

# DRAFT Environmental and Social Impact Assessment Report

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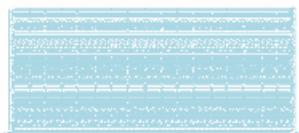
## INO: Riau Natural Gas Power Project ESIA Vol.5\_Technical Appendices Part C

Prepared by ESC for the Asian Development Bank

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## Appendix C. Site Investigation



# Draft Final Report

Project:

**Soil Investigation, Soil Improvement, and  
Topography Study of  
Gas Fired Power Plant Project 275 MW  
In Riau, Indonesia**

Tenayan Raya District,  
Pekanbaru Regency,  
Riau Province



**Year 2017**

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# 1. Introduction

## 1.1 Background

Energy has an important role to support regional development, especially in support of other development sectors. For those reasons, the energy development have targets to provide adequate energy.

In line with the growth of regional development, the demand for energy, particularly electricity will continue to rise. Likewise in the next few years with the transition process of rural communities into urban communities will drive the need for energy.

In order to meet the demand for electricity in accordance with RUPTL 2016-2025 to provide the load demand of Pekanbaru area, especially the management of primary energy, PLN offers private party to build a Gas Engine Power Plant (GFPP) with 275 MW capacity, which is MRPR (Medco Ratch Power Riau).

In preparation of construction the GFPP (275 MW) is necessary to prepare Feasibility Study, Engineering Design, and Tender Documents. Therefore, before the implementation of the necessary physical development, is necessary the study based on primary data (based on survey and investigation) and laboratory test results to determine feasibility of the project.

## 1.2 Project Location

The selected site is located at Badak Village, Badak Jaya Sub-District, Tenayan Raya District Pekanbaru Regency, province of Riau. The site location can be reached by air plane from Jakarta through Pekanbaru Airport, it takes 1 hour by car or land transportation to reach the project site.

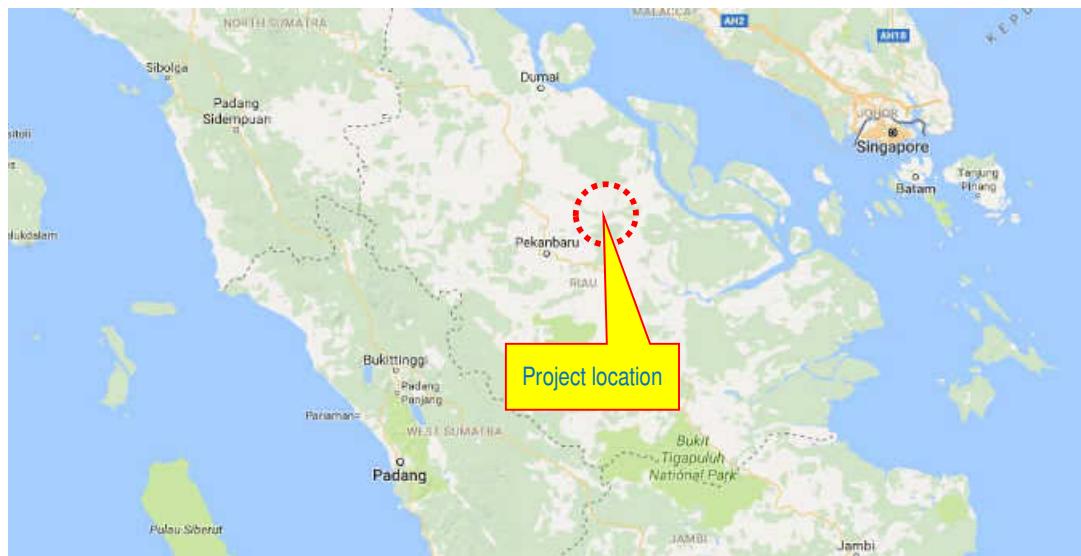


Figure 1-1 Project Location

### 1.3 Scope of Works

The Site Investigation was includes Topographic survey, Geoelectrical survey and modeling, Geotechnical Investigation. A summary of the scope of work for this site investigation typically include the following:

1. Topographic Survey. Performing topographic survey about 9.5 ha area and establishment of 2 units of Benchmark.
2. Leveling measurement to reference Benchmark
3. Performing 3 (three) points of core drilling, with 30 meter depth each and total 90 meter.  
The investigation includes:
  - Standard penetration test (SPT) every 1.5 meter depth of drilling.
  - Permeability test every 5 meter depth of drilling.
  - Extraction of undisturbed sample (UDS) as much as possible (if required).
  - The core shall be store in core box, one box for 5 meter cores.
4. Geoelectrical measurement about 3 (three) points.
5. Laboratory Analysis of Soil Mechanic with following parameters:
  - a. Index Properties :
    - Moisture Content
    - Unit Weight
    - Specific Gravity
    - Grain Size Analysis
    - Atterberg Limits
    - Compaction standard and modified test
    - Amount of material finer than No. 200 Sieve.
  - b. Mechanical Properties :
    - Triaxial Compression test
    - Consolidation Test
    - Direct Shear Test
    - Unconfined Compression Test
6. Geotechnical analysis and recommendation shall includes:
  - Design parameter of shallow foundation
  - Design parameter of deep foundation

Other geotechnical recommendation: Excavation criteria; Recommendation on soil improvement; Coefficient of permeability and Slopes (steepness) of excavation.

### 1.4 Report Organization

Continuing the first chapter was Introduction aspect, this report is organized in to following section:

- Chapter - 1: Introduction
- Chapter - 2: Topography
- Chapter - 3: Geotechnical Investigation
- Chapter - 4: Comparison of geotechnical analysis with previous study
- Chapter - 5: Conclusion and Recommendation

In an integrated book, this report is complement by following appendices:

- Appendix A: Topography Map
- Appendix B: Description of Benchmark
- Appendix C: Borehole Log

- Appendix D: Photo of Boring Activities and Core Boxes
- Appendix E: Data and Interpretation Curve of Geoelectrical survey
- Appendix F: Result of Soil Mechanic Laboratory
- Appendix G: Result of Groundwater Quality and soil Chemistry
- Appendix H: Photo Documentation

## 2. Topography

### 2.1 General

Location of Topography Measurement are at future GFPP 275 MW area (alternative 2), which is slightly hilly. The survey located area at coordinates 0°32'23" N, 101° 31' 13.6" E.

### 2.2 Survey Methodology

Topographic survey is performed at the study area, cover whole area of future GFPP and surrounding.

#### a. Standard and Reference

Standard which applied in execution of this work is Indonesian National Standard (SNI) for category Topographic Surveying, as show below :

*Table 2-1 List of topographic surveying standard.*

| NO | STANDARD         |      |                 | TITLE  |
|----|------------------|------|-----------------|--|
|    | Code             | Year | Standard Items  |  |
| 1. | BAKOSURTANAL     | -    | Standard Survey | Topography Survey and Mapping                |
| 2. | SNI 19-6724-2002 | 2002 | Standard Survey | Horizontal Control Network                   |
| 3. | SNI 19-6988-2004 | 2004 | Standard Survey | Vertical Control Network by Levelling Method |

#### b. Preparation and Secondary Data

Before performing the survey work, it's necessary to prepare and collect secondary data as follows:

- ◆ Prepare National Topographic Map by Bakosurtanal (now named as Badan Informasi Geospasial), sheet of Pekanbaru with index number 0816-52 and sheet of Perawang with index number 0816-61. All of the map provided in scale of 1:50.000
- ◆ Reference coordinate of existing Benchmarks.
- ◆ and other supporting data.

#### c. Horizontal Control (Traverse) Measurement

Measurement of horizontal control network carried out by closed network traverse. The horizontal measurements connected to reference Benchmarks. Measurement of traverse shall be performed by following methods :

- Point of traverse is strived as near with line alignment connecting the Benchmark Existing (reference) at site.

- ❑ Apart closeness of between point of traverse is adapted condition of field range from 10 - 50 meter for area relatively leveled off, and about 25 meter for terrain having height difference enough strike.
- ❑ Measurement was carried out by measuring instrument Total Station with reading accuracy maximum 5", and measured in one series of reading (forward and backward).
- ❑ Measurement of distance every section of traverse done by minimum two times reading (forward-backward).
- ❑ Every execution of measurement of polygon always controlled so that be knowable deviation happened and soon given by correction for returned toward alignment which ought to.
- ❑ Every point of polygon is marking using wooden peg with dimension  $\frac{3}{4}$ " or 30 cm (or other markings) and setup numbering or coding by Surveyor.

#### **d. Vertical Control (Elevation) Measurement**

Vertical control measurement aims to give each points of traverse or control points an elevation value.

Elevation measurements performed by the following:

- ❑ Elevation measurement should starts and ends from Benchmark.
- ❑ Measurement should through the points (peg) of traverse measurement.
- ❑ The elevation measurement conducted using waterpass instrument, a TOPCON ATB4 type.
- ❑ Elevation measurement for each section carried by double stand with complete reading measurement (yarn top, middle and bottom) and double stands.
- ❑ Every step of measurement, maximum distance between instrument and measuring staff is 50 m.
- ❑ Before starting and after completion of daily measurement, waterpass instrument should checked its collimation errors.

#### **e. Measurement of Topographic Situation**

Measurement of topographic situation carried out to get data of land surface, existing building, house, road, drainage, river and other object that represented situation of intention area.

Measurement of topographic situation shall performed by following methods:

- ❑ All detailed measurement should tied to Benchmark or traverse point.
- ❑ Measurement of topographic situation carried out to get data of land surface, measurement of situation also done to get data position of natural objects and made in along with the situations residing in measurement area like, house and other building, road, river, powerline (HVT), plantation boundary, forestry, etc, to be presented as information at situation vector map (topography map)
- ❑ All specific utility such as: existing transmission line, PDAM supply pipe, drainage, etc shall identified and drawn in Topography map

- The detailed situation measurement conducted using Total Station

### 2.3 Reference Coordinate

The existing BM (benchmarks) owned by Regional Government Owned Company (BUMD) was utilized as reference BM. Following are data of reference BM which applied :

- BM name : BM 0
- X value : 783310.000
- Y value : 057048.000
- Z value : 44.690

The reference BM located at BUMD area, about 7 Km from GFPP site.

### 2.4 Benchmark Installation

For the purposes of topographic, conducted Benchmark manufacture and installation of as many as one pair (two units), consisting of BM-03 and CP-03.

### 2.5 Horizontal Control (Traverse) Measurement

The traverse measurement was conducted to determine position of distributed reference point which will function as tied point (traverse point). The traverse point will be utilized by detailed situation measurement. Traverse measurement started at BM-03 and finished at CP-03, which also as initial azimuth.

Implementation of horizontal or traverse measurement are as follows :

- Measurement started at reference Benchmark to project site, conducted by geometric loop (closed loop) and connected to reference points BM-03 and CP-03.
- The measurement conducted using Total Station
- Measurement of horizontal angle carried out by one double series (one times of normal and repetition measurement)
- Distance measurement also get from Total Station for each traverse range and finally average distance of each traverse range.

### 2.6 Vertical Control Measurement

Measurement of vertical control network conducted using levelling (waterpass) method while the route follow horizontal control network (traverse) with closed loop. The measurement connected to BM-0 as starting point of vertical reference (height). The measurement conducted using Waterpass which comply standard and complement by levelling staff. Allowable tolerance of vertical control measurement is under ( $20\sqrt{D}(\text{km})$ ) mm.

## 2.7 Measurement of Detailed Situation

The detailed situation measurement intended to get position (coordinate) and height (elevation) of every measured point, which are terrain of ground surface, every object above ground surface. All detailed situation will presented in the Situation Map. The detailed situation measurement conducted by following terms :

- Measurement by Total Station
- Measurement carried out by trigonometry method
- The detailed spot measured with scale of 1:1000 standard, which all detail such as river, road, gully, and 5-10 meter maximum density of ground surface alteration.
- All detailed situation measurement connected to nearest control network point.

## 2.8 Data Processing and Drawing

Data processing / calculation of control network survey result carried out by bowditch for horizontal control network (traverse), vertical control network and detailed situation calculated by trigonometry method.

The data processing carried out in two (2) steps as follows:

1. Pre data processing directly on site  
This step intended to early make sure the measurement comply with allowable tolerance.
2. Post data processing at office.  
This step conducted by computer based after all measurement completed.  
Data processing of horizontal control network consist of :
  - Calculate arithmetic average angle and arithmetic average distance,
  - Checking angle closure error,
  - Checking linear closure error.

Data processing of vertical control network consist of :

- Checking calculation of total distance,
- Checking height difference,
- Checking height difference closure error.

Drawing work refers to following terms:

- a. Drawing process carried out by computer using AutoCAD Land Development 2009 Software.
- b. Detail Situation Map made in 1 : 1000 scale with 1 meter contour interval,
- c. The Situation map can produced in A1 paper size
- d. Long section drawing made in 1 : 1000 scale of horizontal and 1 : 100 scale of vertical.
- e. Cross section drawing made in 1 : 100 scale of horizontal and 1 : 100 scale of vertical.
- f. All detail situation, natural or man-made shall plotted in Map / drawing and complement with each symbols, comply with cartography standard as follows :
  - Map Title,
  - Map Index,
  - Legend,
  - Grid lines with 10 Cm interval,
  - Bar scale
  - Sheet guideline and North orientation

Information on date/month/year of measurement implementation and drawing

## 2.9 Analysis of Topography Survey

Analysis of topography survey result intended to evaluate the quantity and quality of survey implementation compared to terms of reference.

### a. Analysis based on Quantity

Based on proposed work quantity, the survey result shall meet the requirement, as follows:

1. Quantity of topography survey consist of:
  - a. Preparatory works
  - b. Survey / measurement work
  - c. Data calculation work
  - d. Analysis of survey result
  - e. Drawing
  - f. Reporting
2. Quantity or total area of survey of Riau GFPP 275 MW is 10 Ha,
3. Total distance of levelling measurement is 5830.7 m

### b. Analysis based on Quality

Analysis and checking the horizontal control network result shall refer to allowable tolerance as describes at following table.

**Table 2-2** Analysis of Topography survey

| NO. | ROUTE OF SURVEY | TOTAL DISTANCE (m) | REQUIREMENT     | SURVEY RESULT     | REMARK                  |
|-----|-----------------|--------------------|-----------------|-------------------|-------------------------|
| 1   | BM 0 – BM-03    | 5,830.7            | 20mm $\sqrt{D}$ | 3.2 mm $\sqrt{D}$ | Passing the requirement |

## 2.10 Survey Result

After whole field activities and office activities completed and produced description of Benchmark, Map, Drawing and other related result. Following table describe summary of survey result while the detail result shows in appendix.

**Table 2-3** Coordinate of installed benchmark.

| Number of BM | X (meters) | Y (meters) | Elevation |
|--------------|------------|------------|-----------|
| BM 03        | 780508.180 | 59944.905  | 27.072    |
| CP 03        | 780630.268 | 59965.075  | 23.044    |

**Table 2-4** List of survey result

| No. | Survey Result             | Number of Sheet | Scale             |
|-----|---------------------------|-----------------|-------------------|
| 1   | Topography Map            | 3               | 1: 2000 & 1: 1000 |
| 2   | Land Profile of GFPP area | 18              | 1: 2000 & 1: 1000 |

## 2.11 Quantity of Cut/ Fill and Recommended Level

On construction projects it is often necessary to modify the existing ground levels to create platforms to build on. Accurately calculating the volumes of soil that must be removed (cut) or added (fill) to create the final ground levels is an essential part of the planning process.

For the GFPP 275 MW project, the cut & fill calculation was made to get a ballace quatity (volume) of cut works and fill works as follows:

- Quantity of Cut/Fill : 165778.75/165343.39 M<sup>3</sup> (remaining cut material: 435.35 M<sup>3</sup>)
- Recommended Level : 28.05 m

## 3. Geotechnical Investigation

### 3.1 Geology and Geotechnical Site Investigation Methodology

#### a. Standard and Reference

The Field investigation works was implemented based on common standards and references. The standards and references are shown in Table 3-1 bellow.

*Table 3-1 Applied standard reference of geotechnical investigation.*

| NO. | STANDARD        |      |        | TITLE   |
|-----|-----------------|------|--------|---|
|     | Code            | Year | Source |   |
| 1   | D 1452 - 80     | 1980 | ASTM   | Drilling Operation  |
| 2   | D 1586 - 99     | 1999 | ASTM   | Standard Penetration Test (SPT)   |
| 3   | D-1587 - 00.    | 2000 | ASTM   | Undisturbed Sampling  |
| 4   | D 2487 - 00     | 2000 | ASTM   | Classification of Soils for Engineering Purpose   |
| 5   | D 2488 - 00     | 2000 | ASTM   | Description and Identification of Soils (Visual-Manual Procedure)   |
| 6   |                 | 1981 | ISRM   | Basic Geotechnical Description of Rock Masses   |
| 7   | D6032-02        | 2000 | ASTM   | Rock Quality Designation ("RQD")  |
| 8   | 13-4691         | 1998 | SNI    | Preparation of Geological Map   |
| 9   | 13-6185         | 1999 | SNI    | Preparation of Geomorphological Map   |
| 10  | D 2216 - 98     | 1998 | ASTM   | Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass   |
| 11  | D 854 - 00      | 2000 | ASTM   | Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer  |
| 12  | D 422 - 63 (98) | 1998 | ASTM   | Standard Test Method for Particle-Size Analysis of Soils  |
| 13  | D 2166 - 00     | 2000 | ASTM   | Standard Test Method for Unconfined Compressive Strength of Cohesive Soil   |
| 14  | D 2850 - 95     | 1995 | ASTM   | Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils   |
| 15  | D 4746 - 95     | 1995 | ASTM   | Standard Test Method for Consolidated-Undrained Triaxial Compression Test on Cohesive Soils   |
| 16  | D 2435 - 96     | 1996 | ASTM   | Standard Test Method for One-Dimensional Consolidation Properties of Soils  |
| 17  | D 698 - 00a     | 2000 | ASTM   | Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft <sup>3</sup> (600 kN/m <sup>3</sup> )) |
| 18  | D5878 - 08      | 1998 | ASTM   | Standard Guides for Using Rock-Mass Classification Systems for Engineering Purposes   |

#### b. Core Drilling

The core drilling carried out using drilling machine at each investigation points based on general layout of power plant. The core drilling purposes are to identified the geological and geotechnical condition of sub surface. The Direct Rotary Core Drilling was applied with fresh water as drilling fluids. (ASTM D.2113 - 99). The work implementation shall carried out based on following methods :

1. Location or site of bore hole should be clean up and level to make comfortable work space. The drilling machine are setting up based on its drilling machine *operation manual*,
2. The application of drilling fluids are very important, to assure the cores un-eroded, and cores taken fully recovery and keeps identity of soil/rock.
3. When drilling reach overburden layers or un-stable layers, all potential holes collapse shall be avoid and protect by casing.
4. The ground water table in each bore hole recorded every day during the drilling work implemented and also after drilling complete. Some special condition arise (artesian or water loose) have to recorded also.
5. Prepare the Drilling Daily Report, included:
  - Date of drilling implementation,
  - Location and number of hole,
  - Elevation of water table,
  - Name and type of drilling machine, type of core barrel applied, diameter of bore hole and depth of casing installed,
  - Description of core,
  - Name of Bore Master,
  - Any necessary information about the drilling activities.
6. The core placed into transparent plastic in order to protect it and placed into core box orderly based on drilling depth. On the cover of core box put label or information about:
  - Name / Project Location
  - Number of Bore hole
  - Sequence number of core boxes
  - Depth of drilling of each box.
7. Immediately conduct the core description and continue with log bore preparation. The log bore contains as follows :
  - Date of drilling implementation,
  - Length of core,
  - Rock Quality Designation (RQD),
  - Water table,
  - Rock symbols and its description,
  - Result of on site tests and another necessary/ important description for design needs.

#### **c. Standard Penetration Test (SPT)**

The Standard Penetration Test (SPT) was carried out on each holes during drilling activities, based on the USBR specification in Earth Manual Book, ASTM D 1586-99 or SNI 03-4148. It was conduct using Raymond Sampler and Drive Hammer with  $140 \pm 2$  lb ( $63,5 \pm 1$  kg) weight, every stated depth level.

It was recorded every 15 cm penetration of 75 cm falling of hammer. The SPT report consist of :

- Depth of test
- Number of hit for 15 cm penetration

The N-value is total number of hit for 30 cm penetration.

#### **d. Permeability Test and Ground Water Monitoring**

The Falling Head Test method was applied for non-permeable soil layers (clay and silt) and Constant Head Test method was applied for permeable soil layers (sand, gravel). The testing

carried out based on BS standard 5930 -1999 and Lugeon Test method based on Earth Manual. Interpretation of the test result was referred to SNI 2436:2008 as shown in following table

**Table 3-2 Permeability level (SNI 2436 : 2008)**

| Value of permeability<br>(cm/sec) | Level of permeability |
|-----------------------------------|-----------------------|
| $> 10^{-2}$                       | Very high             |
| $10^{-2} - 10^{-3}$               | High                  |
| $10^{-4} - 10^{-5}$               | Medium                |
| $10^{-6}$                         | Low                   |
| $< 10^{-6}$                       | Very low              |

#### **e. Soil and Ground Water Samples**

The undisturbed sample of soil extracted using Shelby Tube Sampler in drilling hole at designed depth and carried out based on ASTM D-1587 - 00. After soil sample trapped in shelby tube, sealed both side of tube paraffin, and then sending to laboratory to analysis of its properties.

The soil sample will process in Soil Mechanic laboratory and some of them will process in chemical soil laboratory. Whereas water sample of bore hole will process in chemical laboratory. The chemical test will focus in corrosive parameter of soil and ground water.

#### **g. Soil Mechanic Test**

The soil mechanic laboratory test consists of 2 major parameter, physical (index) properties and mechanical (engineering) properties.

##### **Physical Properties :**

- Water content
- Specific Gravity
- Particle-size analysis
- Atterberg Limits
- Unit weight

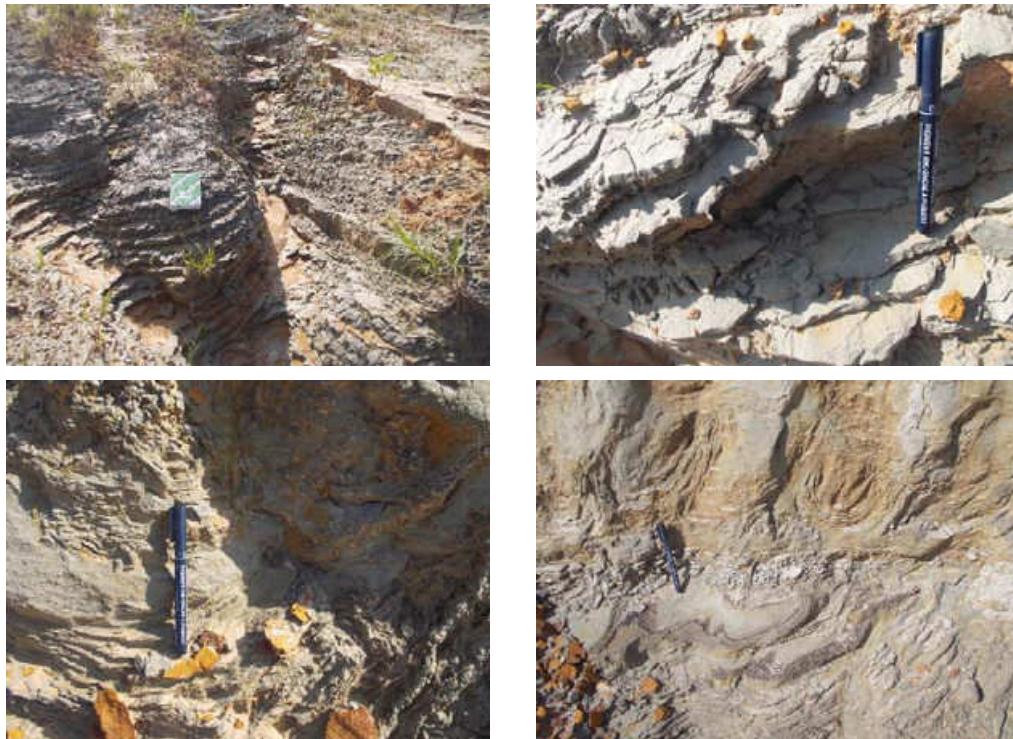
##### **Mechanical Properties :**

- Triaxial Compression Test
- Consolidation Test
- Direct Shear
- Unconfine Compresion Test

## **3.2 Geological Condition**

According to the field geological mapping that have been conducted, the lithology type emerges in the investigation area typically consists of silt and clay. Typically showing massive

to interbedded feature, gently dipping of bedding with gently folding area structures commonly found in the area.



*Figure 3-1 Typical bedrock encountered at investigation.*

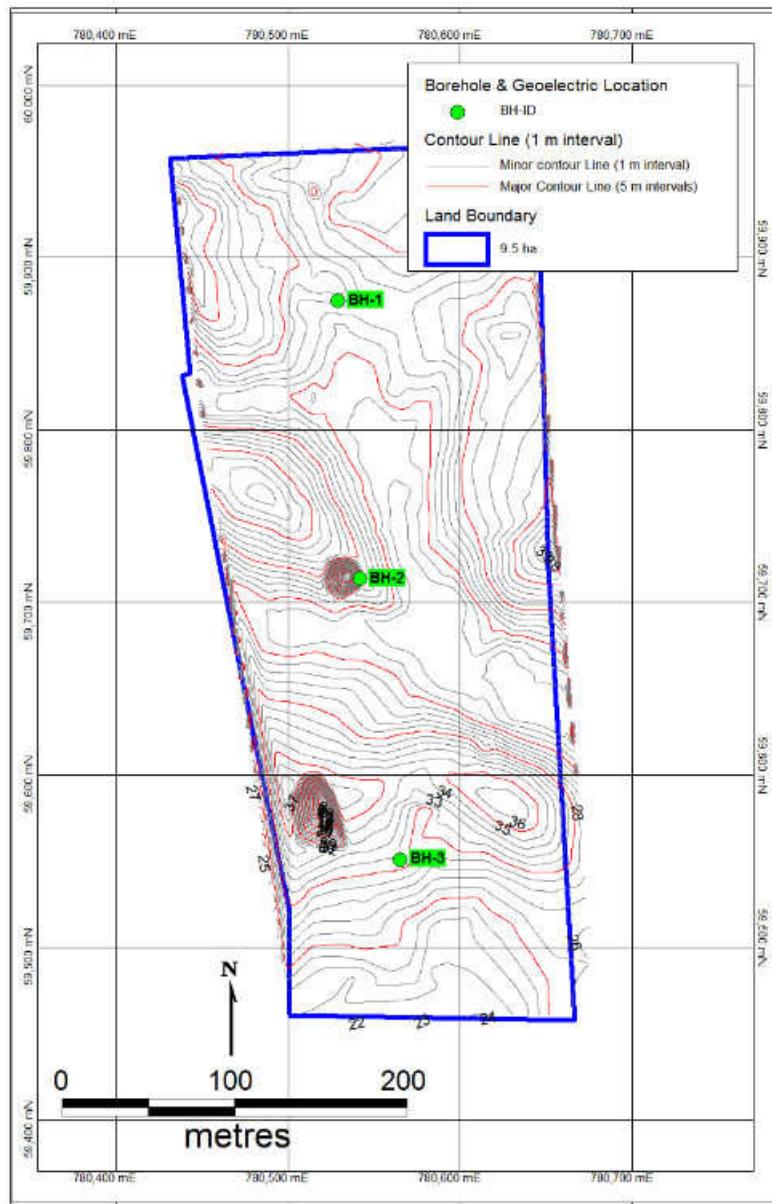
According to regional geology map of Riau Quadrangle this rock unit is part of Minas formation of Quarternary age (pleistocene) associated with gravel and sand deposits which is sometimes interpreted as fluvial origin.

No fault structures encountered in the area, according to regional geology map of Riau Quadrangle (scale 1: 250,000 Clarke. W et al 1982) the nearest large scale fault structure from the area approximately 12 km.

### 3.3 Core Drilling and Insitu Test

In order to understand the behavior, distribution, geological and geotechnical characteristics of rocks in investigation site. Three drilling locations had been undertaken. Namely BH-01, BH-02, and BH-03.

Following map shows the layout of soil investigation area, where the drillholes and land boundary situated and the site investigation work is undertaken.



**Figure 3-2** Map layout of soil investigation and geoelectric survey.

Lithology of site investigation area, according to drilling result consists of consolidated fine grained soil material: silty Clay and Clay. Following table describe soil and rock layer occupying the investigated area.

**Table 3-3** Summary of lithology unit for each borehole location.

| No. | BH-ID | Depth (m) | Lithology   | Hardness  |
|-----|-------|-----------|-------------|---|
| 1   | BH-01 | 0 - 0.40  | clayey SILT | Top Soil (D) soft, dull, blackish brown, clayey SILT, moist, frequent small root encountered. |

| No. | BH-ID        | Depth (m)     | Lithology   | Hardness  |
|-----|--------------|---------------|-------------|---|
|     |              | 0.40 – 1.00   | silty CLAY  | firm - stiff (MW-HW) of light brown - yellowish brown of moist silty CLAY, some fine sand and silt encountered. |
|     |              | 1.00 – 27.00  | CLAY        | very stiff, (MW-HW) of greyish brown - dark brown CLAY.   |
|     |              | 27.00 – 30.00 | CLAY        | very stiff, (MW-HW) of massive greyish brown - dark brown CLAY.   |
| 2   | <b>BH-02</b> | 0 – 0.60      | clayey SILT | Top Soil (D) soft, dull, blackish brown, clayey SILT, moist, frequent small root encount                        |
|     |              | 0.60 – 3.45   | silty CLAY  | firm - stiff (MW-HW) of light brown - yellowish brown of moist silty CLAY, some fine sand and silt encountered. |
|     |              | 3.45 – 30.00  | CLAY        | very stiff, (MW-HW) of massive greyish brown - dark brown lean CLAY.  |
| 3   | <b>BH-03</b> | 0 – 1.20      | Clayey SILT | top soil (D), soft of blackish brown clayey SILT, moist, root frequent.   |
|     |              | 1.20 – 5.60   | Clayey SILT | (MW-HW), soft - firm of light brown - greyish brown silty CLAY. Medium to high plasticity                       |
|     |              | 5.60 – 30.00  | CLAY        | (MW), stiff - very stiff of dark grey to light grey massive lean clay with silt. Medium to high plasticity.     |

In addition to geological description we also undertook the Field Standar Penetration Test (SPT) were performed by 1.5 m interval of testing in regular basis. following tables show field record of SPT data from each borehole.

