

FLOOD RISK ASSESSMENT

FOR

**GHANA NATIONAL GAS LIMITED COMPANY
PROCESSING PLANT TRAIN 1 & 2 (GPP 1 & 2)**

ATUABO, ELLEMBELLE DISTRICT



PREPARED BY

ODUN ENVIRONMENTAL LTD.



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January 2024

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Abbreviations

AMSL	Above Mean Sea Level
CB-FEWS	community-based flood early warning systems
CMIP	Coupled Model Inter-comparison Projects
DRH	Direct Runoff Hydrograph
DSBC	Downstream Boundary Condition
FRA	Flood Risk Assessment
FRM	flood risk management
FRMG	Flood Risk Management Guidelines
GHG	Greenhouse Gas
GMet	Ghana Meteorological Agency
GNGLC	Ghana National Gas Limited Company
GNSS	Global navigation satellite system
GPP	Gas Processing Plant
GWP	Global Water Partnership
HEC-RAS	Hydrologic Engineering Center's - River Analysis System
HSD	Hydrological Services Department
IDF	Intensity Duration Frequency
LiDAR	Light Detection and Ranging
LPG	Liquefied Petroleum Gas
MSL	Mean Sea Level
NADMO	National Disaster Management Organization
NCCP	National Climate Change Policy
NDMP	National Disaster Management Policy
NEP	National Environmental Policy
NFEWS	National Flood Early Warning System
NGO	Non-governmental organization
NSP	National Sanitation Policy
NUP	National Urban Policy
NWP	National Water Policy
RTK	Real-Time Kinematic
SCS	Soil Conservation Service
SSP	Shared Socioeconomic Pathways

TEN fields	Tweneboa-Enyenra-Ntomme Fields
UTM	Universal Transverse Mercator
VRA	Volta River Authority
WGS84	World Geodetic System 1984
WRC	Water Resources Commission

1 Executive Summary

This flood risk assessment report has been prepared for Ghana National Gas Limited Company (GNGLC) processing plant 1 and 2 (GPP 1&2) located in Atuabo, Ellembelle district. The purpose of this report is to assess the flood risk to the plant from all sources of flooding, including Coastal, groundwater, fluvial and pluvial flooding.

Flood risk assessments are essential for ensuring the safety and continuity of operations at gas processing plants to minimize the environmental and safety risks associated with flooding. They are crucial for informed decision-making on plant and facility design, disaster and emergency preparedness and planning, and regulatory compliance.

The report identifies and evaluates the potential risks and consequences of flooding and mitigation measures proposed to ensure the safety of GPP 1&2, the communities around the facility and the reliability of its gas processing operations, comply with safety standards and environmental regulations.

Flood inundation simulation is conducted covering the towns of Atuabo, Asemnda and Anokyi using HEC-RAS. The current condition shows the drainage point just north of the existing GPP1 has a minimal discharge capacity with attenuation of 80 to 90% of the incoming flow. The flow difference results to the water stored at the west side of GPP area leaving it inundated and swampy for an extended period of time.

The existing Atuabo Gas Processing Plant is not affected by flooding. However, it can be observed that some community in the town of Anokyi are susceptible to flood with minor depths of 0.0 – 0.50 meters for the most extreme flood events. It is important to note that this scenario is not caused or intensified by the GPP facilities.

The proposed GPP Train 2 area clearly impedes the natural flow of water which will cause the inundation level at the west to rise even higher. This will then affect the other facility and expand the inundation area without proper drainage.

To prevent this scenario, a drainage culvert is then proposed across the existing road. The discharge will be diverted to the coastal side, instead of the town of Anokyi. This will

effectively eliminate the flooding specifically at the community area. This will also discharge the storage at the west side to prevent other potential major disasters that can occur.

The flood risk assessment also shows the GPP area is not vulnerable to other sources of flooding such as pluvial flooding, coastal flooding and groundwater flooding.

Source of Flooding	Risk Level
Fluvial Flooding	None
Pluvial Flooding	None
Coastal Flooding	None
Groundwater Flooding	None

Considering the research, simulations and analysis conducted, it is strongly recommended that the construction of the new gas processing plant should include the drainage culvert to ease the inundation depth on the west and eliminate the contributed flood water to the town of Anokyi.

The floor level should be elevated to a minimum of 7.0 meters amsl to adapt with the maximum inundation level and ensure a flood free GPP area.

2 Introduction

2.1 Background of the Study

The Ghana gas processing plant of the Ghana National Gas Limited Company in Atuabo Town is a strategic national project that aims to provide a reliable and affordable source of natural gas for domestic use, especially for power generation and industrial applications.

The plant is part of the Western Corridor Gas Infrastructure Project, which involves the development of an integrated gas processing infrastructure that sources natural gas from Ghana's offshore oil fields, such as the Jubilee Oil Field and the TEN fields. The plant has a design capacity of 150 million standard cubic feet per day (MMScfd) and a normal operating capacity of 120 MMScfd. The plant processes the raw gas into various commercial products, such as sales gas, liquefied petroleum gas (LPG) and condensate.

The plant is owned and operated by the Ghana National Gas Limited Company (Ghana Gas or GNGLC), a state-owned entity. The plant is expected to contribute significantly to Ghana's energy security, economic growth, and environmental sustainability.

Ghana Gas Processing Plant Train 2 (GPP 2) involves the construction of a second gas processing plant at Atuabo on the west side of the existing Atuabo Gas Processing Plant. The plant will have a capacity of 225 million standard cubic feet per day (MMscfd) of natural gas, which will be used to generate electricity and supply industries.

The benefits of Ghana Gas Train 2 are manifold. First, it will increase the country's gas processing capacity from 150 MMscfd to 450 MMscfd, which will enable Ghana to utilize its domestic gas resources more efficiently and reduce its dependence on imported gas. Second, it will enhance the reliability and affordability of electricity supply in Ghana, as gas-fired power plants are cheaper and cleaner than oil-fired ones. Third, it will create jobs and stimulate economic growth in the Western Region and beyond, as gas will be available for various industrial uses, such as fertilizer production, petrochemicals, and liquefied petroleum gas (LPG).

Ghana Gas Train 2 is a milestone for the country's energy sector and a testament to its commitment to sustainable development. The project will not only improve Ghana's energy

security but also contribute to its social and environmental goals. By expanding its gas processing capacity, Ghana will be able to reduce its greenhouse gas emissions, diversify its energy mix, and support its transition to a low-carbon economy.



Figure 2-1 Atuabo Gas Processing Plant (GPP1)



Figure 2-2 GPP1 Aerial Photo

2.2 Objectives of the Study

The primary objective of this Flood Risk Assessment is to identify and evaluate potential flood hazards that could affect the gas processing plants (GPP 1 & 2) and its critical infrastructure. The aim is to develop robust mitigation strategies to enhance the facility's resilience and safeguard its operations against flood-related risks as well as perform a thorough analysis, identify potential risk scenarios, and propose effective risk mitigation strategies.

2.3 Detailed Task

The services include the following:

- Desktop study of the areas in order to assess the sites settings, topography, geology, hydrogeological and hydrological conditions including ground water conditions.
- Undertake site inspection and where appropriate carry out site investigation to assess the subsurface conditions at the site.
- Classify and zone the sites flood susceptibility.
- Prepare a comprehensive flood risk assessment report to address all the findings observed. The report shall include technical advice on flood risk potential and recommendations of suitable remedial measures to mitigate potential flooding.

2.4 Scope of Works

The scope of works of this study includes, but is not limited to the following activities:

- Reviewing available data and historical flood records for the site and surrounding area.
- Conducting hydrological and hydraulic modelling to assess flood patterns and potential inundation areas.
- Identify critical assets, equipment, and infrastructure vulnerable to flood risks.
- Evaluating the impact of flooding on plant operations, personnel safety, and environmental considerations.
- Recommending flood mitigation measures, emergency response protocols, and risk management strategies.
- Preparing a comprehensive Flood Risk Assessment report, including maps, diagrams, and vulnerability analysis.

3 Study Area Description

3.1 Project Location

Atuabo is a town in the Western Region of Ghana, located in the Ellembelle District. It is noted for the situation of the Ghana Gas Company's Atuabo Gas Plant and the proposed Atuabo Freeport, which are expected to boost the local economy and create jobs for the people. Atuabo is the last small town that is part of the Ellembelle constituency along the coast of Nzema. It is close to other villages such as Anokyi and Asemnda Suazo; about 32 km away from Nkroful, the capital of Ellembelle District; and 320 km away from Accra, the capital of Ghana.

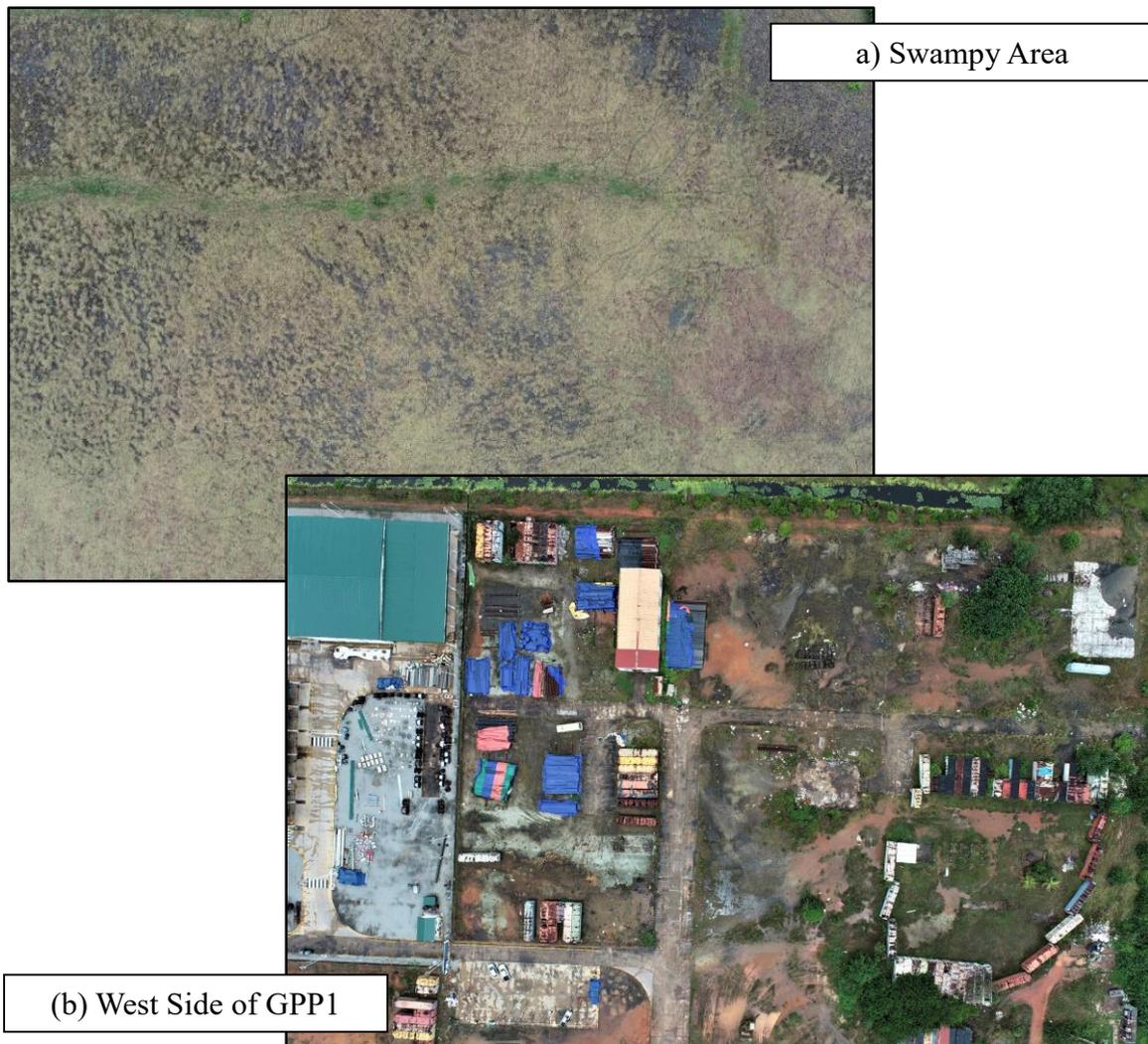


Figure 3-1 Location of the Proposed GPP2 Aerial Photo



Figure 3-2 Google Earth View of the Proposed GPP Train 2

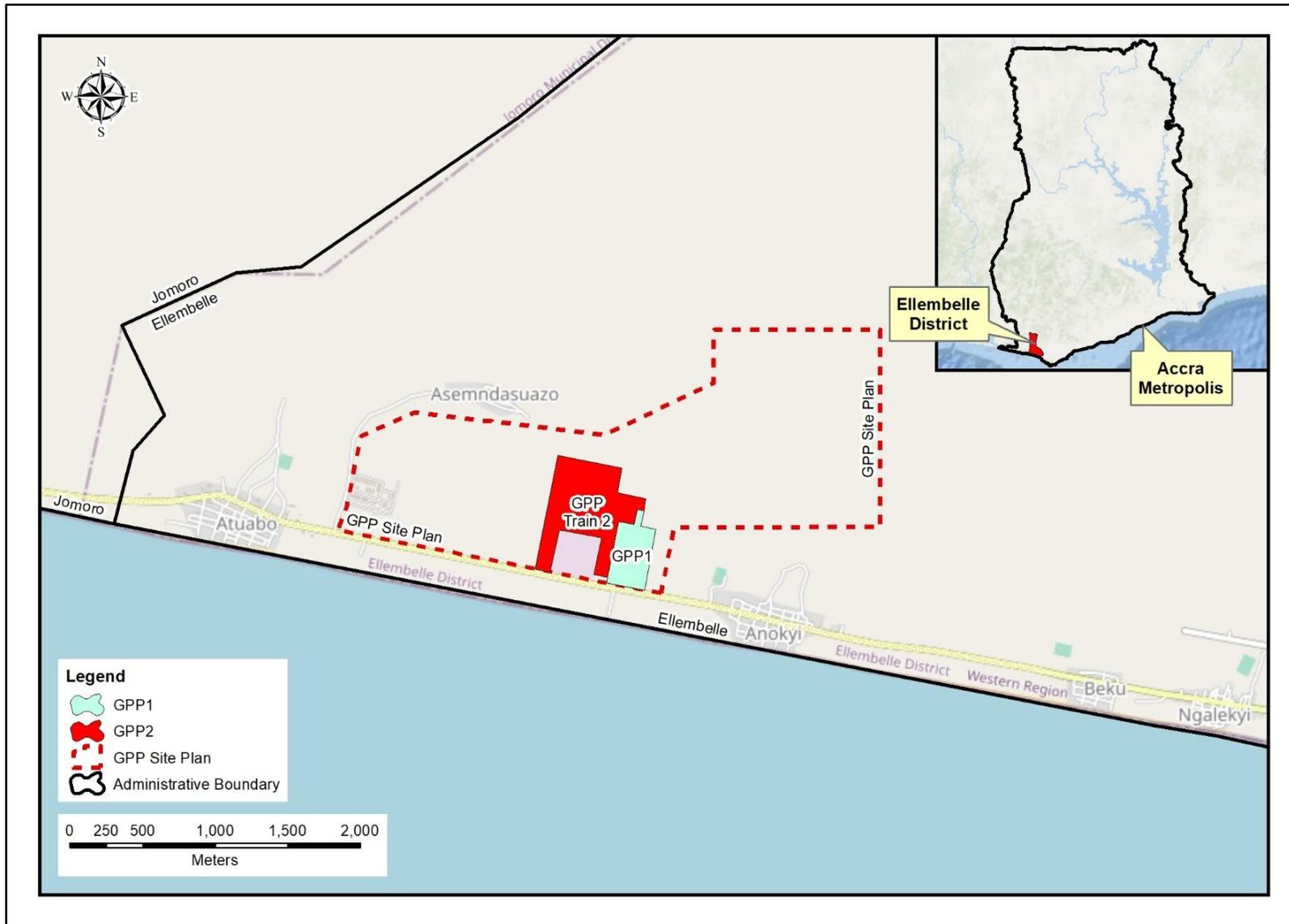


Figure 3-3 Location Map

3.2 Watershed Characteristics

The proposed GPP Train 2 is located within a tributary of the Amansuri River. It has a catchment area of 8.5 sq.km computed at the drainage point located just upstream of the existing GPP1. Its watershed is largely covered with vegetation at the mountainous portion. It is composed mainly of coconut trees, bushes, and grass. The lower portion at the west side of GPP1 is generally a swampy area over a grassland with low level of drainage. Impervious surfaces are also noticeable at the towns of Atuabo and Asemnda including the area of the gas processing plant.

Forested and vegetated land cover has higher roughness surface characteristics that delays runoff, thus, resulting to longer time of concentration and lowers the peak of flood. On the other hand, impervious surfaces allow all rainfall volume to runoff with shorter time of concentration, thus, increases the peak of flood.

3.3 Slope and Elevation

The watershed elevation ranges from 4 to 27 meters with an average of 11 meters. It is characterized as a plain terrain with slopes ranging from 0 to 5% with an average of 0.18%. The proposed GPP Train 2 is located on the low-lying area of the watershed which is a catchbasin due to low drainage capacity and high surrounding elevations. The lowest elevation of the catchbasin is around 4 meters amsl surrounded by natural terrain, roads and the existing GPP1.

The road and the existing GPP1 has elevations of 6 and 8 meters amsl, respectively, while the lowest elevation of the drainage point is approximately 5.2 meters amsl.

3.4 Oceanographic Condition

The hydrography of the study area, which is within the Gulf of Guinea, is influenced largely by subtropical gyres of the north and south Atlantic oceans. The major currents influencing the area include:

- i. the Canary current from the north which splits into the North Equatorial Current and a coastal current which feeds the Guinea Current, and
- ii. the Benguela Current which flows northwards and extends into the Gulf of Guinea as the South Equatorial Current.

The Guinea Current which is the main current in the study area flows eastwards throughout the year over its whole length and obtains velocities close to 100 cm/s. It is however subject to periodical and usually short-term reversals. The reversal of the Guinea current is probably because of the varying strengths of the Equatorial Current and the waters of Benguela origin.

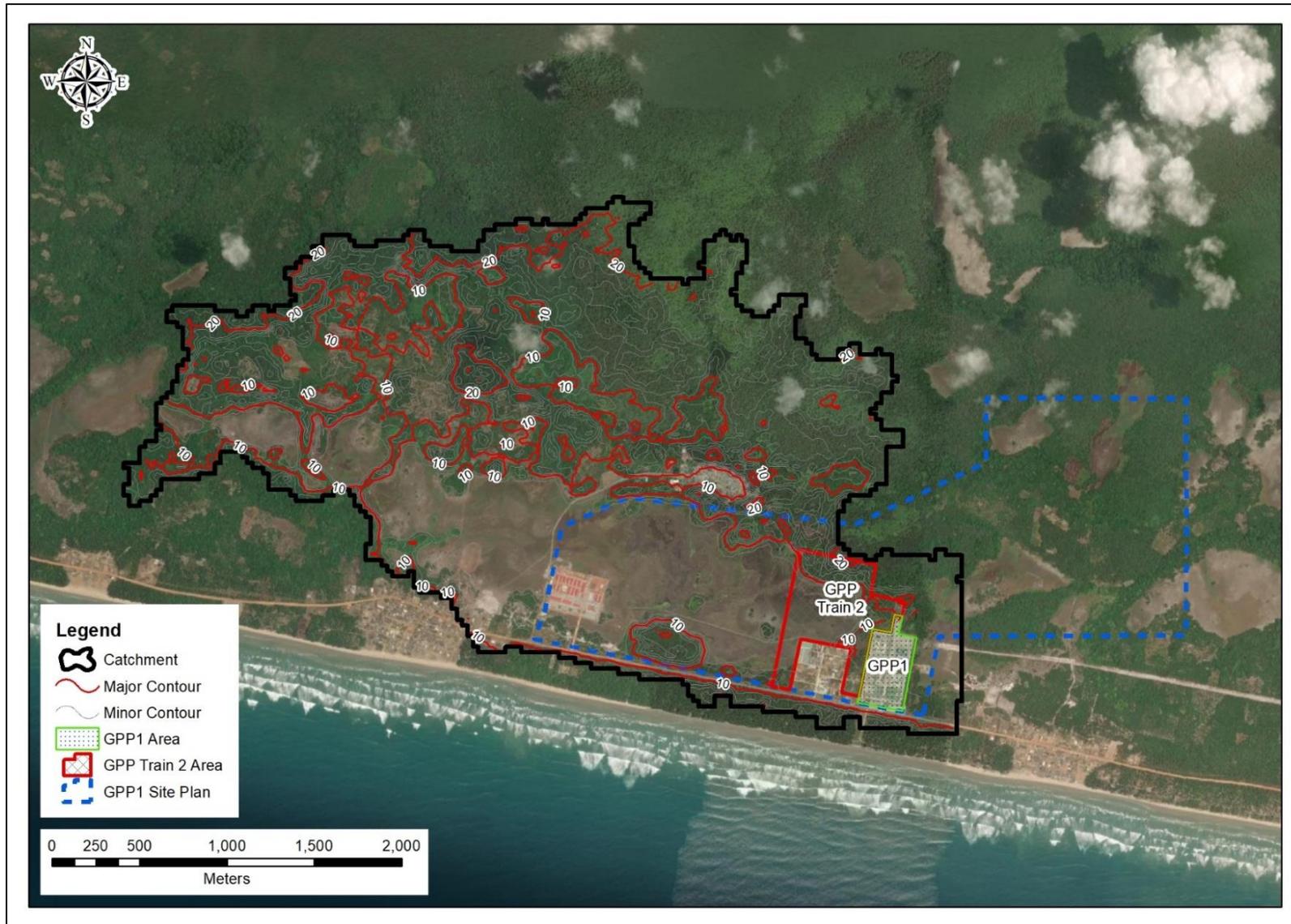


Figure 3-4 Watershed and Elevation Map

The general dynamics of the ocean currents in the Gulf of Guinea depends on the large-scale oceanic climatic seasonal exchanges which occur in the oceans and the morphology of the shelf and the orientation of the coast.

The coastal surface currents are primarily propelled by the wind and are confined to a 10–40 meters thick layer. Breaking waves generate littoral drift, the primary propelling force of coastal circulation in this region. These littoral drifts, which generally move in an eastward direction, have flow rates of less than 1 m/s, but they are responsible for transporting large volumes of littoral sediments and also for rip currents, which are more localized in their action, but transport a significant amount of sediments away from the coast.

The coastline is susceptible to south-southeast to south-southwest lengthy swells generated by fetches in the South Atlantic Ocean. The coast near the Project Area is subject to moderate wave intensity, with 11-16 second swells dominating. The average amplitude of waves in the region is 1 meter, but annual significant surges can occasionally reach 3.3 meters. However, waves reaching heights of 4.8-6 meters occur with a frequency of 10-20 years. The maximal wave period for swells is typically between 7 and 14 seconds. The orientation of swell waves is almost always south or south-southwest. Table 3-1 and Table 3-2 show the results of statistical analysis regarding wave height exceedance statistics and extreme value analysis are summarized, respectively.

Table 3-1 Offshore Wave Height Exceedance Statistics

Heights (m)	Exceedance (%)
<1.0	82.8
<1.5	23.0
<2.0	3.0
<2.5	0.1
3.0	0.0

Table 3-2 Extreme Offshore Waves

Return Period (yrs)	Extreme Heights (m)
10	3.0
20	3.2
50	3.4

Other wave climate observations include a long swell of distant origin and wavelengths ranging from 160 to 220 meters. This swell has a primary period of 12 seconds and an average height between 1 and 2 meters that is relatively consistent. Generally, the waves move from southwest to northeast.

3.5 Surface Water Hydrology

The main river system at the GPP project site is the Amansuri. The tributaries of the Amansuri include Nyanzini, Franza, Amadenra, and Bozoke. The channel breadth of the river where samples were taken for previous hydrological studies is approximately 44.1 meters. This river originates from a network of streams that culminate in the Amansuri lagoon at Nzulezu and then travels towards the coast at Bakanta before entering the sea near Azulenloanu as shown in Figure 3-5. The Amansuri is gauged at a bridge crossing along the Alabokazo – Eikwe Road with the gauge measuring a depth of 32.3 meters at the time of the hydrological studies.

The table below provides the drainage features of the main tributaries in the Amansuri river system.

Table 3-3 Drainage Features

Name of Stream	Length, km	Drainage Area, sq.km	Difference in Level, m	Average Slope
Amansuri	25.68	877.77	0.26	0.00001
Nyanzini	30.44	138.94	60.88	0.002
Franza	21.49	70.31	64.47	0.003

Nyanzini River: The Nyanzini River has a catchment area of about 138.9 sq.km. It travels about 30.4 km before it joins the Amansuri River. The Nyanzini has a slope of 0.002. The difference in level from source to mouth of stream is 60.9 meters.

Franza: The Franza is a sub catchment within the Amansuri catchment. It originates from the Nkroful and the Bomokpole areas. The eastern section of the Amansuri Lagoon is served largely by discharges from the Franza which is also referred to as the Broma or Bonuma at its upper reaches. The Franza with a catchment area of about 70.3 sq.km also has the Subele as a tributary draining Anwea and surrounding areas and traverses about 21.5 km before it empties into the Amansuri Lagoon. Its difference in level from source to mouth is 64.5 meters. with a slope of 0.003.

3.6 Climate Condition

Atuabo has a tropical wet and dry climate, also known as savanna climate. This means that it has distinct wet and dry seasons, with a relatively high and uniform temperature throughout the year. The average annual temperature in Atuabo is 27.5°C which is slightly lower than the national average of 28.9°C. The hottest month is February when the temperature can reach up to 32°C, while the coolest month is August when the temperature can drop to 25°C.

The town of Atuabo has an average rainfall of 1,900 mm. The heaviest rainfall occurs in May and June when thunderstorms are common where the average rainfall can go up to 800 mm. The number of rainy days is around 20 to 28 days. The driest months are January and February when the harmattan wind blows from the Sahara Desert. In the driest month, Atuabo receives lower than 60 mm of rainfall.

The relative humidity of Atuabo ranges from 78% to 91% with an annual average of 85%. The maximum relative humidity occurs in the months of July and August when the temperature is low. On the other hand, the lowest relative humidity occurs in March and April when the temperature is high.

3.7 Climate Change¹

Ghana is one of the countries that faces significant risks from climate change, such as rising temperatures, droughts, floods, sea level rise, and coastal erosion. These threats pose serious challenges to Ghana's development goals, such as reducing poverty, improving food security, enhancing health and education, and promoting economic growth.

Climate projection data is modeled from the global climate model compilations of the Coupled Model Inter-comparison Projects (CMIPs), overseen by the World Climate Research Program. Data presented is CMIP6, derived from the Sixth phase of the CMIPs.

The scenario approach is used to characterize the range of plausible climate futures and to illustrate the consequences of different pathways (policy choices, technological changes, etc). They are chosen to span a wide range without any tie to likelihood; the scenarios serve as ‘what

¹ <https://climateknowledgeportal.worldbank.org/country/ghana>

if' cases. For CMIP6, each SSP drives a corresponding future projection of greenhouse gas emissions and land-use change under the baseline SSP storyline.

The SSPs represent possible societal development and policy paths for meeting designated radiative forcing by the end of the century. CMIP6 includes scenarios with high and very high GHG emissions (SSP3-7.0 and SSP5-8.5) and CO₂ emissions that roughly double from current levels by 2100 and 2050, respectively, scenarios with intermediate GHG emissions (SSP2-4.5) and CO₂ emissions remaining around current levels until the middle of the century, and scenarios with very low and low GHG emissions and CO₂ emissions declining to net zero around or after 2050, followed by varying levels of net negative CO₂ emissions (SSP1-1.9 and SSP1-2.6)

It is shown in Figure 3-6 and Figure 3-7 that the average mean temperature of Western Ghana will continue to rise up to year 2100 where the temperature anomaly varies in each month. The highest mean temperature anomaly is expected in the second (2nd) quarter of the year with a median value of 4.03°C for SSP5-8.5 in the month of May.

