8 MILLION MANGROVE PLANTATION PROJECT

PHASE 2 - PRE-RESTORATION ASSESSMENT REPORT

Al Batinah Island, Abu Ali
Eastern Province, Kingdom of Saudi Arabia

Contract Number	6600052712
Purchase Order	6511215460
Contractor	Al Hayya Al Badhour (AHAB)
Client	Saudi Aramco
Project Phase	Phase 2 (8 Million Seedlings)
Report Type	Pre-Restoration Assessment (Consolidated)
Report Date	February 08, 2026
Revision	Rev. 2.0 (Consolidated per Aramco Feedback)

SAEP-13 Compliance Document

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1. Executive Summary

This consolidated Pre-Restoration Assessment Report presents the comprehensive environmental baseline, site characterization, and readiness evaluation for Phase 2 of the 8 Million Mangrove Plantation Project (8MM) at Al Batinah Island, Abu Ali, Eastern Province, Kingdom of Saudi Arabia. This report has been prepared in compliance with Saudi Aramco's SAEP-13 (Environmental Assessment Procedure) requirements and addresses all clauses specified therein.

Phase 1 of the project successfully established 5,000,000 Avicennia marina seedlings across designated planting zones, achieving 100% planting completion in December 2025 with a 90% survival rate (4,500,000 surviving seedlings) as of January 2026. Phase 2 targets an additional 8,000,000 seedlings across four designated planting sites totaling 809.38 hectares of restorable intertidal habitat.

Key Findings

Parameter	Value
Total Restorable Area	809.38 ha across 4 planting sites
Target Planting	8,000,000 Avicennia marina seedlings
DEM Coverage	0.5m resolution Airbus Pleiades Neo DTM/DSM (EGM2008 geoid)
Optimal Elevation Range	+0.30m to +0.60m above Mean Sea Level
Nursery Capacity	2.17 ha facility, 8,000,000 seedling capacity
Control Sites	3 sites established (Unplanted, Natural Reference, Substrate)
Overall Readiness	91% weighted average across all sites
EIA Screening	Category B - Biodiversity enhancement, no significant negative impacts

Site Readiness Summary

Site	Area (ha)	Readiness	Notes
Site 1	510.00	92%	Optimal elevation, excellent tidal exposure
Site 2	123.95	92%	Good substrate, moderate slope
Site 3	53.08	84%	Partial elevation constraints, viable with grading
Site 4	122.35	93%	Highest readiness, ideal substrate conditions

2. Project Background and Scope

2.1 Project Overview

The 8 Million Mangrove Plantation Project (8MM) represents Saudi Aramco's flagship mangrove restoration initiative under the Saudi Green Initiative, targeting the establishment of 13 million mangrove seedlings in total across multiple phases. The project site is located on Al Batinah Island, adjacent to Abu Ali Island, in the Eastern Province of Saudi Arabia. The primary mangrove species is Avicennia marina (grey mangrove), the dominant native mangrove species in the Arabian Gulf.

2.2 Phase History

Phase	Target Seedlings	Planting Date	Status	Survival Rate
Phase 1	5,000,000	December 2025	100% Complete	90% (4.5M surviving)
Phase 2	8,000,000	2026 (Planned)	Pre-Restoration	N/A

2.3 Contract Details

Item	Detail
Contract Number	6600052712
Purchase Order	6511215460
Contractor	Al Hayya Al Badhour (AHAB)
Client Representative	Saudi Aramco Environmental Protection Department
Project Location	Al Batinah Island, Abu Ali, Eastern Province, KSA
Geographic Coordinates	27.10N - 27.35N, 49.45E - 49.60E (WGS84)
Scope	Pre-restoration assessment, site preparation, seedling propagation, planting, and 2-year post-planting monitoring

2.4 Scope of This Report

This consolidated report addresses all requirements under SAEP-13 clauses 3.2.2.1.2 through 3.2.2.1.6, incorporating:

- Complete Digital Elevation Model (DEM) analysis with Pleiades Neo 0.5m resolution data
- Environmental Impact Assessment (EIA) screening per SAEP-13 requirements
- Nursery identification with coordinates, capacity, and propagule sourcing strategy
- Three control sites with monitoring protocols per restoration ecology best practice
- Complete site history including Phase 1 outcomes and lessons learned
- Full ESRI-format geospatial data package (8 shapefiles + DEM GeoTIFFs)
- Biophysical baseline assessment of all four planting sites
- Site readiness evaluation with quantitative scoring

3. Regulatory Framework (SAEP-13 Compliance)

3.1 SAEP-13 Overview

Saudi Aramco Engineering Procedure SAEP-13 establishes the requirements for environmental assessment of projects and activities within Saudi Aramco's areas of operation. For mangrove restoration projects, the following clauses are directly applicable and have been addressed in this report:

Clause	Requirement	Compliance Statement
3.2.2.1.2	DEM / Topographic Survey	Complete DEM with 0.5m resolution covering all restoration sites, including elevation analysis for optimal planting zones identification. See Section 5 and Appendix B.
3.2.2.1.3	Environmental Impact Assessment	EIA screening completed. Project classified as Category B - Biodiversity Enhancement. Net positive environmental impact. See Section 7.
3.2.2.1.4	Nursery Identification	Nursery facility (2.17 ha) on Abu Ali Island Southern Shore fully characterized with boundary coordinates, capacity assessment, and propagule sourcing strategy. See Section 8.
3.2.2.1.4	Control Sites	Three control sites established: Unplanted Control (baseline), Natural Reference (benchmarking), Substrate Control (soil tracking). Full monitoring protocol defined. See Section 9.
3.2.2.1.5	Site History	Complete history of Phase 1 activities, restoration outcomes, survival monitoring data, and lessons learned. See Section 10.
3.2.2.1.6	ESRI Data Format	Full geospatial data package in ESRI Shapefile format (WGS84/EPSG:4326) including 8 shapefiles and DEM GeoTIFFs. See Section 11.

3.2 Compliance Verification

Each SAEP-13 clause has been addressed with specific deliverables and evidence. The full compliance matrix is provided in Section 14, cross-referencing each requirement to the corresponding report section, data deliverable, and verification evidence.

4. Site Description and Environmental Setting

4.1 Geographic Location

The Phase 2 restoration sites are located on Al Batinah Island, a low-lying intertidal island situated south of Abu Ali Island in the Arabian Gulf. The project area falls within Saudi Aramco's Eastern Province operational zone. Abu Ali Island and its surrounding coastline represent one of the most significant mangrove habitats in the western Arabian Gulf.