**Table 3-4 SPT field record of BH-01.**

| No | Depth         | N1 | N2 | N3 | NSPT (N2+N3) |
|----|---------------|----|----|----|--------------|
| 1  | 1.50 - 1.95   | 3  | 8  | 10 | 18           |
| 2  | 3,00 - 3.45   | 3  | 10 | 10 | 20           |
| 3  | 4.50 - 4.95   | 5  | 8  | 10 | 18           |
| 4  | 6.00 - 6.45   | 2  | 4  | 2  | 6            |
| 5  | 7.50 - 7.95   | 2  | 6  | 9  | 15           |
| 6  | 9.00 - 9.45   | 5  | 10 | 17 | 27           |
| 7  | 10.50 - 10.95 | 8  | 15 | 18 | 33           |
| 8  | 12.00 - 12.45 | 7  | 20 | 18 | 38           |
| 9  | 13.50 - 13.95 | 5  | 12 | 15 | 27           |
| 10 | 15.00 - 15.45 | 8  | 18 | 18 | 36           |
| 11 | 16.50 - 16.95 | 8  | 18 | 30 | 48           |

| No | Depth         | N1 | N2 | N3 | NSPT (N2+N3) |
|----|---------------|----|----|----|--------------|
| 12 | 18.00 - 18.45 | 5  | 16 | 34 | 50           |
| 13 | 19.50 - 19.95 | 10 | 21 | 30 | >50          |
| 14 | 21.00 - 21.45 | 11 | 15 | 32 | 47           |
| 15 | 22.50 - 22.95 | 8  | 26 | 33 | >50          |
| 16 | 24.00 - 24.45 | 17 | 28 | 26 | >50          |
| 17 | 25.50 - 25.95 | 9  | 26 | 34 | >50          |
| 18 | 27.00 - 27.45 | 15 | 40 | 43 | >50          |
| 19 | 28.50 - 28.95 | 20 | 35 | 36 | >50          |
| 20 | 30.00 - 30.45 | 9  | 24 | 34 | >50          |

**Table 3-5** SPT field record of BH-02.

| No | Depth         | N1 | N2 | N3 | NSPT (N2+N3) |
|----|---------------|----|----|----|--------------|
| 1  | 1.50 - 1.95   | 1  | 1  | 1  | 2            |
| 2  | 3.00 - 3.45   | 2  | 3  | 4  | 7            |
| 3  | 4.50 - 4.95   | 5  | 10 | 12 | 22           |
| 4  | 6.00 - 6.45   | 6  | 10 | 16 | 26           |
| 5  | 7.50 - 7.95   | 7  | 19 | 30 | 49           |
| 6  | 9.00 - 9.45   | 8  | 15 | 34 | 49           |
| 7  | 10.50 - 10.95 | 9  | 18 | 27 | 45           |
| 8  | 12.00 - 12.45 | 10 | 20 | 30 | 50           |
| 9  | 13.50 - 13.95 | 10 | 20 | 44 | >50          |
| 10 | 15.00 - 15.45 | 11 | 18 | 33 | >50          |
| 11 | 16.50 - 16.95 | 15 | 32 | 38 | >50          |
| 12 | 18.00 - 18.45 | 20 | 28 | 25 | >50          |
| 13 | 19.50 - 19.95 | 10 | 19 | 30 | 49           |
| 14 | 21.00 - 21.45 | 14 | 29 | 28 | >50          |
| 15 | 22.50 - 22.95 | 9  | 28 | 45 | >50          |
| 16 | 24.00 - 24.45 | 7  | 12 | 25 | 37           |
| 17 | 25.50 - 25.95 | 10 | 18 | 20 | 38           |
| 18 | 27.00 - 27.45 | 7  | 18 | 40 | >50          |
| 19 | 28.50 - 28.95 | 20 | 23 | 35 | >50          |
| 20 | 30.00 - 30.45 | 22 | 24 | 36 | >50          |

**Table 3-6** SPT field record of BH-03.

| No | Depth       | N1 | N2 | N3 | NSPT (N2+N3) |
|----|-------------|----|----|----|--------------|
| 1  | 1.50 - 1.95 | 2  | 4  | 6  | 10           |

| No | Depth         | N1 | N2  | N3 | NSPT (N2+N3) |
|----|---------------|----|-----|----|--------------|
| 2  | 3.00 - 3.45   | 3  | 3   | 5  | 8            |
| 3  | 4.50 - 4.95   | 2  | 2   | 6  | 8            |
| 4  | 6.00 - 6.45   | 2  | 5   | 6  | 11           |
| 5  | 7.50 - 7.95   | 4  | 8   | 10 | 18           |
| 6  | 9.00 - 9.45   | 6  | 12  | 16 | 28           |
| 7  | 10.50 - 10.95 | 8  | 14  | 20 | 34           |
| 8  | 12.00 - 12.45 | 5  | 10  | 25 | 35           |
| 9  | 13.50 - 13.95 | 11 | 15  | 13 | 28           |
| 10 | 15.00 - 15.45 | 6  | 125 | 18 | 30           |
| 11 | 16.50 - 16.95 | 18 | 25  | 21 | 46           |
| 12 | 18.00 - 18.45 | 6  | 12  | 20 | 32           |
| 13 | 19.50 - 19.95 | 6  | 14  | 23 | 37           |
| 14 | 21.00 - 21.45 | 12 | 20  | 40 | 60           |
| 15 | 22.50 - 22.95 | 8  | 20  | 30 | 50           |
| 16 | 24.00 - 24.45 | 29 | 36  | 36 | >50          |
| 17 | 25.50 - 25.95 | 14 | 27  | 50 | >50          |
| 18 | 27.00 - 27.45 | 15 | 25  | 30 | >50          |
| 19 | 28.50 - 28.95 | 15 | 28  | 31 | >50          |
| 20 | 30.00 - 30.45 | 16 | 26  | 39 | >50          |

Following tables described the permeability result obtained from field permeability test, from the test results we might conclude that the permeability value of investigated area ranging from  $10^{-5}$  to  $10^{-4}$  cm/s therefore categorized as medium permeability.

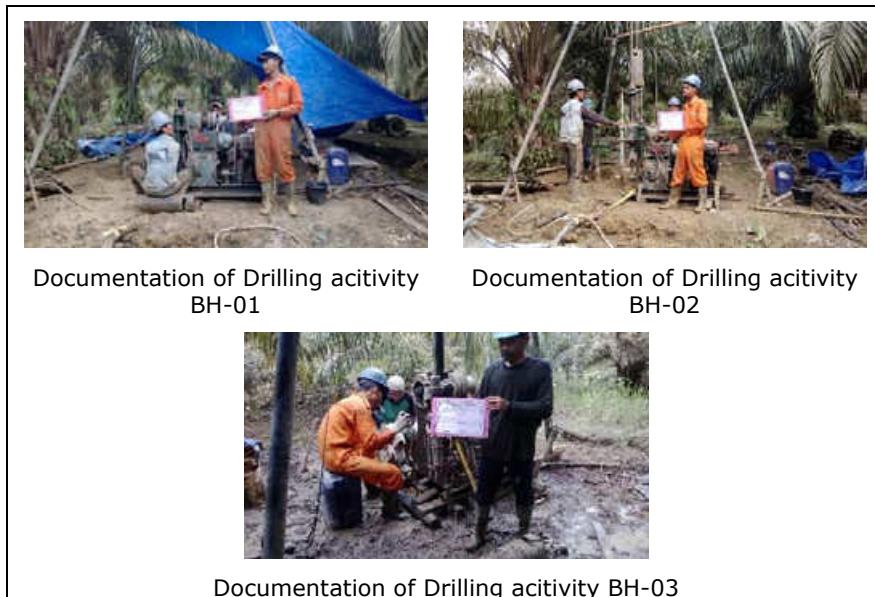
**Table 3-7 Permeability insitu test results.**

| No. | BH-ID        | Depth (m) | Permeability (cm/sec) |
|-----|--------------|-----------|-----------------------|
| 1   | <b>BH-01</b> | 0 - 5     | 2.22E-04              |
|     |              | 2.8 - 10  | 1.24E-04              |
|     |              | 2.8 - 15  | 7.40E-06              |
|     |              | 14.8 - 20 | 1.17E-06              |
|     |              | 19.5 - 25 | 1.85E-06              |
|     |              | 19.3 - 30 | 2.21E-06              |

| No | BH-ID        | Depth (m) | Permeability (cm/sec) |
|----|--------------|-----------|-----------------------|
| 2  | <b>BH-02</b> | 2.95 - 5  | 2.10E-05              |
|    |              | 8.9 - 10  | 2.31E-05              |
|    |              | 14.8 - 15 | 4.13E-05              |
|    |              | 17.8 - 20 | 1.35E-05              |
|    |              | 20.8 - 25 | 1.82E-06              |
|    |              | 20.8 - 30 | 7.50E-07              |

|   |              |          |          |
|---|--------------|----------|----------|
| 3 | <b>BH-03</b> | 2.8 - 5  | 9.96E-05 |
|   |              | 8.8 - 10 | 4.86E-05 |

|  |  |           |          |
|--|--|-----------|----------|
|  |  | 14.8 – 15 | 7.43E-05 |
|  |  | 17.8 – 20 | 5.66E-06 |
|  |  | 23.9 – 25 | 5.27E-06 |
|  |  | 20.8 – 30 | 7.50E-07 |



*Figure 3-3 Documentation of drilling acitivity at investigation area*

### 3.4 Chemical Properties

During implementation of drilling works, ground water of borehole was taken for water quality laboratory test. Each borehole represented by one groundwater sample obtained after drilling work, one sample taken at 10 meter hole depth and other at 30 meter hole depth. Following table is summary of the laboratory result and the detail result attached in Appendix G.

*Table 3-8 Summary of ground water quality result*

| No. | Parameter                            | Unit                      | BH-01      | BH-02      | BH-03      |
|-----|--------------------------------------|---------------------------|------------|------------|------------|
|     |                                      |                           | Depth 28 m | Depth 10 m | Depth 20 m |
| 1   | Acidity (as CaCO <sub>3</sub> )      | mg/L (CaCO <sub>3</sub> ) | 133        | 18         | 104        |
| 2   | Alkalinity (as CaCO <sub>3</sub> )   | mg/L (CaCO <sub>3</sub> ) | 95         | 328        | 132        |
| 3   | Hydrogen Sulphide (H <sub>2</sub> S) | mg/L                      | 0.21       | 28         | 2          |
| 4   | Soluble Chloride (Cl)                | mg/L                      | 21         | 31         | 94         |
| 5   | Soluble Sulphate (SO <sub>4</sub> )  | ppm                       | 36         | 34         | 104        |

|   |                 |      |     |     |     |
|---|-----------------|------|-----|-----|-----|
| 6 | Organic Content | mg/L | 366 | 702 | 304 |
|---|-----------------|------|-----|-----|-----|

**Table 3-9** Summary of Soil Chemistry result

| No. | Parameter                           | Unit                      | BH-01      | BH-02    | BH-03    |
|-----|-------------------------------------|---------------------------|------------|----------|----------|
|     |                                     |                           | Depth 28 m | Depth 10 | Depth 20 |
| 1   | pH                                  | -                         | 7.3        | 9.62     | 9.66     |
| 2   | Acidity                             | Mg/Kg (CO <sub>3</sub> )  | 64.92      | 66.05    | 65.51    |
| 3   | Alkalinity                          | mg/Kg (HCO <sub>3</sub> ) | 264.01     | 266.83   | 266.59   |
| 4   | Sulphur Trioxide (SO <sub>3</sub> ) | ppm                       | 9.62       | 9.76     | 9.48     |
| 5   | Soluble Chloride (Cl)               | ppm                       | 67.32      | 67.19    | 67.29    |
| 6   | Soluble Sulphate (SO <sub>4</sub> ) | ppm                       | 24.01      | 24.44    | 24.62    |
| 7   | Organic Content                     | %                         | 9.00       | 9.11     | 9.17     |

## 3.5 Geoelectrical Survey

### 3.5.1 Implementation of Survey Works

The geoelectric survey work that has been done is 3 (three) points V.E.S. (Vertical Electrical Sounding), where the placement of dots suspect attention to morphological aspects, geology and aspects of local physical infrastructure located at the location of the investigation. Co-ordinates of geoelectric points can be seen in Table 3.10, while the layout map of the geoelectric investigation points can be seen in Figure 3.5

**Table 3-10** Summary of ground water quality result.

| Point | X (m)      | Y (m)     | Z (m) |
|-------|------------|-----------|-------|
| GL-1  | 780533.750 | 59873.540 | 28.62 |
| GL-2  | 780544.970 | 59711.440 | 28.97 |
| GL-3  | 780566.520 | 59551.520 | 31.05 |

*Implementation of geoelectrical survey at GL-1**Implementation of geoelectrical survey at GL-2**Implementation of geoelectrical survey at GL-3***Figure 3-4** Implementation of geoelectrical survey at investigation area

The Geolistrical survey try to penetrate 100 meter of ground consist of 3 (three) points of VES, distributed on future power plant area. Following figure describe lay out of the survey.

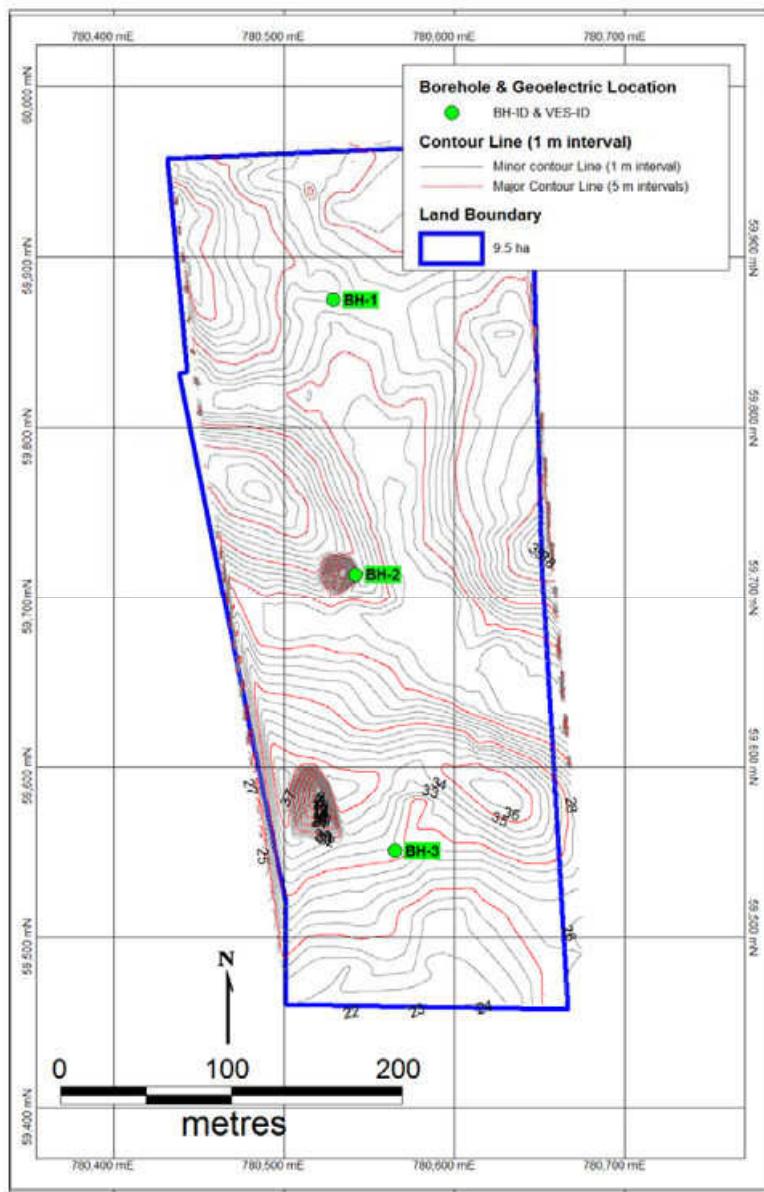


Figure 3-5 Layout of geoelectrical survey

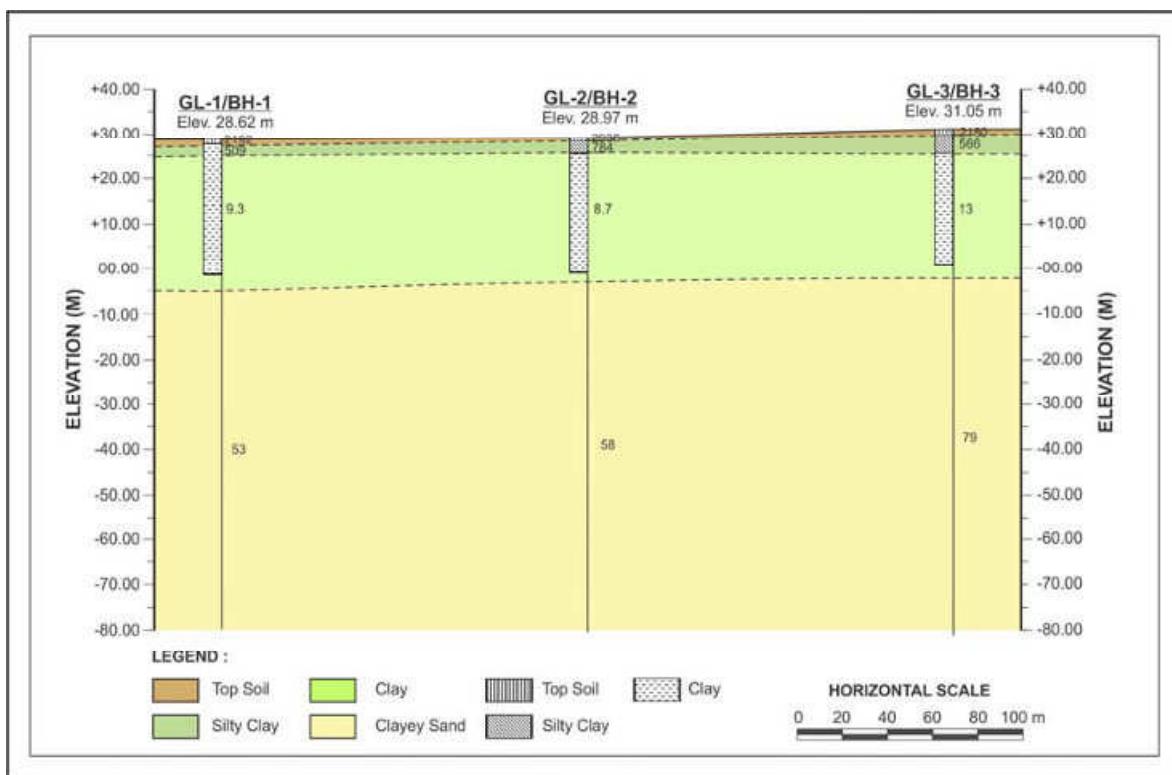
### 3.5.2 Result of Geoelectrical Survey

Based on the results of interpretation of geoelectric data correlated with the drill log data and regional geology sheet Pekanbaru, then the arrangement of layers of soil / rock contained in the area of investigation based on the type of resistivity can be grouped as follows:

1. **The first layer**, interpreted as top soil with a resistivity value of its type ranges from 2100 to 2938 ohm-meters. This unit is found from the local surface to a depth of 1.53 meters with a thickness ranging from 0.64 meters to 1.53 meters.

2. **The second layer**, interpreted as a unit of silty clay, with a resistivity value of the type ranges from 504 to 784 ohm-meter. This layer has a thickness ranging from 2.17 meters to 4.39 meters.
3. **The third layer**, interpreted as a unit of clay, with the resistivity value of the species ranged from 8.7 - 13 ohm-meter. This layer has a thickness ranging from 27.63 to 30.00 meters.
4. **The fourth layer**, interpreted as a unit of clayey sand, with resistivity value of the species ranges from 53 to 79 ohm-meters. This layer has a thickness This layer has a thickness of more than 66 meters

Geological Section Based on Geoelectric Interpretation and Drilling Result (Bor Log) can be seen in Figure 3-6, while Field Data & Interpretation Curve of Geoelectric Survey Results can be seen in Appendix.



**Figure 3-6** Geological cross section based on geoelectrical data (section GL-1 to GL-3).

## 3.6 Geotechnical Investigation and Foundation

### 3.6.1 Recommendation of Design Parameter

Based on field investigation data which includes 3 boreholes with SPT, the general soil stratification of Gas Fired Power Plant 275 MW Riau area are consist of Clay and Silty Clay soil

type. The strength and consistency of soil layers increased within depth. Ground water level was found between -4.00 to -9.00 m from ground surface elevation.

Soil properties are interpreted from field data as describes in following tables.

**Table 3-11** Parameter design of BH-01.

| PARAMETER DESIGN OF BH-01 |                    |              |                                  |             |             |                  |             |             |             |                |
|---------------------------|--------------------|--------------|----------------------------------|-------------|-------------|------------------|-------------|-------------|-------------|----------------|
| Depth<br>(m)              | N-SPT<br>(blow/ft) | Soil<br>Type | $\gamma$<br>(kN/m <sup>3</sup> ) | Su<br>(kPa) | c'<br>(kPa) | $\phi'$<br>(deg) | Eu<br>(kPa) | E'<br>(kPa) | Vs<br>(m/s) | G max<br>(kPa) |
| 0.00                      | 18.00              | Clay         | 19.68                            | 103.02      | 30.01       | 20.69            | 25,108      | 22,926      | 209.44      | 74,677         |
| 1.50                      | 18.00              | Clay         | 19.68                            | 113.82      | 30.01       | 20.69            | 27,740      | 25,329      | 216.10      | 79,915         |
| 3.00                      | 20.00              | Clay         | 19.68                            | 133.48      | 33.35       | 20.69            | 32,533      | 29,705      | 227.19      | 89,062         |
| 4.50                      | 18.00              | Clay         | 18.31                            | 112.41      | 30.01       | 21.99            | 44,566      | 40,298      | 222.34      | 84,995         |
| 6.00                      | 6.00               | Clay         | 18.31                            | 38.52       | 11.50       | 21.99            | 15,270      | 13,807      | 158.83      | 41,028         |
| 7.50                      | 15.00              | Clay         | 18.31                            | 98.43       | 25.00       | 21.99            | 39,021      | 35,284      | 213.25      | 77,652         |
| 9.00                      | 27.00              | Clay         | 18.83                            | 173.45      | 45.04       | 21.46            | 61,259      | 55,551      | 257.94      | 117,249        |
| 10.50                     | 33.00              | Clay         | 18.83                            | 215.30      | 55.06       | 21.46            | 76,040      | 68,955      | 276.06      | 135,813        |
| 12.00                     | 38.00              | Clay         | 18.83                            | 251.28      | 63.41       | 21.46            | 88,748      | 80,479      | 289.78      | 150,862        |
| 13.50                     | 27.00              | Clay         | 18.83                            | 180.67      | 45.04       | 21.46            | 63,812      | 57,866      | 261.27      | 120,549        |
| 15.00                     | 36.00              | Clay         | 18.83                            | 243.47      | 60.07       | 21.46            | 85,992      | 77,980      | 286.93      | 147,660        |
| 16.50                     | 48.00              | Clay         | 18.76                            | 342.01      | 80.11       | 20.76            | 93,880      | 85,572      | 315.00      | 180,743        |
| 18.00                     | 50.00              | Clay         | 18.76                            | 356.26      | 83.45       | 20.76            | 97,792      | 89,137      | 319.07      | 185,830        |
| 19.50                     | 50.00              | Clay         | 18.76                            | 356.26      | 83.45       | 20.76            | 97,792      | 89,137      | 319.07      | 185,830        |
| 21.00                     | 47.00              | Clay         | 18.76                            | 334.89      | 78.44       | 20.76            | 91,924      | 83,789      | 312.93      | 178,173        |
| 22.50                     | 50.00              | Clay         | 18.97                            | 316.33      | 83.45       | 22.13            | 128,083     | 115,728     | 319.07      | 185,830        |
| 24.00                     | 50.00              | Clay         | 18.97                            | 316.33      | 83.45       | 22.13            | 128,083     | 115,728     | 319.07      | 185,830        |
| 25.50                     | 50.00              | Clay         | 18.97                            | 316.33      | 83.45       | 22.13            | 128,083     | 115,728     | 319.07      | 185,830        |
| 27.00                     | 50.00              | Clay         | 19.00                            | 323.05      | 83.45       | 22.42            | 139,079     | 125,469     | 319.07      | 185,830        |
| 28.50                     | 50.00              | Clay         | 19.00                            | 323.05      | 83.45       | 22.42            | 139,079     | 125,469     | 319.07      | 185,830        |
| 30.00                     | 50.00              | Clay         | 19.00                            | 323.05      | 83.45       | 22.42            | 139,079     | 125,469     | 319.07      | 185,830        |

**Table 3-12** Parameter design of BH-02.

| PARAMETER DESIGN OF BH-02 |                    |              |                                  |             |             |                  |             |             |             |                |
|---------------------------|--------------------|--------------|----------------------------------|-------------|-------------|------------------|-------------|-------------|-------------|----------------|
| Depth<br>(m)              | N-SPT<br>(blow/ft) | Soil<br>Type | $\gamma$<br>(kN/m <sup>3</sup> ) | Su<br>(kPa) | c'<br>(kPa) | $\phi'$<br>(deg) | Eu<br>(kPa) | E'<br>(kPa) | Vs<br>(m/s) | G max<br>(kPa) |
| 0.00                      | 2.00               | Clay         | 18.95                            | 8.61        | 4.00        | 28.14            | 8,247       | 7,262       | 105.06      | 16,761         |
| 1.50                      | 2.00               | Clay         | 18.95                            | 9.52        | 4.00        | 28.14            | 9,111       | 8,024       | 108.40      | 17,937         |
| 3.00                      | 7.00               | Clay         | 19.00                            | 38.48       | 13.00       | 22.13            | 15,927      | 14,391      | 163.39      | 43,617         |
| 4.50                      | 22.00              | Clay         | 19.00                            | 125.44      | 36.69       | 22.13            | 51,924      | 46,915      | 236.80      | 97,422         |
| 6.00                      | 26.00              | Clay         | 19.00                            | 120.42      | 43.37       | 26.21            | 95,389      | 84,561      | 251.71      | 111,203        |
| 7.50                      | 49.00              | Clay         | 18.34                            | 231.98      | 81.78       | 26.21            | 183,758     | 162,899     | 309.26      | 173,678        |

| PARAMETER DESIGN OF BH-02 |           |      |          |        |       |         |         |         |        |         |
|---------------------------|-----------|------|----------|--------|-------|---------|---------|---------|--------|---------|
| Depth                     | N-SPT     | Soil | $\gamma$ | Su     | c'    | $\phi'$ | Eu      | E'      | Vs     | G max   |
| (m)                       | (blow/ft) | Type | (kN/m³)  | (kPa)  | (kPa) | (deg)   | (kPa)   | (kPa)   | (m/s)  | (kPa)   |
| 9.00                      | 49.00     | Clay | 18.34    | 236.24 | 81.78 | 26.21   | 187,128 | 165,887 | 311.03 | 175,838 |
| 10.50                     | 45.00     | Clay | 18.34    | 236.29 | 75.10 | 25.43   | 171,524 | 152,529 | 304.29 | 167,701 |
| 12.00                     | 50.00     | Clay | 19.82    | 266.10 | 83.45 | 25.43   | 193,165 | 171,773 | 315.86 | 181,814 |
| 13.50                     | 50.00     | Clay | 19.82    | 311.48 | 83.45 | 22.42   | 134,650 | 121,474 | 317.04 | 183,289 |
| 15.00                     | 50.00     | Clay | 19.82    | 314.81 | 83.45 | 22.42   | 136,090 | 122,773 | 318.10 | 184,620 |
| 16.50                     | 50.00     | Clay | 19.82    | 317.85 | 83.45 | 22.42   | 137,404 | 123,958 | 319.07 | 185,830 |
| 18.00                     | 50.00     | Clay | 19.26    | 374.95 | 83.45 | 20.80   | 106,753 | 97,188  | 319.07 | 185,830 |
| 19.50                     | 49.00     | Clay | 19.26    | 367.45 | 81.78 | 20.80   | 104,618 | 95,244  | 317.05 | 183,295 |
| 21.00                     | 50.00     | Clay | 19.18    | 374.95 | 83.45 | 20.80   | 106,753 | 97,188  | 319.07 | 185,830 |
| 22.50                     | 50.00     | Clay | 19.18    | 374.95 | 83.45 | 20.80   | 106,753 | 97,188  | 319.07 | 185,830 |
| 24.00                     | 37.00     | Clay | 19.18    | 291.41 | 61.74 | 20.73   | 77,752  | 70,913  | 290.28 | 151,424 |
| 25.50                     | 50.00     | Clay | 19.18    | 393.80 | 83.45 | 20.73   | 105,071 | 95,828  | 319.07 | 185,830 |
| 27.00                     | 50.00     | Clay | 19.18    | 393.80 | 83.45 | 20.73   | 105,071 | 95,828  | 319.07 | 185,830 |
| 28.50                     | 50.00     | Clay | 19.18    | 393.80 | 83.45 | 20.73   | 105,071 | 95,828  | 319.07 | 185,830 |
| 30.00                     | 50.00     | Clay | 19.18    | 393.80 | 83.45 | 20.73   | 105,071 | 95,828  | 319.07 | 185,830 |