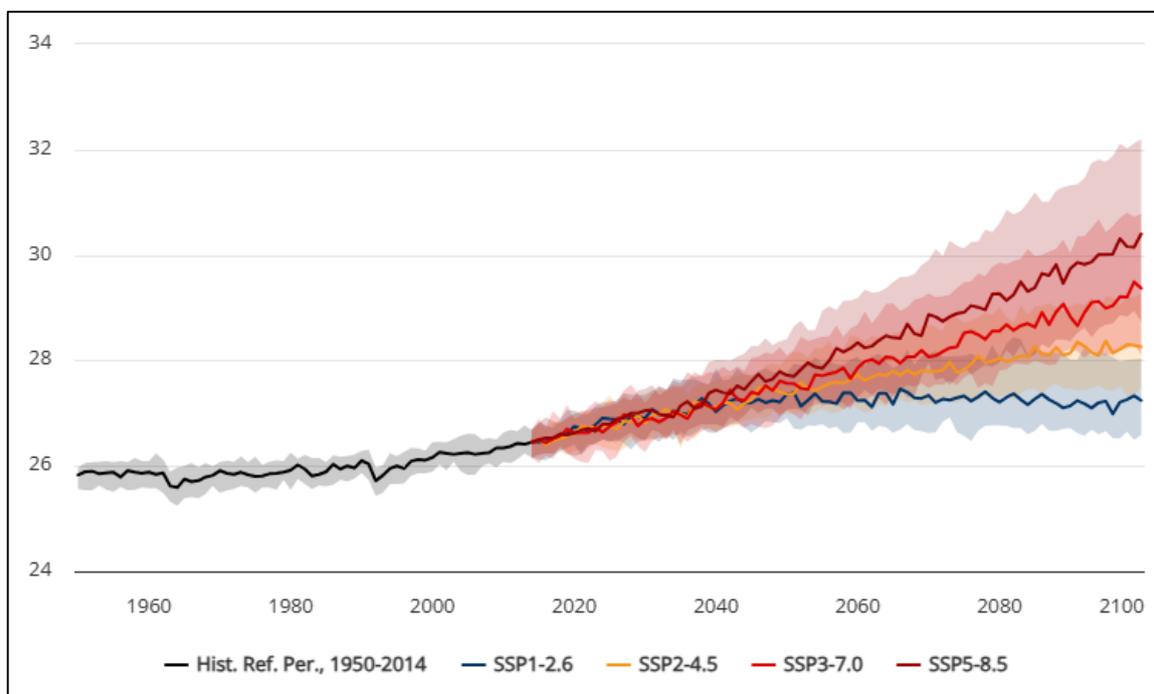


Figure 3-6 Projected Average Mean Temperature in Western Ghana

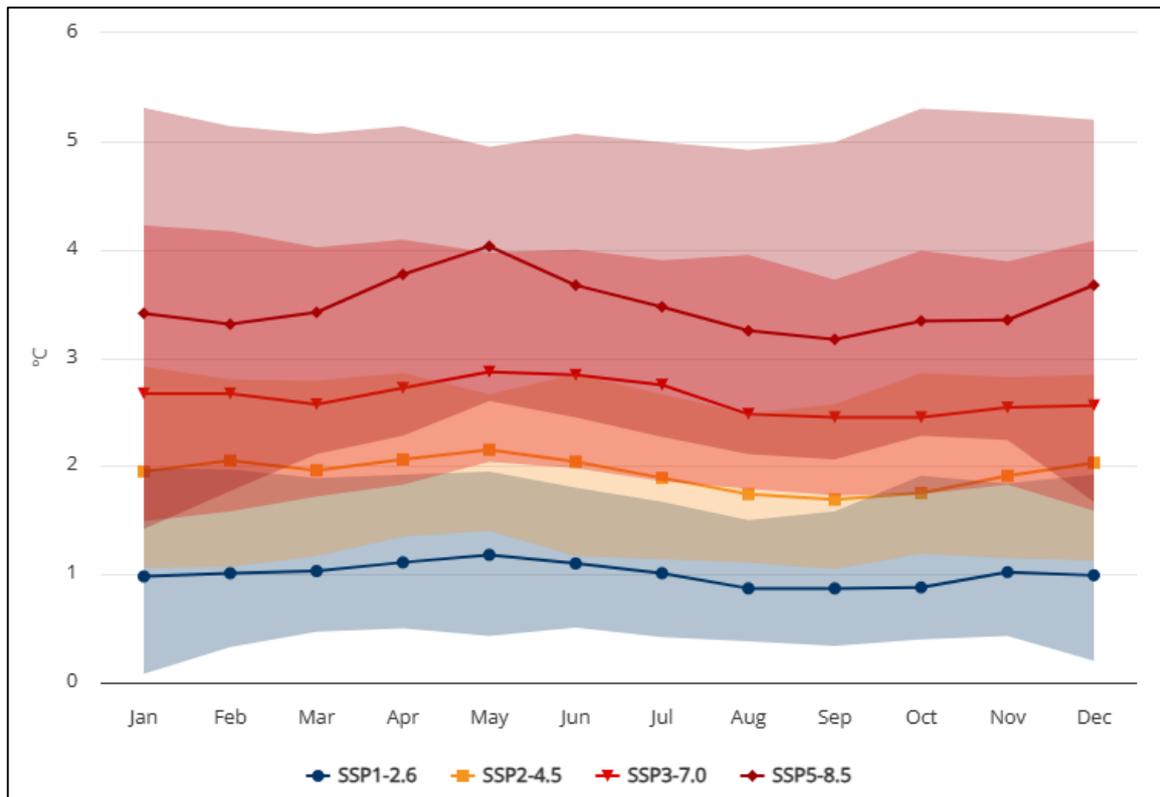


Figure 3-7 Projected Average Mean Temperature Anomaly in Western Ghana for 2080-2099

On the other hand, the projected annual rainfall up to year 2100 seems to fluctuate above and below the observed data as shown in Figure 3-8. However, the highest percent change anomaly in precipitation is expected in the last quarter of the year with a median value of 20% for SSP5-8.5 in the month of November.

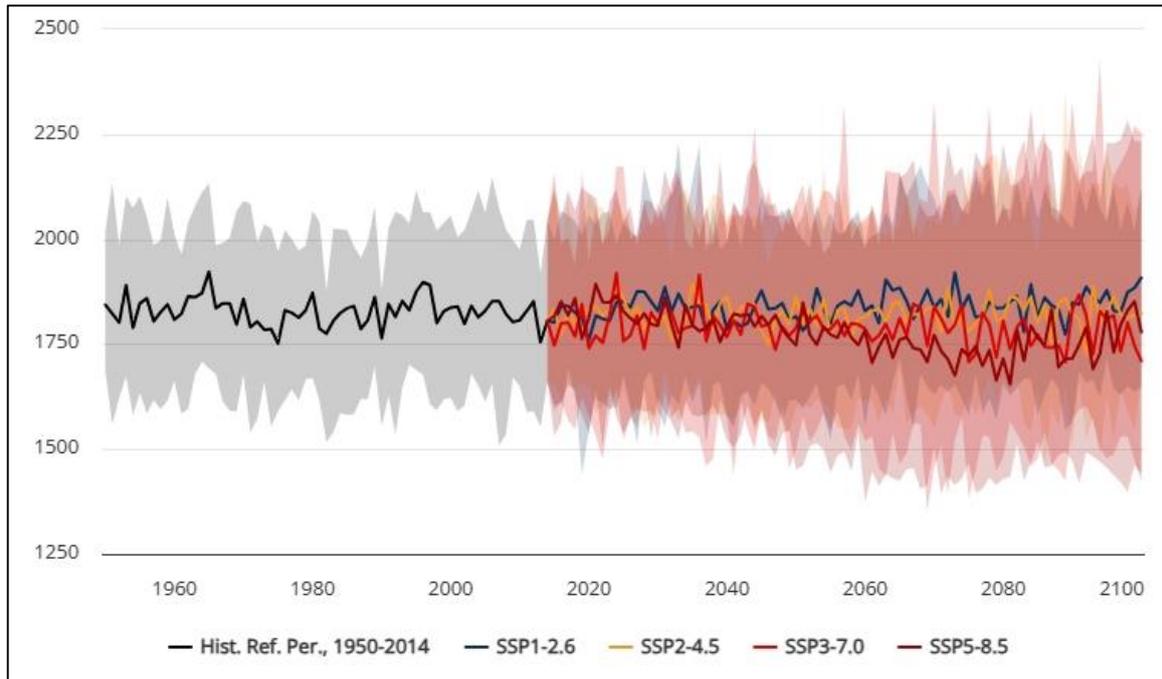


Figure 3-8 Projected Precipitation in Western Ghana

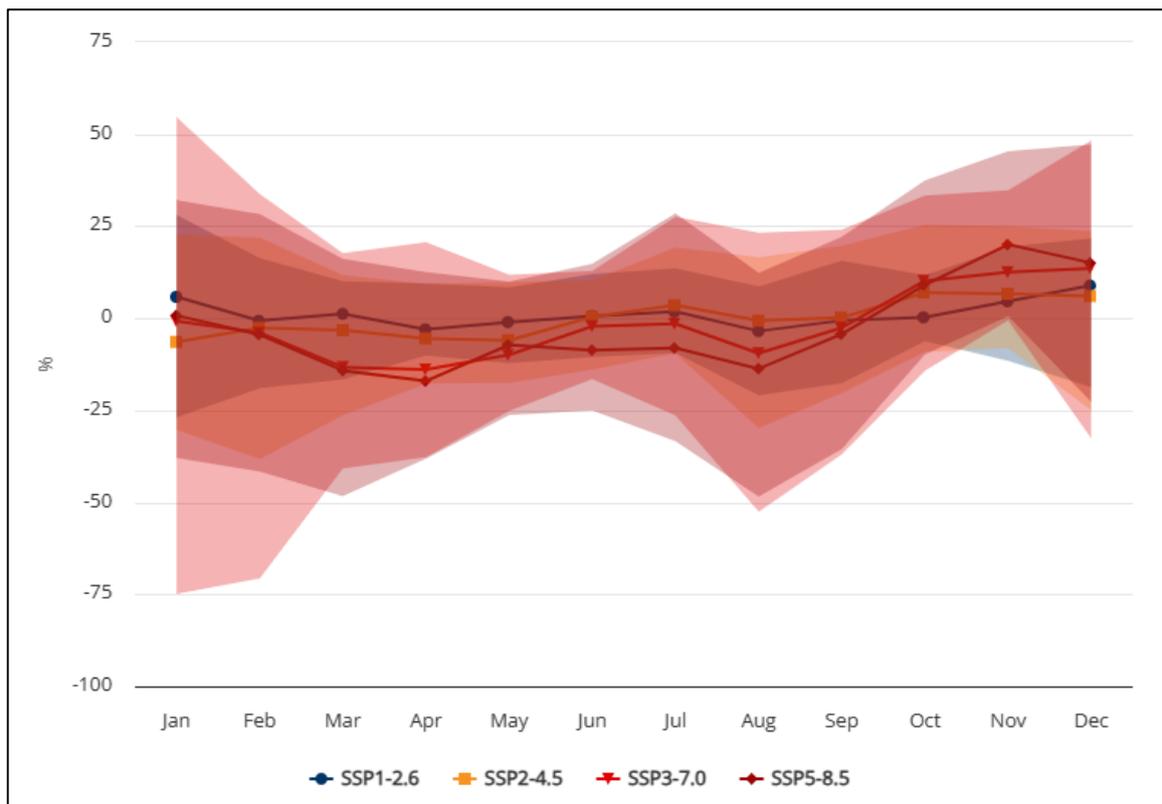


Figure 3-9 Projected Percent Change Anomaly in Precipitation in Western Ghana for 2080-2099

4 Data Collection and Methodology

4.1 Meteorological Data

Ghana Meteorological Agency (GMet) has a network of stations across the country that collect and transmit data on temperature, rainfall, humidity, wind speed and direction, air pressure and other parameters. The nearest GMet station from the town of Atuabo is the Axim Station, located about 34 km to the east which has the same climate type in the Western Region.

The latest available data within the period of eleven (11) years from 2012 to 2022 has been gathered. The meteorological parameters gathered are rainfall, temperature, and relative humidity with intermittent daily observed data. Figure 4-1 summarizes the monthly average data of the three (3) parameters.

GMet also processes rainfall intensity duration frequency data of the Axim Station. Rainfall intensity duration frequency (IDF) is a statistical analysis of rainfall data that provides information on the magnitude and frequency of extreme rainfall events for a given location and duration. IDF curves are typically derived from historical records of rainfall measurements, using methods such as frequency analysis, regionalization, or stochastic simulation. The rainfall intensity duration frequency data of Axim Station is shown in Figure 4-2 and Table 4-1.

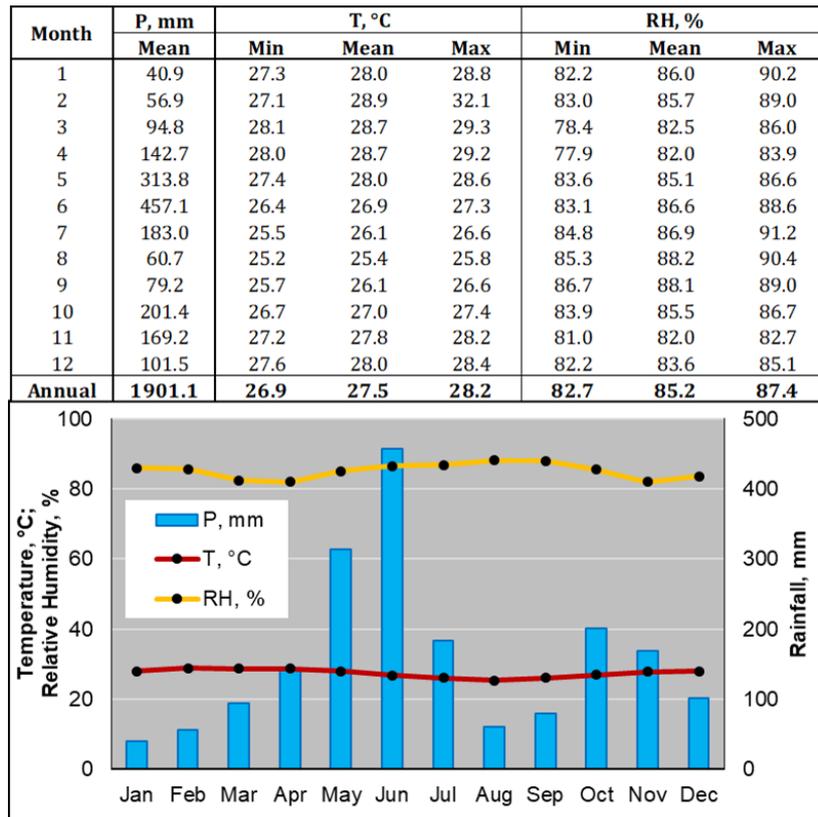


Figure 4-1 Meteorological Data

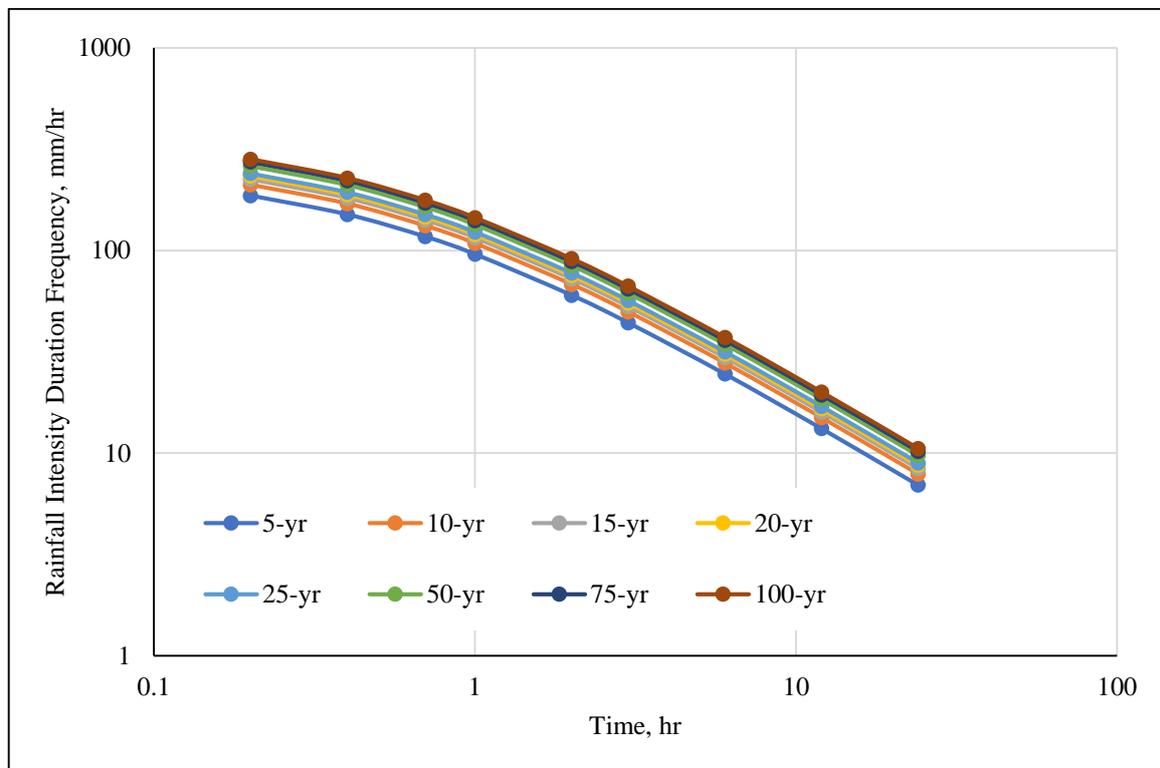


Figure 4-2 Rainfall Intensity Duration Frequency Curves

Table 4-1 Rainfall Intensity Duration Frequency Data, mm/hr

Duration	Return Periods							
	5	10	15	20	25	50	75	100
0.2	186.57	211.15	224.55	233.49	240.19	261.42	273.71	282.64
0.4	150.59	170.43	181.25	188.47	193.88	211.01	220.93	228.14
0.7	117.06	132.48	140.90	146.50	150.71	164.03	171.74	177.35
1	95.91	108.54	115.43	120.03	123.47	134.38	140.70	145.30
2	60.18	68.10	72.43	75.31	77.47	84.32	88.28	91.17
3	44.03	49.83	52.99	55.10	56.69	61.70	64.60	66.70
6	24.61	27.85	29.62	30.79	31.68	34.48	36.10	37.28
12	13.23	14.97	15.92	16.55	17.03	18.53	19.40	20.04
24	6.96	7.88	8.38	8.71	8.96	9.75	10.21	10.54

4.2 Terrain Data

The terrain data of the project area and its vicinity is based on the recently conducted topographic survey and the previous topographic data gathered from GNGC. The recent survey was conducted using M300 RTK drone, equipped with the Zenmuse L1 payload for data collection. The drone was programmed to follow a predetermined flight path to capture aerial imagery and LiDAR data. Collected data was processed using DJI Terra, Agisoft Metashape and Global Mapper, ensuring accuracy and reliability. The previous topographic survey was conducted using Total Station equipment and RTK GNSS.

For both surveys, the Universal Transverse Mercator (UTM) grid coordinate system based on the WGS84 Datum was adopted as the reference horizontal coordinate system. Mean sea level (MSL) was adopted as the vertical datum, thus all elevations are orthometric heights.

Table 4-2 Parameters of Reference Horizontal Coordinate System

Ellipsoid Parameters	Name of Ellipsoid	WGS84
	Semi-major axis, a	6378137.0 m
	Inverse Flattening, 1/f	298.257223563
Projection Parameters	Name of Projection	UTM
	Zone	Zone 30 N
	Central Meridian (CM)	3° W
	Latitude of Natural (or True) Origin	0° N
	Scale Factor on the CM	0.9996
	False Easting	500,000 m (at CM)
	False Northing	0 m (at latitude 0° N)
	Grid Units	Metres (m)

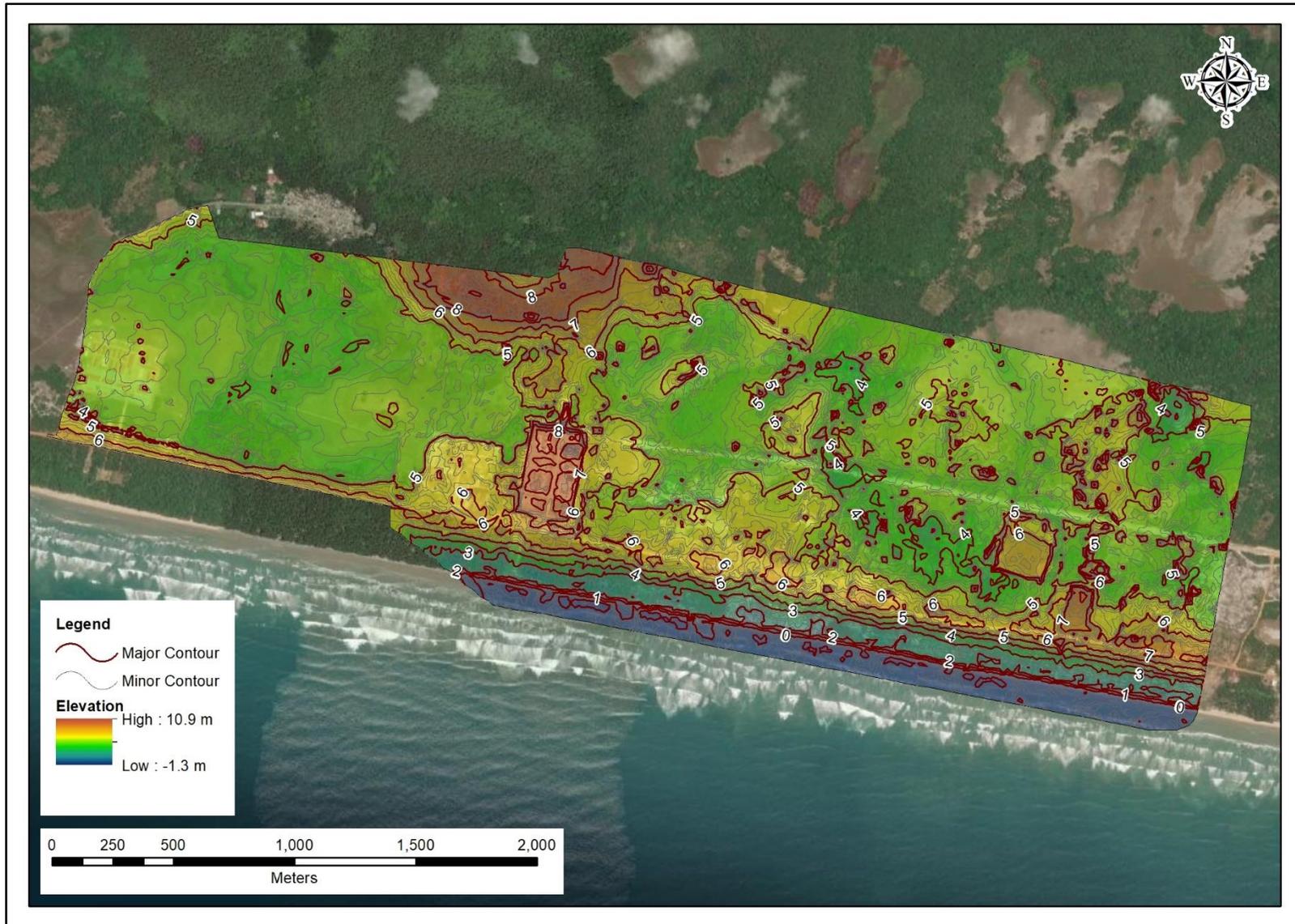


Figure 4-3 Topographic Map

4.3 Design Storm

The design storm event is derived from the rainfall intensity duration frequency of the project area. It is generated with a 24-hr duration where hyetograph values are distributed such that the peak occurs at the 12th hour using the Kimijima Equation as a curve fitting equation for each IDF curves to estimate the hourly rainfall intensity. Twenty percent (20%) increase in rainfall was applied to account the effect of climate change projected up to year 2100.

Table 4-3 Design Hyetograph (Current Condition), mm

Duration, hrs	Return Period, yrs					
	5	10	15	25	50	100
1	0.45	0.53	0.55	0.59	0.65	0.68
2	0.52	0.60	0.62	0.68	0.74	0.78
3	0.60	0.69	0.72	0.78	0.85	0.90
4	0.70	0.81	0.84	0.91	1.00	1.06
5	0.84	0.98	1.02	1.10	1.20	1.27
6	1.04	1.21	1.26	1.36	1.49	1.58
7	1.35	1.56	1.63	1.76	1.92	2.04
8	1.85	2.13	2.23	2.41	2.63	2.80
9	2.78	3.18	3.34	3.61	3.93	4.21
10	4.88	5.55	5.85	6.31	6.86	7.37
11	11.79	13.34	14.14	15.20	16.53	17.84
12	95.91	108.56	115.43	123.48	134.40	145.30
13	24.43	27.58	29.30	31.46	34.18	37.00
14	7.14	8.10	8.57	9.22	10.03	10.80
15	3.59	4.10	4.31	4.65	5.06	5.43
16	2.24	2.57	2.69	2.91	3.17	3.38
17	1.57	1.80	1.89	2.04	2.23	2.37
18	1.18	1.36	1.42	1.54	1.68	1.78
19	0.93	1.08	1.13	1.22	1.33	1.41
20	0.77	0.89	0.92	1.00	1.09	1.15
21	0.64	0.75	0.78	0.84	0.92	0.97
22	0.55	0.64	0.67	0.72	0.79	0.83
23	0.48	0.56	0.58	0.63	0.69	0.73
24	0.43	0.50	0.52	0.56	0.61	0.64

Table 4-4 Design Hyetograph (with Climate Change), mm

Duration, hrs	Return Period, yrs					
	5	10	15	25	50	100
1.00	0.54	0.64	0.66	0.71	0.78	0.82
2.00	0.62	0.72	0.75	0.81	0.89	0.93
3.00	0.71	0.83	0.86	0.93	1.02	1.08
4.00	0.84	0.97	1.01	1.10	1.20	1.27
5.00	1.01	1.17	1.22	1.32	1.44	1.52
6.00	1.25	1.45	1.51	1.63	1.79	1.89
7.00	1.62	1.87	1.95	2.11	2.30	2.45
8.00	2.22	2.55	2.68	2.89	3.15	3.36
9.00	3.34	3.82	4.01	4.33	4.72	5.05
10.00	5.85	6.66	7.02	7.57	8.24	8.85
11.00	14.15	16.01	16.97	18.24	19.83	21.41
12.00	115.09	130.27	138.51	148.18	161.28	174.37
13.00	29.32	33.09	35.17	37.75	41.02	44.39
14.00	8.57	9.72	10.28	11.06	12.03	12.96
15.00	4.31	4.91	5.18	5.58	6.08	6.51
16.00	2.69	3.08	3.23	3.49	3.80	4.06
17.00	1.88	2.16	2.27	2.45	2.67	2.84
18.00	1.42	1.63	1.71	1.84	2.02	2.14
19.00	1.12	1.30	1.35	1.46	1.60	1.69
20.00	0.92	1.06	1.11	1.20	1.31	1.38
21.00	0.77	0.90	0.93	1.01	1.11	1.17
22.00	0.66	0.77	0.80	0.87	0.95	1.00
23.00	0.58	0.68	0.70	0.76	0.83	0.87
24.00	0.51	0.60	0.62	0.67	0.74	0.77

4.4 Flood Hydrograph

A flood hydrograph for a basin can be simulated using a unit hydrograph, defined as the direct runoff from a storm that produces unit of rainfall excess. Using the unit hydrograph method, the DRH at the watershed outlet for given excess rainfall resulting from a particular storm event is calculated. The unit hydrograph method is a useful tool for practical purposes due to its simplicity and usefulness due to its linear assumption.

