THE REPUBLIC OF INDONESIA
NATIONAL DISASTER MANAGEMENT
AUTHORITY

DATA COLLECTION SURVEY ON DISASTER RISK REDUCTION

Input from JICA for Sulawesi Reconstruction Master Plan

FEBRUARY 2019

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)
YACHIYO ENGINEERING CO., LTD.
ORIENTAL CONSULTANTS GLOBAL CO., LTD

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Table of contents

List of Figures

List of Tables

Appendix

- Progress of examination of liquefaction landslide (inland area)

Location Map

Source: U.S. Central Intelligence Agency 2002

CHAPTER 1. Background, purpose and outline of the survey

The disaster data in Indonesia has been collected including Tsunami, flood, sediment disaster and so on in this study as the data collection survey. Meanwhile, the Republic of Indonesia (hereinafter referred to as "Indonesia") has been struck by a major earthquake in September 28, 2018 with the magnitude of 7.4 in the middle of Sulawesi. After the earthquake struck the region, tsunami swallowed at the coastal area of the city as well as liquefied land destroyed number of buildings and houses.
As an emergency response, basic data related to this complex disaster were collected to input for sulawesi reconstruction master plan. The collected data includes the result of geological survey in liquefaction and land slide area in Kota Palu, Kab. Sigi and Kab. Donggala and also in relocation area.

This report shows input from JICA for sulawesi reconstruction master plan and an appendix indicates the result of geological survey.

CHAPTER 2. Purpose of Master Plan

Indonesia has been struck by a major earthquake in September 28, 2018 with the magnitude of 7.4 in the middle of Sulawesi. This devastating earthquake had shaken the region with the epicenter around 80km from Palu city, the capital of Central Sulawesi Province. After the earthquake struck the region, tsunami at several meters in height swallowed the coastal area of the city as well as liquefied land destroyed number of buildings and houses with large amount of casualties reported. According to the official announcement by Badan Nasional Penanggulangan Bencana (BNPB) on October 21st, 2018, death toll accounted at 2,256, missing toll at 1,309, and over 220 thousand people are forced to evacuate. Estimated total loss by the disaster accounts 13.8 trillion Rupiah (approx. 100 billion Japanese yen).

The government of Indonesia after the disaster all together tries to stand together to fight against the disaster effect and recover from it by the slogan of "A Better, Safer, More Sustainable Rehabilitation and Reconstruction." Under such circumstance, a large demand of restoration and reconstruction master plan is growing, and the Japanese government is seeking the way to support Indonesian government to formulate the master plan, which will effectively utilize disaster recovery and reconstruction experiences and technologies of Japan. Through the master plan formulation, disaster reconstruction will take smooth progress by scientific and technological approaches, and the master plan itself should seek continuous reconstruction of the damaged region towards better development in the future. The damage recovery and reconstruction shall not be stalled and the development shall benefit to the region, further the master plan shall contribute to the national development expressed in the national development plan.

Source: Prepared by JICA Mission Team

Figure 1 : Master Plan Target Region

2.1 Master Plan Target Area

The target of the master plan formulation is set in the disaster affected region of Palu, Sigi, Donggala and surrounding areas in Central Sulawesi Province. There are some significant condition before the disaster occurrence of the region described below.

Table 1 : Current Status of the Target Region (Population, Industry and Community)

	Palu	Sigi	Donggala
Population	342,754	215,030	277,620
Industry	Manufacturing, Fishery	Agriculture, Fishery	
Community	SMEs, Co-operative	SMEs, Agricultural Group, Fishery Group	

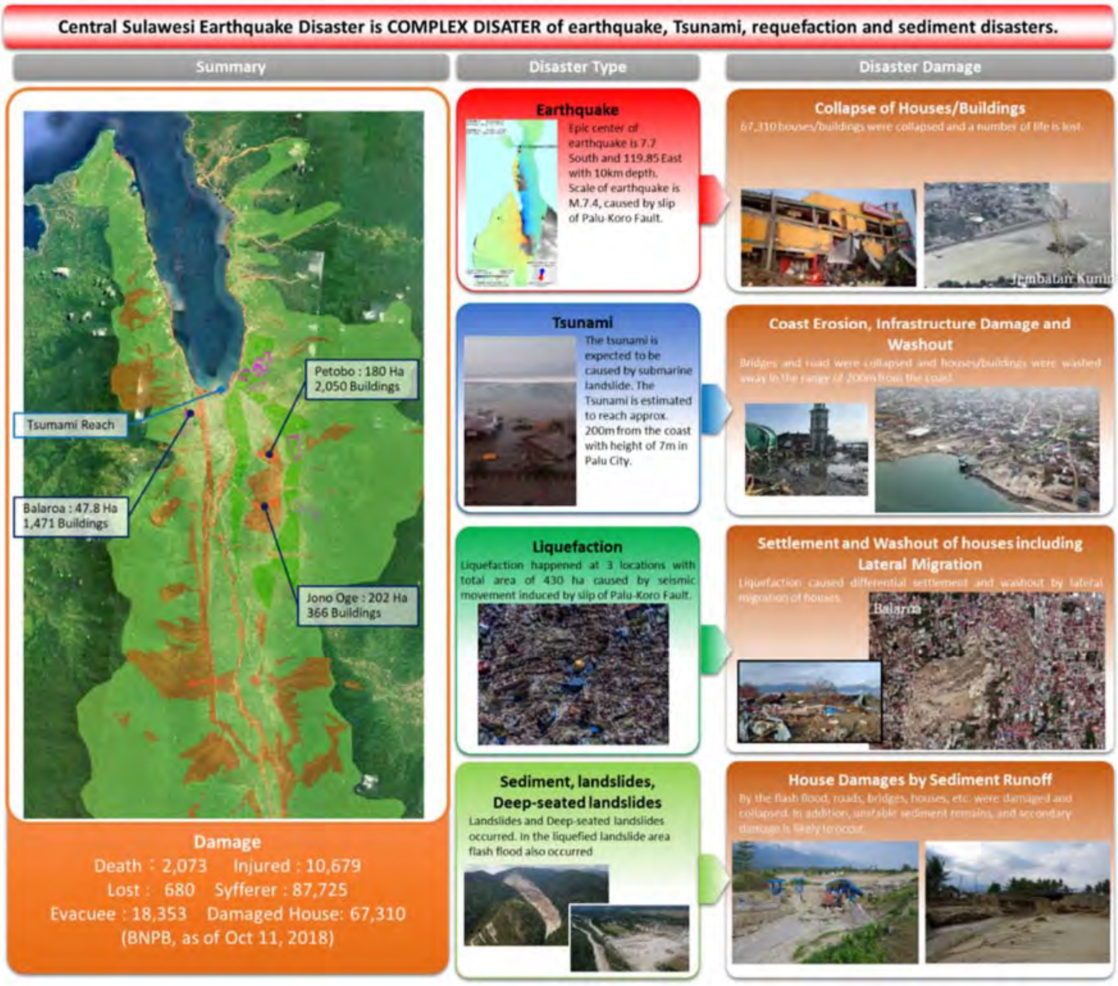
Source: Prepared by JICA Mission Team based on the government agencies provided data.

CHAPTER 3. Major Cause of Damage

The earthquake at magnitude 7.4 was triggered by the lateral deviation to the Palu-Koro fault, and caused number of major effects as listed below.

- Displacement of faults
- Major vibration to corrupt building structures
- Seabed layer slides to generate tsunami
- Liquefaction and landslide at inland locations

As listed above, devastating damages were caused by multiple events of disaster, and the affected area is relatively large. There are two disaster phases, and the first phase has brought major damages to the infrastructure, such as roads, ports, irrigation to the status of dysfunction. The second disaster phase then brought social damages to the region.



Central Sulawesi Earthquake Disaster is COMPLEX DISATER of earthquake, Tsunami, requefaction and sediment disasters.

Damage

Death : 2,073 Injured : 10,679
Lost : 680 Sytferer : 87,725
Evacuee : 18,353 Damaged House: 67,310
(BNPB, as of Oct 11, 2018)

Earthquake

Epic center of earthquake is 7.7 South and 119.85 East with 10km depth. Scale of earthquake is M.7.4, caused by slip of Palu-Koro Fault.

Collapse of Houses/Buildings

67,310 houses/buildings were collapsed and a number of life is lost.

Tsunami

The tsunami is expected to be caused by submarine landslide. The Tsunami is estimated to reach approx. 200m from the coast with height of 7m in Palu City.

Coast Erosion, Infrastructure Damage and Washout

Bridges and road were collapsed and houses/buildings were washed away in the range of 200m from the coast.

Liquefaction

Liquefaction happened at 3 locations with total area of 430 ha caused by seismic movement induced by slip of Palu-Koro Fault.

Settlement and Washout of houses including Lateral Migration

Liquefaction caused differential settlement and washout by lateral migration of houses.

Sediment, landslides, Deep-seated landslides

Landslides and Deep-seated landslides occurred. In the liquefied landslide area flash flood also occurred

House Damages by Sediment Runoff

By the flash flood, roads, bridges, houses, etc. were damaged and collapsed. In addition, unstable sediment remains, and secondary damage is likely to occur.

Source: JICA Mission Team

Figure 2 : Major Disaster Types and their Characteristics occurred in the Region

3.1 Earthquake damaged feature

In order to strategize how to formulate a master plan, it is important to understand current status of disaster damage features in the target region. The following section summarizes damage and current status of critical infrastructure, transportation, irrigation and social service infrastructures.

3.1.1 Road and bridge

(1) Bridges

There are total 82 bridges in Palu City and its perimeter. The table below shows the numbers and rate of the damaged bridges. Number of bridges without damage includes the bridges under construction (Culvert and Steel truss bridge).

Table 2 : Numbers and Rates of the Damaged Bridges

Item	Collapsed or Lost	Heavy Damage	Moderate Damage	Minor Damage	No Damage	Total
Number	2 (Jumbatan Palu Ⅳ) (East Coast)	3 (Donggala) (South Palu) (Pantloan)	3	61	13	82
Rate	2.4	3.7	3.7	74.4	15.8	100%

Source: JICA Mission Team

Table 3 : Legend of Damage Level

Damage Level	Description
Collapsed or Lost	Bridge that original shape is not kept, or it was lost by tsunami.
Heavy Damage	Damage such as cracks with heavy deformation, buckling, break of re-bar rod. Recovery of traffic requires much time.
Moderate Damage	Partial or local cracks, buckling, partial break of re-bar, separation of concrete. Traffic for rescue operation and transportation of help supplies is kept without restoring or within emergency treatment.
Minor Damage	By simple repair, restoring of original functions is possible.

Source: JICA Mission Team

- Damages

Most of the bridges in Palu Ciry and its perimeter were damaged by the earthquake. However, very little bridges were damaged compared with a damage rate in Japan. There are possibility that loosen sand layers, which triggered liquefaction, has been softened by the move of earthquake. Nevertheless the damages of revetment around bridges were observed everywhere. Twelve (12) steel truss bridges, which are very strong structure, keeps their shape without heavy damages. However, small damages to concrete structures have occurred because of the moves of their heavy weights.
One steel arch structure (Jembatan Palu Ⅳ) was destroyed by the earthquake move in north-south direction.

Collapsed Jembatan Palu Ⅳ

Hit of Girder on Abutment

(2) Roads

Damages of the arterial roads in the central area of Palu City are a little except sidewalks. Curbstones and pavement are still crushed without restoring. However, there are many affected sections by the earthquake observed on the arterial road along the coastal line heading for Donggala and Pantoloan. Cracked and waved roads due to earthquake are seen, even though some section were restored. The damage of the road becomes serious so as to approach the stricken area, cracked and partially turned into gravel.

Collapse of Road near Liquefaction Area

Damaged Road Surface by Tsunami

3.1.2 Port and Coastal Facilities

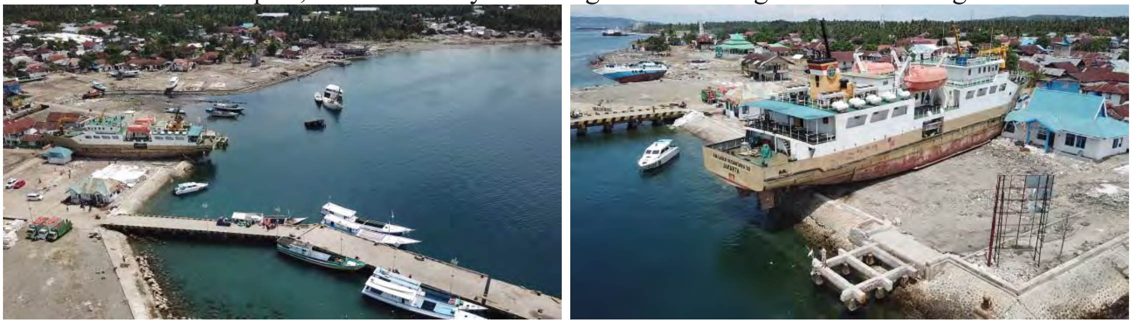
(1) Port

Located in the central part of Sulawesi Island, there are three major harbors in Palu Bay, Pantoloan Port, Wani Port and Donggala Port. Besides this, there are some scattered small-scale ports and private-owned harbors.
The port of Pantoloan is located in the northeastern part of the city of Palu, about 20 km from the city of Palu. It is the largest harbor in the bay. It is positioned as a major port in the National Port Master Plan formulated in 2017 and it is a major gateway to economic activities in the region. Pantoloan Port is a commercial port, and Perindo 4, a state-owned port management company, is managing and operating the port. A regular route is in service between Makassar in the southern part of Sulawesi Island, Balikpapan in Kalimantan Island and Surabaya in Java Island.
Wani Port and Donggala Port are located in the administrative area of Donggala, unlike Pantoloan Port located in the administrative area of Palu City, Wani Port is 3 km north of Pantoloan Port, Donggala Port is Pull City Northwest, It is located about 40 km away from the city of Palu. Both ports are positioned as logistically collector ports in the nationwide port master plan and serve as a base for transporting goods in the port area. Both ports are non-commercial ports, and the management and operation of the ports is carried out by a port operation unit (umbrella of Ministry of Transportation of Indonesia).
In the city area in the Palu Bay including Palu City, the front is surrounded by the Palu Bay and the back is a mountain, and each urban area is connected by a road running along the coast, but from the eastern urban area to the western urban area on land Movement needs to detour greatly around Palu Bay (about 60 km from Donggara Port to Wani Port). For this reason, ports such as Pantoloan Port are important centers for economic activities in each area of the Palu Bay.
In addition, the road running west of the Palu bay is maintained so that the mountain is close to the coast, so it is in line with a steep slope, and in the event that a sediment disaster occurs, transportation of goods will have no choice but to rely on maritime transport. The road is also being maintained in the west side beyond the mountain, but it is similarly maintained along the steep slope along the coast.

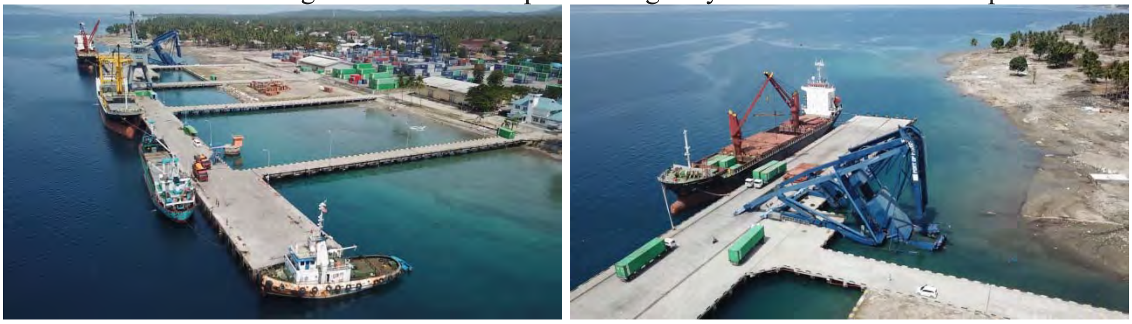
- Pantloan Port
  - Infrastructure of the Port was hardly damaged and can be used.
  - Cranes were damaged and need to be replaced.

  - Road from this port to urban area is fine, so this port can be utilized as a transportation base for restoration and reconstruction.
- Wani & Donggara Port
  - Both ports were heavily damaged by earthquake and tsunami.
  - In Wani Port, there are a lots of Debris and Wastes caused by tsunami and the Dock next to port was also destroyed.
  - In Wani Port, several ships were stranded by tsunami. This can be utilized as Memorial place.
  - In both ports, a restoration and reconstruction policy of port facilities include disposal of Debris and Wastes based on the further survey and assessment.

Wani Port: Seawall / pier, behind facility / housing and other huge tsunami damage. Boat ride

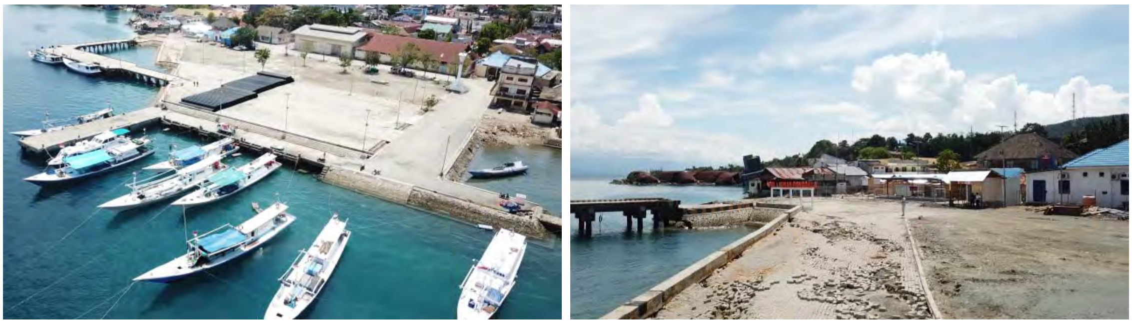


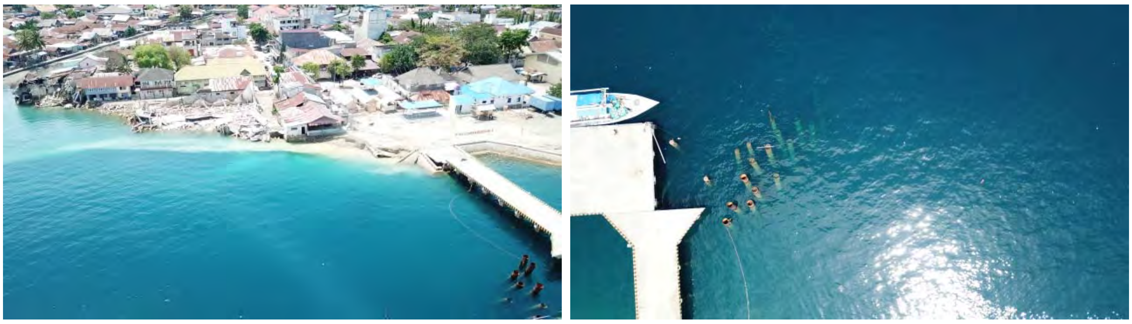
Pantoloan Port: The damage is limited. Collapse of the gantry crane due to the earthquake.



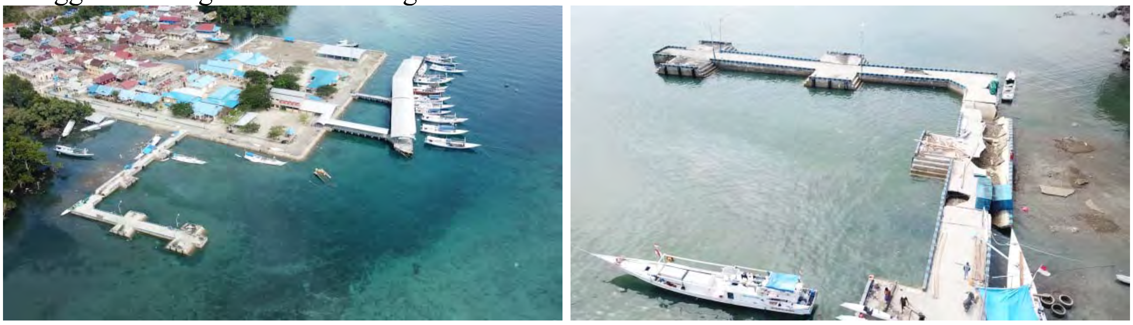
- Donggala Port:

The former pier in the 1950s construction (by the Netherlands) was slightly damaged. Liquefaction in the landfill in recent years, traces of lateral flow. In addition, a part of the newly constructed harbor and pier collapsed due to large-scale collapse of the ground which is thought to be caused by liquefaction.1





Donggala Fishing Port: Pier damage



- Coastal Protection

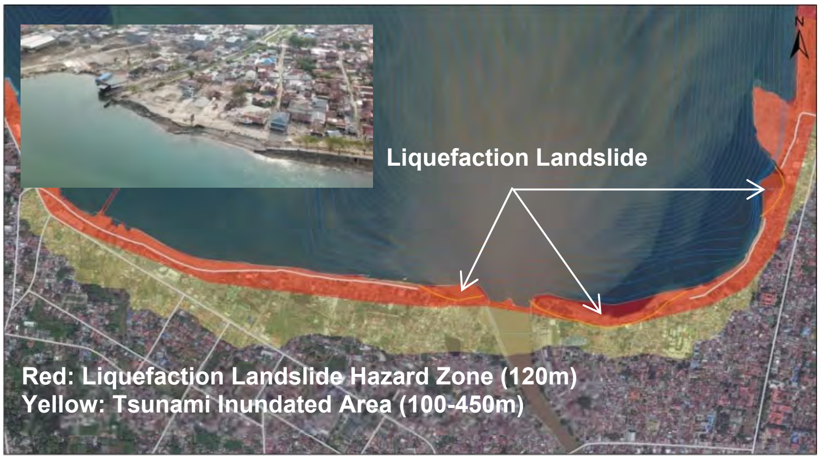
  This section discusses the damage of September, 2018 disaster event and the proposed strategy for rehabilitation and reconstruction. The overall cost estimates for the coastal area is in the range of IDR780-2,600 billion (JPY6-20 billion), including construction of tsunami sea dyke, Donggala seawall restoration, coastal revetment rehabilitation, coast recovery, mangrove rehabilitation and plantation.

In the discussion, the coastal area of Palu Bay is divided into two zones; (1) Palu City Coastal Zone and (2) Palu Bay East and West Coast.

(2) Coastal facilities

1) Palu City Coastal Zone

The coastal part of Palu City has experienced significant structural damage and loss of life due to tsunami inundation and liquefaction landslide. Based on the observed liquefaction landslide (orange lines in below figure), it was judged that the areas within 120m from the coast line are suspicious for potential liquefaction landslide (Red colored zone in below figure). Further assessment of ground stability (e.g. soil boring tests) should be performed in order to determine the potential hazard areas. The tsunami inundation was observed within 100 to 450m from the coast line (red + yellow colored zones in below figure). These areas are prone to tsunami, and therefore should be restricted from being used for residential purpose, unless appropriate structural measures are implemented.

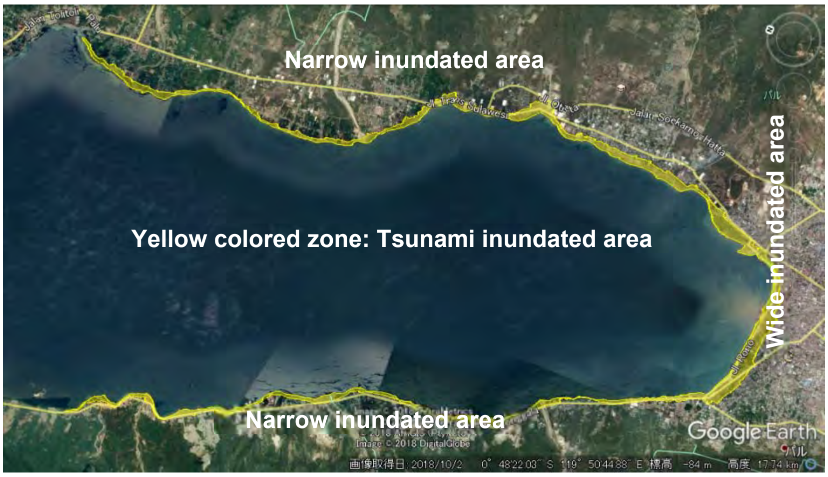


Source: JICA Mission Team

Figure 3 : Location of Liquefaction along Coastline

2) Palu Bay East & West Coast

Tsunami inundation was rather limited to the areas close to the shoreline in the east and west coasts of Palu Bay, thanks to the topographical characteristics where the elevation quickly reaches 10m within tens of meters away from the shoreline. However, many houses and buildings located in the low elevation areas were devastated by tsunami. These areas should be restricted from being used for residential purpose, and limited to the use for day time activities, such as restaurants and fishing huts.



Source: JICA Mission Team

Figure 4 : Tsunami Inundated Area in Palu Bay

Ground soil settlements due to liquefaction and landslide were also observed along the east and west coasts of Palu Bay. In general, they seemed to occur on the beach or on the sea side of the coast line, and therefore did not affect the houses and buildings, except the landslide occurred near the Donggala Port. There was a significant landslide, most likely induced by liquefaction, which destroyed a number of buildings (see photo below). Immediate rehabilitation of the coastal protection structure is required. The inhabitants may need to be relocated considering the tsunami hazard.

Source: JICA Mission Team

Figure 5 : Wide View of Damaged Bay Area

- Many houses and facilities were destroyed by earthquake and tsunami.
- Some coastal area can be utilized as a place to dispose of Debris and Wastes.

3.1.3 Airport

There are several structural damages identified due to earthquake all well as runway and taxiway facility damages.

IMPACT
Sysal jufry – palu Airport ATC Tower, collapse and cannot be operated.
CONTINGENCY PLAN
Crisis-time airplane in control using vhf – portable
FOLLOW-UP
Based on pp 77 on 2014 becoming authority Perum LPPNPI(airnav indonesia), will be fixed this year.

DAMPAK
Terminal Building (15196.72 m^2) experience severe damage
CONTINGENCY PLAN
Passenger in emergency time will be accomodate in temporary terminal.
Follow-Up
Revitalization plan in terminal in 2018 approximated needs Rp. 75.980.000.000,-

Mutiara SIS Al-Jufrie Airport

Air Sector Facility Damage

IMPACT
There is structured damaged in a 500m-long runway.
CONTINGENCY PLAN
In crisis time, runway operated 2000 m x 45 m (able to serve atr 72 and 737 500 (mtow) B737 900/800/a 320 (rtow)
FOLLOW-UP
runway reconstruction require 500 m x 45 m
Approximated cost : Rp. 45.000.000.000,-

3.1.4 Water Resources Facilities

(1) Irrigation Facilities

Irrigation facilities in Sigi Prefecture and Palu City received serious damages due to the earthquake. In the Gumbasa irrigation scheme, the main canal length is 36 km and the irrigation area is approximately 8,000ha, however the supply of irrigation water had been stopped because the facility is broken by the earthquake. Summary of damaged facilities are shown in the table below.[1]

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[1] Interview survey for Balai Wilayah Sungai III (Nov. 27)

Table 4 : Facility Damage Status

Facilities	Damage situation
Weir (river water intake)	There is no serious damage.
Main Canal	The original form of the canal is lost in and around liquefied damage area. Huge number of cracks occur along 29km of the canal.
Secondary Canal	There are 20 secondary canals. Almost secondary canals are damaged.
Diversion Works	There are 58diversion works along main canal. More than half number of diversion works are serious damaged.
River Crossing Works	Many river crossing works allocated along main canal, the almost works is damaged and cannot be functioned.
Irrigable farm Land	Irrigated farm lands were lost due to liquefaction in below three areas Petobo : 14ha Jono Oge : 200ha Sibalaya : 40ha.
other	Many number of tertiary canals, small diversion boxes are damaged

Source: JICA Mission Team

There are 99 medium and small scale irrigation scheme, total irrigation area 11,029ha in Sigi Prefecture. These irrigation facilities also had damage by earthquake, the quake damage assessment is currently proceeding in the prefecture. [2]

Destroyed irrigation canal in petobo area

Destroyed diversion work in Jono Oge area

(2) River Facilities

Most of the revetments along Palu River were damaged: cracked concrete walls, waved tops of bank, collapsed promenade of concrete bricks and lost walls. The small rivers are similar, too, and the same phenomena are seen.

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[2] Interview survey for Palu City is not carried out at the present time(Nov. 28)

Cracks on Top of Banks

Collapse of Revetment

3.1.5 Building Facilities

(1) Damages

The building facilities had major damages due to earthquake and tsunami. Not only coastal area (Palu) but also inland area, such as Sigi, had large damages as well. In particular, damage to the building due to liquefaction of the ground is devastating. The table below summarizes the damage of schools and public facilities.

1) School building

Table 5 : Degree of damages of school buildings

Area	Classification	Degree of the Damages			Total
		Heavy Damage	Slight to moderate Damage	No Damage	
Palu Area	Primary School (SD)	32	73	24	129
	Junior High School (SMP)	3	13	6	22
	Sub-Total	**35**	**86**	**30**	**151**
Sigi Area	Primary School (SD)	68	54	98	220
	Junior High School (SMP)	10	20	23	53
	Sub-Total	**78**	**74**	**121**	**273**
Total of Palu and Sigi area		113	160	151	424

Source: Ministry of Education Palu and Sigi

2) Public building

Table 6 : Degree of damages of the Public building

No	Use	Degree of Damage			Total
		Slight	Modelate	Heavy	
1	Public Office building	1	1		2
2	Ministry and Agency Building	8	8	12	30
3	District Office	2	5		8
4	Village office	25	7	3	46
5	Integrated Processing unit		1	1	2
6	Health Center	8	2	2	14
7	Subsidiary Helper of Community Health Center	10	3	2	28
	Total	**54**	**27**	**20**	**130**

Source: JICA Mission Team

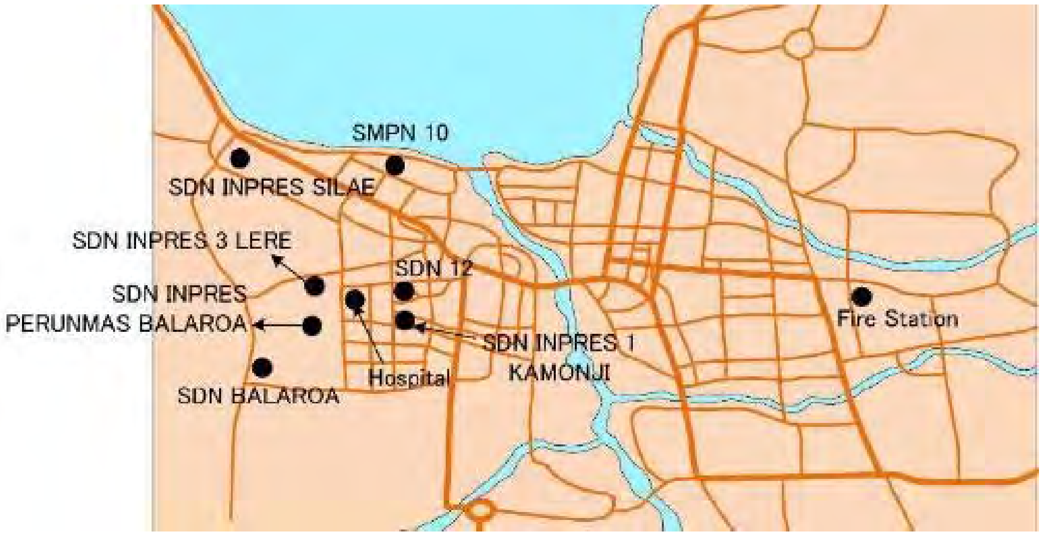
3) Other Buildings

Table 7 : Damages of Buildings

No	Name of the building	Degree of Damages
1	Palu City Hospital ANUTAPURA	Totally damaged.
2	Province Hospital UNDATA	Slightly damaged but structure is not damaged.
3	Palu city fire station	Totally damaged.
4	Ministry of Public works building	Moderate damage but structure is not damaged.
5	Palu city Apartment house	Totally damaged.
6	Airport control tower	Totally damaged.
7	Palu city office	Slightly damaged but structure is not damaged.

Source: JICA Mission Team

(2) Location



Source: JICA Mission Team
Note: SDN (Primary school) SMP (Junior high school)

Figure 6 : Wide View of Damaged Bay Area

(3) Picture

1) Primary school: SDN INPRESS BALAROA (Palu City)

Before Earthquake

After Earthquake

2) Primary school: SDN INPRESS JONO OGE (SIGI prefecture)

Due to earthquake and liquefaction, the school buildings had totally destroyed

3) Palu City Hospital ANUTAPURA

Before Earthquake

After Earthquake: Totally damage

1) Airport control tower

Due to earthquake, the control tower had critical damages

Destroyed control room

Temporary Operation in the Pre-fabrication house

2) City apartment house

3) Shopping mall

CHAPTER 4. Reconstruction Concept

4.1 Basic concept

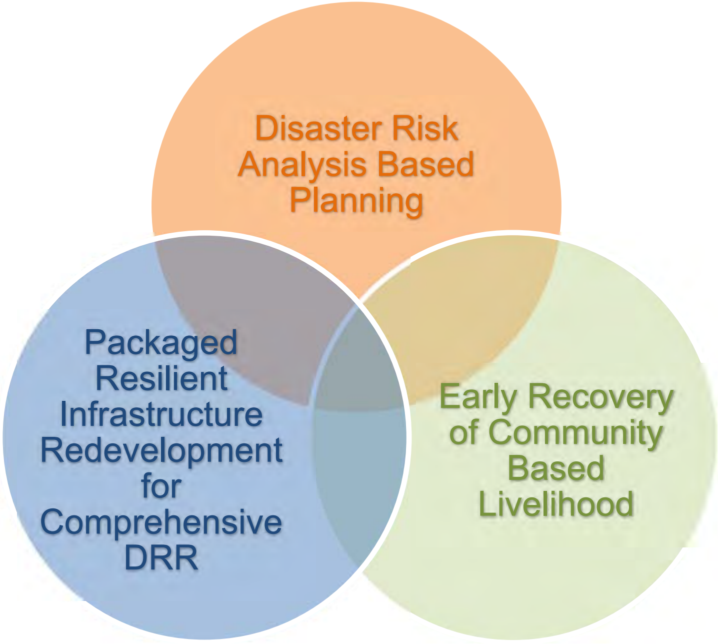
The goal of the reconstruction shall be in line with the national level redevelopment slogan as stated below.

Build Back Better, Safer, More Sustainable for Resilient Indonesia

The purpose of the reconstruction assistance project is to recover and reestablish in the region in the short-term stage, and to reinstate regional industry and bring sustainable economic activities back to the disaster damaged region in the mid to long term stage. In order to achieve such objectives, redevelopment of infrastructure and livelihood in the region is fundamental, so that the effective and well-phased reconstruction plan should be made for appropriate implementation for the regional redevelopment promotion.

Through the reconstruction of the region, resilient society should be formed in order to protect and improve the society itself on both hard (infrastructure redevelopment) and soft (relocation, emergency evacuation, livelihood recovery) aspects, because the region and lives shall be protected against future disaster and uncertainty of effects for better and continuous production and living in a safe environment.

The basic concept for the regional reconstruction will be structured by three core actions as shown below.



Source: JICA Mission Team

Figure 7 : Basic Concept for Regional Reconstruction

The expected regional reconstruction master plan shall be formulated knowing the multiple disaster occurrence mechanism, especially of earthquake, tsunami, liquefaction and landslide. As a matter of fact, this earthquake disaster is very complicated due to the combination of tsunami and liquefaction, especially liquefaction brought enormous number of deaths. People living in there have to face with how to reduce the disaster risk. In order for that, people have to combine probable countermeasures by all means.

The master planning should be implemented taking the following strategical actions into consideration.

- To re-establish resilient society against disaster by "Build Back Better" philosophy
- To formulate effective and efficient reconstruction master plan
- To redevelop resilient region with appropriate urban and spatial development plans

- To setup risk reduction mechanism by infrastructure arrangement considering combination of multiple infrastructure.
- To implement reconstruction projects in appropriate phasing expecting step-by-step method
- To implement reconstruction by people-and-community-based perspective

The regional reconstruction plan should be formulated just after composing reconstruction master plan considering hazard, housing relocation, local industrial rehabilitation, community-based activities, overall infrastructure redevelopment, and others in Palu, Sigi and Donggala. In light of the above described hazard and risk assessment of the target region. There are several aspects to be incorporated in order to improve the affected region.

(1) Disaster Risk Analysis based planning

It is important to understand the mechanism of cascaded effect of disaster. There are several cascaded disasters which took place by mixing of different disasters. Tsunami is one kind of the results. Liquefaction-landslide also occurred in a cascaded mechanism, and made more devastating effect. Buildings noncompliance to the building code also made serial disaster effect leading casualty.

(2) Packaged Resilient Infrastructure Redevelopment for Comprehensive DRR

In order to reduce risk of such a complicated disaster, it must be necessary to combine all countermeasures effectively. That means not to recover each infrastructure as it existed, but to make a comprehensive plan to reduce risk even if there is some difference from original purpose of each infrastructure. For example, the purpose of river improvement is considered mainly for flood or water resources, but it can contribute the risk reduction of liquefaction-landslide by groundwater level reduction in affected area through making the water level of river much lower.

(3) Early Recovery of Community Based Livelihood

The target region has been growing by agriculture, fishery, sea port related industry and SMEs' small manufacturing industry, however there was no major regional core industry. The population has also grown by people seeking SME jobs. Most industrial activities have stalled as they have been affected by the disaster.

4.2 Working Group for Reconstruction

Badan Perencanaan Pembangunan Nasional (hereinafter referred to as "BAPPENAS"), the National Development and Planning Agency since September 28th, 2018 has been working on five (5) working groups.

Working Group 1:	Development of Spatial planning and disaster prone areas
Working Group 2:	Recovery and Reconstruction for infrastructure and areas
Working Group 3:	Recovery and social, culture and economic development
Working Group 4:	Funding and Cooperation
Working Group 5:	Regulation and governance

JICA and the mission team has put effort to prepare base data through series of official meetings and discussions with BAPPENAS and other concerned government agencies for the reconstruction master plan formulation, which is urgently demanded for assistance, and the tasks were more focusing on physical reconstruction and social rehabilitation that are in relation to the working group 1, 2 and 3 above.

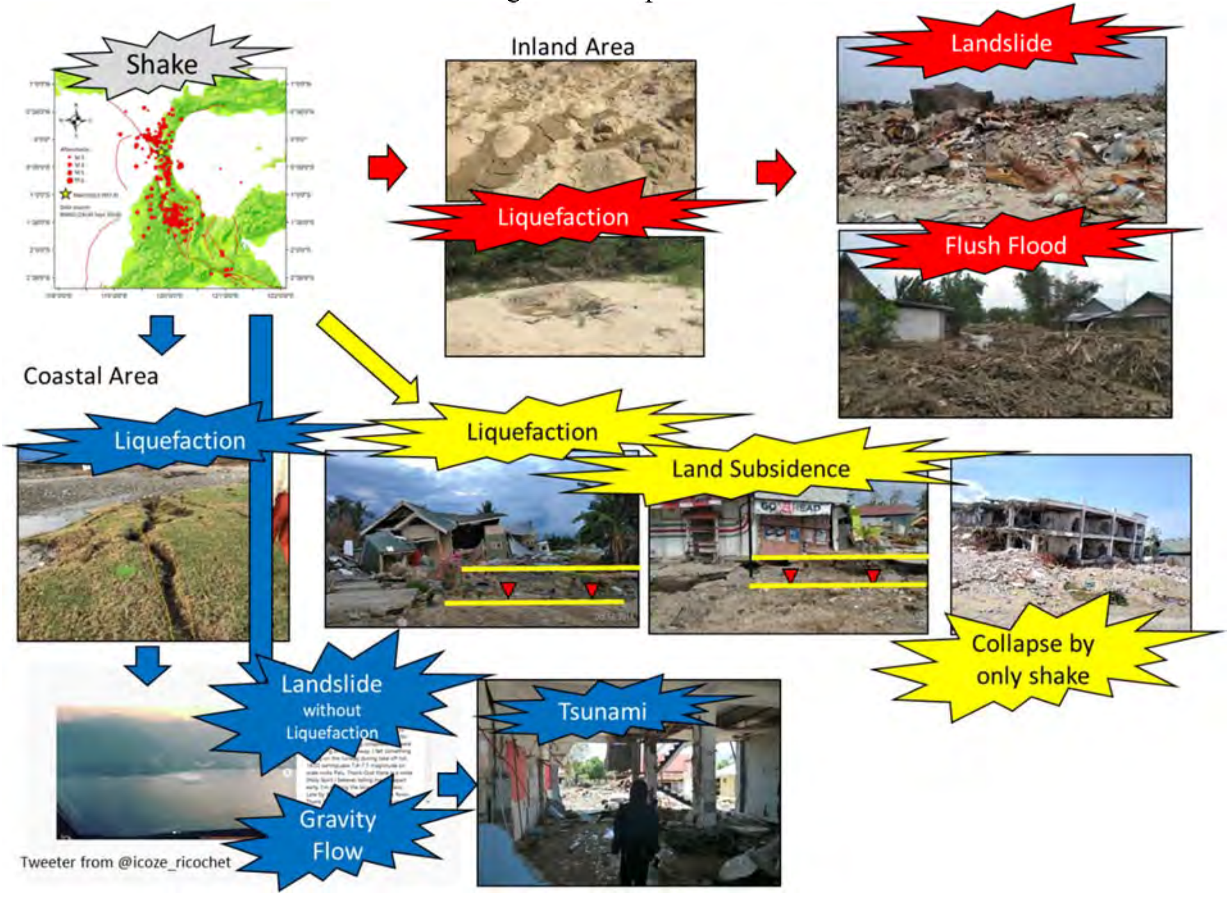
CHAPTER 5. Features of This Disaster

5.1 Analysis of Disaster Mechanism

On the 28th, 2018 M7.5 Earthquake happened by Palu-Koro fault movement. This fault is actually already well-known as one of the dangerous faults in Indonesia and attract attention several researchers to monitor this fault activity (Berlier, 2001; Watkinson, et.al.2017). They have been discussing fault activity mechanism and its possibility to produce a big earthquake in the future. But, no one could expect that future earthquake would induce other kinds of disaster that might cause more serious impact because this earthquake disaster is very rare case in the world. Shake by this earthquake brought tsunami which attacked coastal area promptly and liquefaction which happened at several places and killed more than a thousand of people.

The 28th, 2018 M7.5 Palu earthquake is very special case because the earthquake induced others big disaster in surrounding area. Firstly, earthquake occurred in Donggala districts (Northern part of Palu). Then, tsunami hit Palu bay and coastal area. But actually, right after earthquake happened, liquefaction occurred at a lot of places and it caused enormous damage at various area. For this series of disaster, liquefaction and other Foundation disasters like land subsidence are main cause of damage in this disaster since it claimed many victims.

“Cascaded Disaster”. We can call this disaster like this. This earthquake disaster is not simple, but complicated. In order to accomplish “Build Back Better”, we have to analyze mechanism of each phenomena and consider countermeasures against each phenomenon.



Source: JICA Mission Team
The shake of the earthquake induced other disaster in inland and coastal area and caused a lot of victims and destroyed building.

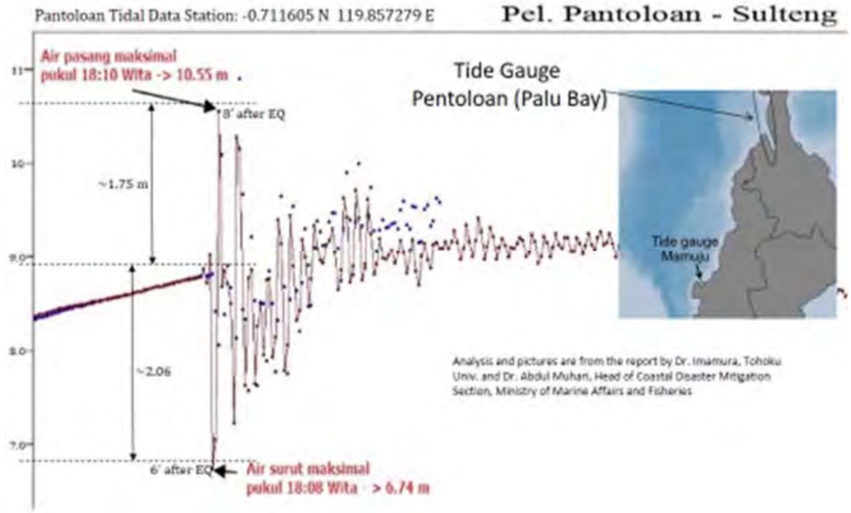
Figure 8 : Illustration of Cascade Damage Mechanism in Central Sulawesi

5.2 Tsunami

5.2.1 Identification the Cause of Tsunami with Simulation

(1) Measurement of Tsunami

- The nearest Tide Gauge at Pantoloan observed Tsunami
- This data was not sent to BMKG because of power failure
- The second nearest Tide Gauge is Mamuju at around 240km distance from Palu



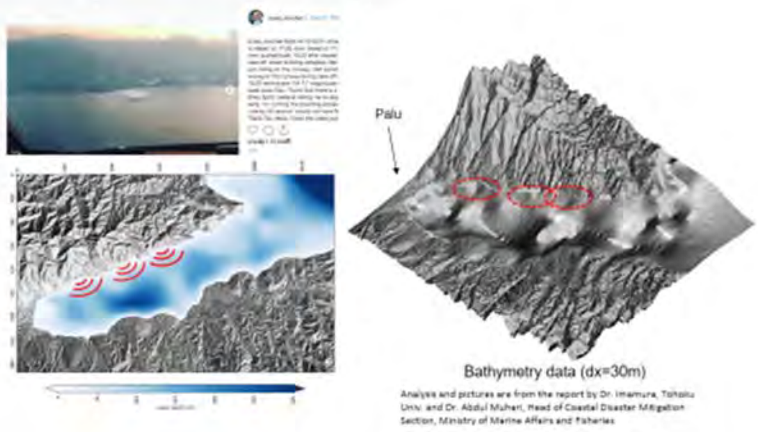
Source: JICA Mission Team

Figure 9 : Damaged Buildings in Biromaru

- Tsunami is preceded by deep receding wave and is followed by maximum tsunami height of about 1.75 m
- Only two peaks of tsunami are observed with very short period of wave. This indicates that the source should be very local and the generation source area should not be too wide as it is represented from the observed wave period.
- After the second peak, tsunami wave heights are no longer significant (less than ~30cm)

(2) Cause of Tsunami

Video capturing the tsunami and immediate tsunami simulation based on the fault model by USGS indicates the devastating tsunami was caused by landslides

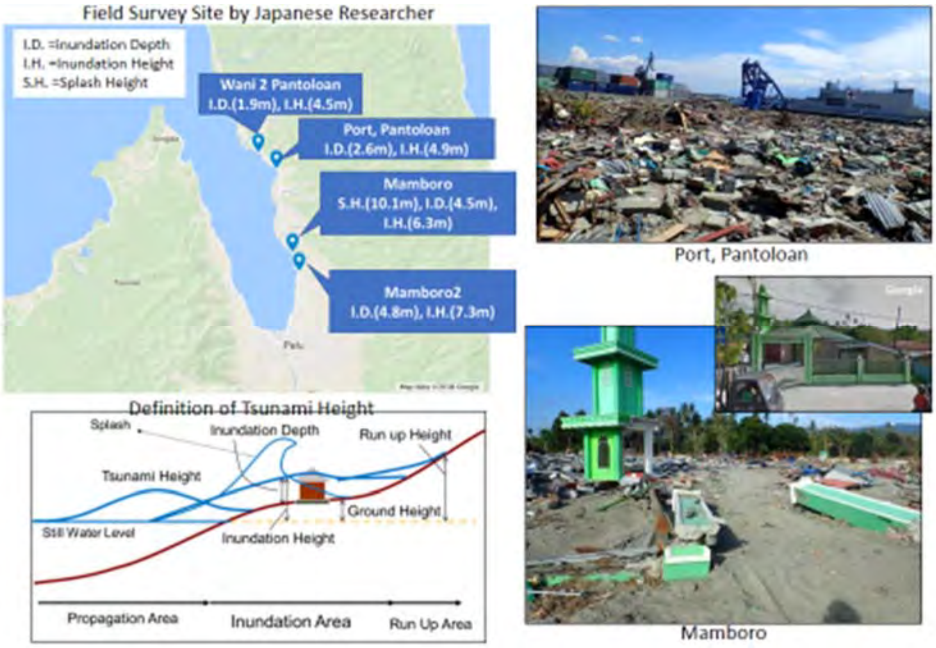


Source: JICA Mission Team

Figure 10 : Analysis of Tsunami Occurrence

1) East Coastal Area of Palu Bay Affected from Tsunami

(Field Survey Site by Japanese Researcher)

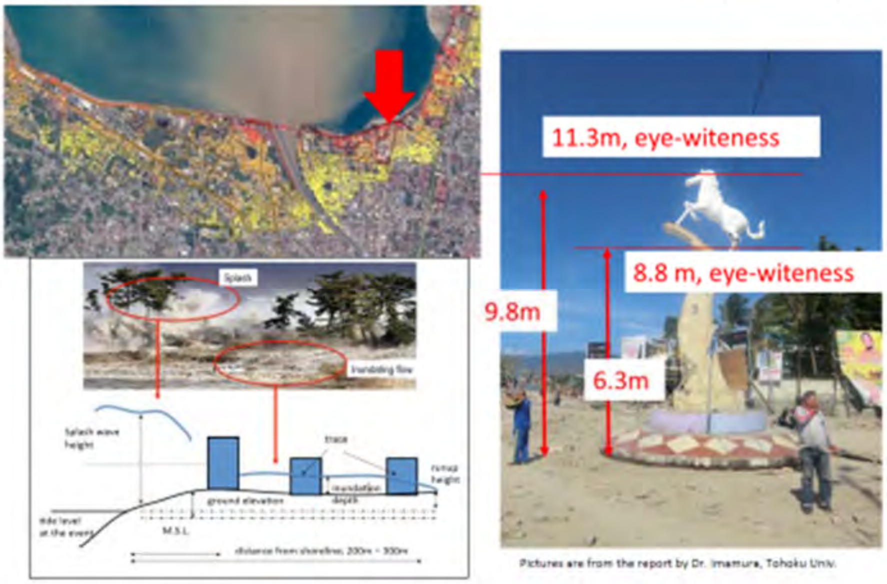


Source: JICA Mission Team

Figure 11 : Tsunami Damage in East Coast

2) South Coastal Area of Palu Bay Affected from Tsunami

- Affected Area was limited up to 200~300m distance from coast line
- Though Splash was high around 10m, however inundation depth was up to 5m



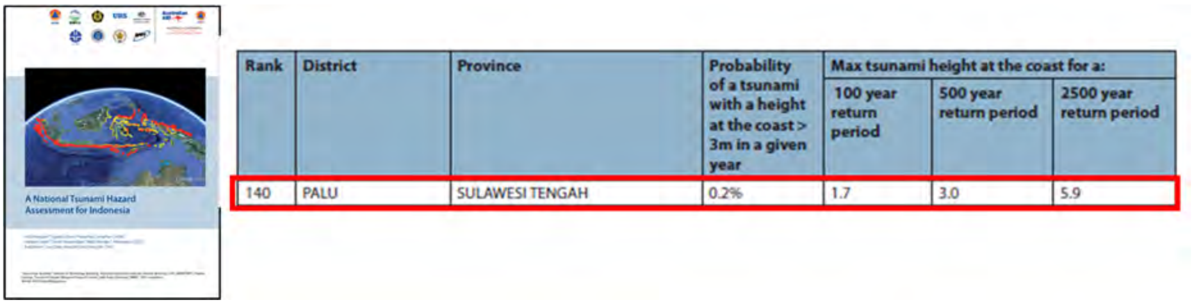
Source: JICA Mission Team

Figure 12 : Tsunami Damage at Shoreline along Palu City

(3) Past Assessment of Tsunami Height in Palu

- This assessment was conducted with Australian assistance in 2013

- These heights don't seem that Landslides were considered as cause of Tsunami
- However, according to this assessment, 3m is the maximum tsunami height at the coast for 500 year return period.
- That means tsunami in this disaster is higher than 500 years return period in most locations, though we have to be careful that the wave length of tsunami by this earthquake is much shorter than tsunami directly caused by rupture.



A National Tsunami Hazard Assessment for Indonesia

Rank	District	Province	Probability of a tsunami with a height at the coast > 3m in a given year	Max tsunami height at the coast for a:		
				100 year return period	500 year return period	2500 year return period
140	PALU	SULAWESI TENGAH	0.2%	1.7	3.0	5.9

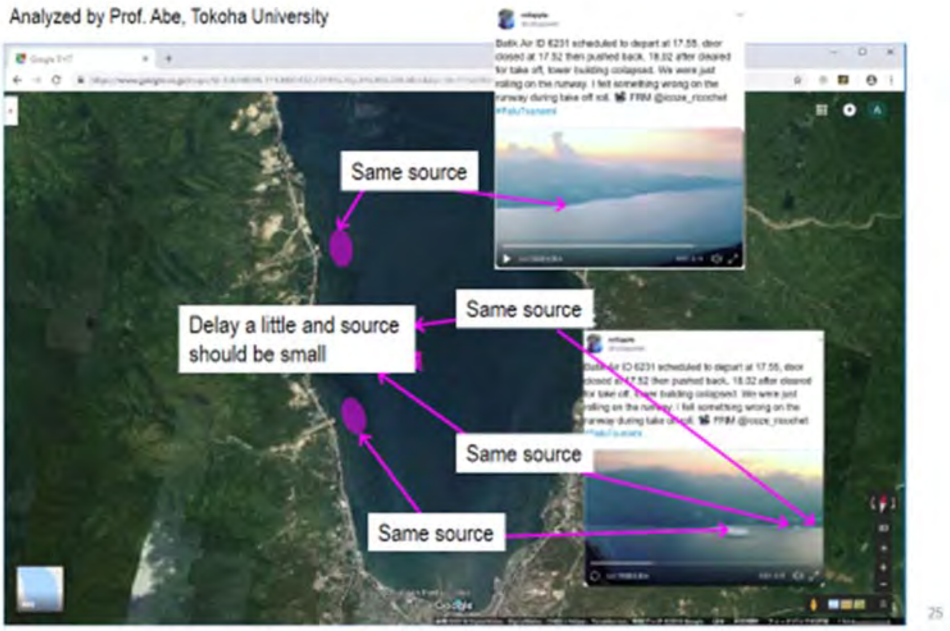
Source: JICA Mission Team

Figure 13 : Assessment of Tsunami Height

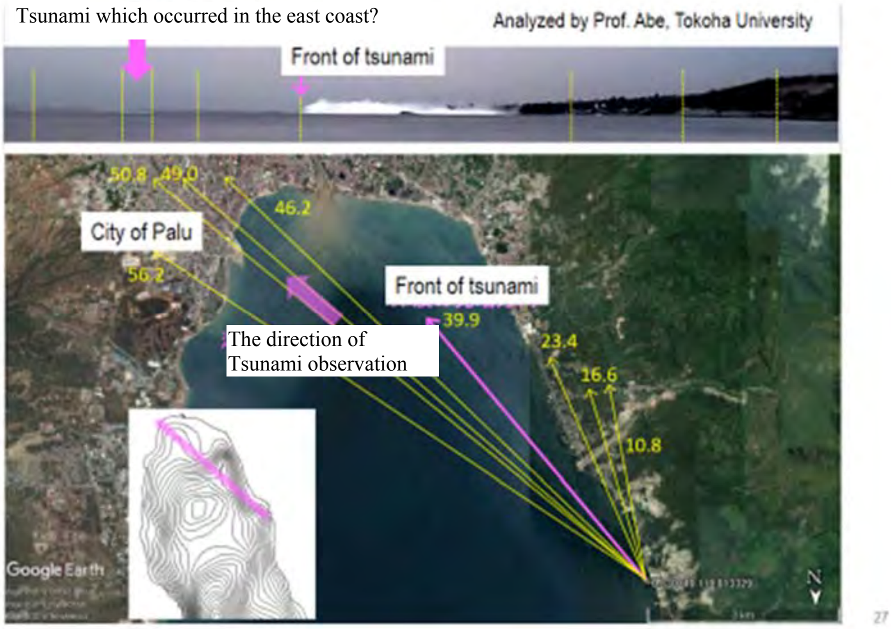
(4) Outline of the tsunami analysis

- Compiling the available data of the tsunami and making the topography and bathymetry data for the numerical simulation.
- The source of the tsunami should be carefully selected by taking account of underwater/coastal landslides.

