއެވެ. މިފެންކޮޅުގައި ހިފެހެއްޓިފައިވާ އަސްލު ބޭސިކް ފެން ފޯރުކޮށްދިނުމަށް ފެންފޯރުކުރާ ހަމަ ދުވަސްކޮޅެއް، ރަށުގެ ރައްކާތެރިކަން ފެނަށް ޖެހޭ ހާލަތުގައި

ފެންފުރު ކޮންޓެއިނަރުގެ ނިޒާމެއް ގާއިމު ކުރުމެވެ. މީގެ، އިތުރުން ރަށުގެ އިލެކްޓްރިސިޓީ ބަރަށް ގެއްލުން ނުވާ ސިސްޓަމެއް ބަހައްޓާ ފެން ވިއުގާގެ އިންތިޒާމުތައް އެކުލަވާލާ ހަމަޖެއްސުމެވެ.

ވީމާ، މިމަޝްރޫޢަކީ ފެނަށްޖެހުމުން ދިމާވާ ދަތިތަކަށް ދާއިމީ ހައްލެއް ގެނެސްދޭނެ، ފެން ނުލިބޭ ސަބަބުން ކުރިމަތިވާ އިލެކްޓްރިސިޓީ މައްސަލަތައް ހައްލުކޮށް ކުރުމުގެ މަސައްކަތްތަކަށް ރޭވާ ހިންގަން ހަމަޖެހިފައިވާ މަޝްރޫޢެއްކަމެވެ. މީގެ،އިތުރުން މިއީ މުސްތަގްބަލުގައި މުޅި ރަށަށް 24 ގަޑިއިރު ފެން ފޯރުކޮށްދިނުމުގެ އިންތިޒާމު ހަމަޖެއްސުމަށްޓަކައި އެކުލަވާލެވިފައިވާ ފުރުޞަތުތަކެވެ.

މަޝްރޫޢުގެ ބައިތައް

މި މަޝްރޫޢުގެ ތެރެއިން، މަޝްރޫޢުގެ ދަށުން ރަށްރަށުގައި ފެން ފިލްޓަރު ކުރުމުގެ ނިޒާމް ގާއިމުކުރުމާއި، ފެން ހިފެހެއްޓުމުގެ ޓޭންކު ބެހެއްޓުމާއި، ސިސްޓަމްތަކަށް ފެން ވިއުގާ ކޮންނެކްޓްކޮށް ރަށުގެ ބަނޑަރުތަކުގައި ޕަންޕު ހަރުކުރުމާއި ޕަންޕް ބިލްޑިންގ ބިނާކުރުމެވެ. ފެން ފިލްޓަރުކުރާ ފެން ވިއުގާގެ 30 ކިލޯލީޓަރުގެ ފެން ހިފެހެއްޓުމެވެ. މަޝްރޫޢުގެ ހިމެނޭ މައިގަނޑު ބައިތަކަކީ:

- ބިނާކުރުމުގެ މަސައްކަތް؛
- ފިލްޓަރ ހައުސް އިމާރާތް ކުރުން؛
- ފެން ފިލްޓަރކުރާ މެޝިނަރީ،
- ވިއުގާ ރޮނގުތައް،
- ބަހާނެ ޓޭންކު ބެހެއްޓުން،
- ޖަނަރޭޓަރު ފިލްޓަރ ހައުސްގައި ހަރުކޮށް ކަރަންޓު ދިނުމެވެ.

މަޝްރޫޢާ ގުޅޭ ބަދަލުތައް

މިމަޝްރޫޢަކީ ސަރުކާރުގެ ކަމާބެހޭ ސިޔާސަތުތަކާއި، ރާއްޖޭގެ ކަމާބެހޭ ގާނޫނުތަކާއި ގަވާއިދުތަކާ ފެތޭގޮތަށް ބާރުއަޅައި ފެނާ ގުޅޭ ތަރައްޤީ ކުރިއަށް ގެންދާ މަޝްރޫޢެކެވެ. މީއީ، ގާނޫނު ތަކާއި ގަވާއިދުތަކާއި، ކަމާބެހޭ ސިޔާސަތުތަކާ ފެތޭ ގޮތުގެ ތަރައްޤީއަށް މަޝްރޫޢެކެވެ.

މަޝްރޫޢުގައި ހިމެނޭ ތަކެތި ހޯދުން

ކ.ގާފަރުގައި މިހާރު ބޭނުންކުރާ ސަރަހައްދުން އިތުރަށް ދުއްވާލައި ވާރޭފެން ހޯދާނެ ރަތްފަރާތް ހުރިހާ ވަރަކަށް ގަސްތަކުގަ ކަނޑާލާނެއެވެ. މިގޮތުން ވިޔަ ގޮވަތި ވާރޭފެން ރައްކާކުރުމުގައި އިތުރު ހަރުފަތް ވަކި ބޭނުން ކުރާނެއެވެ. އަދި އެހެން ސަރަހައްދުތަކުން، ނަޖިހާ ސަރަހައްދު ވަކި ހަދައިގެން ކުރިއަށް ގެންދާ ތަނަށް ބަލާލެވޭނެއެވެ. ގެނބާ ބޭނުންކުރާނެ ދެތިން ގޮތެއް ބަލައިގެން ފެން ދެއްވާ ބަހާ ދުރުމިންވަރު ކަނޑައެޅޭނެއެވެ. ނަމަވެސް މުސްތަގްބަލުގައި ބިމުގެ ފެނުގެ ބޭނުން ގިނަވެ ހިފިދާނެ ކަމަށް ފެންނަތީ ވަކި މިންވަރަކަށް ބޭނުންކުރެވޭނެއެވެ. އެހެން ކަމުން ރަށުގެ ދިރުމަށް ގެނައުމަށް ފައިދާ ބޮޑު އަސާސީ ޒަރިއްޔާއެއް ތަކުގެ ފެން މިއަދާއި އެއްގޮތަށް ހަމަޖެހިގެން ދިއުމަށް ކޮންމެހެން ބޭނުން ވެއްޖެ ކަމެވެ.

ފެން ޕްލާންޓް އެޅުމަށް ހުށަހަޅާފައިވަނީ ރަށުގެ އުތުރު ފަރާތުން 230 އަކަމީޓަރު ހިމެނޭ ބިމެކެވެ. އެސަރަހައްދަށް ދެއްވާ އެކަށީގެންވާ ވަދެ ނިކުތުމަށް ބޭނުން މަގެއް އެބައޮތެވެ. ރަށުގެ އިންޖީނުގެއާއި ކުޅި އަދި ސޯލާރ ހެންނަނީ މިސަރަހައްދަށް މާ ދުރުނޫން ހިސާބެއްގައެވެ. އެސަރަހައްދުގައި ކަނޑެން ޖެހޭ ބޮޑެތި ބިނާ ބޮޑު ގަހެއް ނެތެވެ. ފެންފެން ބޭރުކުރެން ދިސަރަހައްދަށް ދިރުމަތާކުރެވިފައެވެ. ޕްލާންޓުން ފެން ބޭރުކުރާ ހޮޅި ރަށުގެ ހުޅަނގު ފަރާތަށް ދެން އެންމެ އެކަށީގެންވާގޮތަށް ދިރާސާ ހިނގާ ކުރަމުންދާނެއެވެ. ރަށުގައި ޗެކްރިމްދޫގެ ސަބަބުން ރަށުގައި ފެންޕްލާންޓް އަޅާނެ އިތުރު ސަރަހައްދެއް ރަށުގައި ނެތްކަން ފާހަގަކުރެވިފައެވެ.

ލ. ގަމުގައި މޫސުމީ ބަދަލުތަކުގެ ސަބަބުން ވާރޭވެހުމުގެ ދަރަޖަ ދަށްވެ ދިރިތަކާ ކުރިމަތިވާކަން ވަނީ ފާހަގަކުރެވިފައެވެ. މިގޮތުން ގޭގޭގެ އިތުރުން ބަނދަރުގައިވެސް ވާރޭވެހުން ބަލައިގަތުމުގެ ނިޒާމު ގާއިމުކުރެވިފައިވާކަން ވަނީ ބެލެހެއްޓެވިފައެވެ. އަދި ބަނދަރުގެ ބެލެހެއްޓުމާ ހަވާލުވެ ހުރި ފަރާތަކުން ފެން ބެހުމުގެ ނިޒާމެއް ހިންގައެވެ. ރަށުގެ ބޯފެނުގެ ފެން ސަޕްލައިކުރުމާ ގުޅިގެން ވަނީ ބަހައްޓާފައެވެ. ރަށުގެ ގައިގަނޑު ސިޔާސަތުތަކާ ބެހޭ ގޮތުން ވަރަށް ފެން ނުވެވޭ ކަން ވަނީ ފާހަގަކުރެވިފައެވެ. އެހެން ކަމުން މި ރަށަށް ދިއުމުގެ ފުރުޞަތު ދީފައިވާ ގޮތުގައި ރަށުގެ ބިމުގެ ސަރަހައްދުގައި ފެން ލިބޭނެ އިންތިޒާމް ރަށުގައި ހުރިކަން ވަނީ ފާހަގަކުރެވިފައެވެ. ފެން ޕްލާންޓް އެޅުމަށް ހުށަހަޅާފައިވަނީ ރަށުގެ ހުޅަނގު ފަރާތުން 442 އަކަމީޓަރު ހިމެނޭ ބިމެކެވެ. އެސަރަހައްދުގައި ކަނޑެން ޖެހޭ ބޮޑެތި ބިނާ ބޮޑު ގަހެއް ނެތެވެ. އެސަރަހައްދަށް ދެއްވާ އެކަށީގެންވާ ވަދެ ނިކުތުމަށް ބޭނުން މަގެއް އެބައޮތެވެ. މިބިމާ އެންމެ ކައިރިގައި ހުރި އިންޖީނުގެއެވެ. ފެންޕްލާންޓް އެޅުމަށް ހުށަހެޅުނު ބިމުން އެޅޭނެ ސަރަހައްދުތަކަށް ބަލައިލާ މިހާރު މިކަމަށް ކަނޑައެޅިފައިވާ ބިމަކީ ދިމާލުގެ ގޯތިތަކާއި އެންމެ އެކަށީގެންވާ ސަރަހައްދު ކަމުގައި ފާހަގަ ކުރެވޭ. ހ.ގަމުގެ ބޭރު ހަރަކާތްތަކުން މިހެން ދިރިއުޅޭ ބިން ސަރަހައްދުގައި އިސްކާރުބަރި ހަރުކާތްތަކުން، ފެނާ ގުޅުންހުރި އިޖްތިމާއީ ގިނަ މައްސަލަތައް ހައްލު ކުރެވިގެން ދާނެ ކަމަށް ފެނެއެވެ.

ބ. ކެންދޫގައިވެސް މޫސުމީ ބަދަލުތަކުގެ ސަބަބުން ރައްކާތެރި ފެން ހޯދުމަށް ދިރިތަކާ ކުރިމަތިވާކަން ވަނީ ފާހަގަކުރެވިފައެވެ. ރަށުގެ ފެންފަރާތް ވަނީ ތަހައްޓަރު ވެފައެވެ. ރަށުގައި ކުރިއަރަމުން އަންނަ ފަތުރުވެރިކަން ބޭނުން ވާ ވަރަށް ފެން ނިޔަމީ ނަގަން ވަނީ ދަތިވެފައެވެ. އެހެން ނަމަވެސް ރަނގަޅު ދިރުމެއްގެ ބޭނުމަށް ބޯނިއުމީ ގާތުގައި ފެން ލިބުނު ހަމަ ހުރިކަން ދަނެއެވެ. ރަށުގެ އިޅިގަސްދާ ރަށުގެ ކުރިއަރާ ހަމައަށް ހުރިކަން ވަނީ ފާހަގަކުރެވިފައެވެ. ރަށުގެ ފެން ކުންފުނިން ބަލަހައްޓާ ބާރުވެރިކަން ބެލެހެއްޓެވިއެވެ. ފެން ޕްލާންޓް އެޅުމަށް ހުށަހަޅާފައިވަނީ ރަށުގެ ދެކުނު ފަރާތުން 230 އަކަމީޓަރުގެ ބިމުގައެވެ. މި ބިމާ އެންމެ ކައިރިގައި ހުރީ މިހުން ދިރިއުޅޭ ގެތަކެވެ. މިހެން މިކަން އޮތް ކަމުގައި ވިޔަސް ފެންޕްލާންޓް އެޅުމަށް ހުށަހެޅުނު ބިމުން އިތުރު ސަރަހައްދުތަކަށް ބަލައިލާ މިހާރު އެޅުމަށް ހުށަހެޅިފައިވާ ބިމަކީ ގޯތިތަކާއި އެންމެ އެކަށީގެންވާ ސަރަހައްދުކަމުގައި ފާހަގަކުރެވޭ. ފެންޕްލާންޓް އެޅުމަށް ހުށަހެޅިފައިވާ ބިން އާބާދީގެ ބޭރުކަނޑާ ދުރުގައި ކުރިއަށް ރަށުގެ މުދުލަތު އިތުރު އިސްކާރު ބަދަލުއެއް ހަރަކާތްތަކުން އިޖްތިމާއީ ގިނަ މައްސަލަތައް ހައްލު ކުރެވިގެން ދާނެއެވެ.

ތިމާވެއްޓަށް މަޝްރޫޢުގެ ސަބަބުން ކުރާނެ އަސަރު އަދި އަސަރުތައް ކުޑަކުރުމަށް އަޅާނެ ފިޔަވަޅު

މިފަދަ އެހެން މަޝްރޫޢު ތަކާ އެއްފަދައިން ހިނގައިފައިވާ މި މަޝްރޫއަކީ، އާދޭ ޗާޕެގައި ތިމާވެއްޓަށް ނުރައްކާ އަސަރުތަކެއް ކުރާނެ މަޝްރޫޢެއްކަމެވެ. ނަމަވެސް މިހެން އެއްވެސް އަސަރެއް އާދޭ ޗާޕެގައި އިމާރާތް ނުކުރެވޭނެ ފަދަ ބޮޑު ގެއްލުމެއް ލިބޭނެ އަސަރެއް ކަމަށް ފާހަގަ ކުރެވިފައެއް ނުވެއެވެ. މިގޮތުން ފާހަގަ ކުރެވޭ އަސަރުތަކުގެ ޚުލާސާ ތިރީގައި އެވަނީއެވެ.

އިމާރާތް ކުރުމުގެ މަރުޙަލާ:

ދިރާސާތަކުން ހާމަވާގޮތުގައި، މަސައްކަތުގެ މުހިން ރަނގަޅުގައި ގޮތް ވާގޮތް، ބިން ފާރަގަ ކުރުމާއި، ބިން ސާފު ކުރުމާއި، ސާމާނާއި ތަކެތި ގެންދެވޭ ގުދަންކުރުމުގެ ސަބަބުން ކަނި އުފެދުން ފަދަ އަސަރުތައް ކުރިން އެކަށީގެންވެއެވެ. ނަމަވެސް މި ގޮތުން ކުރެވޭ ކަމަށް ބެލޭ އަސަރުތަކަކީ ފާހަގަ ކުރެވޭ ވަރުގެ ބޮޑެތި އަސަރުތަކެއް ނޫނެވެ.

ފެންފޯރުކޮށް އިމާރާތްކުރުމުން ގެންދިއުން، އޮފީސް ކުންތާއި، އަޑުއި، ވައިބްރޭޝަން އަދި ބިމުން ފެން ބޭރުކުރުމުގެ ސަބަބުން ރަނގަޅީ ވެލިން ހޮޅިކަޑު ކަނޑު މަސައްކަތް ހިނގާ ހިސާބު ކައިރި ސަރަހައްދުތަކުގައި ދިރިއުޅޭ ރައްޔިތުންނަށް އަސަރުކުރާނެ ކަމަށް ބެލެވެއެވެ. މިއަސަރުތައް ކުޑަކުރުމުގެ ގޮތުން ރިޕޯޓުގައި ތަފްސީލުކޮށްފައިވާ ފިޔަވަޅުތައް އަޅާ މަސައްކަތުގެ ބޮޑުއިން އުޅޭ ކުނި ބޭރުގައި ގޮތް ވެސް ކުރެވޭ ސަރަހައްދުތަކުން ގެންދިއުން މިހެންނެވެ. ބޯހިޔާ ކުރުމަށް ބިމުން ފެން ބާލާ ފޯރުކޮށްދިނުމަށް ދެމެހެއްޓުމަށް އަޅާ ކުރުމުގެ ގޮތުން ގެންދިއުން ވަރަށް މުހިންމެވެ. މަޝްރޫޢު ހިންގާ ފެން މިނަން ބޯހިޔާ ނަރުދަމާ ނިޒާމު، ރަށުގެ ފެންފޯރުކުރުމާ އިތުރަށް ހަރުދަނާ ފުރުސަތު ލިބުމަށް ބޮޑު ފައިދާ ކުރާނެ ކަމަށް ފާހަގަ ކުރެވެއެވެ. މަޝްރޫއުގެ މުދަލުގައި ފާހަގަކުރެވޭ ގިނަ އަސަރުތަކަކީ ވަގުތީ އަސަރުތަކެކެވެ. ރިޕޯޓުގައި ބަޔާންކޮށްފައިވާ ގޮތަށް މަސައްކަތް ކުރުމުން ނުލުވާ އަސަރުތައް ފަސޭހައިން ކުޑަކުރެވޭނެއެވެ.

ހިންގުމުގެ މަރުޙަލާ

މިމަރުޙަލާގައި ހިމެނޭ ހަރަކާތްތަކުގެ ތެރެއިން ބޮޑަށް އިން ފެންނެގުމުގެ ސަބަބުން ބިމުގެ ފެންފަރާތަށް ނުރައްކާ އަސަރުތައް ކުރާނެ ކަމަށް ބެލޭ ފެނުގެ ތެރޭގައި އޮތް މިންވަރު އިތުރުވުމެވެ. 15 ކޯޓި މިނެޓުގެ ފެން އުފެއްދުމުގައި ބަހައްޓާ ޖެނެރޭޓަރ 86 ކޭވީ މިނެޓުގެ ފެން ބޭނުންވާނެއެވެ. ބިމުގެ މިޔާ ފެން ފަރަތަށް މިފެން ޖަނަރޭޓަރ ފޯރުކޮށްދެނީ ކޮށްގެން ހިމެނޭނެއެވެ. ރިޕޯޓުގައި ބަޔާންކޮށްފައިވާ ގޮތަށް ބޮޑު ބޯހިޔާ ތަނުގައި، 30 މިނެޓު އަޑިން ފެނުގެ ޖަހަށް ގުޅުވައިގެން، ރިޕޯޓުގައި ބަޔާންކުރާ އިތުރު ޖިނސް ކެމިކަލް ބޭނުންކުރުމާ ހިސާބުން ރަނގަޅު ކުރުމުން ކުރިމަތިވާ ބިމުގެ ފެނުގެ ފެން ޖަމާކުރެވޭ ކުރުމުގެ ސަބަބުން، ކުރިމަތިވާނެ ގެއްލުމަކުން ސަލާމަތް ކުރެވޭނެއެވެ.

މިމަރުޙަލާގައި ޖެނެރޭޓަރުން އުފެދޭ ދުން ދުމާއި ބޯހިޔާކުރުމުގެ ސަބަބުން ދުން ބޭރުކުރާ ސަރަހައްދަށް އަސަރު ކުރާނެ ކަމަށް ބެލެވެއެވެ. ނަމަވެސް ރިޕޯޓުގައި ފާހަގަ ކުރެވިފައިވާ ސަރަހައްދުގައިހުރި ގުޅުވައިގެން ޖެނެރޭޓަރުން ބޮޑުވާ ދުމުގެ ސަބަބުން ތިމާވެއްޓަށް ކޮންމެހެން ބުރަ އަސަރުތަކެއް ކުރާނެ ކަމަށް ނުބެލެވެއެވެ. މިސަރަހައްދަކީ ސްކޫލް، ދިރިއުޅޭ ސަރަހައްދު ފަދަ ސަރަހައްދުތަކުން ދުރުގައި ހުރި ތަނެކެވެ. މިގެ އިތުރުން ހޮސްޕިޓަލް ފަދަ ސަރަހައްދުތަކުން ދުރުގައި، ސަބަބަކީ ރިޕޯޓުގައި ފާހަގަ ކުރެވިފައިވާ ފަދައިން ދިރިއުޅޭ ގޮތްގޮތުގައި ކާނާ ބޯހިޔާ، ފަރުބަދަތަކާއި، ފެންބޯ ތަކެތި ދިރުމުގައި އެއްބާރުލުންދޭ ބަދަލު ފޯރުކޮށްދޭ ގެއްލުމެއް ކުރިމަތިވާނެއެވެ.

ހިންގުމުގެ މަރުހަލާގައި ރަނގަޅު ގޮތުގައި ބެލެހެއްޓުމަކީ އެކަށީ ހިންގުމުގެ ޕްރޮޖެކްޓް ނިމުނުމަށް ޕްރޮޖެކްޓްގެ އޮޕަރޭޝަން ނުކުރެވިދާނެވެ
ރިސްކު ބޮޑު މަރުހަލާއެއްކަން ވެސް ފާހަގަ ކުރެވިފައި ވެއެވެ. މިކަމުގެ ސަބަބުން އިމާރާތާއި ގޮންޖެހުން އިޖްތިމާއީ ގޮތުން
އިތުރު ނޭދެވޭ އަސަރުތަކެއްކަމަށް ފާހަގަކުރެވޭ ކަމަށް ބެލެވެއެވެ. ހިންގުމުގެ މަރުހަލާގައި ދުން އަސަރުތަކެއް ކުރާނެ ކަމަށް ބެލެވެނީ
ސައިންޓިފިކް މަސައްކަތް ކުރާ މީހުންނާއި ކައިރިގައި ދިރިއުޅޭ މީހުންނަށް. މިގޮތުން އެކްސްޕޯޝަރ ކުރިމަތި ވެއްޖެނަމަ
މަސައްކަތް ކުރާ މީހުންނަށް ލިބިދާނެ ގެއްލުންތައް، އަދި ސަބަބުން ކައިރި ސަރަހައްދުތަކުގައި ދިރިއުޅޭ މީހުންނަށް ކުރިމަތިވެދާނެ
ހާނިއްކަތަށް ހިމެނެއެވެ. ވ.ގަވާއިދާއި ކ.ގަފަރުގައި ޕްރޮޖެކްޓް އެޅުމަށް ބޭނުންވާ ރަނގަޅު އިންޖީނުގެ ކައިރިގައެވެ. މިއާ،
މިދަރަނިގައި ޕްރޮޖެކްޓްގައި އެކްސްޕޯޝަރ ހިމެނޭ ފެންސަރު ބޭނުމަށް ވަކި ފާހަގަ ކުރެވިފައެވެ. މިގެ އިތުރުން
އިންޖީނުގެ ސަބަބުން ޕްރޮޖެކްޓަށް ގެނަޑުވީގެ އަސަރު ކޮންމެ ކަމަށް ބެލެވެއެވެ. މި އަސަރުތައް ކުޑަ ކުރުމަށްޓަކައި
ޕްރޮޖެކްޓް ހިންގާނެ ޕްރޮފައިލް ތަޔާރުކުރެ ކޮން އެ ޕްރޮޖެކްޓް އާ އެއްބަޔަކު ހިންގުން މުހިންމެވެ. އަދި ހިންގުމުގެ މަރުހަލާގައި
ރިވާރސް އޮސްމޯސިސް ގޮތުން އެފްލުއެންޓް ތަކުގެ ވާރދާލުކުރުން، އިންޖީނުގެ ސަބަބުން ވ.ގަވާއިދާއި، ވ.ގަވާއިދާ އަދި
ޕްރޮޖެކްޓް ކުރާ ގެނަޑުވީގެ އަސަރު ދެރަކަށް ފުރިހަމަ ކުރުމުގެ ހިންގުން މުހިންމެވެ. އަދި ހުރިހާ ފެން ޕްރޮޖެކްޓްގައި ސަލާމަތީ
ފެނަވަރުތައް އިތުރު ކުރުމުން ރިވާރސް އޮސްމޯސިސްގެ ބޭނުމާއި ވަސީލަތް. މިގެ، އިތުރުން ވ. ގަވާއިދާ ބ.ކެންދޫގައި ޕްރޮޖެކްޓް
ހިންގާއިރު ޕްރޮޖެކްޓްގެ އެވެރޭޖް ކުރިމަތިވާ ރިވާރސް އޮސްމޯސިސް ފާހަގަކުރެވޭ އެކަމާ ގުޅުން ކުރުން މުހިންމެވެ.
ޕްރޮޖެކްޓް ހިންގުމުގެ ބޭނުންވާ ހަރަކާތްގެ ސަބަބުން މާޙައުލަށް ބަދަލު އަރާނެ ގޮތްތަކާއި ގޮތް ޖެހުމަށް ބެލެވުން އިތުރުވާނެއެވެ.
އެހެން ކަމުން ޕްރޮޖެކްޓް ހިންގުމަށް ބޭނުންވާ ހަރަކާ އަދިން އެފެއްދުމަކީ މުހިންމު ކަމެކެވެ.

ޖުމްލަ ގޮތެއްގައި މި މަރުހަލާގައި، ފެން ސަޕްލައި ކުރުމުގެ ސަބަބުން މީހާޔަށް ގެނެވޭ ބަދަލުތައް ޖާގަ ފަހަރު ފާހަގަ
ކުރެވުނަ ހުރި އަސަރުތަކެއް ކަމަށް ބެލެވެއެވެ.

ރިވާރސްއޮސްމޯސިސް ގޮތުގެ މަރުން މަޝްރޫއު ހިންގައިފިނަމަ ނޭދެވޭ އަސަރުތަކަށް ކުޑަ ކުރުވި ހަރުދަނާކުރުވަނީއެވެ. މިރިވާރސްއޮސްމޯސިސް
ގޮތުގެ މަރުން ކަން ކުރުމަށް މަޝްރޫއުގެ ވެރިފަރާތުން އެއްބަސްވެއެވެ. އެކަމުގެ ކާރުންތަކަށް ތިރީން ރިވާރސްގައި
ހުސްދަށް ފާހަގަކުރެވެ. ކަނޑައެޅިފައިވާ އުސޫލުތަކާއި އެއްގޮތަށް މަޝްރޫއު ހިންގުމަށްފަހު، މަޝްރޫއުގެ ސަބަބުން ގިނަ އިޖްތިމާއީ
އަދި އިޤްތިޞާދީ ފައިދާތައް ހަރު ފޯރުވަދީގައި، ޕްރޮޖެކްޓް ކަންތައް މެދުވެރިވާ ފާހަގަ ކުރެވިފައިވާނެއެވެ.

ނިންމުން

މަޝްރޫއުގެ ސަބަބުން އާދައިގެ ހާލަތު މާހައުލުގެ ނުރައްކާތެރިކަން ކަމަށް ފާހަގަކުރެވިފައިވާއިރު، އަދި ސަރަހައްދު ގޮތުން ނުލިބޭ
މޮނިޓަރިންގް ހިންގުމަކީ މަރުހަލާއެއް ނިސްބަތުން ފައިދާ ކުރާނެ ނުރައްކާ ނެތްކަމެއް، ޕްރޮޖެކްޓް ވިޔަފާރިން ހިންގުމުގެ ސަބަބުން ނުކުނެން
ކުރާނީ މައުސޫލިއްޔަތު ގަދަ ކުރުމަށް ތިމާވެށީގެ ކިބައިގެ ހިފެހެއްޓުމަށް މާރަ ބިނާކުރުން އެކަށީގެން ކުރަނާކުރުން ހާސިލްކުރުން ބޭނުންވާ
މައުސަލަތަކެއް ކަމަށް ފެނިފައި، ރިވާރސް ފާހަގަ ކުރެވިފައި ވާތީ ކުރިއަށް ކުރީގެ ހިންގުމުގެ ހަރަކާތުގެ އެހެނިހެން މަޝްރޫއު
ކުރިއަށް ގެންދިޔުމަށް ހުއްދަ ދިނުމަށް ނިންމާލެވިފައެވެ.

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NON-TECHNICAL SUMMARY

Introduction

This Report highlights the results of the Environmental Impact Assessment (EIA) carried out for the Development of RO plant in K. Gaafaru, L. Gan and B. Kendhoo proposed by the Ministry of Environment and Energy (MEE).

EIA Objectives

Since the proposed project in the above mentioned islands involve construction of RO plant that exceeds 10-ton daily production capacity preparation of an EIA was commissioned by the EPA as per the EIA Regulation 2012/R-27 **Annex 4**. Hence the EIA report is primarily aimed at capturing and presenting information needed to meet the legal requirements of both Environmental Protection and Preservation Act (4/93) and the Environmental Impact Assessment Regulations of the Maldives.

Project Justification

Site investigations done at K. Gaafaru, L. Gan and B. Kendhoo revealed that availability of freshwater during the northeast monsoon was extremely challenging. During these times, people relied heavily on bottled water which is expensive and subject to availability depending on natural and manmade circumstances since bottled water is not manufactured within the islands and are transported from Male'. Due to transportation and handling costs bottled water tends to be very expensive. All islands reported cases of recurring water shortages due to lack of rainfall and groundwater contamination, which at the time of investigations are largely associated to odour and coliform. Water shortages in these islands have resulted in poor economic growth and low quality of life. In order to address the increasing water shortage reported by Maldivian islands the government have formulated plans to enhance water security and build resilience in the face of climate change to better equip local islands with the means to flourish and adapt.

The project aims to supply water communally at times of need and sell water commercially to local enterprises. The government views establishment of the RO plant as a stepping stone to supply water to individual households 24hrs in the future.

Project Description

The project consists of the establishment of RO plant (30-ton production capacity and 50-ton storage capacity. 100-ton storage capacity in the case of L. Gan), harbour kiosk and tap bay. The system will only provide supply water to the public in times of need, however it is equipped to commercially sell water at the harbour to meet the needs of commercial activities and provide income required to operate the facility and supply water to the public on a need basis.

The major components of the project include:

1. Land allocation and clearance;
2. Construction of the plant house;
3. Installing RO plant, intake and outfall;
4. Operation of RO plant; and
5. Monitoring and adaptation of RO plant.

Components one and two of the project will be undertaken by MEE. Components three and four is planned to be assigned to the existing utility service provider in the island.

Relevant Rules and Regulations

The project has been designed to align with all applicable laws and regulation as detailed in **Section 3** of the report.

Existing Environment of Project Sites

The following observations and findings were made for the project island based on field surveys and data analysis:

K. Gaafaru – The Island mainly uses bottled water and rainwater to meet daily needs. The dry season does cause a depletion in rainwater stock which is why most of the households had increased rainwater storage capacity. The proposed RO plant plot is located on the northern side of the island and does not contain any vegetation. Nearest infrastructure to the site are powerhouse, court and households. There were no environmentally sensitive or protected sites close to the proposed area. The island does not have a viable alternative location to construct the RO plant. The proposed outfall location at the northern lagoon area was identified to be unsuitable in case of future land reclamation. An alternative location towards the west was determined to be more preferred. The proposed harbor kiosk location was determined to be located near the old harbor which has been reclaimed. Hence an alternative location for the harbour kiosk has been proposed close to the new harbour. Impacts arising from brine discharge are anticipated to be minor, as the lagoon was significantly dynamic which would aid in rapid diffusion and did not contain a live coral cover. Noise pollution and dust pollution from adjacent powerhouse was identified to be notable impacts at K. Gaafaru. Major risks during operational pahse had been identified such as development of communal water supply scheme and maintenance of RO plant.

L. Gan – The Island mainly uses bottled water and rainwater to meet daily needs. The dry season does cause a depletion in rainwater stock which is why most of the households had increased rainwater storage capacity and installed communal water storage tanks. The proposed RO plant plot is located on adjacent to the *Thundi* powerhouse. Nearest infrastructure to the site is the powerhouse. There were no environmentally sensitive or protected sites close to the proposed area. An alternative location to establish the powerhouse was identified to the south. The proposed outfall location was to the western lagoon. The proposed singular tap bay and harbour kiosk was identified to be inadequate for the whole island. Mainly because of the significant distances between different wards of the island and RO plant. Impacts arising from brine discharge are anticipated to be minor, as the western lagoon was significantly dynamic which would aid in rapid diffusion. Moreover, the area did not contain a high percentage of coral cover. Dust pollution from adjacent powerhouse was identified to be notable impacts at L. Gan. Noise pollution was minor since residential areas were not located close to the RO plant. Major risks during operational had been identified such as development of communal water supply scheme and maintenance of RO plant.

B. Kendhoo - The Island mainly uses bottled water and rainwater to meet daily needs. The dry season does cause a depletion in rainwater stock. The proposed RO plant plot is located on the far south. Nearest infrastructure to the site are residential areas. There were no environmentally sensitive or protected sites close to the proposed area. An alternative location to establish the powerhouse was east of the proposed plot. Comparisons revealed that proposed plot and outfall was more favorable. The proposed outfall was located towards the southern reef edge. The proposed singular tap bay was identified to be located at an area that is not easily accessible to the public. Hence an additional tap bay is proposed to be installed in the middle of the island. Impacts arising from brine discharge are anticipated to be minor, as the southern side of the island was significantly dynamic which would aid in rapid diffusion. Noise pollution was identified to be significant due to RO plants close proximity to residential areas. Major risks during operational had been identified such as development of communal water supply scheme and maintenance of RO plant.

Impacts and Mitigation Measures

Major findings of this report are based on as much information as possible that could be gathered within the study time constraints, including field inspection of both the existing environment assessments and the features and possible effects of the planned activities. The assessment also included reviewing of virtually the same types of works and methods that will be used at project islands and review of actual effects arising from their construction and operation in very similar island environments. Stakeholder consultations were also relied upon when proposing impact mitigation measures.

The assessment also identified significant gaps in impact assessment due to lack of data and case studies relevant to the Maldives. (See **Section 1.5.7** for details). These gaps made determination of cumulative impacts difficult as a result of increasing water production and installation of more RO plants in the Maldives (See **Section 9.5** for details). Overall a precautionary approach was undertaken to address these limitations when assessing impact of the project.

The following activities of the project were identified to have impacts on the environment.

Construction phase:

1. <u>Settlement of workers:</u> evaluated to have a minor negative impact as approximately 10 workers will be accommodated in local lodging and will only be based until the project is completed;
2. <u>Site demarcation and fencing</u>: evaluated to have a minor negative impact as site has already been cleared in all three islands;
3. <u>Material storage</u>: evaluated to have a minor negative impact as all materials can be safely stored at project area in each island;
4. <u>Land clearance:</u> evaluated to have a minor negative impact as no large trees have been identified for clearance. Yard waste generated from clearing underbrush shall be managed as detailed in **Section 2.9**;
5. <u>RO Plant construction:</u> evaluated to have a major negative impact. These include impacts of construction noise, vibrations and construction waste generation. Borehole construction may have impacts on groundwater during dewatering. Although these impacts are identified to be significant they are reversible short term impacts. Management of waste, proper planning, monitoring and implementation of safety measures as described in the report will lower and prevent negative impacts (See **Section 9.3.5**) ;
6. <u>Transportation of materials, waste etc:</u> evaluated to have a moderate negative impact as waste cannot be managed at any of the project islands, they will have to be transported. Similarly, most of the materials will have to be transported over a long distance which

would result in notable impacts. These impacts are short term and reversible. They can be easily managed by following mitigation measures proposed by following general mitigation measures proposed in **Section 9.3.6**;

7. Resource consumption (Waster, Electricity and Sewerage): evaluated to have a minor impact. The project does not involve heavy resource consumption and will be completed within 66 days. Impacts associated with this activity are short term and reversible. They can be easily managed by following mitigation measures proposed by following general mitigation measures proposed in **Section 9.3.7**;

Operational phase:

1. Water production: Evaluated to have a moderate negative impact. The potential for groundwater impacts as a result of this activity is high. If borehole is not installed at the sufficient depth with appropriate water quality. Feed water intake could deplete the islands groundwater lens. Noise generated during water production could affect the public in B. Kendhoo and K. Gaafaru where the plant is located close to residential areas. Moreover, due to the close proximity of the plant to the powerhouse, in K. Gaafaru and L. Gan risk of accidents and impacts of dust fall will be notable on the plant. This activity also has the highest risk of failure due to equipment malfunction and poor management of the RO plant. Another risk of this activity includes poor quality of product water which can cause health impacts. These impacts can be effectively reduced by ensuring borehole depth exceeds 30 m and by testing water quality prior to feed water intake as suggested in the report. Noise impacts can be controlled by ensuring noise cancellation measures are implement and by monitoring noise levels during operation and taking necessary measures based on finding as described in Section **9.4.1** and **10**. Operational glitches can be prevented by ensuring a detailed operational manual is prepared and followed. Accidents and dust pollution shall be prevented by increasing safety measures and undertaking monitoring and management as proposed in Section **9.4.1, 10** and**2.1**. Health impacts shall be prevented by ensuring product water meets WHO and local guidelines on drinking water which has been detailed in the report.
2. Water disinfection and testing: Evaluated to have minor positive impact
3. Brine discharge: Evaluated to have a moderate negative impact as increase in salinity levels have been identified to have various impacts on marine life. However, these impacts can be significantly mitigated by installing the outfall pipe in areas that have low marine life, with sufficient dynamics to facilitate diffusion. It has to be noted that long term impacts associated with brine discharge have not been studied in detail hence extent of impacts can only be confirmed by undertaking monitoring as described in **Section 10**.
4. Communal water supply: Evaluated to have a minor positive impact. However, it is recommended to install additional tap bays in L. Gan to increase accessibility to fresh water and relocate or add an additional tap bay in B. Kendhoo to enhance positive aspect of this activity.
5. Commercial water supply: Evaluated to have minor positive impact. In order to enhance the positive impact it is recommended to relocate harbour kiosk in K. Gaafaru to the location detailed in **Section 4.**

6. Resource consumption: Evaluated to have a moderate negative impact as GHG and wastes will be produced. The impact would also depend on monthly water production; hence impacts will be cumulative. Since, water production is energy intensive, it is proposed to install solar panels as a renewable source of energy to offset demand on mains electricity and reduce environmental impacts. It will also enhance energy security of the RO plant incase mains electricity malfunctions as observed frequently in project islands. Proper waste management, planning and energy conserving measures will reduce these impacts. (See **Section 9.4.6** for details).

The monitoring plan of the project is designed to address the constructional and operational phase impacts by identifying assessable indicators and assigning relevant stakeholders to prepare and assess the outcome of these indicators. The management plan of the WSS is designed based on adaptability from feedback provided by different levels of management. This is to ensure that cumulative negative impacts do not exceed to a level that could disrupt the proposed WSS system.

Conclusion

On the basis that mitigation measures proposed in this EIA report will be implemented by proponent and the robust environmental monitoring plan suggested in the report will be fully taken into consideration and the recommendations set forth in the report will be duly considered, it is concluded that the benefits of the planned Water Supply Project when implemented will substantially outweigh its imposition on the environment.

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1. INTRODUCTION

1.1 PROJECT BACKGROUND

Under the "Provision of Water Supply, Sanitation and Solid Waste Management Project" financed by the OPEC Fund for International Development (OFID) and facilitated by the Ministry of Environment and Energy, Maldives (MEE), establishment of Water Supply Systems have been proposed for twelve (12) islands in various atolls. The proposed system will be constructed by contractors procured by MEE locally.

The completion of the proposed project will result in the establishment of a:

1) Desalination plant where saltwater sourced from ground through a borehole will be purified into clean drinking water;
2) A tap bay at the RO plant site to provide water for the general public under a social scheme pre-determined by MEE and service provider; and
3) A water supply kiosk at the harbour in each island which can be used commercially, generating an income from the water supply system.

The objective of the project **'is to enhance water security of islands identified to have extremely vulnerable freshwater resources, by providing water to the public at no cost under a predetermined plan, and to lay the foundations for a future tariffed water supply system throughout the islands with individual house connections making desalinated water the primary source of freshwater available these islands'**.

Operation of the RO plant is mainly aimed at enhancing the islands water security until a proper house-connected water supply system is developed, which would further increase clean water accessibility. In this regard, the initial design of the system involves a much lower storage and production capacity with the potential to increase production and storage in the future.

At present natural freshwater resources of these islands have either been polluted by poor sewage management or have been salinized due to over consumption in combination with environmental factors such as poor rainfall and seawater inundation.
Lack of rainfall in combination with inland flooding initiated by swell waves makes availability of clean drinking water challenging in the islands.

The project also aims to meet UN's sustainability goals specifically, access to clean water and sanitation, good health and wellbeing to make sure all of civil life is hygienic. In addition, the project aims to ensure that all Maldivians understand the importance of water conservation and create awareness with regard to water security and develop society through awareness so that it strives to protect and manage the natural resources sustainably.

Prior to construction of the water supply system, preliminary studies such as site selection/approval and environmental impact assessments have to be completed. In order to streamline the process of pre-construction preliminary studies MEE separated the islands into three packages as follows before procuring parties to prepare the EIA.

Package I

i. Hdh. Nellaidhoo
ii. Hdh. Kumundhoo
iii. Hdh. Makunudhoo
iv. Hdh. Vaikaradhoo
v. Hdh. Nolhivaramu

Package II

i. N. Holhudhoo
ii. N. Maafaru
iii. R. Maakurathu
iv. R. Inguraidhoo

Package III

i. K. Gaafaru
ii. L. Gan
iii. B. Kendhoo

The scope of this EIA report includes identification of construction and operational phase impacts of the proposed water supply system in K. Gaafaru, L. Gan and B. Kendhoo (Package III).

Maldives Energy and Environmental Company (MEECO) who was contracted for the task after being the successful bidder, prepared this document in accordance with the EIA Regulation 2012 to obtain the required environmental clearance for the proposed construction of Water Supply System (WSS) with the Regulation enforced by Environmental Protection Agency (EPA). This EIA provides a focused assessment of the proposed WSS in terms of existing environmental conditions and potential environmental impacts on the island. It follows and addresses Terms of Reference (TOR) for the project which is attached in **Annex 2** of the report. The findings of this report are based on information collected from literature, qualitative/quantitative assessments of the project consultations with stakeholders, professional expertise and judgements. For detailed site investigation, a field visit was conducted to K. Gaafaru, L. Gan and B. Kendhoo from 24 August to 1 November 2017.

1.2 INTERPRETATION OF SPECIFIC TERMINOLOGY USED IN THE REPORT

Certain terms used in this report shall be interpreted in the context of the current project taking into account legal and administrative requirements for preparing the EIA report in the Maldives. The term Environment has been used in a broad context to include, natural environment, human environment, heritage, recreation and amenity assets and livelihood, lifestyle and well-being of those affected by the Project. Hence the term Environmental Impact Assessment (EIA) shall be taken synonymous to Environmental and Social Impact Assessment (ESIA).

Proponent in the document implies to the project owner MEE and Project Islands shall be interpreted as the islands included in Package III (B. Kendhoo, L. Gan and K. Gaafaru) unless specified. The term Project means ‘Development of water supply systems in project islands as specified in Section 1.1'. Water supply system (WSS) shall be interpreted as establishment of desalination plant, harbour kiosk, tap bay and their associated infrastructure as described in **Section 1.1** and **Section 2** of the report. Terms such as RO plant, facility are synonymous with the WSS and are used to describe all components of the project as described. The developer shall be interpreted as the company undertaking development works of the Project. Service provider shall be considered as utility or any other entity to whom operation of the RO plant is assigned by the proponent and is interchangeable with operator in the report.

The nearest waste management centre shall be interpreted as the nearest licenced operational waste management centre that accommodates waste from the project islands. At the time of preparing the report. Thilafushi was the nearest waste management centre hence it has been recommended in the report. The term service provider and utility provider shall be interpreted as the party or parties which will undertake the operations of the WSS. At the time of EIA, MEE had officially prescribed Fenaka to undertake the operations of the WSS.

1.3 THE PURPOSE OF THE EIA

Among modern environmental statutes Environmental Impact Assessment (EIA) laws crystallize a preventive approach to environmental protection, because they integrate environmental considerations in decision making processes. Generally, EIA laws require the preparation of an environmental impact assessment for any proposed development activity, to review and assess its environmental impacts. The requirement can be applicable to a broad array of actions, and may include issuance of a permit or prior authorization, the funding of a project, and the adoption of a new statute or policy. The environmental assessment may be required to identify appropriate mitigation measures, or alternatives to the proposed action, that minimize environmental impacts. The Government has thus given due diligence to the formulation of these statutes to regulate environment policies, laws and institutions to deal with all the environmental issues that the country is faced with.

This EIA report is primarily aimed at capturing and presenting information needed to meet the legal requirements of both Environmental Protection and Preservation Act (4/93) and the Environmental Impact Assessment Regulations of the Maldives.

The EIA Regulation 2012/R-27 of the Maldives states that projects carried out in the Maldives which require installation of desalination plants greater than 10-ton capacity, borehole drilling and outfall laying requires an Environmental Impact Assessment prior to its construction and operation. The details of the EIA procedure is stipulated in the EIA regulation 2012/R-27.

The proposed WSS project falls under the category of projects encompasses these activities and meets the EIA requirement of the EIA Regulation 2012/R-27. Hence this EIA is prepared to fulfil this legal requirement.

More specifically, this EIA focuses on the management of potential environmental and social impacts and risks of the proposed waste management project.
Four major objectives of the EIA are to:

- Identify and assess potential impacts or consequences of the project on the natural and human environment in the project area;
- propose measures to avoid or mitigate or control potential adverse impacts and risks and to enhance beneficial impacts;
- develop an environmental monitoring plan (EMP), where the proponent should adhere to during construction and operations of the said project; and
- enhancing sustainability of the project and to promote environmentally sound decision making.

1.4 THE EIA IMPLEMENTATION PROCESS

The EIA implementation process is explained in detail in the EIA Regulations. The process is summarised below in **Figure 1**.

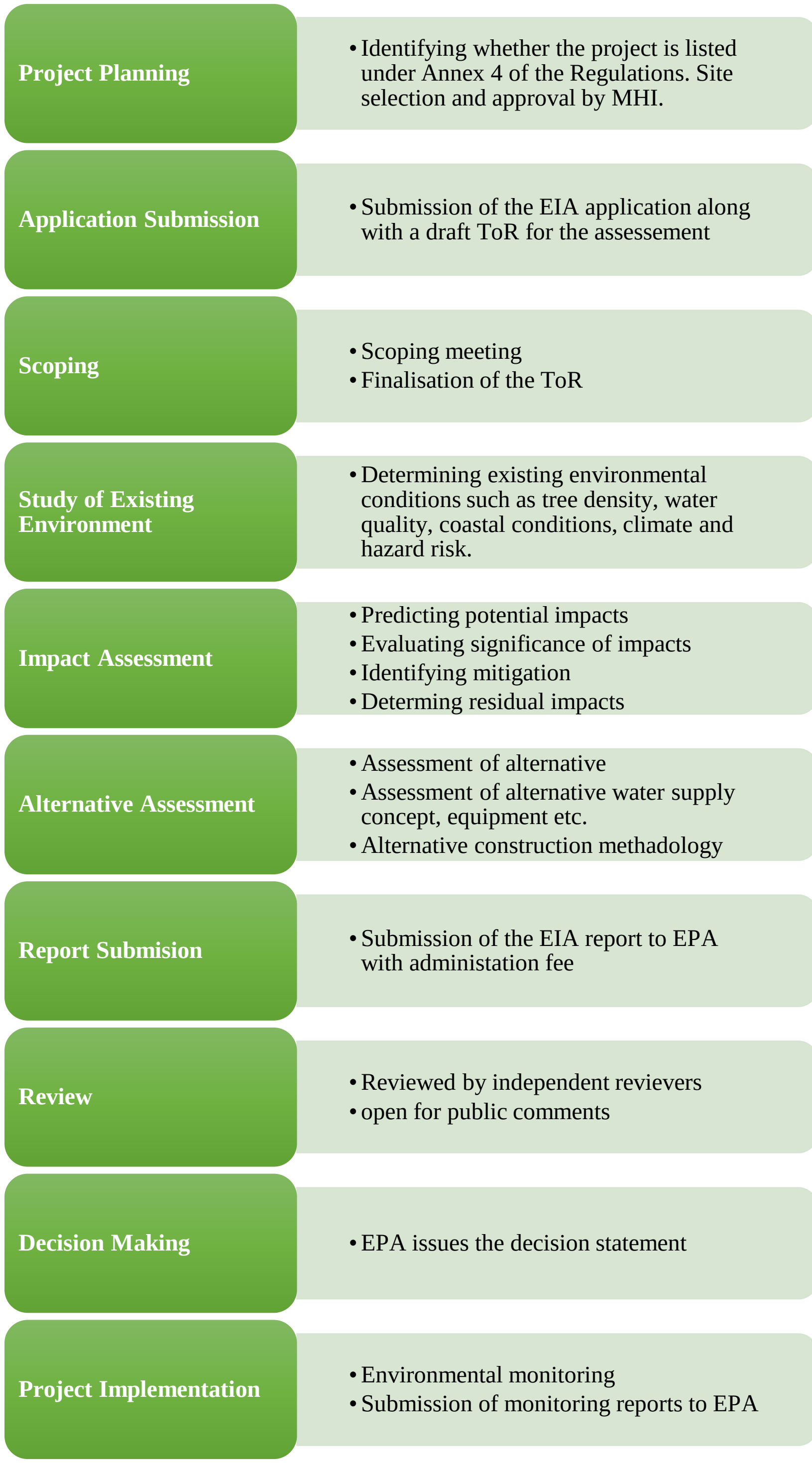


Figure 1: EIA implementation process

1.5 EIA APPROACH & METHODOLOGY

1.5.1 EIA Approach

The approach adapted for this EIA report is primarily aimed at capturing and presenting information needed to meeting the legal requirements of both Environmental Protection and Preservation Act (4/93) and the Environmental Impact Assessment Regulations of the Maldives.

The approach used in this EIA study involved systematically understanding and evaluating the project components and identifying their impacts (both positive and negative) on the bio-physical and socio-environment followed by determination of practical and sound mitigation measures. The EIA also identified and proposed appropriate monitoring mechanism to evaluate the effectiveness of the proposed mitigation measures and evaluates alternative approaches ranging from alternative project options to alternative work methods and designs.

Two most important aspects in impact prediction involved understanding in detail all aspects related to the proposed project, which include, project setting, design, development, operation, decommissioning and the characteristics of the natural and social environment of the project location. Once these have been achieved, it was followed by predicting potential impacts and evaluation of the impact characteristics to determine their significance using generally accepted methodologies. For the identified negative impacts, regardless of the significance level, practical cost effective mitigation measures have been proposed to avoid, or further minimise the negative effects.

1.5.2 Scoping and Terms of Reference

Scoping and finalising the Terms of Reference (ToR) was one of the very first steps in the initiation of the EIA process. The ToR initially drafted by the EIA team based on the experience gained from development projects of similar nature undertaken in the Maldives was submitted to EPA. Following submission of draft ToR and project summary the scoping meeting was held on 17^{th} October 2017 at EPA and attended by project environmental consultant, proponent, Island Council and MHI. Stakeholders present at the meeting discussed the ToR and suggestions were made to the ToR. These suggestions were then incorporated into the revised ToR which was submitted to EPA for final approval.

All issues identified in the ToR have been carefully considered in the relevant chapters of this report. The final ToR was shared on 19 October 2017 and is attached in **Annex 2.**

1.5.3 EIA Methodology

To effectively determine and evaluate the impacts the right mix of expertise in relevant disciplines were chosen. This was followed by a number of critical steps such as, defining the spatial boundary of the study area, identifying specific areas for detailed study to understand the sensitivities of the baseline environment. It also included, a number of specific stages in the preparation of the EIA characterisation of baseline environment, determining project sequence, activities and methodology, alternatives evaluation and review of relevant laws policies. The details of the various aspects involved in identifying impacts are explained in the following sub-sections.

A. ***Identifying Impacts and Analysis***

Impact definition used in the report has been adapted from the United Nations Environment Program (UNEP). Accordingly, an impact or effect used in the current assessment implies the change in an environmental parameter, which results from a particular activity or intervention relating to the proposed Project. Thus, the change or the impact is the difference between the environmental parameter with the Project compared without the Project (baseline) measured over a specified period and within the Project location (UNEP, 2002). In identifying and predicting impacts 'best estimates', past experiences, professional judgements, references, and information collected from stakeholder discussions were the main methods used.

As explained, understanding the baseline condition of the Project environment and determining the extent of an impact were critical initial steps in impacts. The overall methodology applied in studying the baseline conditions included collecting information from the field and review of available relevant literature including reports, other related studies, knowledge of the locals, method statement prepared the contractor and data source. In addition, information obtained from discussions with the stakeholders was also used to characterise specific aspects of the study area. Spatial extent of the affected area/study area was determined by relevant guidance obtained during the scoping meeting, discussions with the stakeholders and professional judgement of the consultant's team.

A modified Leopold Matrix (Leopold, et al., 1971) was applied to evaluate the impacts identified. The steps involved are briefly summarised below:

- Identification of all project related activities;
- identification of impacts associated with significant actions;
- the magnitude of the impact was then determined by assigning a number from 1 to 10 (1 is the minimum and 10 the maximum). This number is placed in the upper left hand corner in the corresponding box of the matrix, representing the scale of the action and its theoretical extent. a plus (+) was used for positive impacts and a minus (-) was used for negative impacts; in the lower right hand corner of each cell a number from 1 (least) to 10 (most) to indicate the importance of the impact was placed. it then gives an evaluation of the extent of the environmental impact according to the judgement of the EIA team; and
- the significance was then determined by the joint consideration of its magnitude and the importance (or value).

These two factors have been applied as per the definitions given below.

Importance

Relative importance of environmental impacts, have been characterised by considering the following;

- Duration over which the impact is likely to occur (temporary, short term, long term, permanent);
- timing or when the impact is likely to occur;
- spatial extent of the impact (such as on-site, local, regional, or national);
- frequency or how often the impact is predicted to occur;
- intensity (negligible, low, medium, high); and

- likelihood (certain, likely, unlikely, likely or very unlikely).

Magnitude

Magnitude of the impact was expressed in terms of relative severity, such as major, moderate or minor/negligible. In determining severity other aspects of impact magnitude, notably whether or not an impact is reversible and the likely rate of recovery were considered.

Hence, the following equation was used to determine the impact significance (UNEP, 2002).

$$Impact\ characteristics\ (magnitude)\ \times\ Importance\ (value) = Impact\ significance$$

The scores obtained for the magnitude of each of the impacts (both positive and negative) were categorised as given in **Table 1**. The method used in assessing significant impacts thoroughly addressed cases where magnitude and importance were not directly related. For instance, in cases where a regulatory clause specifically states a number or condition, the impact significance is greatly increased even though the magnitude of the activity is relatively small.

For example, removal of two coconut palm trees has a relatively minor impact on overall loss of vegetation from the island hence is classified as an activity having a relatively small magnitude, however if the regulation on uprooting palm trees states that removal of two coconut palm trees require approval from the regulatory body, the activity is considered to be very important. In such cases the impact has been classified as a significant major impact.

Hence the impact analysis approach used in the EIA report takes into account two important properties of an impact activity. Its magnitude and its relative importance based on local and national laws and regulations.

Table 1: Categorization of the significance

Total magnitude score	Category
> 40	Major positive
20 – 39	Moderate positive
1 – 19	Minor positive
0	Negligible
-1 – -19	Minor negative
-20 – 39	Moderate negative
< - 40	Major negative

Significance categories of negative impacts given in **Table 1** is defined as explained in **Table 2.**

Table 2: Impact characterization matrix

Significance	Characteristics	
Major	An impact of major significance is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. A goal of the EIA process is to get to a position where the Project does not have any major residual impacts that would endure into the long term or extend over a large area. Similarly a major impact may occur for activities which may have a small magnitude but are considered to be very important.	Requiring appropriate mitigation measures
Moderate	An impact of moderate significance is one within accepted limits or standards. The emphasis for moderate impacts is on demonstrating that the impact has been reduced to a level that is as low as reasonably practicable.	
Minor	An impact of minor significance is one where an effect will be experienced, but the impact magnitude is sufficiently small (with and without mitigation) and well within accepted standards, and/or the receptor is of low sensitivity/value.	

B. <u>Social Assessment</u>

The aim of the social assessment (SA) is to study the potential social and community benefits of proposed project. In recognition of this, the report includes aspects related to social inclusion and labour impacts. The specific objectives of the social assessment are to:

i. Identify major and minor stakeholders of the project;
ii. identify appropriate mechanisms for providing information about the project to all stakeholders;
iii. investigate the impacts to the stakeholders from the implementation of the project;
iv. understand the impacts of the project on the social and socio-economic profile of the island and region as a whole;
v. formulate mitigation and enhancing measures to optimise the benefits for the communities and limit the adverse effects; and
vi. monitor socio-economic impacts during implementation of the project.

C. <u>Cumulative Impacts</u>

Cumulative impacts which may be defined as impacts that result from incremental changes caused by other past, present or reasonably foreseeable activities as a result of the project are generally considered in EIA studies. The proposed approach for assessing cumulative impacts was to consider activities and receptors within the current scope of project that could have a potential negative cumulative impact during the construction and operational phase, in order to prevent it.

1.5.4 Impact Mitigation

Impact mitigation in the report refers to measures that are necessary to avoid, eliminate or reduce the negative effects of the project on the environment and enhance positive effects. The ToR for the EIA requires practical and appropriate mitigation measures for significant impacts identified to be proposed. For each identified significant negative impact in proposing mitigation measures the priority was given to avoidance of a predicted impact by taking measures such as bringing changes to the design and/or work methodology. In cases where avoidance of an impact was not possible practical and cost effective measures have been proposed to reduce the impacts and enhancing positive impacts. Practical experience and lessons learnt by the EIA team from projects of similar nature played a key role in proposing mitigation measures. Hence in interpreting the impacts and mitigation the document as a whole shall be taken into account rather than a particular section of the report. The proponent as part of this report has submitted a letter of commitment stating that all the mitigation measures proposed in the report will be implemented during all phases of the project. Hence the project will be implemented with full commitment of the proponent to undertake the mitigation measures to ensure environmental sustainability of the project.

It should also be noted that in addition to predicting impact of the project on the environment, the EIA regulations also require determining impacts of the environment on the project components for ensuring sustainability of the project. This aspect was well taken into account in the project formulation.

1.5.5 EIA Interpretation

The EIA encompasses three separate islands at which an identical project is to be implemented by a singular proponent. Although the project is identical, its settings, impacts and scale is not identical. Similarly, many components and materials used for the project will be identical. The EIA report takes these differences and similarities into account in its assessment. The EIA aims to propose site specific mitigation measures based on island specific surveys. It highlights potential impacts associated with similar activities based on literature review etc. and aims to quantify the extent of potential impacts based on site specific investigations and findings. It also aims to propose feasible mitigation measures to reduce or prevent these impacts which have been quantified based on project setting, existing environment and site conditions.

The EIA report distinguishes specific information with regard to project islands in the form of subheadings and site specific descriptions. Unless specified all other findings and measures proposed or described in the report shall be applied all three islands.

1.5.6 Gaps in Baseline Information

Availability of quality baseline data is an important element for any EIA study. Most of the baseline information of the existing environment for the project were collected on site and are based on actual topographical, marine and vegetation surveys. As a whole the study consisted of minor limitations in baseline information.

However certain baseline information is limited in the evaluation partly due to capacity constraints. For most of the sites, actual survey data was used to study existing site conditions at project sites and alternative sites of the three island including the marine outfall area. Hence, actual primary data were collected for the project islands with regard to terrestrial and marine environment. Geological parameters such as soil chemical composition, grain size distribution and soil hydro conductivity were referenced from lab analysis done on soil samples collected from similar islands in the Maldives. Due to the similar nature of geology and formation of islands in the Maldives, it was assumed that these results were representative of soil at project site. This represents a sufficiently conservative and cautious approach which takes account of the study limitations.

In contrast baseline information with regard to operational phase of RO plants are limited due to lack of published studies and monitoring reports prepared for similar projects. As such, gaps which exist with regard to baseline information of the operational phase of the project are notable. To address these gaps, the report relies on available similar published local EIA reports, international case studies and peer reviewed research.