The SCS curvilinear dimensionless unit hydrograph procedure is one of the best-known methods for deriving synthetic unit hydrographs in use today. The dimensionless unit hydrograph used by the SCS is derived based on a large number of unit hydrographs from basins that varied in characteristics such as size and geographic location. The unit hydrographs are averaged, and the final product is made dimensionless by considering the ratios of q/q_p (flow/peak flow) on the ordinate axis and t/t_p (time/time to peak) on the abscissa.

Table 4-5 Dimensionless Unit Hydrograph Values

Time Ratio	Discharge Ratio	Time Ratio	Discharge Ratio	Time Ratio	Discharge Ratio
t/t_p	q/q_p	t/t_p	q/q_p	t/t_p	q/q_p
0.0	0.000	1.1	0.990	2.4	0.147
0.1	0.030	1.2	0.930	2.6	0.107
0.2	0.100	1.3	0.860	2.8	0.077
0.3	0.190	1.4	0.780	3.0	0.055
0.4	0.310	1.5	0.680	3.2	0.040
0.5	0.470	1.6	0.560	3.4	0.029
0.6	0.660	1.7	0.460	3.6	0.021
0.7	0.820	1.8	0.390	3.8	0.015
0.8	0.930	1.9	0.330	4.0	0.011
0.9	0.990	2.0	0.280	4.5	0.005
1.0	1.000	2.2	0.207	5.0	0.000

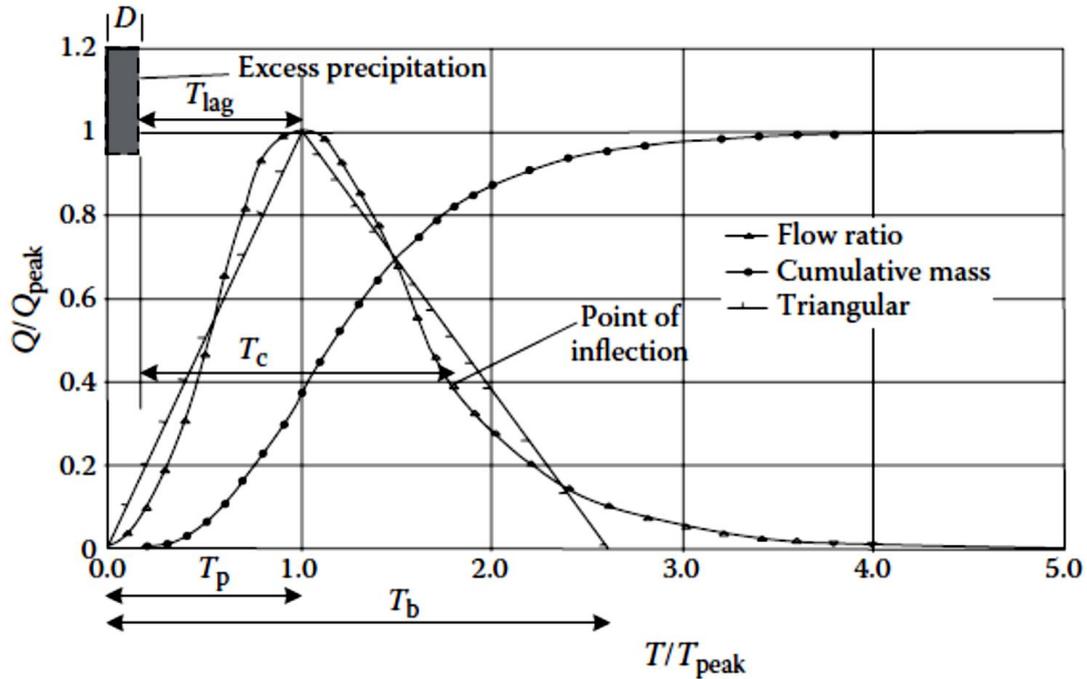


Figure 4-4 Dimensionless Unit Hydrograph Diagram

The following equations and relations are used to derive the unit hydrograph:

$$q_p = \frac{7491AQ}{\frac{D}{2} + L_t}$$

$$L_t = 0.6T_c$$

$$L' = L_t + \frac{D' - D}{4}$$

$$T_c = L^{0.8} \frac{(S' + 25.4)^{0.7}}{4238S^{0.5}}$$

$$S' = \frac{25400}{CN} - 254$$

Where:	q_p	= Unit Peak Flow, cms/cm
	A	= Catchment Area, sq.km
	Q	= Runoff Volume, cm
	D	= Rainfall Duration, hr
	L_t	= Lag Time, hr
	L'	= Adjusted Lag Time, hr
	T_c	= Time of Concentration, hr
	L	= Basin Length, m

The basin parameters are estimated considering the delineation of the watershed as follows:

- Drainage Area = 8.5 sq.km
- Length = 6,456 m
- Centroidal Length = 2,229 m
- Basin Slope = 0.124 %
- Curve Number = 86

With a standard rainfall duration of 1-hr, the adjusted lag time is computed as 8.28 hrs resulting to a time to peak of 8.78 hrs, say 9 hrs. Likewise, the computed unit peak flow is 0.197 cms/cm.

The derived unit hydrograph is shown below:

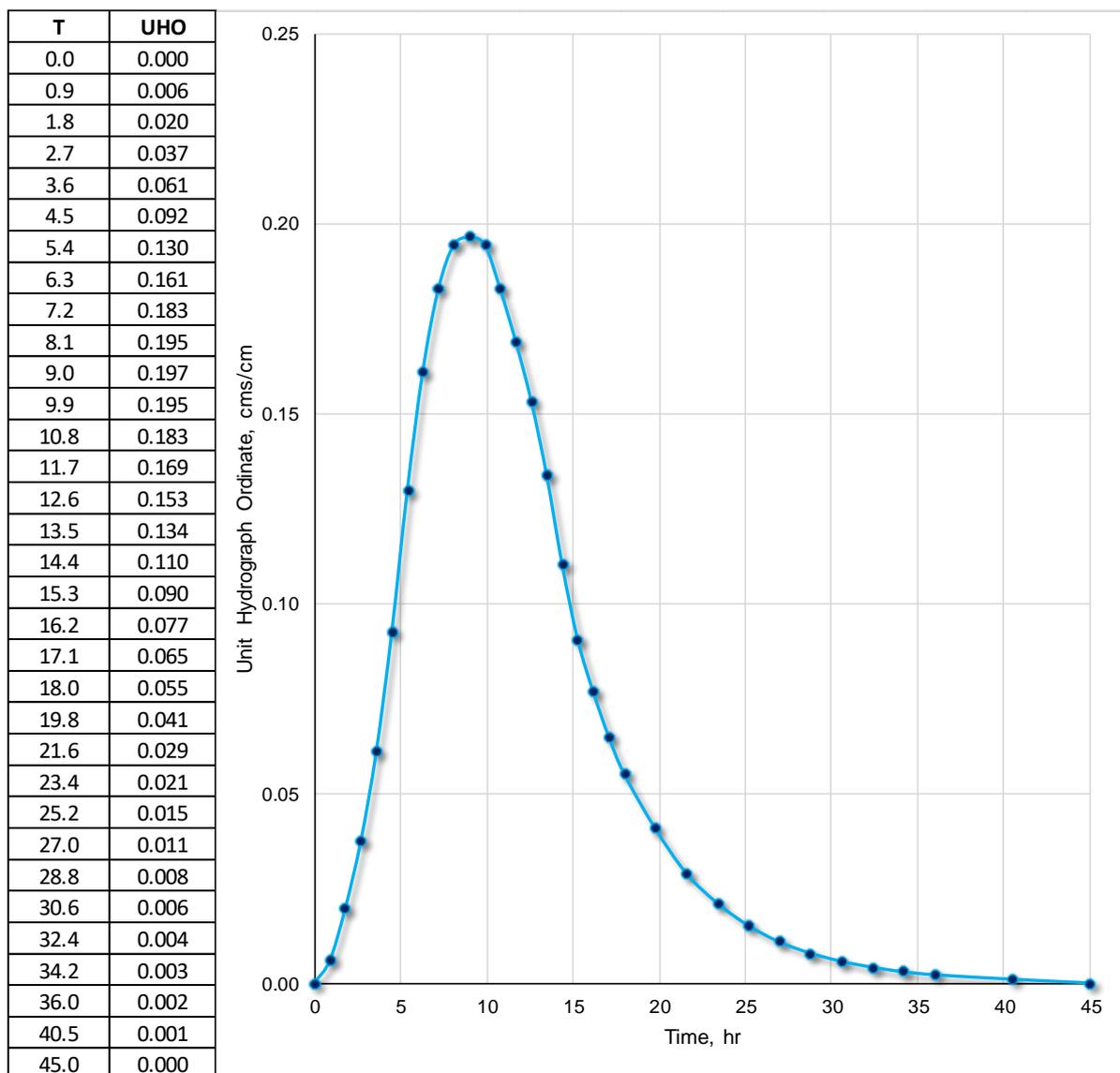


Figure 4-5 Unit Hydrograph

The flood hydrograph is generated by multiplying each unit hydrograph ordinate with the hietograph values through convolution process. The flood hydrograph for each return period is shown below:

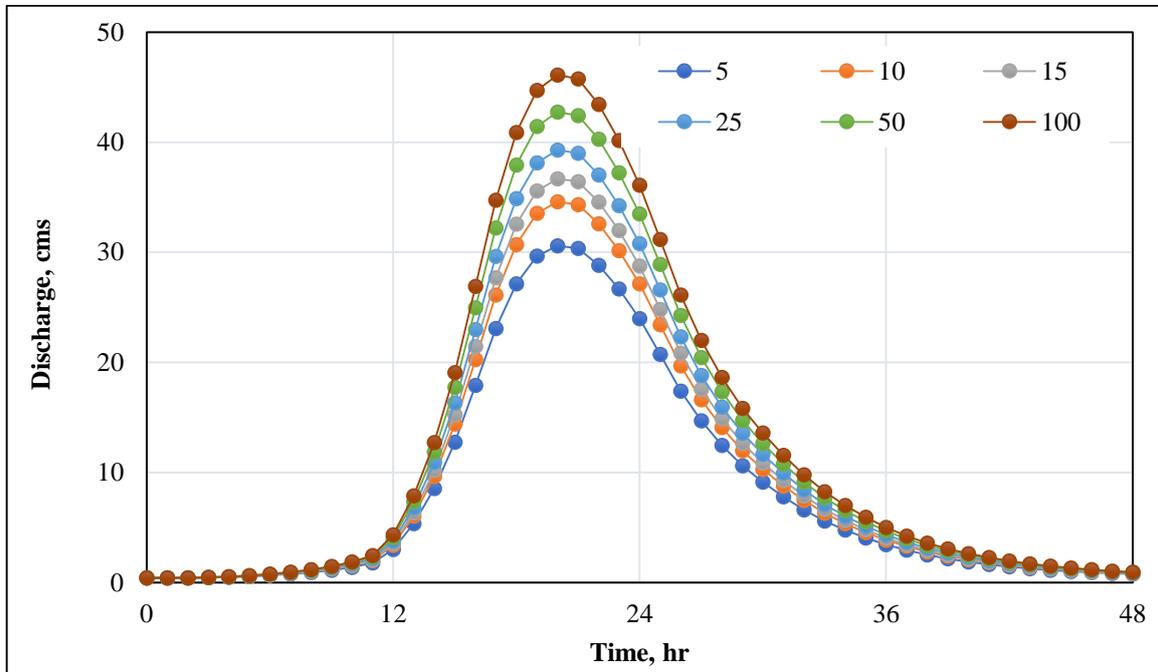


Figure 4-6 Flood Hydrograph (Current Condition), cms

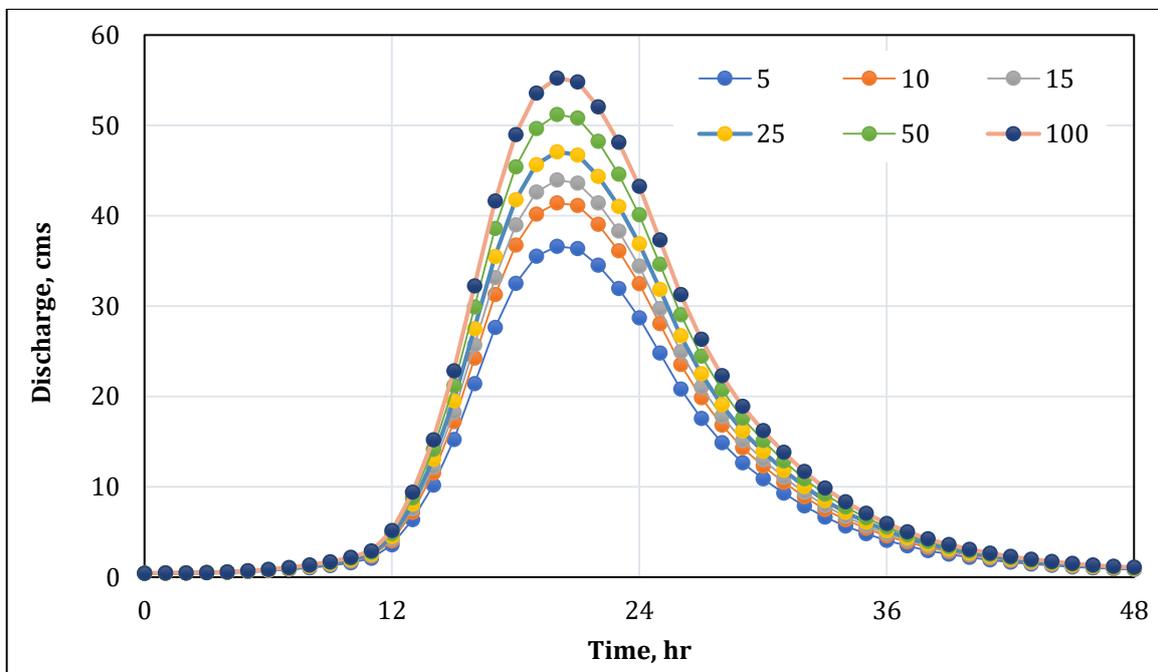


Figure 4-7 Flood Hydrograph (with Climate Change), cms

4.5 Inundation Analysis

HEC-RAS is used to simulate the design flood for each return period in the vicinity of the project area. HEC-RAS (River Analysis System) is a widely used software to simulate flooding and design structural measures for flood mitigation. This software allows the user to perform one-dimensional steady flow, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modeling. For this study, 2D unsteady flow calculation is considered for inundation analysis. 2D flow modeling is accomplished by adding 2D flow area elements into the model that represents the terrain within the area of consideration.

5 Flood Hazard Assessment

Inundation analysis is an important step in conducting flood risk assessment. It is a process of estimating the extent and depth of water on a certain area due to a flood event. From it, we can identify the areas that are most vulnerable to flooding, the potential impacts on people and on the existing and proposed structures and introduce mitigation measures to reduce the flood hazard.

The following sources of flooding have been considered in this assessment:

- Groundwater flooding: Groundwater flooding is caused by the rise of groundwater levels.
- Coastal flooding: Coastal flooding is caused by storm surges and tsunamis.
- Pluvial flooding: Pluvial flooding is caused by intense rainfall.
- Fluvial flooding: Fluvial flooding is caused by the overflow of rivers and streams.

5.1 Geometric Data

The geometric data in HEC-RAS defines the systematic flow of water from one point to another. The boundary conditions are set at the far west as the upstream, and the far east as the downstream as shown in Figure 5-1.

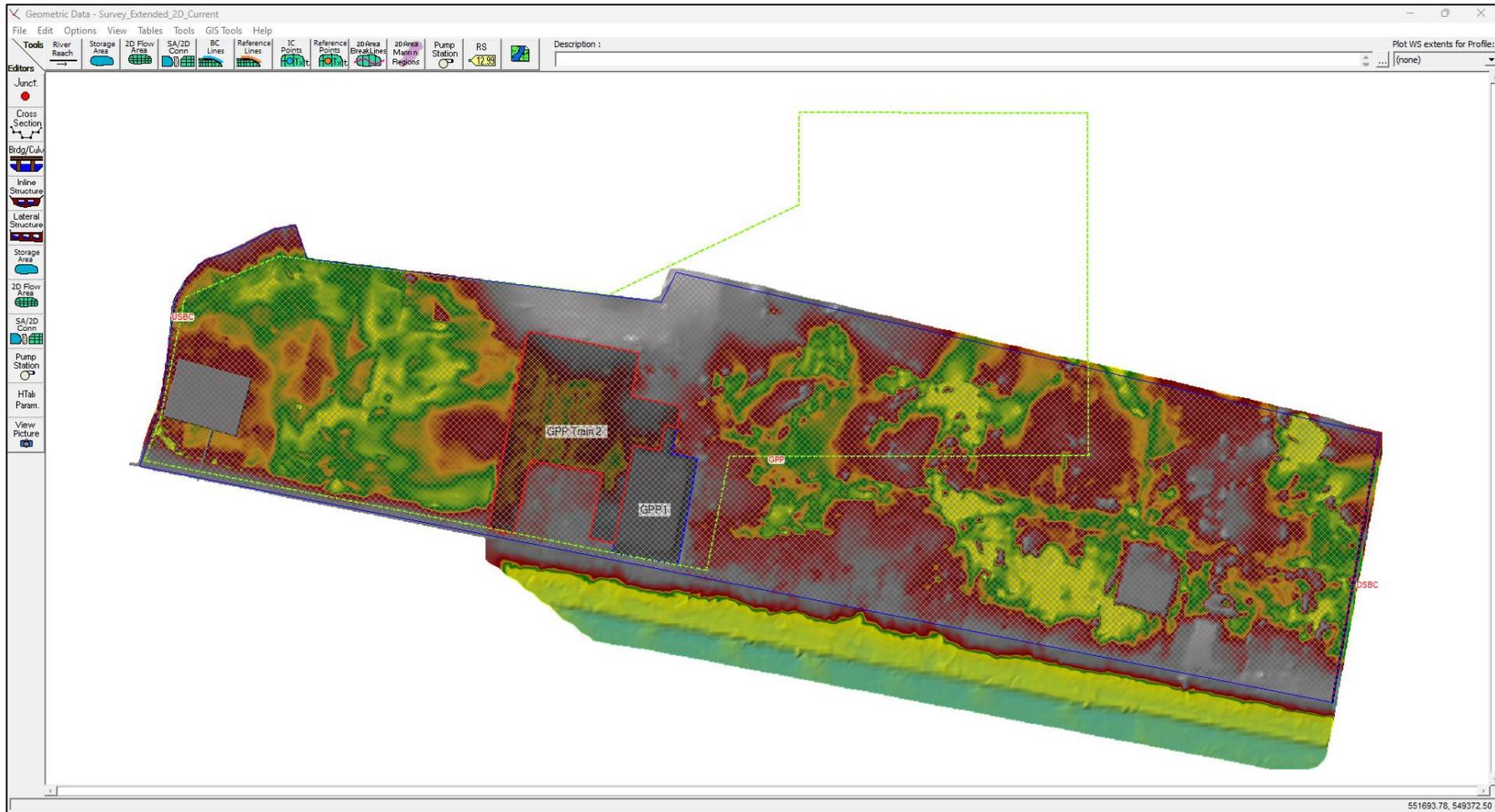


Figure 5-1 Geometric Data Window

The terrain data is generated from the topographic survey data conducted on the project area. It is a combination of the old topographic data and the extension at the right portion covering the industrial facilities and communities of Anokyi. The terrain data is captured in the 2D flow area element with a mesh size of 5mx5m.

5.2 Unsteady Flow Data

Unsteady flow data defines the boundary conditions for the incoming and outgoing flow. The upstream boundary condition (USBC) is set to flow hydrograph where the design discharge per return period is considered as the incoming flow. The downstream boundary condition (DSBC) is set to normal depth where the energy gradient is assumed equal to the average slope of the riverbed.

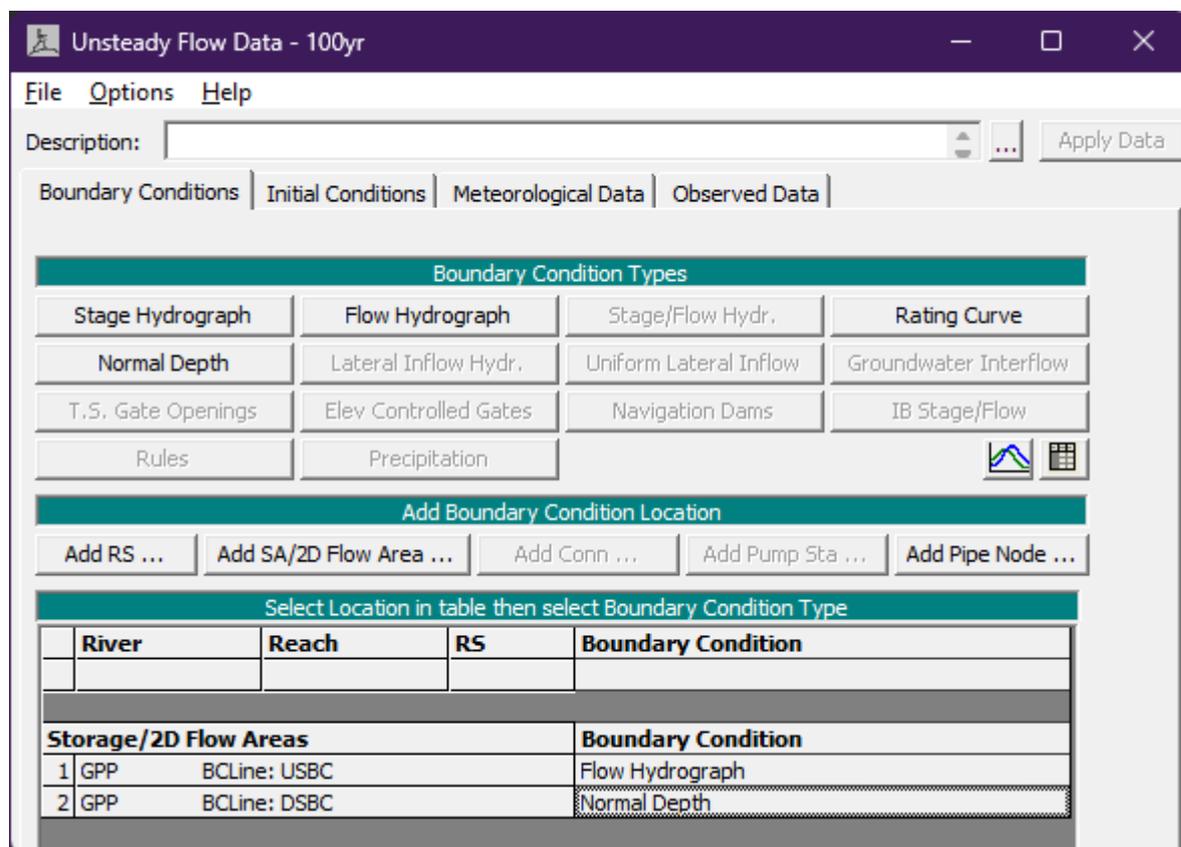


Figure 5-2 Unsteady Flow Data Window

5.3 Unsteady Flow Analysis

The unsteady flow analysis contains the details of the flood simulation time window and how the result will be stored for further analysis. It defines what geometry data and unsteady flow data will be used. The simulation time window is set to 4 days to determine how the design discharge will flow in the system with output interval of 1hr.

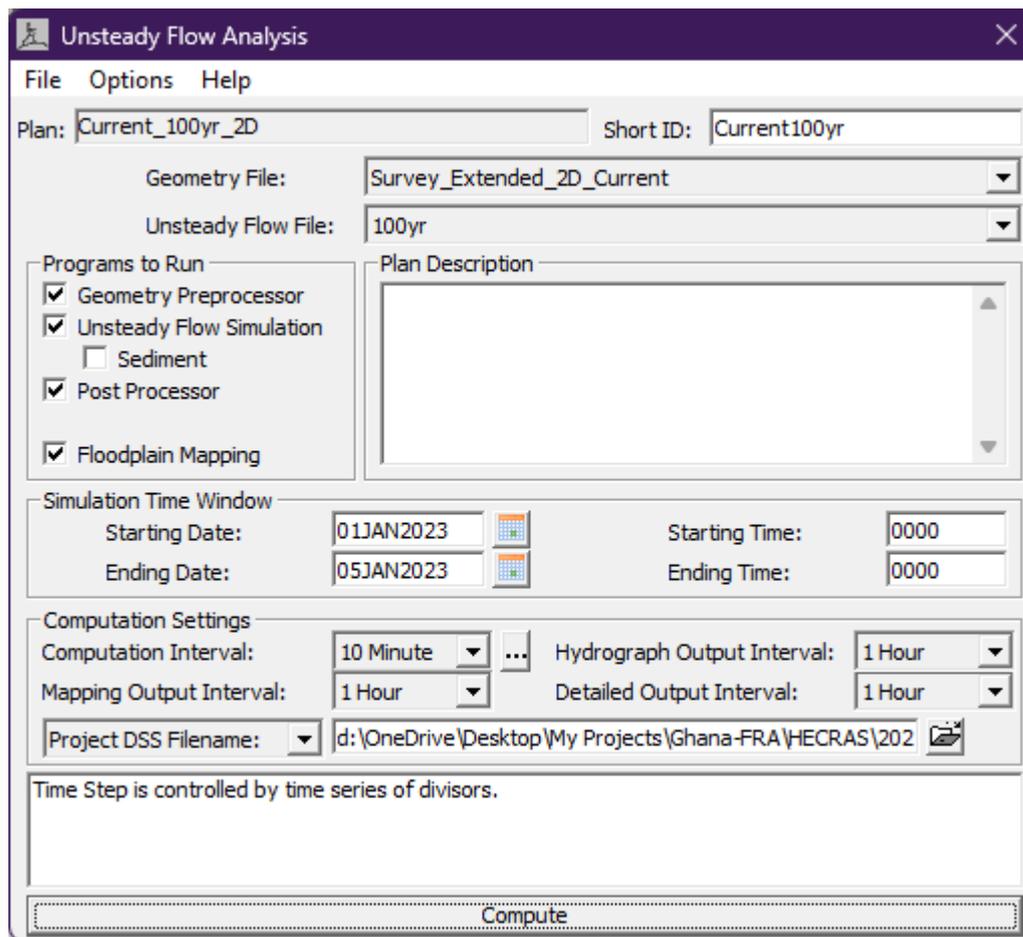


Figure 5-3 Unsteady Flow Analysis Window

5.4 Flood Susceptibility for Current Condition

As observed in the following images, the drainage point just north of the existing GPP1 has a minimal discharge capacity with attenuation of 80 to 90% of the incoming flow. The flow difference results to the water stored at the west side of GPP area leaving it inundated and swampy for an extended period of time.

The maximum inundation depth ranges from 2.13 to 2.42 meters, reaching an elevation of 5.89 meters amsl for the most extreme flood event. This elevation is lower than the floor elevation of GPP1 with an average elevation of 8.0 meters. This is also lower than the elevation of the town of Asemnda at the north-western side, thus, no flooding condition is expected.

However, it can be observed that some community in the town of Anokyi are susceptible to flood with minor depths of 0.0 – 0.50 meters for the most extreme flood events. It is important to note that this scenario is not caused or intensified by the GPP facilities.