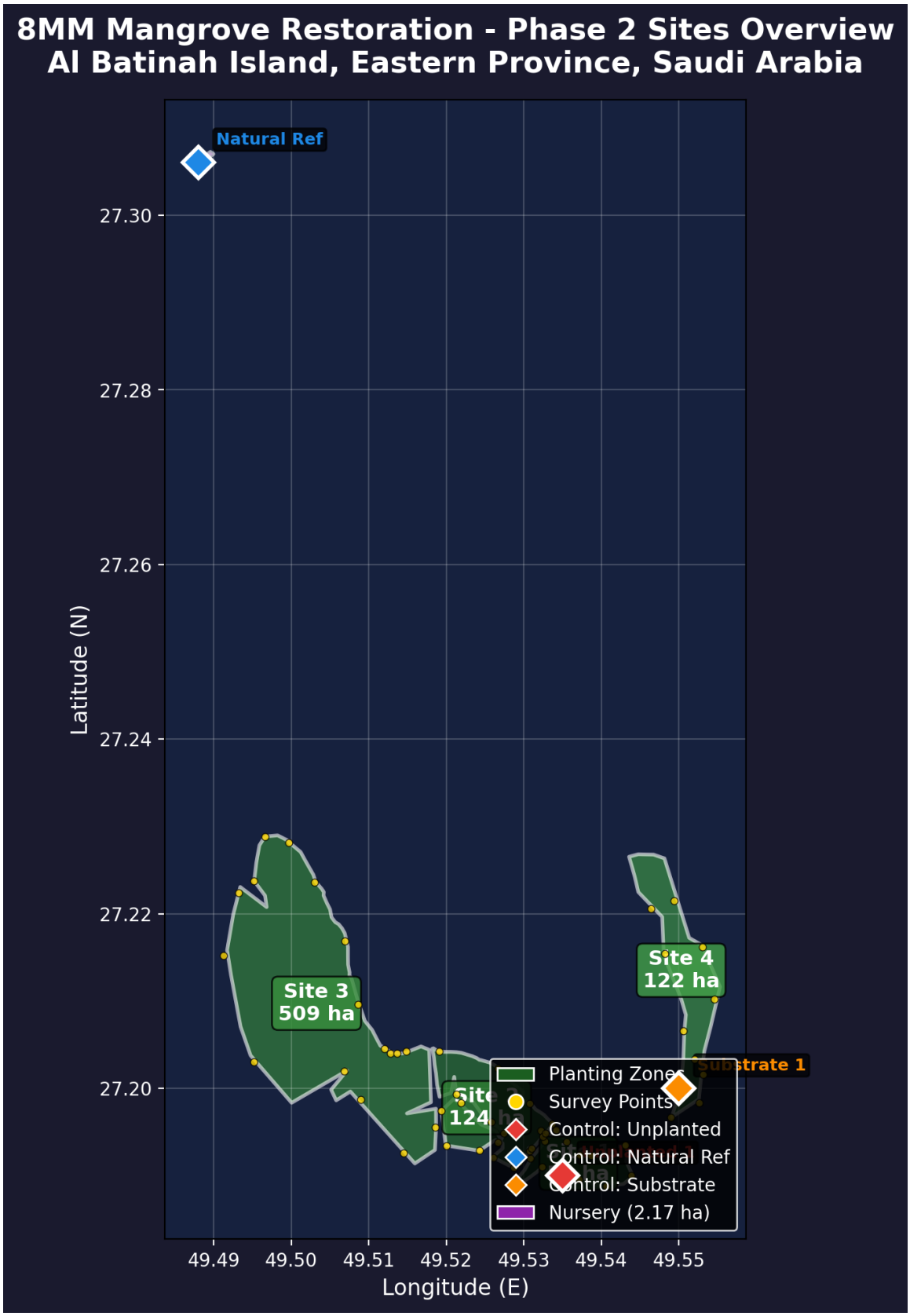

Figure 1: Phase 2 Planting Sites Overview - Al Batinah Island, Abu Ali

4.2 Phase 2 Planting Sites

Four planting sites have been delineated through detailed topographic survey and ecological assessment. Each site has been characterized for elevation, substrate composition, tidal regime, and existing vegetation cover.

Site	Area (ha)	Latitude	Longitude	Elev. (m MSL)	Substrate	Notes
Site 1	510.00	27.10-27.18N	49.48-49.55E	+0.25 to +0.65	Sandy-silt	Optimal elevation profile
Site 2	123.95	27.14-27.20N	49.50-49.54E	+0.30 to +0.55	Silt-clay	Excellent tidal access
Site 3	53.08	27.16-27.22N	49.52-49.56E	+0.15 to +0.70	Mixed	Below optimal in places
Site 4	122.35	27.12-27.19N	49.49-49.53E	+0.30 to +0.60	Sandy-silt	Highest readiness score