**Table 3-13** Parameter design of BH-03.

| PARAMETER DESIGN OF BH-03 |           |      |          |        |       |         |         |         |        |         |
|---------------------------|-----------|------|----------|--------|-------|---------|---------|---------|--------|---------|
| Depth                     | N-SPT     | Soil | $\gamma$ | Su     | c'    | $\phi'$ | Eu      | E'      | Vs     | G max   |
| (m)                       | (blow/ft) | Type | (kN/m³)  | (kPa)  | (kPa) | (deg)   | (kPa)   | (kPa)   | (m/s)  | (kPa)   |
| 0.00                      | 10.00     | Clay | 19.00    | 46.81  | 17.50 | 22.57   | 20,904  | 18,843  | 174.14 | 50,073  |
| 1.50                      | 10.00     | Clay | 19.00    | 51.72  | 17.50 | 22.57   | 23,095  | 20,819  | 179.68 | 53,585  |
| 3.00                      | 8.00      | Clay | 19.00    | 43.67  | 14.50 | 22.57   | 19,502  | 17,579  | 170.38 | 47,763  |
| 4.50                      | 8.00      | Clay | 18.19    | 45.30  | 14.50 | 22.57   | 20,229  | 18,235  | 172.35 | 48,968  |
| 6.00                      | 11.00     | Clay | 18.19    | 64.03  | 19.00 | 22.57   | 28,591  | 25,773  | 192.13 | 61,956  |
| 7.50                      | 18.00     | Clay | 17.71    | 98.44  | 30.01 | 23.93   | 56,495  | 50,578  | 225.81 | 87,902  |
| 9.00                      | 28.00     | Clay | 17.71    | 155.94 | 46.71 | 23.93   | 89,493  | 80,121  | 260.90 | 120,184 |
| 10.50                     | 34.00     | Clay | 19.04    | 193.16 | 56.73 | 24.53   | 122,930 | 109,748 | 278.66 | 138,598 |
| 12.00                     | 35.00     | Clay | 19.04    | 201.54 | 58.40 | 24.53   | 128,260 | 114,507 | 282.40 | 142,657 |
| 13.50                     | 28.00     | Clay | 19.04    | 163.16 | 46.71 | 24.53   | 103,835 | 92,701  | 264.27 | 123,568 |
| 15.00                     | 30.00     | Clay | 19.04    | 176.68 | 50.05 | 24.53   | 112,441 | 100,384 | 270.96 | 130,443 |
| 16.50                     | 46.00     | Clay | 19.04    | 273.53 | 76.77 | 24.53   | 174,075 | 155,409 | 310.82 | 175,587 |
| 18.00                     | 32.00     | Clay | 18.50    | 215.43 | 53.39 | 20.88   | 68,100  | 61,880  | 277.34 | 137,189 |
| 19.50                     | 37.00     | Clay | 18.50    | 249.09 | 61.74 | 20.88   | 78,740  | 71,549  | 290.28 | 151,424 |
| 21.00                     | 50.00     | Clay | 19.14    | 268.24 | 83.45 | 24.12   | 161,223 | 144,207 | 319.07 | 185,830 |
| 22.50                     | 50.00     | Clay | 19.14    | 268.24 | 83.45 | 24.12   | 161,223 | 144,207 | 319.07 | 185,830 |

| PARAMETER DESIGN OF BH-03 |                    |           |                               |                      |          |               |                      |          |                      |             |
|---------------------------|--------------------|-----------|-------------------------------|----------------------|----------|---------------|----------------------|----------|----------------------|-------------|
| Depth<br>(m)              | N-SPT<br>(blow/ft) | Soil Type | $\gamma$ (kN/m <sup>3</sup> ) | S <sub>u</sub> (kPa) | c' (kPa) | $\phi'$ (deg) | E <sub>u</sub> (kPa) | E' (kPa) | V <sub>s</sub> (m/s) | G max (kPa) |
| 24.00                     | 50.00              | Clay      | 18.55                         | 349.79               | 83.45    | 20.88         | 109,707              | 99,687   | 319.07               | 185,830     |
| 25.50                     | 50.00              | Clay      | 18.55                         | 349.79               | 83.45    | 20.88         | 109,707              | 99,687   | 319.07               | 185,830     |
| 27.00                     | 50.00              | Clay      | 18.55                         | 349.79               | 83.45    | 20.88         | 109,707              | 99,687   | 319.07               | 185,830     |
| 28.50                     | 50.00              | Clay      | 18.55                         | 349.79               | 83.45    | 20.88         | 109,707              | 99,687   | 319.07               | 185,830     |
| 30.00                     | 50.00              | Clay      | 18.55                         | 349.79               | 83.45    | 20.88         | 109,707              | 99,687   | 319.07               | 185,830     |

### 3.7.1.5 Embankment Materials

The Gas Fired Power Plant 275 MW Riau area is consist of Clay and Silty Clay soil type with LL = 44.00 – 84.79% and PI = 16.41 – 59.91%, which indicate medium to very high plasticity behaviour. From laboratory data results using Standard Proctor Test at TP-01 and TP-02, we found that the maximum dry density MDD = 1.351 – 1.354 ton/m<sup>3</sup> after compacted. The maximum dry unit weight values are too low for compacted soil. These results indicate that the soil absorbs water, which also indicate swelling behaviour.

Hence, the soil of TP-01 and TP-02 are not good for embankment materials. Soil with medium to high plasticity has potential tendency to shrink when the water content decreased, and swell when the water content increased. These behaviours will cause cracks within embankment bodies that over time will lead to slope failure.

## 3.6.2 Shallow Foundation

Shallow foundation shall be calculated with various factors :

- embedment depth of 0.5 m, 1.0 m, 1.5 m and 2.0 m
- squared base footing size (B, L) of 0.5 m, 1.0 m, 1.5 m, and 2.0 m.
- stripped base footing size (B) of 0.5 m, 1.0 m, 1.5 m, and 2.0 m.

### 3.6.2.1 Shallow Foundation Formula Based on SPT

Shallow foundation formula based on SPT data is adopted from Meyerhoff (1965) such as follows:

$$\text{For } B = L \leq 1.2 \text{ m} : Qa = \frac{N_{SPT}}{0.05} Kd \text{ (unit in kPa)}$$

$$\text{For } B = L > 1.2 \text{ m} : Qa = \frac{N_{SPT}}{0.08} \left( \frac{B + 0.3}{B} \right)^2 Kd \text{ (unit in kPa)}$$

$$\text{Where} : Kd = 1 + 0.33 \frac{D}{B} \leq 1.33$$

This formula especially used for calculate allowable bearing capacity  $Q_a$  in terms of 1 inch settlement and not taken the type of foundation (squared or stripped) into account.

**Table 3-14** Bearing capacity of shallow foundation based on SPT of BH-01.

| <b>BH-01</b> |   |                  |              |                  |              |
|--------------|---|------------------|--------------|------------------|--------------|
| <b>Depth</b> | <b>Squared Allowable Bearing Capacity (kN)</b>    |                  |              |                  |              |
| <b>(m)</b>   | <b>1 x 1</b>                                      | <b>1.5 x 1.5</b> | <b>2 x 2</b> | <b>2.5 x 2.5</b> | <b>3 x 3</b> |
| 0.00         | 360.00  | 729.00           | 1190.25      | 1764.00          | 2450.25      |
| 0.50         | 419.40  | 809.19           | 1288.45      | 1880.42          | 2585.01      |
| 1.00         | 478.80  | 889.38           | 1386.64      | 1996.85          | 2719.78      |
| 1.50         | 478.80  | 969.57           | 1484.84      | 2113.27          | 2854.54      |
| 2.00         | 478.80  | 969.57           | 1583.03      | 2229.70          | 2989.31      |
| <b>Depth</b> | <b>Stripped Allowable Bearing Capacity (kN/m)</b> |                  |              |                  |              |
| <b>(m)</b>   | <b>1 m</b>  | <b>1.5 m</b>     | <b>2 m</b>   | <b>2.5 m</b>     | <b>3 m</b>   |
| 0.00         | 360.00  | 486.00           | 595.13       | 705.60           | 816.75       |
| 0.50         | 419.40  | 539.46           | 644.22       | 752.17           | 861.67       |
| 1.00         | 478.80  | 592.92           | 693.32       | 798.74           | 906.59       |
| 1.50         | 478.80  | 646.38           | 742.42       | 845.31           | 951.51       |
| 2.00         | 478.80  | 646.38           | 791.52       | 891.88           | 996.44       |

**Table 3-15** Bearing capacity of shallow foundation based on SPT of BH-02.

| <b>BH-02</b> |   |                  |              |                  |              |
|--------------|---|------------------|--------------|------------------|--------------|
| <b>Depth</b> | <b>Squared Allowable Bearing Capacity (kN)</b>    |                  |              |                  |              |
| <b>(m)</b>   | <b>1 x 1</b>                                      | <b>1.5 x 1.5</b> | <b>2 x 2</b> | <b>2.5 x 2.5</b> | <b>3 x 3</b> |
| 0.00         | 40.00   | 81.00            | 132.25       | 196.00           | 272.25       |
| 0.50         | 46.60   | 89.91            | 143.16       | 208.94           | 287.22       |
| 1.00         | 53.20   | 98.82            | 154.07       | 221.87           | 302.20       |
| 1.50         | 53.20   | 107.73           | 164.98       | 234.81           | 317.17       |
| 2.00         | 53.20   | 107.73           | 175.89       | 247.74           | 332.15       |
| <b>Depth</b> | <b>Stripped Allowable Bearing Capacity (kN/m)</b> |                  |              |                  |              |
| <b>(m)</b>   | <b>1 m</b>  | <b>1.5 m</b>     | <b>2 m</b>   | <b>2.5 m</b>     | <b>3 m</b>   |
| 0.00         | 40.00   | 54.00            | 66.13        | 78.40            | 90.75        |
| 0.50         | 46.60   | 59.94            | 71.58        | 83.57            | 95.74        |
| 1.00         | 53.20   | 65.88            | 77.04        | 88.75            | 100.73       |
| 1.50         | 53.20   | 71.82            | 82.49        | 93.92            | 105.72       |
| 2.00         | 53.20   | 71.82            | 87.95        | 99.10            | 110.72       |

**Table 3-16** Bearing capacity of shallow foundation based on SPT of BH-03.

| BH-03        |  |           |        |           |         |
|--------------|--|-----------|--------|-----------|---------|
| Depth<br>(m) | Squared Allowable Bearing Capacity (kN)    |           |        |           |         |
|              | 1 x 1                                      | 1.5 x 1.5 | 2 x 2  | 2.5 x 2.5 | 3 x 3   |
| 0.00         | 200.00                                     | 405.00    | 661.25 | 980.00    | 1361.25 |
| 0.50         | 233.00                                     | 449.55    | 715.80 | 1044.68   | 1436.12 |
| 1.00         | 266.00                                     | 494.10    | 770.36 | 1109.36   | 1510.99 |
| 1.50         | 266.00                                     | 538.65    | 824.91 | 1174.04   | 1585.86 |
| 2.00         | 266.00                                     | 538.65    | 879.46 | 1238.72   | 1660.73 |
| Depth<br>(m) | Stripped Allowable Bearing Capacity (kN/m) |           |        |           |         |
|              | 1 m  | 1.5 m     | 2 m    | 2.5 m     | 3 m     |
| 0.00         | 200.00                                     | 270.00    | 330.63 | 392.00    | 453.75  |
| 0.50         | 233.00                                     | 299.70    | 357.90 | 417.87    | 478.71  |
| 1.00         | 266.00                                     | 329.40    | 385.18 | 443.74    | 503.66  |
| 1.50         | 266.00                                     | 359.10    | 412.45 | 469.62    | 528.62  |
| 2.00         | 266.00                                     | 359.10    | 439.73 | 495.49    | 553.58  |

### 3.6.3 Deep Foundation

Considering there are many lenses of hard soil layers with inadequate thickness, it is not preferable to use driven piles. Driven piles are prefabricated piles which had limitation of structural axial capacity, hence, if the bearing capacity of the soil is greater than the structural capacity, the piles cannot be driven into the soil layer without any structural damages. Therefore, bored piles is more suitable choice for deep foundation at Gas Fired Power Plant 275 MW Riau area. However, if under any circumstances driven piles should be used, preboring method must be adopted, to help driven piles reach required depth.

Bored piles and driven piles foundation shall be calculated with various factors :

- diameter size (D) of 0.30 m, 0.40 m, 0.50 m, 0.60 m and 0.80 m.
- different locations based on soil investigation points
- depth limitation due to the termination level of boreholes

#### 3.6.3.1 Bored Piles Based on SPT Data

Bored piles based on SPT data shall be calculated as follows :

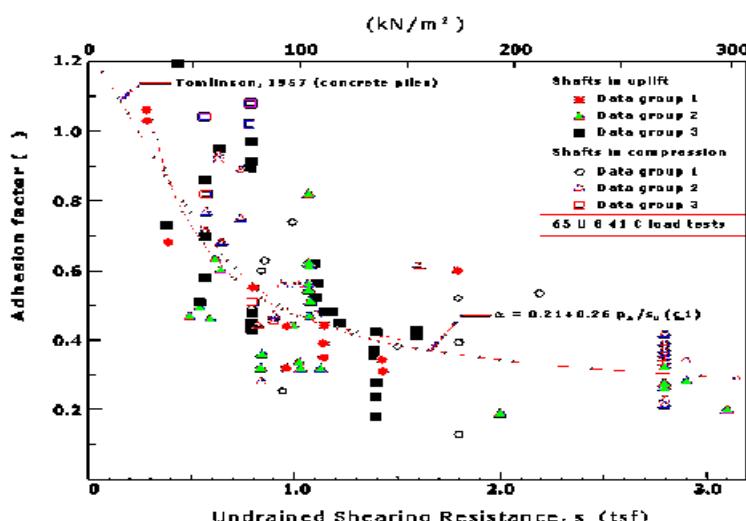
##### For cohesive soil

End bearing :  $q_p = 9 Su$

Sleeves friction :  $f_s = \alpha Su$

**For granular soil**End bearing :  $q_p = 67 \text{ N}_{\text{SPT}}$ Sleeves friction :  $f_s = 3.125 \text{ N}_{\text{SPT}}$ Ultimate bearing capacity :  $Q_u = q_p A_p + \sum f_s A_s$ Allowable bearing capacity :  $Q_a = Q_u / SF$ 

Where :

 $s_u$  = undrained shear strength $A_p$  = area of pile base $A_s$  = area of pile sleeves $\alpha$  = adhesion factor based on graph below**Figure 3-7** Undrained shearing resistance vs adhesion factor.**Table 3-17** Bearing capacity of deep foundation at BH-01 using bored pile based on SPT data.

| Depth<br>(m) | BH-01  |        |        |        |        |
|--------------|--------|--------|--------|--------|--------|
|              | D 30   | D 40   | D 50   | D 60   | D 80   |
| 0.00         |        |        |        |        |        |
| 1.50         | 57.39  | 89.39  | 127.82 | 172.68 | 281.70 |
| 3.00         | 93.14  | 139.27 | 192.95 | 254.18 | 399.26 |
| 4.50         | 116.00 | 167.37 | 225.10 | 289.18 | 436.40 |
| 6.00         | 115.75 | 158.69 | 203.80 | 251.09 | 352.21 |
| 7.50         | 157.36 | 220.94 | 290.08 | 364.78 | 530.88 |
| 9.00         | 211.47 | 301.56 | 401.46 | 511.16 | 759.98 |
| 10.50        | 261.87 | 373.50 | 497.30 | 633.26 | 941.70 |

| Depth<br>(m) | BH-01                           |         |         |         |         |
|--------------|---------------------------------|---------|---------|---------|---------|
|              | Allowable Bearing Capacity (kN) |         |         |         |         |
| (m)          | D 30                            | D 40    | D 50    | D 60    | D 80    |
| 12.00        | 315.52                          | 449.10  | 596.87  | 758.86  | 1125.43 |
| 13.50        | 333.33                          | 464.87  | 606.62  | 758.57  | 1093.13 |
| 15.00        | 392.83                          | 551.30  | 723.53  | 909.51  | 1322.77 |
| 16.50        | 471.89                          | 667.84  | 883.13  | 1117.75 | 1644.98 |
| 18.00        | 530.70                          | 747.88  | 985.18  | 1242.63 | 1817.93 |
| 19.50        | 585.89                          | 821.46  | 1077.17 | 1353.01 | 1965.10 |
| 21.00        | 633.89                          | 883.04  | 1151.12 | 1438.13 | 2068.93 |
| 22.50        | 680.85                          | 943.56  | 1224.14 | 1522.61 | 2173.18 |
| 24.00        | 732.52                          | 1012.46 | 1310.27 | 1625.96 | 2310.98 |
| 25.50        | 784.20                          | 1081.36 | 1396.39 | 1729.31 | 2448.78 |
| 27.00        | 838.20                          | 1154.12 | 1488.29 | 1840.73 | 2600.37 |
| 28.50        | 890.49                          | 1223.84 | 1575.45 | 1945.32 | 2739.82 |
| 30.00        | 942.79                          | 1293.57 | 1662.61 | 2049.91 | 2879.28 |

**Table 3-18** Bearing capacity of deep foundation at BH-02 using bored pile based on SPT data.

| Depth<br>(m) | BH-02                           |         |         |         |         |
|--------------|---------------------------------|---------|---------|---------|---------|
|              | Allowable Bearing Capacity (kN) |         |         |         |         |
| (m)          | D 30                            | D 40    | D 50    | D 60    | D 80    |
| 0.00         |                                 |         |         |         |         |
| 1.50         | 7.80                            | 11.47   | 15.69   | 20.44   | 31.56   |
| 3.00         | 33.70                           | 49.28   | 67.03   | 86.96   | 133.35  |
| 4.50         | 85.62                           | 128.34  | 178.15  | 235.05  | 370.12  |
| 6.00         | 113.54                          | 165.00  | 223.27  | 288.34  | 438.91  |
| 7.50         | 183.98                          | 271.52  | 372.18  | 485.96  | 752.83  |
| 9.00         | 227.64                          | 330.22  | 446.16  | 575.44  | 874.07  |
| 10.50        | 270.24                          | 387.03  | 517.17  | 660.67  | 987.73  |
| 12.00        | 324.10                          | 462.21  | 615.36  | 783.55  | 1165.06 |
| 13.50        | 386.85                          | 551.01  | 732.78  | 932.15  | 1383.71 |
| 15.00        | 439.26                          | 621.26  | 821.06  | 1038.66 | 1527.22 |
| 16.50        | 491.89                          | 691.78  | 909.64  | 1145.46 | 1671.00 |
| 18.00        | 563.07                          | 793.14  | 1044.41 | 1316.87 | 1925.36 |
| 19.50        | 617.23                          | 864.51  | 1132.56 | 1421.38 | 2061.32 |
| 21.00        | 675.80                          | 943.45  | 1232.30 | 1542.33 | 2225.98 |
| 22.50        | 732.46                          | 1019.00 | 1326.73 | 1655.65 | 2377.07 |
| 24.00        | 760.36                          | 1046.75 | 1349.61 | 1668.95 | 2357.03 |
| 25.50        | 844.33                          | 1170.29 | 1518.50 | 1888.97 | 2696.69 |
| 27.00        | 902.26                          | 1247.53 | 1615.05 | 2004.84 | 2851.17 |

| <b>Depth</b> | <b>BH-02</b>                           |             |             |             |             |
|--------------|--|-------------|-------------|-------------|-------------|
|              | <b>Allowable Bearing Capacity (kN)</b> |             |             |             |             |
| <b>(m)</b>   | <b>D 30</b>                            | <b>D 40</b> | <b>D 50</b> | <b>D 60</b> | <b>D 80</b> |
| 28.50        | 960.19                                 | 1324.77     | 1711.60     | 2120.70     | 3005.65     |
| 30.00        | 1018.12                                | 1402.01     | 1808.15     | 2236.56     | 3160.14     |

**Table 3-19** Bearing capacity of deep foundation at BH-03 using bored pile based on SPT data

| <b>Depth</b> | <b>BH-03</b>                           |             |             |             |             |
|--------------|--|-------------|-------------|-------------|-------------|
|              | <b>Allowable Bearing Capacity (kN)</b> |             |             |             |             |
| <b>(m)</b>   | <b>D 30</b>                            | <b>D 40</b> | <b>D 50</b> | <b>D 60</b> | <b>D 80</b> |
| 0.00         |  |             |             |             |             |
| 1.50         | 33.38                                  | 50.36       | 70.26       | 93.08       | 147.49      |
| 3.00         | 50.54                                  | 72.33       | 96.58       | 123.30      | 184.15      |
| 4.50         | 70.16                                  | 98.67       | 129.74      | 163.37      | 238.31      |
| 6.00         | 96.49                                  | 135.89      | 178.92      | 225.56      | 329.69      |
| 7.50         | 131.62                                 | 186.62      | 247.18      | 313.31      | 462.26      |
| 9.00         | 179.51                                 | 256.98      | 343.26      | 438.35      | 654.98      |
| 10.50        | 225.92                                 | 323.06      | 431.12      | 550.09      | 820.80      |
| 12.00        | 265.86                                 | 377.26      | 500.06      | 634.24      | 936.78      |
| 13.50        | 290.05                                 | 405.17      | 529.52      | 663.09      | 957.90      |
| 15.00        | 328.87                                 | 458.46      | 598.04      | 747.61      | 1076.70     |
| 16.50        | 400.66                                 | 565.14      | 745.07      | 940.47      | 1377.63     |
| 18.00        | 425.67                                 | 591.91      | 770.33      | 960.92      | 1378.63     |
| 19.50        | 478.44                                 | 666.08      | 867.80      | 1083.59     | 1557.41     |
| 21.00        | 529.85                                 | 736.79      | 958.89      | 1196.15     | 1716.16     |
| 22.50        | 576.39                                 | 798.84      | 1036.45     | 1289.23     | 1840.26     |
| 24.00        | 651.83                                 | 908.65      | 1185.24     | 1481.60     | 2133.62     |
| 25.50        | 706.54                                 | 981.59      | 1276.41     | 1591.01     | 2279.50     |
| 27.00        | 761.24                                 | 1054.53     | 1367.59     | 1700.42     | 2425.38     |
| 28.50        | 815.95                                 | 1127.47     | 1458.76     | 1809.82     | 2571.26     |
| 30.00        | 870.65                                 | 1200.41     | 1549.94     | 1919.23     | 2717.14     |

### 3.6.3.2 Driven Piles Based on SPT Data

Driven piles based on SPT data shall be calculated as follows :

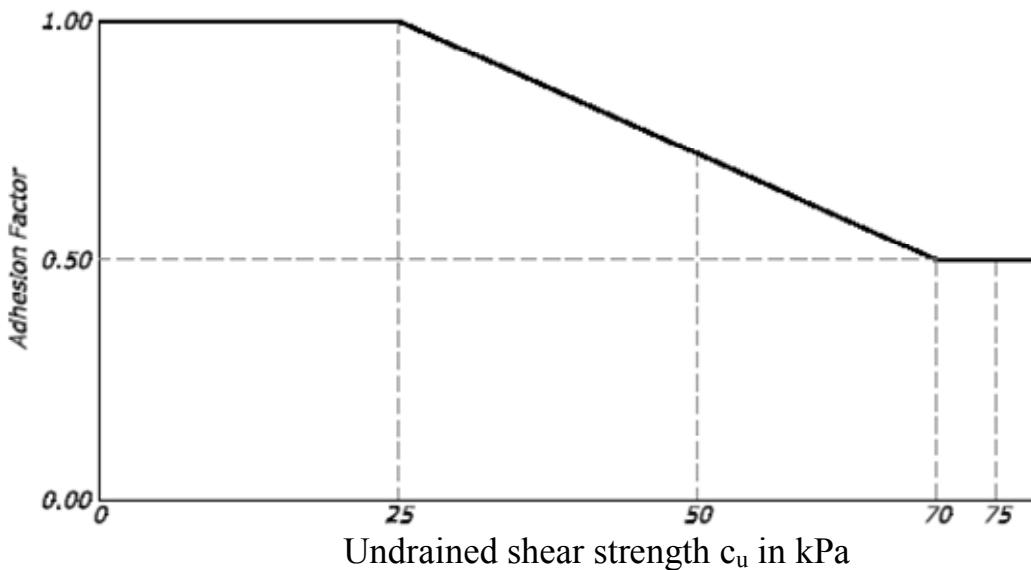
#### For cohesive soil

End bearing :  $q_p = 9 Su$

Sleeves friction :  $f_s = \alpha Su$

**For granular soil**End bearing :  $q_p = 400 \text{ N}_{\text{SPT}}$ Sleeves friction :  $f_s = 2 \text{ N}_{\text{SPT}}$ Ultimate bearing capacity :  $Q_u = q_p A_p + \sum f_s A_s$ Allowable bearing capacity :  $Q_a = Q_u / SF$ 

Where :

 $S_u$  = undrained shear strength $A_p$  = area of pile base $A_s$  = area of pile sleeves $\alpha$  = adhesion factor based on graph below**Figure 3-8** Undrained shear strength vs adhesion factor.

With preboring method, we can drive the piles until they reach required depth. The result of the calculation are presented in the table below.

**3.6.3.3 Driven Pile With Pre-Boring**

Since driven piles should be installed using preboring method, it will eliminate the sleeve friction capacity. Hence, the resistance will depend only to end bearing capacity.

**Table 3-20** Bearing capacity of deep foundation using driven pile based on SPT data with pre-boring at BH-01.

| Depth<br>(m) | BH-01                           |         |         |         |         |
|--------------|---------------------------------|---------|---------|---------|---------|
|              | Allowable Bearing Capacity (kN) |         |         |         |         |
| D 30         | D 40                            | D 50    | D 60    | D 80    |         |
| 0.00         |                                 |         |         |         |         |
| 1.50         | 61.11                           | 94.35   | 134.02  | 180.12  | 291.63  |
| 3.00         | 103.84                          | 153.54  | 210.78  | 275.57  | 427.79  |
| 4.50         | 130.25                          | 186.37  | 248.85  | 317.68  | 474.40  |
| 6.00         | 130.08                          | 177.79  | 227.68  | 279.75  | 390.41  |
| 7.50         | 173.13                          | 241.97  | 316.37  | 396.33  | 572.94  |
| 9.00         | 241.23                          | 341.24  | 451.06  | 570.68  | 839.33  |
| 10.50        | 312.71                          | 441.29  | 582.03  | 734.94  | 1077.28 |
| 12.00        | 392.88                          | 552.24  | 725.80  | 913.57  | 1331.71 |
| 13.50        | 425.98                          | 588.39  | 761.02  | 943.86  | 1340.17 |
| 15.00        | 510.76                          | 708.53  | 920.07  | 1145.36 | 1637.24 |
| 16.50        | 632.47                          | 881.96  | 1150.77 | 1438.92 | 2073.20 |
| 18.00        | 736.78                          | 1022.64 | 1328.64 | 1654.78 | 2367.46 |
| 19.50        | 837.46                          | 1156.88 | 1496.44 | 1856.14 | 2635.94 |
| 21.00        | 926.66                          | 1273.40 | 1639.07 | 2023.67 | 2849.65 |
| 22.50        | 1011.34                         | 1384.21 | 1774.96 | 2183.58 | 3054.48 |
| 24.00        | 1100.73                         | 1503.40 | 1923.95 | 2362.38 | 3292.87 |
| 25.50        | 1190.13                         | 1622.60 | 2072.94 | 2541.17 | 3531.26 |
| 27.00        | 1283.13                         | 1747.35 | 2229.84 | 2730.58 | 3786.84 |
| 28.50        | 1374.42                         | 1869.08 | 2381.99 | 2913.17 | 4030.29 |
| 30.00        | 1465.71                         | 1990.80 | 2534.15 | 3095.75 | 4273.74 |

**Table 3-21** Bearing capacity of deep foundation using driven pile based on SPT data with pre-boring at BH-02.

| BH-02                           |        |        |        |         |
|---------------------------------|--------|--------|--------|---------|
| Allowable Bearing Capacity (kN) |        |        |        |         |
| D 30                            | D 40   | D 50   | D 60   | D 80    |
|                                 |        |        |        |         |
| 7.80                            | 11.47  | 15.69  | 20.44  | 31.56   |
| 33.77                           | 49.38  | 67.16  | 87.12  | 133.56  |
| 91.34                           | 135.97 | 187.69 | 246.50 | 385.38  |
| 124.10                          | 179.07 | 240.86 | 309.45 | 467.05  |
| 218.03                          | 316.93 | 428.94 | 554.06 | 843.64  |
| 285.87                          | 407.86 | 543.21 | 691.91 | 1029.36 |
| 352.66                          | 496.92 | 654.54 | 825.51 | 1207.52 |

| <b>BH-02</b>                           |             |             |             |             |
|--|-------------|-------------|-------------|-------------|
| <b>Allowable Bearing Capacity (kN)</b> |             |             |             |             |
| <b>D 30</b>                            | <b>D 40</b> | <b>D 50</b> | <b>D 60</b> | <b>D 80</b> |
| 435.44                                 | 610.66      | 800.93      | 1006.24     | 1461.97     |
| 535.01                                 | 748.55      | 979.70      | 1228.46     | 1778.78     |
| 624.82                                 | 868.68      | 1130.33     | 1409.78     | 2022.05     |
| 715.42                                 | 989.82      | 1282.19     | 1592.52     | 2267.08     |
| 835.90                                 | 1156.92     | 1499.13     | 1862.53     | 2652.90     |
| 937.83                                 | 1291.98     | 1666.90     | 2062.58     | 2916.25     |
| 1045.70                                | 1436.65     | 1848.79     | 2282.13     | 3212.37     |
| 1151.66                                | 1577.93     | 2025.39     | 2494.05     | 3494.93     |
| 1212.77                                | 1649.96     | 2103.63     | 2573.77     | 3563.45     |
| 1350.09                                | 1844.64     | 2361.45     | 2900.51     | 4045.40     |
| 1461.38                                | 1993.02     | 2546.92     | 3123.08     | 4342.17     |
| 1572.67                                | 2141.41     | 2732.40     | 3345.66     | 4638.93     |
| 1683.96                                | 2289.79     | 2917.88     | 3568.23     | 4935.70     |

**Table 3-22** Bearing capacity of deep foundation using driven pile based on SPT data with pre-boring at BH-03.

| <b>BH-03</b>                           |             |             |             |             |
|--|-------------|-------------|-------------|-------------|
| <b>Allowable Bearing Capacity (kN)</b> |             |             |             |             |
| <b>D 30</b>                            | <b>D 40</b> | <b>D 50</b> | <b>D 60</b> | <b>D 80</b> |
|  |             |             |             |             |
| 33.94                                  | 51.10       | 71.19       | 94.20       | 148.98      |
| 51.64                                  | 73.80       | 98.41       | 125.50      | 187.09      |
| 71.97                                  | 101.09      | 132.76      | 166.99      | 243.14      |
| 97.24                                  | 136.90      | 180.17      | 227.06      | 331.70      |
| 133.82                                 | 189.55      | 250.84      | 317.71      | 468.12      |
| 192.51                                 | 274.30      | 364.91      | 464.34      | 689.63      |
| 256.56                                 | 363.92      | 482.19      | 611.38      | 902.52      |
| 315.65                                 | 443.65      | 583.04      | 733.82      | 1069.55     |
| 352.00                                 | 487.77      | 632.77      | 786.99      | 1123.09     |
| 405.37                                 | 560.46      | 725.54      | 900.61      | 1280.70     |
| 507.30                                 | 707.32      | 922.79      | 1153.73     | 1661.99     |
| 553.40                                 | 762.22      | 983.21      | 1216.38     | 1719.25     |
| 632.35                                 | 871.29      | 1124.31     | 1391.41     | 1967.84     |
| 713.03                                 | 981.03      | 1264.19     | 1562.51     | 2204.64     |
| 788.84                                 | 1082.10     | 1390.53     | 1714.12     | 2406.79     |
| 908.43                                 | 1250.77     | 1612.89     | 1994.78     | 2817.87     |
| 1007.28                                | 1382.58     | 1777.64     | 2192.48     | 3081.47     |

| BH-03                           |         |         |         |         |
|---------------------------------|---------|---------|---------|---------|
| Allowable Bearing Capacity (kN) |         |         |         |         |
| D 30                            | D 40    | D 50    | D 60    | D 80    |
| 1106.13                         | 1514.38 | 1942.39 | 2390.18 | 3345.07 |
| 1204.98                         | 1646.18 | 2107.14 | 2587.88 | 3608.67 |
| 1303.83                         | 1777.98 | 2271.90 | 2785.58 | 3872.27 |

### 3.6.3.4 Driven Pile Without Pre-Boring

Without pre-boring method, the piles cannot be driven deep into the soil without being damaged, considering there is a limit on structural capacity of pile axial load.