1.5.7 Gaps in Understanding Impacts

Impact identification, characterization as well as significance analysis also involved uncertainties as ideally such an exercise should take place against a framework of criteria and measures established for the purpose in the relevant legislation which is not the case in the Maldives at present. Specified criteria necessary for impact evaluation such as environmental standards, baselines and thresholds are yet to develop in order to strengthen the EIA process in the country. In order to address these gaps, where impact magnitude cannot be predicted with certainty, professional experience and scientific literature was used and adapting criteria and measures from elsewhere that are relevant to local circumstances was used.

In relation to the project more specifically long-term impacts of borehole drilling have not been researched in detail. There have been cases recorded in the past where, insufficient borehole depth has led to the depletion of fresh groundwater lens and leading to social unrest.

Moreover, detailed studies including case studies to determine RO plants impacts on marine environment in the Maldives during operational phase are not available. Long term changes that occur in the lagoon benthic cover or the reef eco-system have not been studied or monitored for existing RO plants in the country. Similarly, vertical diffusion of brine discharged, into lagoons have not been determined. Literature available on surface concentration of salinity and temperature within a shallow outfall lagoon have been referenced in the EIA as part of the study. This is one of the only case studies available that provide actual data on lateral and surface concentration dynamics of salinity and temperature of discharged brine from the outfall point. However, the study is also limited in modelling vertical diffusion of high dense waster discharged, which creates uncertainty in understanding the decrease in surface salinity concentration. Such uncertainties can be addressed only by monitoring the biological parameters of the discharge location such as change in benthic cover and dominant species at the discharge location.

Another area of significance with regard to uncertainty is, classification and extent of cumulative impacts with regard to RO plant operation. Establishment of RO plants have become a common practice in the Maldives due to lack of natural freshwater reserves. Similarly, the proposed project is also a component of a nationwide scheme to install RO plants as detailed in **Section 1.1**. Although, impacts from individual RO plants at island levels are expected to be relatively small at the project level, cumulative impacts on the marine environment in the long-run are largely unknown as a result of brine discharged from RO plants installed in nearby islands, resorts, fishing vessels etc. Extent of cumulative impacts as a result of increasing number of desalination plants is yet to be studied.

In order to address these gaps, the report aims highlight existing gaps in assessing impacts. relevant studies and published papers have been extensively studies. Four case studies on monitoring marine impacts associated with brine discharge have been analysed (See **Section 9.4.3** & **1.5.8**).

Similar EIA reports have been reviewed. Activities of the project that could have cumulative impacts have been identified and strong recommendations have been given to undertake continuous monitoring as described in the report. Moreover, in cases where a greater degree of uncertainty is believed to exist, a precautionary approach had been adopted in which likely maximum impact was considered and the potential maximum impact was assigned.

1.5.8 Review of Similar Reports

EIA reports previously prepared for water supply projects was reviewed to address gaps of the study and to determine findings of similar assessments. A summary of reports reviewed for the study are detailed below describing the scope and mitigation measures proposed to reduce impacts.

Special attention was given source reports that characterised actual impacts of RO plant operational phase, as impacts resulting from brine discharge and diffusion lack detailed research.

<u>EIA for the Development of Commercial Mineral Water and Soft Drink Plant at K. Hinmafushi</u>
Saleem, A., (2003)

In order to meet the growing demand for water and soft drinks International Beverage Company Private Limited (IBPCL) developed a full-fledged facility to produce mineral water and soft drinks.
The key components of the developed infrastructure include:

- A 6000 liters per hour RO desalination plant;
- two water-storage tanks;
- seawater intake structure, including onshore pumps, fine screening and UV and ozone treatment units;
- dual seawater supply pipelines each 350.52m long, 4 inches in diameter;
- four seawater return discharge pipelines each 158.50m long, 4 inches in diameter;
- powerhouse with three diesel generators; one 400kVA, one 200kVA and one 100kVAproducing a total of 700kVA;
- in-house laboratory for conducting chemical and microbiological tests for the products;
- beverage processing facilities including refined sugar storage tank, sugar and syrup mixing tanks of capacity 800liters, syrup cooling units;
- filling machine and two blow moulding machines;
- CO_2 production unit;
- staff quarters;
- administration office; and
- sewerage disposal system.

Most of the water production components of the project were identical or similar to the proposed project. One of the main differences include feed water intake. The proposed project will rely on borehole while the reviewed project used seawater intake. Nevertheless, discharge of brine through outfall was the most significant component of the reviewed project that is utilised to quantify and determine impacts associated with discharge during operational phase. Since actual water quality was measured during the operational phase of Hinmafushi water production plant, the uncertainties associated with discharge impacts of the current project was significantly reduced.

Increase in salinity and temperature was determined to be the most significant impacts arising as a result of discharging brine. **Table 3** below shows the difference water quality parameters between feed seawater, discharge water and ambient seawater. The results showed that salinity increased by 26% while temperature increase in the receiving water body was minor.

Table 3: Water quality difference between feed water, discharge water and ambient seawater.

Parameter	Seawater inflow	Final discharge 1st phase	Ambient seawater values	Remarks
Flow (L/d)	-	-	-	rate remains constant
Physical appearance	clear	clear	clear	-
Temperature (°C) at intake	31.5	33	20-24	1.5 degrees above the intake water temperature
pH	~7.5	~7.1	~8	pH slightly increased
Electrical conductivity(µs/cm)	50900	51400		electrical conductivity increased due to increased solids
Total dissolved solids (mg/L)	27400	28000	35900	-
Suspended solids (mg/L)	0	0	n/a	-
Salinity (mg/L)	33600	45800	35000	salinity increased by ~26%

In order to quantify the impacts on marine environment as a result of brine discharge, the study measured salinity and temperature up to a distance of 30 m from the discharge point. The discharge point was located very close to the shore in the shallow lagoon as illustrated in **Figure 2.**

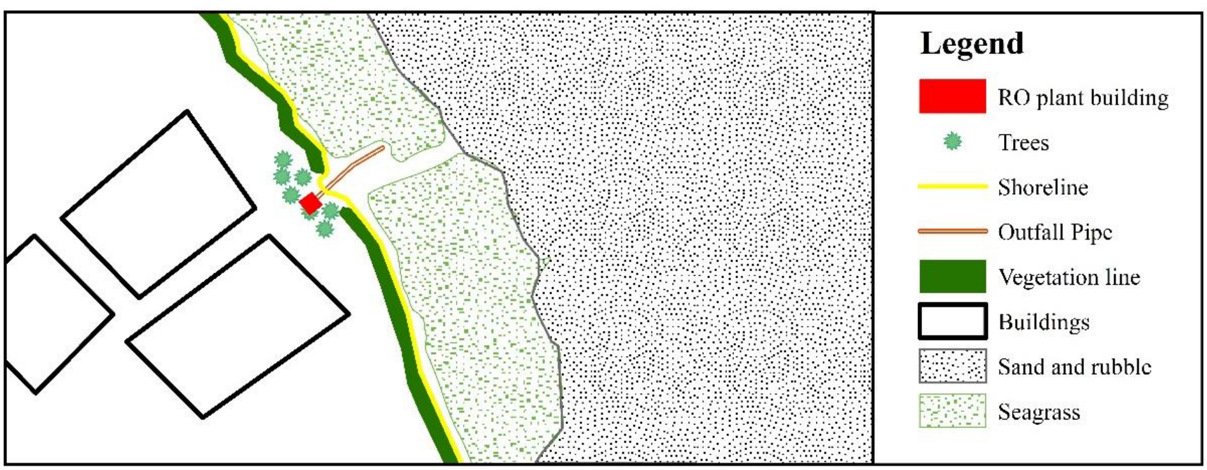


Figure 2: Himmafushi RO plant outfall pipe (dark blue). Located in shallow lagoon. Source: (Saleem, 2003)

The variation in salinity with regard to distance and direction are shown in graphs below.

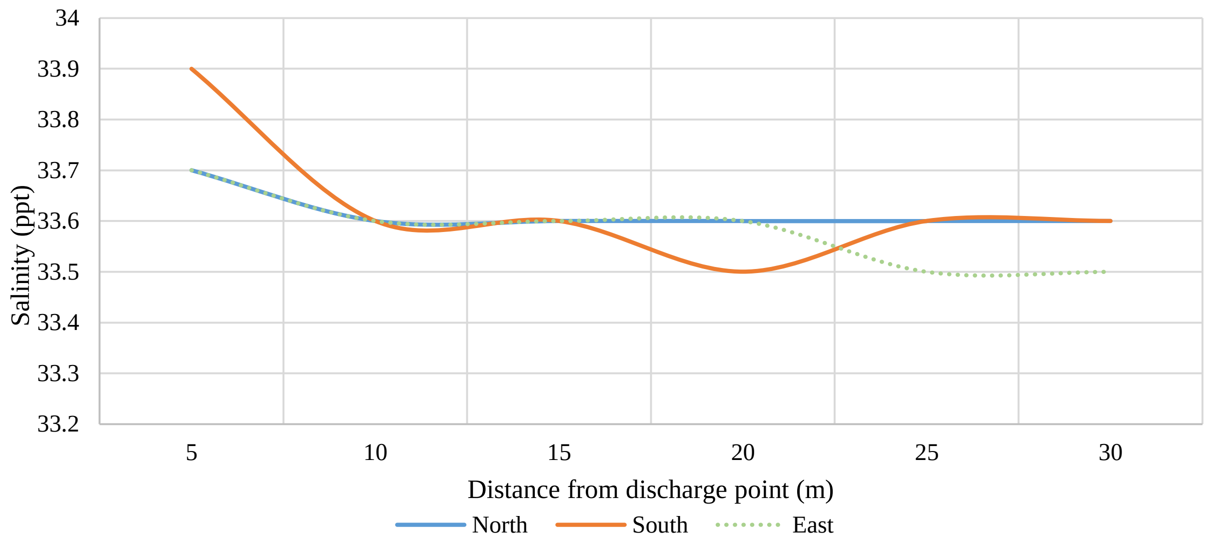


Figure 3: Variation in salinity concentration in the north, south and east directions from the outfall pipe. Source: (Saleem, 2003)

The temperature of the discharge water was found to be 33^{o}C. While the average temperature of the lagoon at the time of investigation was 31.5^{o}C, the temperature of water at the point of contact with the sea was found to be 32^{o}C. The average temperature was achieved at a distance of about 15m from the source point.

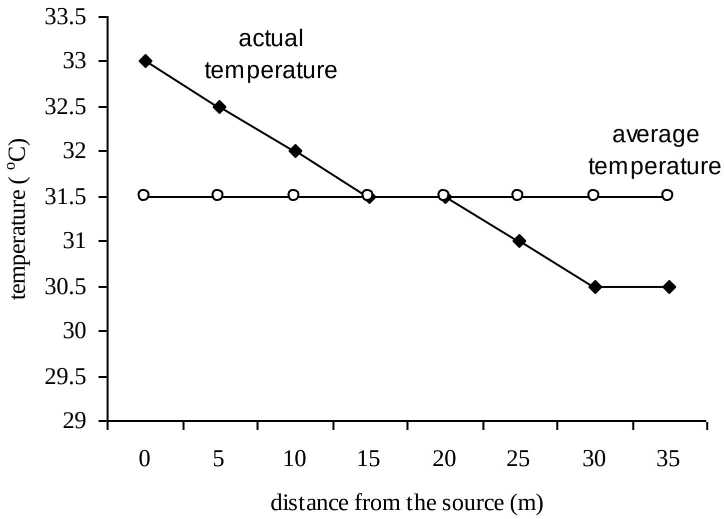


Figure 4: Variation of temperature away from the discharge point. Source: (Saleem, 2003)

In summary the study showed that:

- even in shallow and calm areas of the lagoon salinity and temperature equilibrated extremely quickly and normalised within 10 m from the outfall pipe;
- impacts to marine environment as a result of brine discharge was determined to minor; and
- minor longshore current and tidal changes resulted in rapid diffusion of salinity.

EIA for the Proposed Water Production & Distribution Facility at Th. Guraidhoo
Zuhair, M. & Abdul Fathah, M. S., (2016)

The EIA was conducted for the project proposed by MEE for the water production and distribution facility at Th. Guraidhoo. This project involves production, storage and distribution of desalinated groundwater to households of Th. Guraidhoo. According to the report, the groundwater of the island is heavily utilized, and a lack of a central sewerage system has contaminated the groundwater of the islands. This highlights the need for the project in the island.

The project includes the construction of an RO plant building, drilling of borehole and laying of distribution network and fire hydrant system. The system is also supplemented with rainwater harvested from public roofs. A main storage tank of capacity 500 m^3 and an overhead tank of 150 m^3.

Impacts of the project were identified for both construction and operational phase impacts. These impacts include construction impacts such as water quality impacts from excavation for trenches, foundation, dewatering and construction of borehole. Marine environment impacts were identified for brine discharge pipe laying activities.

Operational impacts identified include noise pollution from operation of engines, marine environment impacts from brine discharge and impacts from product water quality. Positive impact was identified for the social wellbeing attained from access to clean water and improved health. Of these impacts, it was identified that borehole drilling, laying of outfall pipe had major consequences on water quality and marine environment with significant risks while operation of diesel generators, and noise pollution due to operation of heavy machinery were identified to have moderate consequences with high risk.

Alternatives were presented for available source of raw water intake, for which the two options were intake from bore wells 30 m deep at a site near the desalination plant or seawater intake from the lagoon of the island. The option of bore wells was presented as preferred, citing the better quality due to being less vulnerable to contamination from fouling organism and marine debris. It was also noted that with option 2, a settling tank would be required due to suspension of solids, which would ultimately lead to an increase in project cost.

Fourth Addendum for the Environmental Impact Assessment Report for the Reclamation and Expansion at Ibrahim Nasir International Airport *Zahir, H. & Abdulla, A. (2016)*

This EIA addendum consists of – construction of temporary water production facility including an RO plant. This RO plant has a capacity of 250 ton/day, and the plant consists of settlement tanks, 2 water storage tanks of 500 tons each, a brine discharge line and a pipeline connecting the facility to the existing MACL grid. Two boreholes will be constructed for the plant.

Impacts were identified through interviews, field data collection, surveys, and past experiences. Impacts identified for the construction phase include:

- Groundwater contamination / salinization due to extraction of groundwater during and after drilling to clear out chemicals used during the drilling process as a hardening agent for the walls of the borehole. This is foreseen to be minor;
- Groundwater contamination due to leakage of drill slurry from the slurry collection pits; and
- Extraction of groundwater during operation phase which is foreseen to be insignificant due to moderate drilling rates.

Mitigation methods provided for the identified impacts include:

- Choosing a method of drilling that has the least impact on the environment

Proposed alternatives to feed water source were two boreholes or a seawater pipeline from the eastern side reef. Preferred alternative was two boreholes due to possible damage to pipeline from environmental factors such as swell waves approaching from the eastern side as well as wastewater disposal pipelines approximately 300m from the intake point.

The drill slurry which will be output from the construction of boreholes (water mixed with bentonite) is proposed to be re-injected into two mud pits constructed within the plot. It has been noted that bentonite is a naturally occurring non-toxic compound in the form of clay and hence discharge is not foreseen to cause any environmental impacts.

1.6 THE EIA TEAM

This EIA report was prepared by a multi-speciality team of local experts. The team consisted Mr. Ahmed Saleem and Mr. Ali Hammadh registered EIA consultants with the Maldives Environment Protection Agency (EPA). The team members, their respective field of expertise and areas of contribution to the assessment is given in **Table 4**. CV's of members other than main consultant are attached in **Annex 10**

Table 4: The EIA Team

Name	Qualification	Designation/Field of Expertise	Contributing Area
Mr. Ahmed Saleem	MSc. Ecology & Environment	Lead EIA Consultant	• Overall administration of the EIA • Contributed to the various chapters • Report review
Mr. Ali Hammadh	BSc. Environmental Management	EIA Consultant	• Deputy Team Leader • Report writing and compile • Data analysis • Data collection • Water sampling • Stakeholder consultations • Contributed to the various chapters of the report.
Mr. Maumoon Saleem	Bachelor of Civil Engineering (Hons)	EIA Consultant / Civil Engineer	• Data analysis • Data collection • Concept review • Contributed to the various chapters of the report.
Mr. Dinal Shalika		Surveyor	• Terrestrial survey • Preparation of maps and charts
Mr. Muslih Mujtaba		A.Surveyor	• Terrestrial survey • GIS analysis

1.7 PROJECT JUSTIFICATION

Safe, clean water is the foundation of nearly every human development outcome, and water in the Maldives has always been precious. The freshwater table sits just a meter or two below ground on coral substrate that makes up the islands, just inches from seawater below and human waste above. The proximity of groundwater to the surface and the porous nature of the sandy soil make it highly susceptible to pollution and contamination from human activities and saltwater intrusion.

Ensuring adequate quantities of clean, safe water for the needs of humans and ecosystems is one of the greatest challenges worldwide and in the Maldives. Satisfying demands for freshwater is expected to become increasingly difficult in the context of a changing climate, with many regions facing more variable precipitation patterns and decreased water availability.

In the Maldives, the freshwater lens of the islands which is primarily used as the main source of freshwater is under threat as a result of pollution and sea level rise. Most of the islands do not have proper sewerage disposal and management measures in place which has resulted in high levels of faecal coliform in groundwater. A high level of faecal coliform in groundwater makes it unsuitable for consumption and significantly decreases water security in these islands.

Another threat to the freshwater lens are frequent inundation of inland by swell waves as documented in the EIA. Swell waves and flooding events effect project islands frequently resulting in groundwater salinization. The increase in frequency of these events can be correlated to global climate change. Pollution of ground water catalyses spread of water borne diseases and many other health implications. Vulnerability of freshwater resource is evident from the 2004 tsunami, which occurred during the dry season, destroyed approximately 50% of rainwater tanks, rendered entire island populations without access to safe drinking water, and severely degraded groundwater quality and soil fertility (UNICEF, 2017).

All islands reported detrimental impacts to groundwater after the 2004 tsunami. In addition to long term contamination of groundwater the event caused public infrastructure damages which effected transportation and power generation resulting in significant water shortages. Many islands could not obtain water and it was extremely difficult to supply freshwater to these islands even with the help of foreign disaster relief efforts.

The other source of freshwater resource available to these islands are rainwater. However, due to variability in rainfall and inefficiency in collecting and storing rainwater for longer periods of time, rainfall alone by itself is not a long term solution to ensure freshwater security in these islands.

Site investigations done at K. Gaafaru, L. Gan and B. Kendhoo revealed that availability of freshwater during the northeast monsoon was extremely challenging. During these times, people relied heavily on bottled water which is expensive and subject to availability depending on natural and manmade circumstances since bottled water is not manufactured within the islands and are transported from Male'. Due to transportation and handling costs bottled water tends to be very expensive. Considering that each individual in these islands consume or require 150 L of bottled water per day, the yearly cost of water amounts to approximately 55,000 MVR/year/person, which is approximately 50% of annual median income of a Maldivian, which puts into perspective how costly and unviable it is to solely rely on bottled water. Furthermore, any delays or issues with transportation or manufacture of bottled water would have a significant negative impact on the island. This results in a lack of water security and may become a serious issue in times of bad weather, disaster and national emergency. More so since project islands are geographically separated.

Groundwater sampled from the islands show that, even though salinity of water was normal at the time of sampling, there was a foul odour in all of the samples. Low levels of dissolved oxygen and presence of faecal coliform was identified as the cause of current groundwater contamination in project islands.

Moreover, it has been noted through stakeholder consultations that these islands require the aid of disaster management services, occasionally to enhance islands water security restock tanks. Aid water is most commonly stored in communal water tanks from which water is distributed to those in need. There have been cases where supply of aid water has been challenging due to bad weather and transportation difficulties.

Water shortages also disrupts local economies since water is crucial for major economic activities of these islands. In K. Gaafaru, the fishing industry relies heavily on bottled water which is expensive. Complaints of water shortages by fisherman from K. Gaafaru and L. Gan have been noted during site investigations.

Hence in order to ensure, water security and provide water during times of disaster and emergency the project has been sanctioned by MEE. By establishing RO plant, local industries can obtain water easily at a lower cost and the project would be a stepping stone in providing affordable water to individual households and enterprises in the island.

Despite its high energy demands, the Intergovernmental Panel on Climate Change (IPCC) lists desalination as an 'adaptation option' which may be particularly important in geographically adverse areas (Bates, et al., 2008).

2. DESCRIPTION OF THE PROJECT

2.1 PROJECT PROPONENT

The project is proposed by Ministry of Environment and Energy (MEE) of the Government of Maldives (hereinafter referred to as the Proponent).

MEE as the competent authority of the Project will be responsible for the implementation as well as post-project monitoring of the Project outcomes.

The contact details of the Proponent are given below;
Ministry of Environment and Energy
Green Building
Handhuvaree Hingun, Maafannu, Male', 20392
Republic of Maldives
Tel: + (960) 301 8300, Fax: + (960) 301 8301
Email: secretariat@environment.gov.mv

2.2 PROJECT LOCATION & SITE

The proposed Project is located in K. Gaafaru, L. Gan and B. Kendhoo as illustrated in map shown in **Figure 5**. The following subsections describe the geographical context of project islands and the proposed site to establish the RO Plant.

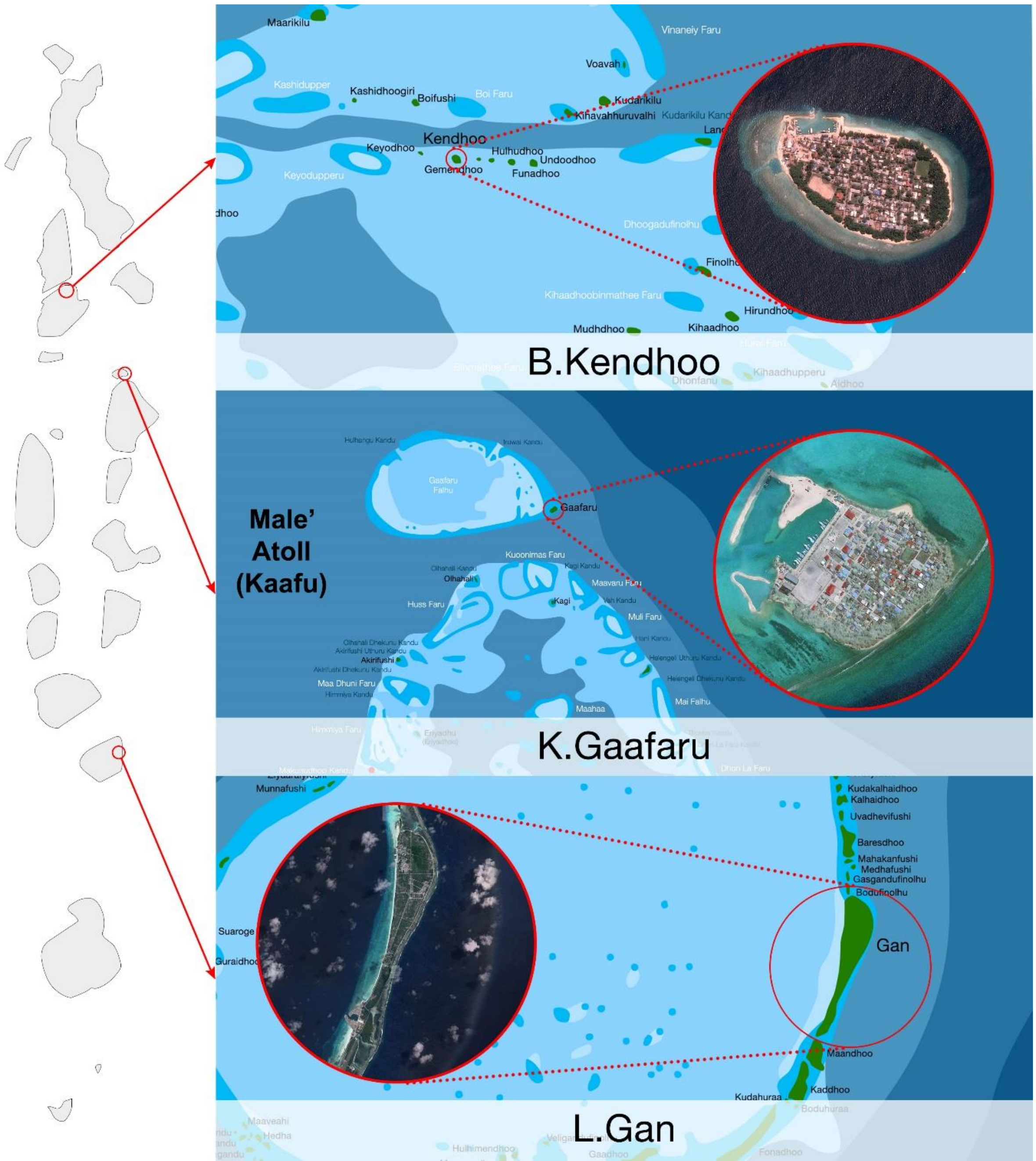


Figure 5: Location map of project islands

2.2.1. K. Gaafaru

K. Gaafaru is an inhabited island belonging to the administrative atoll of North Male. Situated in the northern region of the atoll at 4°44'8.48"N, 73°30'1.52"E, the island is situated north of the nearest inhabited island of K. Dhiffushi separated by approximately 40 km. Gaafaru is approximately 62 km from the capital Male'. Nearest airport is in K. Hulhule, approximately 60 km from the island. The nearest uninhabited island is Olhahali which is located 7 km to the southwest. Gaafaru is located between *Gaafaru Kandu* and *Kaashidhoo Kuda Kandu*.

The proposed area to establish the RO Plant is located on the northern side of the island at (4°44'14.84"N 73°30'0.31"E) and measures 230 m^2. The site has been cleared and do not contain any vegetation. The site is not far from the island's harbour. The harbour is located 250 m to the south west of the plot. There is a major access road to the site which can be used by vehicles. The brine outfall pipe is proposed to be located north of the site into the lagoon close to the coast.

Powerhouse was located closest to the site at 5.3 m. The islands hospital and school were located 45.6 m from the site. A3 drawings of the site are attached in **Annex 3** with surveyed details. A photo profile of the proposed site is shown in **Figure 7.**

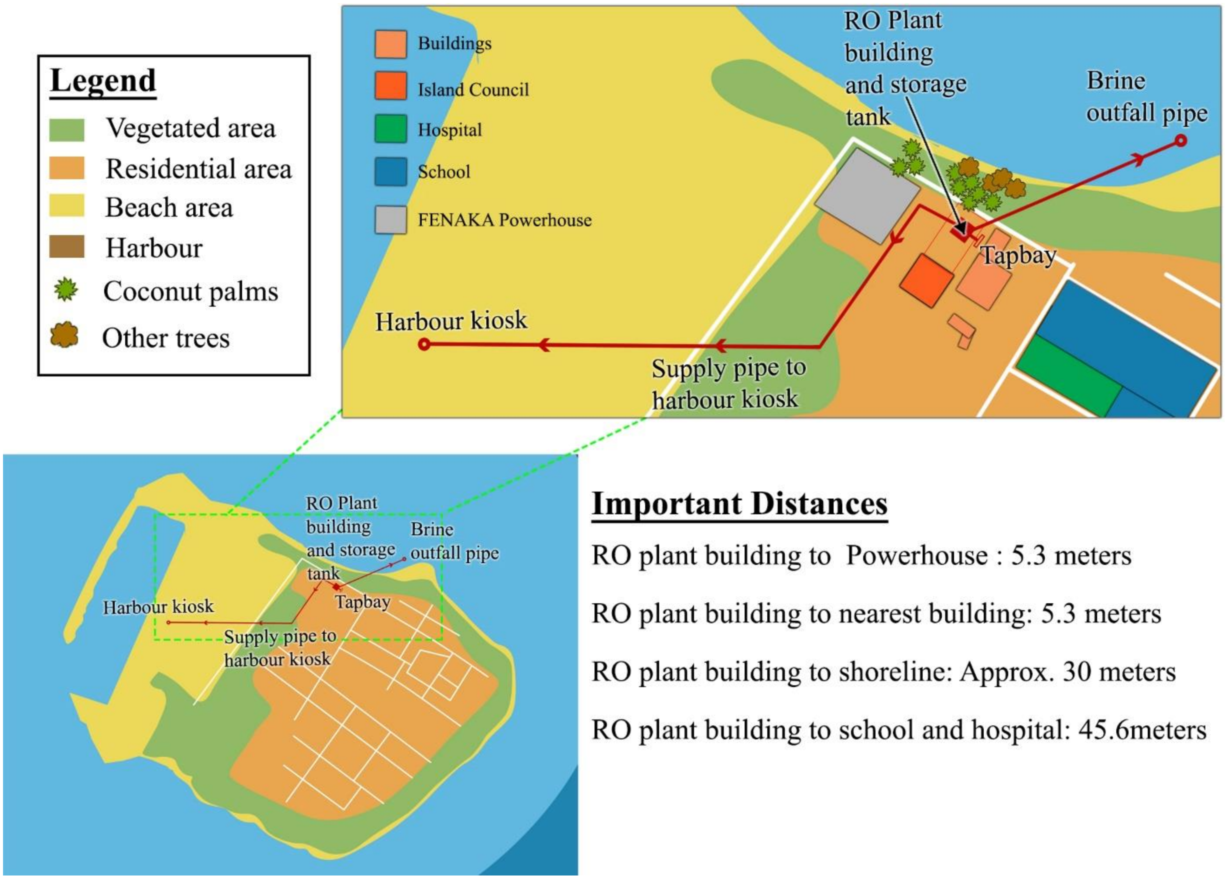


Figure 6: Project site (K. Gaafaru)

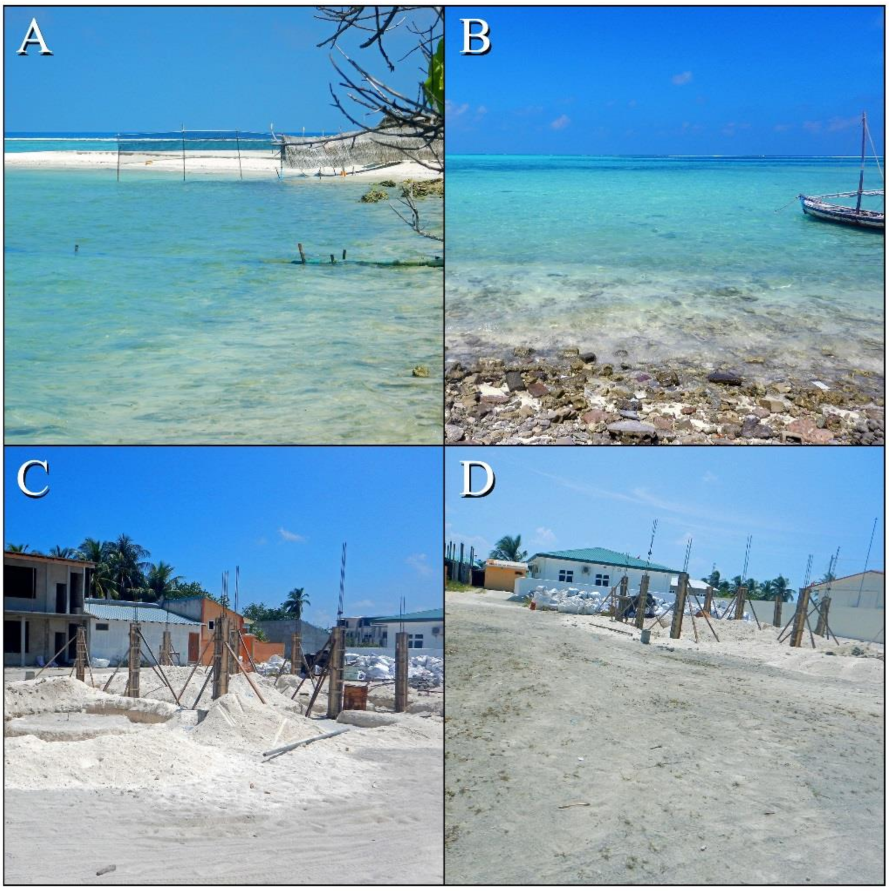


Figure 7: Photo profile of proposed location K. Gaafaru (A)(B) Outfall location (C)(D) RO plant site

2.2.2. L. Gan

L. Gan is the longest and biggest natural island in the Maldives with an area of 583 ha (vegetated area). Gan Island located at latitude 1° 52' 56" N and longitude 73° 31' 50" E. The island approximately 250 km from the Maldives' capital city of Male'. The island is divided into three administrative areas Thundi on the northwest part, Mathimaradhoo on the east part and Mukurimagu on the southern part of the island.

In comparison to the relatively large land area the population is small with a population density of just 7 personha^{-1} (Census 2014). The island has a small enclosed natural water body measuring 27. 7 ha. The industrial island of Maandhoo where fish processing is established is connected to L. Gan. Similarly, Kadhdhoo airport which is also connected by land to Gan lies south of the island.

The project site is located at a latitude of 1° 55' 44" N and longitude of 73° 32' 26" E. The site is located adjacent to the powerhouse of *Thundi* ward. The site is situated south of the *Thundi* ward at the western side of the island. The site measures 442 m^2. The closest building to the site is the powerhouse located 5.3 m south of the site. The nearest residential area is approximately 100+ m from the proposed site. The brine outfall of the RO plant is proposed to be extended from the western side of the island. The site had been cleared and do not require vegetation clearance. A photo profile of the proposed site is shown in **Figure 9.** A3 drawings of the site are attached in **Annex 3.**

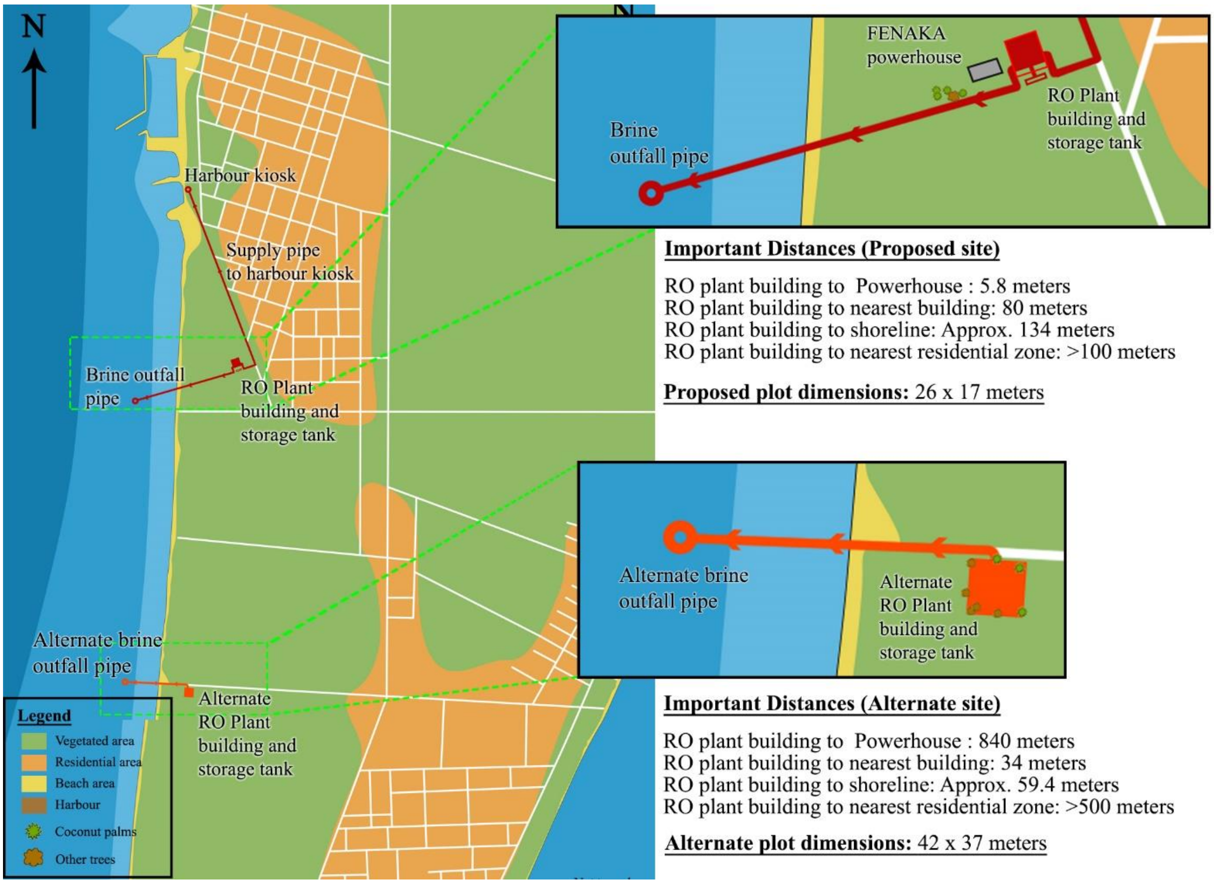


Figure 8: Project site details (L. Gan)

Figure 9: (a, b & c) proposed land for development of RO plant in L Gan. (d) road towards the shoreline closest to the plot

2.2.3. B.Kendhoo

B. Kendhoo is an inhabited island belonging to the administrative atoll of South Maalhosmadulu, situated in the northern region of the atoll situated at 5°16'29.32"N, and 73° 0'42.10"E, the island is situated southwest of the nearest inhabited island of B. Kudarakilu separated by approximately 7 km. Kendhoo is approximately 134 km from the capital Male'. Nearest airport is in B. Dharavanadhoo approximately 18 km from Kendhoo. Kendhoo is surrounded by numerous resorts. The nearest resort Kihaavah is located 5.5 km northeast. Kendhoo is located just south of *Kuda Kaduolhi*.

The proposed area to establish the RO Plant is located on the northern side of the island at (5°16'25.85"N 73° 0'38.17"E) and measures 230 m^2. The site has been cleared and do not contain any vegetation. The site can be accessed with a major access road which can be used by vehicles. The closest infrastructure to the site are residential houses located 5 m away from the site. The powerhouse is located 325 m from the site. Brine outfall is proposed to be located at the southern lagoon area. **Figure 11** shows a photo profile of the project site. A3 drawings of the site are attached in **Annex 3**.

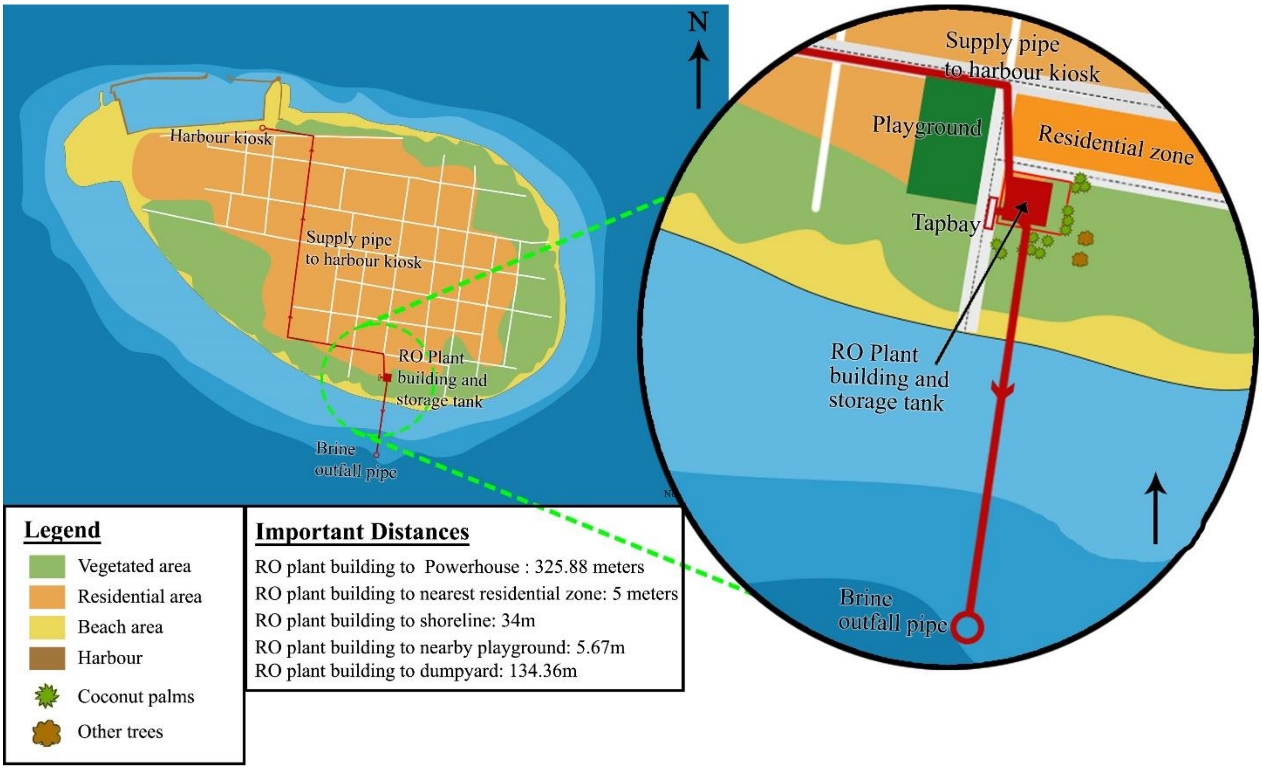


Figure 10: Project site details (B. Kendhoo)

Figure 11: (a) proposed land for development of RO plant. (b) House opposite proposed plot for RO plant (b & c) inland road and road towards the shoreline closest to the plot

2.3 CURRENT STATE OF WATER USAGE

This section highlights, water usage of project islands. Primarily source of freshwater and means by which water is stored at the household level.

2.3.1 K. Gaafaru

Currently the households of K. Gaafaru use rainwater harvested in 2500 L water tanks for all potable needs. Groundwater is used for non-potable needs. Consultation with the council as well as the community revealed that the households have started to increase water storage capacity as they run out of rainwater during the dry period of the north east monsoon. A large portion of the community also relies on bottled water throughout the year. There are no communal water storage tanks on the island. Huge number of fishing vessels operated in the island created demand for freshwater which has not been met.

2.3.2 L. Gan

Currently the households of L. Gan use rainwater harvested in 2500 L water tanks for all potable needs. Groundwater is used for non-potable needs. Consultation with the council as well as the community revealed that the households run out of rainwater during the dry period of the northeast monsoon and have to purchase water from L. Maandhoo as well as local shops. Community water tanks are placed in each ward, although the locals are opposed to use the water collected in these water tanks due to lack of confidence in the quality of the water. Currently a tap bay and rainwater harvesting tanks are placed in the harbor area of *Thundi* ward which is used to sell water to the boat owners. Fishing vessels also purchase water from the nearby L. Maandhoo.

2.3.3 B. Kendhoo

Currently the households of B. Kendhoo use rainwater harvested in 2500 L water tanks for all potable needs. Groundwater is used for non-potable needs. A large portion of the community also relies on bottled water for drinking purposes throughout the year. The island has communal rainwater storage setup. A huge demand for freshwater is created by the island's emerging guest-house tourism.

2.4 PROJECT COMPONENTS AND DETAILS

The proposed project involves provision of a water tap bay for community water supply and a harbour kiosk (in the harbour area for providing water to vessels), 2 nos 15-ton capacity RO plant, 2 nos 50-ton capacity storage tank for L. Gan, and 1 no 50 capacity storage tank for K. Gaafaru and B. Kendhoo would be installed at present. In islands where the future daily demand exceeds 30 tons additional RO plants would be provided at a later stage when the water supply network is installed.

The water abstraction source has been decided to be a borehole constructed on site. The construction phase of the project therefore involves site demarcation and clearance, civil works of the RO plant building structure, laying of pipes to harbour kiosk and brine discharge, as well as construction of the borehole.

The operational phase of the project involves water abstraction, filtration, RO process, disinfection, storage and provision of water to harbour kiosk as well as the tap bay. In addition, brine discharge will be a component of the project.

2.4.1 General layout of the site

The same general layout for the sites have been proposed for all islands. Hence the description here applies to all project islands.

The site consists of the RO Plant building, 50-ton capacity RTP tank, feed water tanks, bore well, backwash tank and area for future rainwater storage.

The RO Plant building is divided into 4 main areas. The RO Plant room consists of the RO Plant, distribution pumps, contact tank, and chlorine storage tank. An area has been provided for backup generator and solar power storage. An operating room is provided inside the plant building which consists of an area for a testing lab.

The outer fence of the site is made of a PVC coated wire mesh. The tap bay is proposed to be located on the outer fence wall next to the entrance to the site, therefore it can be accessed from the road. The proposed layout of RO plant at the three islands are detailed in **Annex 3**.

2.5 PROJECT DURATION AND SCHEDULE

The proposed project is planned to be carried out in approximately 7 months. The preliminaries including site handing over, mobilization, demolishing and site preparation is expected to take 22 days. RO Plant Building construction, services and finishing works are expected to be completed in 124 days. RTP Tank construction is expected to be completed in 155 days. RO Plant installation and commissioning is expected to take 157 days while other miscellaneous works such as construction of bore well, casting of ballast blocks, installation of HDPE pipe for product water and brine outfall are expected to take approximately 96 days. The project is expected to be completed in all 3 islands within 200 days.

Table 5: Work Plan for RO Plant Works

		Months						
No	Activity	1	2	3	4	5	6	7
1	Preliminaries							
2	RO Plant Building Works							
3	Feed & Reject Water Tank Works							
4	RTP Tank Works							
6	RO Plant Works							
8	Misc. Works (Incl. Borehole works)							
9	Demobilisation & Hand over							

2.6 CONSTRUCTION PHASE

2.6.1 Machinery

The following machineries are proposed by the contractor for the construction phase of the project:

- Multipurpose drilling machine Capacity 250 m /BW, Diesel engine powered;
- Hydraulic excavator with maximum 1.4 m^3 bucket capacity and maximum digging depth 22 ft;
- Concrete vibrator;
- 450 L Hand feed concrete mixer machine; and
- Concrete mixer.

2.6.2 Mobilization

Involves sourcing and transport of material and equipment to the respective islands. Material and equipment will be transported by sea if it is not available from the island. Labourers/ workers will be transported by air and sea. All islands contain harbours and access roads to the project site which will ease accessibility to these islands.

2.6.3 Site demarcation and clearance

Prior to beginning construction works, a survey will be done by the contractor to demarcate the limits of the site, determine exact number of trees intersecting with the plot. The site will be fenced off and work will be conducted within these limits.

Since the EIA was conducted based on actual vegetation data, it will be used as a reference to determine the exact number of trees falling into the proposed plot at the project island as described below.

A. *L. Gan*

The proposed site is an empty plot of land with no vegetation or existing structures that require clearance or demolition. Minor vegetation clearance is required for laying of outfall pipe as underbrush and coastal vegetation belt is present in a portion of the access road through which the outfall pipe will be laid. Although 3 mature coconut palms are present in vicinity, the removal of these trees is considered avoidable through planning of pipe laying works.

B. *K. Gaafaru*

The proposed site does not require land clearance.

C. *B. Kendhoo*

The proposed site is an empty plot and does not require major land clearance. Minor area consisting of bushy plants will have to be cleared to install the outfall pipe.

2.6.4 Earthwork

The project includes excavation works, although no excavation reaches depths lower than 750 mm below ground level. This can be achieved through hydraulic excavator proposed for the works. The excavations include excavation for RO plant building foundation beams. 600 mm depth excavations are required to receive the wall footings and below ground portion of the 150 mm thick masonry walls. 600 mm depth excavations are also required to receive perimeter fence footings. The tap bay provided with the RO plant requires a 750 mm depth excavation to receive the footings. The concrete storage tank provided with the RO plant requires a foundation spanning the area of the tank. The foundation consists of foundation beams as well as a 75 mm concrete slab. 400 mm excavations are required to receive the beams, in addition to an additional 400 mm compacted backfilling up to the concrete slab to bring level up to 400 mm above ground level.

Trenching work is required to receive the water supply line to the harbour as well as the brine discharge pipe. 600 mm deep uniform trenches are required for the length of the pipes.

2.6.5 Concrete Works of RO Plant Building

The RO Plant building consists of a single storey structure which houses the RO Plant room, chemical storage room, operation room including the testing lab and backup genset and solar power storage area. The structure is made of reinforced concrete and 150 mm thick brick work. The wall footing consists of a 300 x 200 mm beam with 4 nos. T12 main bars and 6 mm shear links at 150 mm intervals. After excavation, formwork is laid along with reinforcement to receive the concrete mix for the beams. Columns are cast as shown in the engineering details as 150 x 150 mm after setting up the required reinforcement at 4 nos. T10 bars and 6mm shear links at 200 mm intervals. Roof beam plan is identical to the wall footing plan although the roof beams are shallower with a 200 mm depth and 150 mm width. After the brickwork is completed, the sloped roof works are done. The material used for frame of the roof includes 50 x 38 battens at 600 mm centre to centre and 50 x 150 battens at 900 mm centre to centre. Lysaght roofing sheets as well as gutters are installed, in addition to services work as well as finishing works.

2.6.6 Feed and Reject Water Tank Works

The feed water tank is 2.3 x 1.8 m with a height of 1.5 m. The tank is made of reinforced concrete, which will be cast on site. Reinforcement is provided for the feed water tank walls and base in two layers at T10 steel bars at 150 mm distances both horizontally and vertically. The reinforcement work is completed prior to completing the formwork of the tank. In situ mixed concrete is poured into the formwork and vibrated as required. A 600 x 600 mm manhole is provided on the top of the tank for access. The reject water tank is also similar in size and design to the feed water tank and will require a similar procedure.

2.6.7 RTP Tank Foundation Works

RTP 50-ton capacity storage tank is provided with the RO Plant for each island (two tanks will be provided for L. Gan). The RTP tank is placed on top of the RTP tank foundation which will be cast in situ. After excavation works, formwork and reinforcing steel is placed as specified. The foundation beams for the RTP tank are 300 x 600 mm reinforced concrete beams with 8 nos. of T12 bars and 6 mm shear links at 150 mm. After reinforcement and formwork have been placed, in-situ concrete is poured into the beams and vibrated accordingly. Compacted fill is placed on the foundation footprint up to 400 mm above ground level prior to concreting the 75 mm thick slab over the foundation. The slab consists of T10 bars at 150 mm laid at bottom-bottom and bottom-top. In-situ concrete is cast and curing is done.

2.6.8 Construction and Development of Borehole

Borehole drilling is not uncommon in the Maldives for the purpose of installing RO plants and in almost all cases very similar methodology had been adapted. The following methodology extracted from ICRC document: *Borehole Drilling and Rehabilitation under Field Condition, and current practices in Maldives* which is commonly used has been proposed to be applied for the current project.

Initially the location of the borehole is confirmed within the limits of the site and the area will be cleared of any underbrush or debris. Then the drilling machine will be set up in the area. Mud pits will be made to mix bentonite and water. For the required 500 mm borehole with a depth of 30 m, it is calculated that a suction pit of 6 m^3 (1.5m × 2m × 2m) and a settlement pit of 24 m^3 (6m × 2m × 2m) is required (See **Figure 12**). Bentonite (calcium montmorillonite) is a natural clay mineral which swells enormously in water. The mud will be mixed and left for 12 hours before use to allow the viscosity to build up.

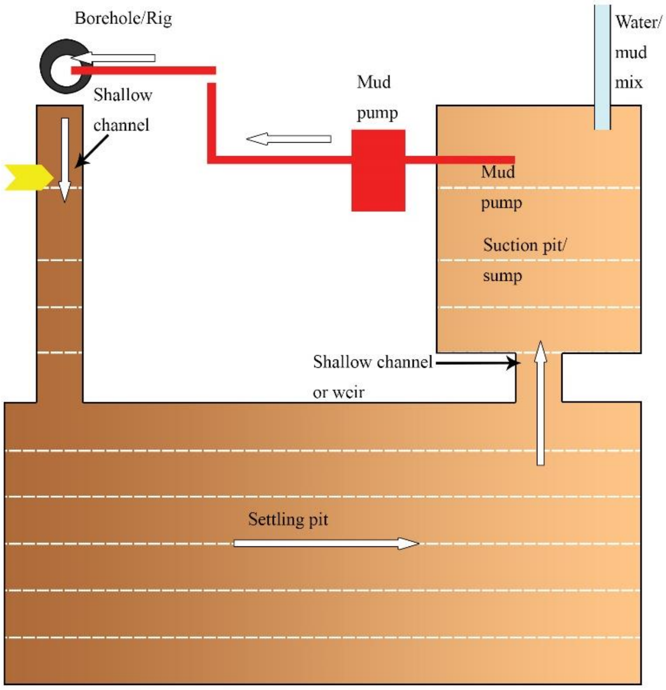


Figure 12: Schematic plan view showing mud pits and mud circulation (anti clockwise white arrows). Source: (ICRC, 2010)

Mud rotary drilling will be used for the purpose of providing cooling and lubrication for the drill bits as well as preventing the borehole from caving in. The drilling mud being of a higher density than water, a significant hydrostatic pressure is applied to the walls of the borehole. A supportive mud cake is formed on the wall of the borehole discouraging collapse.

Drilling rig will be placed on drilling spot with proper platform and vertical alignment. (See **Figure 13**) Verticality and alignment will be checked during process. Maintaining verticality and straightness can be difficult during the early stages of drilling but as the drill string weight increases the problem tends to dissipate. Straightness is important for water boreholes in which long strings of casings have to be installed with a gravel pack filter.

The upper part of the borehole is likely to suffer erosion by circulation fluid and cuttings. The irregular enlargement of the hole can lead to reduction of the up-hole fluid velocity. Therefore, a PVC or 7" temporary steel casing will be placed inside hole down to the top of the stable formation. After placing of the outer casing into required depth drilling will be continued with mud circulation

Formation samples will be obtained with return water with a usual sampling interval of 1m. Formation samples will be preserved in polythene bags marked with borehole number and depth.

Borehole logging will be conducted properly. The length of the drill bit will be noted and a chalk mark '0' is made on the first drill pipe against a suitable fixed point on the rig and at a known height above ground level. Then, marks will be made on the drill pipe at regular intervals (every half meter) to record drilling depth. After drilling is completed up to 30m depth hole will be reamed again using drill bit. Flushing of borehole will be carried out after completion and water sample collected for testing of pH, EC, temperature, salinity, taste, odour and colour. The borehole's depth is determined by the conductivity of water at the depth. The water conductivity should reach 50,000 µS/cm. If not, the borehole should be drilled deeper.

Protective permanent casing will be inserted into the borehole by the drilling rig to the required depth. Casing will be joined together by either screw threads, flange-and-spigot, gluing, riveting or welding. The casing will extend 600 mm above the ground level. The casing material proposed for this project is UPVC. End cap and borehole well screen is installed for the first 5 m of the end of borehole. The well screen consists of a perforated pipe. After the well screen is installed, artificial gravel pack consisting of clean, rounded, quartz pea gravel will be fed by pipe to a height of 25 m from the bottom. The volume of annular space will be calculated to ensure the correct volume of gravel has been installed. Gravel will be placed through the annular space between outer and inner PVC casings. 1 m sand and bentonite layer is placed over the gravel layer. Cement grouting is placed above the sand and bentonite seal up to the 600 mm finish level of the borehole. Pump will be installed at a depth of 25 m on top of the well screen.

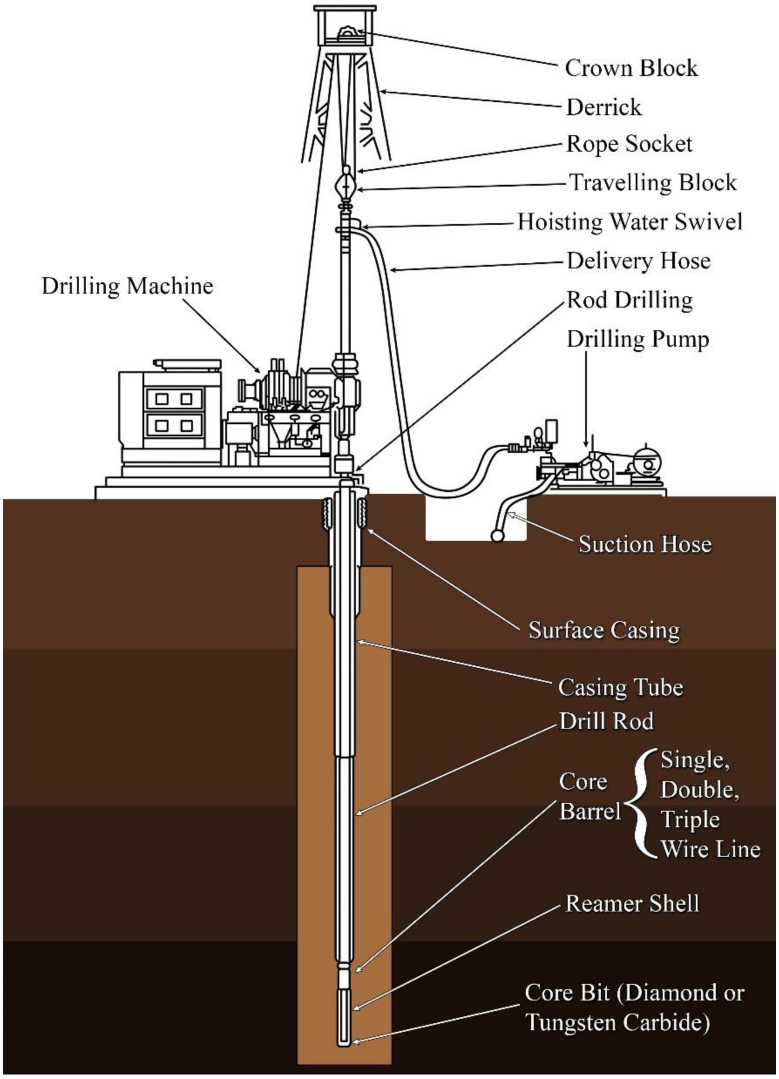


Figure 13: Typical representation of borehole drilling and development. Source: (ICRC, 2010)

<u>Borehole development methods</u>

After the construction of the borehole, borehole development is conducted. This includes surging and blowing of compressed air, and is sometimes helped with the use of additives. Borehole development methods include:

- Mud dispersants such as granular Calgon will be dissolved in hot or boiling water (1 kg in 5 liters). The dosage of Calgon is 10 to 50 kg per cubic meter of water estimated to be in the borehole. The dispersant will be left in the hole overnight to allow the solution to permeate into aquifer formations.
- If the well is developed in calcareous (limestone, chalk or dolomite) formations, acid (HCL) treatment can widen and clean carbonate aquifer fissures.
- Process of surge pumping consists of forcing water up and down a borehole and back and forth through the screens, gravel pack and aquifer matrix. Surging will be accomplished using air lift pumping using the drill pipes on the rig and a compressor.

- Jet washing consists of washing of the well face with high pressure water jets. Jetting pump will be used to inject clean water into the borehole down the drill pipes.

<u>Borehole Completion</u>

After the borehole has been constructed and developed, sanitary seal will be placed to seal the borehole from surface contamination. The sanitary seal is in the form of capping plate. Test pumping will then be carried out to measure performance and efficiency of the borehole.

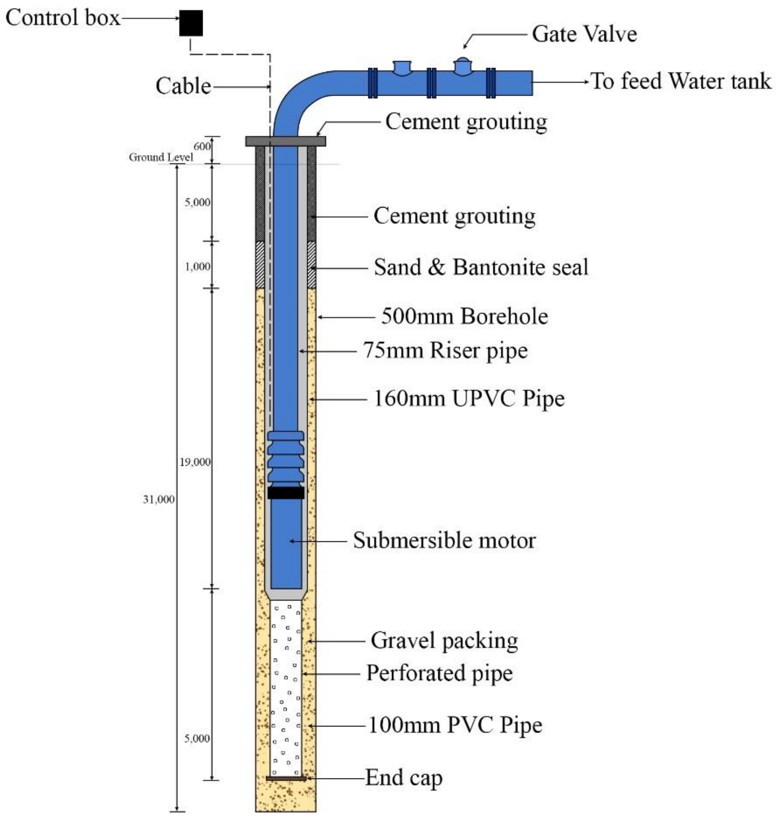


Figure 14: Completed borehole (adapted from detailed design of the project)

2.6.9 Installation of RO Plant Components

The methodology for installation of RO Plant components are as given by the contractor. The RO skid is placed in the plant room, and afterwards the micron filter, high pressure pump, membrane module, panel board, flow meter, dosing pump and pressure gauges are fixed in the RO skid.