1) Identification of Tsunami source



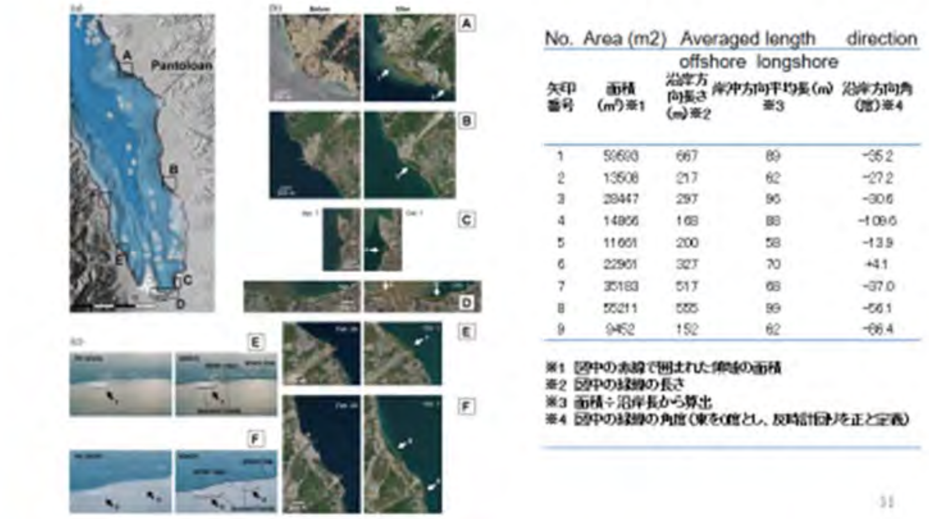
Analyzed by Prof. Abe, Tokoha University



Source: JICA Mission Team

Figure 14 : Tsunami Source Identification

(5) Information of landslide and liquefaction related with tsunami generation



No.	Area (m2)	Averaged length offshore	Averaged length longshore	direction
矢印番号	面積(m²)※1	沿岸方向長さ(m)※2	岸沖方向平均長(m)※3	沿岸方向角(度)※4
1	59693	667	89	-35.2
2	13508	217	62	-27.2
3	28447	297	96	-30.6
4	14866	168	88	-109.6
5	11661	200	58	-13.9
6	22961	327	70	+4.1
7	35183	517	68	-37.0
8	55211	555	99	-56.1
9	9452	152	62	-66.4

※1 図中の赤線で囲まれた領域の面積
※2 図中の緑線の長さ
※3 面積÷沿岸長から算出
※4 図中の緑線の角度（東を0度とし、反時計回りを正と定義）

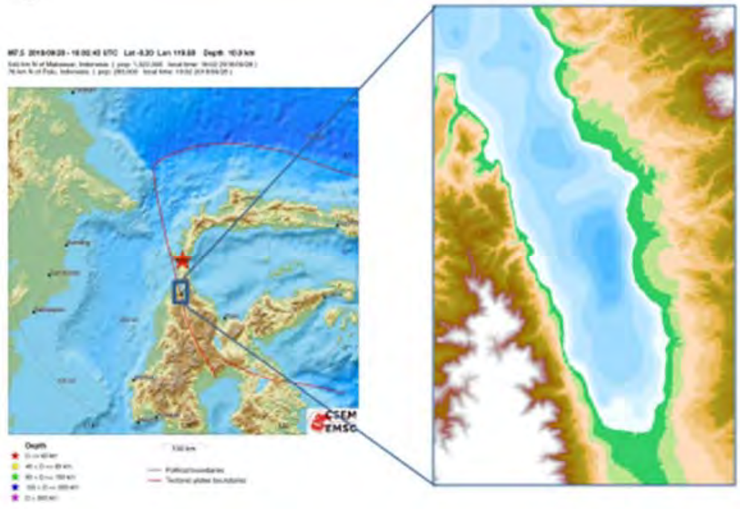
Source: JICA Mission Team

Figure 15 : Landslide and Liquefaction related Tsumnami

(6) Numerical modeling of the tsunami in Palu bay

- Two-layer model is applied for tsunami was well as landslide.
- The computational area focus on the Palu bay only.
- Underwater landslide based on ellipsoid plane
- Safety landslide slope < 14 degree

Computational area



Bathymetry : 30m resolution
Simulation Time : 14 min.
Dt : 1x10E-3 sec.
rSoil : 1,500 kg/m^3
rWater : 1,000 kg/m^3
Manning coef. : 0.025
Landslide move : 1.5 sec.
Initial W/L : +0.00 m. MSL

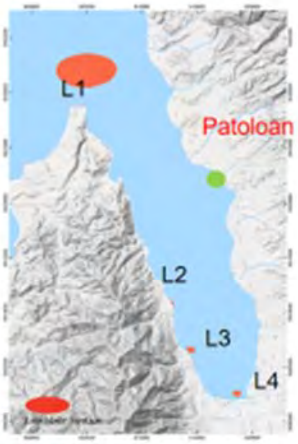
Source: JICA Mission Team

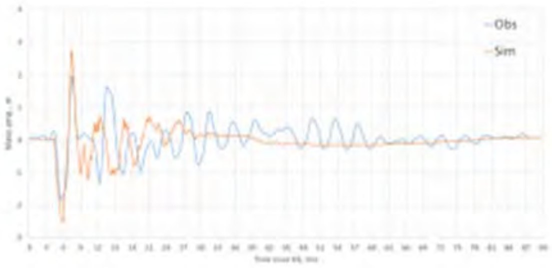
Figure 16 : Tsunami Modeling Basis

(7) Scenario for Numerical modeling of the tsunami

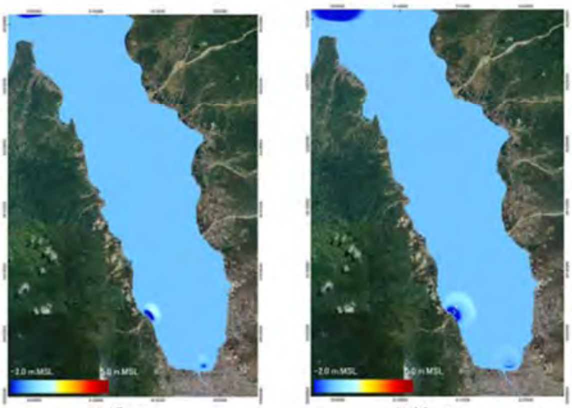
Possible scenario; fitted for the tidal records at the station of Pantoloan and tsunami heights along the coast and tsunami source is L1+L2+L3+L4

- Simulation time 90 min.





Composition of Wave Form at Patoloan Gauge

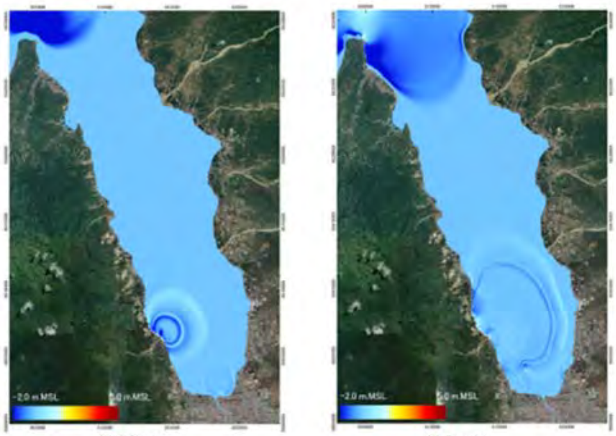


At 15 sec

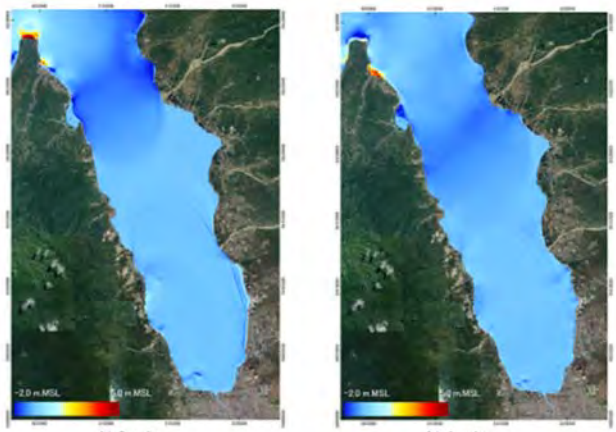
At 30 sec

Source: JICA Mission Team

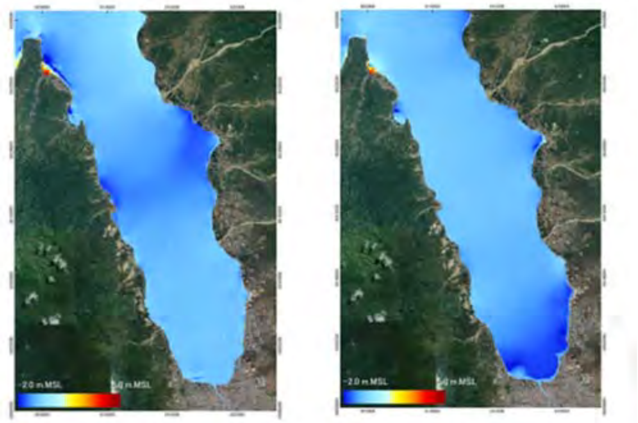
Figure 17 : Tsunami Modeling (1)



At 60 sec At 2 min



At 3 min At 4 min



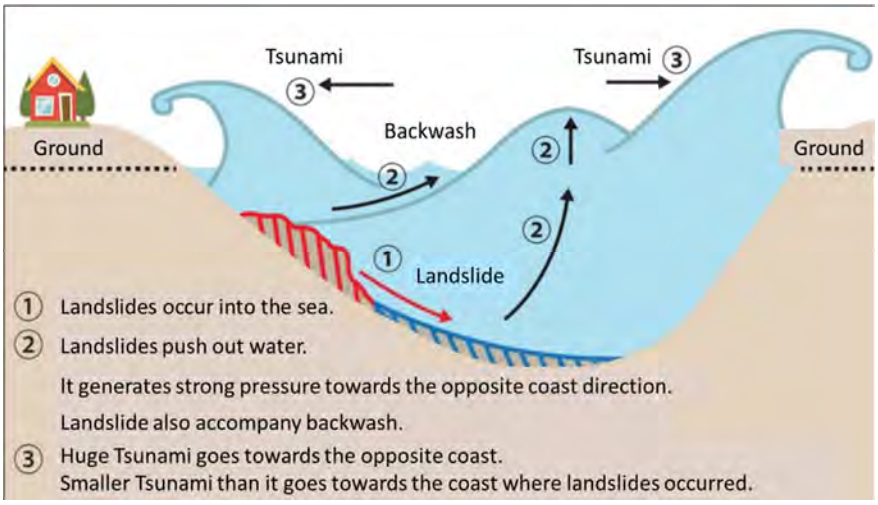
At 5 min At 10 min

Source: JICA Mission Team

Figure 18 : Tsunami Modeling (2)

(8) Consideration

This simulation with available data on the tsunami at Palu bay in 2018/9/28 ; information, observation, survey and so on shows that underwater and coastal landslide should happen to generate the tsunami. There is some possibility that some of landslide was caused by liquefaction after shake.



Source: Jakarta Shimbun

Figure 19 : Mechanism of Tsunami

5.2.2 Possibility of liquefaction along the coastal line

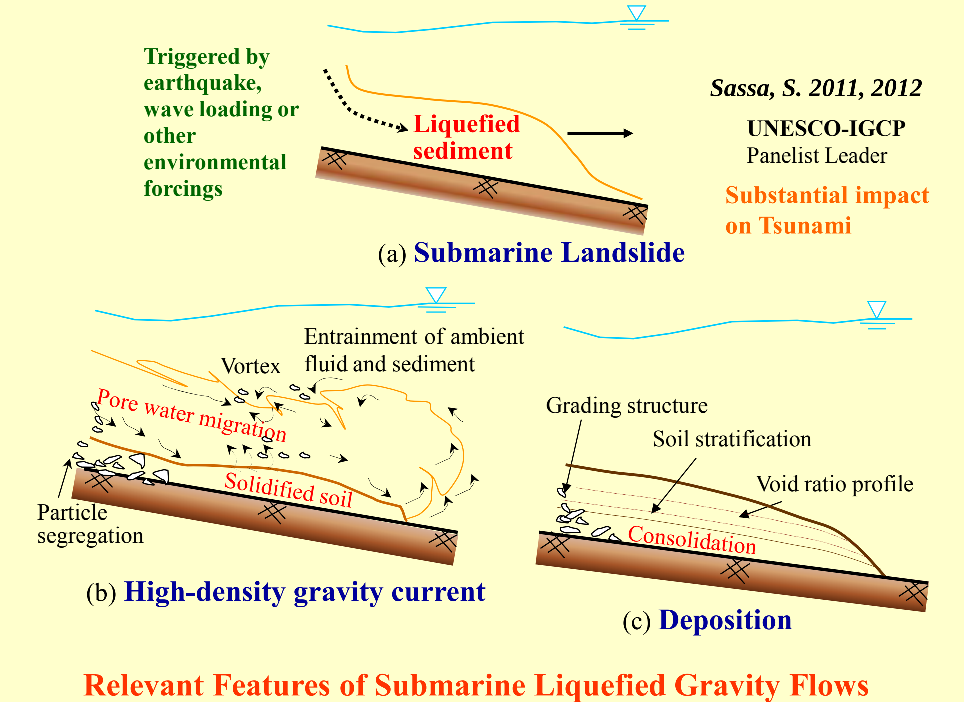
As remarked above, direct cause of tsunami was landslide in coastal and submarine area. In this chapter, mechanism of landslide will be shown.

As a result of the survey of the coastal area of Palu Bay, liquefaction occurred in some coastal areas. Figure 20 shows the representative liquefaction trace corresponding to the identified liquefaction point.
The photo on the upper right shows the situation where the drum tube rises up or buries randomly due to liquefaction and typically shows the effect of liquefaction. In the right center picture, fine grains of silt / clay content deposits on the ground with the sand were produced by liquefaction and thereafter cracks and voids were formed and it remains as a film after drying. The lateral photograph shows the sand trail including the fine grain content, which is evidence of liquefaction.
Furthermore, the photograph at the bottom right is a large spray sand trace directly behind the structure that is not affected by sediment transport by the tsunami, and it shows clearly the fact that liquefaction occurred in the ground. The lateral photograph is the sand deposit layer directly above the original ground.

Source: JICA Mission Team

Figure 20 : Extensive Liquefaction in Coastal Areas

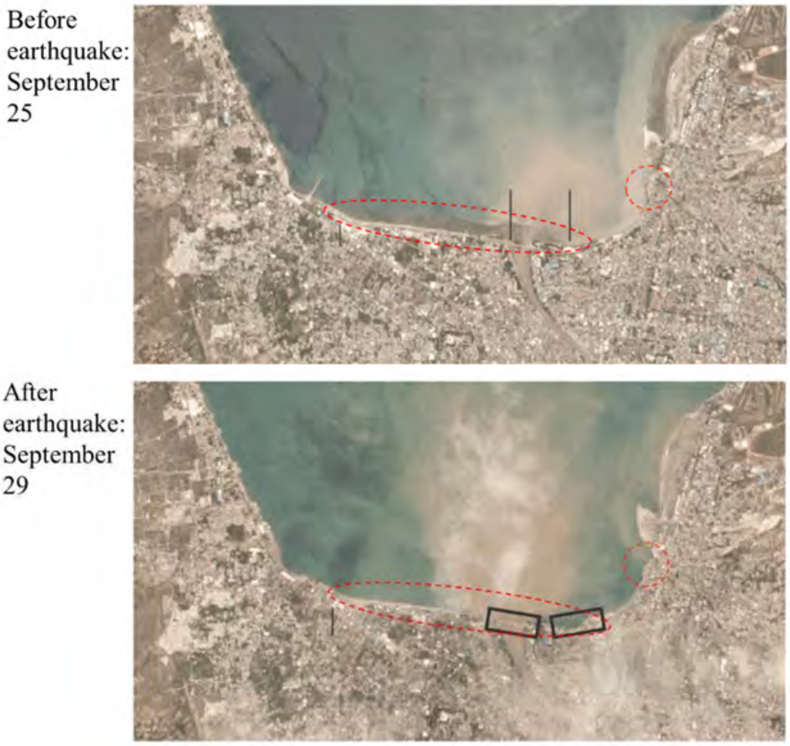
When remarkable liquefaction occurs in the coastal area, the lumps collapse under the action of gravity. It is easy to flow a long distance and re-deposit by transiting in the form of a high concentration gravity flow in the sea. It is a feature, the series of processes from flow start to stop and its dynamics are dominated by the physics of the two-phase system of water and soil (Figure 21). It is clear that such "liquefaction gravity flow" brings about a huge impact on the occurrence of the tsunami (Sasa, UNESCO submarine landslide conference panelist chairman report, 2011, 2012)



Source: JICA Mission Team

Figure 21 : Characteristics of liquefied gravity flow in coastal area

Figure 22 shows the situation immediately before and after the earthquake in the Palu river estuary area. It can be confirmed that the coastal land collapsed / flowed over a wide area of about 2.5 km along the coast and about 200 m in the shore-off direction. The cause of this phenomena would be liquefaction.



Source: JICA Mission Team

Figure 22 : Comparison of the Palu River estuary just before and after the earthquake

Source: JICA Mission Team

Figure 23 : Collapse by liquefaction or simple landslides occurred at many places along coastal line

5.2.3 Analysis of Tsunami

In addition to above, JICA conducted collection of news on tsunami and hearing to local people. The table below is composed of all findings by JICA's survey.

Table 8 : Analysis of Tsunami Phenomena

Fact	➢ "Inundation Depths" are different from place to place, however it is 5m at most ➢ "Inundation Distance" from coast line is 300m at most ➢ "Splash Height" is around twice or more than "Inundation Depths" ➢ "Tsunami Arrival Time" is supposed arrive from a few minutes to 10 minutes after the earthquake ➢ InaTews could not work appropriately because of power failure ➢ Many people did not evacuate from coastal area
Analysis	➢ Landslides near and in Palu Bay caused Tsunami (Short inundation distance, high splash, speedy arrival and reproduction simulation) ➢ Lack of people's awareness against Tsunami amplified casualties ➢ Lack of dike and inappropriate land use amplified casualties and damage

Source: JICA Mission Team

5.3 Liquefaction-landslide

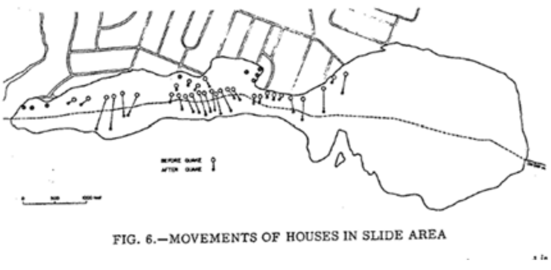
5.3.1 History

"Liquefaction rarely kills people", this sentence is often said. However, more than thousand people were killed in this liquefaction. Lateral flow by liquefaction is usually limited up to around 10 m. However, around 400m at most of land movement occurred. This kind of liquefaction is special to human beings. According to Dr. Ishihara, this kind of phenomena is the third time in the world history and it is the first time that liquefaction killed more than thousand people.

We show one previous case. In 1964, significant liquefaction-landslide occurred in Turnagain Heights in Anchorage. Displacement was of order of 100m.

Source: https://depts.washington.edu/liquefy/selectpiclique/alaska64/landslideintowater.jpg

Figure 24 : Turnagain Heights, Anchorage, 1964



Source: Seed, H. B. and S. D. Wilson (1967) The Turnagain Heights Landslide, Anchorage, Alaska, Proc. ASCE 93(SM4): 325-353.

Figure 25 : Analysis on Anchorage Liquefaction-Landslide

5.3.2 Analysis and Making Assumption

In this time in Palu, liquefaction of foundation ground is induced by geologically young loose filled sand saturated with groundwater and seismic motion with a certain degree of strength. The estuary alluvial plain, where Palu city is located, is a typical liquefaction environment.

However, locally, it is known that the danger level is higher in landfills of old river channel and lake, and the risk is slightly lower in natural embankments such as natural levee. It is important to evaluate the ground properties by boring or simple site penetration test surface wave test, and elastic wave test.

Flow failure of the slope occurred in Balaroa of Pala City West, Petobo, Jono Oge, Shibalaya in the east southern part of the city or Sigi. Between Jono Oge and Petobo there is Biromaru where liquefaction and ground cracks occurred, but it did not result in long movement.

- Tensile crack initiation zone at the top: It has not reached flow (Figure 26).
- A zone where the surface layer is broken into a block of several meters in size and sliding fracture also occurs: Although it collapses, it has not reached a flow failure (Figure 27).
- Ground fluidized zone downstream from the sliding cliff: Long distance flow displacement of several hundred meters occurred, the surface ground was lost, and the lower layer from which water sprang out (Figure 28).
- Terminal flow material sedimentary zone: earth and sand and houses moving from upstream are accumulated (Figure 29)

Figure 26 : Collapse of Petobo Point Top

Figure 27 : Collapse of Petobo Point

Figure 28 : Flow failed part of Petobo point

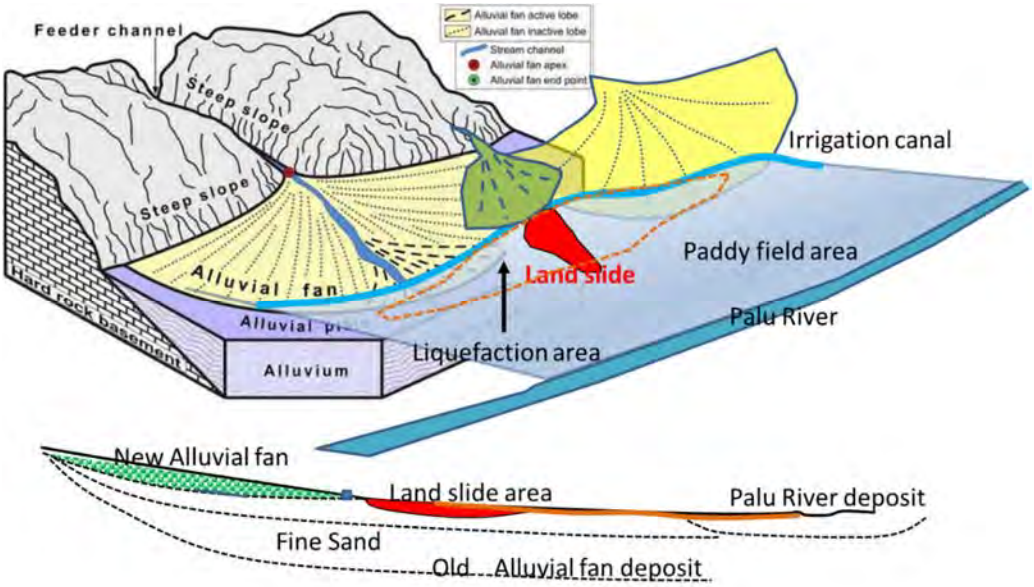
Figure 29 : End deposit part of Petobo point

In the site where the surface layer was lost, the spring water continues as of even 3rd November, indicating that groundwater continues to be supplied from other places. The idle zone was still soft and weak and it was difficult to step in. The gradient from this flow part to the downstream side is only about 2 to 3 degrees.

A small alluvial fan exists from the foot of the mountain above the source head of the collapse slope. It is a usual phenomenon that the abundant water current flowing in the basement of the fan becomes spring water at the fan end. Agricultural water is supplied to the paddy field from the irrigation canal.

Along the flow failure point, a large alluvial fan spreads from the foot of the mountain to the vicinity of the Palu River. However, liquefaction occurred at the toe of young fan, not old fan. The reason is why old fan has been compacted for long time, and water tends to gather to young fan. The lower end of the fluid sediment deposition this time is at the point aligned with the fan end of the large fan. As a result of flow failure occurring elsewhere in the past, the current large-scale alluvial fan was formed.

The collapse in this disaster seems to be the process of growing a small fan-shaped area to a large size. In other words, even in the near future ("the near future" means future on the geological time scale), liquefaction-landslide on the gentle slope like this will occur repeatedly.

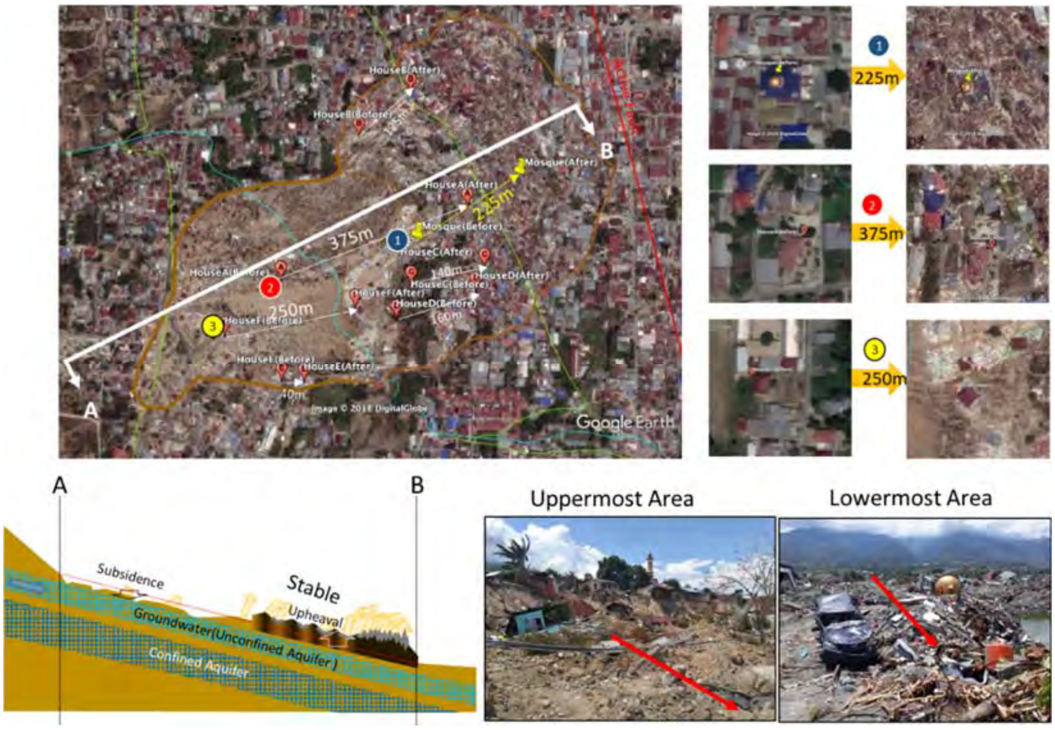


Note: Alluvial fan could be divided into two kinds: "Fan" at steep slope, "Toe of fan" at point of inflection, and "Alluvial plain" at other parts.

Composed by JICA based on the picture from the following paper
Gianluca Norini(2016) Delineation of alluvial fans from Digital Elevation Models with a GIS algorithm for the geomorphological mapping of the Earth and Mars

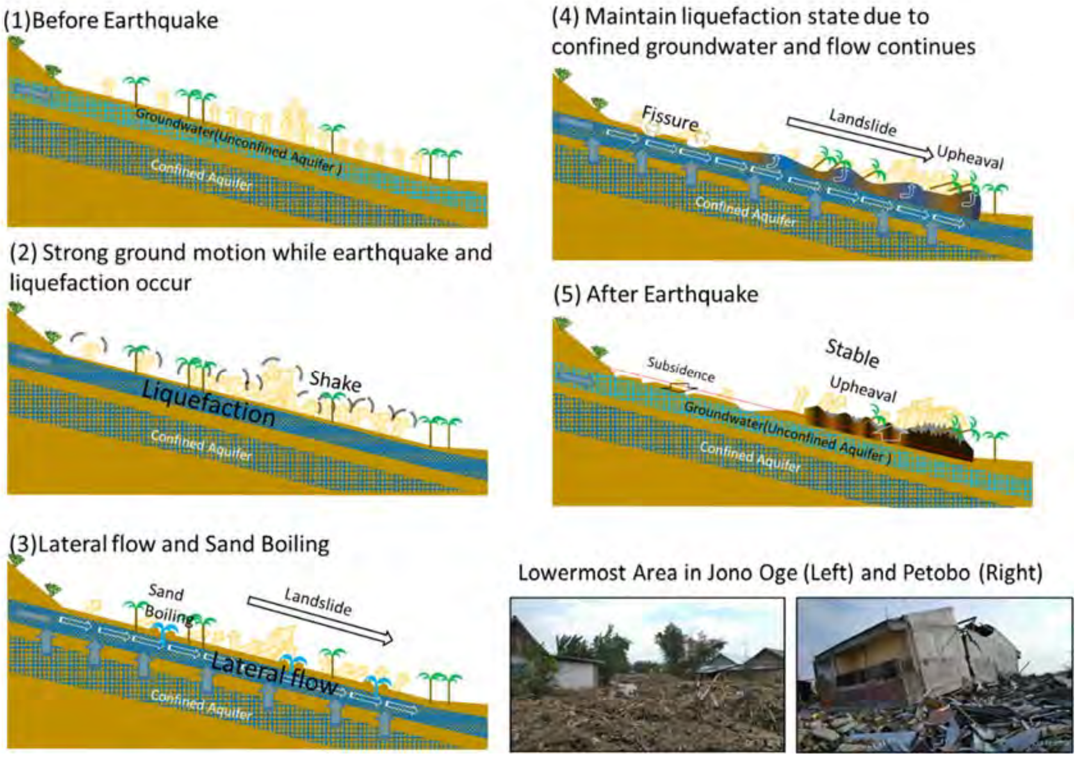
Figure 30 : Relation between alluvial fan and liquefaction-landslide

There are around 400 m movement houses. Lower area of Jono Oge was devastated by flash flood. Those liquefaction kept going for a long time and it was due to plentiful groundwater, especially confined groundwater. However, we have not identified to what extent and to what amount confined aquifer exists under the ground. It should be clarified by further research.



Source: JICA Mission Team

Figure 31 : Diagram of Land Movement



Source: JICA Mission Team

Figure 32 : Diagram of Liquefaction-Landslide Occurrence and Geological Profile

5.3.3 Assuming the Conditions of Liquefaction-Landslide

Based on the assumption of the mechanism stated above, conditions of "liquefaction-landslide" could be arranged as below.

Firstly, 3 conditions are well-known as a general condition of liquefaction.

General 3 Conditions of Liquefaction

1. Strong shake continues for a long time.
2. The nature of soil is mainly loose sand at shallow depth.
3. The ground is saturated with groundwater up to shallow level.

Secondly, based on our analysis, additional 4 conditions should be added when we consider "Liquefaction-Landslide".

Additional 4 Conditions of "Liquefaction-Landslide" (more investigations needed to identify the exact mechanism)

4. There is a slope of very low gradient less than several percent.
5. Widespread capping layer (surface layer) of lower permeability overlying liquefiable loose sand layer.
6. Widespread highly liquefiable sand layer providing water sufficient to destabilize the gentle slope due to very strong shaking in focal area.
7. Artesian pressure leading to further destabilization in the above mechanism.

JICA conducted geotechnical survey, cone penetration test, in Petobo and Jono Oge in order to confirm the assumption. The result of test tells no contradiction to the assumption, however further investigation is necessary in order to prove the assumption. For example, there must have been a lot of confined aquifer under Jono Oge. Without that, such an enormous flood never occurred, and some people say water rose up to dozens meters height just after the earthquake.

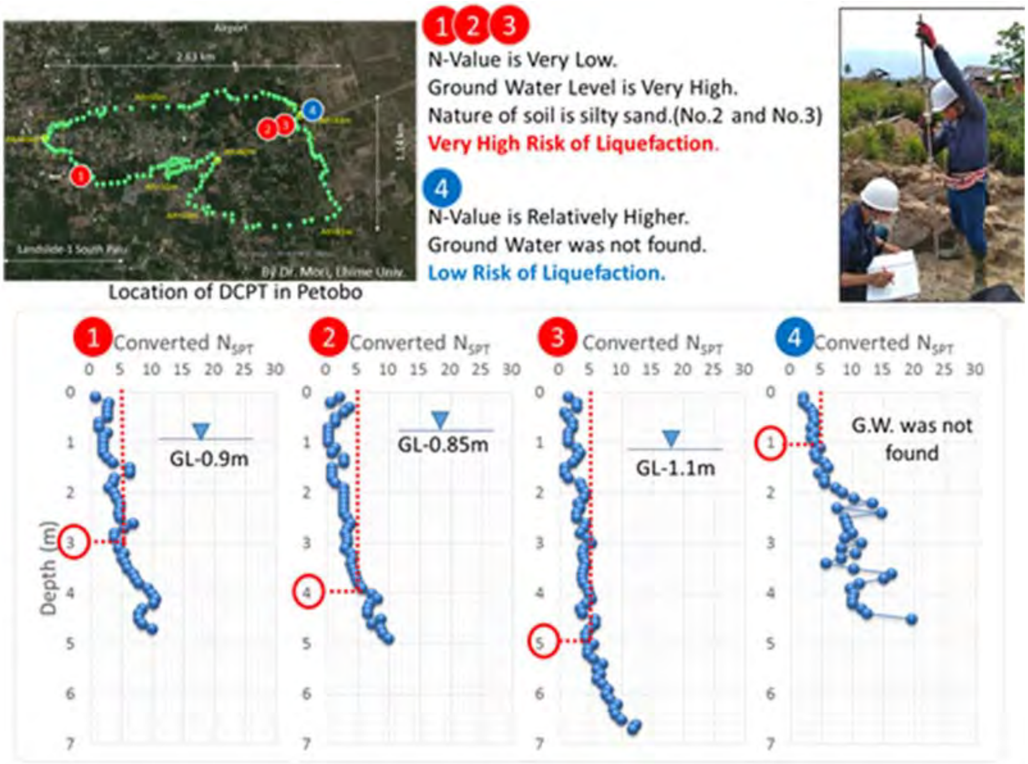


Figure 33 : Cone Penetration Test in Petobo

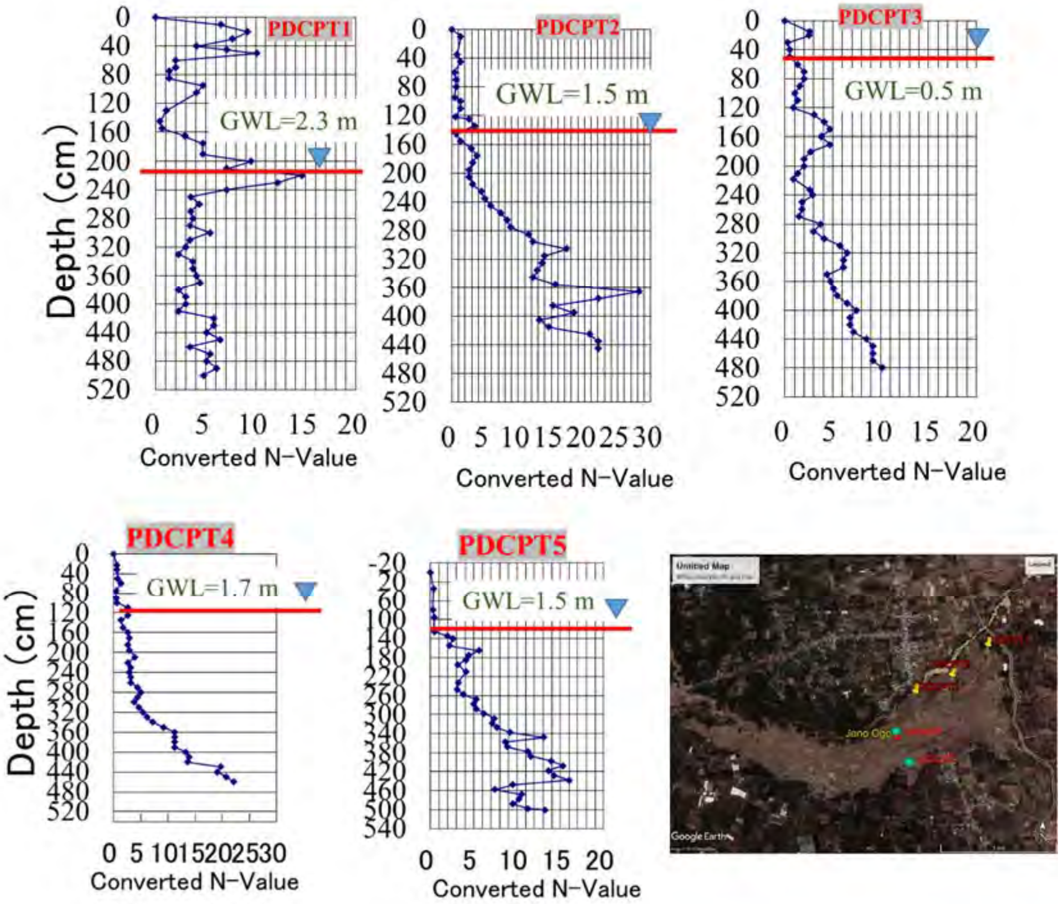
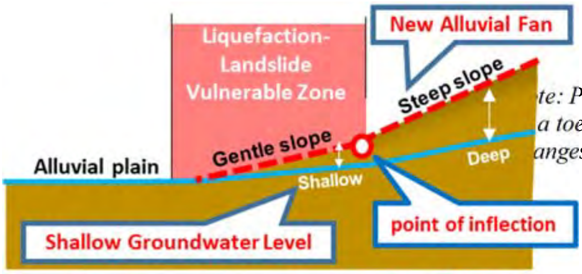


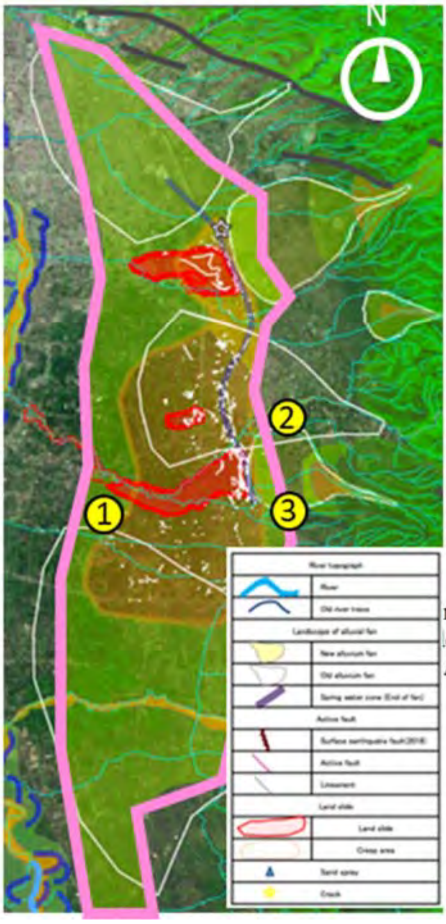
Figure 34 : Cone Penetration Test in Jono Oge

Based on above, JICA proposes a methodology of liquefaction-landslide risk assessment.

1. Alluvial Fan: New? or Small?
2. Point of Inflection: Steep to Gentle?
3. Groundwater Level: Shallow? or "Are there plants which prefer wet soil?"



te: Point of inflection should be interpreted a toe of alluvial fan from where soil anges from gravels to sands, silts & clays.



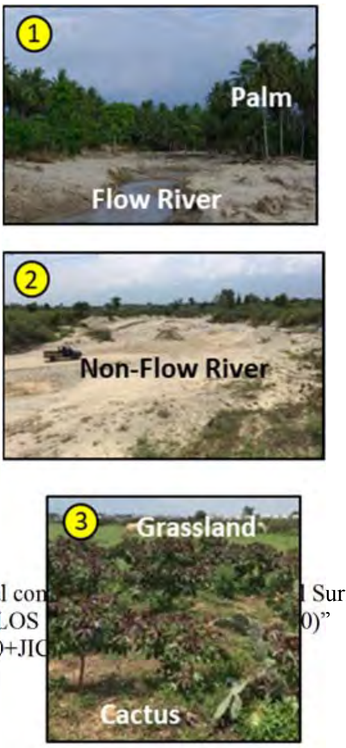


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Figure 35 : Analysis of liquefaction-liquefaction risk

5.3.4 Analysis of Liquefaction-Landslide

Table 9 : Analysis of Liquefaction-Landslide Phenomena

Fact	➢ "Liquefaction" occurred in large areas ➢ Affected areas have common aspects, 1. These areas are located with gentle slope around fan toe part of alluvial fan 2. Some people say groundwater naturally rose up to the ground when they put pipes into the ground of these areas or plants flourish which prefer wet soil 3. "Landslide" occurred in affected areas 4. Most of houses were much more severe damaged than houses in non-liquefaction areas
Analysis	➢ There must be "Confined Aquifer"(pressured groundwater) under each area ➢ Affected areas would be supposed to have the common mechanism ➢ The mechanism is as below 1. "Liquefaction" occurred because of strong shake and "Confined Aquifer" 2. "Landslide" occurred because of slope and large-scale "Liquefaction" (It should be supposed to be like "Mudflow" in steep slope areas) 3. Those phenomena brought about "Upheaval" or "Flush Flood" in downstream areas because a lot of soil surged from upstream 4. They also brought about "Mudflow" with "Fissure" in upstream areas because a lot of soil disappeared towards downstream ➢ There is a possibility to identify risk in accordance with geological points of view. 1. Alluvial Fan is new or small 2. Point of Inflection is steep to gentle 3. Groundwater Level is shallow, or there are plants which prefer wet soil

Source: JICA Mission Team

5.4 Shake

Surface displacement appeared in Lere Sub-district of Palu after disaster and show a lineament pattern to the southern part area. We did observational survey tracing displacement evidence in satellite. Figure 14 shows survey points of field observation. There are several parameters that should be checked to describe the fault characteristic such as calculating the displacement, vertical and horizontal offset also strike direction of the fault.

Source: JICA Mission Team

Figure 36 : Points of observational field survey to identify lateral displacement lineament in Palu which suspected as a fault

For each point survey, there is unique characteristic. It is just one or two house collapse completely, but the house beside it was not destroyed. The destroyed house is located right above the fault exactly. Shortly, in the vicinity of the surface rupture, the houses on the surface rupture zone destroyed, but the houses outside the surface rupture zone escaped collapse as shown in Figure 15.

Surface rupture with left lateral slip appeared over at least 7 km around the terminal part of alluvial fan in the western side of the flood plain as shown in Figure 17 and Figure 18. It has not been identified along the known active fault line in the western alluvial fan and mountainous area. Maximum left lateral displacement was 4.6 m with east side-up vertical offset of about 0.5 m.

Source: JICA Mission Team

Note: Asam Ⅱ str. (Lere Sub-Districts) which have left lateral displacement: 4.5m, Vertical offset: 0.4m east side up, Strike direction: N30°W

Figure 37 : Collapse of the house on the surface rupture zone at 20181103-3 site

Source: JICA Mission Team
Note: Padanjakaya str. Left lateral displacement: 4.6m, Vertical offset

Figure 38 : Collapse of the house on the surface rupture zone at 20181102-10 site

Figure 39 : Surface rupture at 20181102-6 site, Cemara str. Donggala Kodi districts.

- Left lateral displacement: 4.6m
- Vertical offset: None
- Strike direction: N20°W

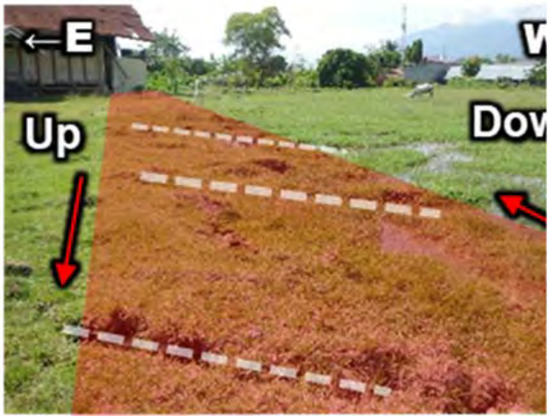


Figure 40 : Surface rupture at 20181103-2 site, Lasoso str., Palu City.

- Left lateral displacement: 3.5m
- Vertical offset: 0.6m east side up
- Strike direction: N15°W
- Surface rupture zone (red color mask) and echelon structure (white dashed lines)
- There is surface water on the down side (west side of surface rupture).

Interpretation of surface rupture

Since this field observation is limited by time and budget, it is necessary for continuation of surface ruptures survey. According to the analysis results using the satellite data from Reuters in Figure 19, it is possible that the surface rupture extended further to the south than our survey range. Investigating the property of the surface rupture is important for elucidating the earthquake mechanism.

According to Watkinson and Hall, 2017 and Hennig et.al., 2017, the undersurface condition of Palu and surrounded area are explain as shown in Figure 42. This is geological map and illustration of cross-section through the Neck and Donggala Peninsula which include active fault, and geological material. Based on that picture, we can see there is an unknown active fault in the middle of Palu that actually close to liquefaction affected area (Balaroa). If we correlate the damage that occured after the disaster due to the shake, we assume that this is a surface rupture from current active fault.

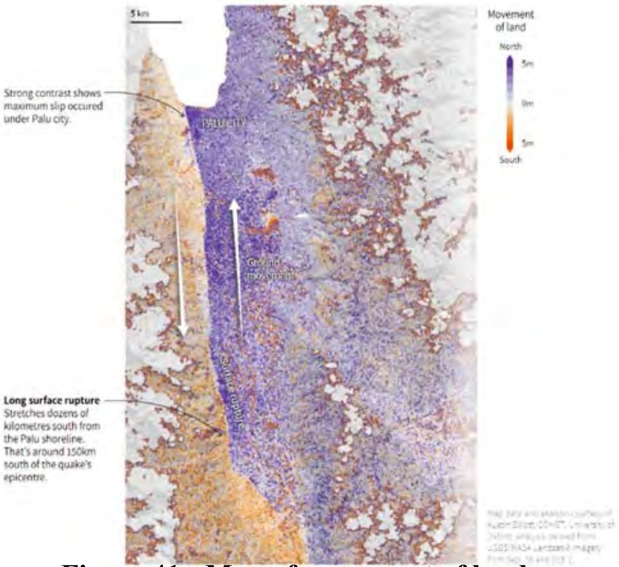
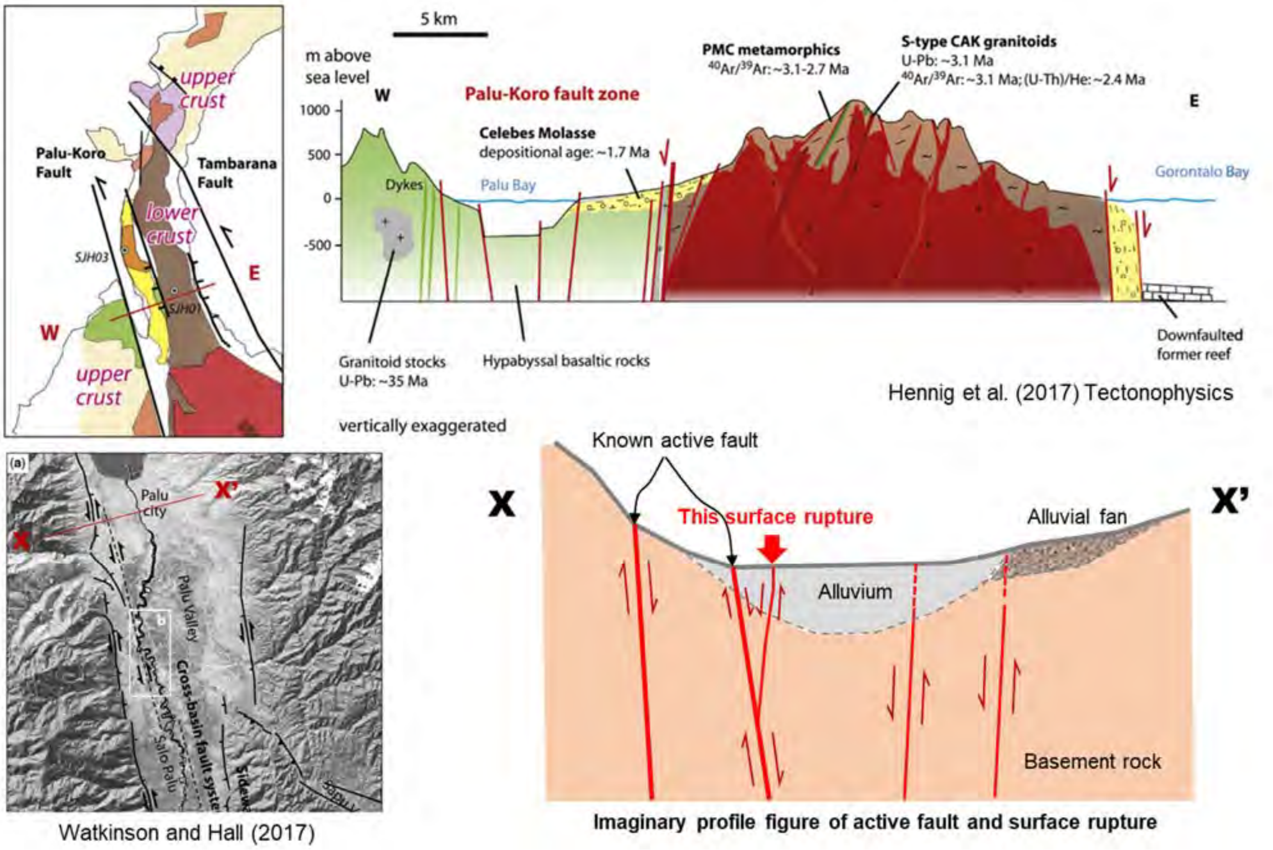


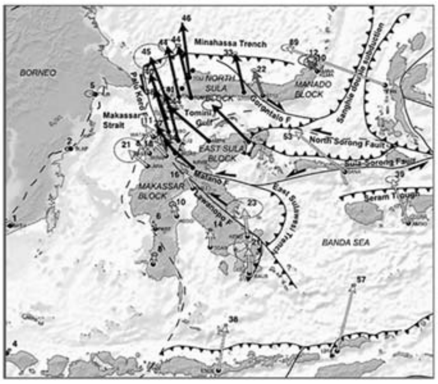
Figure 41 : Map of movement of land (from REUTERS GRAPHICS website)



Source: JICA Mission Team

Note: The surface rupture that currently occurred is assumed as a site effect condition from the known active fault movement.

Figure 42 : Undersurface condition in Palu from Hennig et.al (2017) and surface condition by Watkinson and Hall (2017)



Palu-Koro Fault exists along plate boundary. Around 40mm of movement per year is observed with GPS survey (Socquet et al.2006）. As the maximum movement was 4m in this earthquake, it released accumulated energy around 100 years. That means earthquake with the scale similar to this earthquake may occur once 100 years.

Figure 43 : Present-day GPS Movement in the Sulawesi Region (Socquet et al.2006)

Palu Seismic Station

Figure 44 : Palu class 1 geophysical station

Figure 45 : Seismometer field at Palu class 1 geophysical station

BMKG at Palu (station code: PCI (Palu Celebes Island) is one of key stations that process seismic data to detect an earthquake in and around Palu using Seiscomp3 software, developed by GFZ, Germany. There is a new instrument granted by JICA in Palu BMKG office. This instrument has recorded the September 28th, 2018 earthquake.

The seismic processing system, SeisComP3, is working, but processing parameters might be optimized by BMKG officials. Particularly, a velocity model, or, a travel time table, might be modified so that location of the earthquake would be calibrated by the local or regional agency. The record of PCI station might be merged to the BMKG network data to improve an accuracy of hypocenter or get a better aftershock distribution which gives important information of surface structure. Though it is a "strong motion" of PCI station, it might be improved in order that it could pick an arrival time of each event if it has an amplitude large enough. So, it is recommended to combine those new installed station data to the current network data to locate aftershocks. It would enhance the quality of data processing while identify the location or earthquake mechanism.

5.4.1 Damaged Buildings by Shake

(1) General Condition of Building against to shake

Indonesia have national building code standard (SNI) for earthquake-resistant building, and this regulation should be fulfilled in building construction. One problem is that sometimes this regulation is not observed completely. However, this regulation should be observed while building construction to get earthquake-

resistant building. Another aspect to be consider is ”Resonance”. It depends on natural period for each building and the period of seismic wave that coming. Tall buildings usually have long own natural period, and short houses have short one. When the period of seismic wave matches own natural period, Resonance would occur and it would bring about severe damage.
According to seismometer record, dominant frequency was 0.2 to 0.6 Hz in Palu. That means “Dominant Period of Seismic Wave” was 1.7 to 5 seconds (Middle-Long Period). That would not cause damages of short houses, but cause damages of tall buildings due to “Resonance”.

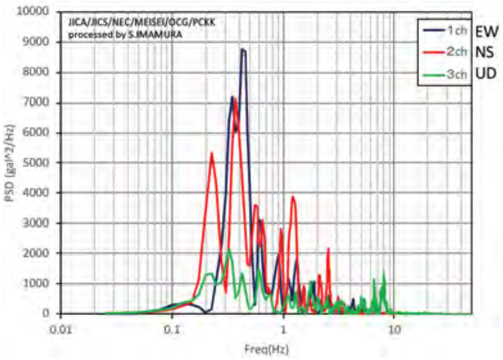


Figure 46 : Record of Seismometer in Palu on 28th Oct, 2018

Phenomena in central Palu is supposed to be the right case rather than the left case. That case is dangerous to high-rise building, but is not dangerous to low-rise building.

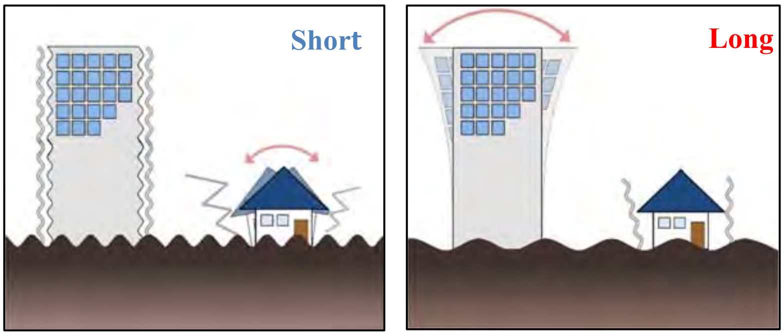
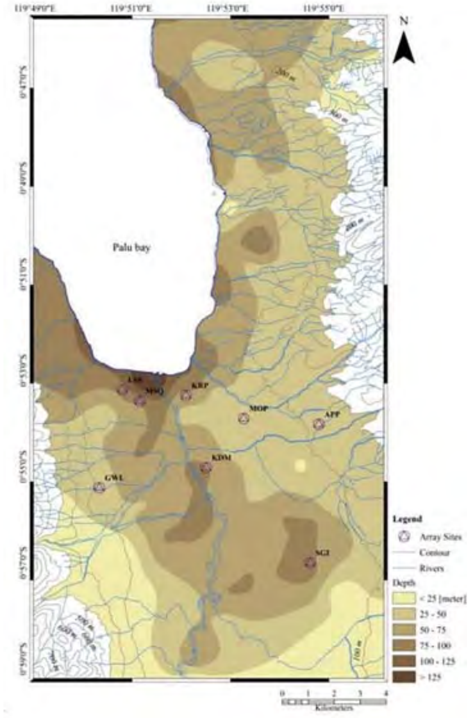


Figure 47 : Resonance



The dominant period of seismic wave is determined by the thickness of sedimentary layer. A thick sedimentary layer might amplify long period of seismic wave, so it is actually dangerous for high-rise building when earthquake happened. Palu has more than one hundred meter of sedimentary layer as result of Thein et.al (2015) that analyzed about estimation of S-wave velocity structure for sedimentary layered.

The thickness of sedimentary layer was estimated by using micro tremor array measurements as shown in Figure19. This thickness should be considered as one of important point in constructing earthquake-resistant building.

Figure 48 : thickness of sedimentary layer to bed rock in Palu Area. Image source: Thein, et.al. (2015)

(2) Damage building and Failure Factors in Central Area of Palu City

There are a lot of high-rise buildings in Palu City since it is the center location of various activity such as tourism, trading, education and culture. But the strike of shake on September 28th, 2018 made a lot of building failures and produced many victims as shown in Figure 49. The analysis to identify the cause of failure building is really important to enhance the quality of building in the future. Here we show examples of building failures after conducting building safety observation by JICA mission team.

In central area of Palu City, there is a unique phenomenon that almost only high-rise buildings (4 stories or more) collapsed, while other low-rise buildings around collapsed high-rise building still stands. As stated, it can be explained because of resonance. The crucial problem is that some of high-rise buildings collapse, but other high-rise buildings remains. The cause of this collapse of some high-rise buildings was dominantly by inappropriate design including foundation or bad construction implementation that were observed in Mall Tatura, Rusunawa Lere, Anatapura Hospital and Roa Roa Hotel. The failures are caused by several points of view as below:

- Collapsed buildings doesn’t seem to have used suitable foundation. Roa roa seems to have used Cakar Ayam Foundation which is suitable for swamp area. Rusunawa Lere seems to have used pile foundation and to have occurred “column sway”, where failure mechanism occurred at column, not at beam (beam sway), and it would cause damage to the whole building (Figure 50 and Figure 51).
- Joint failure seems to have caused by column broken (Figure 52).
- Collapsed buildings doesn’t seem to have used appropriate reinforced bars. Roa Roa hotel seems to have used very small reinforced bars narrower than 13 mm diameters, whereas in building code it should be minimum 13 mm (Figure 53–Figure 55).
- Collapsed buildings doesn’t seem to use good quality of construction material, such as inappropriate size of concrete aggregate, bad quality of brick (Figure 56).
- Collapsed buildings doesn’t seem to set suitable position of main reinforced bars, for example, in Mall Tatura (Figure 57).
- Supervision might be insufficient during construction work, due to the system or shortage of finance.