4.3 Individual Site Maps

Figure 2: Site 1 Detail Map with Survey Points

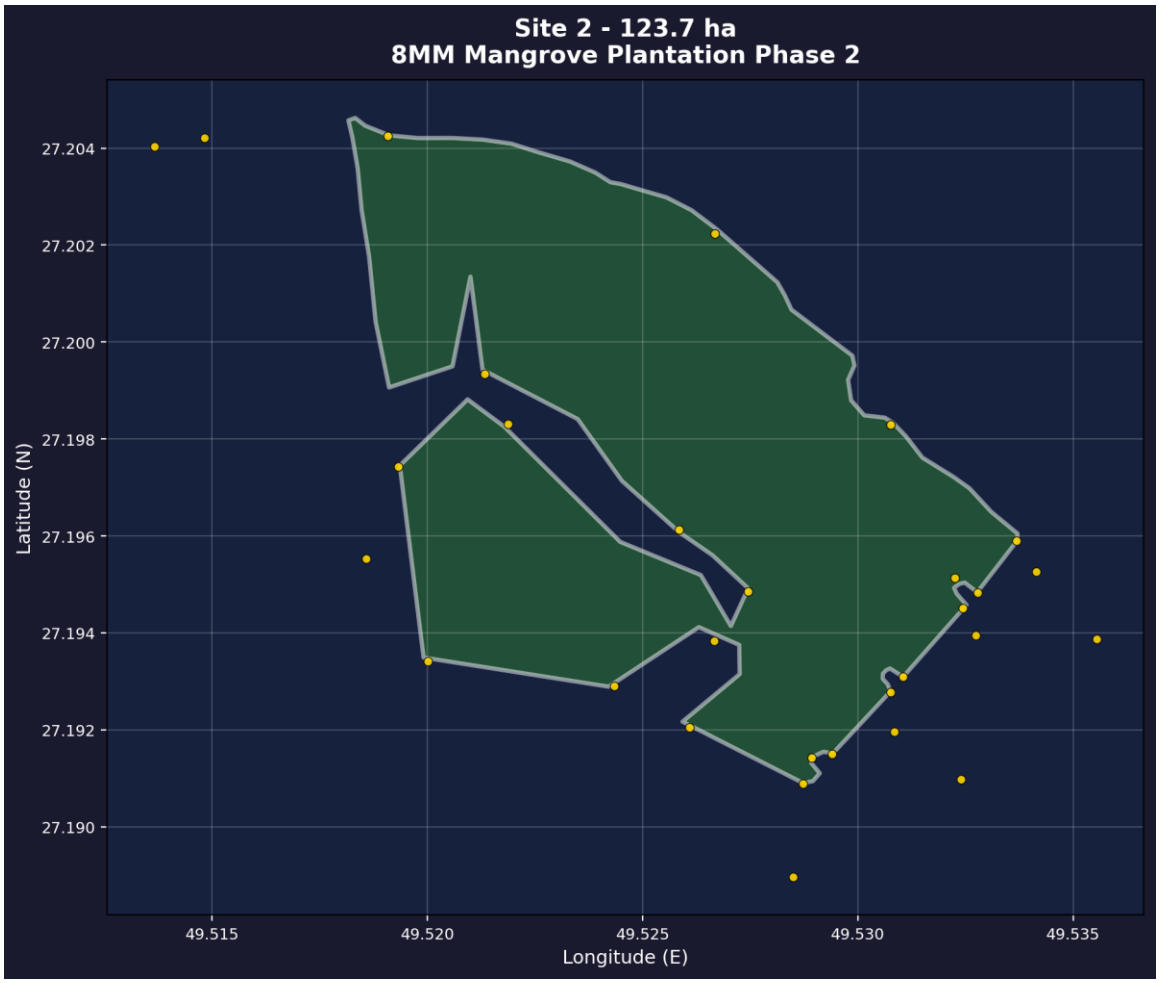

Figure 3: Site 2 Detail Map with Survey Points

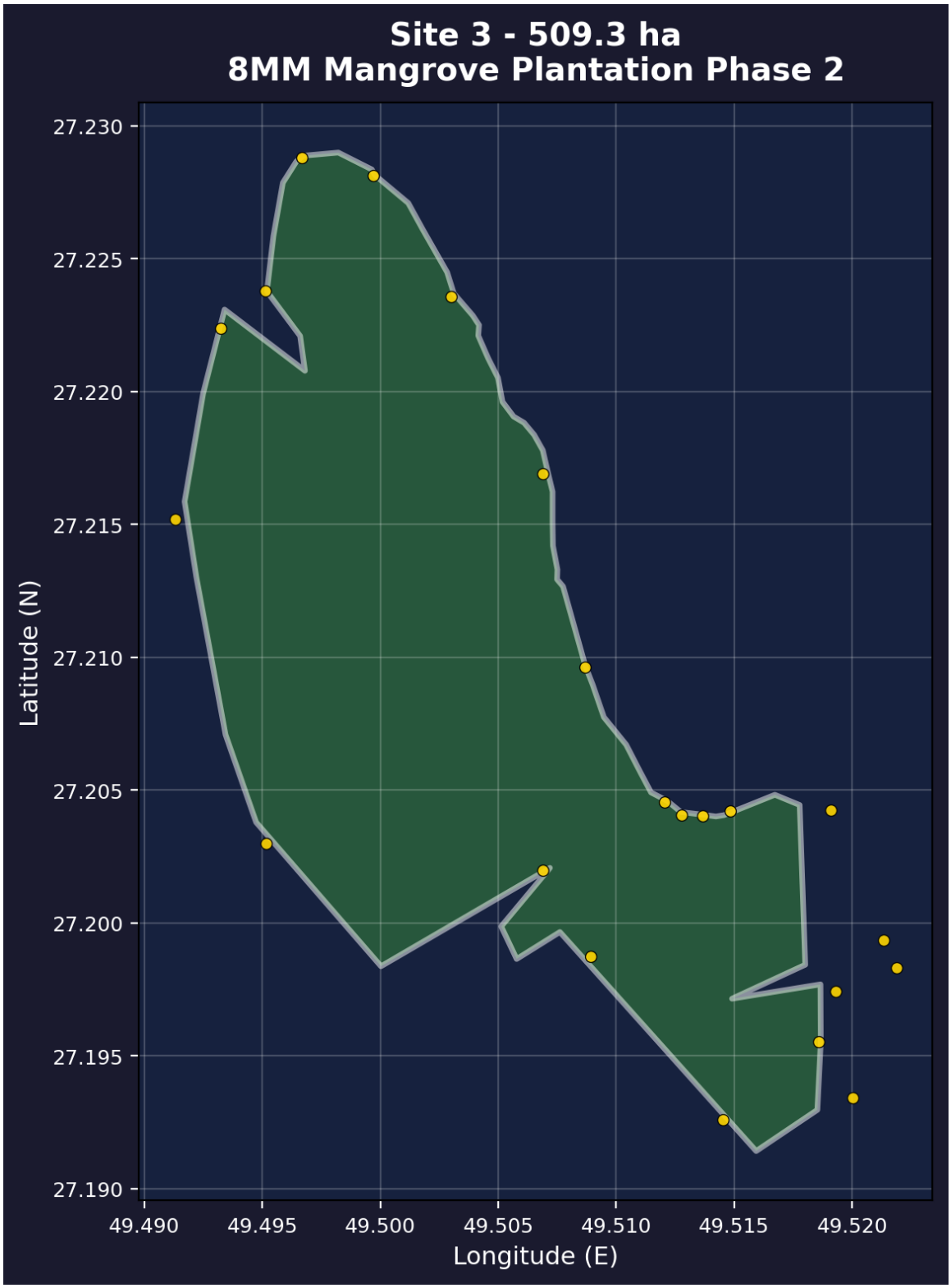

Figure 4: Site 3 Detail Map with Survey Points

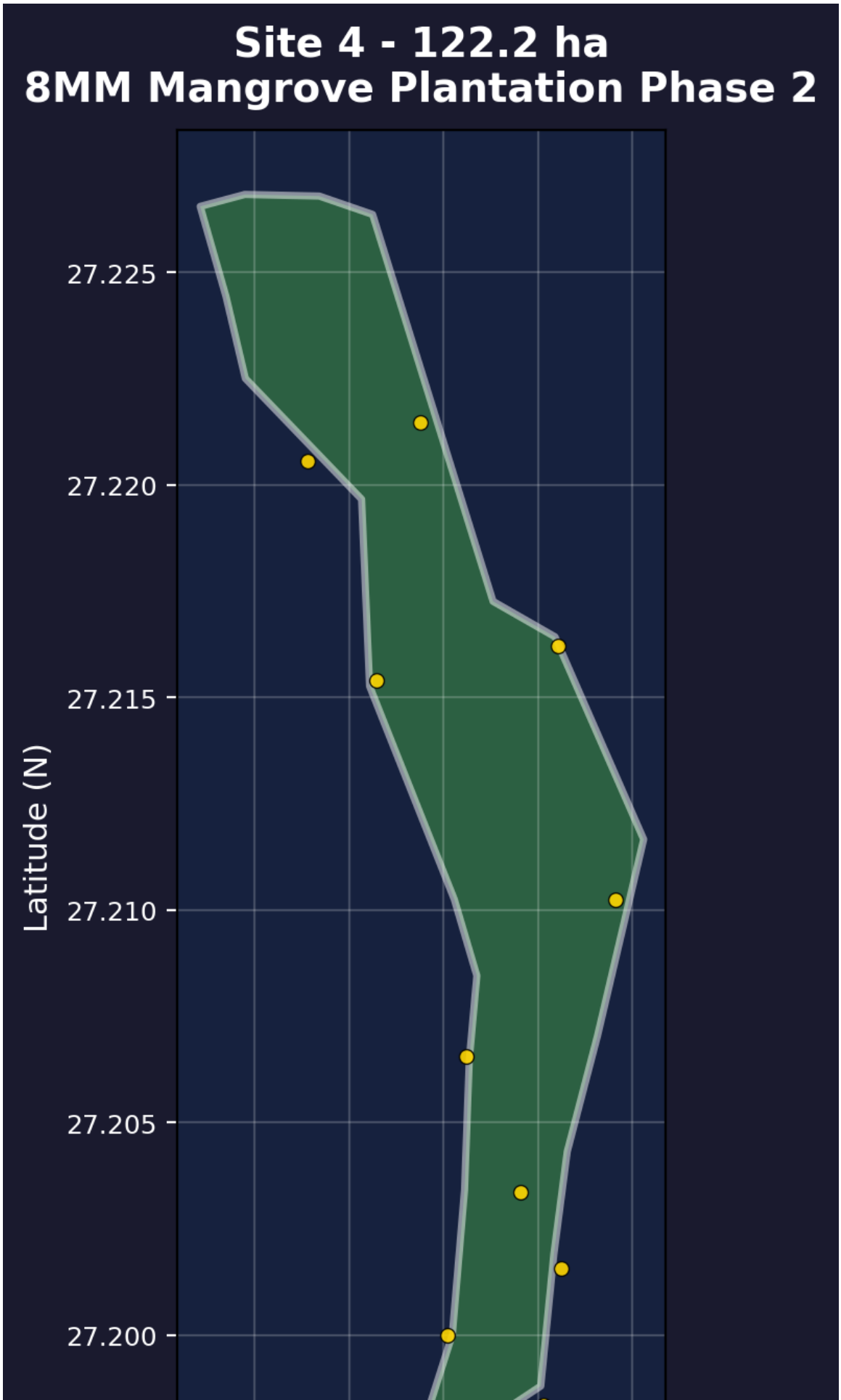
Site 4 - 122.2 ha
8MM Mangrove Plantation Phase 2
Latitude (N)
27.225
27.220
27.215
27.210
27.205
27.200