Then the raw water pump, recirculation pump and transfer pump is placed. The dual medial filter is positioned and the different layers of filter media are filled inside the pressure vessel. The multiport vessel is then fixed on top of the vessel. Interconnecting pipelines and valves are installed prior to laying cable from the main panel to the pumps. RTP tank installation work is conducted afterwards, on top of the RTP tank foundation and slab.

2.6.10 Installation of Harbour Kiosk Pipeline

The installation of pipe line is carried out by locating the positions of the pipe line using the final design and engineering drawings. The detailed working drawings will indicate the alignments, size of pipes width/depth of trenches and nature and type of beddings. As this is a pressure network, all the pipes will be laid at the same depth. The centre line pegs of the pipe line at the chosen road section are driven at a known distance properly maintained by providing an off-set line. The off-setline helps in locating the pipe centre line when excavation is carried out for laying pipe. The excavations will be carried out with or without shoring using a mini excavator depending on the site condition. In order to make sure the pipe network is free from leak PVC pipes get joined using solvent weld using push fit fittings. Before each section of the network line is covered with top soil, a leak test will be carried out. **Figure 15** shows typical workflow followed in laying pipe network.

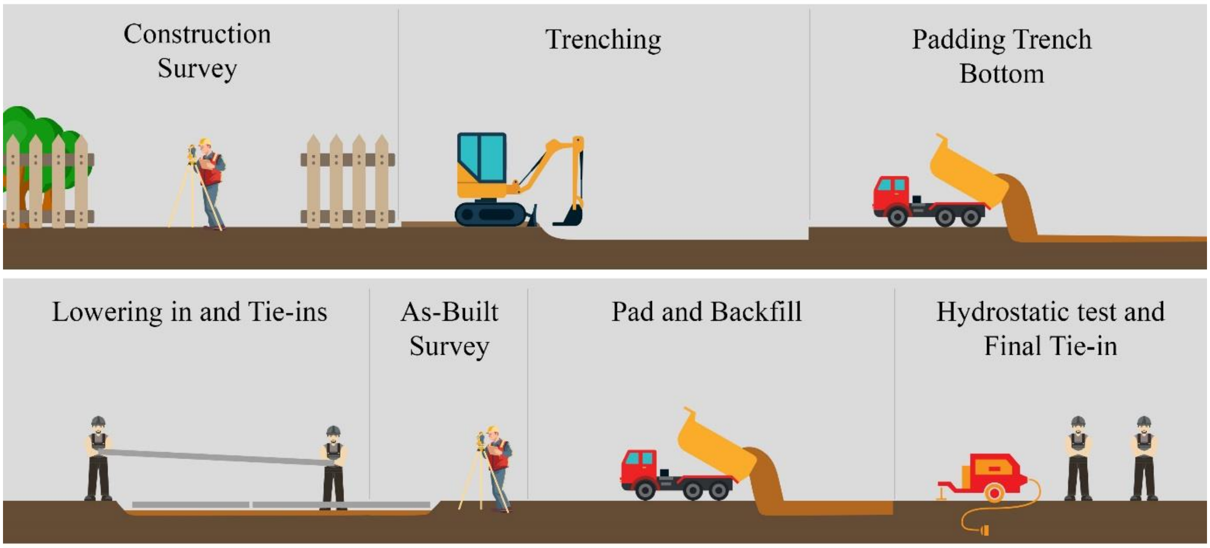


Figure 15: Typical workflow of laying pipe networks (left to right)

2.6.11 Installation of Brine Discharge Outfall

Brine discharge outfalls at each of the project islands are laid on the shallow lagoon floor anchored using concrete anchor blocks at designated locations. Only Outfalls that end at the reef edge are further sloped down along the reef slope from house reef edge (see **Figure 16**).

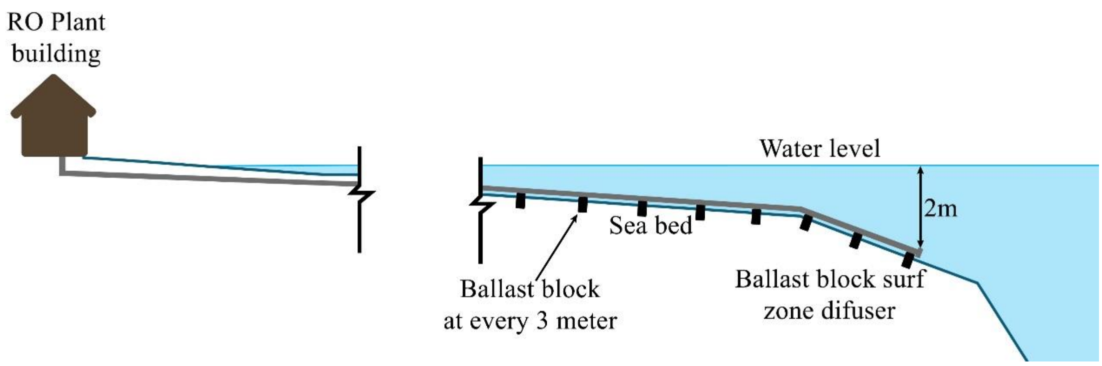


Figure 16 Typical sea outfall

The materials required for the construction of the sea outfall pipelines include 80 mm HDPE pipes, 600 x 600 x 1500 mm ballast blocks, SS pipe clamps as well as T-head diffusers. Pipe sections are fused together, and ballast blocks are placed at 3 m intervals. SS clamps and stainless steel rods are used to fix the pipe the ballast blocks. The pipe is laid along the profile of the seabed. The contractor is to assess the outfall site and its natural profile in order to produce a methodology to install and fix the brine discharge outfall pipeline. The outfall pipe will be laid by certified personnel with the help of survey expertise to obtain the required positioning of the outfall pipe.

2.6.12 Labour Requirements and Availability

A 10-person workforce would be involved in the construction. It is encouraged to choose workers from within the island, to reduce the impacts of influx of non-local workers. If no such arrangements are made, labour accommodation will be arranged for the 10-person workforce in vacant houses. The EIA strongly recommends not to create temporary shelters for the workers to minimise environmental impacts and to enhance socio-economic benefits of the Project to the community.

2.6.13 Demobilization

The demobilization plan will commence in the last week of the contract. This would involve removal of all equipments, machineries, residual materials and project labourer etc from the island. Demobilisation shall involve removal from the island of all waste generated from the construction works.

2.6.14 Testing and Handover

After construction works are complete, the WSS will undergo testing such as test pumping of borehole, trial run (including hydrostatic testing of pipes) and commissioning of WSS. Test pumping of the borehole has been highlighted in **Section 2.6.8.**

After the construction phase works are complete, the WSS will undergo a trial run to test whether its performance is as expected. The test includes hydrostatic testing of pipes to test for leaks and the performance of the pipes under specified test pressure. If the trial run shows any issues and deficiencies, the period of trial run will be extended until the issues are corrected.

Subsequently, commissioning will be undertaken of the whole system. The system will be operated continuously for 24 hours to monitor if it is functional. As part of the handover process, detailed operation manual of the plant will be prepared which shall include all details regarding the operation, maintenance and management of the plan. Commissioning will be complete after the plant has been operated without any issues. After commissioning is complete, the WSS will be handed over to the proponent.

2.6.15 Summary of workflow

A summary of the construction phase is provided below on **Figure 17.**

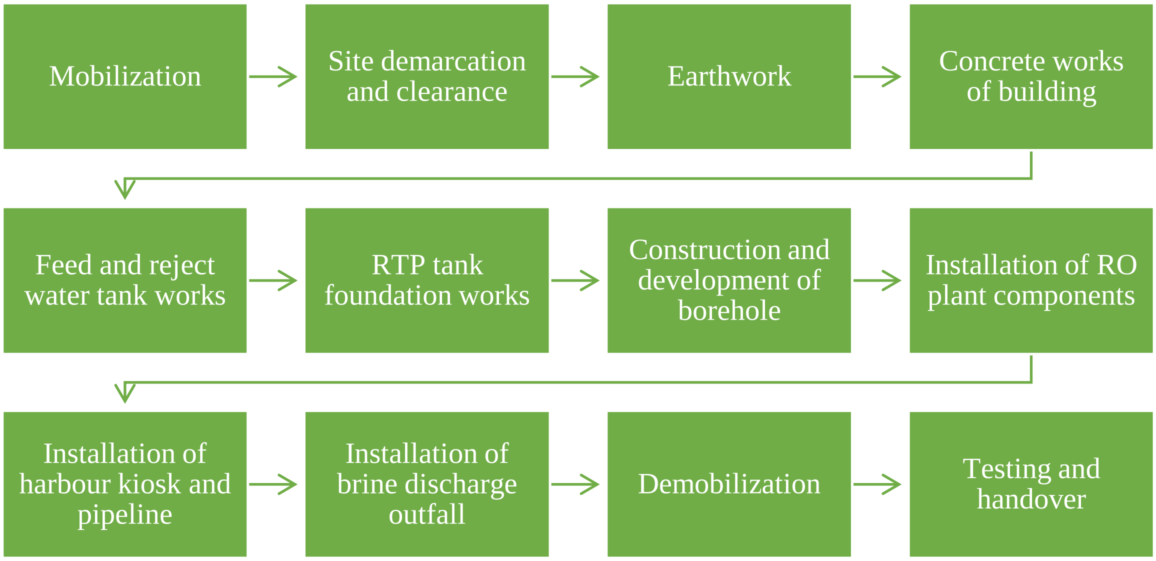


Figure 17 Construction phase workflow summary

2.7 OPERATIONAL PHASE

2.7.1 Water Abstraction

Two options were considered for abstracting water for the reverse osmosis plant. One option was to obtain water directly from the sea and the option was to obtain water from a borehole. After careful consideration, the option of obtaining water directly from the sea was disregarded as this option leaves the feed water pipe open for vandalism and the feed water would contain a lot of sediments (See **Section 8.5** for details). Hence, it was decided to abstract water from a borehole. The borehole diameter and depth was decided considering the size and depth of boreholes drilled for other projects. Thus a borehole of diameter 500 mm and a depth of 30 m was decided. Water will be pumped from borehole to ground level with the help of a submersible pump. The pump needs to have a minimum Head of 35 m and a flow rate of 2 L/s. The sourced water is stored in an RC tank prior to feeding the water to filters. It is expected that 43 m^3/d of water will be abstracted from the borehole per day for each of the project island when water production is at full capacity.

2.7.2 Filtration

Prior to feeding the water to RO plant the TSS concentration will be reduced to reduce RO membrane fouling as much as possible. Thus, the feed water will be passed through a multimedia filter and cartridge filter. The multimedia filter has a pore size of 20 microns and the cartridge filter has a pore size of 5 microns. Thus water leaving the filter configuration, has only solids that are smaller than 5 microns.

Table 6: RO Plant Demand and Backwash Tank Sizing

Demand (m^3/d)	Feed (m^3/d)	Filtration velocity (m/h)	Filter area (m^2)	Backwash velocity (m/h)	Backwash flow (m^3/h)	Volume (5BV) m^3	Backwash time (mins)	Backwash tank size (m^3)
15	43	6.67	0.36	20.00	7.1	1.07	6.67	1.07

Cleaning the filter will be done by backwash mechanism. Backwashing will be initiated when the pressure differential across the filter bed reaches 10 psi above the normal clean filter operating pressure. The recommended pressure head for the filter pump is 20 m, as this pump will have to force water through multimedia filter and cartridge filter, before sending the water to the RO high pressure pump.

2.7.3 RO Plant Operation

The filtered water is fed to the RO plant after adding anti-scalant. This water is called feed water. Pressure of the feed water needs to be raised above the osmotic pressure of the water. This is done by using a high pressure pump. Thus, to accommodate for the pressure loss across RO module, a high water pump capable of maintaining an operating pressure of 60 bars will be selected. The flow rate of this pump will be 0.7 L/s.

Two RO plants are to be setup in each island and each RO plant will have a production capacity of 15 tons/per day of freshwater. The salt and other impurities in water are removed through spiral wound RO membranes that are placed in pressure vessels. It is estimated that the RO plant will run a maximum of 18 hrs per day and the membrane recovery rate is 35%. **Figure 18** below shows the feed, permeate and reject water flow arrangement through the RO module.

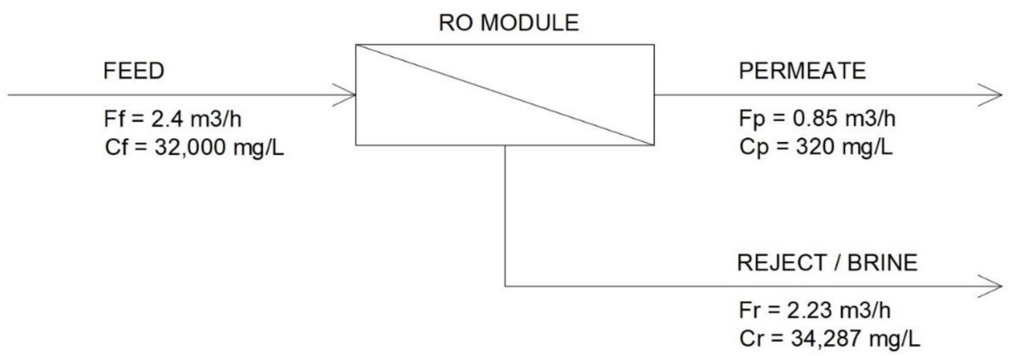


Figure 18: RO Module mass balance

The quality and quantity of permeate flowing out of the RO module will be supervised by conductivity meter and flow meter. When the permeate quality drops below the indicated level, the module should be cleaned. Plant should have flow meters for feed and permeate flow and also pressure sensors so that in case of low feed pressure and high outlet pressure, the plant can be stopped and checked for any defects.

2.7.4 Disinfection

Permeate water produced from the RO module will be disinfected prior to sending the water to the storage tank. Disinfection will be done by Sodium Hypochlorite with chlorine concentration of 1 mg/L. It is assumed that the permeate will have a microbial TVC of 10,000 cfu/mL and it is required to reduce this to 10 cfu/mL. According to Harriet Chick's Law, for the Chlorine concentration specified and microbial reduction required, a contract time of 25 mins is appropriate. 2 contact tanks of 1m^3 is required to carry out the disinfection procedure. The tanks will function alternatively where one tank will always receive water from the RO plant and the other will carry out disinfection.

As soon as disinfection time is over, the disinfected water needs to be quickly pumped to the storage tank, so that the contact can be made empty to start another cycle. The two tank arrangement will be as shown in **Figure 19**.

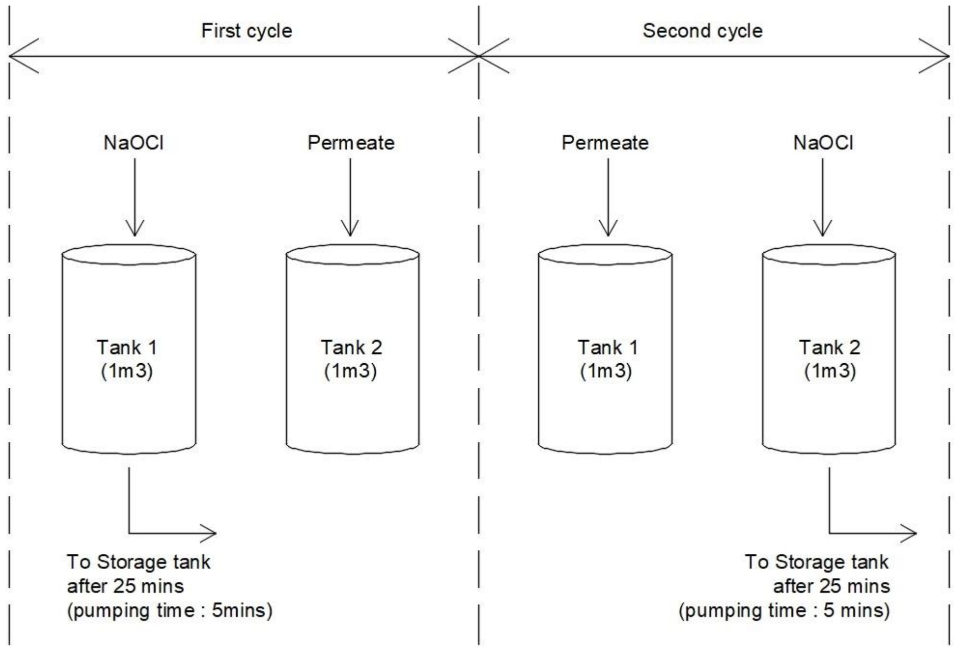


Figure 19: Disinfection arrangement

2.7.5 Storing

Water produced from the RO plant will be pumped and stored in to RTP – Reinforced Thermoset Plastic- tank of capacity 50 m^3. In L. Gan, two RTP tanks are provided each with capacity of 50 m^3.

2.7.6 Harbour kiosk

Under this project a harbour kiosk will be built near the harbour of each island. Water will be supplied to this kiosk via a 63 mm diameter HDPE pipe.

2.7.7 Power consumption

The operations of the RO Plant require power for services as well as the pumps used in the system. The power consumption of the key pumps in the RO plant operation are described as below:

Table 7: RO Plant power requirement

Pump	Number	Total power (kW)
Bore well pump	1	0.58
Anti scalant pump	1	0.19
Filter pump	2	0.28
RO High pressure pump	2	11.64
Backwash pump	1	1.13
Chlorine dosing pump	2	0.04
Harbour kiosk pump	1	1.2
	TOTAL	15 kW

Although there is a designated area to install gensets in the power plant as described in **Section 2.6.5**, primary power required to run the plant will be obtained from existing mains. Each project island has its powerhouse and assessment shows the existing powerhouse on each island has the capacity to provide the operational energy for RO plant. However, since power outs are common and reliability of existing system is poor, power supply is identified to have significant risk during operational phase. Hence, it has been recommended to install a backup generator during the operational phase and install solar panels at the plant to offset demand on mains electricity and mitigate environmental impacts (See Sections **2.8 2.1 2.8 &9.4.6** for details).

2.7.8 Tap bay

The tap bay is located in the RO plant attached to the perimeter fence of the building. The tap bay consists of 4 taps which will be used to provide water to the public in line with the objective of the project.

2.7.9 Brine discharge

As per the design of the system, it is expected that 2.23 m^3/hr of brine will be produced during daily operations. The method of discharge is through a brine discharge pipe which will discharge the brine into the sea. It is expected that 17.84 m^3 of brine will be discharged as a result of the RO operations per day from each of the project islands. Details of brine discharge locations and outfall pipes are given in **Annex 6**.

2.7.10 Water Quality Testing

The project does not include setting up of a laboratory in the plant during the construction phase. Limitations in testing product water during commissioning of the plant is singled out to be a high risk activity. Especially since, plants in L.Gan and K.Gaafaru are located adjacent to a powerhouse which has the potential to contaminate product water as a result of dust pollution (See **Section 2.8 2.1 &9.4.1** for details). Therefore, prior to official commissioning of the power plant the service provider will install a functional laboratory as specified in the operational manual of the RO plant to undertake routine microbiological and chemical tests as specified in EPA guideline to maintain high quality and standard of the products. For tests which cannot be done onsite the operator will use the Public Health Laboratory for regular testing of sample from the plant.

2.7.11 Administration

There will not be separate administration office for the RO plant, the WSS administration will be conducted in the RO plant building to be constructed under this project. Administration will be undertaken by the service provider.

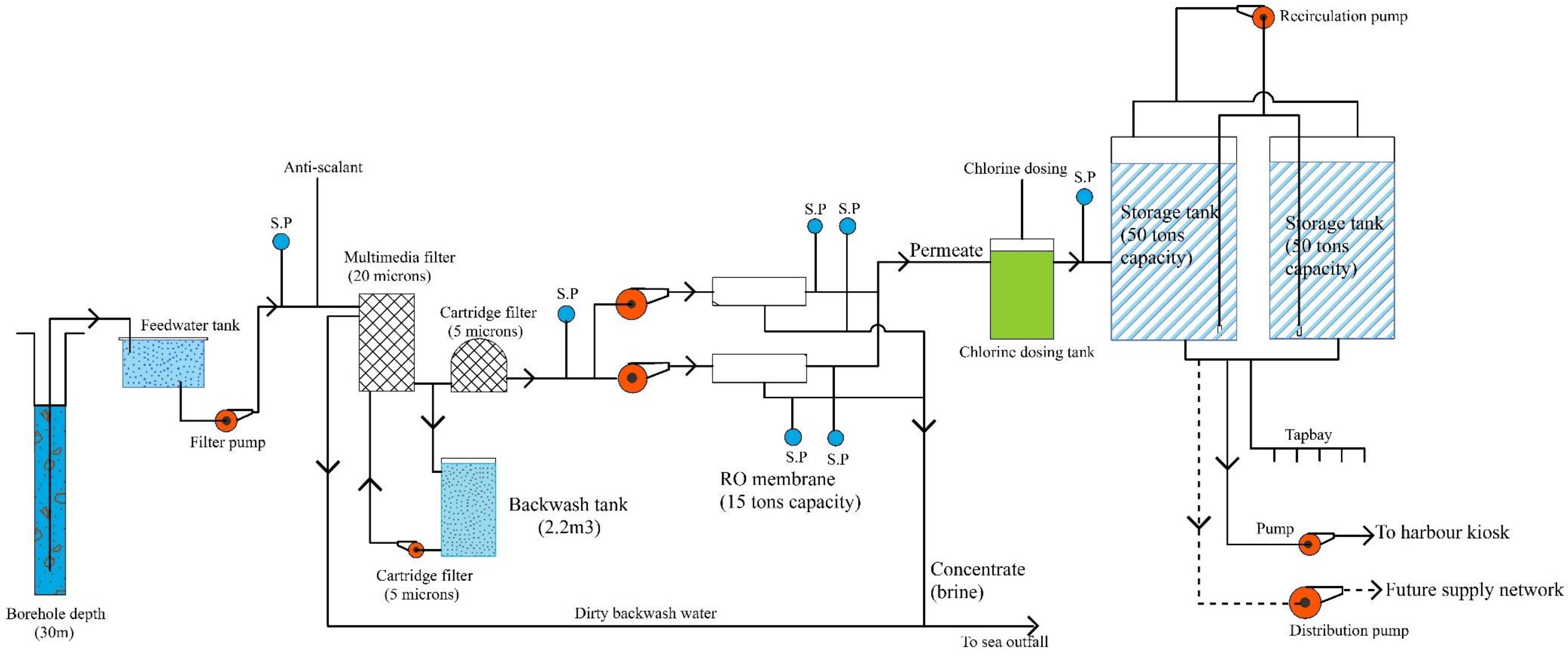


Figure 20: Overall RO plant operation scheme

2.8 EMERGENCY PLAN AND SAFETY MEASURES

Apart from B. Kendhoo, RO plants in the other two islands are proposed to be located adjacent to or very close to the islands' powerhouse. While it is a common practice to have RO plants adjacent to powerhouses in the Maldives for many associated advantages, major fire incidents at powerhouses in recent history in several islands show such arrangements are not free from serous risks. This issue was highlighted during the scoping meeting. It was stressed that due to RO plant's close proximity to the powerhouse, adequate protective measures need to be in place in the event of a major disaster at the powerhouse. It was also highlighted that if electricity and water shortages occur simultaneously on the island, consequences to the locally communities could be significantly high. Especially since numerous accidents and safety related issues had been reported with regard to powerhouse all across the country, a general consensus of the participants were strengthening the emergency plan and safety measures of the RO plant.

As part of mitigating accidents and enhancing safety an Emergency Response Plan (ERP) will be developed by the operator which will subsequently be approved by the MEE which is aimed at defining the response process and responsibilities for managing these situations, thus reducing likelihood and severity of inadequate management and enhancing the safety of the desalination plant. This ERP will be considered to be a "live" document and will need to be amended periodically in light of operational changes, learnings experienced during its implementation and other activities that can affect the risk profiles. The ERP shall be made part of the plant operational manual.

The ERP shall be designed based on the following seven parameters:

i. Hazard identification/assessment;
ii. Emergency resources;
iii. Communication systems;
iv. Administration of the plan;
v. Emergency response procedure;
vi. Communication of the procedure; and
vii. Debriefing and post-traumatic stress procedure.

Based on these factors and the field assessments carried out for the project the following hazards and emergencies have been identified which relate to the project. Hence the ERP shall consider the following hazards, among others, in developing the ERP.

i. **Fire -** Fire protection system is of critical importance for the facility given that fire incidents are not uncommon in the Maldives and in such events major losses have occurred to infrastructures in the islands in the past. This is of particular importance especially when RO plants are constructed near or adjacent to powerhouses. National Fire Code (NFC) and Fire safety standards set by the National Security Service (NSS) shall be strictly followed in setting up of fire protection system at the facility. Fire security and protection devises including smoke detectors, heat detectors, manual call points, fire alarm sounders, water, DCP and CO_2 extinguishers, fire blankets, shall be placed in all areas of the plant. The fire security system shall be designed and maintained by well trained and experienced specialists in the field. Regular fire drills and trainings shall be conducted for the staff. Also important to consider is proper electrical wiring of the facility by a certified electrician so as to avoid any potential short-circuits that may ignite a fire.

ii. **Accidents -** First aid equipment should be made available on the worksite and preferably staff should be trained in first aid during the operational phase. Accidents are common in an island setting which can be triggered by poor maintenance of equipment, negligence and due to natural causes. Details of measures such as training workers to handle emergencies and accidents shall be included in the ERP.

i. **Severe weather (waves and flooding) –** The existing environmental studies identified that risk of swells and rough weather could have impacts on the project. However due to selection of optimal sites for outfall and RO plant which are planned to be located away from directly exposed areas, the risk of severe weather impacts is reduced in all islands. Similarly, land surveys ensured that all sites were located behind the islands Environmental Protection Zone (EPZ), which is essentially the islands coastal vegetation belt that acts as the first line of defense in mitigating weather impacts. Nevertheless, the plant shall be constructed such that drainage of water from the plant is adequate to address frequent local flooding's caused by heavy rainfall. This could be achieved by elevating floor levels and designing the RO plant to maximize drainage.

ii. **Theft and vandalism –** Theft and vandalism of public infrastructure are common in Maldivian islands which makes this a high risk activity to the project during operational phase. The ERP shall highlight measures to ensure that the RO plant is monitored 24h. Security of the plant shall be high. Areas which are critical to the operation of the plant shall be fenced off from the public. CCTV cameras shall monitor the plant and public shall not be given direct access to the power plant.

iii. **Extended power loss –** Frequent power loss was reported by all project islands during the field assessment and is a common occurrence in the Maldives. In order to address these issues the RO plant in L. Gan and K. Gaafaru are located adjacent to powerhouse so that in addition to the cost and loss of power during supply, any issues encountered can be easily fixed. However, this has also enhanced the RO plants exposure to accidents and dust emissions from the power plant which creates additional risks as described in **Table 10** and **Section 9.4.1**.

In order to address issues related to power loss the RO plant has a designated area to house backup generators (See **Annex 3**). Backup generators shall be installed so that it could be used in case of power loss. Hence contingency power supply mechanisms and procedures shall be clearly described in the ERP. The EIA also recommends to install solar panels to offset demand on mains grid which would mitigate occurrence of power loss and enhance energy security of the plant.

iv. **Major breakdown of the plant** – Major breakdown of the plant could result in severe impacts on the public during water shortages and will have numerous impacts on local fisheries and tourism industry which would depend on water supplied. Break down of power plant equipment have been identified as having a high risk. See **Table 10** for details of this risk. The ERP shall ensure that measures proposed help in maintenance of the plant to prevent major break down of the plant which could become a significant economic burden on the islands local economy. **Table 10** highlights measures to be proposed to ensure that major breakdowns are prevented.

2.9 WASTE MANAGEMENT

The proposed project is expected to generate various types of waste during construction and operational phase. Construction waste, would mainly consist of excavated earth, nylon cement bags and general construction debris and sludge from borehole drilling. Main waste generated during the operational phase will be brine from the desalination plant, chemicals used for water treatment and testing and various biodegradable and non-biodegradable waste.

A description of how various types of waste generated from the project is to be managed is given below.

A. Biodegradable waste

Since none of the project islands have an operational waste management plan and waste management centre, biodegradable waste will be burnt and incorporated into island waste stream as described below.

During construction phase: The project is not anticipated to produce large wood stumps as waste since removal of large trees are not required. Only underbrush and wines at the site and outfall area on land is cleared which would generate biodegradable waste. These waste shall be managed by burning them as described below. During construction phase approximately 10 workers will be based on the island temporarily. These workers will be accommodated in existing houses, hence food waste produced by workers can be incorporated into the island waste stream, where it will be buried underground at the island waste disposal site.

During operational phase: Insignificant amounts of bio-degradable waste is expected to be produced during this phase. During operational phase, a handful of locals from the island will be hired. The plant house has not been designed to include staff kitchen or messroon. Hence no such wastes are expected directly arising from the facility.

E. Site Clearance Waste Management

Open burning is defined as the burning of any matter that is not contained within a fully enclosed firebox, structure, or vehicle and from which the products of combustion (such as smoke or ash) are emitted directly to the open atmosphere without passing through a stack, duct, or chimney.

These fires receive little oxygen and discharge a tremendous amount of smoke. Such smoke contains various toxic substances that are released into the air very close to ground level, potentially polluting the air, soil and waters with acidic gases, heavy metals and other pollutants.

Hence only vegetation waste shall be burnt during the site clearance phase and the contractor shall consider wind direction and proper combustion to ensure community in the nearby areas are not affected by burning of waste.

The following materials will have to strictly exclude from burning during any stage of the project: rubber, plastics, insulation, composition board, wiring, paint or paint filters, oil, hazardous wastes, industrial solid waste, and motor vehicles parts. This list is not specific or exclusive, but more an indication of the types of prohibited materials.

Yard waste is allowed to be burned as an attempt to reduce waste volume needing long range haulage. Minor amounts of yard waste are anticipated to be produced from clearing underbrush growth. No large trees are to be cut down as part of the project. By burning the yard waste locally transportation cost and associated GHG emissions will be significantly reduced.

Furthermore, the soil will be nourished by the biological activity facilitated by the buried root bulb and the amount of fill material required for levelling will be significantly reduced.

Prior to burring yard waste at the site, will be left to dry and will be burnt at a designated safe area away from residential areas. Burning will be carried out in an open area that would not impact unintended vegetation. Care should be taken to contain fire within the area of burning to prevent fire becoming uncontrolled. Wood ash contain calcium, potassium, and a variety of trace minerals important for plant health. They also work well as a lime substitute to raise the pH of acid soils. Hence the ash generated from burning site clearance waste can be buried in a pit.

B. Non-biodegradable waste

These will most likely be nylon cement bags, wrappings, steel/glass leftovers and other municipal waste generated at the construction site. Most significant type of non-biodegradable waste produced during construction phase would be cement bags, wrappings, construction debris. During operational phase, wrappings, various types of plastics and steel are anticipated to be produced. Waste generated from the project shall be collected and placed in a designated area. All non-biodegradable waste will have to be collected and transported to the nearest waste management facility for proper disposal. They will not be left on the island or incorporated into the island waste stream which is not being managed properly.

F. Sludge Waste

The semi-solid slurry produced during borehole drilling will be managed appropriately to prevent environmental pollution. Sludge generating from borehole drilling has been categorised as follows:

1. Sludge that do not contain bentonite or soda ash - These can be defined as drill slurry and will consists of water, sand and rubble particles. Borehole drilling during the construction phase would generate significant amounts of slurry, which will be stockpiled in a designated area within the work site to dry. Once the water has been evaporated, the remaining material can be sieved using drums and used for grading and levelling, or it can be utilised for other purposes. It is important to ensure that, water from the initial slurry stream do not flood the surrounding area. If the water content of slurry is high and saline, the slurry will be dried on top of water proof sheets to prevent ground water salinization.

2. Sludge that contain bentonite and soda ash - Bentonite is used as a bonding material in the preparation of moulding sand for the production of iron, steel and non-ferrous casting. The unique properties of bentonite moulds with good flow ability, compact ability and thermal stability for the production of high quality castings. It is especially useful in drilling to lubricate and cool the cutting tools, to remove cuttings, and to help prevent blowouts. Soda ash is used to activate dry bentonite during the drilling process. Although bentonite occurs naturally in volcanic areas, it is not sited in the Maldivian environment. MSDS for bentonite classifies it as a relatively stable and safe compound which disintegrates in the environment over a very long period of time. It is not

classified as a mutagen, carcinogen and is not toxic. However, ingestion of bentonite used for industrial activities may have health implication. Due to its durability in the natural environment and potential for health implications it is considered as a pollutant of the current project, hence will be treated as a hazardous waste.

Sludge that contains bentonite will be stored on spill proof sheets or in pits lined with spill proof membranes. Once dried the sludge will be stored in closed containers and transported to the nearest regional waste management centre where it will be landfilled.

G. ***Hazardous waste***

Hazardous waste is expected to be produced during construction and operation of the water supply system. Wastes that are as one that is toxic, ignitable, reactive, and/or corrosive will be considered as hazardous.

Construction Phase

During construction hazardous waste will mostly come from machineries, vehicles and tools in the form of waste oils, solvents, used batteries mainly used for the heavy machineries vehicles and drilling equipment. The quantity of hazardous waste generated will be small based on the small scale of the project. In order to manage these, waste will be sealed in labelled containers and will be stored on a hard surface before being transported to the nearest waste management centre. They will be stored at a designated area, close to the project site where they will be secured prior to transportation. It is essential to ensure that hazardous waste is fully contained and transported as quickly as possible. It is recommended to install signs in the designated temporary storage area and to seal it to prevent public access.

Operational Phase

During operational phase chemicals and brine are considered to be the main form hazardous waste generated. These types of waste will be discharged as directed. Pre- and post-treatment chemicals can be separated into anti scalants, coagulants and biocides. The project has been designed to reduce use of chemicals as much as possible. The following chemicals are typically used during the operational phase of RO plants.

Common anti scalants used in RO plants include sulphuric acid, polyacrylic acid and polymeric acid to prevent fouling through scale formation in equipment and RO plant membranes. These chemicals work by mainlining an optimum pH to prevent carbonate from precipitating out. A typical dose of 2 ppm is generally injected to the feed water and is generally viewed as having a very low risk on the environment.

Coagulants reduce suspended particulate matter during pre-treatment, through coagulation and flocculation into larger particles that can be more easily removed through backwashing. These by-products will also be realised through the outfall. Common coagulants used include ferric chloride, aluminium sulphate and coagulant aids such as polyacryl amide. The project design report does not specify use of a specific type of coagulants. This is mainly because the design relies on filtration and backwashing without chemicals to remove particles. Sludge accumulated as a by-product of filtration and settling of raw water is another significant type of waste generated during the operations of the RO system. Since these mostly contain natural materials they have been proposed to be discarded through the outfall. However, if chemicals are used in the process it is recommended to trap sludge and transport it to the nearest waste management site. The amount of sludge produced and the need for chemical use depends on the quality and source of raw water.

Biocides are used to remove living organisms in feed water and in permeate water that can foul desalination plants components and render product water unusable. Chlorine is used as a biocide and is a strong oxidant which is a very effective biocide. The proposed RO plant is designed to use biocide sodium hypochlorite (bleach) only on the permeate water which will be disinfected and stored for end use. Hence this class of chemicals is not expected to become an environmental pollutant.

Cleaning chemicals are used in RO plants to maintain its efficiency. Typical RO cleaning solutions are predominantly alkaline (pH 11-12) or acidic solutions (pH 2-3). Chemical used include dodecylsulfate and complexing agents such as EDTA. The type and amount of cleaning chemicals vary depending on the type of membrane. Cleaning solutions are typically used every three to six months and are potentially toxic to aquatic life if discharged without adjusting pH.

The other types of hazardous waste generated during operational phase include reagents used in the chemical testing laboratory. Based on the type of chemical these must be stored and discarded appropriately based on chemical Material Safety Data Sheet (MSDS). By no means will reagents and chemical waste at any stage of the project life cycle be disposed into the general waste stream. Chemicals which are flammable and corrosive will be discarded in labelled containers sealed and transported to nearest waste management centre that accepts hazardous waste. Laboratory glassware will also be discarded as hazardous waste and will not be mixed with the islands general waste stream.

2.6.16 Pollution Control and Safety Measures

Pollution prevention and safety measures will be one of the highest priority areas during the construction and operational phase of the project. It is recognised that poor site management and lack of safety measures for the staff and the facility as a whole can cause disruptions and economical losses for the project. For the operational phase of the project, clearly written SOP on pollution control and safety measures for the facility will be developed and implemented taking into consideration the content of the subsequent paragraphs in this sub-section.

Approaches to pollution prevention include source reduction, the technique of substituting non-hazardous or less-hazardous material, optimizing processes, and using good operating practices, as well as the reuse of materials where feasible.

The following measures will be taken to control pollution during construction stage.

a) All wastes generated during the construction phase will be managed as per **Section 2.9**;
b) Machinery to be properly tuned and maintained to reduce emissions/spills/leaks;
c) Fuel storage, paint, lubricants will be stored securely and bunded;
d) Fire extinguishing equipment would be available at the site;
e) Personal Protection Equipment (PPE) will be available for workers;
f) If work is conducted during the night time, adequate lighting will be available;
g) Only experienced and licensed operators will be allowed to operate heavy machines and
h) Work areas will be sealed for the public with appropriate signs.

The following measures will be taken to control pollution during operational stage.

a) Wastes generated during the operational phase will be managed as per **Section 2.9** of this report;
b) Chemical management shall be detailed in the operational manual of the facility and shall be managed as per the operational manual. The manual shall include but not be limited to the following measures:
    a. All chemical products must be stored and labelled in accordance with the manufacturer's instructions on the safety;
    b. Chemicals must not be stored together with inflammable material and gas cylinders;
    c. Chemical containers must be stored with closed lids when they are not being used;
    d. Chemical stores must not have open floor drains. If there is a floor drain, it must be equipped with protection to prevent leakage. This means for example tight fitting lids, a manual opening and closing function in the drain or other comparable arrangement;
    e. Combustible material must be stored in fireproof cupboards or in separate spaces;
    f. Chemicals must normally be stored in their original packaging. If smaller amounts of a chemical are needed, the new packaging must be suitable for the substance. Labelling must be in accordance with the original packaging. It must always be possible to know what substance the packaging contains and what risks there may be;
    g. Surplus chemicals and hazardous waste must be kept in the hazardous waste containers;
    h. Workplaces must be cleaned regularly. There must not be chemical spills on the floor;
    i. Wash off any chemical traces from the skin immediately and advice from the Island's Health Centre shall be sought.
c) The facility will follow the fire protection measures as per the **Section 2.8**;
d) Workers safety measures will be an integral part of the operational manual of the plant, that shall include but not limited to the following:
    a. Use personal protection equipment (e.g. Gloves, face mask) where necessary;
    b. First Aid equipment must be available;
    c. Smoking is forbidden in the premises of the RO plant areas with clear signs;
    d. Food products must not be stored or eaten in premises where chemicals are handled;
    e. Work clothes must be kept clean. If you have been in contact with chemicals, take a shower before you go home; and
    f. Construction supervisor will be present at the site;
    g. The work force would be equipped with all safety gears and warning signs would be provided; and
    h. PPE should be provided to all workers and the use of PPE enforced.

2.10 PROJECT INPUTS AND OUTPUTS

The table below elaborates the approximate amount of resources that will be required for the project for each island. The main inputs include workers, fuel, water, construction materials and machinery as well as chemicals.

Table 8: List of major inputs into the project

Stage	Input	Source / Type	Estimated Amount	Means of obtaining the resources	Comments
Construction	Workers	Local and foreign	10	Encourage the use of local / regional workers	Per island
	Equipment & Machinery	Multipurpose drilling machine Capacity 250 m /BW, Diesel engine powered	1 nos.	Provided by contractor	Per island
		Hydraulic excavator with maximum 1.4 m^3 bucket capacity and maximum digging depth 22ft	1 nos.	Provided by contractor	Per island
		Concrete vibrator	1 nos.	Provided by contractor	Per island
		450L Hand feed concrete mixer machine	1 nos.	Provided by contractor	Per island
		Hand tools such as wheel barrow, shovel, hoe, loppers, trowel, shovel, hand saw, rake, measuring tape, ropes, bar bender	5 each	Provided by contractor	Per island
	Fuel	Diesel	Approx. 80 l/d	Local Suppliers	Per island
	Water	Groundwater for non-potable use	Average 150 l/p/d	Groundwater wells present in the island	Per island
	Chemicals	Bentonite	40 nos. of 50kg bags	Local / regional suppliers	Per island
	Materials	Reinforced concrete	30 m^3	Local Suppliers	Per island
		Masonry Works (150 mm bricks)	150 m^2	Local Suppliers	Per island
		Structural Steel			
		50mm and 38mm GI Pipe for perimeter fence	49 m	Imported / purchased where available locally	Per island
		Ceramic tiles	11.2 m^2	Local suppliers	Per island
		Plywood ceiling	57.2 m^2	Local suppliers	Per island
		Primer and paint coating	288.7 m^2	Local suppliers	Per island
		Electrical and Mechanical Components			

		Ceiling mount energy saving light	7 nos.	Local suppliers	Per island
		13A power sockets	4 nos.		
		Wall mount exhaust fans	1 nos.		
		Wall mount fan	1 nos.		
		Submersible bore hole pump for bore well	1 nos.		
		Filter pump	1 nos.		
		High pressure RO pump	2 nos.		
		Chlorine dosing pump	2 nos.		
		Recirculation pump	1 nos.		
		Distribution pump	1 nos.		
		Backwash pump	1 nos.		
		Anti-scalant dosing pump	1 nos.		
		15 ton per day capacity RO Plant	2 nos.		
		High pressure RO pumps	2 nos.		
		Doors and windows			
		Doors	9	Local suppliers	Per island
		Windows	4		
		Plumbing			
		Material for drilling borehole for 160 to 110 mm tube well including drilling fluid, lubricant, grease, oil.		Local suppliers	Per island
		Media filters	0.7 m^2		
		Cartridge filters	1 nos.		
		Plastic or fiberglass backwash tank	1 nos.		
		Plastic or fiberglass sodium hypochlorite storage tank	1 nos.		
		Plastic or fiberglass chlorine dosing tank	1 nos.		
		RTP 50 Ton capacity storage tank	1 nos. (2 nos. in L. Gan)		
		63mm HDPE pipe to harbor kiosk	1 nos.		
		80mm HDPE pipe for brine disposal	1 nos.		
		Roofing			
		RO Plant building roof sheets	78 m^2	Local suppliers	Per island
Operation	Feed water	Water pumped from 30 m+ depth under ground	43 m^3 per day	From borehole	Per island
	Electricity	Electricity generated from powerhouse	15 KW	Diesel generator in the island	Per island
	Chemicals	Anti-scalant	5 ppm	Local suppliers	Per island
		Sodium Hypochlorite	8 mL (if 12.5% sodium hypochlorite) per cycle to reach 1 mg/L chlorine concentration	Local suppliers	Per island

		Testing reagents	Depending on testing standard, frequency and needs	Local / regional suppliers	Per island

Table 9: List of major outputs from the project

Stage	Output	Source / Type	Amount	Means of managing	Comments
Construction	Soil	Excavation for substructure	107.23 m^3	To be used back in the levelling and backfilling of excavations	Per island
	RO Plant Building	-	B. Kendhoo RO Plant Building - 62 m^2 L Gan RO Plant Building – 101.4 m^2 K. Gaafaru RO Plant Building - 62 m^2	RO Plant will be managed by party specified by the proponent	-
	Borehole	Borehole of diameter 500 mm and depth of 30 m (if water conductivity does not reach 50,000 µS/cm, borehole should be drilled deeper)	1 nos.	-	Per island
	Tap bay	-	1 nos.	Managed by party specified by proponent	Per island
	Harbor kiosk	-	1 nos.	Managed by party specified by proponent	Per island
	Storage tanks	50 ton capacity storage tank	1 nos. in B. Kendhoo and K. Gaafaru, 2 nos. in L. Gan	Managed by party specified by proponent	-
	Waste	Construction waste	Approx. 1917 kg construction waste in L. Gan Approx. 1177 kg construction waste in B. Kendhoo and K. Gaafaru each	See **Section 2.9**	-
		Yard waste includes a small amount of undergrowth which needs to be cleared to construct outfall pipeline.	Less than 250 kg	See **Section 2.9**	Per island

	Hazardous waste	Empty fuel/lubricant drums, used oil/air filters, scrap batteries, vehicle parts and waste oils/grease, spent solvents/detergents and possibly spent acid/alkali from batteries maintenance.	Approx. 30 -50 l/month	See **Section 2.9**	Per island
	Municipal waste	Workers	346.5 kg	See **Section 2.9**	Per island
	Dust	Excavation	Moderate amount of dust		Per island
		Cement mixing	Moderate amount of dust		
	Green House Gases	Concreting works	Approx. 9720 kg of CO_2 indirect emissions (DEFRA/DECC, 2012)		
	Noise	Construction work. Earthmoving equipment such as excavators produce noise in the range of 73-96 dBA Partially mobile equipment such as concrete mixers/cranes range from 75 to 90 dBA stationary equipment such as pumps/generators range from 70 to 80 dBA	60-80 dbA eq within 5 m of construction site	See **Section 2.9**.	Per island
	Drill slurry	Drill slurry including cement, sand, water and bentonite	Approximately 6 m^3 of drill slurry	See **Section 2.9**	Per island
Operation	Freshwater	RO Plant	15 m^3 per day production	Stored in the storage tanks of 50 tons (and 2 nos. of 50 tons in L. Gan) Supplied to tap bay and supplied to kiosk at the harbor for sale of freshwater.	Per island
	Brine	RO Plant	2.23 m^3 per hour	Disposed into the sea via brine discharge outfall equipped with T-head diffuser	Per island
	Waste	Municipal waste		See **Section 2.9**	
		Hazardous waste		See **Section 2.9**	

	GHG	Electricity usage	Approx. 81 kg CO_2e per day from 15 kW power consumption of the RO Plant daily (DEFRA / DECC, 2012)	N/A	Per island
	Noise	RO plant, intake pump, RO pump, Backwash pump, Harbor kiosk pump, Reticulation pump.	Approximately 65-75 dBA at the facility	See **Section 2.9**	Per island

2.11 PROJECT RISKS

This section addresses foreseeable risks that may be associated with the project. Even though some of these risks may carry a low probability of occurring, it is necessary to consider whether both the risk and the outcome can be managed if at all they occur. Risks can cause unnecessary delays with resulting environmental and cost implications to both the proponent and contractor. Hence identification of potential risks and implementation of management plans will be a very important exercise. Project risks have been compiled based on field surveys, experience from similar projects, published literature and experience of consultants.

Table 10 below summarises the project risks that could potentially slowdown or stop progress of the project.

Table 10: Project risks and management

Type of risk	Risk	Risk significance	Cost driver	Description	Risk Management
Administrative risks	Approvals and environmental clearance	Moderate	Overall project cost	Obtaining necessary approvals from government agencies have been found to be time consuming and causing delays to projects. Required approvals for the current project include, obtaining land approval, approval for the EIA, registration of the RO plant and electrical wiring approval. Such delays can add to project cost and social anxiety.	Ensuring that the proponent, consultants and designers fully comply with regulations and ToR set forth by the EPA. EPA and MEE to fast track the approval process. MEE ensuring to obtain all relevant approvals prior to construction. Better coordination with
	Delays in final design drawings and environmental impact assessments and other design documentation required for the project	Moderate	Overall project cost	Delays in final design could incur additional costs and create additional social issues within the respective island.	Ensuring that time schedule are followed, and provide the facilitation required to complete by proponent and relevant stakeholders. Simple yet efficient design, which would save cost and time.
	Changes in design and construction standards during the construction period	Low	Overall project cost	-	If the original design was deficient risks shall be borne by proponent. If required by the authority without default by proponent then risk shall be mitigated, distributed or alternative options explored.

Site related risks	Land acquisition	Low	Overall project cost	If proposed land is defaulted due to lack of proper procedures in acquisition of land or any other reason such as inappropriate site selection etc., the proposed project is at risk of being delayed or stopped.	Land acquisition shall be followed in accordance with state regulations. All proposed locations for the RO plant have been approved by MHI and are not known to encompass protected species or environmentally sensitive habitats hence this risk is minimal.
	Access risks	Low	Overall project cost and duration	All proposed sites have been previously cleared and is easily accessible by roads. Relatively few vegetation or obstacles exist with regard to accessibility. All three islands have harbours which aid in accessibility during transport of materials etc.	Following the general management and mitigation proposed in the EIA. (See **Section 9**)
	Social	Low	Overall Project	None of the project site requires removal of privately owned trees. Equipment and construction site may be a health hazard to the public in the form of accidents and injuries. Easy access to the construction site may enable criminals to steal valuable equipment and machineries.	To manage this risk, it is important to secure and safely store all equipment on site. Proper information sharing with the local authorities. Establishing a good coordination mechanism with the authorities and Approval of the EIA. Compensation arrangements shall be made if any private coconut palm trees are removed as described in **Section 3**.
	Cultural/archaeological/ heritage	Low	-		-
	Environmental	Low	Construction cost	Prolonged unfavourable weather conditions, incidents of swells flooding the island, high winds and site having unfavourable soil properties.	Weather related impacts are difficult to completely avoid. However, given the nature of the works, weather factor shall be seriously taken into account to minimise the risk. Work could be planned to avoid months of strong wind and wave conditions May-July (See **Section 5.2**). The proposed locations for RO plant developments are in flat areas with typical soil properties hence will not require extensive levelling or reclamation.

Construction Risk	Quality of work	Low	Construction cost	Careless workmanship and poor quality, could have economic and environmental implications.	Proponent should monitor work progress. Qualified site supervisors shall be on site at all times when the work is in progress. Quality control measures should be implemented during construction. Environmental monitoring and site monitoring shall be undertaken routinely as describe in **Sections 9, 10 and 11.** Construction standard and specifications shall be met by the contractor.
Construction /Operational Risk	Delays due to contractor	Moderate	Construction/ Operation cost	These may range from, equipment malfunction, lack of finance, issues with registration and obtaining relevant approval etc.	Contractor shall ensure adequate financing is set aside for the smooth operations of the project activities. Timely settlement of payments both from the contractor side and proponent side. Contractor should ensure time schedule is followed All vehicles, equipment's shall be serviced regularly. Spare parts and backup plants and machineries shall be arranged before work commences. Contractor shall ensure all permits stated in **Section 3** of the report is obtained prior to commencement of work.
Construction/Operation Risk	Delays due to proponent or government	Low	Overall Project Cost	These may include change in rights of the project or changes to the ownership of the project.	All work done shall be compensated and time shall be given to complete work under the changes. Contingency plan shall be in place not to cause disruptions to work even if the project ownership changes.
	Labour and material availability	Moderate	Overall Project Cost	These risks may arise due to unavailability of spare parts, replacements, labour etc.	All major resources shall be made available on site before the work commences Backup arrangements

	Damage/insolvency due to third party	Moderate	Overall Project Cost	If a third party is involved in the project as subcontractor for subcomponents such as removing waste, cutting down of trees, site clearance, implementation of waste management plan etc, and delays from their side would affect the progress of the project.	Proper due diligence will have to take place prior to the engagement of third parties to ensure their capacity to do the work. If third parties are involved in the project, guidelines, rules and standards shall be created and implemented by the proponent.
	Water/air/soil pollution pre-existing or arising from work	Low	Construction and Operation cost	Spills ,accidental or intentional if caused could be costly in terms of time and resources and will cause project delays.	All related mitigation measures and waste management measures prescribed in the EIA report shall be strictly implemented to avoid such incidents from happening.
	Workplace health and safety	Moderate	Construction costs	Injury, damage or loss of life due to site clearance can be extremely costly. Diseases such as diarrhoea, flue that are contagious can affect the workforce severely. If a key member of the work force is lost due to sickness or injury, it can affect the work progress.	Contractor shall be liable to ensure all safety measure are put in place at the work site. These include providing safety gear to workers and installing firefighting and safety equipment on site. Arrangements shall be in place to replace key personnel should a situation of a replacement arises. If signs of a contagious disease is observed, the sick shall be isolated and be not allowed to report to work. First aid services shall be available on site. If a major injury to a worker occurs arrangement shall be in place to transport the injured to the nearest hospital. Contractor shall also implement all mitigation measures stated in the EIA. Proponent shall commit to monitoring and ensure health and safety measures are implemented.

	Loss/lack of technical staff	High	Overall project cost	Describes resignation of technical staff in key roles tasked with the successful implementation of the project during construction and operational phase. Loss of such staff, results in delays and impedes progress of the project. Similarly lack of technical staff to undertake specific trades or manage RO plan can completely disrupt the project development.	In order to address delays and cost acquired by loss/lack of key technical staff plans shall be made by the contractors and operators. Proper handover procedures shall be made part of the employment contract to enable smooth transfer of responsibilities. MEE shall ensure contractor transfers all necessary manuals and trainings to the operator.
Operational Risks	Inadequate RO plant management	High	Operational cost and overall project cost	Lack of qualified staff and procedural norms have been identified as a significant risk to the project that may cause the project to be unsuccessful. Assigning the management of the RO plant to parties that have minimal to no experience at undertaking such a work will have numerous difficulties during the operational phase. Another factor which makes this risk high is the difficulty in obtaining qualified staff specially in low population islands such as B.Kendhoo and K.Gaafaru The projects lack of revenue generation may not successfully sustain the operation due to high cost of operation in relation to income. The project is designed to be partially communal and partially commercial which may result in numerous challenges during its operation. Notable challenges may include setting tariffs and plans to distribute water to the public. Lack of maintenance could quickly damage the filtration system of the RO plant.	Follow emergency and safety management plan as described in **Section 2.1** Client to ensure that selected contractors have experience in building and maintaining RO plants. Client shall ensure contractors provide a detailed plant maintenance and management manual with details regarding troubleshooting the RO plant, human resource allocation and anticipated operating costs. Contractor shall train staff for at least three months. All points highlighted in EPA's technical specification for water supply system shall be followed

	Lack of resources to implement and operate the RO plant	High		These mainly include, human resources and materials required for the daily operations of the RO plant such as lab equipment, chemical reagents and spare parts for pumps, membranes, filters etc. None of the existing utility providers operating in the islands have significant experience in water supply system management and maintenance, which could potentially make the project unsuccessful.	Service provider to demonstrate that they have the capacity and resources to manage the RO plant. Client to ensure that service provider could undertake the operations of the RO plant. Client shall assign work to an operator who has the capability to operate the RO plant according the manual and EPA regulations. Terms of reference shall be prepared between the client and operator clearly identifying objectives future goals according to a proposed time plan. Client to monitor and ensure goals are met
	Environmental Impacts	Moderate	Operation al cost	Details of environmental impacts arising from the project are given in **Section 9**. Marine environment pollution as a result of brine disposal and waste generation during construction and operation have been identified as notable environmental impacts of the project. The risk of groundwater salinization as a result of improper borehole depth is also notable. If the borehole does not penetrate the groundwater water lens, feed water demand for the RO plant could deplete the groundwater lens.	Ensure that waste management plan proposed in the report is followed (See **2.9**) Ensure that all environmental impact mitigation measures proposed in the report is followed (See **Section 9**) Ensure that feed water is tested during and at the end of borehole construction. Ensure the emergency and safety planning proposed in the report is followed (See **Section 2.8**) Ensure that borehole is drilled to a depth of 30 m as specified in the guideline and validate it by conducting water quality testing from a standardised laboratory. Do not commence water production unless water quality results have been validated,\.

	Actual operating and maintenance costs higher than anticipated	High	Operation and maintenance costs	Increasing costs, poor management, lack of resources, ineffective RO plant management plans and prolonged inactiveness of RO plant could leave the infrastructure and equipment in poor shape which can have environmental and social impacts. Such risks can be magnified by currency devaluation, inflation etc.	Recovery through robust tariff schedule. Upgrading the water supply system to provide house connections. Committing to undertake the mitigation and management plans recommended in the EIA.
	Poor quality of product water	High	Operational cost and project viability	If the quality of product water does not meet the WHO and local guideline detailed in **Section 3,** health implication may arise. This is identified to be a high risk, since a proper management or a procedural plant for testing product water have not been designed at this stage of the project. Similarly, procurement of lab equipment and laboratory concept design is not planned for the construction phase and are scheduled for the operational phase and is assigned to the operator. Parameters such as salinity, chlorine concentration and coliform levels in product water can easily increase to malfunction of filters and improper operational procedures. Similarly hydrocarbon and heavy metal levels in product water can increase due to dust fall from the adjacent powerhouse.	Ensure that laboratory design, concept is prepared prior to operations of the plant. Procure all lab equipment and reagents prior to operation of the plant and ensure that all tests are conducted, recorded and submitted to the regulator as detailed in **Section 3**. In cases where tests cannot be done at the plant, ensure that samples are delivered to nearest testing labs for testing. Ensure that all chemical testing procedures and their details are included in the plant operation manual. Ensure that RO plant is operated according to the operation manual. Ensure that plant operations are hygienic. Make sure dust fall is monitored and test product water for heavy metals and hydrocarbons more frequently in case of K.Gaafaru and L.Gan.

	Power supply disruption and impacts of dust fall on RO plant	High	Operation al cost and project viability	Power is supplied through the existing powerhouse which uses fuel based generators. The system has been identified to be extremely vulnerable. Mainly because, fuel is a non-renewable source of energy which is imported and transported to project islands. Price fluctuations and supply issues are known to have significant impacts on islands supply of electricity. Low capacity of generators and poor maintenance of generators are also known to cause frequent power outs in the project islands. Since, the proposed RO plant in L.Gan and K.Gaafaru are located adjacent to the powerhouse, dust pollution have been identified to be a notable operational phase impact which could contaminate product water and RO plant equipment. Overall, vulnerability of power supply is high for all islands.	Ensure, that solar energy is utilised in the project as a source of renewable energy to enhance RO plants adaptability to power outs and increase it energy security. Ensure that backup generators are installed at the RO plant to avoid damage caused to plant during sudden power cuts. Ensure that, dust fall is monitored during the operational phase. This could be achieved by monitoring product water quality as explained above and monitoring dust fall on storage tanks and plant roof top using automatic particle monitoring equipment or testing wipes used to collect dust.
	Breakdown of power plant	High	Operation al cost and project viability	Power plant breakdown due to lack of spare parts negligence or poor maintenance have been identified to have a high risk due to its' common occurrence. Minor troubleshooting knowledge and lack of proper plant inventory could essentially disrupt supply of water which could affect the local fishing and tourism industry that would rely on continuous supply of water.	Ensure that detailed operational manual of the plant is prepared and implemented. Include project ERP in this manual and conduct manual acclimatization workshops. Maintain proper inventory of plant and ensure plant is managed as per the standard of operations (SOP's) proposed in the operational manual. Do not run plant without preparing the operation manual.

Force majeure Risk	Natural disasters, Impacts on project due to environment terrorism	Moderate	Construction cost and operational cost	All three islands have noted swells and rainstorms in the past which have resulted in local flooding with varying degree of damages to property (See **Table 24**) Based on historical events the likelihood of rainstorms and floods are likely to have notable impacts on the plant. Similarly swells and wave action have been known to damage the outfall pipe which have resulted in frequent maintenance.	Although difficult to completely avoid, better planning and proper security and safety measures could greatly reduce the risk. Placement of outfall in optimal areas would greatly reduce impacts on outfall pipe caused by wave action and other natural environmental factors. Outfall locations proposed in in the report are based on such environmental factors (See **Section 5.3** for details).