Ramayana in Mall Tatura with 4 stories was partially collapsed

Rusunawa Lere Palu with 5 stories was partially collapsed

Regional Public Hospital Anutapura Palu with 5 stories was partially collapsed

Roa Roa Hotel with 8 stories was completely collapsed

Source: JICA Mission Team

Figure 49 : Several documentations of damage high buildings in central area of Palu City

Figure 50 : Out-of-plane wall and column sway mechanism

Figure 51 : Too small reinforced bars used in Roa Roa Hotel

Figure 52 : Joint failure

Figure 53 : Inadequate stirrup in Rusunawa Lere

Figure 54 : Inadequate stirrup in Rusunawa Lere

Figure 55 : Non-deformed bars still used in Lere,

Figure 56 : Non-deformed bars still used

Figure 57 : Inappropriate design of column and material

(3) Damage building and Failure Factors in Biromaru, Sigi Area

There are a lot of collapsed house with single story in Biromaru (But, some still stand without damage). This area could have been shaken and liquefied more than other areas around central Palu. Collapsed buildings with one story in Sigi area are shown from Figure 58 to Figure 67. Broken wall and roof and tilting column are found in Sigi. The movement of the ground was found which caused the fence of the house move around 1 meter to 2 meter from the gate (Figure 61), as it was measured.

Figure 58 : Collapsed of Mosque

Figure 59 : Collapsed of Store

Figure 60 : Damaged Roof of Stores

Figure 61 : Tilting column of house and moving fence

Figure 62 : Tilting column of house

Figure 63 : Total Collapsed of House

Figure 64 : Total Collapsed of House

Figure 65 : Partial Collapsed of House

Figure 66 : Collapsed by Land Subsidence

Figure 67 : Collapsed by Land Subsidence

(4) Analysis of building damage phenomena in central area of Palu City

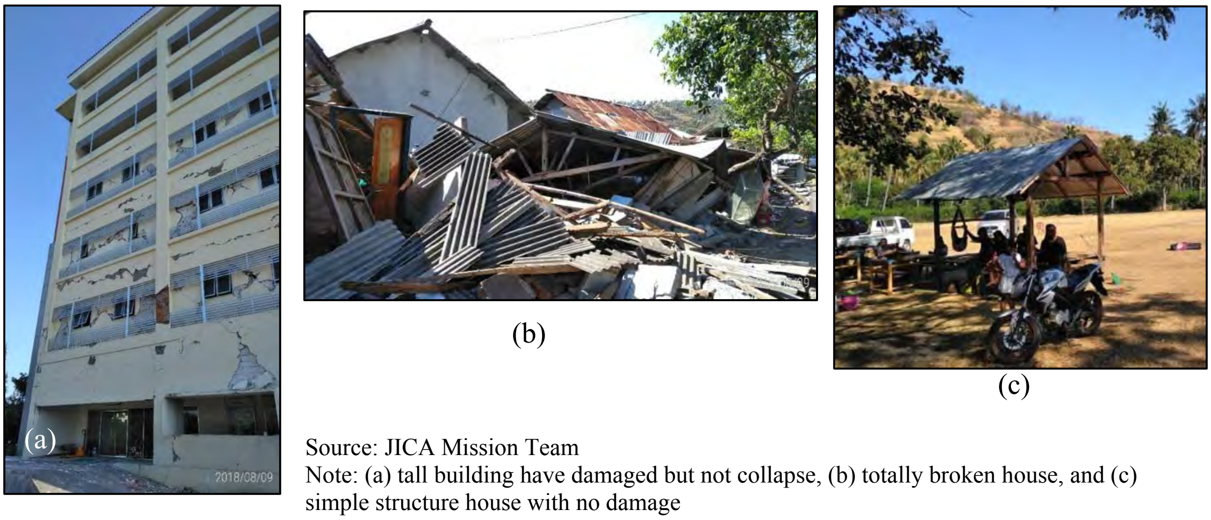
Table 10 : Analysis of building damage phenomena in central area of Palu City

Fact	➢ Several high-rise buildings (4 stories or more) collapsed and damaged ➢ Quite a few short houses were damaged in central Palu ➢ A lot of house were collapsed in Sigi because of shake and land movement.
Analysis	➢ High-rise building collapse seem to have been enhanced by resonance that occurred when building natural period is similar with earthquake natural period. ➢ The reason why most high building collapse and short building remains in central Palu is that it might be caused by long period wave of earthquake which brought severe damage ➢ A thick sedimentary layer might amplify long period of seismic wave since Palu has more than one hundred meter of sedimentary layer ➢ Long period of seismic wave has a feature to reach longer distance without decrease of energy than short period of seismic wave ➢ Building Code should be reviewed from the view point of "Foundation" ➢ The reason of Building collapse was mostly inappropriate design, construction material and construction work

Source: JICA Mission Team

(5) Phenomena on Building Collapse in Palu City Compared with Lombok (Just for reference)

A series of quakes including a powerful 6.9 magnitude tremor struck Lombok Island. This earthquake trigger landslide in some area. There are completely broken houses and non-damaged houses in the same place in Lombok as shown in Figure 41.



(b)

(c)

Source: JICA Mission Team
Note: (a) tall building have damaged but not collapse, (b) totally broken house, and (c) simple structure house with no damage

Figure 43. Building condition in Lombok after strike by series of earthquake

Table 10 : Analysis of building damage phenomena in Palu City and Lombok

Fact	**<High Buildings>** ➢ There was no short house with damage in Mataram by Lombok Earthquake (Mataram is at 50km distance from epicenter) ➢ Some tall buildings were damaged in Mataram ➢ Resonance happened both in Palu and Mataram **<Short Houses>** ➢ Some are completely collapsed, Others are without damage ➢ Even a simple structure stands without damage
Analysis	➢ There is a possibility that disregard of “Building Code” or due to “Construction Failure” exist not only in Central Sulawesi but in most place in Indonesia.

Source: JICA Mission Team

CHAPTER 6. Disaster Risk Analysis Based Planning

6.1 Outline of Disaster Risk Map

Based on this earthquake disaster, from the viewpoint of not receiving the same kind of disaster again, we examined the risks of the area and created a risk map for each kind of disaster.
The criteria for zoning are as shown in the table below, and disaster hazard map based on this standard is shown below.

Table 11 : Criteria and Guidance for Disaster Hazard Zone (ZRB)

Zone	Criteria	Post disaster spatial guidance (requirement for land use)
ZRB 4 PROHIBITED ZONE (very High Level or most affected area in the disaster Sept 28th 2018)	1. Located in liquefaction-landslide zone (after earthquake) (Petobo, Balaroa, Jono Oge, Lolu, Sibalaya and Sidondo 1) 2. Located along the coastline, which is tsunami vulnerable area(outside of tsunami sea dike) or costal landslide vulnerable area. *This zone should be identified after setting the location and strrudture of dike. 3. located right above the active fault appeared on the earth's surface 4. Sediment Disaster Vulnerability Zone level "High"	1. Not allowed to rebuild houses after disaster. Building and Houses in this area should be relocated 2. Prioritized to be used as protected area for DRR (example Tsunami green belt, Open green space) 3. Can be used as disaster awareness area/to build monument
ZRB 3 RESTRICTED ZONE (High Level)	1. Located in the cracked zone by liquefaction-landslide (after earthquake) 2. Located in the tsunami inundated area (after earthquake) 3. Within 15m along the active fault *This distance should be identified in accordance with "earthquake proof design". 4. Sediment Disaster Vulnerability Zone level "Medium" 5. Flood Hazard Zone "High"	1. New building in coastal area where tsunami inundated is limited for high building (>=2 stories), which can be used as multi-function (Tsunami vertical evacuation shelter) with perpendicular direction of the coastline. 2. For Land utilization in Flood hazard area, minimum 2 stories houses are required. 3. Development of roads and places for evacuation and green open space. 4. New building is limited to earthquake, tsunami, liquefaction-landslide, flood and sediment disaster resistance building (using geotechnical and structural engineering) 5. To limit house and land use intensity in level "Low", and periodically monitor the saturation level of ground water. 6. Very strict controlling of existing residential land use and avoiding construction of new high-risk life line/critical facilities. 7. Undeveloped areas in "very high" of liquefaction-landslide or "high" of sediment disaster should be prioritized the function of protected areas or non-built cultivation such as utilization of forestry, agriculture and plantation space for plants that do not require a lot of water.
ZRB 2 CONTROLLED ZONE (Medium Level)	1. Liquefaction-landslide Hazard Zone (High) 2. Buffer zone in which the uncertainty of tsunami risk 3. Within 1km along the active fault 4. Sediment Disaster Vulnerability Zone level "Low" 5. Flood Hazard Zone "Medium"	1. Low Intensity for land utilization/usage 2. Recommendation to follow "resistance building" of ZRB 3 in accordance with each risk.

ZRB 1 PROMOTED ZONE (Low Level)	1. Liquefaction-landslide Hazard Zone (Medium) 2. Low tsunami risk zone 3. Sediment Disaster Vulnerability Zone level "very Low" 4. Flood Hazard Zone "Low"	1. Low - Medium Intensity for land utilization/usage

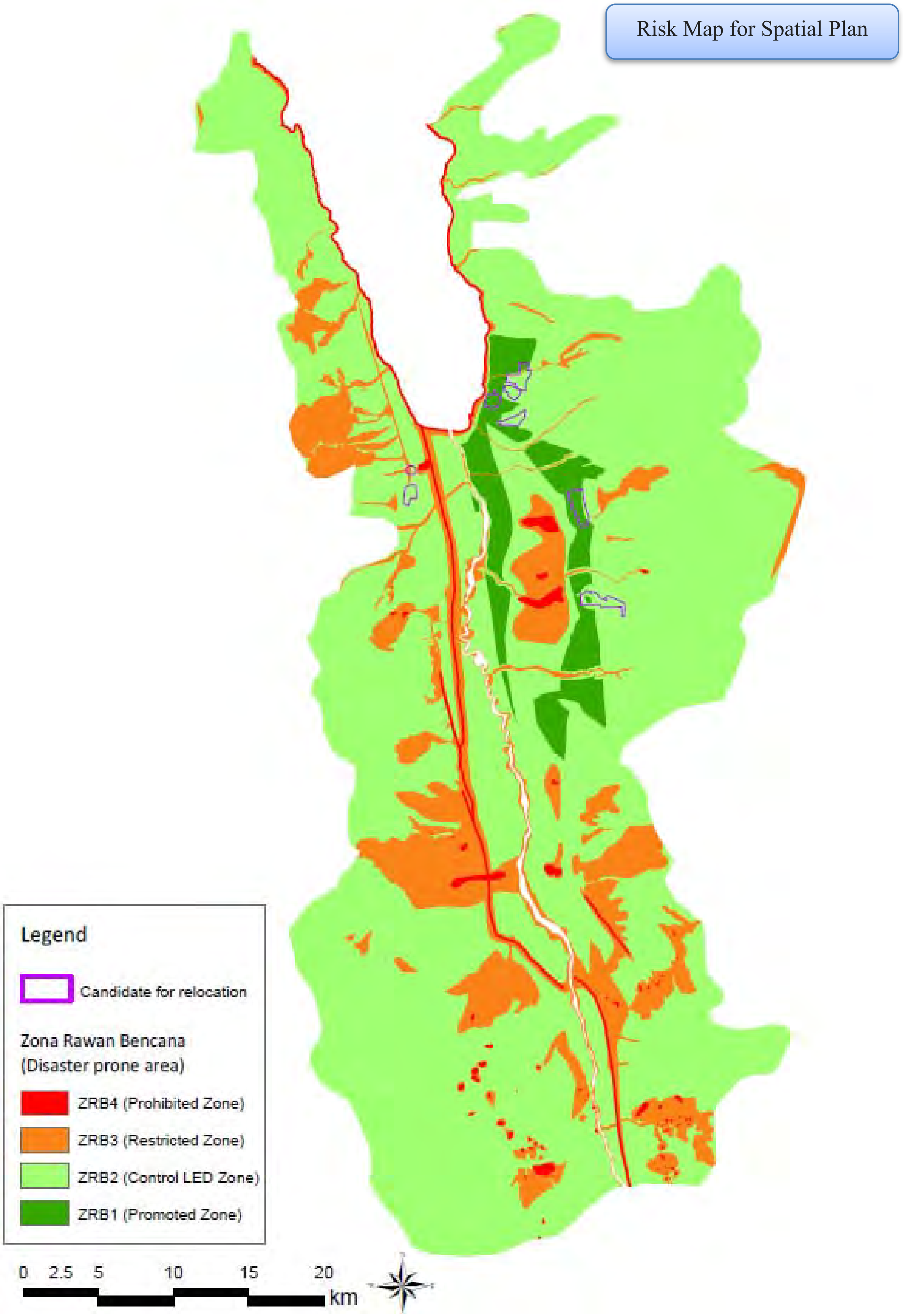
1. The area of “Liquefaction-landslide” in ZRB 3 should be reviewed with detail survey. In parallel, the regulation of “liquefaction-landslide resistance building” should be considered.
2. Assessed risk in this table is not simple “Liquefaction”, but “Liquefaction-landslide”. The reason is why simple “Liquefaction” will rarely kill people.
3. Regarding the earthquake-resilience of buildings, the risk of “Resonance” should be considered in designing by reference to micro zonation map. “Resonance” occurs when "Own Natural Period" of each building matches “The Dominant Period of Seismic Wave” at its location. For example, inspection of construction executing should be more frequent and more strict if there is risk of “Resonance”, such as high-rise buildings in "long dominant period of seismic wave zone“ or low-rise buildings in "short dominant period of seismic wave zone“.

The guidance for each zone is also to be reviewed through further survey. When refining the risk map, risks were reviewed after conducting examinations and field surveys of academics and experts.
In addition to scientific perspective, it is important and efficient to consider the tradition handed over from the ancestors who lives there. Indigenous people, “Kaili”, have a lot of tradition off place-names on disaster as below. However, we have to be careful that all area is not necessarily dangerous even if its name implicates disaster. We should identify where and what traditional name shows because the area of each place indicates a certain distance of land.

Table 12 : Some examples of Kaili tradition of place-names on disaster

Place Name	Meaning
Balaroa (original name was “Puse Ntasi”)	“The center of the sea” (because it was believed that this place connected the sea through mud hole)
Biromaru	“Swamps which decay grass”
Jono Oge	“Swamps where a lot of grass flourishes”
Duyu	“Landslide”

Source: Jakarta Shimbun

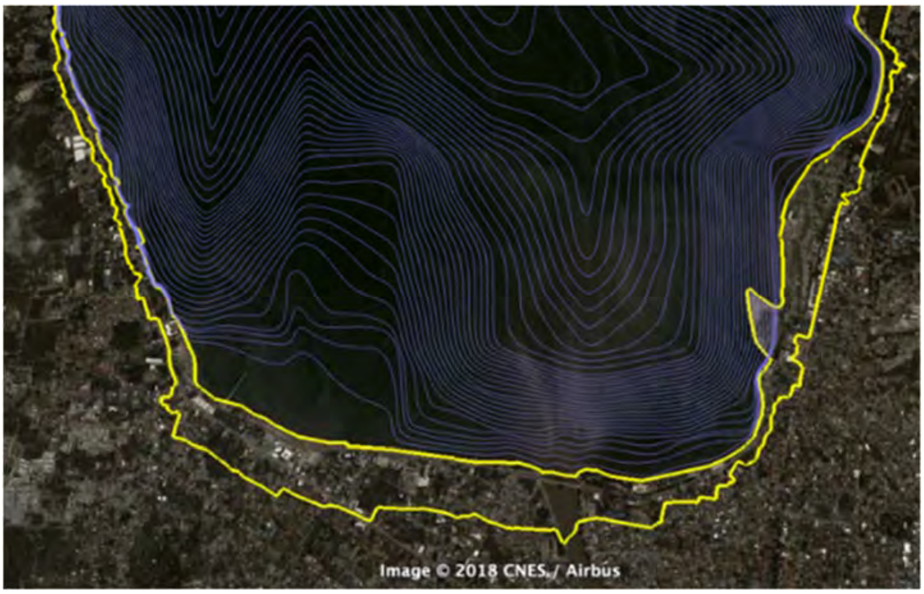


Source: JICA Mission Team

Figure 68 : Disaster Hazard Zone (ZRB)

6.2 Tsunami and Coastal Area

Damaged area in coastal area is confirmed by field survey etc. In coastal area, there are two type of damage. One was inundated by tsunami. The other was collapsed by landslide, which was caused directly by shake or through liquefaction phenomena by shake.

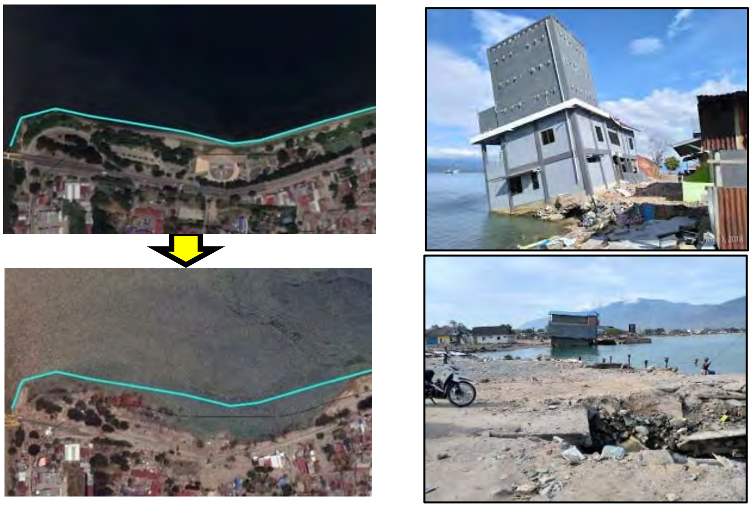


Source: JICA Mission Team

Figure 69 : Tsunami inundated area (Source: Digital Globe Open Data Program)

Source: JICA Mission Team

Figure 70 : Area inundated by tsunami



Source: JICA Mission Team

Figure 71 : Landslide area

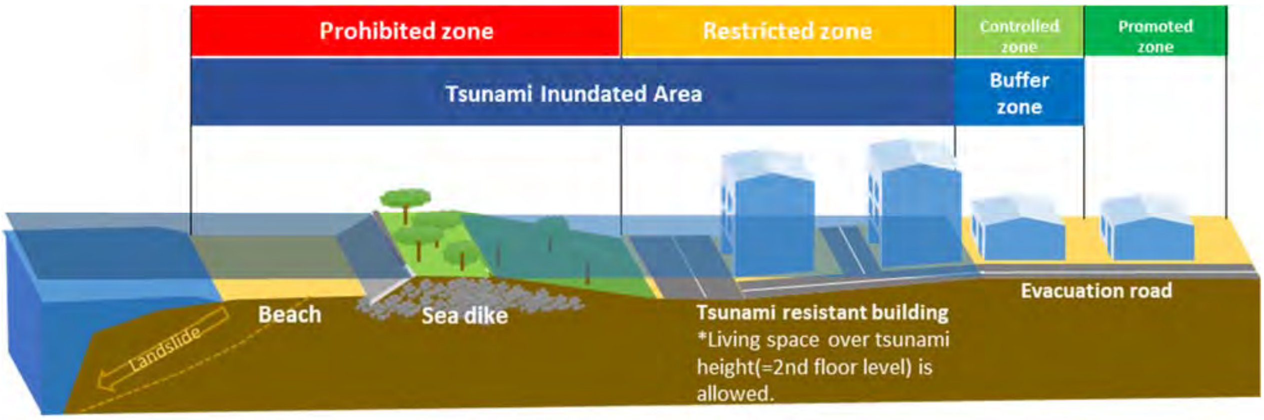
Table 13 : Criteria and Guidance for Disaster Hazard Zone (ZRB) on tsunami and coastal landslide

Zone	Criteria
ZRB 4	Located along the coastline, which is tsunami vulnerable area (outside of tsunami sea dike) or costal landslide vulnerable area. *This zone should be identified after setting the location and structure of dike.
ZRB 3	Located in the tsunami inundated area (after earthquake)
ZRB 2	Buffer zone in which the uncertainty of tsunami risk
ZRB 1	Low tsunami risk zone

Source: JICA Mission Team

Figure 72 : ZRB on tsunami and coastal landslide

The outside of sea dike should be classified into ZRB 4. It depends on the specification of sea dike. Not only tsunami inundation, but also coastal landslide should be considered. Coastal landslide vulnerable are should be reviewed by detail bathymetric survey. The area of ZRB2 should be defined by detail topographic survey.



Source: JICA Mission Team

Figure 73 : Image of spatial plan on tsunami and coastal landslide

6.3 Fault and Shake

Table 14 : Criteria and Guidance for Disaster Hazard Zone (ZRB) on fault and shake

Zone	Criteria
ZRB 4	Located right above the active fault appeared on the earth's surface
ZRB 3	Within 15m along the active fault *This distance should be identified in accordance with "Earthquake-Resistance Design".
ZRB 2	Within 1km along the active fault

Many literature indicate there is main fault along the boundary between the mountains and plain in the west part of Palu. In this time, the fault appeared more 2 km east than the indicated main fault. It means it would be difficult to forecast where fault would appear beforehand. The areas within 1km along faults is appropriate to be assessed ZRB 3 in order to make people to pay attention to earthquake.

Regarding "Earthquake-Resistance Design" of buildings, the risk of "Resonance" should be considered in designing by reference to micro zonation map. "Resonance" occurs when "Own Natural Period" of each building matches "The Dominant Period of Seismic Wave" at its location. For example, inspection of construction executing should be more frequent and strict if there is risk of "Resonance", such as high-rise buildings in "long dominant period of seismic wave zone" or low-rise buildings in "short dominant period of seismic wave zone".

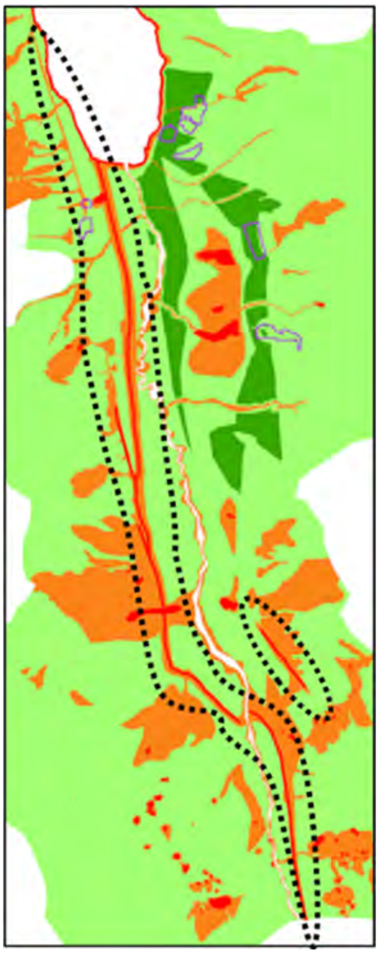


Figure 74 : ZRB on fault and shake

6.4 Liquefaction-Landslide

Liquefaction-landslide occurred not only Petobo, Balaroa, Jono Oge, but also Lolu, Sibalaya and Sidondo 1. These areas should be classified in the ZRB4.

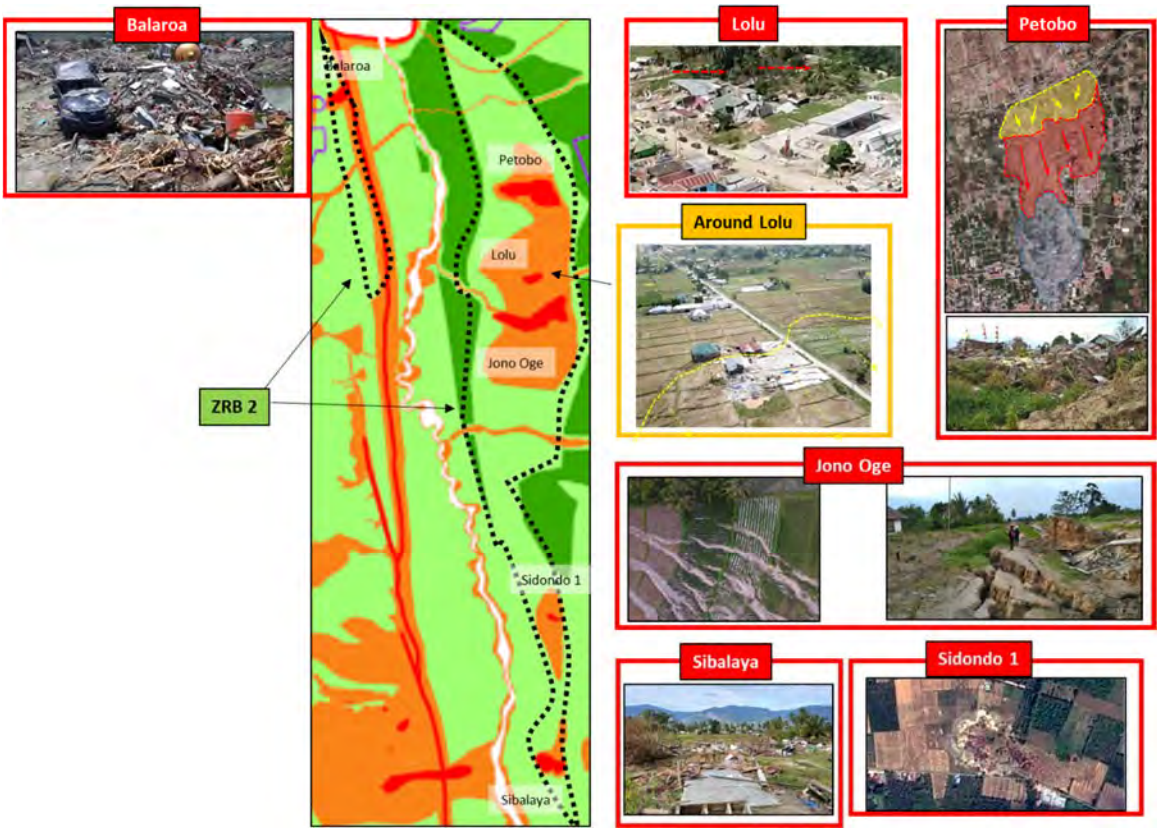
The cracked areas by liquefaction-landslide, however which are not as severe as areas in ZRB 4, should be classified in the ZRB3. The area of "Liquefaction-landslide" in ZRB 3 should be reviewed with detail survey. In parallel, the regulation of "liquefaction-landslide resistance building" should be considered.

Regarding ZRB 2, hypothesis was formulated that there is high risk of liquefaction-landslide at the toe of new alluvial fan. Geotechnical survey including boring will verify this hypothesis by comparing the conditions for liquefaction-landslide with geographical and vegetative features. Vegetation is useful to easily estimate groundwater level. After the verification, the liquefaction-landslide vulnerable zone can be identified by the geographical and vegetative features. It is also important to assess that the presence of confined water.

The reason why the area near Palu River is "ZRB 1" is as below though more investigations needed. The slope of this area is very gentle, though groundwater level in this area is shallow. "Liquefaction-Landslide Risk" is Low though "Liquefaction Risk" is High-Medium

Table 15 : Criteria and Guidance for Disaster Hazard Zone (ZRB) on liquefaction-liquefaction

Zone	Criteria
ZRB 4	Located in liquefaction-landslide zone (after earthquake) (Petobo, Balaroa, Jono Oge, Lolu, Sibalaya and Sidondo 1)
ZRB 3	Located in the cracked zone by liquefaction-landslide (after earthquake)
ZRB 2	Liquefaction-landslide Hazard Zone (High)
ZRB 1	Liquefaction-landslide Hazard Zone (Low - very Low/ safe)



Source: JICA Mission Team

Figure 75 : ZRB on Liquefaction-Landslide

6.5 Flood

The vicinity along the Palu River and its tributaries should be in the ZRB3. Flash flood inundated area from liquefaction-landslide area of Jono Oge should be in the ZRB3 in the view of flood. ZRB 2 should be identified by flood simulation or relative elevation.

Source: JICA Mission Team

Figure 76 : Down stream of Jono Oge

Table 16 : Criteria and Guidance for Disaster Hazard Zone (ZRB) on flood

Zone	Criteria
ZRB 4	-
ZRB 3	Flood Hazard Zone "High"
ZRB 2	Flood Hazard Zone "Medium"
ZRB 1	Flood Hazard Zone "Low"

Source: JICA Mission Team

Figure 77 : ZRB on Flood

6.6 Sediment Disaster

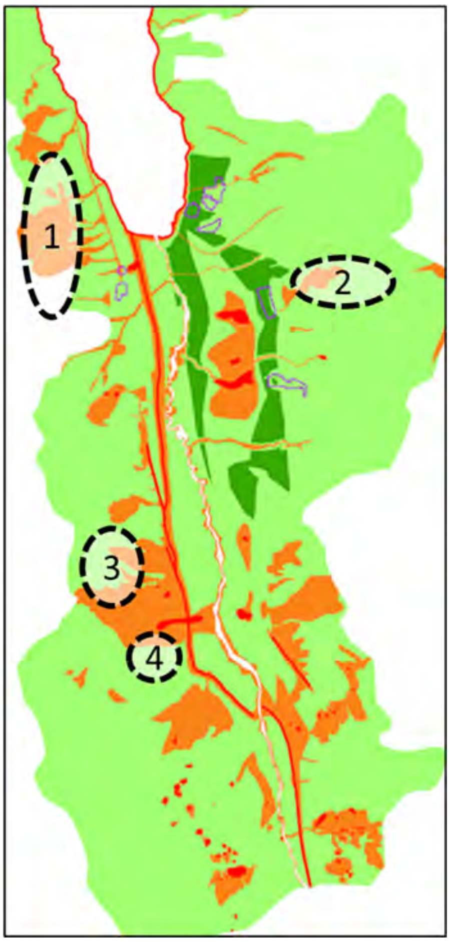
As sediment-related disasters (Flash Flood, Steep Slope Collapse, Landslide, deep-seated landslide) occurred or would occur in various places, JICA confirmed the location of the disaster by field survey.

Table 17 : Criteria and Guidance for Disaster Hazard Zone (ZRB) on sediment disaster

Zone	Criteria
ZRB 4	Sediment Disaster Vulnerability Zone level "High"
ZRB 3	Sediment Disaster Vulnerability Zone level "Medium"
ZRB 2	Sediment Disaster Vulnerability Zone level "Low"
ZRB 1	Sediment Disaster Vulnerability Zone level "very Low"

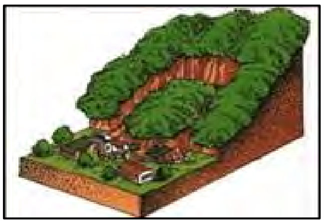
Flash Flood ① ②
A rapid flood with collapsed sediment by rainfall, which speed is very rapid, such as 3~14m per second

Steep Slope Collapse ③
A instantaneous collapse of steep slope by rainfall or earthquake



Source: JICA Mission Team

Figure 78 : ZRB on Sediment Disaster



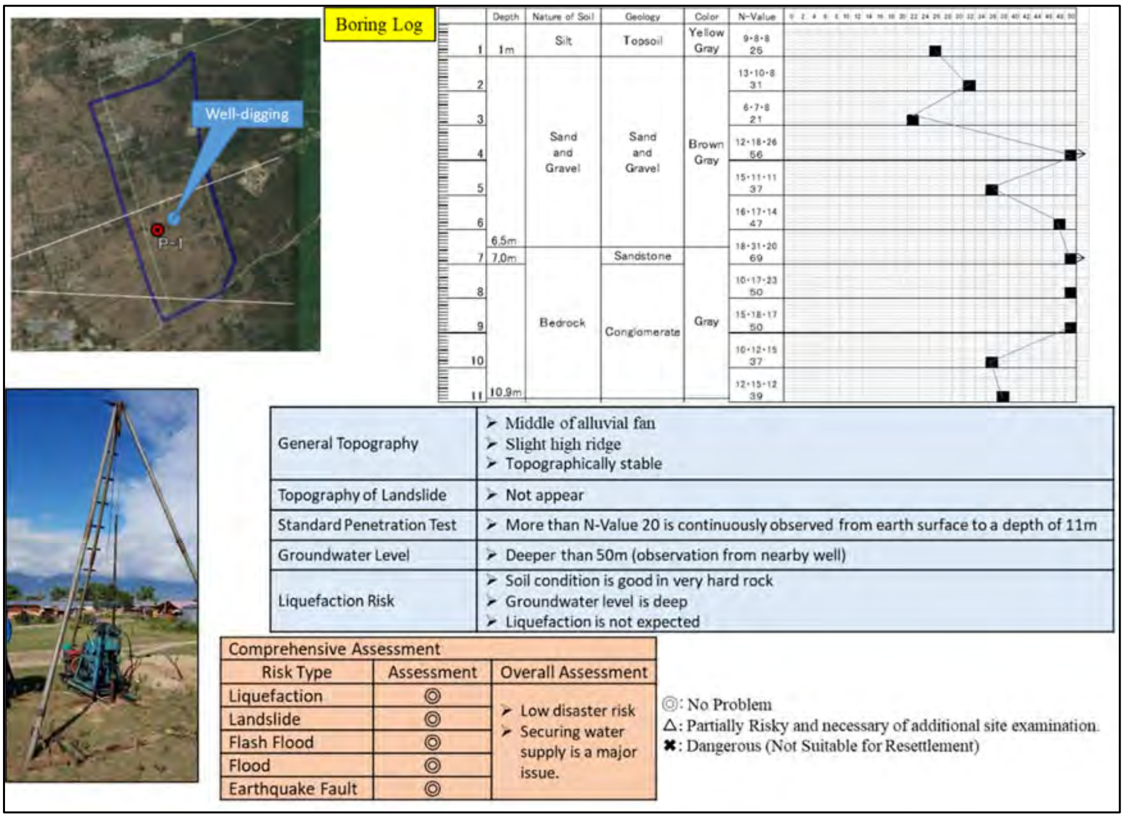
Landslide
Slow slip of a mass of earth because of water on the impermeable layer, which speed is very slow, such as 0.01~10mm per day

Deep-Seated Landslide ④
A landslide with enormous volume from a deep layer by rainfall or earthquake. (This kind of landslide is more difficult to identify the location than other kinds of sediment disasters.)
In this location,

- Huge amount of sediment has collapsed.
- It could cause flash flood by following rain.
- The most severe incident is that it might make natural dam, which would bring devastation of downstream houses.
- Downstream residents should evacuate proactively.

6.7 Risk Assessment of Candidate for Relocation Site

In order to assess the risk, borehole testing has been conducted in each candidate for relocation site.
As a result, Petobo, Pombewe, Talise-Tondo and Duyu could be appropriate for relocation site. For all of them, it is the biggest issue how to secure water supply. Exact relocation site should be requested to pay attention to flood risk in Talise-Tondo. Duyu might have risk of active fault.
On the other hand, Gawalise is not suitable for relocation site. The reason is why some rupture appears on the surface and it might move to open. If we want to know this rupture would be opening and landslide would happen, we have to observe some years because continuous monitoring is necessary. This doesn't meet the condition to select as soon as possible.



	Depth	Nature of Soil	Geology	Color	N-Value
1	1m	Silt	Topsoil	Yellow Gray	9・8・8 25
2		Sand and Gravel	Sand and Gravel	Brown Gray	13・10・8 31
3					6・7・8 21
4					12・18・26 56
5					15・11・11 37
6	6.5m				16・17・14 47
7	7.0m	Bedrock	Sandstone	Gray	18・31・20 69
8			Conglomerate		10・17・23 50
9					15・18・17 50
10					10・12・15 37
11	10.9m				12・15・12 39

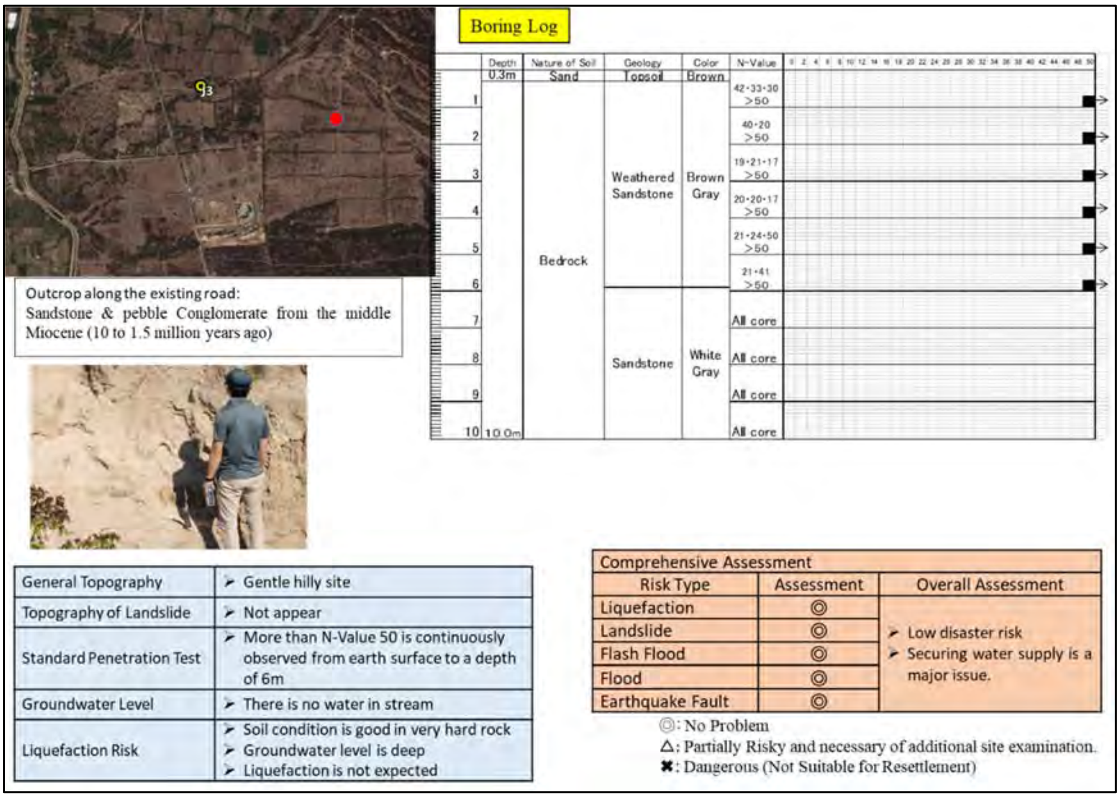
General Topography	➢ Middle of alluvial fan ➢ Slight high ridge ➢ Topographically stable
Topography of Landslide	➢ Not appear
Standard Penetration Test	➢ More than N-Value 20 is continuously observed from earth surface to a depth of 11m
Groundwater Level	➢ Deeper than 50m (observation from nearby well)
Liquefaction Risk	➢ Soil condition is good in very hard rock ➢ Groundwater level is deep ➢ Liquefaction is not expected

Comprehensive Assessment		
Risk Type	Assessment	Overall Assessment
Liquefaction	◎	➢ Low disaster risk ➢ Securing water supply is a major issue.
Landslide	◎	
Flash Flood	◎	
Flood	◎	
Earthquake Fault	◎	

◎: No Problem
△: Partially Risky and necessary of additional site examination
✖: Dangerous (Not Suitable for Resettlement)

Source: JICA Mission Team

Figure 79 : Petobo



Outcrop along the existing road:
Sandstone & pebble Conglomerate from the middle Miocene (10 to 1.5 million years ago)

	Depth	Nature of Soil	Geology	Color	N-Value
	0.3m	Sand	Topsoil	Brown	
1		Bedrock	Weathered Sandstone	Brown Gray	42・33・30 >50
2					40・20 >50
3					19・21・17 >50
4					20・20・17 >50
5					21・24・50 >50
6					21・41 >50
7			Sandstone	White Gray	All core
8					All core
9					All core
10	10.0m				All core

General Topography	➢ Gentle hilly site
Topography of Landslide	➢ Not appear
Standard Penetration Test	➢ More than N-Value 50 is continuously observed from earth surface to a depth of 6m
Groundwater Level	➢ There is no water in stream
Liquefaction Risk	➢ Soil condition is good in very hard rock ➢ Groundwater level is deep ➢ Liquefaction is not expected

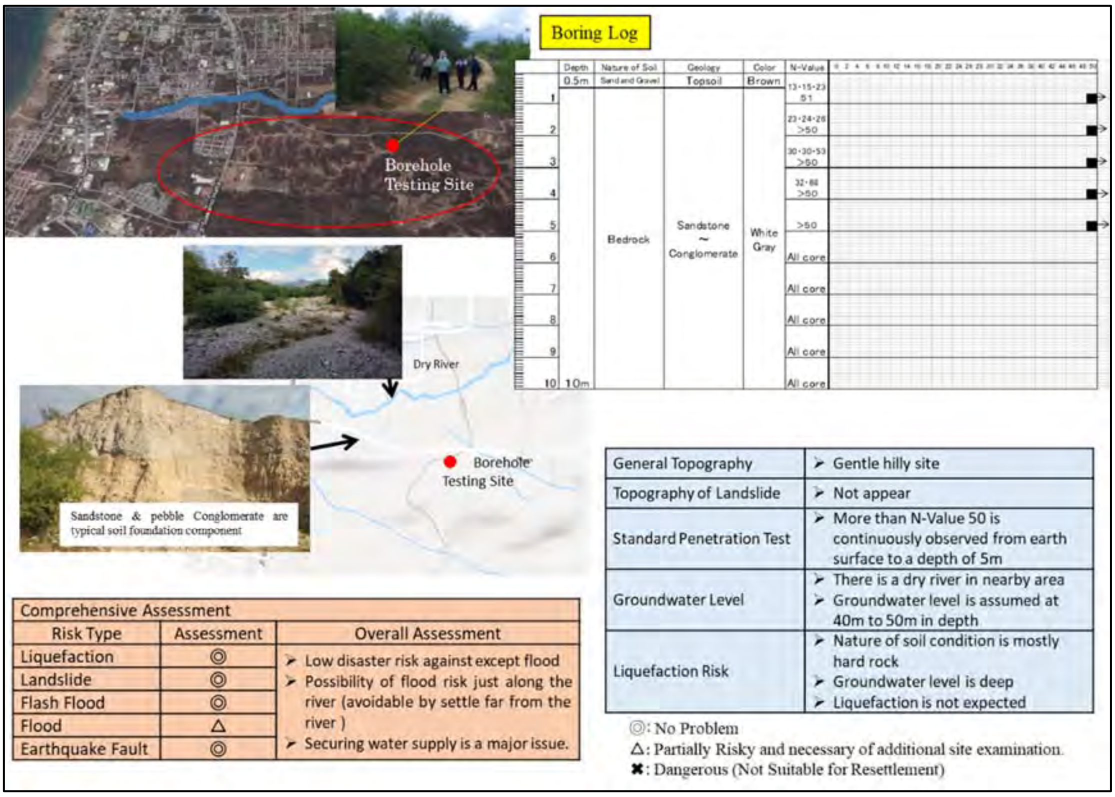
Comprehensive Assessment

Risk Type	Assessment	Overall Assessment
Liquefaction	◎	➢ Low disaster risk ➢ Securing water supply is a major issue.
Landslide	◎	
Flash Flood	◎	
Flood	◎	
Earthquake Fault	◎	

◎: No Problem
△: Partially Risky and necessary of additional site examination.
✖: Dangerous (Not Suitable for Resettlement)

Source: JICA Mission Team

Figure 80 : Pombewe



Sandstone & pebble Conglomerate are typical soil foundation component

	Depth	Nature of Soil	Geology	Color	N-Value
	0.5m	Sand and Gravel	Topsoil	Brown	
1		Bedrock	Sandstone ~ Conglomerate	White Gray	13・15・23 51
2					23・24・26 >50
3					30・30・53 >50
4					32・68 >50
5					>50
6					All core
7					All core
8					All core
9					All core
10	10m				All core

General Topography	➢ Gentle hilly site
Topography of Landslide	➢ Not appear
Standard Penetration Test	➢ More than N-Value 50 is continuously observed from earth surface to a depth of 5m
Groundwater Level	➢ There is a dry river in nearby area ➢ Groundwater level is assumed at 40m to 50m in depth
Liquefaction Risk	➢ Nature of soil condition is mostly hard rock ➢ Groundwater level is deep ➢ Liquefaction is not expected

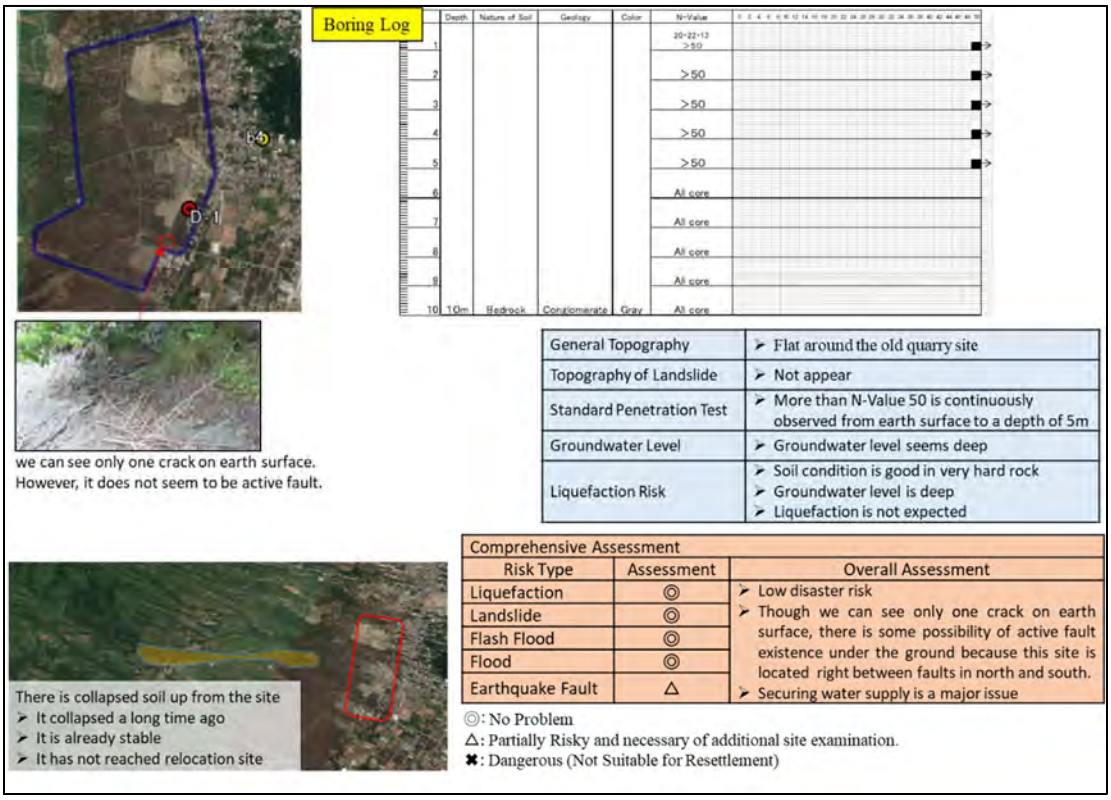
Comprehensive Assessment

Risk Type	Assessment	Overall Assessment
Liquefaction	◎	➢ Low disaster risk against except flood ➢ Possibility of flood risk just along the river (avoidable by settle far from the river) ➢ Securing water supply is a major issue.
Landslide	◎	
Flash Flood	◎	
Flood	△	
Earthquake Fault	◎	

◎: No Problem
△: Partially Risky and necessary of additional site examination.
✖: Dangerous (Not Suitable for Resettlement)

Source: JICA Mission Team

Figure 81 : Talise-Tondo



Depth	Nature of Soil	Geology	Color	N-Value
1				20-22-13 >50
2				>50
3				>50
4				>50
5				>50
6				All core
7				All core
8				All core
9				All core
10 10m	Bedrock	Conglomerate	Gray	All core

we can see only one crack on earth surface. However, it does not seem to be active fault.

General Topography	➢ Flat around the old quarry site
Topography of Landslide	➢ Not appear
Standard Penetration Test	➢ More than N-Value 50 is continuously observed from earth surface to a depth of 5m
Groundwater Level	➢ Groundwater level seems deep
Liquefaction Risk	➢ Soil condition is good in very hard rock ➢ Groundwater level is deep ➢ Liquefaction is not expected

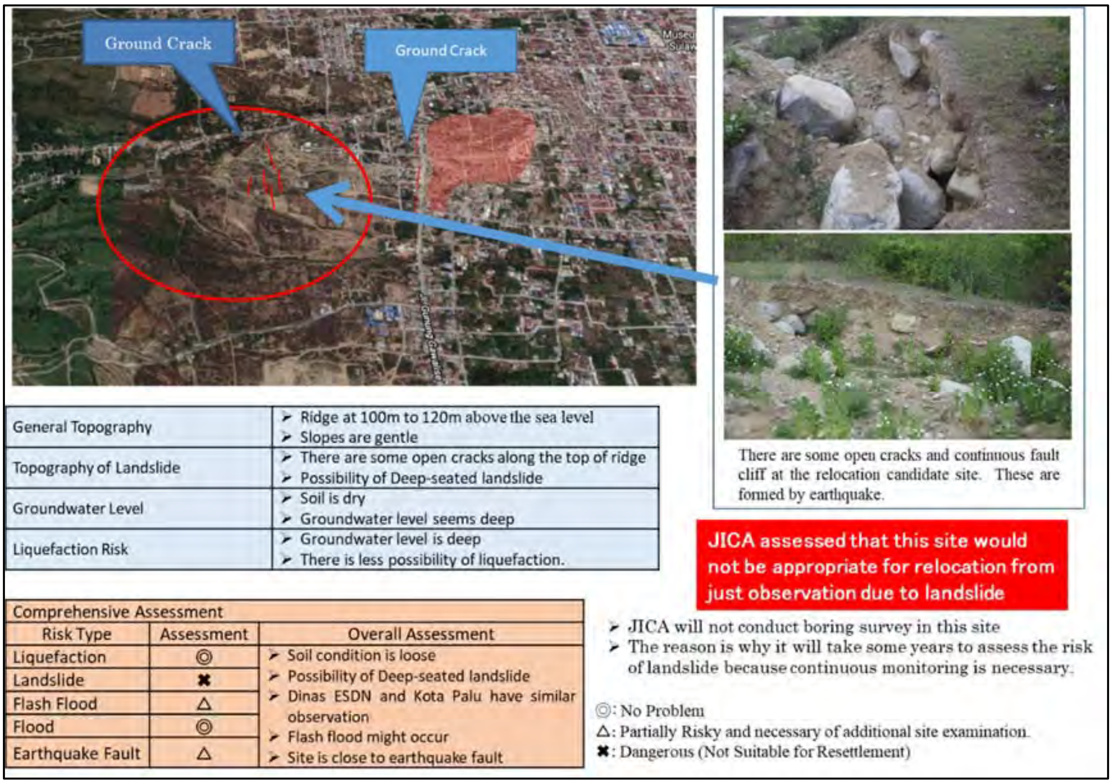
There is collapsed soil up from the site
- It collapsed a long time ago
- It is already stable
- It has not reached relocation site

Comprehensive Assessment		
Risk Type	Assessment	Overall Assessment
Liquefaction	◎	➢ Low disaster risk ➢ Though we can see only one crack on earth surface, there is some possibility of active fault existence under the ground because this site is located right between faults in north and south. ➢ Securing water supply is a major issue
Landslide	◎	
Flash Flood	◎	
Flood	◎	
Earthquake Fault	△	

◎: No Problem
△: Partially Risky and necessary of additional site examination.
✖: Dangerous (Not Suitable for Resettlement)

Source: JICA Mission Team

Figure 82 : Duyu



There are some open cracks and continuous fault cliff at the relocation candidate site. These are formed by earthquake.

General Topography	➢ Ridge at 100m to 120m above the sea level ➢ Slopes are gentle
Topography of Landslide	➢ There are some open cracks along the top of ridge ➢ Possibility of Deep-seated landslide
Groundwater Level	➢ Soil is dry ➢ Groundwater level seems deep
Liquefaction Risk	➢ Groundwater level is deep ➢ There is less possibility of liquefaction.

JICA assessed that this site would not be appropriate for relocation from just observation due to landslide

- JICA will not conduct boring survey in this site
- The reason is why it will take some years to assess the risk of landslide because continuous monitoring is necessary.

Comprehensive Assessment		
Risk Type	Assessment	Overall Assessment
Liquefaction	◎	➢ Soil condition is loose ➢ Possibility of Deep-seated landslide ➢ Dinas ESDN and Kota Palu have similar observation ➢ Flash flood might occur ➢ Site is close to earthquake fault
Landslide	✖	
Flash Flood	△	
Flood	◎	
Earthquake Fault	△	

◎: No Problem
△: Partially Risky and necessary of additional site examination.
✖: Dangerous (Not Suitable for Resettlement)

Source: JICA Mission Team

Figure 83 : Gawalise

CHAPTER 7. Packaged Resilient Infrastructure Redevelopment

7.1 Basic Concept

Realizing resilient region with effective infrastructure, experiences that Japan has been gifted even through tragic events should be referred to implement reconstruction. There would be some importance that could be brought into the region for actual action taking.

Lesson Learned by the Tohoku Great Earthquake and Tsunami in 2011 in Japan are as follows;

- There is no upper-limit of disaster hazard.
- The intensive hazard is unavoidable as long as we live in disaster-prone country.
- The victims, damage and loss cannot be perfectly prevented from the intensive hazard.

From this lesson-learned, the target to reduce intensive & extensive Risks is delivered. That is to minimize victims and economic losses, mobilize the best mix of Structure and Non-Structure measures.

To achieve this target, risk sensitive infrastructure reconstruction plan is crucial and we have to avoid re-producing same vulnerability again through reconstruction process.

The reconstruction process includes;

- To identify the disaster risk (what? How big? How often?) of each area
- To list possible countermeasures
- To consider constraints (cost, time, social acceptance)
- To optimize the countermeasures in the entire region

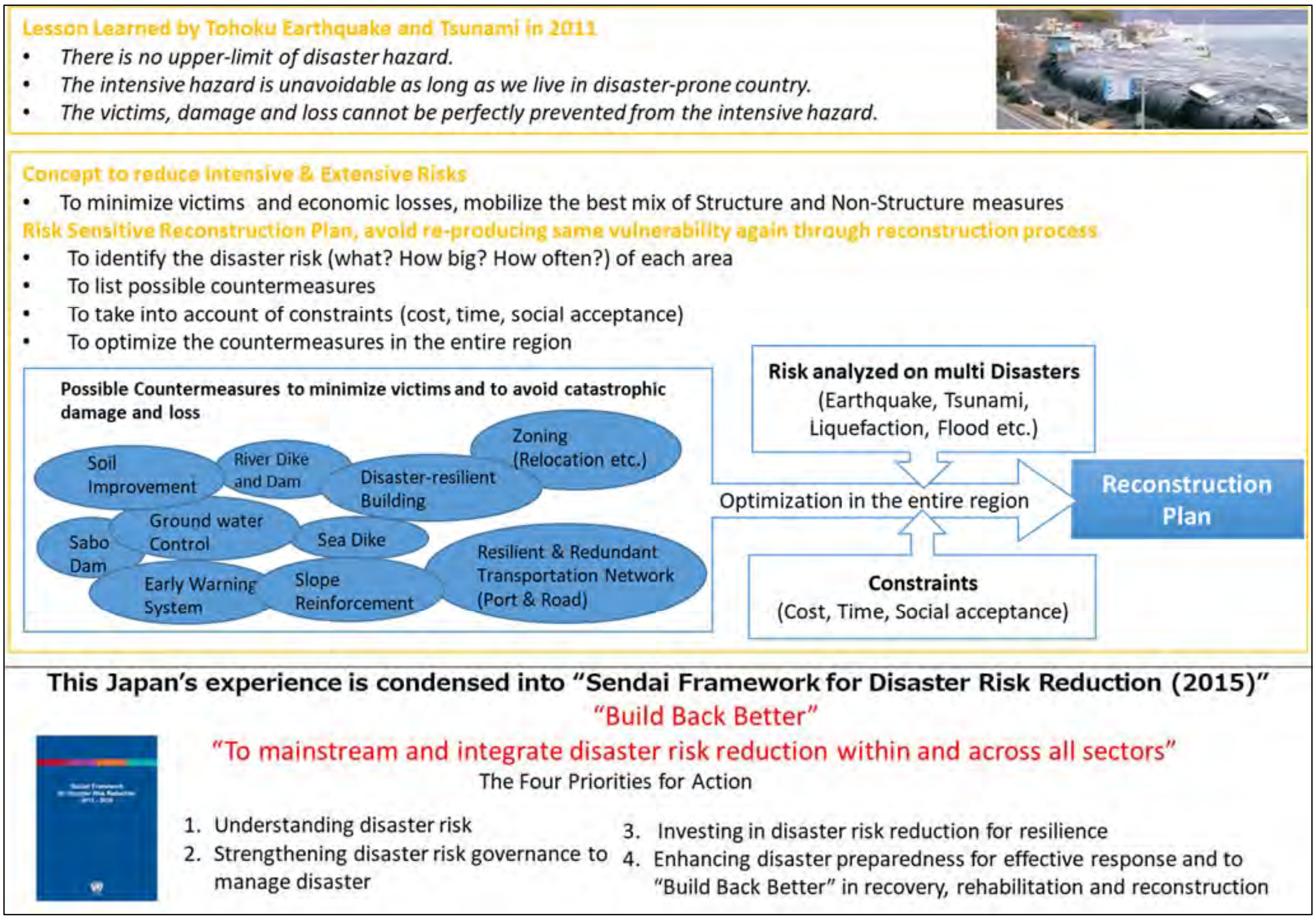
This knowledge delivered by Japan’s experience is condensed into “Sendai Framework for Disaster Risk Reduction (2015)”.