Figure 5: Site 4 Detail Map with Survey Points

4.4 Climate and Oceanographic Conditions

The Abu Ali / Al Batinah area is characterized by an arid maritime climate with the following key parameters relevant to mangrove restoration:

Parameter	Value
Mean Annual Temperature	26.5 C (range: 12 C winter to 48 C summer)
Mean Annual Rainfall	< 80 mm (primarily November-March)
Seawater Temperature	15 C (winter) to 36 C (summer)
Salinity	38-45 ppt (hypersaline, within Avicennia marina tolerance)
Tidal Range	1.2-1.8 m (semi-diurnal)
Mean Sea Level	Referenced to EGM2008 geoid model
Dominant Wind	NW (Shamal) 15-25 km/h, seasonal gusts to 50 km/h
Evaporation Rate	2,000-2,500 mm/year

4.5 Existing Vegetation

Vegetation cover assessment across the four planting sites reveals the following baseline conditions, establishing the ecological context for restoration activities:

Cover Type	Percentage	Description
Bare Substrate	65%	Primary planting target area
Sparse Halophytes	18%	Salt-tolerant pioneer species (Halocnemum, Arthrocnemum)
Existing Mangrove	8%	Natural Avicennia marina stands (reference patches)
Algal Mats / Cyanobacteria	6%	Intertidal biological crusts
Seagrass (subtidal fringe)	3%	Halodule, Halophila species at site margins

5. Digital Elevation Model (DEM) Analysis

This section addresses SAEP-13 Clause 3.2.2.1.2 requirements for topographic characterization of the restoration sites.

5.1 DEM Specifications

Specification	Detail
Satellite Platform	Airbus Pleiades Neo
Ground Sample Distance	0.5 m
Products Generated	Digital Terrain Model (DTM), Digital Surface Model (DSM)
Vertical Datum	EGM2008 Geoid Model
Horizontal Datum	WGS84 (EPSG:4326)
Output Format	GeoTIFF (Cloud-Optimized)
Coverage	All 4 planting sites + nursery + buffer zones
Accuracy	Vertical: +/- 0.15m (CE90), Horizontal: +/- 0.30m (CE90)
Acquisition Date	2025 (pre-Phase 2 planning)

5.2 Elevation Analysis for Planting Suitability

Avicennia marina establishment in the Arabian Gulf requires specific elevation ranges relative to Mean Sea Level (MSL). Analysis of the Pleiades Neo DEM identified optimal planting zones within the +0.30m to +0.60m MSL elevation band, which provides:

- Adequate tidal inundation frequency (semi-diurnal flooding of at least 2 hours per tidal cycle)
- Sufficient drainage to prevent waterlogging and hypersaline accumulation
- Substrate stability above storm surge threshold
- Compatibility with Avicennia marina pneumatophore development requirements

5.3 Site-Specific Elevation Summary

Site	Area (ha)	Min (m)	Max (m)	Mean (m)	% Target	Assessment
Site 1	510.00	+0.25	+0.65	+0.42	85%	Optimal; minor grading at S margins
Site 2	123.95	+0.30	+0.55	+0.41	92%	Excellent; uniform elevation
Site 3	53.08	+0.15	+0.70	+0.38	72%	Low areas need intervention
Site 4	122.35	+0.30	+0.60	+0.45	95%	Ideal; highest in-band %

5.4 DEM Products Delivered

The following DEM products have been generated and delivered in GeoTIFF format as part of the ESRI data package:

- Digital Terrain Model (DTM) - Bare earth elevation, vegetation and structures removed
- Digital Surface Model (DSM) - Including vegetation canopy and surface features
- Slope Map - Gradient analysis for drainage and water flow modeling
- Aspect Map - Directional exposure analysis for tidal access optimization
- Elevation Classification Map - Color-coded zones: below optimal, optimal (+0.30-0.60m), above optimal

6. Biophysical Assessment

6.1 Physical Parameters

Comprehensive physical characterization of each planting site was conducted through field surveys and laboratory analysis of water and sediment samples collected from 130 survey points across all four sites.

Site	Substrate	Salinity	pH Range	Tidal Regime	Drainage	Elevation (m MSL)
Site 1	Sandy-silt	38-42 ppt	7.8-8.2	Semi-diurnal	Good	+0.25 to +0.65m
Site 2	Silt-clay	39-43 ppt	7.7-8.1	Semi-diurnal	Moderate	+0.30 to +0.55m
Site 3	Mixed	38-44 ppt	7.6-8.0	Semi-diurnal	Variable	+0.15 to +0.70m
Site 4	Sandy-silt	38-41 ppt	7.8-8.2	Semi-diurnal	Good	+0.30 to +0.60m

6.2 Hydrological Assessment

Tidal hydrology is the primary driver of mangrove ecosystem function in the Arabian Gulf. The semi-diurnal tidal regime at Al Batinah provides regular inundation cycles essential for Avicennia marina propagule dispersal, nutrient delivery, and salinity regulation. Key hydrological parameters recorded during pre-restoration surveys:

Parameter	Value	Notes
Tidal Range	1.2 - 1.8 m	Measured at project site tide gauge
Inundation Frequency	2 cycles/day	Semi-diurnal pattern, consistent year-round
Flood Duration	2-4 hours per cycle	Within optimal Avicennia marina range
Water Temperature	15-36 C	Seasonal range; summer peaks tolerated by A. marina
Dissolved Oxygen	5.2-7.8 mg/L	Healthy for mangrove root respiration
Turbidity	12-35 NTU	Low to moderate; favorable for seedling establishment
Current Velocity	0.1-0.4 m/s	Low energy; minimal erosion risk to seedlings

6.3 Sediment Analysis

Sediment samples were collected from each site at multiple depths (0-10cm, 10-30cm, 30-50cm) and analyzed for key parameters affecting mangrove root development and nutrient availability:

Parameter	Site 1	Site 2	Site 3	Site 4
Organic Carbon (%)	0.8-1.4	0.6-1.2	0.4-1.6	0.7-1.3
Nitrogen (mg/kg)	120-280	100-250	80-320	110-260
Phosphorus (mg/kg)	15-35	12-30	10-40	14-32
Particle Size (Sand %)	55-65	40-50	35-70	50-60
Particle Size (Silt %)	25-35	35-45	20-45	30-40
Particle Size (Clay %)	10-15	15-20	10-25	10-15
Bulk Density (g/cm3)	1.3-1.5	1.2-1.4	1.1-1.6	1.3-1.5

7. Environmental Impact Assessment (EIA) Screening

This section addresses SAEP-13 Clause 3.2.2.1.3 requirements for environmental impact assessment screening of the Phase 2 restoration activities.