Hence to prevent pile damage during installation, driven piling can be applied directly without pre-boring, with appropriate allowable bearing capacity described as follows:

**Table 3-23** Bearing capacity of deep foundation using driven pile based on SPT without pre-boring at BH-01.

| Depth<br>(m) | BH-01                          |        |        |        |         |
|--------------|--------------------------------|--------|--------|--------|---------|
|              | Ultimate Bearing Capacity (kN) |        |        |        |         |
| (m)          | D 30                           | D 40   | D 50   | D 60   | D 80    |
| 0.00         |                                |        |        |        |         |
| 1.50         | 61.11                          | 94.35  | 134.02 | 180.12 | 291.63  |
| 3.00         | 103.84                         | 153.54 | 210.78 | 275.57 | 427.79  |
| 4.50         | 130.25                         | 186.37 | 248.85 | 317.68 | 474.40  |
| 6.00         | 130.08                         | 177.79 | 227.68 | 279.75 | 390.41  |
| 7.50         | 173.13                         | 241.97 | 316.37 | 396.33 | 572.94  |
| 9.00         | 241.23                         | 341.24 | 451.06 | 570.68 | 839.33  |
| 10.50        | 312.71                         | 441.29 | 582.03 | 734.94 | 1077.28 |
| 12.00        |                                | 552.24 | 725.80 | 913.57 | 1331.71 |
| 13.50        |                                |        |        | 943.86 | 1340.17 |
| 15.00        |                                |        |        |        | 1637.24 |
| 16.50        |                                |        |        |        | 2073.20 |
| 18.00        |                                |        |        |        |         |

**Table 3-24** Bearing capacity of deep foundation using driven pile based on SPT without pre-boring at BH-02.

| BH-02                          |      |      |      |      |
|--------------------------------|------|------|------|------|
| Ultimate Bearing Capacity (kN) |      |      |      |      |
| D 30                           | D 40 | D 50 | D 60 | D 80 |
|                                |      |      |      |      |

|        |        |        |         |         |
|--------|--------|--------|---------|---------|
| 7.80   | 11.47  | 15.69  | 20.44   | 31.56   |
| 33.77  | 49.38  | 67.16  | 87.12   | 133.56  |
| 91.34  | 135.97 | 187.69 | 246.50  | 385.38  |
| 124.10 | 179.07 | 240.86 | 309.45  | 467.05  |
| 218.03 | 316.93 | 428.94 | 554.06  | 843.64  |
| 285.87 | 407.86 | 543.21 | 691.91  | 1029.36 |
|        |        | 654.54 | 825.51  | 1207.52 |
|        |        |        | 1006.24 | 1461.97 |
|        |        |        |         | 1778.78 |
|        |        |        |         |         |
|        |        |        |         |         |
|        |        |        |         |         |
|        |        |        |         |         |

**Table 3-25** Bearing capacity of deep foundation using driven pile based on SPT without pre-boring at BH-03.

| BH-03                          |        |        |         |         |
|--------------------------------|--------|--------|---------|---------|
| Ultimate Bearing Capacity (kN) |        |        |         |         |
| D 30                           | D 40   | D 50   | D 60    | D 80    |
|                                |        |        |         |         |
| 33.94                          | 51.10  | 71.19  | 94.20   | 148.98  |
| 51.64                          | 73.80  | 98.41  | 125.50  | 187.09  |
| 71.97                          | 101.09 | 132.76 | 166.99  | 243.14  |
| 97.24                          | 136.90 | 180.17 | 227.06  | 331.70  |
| 133.82                         | 189.55 | 250.84 | 317.71  | 468.12  |
| 192.51                         | 274.30 | 364.91 | 464.34  | 689.63  |
| 256.56                         | 363.92 | 482.19 | 611.38  | 902.52  |
| 315.65                         | 443.65 | 583.04 | 733.82  | 1069.55 |
|                                | 487.77 | 632.77 | 786.99  | 1123.09 |
|                                |        | 725.54 | 900.61  | 1280.70 |
|                                |        |        | 1153.73 | 1661.99 |
|                                |        |        |         | 1719.25 |

### 3.6.4 Settlement

Guidance on tolerable settlements can be found in engineering textbooks, such as *Soil Mechanics in Engineering Practice* (Terzaghi and Peck), *Foundation Analysis and Design* (Bowles) and *Foundation Engineering* (Hanson, Peck and Thornburn). As a rule, these references indicate that a total settlement of 1 inch (25 mm) is acceptable for the majority of structures, while other structures can tolerate even greater settlements without distress. On the other hand, a more restrictive settlement criterion can be necessary based on the needs of a specific structure. Current engineering practice is often based on an allowable total

settlement of 1 inch (25 mm) with the objective of controlling the differential settlements to  $\frac{3}{4}$  inch (19 mm) or less.

There are two kind of settlements that taken into account : immediate settlement which take places during 0 – 14 days after the load of structure being applied due to the shear distortion, and long term settlement, also known as consolidation settlement which take a long time to occur. The third kind of settlement, secondary settlement, usually considered negligible and not significant. On this analyses, we are going to calculate the maximum load that make the foundations settled at 1 inch.

Immediate settlement caused by distortion of soil due to load and occur immediately after load being applied till 7 days afterward.

$$Si = \frac{qBI_0I_1}{E}$$

Where :

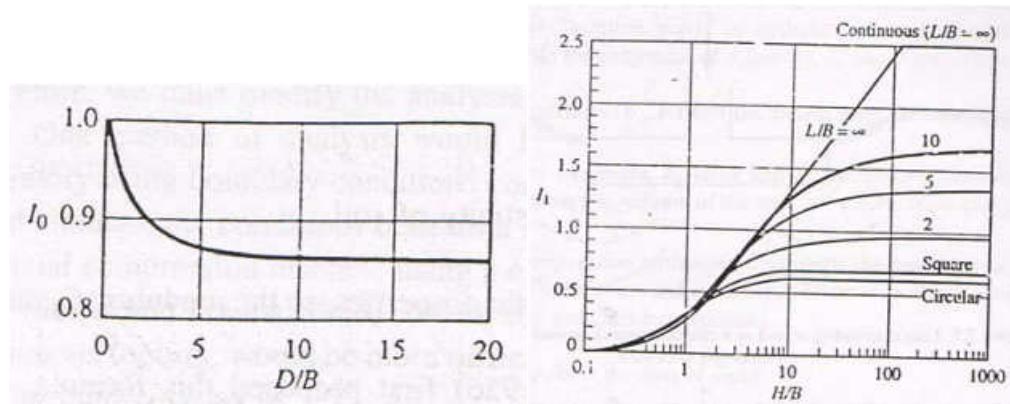
$q = P / A$  = total applied load from upper structure

$B$  = width of foundation base

$I_0$  = influence factor due to the depth of embedment

$I_1$  = influence factor due to the dimension of the base

$E$  = soil modulus elasticity



The results of 1 inch settlement due to maximum load are presented below. Hence, for the safety of design, we recommend to use the lower value, which is the allowable bearing settlement.

### 3.7.4.1 Immediate Settlement

Immediate settlement caused by distortion of soil due to load and occur immediately after load being applied till 7 days afterward.

$$Si = \frac{qBI_0I_1}{E}$$

Where :

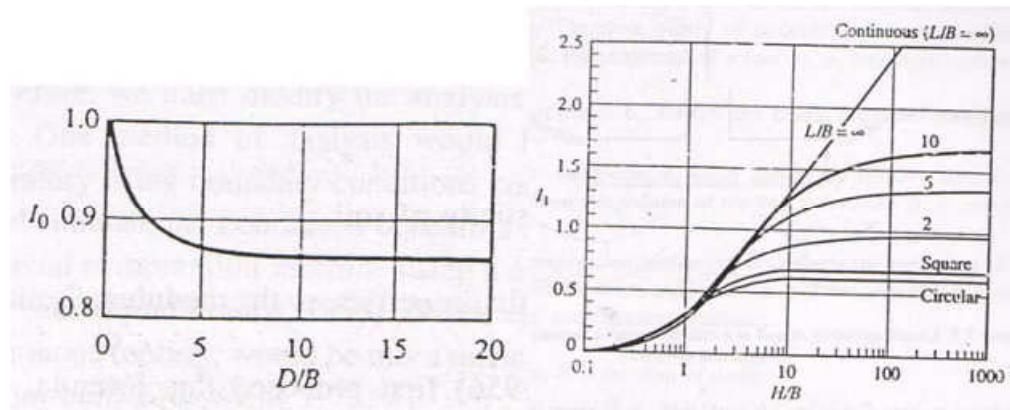
$q = P / A$  = total applied load from upper structure

$B$  = width of foundation base

$I_0$  = influence factor due to the depth of embedment

$I_1$  = influence factor due to the dimension of the base

$E$  = soil modulus elasticity



**Figure 3-9** Immediate settlement curve.

The results of 1 inch settlement due to maximum load are presented below. Hence, for the safety of design, we recommend to use the lower value, which is the allowable bearing settlement.

**Table 3-26** Allowable bearing settlement of BH-01.

| BH-01              |          |                     |          |        |
|--------------------|----------|---------------------|----------|--------|
| Squared Foundation |          | Stripped Foundation |          |        |
| Foundation Size    | Max Load | Foundation Size     | Max Load |        |
| B (m)              | L (m)    | (kN)                | B (m)    | (kN)   |
| 1.00               | 1.00     | 730.00              | 1.00     | 312.00 |
| 1.50               | 1.50     | 1070.00             | 1.50     | 355.00 |
| 2.00               | 2.00     | 1470.00             | 2.00     | 390.00 |
| 2.50               | 2.50     | 1840.00             | 2.50     | 415.00 |
| 3.00               | 3.00     | 2210.00             | 3.00     | 440.00 |

**Table 3-27** Allowable bearing settlement of BH-02.

| BH-02              |          |                     |          |        |
|--------------------|----------|---------------------|----------|--------|
| Squared Foundation |          | Stripped Foundation |          |        |
| Foundation Size    | Max Load | Foundation Size     | Max Load |        |
| B (m)              | L (m)    | (kN)                | B (m)    | (kN)   |
| 1.00               | 1.00     | 265.00              | 1.00     | 150.00 |
| 1.50               | 1.50     | 407.00              | 1.50     | 182.00 |
| 2.00               | 2.00     | 585.00              | 2.00     | 210.00 |
| 2.50               | 2.50     | 770.00              | 2.50     | 234.00 |
| 3.00               | 3.00     | 970.00              | 3.00     | 255.00 |

**Table 3-28 Allowable bearing settlement of BH-03.**

| BH-03              |       |          |                     |  |          |
|--------------------|-------|----------|---------------------|--|----------|
| Squared Foundation |       |          | Stripped Foundation |  |          |
| Foundation Size    |       | Max Load | Foundation Size     |  | Max Load |
| B (m)              | L (m) | (kN)     | B (m)               |  | (kN)     |
| 1.00               | 1.00  | 600.00   | 1.00                |  | 268.00   |
| 1.50               | 1.50  | 870.00   | 1.50                |  | 307.00   |
| 2.00               | 2.00  | 1190.00  | 2.00                |  | 338.00   |
| 2.50               | 2.50  | 1500.00  | 2.50                |  | 365.00   |
| 3.00               | 3.00  | 1800.00  | 3.00                |  | 388.00   |

### 3.6.5 Slope Stability

For open cut excavation requirements, we also provide the calculation of slope stability with various depth and various slope inclination.

The recommendation of minimum safety factor adopted from JM Duncan and AL Buchignani (UC Berkeley, 1974) are as follows:

| No  | Cost and consequences of slope failure                  | Recommendation of Minimum Factor of Safety |       |
|-----|---|--|-------|
|     |   | Uncertainties of Predicting Soil Strength  |       |
|     |   | Small                                      | Large |
| 1 a | If the cost of repairment equal to construction cost    |  |       |
|     | If there are no risks of structures and human life      | 1.25                                       | 1.50  |
| 2 a | If the cost of repairment larger than construction cost |  |       |
|     | If there are risks of structures and human life         | 1.50                                       | 2.00  |

The calculation of slope stability safety factor is as follows :

$$SF = \frac{1}{\tan \alpha} \left\{ \frac{c'}{\gamma H} \sec^2 \alpha + \tan \phi' (1 - r_u \sec^2 \alpha) \right\}$$

Where :

$\alpha$  = slope inclination of excavation

$c'$  = soil cohesion

$\gamma$  = soil unit weight

H = depth of excavation

$r_u = U / W \sec \alpha$  = ratio of pore water pressure with weight of soil

$U = \gamma_w H_w$  = pore water pressure

$\gamma_w = 9.81 \text{ kN/m}^3$  water unit weight

$H_w$  = height of ground water level

$W$  = weight of soil

Following tables show the safety factor of each borehole location regarding to the degree of slope inclination.

**Table 3-29** Safety factor for 75 degrees inclination.

| Depth<br>(m) | SAFETY FACTOR FOR 75 DEGREES INCLINATION |       |       |
|--------------|--|-------|-------|
|              | BH-01                                    | BH-02 | BH-03 |
| 1.00         | 3.43                                     | 0.80  | 2.26  |
| 2.00         | 1.90                                     | 0.55  | 1.34  |
| 3.00         | 1.51                                     | 0.76  | 0.92  |
| 4.00         | 1.22                                     | 1.35  | 0.80  |
| 5.00         | 0.66                                     | 1.34  | 0.82  |
| 6.00         | 0.86                                     | 1.16  | 1.01  |
| 7.00         | 1.08                                     | 1.76  | 1.20  |
| 8.00         | 1.12                                     | 1.57  | 1.20  |
| 9.00         | 1.14                                     | 1.33  | 1.14  |
| 10.00        | 0.87                                     | 1.22  | 0.95  |

**Table 3-30** Safety factor for 60 degrees inclination.

| Depth<br>(m) | SAFETY FACTOR FOR 60 DEGREES INCLINATION |       |       |
|--------------|--|-------|-------|
|              | BH-01                                    | BH-02 | BH-03 |
| 1.00         | 3.74                                     | 0.96  | 2.37  |
| 2.00         | 1.98                                     | 0.75  | 1.30  |
| 3.00         | 1.52                                     | 0.86  | 0.83  |
| 4.00         | 1.18                                     | 1.37  | 0.68  |
| 5.00         | 0.52                                     | 1.41  | 0.70  |
| 6.00         | 0.76                                     | 1.25  | 0.91  |
| 7.00         | 1.02                                     | 1.77  | 1.13  |
| 8.00         | 1.07                                     | 1.61  | 1.12  |
| 9.00         | 1.09                                     | 1.39  | 1.05  |
| 10.00        | 0.78                                     | 1.29  | 0.83  |

**Table 3-31** Safety factor for 45 degrees inclination.

| <b>Depth</b> | <b>SAFETY FACTOR FOR 45 DEGREES INCLINATION</b> |              |              |
|--------------|---|--------------|--------------|
| (m)          | <b>BH-01</b>                                    | <b>BH-02</b> | <b>BH-03</b> |
| 1.00         | 4.18  | 0.99         | 2.85         |
| 2.00         | 2.41  | 0.57         | 1.78         |
| 3.00         | 1.96  | 1.02         | 1.31         |
| 4.00         | 1.65  | 2.04         | 1.16         |
| 5.00         | 0.99  | 1.96         | 1.18         |
| 6.00         | 1.23  | 1.65         | 1.42         |
| 7.00         | 1.47  | 2.68         | 1.64         |
| 8.00         | 1.53  | 2.36         | 1.65         |
| 9.00         | 1.55  | 1.95         | 1.58         |
| 10.00        | 1.23  | 1.77         | 1.36         |

**Table 3-32** Safety factor for 30 degrees inclination.

| <b>Depth</b> | <b>SAFETY FACTOR FOR 30 DEGREES INCLINATION</b> |              |              |
|--------------|---|--------------|--------------|
| (m)          | <b>BH-01</b>                                    | <b>BH-02</b> | <b>BH-03</b> |
| 1.00         | 6.20  | 1.41         | 3.80         |
| 2.00         | 3.15  | 1.17         | 1.95         |
| 3.00         | 2.36  | 1.23         | 1.13         |
| 4.00         | 1.66  | 1.82         | 0.87         |
| 5.00         | 0.59  | 1.91         | 0.91         |
| 6.00         | 0.99  | 1.73         | 1.25         |
| 7.00         | 1.46  | 2.32         | 1.63         |
| 8.00         | 1.56  | 2.14         | 1.61         |
| 9.00         | 1.59  | 1.87         | 1.49         |
| 10.00        | 1.06  | 1.77         | 1.10         |

**Table 3-33** Safety factor for 15 degrees inclination.

| <b>Depth</b> | <b>SAFETY FACTOR FOR 15 DEGREES INCLINATION</b> |              |              |
|--------------|---|--------------|--------------|
| (m)          | <b>BH-01</b>                                    | <b>BH-02</b> | <b>BH-03</b> |
| 1.00         | 7.51  | 2.84         | 5.24         |
| 2.00         | 4.46  | 2.42         | 3.39         |
| 3.00         | 3.67  | 2.43         | 2.57         |
| 4.00         | 3.15  | 3.45         | 2.31         |
| 5.00         | 2.01  | 3.66         | 2.35         |
| 6.00         | 2.42  | 3.36         | 2.79         |
| 7.00         | 2.83  | 4.38         | 3.16         |
| 8.00         | 2.93  | 4.07         | 3.19         |
| 9.00         | 2.96  | 3.59         | 3.07         |
| 10.00        | 2.42  | 3.41         | 2.68         |

### 3.6.6 Liquefaction

Liquefaction usually occur at soil layers with these criteria :

- Saturated fine sand layer with no cohesion
- Saturated cohesive layer with  $LL < 35\%$  and clay content below 15%.

Since the soil classification at Gas Fired Power Plant 275 MW Riau area is consist of Clay and Silty Clay soil type with  $LL = 44.00 - 84.79\%$ , we can conclude that liquefaction will not occur at GFPP 275 MW Riau area.

## 4. Comparison to Location Alternative 1

Comparing the soil investigation results recently at Alternative-2 (Alt-2) area to soil investigation results conducted earlier which located at Alternative-1 (Alt-1) (studied on April 2016), we came into conclusions as follow:

### 4.1 Soil Type and Stratification

At Alt-2 location, the soil types are dominated by Silt (50% average), follow by Clay (25% average) and Sand (25% average), which can be named as Clayey Silt with Sand. These soil types are consistent until depth of boring termination (30 meters).

At Alt-1 location, the same types of soil (Clayey Silt with Sand) also found at the top layer with thickness of 8 – 14 meter. Below Clayey Silt with Sand layer, we found medium to very dense sand layer until depth of boring termination (24 - 26 meters). While at Alt-2 location, no sand layer was found until termination depth.

### 4.2 Soil Plasticity Behaviour

Clayey Silt with Sand soil type at Alt-2 location can be categorized as medium to very high plasticity behaviour, with LL = 47.56 – 84.76% and PI = 29.42 – 59.91%. The Clayey Silt with Sand soil type at Alt-1 location also showed the same behaviour, with LL = 69.52 – 108.20% and PI = 39.30 – 80.61%, slightly higher than Alt-2 location.

### 4.3 Soil Strength and Stiffness

At Alt-2 location, we already found firm to stiff soil at surface layer (N-SPT = 7 – 20), and the strength and stiffness of soil are increasing with depth. The only exception is at BH-02 area, where soft soil layer (N-SPT = 2) with thickness of 2 meter was found.

At Alt-1 location, the soil showed the same tendency, the strength and stiffness are increasing with depth. Soft soil layer as at BH-02 area Alt-2 location was found with thickness of 5 – 7 m.

To summarize, both Alt-2 and Alt-1 location has the same type of soil. The differences are the soil at Alt-1 location has thicker soft layer (5 – 7 meters) and underlaid by medium to very dense sand layer. While at Alt-2 location, the soft soil is much thinner (2 meters) and no sand layer was found until the termination of boring depth.

## 5. Conclusion and Recommendation

Based on geotechnical drilling had been conducted we might conclude the stratigraphy of the soil layer in investigation area by as follows:

- Top Soil consists of clayey SILT layer with thickness approximately 0.4 – 1.2 m and locally up to 5.6 m.
- Silty CLAY, is a soil layer underlying top soil layer with thickness approximately 0.6 – 2.85 m.
- CLAY layer, the lower most layer up to end of drilling depth, approximately 24 – 29 m thick relative to the end of drilling depth.

From geoelectrical survey, based on the resistivity range, we interpret the discontinuity that might reflect the soil layer boundary in subsurface by as follows:

- 1<sup>st</sup> layer with resistivity value ranging from 2100 – 2938 ohm m, with thickness ranging from 0.64 up to 1.53 m. This layer interpreted as top soil cover.
- 2<sup>nd</sup> layer with resistivity value ranging from 504 – 784 ohm m, with thickness ranging from 2.7 up to 4.39. This 2<sup>nd</sup> layer interpreted as silty Clay unit.
- 3<sup>rd</sup> layer with resistivity value ranging from 8.7 up to 13 ohm m, with thickness ranging from 27.63 m up to 30 m. This layer interpreted as Clay unit.
- 4<sup>th</sup> layer with resistivity value ranging from 53 up to 79 ohm m, with thickness approximately more than 66 m. this layer is underlie below drilling depth and interpreted as clayey SAND unit.

Geotechnical analysis is undertaken to understand the geotechnical aspect of investigation area in terms of the bearing capacity of subsurface material regarding to shallow and deep foundation, the settlement analysis, slope stability assesment during construction work, and liquefaction potential.

Detail design parameters from geotechnical aspect that had been deduced from geotechnical analysis can be seen in table 3.11 to 3.13.

The bearing capacity of soil for **shallow foundation** at **BH-01** location is summarized as follows (the detailed result can be seen in table 3.14):

- For 1 x 1 m, 1.5 x 1.5 m, 2 x 2 m, 2.5 x 2.5 m, and 3 x 3 m of **squared foundation** allowable bearing capacity to support load to the ground of **1 m depth** of foundation respectivley are 478.8 kN (47.8 ton), 889.38 kN (88.9 ton), 1386.64 kN (138.6 ton), 1996.85 kN (199.6 ton), and 2719.78 kN (271.9 ton).
- For 1 x 1 m, 1.5 x 1.5 m, 2 x 2 m, 2.5 x 2.5 m, and 3 x 3 m of **squared foundation** allowable bearing capacity to support load to the ground of **2 m depth** of foundation respectivley are 478.80 kN (47.8 ton), 969.57 kN (96.9 ton), 1583.03 kN (158.3 ton), 2229.70 kN (229.9 ton), 2989.31 kN (298.9 ton).
- For 1 m, 1.5 m, 2 m, 2.5 m, and 3 m of **stripped foundation** allowable bearing capacity to support load to the ground of **1 m depth** of foundation respectivley are 478.80 kN (47.8 ton), 592.92 kN (59.9 ton), 693.32 kN (69.3 ton), 798.74 kN (79.8 ton), 906.59 kN (90.6 ton).
- For 1 m, 1.5 m, 2 m, 2.5 m, and 3 m of **stripped foundation** allowable bearing capacity to support load to the ground of **2 m depth** of foundation respectivley are 478.80 kN (47.8 ton), 646.38 kN (64.6 ton), 791.52 kN (79.1 ton), 891.88 kN (89.1 ton), 996.44 kN (99.6 ton).

The bearing capacity of soil for **shallow foundation** at **BH-02** location is summarized as follows (the detailed result can be seen in table 3.15):

- For 1 x 1 m, 1.5 x 1.5 m, 2 x 2 m, 2.5 x 2.5 m, and 3 x 3 m of **squared foundation** allowable bearing capacity to support load to the ground of **1 m depth** of foundation respectivley are 53.20 kN (5.3 ton), 98.82 kN (9.8 ton), 154.07 kN (15.4 ton), 221.87 kN (22.1 ton), and 302.20 kN (30.2 ton).
- For 1 x 1 m, 1.5 x 1.5 m, 2 x 2 m, 2.5 x 2.5 m, and 3 x 3 m of **squared foundation** allowable bearing capacity to support load to the ground of **2 m depth** of foundation respectivley are 53.20 kN (5.3 ton), 107.73 kN (10.7 ton), 175.89 kN (17.5 ton), 247.74 kN (24.7 ton), 332.15 kN (33.2 ton).
- For 1 m, 1.5 m, 2 m, 2.5 m, and 3 m of **stripped foundation** allowable bearing capacity to support load to the ground of **1 m depth** of foundation respectivley are 53.20 kN (5.3 ton), 65.88 kN (6.5 ton), 77.04 kN (7.7 ton), 88.75 kN (8.8 ton), 100.73 kN (10.1 ton).
- For 1 m, 1.5 m, 2 m, 2.5 m, and 3 m of **stripped foundation** allowable bearing capacity to support load to the ground of **2 m depth** of foundation respectivley are 53.20 kN (5.3 ton), 71.82 kN (7.1 ton), 87.95 kN (8.7 ton), 99.10 kN (9.9 ton), 110.72 kN (11.1 ton).

The bearing capacity of soil for **shallow foundation** at **BH-03** location is summarized as follows (the detailed result can be seen in table 3.16):

- For 1 x 1 m, 1.5 x 1.5 m, 2 x 2 m, 2.5 x 2.5 m, and 3 x 3 m of **squared foundation** allowable bearing capacity to support load to the ground of **1 m depth** of foundation respectivley are 266.00 kN (26.6 ton), 494.10kN (49.4 ton), 770.36 kN (77 ton), 1109.36 kN (110.9 ton), and 1510.99 kN (30.2 ton).
- For 1 x 1 m, 1.5 x 1.5 m, 2 x 2 m, 2.5 x 2.5 m, and 3 x 3 m of **squared foundation** allowable bearing capacity to support load to the ground of **2 m depth** of foundation respectivley are 266.00 kN (26.6 ton), 538.65 kN (53.8 ton), 879.46 kN (87.9 ton), 1238.72 kN (12.3 ton), 1660.73 kN (16.6 ton).
- For 1 m, 1.5 m, 2 m, 2.5 m, and 3 m of **stripped foundation** allowable bearing capacity to support load to the ground of **1 m depth** of foundation respectivley are 266.00 kN (26.6 ton), 329.40 kN (32.9 ton), 385.18 kN (38.5 ton), 443.74 kN (44.3 ton), 503.66 kN (50.3 ton).
- For 1 m, 1.5 m, 2 m, 2.5 m, and 3 m of **stripped foundation** allowable bearing capacity to support load to the ground of **2 m depth** of foundation respectivley are 266.00 kN (26.6 ton), 359.10 kN (35.9 ton), 439.73 kN (43.9 ton), 495.49 kN (49.5 ton), 553.58 kN (55.3 ton).

For deep foundation we provided two bearing capacity of soil regarding to the foundation type both bored pile and driven pile type. In addition to driven pile we also provided the bearing capacity with pre-boring and without pre-boring. All the bearing capacity had been calculated with respect to depth and the diameter of pile column. The detail bearing capacity of deep foundation can be seen in section 3.6.3.