1. Understanding disaster risk
2. Strengthening disaster risk governance to manage disaster
3. Investing in disaster risk reduction for resilience
4. Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction

7.2 Target

Resilience means the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

In order for the city to become disaster resilient, infrastructure also need to be resilient. Even the structure is strong, but once that is broken and difficult to recover, that is not called resilient infrastructure.



Lesson Learned by Tohoku Earthquake and Tsunami in 2011

- *There is no upper-limit of disaster hazard.*
- *The intensive hazard is unavoidable as long as we live in disaster-prone country.*
- *The victims, damage and loss cannot be perfectly prevented from the intensive hazard.*

Concept to reduce Intensive & Extensive Risks

- To minimize victims and economic losses, mobilize the best mix of Structure and Non-Structure measures

Risk Sensitive Reconstruction Plan, avoid re-producing same vulnerability again through reconstruction process

- To identify the disaster risk (what? How big? How often?) of each area
- To list possible countermeasures
- To take into account of constraints (cost, time, social acceptance)
- To optimize the countermeasures in the entire region

Possible Countermeasures to minimize victims and to avoid catastrophic damage and loss

Risk analyzed on multi Disasters
(Earthquake, Tsunami, Liquefaction, Flood etc.)

Optimization in the entire region

Constraints
(Cost, Time, Social acceptance)

Reconstruction Plan

This Japan's experience is condensed into "Sendai Framework for Disaster Risk Reduction (2015)"

"Build Back Better"

"To mainstream and integrate disaster risk reduction within and across all sectors"

The Four Priorities for Action

1. Understanding disaster risk
2. Strengthening disaster risk governance to manage disaster
3. Investing in disaster risk reduction for resilience
4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction

Source: JICA Mission Team

Figure 84 : Japan's Experience on Reconstruction Plan

7.3 Procedure

7.3.1 Outline

The infrastructures are categorized into some sectors such as Road and Bridge, Port, Sea Dike, River, Sabo, Irrigation, Water supply system, Public facility, etc. It is important to perform the reconstruction basic plan of each sector to contribute to the realization of "Resilient City against multiple disasters" based on the concept of "Build Back Better".

Concept
Build Back Better

Reconstruction Basic Plan for Infrastructures
Set the safety level
Quantify the target hazard
Counter the target hazard

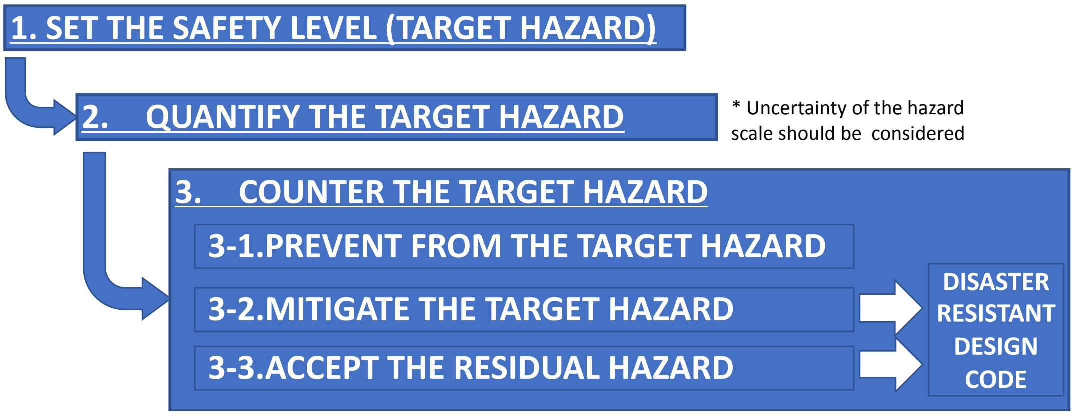
Design Code
Road and Bridge, Port, Sea Dike, River, Sabo, Irrigation, Water supply, Public facility

Implementation

Target
Resilient City against multiple disasters

Source: JICA Mission Team

Figure 85 : Outline of Packaged Resilient Infrastructure Redevelopment



Source: JICA Mission Team

Figure 86 : Procedure of Basic Reconstruction Plan for Infrastructures

7.3.2 Set of the target disaster level (safety level)

To design the structure, the target hazard should be determined. The target hazard is the type and scale. The safety level of structure is endured against the target hazard.

Generally, the target hazard is the biggest recorded disaster. If the data are enough accumulated, the target hazard can be set by simulation model. In the case of tsunami, the recorded tsunami will be the target hazard. But the uncertainty of hazard can be considered.

In Japan, the sea dike was designed by the biggest recorded hazard (tsunami or tide) before the Tohoku Great Earthquake and Tsunami in 2011. This tragedy was occurred by the largest tsunami extremely higher than height of sea dike. Therefore, Japan set 2 levels of tsunami. The level 2 tsunami (bigger one) is for establishing integrated disaster countermeasures focused on the evacuation of people. The level 1 tsunami (smaller one) is for designing the heights of sea dike. The level 2 tsunami is the solution for the uncertainty when the data are enough accumulated. Even it is difficult set the level 2 tsunami, the possibility of bigger target hazard should be considered the design of one structure and multiple protection by another structures.

The target disasters are composed of Earthquake, Tsunami, Liquefaction, Sediment and Flood compositely. However, these disasters don't have the influences on each sector of infrastructures equally. Therefore, safety level should be considered sufficiently based on relations and characteristics of both infrastructure and disaster as shown in Table 18.

Table 18 : Consideration Points in improving infrastructure

Target Infrastructure	Points to consider for resistant design				
	Earthquake	Tsunami	Liquefaction landslide	Sediment	Flood
Road and Bridge	✓	Vulnerable area only	Vulnerable area only	Vulnerable area only	Vulnerable area only
Port	✓	✓	Vulnerable area only	Vulnerable area only	Vulnerable area only
Sea Dike	✓	✓	Vulnerable area only	Vulnerable area only	Vulnerable area only
River / Sabo	✓	Vulnerable area only	Vulnerable area only	✓	✓
Irrigation	✓	Vulnerable area only	Vulnerable area only	Vulnerable area only	Vulnerable area only
Water Supply system	✓	Vulnerable area only	Vulnerable area only	Vulnerable area only	Vulnerable area only
Public facility	✓	Vulnerable area only	Vulnerable area only	Vulnerable area only	Vulnerable area only
Private building	✓	Vulnerable area only	Vulnerable area only	Vulnerable area only	Vulnerable area only
Communications · Broadcasting	✓	Vulnerable area only	Vulnerable area only	Vulnerable area only	Vulnerable area only

Source: JICA Mission Team

7.3.3 Quantification of the Target Hazard

The selecting the target hazard level can quantify the target disaster hazard. In the case of tsunami, the hazard is inundation area, depth, or reach time. The hazard can be used for consideration of countermeasures.

7.3.4 Countermeasures against the target hazard

The design code selection should be carried out based on the procedures that first is to select of the safety level, the second is to quantify the target hazard, and the third is to select countermeasures against the target hazard. The countermeasures are consisted by “Prevention,” “Mitigation,” “Acceptation”.

(1) Prevent from the target hazard

The building control by zoning, or spatial planning can prevent people and buildings from the target hazard. In case of tsunami, the coastal zone can be prohibited for housing.

(2) Mitigate the target hazard

The disaster protection facility can mitigate or reduce the target hazard. In the case of tsunami can reduce the tsunami inundation area.

(3) Accept the residual hazard

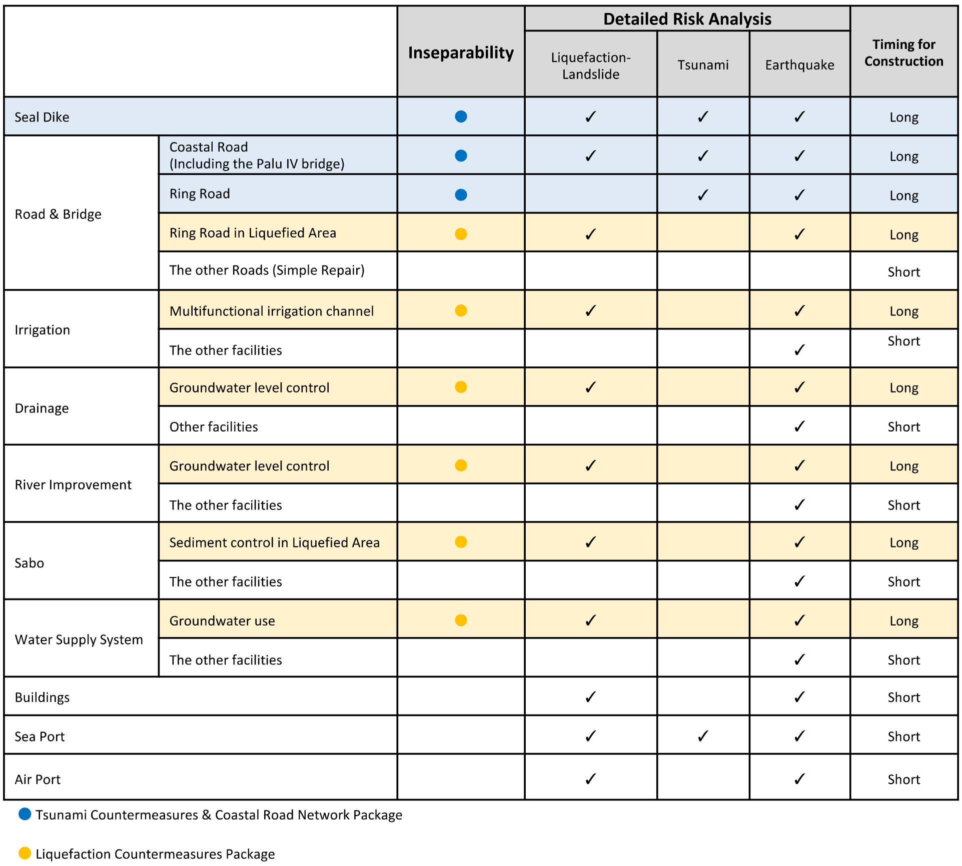
After preventing and mitigation the target hazard, people need to accept the residual hazard. The main countermeasure is evacuation. In the case of tsunami, the tsunami early warning system and evacuation facilities such as tsunami evacuation buildings and roads are necessary. Moreover, disaster education and evacuation drill at schools or communities can secure the safe evacuation.

7.3.5 Design Code

The design code for the infrastructure is necessary for the mitigation and the acceptation of the hazard.
In the case of tsunami, sea dike should be endured against the destructive power of the tsunami and reduce the inundation area. Also, the tsunami evacuation building should be endured in the tsunami inundation for securing the lives of evacuated people.

7.4 Inseparability of Infrastructure for Disaster Risk Reduction

Based on BBB concept, reconstruction of some infrastructures in central Sulawesi Province should be planned in inseparable manner in order to maximize both efficiency of reconstruction process and effectiveness of disaster risk reduction that requires detailed risk analysis and prudent design in order to secure resilience against disaster and/or to mitigate levels of damages from tsunami / liquefaction.
Toward formulation of the regional reconstruction master plan, the potential reconstruction components should be carefully analyzed to understand the latest condition to identify issues and challenges. Only with full understanding of the project issues, actual packages of infrastructure reconstruction in the region could be recognized to promise a better, safer and more sustainable society building. As discussed in the above section of 3.4, there are several infrastructure redevelopment related components considered as necessary to rebuild the region, and each concerned component is examined hereafter to identify challenges and issues toward reconstruction.



		Inseparability	Detailed Risk Analysis			Timing for Construction
			Liquefaction-Landslide	Tsunami	Earthquake	
Seal Dike		🔵	✓	✓	✓	Long
Road & Bridge	Coastal Road (Including the Palu IV bridge)	🔵	✓	✓	✓	Long
	Ring Road	🔵		✓	✓	Long
	Ring Road in Liquefied Area	🟡	✓		✓	Long
	The other Roads (Simple Repair)					Short
Irrigation	Multifunctional irrigation channel	🟡	✓		✓	Long
	The other facilities				✓	Short
Drainage	Groundwater level control	🟡	✓		✓	Long
	Other facilities				✓	Short
River Improvement	Groundwater level control	🟡	✓		✓	Long
	The other facilities				✓	Short
Sabo	Sediment control in Liquefied Area	🟡	✓		✓	Long
	The other facilities				✓	Short
Water Supply System	Groundwater use	🟡	✓		✓	Long
	The other facilities				✓	Short
Buildings			✓		✓	Short
Sea Port			✓	✓	✓	Short
Air Port			✓		✓	Short

🔵 Tsunami Countermeasures & Coastal Road Network Package

🟡 Liquefaction Countermeasures Package

Source: JICA Mission Team

Figure 87 : Basic Criteria for Infrastructure under Disaster

7.5 Tsunami countermeasures and Coastal Road network package

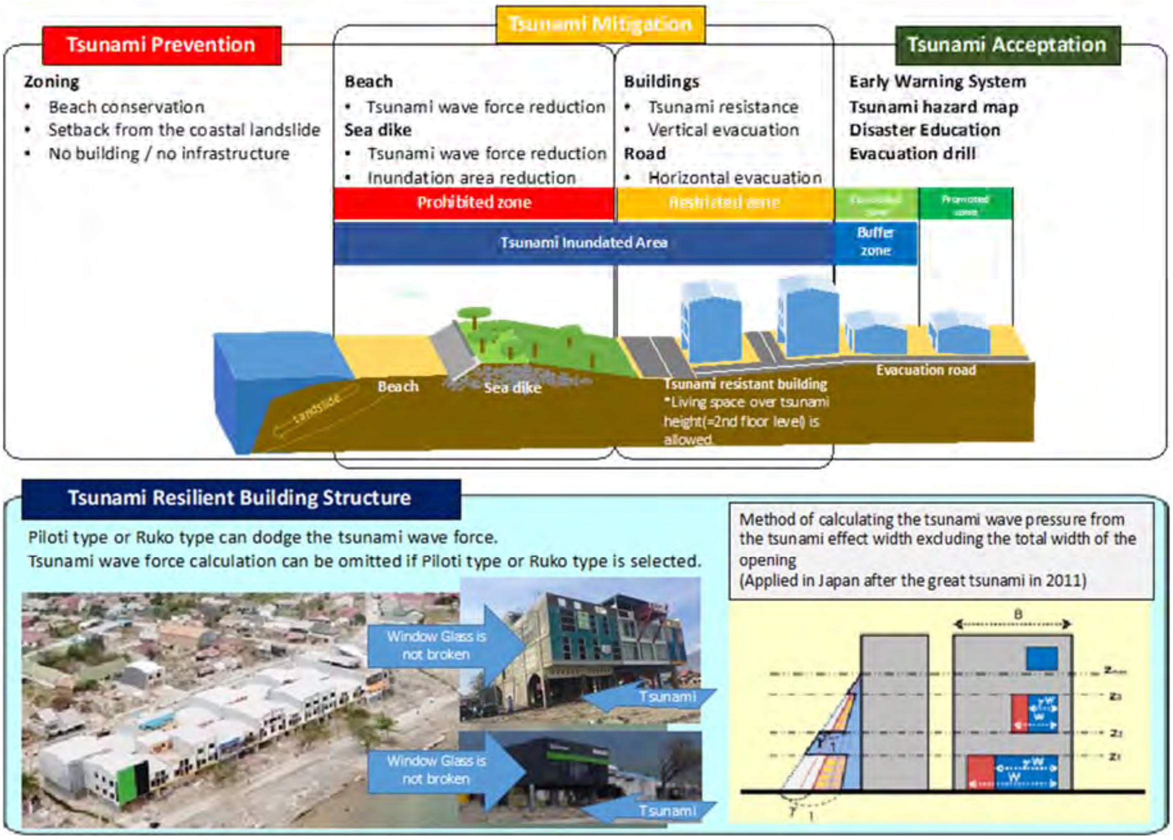
7.5.1 Basic policy

Wide Palu bay coastal area has affected by tsunami, and the area of roughly 400m distance from the coast has been damaged largely. The consideration of future occurrence of such earthquake, tsunami, coastal landslide shall be taken seriously in order to reconstruct the affected coastal areas better and resilient to protect people and society, and planning and designing of sea dike and road at the location as well as land use, and land reallocation should be carefully conducted. In order to effectively reconstruct these facilities at required quality, cost and schedule, the balance between land acquisition and infrastructure development cost has to also be carefully examined. There have been many people restarted their own buildings without permission and land use control within the tsunami affected area, thus there should be different kind of resettlement plan may need to be prepared (refer to Figure 89).

Setting up the land use control and regulation to the tsunami affected and some extended areas is necessary in order to effectively manage actual reconstruction without any unwanted effort, such as negotiation with illegally settled people, etc. Though, minimizing the land reallocation is one of the redevelopment keys to the location. Therefore, comprehensive plan of both land reallocation and infrastructure reconstruction (mainly roads, bridges and sea dikes) is urgently needed. This comprehensive plan should also include public space development for disaster prevention as well as public amenity provision. Considering the function of coastal area with building types is another key to energize the coastal area with safer environment for the people including particular buildings with piloti or the commercial and residential complex building locally called as "Ruko". The tsunami resistant design is required for these building.

Based on the setback distance from the coastal line, spatial design and building types may differ, so that the land use and zoning regulation should also be carefully analyzed for any necessary adjustment specific for the Palu bay area.

The coastal road network needs to be considered with tsunami countermeasures.

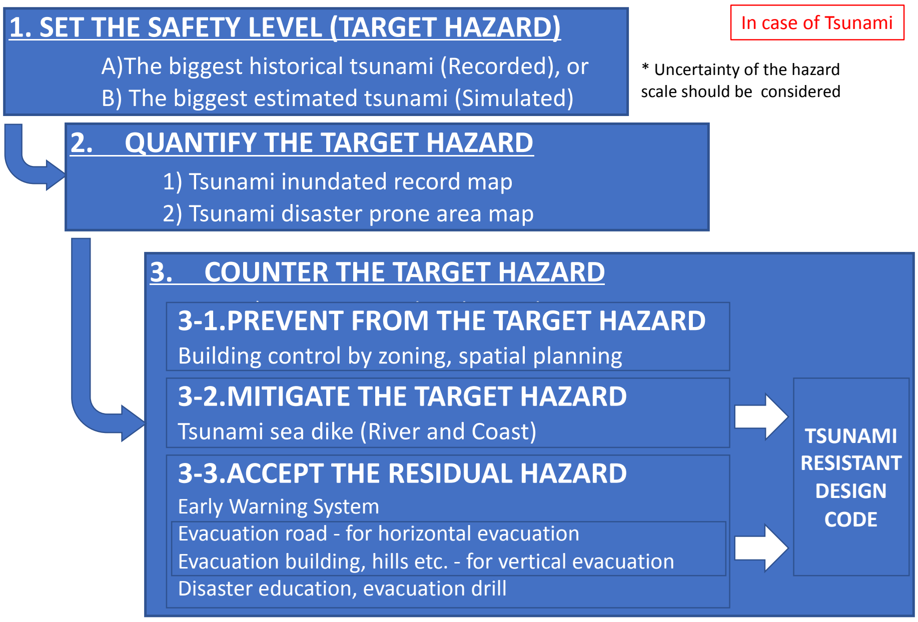


Piloti type or Ruko type can dodge the tsunami wave force.
Tsunami wave force calculation can be omitted if Piloti type or Ruko type is selected.

Method of calculating the tsunami wave pressure from the tsunami effect width excluding the total width of the opening
(Applied in Japan after the great tsunami in 2011)

Source: JICA Mission Team

Figure 88 : Design Code

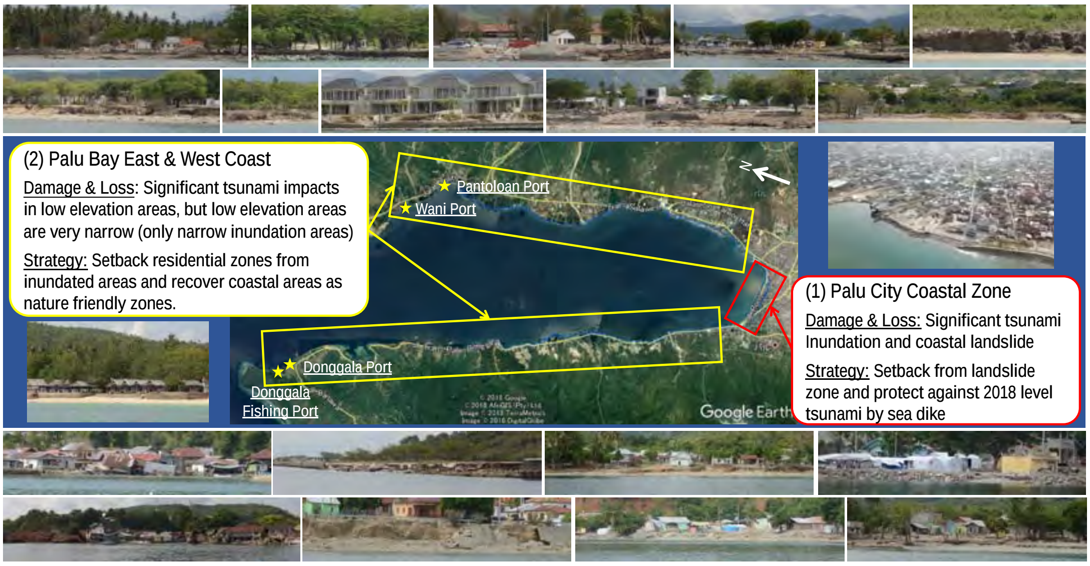


* Uncertainty of the hazard scale should be considered

Source: JICA Mission Team

Figure 89 : Process for Design Code Application

7.5.2 Regional Tsunami Countermeasures


(2) Palu Bay East & West Coast

Damage & Loss: Significant tsunami impacts in low elevation areas, but low elevation areas are very narrow (only narrow inundation areas)

Strategy: Setback residential zones from inundated areas and recover coastal areas as nature friendly zones.

(1) Palu City Coastal Zone

Damage & Loss: Significant tsunami Inundation and coastal landslide

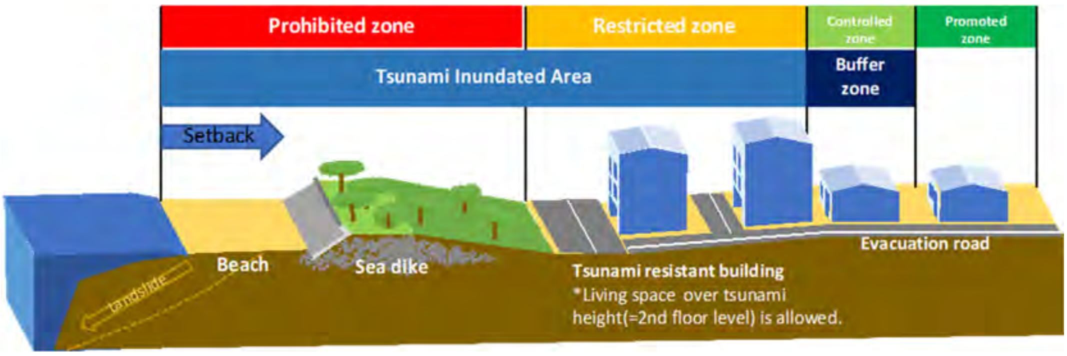
Strategy: Setback from landslide zone and protect against 2018 level tsunami by sea dike

Source: JICA Mission Team

Figure 90 : Regional Countermeasure

(1) Palu city coastal zone

Considering the significant risk of coastal landslide and tsunami inundation, implementation of structural measures is recommended in this area, in order to protect Palu citizens from any coastal landslide and tsunami event equivalent to the 2018 earthquake and tsunami.



Source: JICA Mission Team

Note: The illustration shown is one possible reconstruction options, and examination of options is necessary.

Figure 91 : Coast Area Reconstruction Concept Diagram

Source: JICA Mission Team

Figure 92 : Palu City Coastal Zone (plan image)

- Seafront area of 120m will be prohibited from building construction, considering the risk of coastal landslide. Existing houses and buildings within this zone need to be relocated to outside of this area.
- Earth filling sea dike (utilizing disaster debris) will be constructed behind the seafront area (120m setback), avoiding the coastal landslide hazard zone, in order to ensure the structural stability of the dike. The coastal road will be relocated behind the sea dike. In the Coastal area, it is necessary to reconstruct the provincial road for smooth logistics, reduction in traffic volume passing through Palu city area and improvement of redundancy at the occurrence of disaster. This area will be reserved for green plantation, and no structure or building will be allowed.
- In the areas behind the coastal road (i.e. inundated areas), building construction will be regulated. Only tsunami resistant buildings and structures will be permitted. Ground floor of buildings should not be used for residential purpose, and will be restricted to the use for day time activities (e.g. restaurants, retail shops, supermarket, parking, etc.)

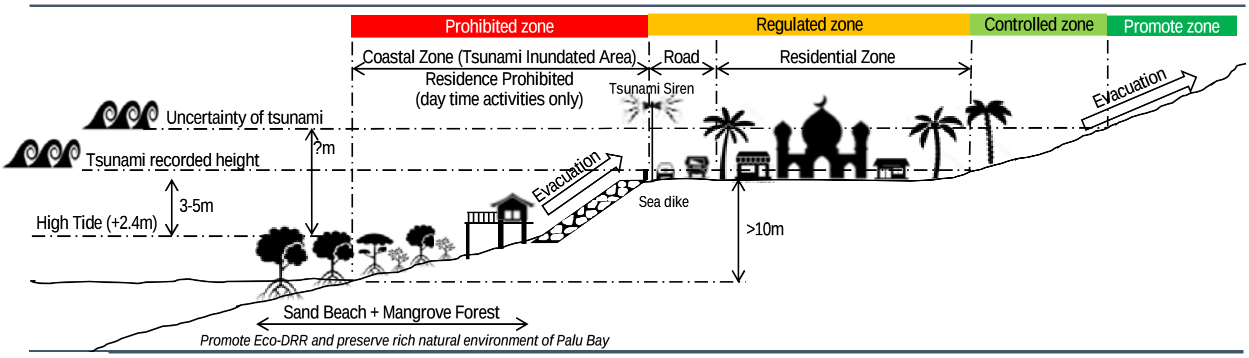
There are a few other possible options that can be considered, such as constructing sea dike on coastal landslide hazard zone without set backing 120m (too risky) or constructing sea dike using rigid double-wall steel sheet pile structure (very expensive). The advantage of the proposed method can be summarized as follows, especially from a viewpoint of "Build Back Better (BBB)".

- **Social Acceptance:**
  Setting development away from the tsunami affected area makes people to feel safer.
- **Risk & Safety:**
  Coastal landslide hazard zone is avoided. Resilient earth fill sea dike is constructed, which is easy to restore even if heavily damaged.
- **Cost:**
  Much less expensive compare to double-walled steel sheet piles. In addition, the sheet pile structure is not easy to restore if damaged. Setback makes the bridge span shorter than the damaged one.

The disadvantage is the wide area of land acquisition, which may require longer time for completing the project due to the negotiation with the land owners and coordination with the stakeholders.

(2) East and West Coast of the Palu bay

On the east and west side of the Palu Bay, the low elevation areas close to the shoreline were devastated by tsunami. However, tsunami inundation was limited to narrow areas, thanks to the topographical characteristics (in general, elevation quickly reaches 10m). Considering that, and the rich and preserved nature in these areas, application of Eco-DRR concept is recommended, as illustrated in the figure below.



Source: JICA Mission Team

Figure 93 : Palu Bay East and West Coast

The strategy is as follows.

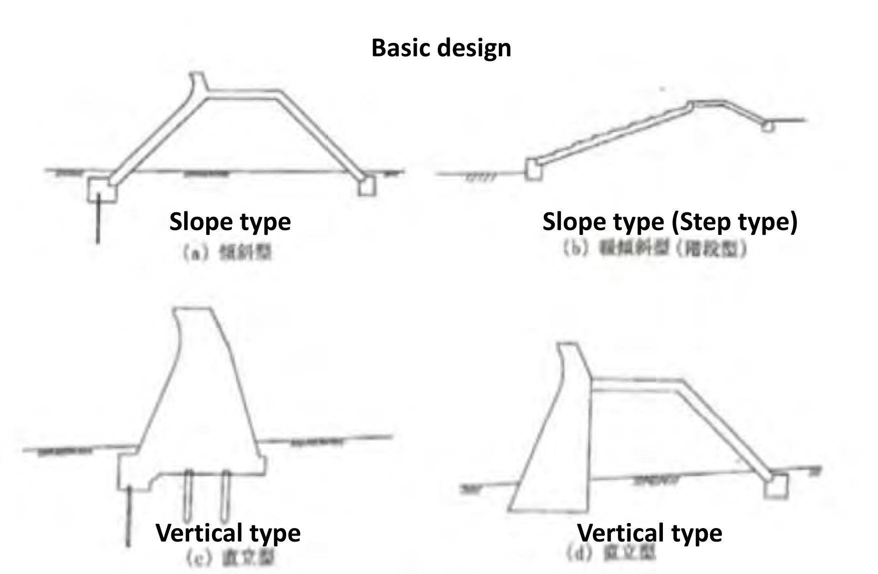
- The residential zone with higher elevation, and prohibited coastal zone from residential use. The coastal zone can only be used for day time activities such as restaurants and fishing ports.
- The sand beach and mangrove forest can decrease the distractive power of tsunami wave and mitigate tsunami impacts.
- Improvement of the tsunami early warning system and tsunami evacuation plan for safe evacuation, especially considering a very rare tsunami event that can impact the residential zone.
- On the west side of the Palu Bay there are several road slopes along the coastal road. It is necessary to protect road slope where landslides are expected due to earthquake or heavy rain.On the east side of the Palu Bay it is necessary to consider constructing a bypass road on the inland side to improve the coastal road redundancy.

For developing a more detailed plan, detailed information such as population data, building inventory data, topographic profiles, bathymetry profiles and soil boring tests are required along the coast of Palu Bay.

7.5.3 Tsunami-resistant design code

(1) Tsunami-resilient sea dike

The basic design of sea dike in Japan shows in Figure 94. The sea dike is resistant against the target tsunami and storm tide.

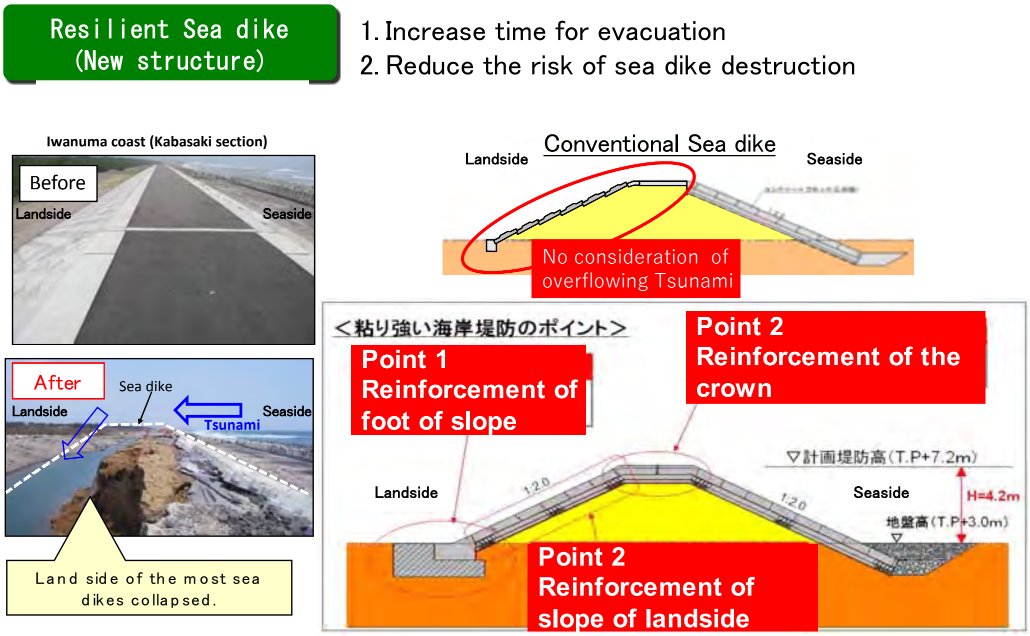


Source: JICA Mission Team

Figure 95 : Basic design of sea dike in Japan

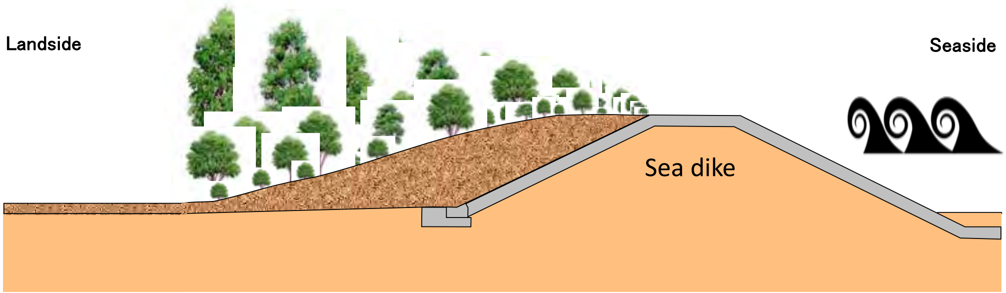
From the experience of the Tohoku great earthquake in 2011, the sea dike design was reviewed and was upgraded with tsunami-resilience. The tsunami-resilience is to reduce the risk of sea dike destruction and to increase time for evacuation.

The green sea dike is the sea dike covered with soil and vegetation behind the dike. The green sea dike can be more tsunami-resilient



Source: JICA Mission Team

Figure 96 : Tsunami-resilient sea dike

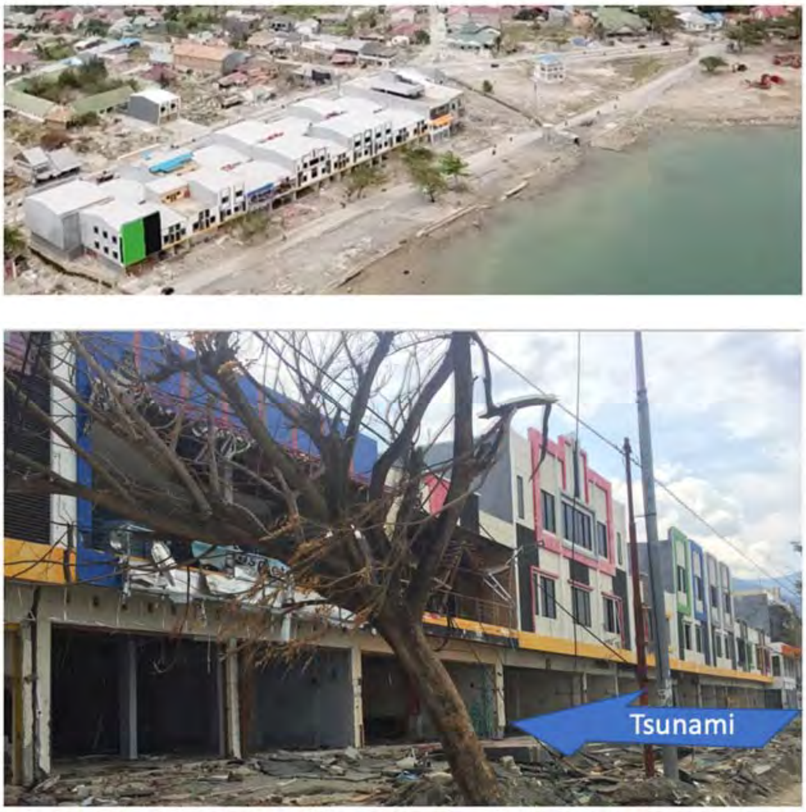


Source: JICA Mission Team

Figure 97 : Green sea dike

(2) Tsunami-resistant building

From the experience of the tsunami in central Sulawesi, the particular buildings with piloti or the commercial and residential complex building locally called as “Ruko” could stand still.

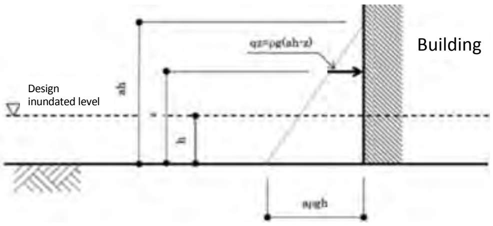


Source: JICA Mission Team

Figure 98 : Ruko type building condition in coastal area

Tsunami wave pressure for structural design is developed based on the research of the Tohoku great earthquake in 2011. When the building has pars of opening, the wave pressure can be reduced. The method of calculating the tsunami wave pressure from the tsunami effect width excluding the total width of the opening is developed.

When the target tsunami hazard is the recorded tsunami in 2018, the tsunami inundation depth is mostly lower than 2nd floor. The tsunami went through the opening of building. If the piloti type or Ruko type is selected, tsunami wave force calculation can be omitted and the building can be resistant enough against tsunami.



$$qz=g\rho(ah-z)$$

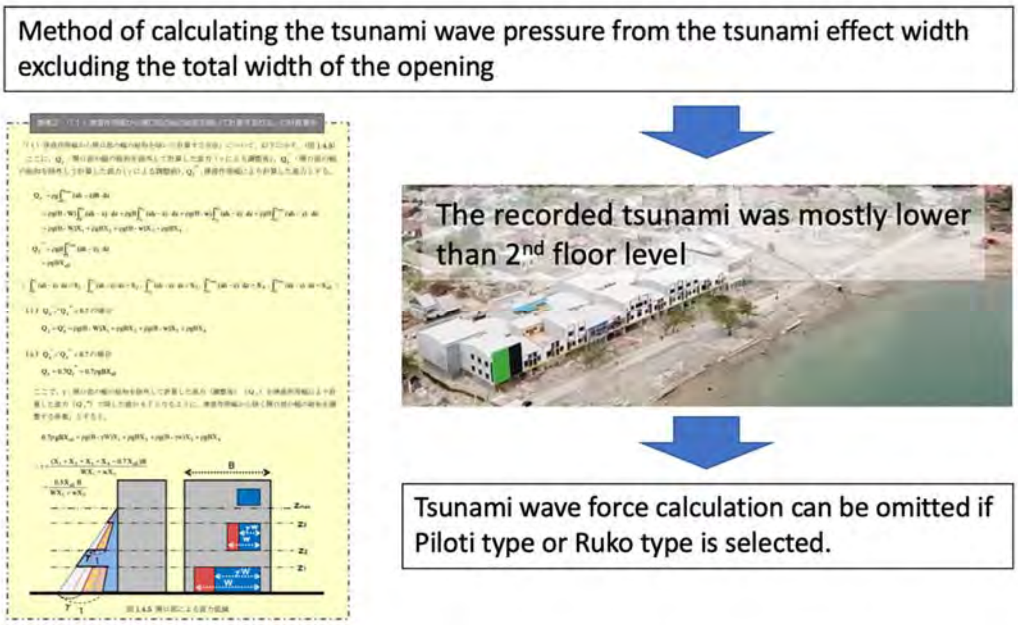
qz: Tsunami wave pressure for structural design □ kN/m^2)
ρ: Weight of water unit volume (t/m^3)
g: Gravitational acceleration (m/s^2)
h: Tsunami inundation depth (m)
z: Height of each part of the building (0≤z ≤ah)
a: Water depth coefficient

Type	Water depth coefficient	Applicable condition
I	3	Other than II & III
II	2	If there are other buildings in the direction of the tsunami (only when the effect of reducing the tsunami is expected)
III	1.5	In the case of II, when the target building is located 500 m or more away from the coast and the river

*This coefficient does not represent the extent of the rise in the water level of the tsunami caused by the raising of the buildings at the front.

Source: JICA Mission Team

Figure 99 : Tsunami wave pressure for structural design



Method of calculating the tsunami wave pressure from the tsunami effect width excluding the total width of the opening

The recorded tsunami was mostly lower than 2nd floor level

Tsunami wave force calculation can be omitted if Piloti type or Ruko type is selected.

Source: JICA Mission Team

Figure 100 : Advantage of the piloti type and Ruko type

7.5.4 Coastal road network

It is necessary to reconstruct four lane provincial road for smooth logistics, reduction in traffic volume passing through Palu city area and improvement of redundancy at the occurrence of disaster. Road alignment of coastal road needs to be considered together with sea dike (Jl. Cumi-Cumi and Jl. Rajamoili). The Palu Ⅳ bridge needs to be reconstructed with a structure of earthquake resistance. The construction site needs to be selected considering road alignment and construction cost.

The coastal road network is the important infrastructure for tsunami evacuation. The radial roads are dangerous road network structure from the viewpoint of evacuation, as evacuation vehicles and people concentrate in the center of the city and cause traffic congestion. For safe and quick evacuation, the road network that does not intersect is necessary so that evacuation traffic does not overlap.

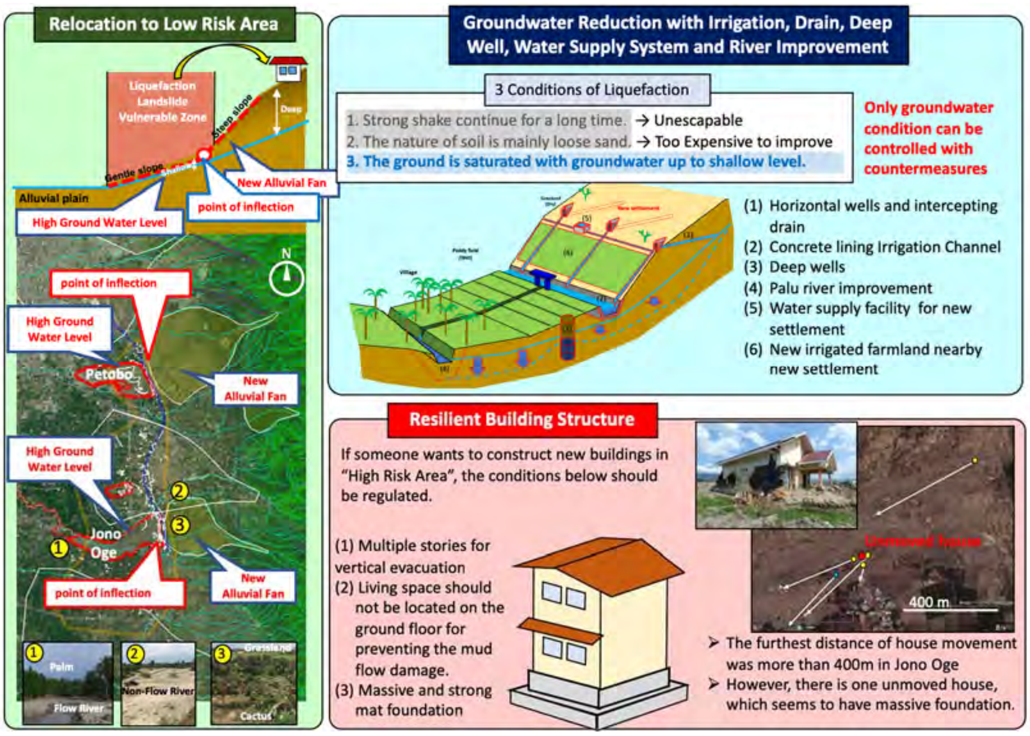
7.6 Liquefaction landslide countermeasures package

7.6.1 Basic policy

The relocation from the vulnerable zone can prevent people from the liquefaction-landslide disaster hazard.

The groundwater control is only mitigation of this hazard, because the shake by earthquake cannot be avoidable, the soil improvement in wide vulnerable area is too expensive.

The reinforcement of the building foundations can be resilient against the liquefaction-landslide.



1. Strong shake continue for a long time. → Unescapable
2. The nature of soil is mainly loose sand. → Too Expensive to improve
3. The ground is saturated with groundwater up to shallow level.

(1) Horizontal wells and intercepting drain
(2) Concrete lining Irrigation Channel
(3) Deep wells
(4) Palu river improvement
(5) Water supply facility for new settlement
(6) New irrigated farmland nearby new settlement

If someone wants to construct new buildings in "High Risk Area", the conditions below should be regulated.

(1) Multiple stories for vertical evacuation
(2) Living space should not be located on the ground floor for preventing the mud flow damage.
(3) Massive and strong mat foundation

- The furthest distance of house movement was more than 400m in Jono Oge
- However, there is one unmoved house, which seems to have massive foundation.

Source: JICA Mission Team

Figure 101 : Fact and Development Policy for Liquefaction Landslide Countermeasure

1. SET THE SAFETY LEVEL (TARGET HAZARD)
The biggest historical liquefaction landslide in 2018

2. QUANTIFY THE TARGET HAZARD
Disaster risk map of liquefaction landslide

* Uncertainty of the hazard scale should be considered

3. COUNTER THE TARGET HAZARD

3-1.PREVENT FROM THE TARGET HAZARD
Building control by zoning, spatial planning (Relocation to Low Risk Area, Memorial Park, Farmland in vulnerable area)

3-2.MITIGATE THE TARGET HAZARD
Groundwater Level Reduction with Irrigation, Drain, Deep Well, Water Supply System and River Improvement

3-3.ACCEPT THE RESIDUAL HAZARD
Design of Resilient Facilities against Liquefaction
Disaster education, evacuation drill

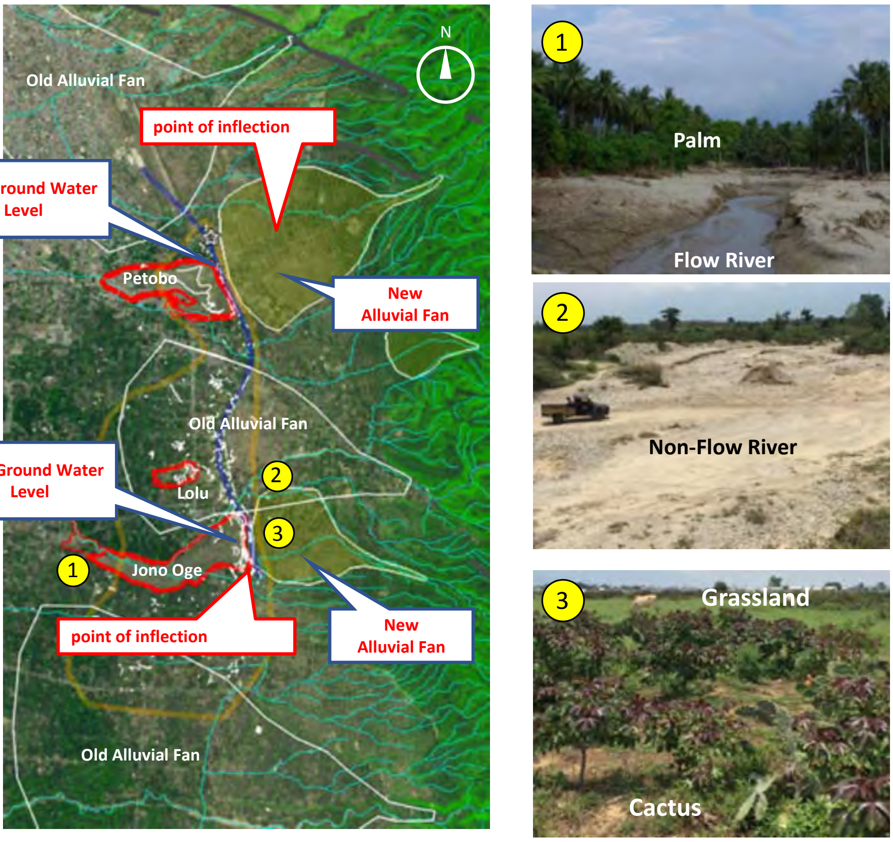
LIQUEFACTION RESISTANT DESIGN CODE

Source: JICA Mission Team

Figure 102 : Process for Design Code Application for Liquefaction Landslide Countermeasure

7.6.2 Relocation to low risk area

Based on the geological and vegetation condition and disaster risk map, the evacuee families should relocate to the safer area. The upper side from the damaged area is identified as the safe area from liquefaction-landslide hazard. The deep ground water of upper side decreases the liquefaction-landslide risk but makes the water supply difficult. The water supply easiness is the key to develop the new settlements.



Source: JICA Mission Team

Figure 103 : Low Risk Sites for Relocation

7.6.3 Groundwater level reduction

(1) Multifunctional irrigation system

Damages took place in the inland area is mainly caused by liquefaction and related landslide. The earthquake oriented loose underground pressure triggered sand boiling by upward pressure of underground water, and the mix with landslide made its impact much larger. For developing safer living environment against such disaster, underground water control is highly necessary to reduce such risk in the region as large area of the region is covered with sand-based soil. The multifunctional irrigation system for the region should be well designed with underground catchment well to pump out underground water, and pumped water should be supplied to also newly developed farmland as well as utilized for potable use. Since many affected families before earthquake had engaged to agricultural production in the region, there is an effective spatial plan of housing and farmland development considering disaster mitigation. The principal of irrigation facilities reconstruction plan is to return to the function before earthquake. However, infiltration of irrigation water from the channel and paddy-fields into the underground can be considered one of the causes of liquefaction, therefore it is necessary to add functions to control infiltration from irrigation water. In addition, the facility to decrease underground water level is also proposed.

a. Proposed facilities

The proposed facilities are shown below table.

Table 19 : proposed facilities

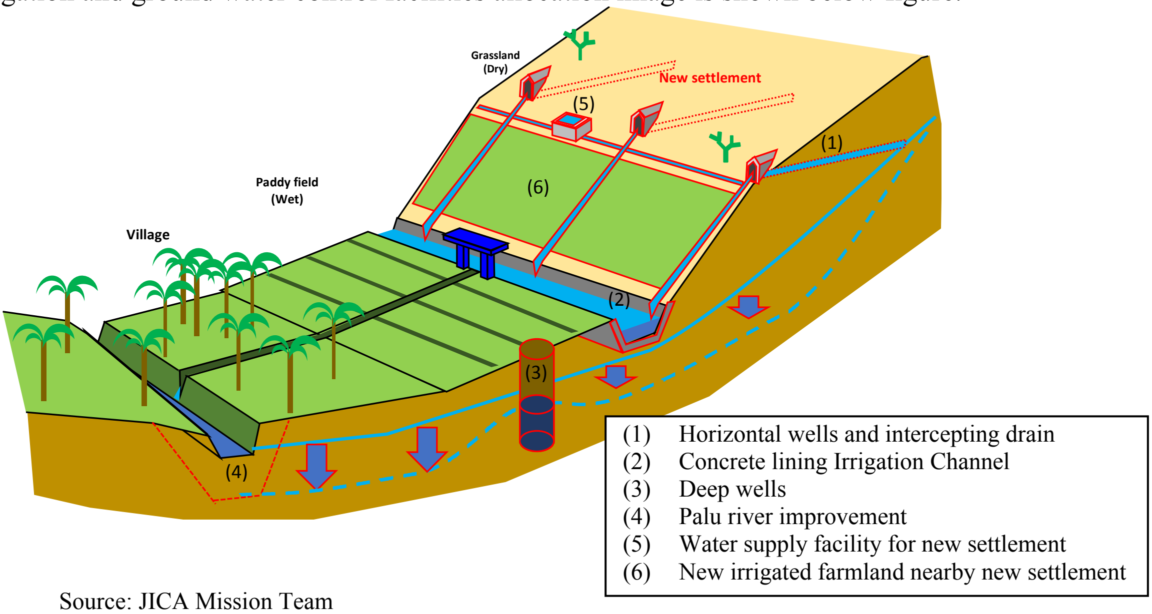
Facilities	Function
(1) Horizontal wells and intercepting drain	To reduce the underground water discharge volume into the liquefaction hazardous area.

(2) Concrete lining for the Gumbasa irrigation main channel	To reduce infiltration water from the Gumbasa irrigation main channel
(3) Deep wells	To reduce infiltration water from paddy-fields in and around the liquefaction vulnerable area
(4) Palu river improvement	To reduce surface water level of the Palu river.
(5) New water supply facility	To utilize the extracted groundwater for new settlement
(6) New irrigated farmland	To utilize the extracted groundwater for new farmland

Source: JICA Mission Team

a. Facilities Allocation Image

Irrigation and ground water control facilities allocation image is shown below figure.



Source: JICA Mission Team

Figure 104 : Irrigation and ground water control facilities

(2) Liquefaction-landslide resistant building

For the new buildings in the liquefaction-landslide high risk area, the conditions below should be regulated.

(i) Multiple stories for vertical evacuation
(ii) Bed rooms should not be locafted on the ground floor
(iii) Massive and strong mat foundation

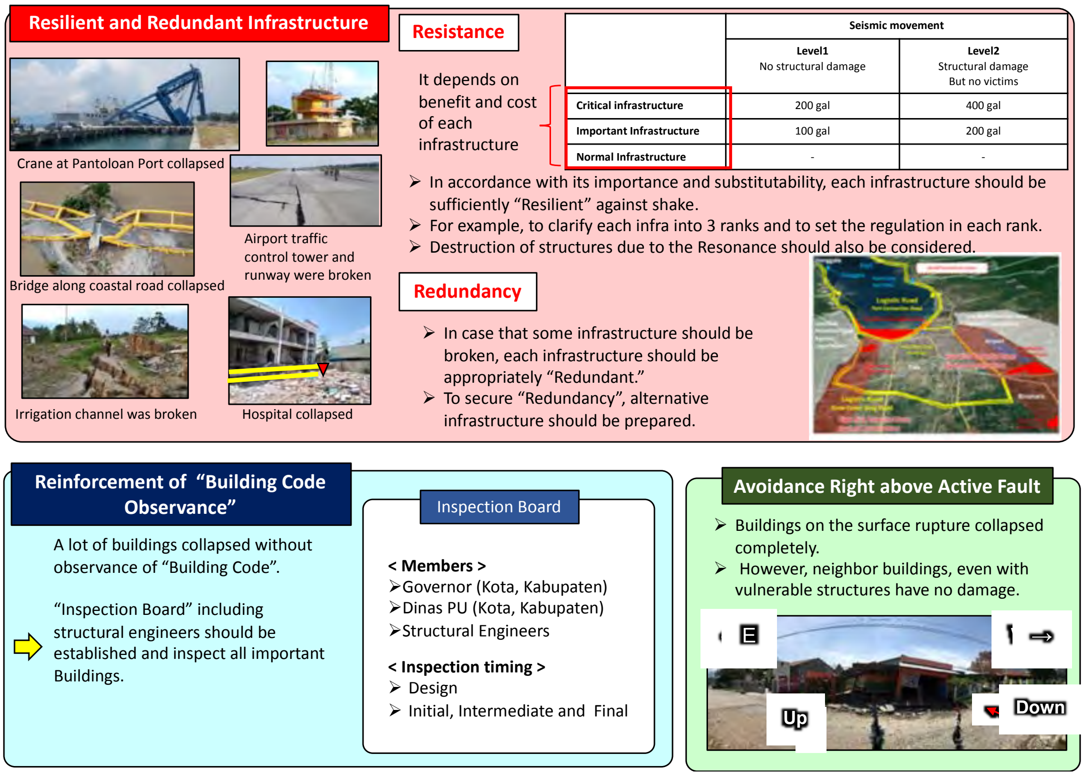
Source: JICA Mission Team

Figure 105 : Unmoved house with massive foundation in Jono Oge liquefaction damage area and image of liquefaction-landslide resistant building Liquefaction resistant building

7.7 Earthquake countermeasures package

7.7.1 Basic policy

The earthquake risk exists everywhere and cannot mitigate. Only avoidance right above active fault is necessary. Therefore, all infrastructure requires to review the earthquake-resistant design. To avoid tragedy by collapse of buildings, the construction quality should be inspected.



Resilient and Redundant Infrastructure

Resistance

It depends on benefit and cost of each infrastructure

	Seismic movement	
	Level1 No structural damage	**Level2** Structural damage But no victims
Critical infrastructure	200 gal	400 gal
Important Infrastructure	100 gal	200 gal
Normal Infrastructure	-	-

- In accordance with its importance and substitutability, each infrastructure should be sufficiently "Resilient" against shake.
- For example, to clarify each infra into 3 ranks and to set the regulation in each rank.
- Destruction of structures due to the Resonance should also be considered.

Redundancy

- In case that some infrastructure should be broken, each infrastructure should be appropriately "Redundant."
- To secure "Redundancy", alternative infrastructure should be prepared.

Reinforcement of "Building Code Observance"

A lot of buildings collapsed without observance of "Building Code".

"Inspection Board" including structural engineers should be established and inspect all important Buildings.

Inspection Board

< Members >
- Governor (Kota, Kabupaten)
- Dinas PU (Kota, Kabupaten)
- Structural Engineers

< Inspection timing >
- Design
- Initial, Intermediate and Final

Avoidance Right above Active Fault

- Buildings on the surface rupture collapsed completely.
- However, neighbor buildings, even with vulnerable structures have no damage.