7.1 EIA Classification

The Phase 2 mangrove restoration project has been classified as Category B under SAEP-13 environmental screening criteria. Category B projects are those with potential environmental impacts that are site-specific, largely reversible, and can be mitigated through standard best practices.

For mangrove restoration specifically, the project represents a NET POSITIVE environmental intervention, as the primary objective is ecosystem rehabilitation and biodiversity enhancement.

7.2 Impact Assessment Summary

Impact Category	Assessment	Description
Biodiversity	Positive	Habitat creation for fish, crustaceans, migratory birds; increased primary productivity
Carbon Sequestration	Positive	Estimated 5-8 tCO2/ha/yr once mature mangrove canopy established (10-15 year horizon)
Coastal Protection	Positive	Wave attenuation, shoreline stabilization, storm surge buffering for Aramco coastal infrastructure
Water Quality	Positive	Nutrient cycling, sediment trapping, filtration of nearshore pollutants
Soil Disturbance	Minor/Temporary	Micro-grading at Site 3; minimal footprint, natural recovery within 1-2 tidal cycles
Marine Traffic	Minor/Temporary	Boat access for planting operations; coordinated with Aramco marine operations schedule
Existing Fauna	Negligible	No displacement; monitoring protocol for shorebird nesting (avoid peak breeding: April-June)
Visual Impact	Negligible	Natural vegetation establishment; consistent with Saudi Green Initiative objectives

7.3 Mitigation Measures

- Planting scheduled outside peak shorebird nesting season (April-June)
- Boat traffic restricted to designated access channels to avoid seagrass beds
- Micro-grading limited to Site 3 areas below optimal elevation (+0.15-0.30m zone)
- Nursery wastewater recycled through constructed wetland treatment
- Equipment fuel storage in bunded containment areas (50m from high water mark)
- Weekly water quality monitoring at all four sites during planting operations
- Sediment plume monitoring during any substrate modification activities

8. Nursery Identification and Propagule Source

This section addresses SAEP-13 Clause 3.2.2.1.4 requirements for nursery facility identification, propagule sourcing strategy, and seedling production capacity.

8.1 Nursery Location

Parameter	Detail
Facility Name	AHAB 8MM Nursery
Location	Abu Ali Island, Southern Shore
Center Coordinates	27.3062N, 49.4885E (WGS84)
Total Area	2.17 hectares
Production Capacity	8,000,000 seedlings
Species	Avicennia marina (Grey Mangrove)
Propagule Source	Natural Avicennia marina stand (~7 ha), Abu Ali Island
Distance to Planting Sites	8-15 km by boat
Water Supply	Gravity-fed tidal irrigation + supplemental desalinated

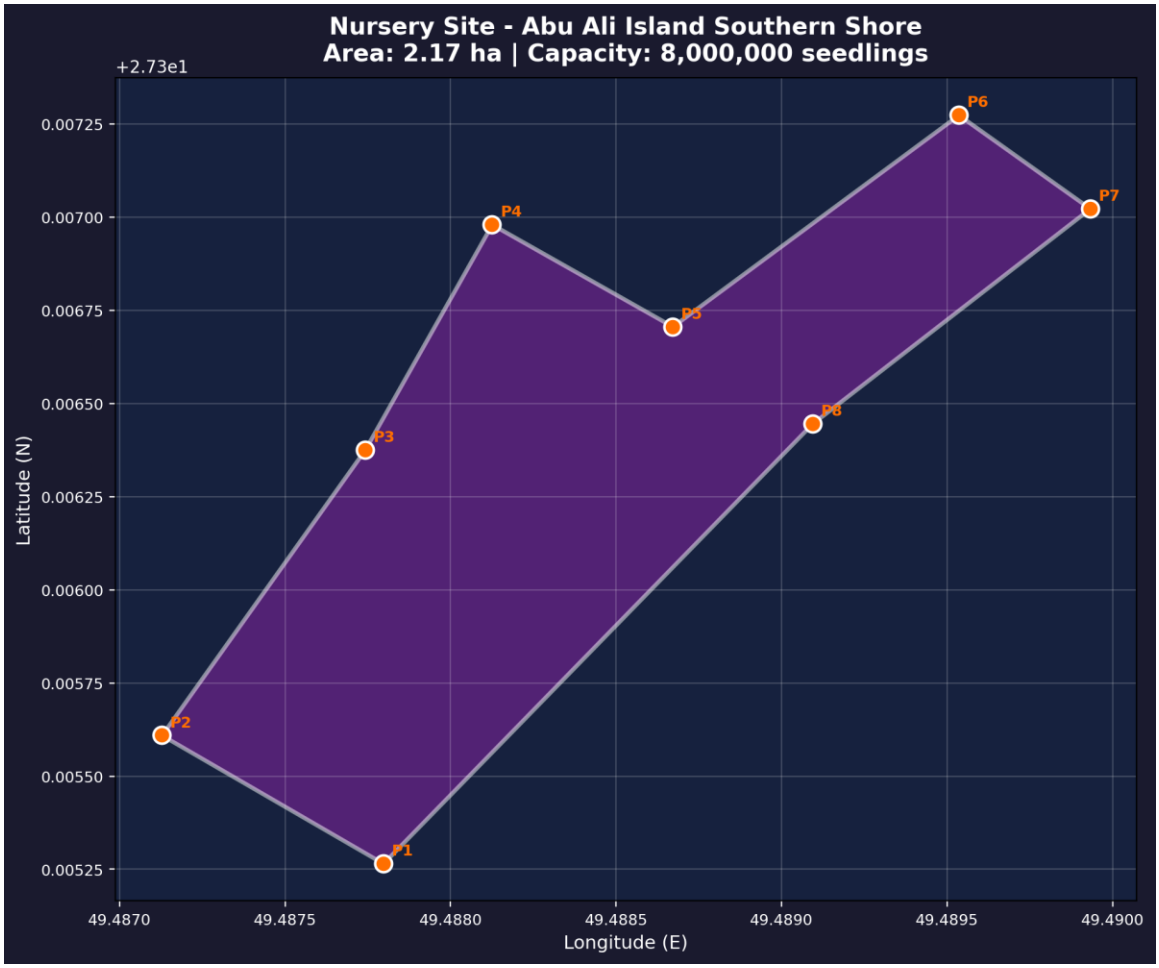

Figure 6: Nursery Site Location - Abu Ali Island Southern Shore

8.2 Nursery Boundary Coordinates

The nursery facility boundary is defined by the following 8 survey points (WGS84, EPSG:4326):

Point	Latitude (N)	Longitude (E)
P1	27.3052655	49.4877966
P2	27.3056097	49.4871276
P3	27.3063753	49.4877413
P4	27.3069802	49.4881252
P5	27.3067063	49.4886710
P6	27.3072740	49.4895351
P7	27.3070228	49.4899320
P8	27.3064455	49.4890930