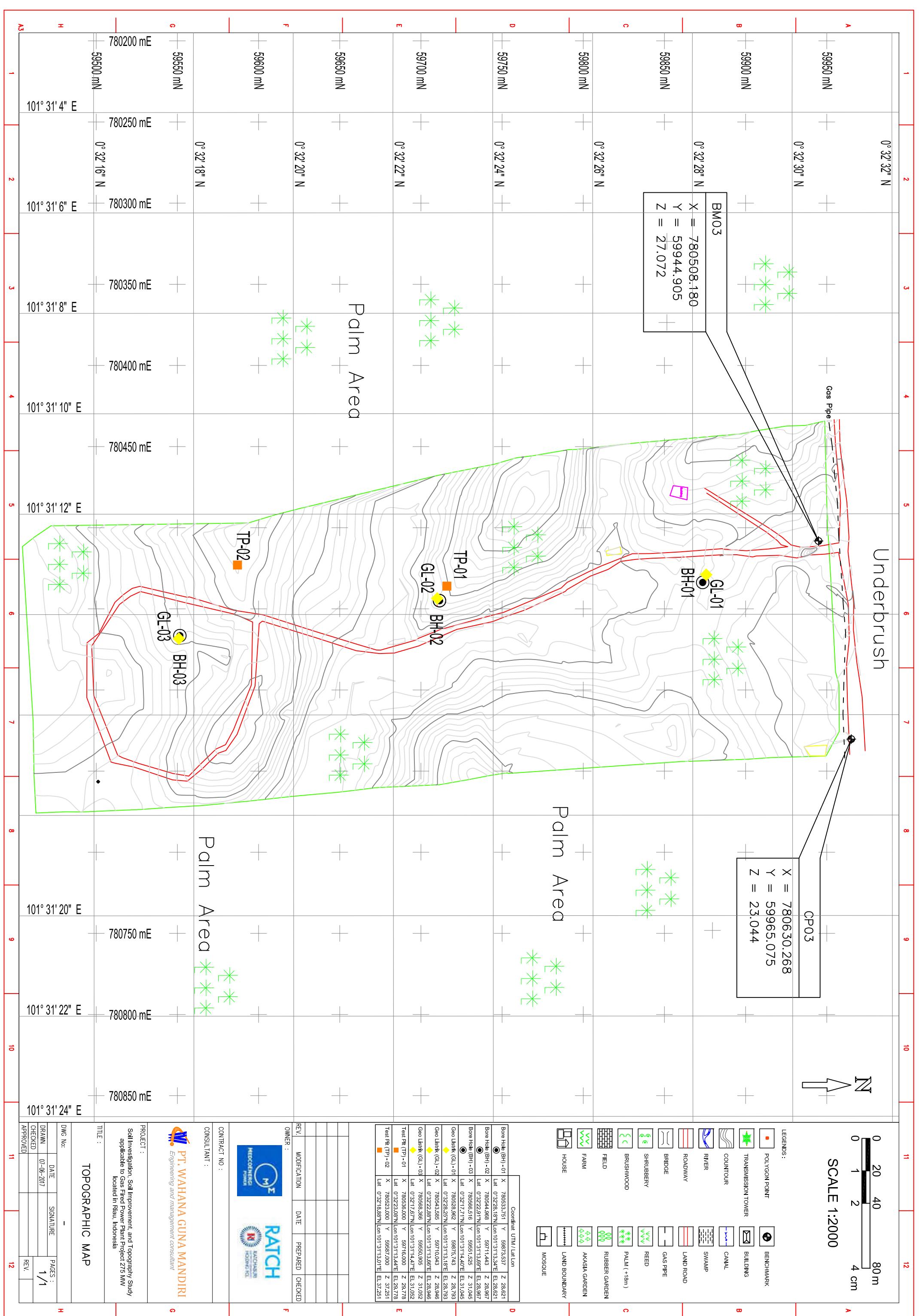
One of the purpose of slope stability analysis is to provide the factor of safety of the slope. We have provided the factor of safety for the slope with respect to the slope angle (inclination) for artificial slope during construction and excavation. For this stage, every selected slope angle with factor of safety can be seen in section 3.6.5 with different factor of safety determination is provided with respect to the depth of excavation during construction work. In particular the detailed factor of safety for given slope inclination can be seen in table 3.29 to table 3.33.

Since the soil layer and lithology unit predominantly consists of cohesive soil layer of Silt and Clay, therefore the potential of soil liquefaction relatively very low. As mentioned at the beginning of section 3.6.6, the criteria for soil material that might undergoing liquefaction are for non-cohesive and cohesive soil with liquid limit (LL) <35%, while based on laboratory data the liquid limit of soil properties in investigation area is > 35% (47.56 – 84.76%), therefore we assume the liquefaction will probably not occurred.

To get a ballace quatity/volume of cut/fill works, it's recommended the design level at 28.05 m. Quantity of Cut/Fill are 165778.75/165343.39 M<sup>3</sup>, with remaining cut material are 435.35 M<sup>3</sup>.

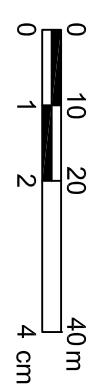
# **APPENDIX A**

## Topography Map



# Underbrush

SCALE 1:1000



59950 mN + Gas Pipe

0° 32' 30" N

59900 mN +

BM03

X = 780508.180  
Y = 59944.905  
Z = 27.072

**GL-01**

CP03  
X = 780630.268  
Y = 59965.075  
Z = 23.044

| Coordinate UTM/Lat.Lon |              |             |          |
|------------------------|--------------|-------------|----------|
| <b>D</b>               |              |             |          |
| Bore Hole (BH) - 01    | X 780533.751 | Y 5987.537  | Z 28.821 |
| Bore Hole (BH) - 02    | X 780544.988 | Y 59711.443 | Z 28.967 |
| Bore Hole (BH) - 03    | X 780566.516 | Y 59851.525 | Z 31.045 |
| Geo Listrik (GL) - 01  | X 780528.982 | Y 59875.743 | Z 28.793 |
| Geo Listrik (GL) - 02  | X 780543.595 | Y 59710.043 | Z 28.946 |
| Geo Listrik (GL) - 03  | X 780566.386 | Y 59850.905 | Z 31.052 |
| Test Pk (TP) - 01      | X 780536.000 | Y 59716.000 | Z 29.778 |
| Test Pk (TP) - 02      | X 780528.000 | Y 59887.000 | Z 37.251 |
|                        | X 780521.887 | Y 59887.000 | Z 37.251 |

## LEGENDS:

POLYLINE POINT BENCHMARK

TRANSMISSION TOWER BUILDING

COUNTOUR CANAL

RIVER ROADWAY

BRIDGE SWAMP

FIELD GAS PIPE

SHRUBBURY REED

FARM PALM (+18m)

AKASIA GARDEN

HOUSE LAND BOUNDARY

MOSQUE

59750 mN + 0° 32' 24" N

780400 mE

0° 32' 30" E

101° 31' 10" E

780450 mE

101° 31' 12" E

780500 mE

101° 31' 14" E

780550 mE

101° 31' 16" E

780600 mE

101° 31' 18" E

780650 mE

101° 31' 20" E

780700 mE

101° 31' 22" E

780750 mE

101° 31' 24" E

780800 mE

101° 31' 26" E

780850 mE

101° 31' 28" E

780900 mE

101° 31' 30" E

780950 mE

101° 31' 32" E

781000 mE

101° 31' 34" E

781050 mE

101° 31' 36" E

781100 mE

101° 31' 38" E

781150 mE

101° 31' 40" E

781200 mE

101° 31' 42" E

781250 mE

101° 31' 44" E

781300 mE

101° 31' 46" E

781350 mE

101° 31' 48" E

781400 mE

101° 31' 50" E

781450 mE

101° 31' 52" E

781500 mE

101° 31' 54" E

781550 mE

101° 31' 56" E

781600 mE

101° 31' 58" E

781650 mE

101° 31' 60" E

781700 mE

101° 31' 62" E

781750 mE

101° 31' 64" E

781800 mE

101° 31' 66" E

781850 mE

101° 31' 68" E

781900 mE

101° 31' 70" E

781950 mE

101° 31' 72" E

782000 mE

101° 31' 74" E

782050 mE

101° 31' 76" E

782100 mE

101° 31' 78" E

782150 mE

101° 31' 80" E

782200 mE

101° 31' 82" E

782250 mE

101° 31' 84" E

782300 mE

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101° 31' 90" E

782450 mE

101° 31' 92" E

782500 mE

101° 31' 94" E

782550 mE

101° 31' 96" E

782600 mE

101° 31' 98" E

782650 mE

101° 31' 100" E

782700 mE

101° 31' 102" E

782750 mE

101° 31' 104" E

782800 mE

101° 31' 106" E

782850 mE

101° 31' 108" E

782900 mE

101° 31' 110" E

782950 mE

101° 31' 112" E

783000 mE

101° 31' 114" E

783050 mE

101° 31' 116" E

783100 mE

101° 31' 118" E

783150 mE

101° 31' 120" E

783200 mE

101° 31' 122" E

783250 mE

101° 31' 124" E

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783500 mE

101° 31' 134" E

783550 mE

101° 31' 136" E

783600 mE

101° 31' 138" E

783650 mE

A  
59700 mN  
B  
59650 mN  
C  
59600 mN

GL-02 BH-02

SCALE 1:1000

LEGENDS:

|                    |               |
|--------------------|---------------|
| POLY-ON POINT      | BENCHMARK     |
| TRANSMISSION TOWER | BUILDING      |
| COUNTOUR           | CANAL         |
| RIVER              | ROADWAY       |
| BRIDGE             | SWAMP         |
| SHRUBBERY          | LAND ROAD     |
| FIELD              | GAS PIPE      |
| BRUSHWOOD          | REED          |
| FARM               | PALM (+18m)   |
| HOUSE              | RUBBER GARDEN |
| MOSQUE             | AKASA GARDEN  |
| LAND BOUNDARY      |               |

D

59600 mN

0° 32' 22" N

0 10 20 40 m

0 1 2 4 cm

A

0° 32' 20" N

101° 31' 10" E

780400 mE

780450 mE

101° 31' 12" E

780500 mE

780550 mE

101° 31' 14" E

780600 mE

101° 31' 16" E

780650 mE

101° 31' 18" E

780700 mE

59550 mN

0° 32' 18" N

0 10 20 40 m

0 1 2 4 cm

H

59500 mN

0° 32' 16" N

0 10 20 40 m

0 1 2 4 cm

G

0° 32' 18" N

0 10 20 40 m

0 1 2 4 cm

F

0 10 20 40 m

0 1 2 4 cm

E

0 10 20 40 m

0 1 2 4 cm

D

0 10 20 40 m

0 1 2 4 cm

C

0 10 20 40 m

0 1 2 4 cm

B

0 10 20 40 m

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0 10 20 40 m

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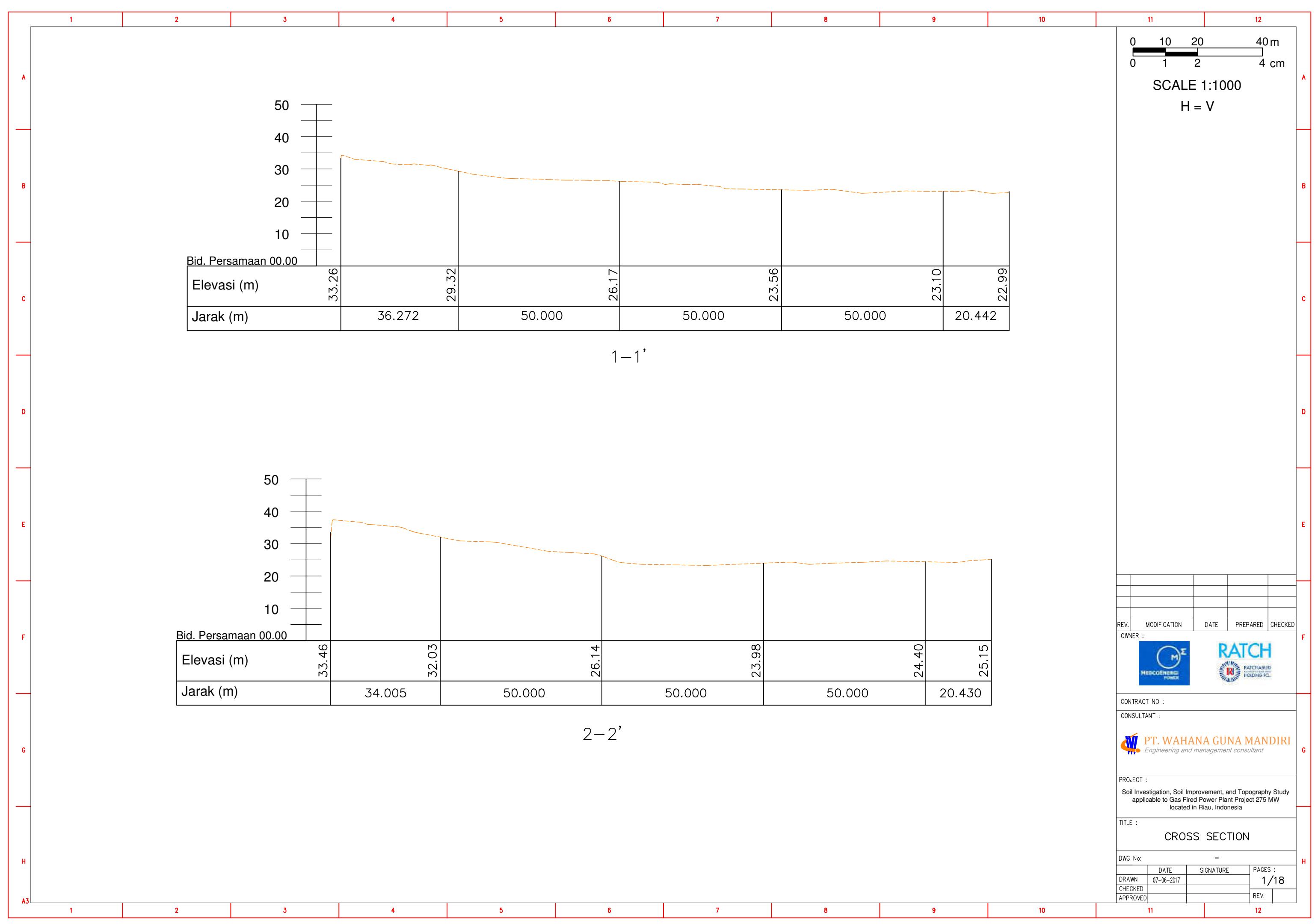
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Bid. Persamaan 00.00

Elevasi (m)

Jarak (m)

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27.205

33.90

50.000

27.17

50.000

27.87

50.000

30.78

50.000

30.72

50.000

23.384

50.000

5-5'

Bid. Persamaan 00.00

Elevasi (m)

Jarak (m)

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31.52

26.43

32.10

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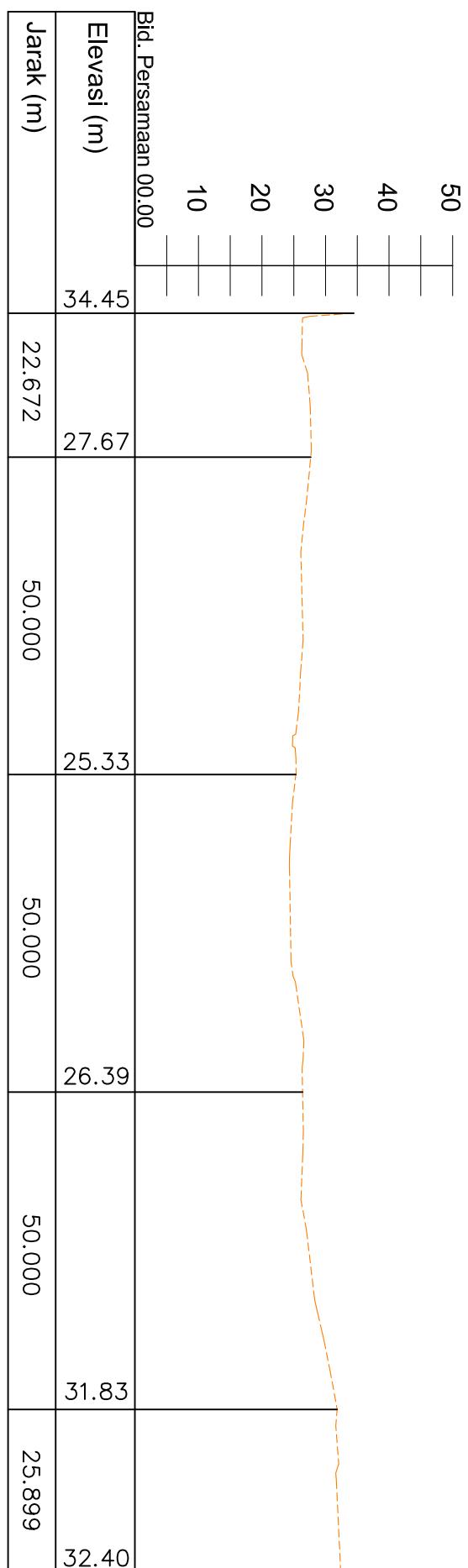
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26.43

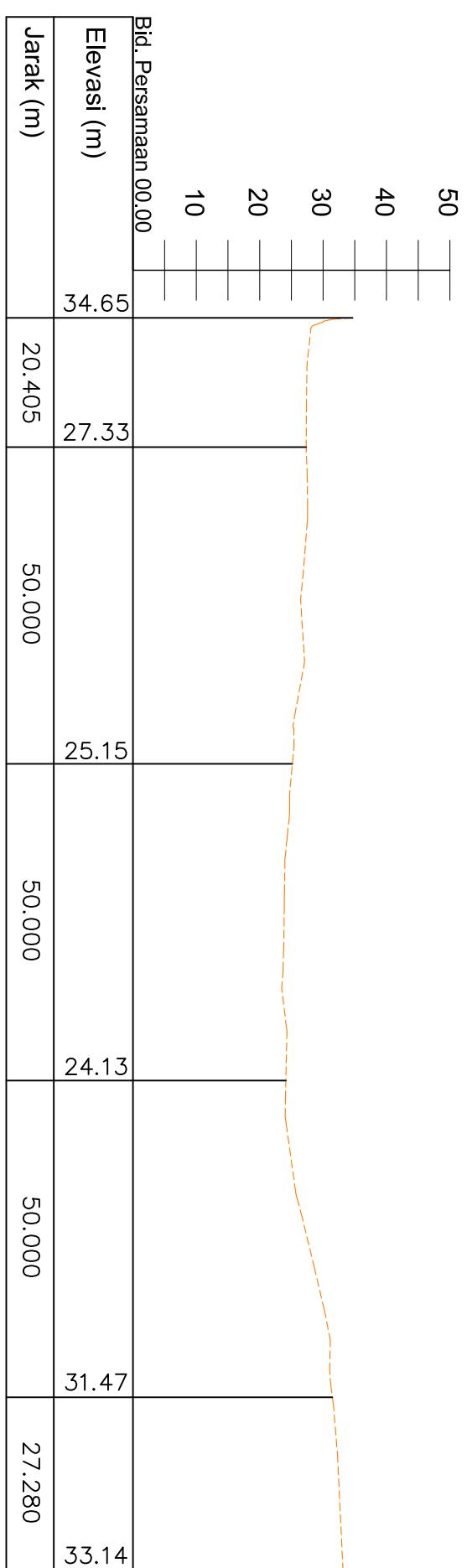
31.67

SCALE 1:1000  
H = V

0 10 20 40 m  
0 1 2 4 cm



7-7'



8-8'

CONTRACT NO. :  
CONSULTANT :



**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*

PROJECT :  
Soil Investigation, Soil Improvement, and Topographic Study  
applicable to Gas Fired Power Plant Project 275 MW  
located in Riau, Indonesia

TITLE :

CROSS SECTION

| DWG. No:   | -    |           |         |
|------------|------|-----------|---------|
| DRAWN      | DATE | SIGNATURE | PAGES : |
| 07-06-2017 |      |           | 4 / 18  |
| APPROVED   |      |           | REV.    |

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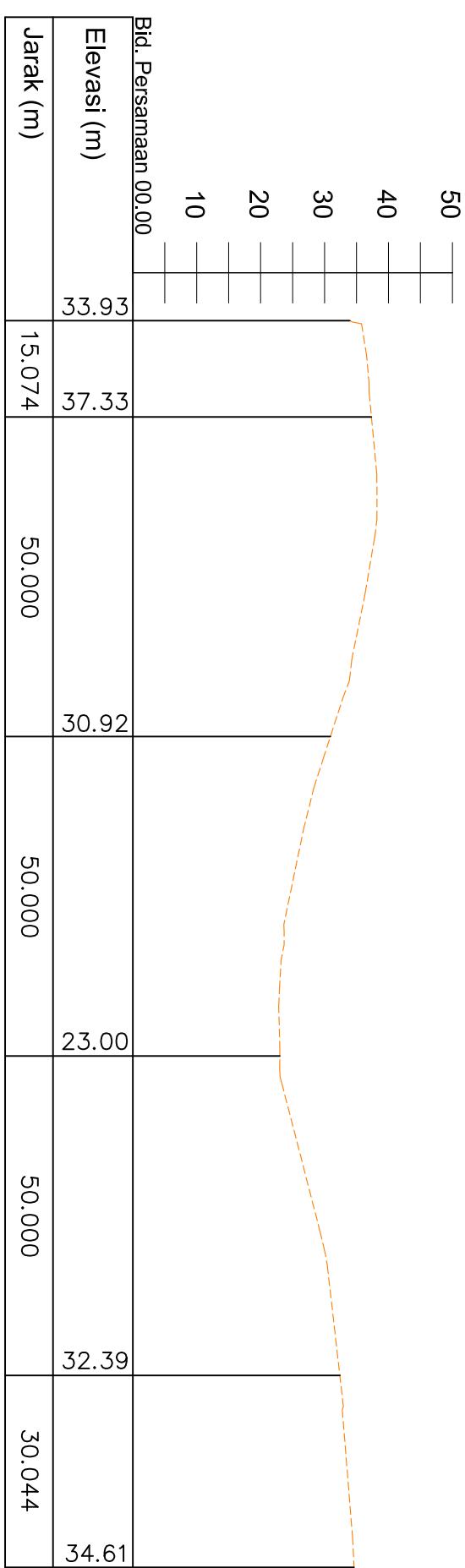
A

SCALE 1:1000  
H = V

0 10 20 40 m  
0 1 2 4 cm

| Bid. Persamaan | Elevasi (m) | Jarak (m) |
|----------------|-------------|-----------|
| 00.00          | 34.68       | 18.019    |
|                | 35.23       | 50.000    |
|                | 28.05       | 50.000    |
|                | 24.00       | 50.000    |
|                | 31.94       | 28.662    |
|                | 33.87       |           |

9-9'



10-10'

**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*



CONTRACT NO. :  
CONSULTANT :

OWNER :  
REV. MODIFICATION DATE PREPARED CHECKED

RATCH



PROJECT :  
Soil Investigation, Soil Improvement, and Topographic Study  
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TITLE :

CROSS SECTION

| DWG. No:   | -    |           |         |
|------------|------|-----------|---------|
| DRAWN      | DATE | SIGNATURE | PAGES : |
| 07-06-2017 |      |           | 5/18    |
| APPROVED   |      |           | REV.    |

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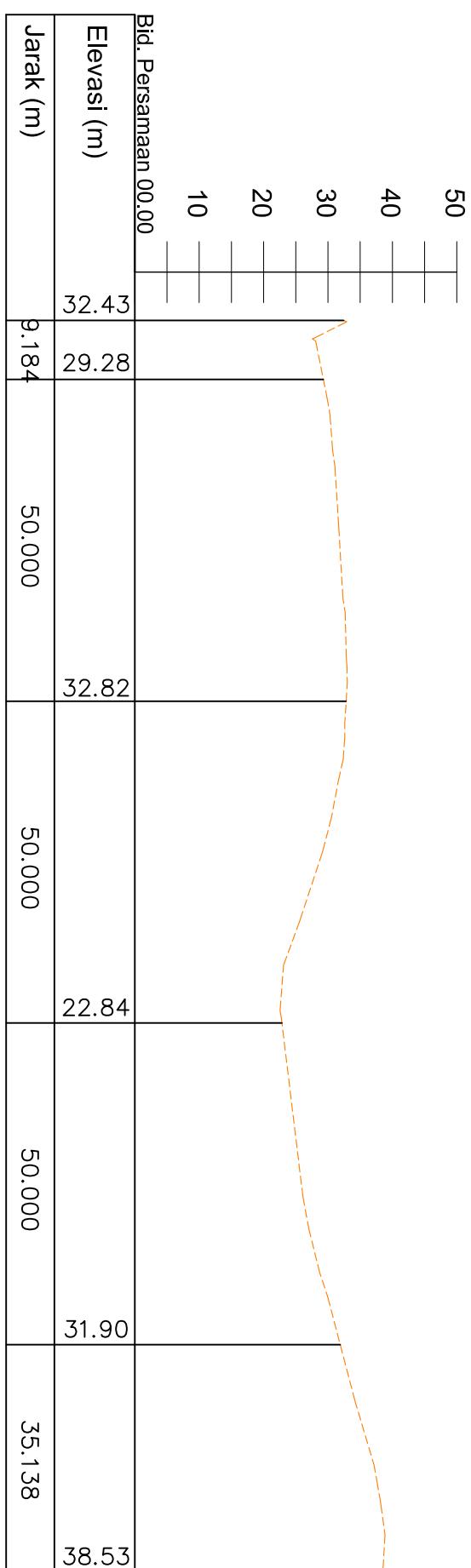
A

SCALE 1:1000  
H = V

0 10 20 40 m  
0 1 2 4 cm

| Bid. Persamaan 00.00 | Elevasi (m) | Jarak (m) |
|----------------------|-------------|-----------|
|                      | 33.18       | 12.129    |
|                      | 34.71       | 50.000    |
|                      | 33.52       | 50.000    |
|                      | 23.20       | 31.983    |
|                      | 31.69       |           |
|                      | 36.15       |           |

11-11'



12-12'

DWG No: -  
DRAWN: 07-06-2017  
CHECKED: APPROVED

SIGNATURE: PAGES: 6/18  
REV.:



CONTRACT NO.: CONSULTANT :

**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*

PROJECT : Soil Investigation, Soil Improvement, and Topographic Study applicable to Gas Fired Power Plant Project 275 MW located in Riau, Indonesia

TITLE :

CROSS SECTION

A3

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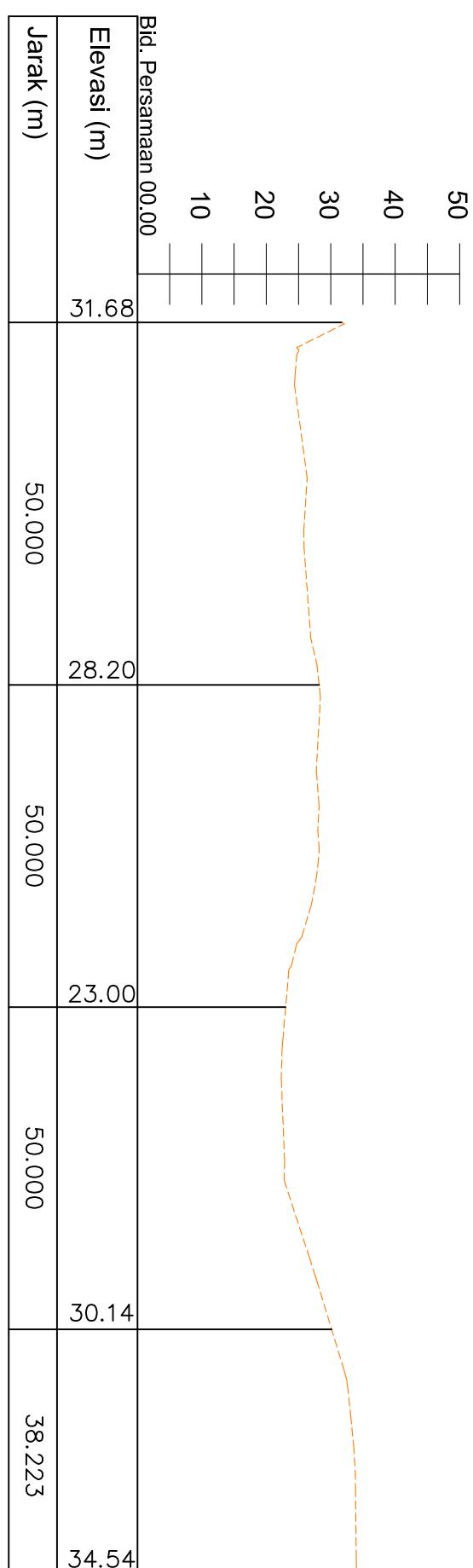
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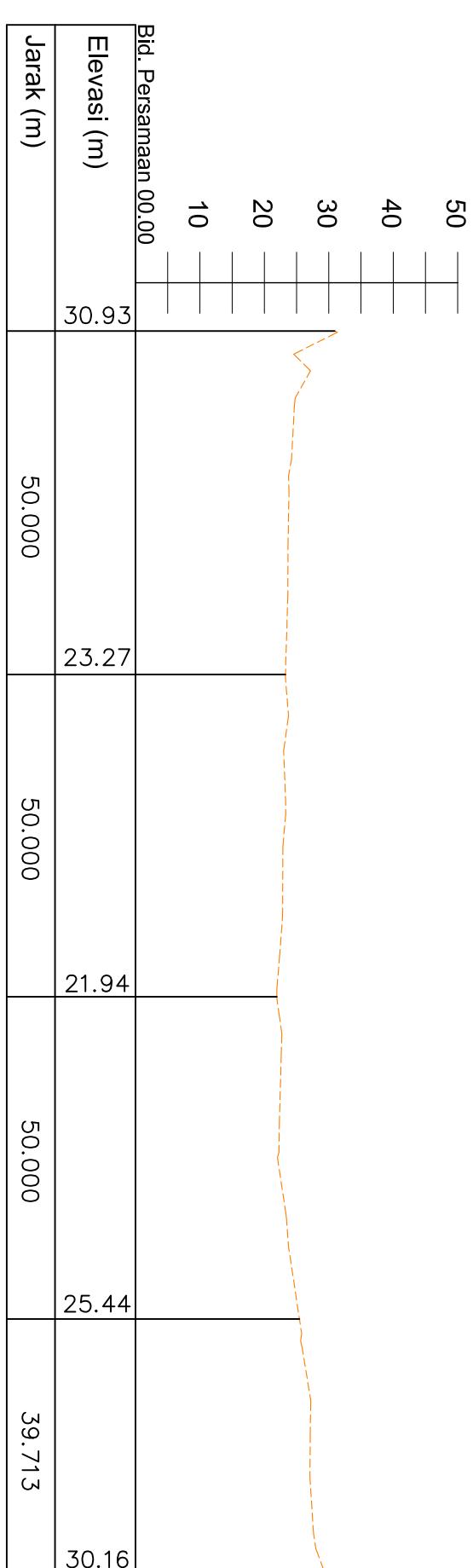
12