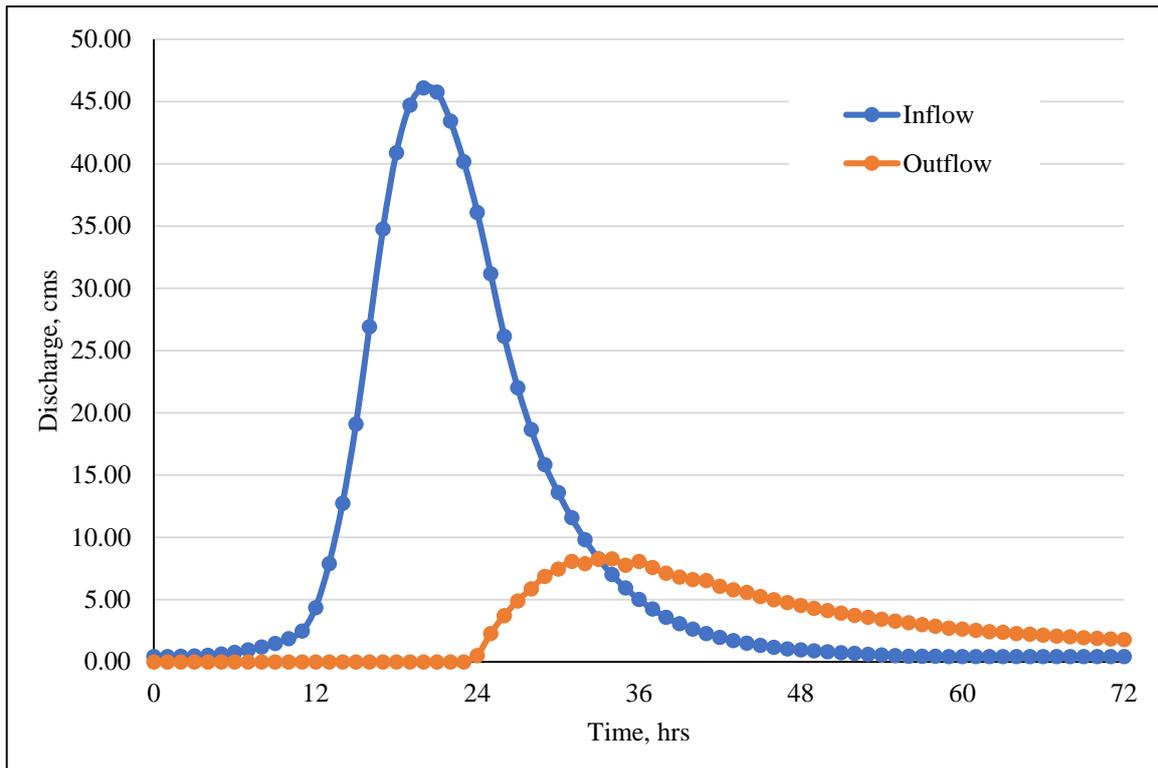


Figure 5-4 Inflow vs Outflow for Current Condition without GPP Train 2 (100-yr Return Period)

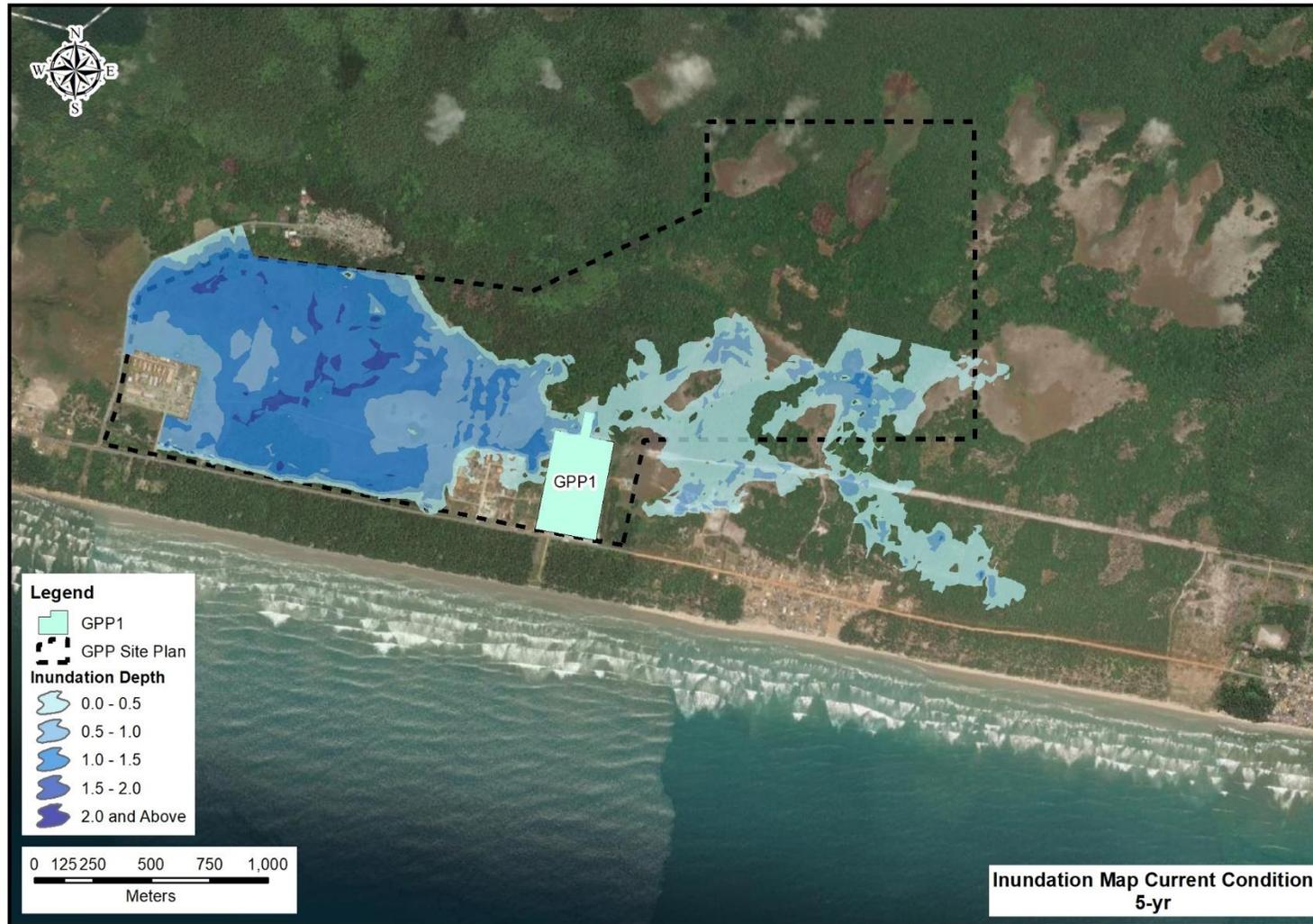


Figure 5-5 Flood Susceptibility Map for Current Condition (Without GPP Train 2) (5-yr Return Period)

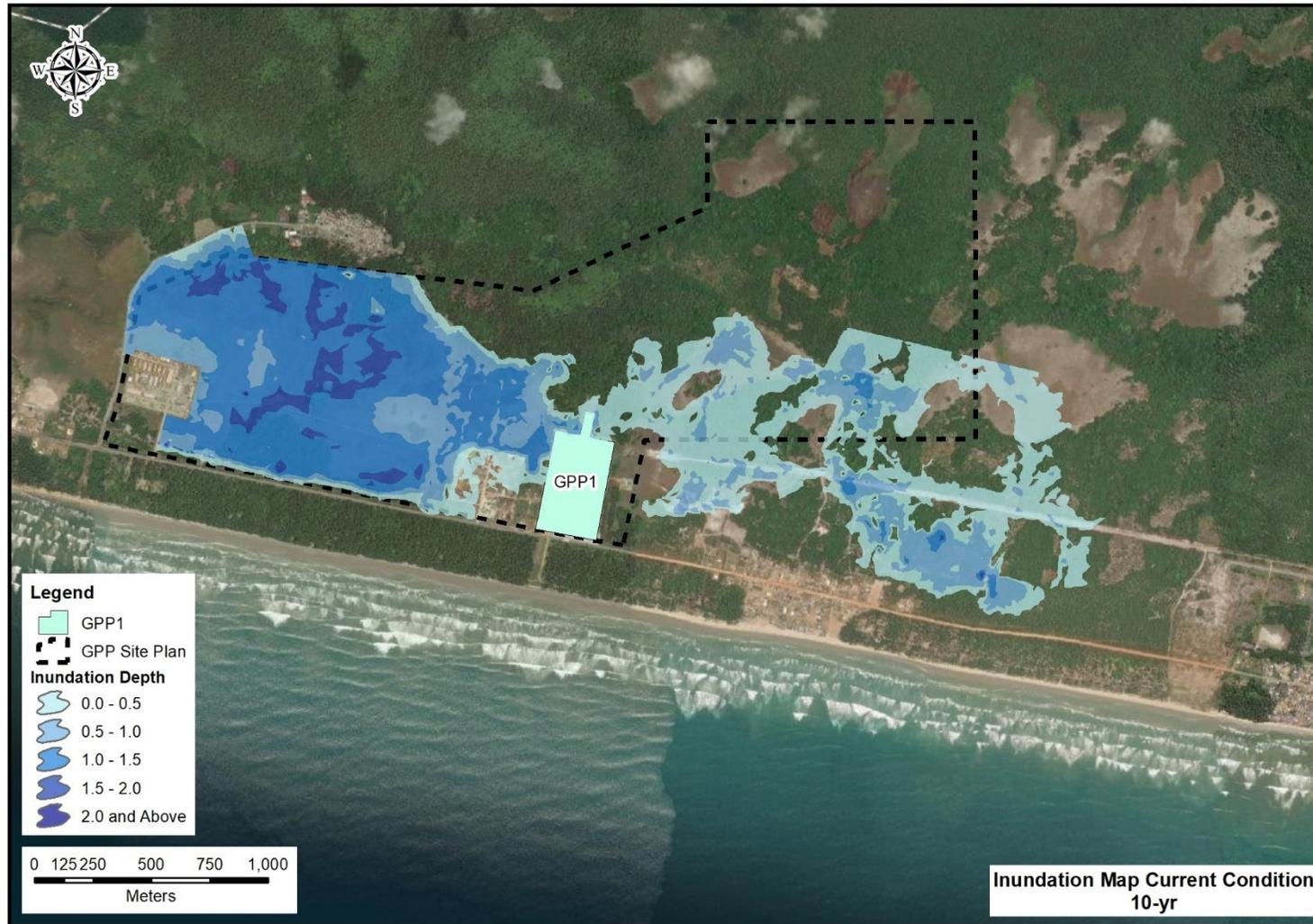


Figure 5-6 Flood Susceptibility Map for Current Condition (Without GPP Train 2) (10-yr Return Period)

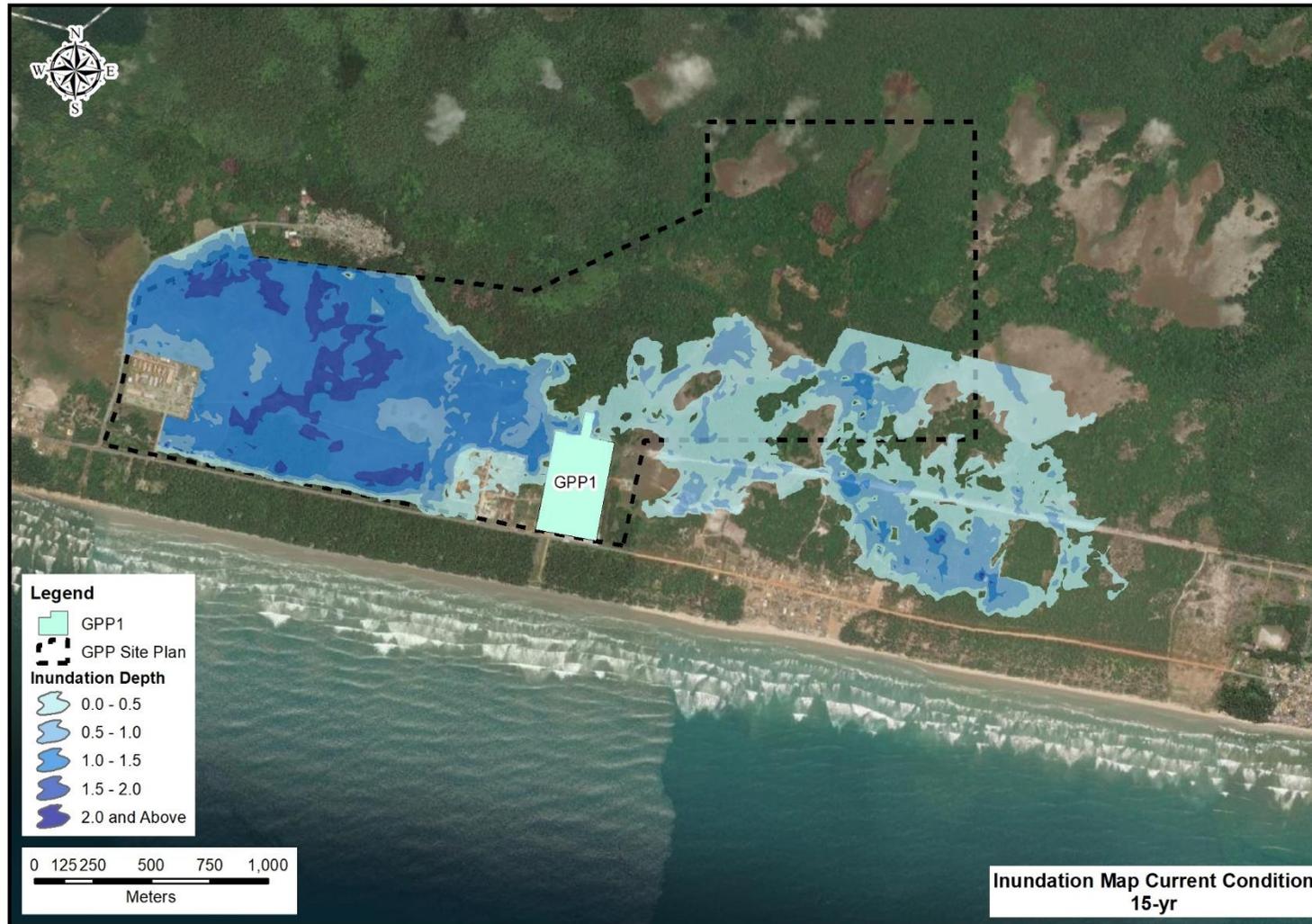


Figure 5-7 Flood Susceptibility Map for Current Condition (Without GPP Train 2) (15-yr Return Period)

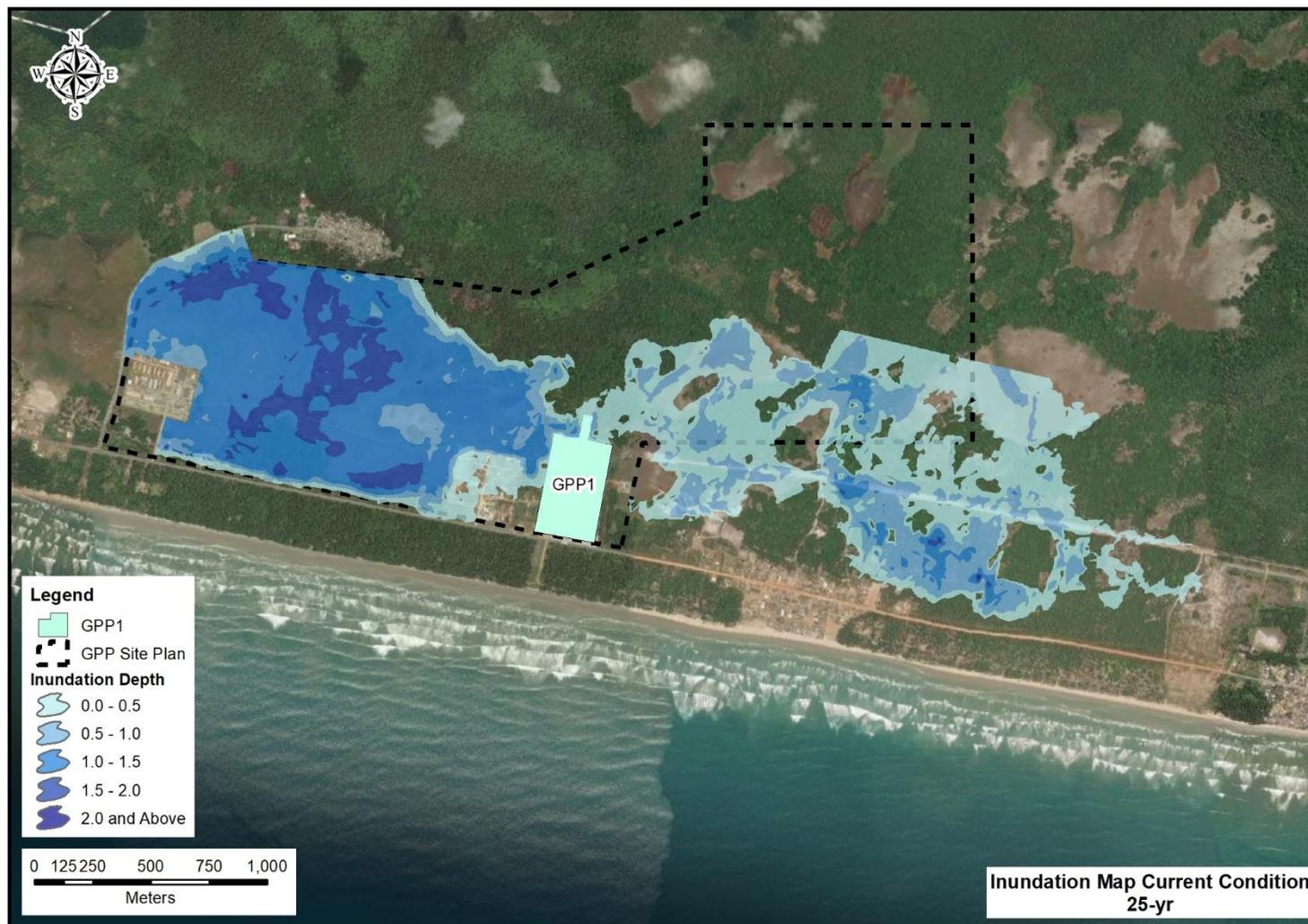


Figure 5-8 Flood Susceptibility Map for Current Condition (Without GPP Train 2) (25-yr Return Period)

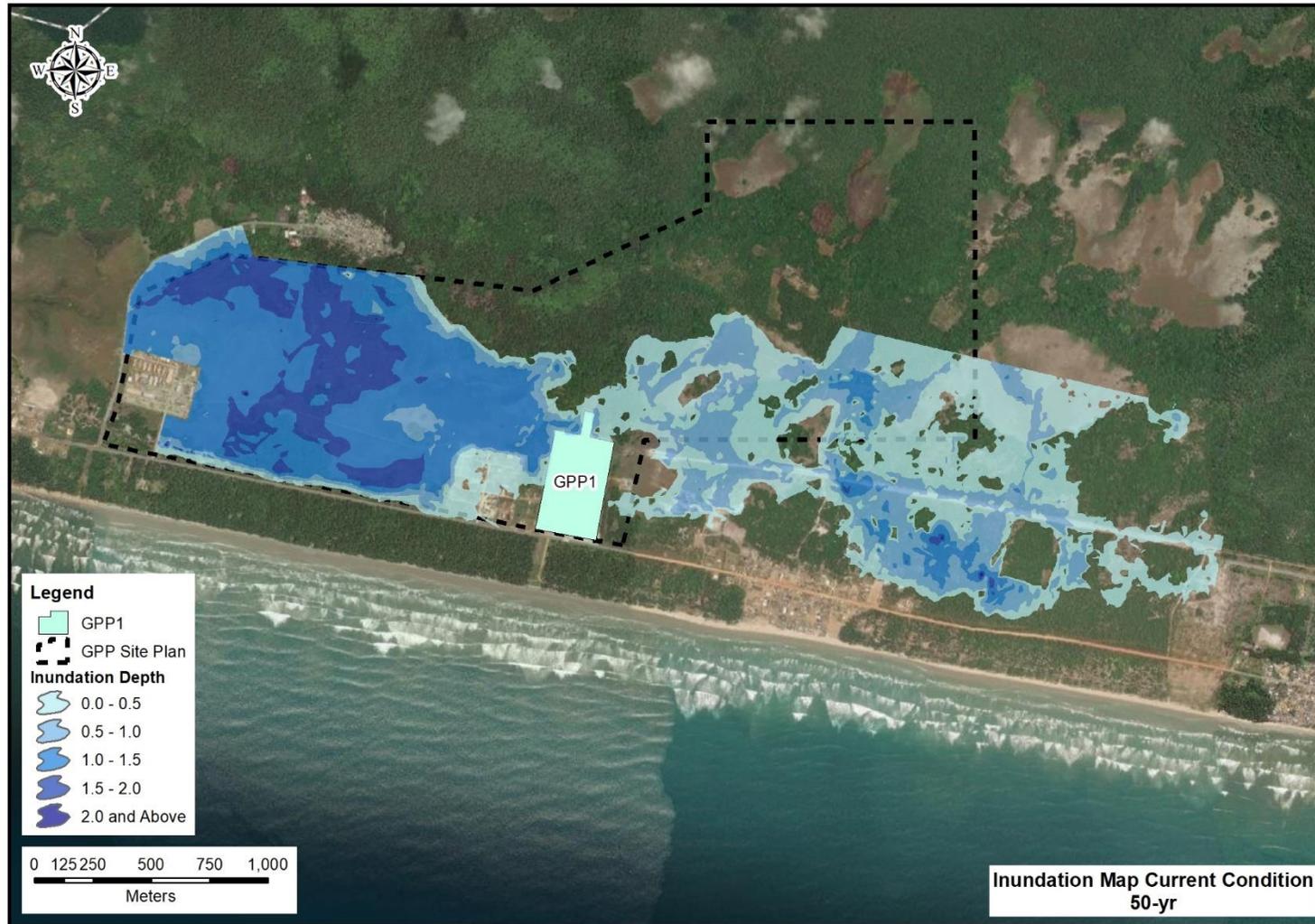


Figure 5-9 Flood Susceptibility Map for Current Condition (Without GPP Train 2) (50-yr Return Period)

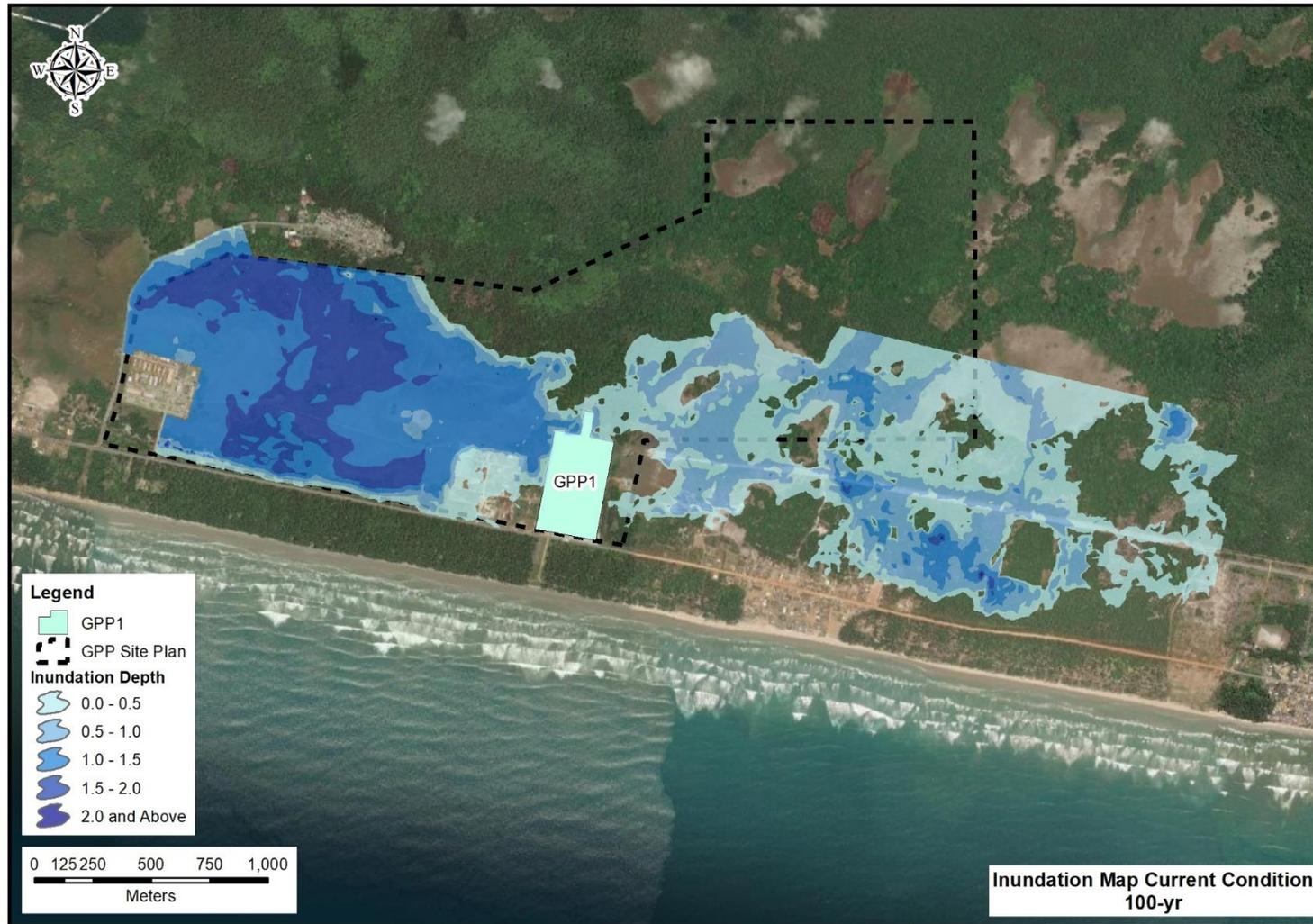


Figure 5-10 Flood Susceptibility Map for Current Condition (Without GPP Train 2) (100-yr Return Period)

5.5 Flood Inundation with GPP Train 2 and Drainage Design

The proposed GPP Train 2 area clearly impedes the natural flow of water which will cause the inundation level at the west side to rise even higher. This will then affect the other facility and expand the inundation area without proper drainage. Furthermore, stored water will seep through soil and embankments which can trigger other problems such as soil consolidation, erosion, piping phenomenon among others.

To prevent this scenario, a drainage culvert is then proposed across the existing road as shown in Figure 5-12. The discharge will be diverted to the coastal side, instead of the town of Anokyi. This will effectively eliminate the flooding specifically at the community area. This will also discharge the storage at the west side to prevent other potential major disasters that can occur.

The maximum water level reached for 100-yr flood event with climate change is computed to be 6.08 meters amsl. The inundation results at the end of 4-day flood simulation with GPP Train 2 and proposed drainage culvert is shown in Figure 5-14 to Figure 5-19. It can be observed that the storage level has lowered which will continue to cease and some will evaporate and free the vicinity from stagnant water.