In general, as can be seen in the risk evaluation table, the perceived risks of the project have been evaluated to be moderate to low during construction phase while it is evaluated to be moderate to high during operational phase. However, these risks can be mitigated by appropriate actions as proposed above. Therefore, it is recommended to consider these risks and their likelihood in managing the project and due attention given by the proponent and the contractor to address and manage these issues as proposed in the report.

3. ADMINISTRATIVE AND REGULATORY FRAMEWORK

3.1 INTRODUCTION

This Chapter highlights relevant national policies and legislative framework applicable to the proposed Project. The relevant national polices and legislative framework provides guidance on several aspects related to planning, and implementation of coastal projects. The legal framework pertaining to the proposed Project is also aimed at sustainable development, impact mitigation and conservation of the country's natural resources.

An institutional mapping and analysis was conducted in the context of the proposed Project on environmental policies and legal frameworks and roles and responsibilities of key institutions driving development and environmental management at the national and local levels as required in the ToR **(Task 3)**. The chapter describes pertinent legislation, regulations, standards, and environmental policies that are relevant and applicable to the Project. In addition, appropriate authority jurisdictions that will specifically apply to the project are also discussed. In keeping to the ToR, the review also identified different articles and clauses in laws and regulations that applies to the Project and explanation provided on how the project meets these requirements.

3.2 ENVIRONMENTAL GOVERNANCE

Environmental governance in the Maldives takes places at two distinct levels; national and local. Central administration in the Maldives is conducted through national ministries headed by Cabinet Ministers based in the capital of Male'. Ministries are responsible for formulating relevant policies, planning development, coordination with donors and to a large extent formulating and implementation of projects in the country. Below the central government are 19 administrative units (roughly one per atoll) and each administrative atoll having an Atoll Council elected under the DA (2010). Each atoll in turn is divided into smaller administrative units comprising usually of inhabited islands and uninhabited islands. The governance system in the Maldives consists of 19 atoll councils, three city councils (Malé, Fuvahmulah and Addu) and 188 island councils. The specific roles and responsibilities of the councils in relation to the project are discussed in detail in the following sub-sections. The island councils are supported by advice from Women's Development Committee comprising of elected members from the community. In addition, Island Councils can seek opinion of youth groups, community elders and individuals on matters related to them. Public information on projects and other important matters is shared through formal and informal meetings organised by the council. All land is the property of the state, however uninhabited islands and land parcels from inhabited islands may be rented out by the government to private individuals or businesses.

The Maldivian institutional structure to protect the environment is relatively young, having been developed in the 20 years or so. Presently, the Environment Department within the Ministry of Environment and Energy (MEE) and Environment Protection Agency (EPA) are the main focal point for all environmental issues in the Maldives.

3.2.1 Ministry of Environment and Energy

The Environment Department of the MEE has a policy making and developmental role in relation to water security and water resource management. MEE has a general mandate to formulate policies, regulations and standards needed for water management, water security, water production and prevention of environmental degradation pursuant to Environmental

Protection and Preservation Act (EPPA). As such MEE is tasked with the overall designing and implementation of Water Management Framework in the Maldives.

The Environment Department has the function of developing and implementing projects targeted for the building of water production/management infrastructure to prevent environmental, economic health and social impacts associated with lack of clean water. The department seeks funds from the national budget and donor sources to enhance water security of the nation. The beneficiaries of such projects are determined on the basis of national development priorities. The department though it has a regulatory function has limited its role to promulgation of regulations, and has delegated monitoring and enforcement function to the Environmental Protection Agency.

In this regard the current project is a donor funded project implemented by MEE to meet its sustainability goals.

3.2.2 Environmental Protection Agency

The EPA is a semi-autonomous regulatory body affiliated to the MEE and operates under the guidance of the Minister in-charge of the MEE.
The EPA has been assigned the following functions pertaining to water supply:

i. Approval of EIA related to development of water supply system;
ii. approval of concept and evaluation of design and technical specification; and
iii. issuing licence for all water and sewerage activities.

EPA is responsible for the discharge of functions and enforcement of the following laws, regulations and guidelines which are related to the current water supply project:

i. The Environmental Protection and Preservation Act of the Maldives, EPPA (Law No. 4/93);
ii. Environment Impact Assessment (EIA) Regulations (2012/R-27);
iii. By law about the cutting down, uprooting, digging out and export of trees and palms from one island to another, 2006;
iv. Waste Management Regulation, (No. 2013/R-58);
v. Regulation on Protecting and managing historically culturally significant trees
vi. Regulation on Dredging and Reclamation (2013/R-15);
vii. Dewatering Regulation (2013/R-1697);
viii. Regulation on Sand and Aggregate Mining (2000);
ix. Regulations for installing and Operating Desalination plants in the Maldives;
x. Design Criteria and Technical Specifications – Design and construction of water treatment and supply system; and
xi. Guideline for Drinking Water.

3.2.3 Ministry of Housing and Infrastructure

The Ministry of Housing and Infrastructure (MHI) has the following functions that have a bearing on public infrastructure:

- Approval of land proposed for the establishment of desalination plant. In islands where a Land Use Plan (LUP) has not been prepared, MHI is tasked to review and approve the proposed land.

- approval of LUP of islands;
- maintain information (database) on use and condition of government and public infrastructure;
- maintenance of an infrastructure register;
- formulate policies for the development of public infrastructure and give technical advice for implementation of such projects;
- plan and manage public infrastructure projects that does not fall under the purview of a specific institution;
- co-ordinate and manage reconstruction of public infrastructure damaged by natural disaster or any other event; and
- co-ordinate activities for reconstruction and repair of public infrastructure damaged by natural calamities.

Specific functions pursuant to the above activities are undertaken and supervised by the Infrastructure Department and the Planning Department of the MHI.

The Infrastructure Department is involved in the planning and budgeting processes within government to ensure harmonisation of implementation of infrastructure development projects, through coordination and collaboration of the work through relevant Ministries and government departments.

3.2.4 Island Council & Atoll Council

Every inhabited island in the Maldives, except islands where city councils are established, is governed by an elected island council which prepares island development plans in consultation with the community, and submits them to the atoll council. On a broader sense atoll councils oversee major development projects within the atolls and is the main trading hub within the atoll. The island councils are also mandated to take all necessary measures to establish a safe and peaceful environment on the island in collaboration with the police. This includes ensuring the overall cleanliness of the island and management of pollution and degradation of the environment.

Each island council has a women's development committee advising on key women's issues, including: income generation and development of women, women's rights, religious awareness amongst women, political participation by women, higher education for women, women's health, and collection of information and statistics on women's issues.

Island Councils have associated rights to enter into ventures with the private sector under Public Private Partnership models to build harbours and other such infrastructure (Clause 86, Decentralisation Act) and to formulate regulations governing the maintenance public infrastructure of the island in consultation with the Local Government Authority (Clause 151, Decentralisation Act). In practice, however, the Island Councils have a limited role in development of island level infrastructure, and the Councils depend on the sectorial ministries to take the necessary actions for building public infrastructure such as IWMC's.

The scope of island council in this particular project includes:

i. Water supply site selection through consultation with the relevant stakeholders and submission of site selection form as per the regulation;
ii. provide an alternative site in case the proposed site was deemed to be inappropriate by EPA and MHI;
iii. monitor and manage land clearance activities as described in the report; and
iv. monitoring and support during construction phase of the desalination plant.

3.2.5 Ministry of Health

The Public Health Preparedness and Response and Epidemiology Division under the HPA has been tasked with the mandate to take the initiative to respond to medical emergency situations brought on due to natural disasters and other crisis situations and to maintain emergency stock of medicines and medical equipment's in accordance with the manner stipulated in disaster preparedness plans prepared and implemented by the Division. The Division has the responsibility to provide the necessary guidance to local level health sector institutions to prepare rapid assessment of medical emergencies or natural disasters and crisis situations and work in accordance with Health Sector Emergency Risk Framework (2014). The Division has also been assigned the function of conducting training programmes and drills to prepare health care personnel on emergency preparedness and response.

3.2.6 Local Government Authority

The LGA is working in close collaboration with the NDMC to incorporate disaster management and disaster risk mitigation into island level development planning. For this purpose, the LGA is revising Island Development Plan templates to include and integrate disaster risk mitigation measures where coastal development is also considered.

3.3 REGULATORY CONSIDERATIONS

In addition to the legislative instruments highlighted in **Section 3.2.2**, the key national legislation, policy, regulation and guidelines governing the water supply projected are highlighted in the table below.

The key national legislative frameworks and other secondary legislative frameworks relevant for the proposed Project and proposed compliance arrangements are summarised in **Table 11.**

Table 11: Relevant laws and regulations pertaining to the Project and measures to ensure compliance.

Law/Regulations & Policies	Measures to comply with the laws/regulation
The Environmental Protection and Preservation Act of the Maldives, EPPA (Law No. 4/93)	
Clause 2: Concerned government authorities shall provide necessary guidelines and advice	EIA prepared as per the EIA 2012/R-27
Clause 3: Environment Ministry responsible for formulating policies as well as rules and regulation;	EIA prepared as per the EIA 2012/R-27
Clause 4: Environment Ministry shall identify and designate protected areas and nature reserves;	The project does not have any impact on a protected area
Clause 5: Environment impact assessment mandatory for any new projects;	EIA prepared as per the EIA 2012/R-27
Clause 6: Power to terminate developments causing significantly detrimental impacts;	No significantly detrimental impacts have been identified that are irreversible. Comprehensive impact mitigation and management measures have been proposed.
Clause 7: Refers to the disposal of oil, wastes and poisonous substances in to the Maldivian territory. According to this clause, any type of waste, oil, toxic gas or any substance that may have harmful effects on the environment should not be disposed within the Maldivian territory. If, however, the disposal of such substances becomes absolutely necessary, the clause states that they should be disposed only within the areas designated for that purpose and if incinerated, appropriate precautions should be taken to avoid harm to the health of the population.	Fully complied to – Waste management during the construction and operational phase are in line with the clause
Clause 8: Disposal and transboundary movements of hazardous wastes banned;	N/A
Clause 9: Fines for damage to the environment;	Commitment letter provided by proponent to implement mitigation measures as proposed in EIA to avoid environmental damage. See **Annex 7**

Clause 10: Compensation for environmental damage that may take place;	Commitment letter provided by proponent to implement mitigation measures as proposed in EIA to avoid environmental damage.
Land Act 1/2002 The Act governs the allocation of Maldivian land for different purposes and uses and other issues regarding the issuing of land, issuing of state dwellings for residential purposes, conduct regarding state dwellings or private dwellings constructed for residential purposes and the sale, transfer and lease of Maldivian Land. All transactions concerning the issuing, receiving, owning, selling, lease, utilizing and using Maldivian land shall be conducted in compliance with this Act. The Ministry of Home Affairs, Housing and Environment shall entrust the land allocated for different purposes and uses in accordance with sections 3 and 4 of this Act to the concerned Ministries	Complied as all the proposed land allocated to construct the RO plant have been approved by Ministry of Housing and Infrastructure (MHI).
Environment Impact Assessment (EIA) Regulations (2012/R-27) • Annex 4 of the regulation states that projects which are aimed at developing desalination plant (10-ton capacity) will be required to submit an EIA. Similarly projects that require sea outfall installation and borehole drilling are also required to submit an EIA	The EIA is submitted to fulfil this requirement as per the regulation.
By law about the cutting down, uprooting, digging out and export of trees and palms from one island to another, 2006.	
Clause 2 (a) States the purpose of this by law is to educate citizens and developers about the importance of trees including best management practices for maintaining trees and to provide standards for the preservation of trees in Maldives and to set down rules and regulations to be adhered to prior to commencing felling, uprooting, digging out and exporting of trees and palms from one island to another in Maldives	-
(b) Palm trees shall be removed and relocated only after exploring all other options	Design changes and relocation of plot were considered in the assessment prior to recommending removal of trees.

(c) States that regulatory authority have the right to issue and approve removal of trees for national development purposes under the condition that 6 new trees are planted for every tree removed.	Fully complied through the approval of EIA
Clause 3 states trees that are prohibited to be removed	
(a) The coastal vegetation growing around the islands extending to about 15 metres into the island are protected by this by law	Has been fully addressed in the project description and Environmental Impacts and Mitigation chapter (**See Sections 2 and 5.6.2**). The project does not involve removal of coastal vegetation from the designated buffer area.
(b) All the trees and palms growing in mangrove and wetlands spreading to 15 metres of land area is protected by this law	Site fully comply with the clause. There are no mangrove areas close to the proposed site.
(c) All trees in Government protected areas	N/A since no protected area on the island is impacted by the project
(d) Trees that are being protected by the Government in order to protect species of animal /organisms that inhabit on such trees.	N/A
(e) Trees / palms those are abnormal in structure.	N/A no such trees were observed in the vicinity of the Project site.
Clause 4 The regulation states that prior permission must be obtained for removal and/or relocation of 10 or more trees or palms. For indiscriminate removal and land clearances and EIA and Decision Note is required. The size of the trees and palms that are allowed to be relocated should have more 15feet from lowest point to the crown spread for palms and 8 feet from the lowest point to the trunk to tip of the highest branch for trees other than palms. The law also states that cutting down and uprooting of the trees shall be made under supervision of the island / atoll offices (in the current context Atoll / Island Councils).	More than 10 trees will not be removed as part of the project hence conditions of the clause will not apply.
Clause 5 of the by law describes Issuance of permits to cut down, uproot, dig out and export trees and palms from one island to another.	
(a) Prior to the commencement of any project(s) that would require the indiscriminate removal and export of trees/palms from one island to another for the purposes of agriculture, development/redevelopment, construction or any other purpose, it is mandatory under this Regulation to prepare an Environment Impact Assessment Report stating clearly the details of the project(s) with all necessary information and submit the same through the relevant Ministry to Ministry of Environment, Energy and Water, and	N/A

	the project(s) can only commence upon the grant of written approval from Ministry of Environment, Energy and Water.	
(b)	In the event that a need arises to remove 10 or more Trees/palms at a time that are grown in private dwellings for one's own use, then the requirements stated in clause 8 a) and b) must be fulfilled.	N/A
(c)	All the persons who are granted a permit to remove trees/palms by the Ministry of Environment, Energy (EPA) must complete the work of removal of the trees/palms before the end of the stipulated time. If the work is not completed in time, then the concerned parties must apply in writing to extend the period to Ministry of Environment, Energy (EPA) and cease work until the issuance of a new permit.	N/A (Since the land clearance required do not fall under the category that requires a permit)
(d)	If it is necessary to export the trees/palms with soil, then it must be done only in nursery bags that measure up to 8"/10".	These type of trees are not present at the proposed site in any of the project islands.
(e)	In the event that the trees/palms are larger than the size specified in clause 8 a) of this Regulation and they are to be removed for export to another island; the tree/palm must be cleaned of all excess black soil from the root balls before it is exported to another island.	These type of trees are not present at the proposed site in any of the project islands.
(f)	If excavators/bulldozers are used for the removal of trees/palms and if it might cause injury to another tree, then such machinery should not be used to remove the tree(s)/palm(s).If damage is caused or might be caused to a neighbouring tree/palm while in the process of removing the desired tree/palm, then the desired plant/palm cannot be removed.	There are no palm trees at any of the islands which will require removal.
(g)	Following clause 5 of the regulation, EPA published the guideline on **cutting down, uprooting, digging out and export of trees and palms from one island to another (2017).** The guideline mainly defines what constitutes as major land clearance and circumstances for which approvals are given and particular permits are required. ***Clause 3*** – States that projects with sufficient funding and approved by the respective governmental ministry/agency will be eligible for land clearance. ***Clause 5*** – States that removal of more than 200 coconut palm trees or clearance of 8250 m^2 land will require preparation of an EIA. If land clearance is smaller, then EPA shall issue permits provided that trees to be removed are not in prohibited areas.	The project does not involve significant land clearance (See **Section 2.2** for details) and does not involve removal of trees from prohibited areas in any of the islands.
Clause 6 states special permit issued to cut down, uproot dig out and export trees and palms from one island to another		The project does not involve removal of palm trees and other large trees from any of the project islands.

Clause 7 states that the maximum number of trees that can be removed from an island will be determined by Ministry of Environment, Energy and Water who shall also permit for the export of trees/palms from one island to another.	N/A
(b) Trees/palms that are in inhabited/uninhabited islands that are used by species of birds as a roosting or breeding spot are protected under this Regulation and if any of these trees/palms are to be removed, a special permit should be obtained from Ministry of Environment, Energy and Water. In addition, if a tree/palm that is a roosting or breeding spot for certain species of birds are to be cut down permission has to be sought from the Ministry of Environment, Energy and Water.	N/A
Clause 9 The holes created from uprooting trees/palms must be covered with soil and made firm, it is prohibited to cover the holes with waste.	N/A
Regulation on Protecting and managing historically culturally significant trees	
Purpose of the regulation is protecting endangered species and other species of historical, cultural and natural significance. The regulation came into being in 5 June 2007 with the aim of fulfilling the agreement of convention on biological diversity.	
Clause 3 states that four types of trees will be protected under the regulation • Trees that are between 50-100 years or more than 100-year-old • Environmentally significant trees • Trees that are protected at the be hence of communities	These types of trees did not intersect with the projects direct footprint area in any of the project island.
Regulation on Dredging and Reclamation (2013/R-15)	
The regulation requires having permission of EPA on projects requiring alteration of the island, either by reclamation or dredging. Specifically, the regulation requires producing scaled maps of the island before and after the proposed intervention. Special provisions have been made on protected and sensitive area restricting changes to the environment of the islands.	N/A
Dewatering Regulation (2013/R-1697) Dewatering regulation no. 2013/R-1697 gazetted on 31 December 2013 has been one of the important regulations enforced by EPA. It helps to protect groundwater aquifers from by avoiding direct pumping for a longer period. Clause 7 (a) of this regulation says, if dewatering is required, dewatering permit is required obtained from EPA or an institute authorized by EPA through an application form. The Dewatering Regulation states that: • If dewatering operations are conducted within 100m of households and farms, the local council shall be informed of the dewatering.	The project requires dewatering during the borehole process. There are households located within a 100 m boundary at the project islands. Multiple areas will not be dewatered as part of the project. Similarly, groundwater will not be discharged into the environment. Groundwater mixed with bentonite will be recharged back to the borehole as described in the report. Residual slurry which remain will be considered as hazardous waste. Dewater permit will be obtained

• Water quality test results of the dewatering area shall be submitted along with the application for the dewatering permit. The test results shall not be older than 45 days from the date of issue to the date of application for the dewatering permit. • Dewatering permits are given after considering the size of the area required for dewatering, the water quality of the area, proposed work schedule, water discharge method and discharge locations. • Application for dewatering for large scale projects that require concurrent dewatering at different locations should be made as an application for a single permit for all the works that will commence within the 28 days the permit is given for. • Dewatering permits are given for 28 days, and if the site engineer deems the dewatering operations will take longer than that, the permit shall be sent for renewal three days before the expiration of the initial permit • Households within 30m of the dewatering are considered to be within the range of impact from the dewatering operations. Therefore, the households shall be informed of the dewatering operations 24 hours prior to starting. In case the households experience difficulty in obtaining groundwater during dewatering, potable water must be supplied to the affected households as stated in the regulation. • Water resulting from dewatering will only be disposed in ways other than recharging the groundwater if the water quality tests show that doing so will contaminate the groundwater lens.	prior to construction work complying with the regulation.
Regulation on Sand and Aggregate Mining (2000)	No locally mined sand or aggregate will be used for the construction purposes. Sand used for backfilling will be obtained by the contractors from registered suppliers.
Waste Management Regulation, (No. 2013/R-58)	
The regulation provides set of comprehensive guidelines on collecting, storing, transporting and managing solid waste as well as management of hazardous waste. The waste management regulation identifies the following areas prohibited from dumping of waste; protected areas under the Environmental Protection and Preservation Act, mangroves, lagoons of islands, coral reefs, sand banks, beaches of islands, coastal vegetated areas of islands, harbour, parks and roads. Additionally, waste management regulation states that those involved in waste management must be permitted by the Environmental Protection Agency.	Construction waste and operational waste from the desalination plant will be discarded according to the waste management regulation (See **Section 2.9** for details).

Employment Act (2/2008)	
• The Employment Act of the Maldives prohibits the employment of a minor under the age of sixteen except for the purpose of training in relation to such minor's education and requires parental consent be obtained for employing minors. The Act makes an exception for children participating, with their consent, in work undertaken by their families. The Employment Act also prohibits the employment of a child (below 18 years of age) in any work or employment that may have a detrimental effect on a child's health, education, safety or morals due to the work or job undertaken or the conditions of work. Those who employ minors are required to maintain a register of minors employed containing their names, addresses and dates of birth The Act also requires a medical fitness test prior to employing minors on vessels and further such tests for continued employment on vessels	No minors will be allowed to work in the Project
Design Criteria and Technical Specifications – Design and construction of water treatment and supply system Since the project does not involve house connections, summarised below are applicable points from the criteria. • RO Plant, Pumping Machinery and water supply wells shall be designed for Maximum Day Demand i.e. 1.5 times the Average Day Demand. • The projected population shall be estimated for a 35-year period. • The RO plants shall be designed for a minimum water consumption rate of 20 litres per capita per day. • Unaccounted for provisions to be taken as 5-10 % of the Average Daily Demand. The water supply shall be continuous throughout the day. • The fire hydrant location and pressure shall be consistent with the fire hydrant regulation • A minimum of 7 days of water demand shall be provided as water storage in the island. The water being supplied should not stay for more than 7 days in the storage tank. • Except where otherwise the water supply systems shall conform to BS-EU standards or equivalent • All storage tanks shall be provided with external level indicators to prevent overflows during filling.	The design has been approved by EPA hence it meets the design criteria and technical specification. (See design report in **Section 2.7** for further details). During the operational phase water quality will be monitored as stipulated in EPA guideline.

- Sampling taps shall be provided at the entry and outlet of the water reservoir and at the reject line.
- Water and water storage facilities, associated piping, and ancillary equipment must be disinfected before use
- Two pumps minimum shall be installed which will operate alternatively as duty and stand-by.
- All pumps shall have the followings as minimum: -
- \- 2 No. isolation valve of same diameter as inlet main shall be located on the water main in the
- \- pump station (incoming). The valve is to be a gate valve.
- \- 2 No. non return valves of swing check type with cast iron casing and bronze disc.
- \- 2 No gate valves as rising main isolation valves with cast iron casing and bronze wedge, anticlockwise closure with non-rising spindles and terminate with a key operated stem cap (outgoing),
- Normal pump operation shall be controlled through an ultrasonic sensor
- Pump controllers shall be microprocessor or microcontroller based and designed to meet pumping station requirements
- Raw water for the RO plant may be drawn from either sea or ground.
- All water removed during excavation for trenching and construction shall be disposed of inland from the excavation for re-percolation back into the water table as outlined in the EPA guidelines.
- The RO plants minimum 2 nos, each having capacity of half of the maximum day demand, shall be fully assembled with all the necessary equipment and all the civil, electrical and mechanical works related to the same to ensure a fully functioning Plant.
- The quality of water produced and distributed shall conform to EPA water quality guidelines and standards.
- Adequate protection and security for the machinery and equipment shall be provided through proper fencing or other means.
- Outfall pipelines shall be High Density Polyethylene (HDPE) minimum class PN16 (nominal working pressure 1.6MPa or 160m head). A t-head diffuser shall be installed at the termination point of the outfall
- An administration building shall be located at the site of the RO plant and should have a minimum covered 1500square meters. The administrative building must have the following facilities:
  1. An office space
  2. laboratory
  3. Generator room

4. Equipment storage
5. Vehicle parking space
6. Electrical mechanical instruments repair workshop

- A fixed back-up electric power generator unit, make of international repute shall be supplied to provide stand-by electric power in case of island power network failure and shall be equipped with a 3m water proof cable and socket for power transfer.

Guideline for Drinking Water –EPA

States that water produced for drinking purposes shall meet the following requirements and shall be tested as stated in the guideline.

Weekly Tests

Parameter	Reference Range
Free chlorine	0.2-0.5 mg/l
pH	6.5-8.5
Physical appearance	Clear & Colourless
Temperature	
Electrical conductivity	<1500μs/cm
Total coliforms	0/100 ml
Faecal coliforms	0/100 ml

Bi Annual Tests

Parameter	Reference Range
Turbidity	<5 NTU
Total Dissolved Solids	<1000 mg/l
Chloride	<250 mg/l
Nitrates	<50 mg/l
Ammonia	<1.5 mg/l
Iron	<0.3 mg/l
Total coliforms (MF)	0/100 ml
Fecal coliforms (MF)	0/100 ml

Annual Tests

Parameter	Reference Range
Sulphate	<250 mg/l
Manganese	<0.1 mg/l
Total Petroleum Hydro Carbon	
Sodium	<200 mg/l
Potassium	
Calcium Hardness	
Total Hardness	

Testing as stated in the EPA guideline will be carried out during the operational phase.

Bromine	
Total Residual Chlorine	
Hydrogen Sulphide	<0.05 mg/l
Mercury	<0.001 mg/l
Lead	<0.01 mg/l
Copper	<2 mg/l
Boron	<0.3 mg/l
Arsenic	<0.01 mg/l
Fluoride	<1.5 mg/l
Phenolic compounds	
Anionic detergents	
Cadmium	<0.003 mg/l
Chromium	<0.05 mg/l
Cyanide	<0.07 mg/l

Desalination Plant Regulation[1] • The draft regulation states that desalination plants shall be operated only after registration • Desalination plants will be registered if it provides water for more than 200 people and if it is planned to be used for large scale agriculture. For other purposes desalination plant maybe registered if the relevant government authority approves.	Plant will be registered prior to operation.
• In order to register the desalination plant, EIA DS shall be provided to the relevant authority	Approved EIA
• Registration procedures can only be succeeded in cases of emergency where the government or the national security forces have to supply water.	N/A
• The draft regulation states that water shall be sourced from the sea or ground. • If water is sourced from the sea water shall be stored in tanks that can hold up to 50% of water required for the desalination plant • The water sourcing setup shall not be impeded or disrupted by weather or any other similar condition.	Water will be sourced from the ground Approved design which complies with the clause. See **Annex 3**. Approved design which complies with this clause Water will be sourced from a depth which exceeds 30 m

[1] The desalination plant regulation has not been officially published on the national gazette, hence is a draft document. Nevertheless, it has been referenced during the preparation of this EIA.

• If water is sourced from the ground, it shall be sourced from a depth that does not impact the freshwater lens of the island. • Water from the freshwater lens shall not seep into the borehole from which water is to be sourced for the desalination plant. • Temperature of sourced water shall not fluctuate. This shall be ensured by using appropriate materials that do not allow heat conduction. • Water level of the borehole well shall be constant and shall be within a range of 50 mm.	See approved design and work method which complies Approved design which complies with the clause Regular monitoring recommended to comply
• Water supply system shall be designed adequately to not exceed the required capacity • Required capacity shall be calculated based on future projections (5 years) and by allocating 150 l/person/day.	Approved design which complies with the clause. See **Annex 3**. Approved design which complies with the clause. See **Annex 3**.
• Water shall be pumped out of the ground according to guidelines/recommendations given by MWSA[2]	Approved design which complies with the clause
• Brine shall not be discharged over the reef. It shall be discharged into the inner lagoon area or 10 m out of the reef into the ocean.	Approved design which complies with the clause. See **Annex 3** and **Section 8** for brine discharge details
• The water supply system shall be adequately designed to protect it from flooding and other natural disaster	Approved design which complies with the clause
• Water plant shall be designed to reduce noise pollution. If noise exceeds 85 dB(A) at the water plant workers shall be provided with adequate noise shielding tools and equipment.	Regular monitoring recommended to comply
• Water plant shall be constructed from materials which are resistant to corrosion	Approved design which complies with the clause
• A manual to operate the water plant shall be prepared	A manual will be prepared during the construction phase. Preparation of manual is highly recommended in the EIA (See **Section 11**)

[2] The responsibilities of MWSA has been passed over to EPA, which the relevant authority.

• Quality of output water shall be regularly monitored	It is recommended to monitor quality of output water according to the EPA guideline.
• A fee for desalination plant registration will be charged	All environmental stated in the report will be procured prior to construction and operation.

3.4 NATIONAL POLICIES

3.4.1 *Saafu Raajje* National Waste Management Policy (2015)

The objective of the policy is to:

i. Create awareness with regard to the waste management policy;
ii. Evolve and develop the society through awareness so that it strives to protect and manage the natural environment sustainably;
iii. Make sure all aspects of civil life are hygienic;
iv. Ensure that air pollution is controlled and prevented; and
v. Make sure that Maldives retains its natural coastal and marine environment without pollution.

It highlights Nationwide Waste Management Guidelines which is aimed at achieving its goals and objectives. In this regard a nationwide consortium was held in 2016 to brief relevant stakeholders about the policy and developmental arrangement that have been planned under the policy. A summary of the main components of the waste management plan given below.

i. Individual are entitled to manage waste generated by themselves according to the guidelines and regulations set by municipal or local council;
ii. Waste generated at the house hold level shall be managed according to the municipal or local waste management guidelines and regulation;
iii. All inhabited islands shall have an approved waste management plan designed by the island council with the help of the public, according to the waste management policy and regulation;
iv. Fees shall be collected from, households, businesses and industries to operate the waste management center according to proposed and approved design;
v. It is advised to involve state utility companies to operate waste management centers;
vi. The government shall construct and provide equipment to facilitate and implement waste management operations according to the approved waste management plan;
vii. The government shall construct and install equipment necessary to operate regional waste management centers for predetermined zones. The regional waste management centers will be utilized to manage waste that is not processed at the island level;
viii. Waste transportation systems shall be designed and operated to transport rejects from the island waste management centers to the regional waste management centers;
ix. Waste shall be reused or recycled for economic gains where viable during the operational stage of waste management center. Income from such activities shall be used to management the day to day activities of the waste management center or increase its efficiency, productivity and profitability; and
x. Waste management awareness and training programs shall be organized and implemented at a national level.

Project waste management measures proposed for the construction and operational phase fully complies with the objectives of the policy (See **Section 2.9** for details).

3.4.2 Maldives National Strategy for Sustainable Development

Maldives National Strategy for Sustainable Development (MNSSD) (2009) sets out the strategy on how the Maldives will fulfil its commitment to meet the challenges of sustainable development. The overall aim of the MNSSD was to identify and develop actions to enable the people of the Maldives to achieve continuing improvement in their quality of life both now and in the future. This guiding policy recognizes seven sustainable development goals for the Maldives (GoM & UNEP, 2009).

The proposed project has been designed with the prime objective of addressing the principles of sustainable development. Sustainable development is the managing and conserving of natural recourse based on technological and industrial changes in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generations (Rio Summit, 1992). Such a development will conserve land, water, plants, animals and genetic resources in environmentally non- degrading, technically appropriate, economically viable and socially acceptable manner.

In this regard, proper planning water plant through reduction of land clearance and damage to reefs have been emphasised. Importance has been given to conserve groundwater lens. Measures have been set in the report to avoid pollution, responsible waste management and re-use of resources. In addition, it has also been proposed to conduct regular monitoring to ensure water quality of product water and groundwater quality. These measures will ensure that the impacts of the project on climate change is minimised and that the project is implemented according to the generally agreed principles of sustainable development.

3.4.3 Third National Environmental Action Plan (NEAP3 2009 – 2013)

NEAP 3 was formulated to set the environmental agenda for the five-year period with an objective of creating liveable and sustainable places in which protection of the environment while making people and properties resilient. It was aimed at promoting resilient island communities, conserving environment, promoting healthy communities, providing safe water and environmental stewardship among other objectives.

As per the action plan, the proposed project is aimed at enhancing availability of clean water to island communities which are geographically isolated. It will also promote the health and wellbeing of the communities.

3.4.4 The Strategic National Action Plan

The Strategic National Action Plan for Disaster Risk Reduction and Climate Change Adaptation (SNAP) (2010-2020) recognizes the islands of the Maldives by nature are low lying exposing the communities to the threat of beach erosion, sea level rise and saltwater intrusion into the groundwater lens and other climate change impacts as natural hazards faced to the Maldives. Among the key goals of the SNAP building resilient communities through empowerment and incorporating disaster risk reduction into government's decentralization policy have been stated.

The water plant fulfils these objectives by enhancing water security. At present, groundwater resources in the project islands have been polluted by poor management of sewage and salt water intrusion. Once operational the water plant will create new job opportunities and provide significant security during times of disaster.

3.4.5 Maldives Climate Change Policy Framework

Maldives Climate Change Policy Framework (MCCPF) (2015) highlights the climate vulnerabilities of Small Island Developing States such as the Maldives and further states that these islands are in a special risk of being inundated as sea-level rise, land loss and beach erosion continues to increase and threatens food and water security. MCCPF calls for strengthening adaptation actions and building climate resilient infrastructure and communities as an adaption and opportunity to address current and future climate vulnerabilities with the following specific objectives;

i. To develop effective adaptation and risk reduction responses and capacity in all climate change priority areas for adaptation and opportunities;
ii. To promote and implement adaptation programmes that support and improve communities' livelihoods to reduce the vulnerability and increase the resilience;
iii. To make the inhabited islands and people of Maldives resilient against the threats posed by global climate change; and
iv. To protect critical infrastructure such as international airports, other inhabited islands and tourist resorts from sea related hazards and predicted climate change impacts.

Since, the water plant is a critical infrastructure it will be constructed with the required setbacks prevent damages during disaster. In addition, minimising vegetation clearance and reuse of resources have been considered in carrying out the works to promote climate resiliency of the project.

3.4.6 National Adaptation Programme of Action

National Adaptation Programme of Action (NAPA) (2006) presents the framework to climate change adaptation to enhance the resilience of the natural, human and social system to ensure their sustainability against predicted climate change. NAPA lays out the national policy framework for the Maldives. The document comprehensively describes the climate vulnerabilities faced to the Maldives. It also emphasizes wetland conservation through priority actions such as flood control, recognizes the importance of coral, and also includes enhancing capacity for solid waste management as a priority action to prevent pollution of the marine environment. The document identifies vulnerability of groundwater resources and identifies climate induced saltwater intrusion as a significant risk.

As described in various sections of the report the design of the project has emphasised on minimising impacts on the environment, specially groundwater lens during construction of the RO plant. The EIA proposes appropriate mechanisms to enhance groundwater security and pollution control is regarded as a priority action to conserve natural resources such as the coral reef.

3.4.7 National Biodiversity Strategy and Action Plan

National Biodiversity Strategy and Action Plan (NBSAP (2016 – 2025) is the government's key policy document on conservation of the nation's biological diversity. It sets out the vision as "a nation of people that co-exist with nature and has taken the right steps to fully appreciate, conserve, sustainably use, and equitably access and share benefits of biodiversity and ecosystem services". The document is guided by three key principles emphasising that the need for everyone's participation in achieving the goal set forth in the NBSAP. The three principles of NBSPA include:

- The people of this generation and the generations to come reserves the right to access and share benefits of rich biodiversity and ecosystem services;
- responsibility of conserving and sustainably using biodiversity lies on every one's shoulders and shall be taken a s a shared responsibility; and
- biodiversity shall be mainstreamed into all sectors and in a manner whereby monitoring progress and accountability is ensured.

NBSAP identifies destruction of habitats, including reefs, lagoons, beaches and mangroves due to development activities as a major threat to conservation of biodiversity. In addition, NBSAP states, increase in population and economic growth intensified the demand on natural resources and space with resulting over-exploitation of biodiversity, decline in certain species such as turtles and tuna catch, clearance of vegetation to meet the demands of development as contributing factors threatening the country's biological diversity. Importing of alien species and those listed in CITES have been included among the growing challenges. Improper waste management, disposal of dangerous chemicals, oils and non – biodegradable wastes into the surrounding sea has also been highlighted posing threats to biological diversity.

In order to address the threats faced to the nation's biodiversity NBSAP identifies six strategies of which Strategy 4: Ensuring sustainable use of biological resources, and Strategy 5: Addressing threats to conserve biological diversity are particularly relevant to the proposed project.
The document highlights over exploitation, habitat loss and unsustainable use as the main precursor to exhaustion of resources.

The proposed project has the potential to deplete the freshwater lens of project islands as a result of improper borehole drilling which could impact the biodiversity of these islands. By ensuring that recommendations and monitoring measures proposed in the EIA is implemented, loss of groundwater resource and associated impacts can be prevented. Similarly, prevention of impacts on coral reef have been given a strong emphasis on this report as a result of brine discharge and waste production, in line with the plans target of reducing anthropogenic pressures on coral reefs, reduce loss of natural habitat and prevent extinction locally known threatened species. For areas where notable impacts are identified, adequate mitigation measures in line with existing regulation have been proposed.

3.5 CONVENTIONS AND AGREEMENTS

The GOM is a Party to a number of international conventions and agreements some of which are of relevance to this project.

3.5.1 Convention on Biodiversity

The objective of the Convention on Biodiversity (CBD) is “the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding”. The Maldives signed the convention in June 1992 and ratified it on 28th October 1992. Maldives is one of the first nations to ratify CBD. Maldives has developed the National Biodiversity Strategy and Action Plan (NBSAP) in 2002. The Maldives made its fourth national communication to CBD in 2010 and the fifth in 2015.

The proposed project involves minor marine habitat alterations, which will result in habitat fragmentation. Terrestrial habitat loss is negligible, minor disturbance to habitats as well as generation of wastes and pollution is anticipated. The compliance arrangements under CBD will be achieved through the proposed mitigation measures in the report. At the national level CBD is implemented through the NBSAP as explained in **Section 3.4.7.**

3.5.2 MARPOL Convention

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention which addresses pollution of the marine environment by ships due to operational and accidental causes. As a party to the MARPOL convention, Maldives is required to oblige and maintain the standards specified by the convention with regard to maritime pollution and their control. These include pollution due to:

- Oil spillage
- Noxious liquid substances in bulk
- Spillage of harmful substances carried by sea in packaged form
- Sewage and garbage from ships
- Air pollution from ships

Marine pollution prevention during all project activities have been given highest importance as explained in the relevant sections of this report.

3.5.3 United Nations Framework Convention on Climate Change

United Nation Framework Convention on Climate Change (UNFCCC) is a global legal instrument on the control and management of greenhouse gases (GHG) to which the Maldives is a Party to. It was adopted in 1992 and entered into force in 1994. The Convention contains two annexes:
Annex 1: countries with obligations to take measures to mitigate the effects of climate change
Annex 2: countries with obligations to provide financing to developing countries for their obligations under UNFCCC.

The overall gall of UNFCCC is to protect the climate system for the benefit of present and future generations of mankind and to achieve stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

In order to protect the climate system, the following general measures have been proposed;

- Enhancement of energy efficiency in relevant sectors and development of new and renewable energy forms/sources;
- Protection of sinks and reservoirs of GHGs; and
- Limitation and reduction of transport and waste management-related emissions.

These aspects have been seriously taken into consideration in preparing the report and in proposing mitigation measures.

National policy documents described in **Section 3.4** are the main means by which this Convention is implemented at the national level.

3.6 ENVIRONMENTAL PERMITS

3.6.1 EIA Decision Statement

The EIA Decision Statement, as it is referred to, shall govern the manner in which the project activities must be undertaken. The environmental permit to commence the proposed project is the decision statement to be made by the EPA. The decision statement will be given to the proponent after independent review of EIA report. The decision statement will be based on the degree/significance of impacts to environment from the proposed development. This EIA report will assist the EPA in making informed decision relevance to the proposed project. The DS will be required to register and operate the desalination plant.

3.6.2 Permit on Uprooting Coconut Palms and Trees

A special permit will not be required for land clearance as the amount of trees and area required for clearance is well below regulatory requirements. Hence approval of the EIA will be sufficient to undertake land clearance work of the project.

3.6.3 Desalination Plant Concept Approval

The desalination plant shall meet the design and technical criteria set forth by the EPA. The concept approval from EPA will be required prior to construction. The concept and design has been approved by the EPA prior.

3.6.4 Desalination Plant Registration

Desalination plant shall be registered with the EPA prior to its operation. During this stage, the plant shall demonstrate quality of product water and ensure that surrounding groundwater has not been polluted. In addition, technical details of the desalination plant, scaled drawings, EIA Decision Statement (DS) and photos of outfall shall be provided to register the plant prior to its mass scale operations.

3.6.5 Dewatering Permit

Since the construction phase of the project involves dewatering during borehole pump installation which required pumping out groundwater (See **Section 2.6.8** for details), a dewatering permit shall be obtained from EPA. Contrary to typical dewatering, the water pumped out will be mixed with bentonite. The slurry will be used in the construction of borehole. Any residuals will be discarded as hazardous waste hence; groundwater will not be discharged into the environment.

4. EXISTING ENVIRONMENT STUDY METHODS

4.1 INTRODUCTION

This section of the report addresses **Task 2** of the TOR and provides descriptions of the methods used to collect data of the existing natural and socio-economic environment of the project site. The chapter also addresses sensitivity and limitations of methods used in the study. Efforts were made to collect as much primary data as possible within the time limitations. Relevant information was also collected through interviews, discussions and formal meetings with stakeholders. Available information from reliable literature was also used to supplement the existing environmental study.

The main environmental component focused on the study was the marine and terrestrial environment based on the projects TOR. The environmental studies were carried out to:

- Identify areas that harboured significant natural bio-diversity (coral reefs and vegetation), to reduce or prevent impacts on these areas;
- study local wind, wave and other climate conditions on each island to prevent or reduce impacts associated with the project on the environment (such as diffusion of brine) and impacts associated with the environment on the project (such as determination of suitable areas for outfall); and
- to collect baseline data environment to be used as a reference for future monitoring.

A team from MEECO conducted site assessments at K. Gaafaru, L. Gan and B. Kendhoo from 24 October - 1 November 2017, to undertake environmental and socioeconomic surveys for this EIA report.

The different methods used in assessing and reporting the conditions of the existing environment of the island are given in the following subsections.

4.2 CLIMATE

Climate conditions at the project site was assessed after compiling recent weather data obtained from weather station in K. Hulhule' and S. Gan. Data from K. Hulhule' was used to study climate properties at K. Gaafaru and B. Kendhoo. Data from S. Gan was used to study climate properties at L. Gan. Although L.Kahdhoo hosted the local airport, long term data for the region was available from S.Gan which is why it was selected for the asessement. The data was provided by Maldives Meteorological Centre (MMS, 2016).

The statistical data were analysed for the following parameters:

- Rainfall;
- temperature; and
- wind.

4.3 WAVES

Long term wave climate at the project area was determined using NOAA long term hind cast data of the region. The study accurately determined the wind wave and swell wave behaviour of the offshore locations. Two locations were selected to collect NOAA data. One was representative of Male' atoll which encompassed K. Gaafaru. This was also used to analyse B. Kendhoo. The other location was used to analyse wave conditions at L. Gan. The study was conducted within the limitations of a 0.5 grid. Data was extracted at a frequency of three hours for the most up to date full set of data available (2015).

4.4 GEOLOGY, SEDIMENTS AND COASTLINE

In the absence of soil testing facilities in the country, information obtained for soils studies for islands of similar setting was used. Soil profile and geological properties of project area was inferred after referencing soil analysis done for R. Vandhoo. Vandhoo was a significant in size and elongated in shape. It was a mature island that is comparable to most of the islands. Since geological formation of islands in the Maldives are quite similar, soil analysis of Vandhoo was considered reliable for the EIA purposes. Samples were collected from the two distinct zones (top soil and bottom soil layer). The samples were stored in airtight sample bags, transported to Sweden and tested for the following parameters:

- Grain size distribution; and
- Permeability of two layers.

The coastal surveys were carried out using the GNSS RTK system. The survey determined the vegetation line and tidal zone of the coastal areas adjacent or closest to the RO plant.

4.5 WATER QUALITY

Water quality assessments were carried out after testing the following parameters on site using *Horiba* Multi Parameter Water Analyser for groundwater and seawater:

- Temperature;
- pH;
- Turbidity(NTU);
- Dissolved Oxygen (mg/L);
- Electrical conductivity (ms/cm);
- Salinity (ppt); and
- Total dissolved solids (g/L).

Hydrocarbon content of groundwater was measured from sites that were close to the powerhouse (K. Gaafaru and L. Gan). The samples were analysed for the parameters as indicated in TOR. BOD_5 level of samples were inferred using *in situ* DO level measurements. This approach was selected mainly because DO level and BOD have a direct inverse relationship. If DO levels are high, it can be safely assumed that oxygen depleting factors are low while oxygen generative factors are high, thus the demand for BOD can be considered normal and low. Moreover, BOD level can only be measured from the laboratory. Hence, if samples are not delivered right after collection the results will not be completely representative of the actual site. However, since DO levels are measured *in situ*, it is considered as a more reliable parameter to determine seawater quality for the project.

The location of data collection sites was marked using the handheld GPS. Survey maps in Figure **21**, Figure **22** and **Figure 23** shows the groundwater and seawater data collection and sampling locations. The groundwater data was also compared with WHO guidelines for drinking water attached in **Table 13**. Seawater results were compared with data from a control point which is tabulated in **Table 14.**

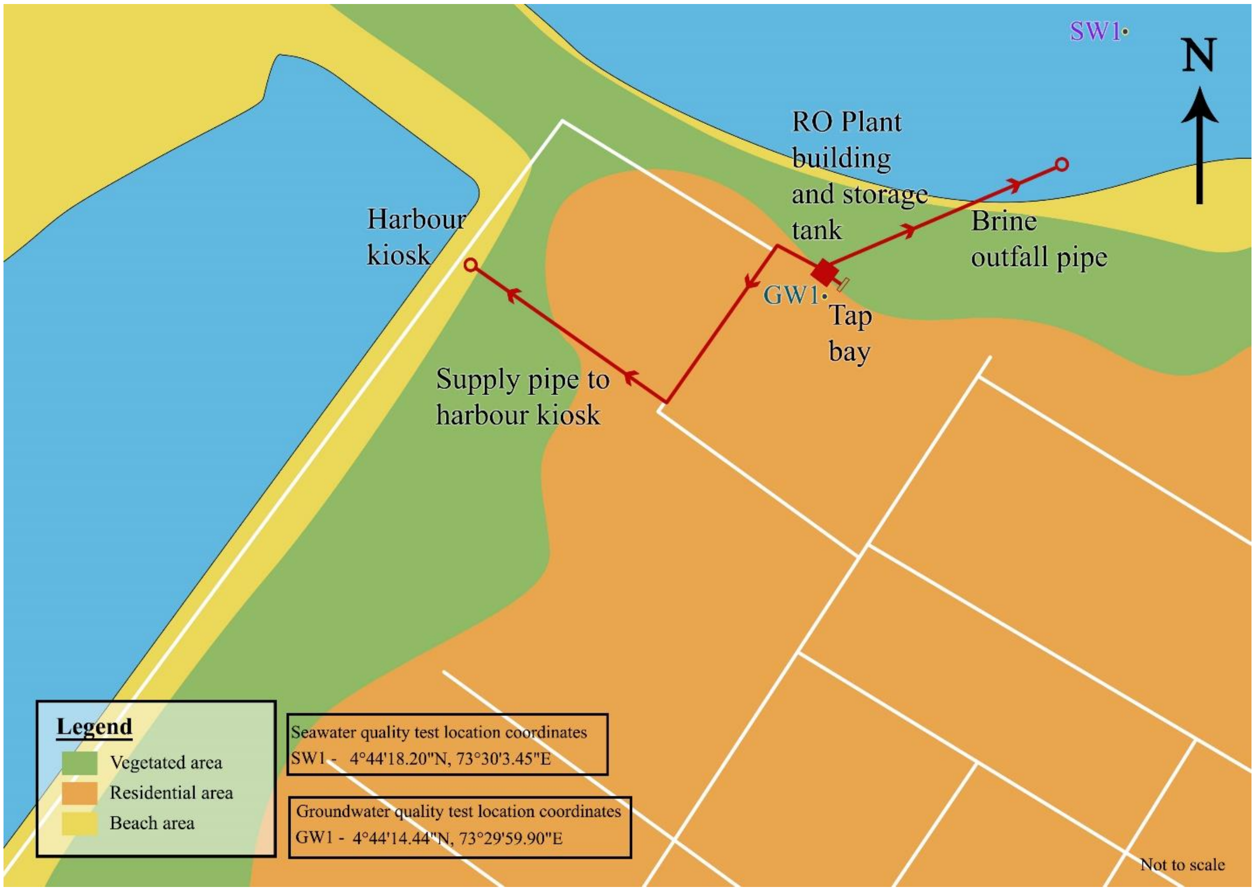


Figure 21: Seawater and groundwater test location (K. Gaafaru)

Figure 22: Seawater and groundwater test location (L.Gan)

Figure 23: Groundwater and seawater collection locations (B.Kendhoo)

Table 12: EPA guideline for water quality

Parameter	Optimal range	Reference
Temperature	18ºC and 32ºC Changes should not surpass 10 ˚C above the average long term maximum	GBRMPA, 2009
Salinity	0.032 - 0.042 ppm	GBRMPA, 2009
pH	8.0-8.3 Levels below 7.4 pH cause stress to corals	
Turbidity	3-5 NTU >5 NTU causes stress to corals	Cooper et al. 2008
Sedimentation	Maximum mean annual rate 3 $mg/cm^2/day$ Daily maximum of 15$mg/cm^2/day$	GBRMPA, 2009
Nitrates	<5 mg l^{-1} NO_3-N	UNESCO/WHO/UNEP, 1996
Ammonia	Max. 2-3 mg l-1 N	UNESCO/WHO/UNEP, 1996
Phosphate	0.005 - 0.020 mg l-1 PO4-P	UNESCO/WHO/UNEP, 1996
Sulphate	2 mg l-1 and 80 mg l-1	UNESCO/WHO/UNEP, 1996
BOD	< 2 mg l-1 O3	UNESCO/WHO/UNEP, 1996
COD	< 20 mg l-1 O2	UNESCO/WHO/UNEP, 1996

Table 13: WHO guideline for drinking water. Source: (WHO, 2006)

Parameter	**Reference Range**
pH	6.5-8.5
Physical appearance	Clear & Colourless
Electrical conductivity	<1500 µs/cm
Total coliforms	0/100ml
Faecal coliforms	0/100ml
Turbidity	<5NTU
Total dissolved solids (TDS)	<1000 mg/l
COD	10mg/l
BOD_5	6mg/l

Table 14: Seawater quality of control point and literature reference

Parameter	**Control point (SW0)**	**Reference Range**
pH	8.2	7.5-8.4
Physical appearance	Clear & Colourless	Clear & Colourless
Electrical conductivity	5.34 S/m	5 S/m
Turbidity	0 NTU	<5NTU
Total dissolved solids (TDS)	32,000 ppm	> 35,000 ppm
Salinity	35.4 ppt	35 ppt
BOD_5[3]	-	2 ppm

4.6 MARINE SURVEY

Reef environment was surveyed to assess and obtain baseline data of the existing reef conditions. Benthic cover composition of the reef-flat and reef slope was studies along with fish communities in each of the survey points. The findings of the surveys were used for impact evaluation and mitigation during the proposed development. Line Intercept Transect (LIT) surveys were carried out to assess the benthic types and coral species at the survey sites. The assessment was done to identify coral forms which include laminar, encrusting free living, columnar, foliaceous, branching, massive, digitate and tabular. The LIT survey done determined benthic cover within a depth of 1-10 m. LIT surveys have been proven to be very efficient for studies of benthic coral reef communities (Loya, 1978), and can be used to evaluate the community structure of corals in terms of species composition and diversity patterns in different zones on a reef.

LIT method also provides a rapid estimate of percent cover of corals, algal cover, and cases of other prominent organisms as well as bare substratum. Quantitative percent cover data of morphological characteristics of the reef community is obtained using this method and it can be repeated over time to obtain temporal changes.

For benthic areas that were observed to largely consist of sand and rubble photographs were taken as records. Figures below shows transect analysis locations for project islands.

[3] Since DO was measured *in situ*, it was used as a reference to assess oxygen level of seawater.

Figure 24: Marine analysis area (K. Gaafaru)

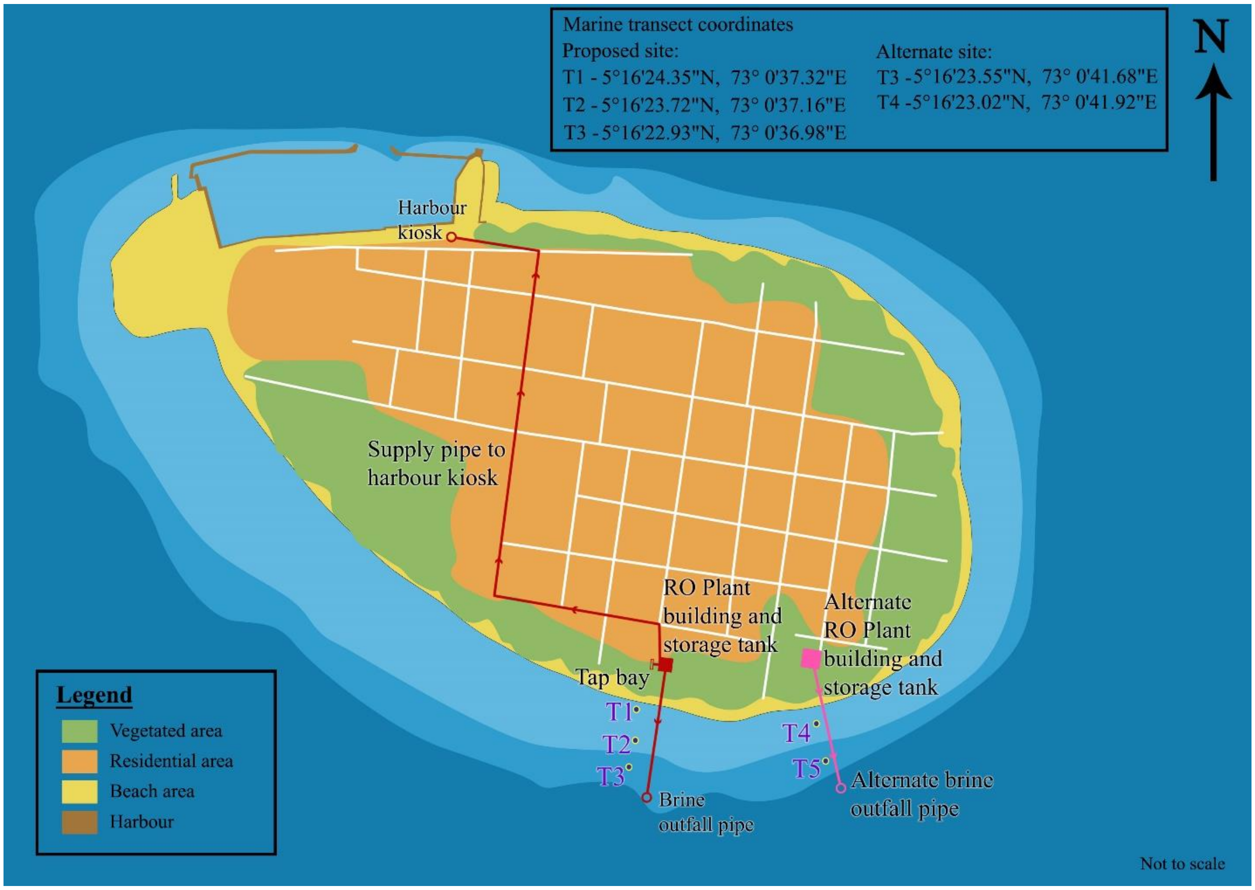


Figure 25: LIT locations (B. Kendhoo)

Figure 26: LIT locations (L. Gan)

The fish study was done by taking timed videos at each station at a specific depth. The camera was held at a uniform angle during the timed swim.

The photographs and videos obtained from the survey locations shown above were later analysed to identify the type of fish species using (Kuiter, 1988) and (Hafiz & Anderson, 1987).

Fish abundance was assigned by counting, and comparing the count to a selected range which was specific for the area. The count and range is given in **Table 15.**

Table 15: Fish abundance range

Fish Abundance	Count Range
Rare	0-10
Common	11-35
Abundant	36+

The method encompasses certain degree of uncertainty. These include:

- Some species may be cryptic in the presence of surveyors; hence these species would not be accounted for in the survey;
- fast moving fishes may not be captured during the timed swim hence these species would also be under estimated;
- some fish may have been captured in the video repeatedly; and
- time of swim may impact observation of certain species as some species are more active at night.

Hence the results obtained through the analysis should be considered as an underestimate of the actual marine biodiversity at the site.

4.7 VEGETATION SURVEY

Vegetation and tree cover of the project area was determined using two methods.

1. The primary method employed involved surveying all the significant trees within the proposed project site and at the footprint of the proposed access road using the GNSS RTK system. The survey recorded actual count, type, position and features of all trees within the project boundary
2. In addition to the methods described above, aerial pictures of proposed sites and alternative sites were taken using a drone, to visually assess the vegetation condition, proximity of coastline, public areas, roads and sensitive sites to the proposed waste management site. The following table was used to classify abundance of trees at the project site.

Table 16: Classification of abundance based on tree count

Abundance	Count
Low	1-10
Medium	10-20
High	20+

Limitations

The limitations of the primary method used to survey vegetation are relatively small since actual tree data were recorded. The main limitation of the method includes sampling errors such as omissions and additions. However, these errors will be significantly reduced as a result of validation checks employed in the survey.

Non-sampling Errors: These are errors associated with humans, rather than chance, mistakes. These include using counting/sampling methods where attributes cannot be accurately counted or measured. Inconsistent field sampling effort, due to difference in effort level also constitutes to non-sampling errors. The method used for the vegetation survey does not incorporate significant sampling errors. Total stations were used to register population and photographs of each numbered data point were recorded for post analysis error mitigation.

4.8 SOCIAL ASSESSMENT

The study was carried out with a participatory approach that aimed at putting the community at the centre and involved a collective process of reflection, discussion and consultation with the public. The social assessment mainly relied on information obtained from questionnaires shared with the council and from the public consultation conducted in the island. The questionnaires were aimed at capturing the existing social condition of the island, such as determining main economic activities, existing education/ health system, existing waste management system and access to basic utilities. The public/community consultation were carried out to discuss the proposed project in order to gather local perspective with regard to the project, its location and to collect local knowledge with regard to existing environment and waste management practices. In order to facilitate participation of all the members of the community, invitations for the meeting were announced publicly in the afternoon. Moreover, published documents and statistics from (DNP, 2016) and (National Bureau of statistics, 2014) were also reviewed for the social assessment.

5. EXISTING ENVIRONMENT

5.1 INTRODUCTION

This Chapter of the report addresses the existing environmental baseline conditions at the project island. The analysis of existing environment is fundamental for the assessment of the projects feasibility and its impacts and determining the effective mitigation measures to avoid or minimise the effects of project activities on the environment.

5.2 CLIMATE

The Maldives, in general, has a warm and humid tropical climate with average temperatures ranging between 25°C - 30°C (MMS, 2016) and relative humidity ranging from 73 per cent to 85 per cent. The country receives an annual average rainfall of 1,948.4 mm (NIRAS, 2013).

Monsoons of Indian Ocean govern the climatology of the Maldives. Monsoon wind reversal plays a significant role in weather patterns. Two monsoon seasons are observed: The Northeast (*Iruvai*) and the Southwest (*Hulhangu*) monsoon. Monsoons can be best characterized by wind and rainfall patterns. These are discussed in more detail in the following subsections. The southwest monsoon is the rainy season which lasts from May to September and the northeast monsoon is the dry season that occurs from December to February. The transition period of southwest monsoon occurs between March and April while that of northeast monsoon occurs from October to November. **Table 17** below shows a summary of four seasons in Maldives.

Table 17: Summary of Seasons in the Maldives

Season	**Months**
North East-Monsoon (*Iruvai Moosun*)	December
	January
	February
Transition Period - 1 (*Hulhangu Halha*)	March
	April
South West-Monsoon (*Hulhangu Moosun*)	May
	June
	July
	August
	September
Transition Period - 2 (*Iruvai Halha*)	October
	November

General meteorological conditions expected to prevail in the project islands based on meteorological data obtained from the nearest weather stations are briefly discussed in the sub sections below.