Source: JICA Mission Team

Figure 106 : Fact and Development Policy for Earthquake Countermeasure

1. SET THE SAFETY LEVEL (TARGET HAZARD)
Level 1 Seismic movement (Middle scale)
Level 2 Seismic movement (Maximum scale)

In case of Earthquake

* Uncertainty of the hazard scale should be considered in Level2

2. QUANTIFY THE TARGET HAZARD
Acceleration (GAL) by Level 1 and 2

3. COUNTER THE TARGET HAZARD

3-1.PREVENT FROM THE TARGET HAZARD
Building control by zoning, spatial planning
(Avoidance right above active Faults)

3-2.MITIGATE THE TARGET HAZARD
No countermeasures for mitigation

3-3.ACCEPT THE TARGET HAZARD
Earthquake-resistant infrastructure
Reinforcement of "Building Code Observance"
Disaster education, evacuation drill

EARTHQUAKE RESISTANT DESIGN CODE

Source: JICA Mission Team

Figure 107 : Process for Design Code Application for Earthquake Countermeasure

7.7.2 Resilient and Redundant Infrastructure

(1) 2 level of seismic movement

In accordance with its importance and substitutability, each infrastructure should be sufficiently "Resilient" against shake.

Earthquake safety level for shake can be classified 2 levels. The level 1 seismic movement is the middle scale and the one which all infrastructure can be experienced in the period of depreciation useful life. The level 2 seismic movement is the assumed maximum one.

Each infrastructure should be designed not to be damaged at all against the level 1 seismic movement. And it should be designed to protect the user's life even the structure might be heavily damaged against the level 2 seismic movement.

(2) Target infrastructure clarification

Each infrastructure can be clarified into 3 ranks (critical infrastructure, important infrastructure, normal infrastructure) for designing against 2 level seismic movements.

For example, the critical infrastructure is the one requires high safety can be the bridge of national road that connects ports, airports and central city. The important infrastructure is not the critical one but needs the earthquake-resistant design. The normal infrastructure is the one that does not need the earthquake-resistant design.

This clarification depends on benefit and cost of each infrastructure.

(3) Safety level against the seismic movement

Safety level for each infrastructure can be clarified by the Gal-value. The image is the safety levels for each type of infrastructure.

(4) Resilience against the resonance

It is assumed that some high-rise buildings collapsed by the resonance. Therefore, destruction of structures due to the resonance should also be considered. The target infrastructure can be the important bridges or high-rise buildings.

(5) Secure the redundancy of infrastructure network

Infrastructure which consists of network, such as road, water supply, telecommunication need to secure the redundancy. Securing redundancy means that even if one is disconnected by the earthquake, the other guarantees the connection.

Because of the earthquake related combined disaster, some important roads and bridges have damaged, and this has been causing difficulty of transportation in the region. It is necessary to repair damaged road and bridge in order to deliver imported emergency supply and food as well as construction materials for reconstruction.

It is beneficial to construct a ring road for smooth transportation of materials required for reconstruction activities, reduction in traffic volume passing through Palu city area and improvement of redundancy at the occurrence of disaster. By improving the existing roads, it is possible to complete the ring road early. (Jl. Munif Rahman, Jl. Gunung Gawalise, Jl. Padanjakaya, Jl. I Gusti Ngurah Rai, Jl. Jenderal Busuki Rahmat, Jl. Professor Mohammad Yamin)

In order to use as a ring road, it is necessary to widen the road, improve the pavement, reconstruct bridges (Jembatan Palu Ⅱ and others) and improve the intersection on existing roads.

Currently, a large vehicle such as a truck cannot pass through the Balaroa area due to liquefaction d amage. Therefore, it is necessary to construct a temporary road in Balaroa area. When constructing a permanent road, there is a method of reinstalling with a Rock bolt and H shape Pile and reconstruct it in its original position.

For roads used for emergency activities and transportation of emergency supplies, Earthquake countermeasures are necessary for bridges and road slopes.

The urban area surrounded by this ring road has been developed, and future social framework analysis is mandatory to finalize the candidate route for the core transport and logistics services.

Source: JICA Mission Team
Note: Yellow line indicates general concept of emergency logistics route

Figure 108 : Concept Diagram of Reconstruction Acceleration Logistics

7.7.3 Avoidance right above the active faults

Buildings on the surface rupture collapsed completely. However, neighbor buildings, even with vulnerable structures have no damage. All active faults cannot be observed on the ground. New active fault might be found after next earthquake as the rupture appeared at 2 km distance in the east from famous active fault by this earthquake.

All infrastructure in this area should be resistant against the shake, and just avoid right above the observed active faults.

7.7.4 Low Reinforcement of the Building Code

Buildings seems collapsed because of the construction failure by neglecting the building code. The low enforcement of building code is necessary to improve the earthquake resistance of buildings. The buildings that many people use, such as public buildings (schools, hospitals), large commercial buildings (hotels, shopping mall) should be inspected carefully.

Therefore, the Inspection Board including structural engineers should be established and inspect every important Buildings.

(1) Establishment of Common Standard for Resistant building

1) Appropriate structural design

In vertical direction with rigid structural frame design, it is important that strong rigid structural parts and weak structural parts shall not be designed in the same elevation, as the earthquake force must be concentrated to the weak structural joints.

a. Adverse effect of the Prototype Design

City apartment house and Gasoline station is constructed by prototype design, same design is applied all of the area of Indonesian country regardless of the Seismic risk zoning and liquefaction area

In case of Palu city, Palu is categorized in the most critical area in the seismic risk zoning map, and as shown in Fig-1, the Spectral acceleration Sa for Palu is around 1.3g to 1.4g for the Period (T) around 0.2s to 1.0s, this values is almost 2 times of north Jakarta area, however, the same design building are constructed in all of the area of Indonesia

In case of the Jakarta area, if five (5) story building, the column dimension shall at least 60 cm x 60cm～80cm x 80 cm, however, in case of Palu apartment column dimension is only 30cm x 50 cm, and main re-bar only 3-D16 was provided.

Comparing to magnitude of the Seismic, the size of the column and beams are too small, and provided re-bar also too small because of the Prototype Design that is not considered seismic risk zoning, this condition is the fundamental issue of the destroy the Building and Facilities

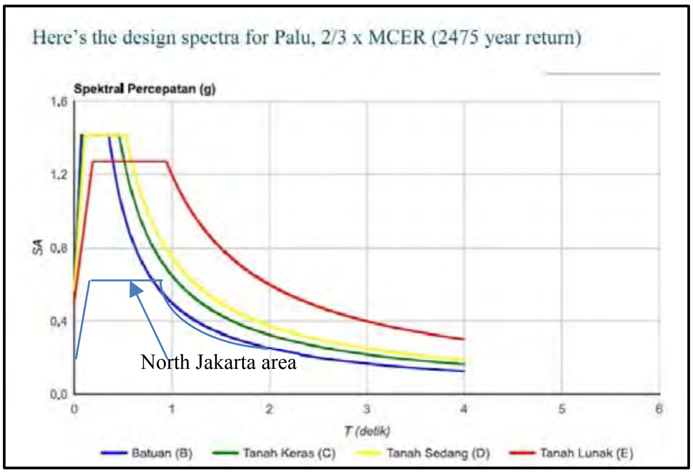


Figure 109: Spectral Acceleration for Palu

b. Different kind of Foundation applied for same building

Building-B was slide away around 50m from the original position due to Earthquake and totally destroyed.

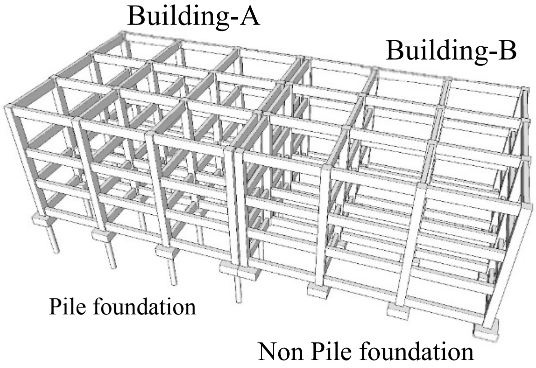
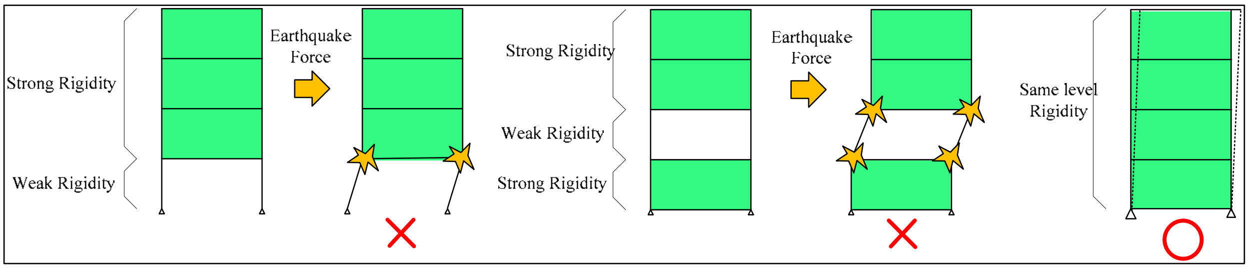


Figure 110 : Image of Foundation Installation (Piling work)

In case of the Hospital building (Anutapura Hospital), the structure of Building-A and B was separated by expansion joint, however due to Earthquake, Building-A is intact on the original position, but Building-B was slid away around 50m from original Position, and has been totally damaged.

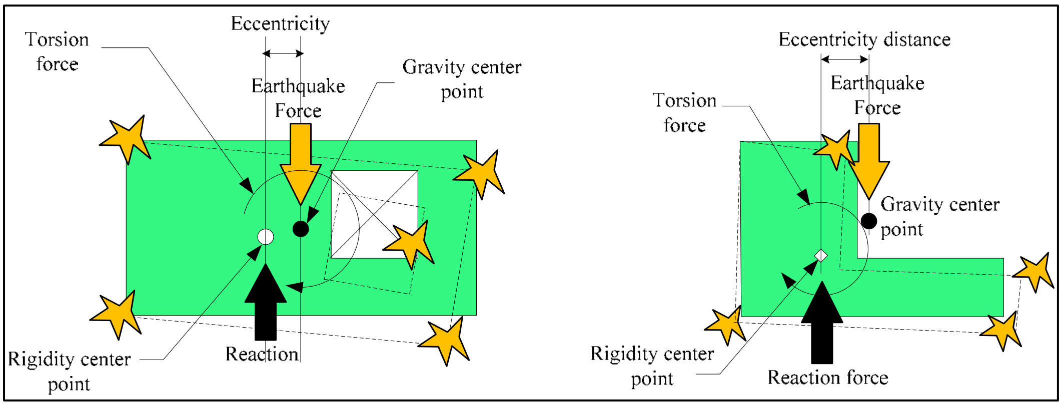
Unlikely happen usually, and structural drawing include foundation drawing is not find out, however, it is a possibility to apply different foundation type such as the Pile foundation was applied for Building-A and Non Pile foundation was applied for Building-B, it must be necessary more detailed investigation.



Source: JICA Mission Team

Figure 111 : Mechanism of Structural Defect

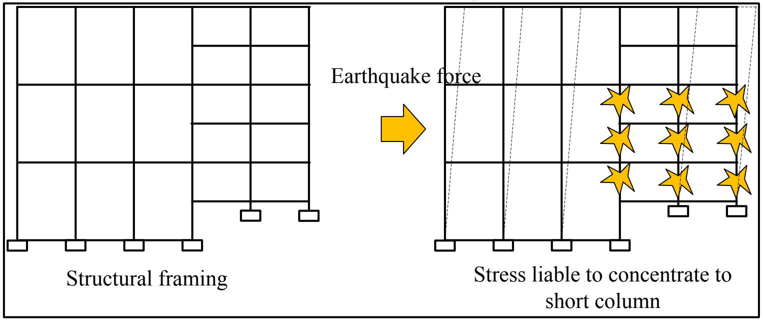
In horizontal direction, the eccentricity distance between building gravity center point and rigid center point of each floor must be less than 0.15, otherwise the building must be destroyed when earthquake occurs due to extra torsional force



Source: JICA Mission Team

Figure 112 : Eccentricity Distance between Gravity Center and Rigid Center

No short column is recommended, otherwise, the earthquake force concentrate to the short column.

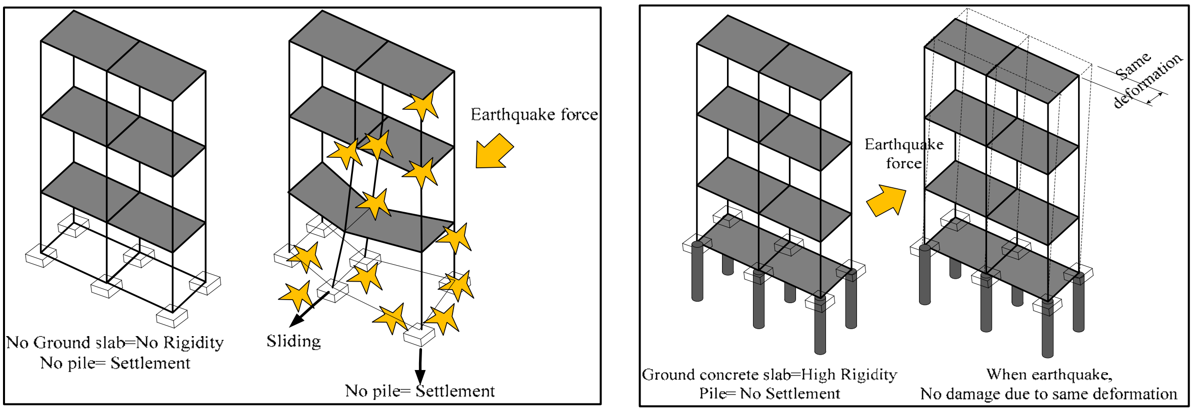


Source: JICA Mission Team

Figure 113 : Earthquake Force Concentration to Short Column

c. Importance of the rigidity of the ground floor concrete slab and Pile

Appropriately designed pile foundation, strong ground beam and ground concrete slab shall be given to a building so as to make toughness structure in order to avoid different deformation and settlement due to earthquake strike.



Source: JICA Mission Team

Figure 114 : Image Figure (3)

(2) Enhancement of “Building Code Observance”

Buildings seems collapsed because of the construction failure by neglecting the building code. The low enforcement of building code is necessary to improve the earthquake resistance of buildings. The buildings that many people use, such as public buildings (schools, hospitals), large commercial buildings (hotels, shopping mall) should be inspected carefully.
Therefore, the inspection Board including structural engineers should be established and inspect every important Buildings.

1) Reinforcing construction supervising work

Present condition of IMB (Building permit) and Supervising for the construction is as shown below. The building permit is issued from DPMPTSP after evaluation by SK (Technical team belong to ministry of public works). However, after issuing of IMB, actual supervision procedure on the construction site by Technical team from the government agency and/or other structural engineer has not been organized properly.

Recommendation of reinforcing of supervising work on the construction site is as below.
i) Incorrect and improper works on site

Incorrect construction work as shown below is one of the critical reason of the building collapse due to earthquake force input.

Mainly, these incorrect works are considered to happen because of:

- ✓ No knowledge of the worker
- ✓ No proper supervision/inspection and quality control on site

Column bottom:
Intentionally, cut away the shear bar

Beam:
Too much re-bar arrangement, and no enough space for the concrete fill around each re-bar

Beam:
Incorrect re-bar lap length

Source: JICA Mission Team

Figure 115 : Images of Incorrect Reinforcement Installation for Concrete Structure

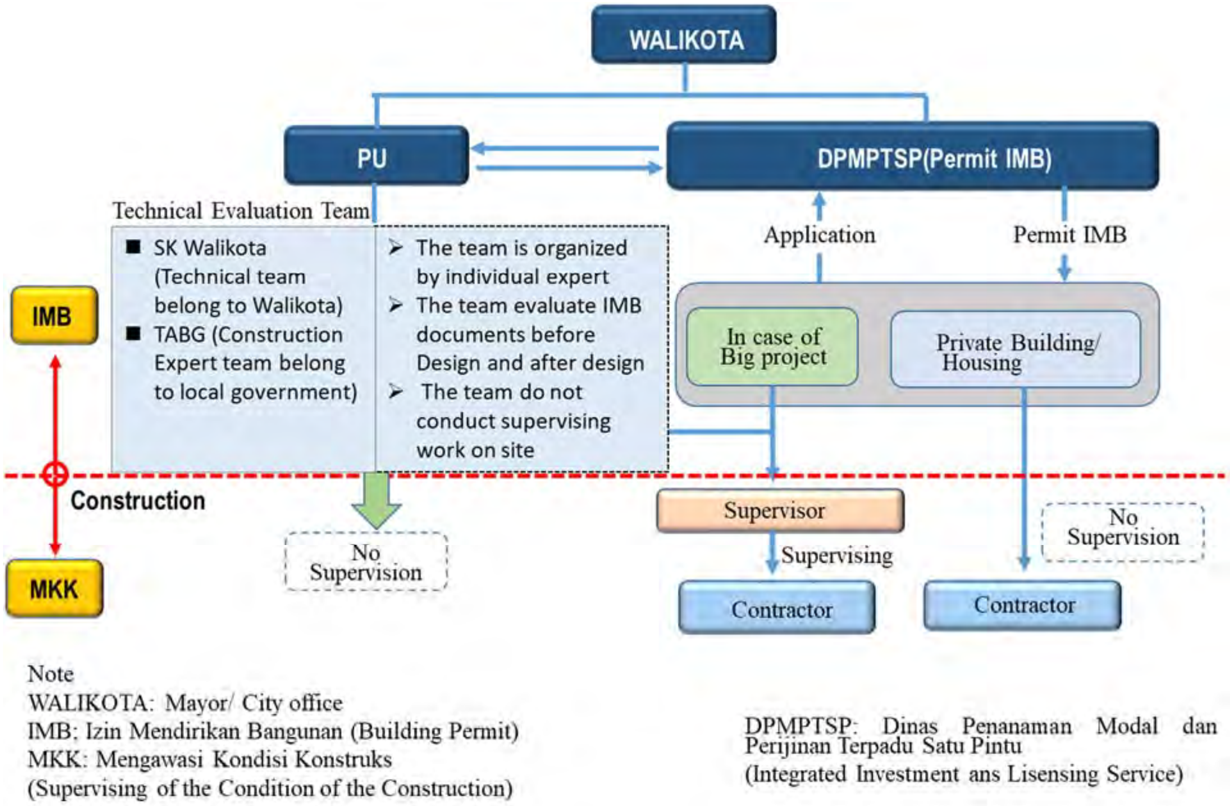
ii) Recommendation about improvement of IMB process and establishment of organization in charge of MKK (Construction Supervision works)

<u>Strengthening IMB procedure</u>

- ✓ Before application of IMB, every applicant must be consulted by SK or TABG (Technical team), and their comments (if any) must be considered into the building design
- ✓ When IMB, every applicant must follow the instruction by SK or TABG
- ✓ In case of the construction works ongoing without IMB, WALIKOTA shall has a power to stop the construction works

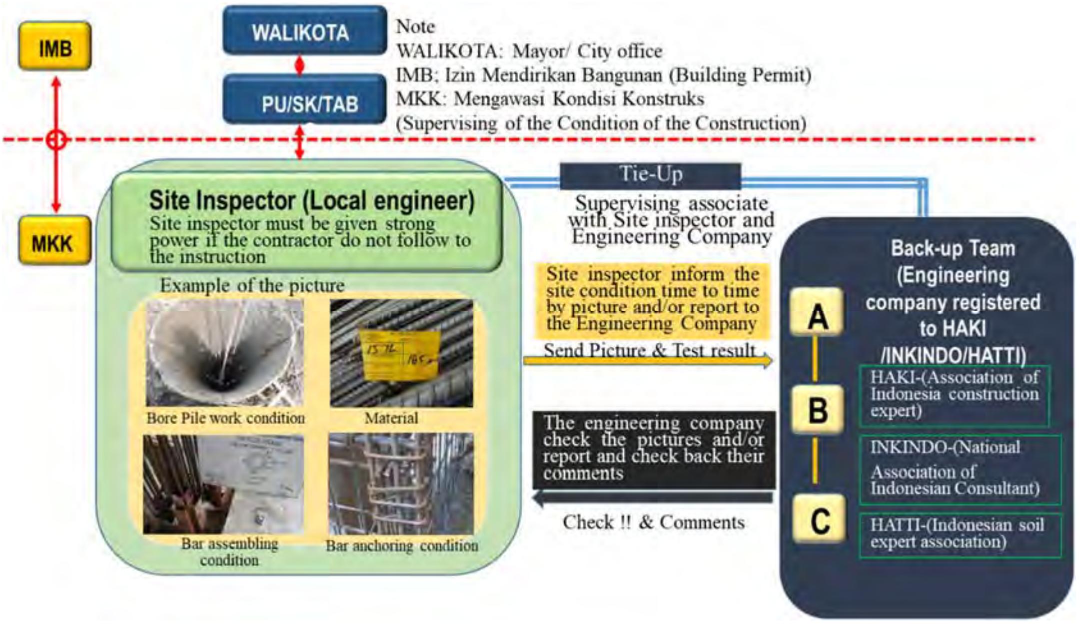
<u>Strengthening MMK procedure (MMK=Construction supervising works)</u>

- ✓ Legalize the supervising work by the engineer for all concrete building works,



Source: JICA Mission Team

Figure 116 : Building Permit (IMB) and Construction Inspection Procedural Outline



Source: JICA Mission Team

Figure 117 : Recommendation about Improvement of IMB Process and MKK

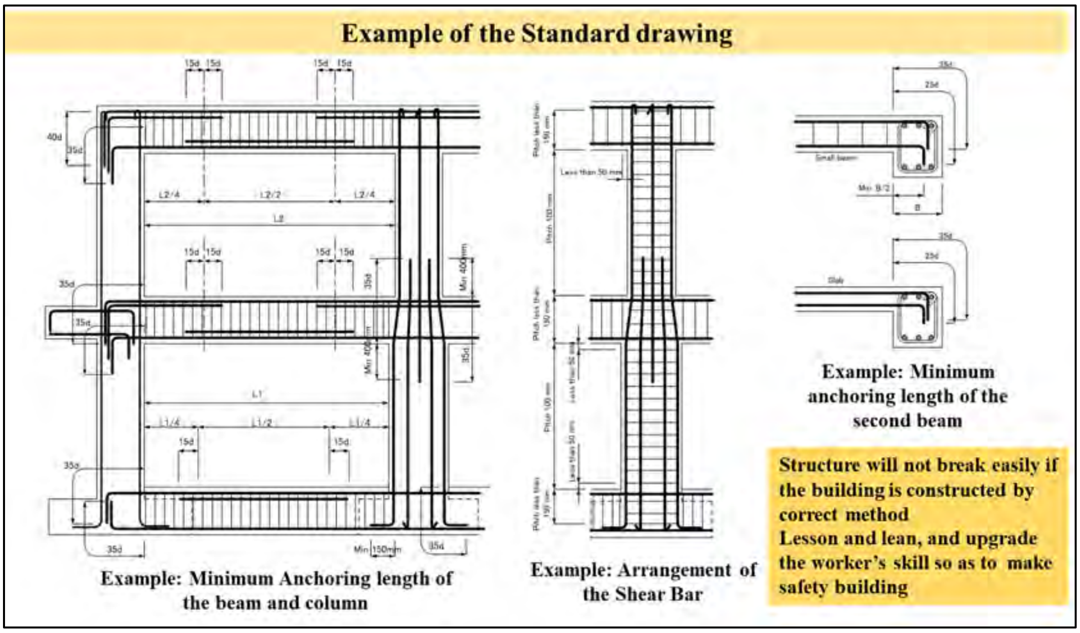
In addition, it is necessary to give strong power to the site inspector so that the contractor must obey to his instruction.

- ✓ Legalize of the periodical site inspection by third engineer who associate in HAKI, INKINDO and/or HATTI

- ✓ Legalize, as one of the conditions of permit of IMB, the building owner must have a contract with the Site inspector and third engineer (Back-up team)

iii) Recommendation to the visualization of construction manual with standard drawing

- ✓ Make standard drawings and manual drawings for bar assembling works, form work and concrete pouring works so as to easy understanding for the site workers, and supervisor as well
- ✓ These standard drawings shall be authorized by SNI

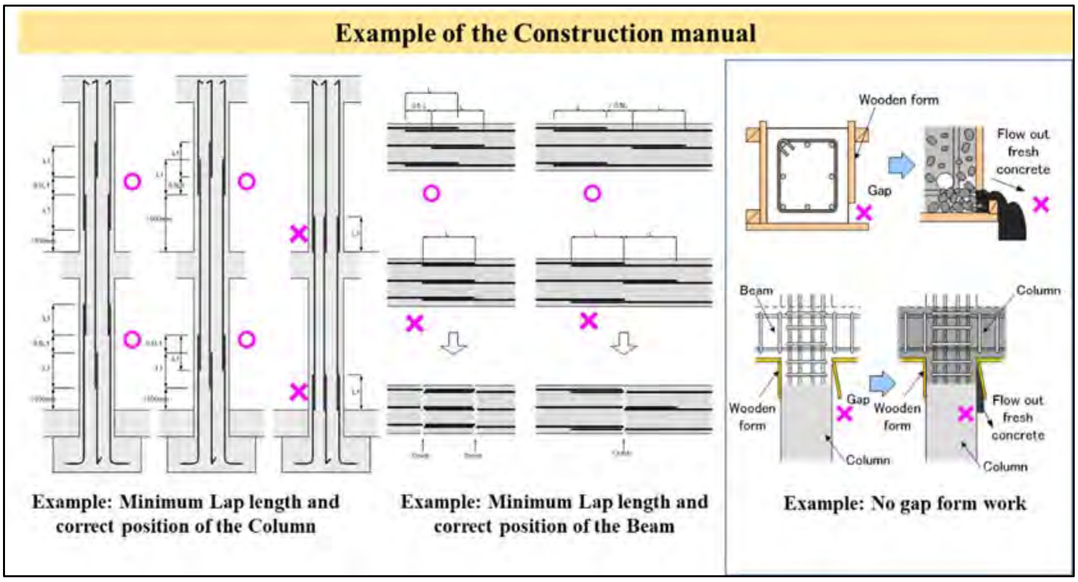


Structure will not break easily if the building is constructed by correct method

Lesson and lean, and upgrade the worker's skill so as to make safety building

Source: JICA Mission Team

Figure 118 : Recommendation for Structural Design and Construction Work Visualization (1)



Source: JICA Mission Team

Figure 119 : Recommendation for Structural Design and Construction Work Visualization (2)

7.8 Flood and sediment disaster countermeasures

7.8.1 Basic policy

In the catchment area of the Palu River that flows through the center of the afflicted area, 9 degrees of small and medium flood damage has occurred during the last 15 years. Flood damage will be expected to expand as the river beds tend to be chronically flooded with low river width, including Mainstream and Tributary, and the riverbed is rising by permanent sediment discharge. On the other hand, the liquefaction-landslides and sediment flows occurred due to the earthquake this time, but in the mountainous area large-scale deep-layer collapse and slope failure occurred, and the amount of sediment produced increased. Due to the situation after such a disaster, the risk of secondary sediment-related disasters is very high. These flood disasters and sediment-related disasters require wide-area measures.

Tabel- 5.8.1 Flood damage history in Palu River

Date	Casualties	Evacuee	Facilities Damaged
Oct 14, 2003	0	0	0
May 7, 2007	2,112	13,280	0
Apr 24, 2008	0	0	0
Sep 17, 2008	0	0	0
Oct 24, 2008	19	98	0
Aug 25, 2012	6	101	212
Jan 16, 2014	0	0	2
Jan 17, 2014	0	1187	34
Oct 3, 2016	0	237	1

Source: BNPB http://bnpb.cloud/dibi/xdibi_list

Flood and sediment disaster countermeasures will be implemented based on the basic concept as follows.

Basic concept I : Improvement of the flood control capacity of the mainstream and tributary of Palu River flowing into the urban districts and suburbs of Palu City.
Basic concept II : Suppression of secondary sediment-related disasters after this disaster.
Basic concept III : Thorough comprehensive sediment control.

According to the basic policy, the following countermeasures are implemented.

Basic policy I

- **I-A**: Expanding the flood capacity (**Riverbed Excavation Work**)
- **I-B**: Fixation of river channel (**Revetment, Series of Consolidation Dam or Ground Sill Work**)
- **I-C**: Reduce the constant water level of river channels (**Lower River Channel Work**)

Basic policy II

- **II-A**: Suppression and capture of secondary movement of sediment (**Check SABO Dam Work**)
- **II-B**: Strengthening warning evacuation system (**The Observation System, The Warning system**)

Basic policy III

- **III-A**: Suppressing harmful sediment discharge into the ocean
  (**Revetment, Series of Consolidation Dam or Ground Sill Work**)
- **III-B**: Sediment supply balance (**Watershed Measures**)

Revetment, Series of Consolidation Dam or Ground Sill Work (BIEI River in Japan)

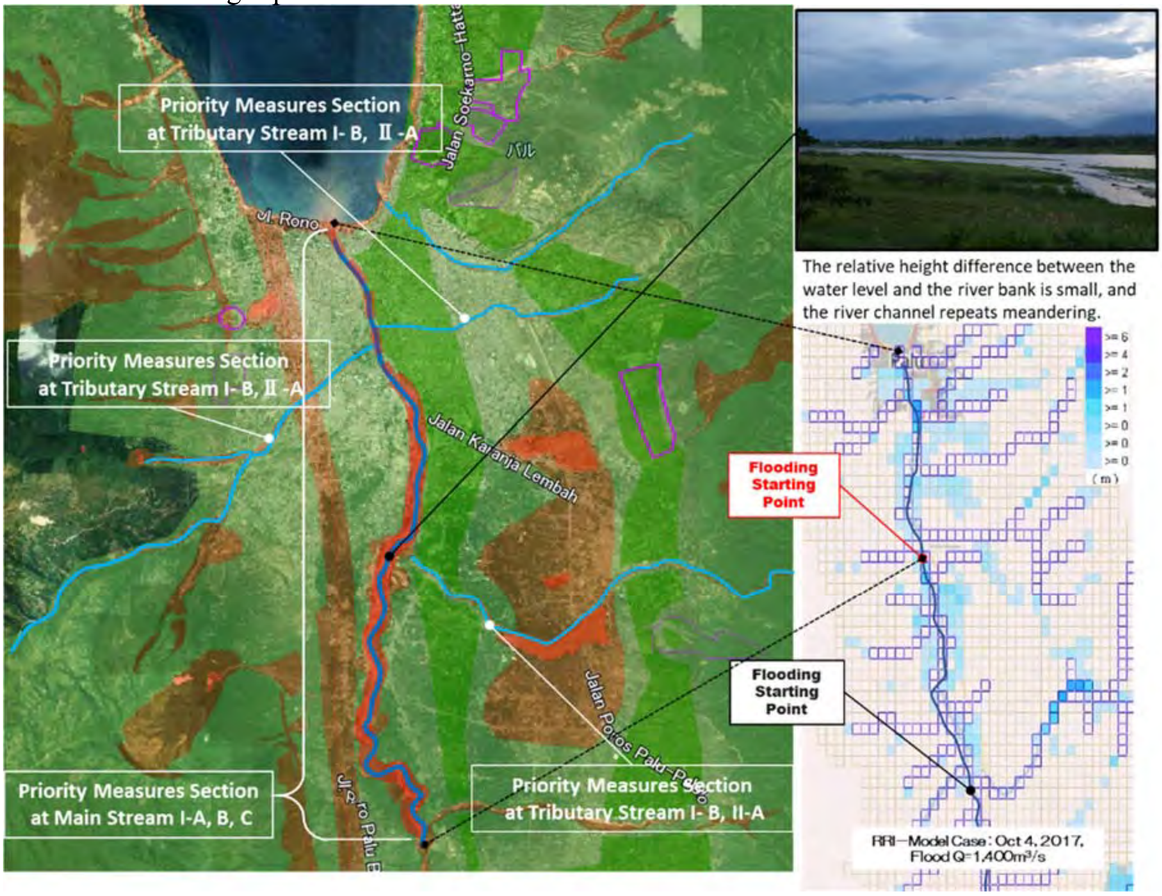
Check SABO Dam

(WASHINO SAWA in Japan)

7.8.2 Countermeasure

(1) The urban districts and suburbs of Palu City Area

In order to improve the safety against flood damage, in the urban areas of the Palu and suburbs, excavate the riverbed of the Palu River to increase flood capacity and constantly reduce running water. In addition, in the tributary river which flows into the Palu River, the three-river inflow of sediment is remarkable, by the revetment and series of ground sill , to suppress the sediment inflow, and to reduce the water level of the water at all times. By lowering the water level of, the groundwater become low in this area, and it is effective for countering liquefaction landslides.



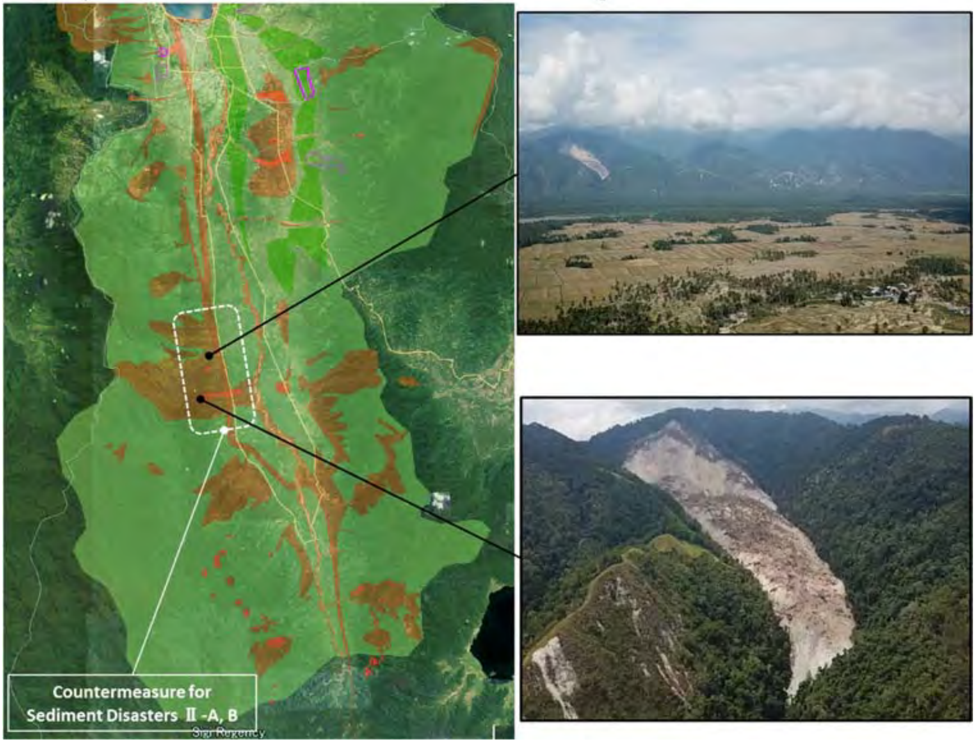
Source: JICA Mission Team

Note : The RRI model analysis results shown in the figure are based on rainfall data acquired from satellite data in the last 15 years and are subjected to flooding analysis.

Figure 120 : Target infrastructure in the urban districts and suburbs of Palu City Area

(2) The East Side Mountain Area

In this area, Large-scale deep-seated landslide caused, by earthquake and slope failures occur frequently. The main road and the village are in close proximity to the collapsed ground. Large-scale deep-seated landslide is likely to cause sediment collapse and outflow secondarily due to rainfall. Since it is difficult to deal with such large-scale collapse, it is necessary to observe soil sediment dynamics and take soft countermeasures by resident relocation and evacuation warning.

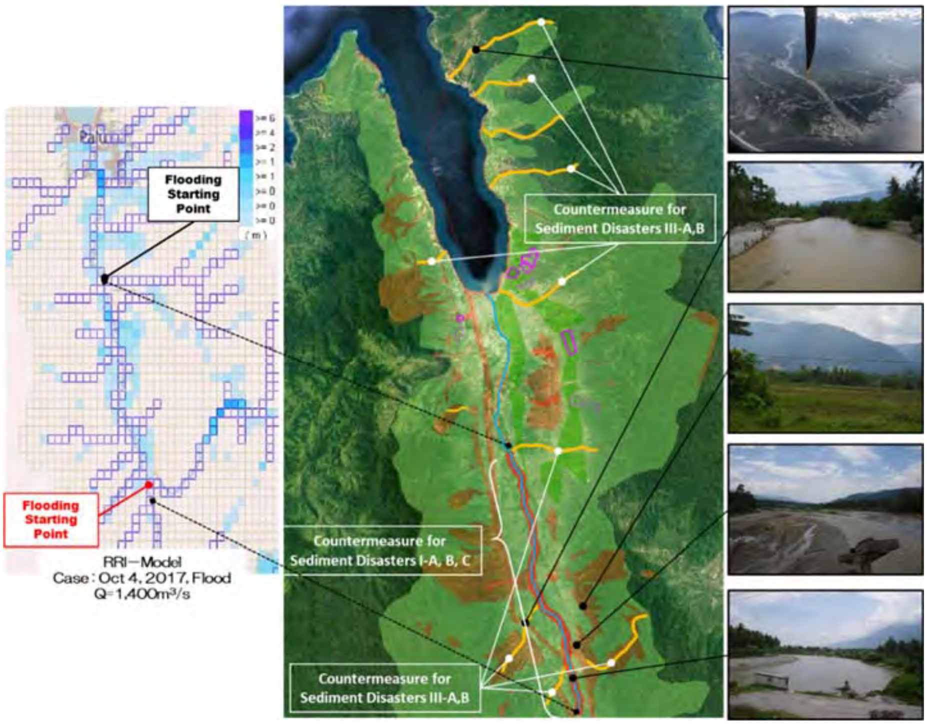


Source: JICA Mission Team

Figure 121 : Target infrastructure in The East Side Mountain Area

The Gulf area and the upper stream area of the Palu River

Sediment discharge is remarkable in rivers dotted in this area. There is a high possibility of causing large sediment disasters in the main roads and villages in the downstream area of each river. In these rivers, a sabo dam is installed upstream and control of sediment discharge by Series of Consolidation Dam is necessary. In addition, in order to balance the supply of soil and sand and to preserve the natural environment that it should have, it is necessary to take measures as a watershed countermeasure.



Source: JICA Mission Team

Figure 122 : Target infrastructure in the gulf area and the upstream area

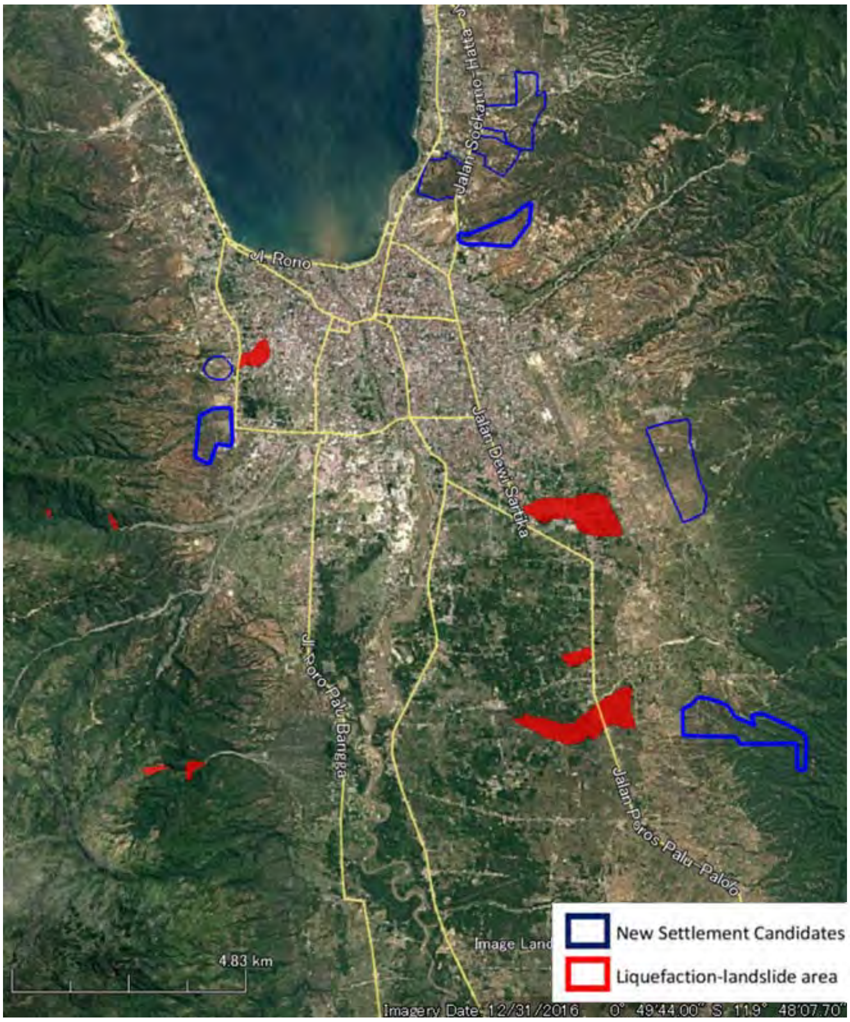
7.9 Infrastructure for new settlement

There are seven (7) major liquefaction and landslides identified in the target area, and three (3) of them are large in area, and four (4) are relatively smaller. The four of these, which are located closer or within the Palu urban area, namely Balaroa, Petobo, Lolu and Jono Oge, have more impact to the people and communities, therefore large number of families should have evacuated (refer to Figure 123). And the people who live in coastal zone also lost their houses by tsunami.

The new settlements for evacuee families were nominated nearby damaged areas. The disaster risk has been already evaluated. To secure their daily lives, basic infrastructure such as road, water supply should be developed.

The settlements are located in mountain side, it is necessary to prevent isolation of settlements. The integrated road network with central Palu urban area and the new settlements should be considered.

Moreover, the settlements are located in dry areas and securing the water is the key for sustainable development of new settlements.The size of damaged farmland by liquefaction-landslide is estimated about 6,000ha, and quite large number of farmers has lost their farmland or production. New and safe farmland for relocated people should be developed nearby new settlement sites.



Source: JICA Mission Team

Note: Red marked areas are disaster affected areas (tsunami and liquefaction landslide)

Figure 123 : Palu Urban Area Liquefaction Landslide Site Map

7.10 Projects in each sector

7.10.1 Road and bridge

With considering the build-back-better of Road and Bridge sector, the following concepts are proposed.

(1) Coastal Road of central Palu city

It is necessary to reconstruct four lane provincial road for smooth logistics, reduction in traffic volume passing through Palu city area and improvement of redundancy at the occurrence of disaster. Road alignment of coastal road needs to be considered together with sea dike. (Jl. Cumi-Cumi and Jl. Rajamoili) The Palu Ⅳ Bridge needs to be reconstructed with a structure of earthquake resistance. The construction site needs to be selected considering road alignment and construction cost.

Source: JICA Mission Team

Figure 124 : Palu City Coastal Zone (plan image)

(2) Central Palu city road

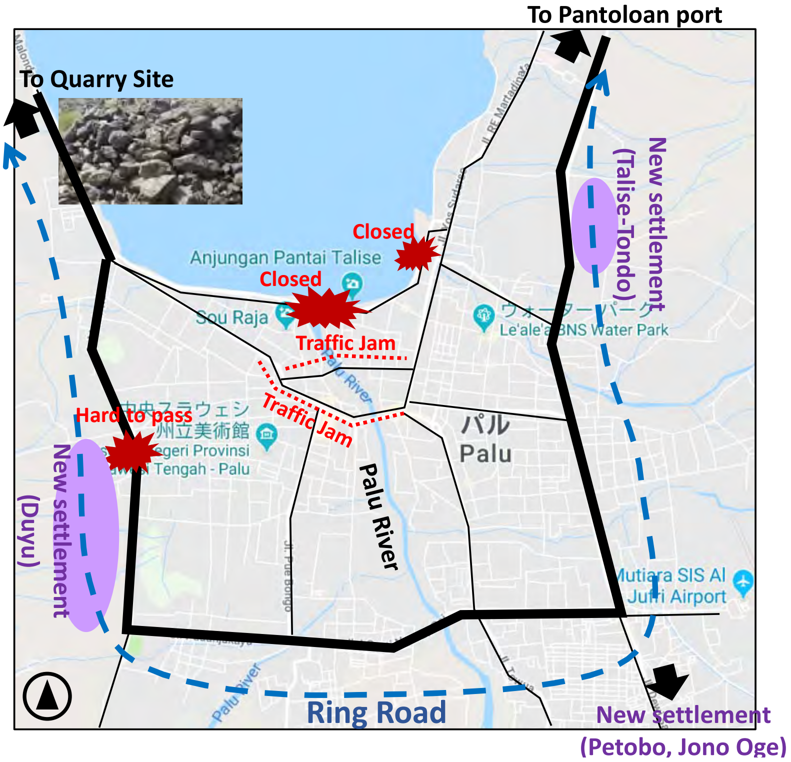
It is beneficial to construct a ring road for smooth transportation of materials required for reconstruction activities, reduction in traffic volume passing through Palu city area and improvement of redundancy at the occurrence of disaster.

In the Balaroa area, large vehicles which necessary for reconstruction activities can't pass through due to liquefaction damage. Therefore, it is necessary to construct a temporary road as soon as possible. When constructing a permanent road, there is a method of reinstalling with a Rock bolt and H shape Pile and reconstruct it in its original position.

Jl. Munif Rahman, Jl.Gunung Gawalise, Jl.Padanjakaya, Jl.I Gusti Ngurah Rai (The length is about 10 km) need to be widened and to improve pavement so that large vehicles can pass. Then, It is necessary to reconstruct the bridge across the Palu River including Jembatan Palu Ⅱ to a four-lane bridge with earthquake resistance.

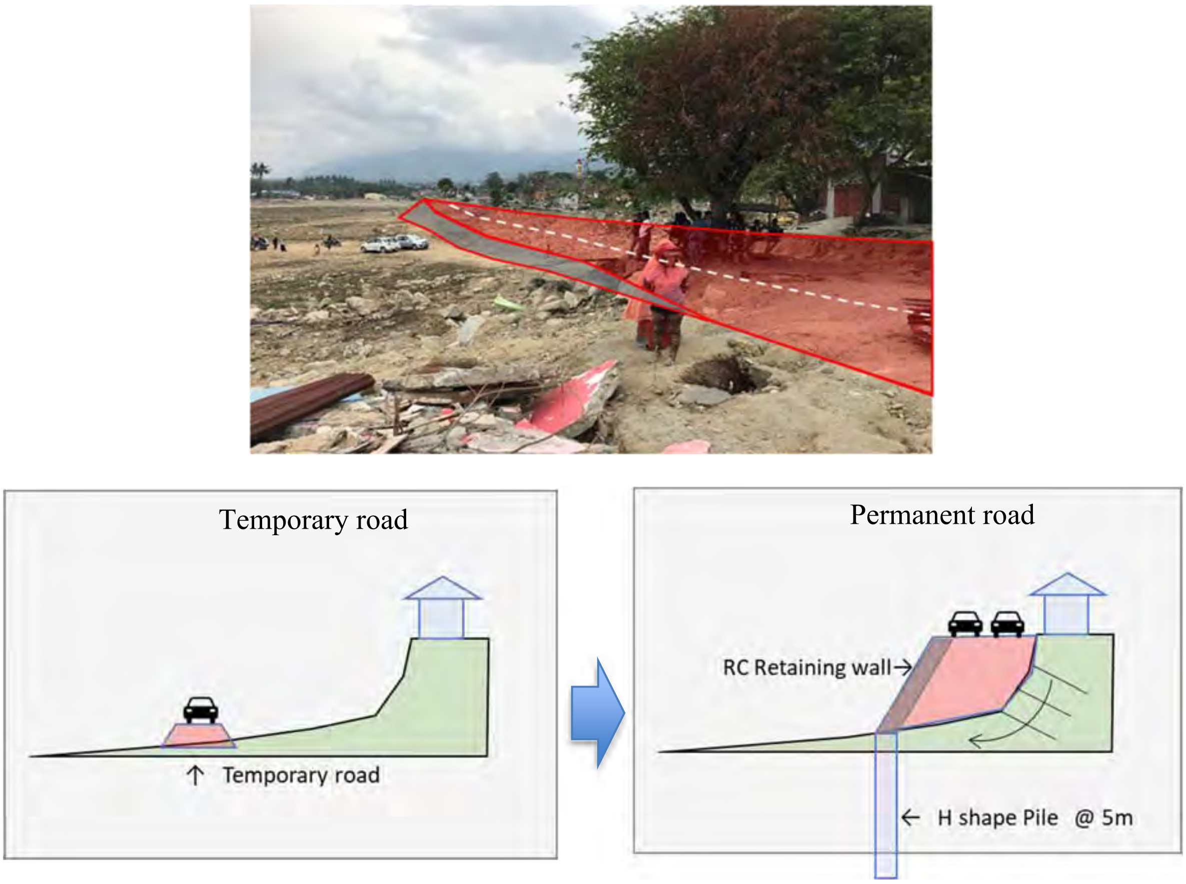
Since the traffic volume increases more than before, it is necessary to change the intersection structure from Roundaboud method to Signaling method.

It is necessary to consider the necessity of construction of a new ring road based on the residence relocation plan in Palu city.



Source: JICA Mission Team

Figure 125 : Image of Ring road



Source: JICA Mission Team

Figure 126 : Image of permanent and temporary road in Balaroa area

Source: JICA Mission Team

Figure 127 : Jembatan Palu II

Source: JICA Mission Team

Figure 128 : Roundaboud intersection in Palu

(3) West and East Coastal Road of Palu Bay

There are several road slopes along the west coastal road. Since it is an important road connecting South Sulawesi Province and Palu city area on the west coastal road, It is necessary to protect road slope where landslides are expected due to earthquake or heavy rain. (Jl. Ampera Surumana and Jl. Trans Palu-Donggala)

Since it is an important road connecting Pantolian port and Palu city area on the east side of the Pal Bay, it is necessary to consider constructing a bypass road on the inland side to improve the coastal road redundancy. (Jl. Trans Sulawesi and Jl. Tolitoli- Palu)

Bridges on roads that deliver emergency supply need to be countermeasures to prevent bridges collapse due to earthquakes.

Source: JICA Mission Team

Figure 129 : Landslides in Donggala

Source: MLIT

Figure 130 : Image of Slope Protection

Source: MLIT

Figure 131 : Earthquake Countermeasure of Existing Bridge

7.10.2 Port

With considering of “build-back-better” for port sector, the following concepts are proposed.

- A new crane will be installed in Pantoloan Port to replace with the corrupted one.
- Wani Port will be reconstructed and be Memorial Place which inform the menace of tsunami.
- Donggala Port will be reconstructed by setting earthquake-resistant berth.

Source: JICA Mission Team

Figure 132 : Coastal Logistic Network

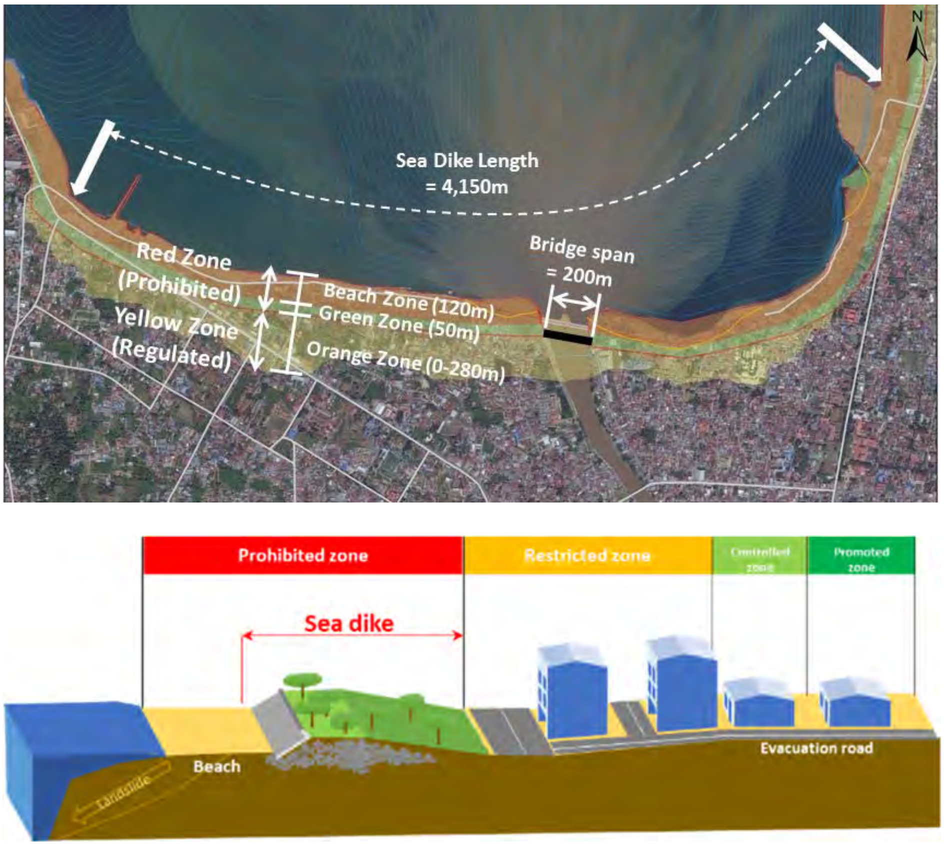
For reconstruction of ports, the followings are proposed.

- To install urgently a new crane urgently in Pantoloan Port for the resumption of Container handling
- To make a policy for restoration and reconstruction of Ports
- To introduce restoration method for damaged port facilities
- Measures to utilize the port and coast area as a place to dispose of Debris and Wastes
- Policy using ports as a transportation base for restoration and reconstruction
- To make a master plan for the utilization of Ports and Coastal area
- To make a roadmap for restoration and reconstruction of Ports
- To make necessary for reconstructing resilient port facilities against earthquake and tsunami
- To establish organization structure consisting of stakeholders related to Port

7.10.3 Water resources

Coastal facilities

For reconstruction of coastal area is becomes a symbolic area of disaster restoration, the followings are proposed.



Source: JICA Mission Team

Figure 133 : Palu City Coastal Zone (plan image)

Sea dike

- In order to have enough time for evacuation, it is necessary to have a tenacious structure that is not easily destroyed.
- The height of the sea dike is set by detailed analysis and simulation in the future.
- By adopting gradual sea dike gradient slope, to make it easy to evacuate, and reduce space division.
- For the material of the sea dike, it is necessary to make good use of disaster debris, and displaced soil at construction.

Reconstruction of beach

- By reconstruction the beach area, regain the prosperity before the disaster.

Evacuation facility

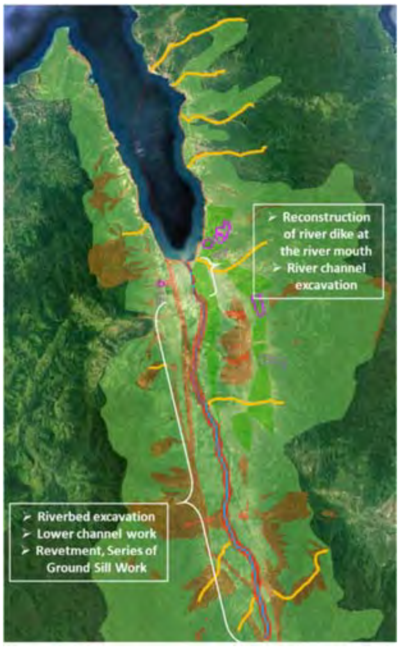
- Evacuation route and evacuation facility should be prepared so that evacuation can be done in a short time from the occurrence of the earthquake to the arrival of the tsunami.

River facilities

The proposed facilities are shown below table.

Table 20 : proposed river facilities

Works	Function
(1) Reconstruction of river dike at the river mouth together with coastal facility.	It is necessary to have the height and structure of river dike that can withstand the flood flow and the tsunami uphill.
(2) River channel excavation	Expanding the flood capacity
(3) Lower River Channel Work	Reduce the constant water level of river channels
(4) Revetment, Series of Ground Sill Work	Fixation of river channel.



Sabo facilities

The proposed facilities are shown below table.

Table 3 : proposed river facilities

Works	Function
(1) Revetment, Series of Consolidation Dam Work	Fixation of river channel
(2) Check SABO Dam Work	Suppression and capture of secondary movement of sediment
(3) The Observation System, The Warning system	Strengthening warning evacuation system
(4) Watershed Measures	Sediment supply balance.

7.10.4 Water supply

In Palu city, only a third of its population was supplied by Donggala PDAM and Palu PDAM and the other by their own source such as deep wells. The coverage rate of water system was considerably low even before the earthquakes.

Due to the earthquakes, distribution networks were severely damaged as most of them were made of old asbestos concrete or PVC pipes.

With development of relocation, more population of Palu city seems to rely on the water supply system of PDAMs. Not only the installation of distribution networks but also the increase of treatment capacity could be urgent issues. For construction of water supply systems, the followings are proposed.