SCALE 1:1000  
H = V

0 10 20 40 m  
0 1 2 4 cm



13-13'



14-14'

CONTRACT NO. :  
CONSULTANT :



**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*

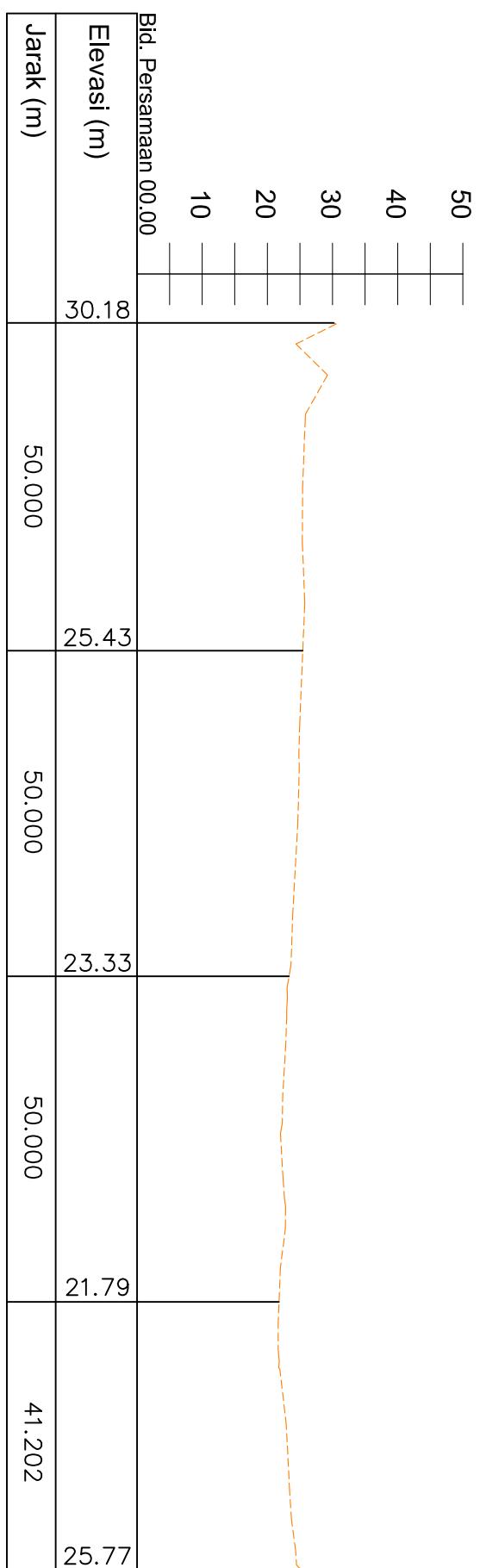
PROJECT :  
Soil Investigation, Soil Improvement, and Topographic Study  
applicable to Gas Fired Power Plant Project 275 MW  
located in Riau, Indonesia

TITLE : CROSS SECTION

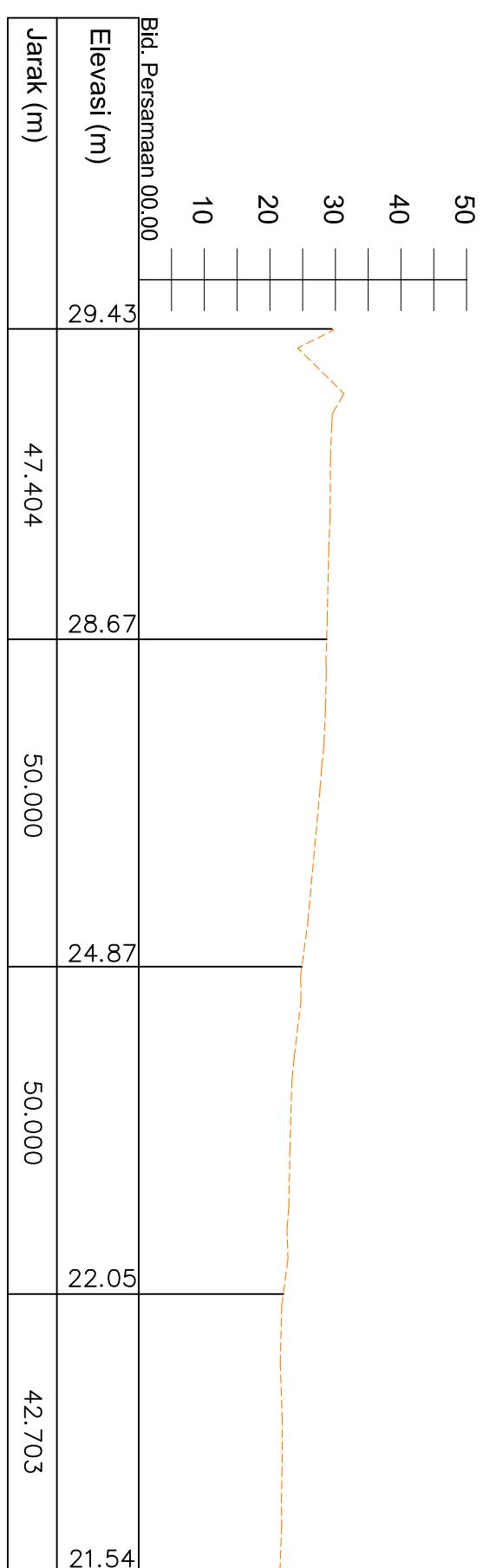
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| A3       | 07-06-2017 |           | 7/18    |
| APPROVED |            |           | REV.    |
| 1        | 2          | 3         | 4       |
| 5        | 6          | 7         | 8       |
| 9        | 10         | 11        | 12      |

SCALE 1:1000  
H = V

0 10 20 40 m  
0 1 2 4 cm



15-15'



16-16'

16-16'

CONTRACT NO. :  
CONSULTANT :



**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*

PROJECT :  
Soil Investigation, Soil Improvement, and Topographic Study  
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located in Riau, Indonesia

TITLE :

CROSS SECTION

| DWG No:    | -    |           |         |
|------------|------|-----------|---------|
| DRAWN      | DATE | SIGNATURE | PAGES : |
| 07-06-2017 |      |           | 8 / 18  |
| CHECKED    |      |           | REV.    |

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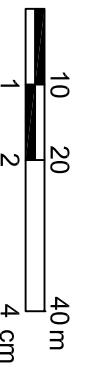
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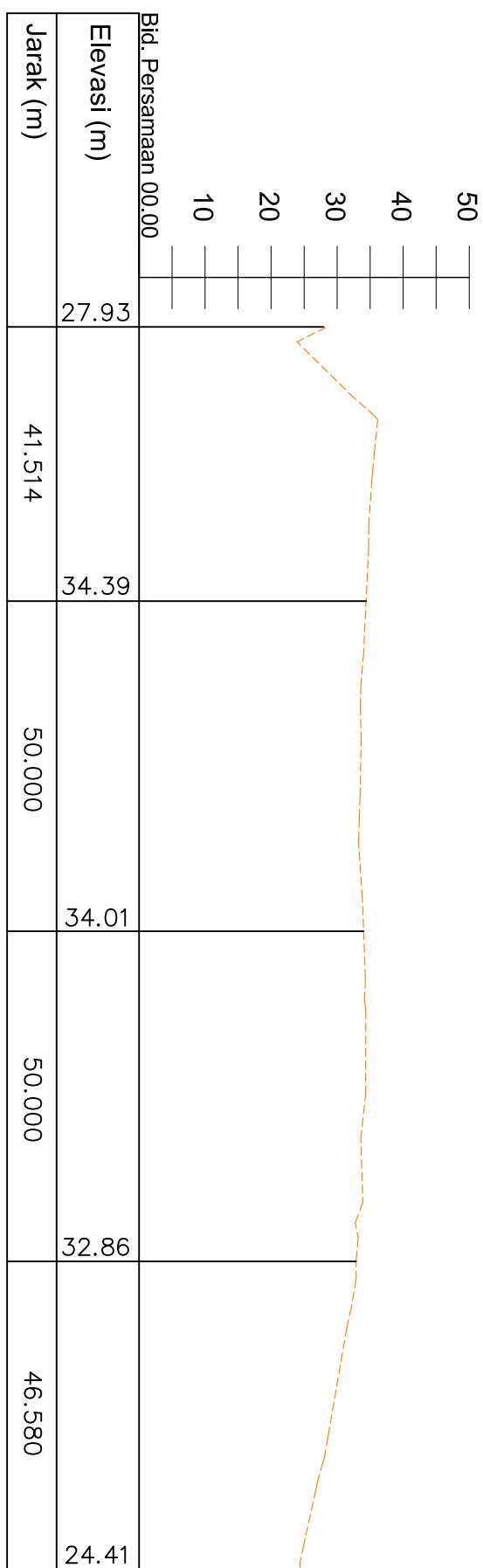
A

SCALE 1:1000  
H = V



|                      |             |           |
|----------------------|-------------|-----------|
| Bid. Persamaan 00.00 | Elevasi (m) | Jarak (m) |
|                      | 28.68       | 44.459    |
|                      | 31.25       | 50.000    |
|                      | 29.12       | 50.000    |
|                      | 25.02       | 44.524    |
|                      |             | 21.61     |

17-17'



18-18'

 PT. WAHANA GUNA MANDIRI  
*Engineering and management consultant*

CONTRACT NO. :  
CONSULTANT :



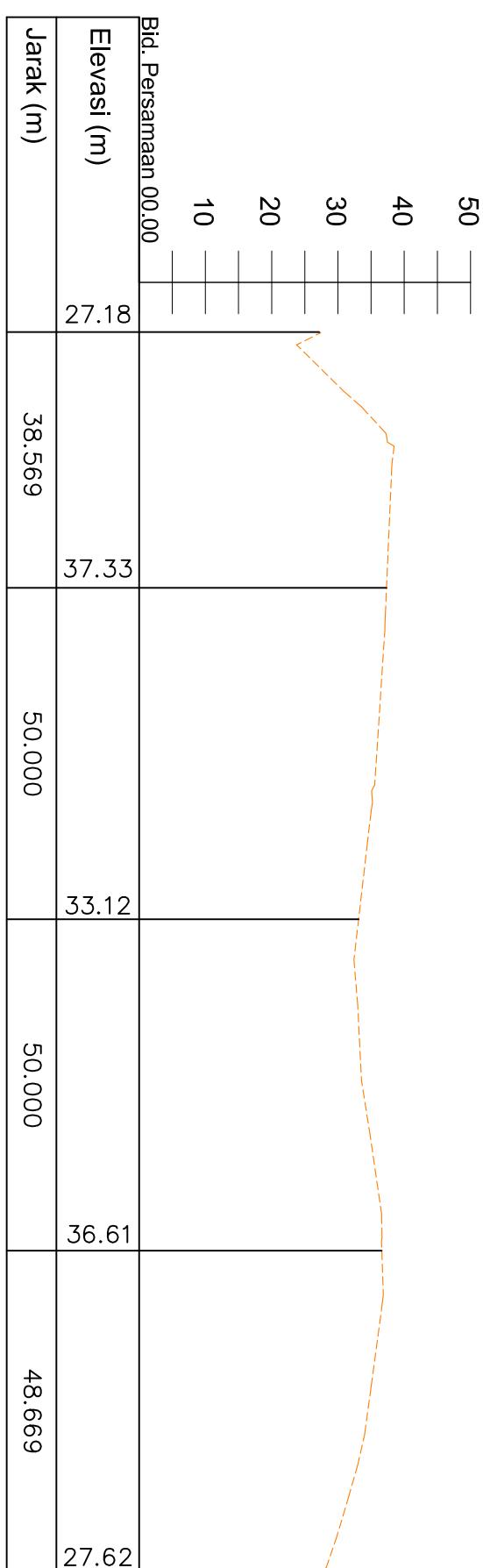
PROJECT :  
Soil Investigation, Soil Improvement, and Topography Study  
applicable to Gas Fired Power Plant Project 275 MW  
located in Riau, Indonesia

TITLE :  
CROSS SECTION

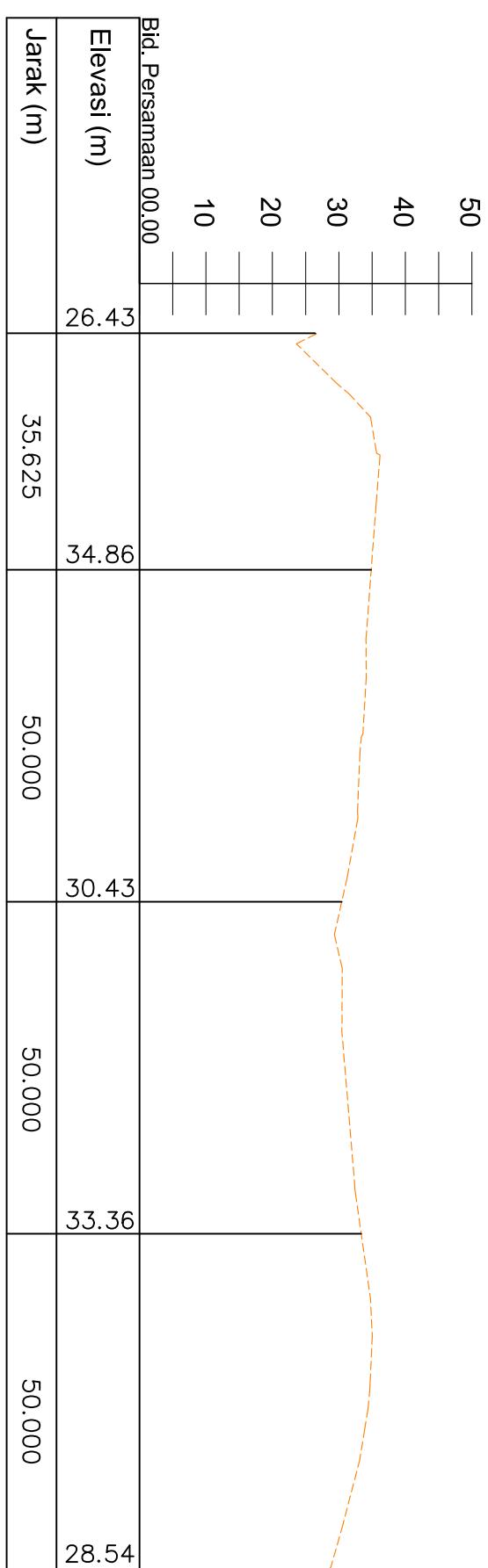
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| 07-06-2017 |      |           | 9/18    |
| CHECKED    |      |           | REV.    |
| APPROVED   |      |           |         |

SCALE 1:1000  
H = V

10 20 40 m  
1 2 4 cm



19-19'



20-20'



OWNER :  
REV. MODIFICATION DATE PREPARED CHECKED

CONTRACT NO. :  
CONSULTANT :

**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*

PROJECT :  
Soil Investigation, Soil Improvement, and Topographic Study  
applicable to Gas Fired Power Plant Project 275 MW  
located in Riau, Indonesia

TITLE : CROSS SECTION

| DWG. No:   | -    |           |         |
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| DRAWN      | DATE | SIGNATURE | PAGES : |
| 07-06-2017 |      |           | 10/18   |
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A3

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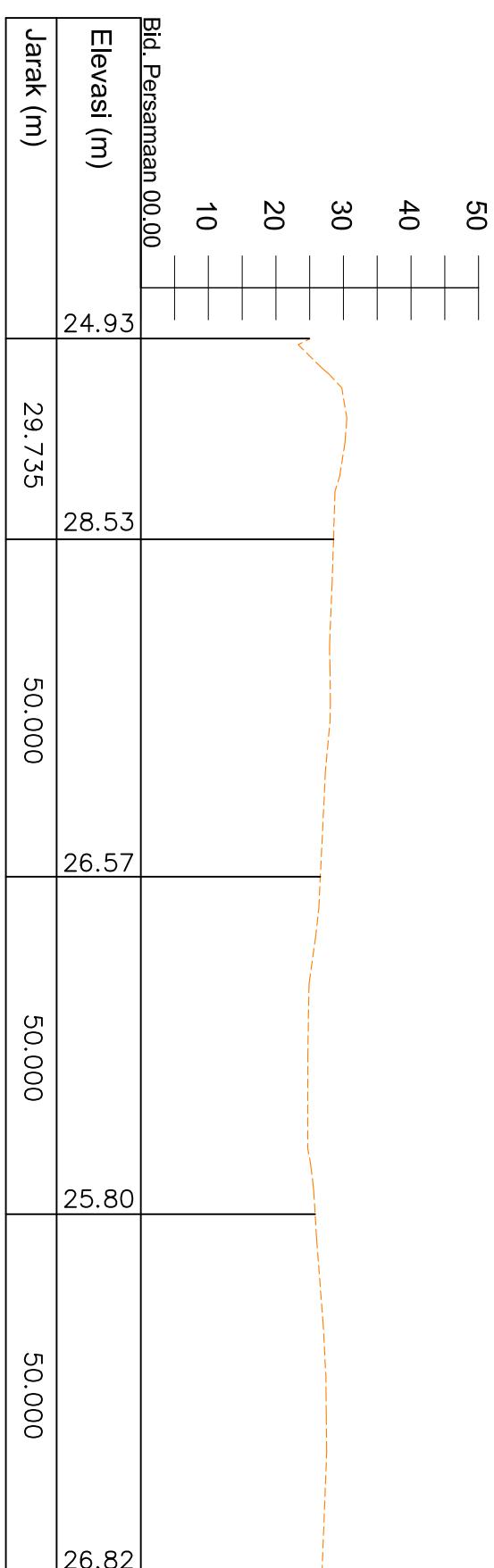
H

1 2 3 4 5 6 7 8 9 10 11 12

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10SCALE 1:1000  
H = V0  
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20  
40 m0  
1  
2  
4 cm

| Bid. Persamaan | Elevasi (m) | Jarak (m) |
|----------------|-------------|-----------|
| 00.00          | 25.68       | 32.679    |
| 00.00          | 29.92       | 50.000    |

21–21'



22–22'

CONTRACT NO. :  
CONSULTANT :
**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*

PROJECT :  
 Soil Investigation, Soil Improvement, and Topography Study  
 applicable to Gas Fired Power Plant Project 275 MW  
 located in Riau, Indonesia

TITLE :

## CROSS SECTION

| DWG. No:   | -    |           |         |
|------------|------|-----------|---------|
| DRAWN      | DATE | SIGNATURE | PAGES : |
| 07-06-2017 |      |           | 11/18   |
| CHECKED    |      |           | REV.    |
| APPROVED   |      |           | REV.    |

A3

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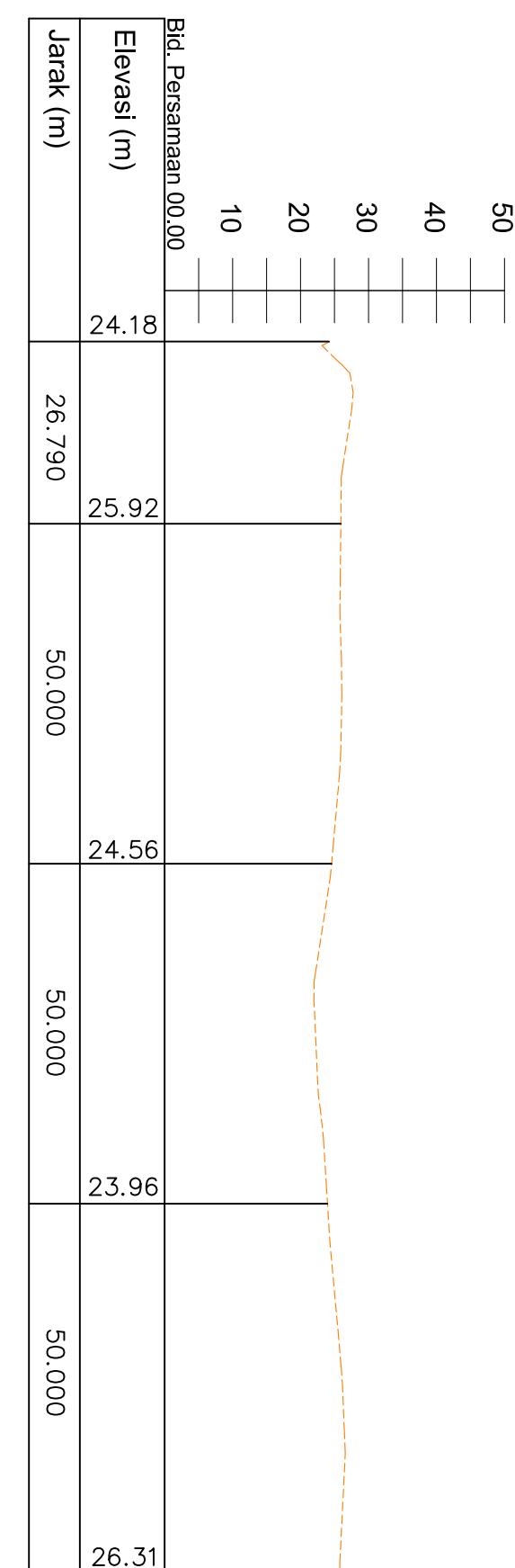
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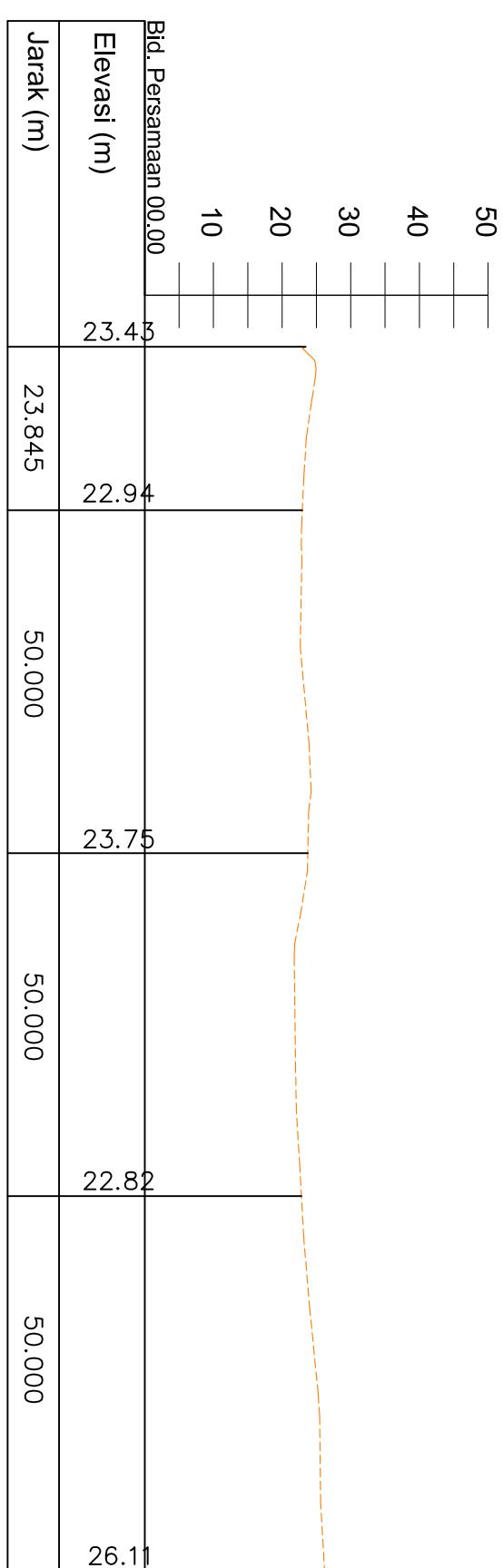
12

SCALE 1:1000  
H = V

0 10 20 40 m  
0 1 2 4 cm



23-23'



24-24'

PT. WAHANA GUNA MANDIRI  
*Engineering and management consultant*

PROJECT :  
Soil Investigation, Soil Improvement, and Topography Study  
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located in Riau, Indonesia

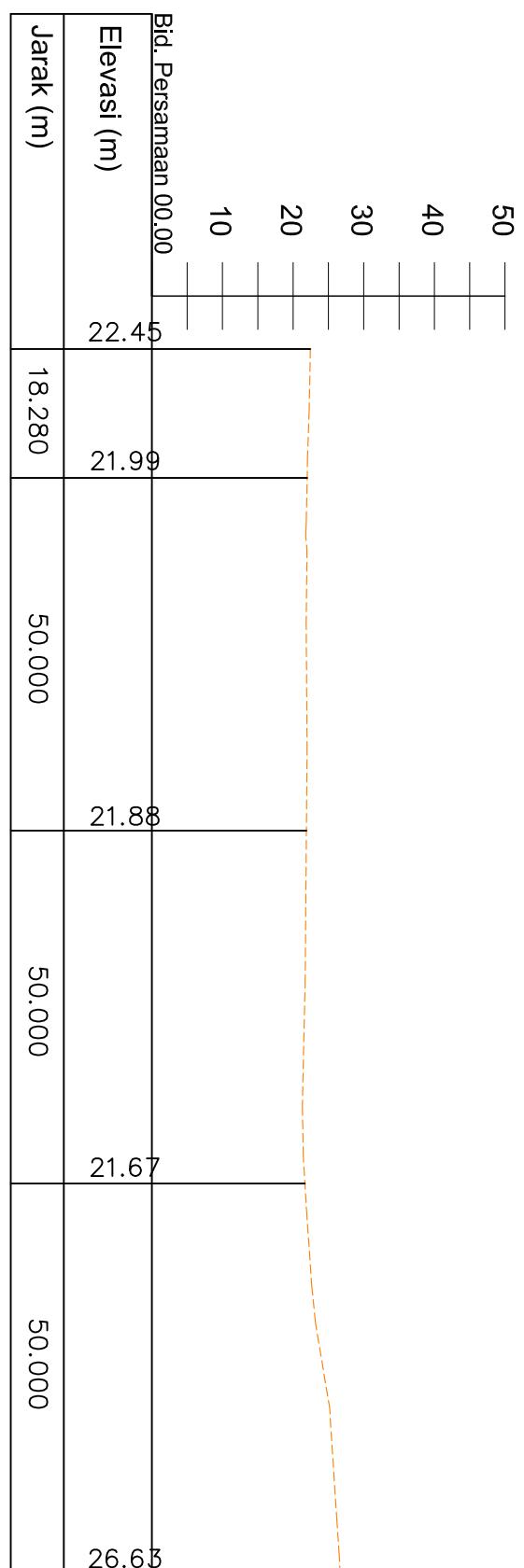
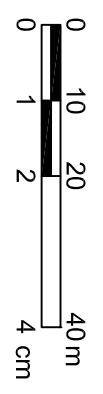
TITLE : CROSS SECTION

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| A3       | 07-06-2017 |           | 12/18   |
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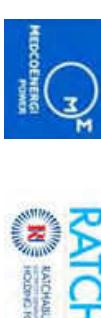
G

SCALE 1:1000  
H = V



25 – 25'

| OWNER : | REV. | MODIFICATION | DATE | PREPARED | CHECKED |
|---------|------|--------------|------|----------|---------|
| RATCH   |      |              |      |          |         |



CONTRACT NO. :  
CONSULTANT :

**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*

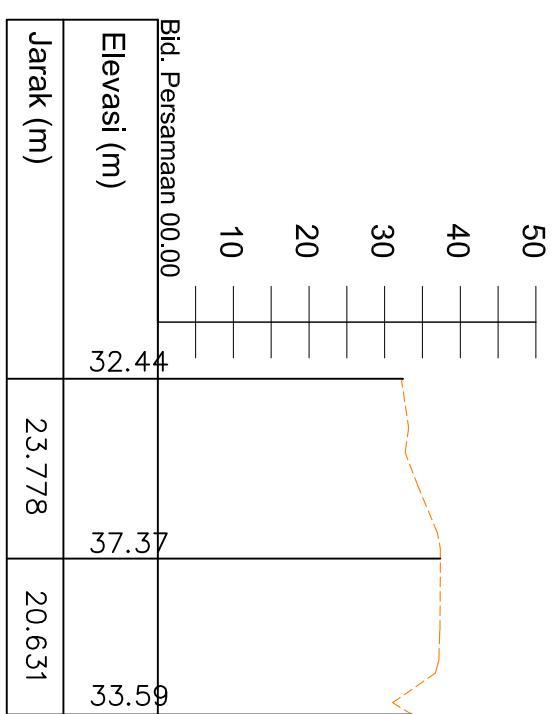
PROJECT :  
Soil Investigation, Soil Improvement, and Topography Study  
applicable to Gas Fired Power Plant Project 275 MW  
located in Riau, Indonesia