5.2.1 Temperature

The northeast monsoon is classified as the dry season and brings less rainfall and higher, high temperatures and higher low temperatures while the opposite is observed for the Southwest monsoon which is the wet season. Based on temperature collected at various centres across Maldives. Minimum and maximum temperature was observed to remain constant with small variances. The minimum low temperature was cooler in the southern atolls compared to the northern atolls (See **Figure 27**).

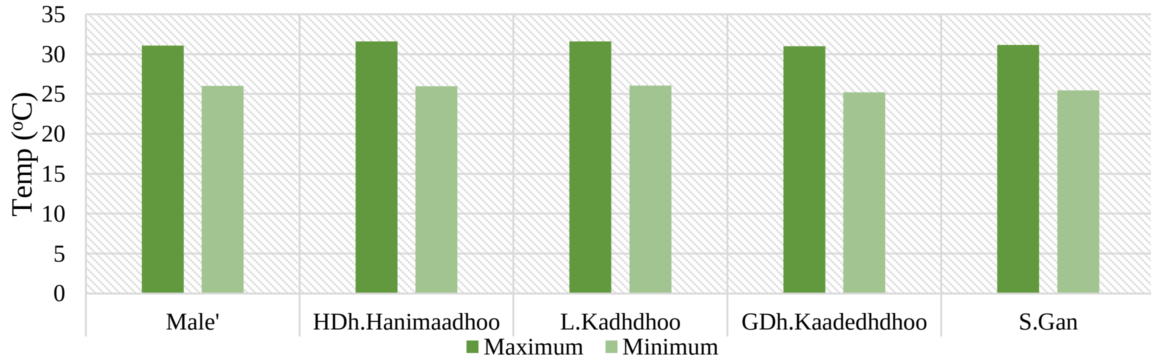


Figure 27: High and low temperature variance between atolls of the Maldives

The mean yearly high temperature for the past 38 years was 30.9 ^{0}C. The mean yearly low temperature for the past thirty-eight years was 24.7 ^{0}C. Yearly temperature variance for the past thirty-eight years was extremely consistent with 0.4 ^{0}C.

5.2.2 Wind

Wind data since 1964 indicate that the Maldives experience southwest to northwest winds (~225 – 315^{o}) from April to November (westerly monsoon) with a mean wind speed of 0.5 ms^{-1}. In contrast, winds from the northeast-east (~ 45 – 90$^{0)}$ prevail from November to March (northeast monsoon) with a mean wind speed of 4.8 ms^{-1}. Wind strength is most variable during the cross-over between northeast and westerly monsoons with mean wind speed falling to 3.5 ms^{-1} in March (DNP, 2016).

Wind pattern influencing project area was assessed after compiling wind data obtained from Maldives Meteorological Centre. **Figure 28** illustrates the wind pattern based on data compiled from S.Gan for past three years which has been applied to the project island of L. Gan.

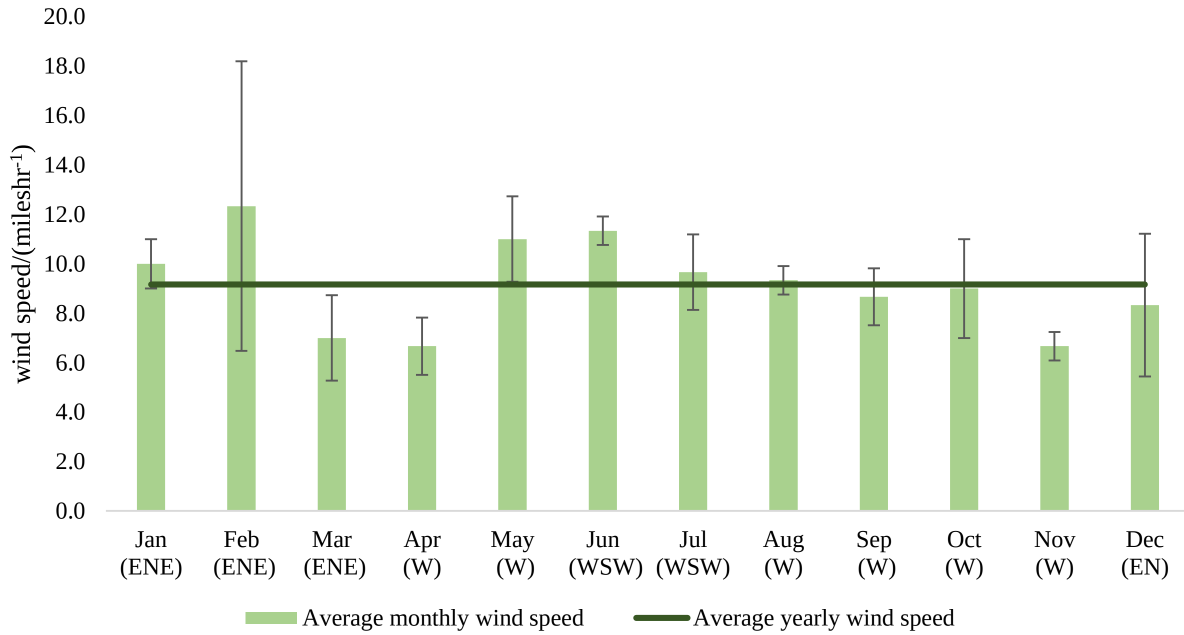


Figure 28: Annual monthly wind speed and average yearly wind speed at S.Gan for the past 3 years

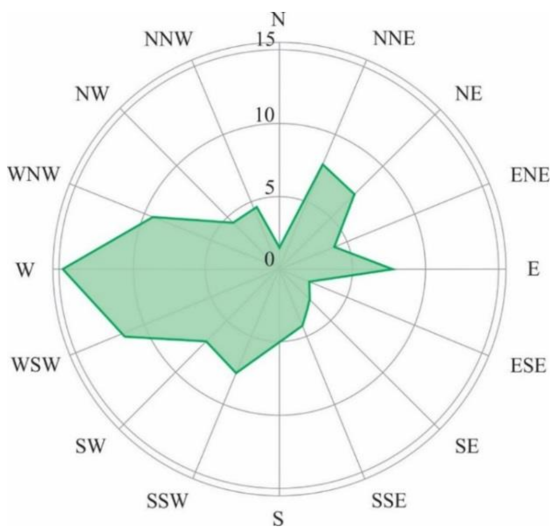


Figure 29: Mean annual wid direction at S.Gan

The findings can be summarized as follows:

- Westerly winds were dominant throughout the year (W – 50% and WSW – 16%);
- easterly winds were observed only during the northeast monsoon for the months December, January and February (ENE 33%);
- the yearly average wind speed was 4 ms^{-1} (9 $mileshr^{-1}$);
- lowest wind speeds were recorded during March (7 $mileshr^{-1}$), April (6.7 $mileshr^{-1}$) and November (6.7 miles/hr); and
- The highest and most variable wind speeds were recorded in the month of February, where average wind speeds reached 5 ms^{-1} (12 $mileshr^{-1}$) with a variance of 3 ms^{-1} (6 $mileshr^{-1}$).

This suggests that at L.Gan, there is a high probability of emissions from the adjacent powerhouse effecting the RO plant. This is because the RO plant is located directly downwind from the powerhouse during the southwest monsoon. Wind direction is mainly from the westerly sector which would carry dust generated from the powerhouse stacks towards the RO plant. This risk is fairly low during the northeast monsoon.

Figure 28 illustrates the wind pattern based on data compiled from K. Hulhule' for past three years which has been applied to the project island of K. Gaafaru and B. Kendhoo.

5.2.3 Rainfall

Data from metrological station at S. Gan was used to assess rainfall at L. Gan. Historical rainfall data analysis showed that:

- The total annual rainfall was 2277.5 mm;
- the mean monthly rainfall was 189 mm;
- during the months May-November (southwest monsoon) on average the total rainfall was 74% greater than during the months from December to April (northeast monsoon);
- the highest rainfall was observed for the months of October and December where the average rainfall was 227 mm 276 mm and 240 mm respectively;
- the highest variance in rainfall was observed for the months of January, October and September, where the variance calculated was 123 mm, 131 mm and 127 mm respectively; and
- February was found to be the month that received the least amount of rainfall (90 mm) with the least variance in rainfall.

.

Figure 30 illustrates comparison monthly rainfall pattern for the past 41 years at S. Gan. The analysis showed that northeast monsoon was the driest, especially February –April. Due to lack of rainfall these months are identified to increase the demand for water in L. Gan. Hence this period have been identified to require increased waster production from the RO plant at L. Gan.

Since major differences in rainfall pattern and variance between S. Gan station and K. Hulhule' station was not observed over long term the findings of S. Gan station was applied to K. Gaafaru and B. Kendhoo as well.

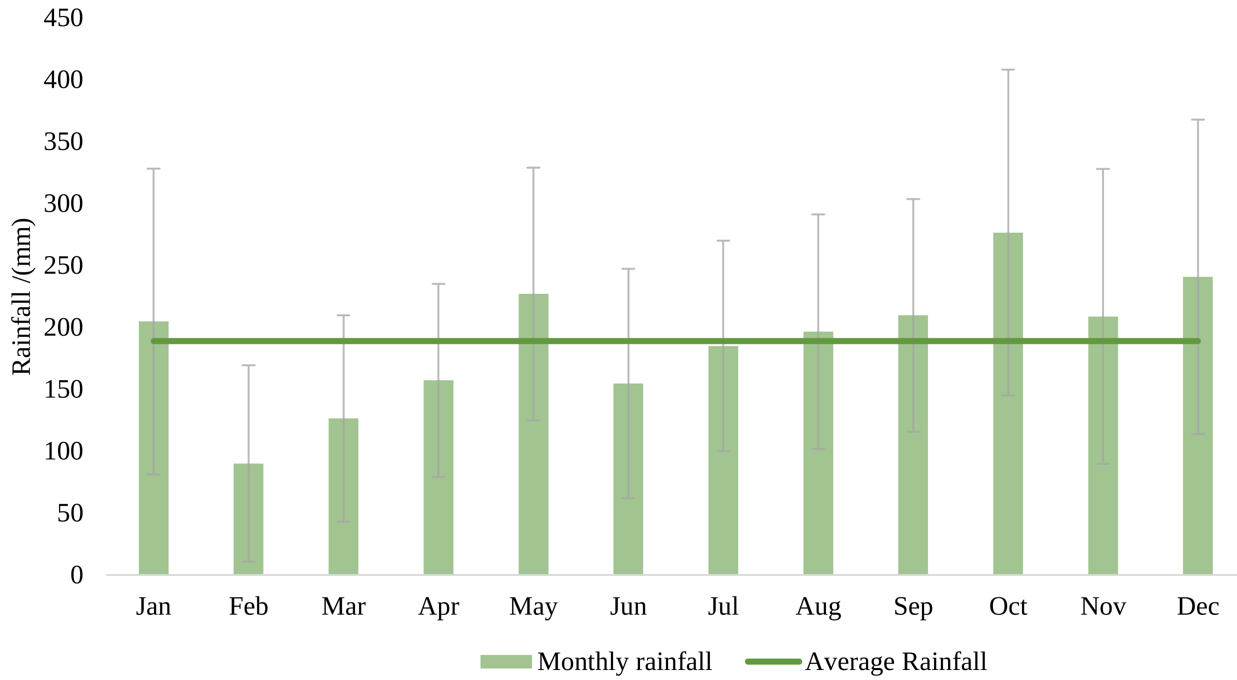


Figure 30: Comparison of monthly rainfall data S.Gan

5.3 WAVES

Data on wave climate in the Maldives is limited, but ten years of satellite altimetry data on wave climate for the region (Young 1999) indicates that the dominant swell approaches Maldivian archipelago from southerly quarters (Young, 1999).

Wave analysis for L. Gan was done using NOAA data. **Figure 31** shows peak wave heights and **Figure 32** shows wave periods for L. Gan. The analysis showed that:

- The average annual wave height was between 0.6 – 1 m from the southwest and northeast side.
- Waves from the north with moderate wave heights and short wave periods were observed suggesting that these were wind generated waves during the easterly monsoon. This was further evident based on wind analysis, strong winds from the ENE direction was experienced during easterly monsoon.
- The analysis showed that south-western waves were swell waves with high wave periods while waves from the southeast were solely wind generated waves with shorter periods.
- L.Gan was exposed to waves from southwest and southeast throughout the year.

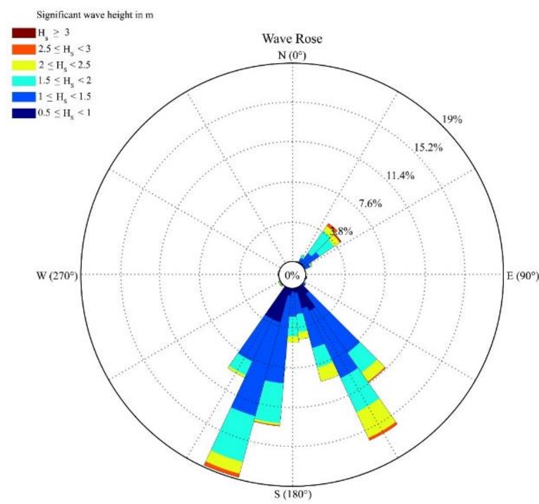


Figure 31: Monthly wave heights based on NOAA data

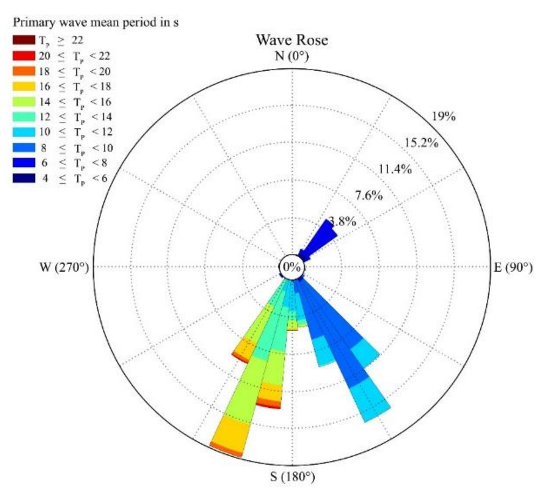


Figure 32: Monthly wave period extracted from NOAA

The analysis showed that eastern side of the island was continuously exposed to swell waves throughout the year while western side was exposed to wind generated waves during the southwest monsoon. This means, by situating the outfall on the eastern side, the risk of environmental damage on the project can be reduced. However, since the eastern side is also exposed to wind waves during the southwest monsoon, the pipe shall be anchored appropriately.

NOAA data from eastern offshore location was used to analyse wave pattern at K. Gaafaru and B. Kendhoo. Annual wave heights and periods obtained from Location 4.0ºN, 74.0ºE are illustrated in **Figure 33.** The wave analysis showed that:

- Waves formed from the south east (120º and 150º) with wave heights in the range of 0.6 – 2.0 m are observed throughout the year. These waves had a typical time period of 8-10 sec. Apart from January and February these waves dominate throughout the year. Since local winds or monsoonal winds are not generated from the south east sector, these waves were likely to be swells generated offshore;
- Local wind waves were prominent from the north eastern direction. These waves had a period of 4-8 seconds and their heights ranged between 1.2 -1.4 m on average. These are considered to be locally generated strong monsoonal wind waves

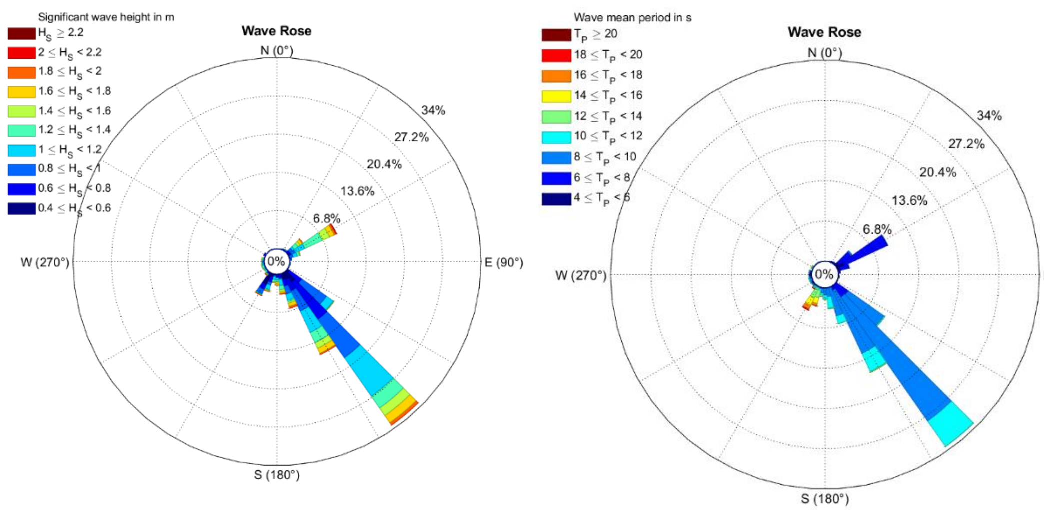


Figure 33: Average yearly peak wave height and direction

In relation to the project area, wave analysis showed that proposed RO plant and outfall location on the northern side of K. Gaafaru will be calm with less chances of swells effecting the RO plant and outfall pipe. The proposed RO plant and outfall location at B. Kendhoo on the southern side of the island will be moderately calm with a low likelihood of swells approaching.

5.4 WATER QUALITY

Baseline water quality assessments was done for ground water and sea water at the outfall location. Chemical parameters tested include, temperature, pH, conductivity, turbidity, DO, total dissolved solids and salinity. In addition to these parameters BOD for saltwater was measured from a control site and hydrocarbon content of groundwater was measured for sites close to the powerhouse **Table 18** shows water quality results of groundwater.

Table 18: Groundwater quality results

Island	ID	Date	Type	Temp /°C	pH	Cond/ mS/cm	Turb/ (NTU)	TDS/ (g/L)	Sal/(ppt)	DO/ (mg/L)	Hydrocarbon/ (ppm)
K.Gaafaru	GW_01	25/10/17	GW	32.23	7.8	1.07	3	0.68	0.5	2.27	3.6
L.Gan	GW_02	24/10/17	GW	31.33	7.6	1.05	1	0.67	0.5	3.03	1.89
B.Kendhoo	GW_03	31/10/17	GW	32.25	7.2	0.9	0.7	0.65	0.4	4.01	N/A

Table 19: Seawater quality results

Island	ID	Date	Type	Temp /°C	pH	Cond/ mS/cm	Turb/ (NTU)	TDS/ (g/L)	Sal/(ppt)	DO/ (mg/L)
K.Gaafaru	SW_01	25/10/17	SW	29.28	8.7	53.9	0	32.3	35.6	9.0
L.Gan	SW_02	24/10/17	SW	-	8.1	52.7	0.2	-	34.7	-
B.Kendhoo	SW_03	31/10/17	SW	30.12	8.9	53.2	0	32.2	35.1	8.5

A. Groundwater

K. Gaafaru – Groundwater sample was collected from a well located inside the powerhouse which is next to the proposed RO plant site. The sample had a distinct foul odour. The groundwater sampled had a temperature of 32.23°C, the sample was collected in an open container. The pH was 7.8, which was within WHO specified range. The sample had a turbidity of 3 NTU. The turbidity was high for the sample due to debris falling into the well. The total dissolved solids (TDS) recorded was 0.68 g/L. TDS of the site was within acceptable limit for drinking. Similarly, the salinity of sample tested was 0.5 ppt which meant that the groundwater sample was non saline. Dissolved oxygen of the sample was low at 2.27 ppm.

The sample had a very high concentration of Total Petroleum Hydrocarbon (TPH) (3.6 ppm) which encompasses aliphatic and aromatic hydrocarbons detectable by the analytical method employed. According to WHO drinking water guidelines, concentration of large aromatic and aliphatic fractions relative to n-Hepatane shall be in the range of 0.09 ppm (Fawell, J K; WHO, 2008). This means ground water sampled at K. Gaafaru exceeds WHO guidelines for TPH by 40 times. This suggests that, groundwater surrounding the powerhouse is significantly affected by fuel contaminations. This may be from spillages and dust fall from the powerhouse. As mitigations measures it is crucial to cover all water tanks and implement measures to prevent fuel spillage.

L. Gan - Groundwater sample was collected from a well located inside the powerhouse which is next to the proposed RO plant site. The sample had a distinct foul odour The groundwater sampled had a temperature of 31.33°C. The pH was 7.6, which was within WHO specified range. The sample had a very low turbidity of 0.2 NTU. The total dissolved solids (TDS) recorded was 0.67 g/L. TDS of the site was within acceptable limit for drinking. Similarly, the salinity of sample tested was 0.5 ppt which meant that the groundwater sample was non saline. Dissolved oxygen of the sample was low at 3.03 ppm.

The sample had a high concentration of Total Petroleum Hydrocarbon (TPH) (1.89 ppm) which encompasses aliphatic and aromatic hydrocarbons detectable by the analytical method employed. According to WHO drinking water guidelines, concentration of large aromatic and aliphatic fractions relative to n-Heptane shall be in the range of 0.09 ppm (Fawell, J K; WHO, 2008). This means ground water sampled at L. Gan exceeds WHO guidelines for TPH by 20 times.

B. Kendhoo - Groundwater sample was collected from a well located close to the RO plant site. The sample had a distinct foul odour. The groundwater sampled had a temperature of 32.25°C. The pH was 7.2, which was within WHO specified range. The total dissolved solids (TDS) recorded was 0.65 g/L. TDS of the site was within acceptable limit for drinking. Similarly, the salinity of sample tested was 0.4 ppt which meant that the groundwater sample was non saline. Dissolved oxygen of the sample was low at 4.01 ppm.

B. <u>Seawater</u>

K. Gaafaru –The seawater sampled had a temperature of 29.28°C. The pH was 8.7, which was typical of seawater. The turbidity was 0 NTU. The total dissolved solids (TDS) recorded was 32.3 g/L. TDS of the seawater was within typical range. Similarly, the salinity of sample tested was 35.6 ppt. Dissolved oxygen of the sample was also found to be normal at 9 ppm. Which meant that BOD of seawater will be low due to their inverse relationship.

L. Gan –Since samples were taken to the lab, temperature was not measured as it would not be representative of natural seawater temperature. The pH was 8.9, which was typical of seawater. The turbidity was 0.2 NTU. The salinity of seawater was 34.7 ppt. which within typical range. Since salinity can be calculated as a function of TDS, the TDS of L. Gan sample is considered to be within the normal range.

B. Kendhoo –The seawater sampled had a temperature of 30.18°C. The pH was 8.7, which was typical of seawater. The turbidity was 0 NTU. The total dissolved solids (TDS) recorded was 32.2 g/L. TDS of the seawater was within typical range. Similarly, the salinity of sample tested was 35.1 ppt. Dissolved oxygen of the sample was also found to be normal at 9 ppm.

In summary, the following conclusion are made based on water quality results:

- Groundwater within the powerhouse area was contaminated with TPH. Hence feed water pumped from the borehole at K. Gaafaru and L. Gan shall be tested to ensure that TPH concentrations are low;
- Groundwater, from all three islands had a distinct odour, which may be due to low DO levels and presence of coliform;
- Groundwater at project islands were non saline;
- All parameters tested for seawater was normal and comparable to the control, for all three islands. These values shall be used as the baseline during construction and operational phase of the project; and
- BOD of seawater is projected to be within the reference range of 2 ppm based on DO levels of the samples.

5.5 MARINE ENVIRONMENT

5.5.1 Benthic Cover and Fish Study

The benthic cover was assessed by transect analysis and photography of the proposed outfall location. Alternative outfall locations were analysed as well to determine areas with lower coral cover (See **Section 8** for details regarding alternative location). Transects were analysed for areas that had a high live coral cover. Sections below describe benthic cover and marine diversity at project islands. The marine survey showed the growth form in the following categories:

1. Laminar (plate-like)
2. Encrusting
3. Free living
4. Columnar
5. Foliaceous

6. Branching
7. Massive (ball-shaped or boulder-like)
8. Digitate (like fingers with no secondary branches

A. K.Gaafaru

The outfall is proposed to be located on the northern side of the island within the shallow lagoon area very close to the shoreline. (See **Annex 6** for outfall length and details)

The proposed site does not contain living corals and mostly contained rubble and sand. Further towards the north, there were significant patches of dead corals. Moreover, the area had a very low fish count.

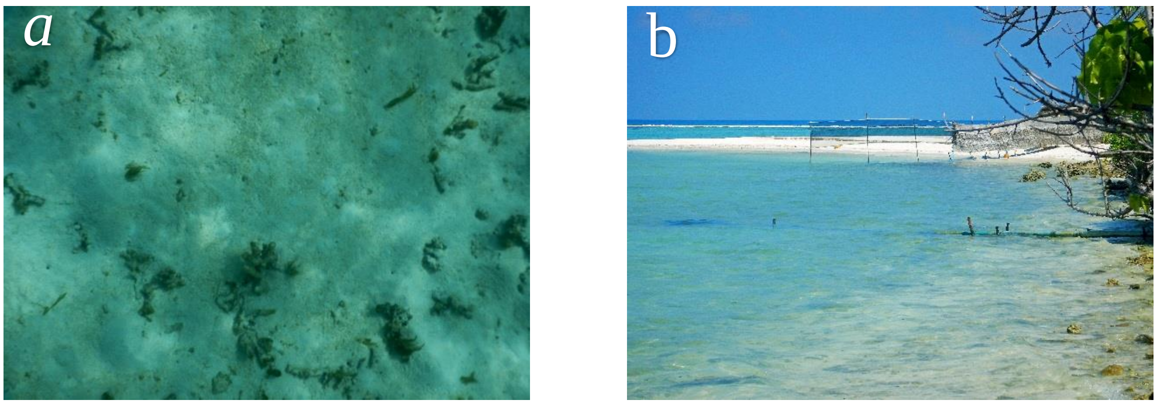


Figure 34: Outfall area at K.Gaafaru. a- no coral cover at proposed area. b- area already used for sewage outfall.

B. L.Gan

The studies were carried out in very low visibility (caused by sedimentation due to an ongoing expansion project of the nearby *thundi harbor*).

Benthic cover at the proposed and alternate outfall locations was studied using the Line Intercept Transect (LIT) method. Two 20 m transects were studied at the proposed outfall location (See **Figure 26**). The proposed outfall was located on the western lagoon of the island. See **Annex 6** for outfall length and details.

Visual observations made at the proposed outfall site showed that the reef flat and lagoon area measured approximately 300 meters. The first 90 meters had a sandy bottom with no rubble or corals. No fish were observed in this area. Patches of live corals were observed beyond 90 meters from the shoreline up to the reef front. Majority of live coral cover at the reef was made up of massive corals (*porites, favia*), while branching corals (*acropora*) and free living – solitary corals (*fungia*) were also observed. Visual observations of marine organisms present at the site showed that sea cucumbers (*holothuroidia*) and small giant clams (*tridacna maxima*) were common at the reef flat area. Surgeon fishes (*acanthuridae*) Damsels (*pomacentiridae),* Groupers (*serranidae),* Wrasses (*labridae),* Butterfly fishes (*chaetodontidae)* were observed at the study area. Majority of fish observed were juvelines. **Table 20** describes the fish census at proposed outfall location.

Transect 1 (T1)

Transect one was studied at the reef flat area approximately 100 meters from the shoreline. Benthic cover of the 20m line covered by the transect was dominated by loose rubble (75%). Sand (10%) and dead corals (15%) made up the rest of the study area. No live corals were observed.

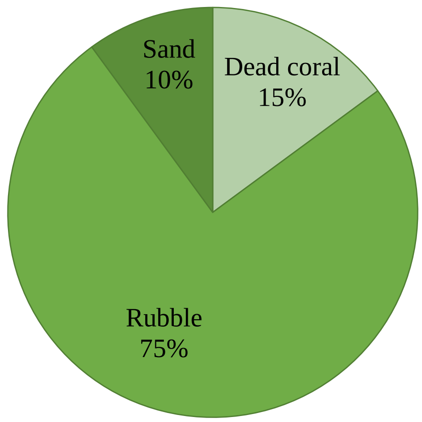


Figure 35: Benthic composition at T_1 (L.Gan)

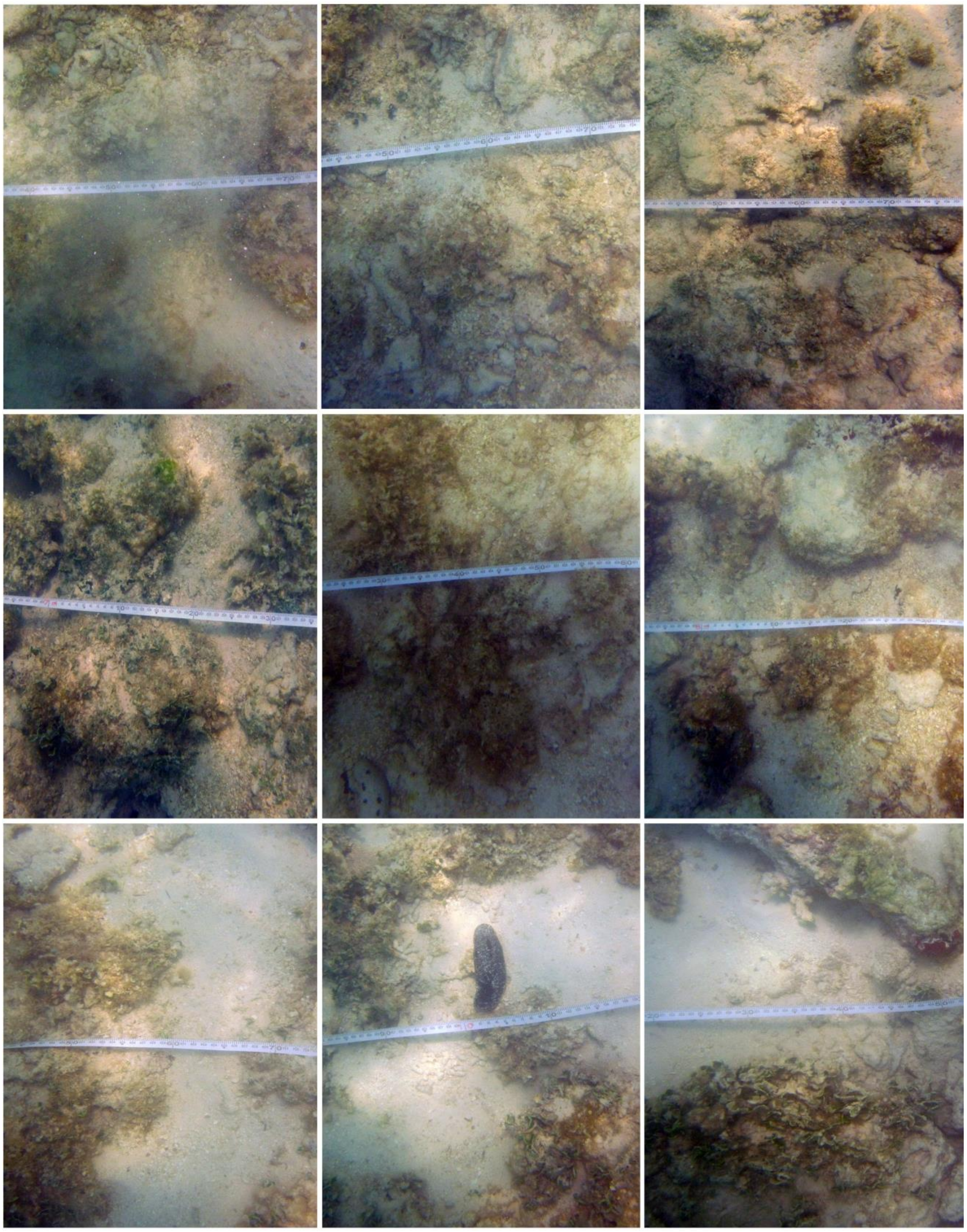


Figure 36: Photo profile T1 L. Gan

Transect 2 (T_2)

Transect three was studied closer to the reef front and analysis of the transect showed that 6% of the study area was made up of live coral cover. Massive corals, branching corals and free living – solitary corals were observed. Majority of the benthic cover studied was made up of loose rubble (63%). Dead corals made up 24% of the study area and sand was observed to make up 7% of the transect line.

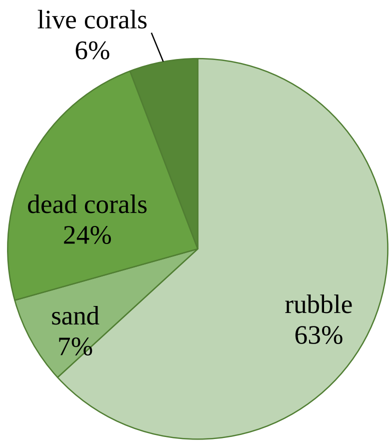


Figure 37: Benthic composition at T2 (L. Gan)

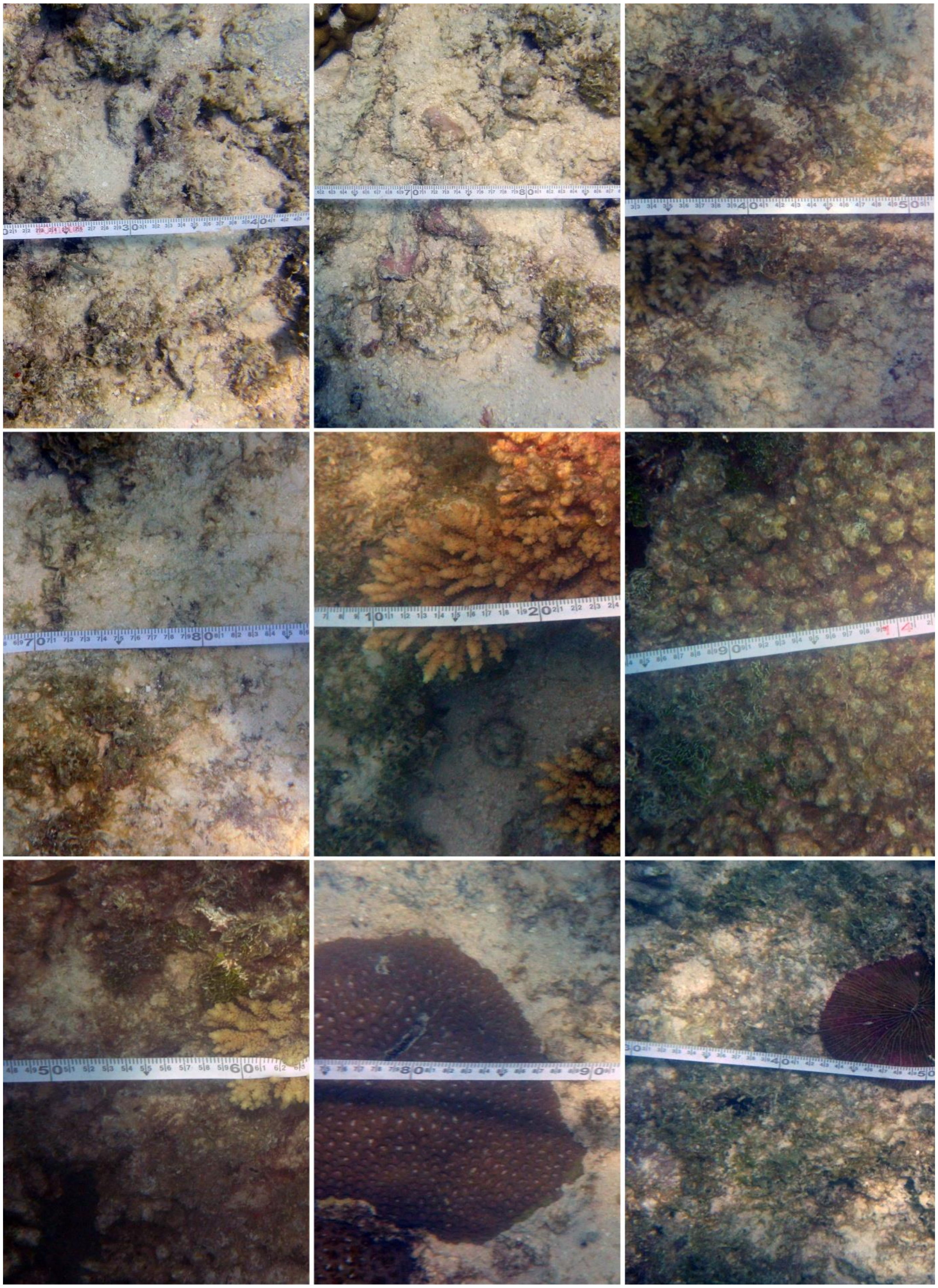


Figure 38: Photo profile T2

Table 20: Fish study at project area (L.Gan)

Common Name	***Scientific Name***	**Abundance**
Family: Pomacentridae		
Blue green puller	*Chromis atripectoralis*	Abundant
Surge damsel	*Chrystiptera brownriggi*	Common
Humbug damsel	*Dascyllus aruanus*	Common
Sergeant major	*Abudefduf vaigiensis*	Common
Family: Serranidae		
Peacock rock cod	*Cephalopholis argus*	Rare
Long - spined grouper	*Epinephelus longispinis*	Rare
Honey comb grouper	*Epinephelus mera*	Rare
Family: nemipteridae		
Monocle bream	*Scolopsis bilineata*	Common
Family: acanthuridae		
Powder blue surgeon fish	*Acanthurus leucosternon*	Common
Fine lined Bristoltooth	*Ctenochaetus striatus*	Common
Sailfin surgeon fish	*Zebrasoma desjardinii*	Rare
Convict surgeonfish	*Acanthurus triostegus*	Common
Lined surgeonfish	*Acanthurus lineatus*	Rare
Family: chaetodontidae		
Triangular butterflyfish	*Chaetodon triangulum*	Common
Chevroned butterflyfish	*Chaetodon trifascialis*	Rare
Lined butterflyfish	*Chaetodon lineolatus*	Rare
Family: Apogonidae		
Toothy cardinalfish	*Cheilodpterus isostigamata*	Rare
Family: Labridae		
Bluestreak cleaner wrasse	*Labroides dimidiatus*	Rare
Zig-zag wrasse	*Hemitautoga scapularis*	Rare
Six bar wrasse	*Thalasomma hardwickle*	Rare
Moon wrasse	*Thalassoma lunare*	Rare
Family: Scaridae		
Bridled parrotfish	*Scarus frenatus*	Common
Family : Mullidae		
Yellow stripe goatfish	*Mulloidichthys vanicolensis*	Common

Figure 39: Marine species observed at outfall site

C. B.Kendhoo

The reef flat and lagoon area at the proposed outfall site measured approximately 83 meters from the shoreline to the reefs edge. Majority of benthic cover at the location consisted of rubble and dead corals. There was no live coral cover at the areas close to the shoreline. Small live coral colonies were observed at areas near the reef edge. Massive corals (porites), free living – solitary corals (fungia) and branching corals (pocillopora) were among the few live corals that were found in the area. Visual observations made to determine fish abundance and diversity showed the presence of the Groupers (*serranidae),* Wrasses (*labridae),* Surgeon fishes (*acanthuridae*), Damsels (*pomacentiridae),* Butterfly fishes (*chaetodontidae)* and Trumpetfishes (*aulostomidae)*. There was a damaged outfall pipe from a previously installed RO plant in close proximity to the site.

Three 20 m transects were studied at varying depth along the reef to determine the benthic cover at the proposed outfall site. Condition of these transects are described below. **Table 21** shows fish study of the project site. The proposed outfall was located on the southern side of the island (See **Annex 6** for outfall length and details).

Transect one (T1)

Transect one was located 7 meters from the shoreline. Analysis of the transect showed that the benthic cover was made up entirely of dead corals (8%) and rubble (92%).

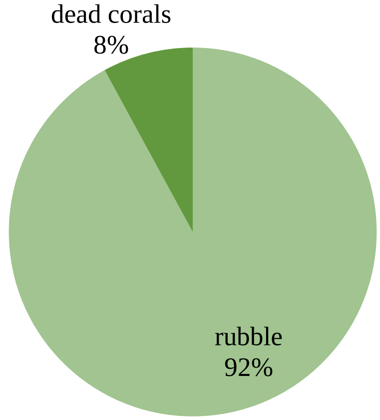


Figure 40: Benthic composition at T1 (B. Kendhoo)

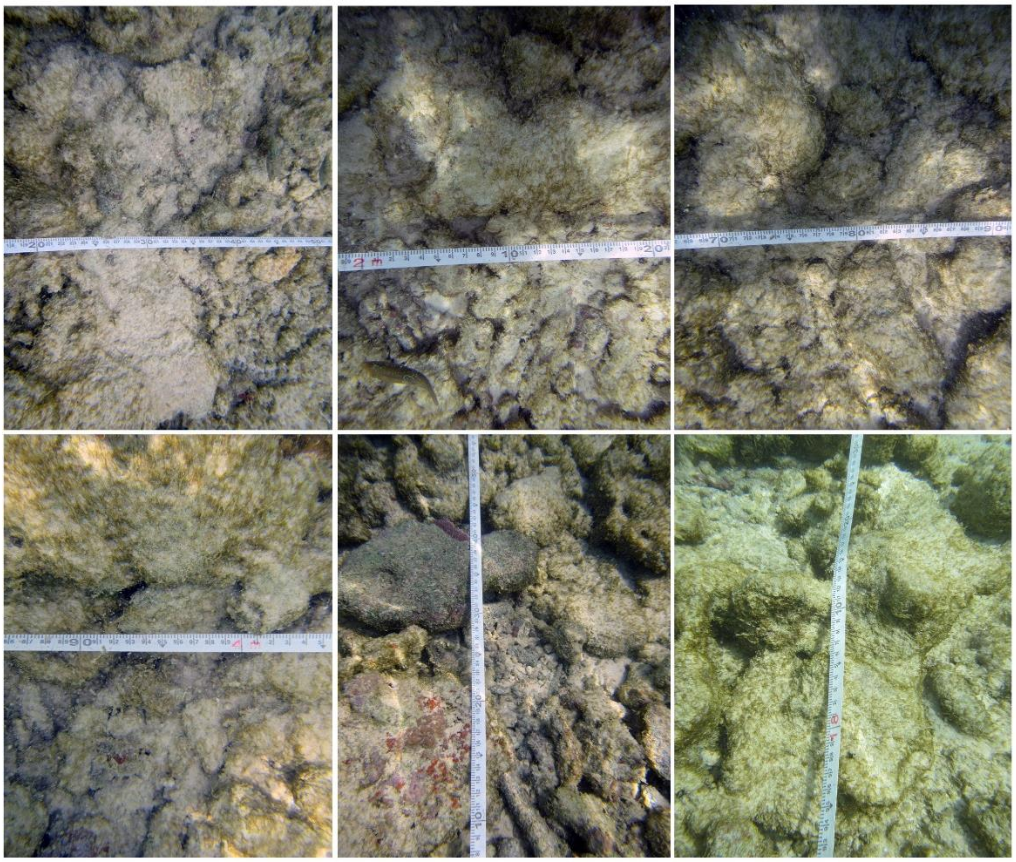


Figure 41: T1 photo profile (B. Kendhoo)

Transect two (T2)

Analysis of transect two showed that that the benthic cover at this area was dominated by dead corals (69%). Rubble was the second most dominant substrate type making up 29% of the transect and live coral cover was minimal at 2%.

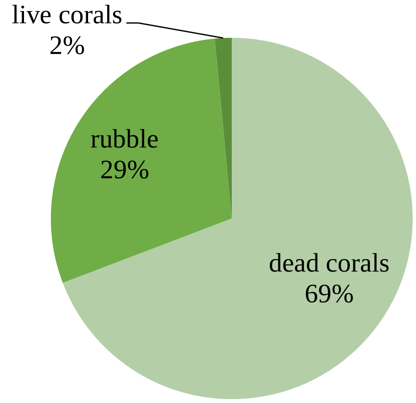


Figure 42: Benthic composition at T2 (B. Kendhoo)

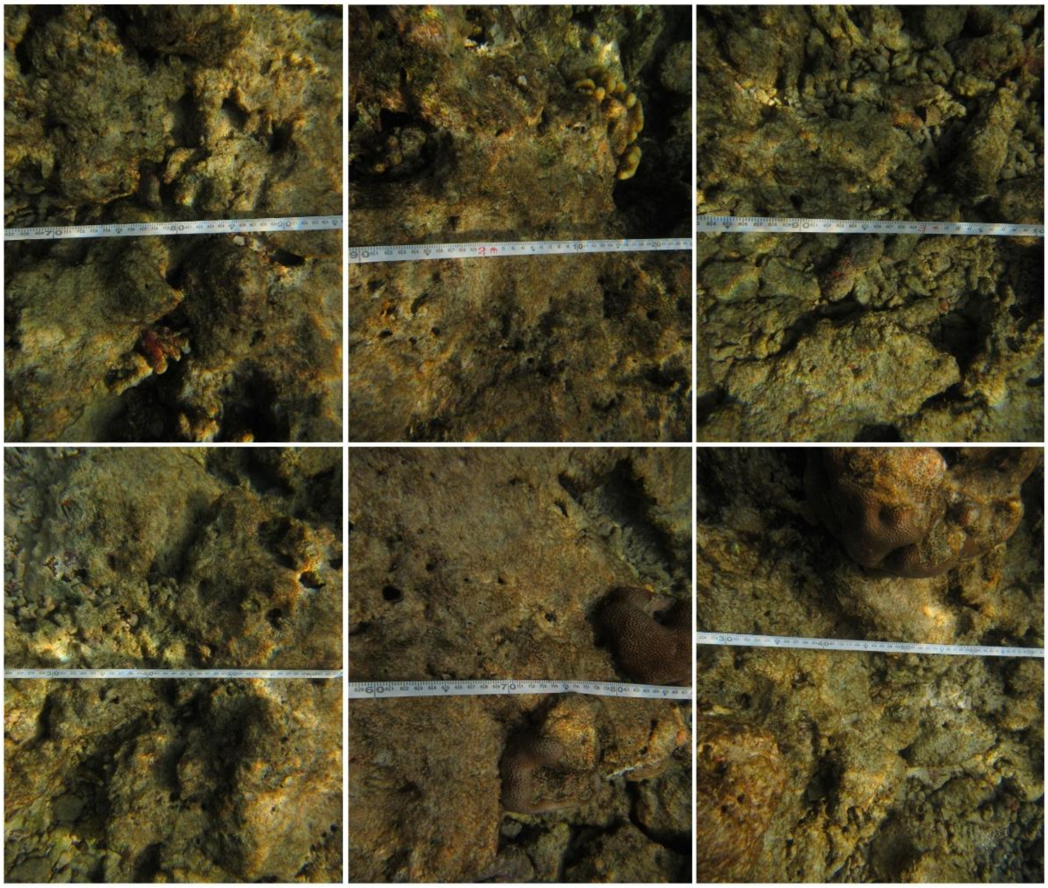


Figure 43: T2 photo profile (B.Kendhoo)

Transect three (T3)

Transect three (T3) was located close to the reefs edge. Analysis of the transect showed that sand and rubble was the dominant substrate type constituting 55% of the transect. Dead corals (42%) and live corals (3%) was observed.

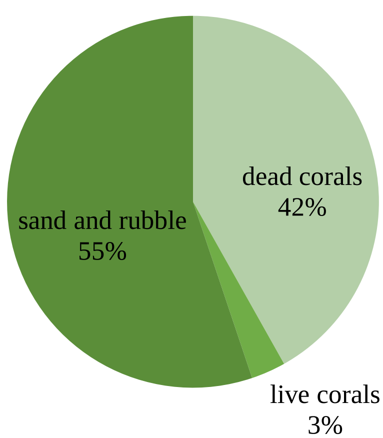


Figure 44: Benthic composition at T3 (B.Kendhoo)

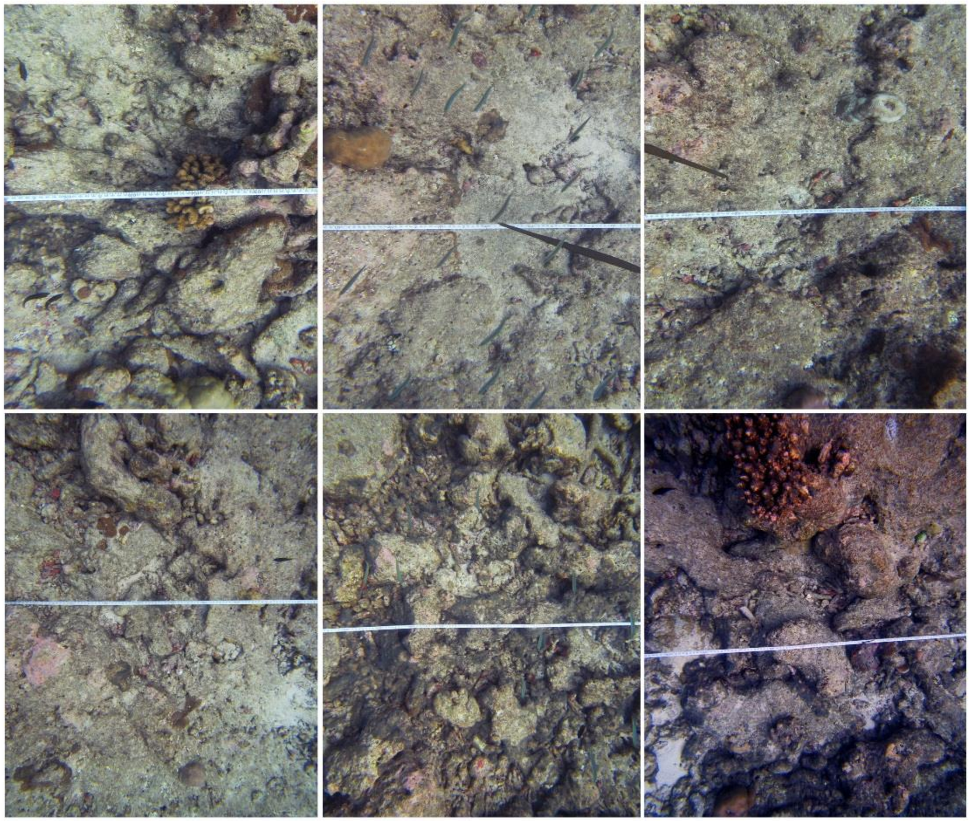


Figure 45: T3 photo profile (B.Kendhoo)

Table 21: Fish study (B.Kendhoo)

Common Name	***Scientific Name***	**Abundance**
Family: Pomacentridae		
Blue green puller	*Chromis atripectoralis*	Abundant
Humbug damsel	*Dascyllus aruanus*	Abundant
Blackfoot anemonefish	*Amphiprion nigripes*	Rare
Sergeant major	*Abudefduf vaigiensis*	Common
Two tone puller	*Chromis dimidiata*	Rare
Clarck's anemonefish	*Amphiprion clarkii*	Rare
Phillipine damsel	*Pomacentrus philippinus*	Rare
Family: Serranidae		
Peacock rock cod	*Cephalopholis argus*	Rare
Honey comb grouper	*Epinephelus mera*	Rare
Family: acanthuridae		
Eyelined surgeonfish	*Acanthurus nigricauda*	Rare
Powder blue surgeon fish	*Acanthurus leucosternon*	Common
Blue spine unicornfish	*Naso unicornis*	Rare
Fine lined Bristoltooth	*Ctenochaetus striatus*	Abundant
Convict surgeonfish	*Acanthurus triostegus*	Common
Lined surgeonfish	*Acanthurus lineatus*	Common
Family: chaetodontidae		
Head band butterflyfish	*Chaetodon collare*	Rare
Brown butterflyfish	*Chaetodon kleinii*	Rare
Longnose butterflyfish	*Forcipiger longirostris*	Rare
Meyers Butterflyfish	*Chaetodon meyeri*	Rare
Reef Bannerfish	*Heniochus acuminatus*	Common
Black pyramid butterflyfish	*Hemitaurichthys zoster*	Abundant
Family: Labridae		
Bluestreak cleaner wrasse	*Labroides dimidiatus*	Common
Six bar wrasse	*Thalasomma hardwickle*	Rare
Family: Scaridae		
Bridled parrotfish	*Scarus frenatus*	Rare
Five saddled parrot fish	*Scarus scaber*	Rare
Dusky Parrotfish	*Scarus niger*	Rare
Family : Mullidae		
Long barbel goatfish	*Parupeneus macronema*	Rare
Family: Belonidae		
Slender needlefish	*Strongylura leiura*	Rare
Family: Diodontidae		
Black spotted porcupinefish	*Diodon hystrix*	Rare
Family: Zanclidae		
Moorish idol	*Zanculus cornutus*	Rare
Family: Holocentridae		
Yellowfin – soldierfish	*Myripristis berndti*	Rare
Family: Tetraodontidae		
Saddled pufferfish	*Canthigaster valentini*	Rare
Black spotted pufferfish	*Arathron nigrapunctatus*	Rare

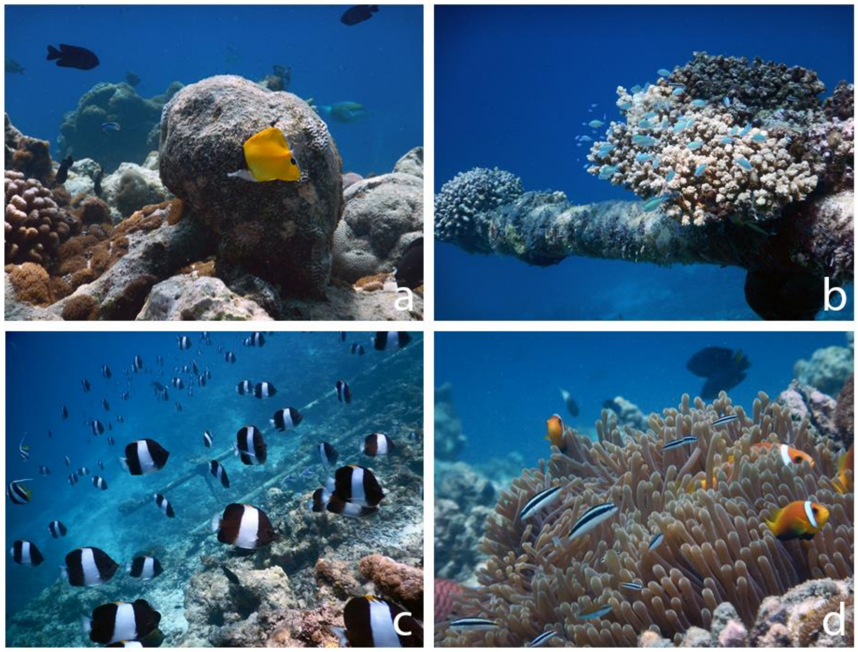


Figure 46: Fish species observed at outfall location

5.5.2 Bathymetry

The bathymetry of the proposed outfall locations was surveyed to determine the average depth and bottom morphology of the area. A description of survey findings at the proposed outfall location in each island is given below.

K. Gaafaru:

The proposed outfall area had an average depth of 1 m. 30 m out of the shore a slightly deeper area was observed with a depth of 1.5 m (See **Annex 6** for bathymetry). Moving further towards the northeast depth decreases up to 0.5 m. This is the area mostly covered with live corals. Sand had been accreting onto the northern side which has resulted in the formation of a *Thundi* beach as described in **Section 5.6.1**.

L Gan:

The proposed outfall area had an average depth of 4 m. Since the outfall is proposed to be located towards the inner lagoon, a significant reef drop off was not observed. Gradual decrease in depth was observed at the outfall location. See **Annex 6** for bathymetry and outfall details.

B Kendhoo:

The proposed outfall location is located in the southern side of the island. The average depth in the area is 1m. The depth increases up to 3 meters near the reef edge before gradually sloping down to a depth of 20m. Live coral cover is higher near the reefs edge than at the areas near the shoreline. (See **Annex 6** for bathymetry).

5.6 TERRESTRIAL ENVIRONMENT

5.6.1 Landform, Soil and Coastal Areas

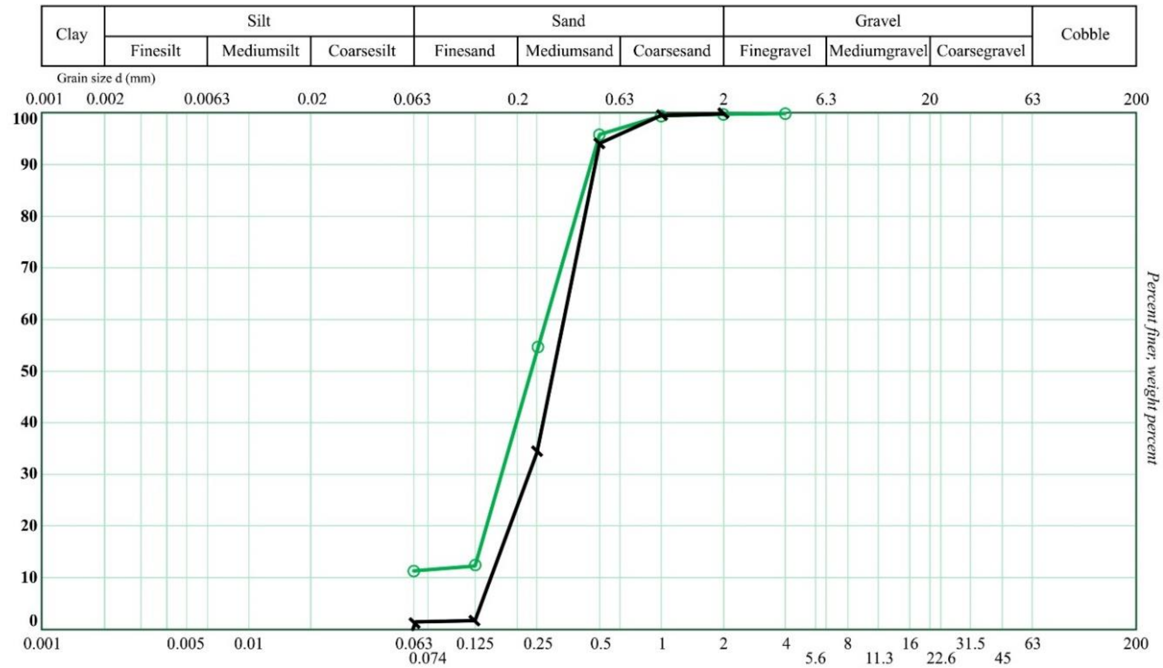
The land allocated from the terrestrial environment for the proposed development had a flat terrain and was not densely vegetated.

Physical inspection of the soil at K. Gaafaru, L. Gan and B. Kendhoo do not show any dissimilarities compared to soils found in other islands. In general Maldivian soils are mainly made up of mineral soils, the basis for soil is calcareous material derived from coral rock fragments intermixed with various amounts of plant litter forming a top soil layer which is generally darker in colour. This thin topsoil layer is underlain by a layer of sand before reaching the water lens. Several past studies indicate that the water lens is generally overlain by just about a meter of sand (FAO, 1974) (SWECO, 2009) which can be safely applied to be the case for the land of the island.

Grain size distribution analysis of top soil extracted from 0.25 m from the surface and bottom soil extracted from 1.3 m below surface from a similar island showed that the soil did not contain silt or cobble. See **Figure 47** for grain size distribution of the top soil and bottom soil layer.

One of the most important physical features to consider is the hydraulic conductivity of the soil which indicates soil's ability to prevent water transport. The high infiltration capacity of the soils would mean susceptibility of the groundwater lens to ground surface pollution.

According to (Selvam, 2007) Maldivian soils are geologically young and consist of substantial quantities of the unweathered coral parent material, coral rock and sand. In most of the places, soils are coarse in texture and shallow in depth with a top layer of brown soil (0 to 40 cm in depth) followed by a transition zone on top of the underlying parent material of coral reef limestone. The soils are generally poor and deficient in nitrogenous nutrients, potassium and several micronutrients particularly iron, manganese and zinc. Though the phosphorus content of the soils is high it is present mostly in the form of calcium phosphate and, thus, remains unavailable to plants. The soils of the Maldives are generally alkaline with pH values between 8.0 and 8.8. This is mainly due to the presence of excess calcium.