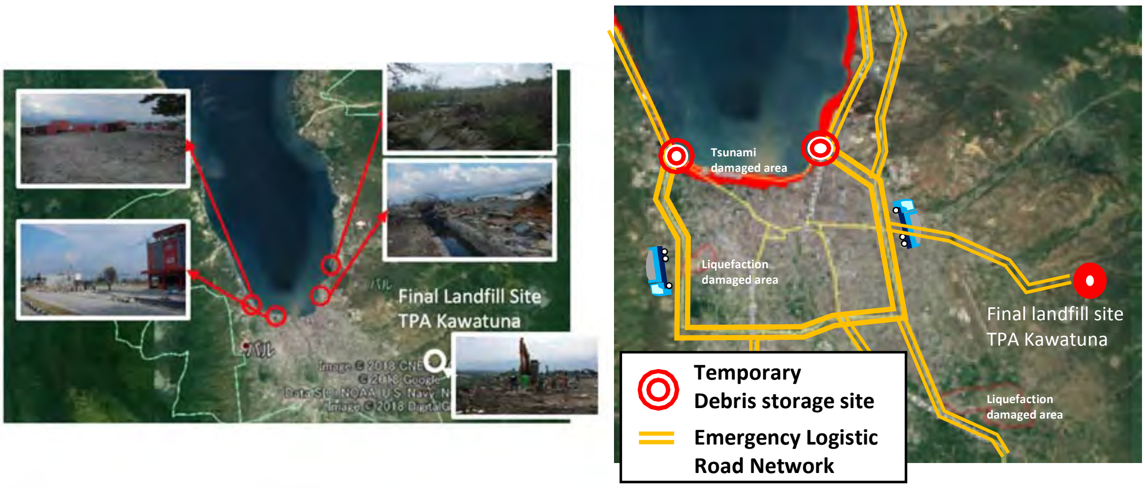
- Damaged facilities, such as intake and transmission channel and treatment plants, should be repaired urgently.
- The new boreholes should be developed in order to recover the damaged facilities and to supply for new residential areas due to the relocation of its population.

- ➢ For the urgent rehabilitation of distribution networks, the identification of vulnerable pipes is necessary to reduce the leakage.
- ➢ For the new Palu city, the improvement plan is necessary to realize the sound and resilient water supply system, such as the increase of water treatment capacities, distribution networks with proper zoning and capacity building of PDAMs to reduce non-revenue water.

7.11 Disaster Debris Management

For disaster debris management, the following contents are proposed.

- ➢ Policy
  - ✓ To decide the basic principle to utilize debris as construction materials for public works projects
  - ✓ To designate the emergency logistic road network for carrying the debris and construction materials
  - ✓ Utilization of disaster debris as material for construction of ports, ring roads and environmental friendly embankments in Palu city for reducing economic costs and environmental burdens due to debris disposal and extraction of virgin construction materials.
- ➢ Action
  - ✓ Temporary debris storage site
    - ・ To prepare temporary debris storage site nearby the public works project (the coastal area).
  - ✓ Emergency Logistic Road
    - ・ To prepare the emergency logistic
  - ✓ Separation, Transportation and Stockpile
    - ・ Conducting feasible separation (e.g. on-site only two types)
    - ・ To separate roughly on the damaged site
    - ・ To carry the debris to the storage site (the other to the final landfill site)
  - ✓ Utilization of Debris
    - ・ To utilize the debris for materials to rehabilitate and reconstruct the infrastructure such as sea dike, road, etc.



Source: JICA Mission Team

Figure 134 : Disaster Debris Management Maps

7.12 Project Road map for implementation

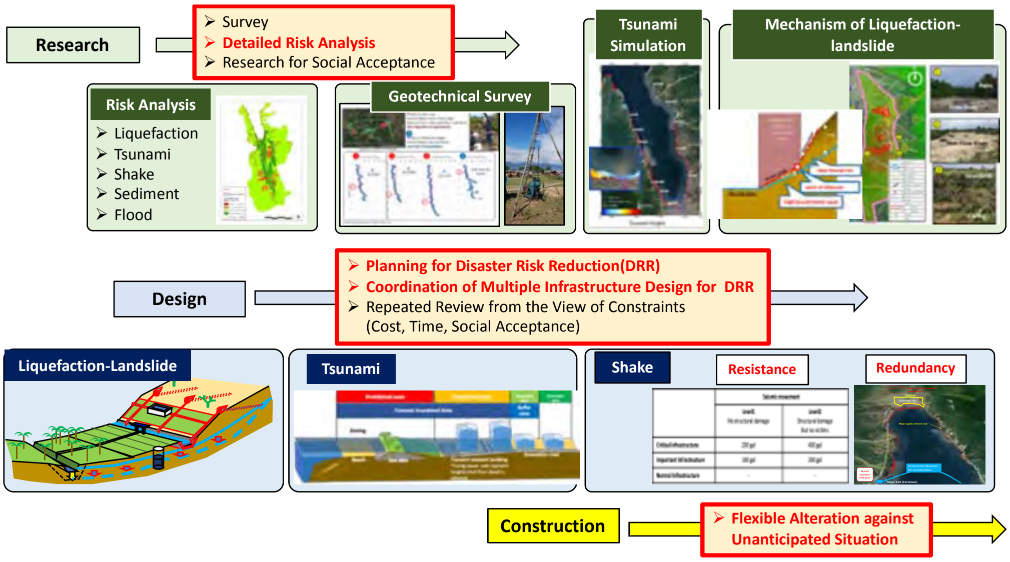
7.12.1 Quick start project

To recover the regional economy and livelihood of people as soon as possible, the infrastructure should be rehabilitated quickly. The infrastructure which does not require the new disaster-resistant design, such as simple road repair, can be implemented anytime.

7.12.2 Next step project

The inseparable project package for DRR, such as tsunami countermeasures and redundancy road network package and liquefaction countermeasures package should be considered thoroughly. Because these packages need following time;

- The detail risk analysis and research for social acceptance
- The planning for DRR
- The review of disaster-resistant design code
- The sufficient coordination of multiple infrastructure design for DRR
- The repeated review from the view of constraints



Source: JICA Mission Team

Figure 135 : Implementation Plan

		Inseparability of Planning	**Detailed Risk Analysis**			**Timing for Construction**
			Liquefaction-Landslide	Tsunami	Shake (Building Code)	
Seal Dike		🔵	✓	✓		6 month later
Road & Bridge	Coastal Road (Including Palu IV)	🔵	✓	✓	✓(Bridge)	6 month later
	Ring Road	🔵				4 month later
	Road in Liquefied Area	🔵🟡	✓			4 month later
	Other Roads (Simple Repair)					2 month later
Irrigation		🟡	✓			6 month later
Drainage		🟡	✓			6 month later
River Improvement		🟡	✓			6 month later
Sabo	Sabo Dam at Sibalaya	🟡	✓			6 month later
	Sabo Dam at Upstream of new settlement candidates					4 month later
Water Supply System					✓	4 month later
Building					✓	4 month later
Sea Port			✓		✓	4 month later
Air Port			✓		✓	2～4 month later

🔵 Tsunami Countermeasures & Road Network Package

🟡 Liquefaction Countermeasures Package

Source: JICA Mission Team

Figure 136 : Risk Analysis by Infrastructure

CHAPTER 8. Early Recovery of Community based Livelihood

8.1 General Condition

(1) Housing

By the disaster, about fifty thousand households are evacuated to the shelters. The disaster affected people have started moving into temporary housing in November, 2018 in Sigi District and these progresses will be extended soon to other areas. According to officials of command post in Palu city and Sigi and Donggala Districts, victims will move into temporary resettlement collectively by original community basis.

Therefore, each community could stay together in same temporary shelter area, and could maintain their solidarity and potential to resume their livelihood activities by re-forming SMEs/Co-operatives/Groups integrating new members who lost their asset such as farming land.

(2) Livelihood

Many SMEs, Co-operatives, and Groups (Agricultural and Fishery) in Kulurahan and Desa have been active since before the disaster. Many victims belonged to small-scale industries as a member of SMEs/Co-operatives/Groups for food processing, handicraft, fish farming, agriculture, etc. Workshops of furniture, accessories and food processing have largely affected, and shopping malls, supermarkets, general markets and small retails were also damaged at large. Rice field, other farming lands and irrigation facilities were largely damaged, and many fishermen have lost their boats, ships, fishnets and fish cages. Some aquaculture businesses and ice factories also have lost their businesses.

(3) Characteristics of SMEs and Co-operative

SMEs and Co-operatives are expected target of livelihood recovery activities because of providing livelihoods for the people. The number of SMEs and Cooperatives existed in the Palu city and Sigi and Donggala Districts is shown in table below.

Table 21 : SMEs and Cooperative existed in the Target Area

	Palu	Sigi	Donggala
SMEs	N/A	28,157	1,058
Co-operative*	216 (182)	72 (56)	132 (80)

Source: JICA Mission Team, interview with department of Co-operative and SMEs of each local govermnet
Note: the number of cooperative means registered number and the number in blanket means number of active cooperatives

According to the Law No.20/ 2008, the SMEs is defined as business entities and categorized into four classes such as micro, small, medium and large according to their business scale as shown in the table below. It means that in order to recover the SMEs, certain amount of financial support is required.

Table 22 : Categories and Definitions of SMEs

	Net assets*	Annual sales
Micro enterprise	Max. Rp 50,000,000	Max. Rp. 300,000,000
Small enterprise	More than Rp.50,000,000 up to a max. Rp. 500,000,000	More than Rp. 300,000,000 up to Rp. 2,500,000,000
Medium enterprise	More than Rp.500,000,000 up to a max. Rp. 10,000,000,000	More than Rp. 2,500,000,000 up to Rp. 50,000,000,000

*Note: Not including land and building of their place of business
Source: Law No.20/ 2008 regard micro, small and medium enterprises

On the other hand, the Co-operative is a legal entity which based on cooperative principles as a peoples economic and kinship value movement with individual or organizational member by Law No.25 /1992: law for cooperative. Therefore, the objectives of some cooperative are not for economic activities but other purpose. Here, it is also shown in above table, it is said that the constant proportion of inactive cooperatives exist due to various reasons. Therefore, the Co-operative who has suitable objective and actual activity record of the activities should be selected as target.

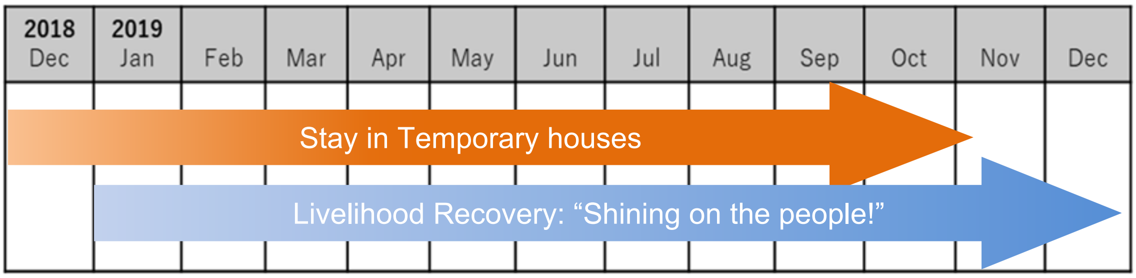
8.2 Livelihood Recovery for "Shining on the People"

In consideration with the above mentioned conditions, it is significant for the government and/or NGOs to facilitate these victims to resume their livelihood activities by providing them with materials, tools/machinery and their working space. These victims are expected to obtain something to live for by resuming their own livelihood activities with neighbors/people in community. The local government shall take important role to provide trauma healing to the victims as well as civil servants throughout these supports.

At the same time, showing victims brighter future by positive slogan for recovery and reconstruction. The followings are one of example:

Livelihood Recovery "Shines on the people" through Restoration for SMEs and Cooperation's Foundation and its Recovery

The livelihood recovery program would be implemented by the tentative schedule shown as below.



Program procedure is summarized hereafter, and one of potential program targets, which could be supported quickly are: Resume Symbolic Snack "Onion Fry", Rattan, Tile, Bamboo goods, Goat, Fish Feed, Bag, Onion Fry in Innovation Village initiated in Palu city; then Market and Workshop should be reconstructed along with near future Relocation Site Plan.

(1) Recovery of Livelihood and Community Restoration

In general, the victims have various constraints on the livelihood recovery. Therefore, the livelihood recovery activities and its procedure should consider the constraints and find required assistances to solve it. In the context of the livelihood recovery, the victims are categorized into two groups that one is a people who live in or will return to original community but lost livelihood and the other is a people who cannot return the original community and move to temporary houses. The both are targets for livelihood recovery program but necessary approaches for them are difference.

Even if the first group continues the same livelihood activities as before the disaster, the causes of loss of their livelihood should be clarified and necessary measures are taken in the improvement. For example, if they lost the workspace by earthquake, the quake-resistant building method should be applied in the reconstruction of workspace. The other group will decide the livelihood activities based on the skills and willingness of the members newly formed.

For both groups, it is important to hold community consultation to make consensus among community to identify their demand and dreams towards implementation of recovery program. The following are main steps forward recovery of livelihood and community restoration:

1. Re-forming Cooperatives/SMEs/Groups by integrating new members with Trauma Healing to

victims in temporary house and others.

2. Provide tools/machinery and temporary workshop for resuming their livelihood activities such as Food processing, Rattan/Basket, Sewing, community-based fish hatchery, etc.
3. Organize/Conduct Training, Marketing Support, cash for works for construction works.

For this purpose, series of the community consultation will be organized. Especially, the community consultation to re-organize the Cooperative/SMEs/Groups and select the livelihood activities should be held at least two times. In the first meeting, their idea and willingness will be listened and concluded draft idea. Then, after the community organizes the internal meeting, like one month after the first meeting, the second meeting will be held to decide their livelihood activities.

For those who lost their livelihood resources such as farmers and their households.

1. Conduct counseling to them for their job creation.
2. Integrate them into the Cooperatives/SMEs/Groups or organize vocational training for their new job.

Based on the livelihood activities carried out in the target area, possible target programs are summarized are shown in table below.

Table 23 : Possible Target Programs for Project Implementation

Sector	Title	Candidate area	Notes and Considerations
Fishery	Restart of Fishery	Donggala and Palu	Renting boat and equipment for fisherman's group
	Reconstruction of ice production facilities for Improvement of fishery	Donggala	Reconstruction of the facilities with considering tsunami
Fish farming	Production of fish feed	Palu, Sigi	Consider synergy with other activities
	Restart of fish hatchery	Palu	Ditto
	Reconstruction of fish farn	Palu, Sigi	Ditto
Agriculture	Intensive vegetable production	Palu, Sigi, Donggala	Consider market
	Poultry and small livestock	Palu, Sigi, Donggala	Consider market
Food production	Reconstruction of workspace and/or providing equipment to produce snacks	Palu, Sigi, Donggala	quake-resistant workspace
Fabric production	Reconstruction of collapsed fabric center	Donggala	quake-resistant workspace, Considering market
	Providing lacking equipment and materials	Donggala	Identify the group and provide the equipment and materials in short term
Furniture and Handcraft	Reconstruction of workspace and/or providing equipment to produce snacks furniture	Palu, Sigi, Donggala	Considering market capacity
Bike repair	Reconstruction of workspace and/or providing equipment for repair the bike	Palu, Sigi, Donggala	quake-resistant workspace
Market	Reconstruction of collapsed market	Palu, Sigi, Donggala	quake-resistant market building
People's Market (Kiosk)	Reconstruction of collapsed Kiosk	Palu, Sigi, Donggala	quake-resistant shop
Women's Empowerment	Increasing women economy by recovering traditional markets and home-based businesses	Palu, Sigi, Donggala	For example, establish bakery in temporary houses

Establishment women friendly center	Palu, Sigi, Donggala	Vocational training , disaster management training and primary health service

Source: JICA Mission Team

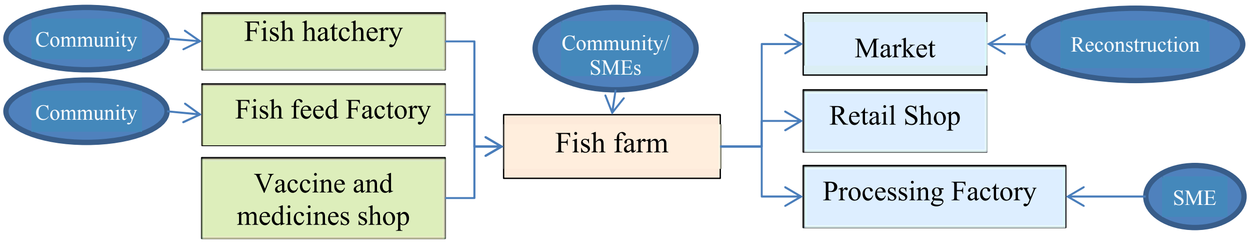
Onion Fry in Innovation Village

Retail shop (SMEs)

Handicraft

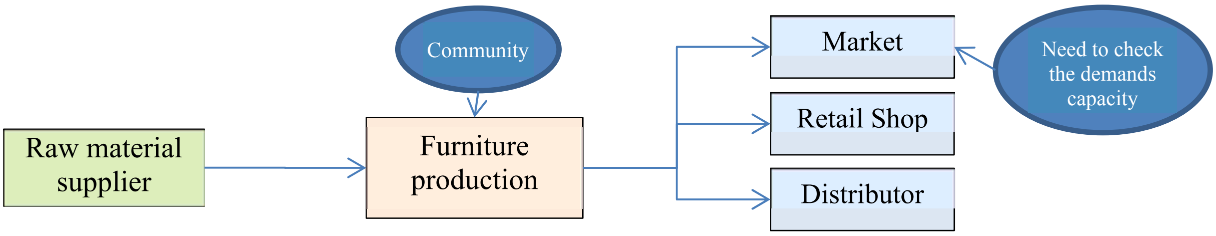
Source: JICA Mission Team

Even the community decides same livelihood recovery activity as the economic activity before the disaster; they might face difficulty due to changes of situation in various locations by the disaster. For example, one community will start aquaculture, but they cannot start properly due to lack of supplying of fish feed and fish juveniles. Moreover, the market of the products should be checked before start the activities too. It means that the value chain should be checked to select the target activities. The value chain means relation between production, processing and distribution and marketing, so that if several activities are implemented in one value chain, the synergistic effect can be expected.



Source: JICA Mission Team

Figure 137 : Example of Value Chain of Fish Farming and Possible Intervention by the Program



Source: JICA Mission Team

Figure 138 : Example of Value Chain of Furniture and Possible Intervention by the Program

(2) Related Institutions and Mechanism

Currently, here are several Ministries and their regional agencies involved in the livelihood support. Their jurisdictions and possible relation to the livelihood recovery is shown in below.

Table 24 : Related Ministries and Their Relation to Livelihood Recovery Program

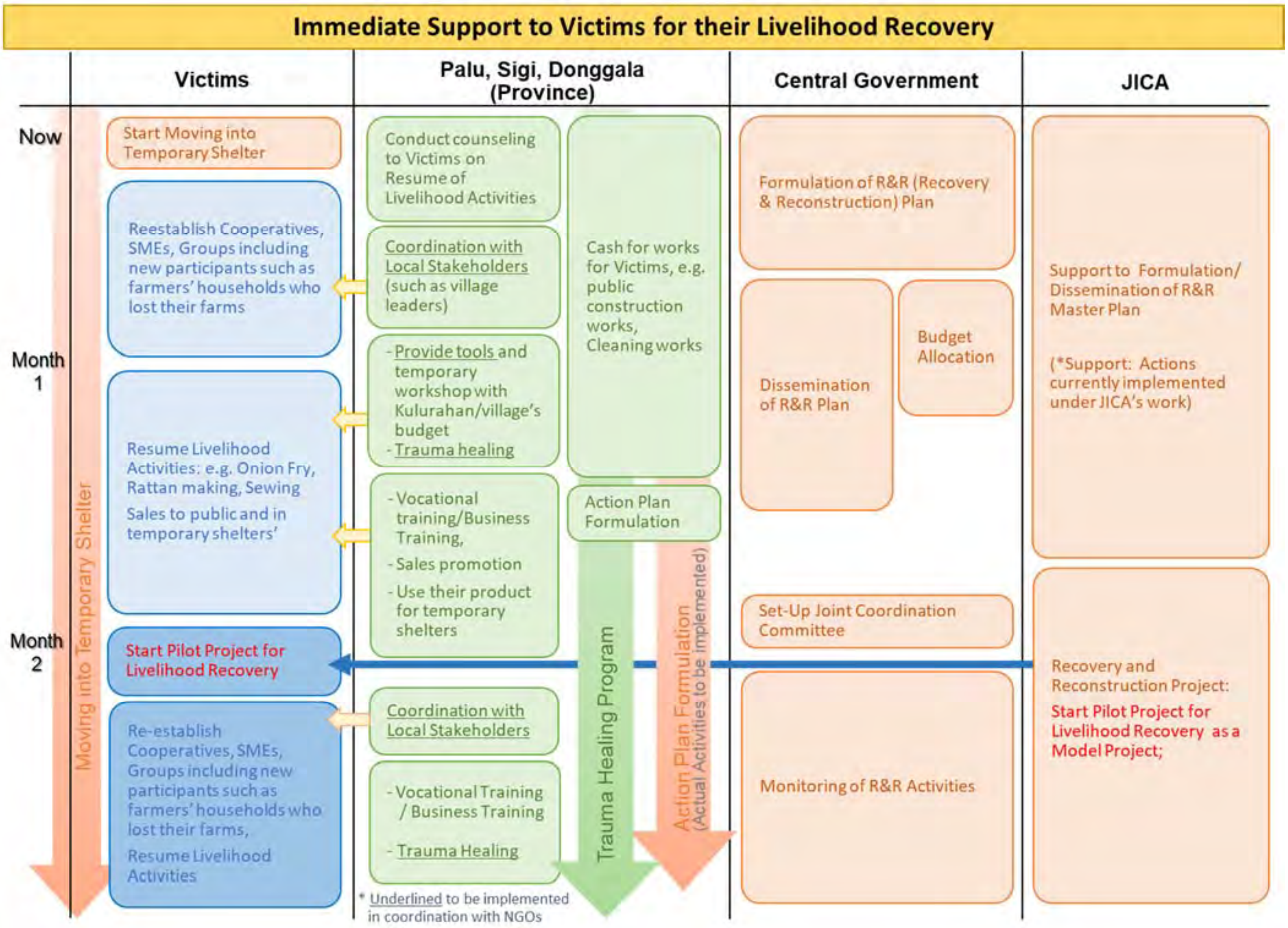
Name of Ministry	Jurisdiction	Related activities with recovery of livelihood
Ministry of Industry and Commerce	Support industrial entities and commercial activities Proving guidance and training for industry and commerce entities Relation with chamber of commerce	Market, Home Industry (furniture production etc.)
Ministry of Cooperative and SMEs	Strengthen the SMEs and cooperatives. Providing training and introducing financial access	Economic activities of micro, small and medium enterprise and cooperatives
Ministry of Fishery and Marine	Promotion of fisheries, aquaculture, food processing. Organization of fishermen	Re-organization of fishery, food processing related to seafood
Ministry of Agriculture	Management of tertiary canal and small reservoir. Extension services	Re-organization of farmers, vegetable production
Ministry of social affair	Conducting social security	Coordinate the trauma healing

Source: JICA Mission Team

Each Ministry and its agencies have its jurisdiction. And, some of them are prohibited to provide the equipment and material directly for the beneficiaries, even it might be effectiveness. So that, in order to implement the activities sustainably, some kinds of mechanism is required, for example necessary equipment for recovery of livelihood will be provided and the group will return its cost to revolving fund like LPDB-KUMKM when they have certain profit.

For smooth implementation of livelihood recovery program, key stakeholders at various level should be included at due step. The key stakeholders are local government, community leader, central government, NGOs, and implementing partners.

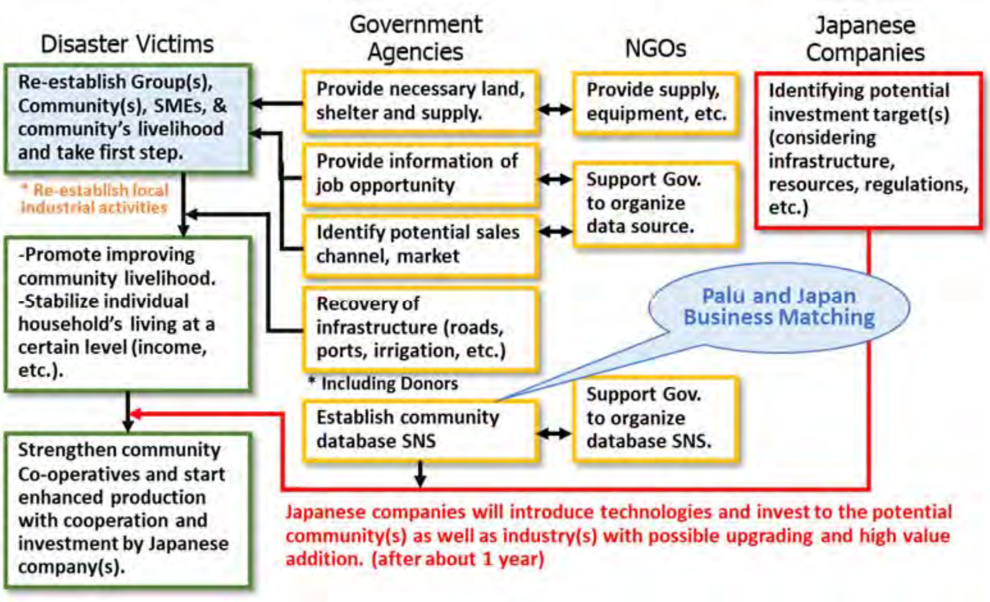
The followings are coming three month’s schedule to support victims in terms of livelihood recovery and community restoration:



Source: JICA Mission Team

Figure 139 : Immediate Support by Stakeholders for Successful Implementation of "Shining on the People" Program

There would be also possible private sector support from Japan in case their technology or know-how matches the community-based livelihood recovery program. In case such business matching could be realized, some more activities among stakeholders would be considered necessary.



Source: JICA Mission Team

Figure 140 : Possible Action Flow between Stakeholders including Japanese Company(s)

CHAPTER 9. New Regulations

9.1 Spatial Plan

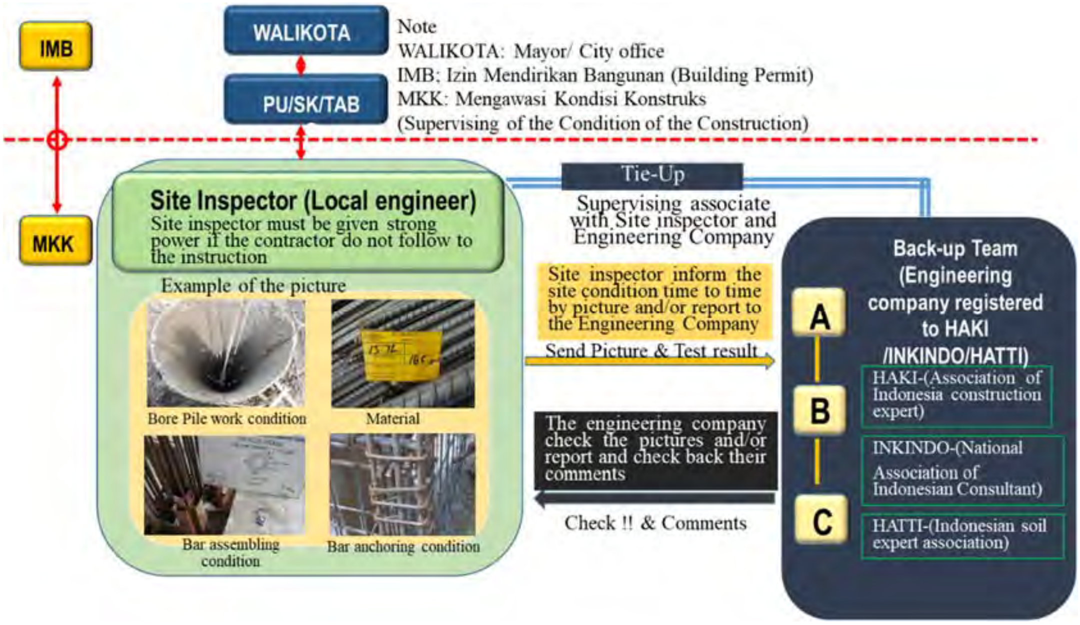
New Regulations should be established to observe the Spatial Plan. In parallel, some kind of mechanism should be considered in order to secure the observance of new regulations.

Table 25 : Guidance for Disaster Hazard Zone (ZRB)

Zone	Post disaster spatial guidance (requirement for land use)
ZRB 4	1. Not allowed to rebuild houses after disaster. Building and Houses in this area should be relocated 2. Prioritized to be used as protected area for DRR (example Tsunami green belt, Open green space) 3. Can be used as disaster awareness area/to build monument
ZRB 3	1. New building in coastal area where tsunami inundated is limited for high building (>=2 stories), which can be used as multi-function (Tsunami vertical evacuation shelter) with perpendicular direction of the coastline. 2. For Land utilization in Flood hazard area, minimum 2 stories houses are required. 3. Development of roads and places for evacuation and green open space. 4. New building is limited to earthquake, tsunami, liquefaction-landslide, flood and sediment disaster resistance building (using geotechnical and structural engineering) 5. To limit house and land use intensity in level “Low”, and periodically monitor the saturation level of ground water. 6. Very strict controlling of existing residential land use and avoiding construction of new high-risk life line/critical facilities. 7. Undeveloped areas in “very high” of liquefaction-landslide or “high” of sediment disaster should be prioritized the function of protected areas or non-built cultivation such as utilization of forestry, agriculture and plantation space for plants that do not require a lot of water.
ZRB 2	1. Low Intensity for land utilization/usage 2. Recommendation to follow “resistance building” of ZRB 3 in accordance with each risk.
ZRB 1	-

9.2 Building Code Observance

New organization should be established in order to observe “Building Code” at the phase of construction work.



Source: JICA Mission Team

Figure 141 : Recommendation about Improvement of IMB Process and MKK

Appendix

- Progress of examination of liquefaction landslide (inland area)

Progress of examination of liquefaction landslide (inland area)

Contents

February 2019

JICA Project Team

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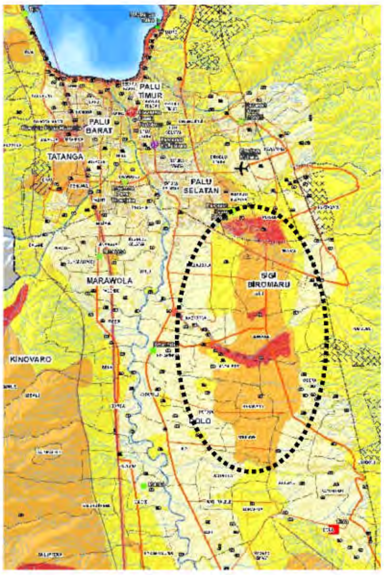
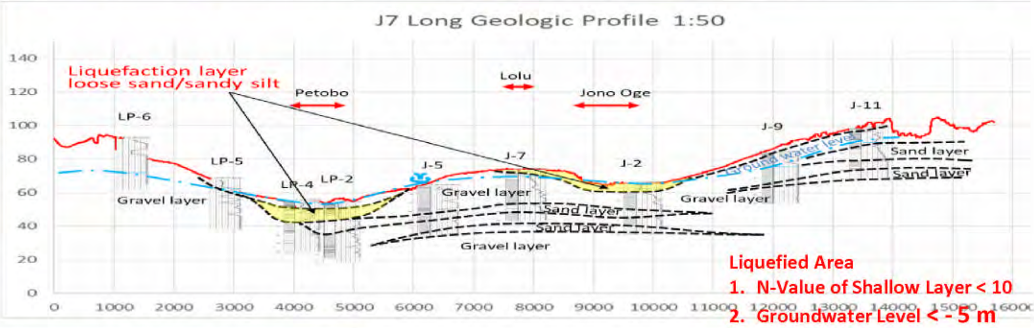
1. Approach on elaboration of ZRB

Present ZRB (by ATR)





Liquefied Area
1. N-Value of Shallow Layer < 10
2. Groundwater Level < - 5 m

Detailed Risk Analysis (for development of space planning)

- Topographical comparison using satellite data (before / after disaster)
- Investigation and analysis to understand the characteristics of surface water and groundwater
- Additional geological survey (boring, trench, Swedish type penetration test) in order to confirm the distribution of the detailed geological layer
- Survey to understand the geological structure over a wide area

1-(1) Liquefaction landslide “Evaluation of risk level (ZRB4 to 1)”

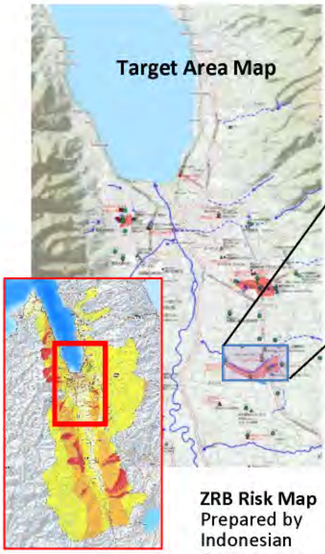
Land-use regulation and building-code in each ZRB

Zone and Typology	Definition/ Criteria	Post Disaster Spatial Direction (Provision on the use of space/area)
ZRB4 (PROHIBITED ZONE)	4 L: Massive liquefacted zone (after earthquake) (such as: Petobo, Balaroa, Jono Oge, Lolu and Sibalaya)	● **Prohibited (not allowed) to rebuild and new development. Existing houses in this zone are recommended to be relocated.** ● **Prioritized to be used as protected area, open green space (RTH) and monument.**
ZRB3 (Limited Zone)	3 L: Liquefaction Hazard Zone “Very High”	● **It is prohibited to build new residential houses and important & high-risk facilities** (according to SNI 1726, including hospitals, schools, meeting venue, stadiums, energy centers, telecommunication centers) ● **Reconstruction of residential houses should be reinforced according to applicable standards** (SNI 1726) ● In area that has not been built yet and inside the Liquefaction zone “very High”, **priority is given as protected area or non-built cultivation area** (agriculture, plantations, forestry). ● **Agriculture with less water (For example, Field crop)**
ZRB2 (CONTROLLED ZONE)	2 L: Liquefaction Hazard Zone “High”	● **New development will require earthquake resistance design** refer to applicable standards (SNI 1726) ● Land utilization/usage level “Low intensity”.
ZRB1 (DEVELOPED ZONE)	1 L: Liquefaction Hazard Zone “Medium”	● **New development will require earthquake resistance design** refer to applicable standards (SNI 1726) ● Land utilization/usage level “Low to Medium Intensity”

**Notes:*
Each disaster-prone area will be equipped with routes, signs and evacuation space. Source: Ministry of ATR/BPN, 2018
Source: Bappenas, 2018

1-(1) Liquefaction landslide “Evaluation of risk level (ZRB4 to 1)”

ZRB-3 and ZRB-4 Building Design Regulation Set-Up



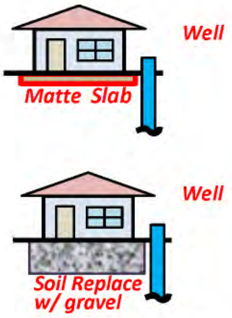
ZRB Risk Map
Prepared by
Indonesian
Government

Jono Oge Nalodo Prone Area

Zoning & Building Design Regulation for Nalodo Prone Area.

Based on the risk analysis;

A) Buildings may be developed with well in ZRB-3 zone.
B) Critical buildings, such as hospital and gas station, should be prohibited in ZRB-3 zone.
C) Public or large size building development in ZRB-3 is regulated as higher occupancy is considered, and strict design & construction inspection should be applied.
D) No building development is allowed in ZRB-4 zone.



Underground water control and building foundation design to be carefully deigned.

Note: “Nalodo” is the local term meaning liquefaction.

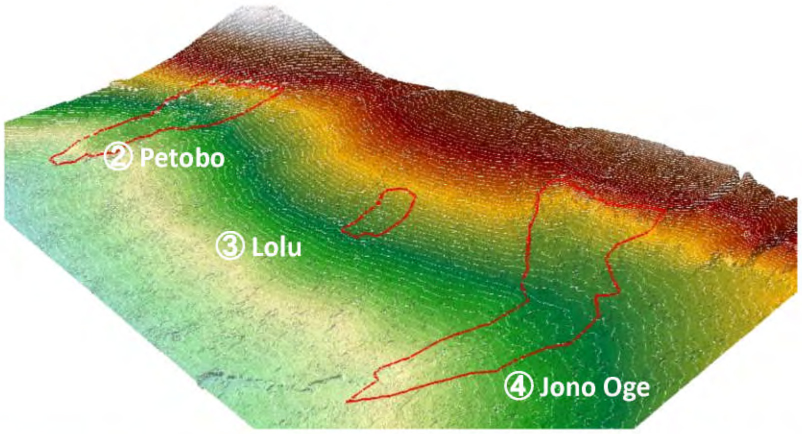
1-(1) Liquefaction landslide “Evaluation of risk level (ZRB4 to 1)”

Draft evaluation methodology of risk level

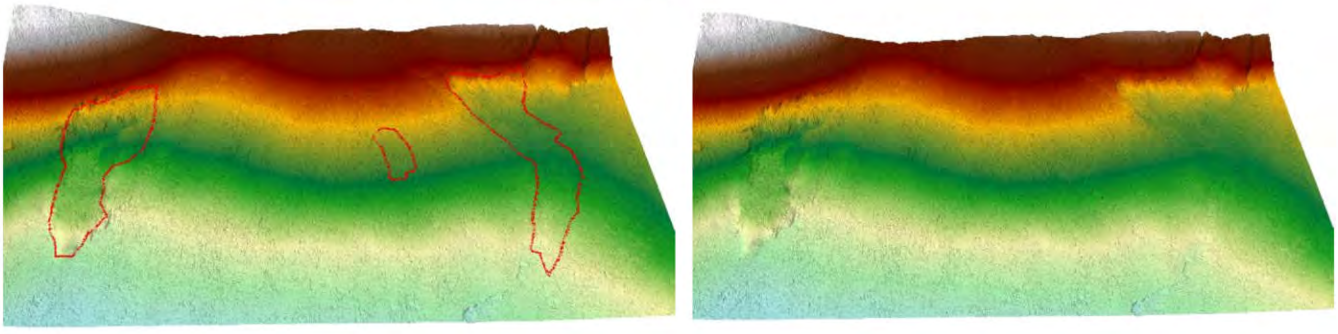
STEP	Contents	Evaluation indicator	Criteria
STEP-1	Interpretation of topographic map, satellite / aerial photo	● Evaluation of topographic change (volume of subsidence, amount of movement and etc.) by comparing the topographic map and satellite / aerial phots before & after disaster ● Evaluation of geography characteristics (Slope factor: 2-3%, top soil: cap effect) * Satellite data and satellite photo before & after the disaster are already procured	Zoning of risk area of liquefaction landslide (ZRB4 to 1) *The affected area of large-scale liquefaction landslide will be selected as ZBR4
STEP-2(1)	Simple soil survey result (Swedish type penetration test, N-value)	● Groundwater level from the ground surface ● Thickness of liquefaction layer (Sand layer with N-value N≦10)	ZRB 4 (If it meets BOTH conditions) • Groundwater level from the ground surface: Less than -3.0m • Thickness of liquefaction layer: More than 2m ZRB 3 (If it meets BOTH conditions) • Groundwater level from the ground surface: Less than -5.0m • Thickness of liquefaction layer: More than 2m ZRB 2 (If it meets EITHER conditions) • Groundwater level from the ground surface: Less than -5.0m • Thickness of liquefaction layer: More than 2m ZRB 1 • Except for ZRB 4, 3, 2
STEP-2(2)	Evaluation by liquefaction resistance (FL)	● Groundwater level from the ground surface ● Thickness of liquefaction layer (FL < 1.0)	Basically, above criteria will be applied, even though STEP-2(2) will be applied to clarify a boundary of ZRB 4 to 2. *Evaluation indicator of liquefaction layer is different (Sand layer with N-value N≦10 or FL < 1.0)

1-(2) Interpretation of topographic map (2m grid)

(after disaster)

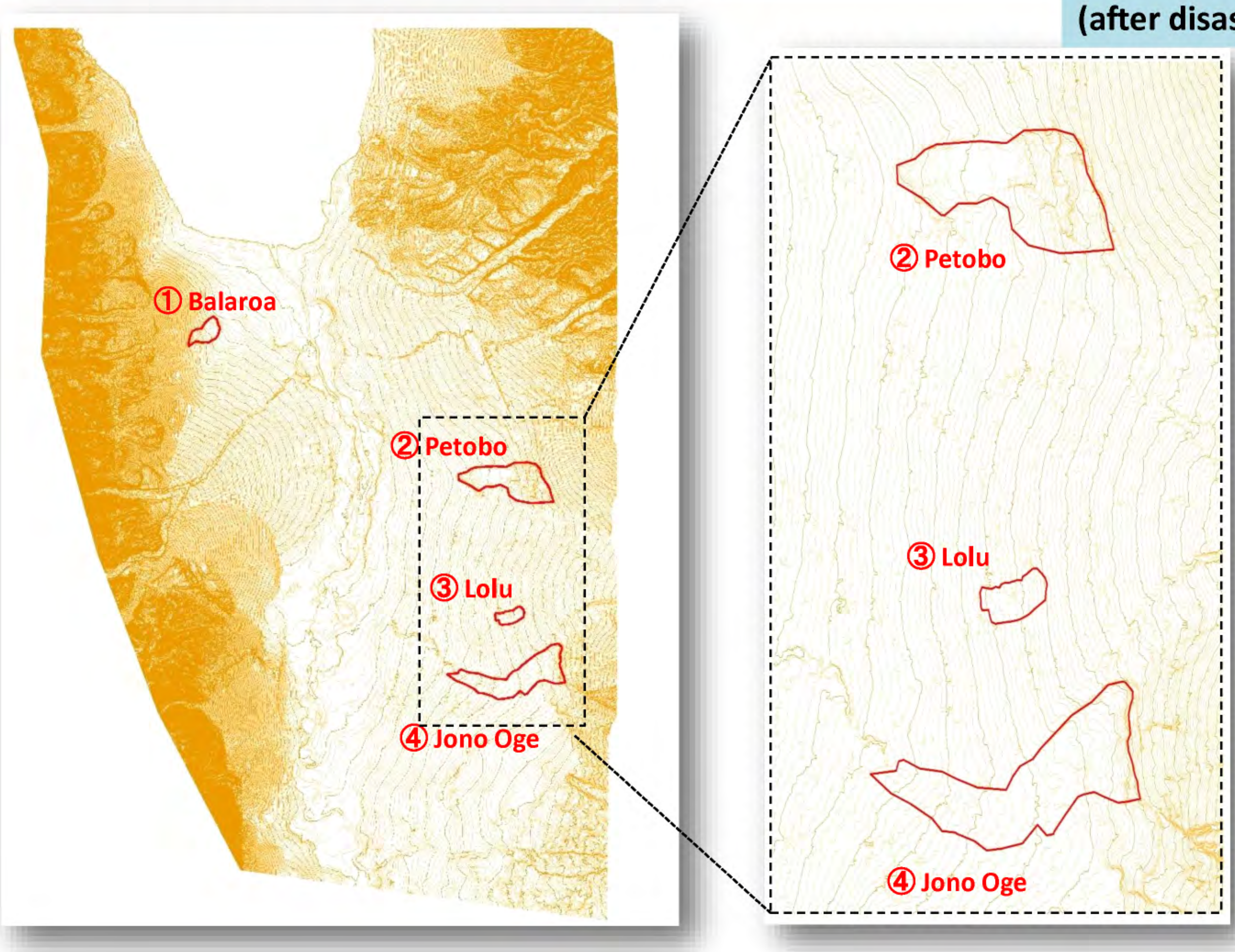


Place	Area (ha)
① Balaroa	32.5
② Petobo	153.7
③ Lolu	22.0
④ Jono Oge	168.8

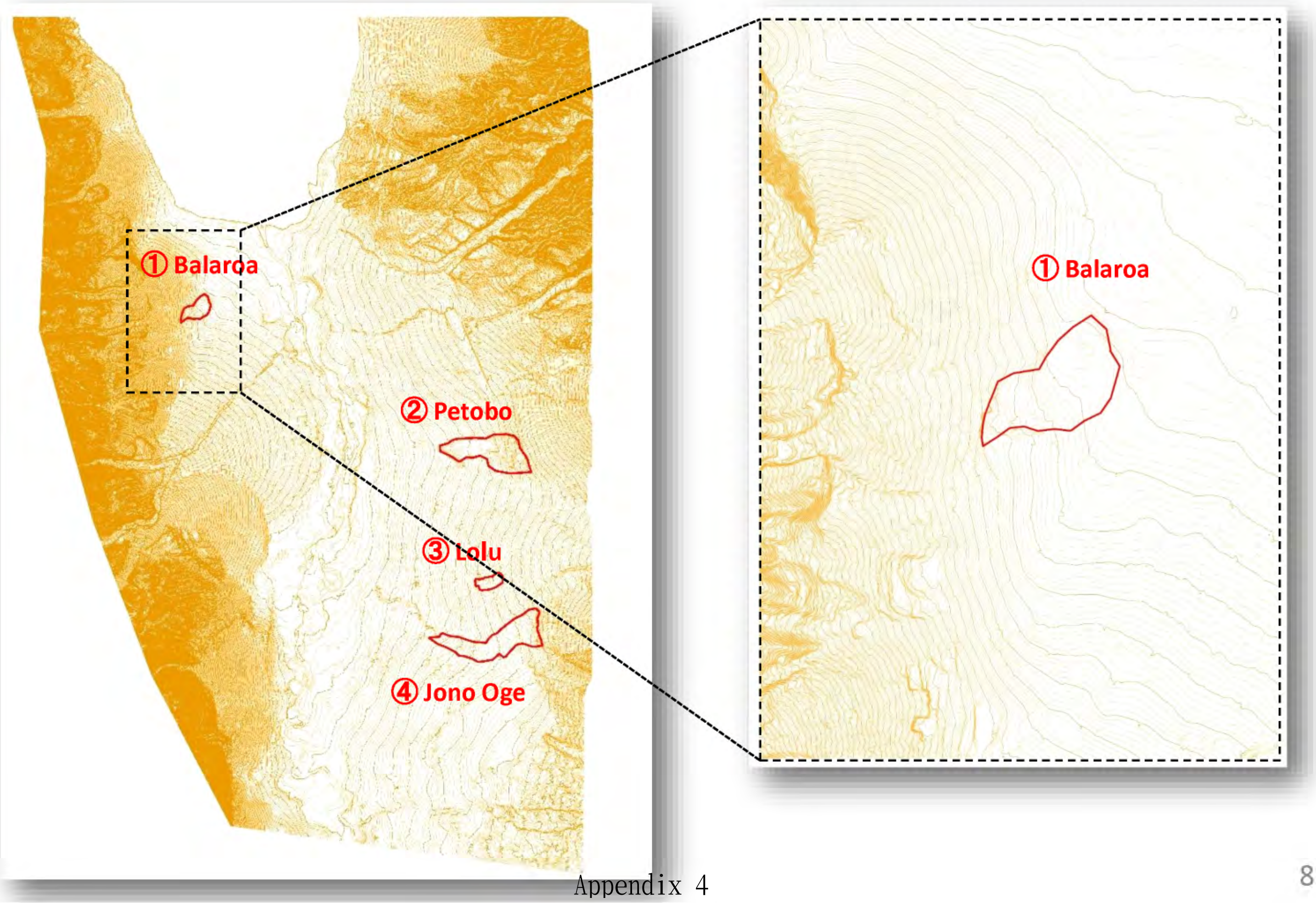


1-(2) Interpretation of topographic map (2m grid)

(after disaster)

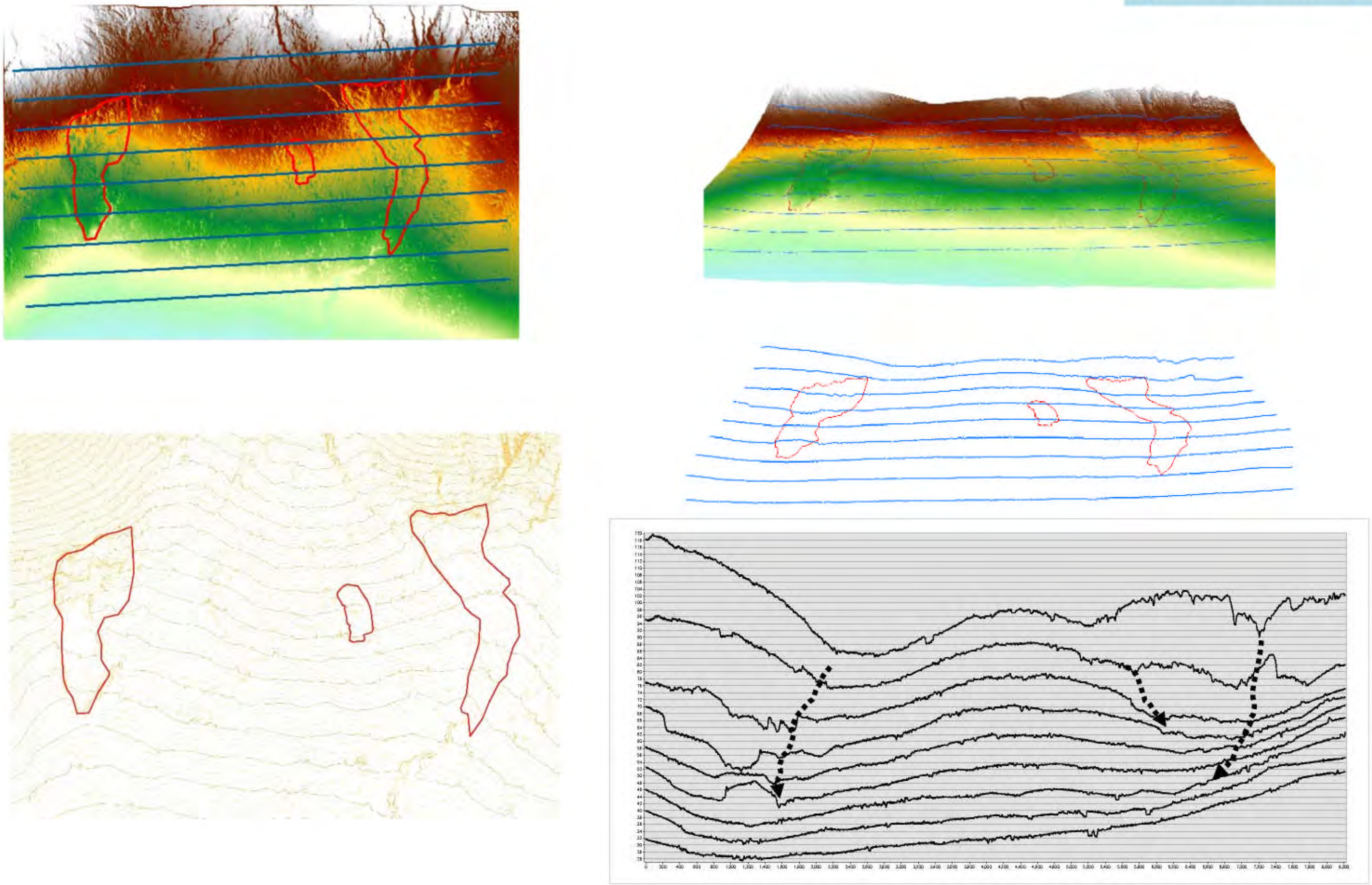


1-(2) Interpretation of topographic map (2m grid)



1-(2) Interpretation of topographic map (2m grid)

(after disaster)



1-(2) Interpretation of topographic map

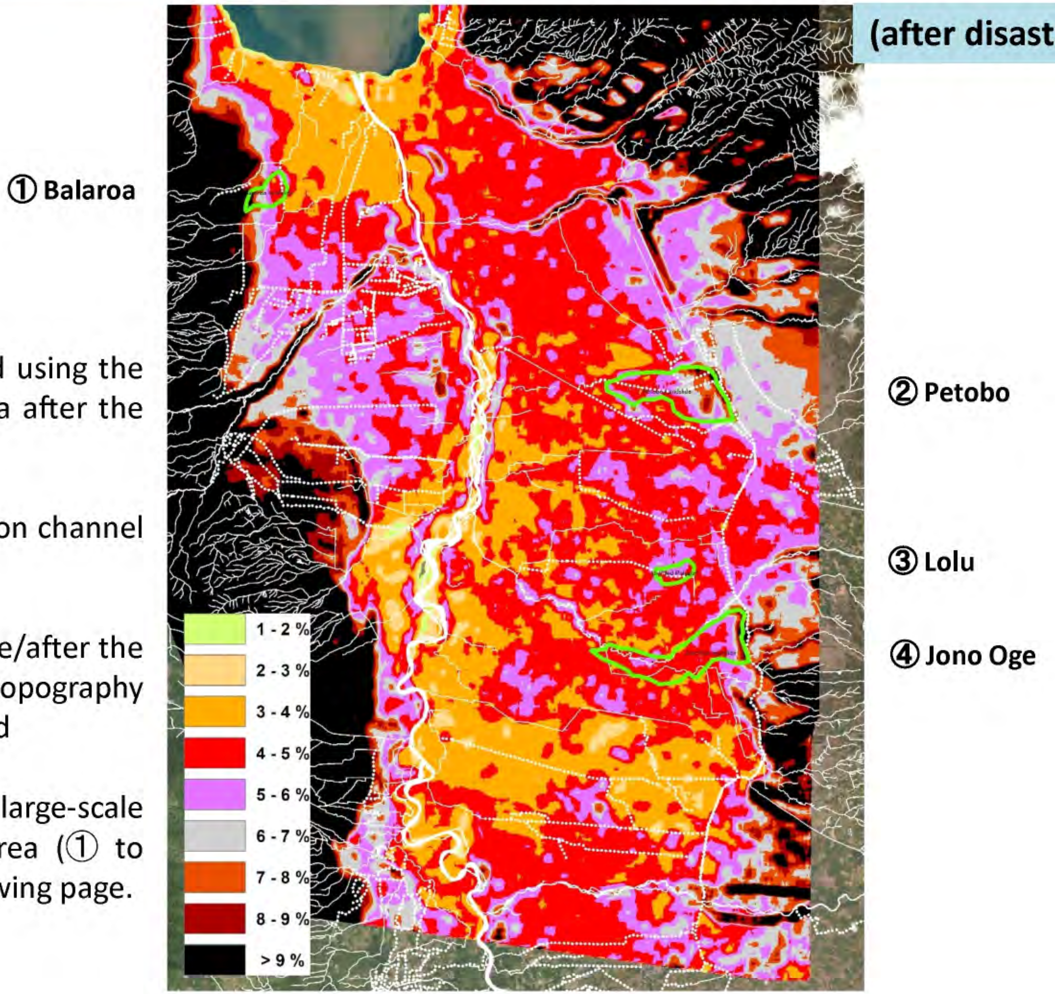
(after disaster)

Slope factor is visualized using the satellite topography data after the disaster.

Data of river and irrigation channel are added.

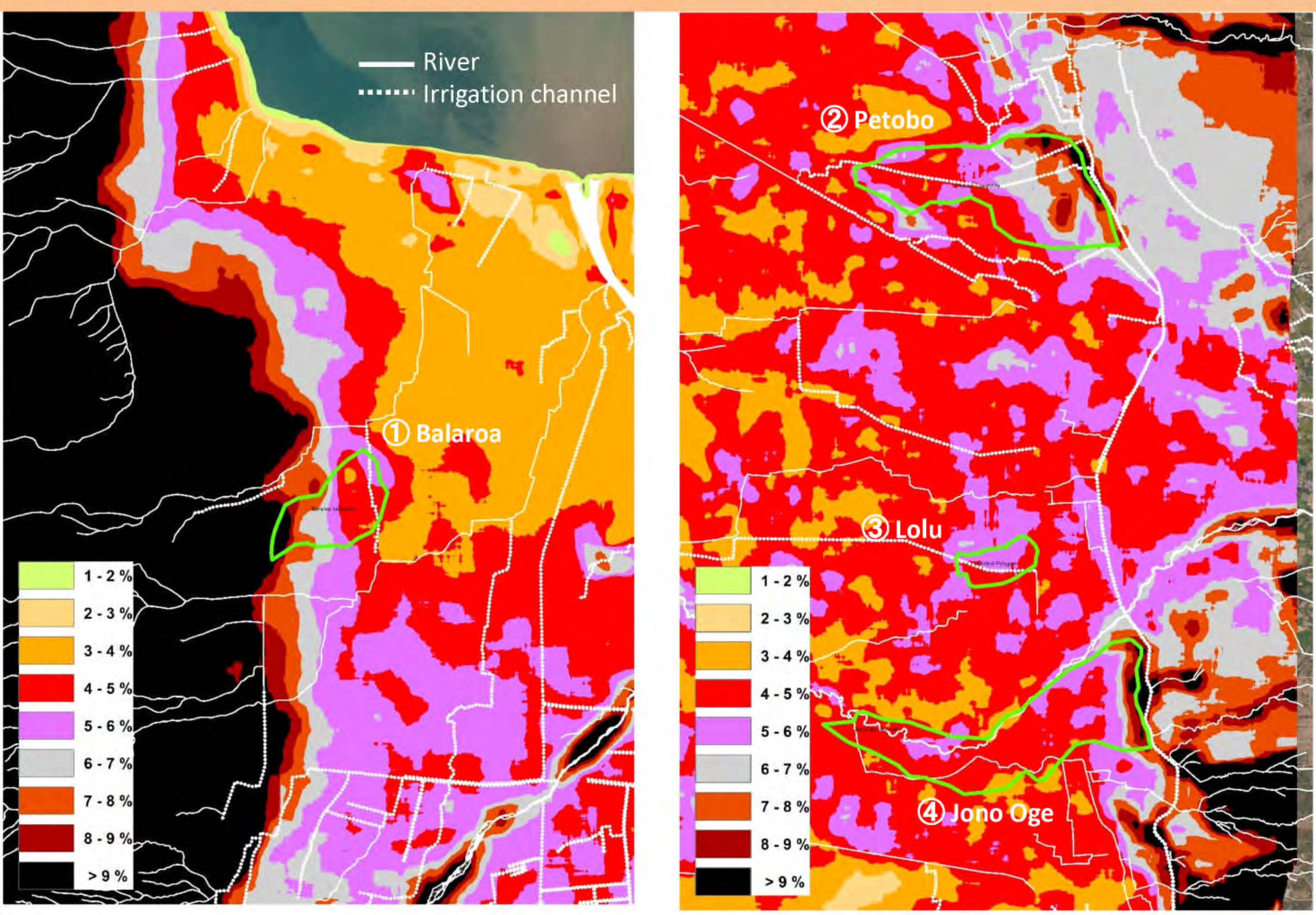
Amount of change before/after the disaster using satellite topography data will be implemented

Condition of large-scale liquefaction landslide area (① to ④) is shown in the following page.