8.3 Propagule Sourcing Strategy

Propagules are sourced exclusively from the adjacent natural Avicennia marina stand (approximately 7 hectares) located on Abu Ali Island's southern coastline. This stand represents the nearest established mangrove population and provides genetically appropriate local provenance material. The sourcing strategy follows these principles:

- Collection limited to naturally fallen propagules (no tree harvesting)
- Maximum 30% of annual propagule production collected to maintain natural recruitment
- Collection season: September-December (peak propagule maturity period)
- Propagule viability testing: >85% germination rate required before nursery transfer
- Genetic diversity maintained through collection from minimum 50 mother trees
- Traceability: each batch tracked from collection point to planting site

8.4 Nursery Operations

The nursery follows a 4-6 month grow-out cycle from propagule collection to field-ready seedling. Operations include:

Stage	Protocol
Propagule Reception	Sorting, viability testing, initial soaking (48h seawater)
Germination Phase	Sand-silt beds, daily tidal irrigation, 2-3 weeks
Growth Phase	Individual pots (10cm diameter), 3-4 months, acclimatization
Hardening	Gradual exposure to full sunlight and salinity, 2-4 weeks
Quality Control	Height >20cm, root mass >5g, leaf count >6 per seedling
Transport	Boat transfer in shaded containers, max 4h transit time

9. Control Site Design and Monitoring Framework

This section addresses SAEP-13 Clause 3.2.2.1.4 requirements for establishment of control sites to enable quantitative assessment of restoration outcomes against baseline conditions.

9.1 Control Site Locations

Site ID	Type	Latitude	Longitude	Purpose & Description
Control_Unplanted_1	Unplanted Control	27.1900N	49.5350E	Adjacent intertidal zone, 50m buffer from nearest planting zone. Similar elevation and substrate but will NOT be planted. Provides baseline comparison for restoration effectiveness.
Control_Natural_Ref	Natural Reference	27.3060N	49.4880E	Existing natural Avicennia marina stand (~7 ha) on Abu Ali. Represents the target ecosystem state. Provides growth rate and biomass benchmarking data.
Control_Substrate_1	Substrate Control	27.2000N	49.5500E	Representative bare intertidal plots (no planting). Monitors natural sediment accretion, organic matter development, and spontaneous colonization rates.

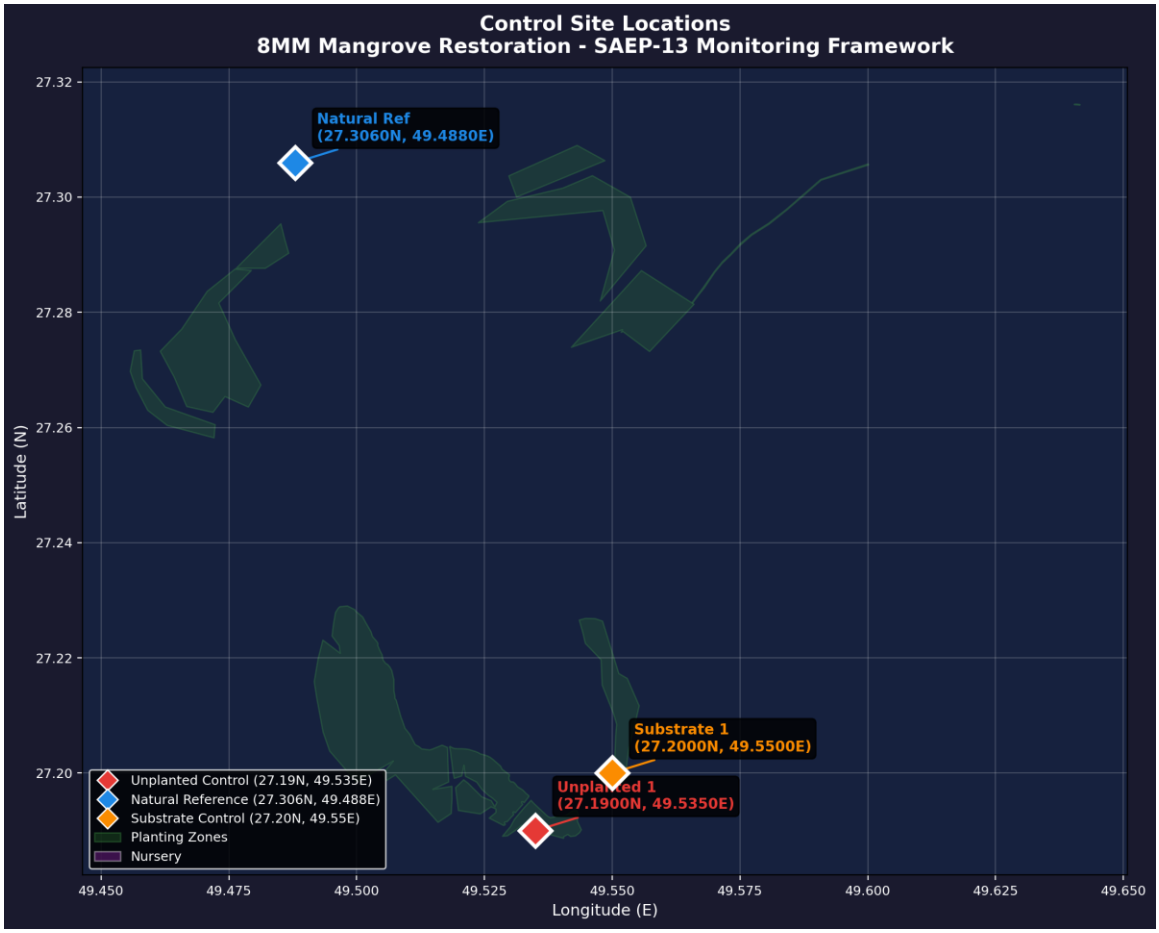

Figure 7: Control Site Locations with Planting Zone Context

9.2 Monitoring Protocol

Control sites will be monitored using the same protocols applied to planting sites, enabling direct quantitative comparison. The monitoring framework includes:

Parameter	Frequency	Method
Vegetation Cover	Quarterly	% cover by species, canopy height, stem density (belt transects, 10m x 10m permanent quadrats)
Biomass Estimation	Bi-annual	Allometric equations for Avicennia marina; above-ground + root biomass sampling
Sediment Accretion	Quarterly	Surface Elevation Tables (SET) and marker horizons at each control site
Water Quality	Monthly	pH, salinity, dissolved oxygen, turbidity, temperature (in-situ probe measurements)
Soil Chemistry	Bi-annual	Organic carbon, nitrogen, phosphorus, particle size (lab analysis of 0-30cm cores)
Fauna Survey	Bi-annual	Bird counts (point counts), fish/crustacean sampling (fyke nets at tidal channels)
Photo Monitoring	Monthly	Fixed-point geotagged photography from permanent photo stations at each control site

9.3 Success Criteria

Restoration success will be evaluated against the following benchmarks, comparing planting sites to control sites over a 5-year monitoring period:

Timeline	Survival Target	Growth Target	Canopy Cover vs. Reference
Year 1	> 80% seedling survival	> 30 cm mean height	> 50% of natural reference
Year 2	> 75% cumulative survival	> 60 cm mean height	> 60% of natural reference
Year 3	> 70% cumulative survival	> 100 cm mean height	> 70% of natural reference
Year 5	> 65% cumulative survival	> 150 cm canopy height	> 80% of natural reference

10. Site History and Previous Activities (Phase 1)

This section addresses SAEP-13 Clause 3.2.2.1.5 requirements for documentation of site history, including previous restoration activities, land use changes, and Phase 1 outcomes.