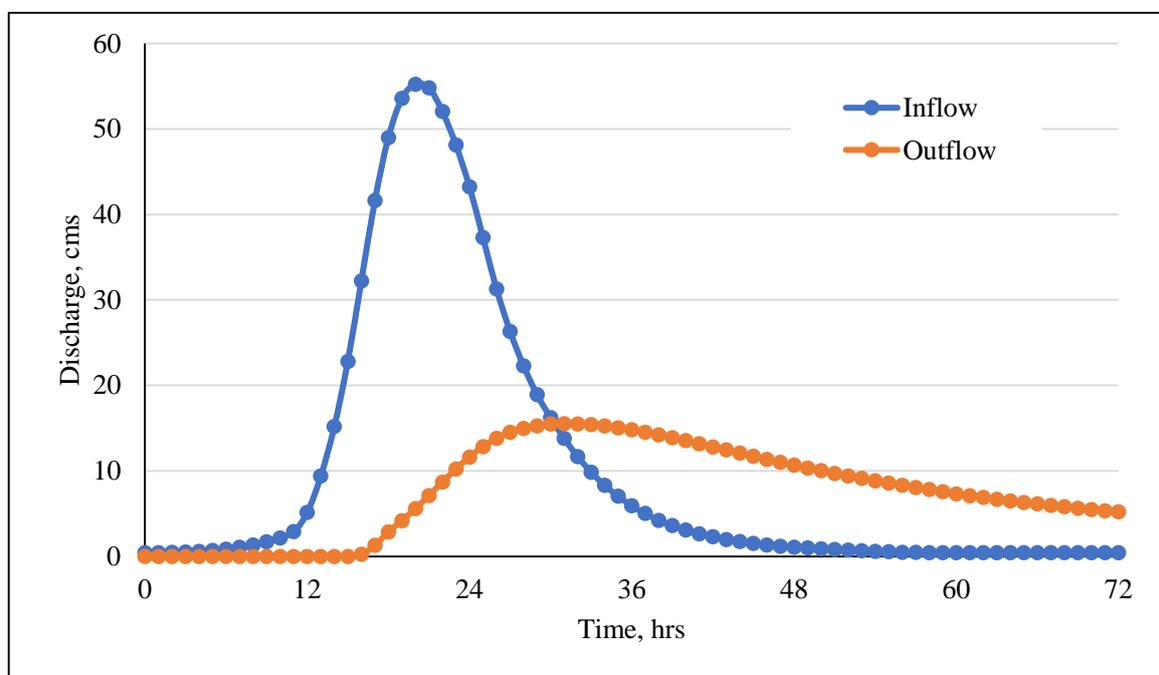


Figure 5-11 Inflow vs Outflow with GPP Train 2 and Drainage Culvert (100-yr Return Period)

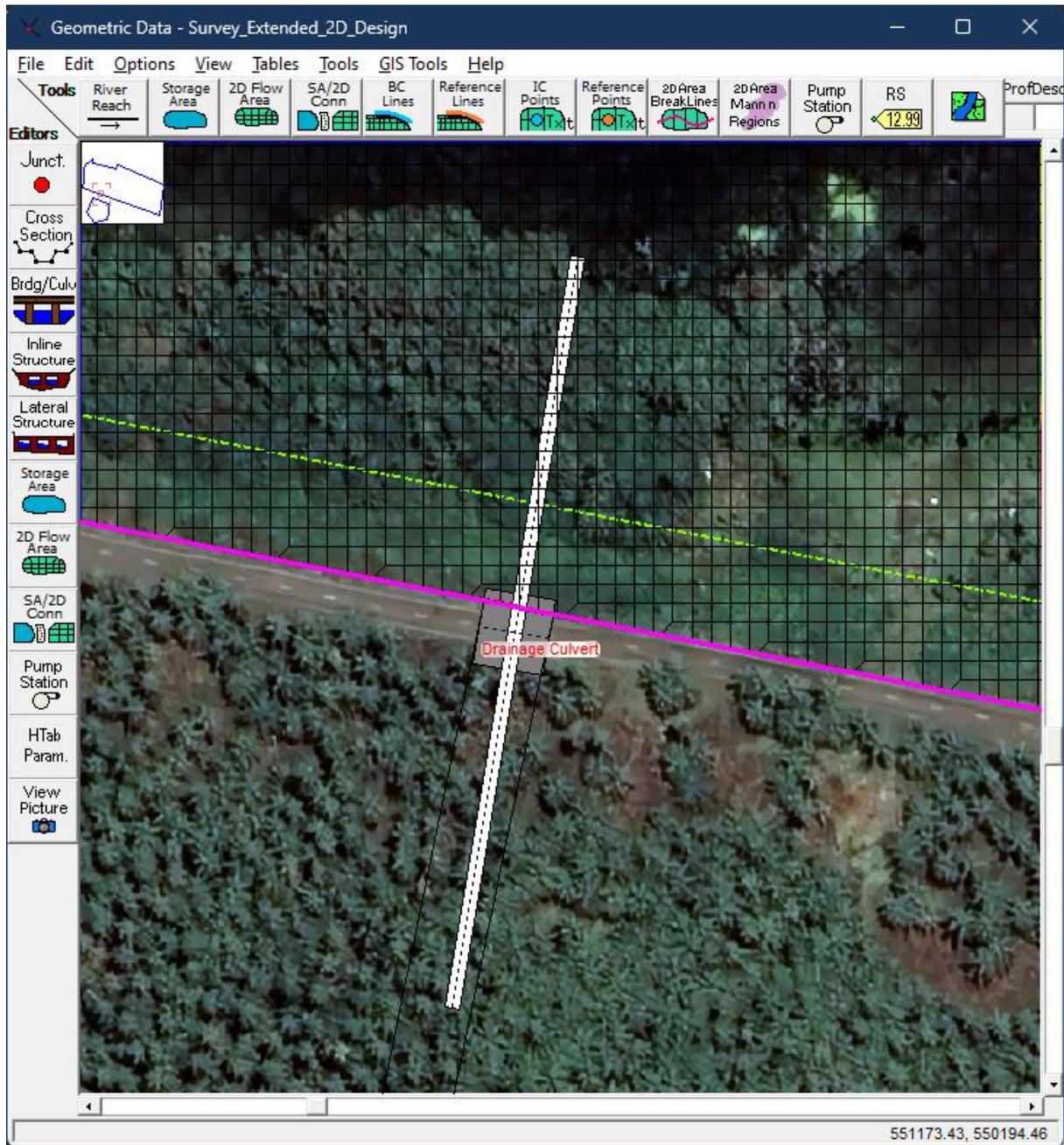


Figure 5-12 Drainage Culvert Model in HEC-RAS

The drainage culvert is designed as box type with a span of 4.0 meters, a rise of 2.0 meters and slope of 0.005. The entrance is provided with flared wingwalls to increase discharge and decrease entrance losses with a coefficient of 0.2. The upstream invert is set equal to the average minimum elevation of the swampy area to lower the flood depth effectively.

Culvert Data Editor

Culvert Group: Culvert #1 ↓ ↑ 📄 🔄 ✖ 📄

Solution Criteria: Computed Flow Control

Shape: Box Span: 4 Rise: 2

Chart #: 8 - flared wingwalls

Scale #: 1 - Wingwall flared 30 to 75 deg.

Culvert Length: 200 Depth to use Bottom n: 0

Entrance Loss Coeff: 0.2 ? Depth Blocked: 0

Exit Loss Coeff: 1 ? Upstream Invert Elev: 4.2

Manning's n for Top: 0.015 ? Downstream Invert Elev: 3.2

Manning's n for Bottom: 0.015

Culvert Barrel Data

Barrel Centerline Stations # Barrels: 1

	Barrel Name	US Sta	DS Sta	GIS Sta	
1	1	9	9		
2					
3					
4					
5					

Barrel GIS Data: 1
Length: 0

	X	Y	
1			
2			
3			
4			
5			

Individual Barrel Centerlines ... Show on Map OK Cancel Help

Select culvert to edit

Figure 5-13 Culvert Data Editor



Figure 5-14 Inundation Map with GPP Train 2 and Drainage Design for 4 Days Flood Simulation (5-yr Return Period)



Figure 5-15 Inundation Map with GPP Train 2 and Drainage Design for 4 Days Flood Simulation (10-yr Return Period)



Figure 5-16 Inundation Map with GPP Train 2 and Drainage Design for 4 Days Flood Simulation (15-yr Return Period)



Figure 5-17 Inundation Map with GPP Train 2 and Drainage Design for 4 Days Flood Simulation (25-yr Return Period)



Figure 5-18 Inundation Map with GPP Train 2 and Drainage Design for 4 Days Flood Simulation (50-yr Return Period)



Figure 5-19 Inundation Map with GPP Train 2 and Drainage Design for 4 Days Flood Simulation (100-yr Return Period)

6 Vulnerability Assessment

Vulnerability assessment involves identifying, analyzing, and evaluating the potential impacts of flooding on people, property, and the environment of the proposed gas processing facility. The main objective is to provide information and recommendations for reducing the risk and enhancing the resilience of the affected communities, critical assets, infrastructure and systems.

6.1 Fluvial Flooding

Fluvial flooding is the result of water overflowing from rivers or streams due to excessive rainfall. Fluvial flooding can cause significant damage to infrastructure, property, and ecosystems, as well as pose risks to human health and safety. Fluvial flooding can be classified into two types: overbank flooding and flash flooding. Overbank flooding occurs when water levels exceed the capacity of the river channel and spill onto the adjacent floodplain. Flash flooding occurs when water levels rise rapidly and unexpectedly, often due to intense rainfall or dam failures.

The proposed gas processing facility is situated in a catchbasin where flood waters accumulate due to low level of drainage. However, as observed with the four (4) days simulation in the previous chapter, the proposed GPP Train 2 is not vulnerable to flood even with the most extreme flood event.

The drainage culvert can effectively lower the inundation level at the west side of GPP 1 and 2 to a minimum elevation of 4.2 meters amsl. It is designed with drainage capacity of 13 cms, 4.6 cms greater than the existing drainage condition of the GPP Area.

The floor level is designed with floor elevation of 7.0 meters amsl. The maximum water level reached for the most extreme flood event is 5.84 meters amsl which clearly shows the design floor level is effective to adapt with the rising inundation depth with available freeboard of 1.16 meters. Also, it is worth noting that this water level occurs only for a short period of time with 1% probability (100-yr return period).

The floor level is also higher than the existing road with lower elevations ranging from 6.4 to 6.9 meters amsl. In cases of overtopping or failure of drainage systems, the flood water will

spill over the existing road to the coastal side considering the design floor level with enough freeboard. It is assured that the gas processing plant can still operate during flood events.

6.2 Pluvial Flooding

Pluvial flooding is a type of flooding that occurs when an extreme rainfall event creates a flood independent of an overflowing water body. It can happen in any location, urban or rural, even in areas with no nearby bodies of water. Pluvial flooding can be caused by two common scenarios: surface water flooding and run-off flooding. Surface water flooding occurs when an urban drainage system is overwhelmed, and water flows out into streets and nearby structures. Run-off flooding occurs when rain falls on hillsides that are unable to absorb the water, creating fast-moving streams that can erode soil and damage property. Pluvial flooding can pose serious risks to people, infrastructure, and the environment, especially as climate change increases the frequency and intensity of extreme rainfall events.

Since most components of the proposed GPP Train 2 is designed without roof covering or shading, rainwater is directed to the facility. However, the floor level is elevated enough to prevent the accumulation of rainwater within the working area. No stagnant water is expected that can disrupt any on-foot operations both in GPP 1 and 2.

It is considered as well that the location of the communities of the towns of Atuabo, Asemnda and Anokyi are located far away to be exposed to any threat of pluvial flooding from the GPP 1 and 2.

6.3 Coastal Flooding

Coastal flooding occurs when seawater inundates land areas that are normally dry, either due to storm surges, high tides, or sea level rise. Coastal flooding can cause damage to infrastructure, property, and human lives, as well as erosion, salinization, and habitat loss. Coastal flooding is expected to worsen in the future due to climate change, which will increase the frequency and intensity of extreme weather events and accelerate the melting of ice sheets and glaciers.

The GPP 1 and 2 is located near the coast, however, the elevation is high enough to be protected from high tide, surge, or sea level rise. The extreme offshore wave is computed to be 3.4 meters

with probability of 2% (50-yr return period), way below the design floor level and the elevation of the existing road. Therefore, GPP area is not vulnerable to coastal flooding.

6.4 Groundwater Flooding

Groundwater flooding is a type of natural hazard that occurs when the water table rises above the ground surface. It can be caused by prolonged rainfall, snowmelt, or changes in aquifer conditions. Groundwater flooding can have significant impacts on human activities and the environment, such as damaging buildings and infrastructure, contaminating water supplies, and affecting ecosystems.

The groundwater condition of the GPP area is influenced only by rainfall as evident of the conducted subsurface investigation. It is also observed that the tidal level has no influence on the groundwater level as evident between readings in the morning and in the afternoon.²

For this situation, the groundwater effect in the flooding condition of the GPP area can be considered in the baseflow of every rainfall event. Since the catchment of the GPP Area is very small, the baseflow is very minimal which is estimated to be 0.43 cms imposing no risk for GPP 1 and 2.

² Preliminary Soil Investigation for Gas Processing Plant Phase 2. February 2019

7 Consequence Assessment

An assessment of the potential consequences of flooding with regards to safety and operational disruptions was undertaken.

Flooding is a natural phenomenon that can have both positive and negative effects on humans and the environment. However, when flooding occurs in a gas processing plant, it can cause serious damage and disruption to the facility and its operations. Some of the possible consequences of flooding in a gas processing plant are:

- **Damage to equipment and infrastructure:** Flooding can submerge, corrode, or wash away pipes, valves, pumps, compressors, tanks, electrical systems, and other components of the gas processing plant. This can result in gas leaks, explosions, fires, or loss of production capacity. Repairing or replacing the damaged equipment can be costly and time-consuming.
- **Disruption to supply and demand:** Flooding can affect the transportation and distribution of natural gas from the gas processing plant to the customers. It can also affect the availability and quality of feedstock for the plant. This can lead to supply shortages, price fluctuations, contractual penalties, or loss of market share.
- **Environmental impacts:** Flooding can contaminate the water, soil, and air with chemicals, hydrocarbons, or hazardous waste from the gas processing plant. This can pose health risks to humans, animals, and plants, as well as damage the ecosystems and biodiversity in the affected area.
- **Social impacts:** Flooding can affect the safety, health, and well-being of the workers and residents near the gas processing plant. It can cause injuries, deaths, diseases, displacement, or psychological stress. It can also affect the livelihoods, education, and social services of the affected communities.

The proposed GPP Train 2 and the existing Atuabo Gas Processing Plant is not vulnerable from any sources of flooding, therefore, no consequences are expected within the GPP area and its surrounding environment including the towns of Atuabo, Asemnda and Anokyi.

8 Flood Risk Assessment

We have evaluated the susceptibility of GPP 1&2 to flood risk by using the flood hazard, vulnerability and consequence assessments to calculate flood risk levels for the facility. This was done to identify any high-risk areas within the facility.

The proposed GPP Train 2 and the existing Atuabo Gas Processing Plant is not vulnerable from any sources of flooding, therefore, no facilities, humans and natural resources are at risk of flooding. It is assured that the gas processing plant can still operate during flood events. Summarized in Table 8-1 are the risk levels for each source of flooding.

Table 8-1 Summary of Risk per Source of Flooding

Source of Flooding	Risk Level
Fluvial Flooding	None
Pluvial Flooding	None
Coastal Flooding	None
Groundwater Flooding	None

9 Mitigation Measures and Recommendations

Mitigation measures were considered and recommended as a safety measure to ensure the proposed GPP Train 2, the existing Atuabo Gas Processing Plant and the surrounding communities are not in any risk of flooding.

It is clearly identified that the proposed GPP Train 2 and the existing Atuabo Gas Processing Plant has no risk in terms of flooding.

The Recommendations are:

- It is strongly recommended that the construction of the new gas processing plant should include the drainage culvert to ease the inundation diverting the flood water to the coastal area. This will effectively decrease the stored water on the west and avoid being swampy over an extended period of time. It will ensure that the vicinity of the plant is desaturated giving more room for land development or other expansion of facilities.

The contributed flooding to the town of Anokyi, on the other hand, can be eliminated since no more flow is coming from the west. Nevertheless, saturation of the area can still be expected with local precipitation and runoff from its own catchment.

The discharge on the coastal area, however, imposes no substantial damage and negative effect due to minimal discharge with a peak of only 15.53 cms at a velocity of 1.39 m/s.

- The floor level should be elevated to at least 7.0 meters amsl or can be leveled with the existing GPP1 at an elevation of 8.0 meters to make sure a smooth transition of facilities and mobility in between the GPP areas. This will also allow enough freeboard from the maximum water level of the most extreme flood event.
- Floor surface should be sloped at a minimum of 1% gradient to allow runoff and avoid accumulation of rainwater that may disrupt operation of the facility, and movement of people and equipment.

10 Regulatory Compliance

A review of applicable safety and environmental regulations and standards related to flood risk management with regards GPP1&2 was conducted to ensure this Flood Risk Assessment meets or exceeds the standard required.

Ghana is one of the most flood-prone countries in West Africa, and floods have caused severe damage to lives, property, infrastructure, and the environment. Therefore, it is important to adopt a proactive and preventive approach to flood risk management (FRM) that considers the social, economic, and environmental aspects of flooding.

10.1 The Flood Risk Management Guidelines (FRMG)

The FRMG are a set of technical guidelines for FRM in Ghana. They were developed in 2018 by the WRC with support from the Global Water Partnership (GWP). The FRMG aim to provide practical guidance on how to assess, plan, design, implement, monitor, and evaluate FRM interventions at different scales. They also aim to promote a holistic and integrated approach to FRM that considers the multiple causes, impacts, and coping strategies of floods. The FRMG cover four main topics: (1) flood hazard assessment; (2) flood risk assessment; (3) flood risk management planning; and (4) flood risk management implementation. The FRMG provide step-by-step procedures, methods, tools, examples, and references for each topic which are intended for use by various actors involved in FRM, such as government agencies, development partners, NGOs, consultants, contractors, researchers, academics, students, and communities.

10.2 The National Flood Early Warning System (NFEWS)

The NFEWS is a key component of FRM in Ghana. It was established in 2010 by the Water Resources Commission (WRC) with support from the World Bank. The NFEWS aims to provide timely and reliable information on flood hazards and risks to decision-makers and stakeholders at different levels. It also aims to enhance the capacity of communities to prepare for and respond to floods.

The NFEWS consists of three main elements: (1) a network of hydro-meteorological stations that collect data on rainfall, river flow, water level, and soil moisture; (2) a data management system that processes, analyzes, and disseminates the data; and (3) a communication system

that delivers flood alerts and warnings to relevant authorities and communities through various channels, such as radio, SMS, email, and social media.

The NFEWS is coordinated by the WRC in collaboration with other institutions, such as the Ghana Meteorological Agency (GMet), the Hydrological Services Department (HSD), the National Disaster Management Organization (NADMO), and the Volta River Authority (VRA). The NFEWS also involves local communities in its operation and maintenance through community-based flood early warning systems (CB-FEWS).

10.3 The National Water Policy (NWP)

The NWP is the overarching policy framework for water resources management in Ghana. It was adopted in 2007 and revised in 2012. The NWP aims to ensure the sustainable development, management, and use of water resources for the benefit of all sectors of society. It also creates measures to mitigate floods by adopting flood early warnings, by ensuring that mitigation strategies are implemented in consultation with the affected communities, and by enforcing buffer zone laws.

The NWP is implemented through various sectoral policies and plans, such as the National Climate Change Policy (NCCP), the National Disaster Management Policy (NDMP), the National Environmental Policy (NEP), the National Sanitation Policy (NSP), and the National Urban Policy (NUP). These policies provide specific guidelines and objectives for FRM in different domains, such as climate change adaptation, disaster risk reduction, environmental protection, sanitation improvement, and urban planning.

11 Emergency Preparedness

Gas processing plants are complex facilities that handle large volumes of flammable and hazardous materials. In the event of an emergency, the plant operators must act quickly and effectively to protect the safety of the workers, the environment, and the surrounding communities. This requires having well-defined emergency response procedures and coordination with local authorities and the communities around the facility.

Emergency response procedures are the set of actions that the plant personnel must follow in case of an emergency which include:

- Identifying the type and severity of the emergency
- Alerting and evacuating the workers and visitors
- Activating the emergency shutdown systems
- Isolating and securing the affected areas
- Mobilizing the onsite emergency response team
- Communicating with the plant management and external stakeholders
- Implementing the appropriate mitigation and recovery measures

Coordination with local authorities is the process of establishing and maintaining a working relationship with the relevant agencies and organizations that can assist in the emergency response. They include:

- Fire departments
- Police departments
- Emergency medical services
- Environmental agencies
- Utility companies
- Media outlets

Coordination with local authorities involves:

- Sharing information about the plant operations and potential hazards
- Developing mutual aid agreements and joint response plans
- Conducting regular drills and exercises
- Providing training and resources
- Reporting and documenting incidents and lessons learned

Community Emergency Response Consultation, Coordination and Awareness:

The Ghana gas processing plants have a responsibility to ensure that they are prepared for any emergency that may occur. By having effective emergency response procedures, coordination with local authorities and the communities they can minimize the risks and impacts of such events and protect the interests of all stakeholders.

12 Public and Stakeholder Engagement

Public and stakeholder engagement is a key component of any successful project or initiative. It involves identifying, communicating, and collaborating with the people who are affected by or interested in the outcomes of the project. The purpose of public and stakeholder engagement is to gather feedback, input and perspectives that can inform decision-making, improve the quality and relevance of the project, and enhance trust and transparency.

Public and stakeholder engagement was conducted with various groups and communities on October 9 to 19, 2023. The engagement and survey involved the Ghana National Gas Limited Company (GNGLC), concerned government offices and authorities, all the neighboring and affected communities and several facilities.

Issues and concerns were gathered, and the only notable concern and discussion related to the flood risk assessment is the occasional flooding at the towns of Atuabo and Asemnda.

It is important to note that the flooding cases are not caused or intensified by the existing Atuabo gas facility and certainly will not with the proposed GPP Train 2. The occasional flooding may have caused by direct rainfall and local runoff from each own catchment. The flood simulation conducted on the vicinity of the GPP area shows the inundation by the gas processing plants will not affect the said communities.

13 Conclusion

GPP1&2 is not susceptible to flooding, however mitigation measures have been identified and recommended to ensure there is no flood risk to the facility and surrounding environment. The following recommendations are made:

- Implement the mitigation measures identified in this report
- The construction of the new gas processing plant should include the drainage culvert to ease the inundation diverting the flood water to the coastal area. This will effectively lower the stored water on the west and avoid being swampy over an extended period of time. It will ensure that the vicinity of the plant is desaturated giving more room for land development or another expansion of facilities.
- The floor level should be elevated to at least 7.0 meters amsl or can be leveled with the existing GPP1 at an elevation of 8.0 meters to make sure a smooth transition of facilities and mobility in between the GPP areas. This will also allow enough freeboard from the maximum water level of the most extreme flood event.
- Floor surface should be sloped at a minimum of 1% gradient to allow runoff and avoid accumulation of rainwater that may disrupt operation of the facility, and movement of people and equipment.

14 References and Appendices

14.1 Daily Rainfall

NAME	YEAR	MONTH	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9	DAY10	DAY11	DAY12	DAY13	DAY14	DAY15	DAY16	DAY17	DAY18	DAY19	DAY20	DAY21	DAY22	DAY23	DAY24	DAY25	DAY26	DAY27	DAY28	DAY29	DAY30	DAY31	
Axim	2012	1	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.5	0.0	0.0	0.0	0.0	0.0	12.9	0.0	0.0	0.0	0.0	
Axim	2012	2	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	8.6	16.0	0.0	0.0	0.0	0.0	2.9	0.1			
Axim	2012	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8	0.0	0.0	0.0	2.1	0.0	0.8	
Axim	2012	4	0.0	0.0	7.5	0.0	0.0	1.6	0.0	7.3	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	25.8	0.0	14.3	0.0	0.0	0.0	0.0	4.5	4.4	0.0	0.0	0.0	0.0	1.9		
Axim	2012	5	0.0	54.3	37.6	0.6	0.0	0.3	0.0	7.4	34.8	0.0	26.1	0.0	0.0	5.5	0.4	0.0	0.0	0.0	38.6	0.0	2.9	0.0	3.1	129.9	29.6	7.6	0.0	10.5	5.3	34.0	0.8	
Axim	2012	6	0.0	45.2	1.0	2.5	33.8	2.6	0.4	0.1	0.0	0.0	9.0	0.4	0.0	7.9	30.2	37.2	52.4	3.4	6.0	28.2	9.9	0.3	11.2	20.8	5.3	4.0	15.7	1.6	2.2	2.5		
Axim	2012	7	4.8	0.2	65.3	3.4	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0	23.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.5	2.8	0.0	0.0	0.0	0.0	
Axim	2012	8	9.6	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	1.4	0.0	0.0	0.8	0.0	0.0	15.8	1.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	
Axim	2012	9	0.0	4.9	4.4	0.0	2.1	0.0	0.0	0.0	0.0	0.4	0.5	0.5	0.0	0.0	1.6	0.0	0.0	0.0	1.8	0.0	0.7	0.0	0.0	0.0	13.8	28.0	8.1	0.0	0.0	0.0		
Axim	2012	10	0.9	0.2	3.9	0.4	56.4	5.8	1.6	0.5	0.8	0.6	3.2	7.2	2.6	0.0	0.0	4.4	12.5	0.0	98.0	0.0	1.9	2.2	10.6	14.4	4.3	0.0	0.0	0.4	6.6	0.0	0.0	
Axim	2012	11	0.0	21.8	0.0	10.8	4.8	3.2	3.5	0.0	6.4	12.1	0.0	0.0	0.3	0.1	0.0	0.0	1.6	0.0	50.4	0.0	6.4	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	3.1		
Axim	2012	12	0.3	5.5	14.2	2.8	23.7	31.4	0.1	0.0	0.0	4.7	6.1	4.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2013	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2013	2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.0	0.0	0.0				
Axim	2013	3	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	20.2	0.0	0.4	40.5	0.0	0.0	0.0	0.0	9.1	12.1	0.0	0.0	0.0	0.3	0.0	0.0	4.6	0.0	0.0	0.0	
Axim	2013	4	0.0	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	0.1	3.2	7.7	0.0	0.0	3.6	3.1	0.0	0.0	17.0	0.0	0.0	0.0	18.2		
Axim	2013	5	2.7	0.0	0.0	0.4	0.0	0.0	9.5	0.0	0.0	0.0	39.2	10.5	0.0	0.0	33.2	0.3	23.7	17.4	1.4	0.0	0.0	6.5	4.4	0.1	0.0	14.4	0.5	0.0	5.3	76.7	66.4	
Axim	2013	7	0.0	0.0	0.0	17.0	1.6	0.5	3.7	2.0	0.0	0.0	0.0	22.9	16.3	0.6	0.0	0.0	2.8	0.0	2.3	1.0	0.0	0.0	1.7	15.3	2.9	20.8	2.6	19.7	0.6	0.0	0.0	
Axim	2013	8	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0		
Axim	2013	9	5.4	9.3	0.0	0.0	0.0	0.5	7.8	1.1	2.1	0.0	0.0	0.3	3.2	0.2	0.0	0.8	0.7	1.4	0.0	0.8	1.0	0.0	9.5	5.5	0.0	0.0	6.5	4.0	0.0	0.0		
Axim	2013	10	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0	0.0	0.5	0.0	0.0	0.0	0.5	1.6	15.8	0.5	0.0	0.0	21.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	4.4	4.3	
Axim	2013	11	70.1	3.5	10.5	19.2	26.7	0.0	0.3	0.0	0.0	0.0	0.4	0.6	1.1	12.9	15.8	1.6	0.0	0.2	0.0	0.0	0.0	27.0	1.1	0.0	0.0	1.6	1.4	0.0	0.0	0.0		
Axim	2013	12	4.3	0.0	4.9	10.2	0.3	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	10.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.2	0.0	0.5	0.0	
Axim	2014	1	0.0	42.3	0.0	0.0	0.0	0.4	0.0	0.0	0.0	7.0	0.0	0.0	0.7	0.0	0.0	0.0	3.5	0.0	0.0	0.0	6.6	0.0	0.3	0.0	7.8	0.0	0.0	0.0	0.0	0.3	0.0	
Axim	2014	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	13.5	1.4	3.7	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	32.9	0.4	0.0	0.4	79.2				
Axim	2014	3	28.3	0.0	0.0	0.0	0.0	54.5	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.2	0.0	0.0	0.0	0.0	0.0	0.0	3.9	
Axim	2014	4	0.0	0.0	8.1	0.0	0.0	0.0	2.1	0.0	0.0	3.2	18.1	0.6	21.0	0.0	0.0	0.0	0.0	15.9	0.0	0.4	23.3	33.1	1.3	0.0	0.0	2.8	0.0	0.3	2.7	6.8		
Axim	2014	5	10.2	0.0	0.0	0.0	5.9	46.7	39.9	28.1	10.1	0.0	4.9	0.0	17.5	0.0	7.3	0.4	0.0	0.0	32.4	0.0	12.6	4.0	0.0	5.7	1.3	0.9	26.4	6.4	57.2	23.1	0.0	
Axim	2014	6	42.5	0.0	0.7	87.7	25.2	22.7	26.5	0.2	31.1	39.9	13.0	56.1	11.3	1.4	114.5	33.6	4.1	0.2	0.3	40.3	24.9	9.4	19.1	0.0	0.8	1.9	0.2	0.0	8.4	58.3		
Axim	2014	7	67.7	3.2	0.0	6.8	7.7	0.2	0.0	0.0	0.0	0.3	0.0	0.0	0.0	9.1	0.0	55.2	2.0	0.0	0.0	2.0	0.0	0.0	0.6	3.8	0.9	0.4	4.2	3.5	6.5	2.0	1.6	
Axim	2014	8	2.0	1.2	0.0	0.0	5.2	2.1	8.4	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.5	0.0	0.0	0.0	2.0	2.4	0.5	0.0	0.4	3.3	13.8	2.3	0.0	0.0	0.0	6.8	
Axim	2014	9	9.6	0.0	0.3	0.0	0.1	1.9	5.5	0.0	0.6	0.0	0.0	0.0	0.7	0.0	1.1	1.3	7.4	32.5	0.3	0.0	0.0	1.2	0.7	7.6	1.8	34.0	12.9	7.4	2.2	16.2		
Axim	2014	10	2.2	0.2	0.3	0.6	4.2	0.3	0.1	0.0	0.4	2.2	0.0	0.0	6.5	2.1	0.0	0.3	4.0	0.0	45.9	9.0	0.0	0.0	0.0	1.9	29.1	0.7	1.1	0.0	1.3	0.0	0.4	
Axim	2014	11	9.4	0.0	0.1	19.4	48.0	0.0	0.2	0.0	12.9	40.7	0.1	0.0	0.0	0.0	0.0	7.9	0.3	0.0	0.0	0.0	0.0	0.0	6.9	1.0	34.0	0.0	0.5	0.0	0.0	0.0		
Axim	2014	12	0.0	0.0	17.5	19.9	0.0	0.0	18.6	0.0	0.0	0.0	1.6	0.0	0.0	1.5	0.0	7.2	0.0	0.0	0.0	0.0	26.4	9.0	6.0	0.0	5.1	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2015	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	21.5	0.0	0.3	10.7	0.2	0.0	0.0	0.0	0.0	0.0	
Axim	2015	2	1.1	0.0	0.0	4.1	0.0	0.4	17.1	0.0	0.0	0.0	51.4	0.0	0.0	2.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2015	3	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	61.7	0.8	6.2	0.3	0.0	9.6	2.3	0.0	0.0	5.5	0.0	0.1	0.0	0.0	0.0	7.4	0.8	
Axim	2015	4	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	31.6	4.9	3.2	0.0	4.5	0.0	0.0	0.0	0.0	1.1	1.1	0.3	0.0	19.6	0.9	0.0	0.0	0.0	0.5	0.5	0.0		
Axim	2015	5	0.0	0.0	41.7	0.7	1.9	0.0	3.2	5.2	0.0	7.6	0.0	0.0	0.0	0.0	0.8	0.0	0.6	24.6	0.0	3.5	0.0	17.2	14.0	0.0	0.0	0.0	7.6	0.0	10.6	0.0	2.1	
Axim	2015	6	7.4	88.3	123.2	4.7	121.8	0.7	1.8	1.9	0.3	11.8	1.2	64.3	0.0	50.8	0.7	0.0	0.0	0.0	0.0	16.1	0.7	0.3	0.0	0.0	0.7	0.1	0.0	0.0	0.3	0.4		
Axim	2015	7	0.0	0.0	4.7	2.7	0.0	0.0	0.0	0.3	0.0	0.4	0.0	0.0	2.1	0.4	4.2	0.0	1.3	0.0	0.0	0.4	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2015	8	0.0	0.0	5.6	5.0	0.0	0.8	12.9	0.0	0.0	24.4	3.9	0.6	0.1	0.2	0.3	0.0	0.0	0.0	0.0	0.0	4.7	0.3	0.0	0.0	1.3	0.0	0.					