1-(2) Interpretation of topographic map

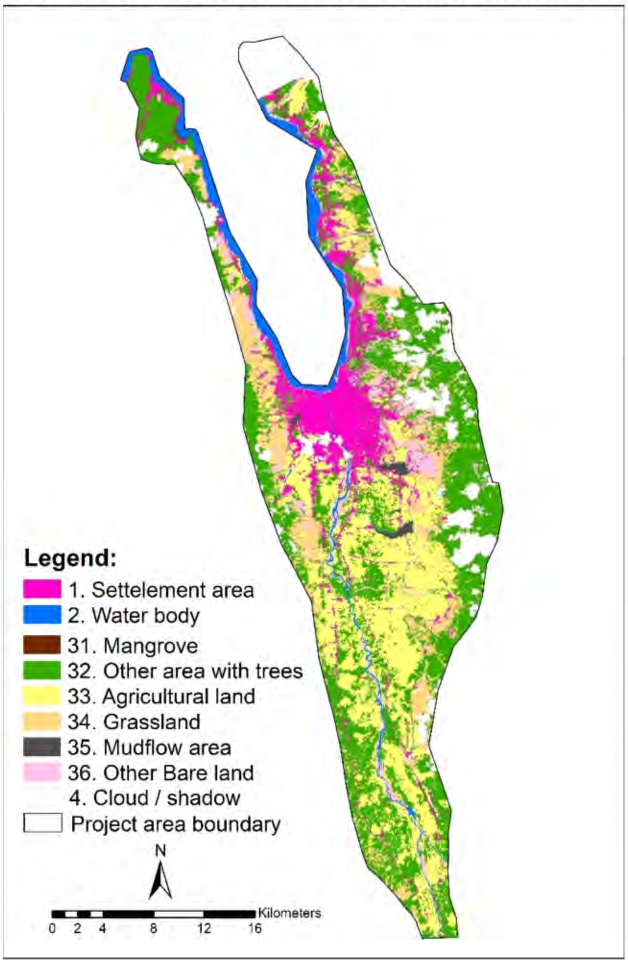
(after disaster)



1-(2) Interpretation of topographic map (surface vegetative cover)

(after disaster)

Land Cover Map of Part of Central Sulawesi



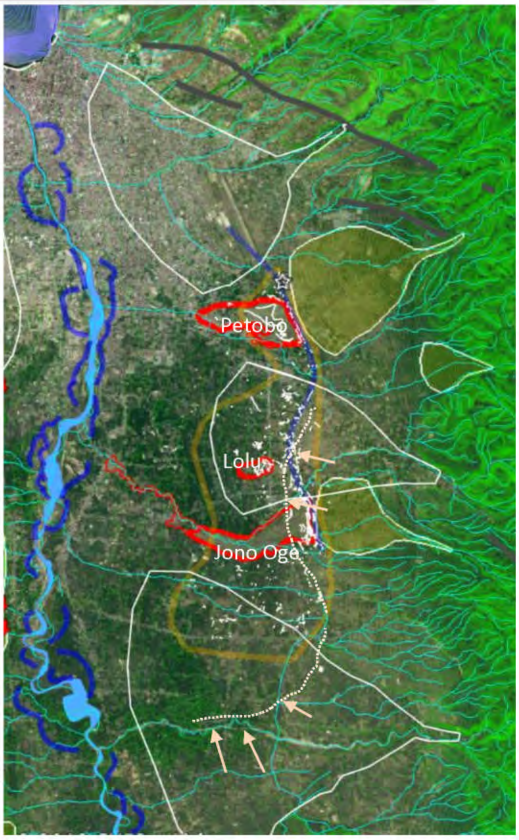
<u>Result of the vegetation survey in the Palu River basin</u>

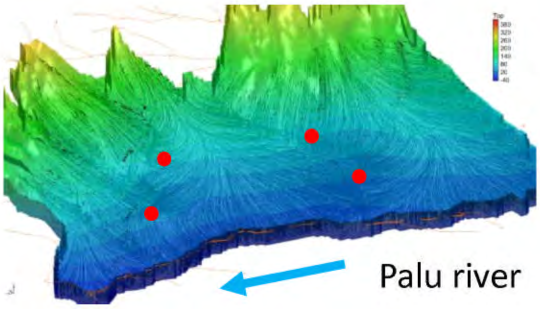
Assuming the surface land cover, such as cap effect: aquiclude distribution, based on the result of the vegetation survey in the Palu River basin (implemented in Dec. 2017)

The land is basically used as an agricultural land except for the urban area of Palu. Condition of surface cover can be one of the factors of cap effect, which takes an important role in liquefaction landslide.

1-(3) Evaluation by groundwater level (Groundwater flow analysis & Monitoring of groundwater)

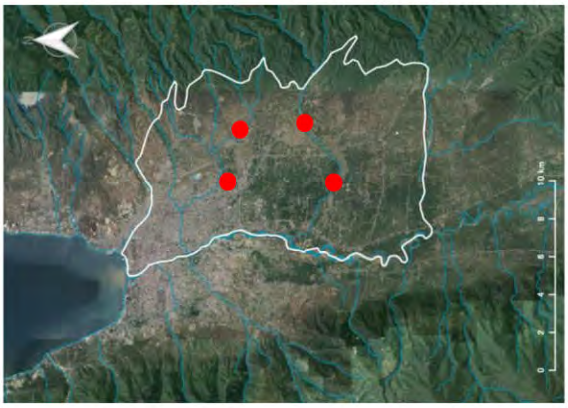
Confirmation of the groundwater level





Groundwater flow analysis

Confirmation of the groundwater flow



Proposed place of groundwater level monitoring

Water leakage from the irrigation channel will be included in the analysis condition

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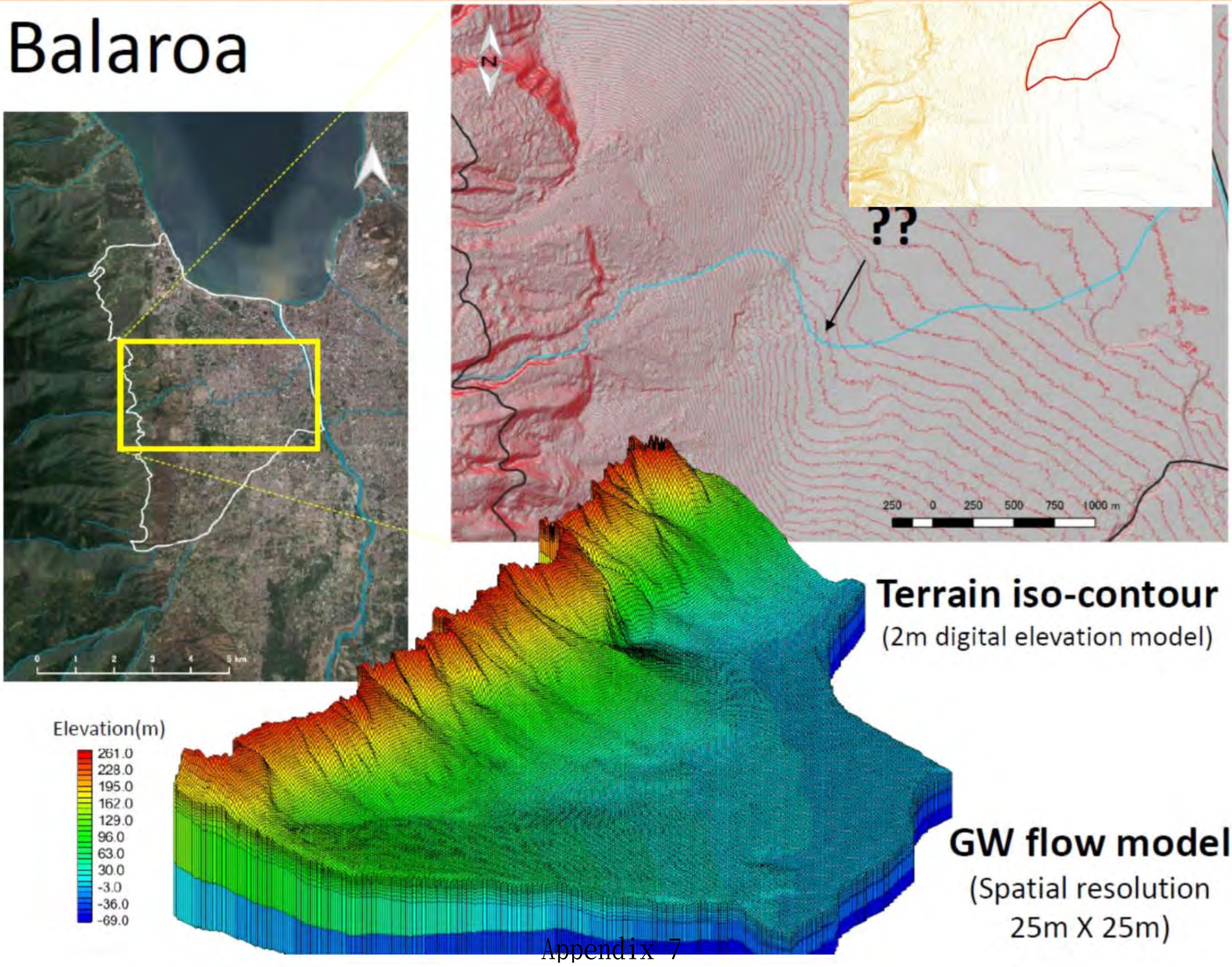
1-(3) Evaluation by groundwater level (Groundwater flow analysis & Monitoring of groundwater)

Balaroa

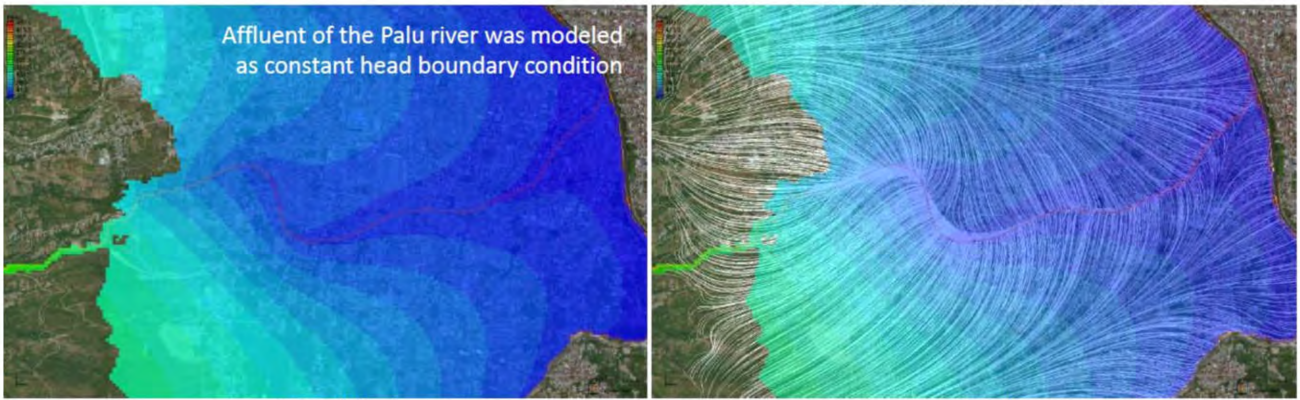


Terrain iso-contour
(2m digital elevation model)

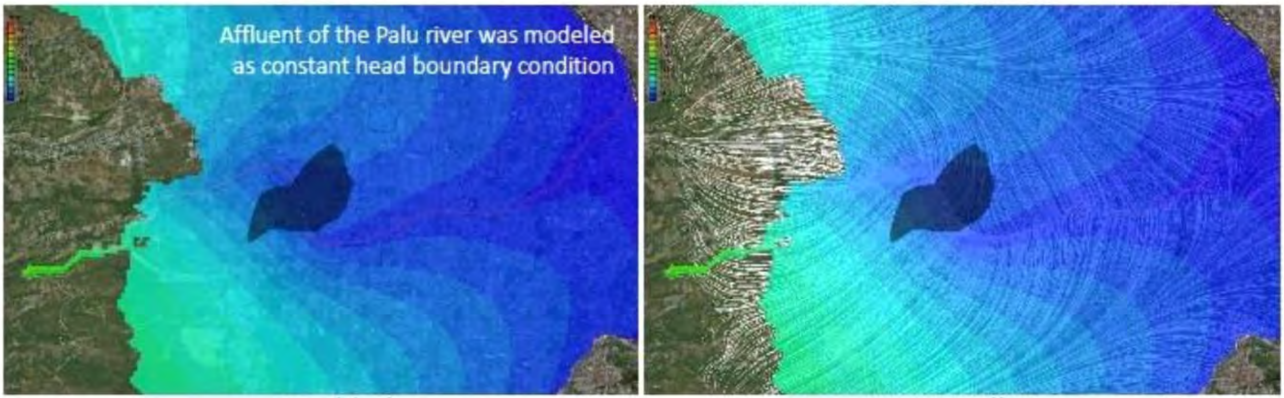
GW flow model
(Spatial resolution 25m X 25m)

1-(3) Evaluation by groundwater level (Groundwater flow analysis & Monitoring of groundwater)

Computed head and streamlines



Head (m) Streamlines



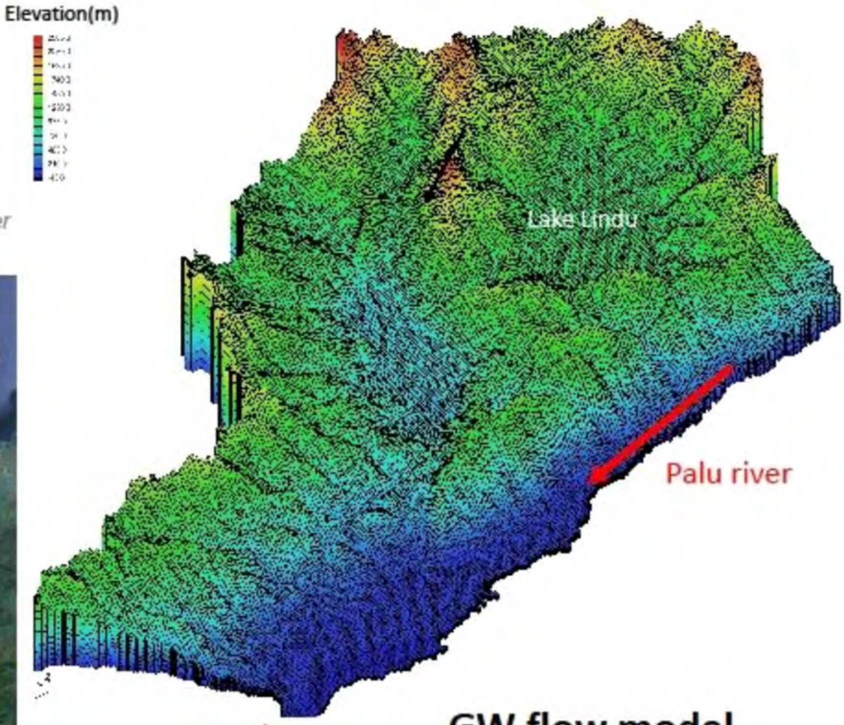
Head (m) Streamlines

1-(3) Evaluation by groundwater level (Groundwater flow analysis & Monitoring of groundwater)

Gumbasa

Stream network
Sungai Sulawesi (ArcGIS online)

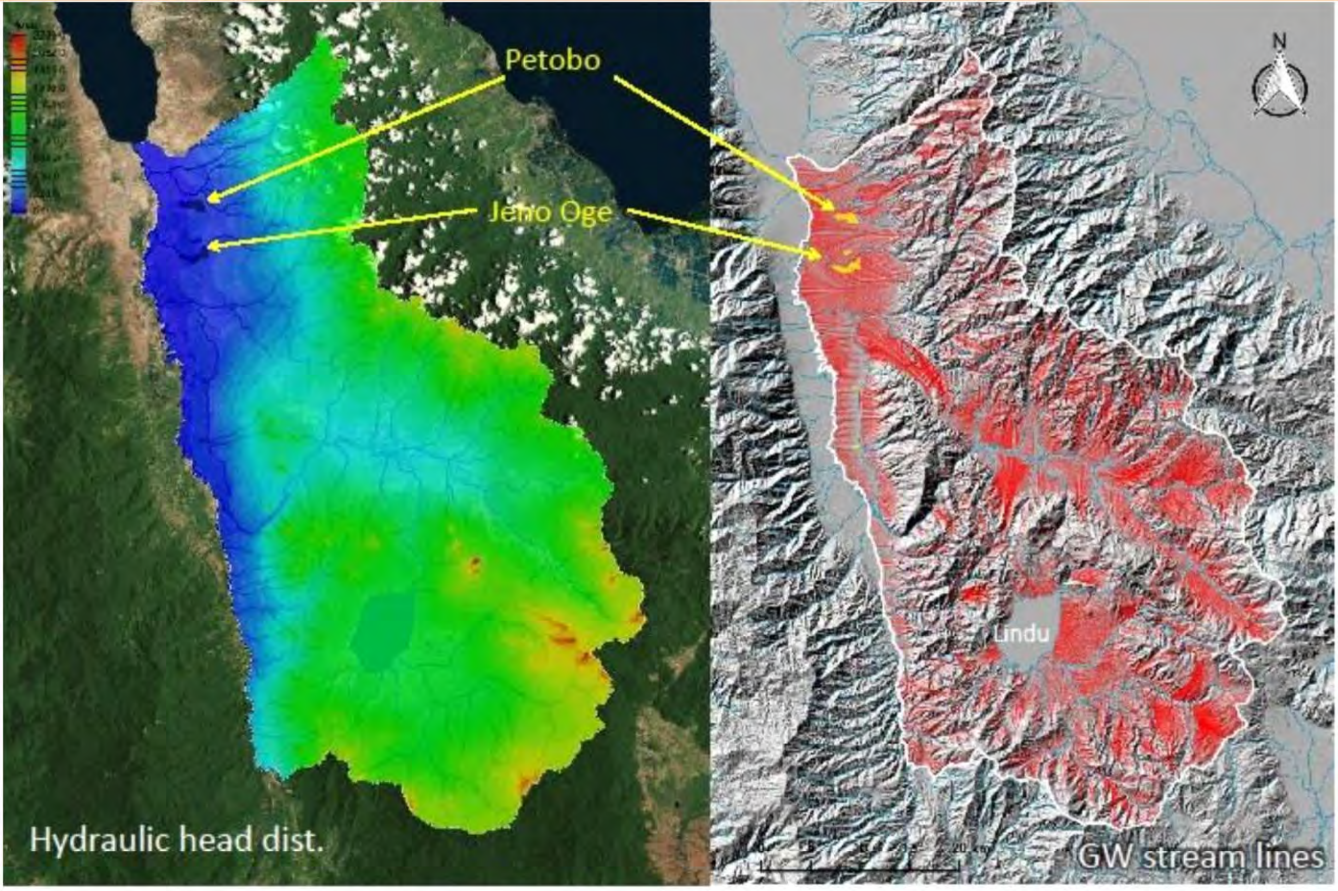
: this map use data by geographic information agency, scale 1:250.000 this river use data RBI(scale 1:250.000)



GW flow model
(Spatial resolution 250m X 250m)

Homogeneous distribution of hydraulic conductivity was assumed because of the roughly visual estimation of the possible GW flow pattern.

1-(3) Evaluation by groundwater level (Groundwater flow analysis & Monitoring of groundwater)



Preliminary visualized GW flow pattern depicted by using 3D numerical model

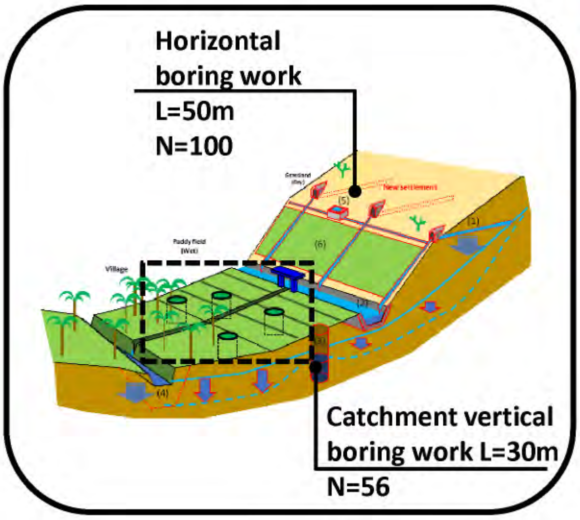
Gumbasa (Model A2)

2. Design policy of measures against liquefaction landslide (tentative)

Risk reduction measures

(1) Drainage inside target area
(2) Deep wells
(3) Irrigation channel with concrete lining
(4) River improvement of the Palu River

Groundwater reduction can be a feasible measure against liquefaction landslide



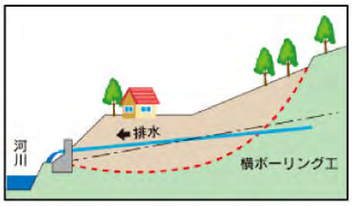
Horizontal boring work L=50m N=100

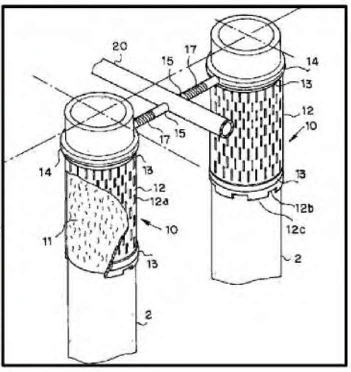
Catchment vertical boring work L=30m N=56

2-(1) Measures against liquefaction landslide (tentative)

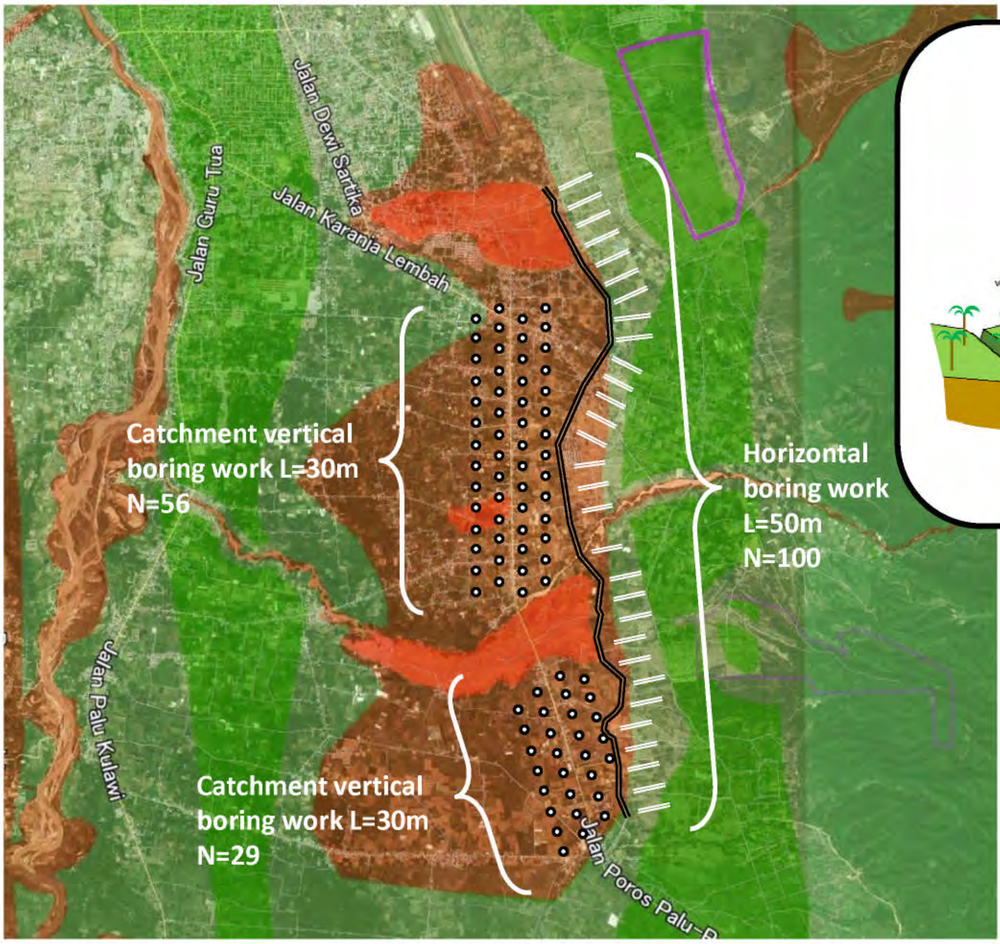
Risk reduction measures

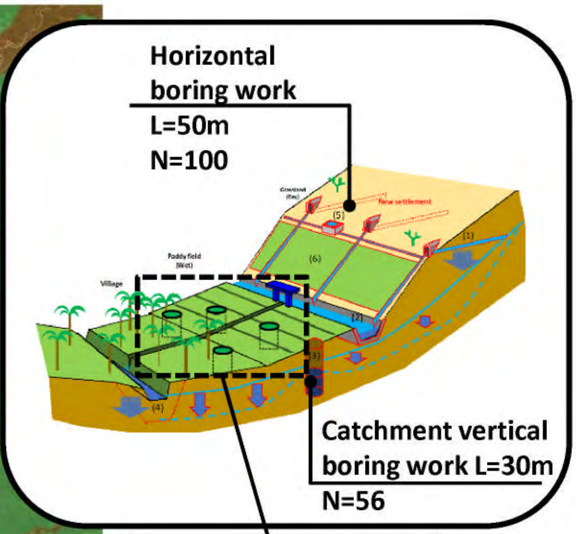
(1) Drainage inside target area
(2) Deep wells

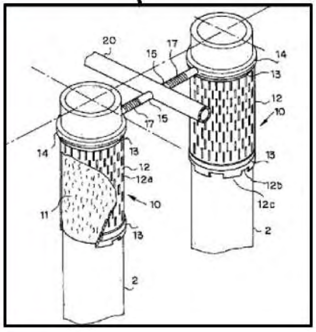




2-(1) Measures against liquefaction landslide (tentative)



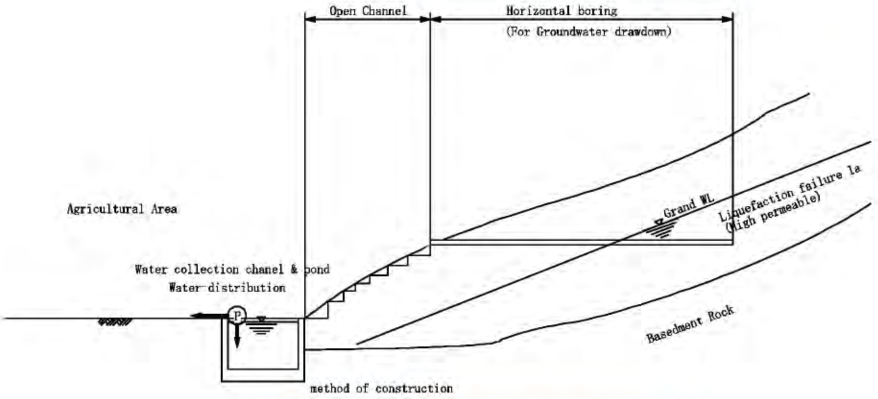




2-(1) Measures against liquefaction landslide (tentative)

Risk reduction measures

(1) Drainage inside target area
(2) Deep wells



Input for Spatial Planning (Reduce Risk Level)

Groundwater reduction measure near the mountain

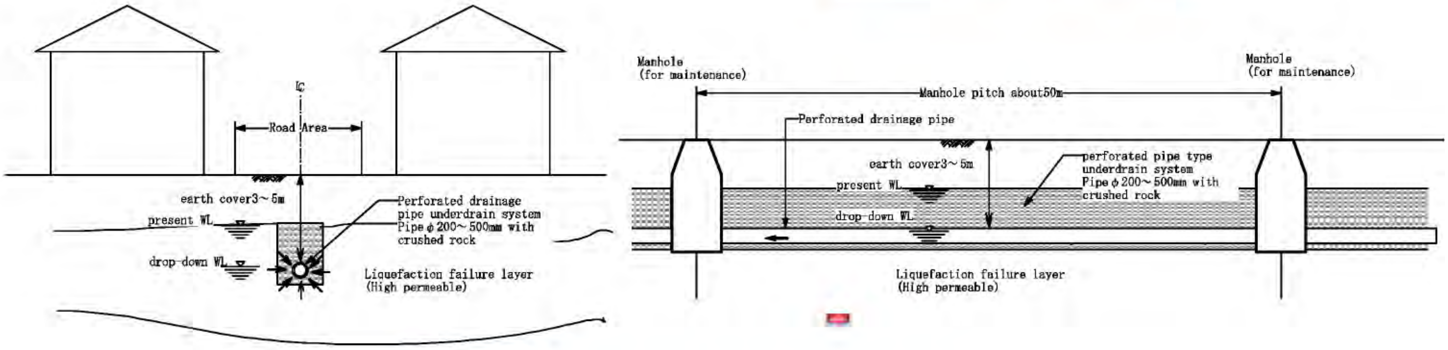
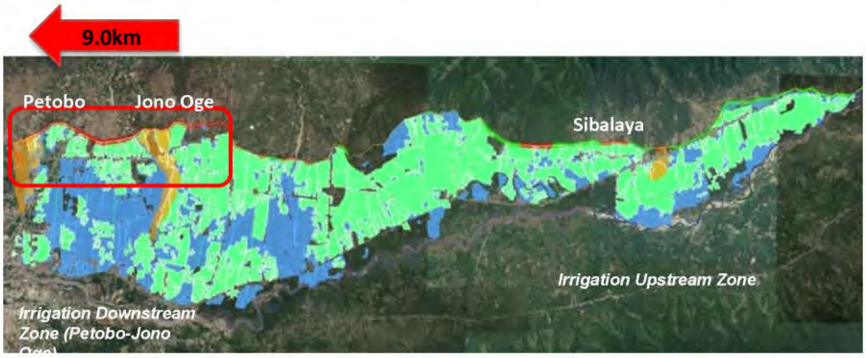


Diagram of infiltration pipe at the urban area

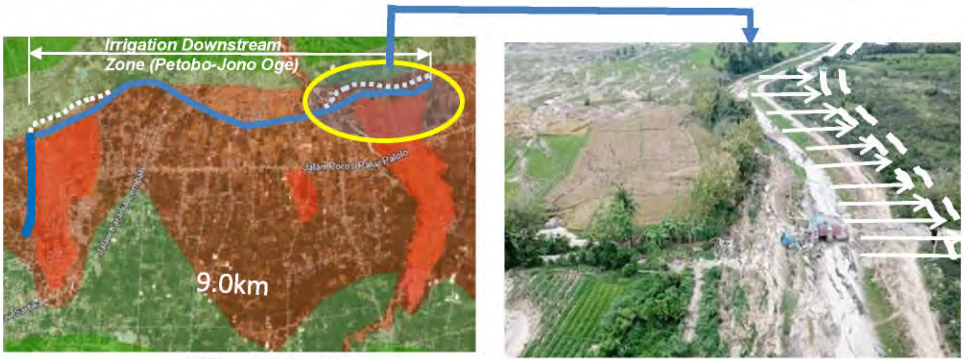
2-(1) Measures against liquefaction landslide (tentative)

Risk reduction measures

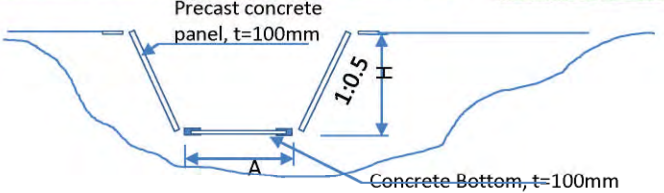
(3) Irrigation channel with concrete lining



- **Review of irrigation plan** ***by JICA TA***
- **Detailed Design at Liquefaction-Landslide area** ***by JICA Loan***
- **Main canal reconstruction** ***by JICA Loan***



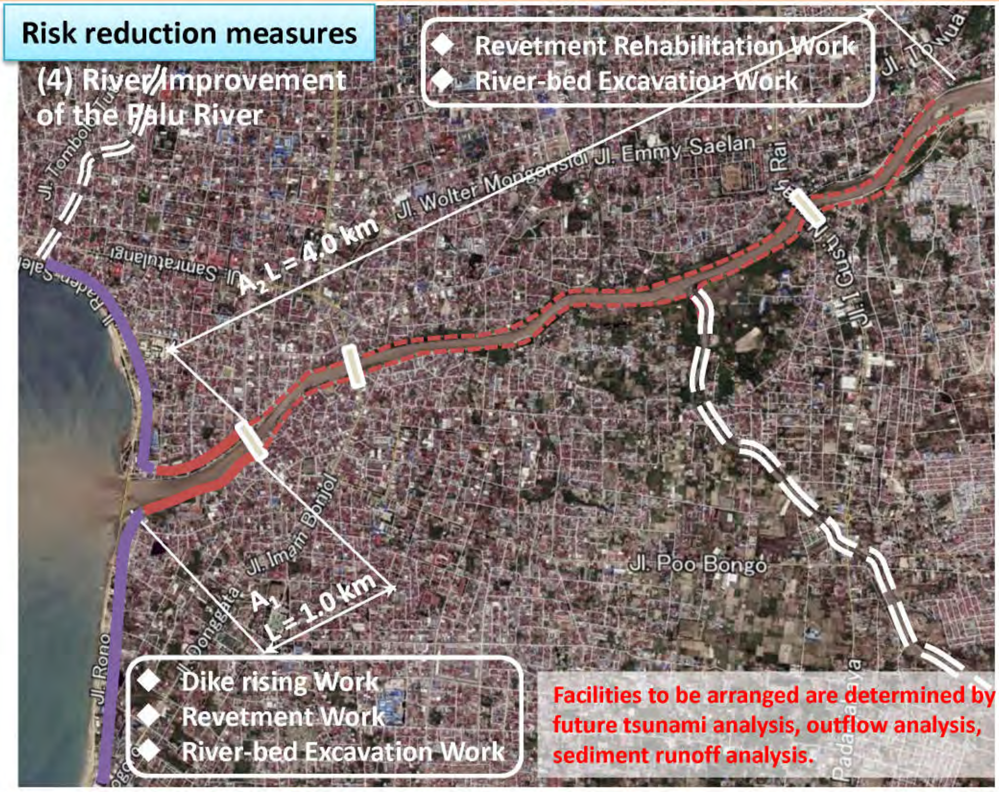
- The current canal slope and bottom will be filled and compacted according to the dimensions of the plan and fill in the defects / cracks caused by the earthquake.
- Reinstalling the precast panel on the left and right wall of the channel
- Casting the concrete floor or landfill is compacted on the bottom of the channel
- Joint line between the precast concert panels will be filled up joint to use water leakage prevention material



2-(1) Measures against liquefaction landslide (tentative)

Risk reduction measures

(4) River improvement of the Palu River

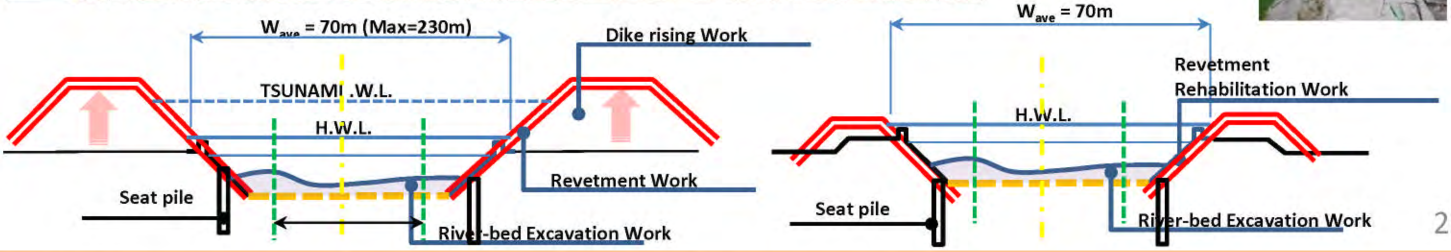


- Revetment Rehabilitation Work
- River-bed Excavation Work

- Dike rising Work
- Revetment Work
- River-bed Excavation Work

Facilities to be arranged are determined by future tsunami analysis, outflow analysis, sediment runoff analysis.

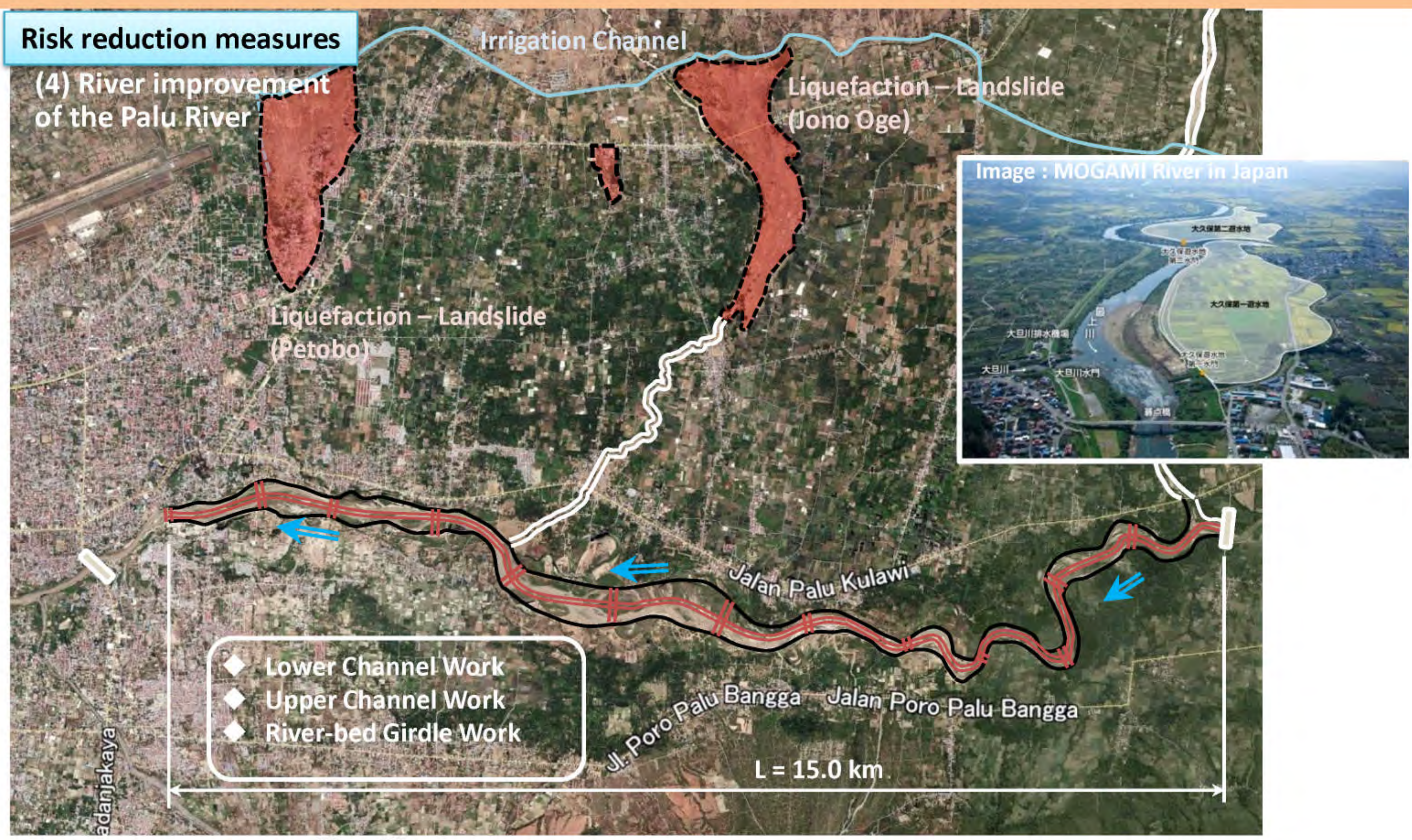
Zone A : The existing revetment is installed



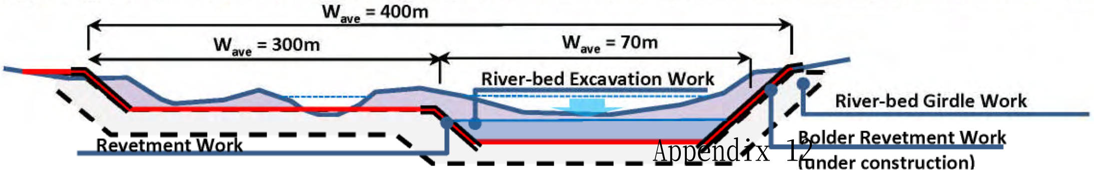
2-(1) Measures against liquefaction landslide (tentative)

Risk reduction measures

(4) River improvement of the Palu River



- Lower Channel Work
- Upper Channel Work
- River-bed Girdle Work



2-(2) Other measures against liquefaction landslide

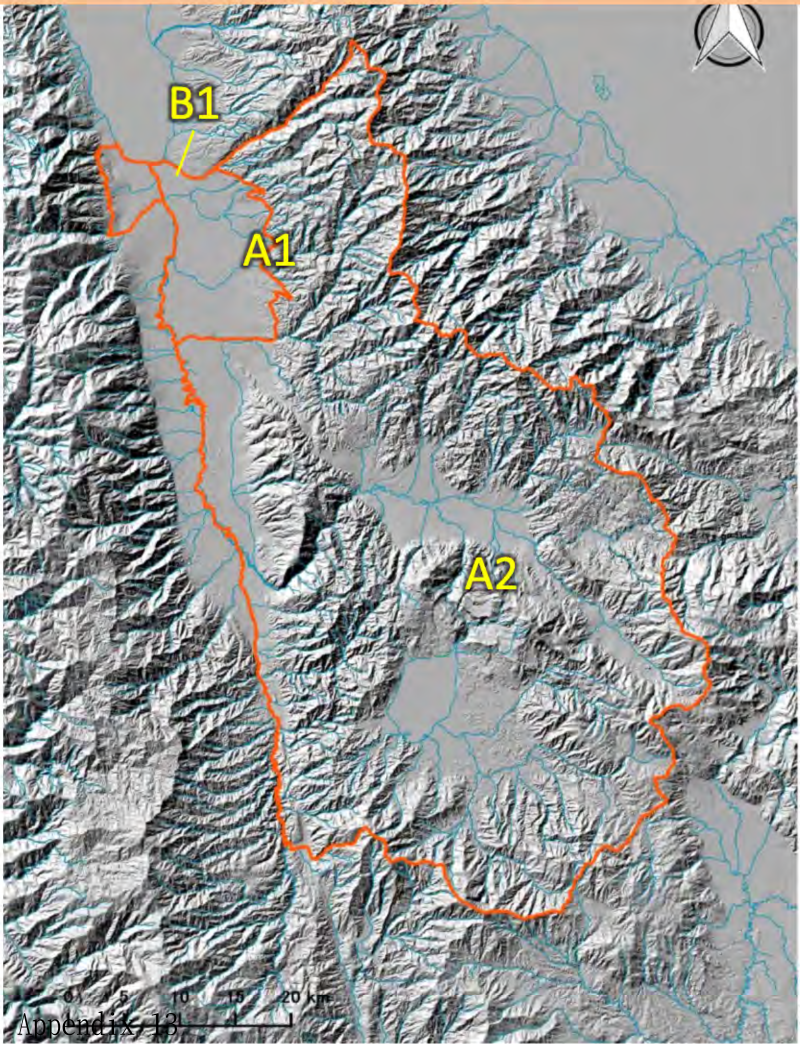
Other measures against liquefaction landslide

Measures	Contents	Detailed contents
Compaction measures	1) Rod compaction	Penetrate an iron rod with vertical vibration into a loose sandy soil (limitation of penetration depth will be approximately 5m)
	2) Vibro-flotation	Water is injected from the edge of the steel pipe (hollow cylinder) in addition to vibration
	3) Sand compaction pile	Openable and closable device is attached on edge of the steel pipe (30-40cm in diameter)
Drain acceleration measure		Excess pore water pressure is dissipated since excess pore water pressure in the sand layer increases during earthquake (gravel drain)
Groundwater reduction measure		Put a splitter wall (5 to 10m intervals) underground. Pump up groundwater inside the splitter wall
Grid-improvement measure		Put the grid-splitter wall underground. Enhance the stiffness of entire soil. Control the soil deformation during earthquake.

*Not only groundwater reduction measure, but also other measures will be examined and utilized, and select the best measure for the target area

3. Groundwater flow analysis(Getflows) & Monitoring of groundwater

Boundaries of groundwater flow simulation models



Model	Region	Area
A1	Petobo, Jeno Oge	140km^2
A2	Gumbasa	2180km^2
B1	Balaroa	28km^2

3. Groundwater flow analysis(Getflows) & Monitoring of groundwater

Parameter setting

Geology	Hydraulic conductivity (m/s)	Porosity (-)
Surface soil	1.15×10^{-5}	*Not used (in steady state run)*
Sand gravel	1.15×10^{-5}	*Not used (in steady state run)*
Basement	impermeable	*Not used (in steady state run)*

Meteorology	Value	Note
Precipitation(mm/d)		Averaged in 1976-2017
Air temperature (degC)		
Evapotranspiration (mm)		Harmon's equation

Boundary conditions	Assign to
Recharge	Ground surface without streams
Constant head	Streams
No flow	All lateral faces

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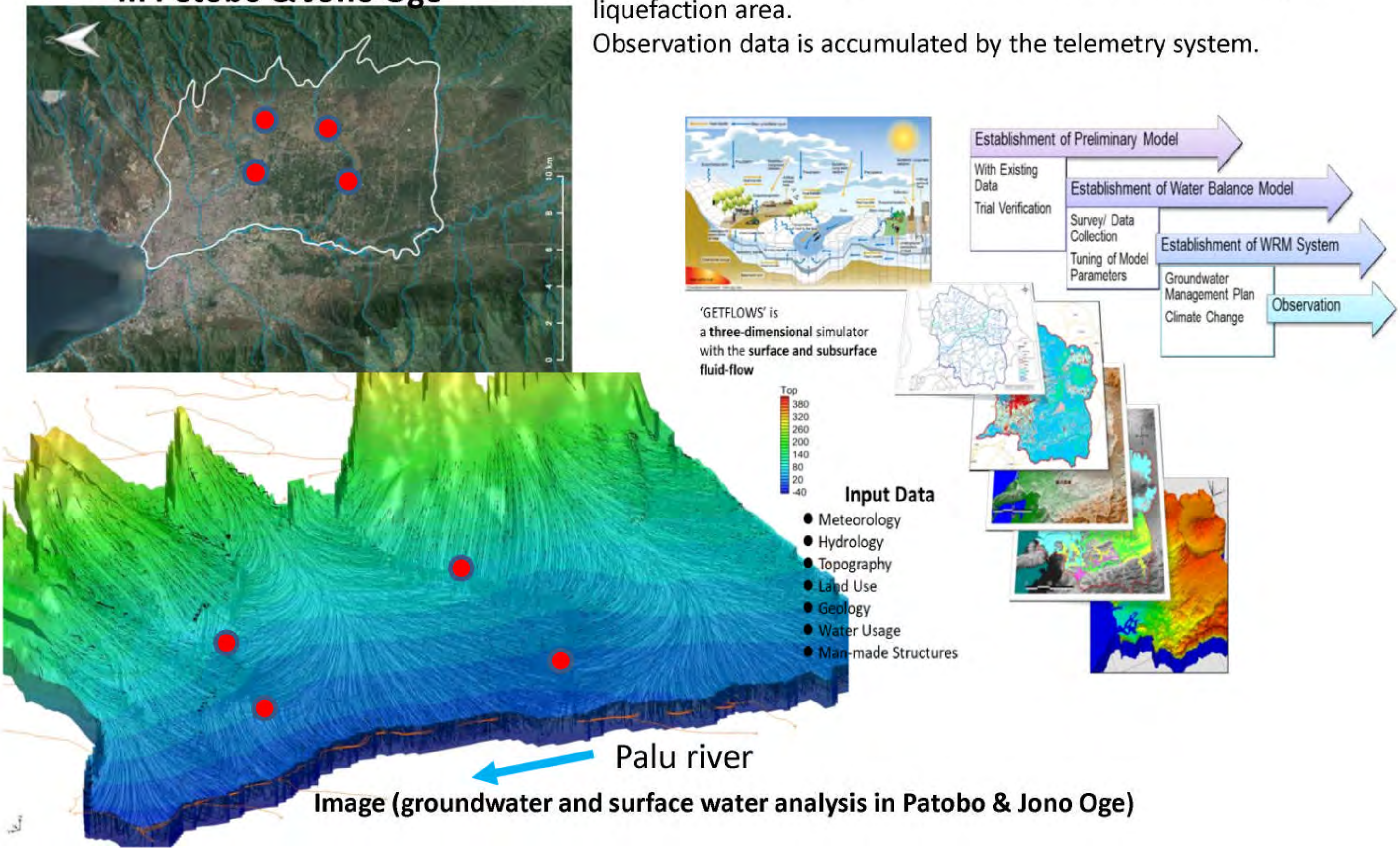
3. Groundwater flow analysis(Getflows) & Monitoring of groundwater

Monitoring points Image
In Petobo & Jono Oge

Observation of groundwater and surface water

Continuously observe groundwater and surface water mainly in liquefaction area.

Observation data is accumulated by the telemetry system.