Location	Sieved legend	Soil classification	Quantity Sieved	Frost-heav cap	d10	d60	d90
Bottom Soil Layer Vandhoo		Sand	310	2/1*	0.149	0.336	0.476
Top Soil Layer Vandhoo		Sand	309	2/1*		0.273	0.453

Figure 47: Grain size profile of typical Maldivian Islands (Data from Vandhoo soil samples tested in Jan 2017)

The grain size analysis for a soil sample obtained from a similar location in the Maldives showed that:

- Bottom soil contained less fine sand compared to top soil. Fine sand was the least prominent type of sand in both layers.
- Medium sand with lower grain size (approximately 0.2 mm) comprised of about 40% weight percent of the topsoil while it was 35% weight percent in bottom soil.
- The difference between sand composition between the top soil and bottom soil layers decreased significantly as grain size increased.
- Coarse sand and fine gravel (grain size of approximately 1-3 mm) comprised the majority of the two soil fractions

Permeability of water is a crucial factor of soil as it determines infiltration rate or potential to contaminate the ground water should a pollutant is spilled on the soil surface. In other words, it indicates soil's ability to transport fluids through it.

Graph illustrated in **Figure 48** shows the permeability test and results of top soil.

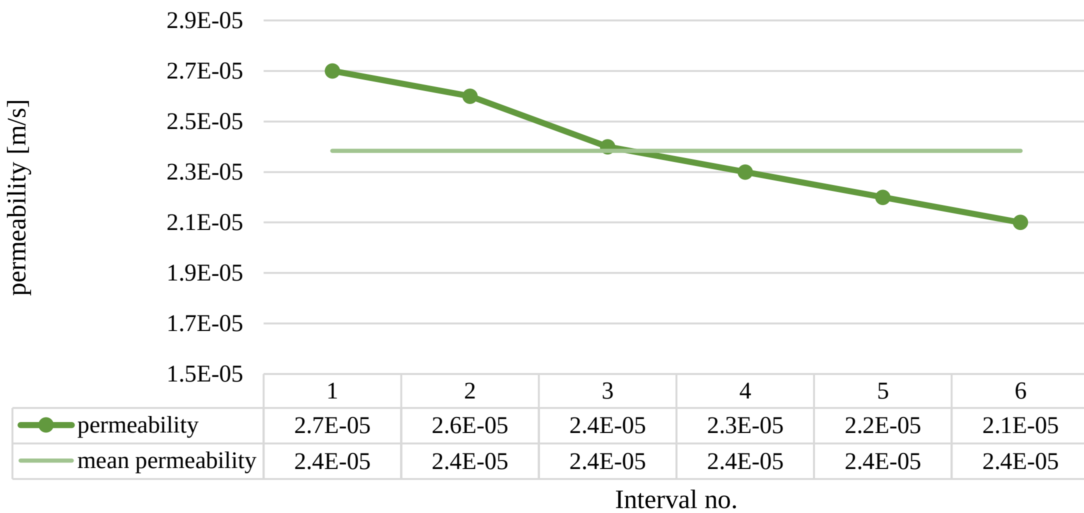


Figure 48: Permeability of top soil

Top soil had a density of 1.59 g/cm^3 with a water ratio of 8%. The mean permeability of top soil was found to be 2.4×10^{-5} m/s.

Graph illustrated in **Figure 49** shows the permeability test and result of bottom soil layer.

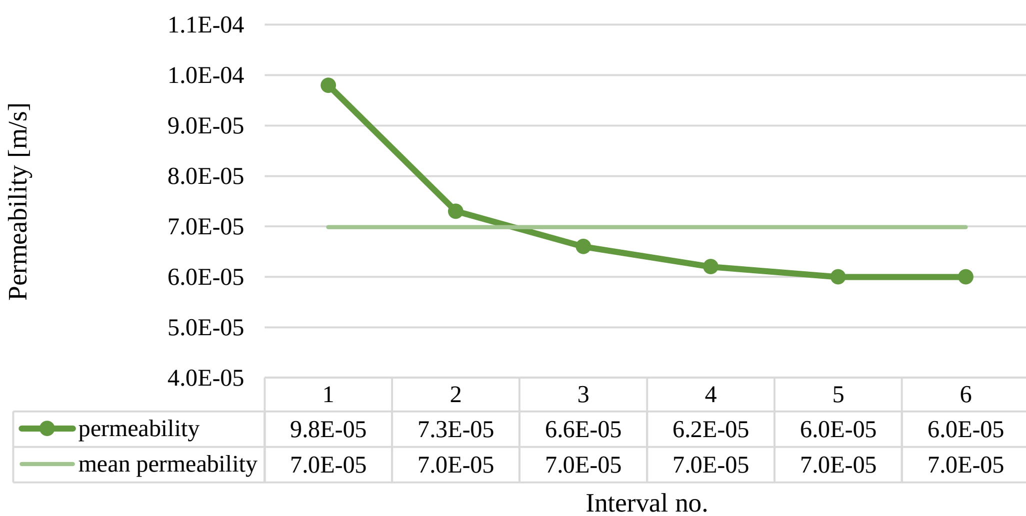


Figure 49: Permeability of bottom soil

Bottom soil had a density of 1.59 g/cm^3 with a water ratio of 6%. The mean permeability of bottom soil was found to be 7.0×10^{-5} m/s.

The lower the permeability figure, the better for protecting the groundwater, since it represents a large resistance to water transport, i.e. transport of possible pollutants into the water table which is generally found a meter below the surface. Increased hydraulic conductivity is anticipated in the project islands as much of Maldivian soils are composed of course sand to fine gravel that are poor at retaining water.

Surveys were also conducted at the nearest coastal area to determine the beach profile and condition of coastal areas. Sections below shows the beach profile, tidal zones and vegetation line at project islands.

A. K. Gaafaru

Beach profiles from the project area shows signs of erosion with high gradient (See **Annex 6** for details). The coastal area at adjacent to project area consisted of coarse sand and rubble sized particles. Sand was accumulating on the northern side perpendicular to the coast which had resulted in the formation of a sandy *Thundi* which extends approximately 85 m from the island coast. This strip of sand is mainly used by tourists. A sewage outfall exists adjacent to the sand bank close to the area proposed for brine outfall. Sand accumulation has initiated since the harbour project and have been rapidly progressed by the reclamation project. Sand from the western reclaimed area is readily carried by prominent currents in the W-E direction. A groin has been constructed to reduce loss of sediments from the reclaimed area.

B. L. Gan

Beach profile of the proposed and alternative site were of similar condition due to the proximity (See **Figure 50**). The beach face had a gentle slope of approximately 0.06. Severe erosion was not observed on the beach in both locations. The beach face extended approximately 7+ m from the scarp to the surf zone at the alternative site while the beach face was observed to be wider than 10 m at the proposed site. Surveys were done during the SW monsoon, and with the outfall being proposed at western side of the island, it is expected a portion of the beach to have eroded from monsoonal sediment transport due to the wind generated wave action from the SW.

Figure 50: a&b: beach area of proposed outfall site, c&d: beach area of the alternative outfall site with concrete jetty.

C. <u>B.Kendhoo</u>

Beach profiles from the project area shows normal gradients (See **Annex 6** for details). The coastal area at adjacent to project area consisted of coarse sand and rubble sized particles.

5.6.2 Vegetation

A. K.Gaafaru

There were no vegetation in K.Gaafaru project area. In general vegetation was very low in the island. The vegetation belt of the island was found to be depleted. The vegetation belt adjacent to the project area in Gaafaru was observed to be very narrow. **Table 22** shows the type of trees observed at the vegetation belt closest to the plot since there are no trees within the plot.

Table 22: Types of trees observed at K. Gaafaru

Common name	Scientific name	Local name	**Abundance**		
			Low	Moderate	High
Coconut	*Cocos nucifera L.*	Ruh			
Screwpine	*Pandanus absonus*	Kashikeyo			
Nit Pitcha	*Guettarda speciosa*	Uni			

B. L. Gan

There was no vegetation at the proposed site for the RO plant in L. Gan. Although, a portion of the access road to the site and powerhouse has not been cleared towards the beach. 4 mature coconut palms, a *dhiggaa* tree are in proximity of this access road with 1 mature coconut palm and *dhiggaa* tree falling on the path of the access road. In addition, dense underbrush is present up to a length of approximately 43 m after which the coastal vegetation belt of approximately 25+ m is present.

C. B. Kendhoo

There was no vegetation at the proposed RO plant site in Kendhoo. 15 coconut palm trees were found close to the project area outside the direct impact area. These trees are not anticipated to be impacted during the construction or operation phase of the project.

5.6.3 Terrestrial Fauna

Most of the common terrestrial invertebrates of the country are observed on the islands. In general, several terrestrial and intertidal crabs, butterflies, moths, beetles and spiders were observed on the Island. No unusual invertebrate was encountered during the limited survey period. The fruit bat (*Pteropus medius*), the only endemic terrestrial mammal in the Maldives was observed in L.Gan. However, the proposed project area is located away from densely vegetated areas.

In general terrestrial fauna was observed to be lowest at K. Gaafaru as most of the vegetation in the island have been cleared. Bird calls and sightings were most common in L.Gan compared to other two islands. In L. Gan *Eudynamys scolopacea* (Asian koel) *Ardea cinerea* (grey heron), *Areneria melanocephala* (black turnstone) and *Tringa hypoleucos* (common sandpiper) were believed to be found in reasonable numbers. The island is also frequented by numerous migratory birds.

Compared to L.Gan, K.Gaafaru was not particularly known for harbouring protected bio-diversity. In B.Kendhoo, *Eudynamys scolopacea* (Asian koel) call were heard.

Two species of reptiles; the mourning gecko (*Lapidodactylus lugubris*) and the garden lizard (*Calotes versicolor*) were also observed at the islands. All three islands harboured the common crow, house rats, and mosquitoes.

5.6.4 Protected Areas and Sensitive Sites

K. Gaafaru – The closest protected (Makunudhoo Kandu) area is located 22 km south west of the island.

B. Kendhoo – The closest protected area to Kendhoo are Bathala Region located 10 km away to the north east, Anga Faru located 12km away to the south east, Hanifaru located 17km to the south east and Mendhoo Island located 10km away to the south.

L. Gan – There are no protected areas close to the island.

The project is not expected to have any negative impacts on protected sites as they are located at a considerable distance away.

5.7 HAZARDS AND VULNERABILITY

In general, natural hazards that occur in Maldives can be broadly distinguished into geological and meteorological hazards. Based on the DIRAM UNDP 2006 the following hazards are relevant to the project location.

- Wind storms;
- Swell waves and wind waves;
- Flooding due to heavy rainfall/storms;
- Gravity waves (sea swells and *udha*); and
- Tsunami.

DIRAM report stated that major natural hazards in the Maldives are strictly controlled by the geophysical and climatic settings and shows quite different patterns in their distribution, as shown in **Figure 51.**

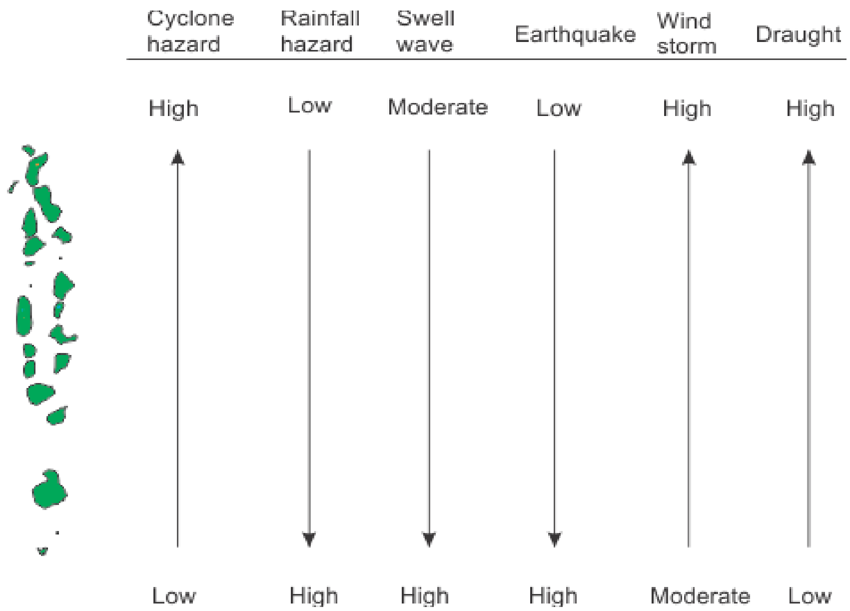


Figure 51: Exposure to hazards based on geographic location of atolls (source: UNDP, (2006)

The damage potential based on frequency of natural hazard to the Maldives is summarized in **Table 23**.

Table 23: Damage potential based on frequency of hazard (UNDP, 2006)

Hazard	Tsunami	Swell waves or storm surges	Rainfall flooding	Strong winds
Frequency	Once in 200 years	Occasionally every year	Once every year	Several times a year
Potential damage	Very high	high	moderate	low

Maldives being located within the equatorial region of the Indian Ocean is generally shielded from cyclonic activity (UNDP, 2005). There have only been a few cyclonic strength depressions that have tracked through the Maldives, all which occurred in the northern and north central regions. Only 11 cyclones crossed the islands over the entire span of 128 years. None of them passed the southern islands.

Figure 52: Tracks of cyclones affecting Maldives, 1877 - 2004 (Source: UNDP, 2009)

The northern atolls are at a greater risk from being effected by cyclonic winds and storm surges compared to southern atolls as depicted in **Figure 52** (UNDP, 2009). Hence compared to L.Gan, K.Gaafaru and B.Kendhoo have a higher risk of wind storms.

Based on findings of the previous studies and hazard assessment the most common risks to the project islands are flooding caused by heavy rainfall, swell surges and wind storms including cyclones. These were in line with the previous studies conducted by UNDP for the Maldives. **Table 24** describes significant vulnerabilities of the project islands to natural hazards.

Table 24: Vulnerability of Project Island to natural hazards

Hazard	**Time**	**Description**	**K. Gaafaru**	**L. Gan**	**B. Kendhoo**
Flooding caused by heavy rainfall	Commonly during SW monsoon	Flooding occurs in settlements situated at low areas of the island. Minor disruption to daily activities are caused by flooding (UNDP, 2007)	High risk Natural drainage from wetlands help to mitigate flooding. The island does not have wetlands and do not have storm water drainage systems. Low lying nature of the island makes it more vulnerable.	High risk Flooding occurs in settlements situated at low areas of the island. Minor disruption to daily activities are caused by flooding (UNDP, 2007)	High risk Two extreme weather conditions were observed in the island during 1 June 1991 and 22 November 1991 during the SW monsoon.
Flooding caused by swell surges	Commonly during SW monsoon	On top of damaging coastal integrity of island, swell waves damage farming lands and causes flooding and damages to infrastructure.	High Risk Exposed from the eastern side to the open ocean. There have been records of moderate to major swells specially during the northeast monsoon	Moderate Risk A major flooding event occurred during the 50's which mostly effected the northern part of L. Gan. However, this event did not have a huge impact on settlements since most of them were located on the western side of the island.	High Risk Risk of swells waves are significant around the island. The 2004 Tsunami had a significant effect on the island. It is common for swell waves to reach 3ft inland.
Windstorms	SW monsoon	Strong winds, cyclones have been known to cause physical damages. These include damage to farms and infrastructure.	Minor Risk Island is located on the southern half which is rarely effected by cyclonic winds and storm surges.	Minor Risk No major recent wind storms have been recorded. There have been recorded wind storms from 60's until the 80's. Written records show that no major, damage was cause as a result of these wind storms.	Moderate Risk Wind storms have affected the island on occasion. A notable windstorm was observed on 15 November 1997, where 21 houses incurred damage.
Droughts	-	-	-	-	-
Earthquake	-	-	-	-	-
Disease	-	-	-	-	During 1983, shingles caused

					two deaths in the island.
Tsunami	26th December 2004	70% of the islands were flooded. The primary reason for Tsunami inundation was due to the low ridge of the island and low areas located at the center of the island. (UNDP, 2005)	Low Risk	Low Risk	Low risk

6. SOCIO-ECONOMIC ENVIRONMENT

This chapter covers socioeconomic environment of project islands as required in **Task 2** of the TOR for the EIA study. The demographical, economic situation, land use planning, natural resource use, accessibility, transport services, basic infrastructure services such as water supply, wastewater disposal, solid waste disposal, energy supply and social services (health, education, security and recreation) and community needs of the local population is covered in the chapter.

A summary of the socio economic condition of the islands are given in **Table 25.** Sections below gives socio-economic condition of the island obtained through conducting a questionnaires.

Table 25: Socio-economic condition of project Island

Island	Crime	Youth employment	Legal services	Health services	Bank	Police	Harbour	Electricity	Safe water	Sewerage service	Waste management	Transport services	School	Tourism	NGOs
L. Gan	low	moderate	yes	yes	yes	yes	yes	yes	no	yes	no	yes	yes	yes	yes
B. Kendhoo	low	moderate	no	yes	no	no	yes	yes	no	no	no	no	yes	yes	no
K. Gaafaru	low	moderate	yes	yes	no	no	yes	yes	no	no	no	no	yes	no	no

A. K. Gaafaru

Gaafaru has a population of 1437 people. The island has three cafes. Fishing has been identified as the main economic activities of the island.

Electricity is provided by STELCO throughout the day. The island does not have a proper water or sewage systems. Rainwater is stored in tanks which is mainly used by households. The island community faces water shortage during dry season. Septic tanks are used for sewerage management.

The island has a health centre. The centre does not provide specialty services and can only attend common injuries and diseases.

Waste management in the island is a challenge. Waste is burned at the islands dump site.

Telecommunication services are provided by Dhiraagu and Ooredoo. The island has harbour which is crucial to access the island and plays a significant role in the economic activities of the island.

In terms of transportation the island has routine MTCC ferry services and a locally operated speedboat. On land battery pickups are operated in the island which are used to transport goods and commodities.

The island does not have a public transport system.

B. L. Gan

According to Census (2014) results, the Laamu Atoll has a population of 12,075, making it 6th most populous administrative atoll of the Maldives of these 11,858 are Maldivians. Of the 12 inhabited islands, Gan by far has the largest population (locals as well as foreigners) accounting for 28% of the entire atoll followed by Fonadhoo and Maavah. Of the registered population of 4574 for Gan 2368 are males and 2206 are females with population density of 7 (NBS, 2015). Kalhaidhoo was inhabited island in 2006 but uninhabited now. L. Kalhaidhoo population is residing in L. Gamu since 2010. It was a ward of L. Isdhoo in 2006. L. Kalhaidhoo and some proportion of L. Mundoo population has been relocated to L. Gamu in 2006 following Indian Ocean Tsunami of 2004.

Gan is renowned for their agricultural farming. Farmers in Laamu grow a variety of crops with some of the most valuable being coconut, chilli peppers, watermelon and banana. Others include papaya, brinjal, taro, pumpkins, gourds, Chinese cabbage, red onions, eggplants, cucumber, mangoes, and a few others.

L. Gan has 24 hrs electricity services provided by the state owned company of FENAKA. For the ordinary people currently the main source of drinking water is rainwater which is collected on roofs and stored in tanks. Rainwater is collected and stored in community water tanks within household compounds. Well water is contaminated and is not suitable for drinking purposes. A water supply system has not been developed in the island. There is a modern sewerage system developed with road sewers, road manholes, house connections and sewage treatment. The entire island is covered and sewerage service is provided to all houses. The service is provided by FENAKA Cooperation. The modern sewerage system in the 3 wards of L Gan was built in 2015. The island wide sewerage system was built with secondary treatment facility

L. Gan has a referral Regional Hospital. The hospital's service began as the Atoll Health Centre in 1993. It provides health care services to all the people living in the L Atoll. The hospital provides medical care for General Medicine, Paediatric care, Gynaecology, Surgical, Orthopaedic, ENT, Ophthalmology Communicable Diseases and Nursing Care. The hospital also handles accidents and an emergency case for that emergency response plan is in place

In L Gan, education is provided for pre-primary, primary, lower secondary and higher secondary levels. Hamad Bin Khalifa Al Thani School donated by the Qatari government is one of the reputed educational institutes in L Gan. The school was formerly known as Qatar Ameer School, and later renamed as Hamad Bin Khalifa Al Thani School. The school started with Grade 6 in 1998 and reached a new milestone by commencing Higher Secondary in 2010.

Telecommunication services to the island are provided by Dhiraagu and Ooredoo. Landline telephone communication service to the island is provided by Dhiraagu. However, Ooredoo along with Dhiraagu provides mobile communication services. Almost all the people in the working population have a mobile phone. Internet services are provided by Dhiraagu and Focus Infocom private limited.

Gan is approximately 6 hours from Male by speedboat and 55 minutes by airplane. The atoll has 293 registered marine vessels of which 156 are *dhonis*. It has 62 high speed launches, 13 traditional cargo and passenger boats (*baththeli*). Limited transport services are offered by the intra-atoll ferry operator although this services does not meet demand. There is no regular ferry to/from Male to Gan although private operators can arrange upon request. Small boat harbours facilities have been developed in almost all inhabited islands and two such harbours are found in Gan island; one at *Mukurimagu* with harbour size 250 x 500 feet. The second harbour is at *Thundi* measuring 700 x 250 feet. Domestic airport at Kadhdhoo located within very close proximity to Gan has been in operation for almost 20 years and is connected by land to Gan. Since opening of the resorts most tourists arrive in the atoll via this airport.

C. B. Kendhoo

Kendhoo has a population of 1287 people. The island has 195 registered houses of which people live in 182.

The island has two cafes. Construction, rope making and fishing has been identified as the main economic activities of the island. There is land allocated in the island for fibre works, to trade oil, develop fish products, to store cement and aggregate and for agriculture. The island does not have an approved land use plan; hence land is allocated on a need basis.

Electricity is provided by FENAKA throughout the day. The island does not have a proper water or sewerage systems. Rainwater is stored in tanks which is mainly used by households. The island community faces water shortage during dry season. Septic tanks are used for sewerage management.

The island has one public school which teaches up to grade 10. There is a privately run pre-school and two privately owned Quran centres on the island.

The island has a health centre with 4 nurses and one general doctor. The centre does not provide specialty services and can only attend common injuries and diseases. Waste management in the island is a challenge. Waste is burned at the islands dump site.

Telecommunication services are provided by Dhiraagu and Ooredoo.

The island has harbour which is crucial to access the island and plays a significant role in the economic activities of the island. In terms of transportation the island has1 large vessel which is used to carry goods to and from the island. There are 10 speed boats in the island which is mainly used for transportation within the island. On land one pickup is operated in the island which is used to transport goods and commodities. The island does not have a public transport system.

7. STAKEHOLDER CONSULTATION

This section of the report aims to address **Task 8** of the TOR. The key stakeholders of the project include:

1. Ministry of Environment and Energy (MEE);
2. EPA;
3. Island Councils;
4. General Public;
5. Contractor and
6. Consultants.

The stakeholders that participated in the consultations extensively discussed the issues relating to the project and their perception and recommendation to enhance the project. The consultations highlighted a wide array of concerns and recommendations which included critical assessments of proposed locations and its direct and indirect short term and long term impacts.

Sections below summarises the outcome of all the consultations held with the primary stakeholders with regard to the project.

7.1 CONSULTATION WITH EPA

7.1.1 Scoping Meeting

The scoping meeting was held on 17 October 2017 to set the scope for the project. Representatives from EPA, Ministry of Environment and Energy (Proponent), Gaafaru Council and Environmental consultant was present at the scoping meeting. Representatives of L. Gan and B. Kendhoo council were not present at the meeting.

Meeting Summary

- Brief overview of the project was provided by the proponent. The proponent stated that objective of the project is to provide freshwater to the public during water shortage.
- Proponent also highlighted that operation of the RO plant will be handed to the islands utility provider FENAKA or STELCO.
- Proponent highlighted that house connections will be made in the future and is not included in the scope of current project.
- Proponent highlighted that water will be tariffed and supplied for commercial use through a kiosk installed at the harbour of each island. Proponent stated that through the harbour kiosk the RO plant would generate an income for operation.
- Proponent informed that they preferred locations close to the powerhouse to establish RO plant. This is to reduce cost of electricity, infrastructure development and by placing RO plant close to the powerhouse it can be easily managed and looked after by the utility company.
- Representatives of EPA informed that they do not recommend to situate the RO plant close to the powerhouse as there is a higher risk of pollution by dust emitted from the powerhouse vents, which could affect the storage tank and taps. Moreover, EPA highlighted that risk of accidents is increased by situating the RO plant close to the powerhouse.

- EPA informed that a clear management, tariffing and water testing plan shall be demonstrated to EPA in order to obtain the operating licence.
- EPA also informed that brine discharge options shall be explored since it causes marine pollution.
- EPA also informed to include groundwater and seawater baselines and to measure hydrocarbon content of groundwater at project location since it is located close to powerhouse which has been reported to pollute the groundwater film.
- EPA informed to ensure the project meets all their guidelines and regulations, and to obtain assurance from utility providers to meet these requirements.
- Gaafaru council members who were present highlighted that it is important to ensure safety and build adequate capacity to operate the RO plant.

7.2 CONSULTATIONS WITH ISLAND COUNCILS & PUBLIC

Island councils and the public are one of the main stakeholders of the project. Consultations with Island Councils were held to:

i. Explain the project components;
ii. Discuss likely environmental and social issues associated with project;
iii. Discuss project alternatives;
iv. Discuss ways of enhancing positive aspects and minimising negative impacts of the project; and
v. Enhance community ownership of the project.

7.2.1 Meeting with K. Gaafaru Council

Meeting with K. Gaafaru council was held on 25/10/2017. Meeting attendance sheet is attached in **Annex 5** of the report.

Meeting Summary

- The council informed that the project will be viable in the island mainly because, there will be a high demand for freshwater by the fishing vessels, hence they anticipate the project to be commercially feasible.
- The council highlighted that proposed outfall location is not the most ideal as it will have to be extended in case land is reclaimed at Gaafaru in the future.
- The council informed that, an alternative for outfall location could be placing it on the western side of the island.

7.2.2 Community Consultation (K. Gaafaru)

Community consultation at K. Gaafaru was held on 26/10/2017. Meeting attendance sheet is attached in **Annex 5** of the report.

Meeting Summary

- Representative of boat owners suggested to relocate the harbour kiosk towards the middle of the harbour so that it would be easier to access it. They highlighted that the new harbour is relatively huge and currently the harbour kiosk is proposed to be located close to the area allocated for vessels with a hull size of under 36 ft.
- Members of the community highlighted that they preferred to locate the outfall pipe on the western side of the island.
- Members also highlighted that most households harvest rainwater which runs low during the dry months, hence if water is supplied to the public during these days the project would enhance water security.

7.2.1 Meeting with L.Gan Council

Meeting with L. Gan Council was held on 24th October 2017. Meeting attendance sheet is attached in **Annex 5** of the report.

Meeting Summary

- Rainwater shortage are experienced during the months of February to April, and during this period, water is sourced from Maandhoo.
- Community rainwater collection and storage tanks have been placed in the islands, although locals are averse to using the tanks due to lack of maintenance decreasing their confidence in the stored water.
- Council stated that the current population would not be very receptive towards house connections if they have to pay a tariff.
- Due to the distances between the wards of L. Gan and the proposed RO plant, the council stated that a delivery service is important to provide the water to the community.
- The council stated that currently there is an abandoned RO Plant in a location which the council prefers to the proposed location. The council proposed to study this site as an alternative location for the RO Plant.

Council stated that as the outfall is proposed on the eastern side of the island, strong wave action is expected. A temporary sewerage outfall pipe was constructed in 2014 in a similar location which resulted in damages due to the strong wave action.

7.2.3 Community Consultation (L. Gan)

Community consultation at L. Gan was held on 26th October 2017. The team visited randomly selected houses in the three wards of L. Gan to consult with the community. List of members of the community consulted is attached in **Annex 5** of the report.

Meeting Summary

- The community currently uses household tanks of 2500 L to harvest rainwater, although scarcity is experienced during the dry season, and water runs out in some households. Therefore, the provision of water during the dry period would be a positive.
- The community shared their concerns regarding the distance of the tap bay to the wards, especially Mukurimagu and Mathimaradhoo. They stated that the cost of transport is high and it would be an inconvenience with regards to accessibility. Residents stated that to ensure equal provision of the service, each ward should have a tap bay in a public area.
- The community also shared their concerns regarding possible vandalism of the plant due to it being situated away from the residential area.
- Concerns were raised regarding possible impacts from pollution by dust emitted from the powerhouse contaminating the water. A similar situation was cited in L. Maavah.
- The harbour kiosk would be a positive as fishermen currently purchase water from L. Maandhoo.
- Some members of the community also stated a preference to the alternative site due to an RO plant being previously run in the location.

7.2.2 Meeting with B. Kendhoo Council

Meeting with B. Kendhoo Council was held on 29th October 2017. Meeting attendance sheet is attached in **Annex 5** of the report.

Meeting Summary

According to the council the proposed location of the RO plant used to have an established RO plant constructed with help from a nearby resort, the plant failed to work after a short amount of time due to lack of maintenance.

Regarding the status of groundwater and rain water at the island

- Status of ground water at the island has deteriorated since the tsunami of 2014.
- Majority of complaints with regard to groundwater contamination come from households in central areas of the island.
  (They use oxygen pumps and construct new wells to bring the ground water to bring the water a usable state)
- There is one guesthouse on the island and they use oxygen pumps in addition to a rain water storage connected to groundwater well to purify water.
- 80 – 90 % of households at the island has rainwater storage tanks.
- Most locals use mineral water for drinking purposes.
- Annual rainwater shortages have been experienced (if it does not rain for more than 3 months.
- Water has been brought to the island from Kulhudhuffushi, Dhuvaafaru and Felivaru with the help of disaster management to cater to locals in these times.

Regarding planned harbour kiosk and community water outlet from the RO plant

- Location of the community tap bay is not easily accessible to all islanders from its current planned location.
- Council proposes to look into the possibility of constructing more tap bays at locations where people usually gather (School, Football grounds and mosque) to cater to needs of locals more effectively.

Regarding contractor's lodgings, storage area for waste generated during construction phase of the project.

- Contractor's workforce can be easily accommodated in local households.
- Waste generated during construction phase of the project can be stored at the project site and temporarily stored at the island waste dump site before transportation.
- Council looks into the possibility of using the sludge gathered during drilling of the borehole to reclaim eroded areas of the islands (most notably the shore side of current waste management areas which have eroded).
- Site clearance works have been outsourced to a local third party by the main contractor of the project.

7.2.4 Community Consultation (B.Kendhoo)

Community consultation at B. Kendhoo was held on 30 October 2017. Meeting attendance sheet is attached in **Annex 5** of the report. Summary of the discussion is highlighted below:

Meeting Summary

- More tap bays constructed at convenient locations would make things easier as the current location of the tap bay is at the southern end of the island and most people do not go to this area.
- Status of groundwater has deteriorated since the tsunami and requires oxygen tanks or construction of new wells to bring the water to an acceptable state
- Locals stressed that 5 new guest houses will be operational (plus the existing one guest house) and the possibility of developing connection lines to the guesthouses was discussed.
- All the locals who took part in the consultation were willing to pay household connection fees and water usage fees.
- Locals said that ground water at their households was smelly and murky; they use oxygen tanks and construct new wells when oxygen tanks alone do not fix the problem.

Most of the locals did not have any complains about shortage of rain water, they stressed that groundwater was a bigger problem for them as most of them already use bottled water for drinking on a regular basis

Note:

*Since the project involves supply of freshwater to the public, Health Protection Agency (HPA) was identified as a stakeholder during the scoping stage of the project. A consultation was requested on 30 October 2017. However, a consultation meeting was not arranged at the time of report submission. Consultation request is attached with the document as a reference (See **Annex 5**).*

8. ALTERNATIVES

This section explores alternatives for the proposed project as required by **Task 5** of the TOR for the EIA. The options explored include:

1. No project option;
2. Alternative location to construct the RO plant;
3. Alternative outfall location;
4. Alternative location for harbour kiosk and tap bay; and
5. Alternative borehole drilling methods.

The following sections compares alternatives in detail. When comparing the alternatives, environmental, economic and social considerations were taken into account. The principle of sustainable development is used as the guiding principle in selecting the preferred alternative. Sustainable development has been broadly defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. (UNWCED, 1987).

Hence, the aim is to ensure that all project activities are undertaken without any adverse long term irreversible environmental damages that cannot be mitigated. This is the principle that is applied when discussing the preferred alternative through the discussions that entails in the sections below.

8.1 NO DEVLOPMENT OPTION

Under the current scenario all project islands expressed challenges in obtaining freshwater. Scarcity of rainwater during dry season and inefficient rainwater collecting systems have been identified as major challenges to sourcing rainwater. Apart from L. Gan, the other islands do not have means to properly supply water to fishing vessels and other types of vessels. This demand is not met in Gaafaru and Kendhoo which rely heavily on fishing as a source of income. In L. Gan, rainwater tanks are used to supply vessels. When rainwater runs out, groundwater is used which is contaminated (See **Section 5**). Kendhoo is an island that has a budding local tourism sector which demands freshwater as well which is not easily available from the island. The **Table 26** below shows comparison of no development option with the development option at project islands.

Table 26: Comparison of the no development option with development option

Option	Environmental	Social	Economic
No Project Alternative	Island largely remains in its current status. The island environment may continue to slowly deteriorate due to pollution of groundwater lens by sewerage and salinization. Corals and marine life will not be impacted as a result of RO plant discharge. Potential for oil spills and accidents are prevented. Land clearance can be avoided. Pollution of the environment and island as a result of construction and general waste is avoided. All negative impacts to the environment of the project detailed in **Section 9** can be avoided with the no project alternative. Space used for installing RO plant can be put to another use.	Benefit to the society by the project will be missed which include availability of freshwater at times of need. Water security of the island will be compromised. The risk of water availability during dry season and at times of disaster will be greatly increased.	No significant improvement to the local and regional economy. New job opportunities and knowledge base will not be created Income opportunities missed. Difficulty in meeting the water demand created by local fishing and tourism sector of the island.
Project Alternative	**K. Gaafaru**		
	The project does not involve, vegetation clearance. It will generate waste and GHG and bring irreversible change to existing landscape. This would have negative impacts on the soil and biological environment of the island. Stress on groundwater will be prevented allowing it to recharge. The project involves discharge of brine into the marine environment which would pollute the marine environment.	Increased direct and indirect employment opportunities for the locals as RO plant becomes operational. Knowledge transfer and development of technical capacity. During the operational phase of the project, noise from RO plant will have impacts on nearby households and buildings.	Enhanced opportunity for locals to start and diversify commercial activity Creation of job opportunities and skilled labour. Development and expansion of agriculture and fisheries market in in the island.

	However almost all the foreseeable impacts of the project can be mitigated and kept at an acceptable level and the project will not result in a loss of a sensitive or critical habitat or species.		
	L. Gan		
	The project site does not have any vegetation, although clearing of underbrush is required to lay the brine discharge pipeline. The project would result in the generation of waste and irreversible change to the landscape which would result in negative impacts to the soil and biological environment of the island. Brine will be discharged into the marine environment which will cause pollution of the area. However almost all the foreseeable impacts of the project can be mitigated and kept at an acceptable level and the project will not result in a loss of a sensitive or critical habitat or species.	Households of L Gan will have water security during the dry seasons when the household storage tanks run out of rainwater Increased direct and indirect employment opportunities for the locals as RO plant becomes operational. Knowledge transfer and development of technical capacity. The RO plant is proposed next to the powerhouse near *Thundi* ward and noise generated from the RO plant is not expected to impact households.	Job opportunities and skilled labour will be created Business opportunities will be created such as supplying of water to cafés, guest houses and households Currently the fishing boats of L Gan purchase water from L Maandhoo. Availability of water at the *Thundi* harbour would result in easier access and development of the fisheries sector.
	B. Kendhoo		
	The project does not involve, vegetation clearance. It will generate waste and GHG and bring irreversible change to existing landscape. This would have negative impacts on the soil and biological environment of the island. Stress on groundwater will be prevented allowing it to recharge. The project involves discharge of brine into the marine environment which would pollute the marine	Increased direct and indirect employment opportunities for the locals as RO plant becomes operational. Knowledge transfer and development of technical capacity. During the operational phase of the project, noise from RO plant will have impacts on nearby households and buildings	Enhanced opportunity for locals to start and diversify commercial activity Creation of job opportunities and skilled labour. Development and expansion of local tourism industry and fishing sector.

	environment. The marine environment of Kendhoo was diverse. Extensive groundwork required to lay power cables and water supply pipe. However almost all the foreseeable impacts of the project can be mitigated and kept at an acceptable level and the project will not result in a loss of a sensitive or critical habitat or species.		

Based on the above evaluation, the ***no development option*** is ***rejected*** in the absence of any significant benefits associated by not undertaking the project.

8.2 ALTERNATIVE LOCATION TO CONSTRUCT RO PLANT

The current proposed/preferred location defined as option 1, to construct the RO plant is assigned and allocated by the council and approved by MHI. Since alternative areas were identified by the council in L. Gan and B. Kendhoo and due to concerns highlighted at the scoping meeting with regard to dust emissions from powerhouses if RO plant is located on lands close to the powerhouse alternative locations were analysed.

Hence, this section aims to apply a consistent alternative analysis method for all the project islands in order to determine the most feasible location. Information required for the analysis was gathered from stakeholder consultations and existing environmental studies.

Evaluation of alternatives was conducted using a simple matrix based upon a scoring criteria (**Table 27**) which was applied to predetermined key parameters. The key parameters used in the option analysis are highlighted in **Table 28**.

Table 27: Scoring Criteria

Range	Major Negative	-3
	Moderate Negative	-2
	Minor Negative	-1
	No Change	0
	Minor Positive	1
	Moderate Positive	2
	Major Positive	3

Table 28: Parameters used in option analysis

Number	Parameter	Code	Description
1	Health/Wellbeing	S1	Health/wellbeing describes impacts of smell, smoke and noise on closest residential area as a result of the proposed project location.
2	Accessibility	S2	Describes the ease of accessibility from residential areas to the RO plant.
3	Environmentally sensitive sites	S3	Describes proximity and impact to sensitive sites, such as wetlands, protected trees etc as a result of proposed WSS site.
4	Vegetation cost	S4	Describes the cost incurred to clear vegetation for the. This may include cost as compensation etc. This parameter is assessed based only on financial terms.
5	Power supply cost	S5	Describes cost incurred to provide electricity at the proposed location, mainly based on information provided by council and FENAKA representatives.
6	Environmental impact	S6	Describes loss of vegetation, hazard/vulnerability and impacts to shoreline as a result of the proposed location
7	Land use plan	S7	Describes current usage of land and future population growth direction, rate and usability of proposed land for other purposes such tourism etc.

8.2.1 K. Gaafaru

Due to lack of land availability, the island does not have an alternative location with enough space to establish the RO plant. The current location does not have any vegetation and is adjacent to the powerhouse. The location is approved by MHI and the council informed during stakeholder consultations that the island does not have any viable space to move the RO plant. Details of the proposed location are given in **Section 2.2**.

Conclusion: The proposed site was determined to be the preferred location at K. Gaafaru.

8.2.2 L. Gan

Two sites were evaluated in L. Gan. The proposed site and alternative site which are described below.

Table 29 shows evaluation matrix of the two options.

1. ***The proposed site (option 1***)
   The proposed location for RO plant (option 1) is on the western side of the island next to the powerhouse of *Thundi* ward of the island as illustrated in **Figure 53.** The number of trees intersecting with the proposed plot including the access road was zero (0). Although, to provide a path for the brine discharge pipe, underbrush is required to be cleared on the road westwards. Three coconut palms are present in this area of road. Nearest infrastructure to the site is the powerhouse located next to the proposed site. The nearest households are the new settlement areas of *Thundi* ward and the nearest plot is more than 100 m away from the site.

Figure 53: Proposed and alternative RO plant locations at L.Gan

2. ***Alternative site 1 (option 2)***

The proposed alternative location for RO plant (option 2) is also on the western side of the island as illustrated in **Figure 53**. The site is west of *Mathimaradhoo* ward of L Gan, at the end of main road going along the width of L Gan in the ward and intersecting with the main road of L Gan going along the length of the island. The site currently consists of dilapidated infrastructure for a previous RO plant which has been vandalized after operations were ceased. The site will require demolishing of the old infrastructure prior to works. The site is facing the L Gan Customs Office on the adjacent side of the road. Nearest households to the site are residential plots located in *Mathimaradhoo* more than 500 m from RO plant. An access road is present which enables access to the RO plant, and no vegetation is required to be cleared to lay the brine discharge pipe to the sea. (See **Annex 6** for surveyed Drawing).

Figure 54: a&b: proposed site at L Gan. c&d: alternative location at L. Gan

Table 29: Option evaluation matrix for L.Gan

	Option 1	Option 2		
Option 1		Code	Option 1	Option 2
		S1	-1	0
		S2	-3	-3
		S3	0	0
		S4	-1	0
		S5	-1	-3
		S6	-1	-1
		S7	0	-2
		Total	-7	-9

Evaluation Summary (L. Gan)

The overall score for the proposed site is -7 while the overall score for the alternative site is -9. The proposed site is approximately 100+ m from the nearest residential areas therefore the impact to receptors are minimal at -1, while the alternative site is situated approximately 500+ m to the nearest residential area, therefore any health and wellbeing impacts due to proximity are negligible. The proposed site is close to the new settlement area of *Thundi* ward, although this results in the site being far away from both *Mathimaradhoo* and *Mukurimagu* wards which poses issues regarding accessibility. The alternative site is situated in a way that the relative distance between the site and *Mathimaradhoo* and *Mukurimagu* wards ward is closer except for *Thundi* ward. Both sites score -3 for accessibility due to distance required to travel by the residents to obtain water. The proposed site and alternative site are both not in proximity to any environmentally sensitive areas such as wetlands / protected trees. Only a small amount of vegetation (underbrush) will be needed to be cleared to lay the brine discharge pipe for the proposed site while vegetation clearance can be easily avoided for the alternative site for both the RO plant building and the brine discharge pipe. High voltage power supply is required for the RO plant, therefore the proposed site being next to the powerhouse would result in only a minor negative while the alternate site would incur more costs to provide power supply to the site, due to no powerhouse being present in proximity to the site from the wards of L. Gan. Environmental impacts due to loss of vegetation, hazard/vulnerability and impacts to shoreline are considered as minor negatives for both locations. The current proposed plot for the RO plant is allocated for utilities in the L Gan land use plan, while the alternate site is proposed within the area allocated for local tourism development. Therefore, the proposed site is in line with current and future usage of land, while the proposed site is in contrary to that.

Conclusion: The proposed site was determined to be the preferred location at L. Gan.

8.2.3 B. Kendhoo

Two sites were evaluated in L. Gan. The proposed site and alternative site which are described below.

Table 30 shows evaluation matrix of the two options.

1. ***The proposed site (option 1)***
The proposed location for RO plant (option 1) was on the southern side of the island as illustrated in **Figure 55.** There are few trees around the proposed plot while all vegetation covers inside the plot had been cleared. The nearest infrastructure to the site is the residential zone located on the opposite side of the road to the north, approximately 5 meters from the proposed location. The proposed location is approximately 325m away from the islands powerhouse. This site previously housed another RO unit that was developed with assistance from a nearby resort which has since been damaged and decommissioned.

Figure 55: Proposed and alternative RO plant location B. Kendhoo

2. ***Alternative site 1 (option 2)***
The proposed first alternative location for RO plant (option 2) was on the southern side of the island on a piece of land adjacent to the existing communications tower as illustrated **Figure 55.** The alternate site is located approximately 100 meters to the east of the proposed location for construction of the RO plant. Vegetation cover at the site was dominated by coconut palms (*Dhivehi ruh*). Other large trees were also present at the site including Breadfruit (*Banbukeyo*) and Sea hibiscus (*Dhigga*). Nearest infrastructure to the site are the existing communications tower and the residential zone to the north of the plot across the road approximately 5 meters away. The existing waste management center of the island is located approximately 100 m to the east of the plot. The existing access road would have to

be widened to enable access to the RO plant. The site is located at a distance of approximately 410 meters from the islands powerhouse.

Figure 56: a) Proposed location for development of RO plant b) Vegetation cover towards the southern beach c) Nearest residential zone and road north adjacent to the plot d) road leading to the beach directly west of the plot

Table 30: Option evaluation matrix for B. Kendhoo

	Option 1	Option 2		
Option 1		Code	Option 1	Option 2
		S1	-3	-3
		S2	1	1
		S3	-1	-2
		S4	-1	-3
		S5	-3	-3
		S6	-1	-2
		S7	-1	-1
		Total	-9	-13

Evaluation Summary

Analysis of both the proposed location for development of the RO plant and the alternative location for development of the RO plant showed that the proposed location is more preferred. This is mainly because even though both the sites are located close to residential zone, vegetation at the proposed location had already been cleared and choosing this site would minimise environmental impacts caused by land clearance.

Another factor that weighed in favour of the proposed location is the distance of the site from the islands powerhouse which would be used to provide power to the plant. The proposed alternative site is 410m away from the powerhouse while the proposed location is at a distance of 325 m from the powerhouse. Utilising the proposed location for development of the RO plant would save the energy and cost required to supply power to the plant as it is 85m closer.

Conclusion: The proposed site was determined to be the preferred location at B. Kendhoo.

8.3 ALTERNATIVE OUTFALL LOCATION

The outfall location has the greatest potential to mitigate marine environment pollution during the operational phase of the project. Evaluation of outfall alternatives was conducted using a simple matrix based upon a scoring criteria (**Table 31**) which was applied to three predetermined key parameters. These were namely, the economic environmental and future development factor.

Table 31: Scoring Criteria

Type	Score
Negative	-1
No Change	0
Positive	1

The economic factor encompassed the cost of laying the outfall pipe, this includes contracting and material costs associated with laying the outfall pipe. Its significance was dependent on the environmental condition of the outfall location and existing infrastructure in place.

The environmental factors encompassed the increase or decrease in marine environment pollution potential. The significance of marine environment pollution was based on the live coral cover at the proposed outfall site and alternative site.

The future development factor takes into account potential future development of the outfall location such as land reclamation.

The alternative outfall locations proposed in the report were mainly determined after stakeholder consultations, based upon the evaluation of future development and existing limitations. The proposed locations were determined by project designer MEE. Sections below describe in detail the proposed outfall locations and alternative outfall location and its comparison.

8.3.1 K. Gaafaru

Two outfall options were compared in Gaafaru as described below:

1. **The proposed outfall location (Option 1)** was to the north adjacent to the RO plant inside the lagoon area close to the coastal area as illustrated in **Figure 6**.

2. **The alternative outfall location (Option 2)** was situated towards the western lagoon, as illustrated in **Figure 57**.

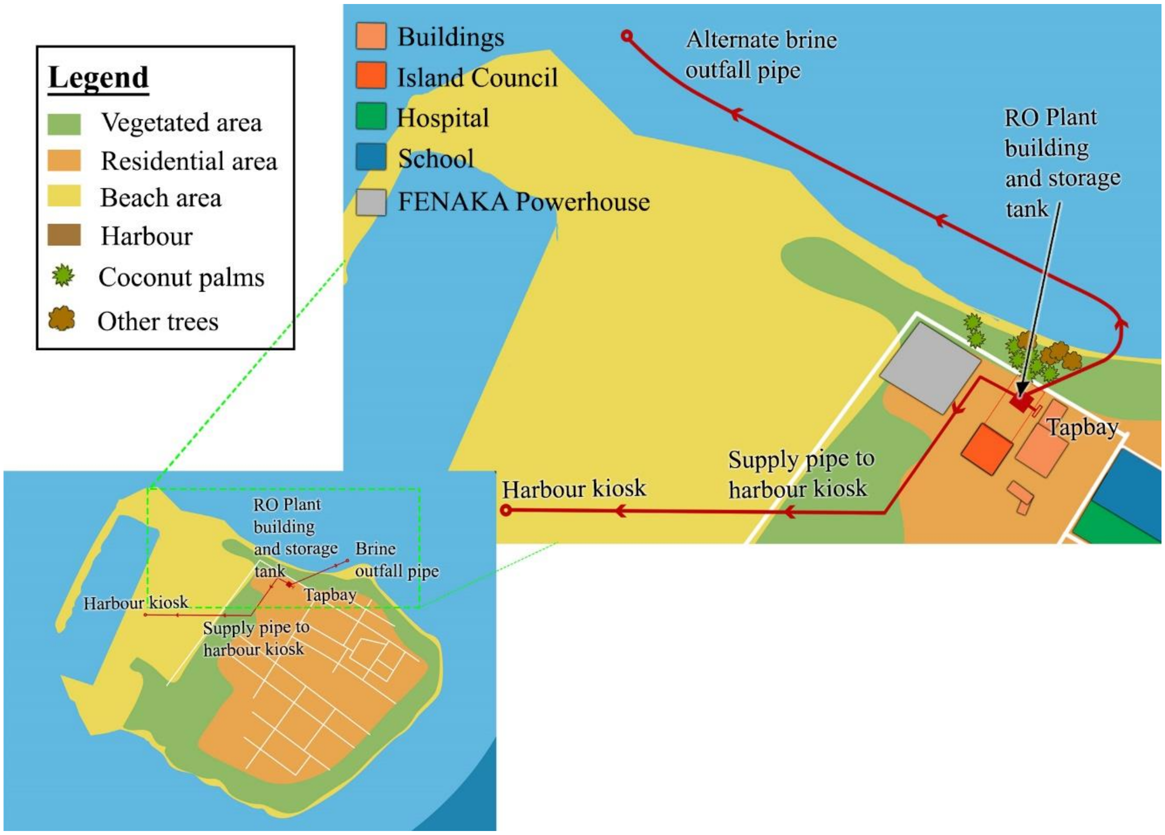


Figure 57: Alternate outfall and harbour kiosk location

Table 32 shows the simple scoring matrix for both options. Evaluation showed that option 2 was more preferred compared to Option 1.

Table 32: Option evaluation matrix, K. Gaafaru Outfall

Parameters	**Option 1**	**Option 2**
Economic	1	-1
Environmental	-1	0
Future development	-1	1
Total Score	**-1**	**0**

This is mainly because, even though the proposed outfall location is economically more ideal, it is not preferred over the long run as the northern section of the lagoon is most viable for future land reclamations. In case land is reclaimed, the pipe will have to be extended further to the north which would require a more powerful pump. Moreover, extending the pipe exposes live corals located near the reef edge to brine discharged from the RO plant resulting in a greater marine environment pollution. In terms of future land reclamation option 1 is not preferred. Environmentally discharging brine to the near coastal area where two headland type beaches formed on the east and west creates a less dynamic area which reduces diffusion of brine. However, the proposed area do not harbour live corals and abundant marine life. It is suitable as a temporary short term solution to discharge brine.

The alternative location is costlier as it involves trenching and laying the pipe over a long distance inland. A significant amount of coastal work will be required to take the pipe past the revetment. In terms of environmental impacts, the alternative location is not envisaged to have significant negative impacts as the area was observed to be dynamic and contained very little to no live coral cover.

Conclusion: the proposed alternative outfall area is preferred at K.Gaafaru.

8.3.2 L. Gan

Two outfall options were compared in Gan as described below:

1. **The proposed outfall location (Option 1)** is to the west of the RO plant inside the lagoon area as illustrated in **Figure 53**.
2. **The alternative outfall location (Option 2)** is situated west of the alternative RO plant location inside the lagoon area as illustrated in **Figure 53**.

Table 33 sows the simple scoring matrix for both options. Evaluation showed that option 1 was more preferred compared to Option 2.

Table 33: Option evaluation matrix, L. Gan Outfall

Parameters	Option 1	Option 2
Economic	1	1
Environmental	-1	-1
Future Development	1	-1
Total Score	**1**	**-1**

Both outfall locations are similar with regards to the distance required to place the discharge pipe, as well as beach slope, and coral cover and marine life present in the areas. Therefore, both outfalls score similarly for economic and environmental parameters, although with regard to future developments, option 2 is regarded less favourable. This is due to the location of the outfall being allocated for future development of local tourism, and the presence of a brine discharge pipe in the area would be less favourable in such an area.

Conclusion: the proposed outfall area is preferred at L. Gan.

8.3.3 B. Kendhoo

Two options were compared in Kendhoo for outfall as described below.

The proposed outfall location (Option 1) was located directly south of the RO plant with 26m of the outfall pipe situated on land and 72m of the pipeline submerged in the rocky lagoon area extending away from the shoreline towards the reefs edge.

The alternative outfall location (Option 2) was located south of the proposed alternative location for the RO plant, 28m of the pipeline will be located on land and 54m of the pipe will be located in the lagoon extending away from the shoreline towards the reefs edge. See **Figure 55.**

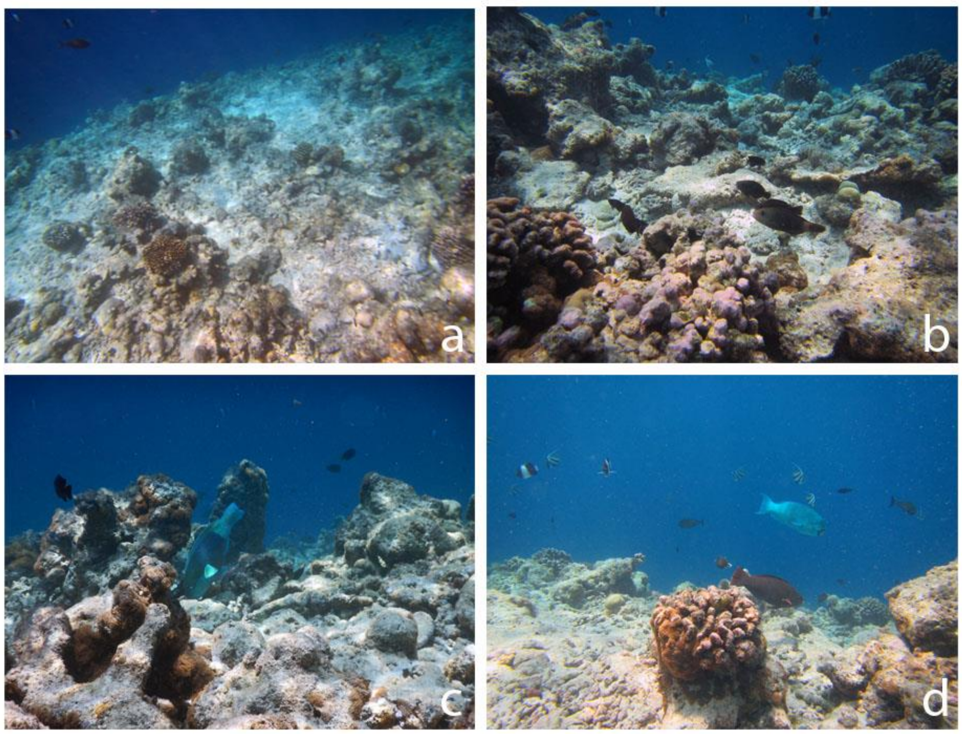


Figure 58: Marine photo profile of alternative outfall location at B. Kendhoo. a-d: photos at reef edge.

Figure 59: a) alternate outfall location b) vegetation at the proposed alternate location for RO plant c) access road adjacent to the proposed alternate location d) vegetation at the area between the beach and the proposed alternate location

Table 34: Option evaluation matrix, B Kendhoo Outfall

Parameters	**Option 1**	**Option 2**
Economic	1	1
Environmental	-1	-2
Future Development	-1	-1
Total Score	**-1**	**-2**

As both the sites evaluated are situated in the same area of the island and marine survey results showing similar marine environments, impacts to the marine environment by utilising either of the sites were deemed to be relatively equal. However, the proposed alternative site would require more vegetation clearance resulting in loss of habitat for some of the islands local wildlife. Economical and future development factors when considered during the evaluation were deemed to be very similar as there are no future developments planned for either of the locations and the locations are currently not being used for any economical purpose by the islanders.

Conclusion: the proposed outfall area is preferred at B. Kendhoo.

8.4 ALTERNATIVE LOCATION FOR HARBOUR KIOSK AND TAP BAY

Since the project aims to commercially sell water through the harbour kiosk and provide water to the public through the tap bay in case of need, the location of these two outlets shall be easily accessible.

In some of the islands, the proposed location of harbour kiosk and tap bay was found disrupt harbour activities or was not easily accessible equally from all parts of the island. These types of issues were more prominent in large harbours and islands. The following sections below describes the proposed location for the harbour kiosk/tap bay and alternative locations proposed based on surveys and consultations. The advantages and disadvantages are summarised for the two options evaluated.

8.4.1 K. Gaafaru

In Gaafaru, the harbour kiosk is proposed to be located on the eastern side of the old harbour as illustrated in **Figure 6**. However, due to the harbour expansion and reclamation project, the proposed location is inappropriate and unsuitable to supply water to vessels berthing at Gaafaru harbour. The proposed design does not take into account the islands ongoing harbour expansion and reclamation project.

Hence installing the harbour kiosk at the proposed location would mean that it is approximately 100 m away from the new harbour, which would make it unusable to supply water. Hence, it is proposed to install the harbour kiosk in the middle of the expanded harbour as illustrated in **Figure 57**

By installing the kiosk in the middle, it could be easily accessed from the western and eastern side of the harbour. It is important to situate the kiosk towards the middle of the harbour, because Gaafaru harbour is designed such that eastern side of the harbour will be utilised by vessels up to 37 ft while the western side of the harbour will be utilised by vessels greater than 37ft. Hence if the kiosk is located at one edge of the harbour, it would be very difficult to supply water in according to harbour usage guideline prepared by the island council.

Therefore, based on the advantages and disadvantages of the two options, it is recommended to select the alternative kiosk installation location.

Since Gaafaru is a relatively small island and population of the island is distributed towards the east and due to the fact that there is no alternative area to locate the RO Plant within the existing land area (excluding the reclaimed area) the proposed tap bay location was found to be easily accessible by the general public and no issues with regard to its current location was highlighted.

Conclusion: the proposed alternative kiosk area is preferred at K. Gaafaru.

8.4.2 L. Gan

The kiosk is proposed to be situated in the land which is currently allocated to provide rainwater to the vessels at the *Thundi* harbour. The kiosk is proposed to be located next to the rainwater storage tank tap bay. Due to the dispersion of the three settlement wards of L Gan, and *Mukurimagu* being at the southern end of the island, a smaller harbour has been developed for *Mukurimagu.* This sites shown in **Figure 60** is studied as an alternative location for the kiosk.

Figure 60: Alternate location for harbour kiosk and tap bay at L. Gan

Mukurimagu harbour harbour has a size of 250 x 500 feet while *Thundi* harbour measures 700 x 250 feet, and harbour extension works were underway during the field visit. Therefore, *Thundi* harbour is the preferred alternative in terms of access to a greater number and larger vessels. In addition, the *Thundi* harbour is situated closer to the proposed RO plant location which would decrease costs of laying longer pipeline as well as a more powerful pump to the *Mukurimagu* harbour.

The main concern of the residents of L Gan during community consultation, especially those of Mathimaradhoo and Mukurimagu ward was that the tap bay is located near the powerhouse of the Thundi ward, which would cause accessibility issues for the residents of the aforementioned wards, and thus would require hiring of vehicles to and from the tap bay to obtain water. Therefore, in addition to accessibility, this becomes a financial burden on the population in times of water scarcity and some households may opt to purchase water from nearby shops to avoid transportation costs. As L. Gan is the largest natural island in Maldives and the population is dispersed into three areas, the alternative to providing 1 tap bay in the RO plant location (which is closer to Thundi ward) is providing tap bays in Thundi, Mathimaradhoo and Mukurimagu wards in an allocated public area. Various impacts have been discussed in **Section 9** arising from the proximity of the RO Plant location to the powerhouse which can also be mitigated through the preferred alternative of locating tap bays in public areas of the three wards.

Conclusion: the proposed alternative tap bay areas are preferred at L. Gan.

8.4.3 B. Kendhoo

The harbour kiosk at B. Kendhoo is proposed to be located on the eastern edge of the islands harbour. The proposed location for the kiosk was selected to primarily supply water to large vessels that dock at the harbour as larger vessels primarily dock at the eastern side of the islands harbour. By changing the location of the kiosk to the middle of the Harbour, it would be possible to make supplying water to vessels on either side of the harbour easier, but may however cause some disruptions in loading – unloading and movement of passengers that arrive and depart the island as they usually utilise the middle area of the harbour for these purposes.