Flood Risk Assessment
Ghana Gas Processing Plant Train 2

NAME	YEAR	MONTH	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9	DAY10	DAY11	DAY12	DAY13	DAY14	DAY15	DAY16	DAY17	DAY18	DAY19	DAY20	DAY21	DAY22	DAY23	DAY24	DAY25	DAY26	DAY27	DAY28	DAY29	DAY30	DAY31	
Axim	2015	9	1.1	2.6	0.1	0.3	0.0	0.0	0.0	0.0	1.3	0.0	2.8	0.0	0.7	0.2	0.3	1.2	0.0	0.7	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0		
Axim	2015	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.1	20.4	3.1	0.0	0.0	0.0	9.5	5.0	27.2	9.8	2.4	1.1	9.1	2.8	0.5	0.0	2.4	1.5	0.8	5.0	0.0	6.0	17.8	9.9	
Axim	2015	11	10.4	8.2	0.0	3.0	0.0	105.2	17.9	0.0	8.6	0.0	0.0	7.6	0.0	0.2	0.0	0.0	13.9	0.0	0.0	0.0	0.0	10.1	0.0	0.0	0.0	1.9	0.0	0.0	0.0	2.3		
Axim	2015	12	24.7	9.8	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Axim	2016	1	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Axim	2016	2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.8	0.3	0.0	0.3	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.4	0.0	2.9			
Axim	2016	3	0.3	0.0	0.0	0.0	2.5	0.0	0.0	84.7	0.0	0.0	0.4	0.0	1.2	19.9	0.0	0.0	32.4	0.0	0.0	0.0	1.7	0.0	46.5	0.3	0.0	43.2	15.1	0.0	0.2	0.0	0.0	
Axim	2016	4	20.0	0.0	0.0	0.0	0.0	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	14.2	0.2	20.8	1.8	34.3	0.0	0.3		
Axim	2016	5	9.2	0.1	1.6	0.0	30.9	2.0	0.0	0.0	0.0	0.0	0.0	45.7	0.2	0.0	0.1	0.1	44.2	0.2	1.4	0.1	0.1	3.9	5.8	0.0	17.7	4.1	2.2	0.4	2.4	24.1	3.9	
Axim	2016	6	0.0	43.9	22.6	3.1	0.5	0.9	5.8	34.8	44.5	42.9	0.0	114.8	2.7	46.1	13.6	0.1	0.0	0.0	93.8	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2	7.1	0.2		
Axim	2016	7	11.3	5.0	23.4	0.0	0.0	3.1	0.6	0.0	3.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	30.1	0.0	0.0	21.3	3.8	0.0	0.5	0.0	7.3	6.9	0.2	1.4	1.6	0.4	0.3	
Axim	2016	8	0.0	0.0	0.0	0.3	1.1	0.4	1.2	0.2	4.1	0.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	67.0	42.2	6.4	0.0	1.6	0.0	0.0	0.0	3.6	4.7	51.8	0.2	
Axim	2016	9	0.0	0.0	0.0	9.3	0.0	0.2	0.2	0.0	1.2	2.2	3.5	0.0	0.0	4.0	0.4	0.0	1.8	0.0	1.5	3.4	8.5	3.6	0.0	10.2	6.6	0.0	10.2	14.9	0.7	0.0		
Axim	2016	10	3.8	2.3	0.3	0.6	0.0	0.0	0.3	3.9	6.6	11.4	8.4	5.8	0.3	0.0	4.6	0.2	1.7	19.6	16.9	0.0	2.2	2.8	14.0	0.0	0.0	0.0	0.3	0.0	0.0	58.1	0.0	
Axim	2016	11	2.3	0.0	0.0	0.0	13.5	3.7	1.9	6.6	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	2.9	5.7	0.0	2.0	12.9	6.0	48.0	9.9	0.0	0.0		
Axim	2016	12	0.0	1.0	2.4	0.0	0.0	0.0	0.8	14.8	0.0	3.6	0.2	0.0	0.0	4.4	5.0	0.0	2.2	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	7.8	0.0	0.0	0.0	0.0	0.0	
Axim	2017	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.4	0.0	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3	
Axim	2017	2	0.0	0.0	0.0	1.1	3.9	0.0	0.0	0.0	0.0	0.7	0.0	2.9	51.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.4	0.0	0.0				
Axim	2017	3	0.0	0.0	0.0	0.0	3.8	0.0	0.0	10.7	1.7	10.2	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2017	4	12.3	0.0	26.4	0.0	0.0	0.0	0.2	5.1	43.7	0.0	0.0	0.0	57.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	11.3	0.0	0.0	0.3	0.0	0.0			
Axim	2017	5	0.9	0.5	1.2	6.1	0.0	0.4	0.8	0.8	0.6	0.5	74.0	0.0	0.8	19.4	27.0	153.5	37.9	0.0	0.0	17.0	0.2	28.8	0.8	24.7	75.6	0.0	0.0	12.4	9.4	15.6	3.2	
Axim	2017	6	0.0	42.3	4.3	0.0	31.7	0.0	0.5	0.3	40.3	139.1	66.3	27.8	0.7	0.6	0.0	0.0	5.6	0.0	17.6	0.2	0.2	2.4	16.6	20.5	0.0	0.0	2.8	5.4	0.0	0.0		
Axim	2017	7	11.2	60.5	5.1	33.7	29.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	14.7	1.7	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2017	8	0.8	2.2	0.7	0.0	0.5	0.7	0.0	0.0	0.0	1.5	0.0	0.0	1.9	0.0	0.0	0.0	2.9	0.0	0.0	0.0	0.0	2.8	0.0	0.0	16.9	0.0	0.0	0.0	0.0	2.9	0.9	
Axim	2017	9	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.5	0.0	10.6	0.0	0.4	0.0	0.0	6.9	5.9		
Axim	2017	10	2.2	23.7	0.3	2.4	0.0	69.1	27.7	20.5	0.0	13.5	2.8	0.4	0.0	0.8	0.2	0.0	0.0	5.4	0.0	0.2	0.0	0.0	1.3	0.3	0.0	0.0	4.7	23.1	0.0	0.0	0.3	
Axim	2017	11	12.8	0.0	0.0	3.1	165.1	0.0	0.0	0.0	0.0	10.2	9.7	0.0	0.0	0.0	28.3	0.0	0.0	27.0	10.5	4.0	0.0	0.0	3.4	0.0	10.8	0.0	0.0	0.0	0.0	0.0		
Axim	2017	12	0.0	3.4	9.0	0.0	28.8	23.8	0.0	5.6	16.0	0.0	0.0	0.0	0.0	0.0	0.0	79.1	0.0	25.8	2.9	10.1	18.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2018	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2018	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	11.3	3.2	0.0	5.1	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0				
Axim	2018	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	1.4	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	
Axim	2018	4	2.1	0.0	0.2	0.2	0.0	0.0	0.0	3.2	28.3	0.7	0.0	26.6	6.8	0.0	0.0	0.0	3.4	18.6	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.0	10.5	0.0		
Axim	2018	5	0.0	27.3	0.6	0.0	9.4	0.0	0.0	13.4	26.4	66.1	28.2	0.0	0.0	2.1	30.0	17.2	9.4	6.3	0.0	1.1	0.9	0.0	0.8	32.3	16.9	26.7	4.2	0.0	33.0	4.2	2.5	
Axim	2018	6	0.0	0.5	8.2	0.0	11.4	26.7	0.0	5.5	0.0	1.6	0.0	0.0	0.0	0.0	67.0	0.0	0.0	41.7	2.3	0.0	9.9	0.0	1.9	0.0	0.0	5.3	3.1	6.3	0.6	18.2		
Axim	2018	7	12.4	97.0	0.9	1.3	8.4	0.0	0.0	21.4	0.0	2.1	2.0	1.3	8.4	0.0	127.7	51.7	50.2	19.5	0.0	0.0	0.2	0.0	2.4	51.4	49.1	1.1	0.0	0.0	0.0	0.0	0.0	
Axim	2018	8	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.4	0.3	0.0	4.4	0.0	3.9	6.0	0.3	0.8	1.4	6.6	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2018	9	3.5	0.0	9.4	10.4	3.4	1.9	3.4	6.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	0.0	0.3	0.0	0.0	1.3	2.5	0.0	0.0	0.1	41.9	14.5	0.0	0.0		
Axim	2018	10	1.0	0.0	0.0	0.0	0.0	0.4	22.8	12.7	1.6	1.6	9.6	0.0	0.0	0.3	0.0	128.8	0.9	0.0	0.2	0.0	8.8	0.0	4.3	3.4	0.0	0.9	1.6	11.0	3.7	0.3	0.0	
Axim	2018	11	0.8	0.0	0.0	10.7	0.0	61.2	1.8	0.0	0.0	0.0	0.0	0.0	10.7	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0		
Axim	2018	12	0.0	0.0	0.0	1.5	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.6	10.1	0.0	0.0	0.1	0.0	11.2	0.1	0.0	0.0	0.0	22.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2019	1	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	8.4	0.0	2.6	28.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.9	0.0
Axim	2019	2	0.0	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	34.1	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	19.7				
Axim	2019	3	1.5	0.0	0.0	0.0	0.0	35.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	4.2	0.0	0.0	0.0	2.3	24.9	4.2	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Axim	2019	4	0.0	0.0	0.5	122.6	0.0	0.0	54.6	0.0	0.0	0.0	10.2	0.0	0.8																			

**Flood Risk Assessment
Ghana Gas Processing Plant Train 2**

NAME	YEAR	MONTH	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9	DAY10	DAY11	DAY12	DAY13	DAY14	DAY15	DAY16	DAY17	DAY18	DAY19	DAY20	DAY21	DAY22	DAY23	DAY24	DAY25	DAY26	DAY27	DAY28	DAY29	DAY30	DAY31
Axim	2019	7	0.2	0.0	2.5	0.0	2.5	2.4	2.2	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.3	5.8	6.0	1.7	0.2	0.0	0.0	0.0	0.0	2.2	2.0	6.3	2.6	0.0
Axim	2019	8	0.0	4.0	0.0	0.0	5.1	18.2	13.2	2.9	5.9	0.6	1.9	0.0	3.7	1.9	0.0	1.2	0.0	0.0	0.0	8.8	7.0	0.0	0.0	0.0	2.8	0.0	0.5	0.0	0.0	6.3	2.1
Axim	2019	9	1.9	8.3	0.7	0.0	0.0	0.0	1.4	1.6	0.0	1.6	0.0	3.9	0.0	3.3	4.1	0.0	0.0	21.7	21.6	7.0	2.5	0.5	0.0	0.0	0.0	0.0	6.6	0.0	0.0	19.3	
Axim	2019	10	1.2	3.8	0.0	17.2	0.0	1.4	1.6	1.3	11.1	0.8	56.1	86.1	0.0	1.3	0.0	0.0	0.0	0.0	25.4	49.3	0.0	9.4	15.5	1.6	16.9	0.0	31.6	87.5	10.5	21.2	0.0
Axim	2019	11	0.0	0.0	0.0	13.1	0.0	0.8	1.3	0.0	0.0	5.4	0.0	0.4	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	26.4	0.0	0.0	0.0	0.0	0.0	36.0	8.7	3.5	0.0	
Axim	2019	12	3.2	1.4	13.0	7.6	32.2	0.0	0.0	0.0	3.8	35.5	20.5	2.4	17.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.7	11.8
Axim	2020	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0	0.0	0.0	4.7	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Axim	2020	2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	6.2	0.0	0.0	0.6	0.0	0.0	7.9	0.0	0.0		
Axim	2020	3	0.0	0.0	42.6	0.0	31.6	0.0	18.0	2.7	0.8	0.0	0.0	4.0	1.5	36.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Axim	2020	4	24.5	0.0	0.0	1.1	0.0	0.0	0.0	1.1	0.0	36.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	9.7	0.0	15.2	48.1	0.0	0.0	0.0	78.7	0.0	0.0	0.0	8.8	
Axim	2020	5	0.0	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	111.9	1.7	0.0	0.0	0.0	5.2	0.0	0.0	1.7	5.6	0.0	0.0	9.1	0.6	22.8	15.9	1.8	50.8	39.4	0.0	0.0	1.3
Axim	2020	6	2.2	15.0	0.0	0.0	0.0	1.6	0.0	42.4	93.2	151.5	3.6	0.9	49.6	2.7	0.0	17.6	71.5	3.3	0.0	48.7	63.3	3.7	0.0	16.4	136.4	18.0	4.8	28.8	24.6	0.0	
Axim	2021	5	0.0	1.0	0.0	0.0	2.3	0.6	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	12.2	1.2	0.2	0.0	0.0	119.4	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	26.7	0.0
Axim	2021	6	0.0	6.4	0.0	7.7	2.2	0.0	0.0	2.6	20.6	42.6	30.6	0.0	0.0	0.0	1.8	34.2	0.0	0.0	12.2	97.0	9.1	15.2	22.3	0.0	2.0	11.5	0.0	4.0	26.3	0.8	
Axim	2021	7	14.8	60.6	26.8	0.0	93.4	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	14.0	68.0	86.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	0.0
Axim	2022	9	9.8	4.1	0.0	2.5	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.2	21.2	2.9	0.7	0.0	0.0	20.2	22.8	1.4	5.2	0.8	2.7	6.9	

14.2 Daily Temperature

NAME	YEAR	MONTH	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9	DAY10	DAY11	DAY12	DAY13	DAY14	DAY15	DAY16	DAY17	DAY18	DAY19	DAY20	DAY21	DAY22	DAY23	DAY24	DAY25	DAY26	DAY27	DAY28	DAY29	DAY30	DAY31
Axim	2012	1	25.1	26.7	27.2	27.5	27.3	27.0	27.6	27.0	26.9	28.1	28.0	27.7	28.0	27.9	26.2	26.0	25.6	26.1	28.0	27.9	28.3	26.2	26.5	26.8	27.6	28.8	29.0	27.2	27.4	28.8	28.5
Axim	2012	2	28.6	28.8	26.7	28.6	27.6	26.4	26.7	25.3	25.0	26.1	27.1	27.8	27.3	27.5	27.6	27.7	27.8	27.7	27.0	26.3	27.2	26.9	26.0	25.9	27.0	27.9	28.5	27.9	26.1		
Axim	2012	3	27.1	27.8	26.8	28.7	26.9	27.1	26.8	29.0	29.2	28.4	28.1	28.5	28.5	28.8	29.7	30.0	29.9	27.2	28.7	30.0	30.2	30.1	30.3	30.0	28.2	26.6	28.9	29.8	30.1	29.4	28.2
Axim	2012	4	29.9	29.1	26.9	25.8	27.7	29.0	28.4	28.5	27.2	27.7	28.4	29.1	27.5	27.6	28.8	28.6	27.8	26.4	28.1	25.7	26.9	29.4	29.2	28.8	28.5	27.0	27.9	28.4	28.5	28.4	
Axim	2012	5	28.5	28.4	27.6	25.7	27.5	28.7	29.5	29.3	26.5	27.3	27.2	26.6	27.9	27.5	26.5	27.3	28.6	28.0	28.8	26.5	28.0	26.5	27.5	28.1	25.4	25.6	26.3	27.4	26.6	26.1	27.6
Axim	2012	6	26.5	27.6	25.5	27.0	27.2	26.3	26.5	27.3	27.0	27.9	27.4	26.9	27.3	27.3	26.5	26.1	25.0	24.5	26.6	26.8	23.9	25.5	26.9	25.3	25.1	26.1	26.7	25.6	25.9	26.5	
Axim	2012	7	26.0	25.9	26.3	25.2	26.8	26.7	26.0	26.9	26.1	26.7	26.5	26.3	26.7	26.6	25.1	25.9	24.9	25.6	25.9	26.3	25.7	25.7	25.5	25.5	25.4	25.7	25.2	25.1	25.5	25.3	25.3
Axim	2012	8	25.2	24.8	25.1	25.0	25.6	25.2	24.5	25.7	25.4	24.7	24.8	25.3	25.0	24.8	25.8	25.7	25.1	25.0	24.6	25.3	25.3	24.4	24.8	25.4	25.7	25.6	25.6	25.3	25.9	25.9	25.7
Axim	2012	9	25.7	25.2	24.5	25.0	25.2	25.1	25.0	25.3	25.4	25.5	25.7	25.3	25.7	25.9	25.9	26.2	26.3	26.1	26.4	26.5	26.1	26.6	26.7	26.7	27.2	25.8	26.0	26.6	26.9	26.0	
Axim	2012	10	27.3	26.4	26.2	26.8	26.4	25.9	26.6	26.7	26.8	27.1	26.8	26.8	26.5	27.0	27.3	27.1	26.6	27.0	27.8	24.9	26.9	27.4	27.3	24.8	26.0	25.4	27.2	26.5	27.2	27.8	28.3
Axim	2012	11	27.4	28.6	27.7	27.6	27.9	27.5	27.6	27.6	25.9	26.8	27.1	26.8	27.3	27.9	28.0	28.5	28.5	27.6	28.4	27.1	29.9	27.7	28.2	28.2	27.3	27.0	26.9	28.0	28.4	28.6	
Axim	2012	12	27.7	28.9	26.8	25.8	28.0	27.9	26.7	27.4	27.8	27.9	27.3	27.3	26.6	27.8	27.8	28.4	28.5	27.7	27.9	28.0	27.3	27.7	28.2	29.1	27.7	28.4	28.1	27.9	27.8	27.7	27.4
Axim	2013	2	28.1	27.7	26.5	28.5	28.2	29.5	28.8	27.7	29.3	29.6	29.5	29.9	30.0	27.6	30.0	30.1	28.8	29.8	29.7	29.7	28.8	28.5	29.2	29.9	30.5	27.2	28.9	29.8			
Axim	2013	3	29.8	29.5	30.3	29.6	26.7	27.2	29.9	30.2	28.9	27.6	28.8	28.7	29.0	28.6	28.3	26.7	29.3	28.3	29.1	30.1	27.7	27.2	28.2	29.3	29.2	29.0	28.4	28.8	27.1	28.1	28.1
Axim	2013	4	27.3	28.9	27.2	28.4	28.8	30.1	28.2	28.0	28.0	28.4	29.5	29.0	28.3	28.2	30.2	29.3	29.0	28.9	28.2	28.3	27.9	29.8	26.2	27.8	28.8	28.3	26.9	29.3	29.2	29.3	
Axim	2013	5	28.3	28.3	28.6	29.4	27.2	28.2	29.0	27.9	28.3	28.7	28.7	27.2	27.5	27.5	28.1	26.4	27.5	27.0	25.6	27.7	28.3	27.5	27.7	27.9	28.2	29.1	25.5	27.1	27.4	26.6	27.4
Axim	2013	7	25.8	25.8	26.5	26.4	24.8	25.9	25.4	25.9	25.5	26.3	26.5	26.3	25.8	25.2	26.3	26.8	26.1	26.2	25.5	25.4	25.8	25.7	26.1	24.1	24.1	24.0	24.6	23.8	24.4	24.8	25.3
Axim	2013	8	25.4	25.1	25.1	25.3	24.8	24.8	25.0	25.4	25.6	24.2	24.3	24.9	25.2	25.0	25.0	25.0	25.4	25.2	25.5	25.7	25.0	25.4	25.4	25.1	25.5	26.2	26.0	26.1	25.5	25.3	24.8
Axim	2013	9	25.8	24.7	25.2	26.1	26.4	25.9	26.0	25.9	25.6	25.4	26.0	26.2	26.0	25.7	27.0	26.1	26.1	25.8	26.8	26.8	26.1	25.9	25.9	24.3	25.8	26.5	25.5	24.7	25.9	26.3	
Axim	2013	10	25.4	26.0	26.0	26.3	26.3	26.5	26.7	26.9	27.0	26.5	25.7	26.4	26.3	27.1	25.3	27.0	26.9	26.5	27.3	27.5	27.8	27.1	27.2	26.8	28.1	27.8	27.2	27.6	27.9	27.5	27.3
Axim	2013	11	27.5	26.0	26.5	26.8	27.6	27.0	28.2	28.0	26.8	28.0	28.6	28.0	28.5	28.8	27.9	26.8	27.7	27.7	28.5	27.7	28.3	27.7	27.3	27.1	28.4	26.9	28.3	27.9	28.3	28.8	
Axim	2013	12	28.4	28.5	28.1	26.9	27.0	28.9	28.3	27.4	27.3	28.5	28.5	28.5	27.8	26.6	26.8	27.0	27.4	27.6	27.0	27.0	27.3	27.6	27.8	27.2	26.8	27.1	28.5	28.0	28.6	29.0	27.0
Axim	2014	1	28.4	27.6	26.3	27.6	28.2	27.5	27.4	27.3	27.8	27.9	27.8	28.1	28.0	28.7	29.6	29.2	28.7	28.1	27.4	28.0	29.1	28.8	29.1	27.7	28.7	26.6	27.1	28.2	28.5	27.8	28.1
Axim	2014	2	27.1	27.1	26.9	26.4	27.1	27.5	28.2	28.7	28.7	26.5	26.8	28.1	26.7	27.8	26.8	29.1	26.9	27.8	28.												