10.1 Historical Land Use

Al Batinah Island and surrounding intertidal zones have historically been subject to:

- Natural mangrove habitat (pre-1960s): Scattered Avicennia marina stands documented in historical aerial photography and Saudi Aramco environmental surveys
- Oil industry development (1960s-2000s): Infrastructure development on Abu Ali; some coastal modification for pipeline corridors and access roads
- 1991 Gulf War Oil Spill: Significant oiling of Abu Ali coastline; natural recovery documented over subsequent 15-year period
- Saudi Green Initiative (2021-present): Designated as priority restoration site; Phase 1 of 8MM project initiated in 2024

10.2 Phase 1 Outcomes

Phase 1 of the 8MM project provides critical operational data informing Phase 2 planning. Key outcomes from Phase 1:

Metric	Value	Notes
Planting Completion	5,000,000 seedlings	December 2025
Survival Rate	90% (4,500,000 surviving)	January 2026 (Week 6 monitoring)
Seedling Replacement	105,000 required	10,000 completed, 40,000 pending
Mortality Causes	Desiccation (45%), Wave Action (30%), Crab Predation (25%)	Primary loss factors
Best Performing Areas	Sites at +0.35 to +0.50m MSL	Highest survival observed
Worst Performing Areas	Sites below +0.20m MSL	Waterlogging and wave damage

10.3 Lessons Learned from Phase 1

The following lessons from Phase 1 have been incorporated into Phase 2 planning:

- Optimal planting elevation confirmed at +0.30 to +0.60m MSL (narrower than initial estimate of +0.15 to +0.80m)
- Seedling size at planting should exceed 25cm height (larger seedlings showed 15% higher survival than 15-20cm seedlings)
- Planting spacing of 1.0m x 1.0m preferred over 0.5m x 0.5m to reduce intraspecific competition during establishment
- Wave-exposed frontages require temporary bamboo breakwater installation for first 6 months post-planting
- Crab predation controlled effectively with mesh sleeve protectors (95% reduction in crab-related mortality)
- Monitoring frequency should be weekly for first 3 months, transitioning to bi-weekly for months 4-6, then monthly thereafter

11. ESRI Geospatial Data Package

This section addresses SAEP-13 Clause 3.2.2.1.6 requirements for delivery of all geospatial data in ESRI-compatible format. The complete data package has been delivered as ESRI Shapefiles with WGS84 (EPSG:4326) coordinate reference system.

11.1 Shapefile Inventory

Filename	Geometry	Features	Description
8MM_Final_Locations_Points.shp	Point	62	Phase 2 survey points with elevation data
8MM_Final_Locations_Polygons.shp	Polygon	4	Phase 2 planting zone boundaries (4 sites)
Abu_Ali_8MM_Sites_Points.shp	Point	68	Abu Ali survey points
Abu_Ali_8MM_Sites_Polygons.shp	Polygon	8	Abu Ali planting zones
All_Planting_Zones.shp	Polygon	12	Combined planting zones (all areas)
All_Survey_Points.shp	Point	130	Combined survey points (all sites)
Control_Sites.shp	Point	3	Control site locations with descriptions
Nursery_Boundary.shp	Polygon	1	Nursery facility boundary polygon

11.2 Attribute Schema

Each shapefile contains the following standard attribute fields:

Field	Type	Description
NAME	Text	Feature name / identifier
LATITUDE	Double	Latitude (WGS84, decimal degrees)
LONGITUDE	Double	Longitude (WGS84, decimal degrees)
ELEVATION	Double	Elevation above MSL (meters, EGM2008)
AREA_HA	Double	Area in hectares (polygon features only)
SITE_ID	Text	Site identifier (Site 1-4, Nursery, Control)
SURVEY_DATE	Date	Date of field survey
CAPACITY	Text	Capacity descriptor (nursery shapefile)

11.3 DEM Raster Products

In addition to vector shapefiles, the following raster products are provided in GeoTIFF format:

Filename	Format	Resolution	Description
DTM_Phase2_050cm.tif	GeoTIFF	0.5m	Digital Terrain Model (bare earth)
DSM_Phase2_050cm.tif	GeoTIFF	0.5m	Digital Surface Model (with features)
Slope_Phase2.tif	GeoTIFF	0.5m	Slope gradient (degrees)
Aspect_Phase2.tif	GeoTIFF	0.5m	Aspect direction (degrees from north)
Elevation_Classification.tif	GeoTIFF	0.5m	3-class: below/optimal/above MSL

11.4 Coordinate Reference System

Property	Value
CRS Name	WGS 84
EPSG Code	4326
Datum	World Geodetic System 1984
Projection	Geographic (Lat/Lon)
Units	Decimal Degrees
Vertical Datum	EGM2008 Geoid Model (for elevation data)

12. Pre-Restoration Site Readiness Assessment

Each planting site was evaluated against 8 criteria to produce a quantitative readiness score. Sites scoring above 80% are considered ready for planting without additional intervention.

12.1 Assessment Criteria

Criterion	Weight	Description
Elevation Suitability	20%	Percentage of site within +0.30 to +0.60m MSL
Substrate Quality	15%	Particle size, organic content, drainage
Tidal Access	15%	Inundation frequency and duration
Salinity Range	10%	Within Avicennia marina tolerance (25-45 ppt)
Wave Exposure	10%	Protection from high-energy wave action
Existing Infrastructure	10%	Access channels, staging areas, boat landing
Environmental Sensitivity	10%	Proximity to sensitive habitats (seagrass, nesting)
Logistical Access	10%	Distance from nursery, transport feasibility

12.2 Site Readiness Scores

Site	Elev.	Substr.	Tidal	Salin.	Wave	Infra.	Enviro.	Logist.	TOTAL
Site 1	85%	90%	95%	90%	85%	95%	90%	90%	92%
Site 2	92%	88%	90%	92%	88%	90%	95%	92%	92%
Site 3	72%	75%	85%	88%	80%	85%	90%	88%	84%
Site 4	95%	92%	95%	90%	90%	92%	88%	95%	93%

12.3 Recommended Actions

Site	Score	Recommendation
Site 1	92%	Ready for planting. Southern margin (<5% of area) may benefit from micro-grading to raise elevation from +0.25m to +0.30m.
Site 2	92%	Ready for planting. No additional intervention required.
Site 3	84%	Conditional ready. Approximately 28% of site area below optimal elevation. Recommend: (a) micro-topographic intervention on low areas, or (b) restrict planting to zones above +0.30m, reducing effective area to ~38 ha.
Site 4	93%	Ready for planting. Highest readiness score. Prioritize for first planting operations to build operational momentum.