The proposed site for development of the RO plant was located on the southern side of the island. Though the island is relatively small in size, it was noticed that not many people venture to this area of the island on a daily basis (This was also pointed out in the community consultations). Hence, other possible locations to develop tap bays to make the service more accessible to the locals were explored. These areas are shown in **Figure 61**. The location on the north-eastern corner of the islands school was found to be a possible additional location for the tap bay as it is in close proximity to the harbour water pipe. Moreover, there is a rainwater tap bay already established in the area which would make RO connection easier.

Conclusion: the proposed alternative tab bay area is preferred at B. Kendhoo.

Figure 61: Alternate tap bay location B. Kendhoo

8.5 ALTERNATIVE INTAKE METHODS

Two main types of intake methods were considered for this project.

i. Subsurface intake; and
ii. Sea intake.

Figure 62 below shows the layout of the two intake methods.

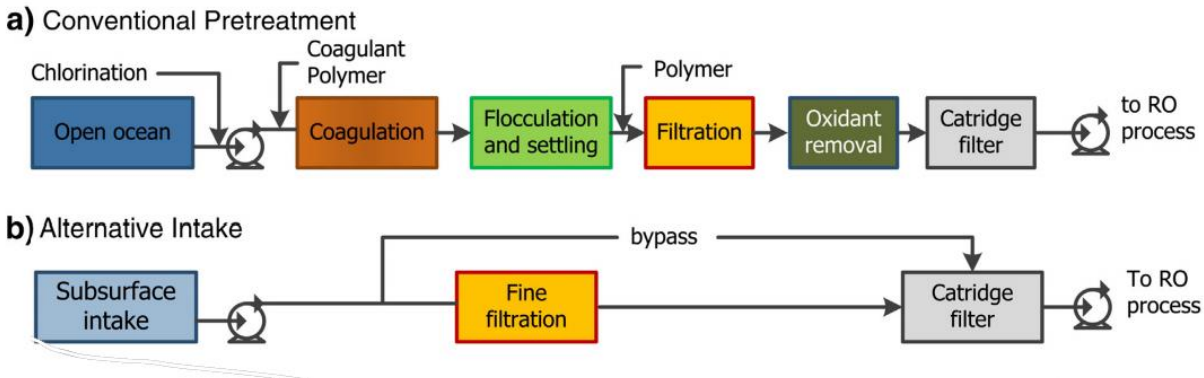


Figure 62: Intake methods considered for the project

A. Proposed intake method - Subsurface intake

Subsurface intake is the proposed feed water intake system for this project. This project uses a borehole drilled 30 m (or more depending on conductivity properties of the water) to provide the required feed water to the RO Plant. The borehole construction process and development method has been detailed in **Section 2.** The first 5 m of the bore well consists of gravel packing and a perforated pipe for ingress of water. The gravel packing and perforated pipe act as pre-treatment filtration prior to water intake. A submersible pump is placed over the perforated pipe for water intake from a 75mm riser pipe which leads to the feed water tank. The gravel packing section ends at 24 m from the bottom, and above that a sand a bentonite seal followed by cement grouting is placed.

Boreholes for extracting water consist essentially of a vertically drilled hole (inclined and horizontal boreholes are rare), a strong lining to prevent collapse of the walls, which includes a means of allowing clean water to enter the borehole space (screen), surface protection, and a means of extracting water (ICRC, 2010).

Subsurface intakes such as boreholes use the natural geological properties to remove organic matter, suspended sediment and dissolved organic compounds. This results in a reduction of organic biofouling (Missimer et. al, 2013). Therefore such intakes reduces the need for extensive pre-treatment process thus reducing the need for chemicals (See **Figure 62**). Due to the reduction of the pre-treatment processes, capital costs are reduced for construction and pre-treatment as well as operational costs are reduced for maintenance and chemical use.

B. Alternative intake method - Open ocean intake

For this alternative, the feed water pipe is constructed in the lagoon. The incoming feed water is pre-screened, and afterwards a coagulation and flocculation process is undergone prior to filtration. Then the feed water undergoes oxidant removal, through the cartridge filter to the RO process. The required pre-treatment process results in open ocean intakes being more complex compared to subsurface (borehole) intake.

Environmental impacts from open water intake include impingement and entrainment of marine biota, disposal of macro-organic debris on traveling screens, and use of chemicals such as ferric chloride to keep intake pipes clean. Open ocean intake are easily clogged by seaweed. Pre-treatment systems can be caused to temporarily stop by red tides and algal blooms (Missimer et. al, 2013).

In addition, open ocean intakes are posed with the risk of damage from strong wave action, which would result in the operation downtime.

Conclusion

Due to the reliability and cost effectiveness of the subsurface intake, and due to the open ocean intake posing greater negative environmental impacts, the subsurface intake using a borehole as proposed in the project is the preferred method.

8.6 ALTERNATIVE BOREHOLE METHODS

Alternate borehole drilling methods are compared in this section with regard to their advantages and disadvantages. Five options are studied, namely hand-auger drilling, jetting, sludging, percussion drilling and rotary drilling. Of the five, the first four methods are manual shallow drilling techniques except for rotary drilling.

Table 35: Comparison of alternate borehole methods

Option	Detail	Advantages	Disadvantages
Hand-auger drilling	Auger drills are rotated by hand. The blades cut into the soil and pass the material into a bucket. Excavated material will be removed continuously.	Low-cost Simple	Slow Limited to 10 m
Jetting	Water is pumped down rods, and it cuts into the soil as a jet. Water is circulated to wash out cuttings.	Useful in unconsolidated soils	Limited to shallow depths Halted if rocks are encountered
Sludging	A pipe is lowered into the hole and moved up and down by a lever arm. Water is fed into the hole and returns up the drill pipe.	Low-cost Simple	Slow Limited to shallow depths
Percussion drilling	Percussion drilling is done by dropping a heavy cutting tool repeatedly into the borehole.	Low-cost Simple	Slow Limited to shallow depths
Rotary drilling	As described in **Section 2**	Fast drilling No depth limit Needs temporary casing	Expensive Working space required for rig and mud pits Mud-cake build up may hamper development

The first four techniques are low cost alternatives to rotary drilling method. Although cheap and easily set up, the techniques have the disadvantage of being slow and limited to shallow depths. The EPA guidelines state that boreholes shall be constructed to a minimum depth of 30 m or more if the electrical conductivity has not reached 50 – 60 mS/cm. Therefore, the manual techniques are inadequate for the proposed use. In addition to having no depth limits, rotary drilling can be completed in a shorter period compared to manual methods. Therefore, the preferred alternative is the proposed method of rotary drilling.

8.7 ALTERNATIVE DISINFECTANT METHODS

Two primary methods are used for disinfection of water. These include use of:

1. Chlorine to disinfect water which is the proposed method. it controls the growth of such unwelcome bacteria as E-coli and Giardia. However, chlorine is a biocide and its sole purpose is to kill living organism. It can be easily absorbed by the body and are known to have various impacts on health depending on exposure level.
2. UV to disinfect drinking water which is the proposed alternative method. The sterilization is accomplished without adding any potentially harmful chemicals to water Although ultraviolet light is more expensive than biocides it is an effective and a more environment friendly method.

Conclusion

Due to evident benefits of UV as primary disinfectant, the alternative disinfectant method is preferred and recommended.

9. ENVIRONEMNTAL IMPACTS AND MITIGATION

9.1 INTRODUCTION

This section aims at addressing **Tasks 4 and 6 of the TOR**. The aim of the section is to identify all the impacts that may arise during the construction and operational phase of the project, and propose mitigation measures to address the negative impacts to make the project environmentally sustainable. The methodology applied is described in detail in **Section 0.**

In assessing the impacts, a differentiation was made between the construction and operational phase of the project, since impacts during the construction phase of the project and operational phase of the project are vastly different. Environmental receptors were classified under three main subheadings which include *physical environment, biological environment* and *social environment*. Under each component environmental receptors were adapted from the Leopold method. Mitigation measures for all relevant activities that may have an effect on the natural and socio-economic environments have been identified. Elaboration of the assessed effects of impact factors on environmental components have been discussed in the following Sections.

9.2 THE IMPACT BOUNDARY

Impacts from the proposed project has been differentiated into three main categories depending on their nature and spatial extent. The impact categories of the project include:

1. **Primary Impact Zone:** The primary impact zone is defined as the area that will have a direct impact as a result of the project. The direct impact footprint area is defined as the area enclosed within a 10-m buffer of the construction and land clearance activities. Direct impacts are mainly caused by human activities such as site selection, land clearance, excavation etc.

   The projects primary impact area can be completely altered, due to long term irreversible changes brought to it by the proposed development. In general, the primary impact area encompasses the most negative environmental impacts over the smallest area. **Figure 63 Figure 64**, **Figure 65** illustrates and details the impact areas of each of the project islands.

2. **Secondary Impact Zone:** The secondary impact zone is defined as areas that may be effected as a result of the projects direct impacts. Spatial extent of the secondary impact zone depends on factors related to direct impacts.

   Secondary impact zone mostly will encounter short term, reversible, cumulative impacts that may or may not be exacerbated depending on the time, scale and place. This is because secondary impact zone is mostly influenced by a mixture of natural factors such as wind, waves etc and manmade factors such as Land Use Plan (LUP). In general, the secondary impact zone encompasses minor to moderate negative environmental impacts over moderately large areas.

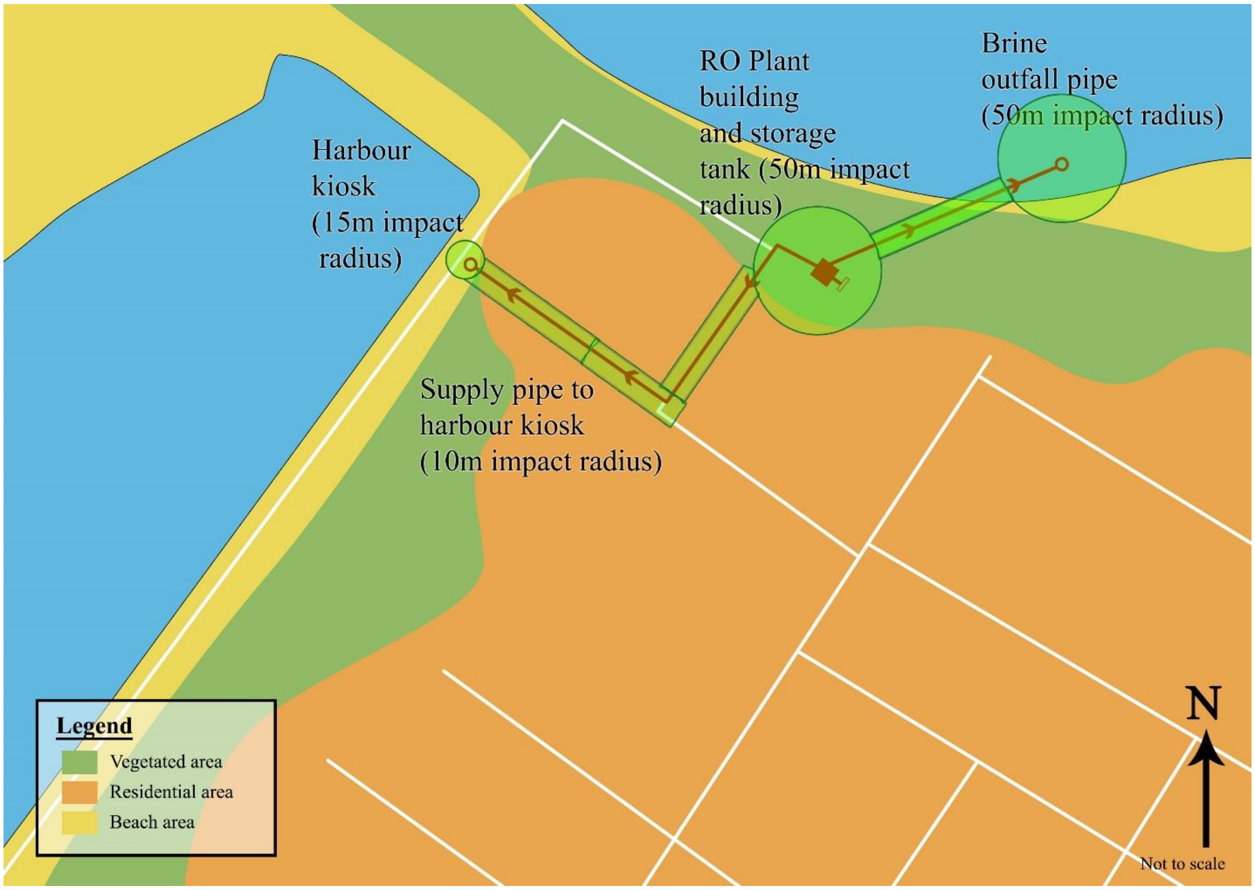


Figure 63: Area encompassing primary and secondary impact area (K. Gaafaru)

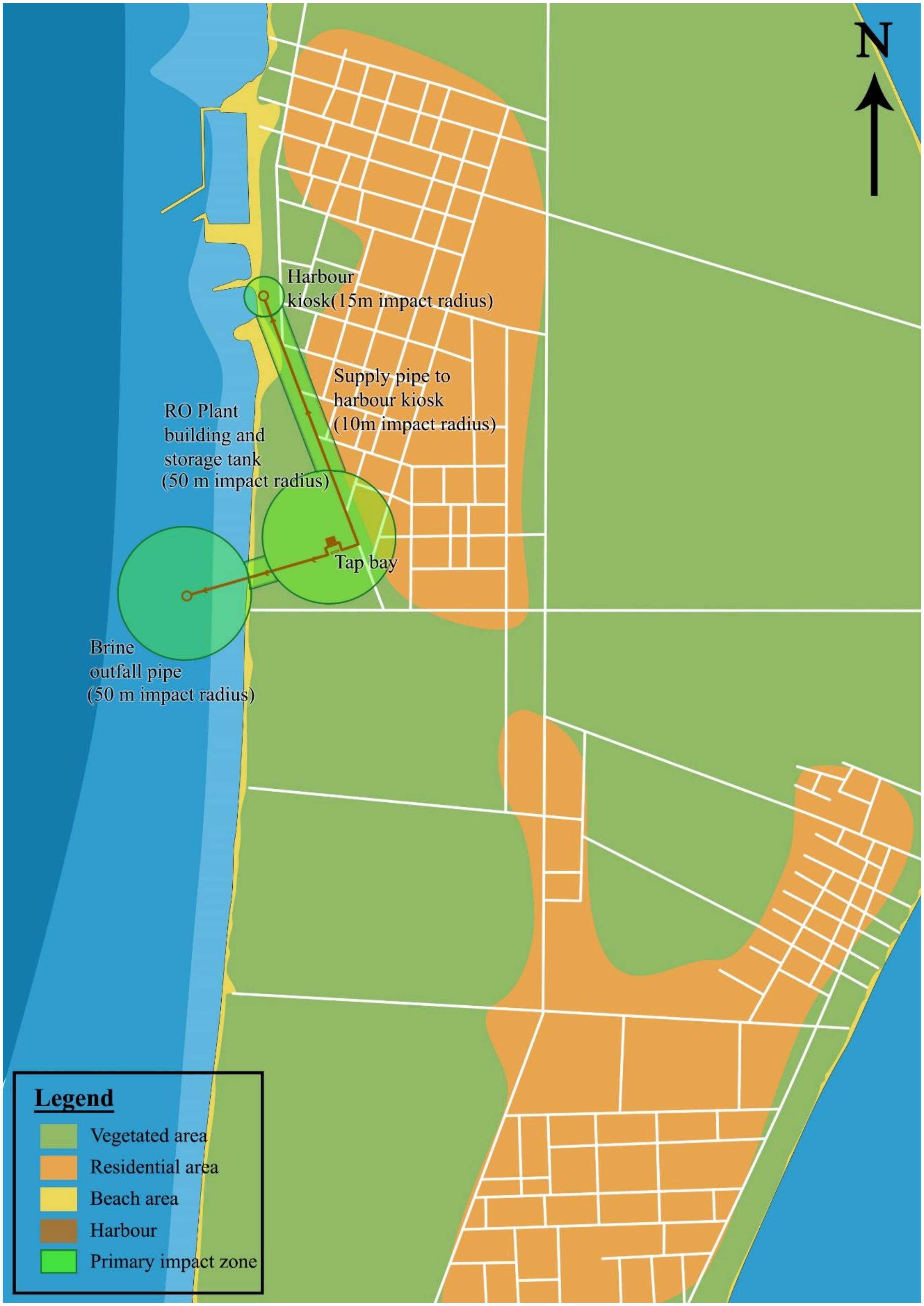


Figure 64: Area encompassing primary and secondary impact zone (L. Gan)

Figure 65: Area encompassing primary and secondary impact zone (B. Kendhoo)

3. **Tertiary Impact Zone:** The tertiary impact zone for the project is defined as areas that may or may not be effected by the proposed project activities. Tertiary impact zone will encounter minor to negligible impacts which are mostly temporary and cumulative. These impacts can be easily managed or prevented. The tertiary impact zone for the project is illustrated below and encompass large areas. The tertiary impact zone is classified based on anticipated material/waste etc transfer routes. Hence three distinct areas have been identified to have tertiary impacts as shown in **Figure 66**.

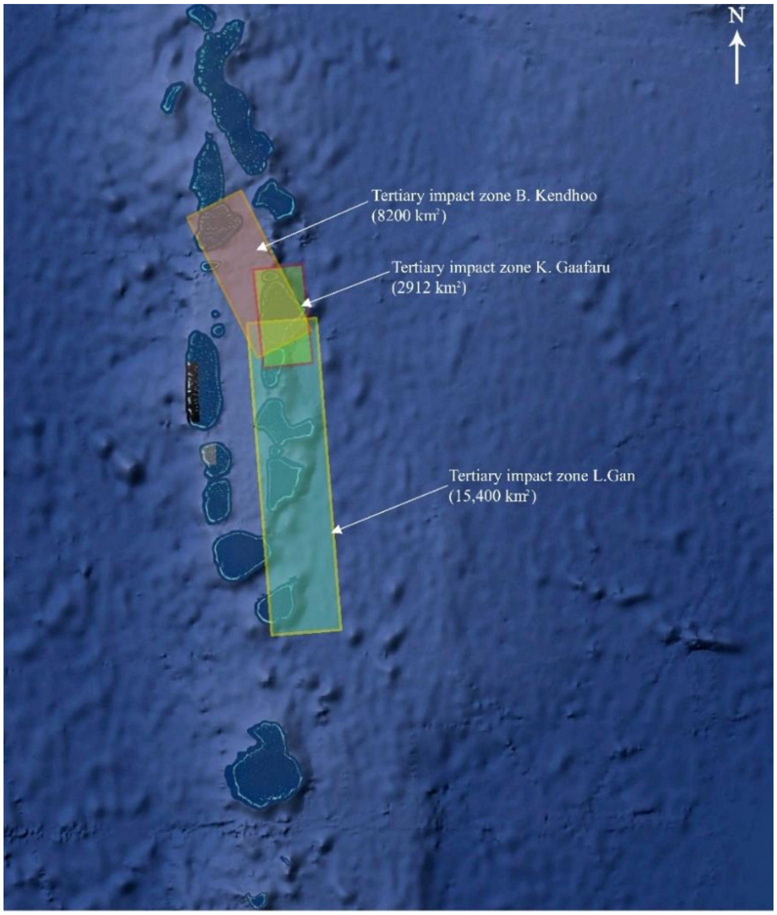


Figure 66: Tertiary impact zone

9.3 CONSTUCTION PHASE IMPACTS AND MITIGATION

In order to measure impacts during the construction phase of the project, the following major activities of the construction phase have been identified which could have potential impacts on the environmental receptors.

The main activities of construction phase are:

1. C1 – Settlement of workers
2. C2 – Site demarcation and fencing
3. C3 - Material storage
4. C4 – Land clearance
5. C5 – WSS construction
6. C6 – Transportation of material, waste and trees
7. C7 – Resource consumption (Water, Electricity and Material)

Leopold Matrix for the construction phase of the project for K. Gaafaru, L. Gan and B. Kendhoo is shown in **Table 36, Table 37 and Table 38** for K. Gaafaru, L. Gan and B. Kendhoo respectively.

Matrix analysis showed that impacts were mostly identical for all islands. This was mainly because, existing environmental conditions were similar for the three islands, and hence implementation of the identical project on all three islands yielded similar outcomes. A summary of the major activities and their associated overall impact represented by colour codes are given **Table 39.** The table also, describe the impact properties such as its duration and reversibility.

Table 36: Impact matrix for the construction phase (K.Gaafaru)

	Envisaged impact factors	C1 Settlement of Workers	C2 Site Demarcation & Fencing	C3 Material Storage	C4 Land Clearance	C5 WSS Construction	C6 Waste Transportation	C8 Resource Consumption (Water, Electricity)	Total (Impact Area)
Physical Components	Seawater	-2		-2			-4		-8
		1		2			4		7
	Ground water					-6		-5	-16
						6		5	17
	Air	-3	-2			-6	-8	-7	-26
		2	2			4	6	6	20
	Noise		-1			-9	-2		-12
			2			6	2		10
	Coastal Zone				-3	-5			-8
					3	7			10
Biological Components	Flora	-2			-3	-5			-14
		2			4	5			14
	Endangered species/protected areas								0
									0
	Coral Reef					-4	-2		-6
						4	2		6
	Fauna					-3			-3
						3			3
Socio-Cultural Component	Aesthetics	-2		-5	-2	-5			-14
		2		2	3	5			12
	Accidents	-1	-2	-5		-7	-6		-21
		1	1	5		4	5		16
	Landscape				-5	-7			-12
					5	7			12
	Health/Well being	-1	-1	-4	-3	-5	-6		-20
		1	2	1	3	3	6		16
	Cultural heritage								0
									0
	Local economy	4	1			7		2	14
		1	2			5		2	10
Total (Construction Activity/Risk)		**-7**	**-5**	**-16**	**-16**	**-55**	**-28**	**-10**	
		10	**9**	**10**	**18**	**59**	**25**	**13**	

Table 37: Impact matrix for the construction phase (L Gan)

	Envisaged impact factors	C1 Settlement of Workers	C2 Site Demarcation & Fencing	C3 Material Storage	C4 Land Clearance	C5 WSS Construction	C6 Waste Transportation	C8 Resource Consumption (Water, Electricity)	Total (Impact Area)
Physical Components	Seawater	-1		-3			-5		-9
		1		2			4		7
	Ground water					-7		-2	-14
						6		5	17
	Air	-1	-2			-5	-5	-6	-26
		2	2			4	6	6	26
	Noise		-1			-6	-4		-11
			2			6	2		10
	Coastal Zone				-3	-7			-10
					3	7			10
Biological Components	Flora	-2			-3	-6			-15
		2			4	5			14
	Endangered species/protected areas								-1
									2
	Coral Reef					-5	-1		-6
						4	2		6
	Fauna					-4			-7
						3			5
Socio-Cultural Component	Aesthetics	-2		-3	-2	-2			-13
		2		2	3	5			15
	Accidents	-1	-1	-3		-6	-4		-17
		1	1	5		4	5		21
	Landscape				-3	-6			-14
					5	7			16
	Health/Well being	-1	-1	-2	-3	-5	-4		-21
		1	2	1	3	3	6		21
	Cultural heritage								0
									0
	Local economy	3	1			8		1	15
		2	2			5		2	14
Total (Construction Activity/Risk)		**-7**	**-4**	**-11**	**-14**	**-51**	**-23**	**-7**	
		10	**9**	**10**	**18**	**59**	**25**	**13**	

Table 38: Impact matrix for the construction phase (B. Kendhoo)

	Envisaged impact factors	C1 Settlement of Workers	C2 Site Demarcation & Fencing	C3 Material Storage	C4 Land Clearance	C5 RO Plant Construction	C6 Waste Transportation	C7 Resource Consumption (Water, Electricity)	Total (Impact Area)
Physical Components	Seawater	-2		-2			-2		-6
		1		2			5		8
	Ground water					-3		-7	-15
						5		5	16
	Air	-3				-5	-3	-7	-24
		2				6	5	6	25
	Noise			3		-6	-3		-6
				3		8	3		14
	Coastal Zone				-2	-5			-9
					5	7			14
Biological Components	Flora	-2	-1		-1	-3			-8
		2	1		1	5			10
	Endangered species/protected areas								0
									0
	Coral Reef					-4	-2		-6
						6	2		8
	Fauna					-1			-3
						3			5
Socio-Cultural Component	Aesthetics	-2		-2	-2	-3	-2		-14
		2		2	3	5	3		20
	Accidents	-1		-5		-5	-6		-22
		1		5		4	5		20
	Landscape				-2	-6	-1		-14
					5	7	1		16
	Health/Well being	-1		-4	-2	-9	-7		-24
		1		1	3	3	6		19
	Cultural heritage								0
									0
	Local economy	4				7		2	17
		1				5		3	13
Total (Construction Activity/Risk)		-7	-1	-10	-9	-50	-26	-12	
		10	1	13	17	64	30	14	

Table 39: Construction phase impact summary, its properties and mitigation cost indicator.

No	Potential Risk/Impact	Receptor	Nature	Reversibility	Significance	Mitigation	Cost indication of measure
	Description	**Description**	**Positive** **Negative**	**Reversible** **Irreversible**	**Major Negative** **Moderate Negative** **Minor Negative** **Neutral** **Minor Positive** **Moderate Positive** **Major Positive**	**Description**	**USD**
C1	See **Section 9.3.1**	See **Section 9.3.1**	Negative	Reversible (Short term)		See **Section 9.3.1**	Included in construction costs
C2	See **Section 0**	See **Section 09.3.2**	Negative	Irreversible (Long term)		See **Section 0**	$ 2,000
C3	See **Section 9.3.3**	See **Section 9.3.3**	Negative	Reversible (Short term)		See **Section 9.3.3**	Included in construction costs
C4	See **Section 9.3.4**	See **Section 9.3.4**	Negative	Reversible (Long term)		See **Section 9.3.4**	$5,000 – 10,000
C5	See **Section 9.3.5**	See **Section 9.3.5**	Negative	Reversible (Long term)		See **Section 9.3.5**	Included in construction costs
C6	See **Section 9.3.6**	See **Section 9.3.6**	Negative	Reversible (Short term)		See **Section 9.3.6**	Included in construction costs
C7	**9.3.7**	**9.3.7**	Negative	Reversible (Long term)		**9.3.7**	Included in construction costs

Note:

1. *C1 – Settlement of workers*
2. *C2 – Site demarcation and fencing*
3. *C3 - Material storage*
4. *C4 – Land clearance*
5. *C5 – WSS construction*
6. *C6 – Transportation of material, waste and trees*
7. *C7 – Resource consumption*

9.3.1 C1 Settlement of Workers

Potential Impacts

The project will require a total of 10-15 workers including technical staff and laborers. Workers will be sourced by the contractor. Due to small workforce, the workers will be accommodated within existing houses. Direct impacts as a result of their settlement will not be significant. Impacts associated with worker's settlement are anticipated to be identical for all islands.

Specific Impacts and Mitigation Measures

K. Gaafaru

Overall multi criteria impact for this activity was -7, which meant that the activity would have a minor negative impact on the environmental receptors. All potential impacts can be prevented by following the general mitigation measures proposed in the report.

L. Gan

Overall multi criteria impact for this activity was -5, which meant that the activity would have a minor negative impact on the environmental receptors. Construction companies are active in the island, which provides the opportunity to subcontract parts of the work to such companies who will be using their own workforce already based on the island. Provision of subcontracts to such companies can altogether mitigate the negative impacts envisaged as well as by following the general mitigation measures proposed.

B. Kendhoo

Overall multi criteria impact for this activity was -7, which meant that the activity would have a minor negative impact on the environmental receptors. All potential impacts can be prevented by following the general mitigation measures proposed.

General Mitigation Measures

i. Workers rules must be in place before the work begins;
ii. avoid construction of new buildings/structures, make use of the existing facilities on the island;
iii. provide medical assistance and relevant PPG to workers;
iv. hire locals for the workforce as much as possible;
v. recruit skilled and experienced workers as much as possible;
vi. give proper instruction for environmental safeguards before work is commenced;
vii. awareness signs shall be placed on the site to display "do's" and "dont's" with respect to protecting the environment;
viii. expatriate workers shall be briefed with regard to local customs and culture if they are new to the island;
ix. catching, killing, keeping or disturbing birds and other animals will be prohibited at the project site;
x. waste generated by workers shall be managed as per **Section 2.9**;
xi. orient foreign workers on how to communicate with locals and personal hygiene and sanitation and prevention of sexually transmitted diseases and other infectious diseases; and

a) ensure proper documentation for foreign labourers to avoid use of illegal expatriates for the Project.

9.3.2 C2 Site Demarcation & Fencing

Specific Impacts and Mitigation Measures

K. Gaafaru

Overall multi criteria impact for this activity was -3, which meant that the activity would have a minor to negligible negative impact on the environmental receptors. The site has been surveyed and there are no trees within the plot that requires removal. A screwpine tree may have to be removed to accommodate the outfall pipe. All potential impacts can be prevented by following the general mitigation measures proposed.

L. Gan

Overall multi criteria impact for this activity was -4, which meant that the activity would have a minor negative impact on the environmental receptors. There is no vegetation present in the RO plant site allocated. A coconut palm tree may have to be removed to accommodate the outfall pipe although this can be avoided with precise planning on the contractor's part in laying the outfall pipe. Underbrush and coastal vegetation requires removal, as the road where the outfall pipe is proposed to be laid is not cleared west of the power plant. All potential impacts can be prevented by following the general mitigation measures proposed.

B. Kendhoo

Overall multi criteria impact for this activity was -1. No large trees were identified to require removal at the site. However, some small shrubs and undergrowth way have to be removed from the proposed outfall location. All potential impacts can be prevented by following the general mitigation measures proposed.

General Mitigation Measures

a) Ensure that the surveyors and helpers engaged in site demarcation properly understand the scope of works and recommendations of this report;
b) Involve island council representatives in the site demarcation to avoid any future issues;
c) qualified surveyors shall be engaged in site demarcation;
d) accurate and reliable equipment shall be used to minimize errors;
e) ensuring proper labelling of site boundary**;**
f) wearing, clothes/helmets to protect against thorns/mosquitoes and wearing protective clothing;
g) carrying out the works during the day time; and
h) ensure mosquito repellants are available for the workers.

9.3.3 C3 Material Storage

Potential Impacts

Material storage includes, storing all the vehicles, machineries, and tools required for construction of the RO plant. Since RO plant construction work do not require a lot of material, hence they can be effectively stored within the project area.

However potential impacts due to material storage include a risk of accidents, such as fires, oil spills, and trespassing. Improper storage of materials may result in loss of material and its quality due to rusting or theft. Improper storage of fuel may cause spills which may pollute groundwater and surrounding terrestrial environment through leaching.

Specific Impacts and Mitigation Measures

K. Gaafaru

Overall multi criteria impact for this activity was -16, which meant that the activity would have a minor negative impact on the environmental receptors. Potential impacts can be mitigated by following the general mitigation measures.

L. Gan

Overall multi criteria impact for this activity was -11, which meant that the activity would have a minor negative impact on the environmental receptors. All potential impacts can be prevented by following the general mitigation measures proposed.

B. Kendhoo

Overall multi criteria impact for this activity was -10, which meant that the activity would have a minor negative impact on the environmental receptors. All potential impacts can be prevented by following the general mitigation measures proposed in the report. However, it has to be noted that, there are households close to the project site hence all materials as well as waste shall be secured within the limits of the plot.

General Mitigation Measures

i. Equipment and vehicle shall be stored in fenced site area and maintained appropriately during the cause of the project and no new such facilities shall be developed for the purpose of the project;
ii. materials shall be covered from rain and direct sunlight;
iii. fuel shall be stored in an even paved area and shall be secured enough to prevent spillage. It shall also be covered to prevent contamination;
iv. portable extinguishers shall be made available at construction site in case of an accident;
v. a security guard shall be present at the site during non-work hours;
vi. The council shall be notified with regard materials and equipment stored, and clear sign posts shall be installed notifying the public;

9.3.4 C4 Land Clearance

Potential Impacts

The project will not result in a loss of protected species or have an effect on threatened or rare plant species. There are no significantly large trees intersecting the proposed site. Moreover, the direct footprint area of the project is small in scale. Due to the small size and absence of large trees present at the project area, the net loss of carbon balance as a result of land clearance is considered to be minor. There are no privately owned trees including coconut palms at the project area hence social impacts arising from land clearance will be prevented.

The extent of land clearance is limited only to removal of underbrush. Hence impacts associated with removal of trees are prevented.

Specific Impacts and Mitigation Measures

K. Gaafaru

Overall multi criteria impact for this activity was -16, which meant that the activity would have a minor negative impact on the environmental receptors. There are no trees to be removed from the project site. However, underbrush and screw pine trees may have to be removed from the vegetation belt to install the outfall pipe at the proposed location. However, these impacts can be completely avoided by selecting the alternative outfall site as detailed in **Section 8.1**. The impacts arising from land clearance on the vegetation belt can be effectively prevented by following general mitigation measures proposed.

L. Gan

Overall multi criteria impact for this activity was -14, which meant that the activity would have a minor negative impact on the environmental receptors. No land clearance is required for the proposed site, although vegetation is present in a portion of the road where the outfall pipe is proposed to be laid. A coconut palm and underbrush in addition to coastal vegetation such as screw pine may have to be removed. The removal of the coconut palm can be avoided with prior planning on placement of the pipe at an offset to the tree, while still maintaining inside the extents of the road. The impacts arising from clearing the vegetation belt can be prevented by following the general mitigation measures proposed in the report.

B. Kendhoo

Overall multi criteria impact for this activity was -9. The site has already been cleared of vegetation only some shrubs were present at the proposed outfall location. The site is very close to the nearest residential zone. All potential impacts can be prevented by following the general mitigation measures proposed in the report.

General Mitigation Measures:

Measures to Minimise Accidents and Injuries to Workers

i. Work shall be carried out only during fair weather. Work shall be terminated and employees moved to safety when environmental conditions such as but not limited to high winds, heavy rain, and flooding that may endanger employees in the performance of their jobs;

ii. hard hats, eye protection, hearing protection, and foot protection shall be used by the workers during work times. Equipment operators should wear seat belts. Wear high visibility clothing as well;
iii. work shall be supervised properly;
iv. work shall be completed within the shortest time frame possible;
v. all pollution control and safety measures proposed in **Section 2.6.16** shall be followed and
vi. site clearance waste shall be managed as per **Section 2.9**.

9.3.5 C5 WSS Construction

Potential Impacts

The inputs of the project elaborated in **Section 2** show the amount of resources that will be used for the project. The use of resources for the project can have indirect impacts of GHG emissions from the production process. The main materials used in this project include concrete, reinforcing steel, structural steel, in addition to PVC pipes. (Defra/DECC, 2012) states that for every tonne of concrete casted, 135 kg of indirect CO_2 emissions result. Therefore, for this project, an estimated 29,000 kg of CO_2 emissions are expected for the concrete casted at the three islands.

Due to the small scale of the construction, the estimated indirect CO_2 emissions from other material usage are moderate for this project. Concrete mixed during the construction phase will cause release of dust particles.

The use of heavy vehicles on unpaved roads can cause compaction of the soil by the force applied by the tires of the vehicles. Heavy vehicles will be used during transport of materials and earth works. Other impacts on roads due to transportation include the generation of dust during transportation. These will be minor as not a lot of land transportation is required during construction.

Dewatering, excavation works and installation of outfall pipes will result in notable impacts. For instance:

- Dewatering and excavation can cause ground settlements A significant settlement is not anticipated as a result of dewatering at the project site since dewatering is limited to the borehole;
- When groundwater is pumped from well, hydraulic gradients are generated, which draws the groundwater toward the well. If dewatering is carried out on or near a site which has a historic legacy of groundwater pollution, then these hydraulic gradients may cause the existing contamination to move and migrate toward the dewatering system. This impact is applicable in the current case as dewatering from borehole can result in loss of groundwater with the possibility of causing increased salinization of groundwater lens.

It is important to identify the sources of noise and vibrations and the intensity of such impacts on the project island. Noise impacts are expected to be minor during construction phase for L. Gan as construction activities will take place away from public areas. However, in K. Gaafaru and B. Kendhoo noise will have impacts on public areas as such areas are very close to the site. See **Annex 6** for details.

The main source of noise from the construction phase of the project will be from the engines used in the machinery and vehicles. No high impact works such as pile driving or demolishing structures are part of the proposed construction. Typical noise level of construction equipment is detailed below:

Table 40: Typical construction equipment and their noise levels 50ft from the source

Equipment	**Typical Noise Level (dBA) 50ft from source**
Concrete mixer	85
Concrete pump	82
Concrete vibrator	76
Pump	76
Saw	76
Shovel	82
Tie Cutter	84
Truck	88

Assuming the highest noise produced during construction is at 85 dBA, a noise decay calculation was done using initial assumptions without factoring for dampening effects due to obstacles and vegetation. From the initial calculations, the noise levels are projected to decrease at a rate of 0.1 $dBAm^{-1}$ down to 61 dBA. This means that a continuous noise source producing 85 dBA will be at:

- 80 dBA at the at the public school in K. Gaafaru
- 64 dBA at the residential area in L. Gan
- 83 dBA at the residential area in B. Kendhoo

These levels are further expected to decrease taking into consideration the vegetation surrounding the proposed site, as well as the soil characteristics of the ground. Moreover, it is unlikely that a noise level of 85dBA will be maintained continuously for more than 30 minutes during construction phase of the project.

One of the main components of the construction phase involves borehole drilling which can accompany related impacts. Initially as drilling progresses toward the groundwater table the groundwater will be suppressed as a result of the downward pressure being excreted by the drilling. The process may cause localised salinization of groundwater film. During the process, sealants used for the borehole may seep into groundwater film. There is a risk of waste and other pollutants falling into the borehole. Drilling activities will have an immediate impact on ground dwelling and burrowing species at the site. Moreover, drill waste and slurry will be a significant waste output of construction phase that will act as an environmental pollutant. Moreover, if the borehole is not drilled to a sufficient depth, risk of groundwater lens depletion is extremely high as a result of feed water intake, which could make the ground water lens of the whole island saline.

Trenching works to lay water pipes to harbour and electricity pipes will have various impacts on the roads and existing cables. However, since house connections are not part of the project, trenching impacts are considered to be moderate. Similarly, outfall pipe works could have impacts on the marine environment. Sedimentation and damage to corals are likely during the construction works. Marine impacts are anticipated to increase based on the condition of where outfall pipe is proposed. In all islands outfall area is not observed to have high coral cover. However in B. Kendhoo, the pipe will be installed under slightly rough conditions which could increase impacts on marine environment.

Similar to all construction projects, the proposed project will result in visual impacts, considering that some islands such as K. Gaafaru is visited by tourists and the project site is close to a tourist beach area.

Waste generated during the construction phase will also have significant impacts on the islands environment. The most significant form of waste produced during construction phase will be non-biodegradable packaging waste. Concrete, wood and steel will be generated as waste in minor quantities.

Municipal wastes are also expected to be generated during the construction phase by the workers will be minor.

Vehicle maintenance and temporary generator usage will likely be the primary source of chemical wastes during the construction period. The majority of chemical waste produced is therefore expected to consist of waste oils and solvents in small quantities.

Yard waste will also be a component of construction waste generated. Waste burned onsite would generate smoke, possibly impacting negatively on ambient air quality and human health. Chemical waste could have detrimental effects on health and wellbeing of people. Some of the chemical wastes may be bio hazards and may have the potential for bio accumulation. Chemical wastes may be easily flammable which could cause accidents.

Another area that will be effected during the construction of WSS is health and wellbeing of worker mainly in the form of accidents and injuries. There could be many risks (hazards) and accidents to consider associated with many possible scenarios that could unfold depending on time, magnitude and the location it occurs

<u>Hazards during construction</u>

- Inhalation of cement during the site cast and pre-casting of concrete: inhaling high levels of cement dust during construction can be irritating to the nose and throat. Prolonged exposure to cement dust can result in silicosis (CSAO, 2001);
- contact with concrete mix: concrete has caustic, abrasive and drying properties and prolonged contact with concrete allows the alkaline compounds such as calcium oxide to burn the skin. Wet concrete trapped against the skin can cause first, second, or third degree burns;
- falling of heavy objects: constructions sites are prone to falling of heavy objects which can be fatal to workers;
- falls: workers may be under the risk of falling into open trenches and seriously injuring themselves;
- being struck by moving equipment and vehicles; and

Specific Impacts and Mitigation

K. Gaafaru

Overall multi criteria impact for this activity was -55, which meant that the activity would have a major negative impact on the environmental receptors. The impacts arising from WSS construction can be effectively prevented by following general mitigation measures proposed below. The negative impacts arising are short term and reversible impacts.

L. Gan

Overall multi criteria impact for this activity was -51, which meant that the activity would have a major negative impact on the environmental receptors. The impacts arising from WSS construction can be effectively prevented by following general mitigation measures proposed below. The negative impacts arising are short term and reversible impacts. In L.Gan it is recommended to undertake outfall works during the northeast monsoon when conditions are more favourable to mitigate impacts arising from outfall installation.

B. Kendhoo

Overall multi criteria impact for this activity was -50, which meant that the activity would have a moderate negative impact on the environmental receptors. Most notably since the site is located very close to the residential zone in Kendhoo and extensive ground work is required to lay water supply pipe to the harbour kiosk and supply power to the RO plant. Hence, special attention shall be given to monitor and manage the noise pollution during construction phase. In B. Kendhoo it is recommended to undertake outfall works during the northeast monsoon when conditions are more favourable to mitigate impacts arising from outfall installation.

General Mitigation Measures:

Measures to minimise road impacts

- The contractor shall only bring in the necessary number of vehicles and plant to the island for the project. Oversized heavy vehicles which are not required for this project, shall not be used in the island for transportation and construction purposes;
- it shall be stated in the contract that any damages to the roads from transportation of construction materials and machinery shall be assessed after the civil works are completed, and the damages shall be repaired by the contractor.
- use the direct route of the main road from the harbour area to the site;
- avoid use of heavy vehicles during rough weather;
- vehicle speed shall be within legal limits to avoid accidents and dust emissions;
- cover the materials being transported to and from the site; and
- spray water on the road surface during dry periods to suppress dust.

Measures to Minimise Noise Impacts

- Provide workers with noise cancelling headphones;
- sensitive hours are taken as prayer times and between 10pm and 6am except Fridays and on Fridays between 10 am and 2 pm in the context of the Maldives. Work shall be halted during these time;
- use quieted equipment where possible, such as mufflers on engines;

- use of well serviced vehicles and plant; and
- switching off equipment and vehicles when not in use.

Measures to Minimise Accidents and Injuries

- The contractor shall be required to develop occupational safety management plan, and safety guidelines shall be displayed in the work site at all times;
- all pollution control and safety measures proposed in **Section 2.6.16** shall be followed;
- occupational safety training should be given to all workers present on site;
- workers should be provided Personal Protective Equipment (PPE) and the use of PPE shall be enforced;
- site visitors shall be accompanied at all times and required PPE shall be provided;
- provide first aid box shall be available at the site;
- proper signage and fencing should be provided around the site;
- carry out works during good weather;
- well trained personnel to use machinery and vehicles;
- avoid transportation during night and maintain legal speed limits at all times; and
- securing any loads on vehicles during transportation.

Measures to Minimise Borehole Impacts

- Borehole area shall be cleaned and maintained;
- groundwater shall be tested routinely during borehole construction. Water quality of surrounding houses within a set boundary shall be tested for salinization during borehole process. Any complaints with regard to groundwater availability shall be compensated by the contractor after appropriate testing. Arrangements shall be in place to provide freshwater to affected households;
- method described in **Section 2.6.8** shall be applied or adapted for the construction of borehole and testing of borehole water samples shall be carried out as proposed;
- borehole depth shall not be less than 30 m and the conductivity of feed water shall be 50,000 µS/cm;
- feed water quality of borehole and its depth shall be shared with EPA for validation;
- feed water quality shall be determined from a standardised laboratory;
- groundwater quality from a station/well within 30 m shall be monitored during borehole process;
- permit to dewater shall be obtained prior to dewatering process;
- all pollution control and safety measures proposed in **Section 2.6.16** shall be followed;
- quantity of pumped water shall be documented daily and maintained;
- the dewatering pump used should comply with the standards of the EPA. Compliance to the standard will avoid removal of fine sand particles from the ground that can exacerbate ground settlement. It can also prevent the formation of sediment plume;
- geotextile materials shall be installed to control mud or silt at the water outlet;
- borehole shall be constructed as stipulated in relevant regulations proposed in the report and
- slurry and sludge waste shall be stored and managed as described in the report (See **Section 2.9**).

Measures to Minimise Trenching and Pipe Laying Impacts

- Any trenches dug during the construction phase should be kept water free. Pipe shall be laid above the groundwater table to prevent contamination of groundwater to avoid dewatering;
- discuss with utility service providers to obtain accurate information on underground cable networks, piping etc to ensuring that there are no underground pipes or cables in excavation;
- zone alternative arrangements shall be in place to avoid service disruptions in such cases;
- Supply cables shall be buried on roads and land that have already been cleared to avoid cutting down trees;
- ensure that trenches are backfilled, levelled and well compacted. Implement method proposed in **Section 2.6.10;**
- Pipes and cables shall be buried in accordance with best practice. Water pipes shall not be lain next to sewerage pipes in order to prevent contamination and
- It should be considered that there might be previously buried utility cables underground and care should be taken not to damage these during the construction phase. Furthermore, it should be pointed out that the cables buried for this project could potentially be damaged in the future dude to environmental disasters, failure of equipment or third-party damage.

Measures to Minimise Brine Discharge Pipe Laying Impacts

- Silt screens shall be installed to prevent sedimentations;
- areas identified to have high live coral cover shall be avoided. Preferred outfall locations proposed in the EIA shall be selected (See **Section 8.1 and Annex 6**); and
- pipes shall be adequately protected to avoid it from breaking and malfunctioning.

Measures to Minimise Waste Pollution

- Ensure to manage waste as described in **Section 2.9** of the EIA report; and
- all pollution control and safety measures proposed in **Section 2.6.16** shall be followed.

9.3.6 C6 Transportation of Waste/ Materials

Potential Impacts

The project involves land and sea transportation. Most significant of these will be materials transportation to the island at the start and transport of waste out of the island and the final transportation of vehicles and equipment during the decommissioning phase. All these transportations will be undertaken on sea. Notable land transportation includes, transport of equipment and materials to project site. Since the project is localised to a relatively small area transportation within land is minor compared to sea transportation hence potential impacts arising from transportation activity include:

Long haulage of waste/materials would result in burning of fuel that would emit greenhouse gases in addition to extensive costs. Navigation risks such as rough weather are common occurrence during sea transportation. There is a risk of accidents such as beaching on shallow reefs due to incorrect navigation and malfunction of navigation equipment and vessels machinery. There is risk of fire and oil spills during sea transportation. Noise pollution, especially to the marine environment by engines and propellers are significant to some of the mammals and marine species.

Pollution of marine environment by the crew of vessels have been recorded previously. Plastics thrown into the sea is not only a local issue but a worldwide epidemic. On occasion cases of food shortages and lack of first aid measures on vessels have led to tragic outcomes.

The project will not be using heavy vehicles frequently on dirt roads largely preventing damage to roads in the form of depressions which are prone to retain water puddles. Heavy vehicles also can damage property and infrastructure. They may be a danger to children and civilians.

Hence careful planning and adopting to the proposed waste management strategies will have to be taken into consideration to minimize environmental and economic impacts associated with site preparations.

This activity will generate noise and constitute to air pollution, it has the potential to damage flora and fauna outside the project direct footprint area. Accident such as spills and fires could exacerbate the impacts. Although extent of direct impacts is low, likelihood of accident are high for this activity. Hence it has been classified as having a moderate negative impact.

Specific Impacts and Mitigation Measures

K. Gaafaru

Overall multi criteria impact for this activity was -28, which meant that the activity would have a moderate negative impact on the environmental receptors. There are no trees to be removed from the project site, hence transportation of trees will not be involved. However, material will be transported to and from site at the start and during decommissioning phase. Since there is no land clearance involved waste generated during construction phase will be greatly reduced. Construction waste as specified in **Section 2.9** of the report will have to be transported to the nearest waste management center at Thilafushi. Waste transportation and decommissioning trip is planned to be merged so that total distance travelled will be reduced significantly. Due to the project locations close proximity to the harbour only few land transportation trips are envisaged which would have fewer impacts. All potential impacts can be prevented by following the general mitigation measures proposed.

L. Gan

Overall multi criteria impact for this activity was -23, which meant that the activity would have a moderate negative impact on the environmental receptors. There are no trees to be removed from the RO Plant site, although vegetation may need to be removed to lay the outfall pipe, which would result in yard waste. Construction waste generated during the construction works shall be collected and stockpiled inside the site boundaries prior to being transported. Waste transportation and decommissioning trip shall be merged so that total distance travelled will be reduced significantly. All potential impacts can be prevented by following the general mitigation measures proposed.

B. Kendhoo

Overall multi criteria impact for this activity was -26, which meant that the activity would have a moderate negative impact on the environmental receptors. There are no trees to be removed from the project site, hence transportation of trees will not be involved. However, material will be transported to and from site at the start and during decommissioning phase. Since there is no land clearance involved waste generated during construction phase will be greatly reduced. Waste would have to be transported to the islands waste management area via an existing road north of the site that provides a direct transport route where it shall be stored until it is transported out of the country to nearest waste management facility. Furthermore, since the powerhouse at B. Kendhoo is located approximately 325 m from the proposed site, any waste generated during construction of power lines to supply power to the RO plant will have to be transported to the islands waste management area. This increases the impact area of the project and adds to the amount of waste expected to be produced.

Since waste is not properly managed at B. Kendhoo and they lack the resources to properly manage the waste produced, it shall only be stored at the waste dumpsite and all construction waste shall be transported to nearest waste management centre at Vandhoo. Waste transportation and decommissioning trip is planned to be merged so that total distance travelled will be reduced significantly. All potential impacts can be prevented by following the general mitigation measures proposed.

General Mitigation Measures

Measures to Minimize Waste Needing Transportation

i. Waste shall be managed as described in **Section 2.9.** By following the waste management plan proposed in the report all yard waste can be managed at the island itself;
ii. replant as many trees as possible; and
iii. advertise as widely as possible to encourage buyers who may relocate trees.

Measures to Avoid Accidents and Injuries

i. Avoid land transport of materials during night time;
ii. vehicles and vessels shall be operated by competent and qualified personnel;
iii. travel paths shall be predetermined and inspected beforehand;
iv. all vehicles and vessels shall be inspected prior to commencing the journey;
v. all vessels and vehicles shall have firefighting and first aid equipment as specified by the transport ministry of the Maldives;
vi. all sea transportation shall be undertaken with adequate supplies and supplies shall be procured based on contingency planning;
vii. travel routes shall be clear of public area on land and areas identified to harbour significant marine life;
viii. oil spill containment equipment shall be installed in vessels and vehicles;
ix. Safety measures proposed in **Section 2.8** of the report shall be followed and applied;
x. materials shall not be transported during bad weather conditions. Ensure to get clearance from Maldives Meteorological Centre; and
xi. marine vessels used for transport of waste shall have seaworthiness certificates and experienced crew.

Measures to minimise climate impacts

i. It is recommended to consider sourcing material from the closest point to project site;
ii. the materials shall be bought in bulk and transported to the island within a single trip where possible;
iii. detailed BOQ has been produced by the proponent, which shall be followed by the contractor when purchasing materials in order to reduce wastage of materials as well as the number of trips;
iv. the materials shall be stored on the project site to eliminate transportation of vehicles within the island throughout the construction phase;
v. idle time of the vehicles shall be avoided in order to reduce emissions;
vi. the contractor shall use serviced vehicles and plant equipment for the project;
vii. the contractor shall only use the needed amount of vehicles and plant for project; and
viii. the vehicle used for the purpose should comply with the roadworthiness requirements of the Transport authority and display the compliance stickers.

9.3.7 C7 Resource Consumption

During the construction phase, construction materials, RO plant, water, electricity will be required as explained in **Section 2**. Almost all of these resources will be sourced from outside the island. Resource use itself is environmentally impactful although resource consumption cannot be avoided for the completion of the project. Given the small scale of the project relatively small volumes of resources will be required and hence associated impacts are not expected to be major. Of the resources required only water will be used from the island as it is found to be suitable for construction activity use (See **Table 18**); and electricity will be generated on site using a small genset. Water use from the island's aquifer will have a negative impact although it will be short term and reversible. Notable impacts of electricity generation include, generation of waste oil, increased air pollution, risk of spillage, impacts to health/wellbeing and accidents.

The primary pollutants generated due to power production from diesel based generator system include Nitrogen oxides (NO_X), Sulphur dioxide (SO_2), Carbon monoxide (CO), Hydrocarbons/ Polycyclic Aromatic Hydrocarbons (HC/PAH), Particles (PA) and Carbon dioxide (CO_2) in the form of emission although the exact amount is difficult to quantify.

The visible pollution generated by burning diesel contains elemental carbon as soot. The typical odour comes from polycyclic aromatic hydrocarbons, which also are cancer causing components. **Table 41** shows NO_x and particles emission of burning a cubic meter of diesel by a generator.

Table 41: Emission from a typical diesel generator

Pollutant	**Diesel generator mg/m^3**
NO_x	4000
Particles	100

The emission of nitrogen oxides is a serious problem and is often overseen. Nitrogen oxides are as seen in **Table 41** responsible for a number of negative impacts on the environment. People living close to a generator will be affected by an elevated concentration of nitrogen oxides.

Water used during construction will be sourced from groundwater well-constructed at the project site. Water used for drinking and cooking will be purchased from local shops or collected from existing rainwater tanks or from the groundwater well in the island. If heavily relied on the islands water resources, there is a possibility of islands freshwater stock depleting. Water and electricity consumption for the project is considered to be minor.

Specific Impacts and Mitigation Measures

K. Gaafaru

Overall multi criteria impact for this activity was -10, which meant that the activity would have a minor negative impact on the environmental receptors. This is mainly because, water used for borehole drilling is re-used as described in **Section 2.6**. Water and electricity used for concrete works will be moderate (See **Table 8** for estimation) and water for labour consumption will be minor.

L. Gan

Overall multi criteria impact for this activity was -7, which meant that the activity would have a minor negative impact on the environmental receptors. The resource consumption envisaged for this project small due to the comparatively small scale of the project. Water used to mix the drill slurry will be reused. The size of the workforce is approximately 15 and therefore water consumption will be minor. All potential impacts can be prevented by following the general mitigation measures proposed.

B. Kendhoo

Overall multi criteria impact for this activity was -12, which meant that the activity would have a minor negative impact on the environmental receptors. All potential impacts can be prevented by following the general mitigation measures proposed.

General Mitigation Measures

i. All materials shall be bought from nearest source and shall be brought to islands in bulk to minimize transport impacts;
ii. Proper BoQ shall be made for each island separately;
iii. material use shall be carefully controlled to avoid wastage to minimise resource use as well as waste generated;
iv. Sand shall not be mined from island's beaches as it is banned and if coral sand is to be used it permit to mine sand shall be obtained; and
v. Energy and water conservation measures shall be in place and workers shall be educated on good practices
    a. use well maintained, energy efficient equipment. Energy efficiency measures are of high importance for generators that operate for 24 hrs of each day both with regard to economy and the release of CO_2 and other pollutants. The emission of carbon dioxide is directly related to the amount of fuel used. High efficiency is therefore important to reduce the amount of released carbon dioxide and consequently to reduce the global greenhouse effect;
    b. reduce idle time of machineries and vehicles. Switch them off after use;
    c. utilize day time hours for the construction when plenty of light is available, and
    d. where possible obtain electricity from island grid during construction to prevent handling of fuel and genset.

9.4 OPERATIONAL PHASE IMPACTS AND MITIGATION

In order to measure impacts during the operational phase of the project, the following major activities of the operational phase have been identified.

The main activities of operational phase are:

1. O1 – Water Production
2. O2 – Water disinfecting and testing
3. O3 – Brine Discharge
4. O4 – Communal Water Supply
5. O5 – Commercial Water Supply
6. O6 – Resource Consumption (Water/Electricity)

Leopold Matrix for the operational phase of the project at K. Gaafaru, L. Gan and B. Kendhoo is shown in **Table 42 Table 43** and **Table 44** for K. Gaafaru, L. Gan and B. Kendhoo respectively.

Matrix analysis showed that impacts were mostly identical for all islands. A summary of the major activities and their associated overall impact and its properties represented by colour codes are given **Table 45.**

Table 42: General operational phase impact matrix (K.Gaafaru)

	Envisaged impact factors	**O1 Water Production**	**O2 Water disinfection and testing**	**O3 Brine Discharge**	**O4 Communal Water Supply**	**O5 Commercial Water Supply**	**O6 Resource Consumption (Water/Electricity)**	**Total (Impact Area)**
Physical Components	Seawater			-7				-7
				6				6
	Ground water	-2						-2
		2						2
	Air	-6		-2	-4		-8	-20
		5		2	4		8	19
	Noise	-6						-6
		5						5
	Coastal Zone							-4
								7
Biological Components	Flora							-2
								4
	Endangered species/protected areas			-1				-1
				1				1
	Coral Reef			-7				-7
				6				6
	Fauna			-1				-1
				1				1
Socio-Cultural Component	Aesthetics							0
								0
	Accidents	-9	-3				-7	-23
		8	4				6	23
	Landscape	-4		-1				-5
		4		2				6
	Health/Well being	-6	9	-2	9		-6	-1
		6	8	2	8		5	35
	Cultural heritage							0
								0
	Local economy	3	2	-2		8		11
		5	4	4		8		21
Total (operational Phase Activity/Risk)		**-30**	**8**	**-23**	**5**	**8**	**-21**	
		25	**16**	**23**	**12**	**8**	**19**	

Table 43: Operational phase impact matrix (L Gan)

	Envisaged impact factors	O1 Water Production	O2 Water disinfection and testing	O3 Brine Discharge	O4 Communal Water Supply	O5 Commercial Water Supply	O6 Resource Consumption (Water/Electricity)	Total (Impact Area)
Physical Components	Seawater			-8				-8
				6				6
	Ground water	-2						-2
		2						2
	Air	-6		-3	-4		-9	-22
		5		2	4		8	19
	Noise	-7						-7
		5						5
	Coastal Zone							-5
								7
Biological Components	Flora							-3
								4
	Endangered species/protected areas			-1				-1
				1				1
	Coral Reef			-4				-4
				4				4
	Fauna			-3				-3
				3				3
Socio-Cultural Component	Aesthetics							0
								0
	Accidents	-9	-4				-6	-23
		8	4				6	23
	Landscape	-3		-2				-5
		4		2				6
	Health/Well being	-4	10	-2	9		-5	5
		6	8	2	8		5	29
	Cultural heritage							0
								0
	Local economy	4	3	-2		9		14
		5	4	4		8		21
Total (operational Phase Activity/Risk)		**-27**	**9**	**-25**	**5**	**9**	**-20**	-64
		29	**16**	**24**	**12**	**8**	**19**	130

Table 44: General operational phase matrix (B.Kendhoo)

	Envisaged impact factors	O1 Water Production	O2 Water disinfection and testing	O3 Brine Discharge	O4 Communal Water Supply	O5 Commercial Water Supply	O6 Resource Consumption (Water/Electricity)	Total (Impact Area)
Physical Components	Seawater			-7				-7
				6				6
	Ground water	-2						-2
		2						2
	Air	-6		-2	-4		-8	-20
		5		2	4		8	19
	Noise	-9						-9
		6						6
	Coastal Zone							-4
								7
Biological Components	Flora							-1
								3
	Endangered species/protected areas			-3				-3
				3				3
	Coral Reef			-7				-7
				6				6
	Fauna			-3				-3
				5				5
Socio-Cultural Component	Aesthetics	-3						-6
		3						7
	Accidents	-3	-3				-7	-17
		6	4				6	21
	Landscape	-3		-1				-4
		4		2				6
	Health/Well being	-6	9	-2	9		-6	-1
		6	8	2	8		5	35
	Cultural heritage							0
								0
	Local economy	3	2	-2		8		11
		5	4	4		8		21
Total (operational Phase Activity/Risk)		-29	8	-27	5	8	-21	
		37	16	27	12	8	19	

Table 45: Operational phase impact summary, its properties and mitigation cost indicator.