**Flood Risk Assessment
Ghana Gas Processing Plant Train 2**

NAME	YEAR	MONTH	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9	DAY10	DAY11	DAY12	DAY13	DAY14	DAY15	DAY16	DAY17	DAY18	DAY19	DAY20	DAY21	DAY22	DAY23	DAY24	DAY25	DAY26	DAY27	DAY28	DAY29	DAY30	DAY31	
Axim	2014	5	27.6	27.7	28.7	28.8	29.3	26.5	26.3	25.3	25.0	27.3	27.5	28.0	28.2	26.8	28.0	27.2	28.3	28.8	28.2	26.8	28.3	28.0	28.5	28.5	28.2	28.2	29.0	26.0	26.5	25.5	26.7	
Axim	2014	6	28.5	26.3	28.3	28.6	25.0	27.2	25.7	26.4	26.8	25.9	26.5	26.3	25.2	25.9	26.3	26.3	26.8	27.5	27.8	27.2	26.1	27.3	26.3	24.6	27.5	27.2	27.0	27.7	27.7	26.9		
Axim	2014	7	24.7	25.7	25.6	26.0	25.2	26.7	26.8	26.8	25.3	26.7	26.9	26.6	27.4	27.3	27.0	26.1	24.5	26.1	26.4	26.1	26.0	25.8	25.6	25.1	24.8	25.8	26.3	26.0	25.7	24.6	25.7	
Axim	2014	8	26.0	25.2	26.0	25.8	25.1	25.2	24.8	24.9	25.8	25.2	25.7	24.9	25.4	25.3	24.8	24.9	25.6	25.5	25.0	25.3	25.0	25.2	25.1	25.4	25.7	24.5	25.5	25.2	25.7	25.7	25.1	
Axim	2014	9	25.6	25.5	25.6	25.4	25.0	25.9	25.0	25.3	25.2	25.9	25.7	25.5	26.3	26.2	26.2	26.1	26.2	24.5	25.5	26.0	26.4	26.2	26.4	26.1	26.8	26.2	24.9	24.9	25.5	25.5		
Axim	2014	10	25.3	25.9	26.2	26.1	26.5	26.1	26.5	26.7	27.0	27.4	26.5	26.6	26.3	26.0	26.9	27.8	27.0	27.1	27.2	24.8	25.8	27.2	27.4	27.2	27.2	25.8	25.6	27.0	27.8	27.6	28.0	
Axim	2014	11	28.2	27.5	27.0	27.1	25.5	25.8	26.9	26.6	27.2	27.2	27.0	26.9	27.6	28.3	27.4	27.1	26.8	26.1	26.7	27.6	27.8	27.8	27.4	27.4	27.2	27.3	26.5	27.4	28.0	27.7		
Axim	2014	12	28.4	27.8	29.4	27.5	26.2	26.9	28.4	28.1	29.0	29.2	29.3	27.6	26.8	27.4	28.5	28.0	28.2	28.3	28.2	28.0	27.8	27.4	27.2	27.6	27.6	27.3	26.9	26.0	25.9	26.7	28.1	
Axim	2015	1	26.8	26.5	27.0	27.5	27.3	26.8	26.7	27.6	27.8	27.3	25.5	26.5	26.5	25.5	26.3	26.3	27.2	28.8	29.1	29.2	29.3	28.3	26.4	29.3	28.7	29.0	27.3	28.8	29.1	29.1	29.4	
Axim	2015	2	27.7	29.4	29.6	29.8	29.5	29.7	29.3	28.1	29.4	29.7	29.6	25.4	27.2	29.0	28.9	29.2	28.9	27.5	27.4	27.5	28.2	27.9	28.0	26.6	29.0	28.9	28.9	27.4				
Axim	2015	3	27.8	28.8	29.4	29.8	28.3	29.0	28.3	29.8	30.3	30.6	30.6	30.5	27.4	28.4	28.3	25.3	27.2	26.1	27.2	28.8	28.6	27.5	28.3	29.8	26.7	28.3	27.6	28.2	28.2	28.3	27.1	
Axim	2015	4	28.5	29.1	29.5	29.6	28.4	28.6	29.3	29.7	29.4	28.2	29.8	26.2	27.9	28.6	29.0	29.8	30.3	29.0	29.9	29.6	29.3	30.7	28.1	27.5	28.0	30.0	27.8	29.1	29.3	30.4		
Axim	2015	5	30.6	30.4	29.8	24.7	26.1	28.1	28.8	29.5	28.8	28.5	28.5	29.4	29.0	28.8	28.5	28.5	29.4	28.5	28.5	28.0	27.3	27.6	26.1	26.6	28.3	29.5	29.0	27.9	27.6	27.0	26.2	
Axim	2015	6	26.8	26.6	25.0	25.6	26.3	24.0	25.7	26.9	27.0	28.0	26.7	26.9	27.4	27.0	25.8	26.9	27.1	27.3	27.5	27.4	24.9	26.5	27.3	27.6	27.5	26.9	27.6	27.2	27.5	27.5		
Axim	2015	7	27.4	27.3	26.8	26.0	26.4	27.5	26.7	27.6	28.0	27.4	25.7	26.3	26.0	26.4	25.8	26.8	26.2	26.4	26.0	26.2	26.7	26.3	25.8	26.0	26.4	26.1	25.4	26.1	25.8	25.7	25.3	
Axim	2015	9	25.0	25.2	25.7	26.3	25.8	26.1	25.5	25.7	25.9	25.8	25.7	26.3	26.1	25.5	25.2	25.6	25.5	25.4	25.8	26.0	26.4	26.0	26.3	26.4	26.5	26.8	26.6	26.6	26.6	26.7	27.3	
Axim	2015	10	27.3	26.9	27.2	27.2	27.5	27.6	27.4	27.7	24.5	25.8	27.1	27.6	27.6	27.5	26.4	27.0	27.5	27.0	27.9	27.0	26.4	26.3	28.2	28.6	27.8	27.5	28.3	26.9	27.7	26.5	26.7	
Axim	2015	11	26.3	26.3	26.8	26.8	28.3	27.3	24.8	26.9	26.2	27.6	27.8	27.5	28.0	28.5	28.6	27.9	26.7	27.0	28.0	27.8	28.2	27.7	27.4	28.2	28.6	29.2	28.6	29.2	28.7	29.0		
Axim	2015	12	29.7	28.1	26.8	26.9	27.3	27.2	27.9	28.7	27.8	27.5	27.9	28.7	28.3	28.4	28.0	28.0	27.8	26.8	27.8	26.8	27.3	28.1	28.0	28.1	28.5	26.8	26.8	27.4	29.1	27.3	29.5	
Axim	2016	1	29.0	28.5	28.2	27.5	27.6	27.0	25.9	27.2	26.2	27.6	28.6	28.6	29.2	28.6	29.2	29.0	29.0	29.1	27.1	28.0	28.7	28.1	28.8	28.4	27.8	27.8	27.6	27.3	27.5	27.2	26.0	
Axim	2016	2	27.2	27.5	27.2	27.4	27.5	27.9	28.7	28.9	28.7	28.5	27.3	27.9	29.2	29.2	29.1	28.0	28.4	29.1	29.1	29.5	29.7	29.9	29.9	28.7	29.6	29.5	28.9	28.8	29.8			
Axim	2016	3	28.1	28.3	29.4	29.6	29.8	28.1	28.4	28.9	27.2	29.6	29.6	29.5	29.7	28.8	27.4	28.4	29.6	26.8	28.4	28.9	28.9	27.8	29.4	24.9	26.6	29.0	28.4	28.3	29.3	30.1	29.9	
Axim	2016	4	30.0	26.8	28.3	30.2	30.3	30.4	28.9	29.9	27.8	27.5	28.6	29.3	28.4	28.4	29.4	30.1	29.1	28.7	29.4	30.4	29.2	29.7	29.4	30.9	29.3	30.4	29.6	29.6	27.8	28.7		
Axim	2016	5	30.0	29.4	29.3	28.1	28.8	27.2	27.1	28.0	29.3	29.7	29.0	29.5	27.0	27.2	27.4	28.2	27.8	27.0	26.9	27.6	29.3	26.8	26.5	26.7	29.2	27.3	27.9	27.9	27.5	27.3	26.9	
Axim	2016	6	28.3	28.8	25.7	26.7	28.1	28.7	27.7	27.1	27.2	24.5	27.3	28.0	24.9	25.9	26.0	26.5	27.3	26.5	27.1	25.4	27.3	26.8	27.3	27.3	27.1	26.9	26.7	27.1	26.1	26.8		
Axim	2016	7	27.0	27.1	27.2	26.7	26.4	26.8	26.1	26.4	26.6	26.2	26.7	26.2	25.0	25.4	25.3	24.9	24.8	26.0	26.1	26.4	24.7	24.7	25.2	24.3	24.4	24.8	25.8	25.7	25.2	25.0	25.8	
Axim	2016	8	25.8	26.0	26.0	25.8	24.9	25.7	25.6	25.6	25.6	24.2	25.5	25.9	25.8	25.6	25.3	25.1	25.0	24.8	24.6	25.3	24.4	24.5	25.4	26.2	25.8	26.0	25.7	25.7	24.5	25.0	25.1	
Axim	2016	9	26.0	26.0	26.2	26.3	26.5	26.0	26.2	26.1	26.1	26.0	25.2	25.4	25.7	26.4	26.6	26.5	26.1	26.6	26.3	26.9	25.8	26.6	26.7	26.3	26.0	27.4	27.3	26.0	26.0	26.9		
Axim	2016	10	27.2	27.1	26.2	27.3	27.5	27.2	28.0	27.2	26.4	26.7	27.3	27.5	27.1	27.0	27.2	26.7	26.6	27.9	26.6	27.7	27.3	26.4	26.7	27.0	28.0	28.1	27.8	28.7	29.1	27.6	27.0	
Axim	2016	11	27.2	27.4	28.3	27.8	28.7	27.3	28.1	26.9	28.2	27.5	27.1	29.4	27.9	28.2	28.8	28.6	27.9	28.5	28.5	28.4	28.2	28.3	29.1	29.0	28.0	29.4	28.6	27.7	28.5	28.5		
Axim	2016	12	28.5	29.2	27.6	27.3	28.5	28.9	29.5	29.1	28.2	29.1	26.0	28.4	28.0	28.5	27.6	27.1	28.1	26.8	27.3	28.7	29.7	30.3	28.8	29.7	29.0	29.0	29.0	27.3	27.9	27.6	27.6	
Axim	2017	1	27.7	28.5	28.8	28.6	29.2	27.4	29.4	28.6	26.7	28.4	29.5	29.6	28.5	27.5	26.5	26.5	26.8	27.8	28.1	28.9	29.3	27.7	25.6	27.1	27.3	26.8	27.4	27.7	28.9	28.8	28.6	
Axim	2017	2	28.5	32.2	32.0	32.4	32.9	32.2	32.4	33.0	32.9	32.4	32.2	32.0	30.2	31.2	32.0	32.4	33.0	33.7	32.5	32.1	32.9	32.6	32.5	32.5	32.8	31.2	30.7	32.2				
Axim	2017	3	30.2	28.7	30.2	28.3	29.2	28.5	27.4	30.0	30.0	27.6	29.2	28.6	28.1	29.3	28.8	30.3	30.3	30.2	29.5	28.9	28.9	28.9	27.3	29.0	29.1	29.5	30.1	28.7	30.6	30.9	28.9	
Axim	2017	4	28.9	28.2	29.1	26.8	29.1	30.2	29.0	30.1	27.6	26.7	28.5	30.6	30.0	27.4	27.4	27.8	28.7	29.5	28.1	28.5	27.0	28.2	29.4	29.3	27.6	27.4	27.9	29.3	28.4	29.3		
Axim	2017	5	29.9	27.2	28.6	26.8	27.3	29.0	29.0	28.0	29.2	28.9	28.5	28.3	29.0	30.4	27.0	27.9	26.0	28.0	29.5	28.5	26.7	28.1	28.3	29.2	28.2	25.5	27.9	27.8	28.2	28.3	26.2	
Axim	2017	6	27.1	29.0	25.9	27.5	28.2	27.6	28.2	28.0	28.5	26.7	26.0	25.5	24.4	26.6	28.1	27.8	27.0	26.1	26.8	26.8	27.1	26.6	26.7	25.2	26.7	26.5	27.3	26.6	25.4	25.3		
Axim	2017	7	25.9	25.1	24.7	25.0	24.5	25.4	26.8	26.3	26.9	26.5	25.5	25.5	26.0	26.2	26.5	26.2	26.6	27.1	27.2	26.5	26.7	25.6	25.5	25.4	25.6	26.2	26.6	26.3	26.2	26.3	25.9	
Axim	2017	8	26.3	25.5	25.1	25.6	24.8	25.7	25.2	25.7	25.8	25.6	25.9	25.8	26.2	26.0	26.2	24.8	24.8	24.7	25.8	25.8	25.6	25.6	25.5	25.4	25.3	23.6	25.7	24.6	25.2	25.3	25.3	
Axim	2017	10	27.0	27.1	27.1	27.4	27.2	27.2	26.1	24.2	25.6	27.8	26.0	27.1	26.4	28.0	27.4	27.3	26.7	2														

**Flood Risk Assessment
Ghana Gas Processing Plant Train 2**

NAME	YEAR	MONTH	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9	DAY10	DAY11	DAY12	DAY13	DAY14	DAY15	DAY16	DAY17	DAY18	DAY19	DAY20	DAY21	DAY22	DAY23	DAY24	DAY25	DAY26	DAY27	DAY28	DAY29	DAY30	DAY31
Axim	2018	5	28.4	30.0	27.6	27.6	28.6	26.3	28.5	28.7	25.4	27.1	24.6	25.7	26.4	28.2	27.3	27.4	26.8	26.4	27.5	28.9	28.7	28.7	28.5	28.4	28.3	25.6	27.5	27.4	28.4	27.1	26.8
Axim	2018	6	27.5	28.3	26.8	27.2	27.9	27.6	27.4	27.9	26.8	27.7	27.3	28.1	28.2	28.1	27.8	27.0	28.2	27.1	24.4	26.1	26.0	26.0	27.0	26.7	26.8	26.1	26.5	24.8	25.3	25.3	
Axim	2018	9	26.3	26.5	26.6	25.8	25.1	26.1	25.3	25.9	26.1	26.0	26.4	26.6	27.0	26.6	26.5	27.2	27.6	27.0	27.0	26.7	27.5	27.3	26.7	26.4	27.1	27.0	27.3	25.7	26.2	27.0	
Axim	2018	10	27.0	26.7	26.4	27.2	27.9	27.3	27.4	26.5	25.5	27.0	27.5	26.2	26.8	27.4	28.0	27.5	27.1	27.8	28.0	27.9	28.4	27.6	26.3	27.9	26.7	27.5	28.0	27.8	25.9	26.6	27.6
Axim	2018	11	28.4	28.0	28.0	27.3	27.5	27.2	26.4	27.3	28.5	27.9	29.0	28.4	27.9	29.0	28.7	28.5	28.4	28.3	28.5	25.9	28.1	28.1	29.0	28.2	28.1	30.1	28.5	28.9	28.4	28.9	
Axim	2018	12	28.9	28.5	27.8	28.8	28.8	29.1	29.0	28.1	28.6	28.6	28.8	28.1	28.1	28.7	28.3	28.6	29.2	28.9	27.6	28.8	28.5	28.8	29.0	27.8	28.1	27.2	26.6	27.4	28.3	28.4	28.5
Axim	2019	1	29.2	29.1	29.1	29.6	28.3	27.9	27.4	27.6	28.0	29.3	29.7	28.6	29.4	30.2	30.0	29.9	26.1	27.6	29.0	27.1	28.4	29.2	29.5	29.5	28.5	29.3	28.8	29.2	28.6	29.5	28.1
Axim	2019	2	27.5	28.1	27.2	28.3	28.6	28.3	28.4	28.5	28.8	28.7	29.0	29.3	28.7	29.8	29.6	30.0	30.1	30.4	28.4	27.2	28.5	30.3	30.5	30.5	29.6	27.9	27.6	27.9			
Axim	2019	3	25.8	27.7	28.1	29.6	29.6	30.0	26.7	28.1	27.4	28.1	28.0	30.2	30.2	30.5	27.4	29.2	26.7	27.9	30.6	29.6	28.4	24.7	26.9	29.4	27.5	28.5	28.6	29.0	30.7	30.5	30.5
Axim	2019	4	29.3	29.7	30.3	29.3	27.3	28.8	30.5	28.1	28.2	27.8	29.7	26.7	28.8	29.6	27.1	28.6	28.8	28.9	30.0	28.8	29.4	30.6	30.5	27.9	29.0	27.7	29.1	29.5	30.8	30.8	
Axim	2019	5	29.3	27.1	28.7	27.6	28.6	30.2	29.5	29.0	29.5	27.0	28.8	28.3	28.4	27.6	26.8	27.2	28.7	28.6	29.5	26.5	27.6	27.9	27.9	28.6	28.3	27.0	27.1	26.3	28.0	30.3	27.4
Axim	2019	6	26.0	27.5	27.6	28.4	27.5	28.8	25.1	27.5	28.0	28.1	28.3	28.0	28.1	27.6	27.3	27.4	27.0	28.1	27.9	28.5	27.9	26.9	26.3	24.7	23.7	25.4	26.5	27.1	26.3	27.2	
Axim	2019	7	27.1	27.5	27.7	27.3	27.8	26.9	26.5	26.9	25.7	25.8	25.3	26.0	27.2	25.4	26.5	27.0	26.7	26.7	26.0	26.0	26.4	26.5	26.6	26.6	26.9	26.8	26.8	26.5	26.5	25.9	26.5
Axim	2019	8	26.4	26.1	25.9	26.2	26.8	25.3	24.9	25.1	25.1	25.4	25.3	25.2	25.1	26.7	26.8	25.8	25.3	25.6	25.5	25.8	25.1	25.3	25.3	25.5	26.0	26.0	26.2	26.5	26.6	26.7	25.5
Axim	2019	9	25.6	25.2	26.2	26.0	26.7	26.7	26.4	25.6	25.7	26.6	26.9	26.3	27.5	26.2	26.4	26.9	27.3	26.8	26.3	26.1	26.6	26.4	26.4	26.8	27.4	27.1	26.9	26.1	26.5	27.2	
Axim	2019	10	25.1	26.7	27.5	27.1	26.8	27.4	27.5	27.4	27.0	26.4	27.5	25.8	25.8	27.0	26.5	27.6	27.4	27.9	25.9	25.6	26.5	27.3	27.4	27.3	27.2	25.8	26.6	26.9	26.7	26.9	27.0
Axim	2019	11	27.3	27.9	27.5	27.9	28.0	27.9	27.7	28.4	28.0	27.5	27.0	27.8	27.5	28.2	27.8	27.5	28.4	29.2	29.5	29.3	27.6	27.6	28.4	29.2	28.4	27.6	28.5	27.3	28.0	28.2	
Axim	2019	12	28.5	28.8	29.8	28.2	27.8	26.7	26.9	28.6	28.5	28.4	27.9	27.8	27.6	28.1	28.2	28.5	28.8	28.8	28.4	28.8	29.5	28.7	28.6	28.6	28.0	28.4	28.8	28.7	29.0	29.5	28.0
Axim	2020	1	28.6	28.4	26.6	25.9	25.9	26.3	26.9	27.5	28.3	27.9	30.3	28.5	28.9	27.8	28.3	28.6	28.5	30.1	28.3	29.0	29.1	28.5	29.1	30.0	29.6	28.9	28.1	28.2	28.3	29.2	30.1
Axim	2020	2	28.8	28.9	28.4	28.2	28.2	29.2	28.9	28.9	28.9	29.5	29.5	29.3	29.4	28.8	29.0	29.2	30.9	31.1	30.0	29.1	30.5	30.2	31.1	30.9	29.9	29.8	30.4	30.0	30.2		
Axim	2020	3	30.9	30.6	31.2	27.9	29.9	26.4	29.3	28.5	30.2	29.1	28.6	28.7	28.3	29.5	28.1	28.6	29.8	29.7	29.6	29.6	29.4	29.8	27.8	26.1	25.8	27.0	27.9	28.4	28.6	28.6	29.1
Axim	2020	4	27.5	26.2	28.6	29.1	28.5	29.0	28.7	30.7	28.8	29.5	28.2	27.9	28.8	29.6	29.7	29.4	27.8	29.0	30.0	29.2	28.1	29.0	26.5	27.9	28.8	29.3	26.7	27.9	28.7	28.8	
Axim	2020	5	27.7	29.2	30.7	29.0	29.4	29.3	29.2	29.1	29.7	30.3	26.8	28.2	28.8	28.9	29.4	29.3	29.2	28.9	28.3	28.4	29.2	29.3	27.0	28.3	28.6	27.0	27.9	27.9	26.8	27.0	27.6
Axim	2020	6	27.7	28.3	27.0	28.9	27.3	27.9	28.0	27.6	26.3	26.5	25.4	26.6	27.4	26.5	27.2	27.7	27.1	25.8	27.3	27.1	24.2	26.1	27.2	26.9	26.9	24.9	26.1	25.8	24.7	26.0	
Axim	2021	5	29.9	29.8	29.8	26.9	28.3	28.4	28.4	27.0	27.2	27.2	28.1	29.4	29.4	29.9	28.8	28.6	28.9	29.0	28.3	28.2	26.9	27.6	27.3	27.4	27.4	28.7	28.6	29.0	28.2	28.7	27.1
Axim	2021	6	27.4	28.0	28.3	28.2	27.9	28.6	28.5	27.8	27.7	27.0	27.2	27.0	27.5	28.3	28.6	27.8	28.7	28.8	28.7	26.4	25.4	27.2	26.9	25.4	26.4	26.3	25.9	26.7	26.9	24.6	
Axim	2021	7	26.0	26.3	24.9	24.2	26.3	24.8	27.3	27.2	26.5	26.8	26.6	26.6	27.5	27.2	25.6	24.8	25.7	27.0	26.8	27.0	27.0	27.2	27.3	26.8	26.5	26.4	26.7	26.5	26.0	26.9	26.6
Axim	2022	9	25.5	25.7	25.6	26.0	24.9	25.4	26.2	25.9	25.9	26.2	26.0	26.0	25.8	25.9	26.7	25.7	26.2	26.4	25.4	24.9	26.1	26.3	26.3	26.0	26.0	25.7	26.3	25.7	26.4	26.0	

14.3 Daily Relative Humidity

NAME	YEAR	MONTH	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9	DAY10	DAY11	DAY12	DAY13	DAY14	DAY15	DAY16	DAY17	DAY18	DAY19	DAY20	DAY21	DAY22	DAY23	DAY24	DAY25	DAY26	DAY27	DAY28	DAY29	DAY30	DAY31
Axim	2012	1	87	92	89	96	93	92	89	92	88	88	88	93	92	94	82	72	75	85	76	80	81	91	84	91	88	78	81	84	82	81	88
Axim	2012	2	77	85	87	81	88	92	65	63	61	87	89	88	92	90	92	89	90	91	90	90	87	82	91	87	87	81	83	85	82		
Axim	2012	3	83	80	82	81	87	80	87	80	78	83	78	78	77	75	72	76	80	89	83	78	76	78	75	78	83	77	75	77	78	84	76
Axim	2012	4	78	76	78	85	87	84	80	85	87	81	81	77	86	84	86	86	91	85	87	96	83	81	86	84	88	84	83	81	85	82	
Axim	2012	5	79	82	91	99	81	83	81	78	88	87	81	88	85	88	86	83	86	83	78	84	89	89	79	86	98	97	83	87	95	85	82
Axim	2012	6	84	83	84	85	87	90	92	84	85	83	85	90	78	86	93	86	97	96	82	87	96	89	81	88	85	85	81	91	86	80	
Axim	2012	7	90	88	83	86	84	84	84	82	86	83	80	80	82	82	87	82	82	82	83	85	85	87	87	81	85	84	92	88	87	87	92
Axim	2012	8	87	95	85	88	88	81	88	84	84	80	88	84	80	83	84	84	80	89	92	85	88	96	91	90	86	88	86	90	88	84	86
Axim	2012	9	86	88	93	90	90	92	89	93	89	88	92	92	88	88	83	89	83	83	83	84	82	88	86	83	86	97	92	89	84	81	
Axim	2012	10	89	88	86	84	88	86	95	79	81	88	95	90	84	87	81	80	88	90	81	96	77	90	91	94	88	94	84	86	90	82	76
Axim	2012	11	82	79	80	84	82	85	84	85	84	86	80	82	77	87	79	83	78	86	76	85	79	78	83	82	82	84	92	77	81	75	
Axim	2012	12	81	86	95	82	78	88	89	88	79	83	80	85	86	85	83	84	83	84	92	91	76	85	85	83	86	88	82	82	89	88	75
Axim	2013	2	96	71	86	93	92	88	84	87	85	80	82	81	79	89	81	82	81	87	79	78	81	86	82	84	79	85	81	85			

Flood Risk Assessment
Ghana Gas Processing Plant Train 2

NAME	YEAR	MONTH	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9	DAY10	DAY11	DAY12	DAY13	DAY14	DAY15	DAY16	DAY17	DAY18	DAY19	DAY20	DAY21	DAY22	DAY23	DAY24	DAY25	DAY26	DAY27	DAY28	DAY29	DAY30	DAY31
Axim	2013	4	81	77	88	77	81	78	78	81	80	78	75	80	80	81	72	71	88	80	91	84	85	82	94	88	78	81	88	80	87	83	
Axim	2013	5	90	83	81	82	91	81	80	95	83	79	83	85	88	78	74	97	84	91	97	86	74	81	84	96	83	78	91	82	85	94	88
Axim	2013	7	91	90	76	80	87	79	84	81	84	77	84	85	91	91	89	85	89	91	91	84	83	81	84	95	91	94	96	91	96	88	84
Axim	2013	8	85	79	83	87	92	91	88	85	81	83	84	91	84	79	80	84	84	84	84	85	90	90	84	85	88	86	88	85	83	87	86
Axim	2013	9	85	95	88	91	85	84	84	90	93	88	88	84	81	92	83	83	84	94	88	84	83	89	83	90	88	80	82	96	85	80	
Axim	2013	10	88	88	88	89	86	79	82	82	92	84	86	81	82	83	83	93	84	88	82	85	77	84	84	81	77	81	81	81	80	87	82
Axim	2013	11	87	96	85	83	83	78	75	80	79	75	75	74	74	74	81	89	81	84	88	85	80	78	84	81	83	74	81	87	81	76	
Axim	2013	12	80	77	78	85	81	82	82	85	66	82	77	79	83	83	92	92	85	80	83	83	85	87	87	86	87	87	79	83	90	83	86
Axim	2014	1	72	85	92	89	87	88	88	88	88	85	89	89	88	85	80	79	82	89	85	85	81	84	84	89	88	86	88	88	88	92	84
Axim	2014	2	84	92	96	90	93	91	91	86	85	77	85	85	90	88	88	80	83	88	85	87	82	87	85	86	93	85	92	90			
Axim	2014	3	93	90	85	79	79	83	87	88	81	78	81	85	79	78	81	82	81	79	80	77	82	82	82	78	78	81	81	93	86	75	86
Axim	2014	4	80	79	78	83	76	82	76	80	74	77	88	92	84	92	78	79	79	75	81	78	85	93	96	75	78	79	93	81	85	88	
Axim	2014	5	85	85	88	81	77	88	95	95	92	85	81	81	84	95	87	82	92	83	84	88	85	85	85	79	91	85	78	89	96	82	91
Axim	2014	6	80	87	81	85	95	91	89	87	89	82	92	96	96	86	87	96	85	84	83	81	96	83	90	86	81	83	78	84	83	93	
Axim	2014	7	96	90	89	90	94	85	80	71	79	87	83	81	77	83	85	92	96	87	89	85	88	86	82	92	95	81	85	92	92	95	85
Axim	2014	8	86	91	85	86	91	92	93	88	84	87	84	81	85	76	77	84	91	82	90	92	95	90	86	86	92	96	92	88	89	88	89
Axim	2014	9	91	92	88	89	92	87	95	89	89	89	88	88	89	89	88	82	90	92	92	92	89	81	82	88	86	88	95	88	93	88	
Axim	2014	10	88	93	84	89	89	96	84	84	82	86	84	85	81	96	82	83	82	81	88	97	88	81	79	77	77	87	96	83	91	83	80
Axim	2014	11	89	84	79	84	81	93	76	78	78	84	84	85	80	77	77	78	92	88	85	79	78	78	80	83	87	81	85	83	78	74	
Axim	2014	12	75	80	79	78	96	81	78	74	78	76	79	87	91	85	81	85	85	85	81	81	91	91	90	90	87	89	86	73	86	85	88
Axim	2015	1	81	72	85	88	92	90	92	83	87	86	71	76	75	79	95	87	91	78	79	75	90	85	80	81	79	82	88	78	81	81	79
Axim	2015	2	82	87	82	83	79	78	80	85	80	79	84	91	78	78	83	74	86	85	88	81	87	79	87	89	86	85	83	85			
Axim	2015	3	94	88	80	81	81	80	88	76	77	80	71	75	91	84	78	92	87	96	85	78	92	94	85	80	87	84	77	85	78	75	79
Axim	2015	4	78	80	72	73	72	78	76	82	78	79	80	90	85	88	83	74	73	79	78	78	77	74	78	79	81	73	72	74	78	76	
Axim	2015	5	71	80	77	96	85	81	78	78	80	86	80	75	81	81	90	85	79	86	89	81	87	88	95	88	81	78	81	94	83	87	95
Axim	2015	6	85	84	96	98	77	96	90	84	78	77	89	88	84	80	88	77	77	80	79	80	84	78	77	77	77	84	83	83	83	80	
Axim	2015	7	85	84	93	95	85	81	84	90	88	89	83	92	86	89	89	87	82	89	86	85	84	82	83	87	79	80	76	70	82	80	84
Axim	2015	9	88	93	94	84	88	87	90	88	89	91	88	85	89	95	89	84	88	89	88	85	86	88	86	86	91	84	87	84	88	81	
Axim	2015	10	84	84	81	85	83	81	83	86	97	87	84	85	87	88	84	90	85	95	87	82	93	79	81	78	85	85	83	89	85	86	83
Axim	2015	11	93	91	89	83	83	78	92	90	85	88	85	86	83	83	84	75	85	78	73	83	78	85	83	81	78	76	78	81	77	78	
Axim	2015	12	77	87	85	86	80	82	88	85	81	87	84	85	86	85	87	85	79	81	79	79	71	84	87	88	88	74	75	84	84	81	78
Axim	2016	1	85	92	91	94	92	60	43	58	81	86	78	85	81	86	81	84	81	81	92	87	86	88	88	89	90	93	91	87	60	72	86
Axim	2016	2	92	92	92	90	92	90	88	92	87	88	92	90	88	84	85	97	90	86	89	87	84	88	85	88	90	89	91	88	86		
Axim	2016	3	98	85	81	89	87	82	90	82	88	84	82	84	83	83	73	87	86	90	80	85	81	81	81	96	82	80	94	89	82	81	77
Axim	2016	4	81	92	89	78	78	78	85	80	81	82	88	82	83	82	86	77	84	79	81	77	78	83	79	77	87	89	82	82	89	84	
Axim	2016	5	80	82	84	89	81	92	86	82	80	78	82	80	92	93	83	85	83	94	83	88	81	90	83	87	80	86	85	90	92	87	93
Axim	2016	6	87	85	96	97	91	81	88	75	92	89	76	77	87	92	97	88	78	91	85	99	89	82	83	82	83	78	82	84	90	93	
Axim	2016	7	86	93	96	92	88	90	87	88	89	93	97	86	89	90	92	92	91	93	90	84	94	93	93	97	95	91	97	93	83	92	93
Axim	2016	8	84	84	82	87	91	90	92	95	92	96	92	92	91	91	85	84	88	92	92	92	97	97	92	89	89	85	89	88	98	95	92
Axim	2016	9	91	88	95	88	92	86	89	92	89	91	86	86	86	89	81	83	88	83	84	92	93	87	92	86	86	87	80	92	85	84	
Axim	2016	10	96	88	85	81	84	85	80	82	86	85	82	85	95	85	83	88	94	83	91	85	80	95	83	81	77	85	81	80	79	85	82
Axim	2016	11	83	88	78	79	81	88	85	91	88	82	77	78	80	78	82	82	84	87	79	84	82	78	81	78	81	78	78	85	87	84	
Axim	2016	12	85	79	90	86	79	84	75	86	88	77	88	78	75	83	89	87	84	84	84	88	75	83	89	86	84	86	93	79	77	84	86
Axim	2017	1	87	84	86	91	87	88	84	91	93	89	91	81	86	91	85	92	93	94	92	92	89	87	94	93	94	95	88	92	91	85	83
Axim	2017	2	97	87	86	84	89	84	88	84	82	80	92	85	86	89	85	82	87	80	87	80	86	85	82	82	78	78	90	77			
Axim	2017	3	78	83	78	79	80	87	80	82	85	88	82	88	90	86	85	79	76	80	84	84	91	81	77	76	85	84	81	76	79	77	82