TITLE : CROSS SECTION

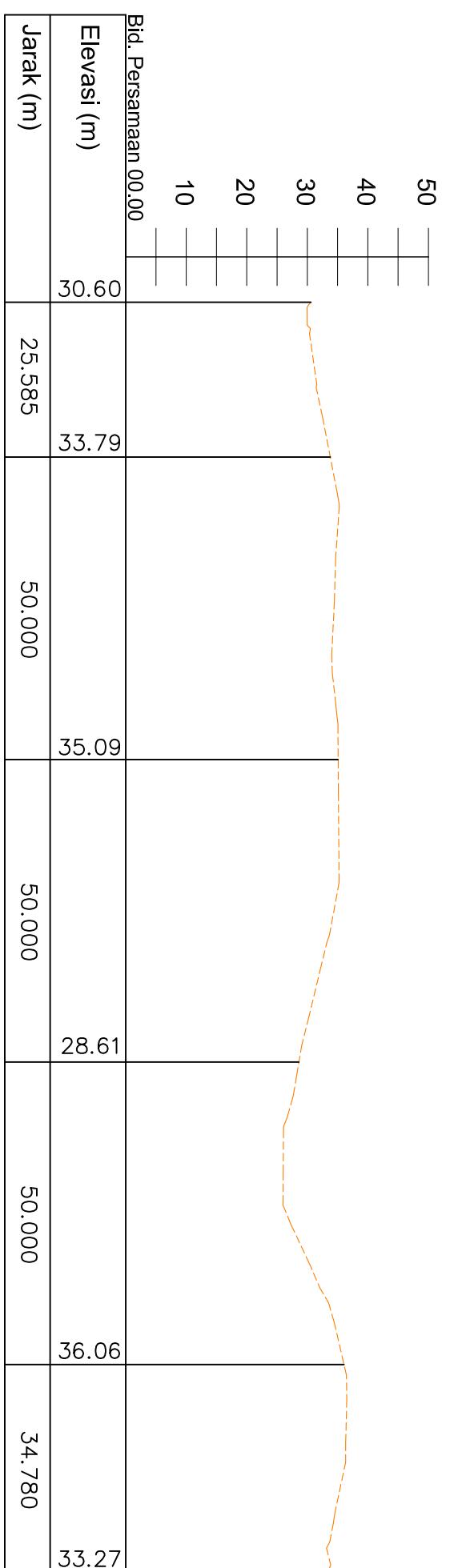
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| DRAWN    | DATE       | SIGNATURE | PAGES : |
| A3       | 07-06-2017 |           | 13/18   |
| APPROVED |            |           | REV. 12 |

SCALE 1:1000  
H = V

0 10 20 40 m  
0 1 2 4 cm



A-A'



B-B'

**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*



**RATCH**  
RATCHAUBON HOLDING CO.

CONTRACT NO. :

CONSULTANT :

PROJECT :  
Soil Investigation, Soil Improvement, and Topographic Study  
applicable to Gas Fired Power Plant Project 275 MW  
located in Riau, Indonesia

TITLE :

CROSS SECTION

| A3 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|----|---|---|---|---|---|---|---|---|---|----|----|----|
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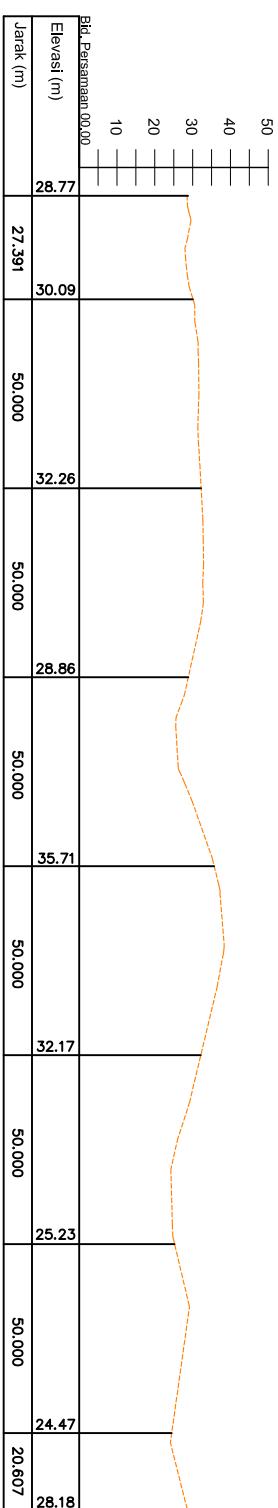
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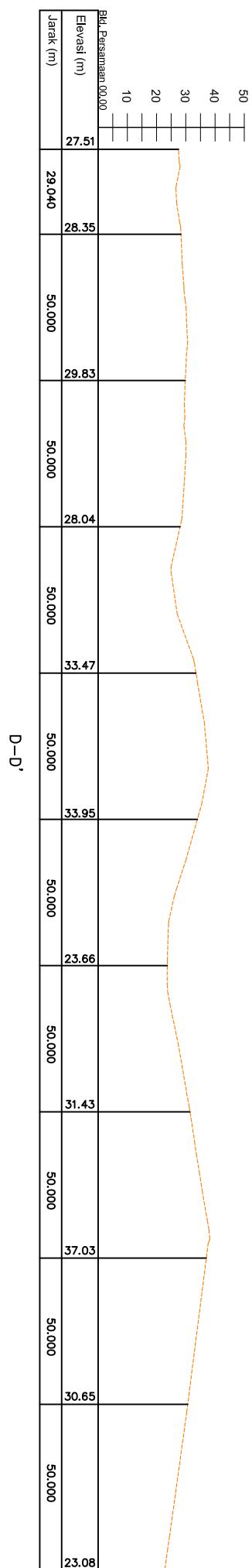
&lt;p

0 20 40  
0 1 2 4 cm  
80m

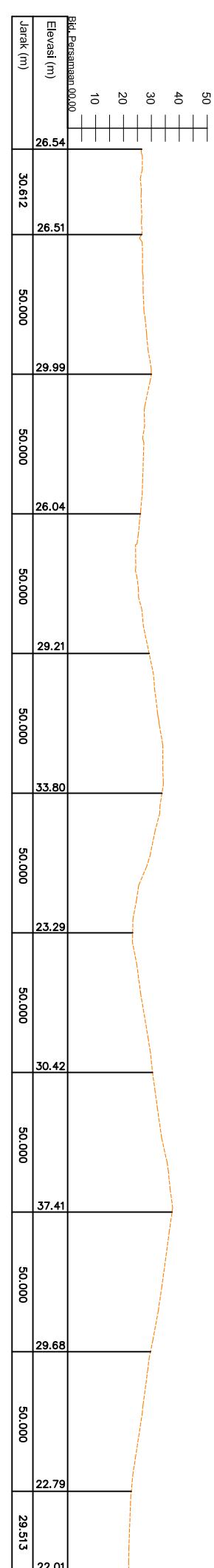
SCALE 1:2000  
H = V



C-C'



D-D'



E-E'



PT. WAHANA GUNA MANDIRI  
*Engineering and management consultant*

PROJECT :  
Soil Investigation, Soil Improvement, and Topography Study  
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located in Riau, Indonesia

TITLE :

CROSS SECTION

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|------------|------|-----------|---------|
| DWG No:    | -    |           |         |
| DRAWN      | DATE | SIGNATURE | PAGES : |
| 07-06-2017 |      |           | 15/18   |
| CHECKED    |      |           | REV.    |

APPROVED

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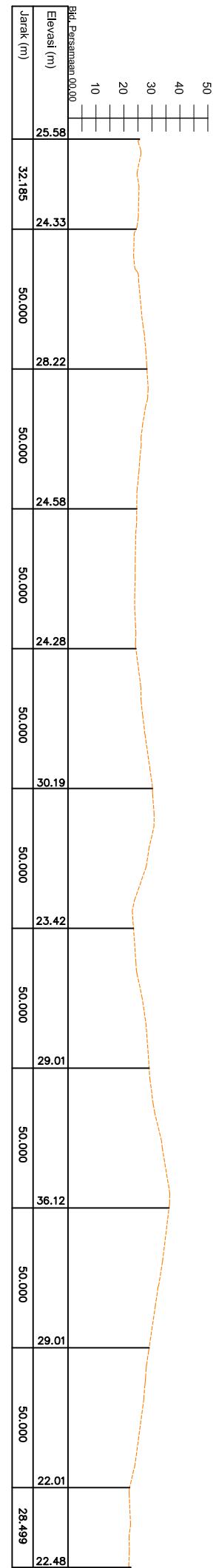
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0 20 40  
0 1 2 4 cm  
**SCALE 1:2000**  
**H = V**

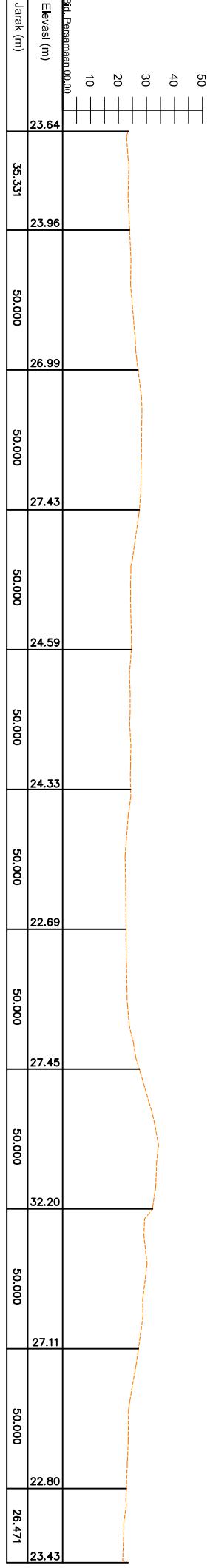
**A**



F-F'



G-G'



H-H'

**RATCH**  
RATCHADABURI HOLDINGS CO., LTD.

**OWNER :**  
RATCHADABURI HOLDINGS CO., LTD.

**CONTRACT NO. :**  
RATCHADABURI HOLDINGS CO., LTD.

**CONSULTANT :**  
RATCHADABURI HOLDINGS CO., LTD.

**PT. WAHANA GUNA MANDIRI**  
*Engineering and management consultant*

**PROJECT :**  
Soil Investigation, Soil Improvement, and Topography Study  
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located in Riau, Indonesia

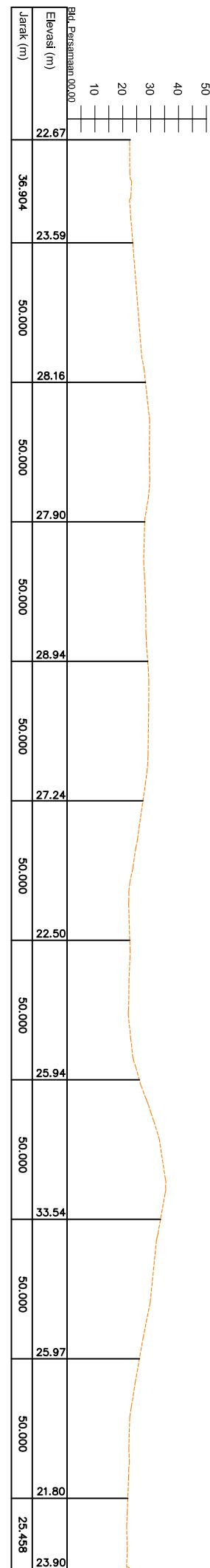
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**CROSS SECTION**

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**DRAWN** 07-06-2017  
**CHECKED**  
**APPROVED**

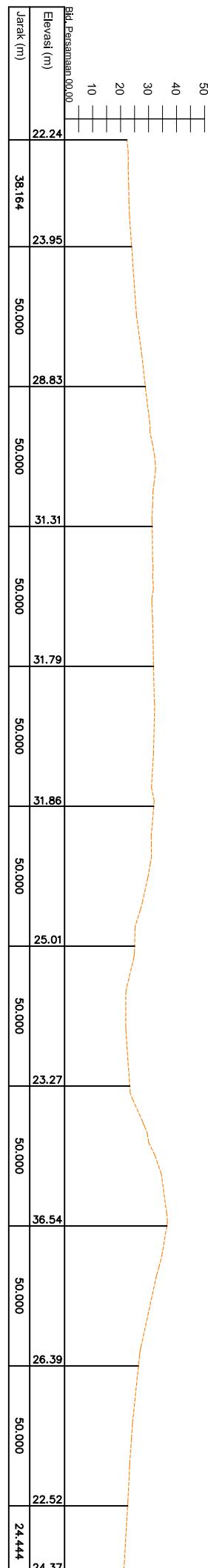
**H**  
**PAGES :** 16/18  
**REV.:**

**A3**  
1 2 3 4 5 6 7 8 9 10 11 12

0 20 40  
0 1 2 4 cm  
SCALE 1:2000  
H = V



|—|'



J—J'

F

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D

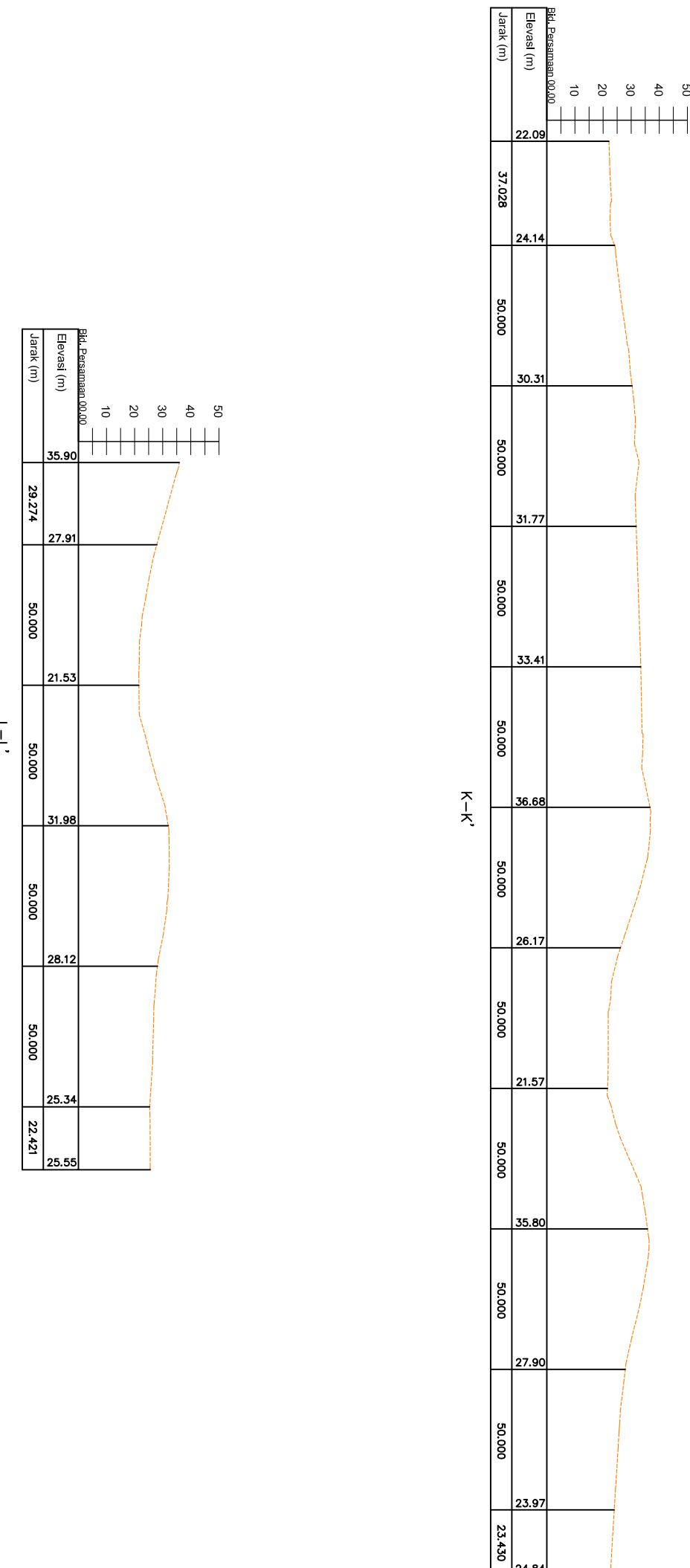
C

B

A

| 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 |
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| 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 |
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| 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 |
| 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 |
| 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 |

0 20 40  
0 1 2 4 cm  
SCALE 1:2000  
 $H = V$



| 1  | 2          | 3     | 4 | 5    | 6 | 7         | 8 | 9      | 10 | 11   | 12 |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
|--|------------|-------|---|------|---|-----------|---|--------|----|------|----|---------|--|---|--|------|--|-----------|--|--------|--|------|--|-------|------------|-------|--|--|--|--|--|--|--|--|---------|--|--|--|--|--|--|--|--|--|--|----------|--|--|--|--|--|--|--|--|--|--|
| A3   | 1          | 2     | 3 | 4    | 5 | 6         | 7 | 8      | 9  | 10   |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| H  |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| G  |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| F  |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| E  |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| D  |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| C  |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| B  |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| A  |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| <p style="text-align: center;">CROSS SECTION</p> <table border="1"> <tr> <td colspan="2">DWG No:</td> <td colspan="2">-</td> <td colspan="2">DATE</td> <td colspan="2">SIGNATURE</td> <td colspan="2">PAGES:</td> <td colspan="2">REV.</td> </tr> <tr> <td>DRAWN</td> <td>07-06-2017</td> <td>18/18</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>CHECKED</td> <td></td> </tr> <tr> <td>APPROVED</td> <td></td> </tr> </table> <p style="text-align: center;">H</p> <p>PROJECT : Soil Investigation, Soil Improvement, and Topography Study applicable to Gas Fired Power Plant Project 275 MW located in Riau, Indonesia</p> <p>TITLE :</p> <p>PT. WAHANA GUNA MANDIRI<br/>Engineering and management consultant</p> <p>W</p> <p>REV. 1</p> |            |       |   |      |   |           |   |        |    |      |    | DWG No: |  | - |  | DATE |  | SIGNATURE |  | PAGES: |  | REV. |  | DRAWN | 07-06-2017 | 18/18 |  |  |  |  |  |  |  |  | CHECKED |  |  |  |  |  |  |  |  |  |  | APPROVED |  |  |  |  |  |  |  |  |  |  |
| DWG No:  |            | -     |   | DATE |   | SIGNATURE |   | PAGES: |    | REV. |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| DRAWN  | 07-06-2017 | 18/18 |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| CHECKED  |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |
| APPROVED   |            |       |   |      |   |           |   |        |    |      |    |         |  |   |  |      |  |           |  |        |  |      |  |       |            |       |  |  |  |  |  |  |  |  |         |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |

## **APPENDIX B**

### Description of Benchmark

## DESCRIPTION OF BENCH MARK DESKRIPSI BENCH MARK

|                            |           |                             |                |
|----------------------------|-----------|-----------------------------|----------------|
| <b>Location / Lokasi</b>   | : Tenayan | <b>District / Kecamatan</b> | : Tenayan Raya |
| <b>Village / Kampung</b>   | : Tenayan | <b>Regency / Kabupaten</b>  | : Pekanbaru    |
| <b>Sub District / Desa</b> | : Tenayan | <b>Province / Propinsi</b>  | : Riau         |

**BENCH MARK PHOTO / FOTO BENCH MARK**



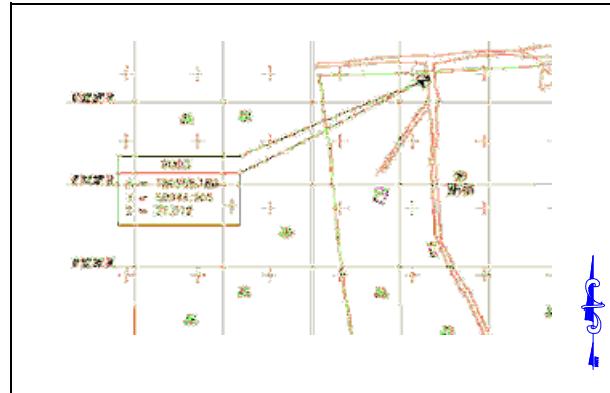
| <b>COORDINATE SYSTEM :</b><br>SISTEM KOORDINAT : |          | <b>PROJECTION COORDINATE</b><br>KOORDINAT PROYEKSI  |  |  |  |
|--|----------|---|--|--|--|
| <u>Map Projection</u><br>Proyeksi Peta           | UTM      | <u>Number</u><br>Nomor                              | <u>Easthing ( E )</u><br>Absis ( X ) m | <u>Northing ( N )</u><br>Ordinat ( Y ) m | <u>Elevation ( H )</u><br>Tinggi ( Z ) m |
| <u>Horizontal Datum</u><br>Datum Horisontal      | WGS-1984 | BM 03   | 780508.180                             | 59944.905                                | 27.072                                   |
| <u>Z o n e</u><br>Zona                           | 47 N     | <b>GEOGRAPHYC COORDINATE</b><br>KOORDINAT GEOGRAFIS |  |  |  |
| <b>ELEVATION SYSTEM :</b><br>SISTEM TINGGI :     |          | <u>Latitude ( j )</u><br>Lintang ( L )              | <u>Longitude ( l )</u><br>Bujur ( B )  |  |  |
| <u>Vertical Datum</u><br>Datum Vertikal          |          | 0° 32' 30.52"                                       | 101° 31' 12.54"                        |  |  |

### **LOCATION SKETCH OF ABOUT / SKETSA LOKASI SEKITAR :**

#### **GENERAL SKETCH/SKET UMUM**



#### **DETAIL SKETCH/SKET DETAIL**



### **INFORMATION / INFORMASI :**

**BM 03** Located inside a palm plantation (on plantation road side)/Terletak di dalam kebun sawit (di pinggir jalan kebun).

## DESCRIPTION OF BENCH MARK DESKRIPSI BENCH MARK

|                            |           |                             |                |
|----------------------------|-----------|-----------------------------|----------------|
| <i>Location / Lokasi</i>   | : Tenayan | <i>District / Kecamatan</i> | : Tenayan Raya |
| <i>Village / Kampung</i>   | : Tenayan | <i>Regency / Kabupaten</i>  | : Pekanbaru    |
| <i>Sub District / Desa</i> | : Tenayan | <i>Province / Propinsi</i>  | : Riau         |

*BENCH MARK PHOTO / FOTO BENCH MARK*



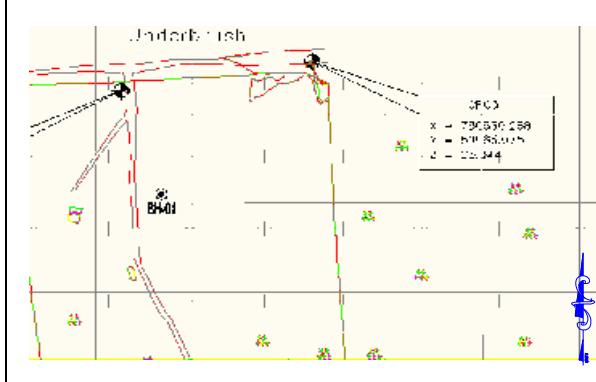
| <i>COORDINATE SYSTEM :</i><br>SISTEM KOORDINAT : |          | <i>PROJECTION COORDINATE</i><br>KOORDINAT PROYEKSI  |  |  |  |
|--|----------|---|--|--|--|
| <i>Map Projection</i><br>Proyeksi Peta           | UTM      | <i>Number</i><br>Nomor                              | <i>Easthing ( E )</i><br>Absis ( X ) m | <i>Northing ( N )</i><br>Ordinat ( Y ) m | <i>Elevation ( H )</i><br>Tinggi ( Z ) m |
| <i>Horizontal Datum</i><br>Datum Horisontal      | WGS-1984 | CP 03   | 780630.268                             | 59965.075                                | 23.044                                   |
| <i>Z o n e</i><br>Z o n a                        | 47 N     | <i>GEOGRAPHYC COORDINATE</i><br>KOORDINAT GEOGRAFIS |  |  |  |
| <i>ELEVATION SYSTEM :</i><br>SISTEM TINGGI :     |          | <i>Latitude ( i )</i><br>Lintang ( L )              | <i>Longitude ( l )</i><br>Bujur ( B )  |  |  |
| <i>Vertical Datum</i><br>Datum Vertikal          |          | 0° 32' 31.17"                                       | 101° 31' 16.49"                        |  |  |

*LOCATION SKETCH OF ABOUT / SKETSA LOKASI SEKITAR :*

*GENERAL SKETCH/SKET UMUM*



*DETAIL SKETCH/SKET DETAIL*



*INFORMATION / INFORMASI :*

CP 03 Located on the road side/ Terletak di Pinggir Jalan

## **APPENDIX C**

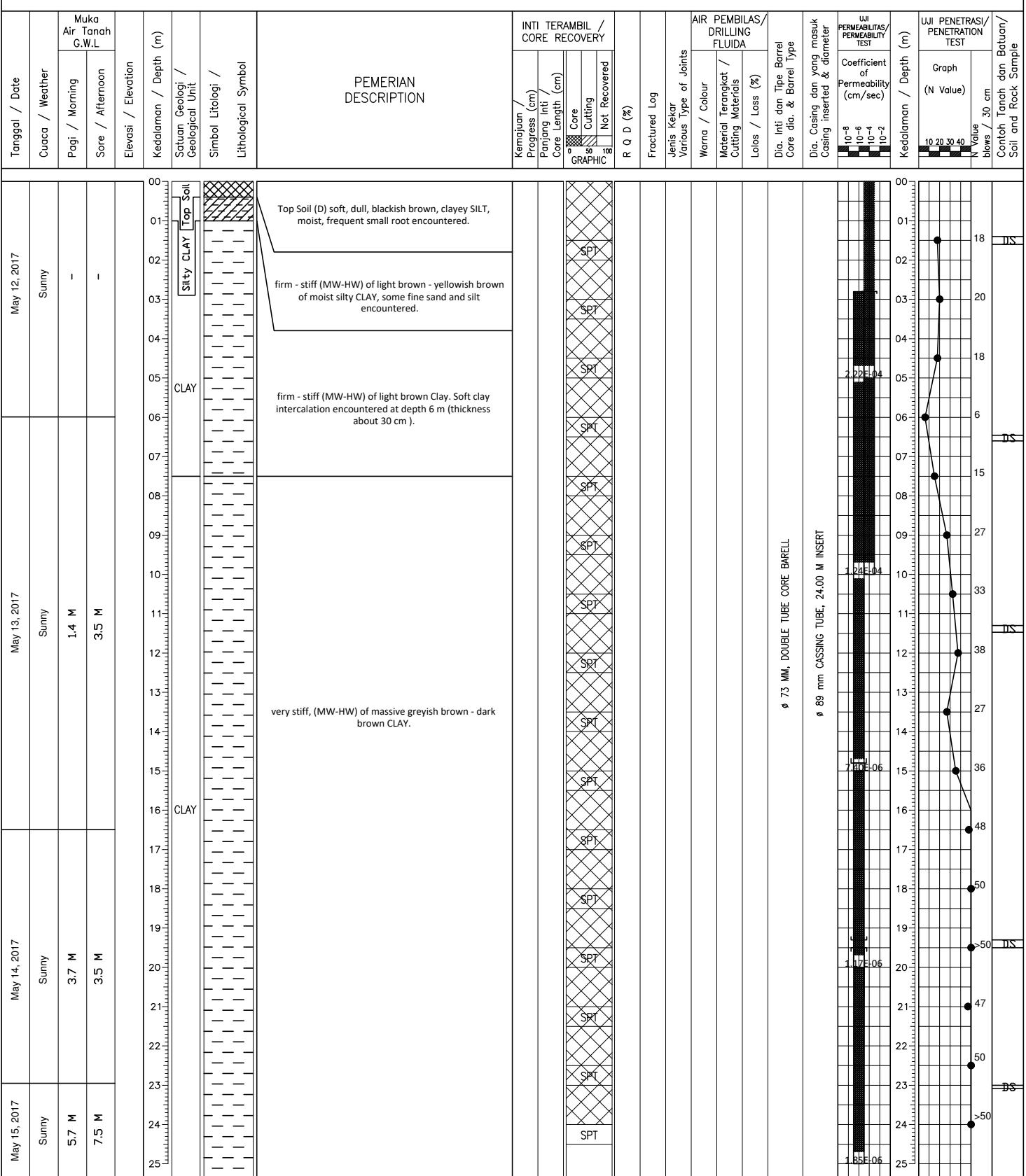
### Borehole Log

## LOG BOR GEOLOGI / GEOLOGICAL DRILLING LOG

NO. LUBANG BOR  
BORE HOLE NUMBER

BH-01(1/2)

|  |  |                                     |             |                            |                |                                |              |
|--|--|-------------------------------------|-------------|----------------------------|----------------|--------------------------------|--------------|
| Proyek / Project :                         | SITE INVESTIGATION<br>RIAU GFPP (275 MW) | Metoda Pemboran / Drilling Method : | Rotary      | Mesin Bor / Bore Machine : | YBM            | Juru Bor / Bore Master :       | Iman F       |
| Lokasi / Location :                        | Tenayan<br>Riau Province, Indonesia      | Inklinasi / Inclination :           | Vertical    | Mulai / Start :            | May 11th, 2017 | Log olch / Log by :            | Ar Muttaqien |
| Daerah Pengamatian / Area of Designation : | -  | Kedalaman / Depth :                 | 30.00 m     | Selesai / Finished :       | May 16th, 2017 | Diperiksa oleh / Checked by :  | Fadhl        |
| Koordinat / Coordinate :                   | X = 780533.75<br>Y = 59873.54            | Elevasi / Elevation :               | Z = 28.62 m | Skala / Scale :            | 1 : 100        | Disetujui oleh / Approved by : | -            |



CORE BARREL TYPE

- STCB : Single Tube Core Barrel
- DTCB : Double Tube Core Barrel
- TTCB : Triple Tube Core Barrel

WEATHERING CONDITION

- 1. Fresh Rock : (F)
- 2. Slightly Weathered Rock : (SW)
- 3. Moderately Weathered Rock : (MW)
- 4. Highly Weathered Rock : (HW)
- 5. Completely Weathered Rock : (CW)
- 6. Decomposed : (D)

ROCK STRUCTURES AND DISCONTINUITIES

- Broken Core
- Various Type of Joints

R.Q.D

- |            |             |
|------------|-------------|
| 90 - 100 % | : Excellent |
| 75 - 90 %  | : Good      |
| 50 - 75 %  | : Fair      |
| 25 - 50 %  | : Poor      |
| < 25 %     | : Very Poor |

FRACTURE LOG

- 1. 1 Joint / m
- 2. 1 - 5 Joints / m
- 3. 6 - 10 Joints / m
- 4. 11 - 20 Joints / m
- 5. > 20 Joints / m