No	Potential Risk/Impact	Receptor	Nature	Reversibility	Significance	Mitigation	Cost indication of measure
	Description	**Description**	**Positive**	**Reversible**	**Major Negative**	**Description**	**USD**
					Moderate Negative		
					Minor Negative		
					Neutral		
			Negative		**Minor Positive**		
					Moderate Positive		
				Irreversible	**Major Positive**		
O1	See **Section 9.4.1**	See **Section 9.4.1**	Negative	Reversible (Long term)		See **Section 9.4.1**	Included in operational costs
O2	See **Section 9.4.2**	See **Section 9.4.2**	Positive	Reversible (Short term)		See **Section 9.4.2**	$ 2,000
O3	See **Section 9.4.3**	See **Section 9.4.3**	Negative	Reversible (Long term)		See **Section 9.4.3**	See **Table 50** for monitoring costs
O4	See **Section 9.4.4**	See **Section 9.4.4**	Negative	Reversible (Long term)		See **Section 9.4.4**	Included in project construction and operational cost
O5	See **Section 9.4.4**	See **Section 9.4.4**	Positive	Reversible (Long term)		See **Section 9.4.4**	Included in project operational cost
O6	See **Section 9.4.6**	See **Section 9.4.6**	Negative	Reversible (Long term)		See **Section 9.4.6**	Included in project operational cost.

Note:

1. O1 - Water Production
2. O2 – Water disinfecting and testing
3. O3 – Brine Discharge
4. O4 – Communal Water Supply
5. O5 – Commercial Water Supply
6. O6 – Resource Consumption (Water/Electricity)

9.4.1 O1 Water Production

Potential Impacts

As described in **Section 2.7**, RO plant water production involves extensive energy consumption. The project also involves use of pumps that will generate noise. A total of seven pumps have been proposed to be used for the proposed WSS. The noise emitted by pump systems will cause vibrations in the piping and the pump casing. These vibrations interact with the surrounding air and are perceived as airborne sound. It must be noted that pump operating noise levels are affected by many factors. The foremost being the method of mounting the pump base plate to its supporting surface. If the mounting surface is not flat and the base plate can distort or twist sound can be compounded. According to (Chavand & Evenden, 2010) the typical noise level of feed booster pumps and seawater pumps range between 80-90 dBA. However, it has to be noted that these estimates were from significantly large pumps (power consumption in the range 760 kW). In contrast the RO plant pumps used for the project has a rating of 15kW. Although actual noise levels from the WSS will be lower compared to referenced levels, for the purpose of impact assessment, the lower range of referenced noise level have been considered.

Noise above safe levels leads to a number of known health impacts which include:

- annoyance;
- stress;
- high blood pressure;
- sleep loss;
- the inability to concentrate;
- the inability to learn and
- loss of productivity.

Another area of concern is impacts on children and on learning. The concerns are that hearing could be impaired at a young age and never fully develop. Also, noise affects concentration and behaviour in youngsters, and thus their ability to learn. This applies to children at school as well as children at home trying to study.

Another potential impact arising during the operational phase include air pollution as detailed in **Section 9.3.7**.

The risk of accidents is also high during the operational phase of the project. Mostly fire related incidents are common in inhabited islands, mainly due to poor fire/safety measures employed at powerhouses etc. The WSS during its operational phase will house flammable chemicals and materials which further increases the risk for such accidents. Swell waves have been identified to be a natural hazard to all the project islands. Significant swells have the potential to damage the RO plant completely during operational phase. Salt spray have been known to reduce the lifetime of materials and equipment. Salt combined with the heat have been known to significantly reduce lifetime of materials which operate efficiently in normal climate conditions. Another potential impact during water production include equipment malfunction or damage due to poor maintenance or other related issues. This would have a strong impact on social aspect as well as on economic aspects. Mainly because local industries will depend on the WSS for their freshwater needs daily and the public will rely on it at times of need.

Equipment malfunction have also been identified as a high risk for the project which shall require a management plant during operational phase (See **Section 2.8** and **2.11**).

The impacts related to water intake are significantly low as seawater water will be sourced from underground, which means, many impacts associated with open water intake such as impingement and entrainment are prevented. However, feed water intake during the operational phase have the highest risk of depleting the islands natural groundwater lens. This risk will materialise only if the borehole depth is insufficient which would result in the intake of fresh groundwater for the RO plant. If this happens, the islands groundwater lens will be depleted and salinized which would have detrimental impacts. Such events have occurred in the past in Maldives where groundwater lens have been depleted by insufficient borehole depth. Another notable impact during water production will be formation of biofilm in the filtration system have impact on the overall efficiency of the WSS.

Water production during operational phase can be affected by adjacent powerhouse in L. Gan and K. Gaafaru. As described in **Section 2.8 & 2.11**, dust pollution from the powerhouse may result in the presence of high THC and heavy metals in product water supplied. Higher THC's are known to have health implications on humans according WHO. It can also pollute the roofs, taps and outer covering of the storage tanks. Another critical risk which can impede this activity includes power loss which has been describe in **Table 12.**

Waste generation during water production is classified to have negative impacts. Chemical waste generated during the operational phase can become a safety hazard. These waste will mostly comprise of chemical testing reagents and solution which may be flammable or highly oxidising. Other types of hazardous waste anticipated to be generated during the operation phase of the project include waste oils, cleaning solvents and waste generated from daily maintenance of WSS system, which may include pump fluids, filters etc. These wastes may have varying degree of health implications. Exposure pathways include inhalation, ingestion and skin contact. These wastes may become environmental toxin and may bio-accumulate in the food chain. Inorganic waste such plastics do not decompose in the environment naturally resulting in pollution of the island, coastal areas and marine environment.

This activity is also highlighted to have a positive impact on the islands local economy and health and wellbeing of the public, as production of water would enhance water security. In addition, commercialisation of this water to industries would provide income operate the plant and distribute water to the public.

Specific Impacts and Mitigation

K. Gaafaru

Overall multi criteria impact for this activity was -30, which meant that the activity would have a moderate negative impact on the environmental receptors. Social-cultural component was determined to have the biggest negative impact followed by physical environmental component. This is mainly because, the RO plant is situated next to the powerhouse which greatly increases the risk of accidents. Moreover, since the RO plant is located so close to the powerhouse, there is a risk of dust fall which has the potential to cause site specific pollution. It has to be noted that, the island has a fairly up-to-date powerhouse and generator which is maintained daily. As a result, dust emitted from the powerhouse is notably less compared to community run powerhouses. Monthly wind data shows that annual winds are from the SW-W sector and NE sector (approximately 30% of the year) which means dust fall impacts will be exacerbated and significant on RO plant when wind is blowing directly from the western sector. Mainly during the months June-August.

Furthermore, the proposed RO plant location is very close to the shoreline and the island is known to experience swells. However, impacts from swells will be minor on the project as most significant swells effecting the island are from NE effecting the north western side of the island (See **Section 5**).

Groundwater tests showed presence of THC, hence product water and feed water from K. Gaafaru shall be tested for THC and heavy metals that make up dust particles, more frequently to ensure THC impacts from powerhouse is not significant on feed water and product water.

In terms of noise impacts, the proposed RO plant is located fairly close to residential areas, public school and a children's playground in the islands. Assuming the highest noise produced during operational phase during continuous operation of the plant is at 80 dBA, a noise decay calculation was done using initial assumptions without factoring for dampening effects due to obstacles and vegetation. From the initial calculations, the noise levels are projected to decrease at a rate of 0.1 $dBAm^{-1}$ down to 60 dBA. This means that a continuous noise source producing 80 dBA will be at:

- 75 dBA at the at the public school in K. Gaafaru
- 64 dBA at the residential area in L. Gan
- 79 dBA at the residential area in B. Kendhoo

These are significant noise exposure levels hence apart from the general mitigation measures proposed, the following mitigation measures shall be undertaken for Gaafaru:

- Pumps shall be housed to reduce noise levels;
- ensure noise cancellation cladding and barriers are installed at the RO plant;
- ensure that, all water storage tanks are tightly sealed;
- undertake cleaning and maintenance work of the storage tanks when wind direction is favourable (Preferably during the NE monsoon);
- undertake routine cleaning and maintenance of the RO plant and monitor dust fall as specified in the report and
- notify powerhouse manager with regard to maintenance work and dust fall.

GHG emissions and resource consumption during the operational phase of the project is considered to be relatively minor as, the plant will not be run 24 hrs. Since the RO plant is designed to provide water when other sources of freshwater has been exhausted or are depleting. Based on existing environment studies, the highest demand for water production will be during the NE monsoon (January – May). As described in **Table 10** (project risks), the risk for groundwater salinization is high for the island. Mitigation measures proposed in **Section 9.3.5** during construction shall be fully employed to protect the groundwater lens during water production.

L. Gan

The overall multi criteria impact for this activity was -27, which meant that the activity would have a moderate negative impact on the environmental receptors.

The RO plant is situated next the powerhouse which greatly increases the risk of accidents. Moreover, this can result in pollution due to dust from the powerhouse emissions. Monthly wind data shows that annual winds are from the SW-W sector and NE sector (approximately 30% of the year) which means dust fall impacts will be exacerbated and significant on RO plant when wind is blowing from directly from the western sector. The powerhouse is located west of the RO plant, which would result in dust being directed towards the RO plant during the southwest monsoon.

The RO plant is located approximately 150 m from the shoreline of the island. DIRAM volume 3 states that the common surge related flooding area is the eastern coastline and the island extent of flooding is greatest towards the northern wetland of the island. The closest coastline to the RO plant is the western coastline and this region is exposed to wind waves originating within the atoll due to the 30 km fetch with wave heights of 0.5 m or less (DIRAM, 2008). Therefore, impacts from swells will be minor for the project location.

In terms of noise impacts, the proposed RO plant is located approximately 100 m away from any residential zone. Assuming the highest noise produced during operational phase during continuous operation of the plant is at 80 dBA, a noise decay calculation was done using initial assumptions without factoring for dampening effects due to obstacles and vegetation. From the initial calculations, the noise levels are projected to decrease at a rate of 0.1 $dBAm^{-1}$ down to approximately 64 dBA. The proposed area has a significant amount of vegetation which would provide dampening effects on the noise generated bringing down the noise levels lower than the initially calculated value.

These are significant noise and dust exposure levels hence apart from the general mitigation measures proposed, the additional mitigation measures proposed for K.Gaafaru shall also be applied to L. Gan. Similarly, groundwater protection measures shall be ensured for L.Gan as well.

B. Kendhoo

Overall multi criteria impact for this activity was -29, which meant that the activity would have a moderate negative impact on the environmental receptors. Noise generated during operations of the RO plant is expected to cause disturbances to nearby residential and public areas of the island. Since noise pollution has been identified as a significant impact during operational phase additional measures shall be taken to reduce noise pollution which could become a cumulative irreversible impact. In addition to general mitigation measure, specific mitigation measures proposed for K. Gaafaru shall be applied at B. Kendhoo as well. Noise shall be monitored as detailed in **Section 10** and if people are exposed to L_{eq} levels 65 dBA at residences, more drastic measures such as relocation shall be considered.

Impacts of dust fall are negligible at Kendhoo since the powerhouse is not close to the proposed RO plant site. Similar to other two islands, risk of groundwater impacts are high during water production hence monitoring and mitigation measures proposed for construction phase shall be implemented to prevent impacts on groundwater lens.

General Mitigation Measures

i. All operational phase risk management measures proposed in **Section 2.11** shall be followed;
ii. emergency and safety planning measures proposed in **Section 2.8** shall be followed;
iii. to reduce noise levels, it is highly recommended that the base plate be grouted in or filled with concrete. This acts as a noise absorption device and anchors the base plate to the supporting surface (Chavand & Evenden, 2010);
iv. use of flex connectors to isolate the pump inlet and outlet piping from the pump to reduce noise levels;
v. using noise cancellation cladding on walls;
vi. ensuring workers are provided with PPG, specially noise cancellation equipment if noise levels exceed 85 dBA;
vii. ensuring that the WSS design meets EPA regulation as detailed in **Section 3**;
viii. ensuring waste, specially chemicals are managed and discarded as detailed in **Section 2.9;**
ix. all pollution control and safety measures proposed in **Section 2.6.16** shall be followed;
x. backwash filter system regularly to remove biofilm;
xi. the proponent shall review the WSS operations within the island regularly;
xii. contactor must ensure that the final depth of the borehole reached the required depth and this shall be proved by conductivity test ensuring electrical conductivity of the source water exceeds 50,000 µS/cm;
xiii. undertake groundwater monitoring regularly as specified in **Section 10** to prevent impacts on groundwater as a result of feed water intake;
xiv. ensure that all relevant permits/approvals and tests have been completed during construction stage prior to water production; and
xv. ensure monitoring and management plan proposed in **Section 10** of the report is followed.

9.4.2 O2 Water disinfection and testing

Water quality assurance by disinfection and regular testing are important aspects of the proposed project. Since feed-water is highly saline and chemical parameters exceeding that is recommended for drinking water, the service provider must ensure that water supplied to general public are quality enough for potable purposes. Poor quality of product water can cause health effects as well as social issues. Hence, water testing and disinfecting are considered activities of positive impact. It is a crucial part of the RO plant operation and it ensures product water meets the WHO and EPA requirements. This activity is anticipated to have an overall positive outcome. Even though there will not be an in-house laboratory in the beginning that would use chemicals, however, chemicals are used for operation and maintenance of the RO system, it has the potential to generate chemical waste as explained in **Section 9.4.1**. Laboratory testing for the product water will be conducted in Male', the project indirectly will contribute to chemical wastes in the respective laboratories in Male as a result. However this is expected to be insignificant. Therefore, the following measures shall be undertaken to enhance positive impacts.

Measures to Enhance Positive Impacts:

- Ensure that chemicals are managed and disposed as described in **Section 2.9**;
- follow emergency and safety planning as detailed in **Section 2.8**;
- all safety gear illustrated in **Figure 67** shall be worn by workers during handling of chemicals;

Figure 67: Safety gear to be worn by WSS workers

- follow all regulation described in **Section 3** and
- manage risk as detailed in **Section 2.1**.

9.4.3 O3 Brine Discharge

Potential Impacts

Discharge of brine has been identified as an activity which could have environmental impacts. Currently, all seawater desalination plants of significant capacity worldwide discharge brine into oceans and estuaries. Brine from a seawater desalination plant is typically twice as saline as the ocean. Because of its relatively high salt concentration, brine has a greater density than the waters into which it is discharged, and when released from an outfall, tends to sink and slowly spread along the ocean floor (Cooley, et al., 2013). There is typically little wave energy on the ocean floor to mix the brine, and as a result, dilution occurs more slowly than at the surface. Many studies have noted that, brine concentrations are significantly high at the mouth of outfall. The discharge brine has the ability to change the salinity, alkalinity and the temperature averages of the seawater and can cause change on marine habitat. The highest temperature value in the surrounding area of the brine discharge has been found to occur very close to the mouth of the outfall.

According (Abdul-Wahab, 2007) the salinity of seawater might not be remarkably different in profile from the surface to the bottom of the sea; however, in the ambient area of the discharge brine outfall can significantly fluctuate between the surface and ten meters depth for instance **Figure 68**.

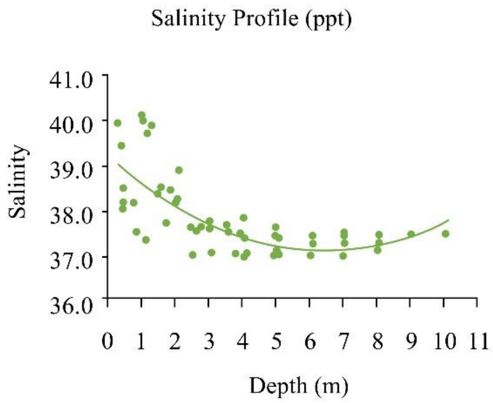


Figure 68: Brine outfall salinity dynamics relative to depth

In shallow lagoons of the Maldives discharged brine is observed to diffuse very quickly as described in **Section 1.5.8**.

Another potential impact resulting from discharge of brine include changes to the alkalinity of surrounding environment. The alkalinity of the seawater is defined as the number of equivalents of calcium carbonate in the seawater (RPS, 2009). The total alkalinity tolerance of the marine life and the changes rate of alkalinity that the brine discharge cause to the seawater has not been exactly determined yet due to a very limited number of experiments. As far as marine biologists are aware, this phenomenon has not been adequately documented and very limited experimental data exists. There is also limited literature available, which explores the impact of total alkalinity on marine life. Desalination seawater plant has the ability to increase the total alkalinity level of the brine discharge and to the seawater in the area of discharge afterwards.
Toxic effects of brine discharge on marine species is limited. There is potential for both short and long-term toxic effects of RO waste brine on marine ecosystems, but any such effects remain unquantified. The potential for toxicity is significantly increased by chemicals such as biocides used in desalination plant operations. However, the plant is designed such that chemical use is prevented or minimized (See **Section 2.7**). Hence risk of toxicity from biocides and other anti-coagulating chemicals are prevented.

In terms of ecological risks, the few studies available indicate that the ecological impacts of brine discharge vary widely and are a function of several factors, including the characteristics of the brine, the discharge method, the rate of dilution and dispersal, and the sensitivity of organisms. For example, brine discharge can cause widespread changes in the benthic community in shallow and/or semi enclosed bays, whereas impacts can be undetectable in areas with heavy wave activity or significant flushing (RPS, 2009).

Based on a literature review, (Jenkins, et al., 2012) found that some species are affected by salinity increases of only 2-3 parts per thousand (ppt) above ambient, while others are tolerant of salinity concentrations of 10 ppt above ambient. Water salinity changes may influence:

- development of species and faster individual growth;

- survival of larval stages of animals and life expectancy (shorter or longer generation time);
- population density of organisms (higher or lower population growth rate) and
- breeding of species and reproductive traits.

However, effects of RO plant discharge on impacts to marine species have not been studied extensively, to provide quantifiable data to establish a concrete causal link.

Due to lack of quantifiable research on the impacts of brine discharge on the marine environment, four case studies are referenced to assess potential impacts. These studies investigated the impact of desalination plants on marine environment through environmental monitoring in

1. Canary Islands,
2. North-west Mediterranean Sea, Blanes, Spain,
3. North-west Mediterranean Sea, Alicante, Spain; and
4. Himmafushi Island RO Plant, Maldives**.**

1. Canary Islands: RO study monitoring did not find evidence that the desalination plant had any detrimental impact on seagrass or algae. The study found that *Cymodocea nodosa* and *Caulerpa prolifera* were more negatively impacted by wastewater treatment outfall compared to increased salinity near the desalination plant.
2. North-west Mediterranean Sea, Blanes, Spain: The study was conducted at multiple, before after locations monthly for a year. The study showed no significant variation attributable to the brine discharge. The habitat at the brine outfall was dominated by sand, in which biota typically exhibit great natural variability in abundance.
3. North-west Mediterranean Sea, Alicante, Spain: The monitoring study showed that echinoderms were highly sensitive to salinity changes. Hence echinoderms were observed to relocate themselves two kilometres upstream from the discharge location. Similarly, Polychaeta assemblage were also found to be notably effected by brine discharge outfall.
4. Himmafushi Island RO Plant, Maldives: Water quality monitoring at the discharge point showed that salinity and temperature equilibrated within 5 m from the discharge pipe in the shallow lagoon. (See **Section 1.5.7** for details**)**

In general, the case studies showed that salinity and temperature equalised rapidly within the lagoons of Maldives and certain classes of marine species such as Echinodermata and Polychaeta were more susceptible to salinity changes.

In general, little is known about the tolerance of marine species or ecosystem to long term increases in salinity particularly corals (Cooley, et al., 2013) (Jenkins, et al., 2012) (RPS, 2009).

Corals are the most significant species identified in the current project context that may have potential negative impacts. Since they are immobile and cannot relocate like some other marine species they are more vulnerable to negative exposure. At small scale, however there are a number of experimental studies that examine responses of corals to short-term exposures to increased salinity.

It has to be noted that, on an evolutionary scale, a number of coral species are known to withstand salinities well above average (50 ppt) in locations such as the Arabian Gulf, Red Sea and in lagoons of oceanic atolls (RPS, 2009). For the purpose of impact quantification, natural upper salinity tolerances (See **Table 46**) and experimental upper salinity tolerances of coral species (See **Table 47**) were assessed.

Table 46: Natural upper salinity tolerances of coral species. Reference: RPS, 2009

Coral Family	Coral Species	Upper Salinity Limit (ppt)	Sites where species present
Acroporidae	*Acropora sp*	48	L.Gan
Acroporidae	*Acropora sp*	51-52	L.Gan
Dendrophyllidae	*Turbinaria sp*	42-45	-
Faviidae	*Cyphastrea micropthalma*	50	-
Faviidae	*Cyphastrea seralia*	46	L.Gan, B.Kendhoo
Faviidae	*Favia favus*	42-45	L.Gan, B.Kendhoo
Faviidae	*Favia pallida*	44-45	L Gan, B. Kendhoo
Faviidae	*Favia speciosa*	48	L Gan, B. Kendhoo
Faviidae	*Favites chinensis*	48	L.Gan, B.Kendhoo
Faviidae	*Favites pentagona*	44-45	L.Gan, B.Kendhoo
Faviidae	*Leptastrea purpurea*	48	-
Faviidae	*Platygra daedalea*	48	L Gan, B. Kendhoo
Faviidae	*Platygra lamelina*	42-45	-
Faviidae	*Platygra sinensis*	44-45	L.Gan, B.Kendhoo
Faviidae	*Plesiastrea sp*	42-45	B. Kendhoo
Pocilloporidae	*Stylophora pistillata*	42-45	B. Kendhoo
Poritidae	*Porites compressa*	46	L.Gan, B.Kendhoo
Poritidae	*Porites nodifera*	50	L.Gan, B.Kendhoo
Siderastreidae	*Coscinarea monile*	44-45	-
Siderastreidae	*Psammoccora sp*	42-45	L.Gan, B.Kendhoo
Siderastreidae	*Siderastrea savingyana*	50	-

Table 47: Experimental upper salinity of coral species. Reference: RPS, 2009

Coral Family	Coral Species	Maximum salinity exposure/ (ppt)	Response
Acroporidae	*Montipora verrucosa*	45	20 day exposure; at 40ppt 50% normal 50% pale, at 45 ppt 100% died
Faviidae	*Montastrea annualaris*	40	30 hr exposure; reduced photosynthesis, respiration and p/r ratio but no mortality
Pocilloporidae	*Posillopora damicornis*	45	20 day exposure; at 40 ppt 80% bleached 10% pale 10% normal, at 45 ppt 100% died
Pocilloporidae	*Stylophora pistillata*	51	20 day exposure; at 43 ppt 100% normal, at 49 ppt and 50 ppt 100% died
Poritidae	*Porites compressa*	51	20 day exposure; at 45 ppt 100% normal, at 49ppt 50% dead 40% pale 10% bleached, at 51 ppt 100% died
Poritidae	*Porites porites*	45	3 day exposure; at 37 ppt 100% normal, at 40 ppt bleached, at 45 ppt mortality
Poritidae	*Porite furcata*	45	2-hour exposure; significant drop in net photosynthesis, 4 hr exposure; no change in photosynthesis, 10 hr exposure; no change in photosynthesis. No tissue mortality after 24 hrs, recovery complete within 1 week. Effects at 45 ppt less severe compared to hyposalinity, but recovery from hypersalinity more.
Siderastreidae	*Siderastrea radians*	45	21 day exposure; decrease in photosynthesis linearly related to exposure time, few colonies had partial mortality, colonies exposed to hypersalinity less able to clear sediments from tissue, effects more severe at hyposalinity but recovery took longer at hypersalinity
Siderastreidae	*Siderastrea siderea*	42	30 day exposure ro gradual increase from 32 to 42 ppt; no change in respiration, but a 25% decrease in photosynthesis, increase from 28 to 42 ppt caused a decrease in both photosynthesis and respiration but no mortality

Experimental evidence suggests that elevated salinities of up to 40 ppt will be tolerated by many species; however, few coral species would be expected to withstand salinity levels in excess of this (Coles & Jokiel, 1978) (RPS, 2009).

Studies have shown that under normal conditions where brine is discharged to the ocean, its concentration will dilute to within 2% of background salinity levels within 30-50 m from discharge pipe. In shallow lagoons of Maldives where longshore currents were active, salinity diffusion to ambient levels occurred within 10 m (Saleem, 2003). A salinity of less than 1 ppt above ambient, could be easily tolerated by most coral species (Cooley, et al., 2013).

Compared to corals, studies have found that marine seagrass are more tolerant to increasing salinity. A study that investigated tolerance levels of *Thalassia testudinum, Halophila engelmanni, Halodule wrightii, Ruppia* maritime and *Syringodium filiforme* exposed these angiosperms to salinities that increased by 0.75 ppt/day (McMillan & Moseley, 1967). The study showed that some of these plants were able to tolerate 60 ppt. Optimum growth of seagrass was achieved between 30 to 40 ppt, but a significance decrease in survival was observed at salinities above 50 ppt. 100% mortality occurred at 70 ppt.

Both corals and seagrass were observed to tolerate minor temperature changes. Photosynthetic rate was found to increase up to 30 ºC and a sharp decline was observed from 42 ºC. Temperature increase associated with brine discharge may become a significant impact to corals and seagrass if temperature is not equalized near corals and seagrass beds.

Moreover, the outflow of waste brine has the potential to alter planktonic productivity by altering temperature and in some cases nutrient loads. According to (Abdul Aziz, et al., 2003), population of zooplankton increased by 55% compared to open ocean at the outfall from a desalination plant. However, it has been acknowledged that the increase may not solely depend on discharge of brine. Similarly impacts of brine discharge on larger marine animals such as sea turtles lack concrete evidence. It has been noted that sea turtle uses a mixture of magnetic, visual and chemoreceptive ques from the environment to navigate long distances. The effect of increased salinity on its ability to navigate has not been extensively studied. However, studies have shown that they can successfully navigate in the absence of one of these ques (RPS, 2009).

A literature review on the effects of desalination plant brine upon cetaceans also concluded there is currently no information to suggest brine discharge will have a negative effect on cetaceans' health, but noted effects have not been studied specifically at existing RO desalination plants. However, past studies have shown that mobile species, relocate to favourable areas with optimum conditions when stress is applied. Based on literature and referenced case studies the proposed outfall locations have not been identified to have a significant impact on the environment.

Specific Impacts and Mitigation Measures

K. Gaafaru

Overall multi criteria impact for this activity was -23, which meant that the activity would have a moderate negative impact on the environmental receptors. Proposed outfall location was not observed to be rich in marine life. Marine assessment showed that the area comprised of sand and harboured very low fish species. In terms of diversity and environmental conditions the area was ideal to situate the outfall pipe. Similarly, the area was dynamic with wind driven waves and currents along the islands coast. Live corals were observed 300 m to the north of proposed outfall locations. These were mainly staghorn corals which are known to be the most tolerant to salinity fluctuations. However, since the proposed site is located close to the coast and is proposed to be situated in between two headland shaped sand banks, the efficiency of diffusion and mixing will be lowered. Similarly, the proposed location may become an issue for future land reclamation. Under such a development the pipe will have to be extended towards live corals and will require more energy to discharge the brine. Hence following measures shall be undertaken in addition to general mitigation measures:

i. Relocate pipe towards the western lagoon as detailed in **Section 8.3.1 (alternative assessment for outfall)**.

L. Gan

Overall multi criteria impact for this activity was -23, which meant that the activity would have a moderate negative impact on the environmental receptors. The marine environment of the proposed outfall location was studied and results showed that the lagoon area with a sandy bottom stretched approximately 100m from the shoreline, beyond this mark the reef slopes deeper gradually and patches of live coral colonies were observed. It is recommended to locate the outfall pipe 200m from the shoreline at a depth of -4m where live coral cover was lowest. In addition to low coral cover this area was dynamic to aid in rapid diffusion and was environmentally favourable. However as noted in **Section 3**, the area could become rough during the SW monsoon. Hence sufficient anchoring shall be place to prevent outfall damage.

B. Kendhoo

Overall multi criteria impact for this activity was -27, which meant that the activity would have a moderate negative impact on the environmental receptors. Live coral cover was observed to be very low at 3% near the reefs edge and no live coral cover observed in the areas near the shoreline. Marine life diversity near the reef edge was observed to be higher relative to the areas of the reef near the shoreline. The brine discharge could potentially cause some disturbances to the marine life in this area. However, the proposed outfall location was observed to be dynamic with wind induced waves and currents around the islands coast and swells at the reef edge which would help in the rapid diffusion of salinity and temperature. Details of proposed outfall are attached in **Annex 6.** The site is selected as it provides sufficient diffusion and harbours low coral cover.

General Mitigation Measures

i. The addition of diffusers can promote mixing and improve dilution of the brine and are commonly used at desalination plants worldwide. The diffusers may consist of a single port at the end of the pipe or multiple ports along a section of the pipe and are generally angled upwards to promote mixing. Recent research and modelling efforts suggest that a discharge angle of 30º–45 º enhances mixing and dilution in moderate-to-steep coastal waters (Cooley, et al., 2013). There is also general consensus among modelling studies that optimal mixing is achieved by discharging the brine in sub-tidal, off-shore environments with persistent turbulent flow (Roberts, et al., 2010). Hence outfall location plays a crucial role in mitigating impacts associated with brine discharge. The outfall location shall be selected based on finding of the environmental surveys as proposed in the report;
ii. brine dilution prior to disposal is also being used by some plants to reduce the potential marine impacts. For instance, many desalination plants mix brine with cooling water from nearby power stations to reduce salinity prior to discharge. Brine dilution may be implemented only after determining salinity concentration of reject water. If it is significantly greater than ambient levels and if salinity equilibration has not occurred within 10 m from the discharge pipe dilution shall be considered;
iii. reducing the amount of chemicals used in the desalination process can decrease the environmental impact of brine discharge;
iv. install brine discharge pipe in locations where benthic diversity is low as proposed in the report (See **Section 8.1** and **Annex 6** for details);
v. ensure that waste and chemicals are handled and discarded as described in **Section 2.9** of the report; and

vi. ensure that salinity do not exceed 40 ppt and temperature do not exceed 40 ºC 10 m away from the discharge outfall pipe. Undertake monitoring as proposed in **Section 10**. Monitoring can only effectively determine the spatial extent of the impact in project sites hence is highly recommended.

9.4.4 O4 Communal Water Supply

Communal water supply is an activity of the project in operational phase that has an overall positive impact on the environmental receptors. It is one of the objectives of the project. Water shall be provided to island community free of cost in times of need as arranged by the utility provider, proponent and island council. Overall multi criteria impact for this activity in all project islands were 5. However, this activity also faces numerous risks during operational phase as detailed in **Table 10**. Especially in L. Gan as described below.

L Gan

- The issues which may arise from the currently proposed tap bay location has been discussed in the **Section 8.3.2** (alternative location of tap bay). In addition to this, due to the proximity of the RO plant to the powerhouse, it will be a health risk for the residents to que at the tap bays during times of water shortage due to the dust emitted by the powerhouse, as well as the high noise levels experienced at the site. It is recommended to follow the preferred alternative of providing a tap bay each in a public area of the three wards to mitigate the negative impacts of the currently proposed location.

Similar issues may arise in B. Kendhoo as well where the tap bay is located on the far end of the island. Hence, the following measures shall be undertaken to enhance positive impacts.

Measures to Enhance Positive Impacts:

i. Ensure that a thorough WSS management manual is prepared and followed;
ii. develop a feasible communal water supply scheme based on water production and OPEX of the project;
iii. adapt the water supply scheme based on operational data, to increase water supply to community;
iv. ensure that water will be available (stored) during dry months or in case of emergency. The communal water supply scheme shall be developed under the framework of operational risks and vulnerabilities as described in **Table 10**;
v. islands where powerhouse is located close to the WSS, ensure that all taps are cleaned prior to supplying water to the public and ensure that dust fall is monitored and recorded as described in the report;
vi. ensure that taps are accessible to the public and maintained. Follow recommendations proposed in **Section 8.4**. Currently proposed tap bays in L.Gan are not accessible due to islands size and dispersal of populated areas, accessibility shall be enhanced by following measures proposed in the report;
vii. ensure that any changes or updates brought to the communal water supply scheme is communicated with the public. The utility service provider and island council shall communicate water supply scheme, basis and any other relevant information required with the public;

viii. the service provider, island council and proponent shall ensure to include input from public when planning and implementing the water supply scheme;
ix. follow emergency and safety planning as detailed in **Section 2.8**;
x. follow all regulation described in **Section 3;** and
xi. manage risk as detailed in **Section 2.1**.

9.4.5 O5 Commercial Water Supply

Commercial water supply is an activity of the project in operational phase that has an overall positive impact on the environmental receptors. It has the biggest impact on the local economy of the islands where fishing is a crucial component of the economy. The activity is also crucial as it is the only activity during operational phase of the project that generates an income. Overall multi criteria impact for this activity in K.Gaafaru was 8, L.Gan was 9 and B.Kendhoo was 8.

Measures to Enhance Positive Impacts:
In addition to measures proposed in **Section 9.4.4**. The following measures shall be applied:

i. An affordable tariff system shall be developed. The tariff system shall be feasible to operate the WSS;
ii. water production shall meet the commercial demand; therefore, water supply levels shall be regularly monitored;
iii. monitoring and management scheme provided in **Section 10** of the report shall be followed and adapted;
iv. harbour kiosks shall be easily accessible. In this regard all recommendations detailed in **Section 8.4** shall be followed. This means, relocating the harbour kiosk in K.Gaafaru to the new harbour as detailed in the report; and
v. all stakeholder consultations demonstrated that, businesses as well as households had a demand for individual connections. Facilitation for such arrangements is suggested to enhance commercial water supply aspect of the island.

9.4.6 O6 Resource Consumption

Potential Impacts
The power required to run all major electrical appliances of the WSS is approximately 30.1 kW. Electricity will be the main resource consumed during the operational phase of the project. It is estimated that the plant would require at least 80l of fuel per day. The required electricity will be provided by the island powerhouse. Water will also be a resource which will be utilised during the operational phase. It will be mainly used for cleaning and maintenance work. Water required for WSS will be sourced from the plant, which would minimise impacts associated with transportation of water. Product water from RO plant will also be a significant resource which will be used during the operational phase. The plant has a capacity to generate 30 tons of product water per day. These will be sold commercially and distributed to locals communally. Communal distribution of water is an activity which could be abused without proper guidelines on distribution of water in cases of emergencies.

As discussed in **Section 9.3.7** GHG emission will be the main impact arising as a result of resource consumption during operational phase of the project. Based on the total power requirement for the system, it is estimated that 15[4] tons of CO_2-eq per month will be emitted during operational phase. Various impacts of GHG have been described in **Section 9.3.7** of the report. Climate change and associated sea level rise has been identified as a significant risk factor to project islands as described in **Section 5.7** of the report. Based on historical disaster analysis swells and natural hazards have directly contributed to the routine salinization of ground water in project islands.

Another resource which will be required frequently during operational phase include, chemicals and spare parts such as filters required for the RO plant. Use of these results in waste generation as discussed before. If these resources are not available during the operational phase it is highly likely that the plant could become non-operational. This has been identified as a high risk to the project (See **Table 12**).

This activity has been identified to have a minor-moderate impact on the environment in all islands. Impacts associated with resource consumption can be mitigated in all islands by following general measures proposed below.

General Mitigation Measures

- Use of solar energy at the RO plant to offset demand on mains' power as detailed in **Section 2.8** and **2.11**.
- if a separate generator is installed in the future to power the plant, fuel storage and operation shall be in accordance with Maldives Energy Authority (MEA) guideline for power systems approval and guideline for approval of standby power generation and electricity regulations of the Maldives. In this regard following directions will be taken into account:
    - The generator house will be soundproofed;
    - stack height will be such that it will meet the regulatory requirements with the objective of avoiding any disturbance by exhaust emission from the generator;
    - temperature immediately outside the wall where the generator is located will not be more than 10 degrees Celsius higher than the ambient temperature and
    - cooling air released from the generator will not be faster than 5 meter per second and
    - fuel shall be stored in a secure roofed area with flooring to contain spills, comparable to **Figure 69**.

[4] This calculation was made assuming that the plant will be operated 24hrs. In reality this value will be lower as water will be provided to public on a need basis and production will mainly depend on commercial demand.

Figure 69: Proposed fuel storage for backup generator at RO plant

- it is not recommended to use the backup generator as the primary source of power supply, instead the existing mains capacity shall be increased to prevent power outs if load is too high. The demand on mains can be reduced by installing solar panels. If roof area of the plant is observed to be less, sheds and roof panels can be constructed on the RO plant to increase solar capacity. Solar energy is a viable alternative that could be explored in the project islands to reduce use of fossil fuels;
- implement daylight saving measures at the WSS. This include switching of lights during the day time and opening windows and shutters;
- switch off machineries, equipment and tools when not in use;
- properly maintain all electrical appliances, tools and machineries;
- procure energy saving and energy efficient appliances;
- operation time of the WSS system is key to reducing resource consumption during operational phase. Depending on the water supply demand and needs, run time of the WSS system shall be reduced and adjusted. This can only be achieved by following an effective monitoring and management plan. Hence all monitoring and management measure proposed in the report, notably **Section 2** and **Section 10** shall be followed and
- feedback monitoring measures shall be implemented. Service provider shall incentivise staff to save energy.

9.5 CUMULATIVE IMPACTS

It is important to identify activities of the project that have a high probability of increasing the negative impacts. During construction phase, majority of the negative impacts can be significantly increased as a result of project delays which have been detailed in the project risks sections.

If borehole is installed at a wrong depth, water production impacts can become cumulative. This is mainly due to depletion of groundwater lens as described. Similarly, if the project is not properly implemented as described in the EIA report, activities identified to have positive impacts could drastically change to result in negative impacts.

Another potential factor that could result in cumulative negative impacts to the marine environment during operational phase includes monthly water production. Since the project is designed to supply water communally on need basis and commercially on a demand basis, these two factors will determine the extent of many operational phase impacts described. Considering that the plant is run at full capacity approximately 441 m^3 of brine will be discharged weekly which could result in cumulative negative impacts to the marine environment. However, due to gaps in understanding these impact as described in **Section 1.5.7**, quantification of these potential cumulative impacts remain largely unknown.

Similarly, potential for accumulation of negative impacts exist due to establishment of additional RO plants within the same island, lagoon system or atoll and as a result of outfall location selected. Less dynamic shallow water could drastically decrease diffusion of brine which may result in greater impacts.

In order to ensure that the proposed impacts are not cumulative as a result of these factors and to better address gaps identified in the impact assessment it is crucial that monitoring is undertaken as described in the subsequent section. Specially assessment of water quality and marine biodiversity simultaneously.

10. ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

10.1 AIMS AND OBJECTIVES

In order to demonstrate the effectiveness of the proposed mitigation measures and to ensure unforeseen impacts and to ensure project activities are controlled in a timely manner a robust environmental monitoring and management program is essential. Additionally, the monitoring program is also important to bring desired changes to the proposed mitigation measures as and when necessary and to enhance benefits of the Project. This chapter presents in detail the management and monitoring program put in place under the proposed project to evaluate the actual impacts and the effectiveness of the proposed mitigation measures and to ensure that the project is implemented responsibly ensuring that the project activities do not result in unacceptable changes to the environment. This plan primarily focuses on:

a) Ensuring that groundwater lens is not depleted during operational phase;
b) ensuring that marine environment is not damaged by brine discharge;
c) ensuring that product water is not affected by pollution from the powerhouse in L.Gan and K.Gaafaru;
d) ensuring that project risks described in **Section 2.11** are managed;
e) collecting information that can be used for improving project performance and environment;
f) collecting information that can be used for evaluating the effectiveness of implemented mitigation measures so it can provide information for better decision making and future improvement of environmental quality for similar projects;
g) ensuring that the impacts are eliminated in a timely manner and to ensure project risks discussed in **Table 10** are managed; and
h) providing evidence of compliance assurance to laws and regulations and requirements of enforcement agencies.

The detailed impact monitoring plan for the proposed project is given in **Table 50**. Indicative cost of the monitoring and environmental management is also given in the same Table. The Proponent will ensure that the monitoring program is carried out in a timely manner. A commitment letter confirming to undertake the mitigation measures and monitoring is given in **Annex 7** of the report**.**

Activities and parameters proposed to be monitored during the construction and operational phase, of the project include:

- Benthic cover and fish count at the proposed outfall location and nearby marine environment;
- Water quality, mainly sedimentation during construction phase and routine water testing during operational phase as stated in **Table 50**.
- All changes to the terrestrial environment associated with removal and relocation of trees;
- Exact record of species, count and type of tree removed during construction phase;
- Detail log of the fate of uprooted trees and
- Health of relocated and replanted trees.

In addition, the project will also record all significant matters such as:

- Outbreak of diseases and invasive organisms;
- Accidents, injuries and occupational illness; and
- Incidents and emergencies such as spills and other potentially dangerous incidents.

The long term management plan for the RO plant is highlighted in **Table 49**. An adaptive management plan is proposed where stakeholders and their responsibilities are clearly defined.

10.2 ENVIRONMENTAL MANAGEMENT STRUCTURE

This sections detail the various parties involved in the implementation of the environmental plan and their responsibilities.

10.2.1 The Proponent, Ministry of Environment and Energy

MEE will be responsible for the execution of all the project activities within the required timeframe. MEE is also responsible of policy level decisions and provision of support regarding the RO plant management works undergone in the island as well as on the national level.

10.2.2 The Contractor

Contractors to construct the RO plant and undertake land clearance work as decided by MEE and the Island Council. The contractor will undertake the project in accordance with the EIA and will report to the proponent and environment consultant about any unexpected environmental impact or health and hazard issues. During the construction stages, the contractor will follow all mitigation and management measures proposed in the report, mainly waste management, pollution control, accident prevention and work methodology proposed. The contractor shall provide all necessary training and manuals required to operate the RO plant prior to handing over.

10.2.3 Service Provider

The service provider shall take over from the contractor and ensure that RO plant will be managed as per the regulations discussed in **Section 3.3**. The service provider shall ensure high risk activities discussed in **Table 10** adequately addressed prior to undertaking the work. The service provider shall establish and operate water testing laboratory prior to supplying water. The service provider shall report to MEE as specified in the report

10.2.4 Environmental Consultant

The environmental consultant shall prepare the EIA and EMP based on field visits and surveys and based on past project experiences in similar settings. If there are any modifications to be made to the EMP during any stages of the project, the consultant would do the modification and would conduct the environmental monitoring according to the monitoring framework. The environmental consultants are also responsible for auditing the management/monitoring plan to identify gaps, limitation in management and propose remedial measures to ensure the project is sustainable. The Environmental Consultant shall report and advise MEE with regard to proper management of the impacts and project risks.

10.2.5 Environmental Protection Agency

The Environmental Protection Agency would review the monitoring reports submitted by the proponent and would commission and ensure regulatory monitoring visits to the project site upon their needs.

10.2.6 Island Council

The island council is responsible for facilitating and assisting contractors and service provider. They shall also ensure monitoring and management plan is implemented as per the EIA. The island council is also responsible for recording grievances and communicating major social and environmental issues related to project with MEE. The island council shall facilitate and monitor removal and transport of trees from the island.

10.3 MANAGEMENT PLAN OF THE WSS

A practical plan taking into consideration available resources is proposed to meet the aims and A practical plan taking into consideration available resources is proposed to meet the aims and objectives of the EMP stated in above. One of the major risks to the investment and operation of the RO plant is lack of resources and management challenges during operational phase. Hence the proposed RO plant management plan aims to control and mitigate operational phase risks described in **Table 10** which could lead to negative impacts. **Table 48** shows the proposed environmental management plan.

Table 48:Details of environmental management plan proposed for the RO Plant

Activity	Phase	Measures	Time frame	Responsible person
Training of workers and contractors	Pre-construction	Contractor and project workers are provided with detailed information on the project, impact mitigation measures, compliance with environmental permits and the EMP. Workers are also provided with the information on sensitive areas of the island and other environmental issues. Training of staff involved in the monitoring of the construction phase and familiarisation with recommendations of the EIA.	Prior to construction works	Proponent Environmental Consultant
Documenting non-conformances and corrective actions	Construction Operation	Non-conformances to the environmental regulations, permits and the EIA is monitored and documented. Corrective measures are taken and follow ups are done. RO plant operations reports and public grievances are compiled by the island council and reported to the proponent within the prescribed frequencies as stated in **Table 49.**	Construction and Operation phase	Construction phase: Proponent & Environmental Consultant Operational phase: Island Council, Service Provider and Proponent
Supervision of activities	Construction & Operation	The project activities are to be supervised by the proponent throughout the construction and operational phase to ensure the activities are carried out accordingly and the impacts are minimised. The proponent shall review the RO plant operations reports from the island councils, and provide the required support, bring about any necessary policy updates	Construction and Operation phase	Proponent

Table 49:Details of the reporting mechanism proposed for the WSS

RO Plant (Contractor and Operator)

Reporting	Details	Frequency
General report	Logs of the incoming waste Classified by type and weight	Monthly
	Water produced, stored and RO plant run time and electricity consumed. Water availability shall be shared with Island Council so that necessary arrangements can be made during emergency	
	Machinery maintenance details	
RO plant capacity	Details of the utilized and remaining water. Data shall be logged to determine most efficient RO plant running.	Every two months
	Chemical and reagent audit	
RO Plant inventory status report	Details of the status of equipment	Bi-Annually
	Details of the status of emergency kits and firefighting equipment	
EMP	Environmental Monitoring Report	As stated in table
Income report	Financial report shall be prepared and shared with the island council and MEE.	Monthly
Noise complaints	Log of noise and other complaints	Every two months
	Complaints to be provided along with weather conditions and incoming waste details coinciding with the dates of complaints	

Island Council (Municipal Unit)

Components	Details	Frequency
Public grievances	Log of public grievances regarding Propose remedial measures	Bi-Annually
	Community water supply scheme and its review.	
	Noise and odor complaints	
Income report	Summary of WSS operations income	Bi-Annually

MEE

Components	Frequency
Review of Reports from Councils and Service Provider	Bi-Annually
Update Water Policy	
Provision to support Water Supply System Enhance adaptability of the RO plant	

10.4 MONITORING PLAN OF THE WSS

The plan is prepared to ensure all mitigation measures proposed in **Section 9** of the report is implemented to ensure that the project meet the monitoring and management goals. The monitoring plan is based on identification of stakeholders and their responsibilities during each major component of the project. To ensure the monitoring plan and management plan is implemented successfully a third-party review and audit has been proposed. This is because in projects where there are numerous components there will be gaps and challenges which may not be addressed during the implementation which may result in exacerbation of impacts and failure of the proposed project.

Table 50: Environmental Monitoring and Management Plan

Objective	Activity	Parameters to be monitored	Location	Method	Frequency	Responsible Agency	Verifiable indicator	Cost (MVR)	Phase[5]

[5] C = construction phase, O = Operational phase

Ensuring that the project activities does not affect the quality of the groundwater	Establish baseline just before the construction works begin and continue monitoring during borehole construction and feed water intake. Establish a groundwater monitoring stations and geo-reference it. Preferably close to the borehole location (within 20-50 m radius) Ensure that quality of feed water is acceptable	Groundwater quality for electrical. conductivity, temperature, DO, BOD_5, Nitrates, phosphates, Turbidity, pH, hydrocarbon, total coliform and faecal coliform from borehole site and surrounding area/monitoring station Salinity of borehole shall be measured from laboratory to ensure depth of borehole is sufficient during construction Salinity of surrounding area within 20-50 m shall be monitored during construction and operational phase. Above mentioned parameters of feed water shall be tested routinely as part of the operations	**Project site**	Potable water quality testing equipment and/ or by sending samples to the lab or from the lab that will be established in the plant.	Baseline data before work begins. During construction phase (borehole construction phase) During Operational Phase. Bi annually	Proponent/ Contractor/ Operator	Water quality report comparable to baseline levels Conductivity of feed water 50,000 µS/cm.	12,000 per monitoring trip	C&O

Ensure waste generated at work site is audited and managed responsibly	Management of waste generated as described in **Section 2.9** of the report	Estimation of waste generated at project site and recording these data routinely. This includes quantifying and recording the amount of yard waste, hazardous waste and general waste stacked and stored for transportation.	**Work site & RO Plant**	Keep records in a log book, or data sheet	Every two months during construction and operation	Operational Contractor Construction Contractor	Record sheets, photographs and quantity of waste processed at nearest waste management center and at the source. If there are no significant discrepancies between the quantity of waste generated on site and processed at regional waste management facility, it can be safely assumed that impacts of waste on the environment was reduced.	Included in the project costs	C&O

Ensuring survival of corals and to protect the marine environment	Prevent impacts to live corals as a result of brine discharge from RO plant Prevent sedimentation impacts during construction phase of the project Ensure that seawater quality is normal	The parameters for monitoring include: Benthic cover and fish count Seawater quality testing, to ensure that salinity does not exceed 40 ppt 10 m from outfall pipe and to ensure sedimentation is kept under control. Hence most important parameters to monitor are salinity, temperature, turbidity and DO level.	**Outfall Location**	Photo records and transect analysis reports Water quality reports	Monitoring shall be undertaken for a period of 4 years, bi-annually.	Proponent and Operational Contractor	Monitoring reports which shall include diagnosis, remedial measures and observations after remediation.	MVR 10,000 per trip	O&C
Monitoring Product Water Quality	Prevent health implications and to ensure water quality of product water meets EPA's regulation. Ensure that dust pollution from adjacent powerhouse do not have impacts on product water in L.Gan and K.Gaafaru	The parameters to be monitored are stated in **Table 11.** In Addition heavy metals and THC shall be monitored at least weekly until impacts are not known to be significant.		Water test reports	Monitoring shall be undertaken as stated in **Table 11**	Service Provider	Water test results	Included in project operational cost	O

Monitoring Health and safety of workers and the public	Accidents during construction, land clearance, operation of RO plant and maintenance of RO plant. Fire hazards and natural disaster events. Noise complaints during operation and construction phase. Routine noise monitoring during operational phase to ensure that public is not exposed to Leq 65 dBA	Type of accident/complaint Cause of accident/complaint Date and time.	**RO Plant**	Keep records in a log book, or data sheet	Monthly during construction phase and Bi-annually during operational phase	Service provider and contractor	Measures to adapt and prevent accident and risks. Health assessment reports published or available from the local health center. Policy changes and upgrades. Financial reports of the RO plant Noise measurement data	Included in project cost.	C&O

10.5 RESOURCE REQUIREMENT FOR MONITORING

For the monitoring program to be successful, it is important that adequate financial and human resources are available and strong coordination among the key stakeholders is maintained.
The primary function of implementing the mitigation and monitoring plan will lie with the proponent. Since the project at developmental and operational stage will be engaged by the proponent it will be the responsibility of the proponent to take care of the environmental safeguards at all stages of the project during implementation and at operational phase. The proponent should prepare an Environmental Action Plan, which states all measures for mitigation and enhancement and monitoring as described here in the EIA with their responsible organisation and person, planning, methodology, timing and other relevant aspects.

An independent registered environmental consultant shall be hired and contacted to undertake the monitoring program prescribed in this report. Following each monitoring visit the consultant will prepare a report with clear recommendations and corrective measure if necessary. The report will have to be submitted to EPA for their review and actions.

10.6 MONITORING SCHEDULE

Table 51 highlights the monitoring plan in which responsibilities of main stakeholders has been assigned. In order to track and compile the findings of these measures an independent environmental consultant shall be tasked to audit the projects EMP. This is to

- identify gaps in monitoring and mitigating impacts arising from the project;
- determine the challenges and resource inadequacies to implement the proposed EMP; and
- determine the current environmental condition and propose modification/upgrades to the initial EMP.

Monitoring frequency for various individual components given **Table 50** shall be followed by all responsible parties. **Table 51** gives indicative timeline for the monitoring visits by third party consultant.

Table 51: Monitoring visit schedule

Visit	Indicative timeline	Indicative parameters to monitor	Reporting	Cost (MVR)/per report/island.
Visit 1 (Construction Phase)	During land clearance and construction of RO Plant	Setting out survey, work method, waste management monitoring and monitor health and safety of workers. Review reports by contractors and proponent. Monitor impacts on groundwater during borehole construction. Monitor work method, Monitor impacts to nearby vegetation and ensure vegetation removal is as per set out survey. Review reports prepared by contractors.	Submit monitoring summary report 1 to Proponent within 2 weeks	15,000.00
Visit 2 (Construction Phase)	During Outfall Pipe Construction	Monitor work method, Monitor impacts on vegetation belt, Measure sedimentation and impacts on benthic cover	Submit monitoring summary report 2 to Proponent (MEE) within 2 weeks	10,000.00
Visit 3 (Operational Phase)	At the Start of RO Plant Operation and bi – annually for four years	Monitor health and safety, Monitor seawater quality, Monitor Marine Environment and Inspect RO plant for dust fall. To ensure that salinity and temperature does not exceed threshold levels described in **Section 9** within 10m of the outfall pipe. To ensure that the public is not exposed to L_{eq} greater than 65 dBA	Submit summary report 3 within 2 weeks Continue monitoring for 4 years bi-annually	25,000.00 per monitoring report

		To ensure feed water intake does not have an impact on groundwater lens.		

As indicated, during the course of the Project implementation summary reports following each trip is expected to be submitted by the Project's environmental consultant. These environmental audits will provide a basis for assessing at least the shorter-term efficacy of the environmental measures and thereby provide lessons to be learned for future monitoring sessions and other projects with similar impacts. The consultant will prepare and submit the reports to Proponent and Proponent in turn will submit it to EPA. Based on the findings of the report, the management approach may be adapted and its efficacy will be determined in the consecutive monitoring trip.

Long-term monitoring has been proposed as impacts on marine environment and impacts related to management of the RO plant may be felt over a longer period of time.

10.7 MONITORING REPORT

Reporting will be carried out by the environmental consultant assigned for the purpose by the proponent.

The report will include among other information:

- Details of what was being monitored;
- Methodology of data collection and data analysis;
- Major findings;
- Effectiveness of the mitigation measures in place and
- Recommendations and conclusions.

A detailed environmental monitoring and management report is required to be compiled and submitted to the EPA. In addition to this, regular site monitoring would be carried out by the proponent that requires maintaining logs of events as explained in this report. Enforcement officers from EPA may also visit the site for inspection from time to time.

10.7.1 Monitoring Report Format

The environmental monitoring report outlined in **Table 52** below will be used in reporting environmental monitoring to be carried out as given in the monitoring plan.

Table 52: Monitoring report format

Project Title:
Name of the Island:
Monitoring Date:
Period Covered:
Prepared by:
Contributions:

A. Introduction
Give a brief introduction about the project and the monitoring carried out

B. Methodology
Brief detail of the methodology applied for undertaking the monitoring assessment

C. Environmental Monitoring

a. Seawater quality
Parameters given in the monitoring plan need to be assessed

b. Management of trees removed
These include monitoring trees removed, its fate and validation of number of trees removed.

c. Benthic cover and fish study
These include monitoring sedimentation and changes in the eco-system.

d. Waste generation and management
Waste generated during the operational phase of the project.

D. Risks and Mitigations
Please indicate any critical unresolved risks that affect the course of the system operation, analyse the cause, assessing the potential impacts on the environment providing the proposed mitigation strategy

E. Problems Encountered
Indicate any problem areas encountered and any corrective measures that will have to be taken.

F. Recommendations and Adaptations as Solution
If specific recommendation is noted during the monitoring phase, specify it in the report

G. Conclusions

Reference

Appendix

11. CONCLUSION AND RECCOMENDATION

The assessment has been based on as much information as possible that could be obtained within the study time constraints on both existing environment and the features and possible effects of the planned development.

The study has identified that the proposed construction of WSS will enhance water security of islands. It also serves as a basis for the development of a freshwater supply network in the islands. The proposed areas to construct the RO plant has been approved by the respective ministry. There are no significantly large trees or coconut palms (privately or state owned) at the project sites which will be required for removal.

The study found no evidence that the project requires or involves:

- loss of unique habitat or wilderness areas;
- loss of protected area;
- loss of protected flora or fauna;
- removing or destroying cultural properties;
- resettling of local communities;
- contravening with national laws, regulations, policies or multinational environmental agreements to which the Maldives is a Party to or customs or aspirations concerning environment, economy, employment, cultural traditions or life styles.

However, the study identified the following potential impacts due to proposed development works:

- Potential for groundwater salinization during construction and operational phase;
- Noise pollution during the operational phase of the project;
- A high risk to water production during operational phase;
- Waste generation during construction phase of the project and
- Impacts to marine environment during operational phase as a result of brine discharge.

The study also found that during the operational phase of the project, there is a high potential for cumulative negative impacts. The study also identified significant risks to the project in the absence of proper management measures and planning which have been elaborated in **Section 2**.

The study also found that through the implementation of the proposed practical and cost effective mitigation measures almost all significant impacts can be brought to an acceptable level. Morover, the assessment found that the project was complaint to existing laws and regulations.
On the basis that this EIA will be thoroughly followed and all mitigation measures will be implemented by the proponent, it is concluded that the benefits of the planned development works will substantially outweigh its imposition on the environment.

RECCOMENDATIONS

- The EIA report shall be taken as a whole in its entirety and be made part of the legal contract with the contractors;
- Preferred project alternates detailed in the EIA shall be considered and selected;
- Implement the work method and mitigation plan as prescribed in the report to the fullest;
- Implement monitoring and environment supervision during all phases of the project. Specially groundwater monitoring shall be implemented during construction and operational phase to prevent groundwater salinization and depletion and to ensure impacts of dust fall from adjacent powerhouse in L. Gan and K. Gaafaru plant are controlled and mitigated;
- Ensure that borehole is drilled beyond 30 m and confirm conductivity of feed water to be 50,000 µS/cm;
- Ensure that laboratory facilities are available at the plant to undertake routine tests;
- Ensure that spare parts such as filters are readily available;
- Renewable solar energy shall be used to provide power for the plant and offset demand on mains;
- Awareness with regard to water usage shall be created among the public by implementing a water education strategy;
- Train individuals at the island level with regard to operation/maintenance of the RO plant to develop capacity within the island;
- Main grids power capacity shall be increased instead of using a separate generator at the RO plant. Only a backup generator shall be installed in the plant.
- Frequency of heavy metal and THC monitoring at L. Gan and K. Gaafaru plant shall be increased until to determine extent of dust fall impacts;
- Operation of the RO plant shall commence only after the preparation of detailed plant operating manual which shall include plant ERP, safety protocols, technical operational details/troubleshooting, laboratory management plan/concept and chemical management plan;
- Marine water quality and biodiversity shall be monitored in conjunction as described in the report to ensure brine discharged from the outfall diffuses and does not have significant impacts on the marine environment as a result of gaps described in the study;
- Monitoring of seawater quality shall be undertaken as proposed to address potential cumulative impacts which could occur as a result of increasing water production capacity and number of RO plants nationwide.
- Allocate adequate resources for the environmental monitoring of the project;
- Ensure that the necessary clauses regarding the worker’s safety are fully implemented;
- Ensure that solar panels are installed to offset electricity demand on powerhouse and to enhance energy security of the RO plant;
- The enforcement agency to make an effort to make at least one visit to the project site during the construction phase to ensure environmental compliance of the project activities;
- Proponent appoints a focal point to coordinate activities relating to monitoring and reporting.
- It is recommended to use UV sterilisation instead of chlorine as a disinfectant.

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13. ANNEX 1: DECLARATION (PROPONENT)

14. ANNEX 2: TERMS OF REFERENCE

15. ANNEX 3: APPROVED CONCEPT PLAN & DESIGN REPORT

16. ANNEX 4: LAND USE PLAN

Only L.Gan had an approved LUP

17. ANNEX 5: STAKEHOLDER ATTENDANCE

18. ANNEX 6: A3 SITE LOCATION & SITE DETAIL SURVEY DRAWINGS

19. ANNEX 7: COMMITMENT LETTER (PROPONENT)

20. ANNEX 8: LETTER BY ATOLL COUNCIL

21. ANNEX 9: DECLARATION OF AUTHORS

22. ANNEX 10: CV'S

23. ANNEX 11: WATER TEST REPORT