Flood Risk Assessment
Ghana Gas Processing Plant Train 2

NAME	YEAR	MONTH	DAY1	DAY2	DAY3	DAY4	DAY5	DAY6	DAY7	DAY8	DAY9	DAY10	DAY11	DAY12	DAY13	DAY14	DAY15	DAY16	DAY17	DAY18	DAY19	DAY20	DAY21	DAY22	DAY23	DAY24	DAY25	DAY26	DAY27	DAY28	DAY29	DAY30	DAY31
Axim	2017	4	79	88	86	93	78	79	83	79	79	88	88	80	79	93	86	93	82	79	83	78	90	85	79	81	84	88	81	80	88	81	
Axim	2017	5	77	84	81	88	87	80	82	84	82	82	78	84	88	82	85	76	93	75	76	80	90	85	97	88	88	93	85	84	91	93	97
Axim	2017	6	92	80	97	90	83	84	85	85	86	96	93	88	95	83	79	79	88	86	84	82	81	90	90	92	93	92	87	90	89	87	
Axim	2017	7	92	95	97	97	97	96	88	84	82	78	73	80	77	85	84	80	80	87	87	85	86	89	89	89	94	91	85	88	84	85	85
Axim	2017	8	86	90	94	88	89	86	90	89	85	86	88	89	89	92	86	87	92	97	83	83	84	88	93	89	92	89	91	90	91	88	96
Axim	2017	10	89	94	87	85	88	82	96	97	90	85	90	83	80	83	91	81	74	85	92	79	85	80	81	82	85	83	85	81	81	85	81
Axim	2017	11	78	85	81	85	82	95	82	80	79	83	78	79	78	86	81	90	76	85	92	91	75	85	83	78	82	82	74	81	79	84	
Axim	2017	12	81	78	81	77	85	89	92	88	80	90	92	85	88	84	76	83	95	82	87	82	94	93	66	79	84	87	89	88	85	88	89
Axim	2018	1	91	97	96	80	80	88	85	89	92	92	95	88	93	92	88	90	90	91	91	87	89	93	84	92	96	92	96	93	94	87	86
Axim	2018	2	88	81	90	85	85	86	83	87	85	86	84	88	88	92	88	85	83	88	91	84	87	76	82	81	92	84	84	83			
Axim	2018	3	84	83	85	81	80	72	70	81	71	75	75	81	83	76	74	74	79	85	73	77	74	83	81	80	75	81	85	78	76	80	78
Axim	2018	4	82	78	80	84	77	84	76	80	78	95	84	69	92	79	83	81	76	84	78	78	82	75	78	69	72	81	78	88	84	86	
Axim	2018	5	79	76	89	84	81	85	81	80	93	93	96	90	90	86	87	95	92	88	89	79	82	81	83	84	93	86	95	88	82	92	85
Axim	2018	6	84	81	89	91	83	86	98	83	86	83	83	85	85	79	85	93	79	80	84	89	88	92	83	85	84	93	88	93	93	88	
Axim	2018	9	92	87	90	92	98	92	91	92	89	92	87	86	88	88	85	84	97	88	85	85	82	89	82	87	82	86	90	90	86	85	
Axim	2018	10	86	86	88	86	81	86	84	96	84	91	89	92	85	85	80	83	94	83	84	85	75	84	79	89	85	83	85	83	97	92	81
Axim	2018	11	86	81	85	85	86	82	87	95	73	78	78	76	85	87	84	79	82	80	81	85	83	84	78	78	84	74	87	81	82	73	
Axim	2018	12	80	85	83	85	83	84	81	87	80	84	79	91	82	85	89	78	78	76	89	80	86	75	86	91	76	74	68	76	87	85	86
Axim	2019	1	86	87	83	82	93	85	91	88	89	79	83	92	91	80	88	89	92	88	85	96	86	91	86	86	78	92	90	86	89	88	93
Axim	2019	2	89	85	93	89	89	92	90	90	90	92	95	93	92	86	85	86	79	82	87	89	81	79	79	82	87	89	86	85			
Axim	2019	3	96	84	88	85	83	82	92	83	85	81	78	84	76	76	92	79	94	81	78	78	86	92	92	81	86	81	82	79	79	84	77
Axim	2019	4	82	79	79	83	96	82	82	88	89	83	81	92	75	87	78	85	87	86	84	85	81	80	78	90	85	91	85	84	76	75	
Axim	2019	5	80	90	85	90	89	80	81	82	85	84	85	85	86	85	91	81	85	85	80	89	85	93	82	82	88	91	92	94	80	76	82
Axim	2019	6	96	81	86	83	87	81	97	91	79	76	75	78	75	81	93	92	91	87	85	82	81	84	97	97	96	94	89	89	88	86	
Axim	2019	7	86	85	86	88	83	84	87	88	95	93	91	92	84	89	86	86	86	94	91	94	95	92	88	86	90	88	87	87	89	89	85
Axim	2019	8	87	88	88	82	87	92	95	96	89	92	93	88	92	92	89	91	88	92	91	94	94	96	92	91	92	89	87	93	85	85	89
Axim	2019	9	92	89	96	85	95	87	87	96	89	88	92	86	88	84	93	85	83	90	90	89	87	96	83	89	85	83	85	88	87	88	
Axim	2019	10	83	84	85	84	83	82	79	86	83	90	86	96	96	88	88	84	85	83	87	96	88	81	82	89	88	88	84	82	94	92	81
Axim	2019	11	80	78	86	77	82	80	84	85	85	87	91	79	83	79	86	80	82	79	81	74	78	85	86	80	79	76	81	89	86	84	
Axim	2019	12	82	79	80	86	84	94	89	80	79	83	84	78	82	90	89	88	81	86	88	84	80	86	88	86	82	82	93	86	83	84	81
Axim	2020	1	88	73	65	50	67	77	75	81	88	79	82	85	88	95	89	94	85	91	89	91	92	91	89	87	91	89	89	92	91	85	76
Axim	2020	2	86	88	92	90	87	88	89	86	89	88	86	91	91	95	86	77	77	78	86	89	86	81	82	83	88	88	80	90	89		
Axim	2020	3	85	82	79	89	83	92	87	84	84	87	78	89	84	84	88	86	88	87	89	88	85	85	85	94	88	87	88	85	84	88	83
Axim	2020	4	84	92	90	89	85	84	88	74	85	80	81	79	84	83	80	81	83	82	82	82	79	85	92	81	62	78	89	84	81	81	
Axim	2020	5	92	85	80	82	82	76	82	80	78	75	96	85	83	81	82	89	83	85	84	78	77	72	84	89	91	93	85	89	93	83	88
Axim	2020	6	86	84	80	81	90	83	89	87	94	81	92	96	80	97	83	86	89	96	80	82	97	96	93	85	95	98	84	93	96	85	
Axim	2021	5	82	80	79	91	92	85	82	89	84	85	76	74	77	77	81	87	82	85	82	82	91	86	80	86	88	86	84	79	82	85	94
Axim	2021	6	83	81	87	84	89	87	81	82	80	94	99	91	87	89	81	83	92	70	83	94	88	77	78	92	94	90	93	89	86	95	
Axim	2021	7	91	96	96	95	91	92	85	82	83	81	76	81	77	83	95	97	86	79	79	85	79	81	78	83	80	74	82	81	88	95	88
Axim	2022	9	98	95	89	85	92	88	88	86	84	87	85	88	88	85	83	90	91	87	90	96	89	92	89	91	88	94	86	90	86	88	

14.4 Topographic Mapping and Drone Aerial Survey for GPP1 and GPP2

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1 Introduction

ODUN ENVIRONMENTAL LIMITED, a limited liability company established under the laws of the Federal Republic of Nigeria, and having its registered office at 2nd Floor, 38 Kofo Abayomi Street, Victoria Island, Lagos State, Nigeria intends to conduct a topographical mapping and drone aerial survey for gpp1 and gpp2 and surrounding area at Atuabo, Ghana. Ghana National Gas Company (GNGC) has commissioned to construct a new Gas Processing Plant (GPP Train 2) and associated facilities which will process raw gas from off-shore Ghana. The Project Sponsors for the development of the 300MMSCF Gas Processing Facility Project in Atuabo, Ghana also referred to as the 'Consortium' which includes Integrated Logistics Bureau Limited (INTELS), Axxela Ghana Limited (AXXELA), John Moore International (JMI), The Natural Gas company of Trinidad and Tobago Limited (NGC) and Phoenix Park Gas Processors Limited (PPGPL) with the African Finance Corporation (AFC) as Transaction Advisers and Lead arrangers have requested for relevant environmental and social (E&S) studies including Quantitative Risk Assessment, Fire & Explosion Risk Assessment and Flood Risk Assessment and ESIA Gap Analysis and associated studies to achieve Ghana EPA approval while meeting requirements in line with World Bank, IFC requirements and Sustainable financing principles.

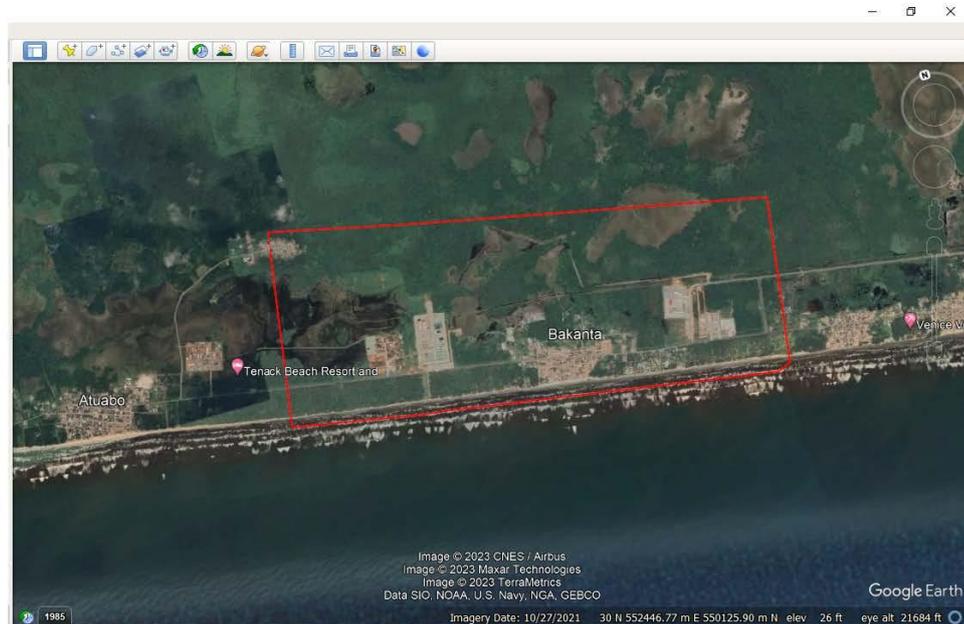


Figure 1: Proposed Survey area mapped

1.1 Scope of Work

- Survey activities carried out to produce detailed topographical map of the proposed study area include;
- Establishment of at least two (2) Benchmark Pillars within and around the site to be mapped.(Existing controls were Used)
- Aerial Lidar survey for the Proposed site .

1.2 Site Description

The site selected for the topographical survey covered an area of 480 Hectares and lies within the Atuabo district, Ghana .

The terrain of the site can be described as fairly flat with intermittent bounding low-lying areas and swampy areas running through the middle of the proposed site from west to east. The south western section commences from a low Grass and descends to a fairly populated Tree Canopy

Access to most parts of the sites is both by trekking on mud paths and walking through footpaths traversing through farms and thick vegetations. Vegetation on the proposed site is mostly shrubs and trees.



Figure 2: Thick vegetation

1.3 Sensitization

Prior to the start of the survey project ,all stakeholders(Atuabo residents and Gh gas) personnel were informed about albtech consult survey personnel on site. All permissions were sought and the green light was given for the survey to proceed. Subsequently, the site survey commenced on 17th of October 2023.

2 PROJECT EXECUTION AND DELIVERABLES

The following activities were undertaken for field data collection survey.

2.1 Datum and Coordinate System

The Universal Transverse Mercator (UTM) grid coordinate system based on the WGS84 Datum was adopted as the reference horizontal coordinate system for the survey and mapping aspects of this project.The Mean Sea Level (MSL) was adopted as the vertical datum for this project, and thus all height values presented in this project are orthometric heights.

Table 1: Parameters of Reference Horizontal Coordinate System

Ellipsoid Parameters	Name of Ellipsoid	WGS84
	Semi-major axis, a	6378137.0 m
	Inverse Flattening, 1/f	298.257223563
Projection Parameters	Name of Projection	UTM
	Zone	Zone 30 N
	Central Meridian , CM	3° W
	Latitude of Natural (or True) Origin	0° N
	Scale Factor on the CM	0.9996
	False Easting	500,000 m (at CM)
	False Northing	0 m (at latitude 0° N)
	Grid Units	Metres (m)

2.2 Reconnaissance and Bringing Control to Site

A 3-man team led by an experienced surveyor carried out the survey activities, which commenced on 16th of October 2023. 2 Surveyors were assigned from Ghana Gas to assist with the survey. The following survey equipment and accessories were mobilized for the site survey;

- 1 no. vehicle for site works
- 2 no. units of GNSS dual frequency receivers.
- 1 no. hand-held GPS equipment.
- 1. No. Lidar drone with sensor on board
- Full set of the necessary personnel protection equipment (PPE)

Initial reconnaissance survey undertaken to ascertain the location and accessibility to the route and condition as well as features within the site. There was a need to locate control within or near the proposed plot areas which served as the reference to coordinate all points and measure all features within the survey area.



Figure 3 TEAM LEADER WITH SURVEYORS

Subsequently a total of two(2) reference pillars were located around the survey area specifically to the north of the proposed site. This reference benchmarks will serve as point-of departures for future surveys within the site. All reference stations are in meters.

Initial point of departure used for establishing these reference pillars on site were taken from the Ghana Gas Valve station to the east of the proposed site. These reference pillars were used for the Ghana Gas ROW survey. Two permanent benchmarks were located . These benchmarks are about 500meast of the proposed site.



Figure 4: SGW 508 Reference Benchmarks

SGW/B508/12/6

N 550472.462

E 549983.330

H 6.592



Figure 5: Location of existing Reference Benchmarks close to the Ghana Gas station

2.3 Establishment of Benchmarks

After commencement of the survey works,

GPS static survey method was used to transfer coordinates and elevations to the Lidar Drone. All reference pillars are type 'C' Pillars with dimension of 15cm diameter with a 12mm iron rod clearly defining the center.

All the reference pillars have been firmly secured to the ground with concrete and caution tape wrap around their perimeter secured in place.

Figure 6: Survey Photos



3 SITE AND DETAILS SURVEY

Above are some photos during survey

4 Aerial Survey

Since large portions of the site is covered by vegetation, aerial lidar survey techniques was employed to collect the topographic data for the entire site.

The DJI Zenmuse L1, a powerful lidar system with the Livox scanner on board a DJI M300 drone was employed for this project. Due to its unique scanning capability of not only scanning in strips but also employs a repetitive scanning pattern in a circular motion of throwing the laser onto the ground. This technique helps to have more penetratability of the lidar lasers. The lidar was set to record multiple returns at a height of 60m with real time point coloring modes from the 20MP camera on board the lidar sensor with image overlap of 80% due to the thick vegetation to aid alignment of final images.

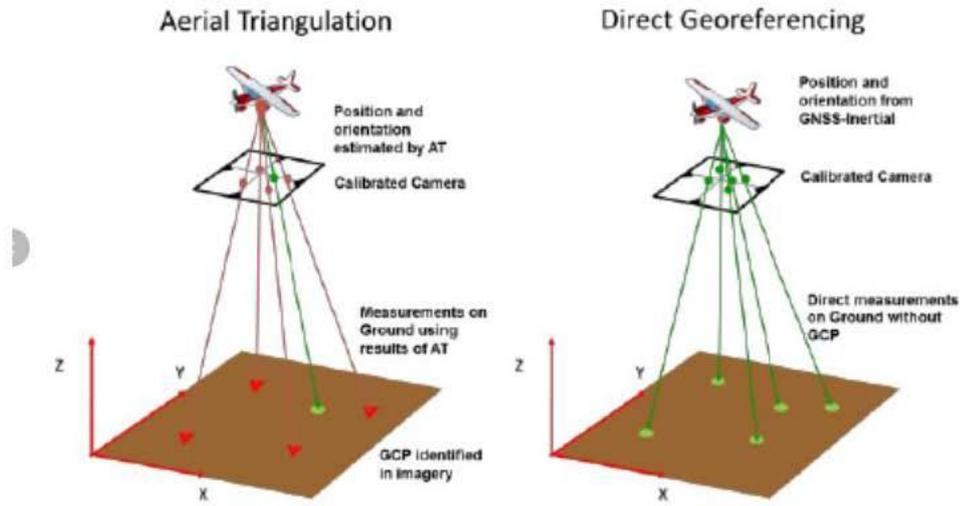


Figure 7: DJI Zenmuse L1 lidar with camera

Direct geotreferencing technique was employed here for data collection where one directly measures the position and orientation of an airborne mapping sensor, such as a digital camera or a laser scanner. This makes it possible to assign a geographical location on the earth to a pixel from a camera image or a digital point from a laser, without the need for ground control points or any additional measurements referencing the ground.

At its core, Direct Georeferencing uses two systems: Global Navigational Satellite Systems (GNSS) and [Inertial Navigational System \(INS\)](#). GNSS recording the coordinates "X, Y, Z", and INS recording the camera or lidar orientation angles " w , ϕ , k " at the time of exposure. These parameters are merged and tagged to each photograph in the processing stage, or in the case of scanning systems, such as LiDAR, to each point.

The GNSS measuring the raw static file was set to 5sec to intercept the IMU orientation cycle as the drone moves in the air. After the lidar flight, the data collected from both IMU and the raw static file from the GNSS were merged and post processed to produce a colourised point cloud. To ensure accuracy and checks, the flight was done with a double grid where one flight direction was overlapped with intersecting flight in the opposite direction. Data from these flight paths were checked against each other to ensure elevation and horizontal conformity.



Direct Georeferencing Concept versus Aerial Triangulation

Figure 8: Direct Georeferencing Concept

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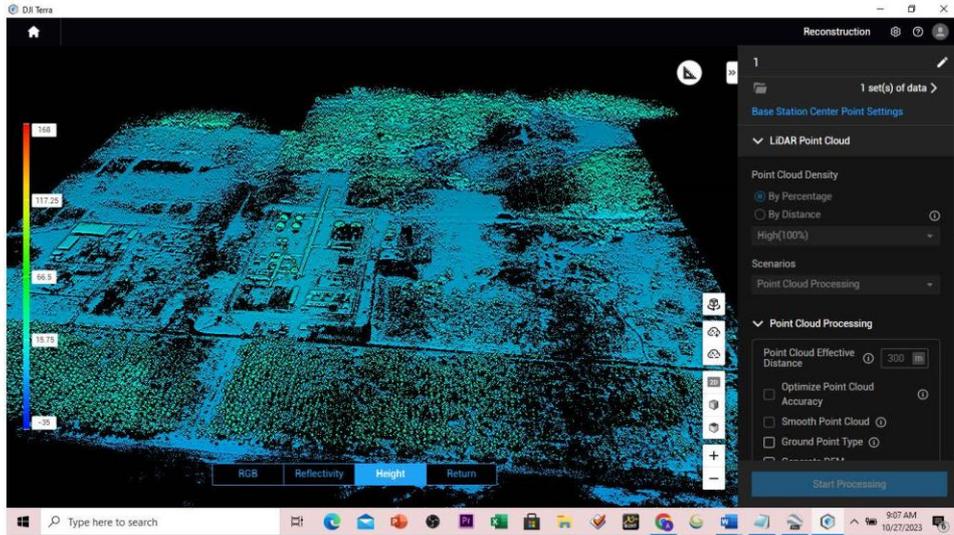


Setting-up of the Lidar Sensor



Figure 9: Setting up of the Lidar sensor (top) and warming up of the IMU of the Lidar system for take-off (above)

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4.1 Data Processing and Production of Orthophotos

The survey data collected from the site was processed using appropriate software. The ground survey data collected from the field survey was imported into Excel Spreadsheet to obtain an ASCII file (X, Y, Z Coordinates of data collected from site). These points were then plotted and analysed in AUTOCAD software.

The aerial images collected were processed using SBET DATA from the LIDAR data using the Agisoft Photoscan software to generate Orthophoto maps which was used for digitization purposes and background for the survey data collected.

Digitization of features especially building corners, footpaths and powerlines within and around the survey area. Digitizing on the Orthomosaic was carried out in the Global Mapper software. All the processed Lidar ground and aerial survey data was then imported into AutoCAD to generate the final topographical maps.

Pointclouds were also obtained from the processing of the Lidar data. This served as a basis for generating spotheights within the proposed site. These spotheights were gridded into 10m interval elevation models and was exported together with the details obtained from the orthomosaic into a CAD environment where point triangulation method was used to create a surface for final contouring. Digital Terrain Model was also exported as part of the deliverables.

Below is a TIN (Triangulated Irregular Network) and its associated DTM for the site. *The red areas depict high elevated areas with the blue areas denoting low lying areas for the elevation range within the site* with highest elevation been 12.3 located to the north east of the site and the lowest area been -1 located to the southern area within the sea

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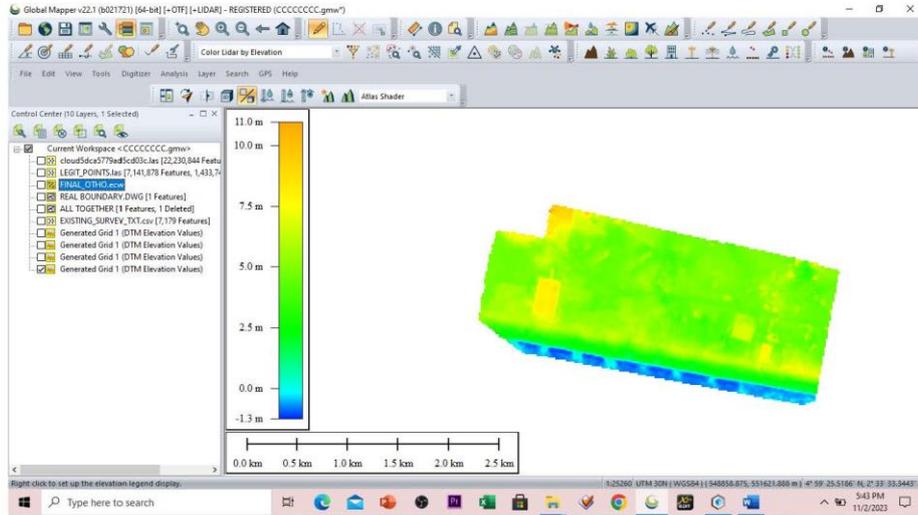


Figure 10: TIN file exported of the site showing low and high areas



Figure 11: Orthomosaic for Proposed site

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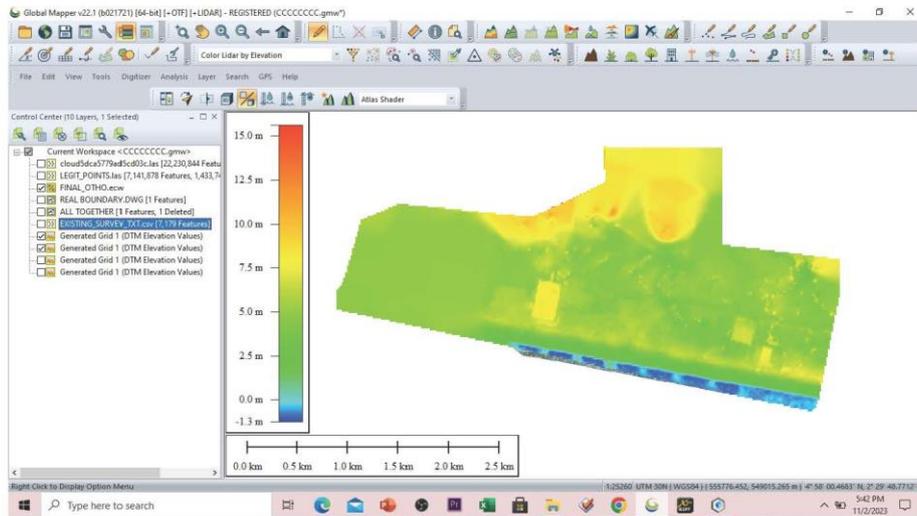


Figure 12 DTM MERGE WITH EXISTING DATA

5 PRODUCTION OF TOPOGRAPHICAL MAPS AND OTHER DELIVERABLES

The following details all the deliverables following the topographical survey of the project sites.

- Topographical Map with 15m Contour of the site
 - Digital Color (RGB) orthophotos in .png format inserted into drawing
 - Spot Height for existing Survey and New Survey
 - Digital elevation Model for both Surveys
 - Report on Discrepancies on both Surveys elevation
- Survey Project report.

Final Report on Odun Environmental Limited Site Survey 2023

6 Conclusion

The successful execution of this project has resulted in the production of topographical maps for proposed Odun Environmental Limited site.

This report and all associated deliverables will assist Odun Environmental Limited and all other stakeholders in developing strategies for the overall development and implementation of the proposed Site.