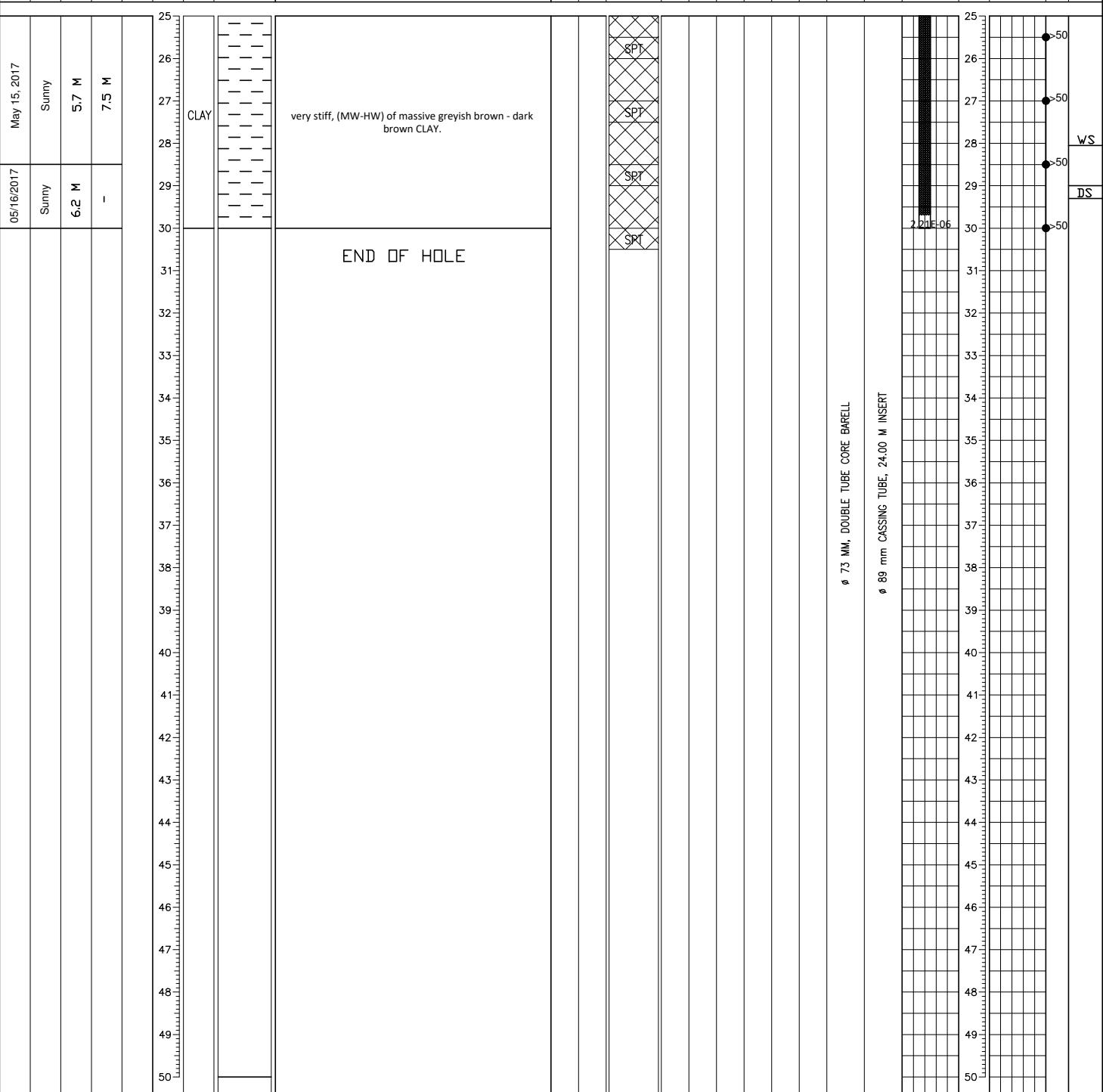
**LOG BOR GEOLOGI / GEOLOGICAL DRILLING LOG**

NO. LUBANG BOR  
BORE HOLE NUMBER

**BH-01(2/2)**

|   |  |   |  |  |
|---|--|---|--|--|
| Proyek / Project :                        | SITE INVESTIGATION<br>RIAU GFPP (275 MW) | Metoda Pemboran / Drilling Method :<br>Rotary | Mesin Bor / Bore Machine :<br>YBM      | Juru Bor / Bore Master :<br>Iman F     |
| Lokasi / Location :                       | Tenayan<br>Riau Province, Indoensia      | Inklinasi / Inclination :<br>Vertical         | Mulai / Start :<br>May 11th, 2017      | Log oleh / Log by :<br>Ar Muttaqien    |
| Daerah Pengamatan / Area of Designation : | -  | Kedalaman / Depth :<br>30.00 m                | Selesai / Finished :<br>May 16th, 2017 | Diperiksa oleh / Checked by :<br>Fadhl |
| Koordinat / Coordinate :                  | X = 780533.75<br>Y = 59873.54            | Elevasi / Elevation :<br>Z = 28.62 m          | Skala / Scale :<br>1 : 100             | Disetujui oleh / Approved by :<br>-    |

| Tanggal / Date | Cuaca / Weather  | Muka Air Tanah G.W.L | Kedalaman / Depth (m)            | PEMERIAN DESCRIPTION                  | INTI TERAMBIL / CORE RECOVERY | Kemajuan / Progress (cm) | Panjang Inti / Core Length (cm) | AIR PEMBILAS / DRILLING FLUIDA | UJI PERMEABILITAS / PERMEABILITY TEST | UJI PENETRASI / PENETRATION TEST |
|----------------|------------------|----------------------|----------------------------------|---------------------------------------|-------------------------------|--------------------------|---------------------------------|--------------------------------|---------------------------------------|----------------------------------|
| Pagi / Morning | Sore / Afternoon |                      | Solusi Geologi / Geological Unit | Simbol Litologi / Lithological Symbol | R Q D (%)                     | Core                     | Cutting                         | Not Recovered                  | Coefficient of Permeability (cm/sec)  | Graph (N Value)                  |


**CORE BARREL TYPE**

STCB : Single Tube Core Barrel  
DTCB : Double Tube Core Barrel  
TTCB : Triple Tube Core Barrel

**WEATHERING CONDITION**

1. Fresh Rock : (F)
- 
2. Slightly Weathered Rock : (SW)
- 
3. Moderately Weathered Rock : (MW)
- 
4. Highly Weathered Rock : (HW)
- 
5. Completely Weathered Rock : (CW)
- 
6. Decomposed : (D)

**ROCK STRUCTURES AND DISCONTINUITIES**

**R.Q.D**

90 - 100 % : Excellent  
75 - 90 % : Good  
50 - 75 % : Fair  
25 - 50 % : Poor  
< 25 % : Very Poor

**FRACTURE LOG**

1. 1 Joint / m
- 
2. 1 - 5 Joints / m
- 
3. 6 - 20 Joints / m
- 
4. 11 - 20 Joints / m
- 
5. > 20 Joints / m

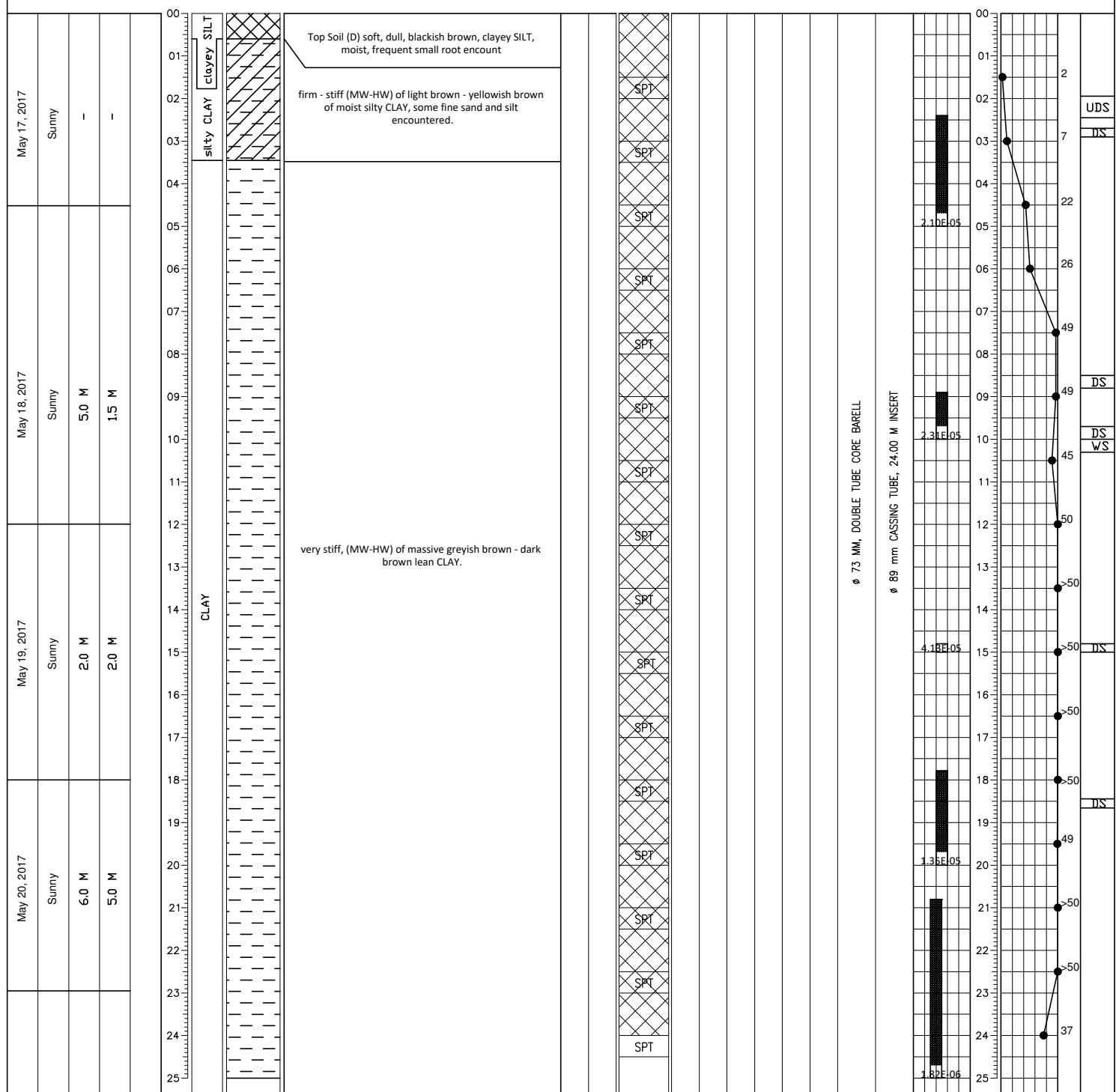
# LOG BOR GEOLOGI / GEOLOGICAL DRILLING LOG

NO. LUBANG BOR  
BORE HOLE NUMBER

BH-02(1/2)

|   |  |                                     |             |                            |                |                                |              |
|---|--|-------------------------------------|-------------|----------------------------|----------------|--------------------------------|--------------|
| Proyek / Project :                        | SITE INVESTIGATION<br>RIAU GFPP (275 MW) | Metoda Pemboran / Drilling Method : | Rotary      | Mesin Bor / Bore Machine : | YBM            | Juru Bor / Bore Master :       | Iman F       |
| Lokasi / Location :                       | Tenayan<br>Riau Province, Indonesia      | Inklinasi / Inclination :           | Vertical    | Mulai / Start :            | May 17th, 2017 | Log oleh / Log by :            | Ar Muttaqien |
| Daerah Pengamatan / Area of Designation : | -  | Kedalaman / Depth :                 | 30.00 m     | Selesai / Finished :       | May 21st, 2017 | Diperiksa oleh / Checked by :  | Fadhilli     |
| Koordinat / Coordinate :                  | X = 780544.97<br>Y = 59711.44            | Elevasi / Elevation :               | Z = 28.97 m | Skala / Scale :            | 1 : 100        | Disetujui oleh / Approved by : | -            |

| Tanggal / Date | Cuaca / Weather | Muka Air Tanah G.W.L | Kedalaman / Depth (m) | Elevasi / Elevation | PEMERIAN DESCRIPTION | INTI TERAMBIL / CORE RECOVERY | AIR PEMBILAS/ DRILLING FLUIDA | UJI PERMEABILITAS/ PERMEABILITY TEST | UJI PENETRASI/ PENETRATION TEST |
|----------------|-----------------|----------------------|-----------------------|---------------------|----------------------|-------------------------------|-------------------------------|--------------------------------------|---------------------------------|
|                |                 |                      |                       |                     |                      |                               |                               |                                      |                                 |



#### CORE BARREL TYPE

- STCB : Single Tube Core Barrel  
DTCB : Double Tube Core Barrel  
TTCB : Triple Tube Core Barrel

#### WEATHERING CONDITION

1. Fresh Rock : (F)
2. Slightly Weathered Rock : (SW)
3. Moderately Weathered Rock : (MW)
4. Highly Weathered Rock : (HW)
5. Completely Weathered Rock : (CW)
6. Decomposed : (D)

#### ROCK STRUCTURES AND DISCONTINUITIES

- Broken Core  
Various Type of Joints

#### R.Q.D

- 90 - 100 % : Excellent  
75 - 90 % : Good  
50 - 75 % : Fair  
25 - 50 % : Poor  
< 25 % : Very Poor

#### FRACTURE LOG

1. 1 Joint / m
2. 1 - 5 Joints / m
3. 6 - 10 Joints / m
4. 11 - 20 Joints / m
5. > 20 Joints / m



# LOG BOR GEOLOGI / GEOLOGICAL DRILLING LOG

NO. LUBANG BOR  
*BORE HOLE NUMBER*

BH-02(2/2)

|   |  |                                     |             |                            |                |                                |              |
|---|--|-------------------------------------|-------------|----------------------------|----------------|--------------------------------|--------------|
| Proyek / Project :                        | SITE INVESTIGATION<br>RIAU GFFF (275 MW) | Metoda Pemboran / Drilling Method : | Rotary      | Mesin Bor / Bore Machine : | YBM            | Juru Bor / Bore Master :       | Henri A      |
| Lokasi / Location :                       | Tenayan<br>Riau Province, Indonesia      | Inklinasi / Inclination :           | Vertical    | Mulai / Start :            | May 17th, 2017 | Log oleh / Log by :            | Ar Muttaqien |
| Daerah Pengamatan / Area of Designation : | -  | Kedalaman / Depth :                 | 30.00 m     | Selesai / Finished :       | May 21st, 2017 | Diperiksa oleh / Checked by :  | Fadhl        |
| Koordinat / Coordinate :                  | X = 780544.97<br>Y = 59711.44            | Elevasi / Elevation :               | Z = 28.97 m | Skala / Scale :            | 1 : 100        | Disetujui oleh / Approved by : | -            |

CORE BARREL TYPE  
STCB : Single Tube Core Barrel  
DTCB : Double Tube Core Barrel

#### WEATHERING CONDITION

- WEATHERING CONDITION

  1. Fresh Rock : (F)
  2. Slightly Weathered Rock : (SW)
  3. Moderately Weathered Rock : (MW)
  4. Highly Weathered Rock : (HW)
  5. Completely Weathered Rock : (CW)
  6. Decomposed : (D)

BLOCK STRUCTURES AND DISCONTINUITIES

 Broken Core  
 Various Type of Joints

|            |             |
|------------|-------------|
| R.Q.D      |             |
| 90 - 100 % | : Excellent |
| 75 - 90 %  | : Good      |
| 50 - 75 %  | : Fair      |
| 25 - 50 %  | : Poor      |
| < 25 %     | : Very Poor |

FRACTURE LOG

1. 1 Joint / m
  2. 1 - 5 Joints / m
  3. 6 - 10 Joints / m
  4. 11 - 20 Joints / m
  5. > 20 Joints / m

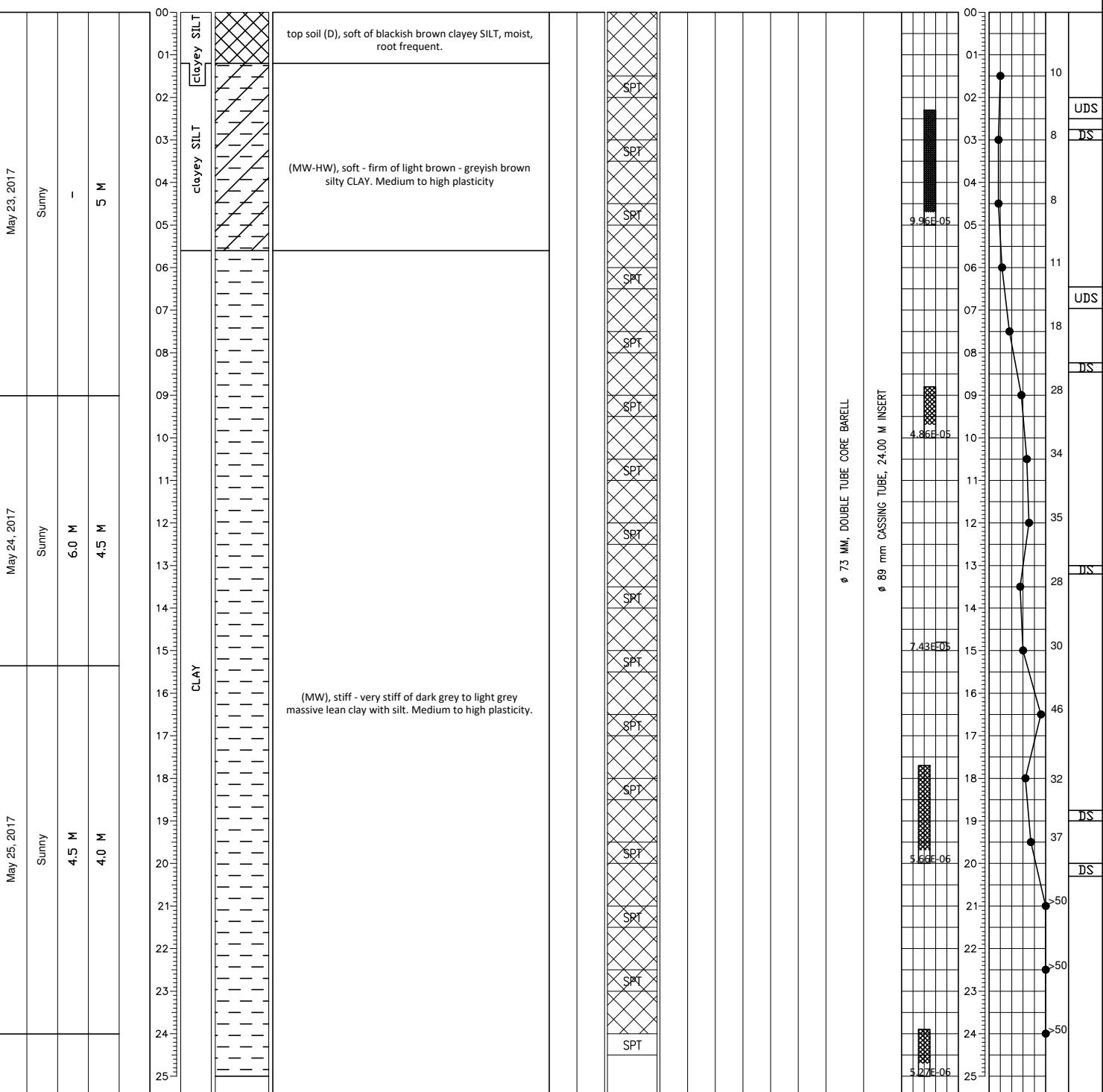
## LOG BOR GEOLOGI / GEOLOGICAL DRILLING LOG

NO. LUBANG BOR  
BORE HOLE NUMBER

BH-03(1/2)

|   |   |                                     |             |                            |                |                                |              |
|---|---|-------------------------------------|-------------|----------------------------|----------------|--------------------------------|--------------|
| Proyek / Project :                        | SITE INVESTIGATION<br>RIAU GPP (275 MW) | Metoda Pemboran / Drilling Method : | Rotary      | Mesin Bor / Bore Machine : | YBM            | Juru Bor / Bore Master :       | Iman F       |
| Lokasi / Location :                       | Tenayan<br>Riau Province, Indonesia     | Inklinasi / Inclination :           | Vertical    | Mulai / Start :            | May 23rd, 2017 | Log oleh / Log by :            | Ar Muttaqien |
| Daerah Pengamatan / Area of Designation : | -                                       | Kedalaman / Depth :                 | 30.00 m     | Selesai / Finished :       | May 26th, 2017 | Diperiksa oleh / Checked by :  | Fadhl        |
| Koordinat / Coordinate :                  | X = 780566.52<br>Y = 59551.52           | Elevasi / Elevation :               | Z = 31.05 m | Skala / Scale :            | 1 : 100        | Disetujui oleh / Approved by : | -            |

| Tanggal / Date | Cuaca / Weather | Muka Air Tanah G.W.L | Kedalaman / Depth (m) | Satuan Geologi / Geological Unit | Symbol Litologi / Lithological Symbol | PEMERIAN DESCRIPTION |                       | INTI TERAMBIL / CORE RECOVERY | Kemajuan Progress (cm) | Panjang Inti Core Length (cm) | AIR PEMBILAS/ DRILLING FLUIDA | UJI PERMEABILITAS/ PERMEABILITY TEST | UJI PENETRASI/ PENETRATION TEST |  |
|----------------|-----------------|----------------------|-----------------------|----------------------------------|---------------------------------------|----------------------|-----------------------|-------------------------------|------------------------|-------------------------------|-------------------------------|--------------------------------------|---------------------------------|--|
|                |                 |                      |                       |                                  |                                       | Elevasi / Elevation  | Kedalaman / Depth (m) |                               |                        |                               |                               |                                      |                                 |  |
|                |                 |                      |                       |                                  |                                       |                      |                       |                               |                        |                               |                               |                                      |                                 |  |



CORE BARREL TYPE

STCB : Single Tube Core Barrel  
DTCB : Double Tube Core Barrel  
TTCB : Triple Tube Core Barrel

WEATHERING CONDITION

1. Fresh Rock : (F)
2. Slightly Weathered Rock : (SW)
3. Moderately Weathered Rock : (MW)
4. Highly Weathered Rock : (HW)
5. Completely Weathered Rock : (CW)
6. Decomposed : (D)

ROCK STRUCTURES AND DISCONTINUITIES



R.Q.D

- |            |             |
|------------|-------------|
| 90 - 100 % | : Excellent |
| 75 - 90 %  | : Good      |
| 50 - 75 %  | : Fair      |
| 25 - 50 %  | : Poor      |
| < 25 %     | : Very Poor |

FRACTURE LOG

1. 1 Joint / m
2. 1 - 5 Joints / m
3. 6 - 10 Joints / m
4. 11 - 20 Joints / m
5. > 20 Joints / m

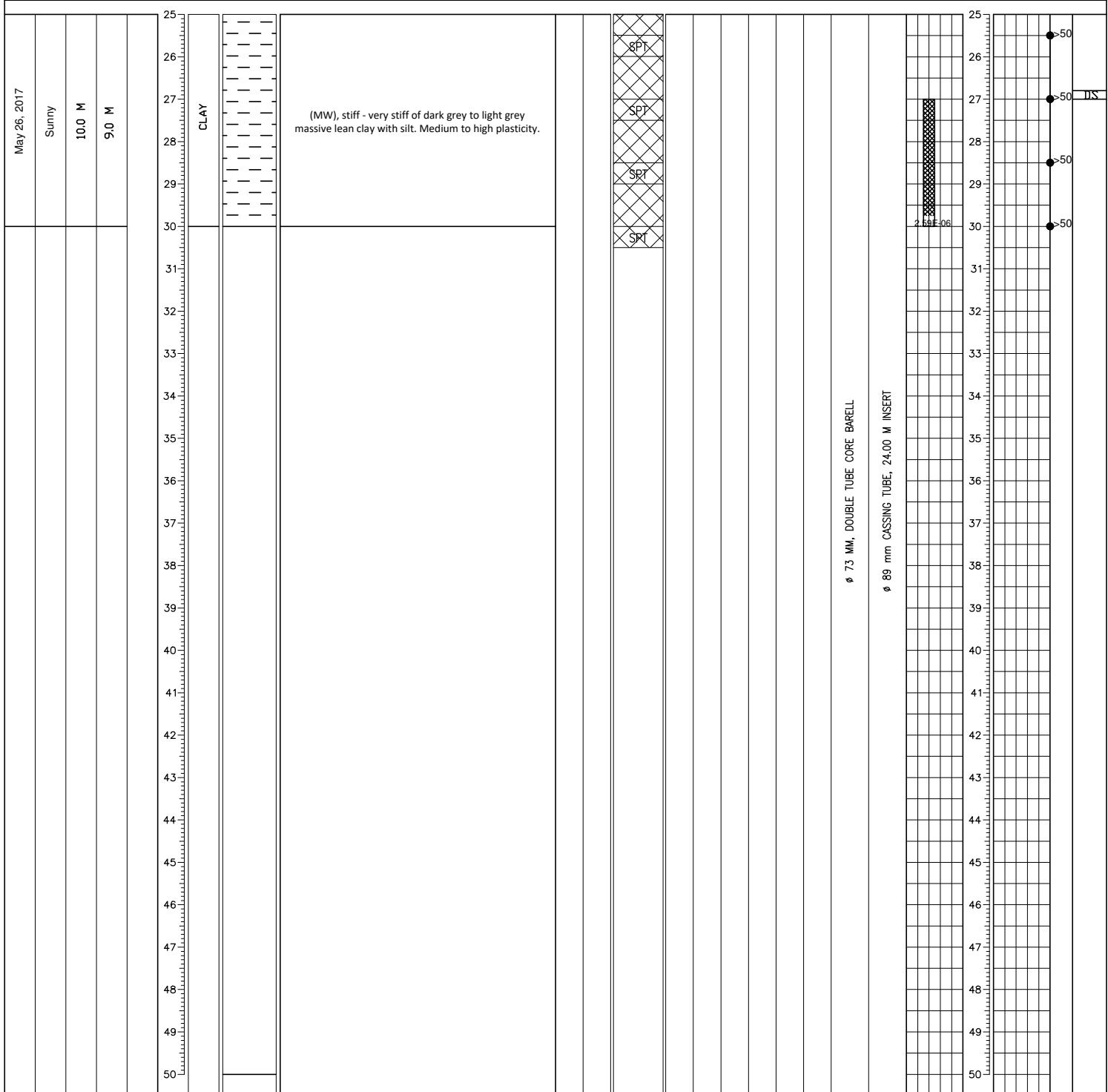
# LOG BOR GEOLOGI / GEOLOGICAL DRILLING LOG

NO. LUBANG BOR  
BORE HOLE NUMBER

BH-03(2/2)

|   |  |                                     |             |                            |                |                                |              |
|---|--|-------------------------------------|-------------|----------------------------|----------------|--------------------------------|--------------|
| Proyek / Project :                        | SITE INVESTIGATION<br>RIAU GFPP (275 MW) | Metoda Pemboran / Drilling Method : | Rotary      | Mesin Bor / Bore Machine : | YBM            | Juru Bor / Bore Master :       | Henri A      |
| Lokasi / Location :                       | Tenayan<br>Riau Province, Indonesia      | Inklinasi / Inclination :           | Vertical    | Mulai / Start :            | May 23rd, 2017 | Log oleh / Log by :            | Ar Muttaqien |
| Daerah Pengamatan / Area of Designation : | -  | Kedalaman / Depth :                 | 30.00 m     | Selesai / Finished :       | May 26th, 2017 | Diperiksa oleh / Checked by :  | Fadhl        |
| Koordinat / Coordinate :                  | X = 780566.52<br>Y = 59551.52            | Elevasi / Elevation :               | Z = 31.05 m | Skala / Scale :            | 1 : 100        | Disetujui oleh / Approved by : | -            |

| Tanggal / Date | Cuaca / Weather | Muka Air Tanah G.W.L | Kedalaman / Depth (m) | Satuan Geologi / Geological Unit | Simbol Litologi / Lithological Symbol | PEMERIAN DESCRIPTION  | INTI TERAMBIL / CORE RECOVERY | AIR PEMBILAS/ DRILLING FLUIDA   | UJI PERMEABILITAS/ PERMEABILITY TEST | UJI PENETRASI/ PENETRATION TEST |               |           |                 |                 |
|----------------|-----------------|----------------------|-----------------------|----------------------------------|---------------------------------------|---|-------------------------------|---------------------------------|--------------------------------------|---------------------------------|---------------|-----------|-----------------|-----------------|
|                |                 |                      |                       |                                  |                                       |   | Kemajuan / Progress (cm)      | Panjang inti / Core Length (cm) | Core                                 | Cutting                         | Not Recovered | R Q D (%) | Graph (N Value) | Graph (N Value) |
| May 26, 2017   | Sunny           | 10.0 M               | 9.0 M                 | CLAY                             |                                       | (MW), stiff - very stiff of dark grey to light grey massive lean clay with silt. Medium to high plasticity. |                               |                                 |                                      |                                 |               |           |                 |                 |



#### CORE BARREL TYPE

- STCB : Single Tube Core Barrel  
DTCB : Double Tube Core Barrel  
TTCB : Triple Tube Core Barrel

#### WEATHERING CONDITION

1. Fresh Rock : (F)
2. Slightly Weathered Rock : (SW)
3. Moderately Weathered Rock : (MW)
4. Highly Weathered Rock : (HW)
5. Completely Weathered Rock : (CW)
6. Decomposed : (D)

#### ROCK STRUCTURES AND DISCONTINUITIES

- Broken Core  
 Various Type of Joints

#### R.Q.D

- |            |             |
|------------|-------------|
| 90 - 100 % | : Excellent |
| 75 - 90 %  | : Good      |
| 50 - 75 %  | : Fair      |
| 25 - 50 %  | : Poor      |
| < 25 %     | : Very Poor |

#### FRACTURE LOG

1. Joint / m
2. 1 - 5 Joints / m
3. 6 - 10 Joints / m
4. 11 - 20 Joints / m
5. > 20 Joints / m