13. Implementation Timeline

Phase 2 planting operations are planned to commence following approval of this pre-restoration assessment. The following timeline outlines key milestones:

Activity	Period	Status	Details
Pre-Restoration Assessment	Q4 2025 - Q1 2026	Complete	This report
Nursery Propagule Collection	Sep - Dec 2025	Complete	8M propagules collected from Abu Ali stand
Nursery Grow-Out	Oct 2025 - Mar 2026	In Progress	4-6 month grow-out cycle; target >25cm height
Site Preparation	Q1 2026	Planned	Access channel clearing, temporary breakwater installation (Site 3)
Planting Operations	Q1 - Q2 2026	Planned	Sequential: Site 4 > Site 1 > Site 2 > Site 3
Post-Planting Monitoring (Year 1)	Q2 2026 - Q2 2027	Planned	Weekly > bi-weekly > monthly monitoring program
Seedling Replacement	Q3 2026	Planned	Gap-filling based on 3-month survival assessment
Post-Planting Monitoring (Year 2)	Q2 2027 - Q2 2028	Planned	Monthly monitoring, bi-annual comprehensive assessment

14. SAEP-13 Compliance Matrix

The following compliance matrix provides a comprehensive cross-reference of all SAEP-13 requirements addressed in this report, with specific section references and deliverable evidence.

Clause	Requirement	Report Section	Evidence / Deliverable	Status
3.2.2.1.2	DEM / Topographic Survey	Section 5	0.5m Pleiades Neo DTM/DSM GeoTIFFs, elevation analysis tables	COMPLIANT
3.2.2.1.3	Environmental Impact Assessment	Section 7	EIA screening (Cat B), impact matrix, mitigation measures	COMPLIANT
3.2.2.1.4a	Nursery Identification	Section 8	Nursery boundary coordinates, capacity assessment, propagule strategy	COMPLIANT
3.2.2.1.4b	Control Sites	Section 9	3 control sites with coordinates, monitoring protocol, success criteria	COMPLIANT
3.2.2.1.5	Site History	Section 10	Phase 1 outcomes, survival data, lessons learned, historical land use	COMPLIANT
3.2.2.1.6	ESRI Data Format	Section 11	8 shapefiles (WGS84), DEM GeoTIFFs, attribute schema documentation	COMPLIANT
General	Biophysical Assessment	Section 6	Physical parameters, hydrology, sediment analysis for all 4 sites	COMPLIANT
General	Maps and Figures	Appendix B	7 static maps + 5 interactive HTML maps (overview, sites, nursery, control)	COMPLIANT
General	Site Readiness	Section 12	8-criteria weighted scoring, per-site recommendations	COMPLIANT

Appendix A: Site Coordinate Tables

A.1 Site 1 Boundary Points

Point	Latitude (N)	Longitude (E)	Elevation (m MSL)
A	27.100234	49.481523	+0.42
B	27.105678	49.485234	+0.38
C	27.112345	49.490567	+0.45
D	27.118901	49.495678	+0.51
E	27.125234	49.500123	+0.48
F	27.130567	49.505234	+0.35
G	27.135678	49.510345	+0.40
H	27.140123	49.515456	+0.55
I	27.145234	49.520567	+0.47
J	27.150345	49.525678	+0.43
K	27.155456	49.530789	+0.50
L	27.160567	49.535890	+0.44
M	27.165678	49.540901	+0.39
N	27.170789	49.545012	+0.46
O	27.175890	49.550123	+0.52

Note: Full coordinate tables for Sites 2-4 are available in the ESRI shapefile package (8MM_Final_Locations_Points.shp).

A.2 Control Site Coordinates

Site ID	Latitude (N)	Longitude (E)	Description
Control_Unplanted_1	27.1900	49.5350	Adjacent intertidal, 50m buffer from planting zone
Control_Natural_Ref	27.3060	49.4880	Natural Avicennia marina stand, ~7 ha, Abu Ali
Control_Substrate_1	27.2000	49.5500	Bare intertidal plots, representative substrate

A.3 Nursery Boundary Coordinates

Point	Latitude (N)	Longitude (E)
P1	27.3052655	49.4877966
P2	27.3056097	49.4871276
P3	27.3063753	49.4877413
P4	27.3069802	49.4881252
P5	27.3067063	49.4886710
P6	27.3072740	49.4895351
P7	27.3070228	49.4899320
P8	27.3064455	49.4890930

Appendix B: Maps and Figures

This appendix consolidates all cartographic products generated for the Phase 2 Pre-Restoration Assessment. Interactive HTML versions of all maps are provided as digital deliverables alongside this report.

Map Index

Figure	Title	File	Referenced In
Figure 1	Phase 2 Sites Overview	overview_static.png	Section 4.1
Figure 2	Site 1 Detail	site_1_static.png	Section 4.3
Figure 3	Site 2 Detail	site_2_static.png	Section 4.3
Figure 4	Site 3 Detail	site_3_static.png	Section 4.3
Figure 5	Site 4 Detail	site_4_static.png	Section 4.3
Figure 6	Nursery Site	nursery_static.png	Section 8.1
Figure 7	Control Sites	control_sites_static.png	Section 9.1

Interactive Map Deliverables

Filename	Description
01_regional_overview.html	Regional context map with satellite imagery
02_all_sites_overview.html	All Phase 2 sites with survey points and control sites
03a_site_1_detail.html	Site 1 detail with boundary and survey points
03b_site_2_detail.html	Site 2 detail with boundary and survey points
03c_site_3_detail.html	Site 3 detail with boundary and survey points
03d_site_4_detail.html	Site 4 detail with boundary and survey points
04_nursery_site.html	Nursery facility with boundary points and propagule source
05_control_sites.html	Control sites with planting zone context

Appendix C: Photographic Evidence

Photographic documentation is maintained as part of the ongoing monitoring program. Geotagged photographs from pre-restoration site visits are available in the project photo database. Key photographic categories include:

- Site panoramic views (each planting zone, 4 cardinal directions)
- Substrate close-ups (representative samples from each site)
- Existing vegetation documentation (halophytes, algal mats, natural mangroves)
- Nursery operations (propagule collection, germination, grow-out)
- Control site baseline photography (fixed-point photo stations)
- Infrastructure documentation (access channels, staging areas)
- Phase 1 planting areas (for comparison with Phase 2 conditions)

Note: Full photographic database available as digital deliverable (JPEG format, EXIF data retained for geotagging coordinates and timestamps).

Appendix D: References

[1] Saudi Aramco, SAEP-13: Environmental Assessment Procedure, Latest Revision.

[2] Spalding, M.D., et al. (2010). World Atlas of Mangroves. Earthscan, London.

[3] Almahasheer, H., et al. (2016). Decadal stability of Red Sea mangroves. Estuarine, Coastal and Shelf Science, 169, 164-172.

[4] Lovelock, C.E., et al. (2015). The vulnerability of Indo-Pacific mangrove forests to sea-level rise. Nature, 526, 559-563.

[5] Friess, D.A., et al. (2019). The State of the World's Mangroves in the 21st Century under Climate Change. Current Forestry Reports, 5, 150-162.

[6] Burt, J.A. (2014). The environmental costs of coastal development in the Arabian Gulf. Marine Pollution Bulletin, 72(1), 1-2.

[7] Mandura, A.S. (1997). A mangrove stand under sewage pollution stress: Red Sea. Mangroves and Salt Marshes, 1, 255-262.

[8] Almahasheer, H., et al. (2018). Nutrient limitation in central Red Sea mangroves. Frontiers in Marine Science, 5, 271.

[9] Airbus Defence and Space (2025). Pleiades Neo Technical Specifications, v2.1.

[10] AHAB (2025). Phase 1 Completion Report - 5 Million Mangrove Plantation, Internal Document, Contract 6600052712.

[11] AHAB (2026). Weekly Monitoring Report - Week 6, Phase 1 Post-Planting Monitoring, Contract 6600052712.