'GETFLOWS' is a **three-dimensional** simulator with the **surface and subsurface fluid-flow**

Input Data

- Meteorology
- Hydrology
- Topography
- Land Use
- Geology
- Water Usage
- Man-made Structures

Image (groundwater and surface water analysis in Patobo & Jono Oge)

4. Land-use after completion of measures against liquefaction landslide

Future land-use of ZRB 4

■Present land-use of ZRB 4
- ✓ Off-limits zone / Residence-prohibited area (Open green space, memorial area)

■Future land-use of ZRB 4 after completion of measures
- ✓ Open green space
- ✓ Memorial park
- ✓ Agricultural land (except for paddy field)
- ✓ Agricultural land
- ✓ Residential area

Place	Area (ha)
① Balaroa	32.5
② Petobo	153.7
③ Lolu	22.0
④ Jono Oge	168.8

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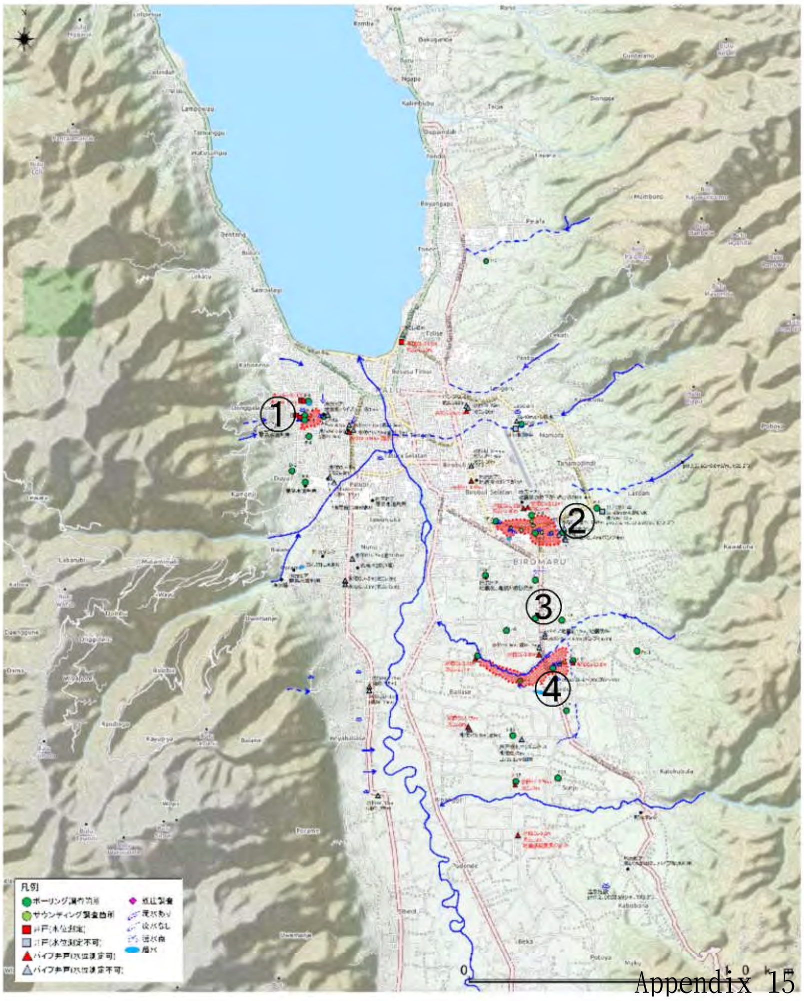
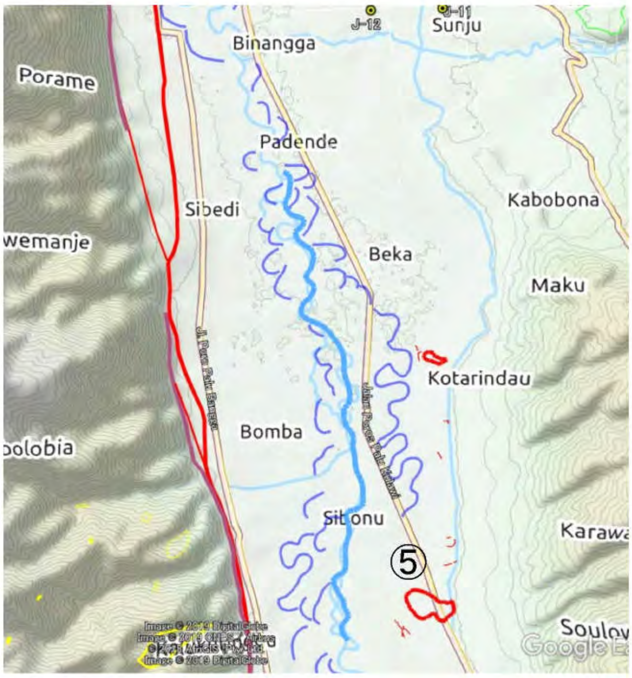
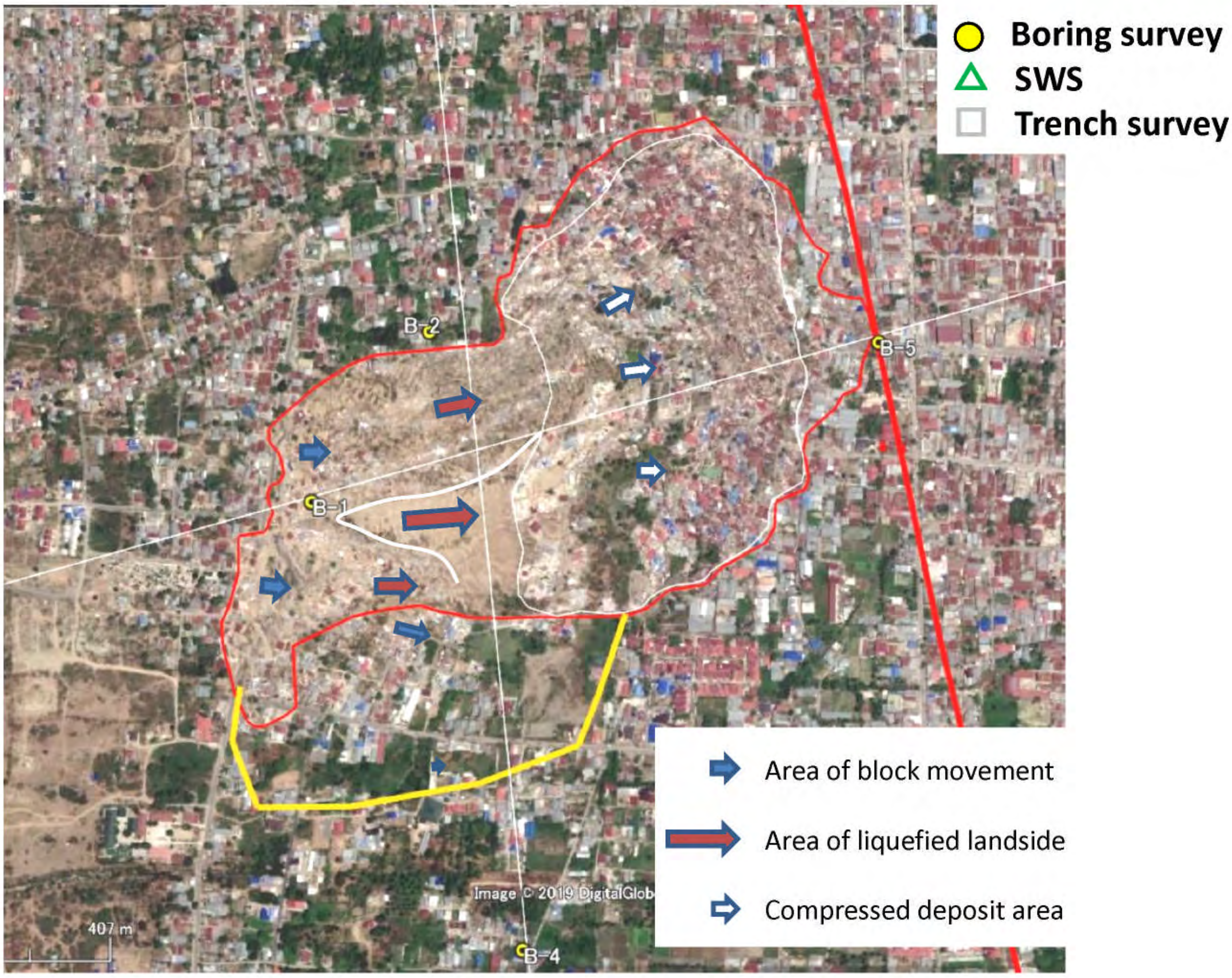
5. Progress of survey and analysis



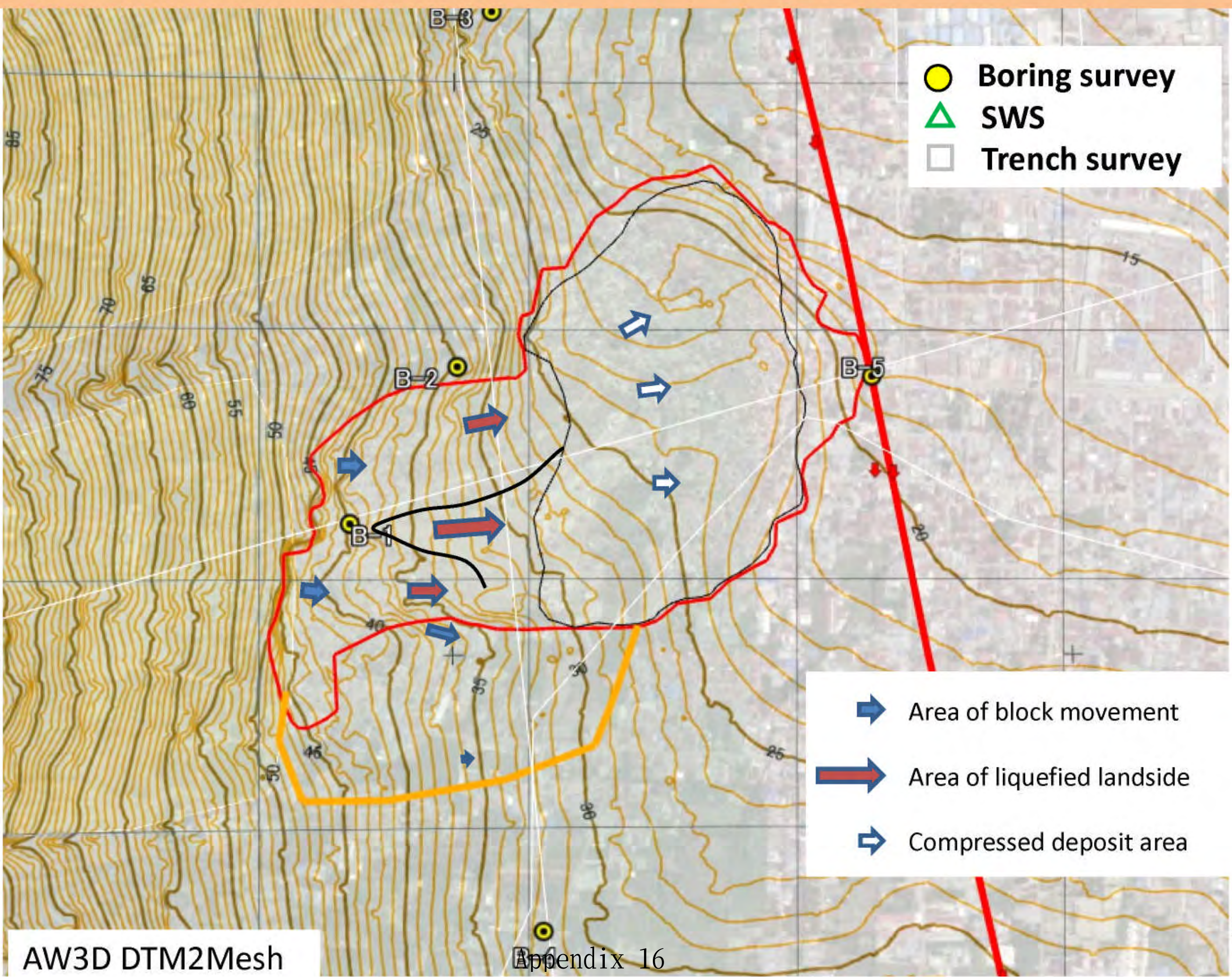
- ① Balaroa
- ② Petobo
- ③ Lolu
- ④ Jono Oge
- ⑤ Sibalaya



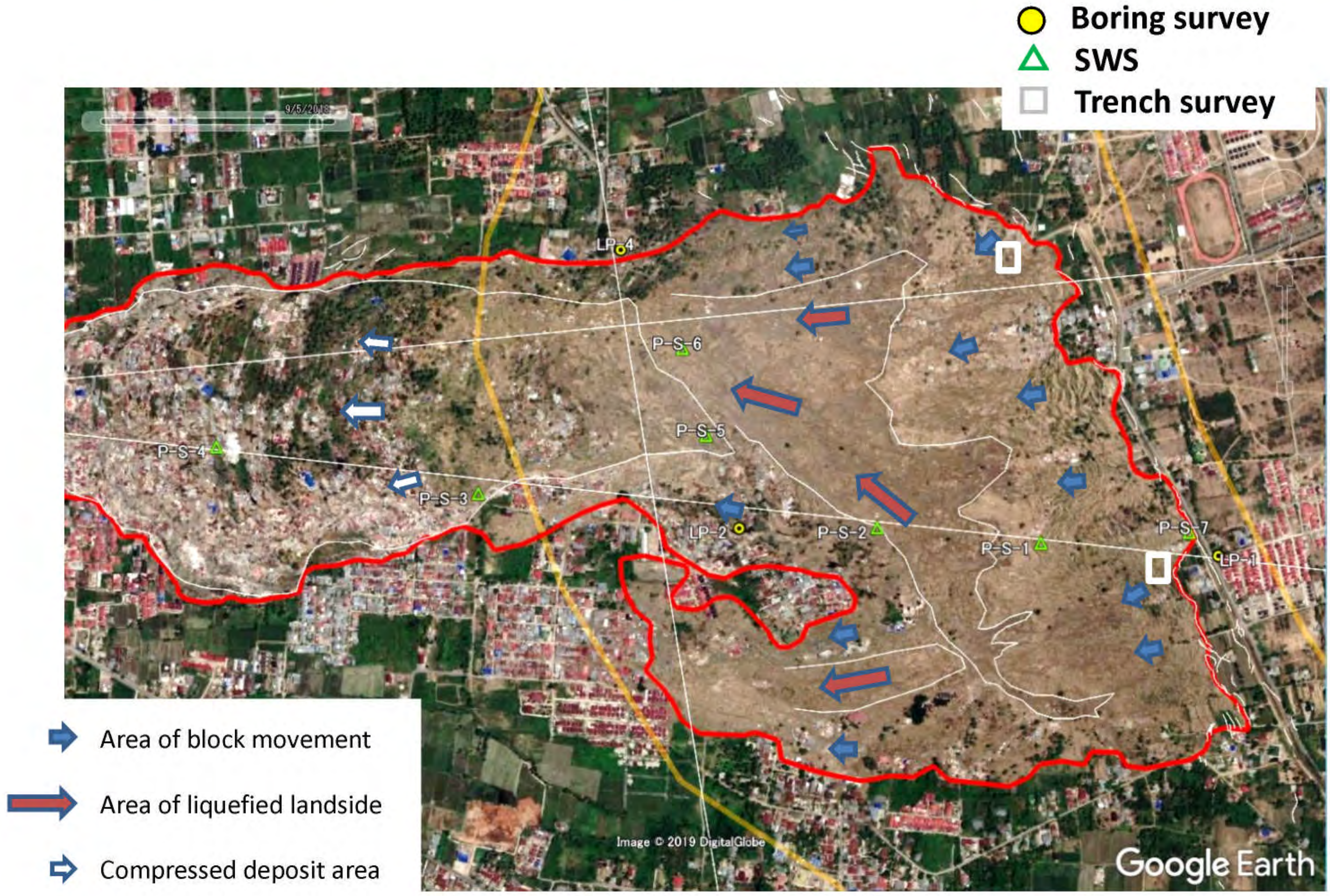
5-(1) Examination of liquefied landside (Nalodo) blocking (Balaroa)



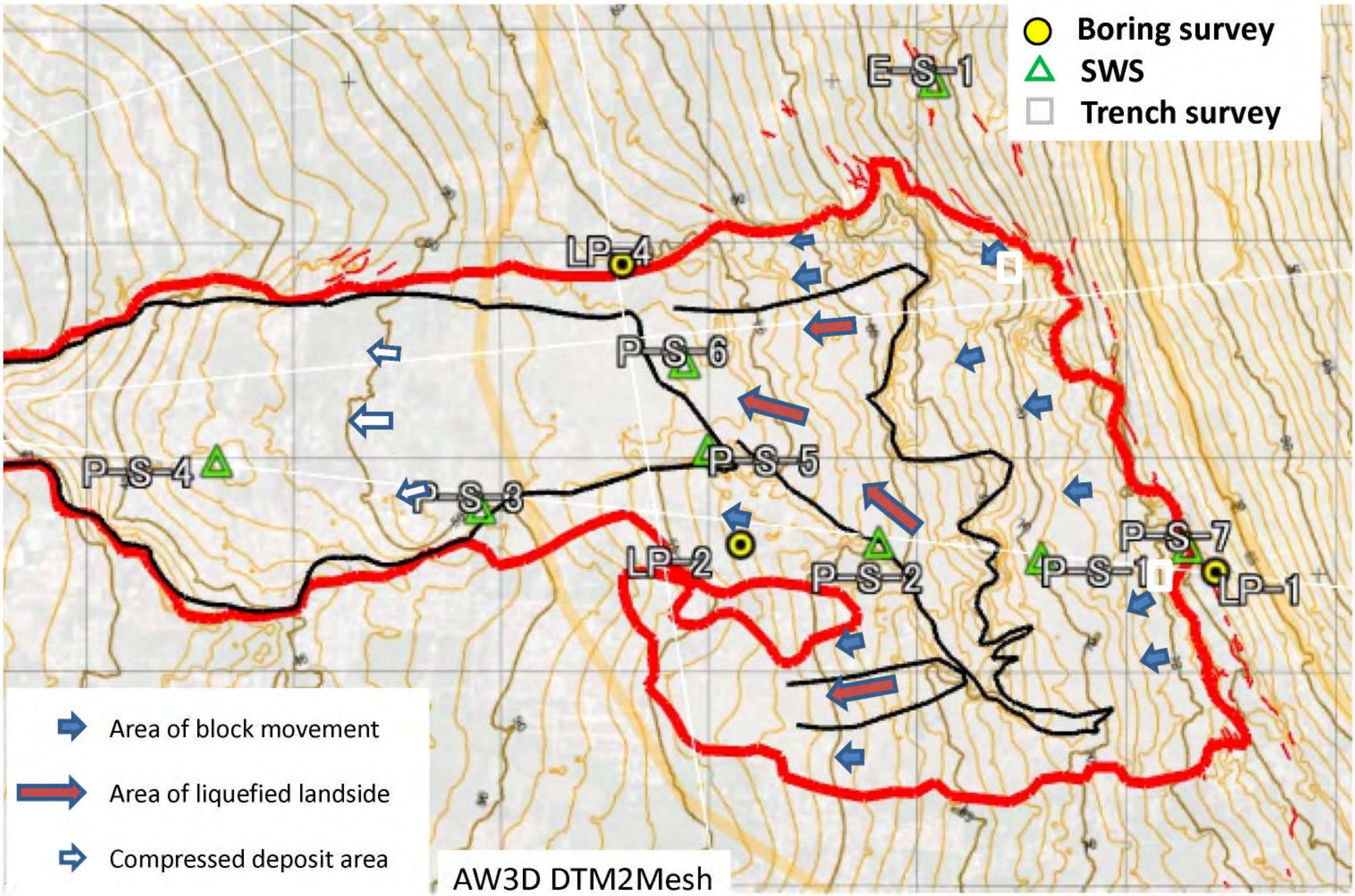
5-(1) Examination of liquefied landside (Nalodo) blocking (Balaroa)



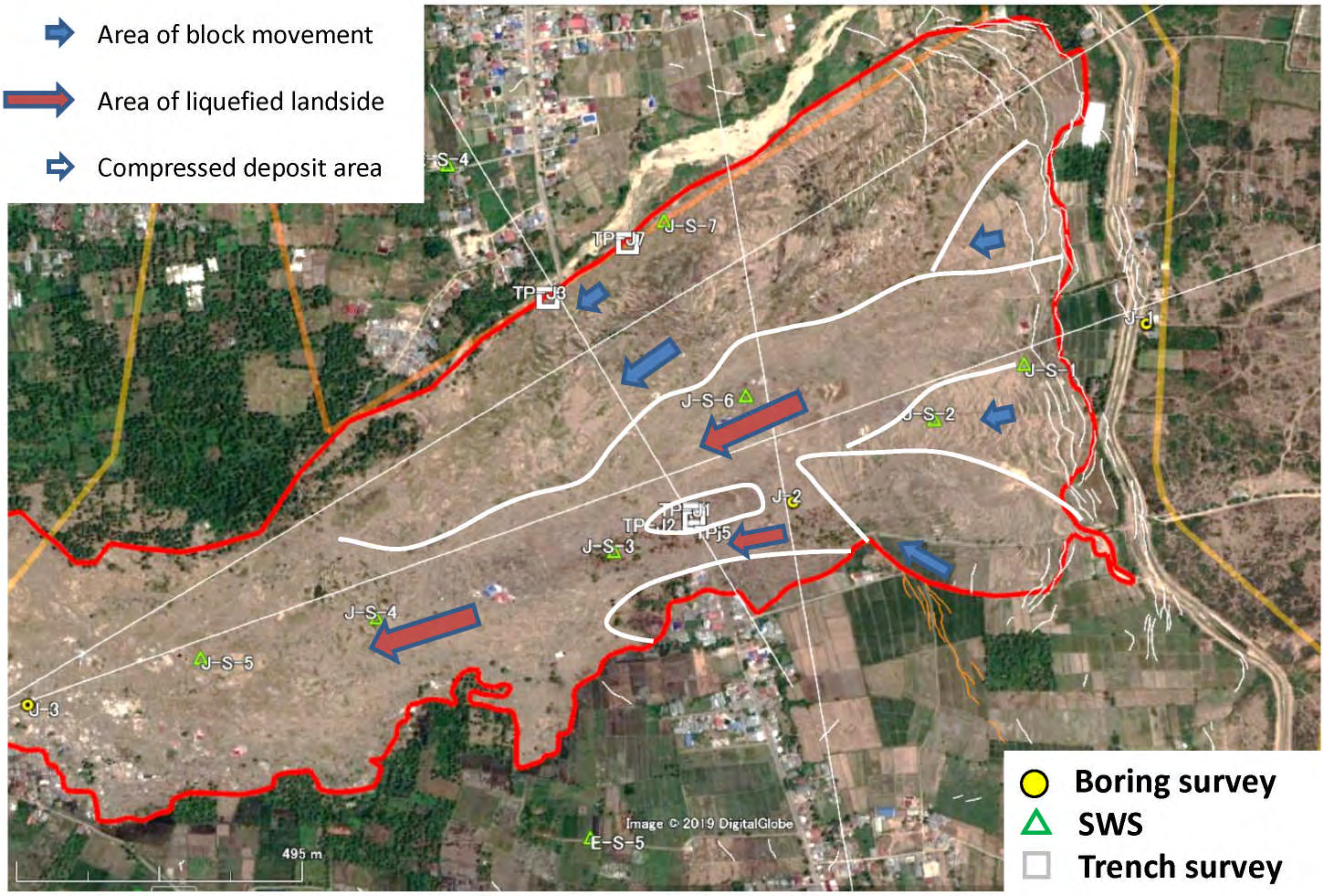
5-(1) Examination of liquefied landside (Nalodo) blocking (Petobo)



5-(1) Examination of liquefied landside (Nalodo) blocking (Petobo)



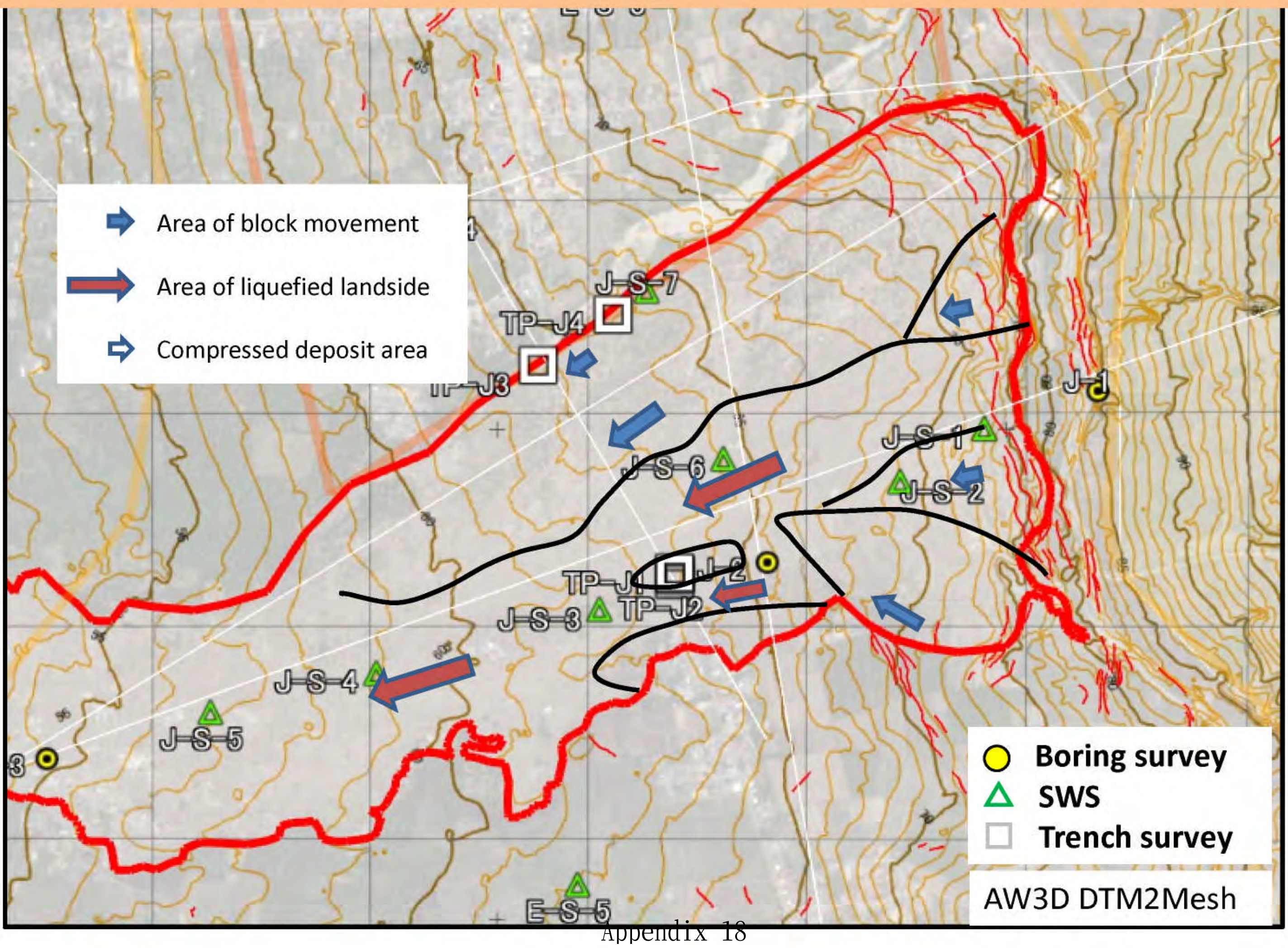
5-(1) Examination of liquefied landside (Nalodo) blocking (Jono Oge)



- ➡ Area of block movement
- ➡ Area of liquefied landside
- ⇨ Compressed deposit area

- ○ **Boring survey**
- △ **SWS**
- ☐ **Trench survey**

5-(1) Examination of liquefied landside (Nalodo) blocking (Jono Oge)



- ➡ Area of block movement
- ➡ Area of liquefied landside
- ⇨ Compressed deposit area

- ○ **Boring survey**
- △ **SWS**
- ☐ **Trench survey**

AW3D DTM2Mesh

5-(1) Examination of liquefied landside (Nalodo) blocking (Jono Oge)

Summary

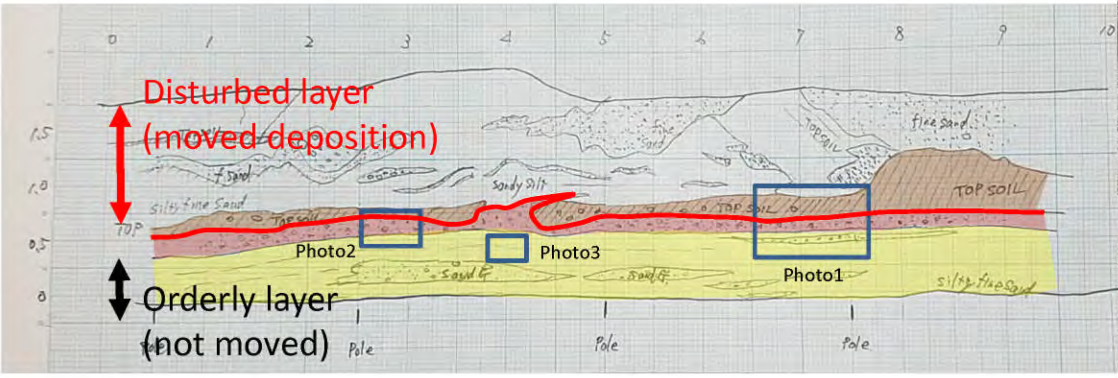
- Nalodo can be classified roughly, “Area of block movement”, “Area of liquefied landside”, and “Compressed deposit area”.
- “Area of block movement” is located near the top of the Nalodo, “Area of liquefied landside (core of Nalodo)” is located at the central upper part and “Compressed deposit area” is located at the end.
- One stream of “Area of liquefied landside” and “Area of block movement” is identified in Balaroa and several streams are identified in Petobo and Jono Oge. Depth of flowage and amount of movement are differ at a place.

5-(2) Result of additional trench survey (Sibalaya TP-S2)

Topsoil demarcats..
Upper layer: Disturbed layer
Lower layer: Orderly layer

Horn-shaped structure in rudaceous sandy layer. It seems that this layer is the boundary with the moved layer

Photo1



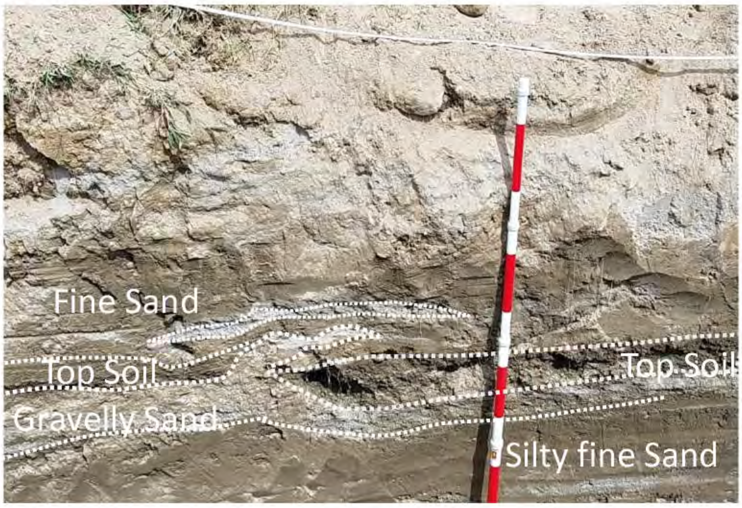
Rough drawing of TP-S2

Photo2

Photo3

5-(2) Result of additional trench survey (Sibalaya TP-S2)

TP-S2 Trench

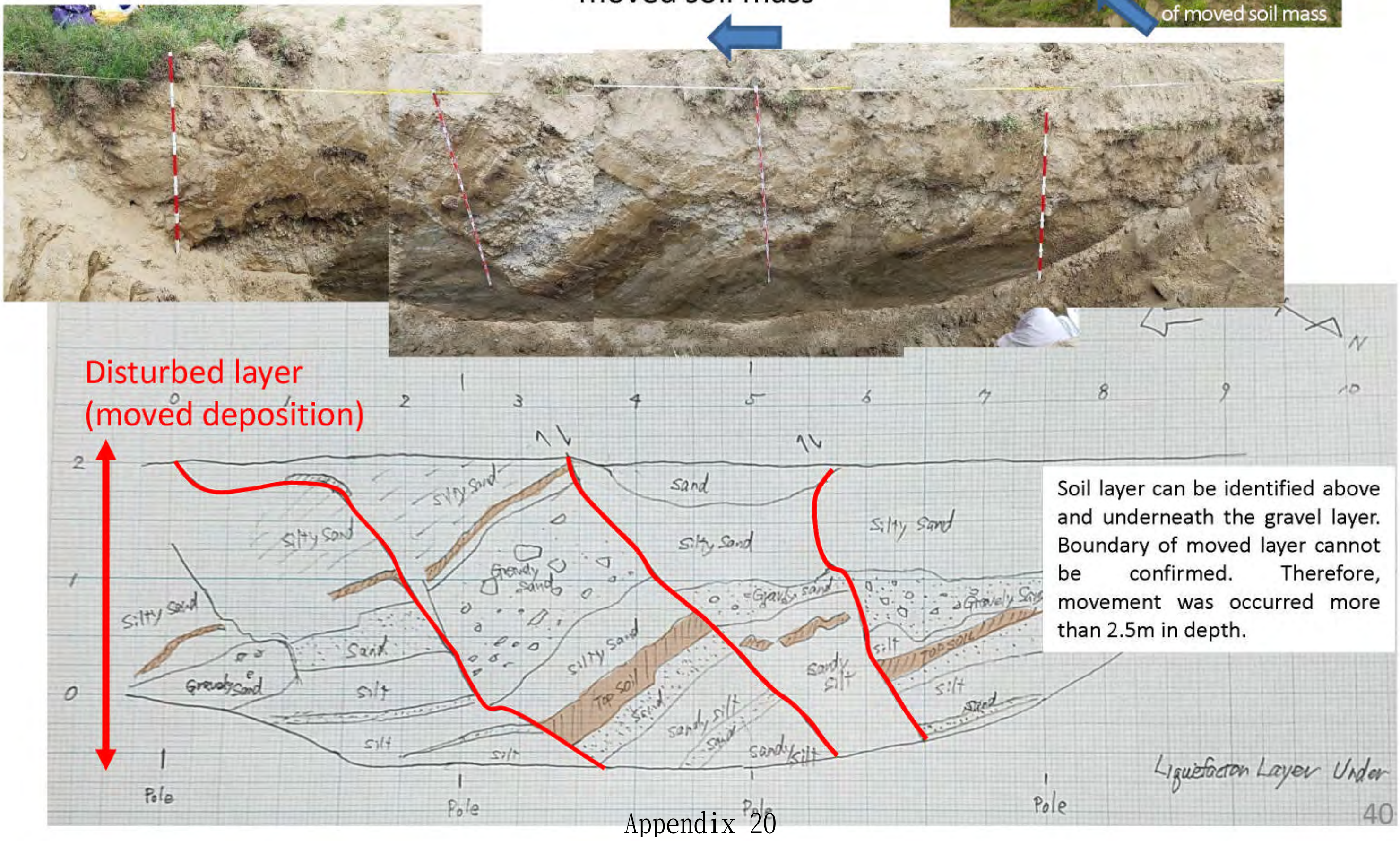


Horn-shaped structure is identified between humus soil layers. It can be an evidence of liquefaction.

Cross-section of the deposited area in Sibalaya. Trench survey will be implemented in the future.
Extruded deposition and old surface soil (humus soil layer) can be identified on the bottom.

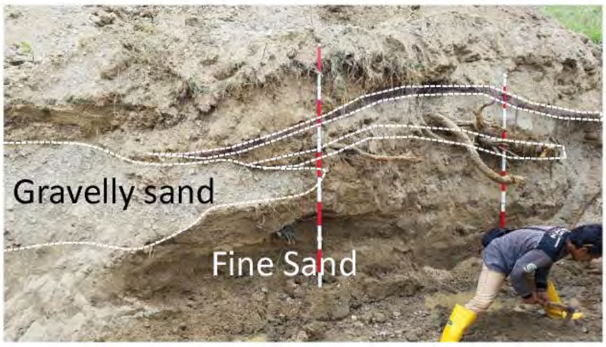
5-(2) Result of additional trench survey (Sibalaya TP-S3)

Movement direction of moved soil mass

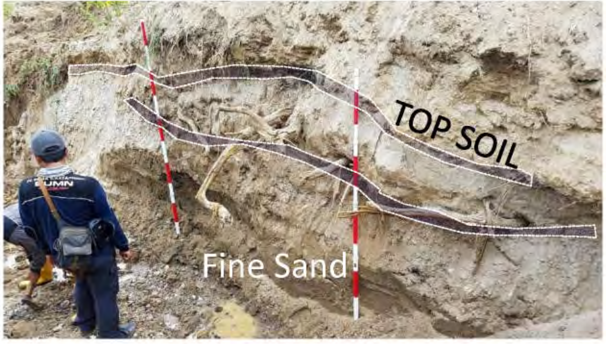


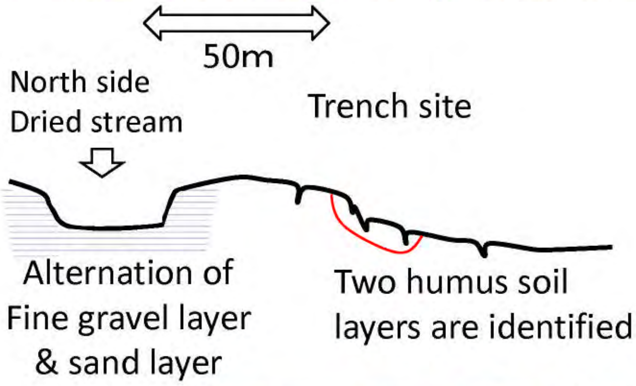
Soil layer can be identified above and underneath the gravel layer. Boundary of moved layer cannot be confirmed. Therefore, movement was occurred more than 2.5m in depth.

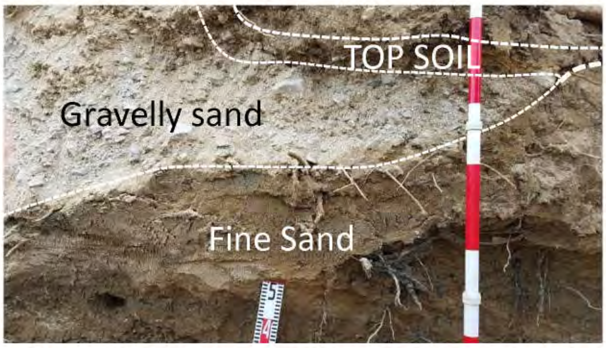
5-(2) Result of additional trench survey (Jono Oge TP-Jo7)



The details can not be observed due to ground collapse







5-(2) Result of additional trench survey

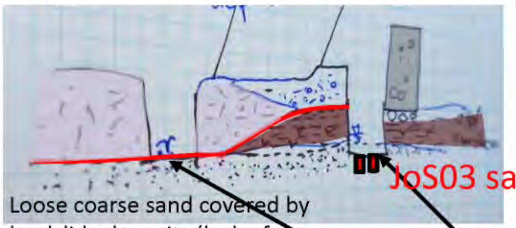
- Additional trench survey (approx. 2m in depth), 2 sites @ Sibalaya, 1 site @ JonoOge
- TP-S2: It is assumed that the lower surface of humus soil layer (aquiclude) is the boundary of moved layer (1m in depth from the ground surface).
- TP-S3: Moved layer (layer of liquefied landside) was not confirmed up to 2.5m in depth. Therefore, it is assumed that the movement was occurred more than 2.5m in depth.
- Thickness of gravelly sandy layer underneath of humus soil layer is 20cm at TP-S2 and 1m at TP-S3, which is located 200m away from TP-S2. Horn-shaped structure is identified between humus soil layers. It can be an evidence of liquefaction.
- Several humus soil layers are formed in-between the sand, which produced by floods and from the upper slope, and sand and gravel according to the survey at the 2 sites in Sibalaya. These humus soil layers and unconsolidated sand produced by floods form the alternation structure. It seems that the layers become saturated condition and liquefied by earthquake vibration, and functioned as an impervious membrane.
- TP-Jo7: Disturbed layer including two humus soil layers is confirmed. Alternation of fine gravel layer & sand layer, whose thickness is 2.5m in depth, is confirmed at the adjacent dried stream in north side. Even though, different depositions are distributed along the stream and in the flood plain. Difference of deposition (existence of humus soil layers) might be one of the occurrence factors of the Nalodo.

Jono Oge Trench

Existing trench

Trench survey results

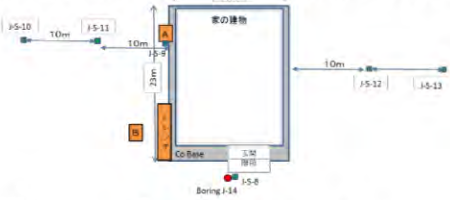
We confirmed that the surface soil layer of 40 cm in thickness remains under the foundation of a red house, but 2 m beside the house it is missing. Fluidization occurred at the bottom of the soil layer, and the soil layer moved in the northern region of this site, and it is thought that it was carried to the west along with the house on it.



JoS03 sample

Loose coarse sand covered by landslide deposits (lack of top soil layer)

The surface soil layer covers the loose coarse-grained sand, the concrete foundation is placed on it, and the sediment flow deposit covers it



Top soil

Sand Flow deposit

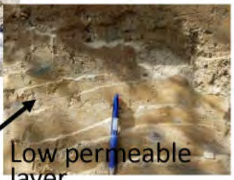
Jono Oge trench survey

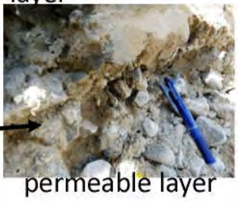
Existing trench

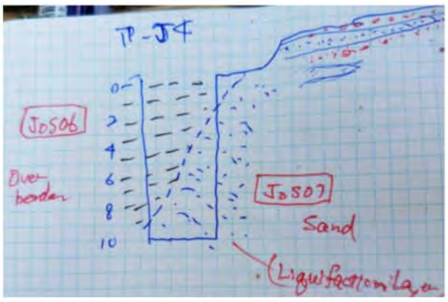
TP-J4

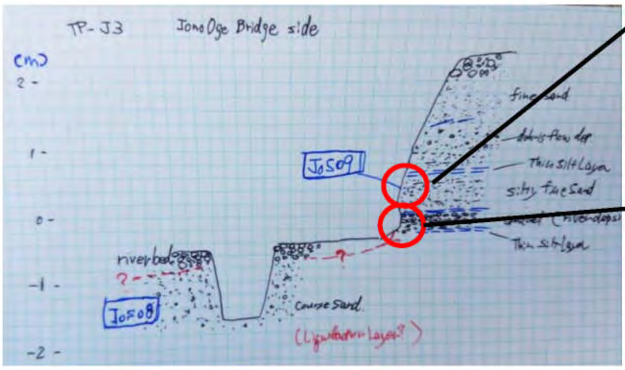
TP-J4

TP-J3





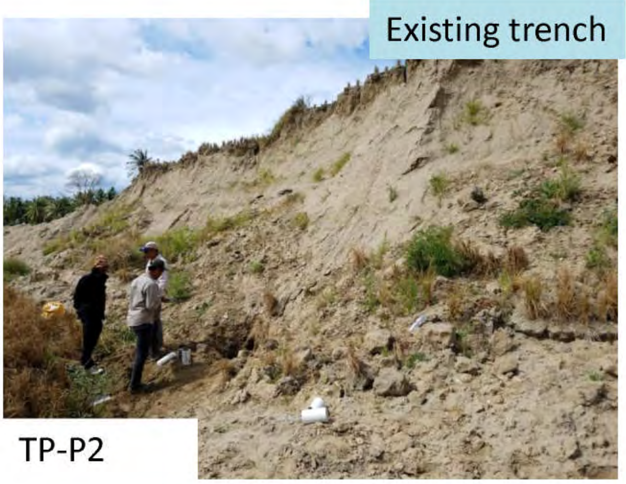




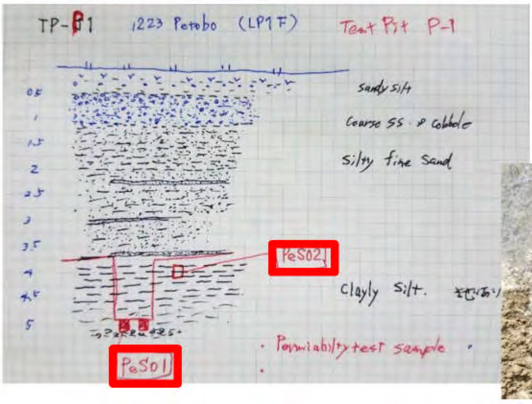
Confirm boundary between sediment and foundation ground

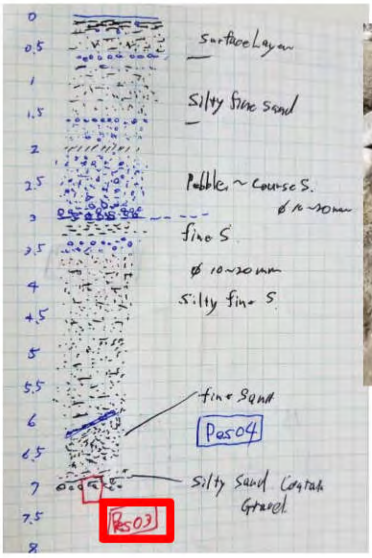
Petobo Test Pit


TP-P1

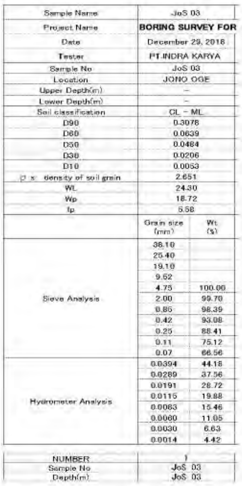

Existing trench

TP-P2

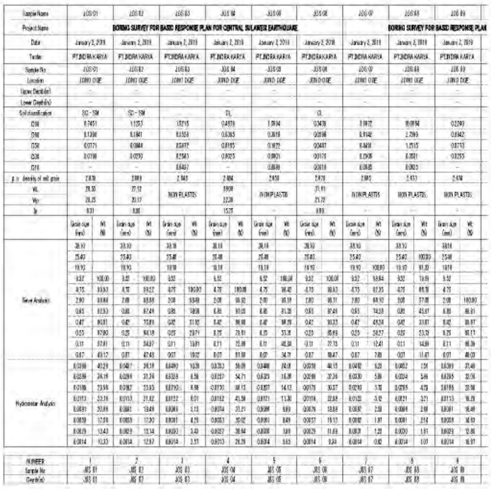


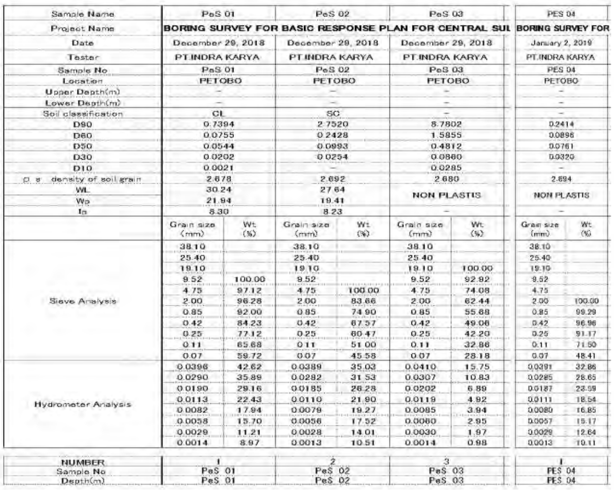


Trench sample analysis

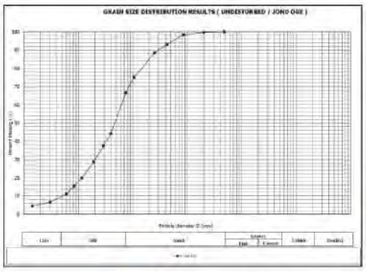


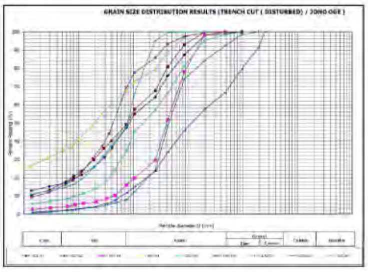
Sample Name	JoS 03	
Project Name	BORING SURVEY FOR	
Date	December 29, 2018	
Tester	PT.INDRA KARYA	
Sample No	JoS 03	
Location	JONO OGE	
Upper Depth(m)	–	
Lower Depth(m)	–	
Soil classification	CL – ML	
D90	0.3078	
D60	0.0639	
D50	0.0484	
D30	0.0206	
D10	0.0053	
ρ s density of soil grain	2.651	
WL	24.30	
Wp	18.72	
Ip	5.58	
	Grain size (mm)	Wt (%)
Sieve Analysis	38.10	
	25.40	
	19.10	
	9.52	
	4.75	100.00
	2.00	99.70
	0.85	98.39
	0.42	93.08
	0.25	88.41
	0.11	75.12
	0.07	66.56
Hydrometer Analysis	0.0394	44.18
	0.0289	37.56
	0.0191	28.72
	0.0115	19.88
	0.0083	15.46
	0.0060	11.05
	0.0030	6.63
	0.0014	4.42
NUMBER	1	
Sample No	JoS 03	
Depth(m)	JoS 03	

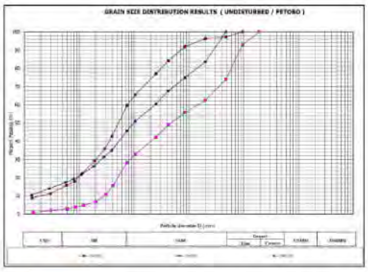


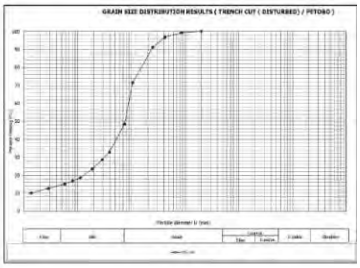


Sample Name	PeS 01		PeS 02		PeS 03		PES 04	
Project Name	BORING SURVEY FOR BASIC RESPONSE PLAN FOR CENTRAL SUL						BORING SURVEY FOR	
Date	December 29, 2018		December 29, 2018		December 29, 2018		January 2, 2019	
Tester	PT.INDRA KARYA		PT.INDRA KARYA		PT.INDRA KARYA		PT.INDRA KARYA	
Sample No	PeS 01		PeS 02		PeS 03		PES 04	
Location	PETOBO		PETOBO		PETOBO		PETOBO	
Upper Depth(m)	–		–		–		–	
Lower Depth(m)	–		–		–		–	
Soil classification	CL		SC		–		–	
D90	0.7394		2.7520		8.7802		0.2414	
D60	0.0755		0.2428		1.5855		0.0896	
D50	0.0544		0.0993		0.4812		0.0761	
D30	0.0202		0.0254		0.0860		0.0320	
D10	0.0021		–		0.0285		–	
ρ s density of soil grain	2.678		2.692		2.680		2.694	
WL	30.24		27.64		NON PLASTIS		NON PLASTIS	
Wp	21.94		19.41					
Ip	8.30		8.23		–		–	
	Grain size (mm)	Wt (%)	Grain size (mm)	Wt (%)	Grain size (mm)	Wt (%)	Grain size (mm)	Wt (%)
Sieve Analysis	38.10		38.10		38.10		38.10	
	25.40		25.40		25.40		25.40	
	19.10		19.10		19.10	100.00	19.10	
	9.52	100.00	9.52		9.52	92.92	9.52	
	4.75	97.12	4.75	100.00	4.75	74.08	4.75	
	2.00	96.28	2.00	83.66	2.00	62.44	2.00	100.00
	0.85	92.00	0.85	74.90	0.85	55.68	0.85	99.29
	0.42	84.23	0.42	67.57	0.42	49.06	0.42	96.96
	0.25	77.12	0.25	60.47	0.25	42.20	0.25	91.17
	0.11	65.68	0.11	51.00	0.11	32.86	0.11	71.50
	0.07	59.72	0.07	45.58	0.07	28.18	0.07	48.41
Hydrometer Analysis	0.0396	42.62	0.0389	35.03	0.0410	15.75	0.0391	32.86
	0.0290	35.89	0.0282	31.53	0.0307	10.83	0.0285	28.65
	0.0190	29.16	0.0185	26.28	0.0202	6.89	0.0187	23.59
	0.0113	22.43	0.0110	21.90	0.0119	4.92	0.0111	18.54
	0.0082	17.94	0.0079	19.27	0.0085	3.94	0.0080	16.85
	0.0058	15.70	0.0056	17.52	0.0060	2.95	0.0057	15.17
	0.0029	11.21	0.0028	14.01	0.0030	1.97	0.0029	12.64
	0.0014	8.97	0.0013	10.51	0.0014	0.98	0.0013	10.11
NUMBER	1		2		3		1	
Sample No	PeS 01		PeS 02		PeS 03		PES 04	
Depth(m)	PeS 01		PeS 02		PeS 03		PES 04	









Sample No. JoS_03

Continuous triaxial test
is implemented @ ITB

Sample No. PeS_01～03

Aquiclude
Laboratory permeability test
is implemented @ ITB

5-(3) Evaluation of liquefaction resistance (FL)

Calculation condition of liquefaction resistance(FL)

- Calculation of liquefaction resistance is based on the “Road bridge specifications”. Tentatively applied earthquake vibration for evaluation of liquefaction is level 2 (type 2). Design horizontal seismic factor on the ground surface is set as K_{hgL0}=0.6, which is the standard value of 3rd soil of level 2 earthquake vibration.
- It is a bigger value comparing with the surface horizontal maximum acceleration at the BMKG observation point, α_{max}= 281cm/sec²

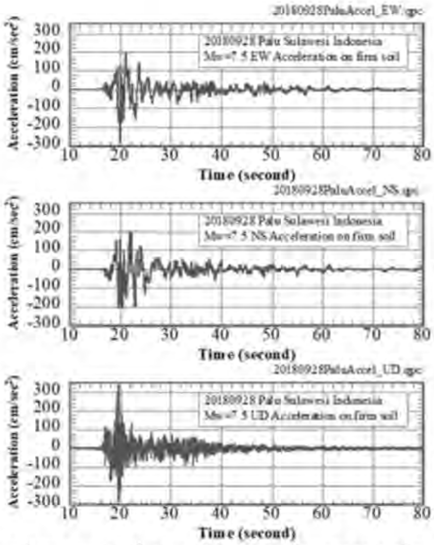
Primary evaluation of liquefaction (construction and road bridge)

Design criteria of construction fundamental structure:

Alluvial deposit less than 20m in depth from the ground surface; the soil whose content rate of granule is less than 35%; buried / filled soil whose content rate of clay is less than 10% or plastic index is less than 15%; the gravel surrounded by fine grained soil or low permeability soil layer

Road bridge specifications:

Saturated soil, which is located within 20m in depth from the ground surface and whose groundwater level is less than 10m from the ground surface; soil layer whose content rate(FC) of granule is less than 35% or plastic index(IP) is less than 15% even though the FC is more than 35%; soil layer whose average grain diameter (D50) is less than 10mm and 10% grain diameter (D10) is less than 1mm.

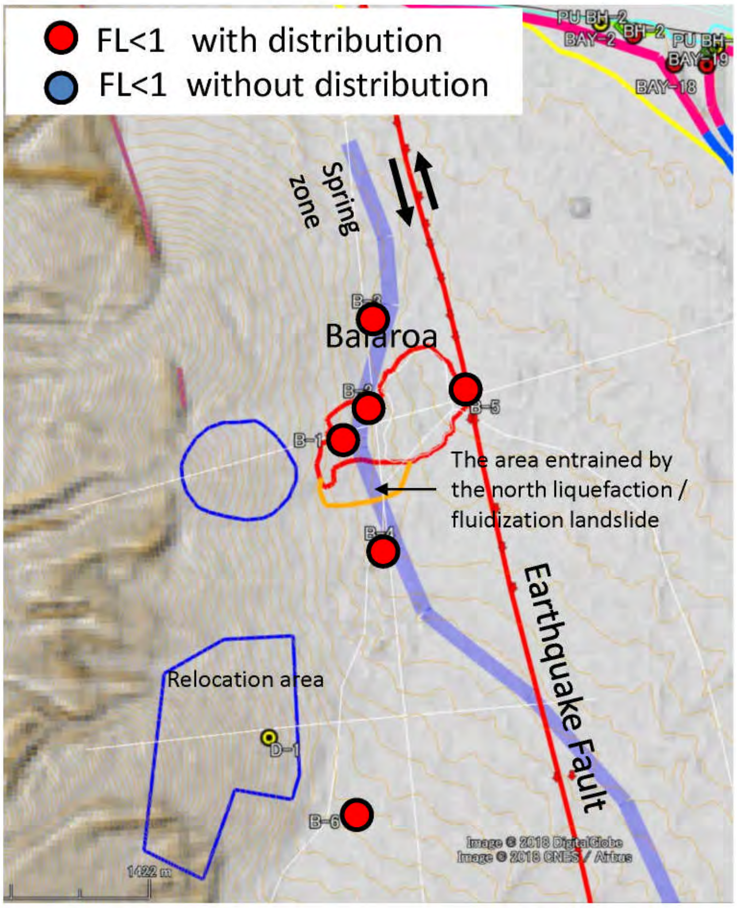


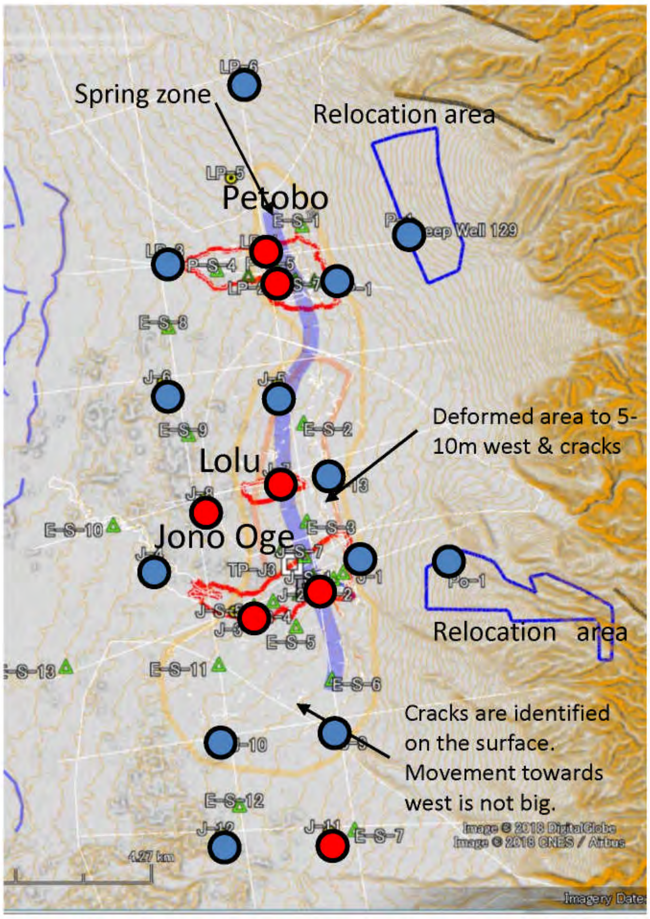
BMKG observed earthquake accelerogram

*Concern: Maximum acceleration in a vertical element is bigger than a horizontal element

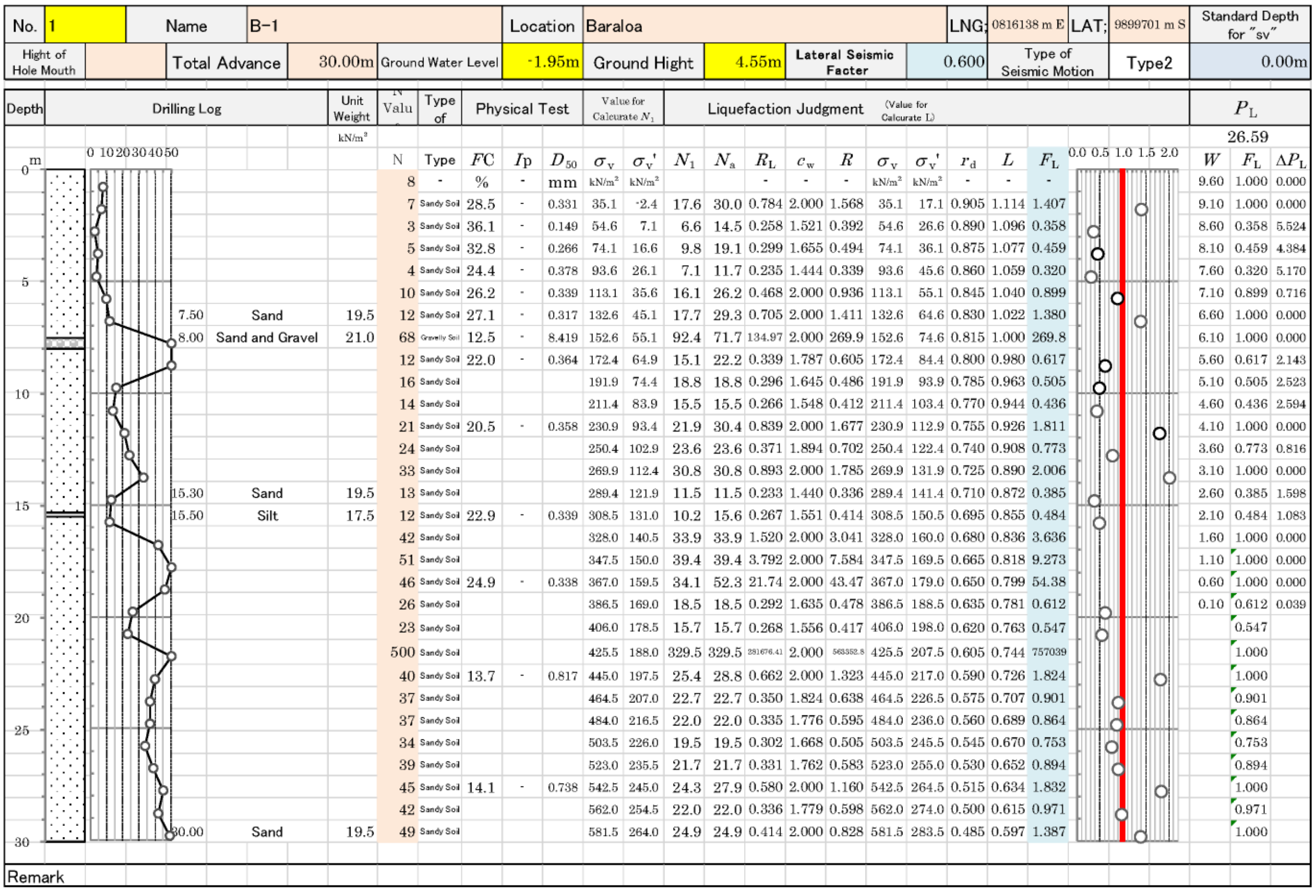
5-(3) Evaluation of liquefaction resistance (FL)

Horizontal distribution of liquefaction resistance (FL)





Boring (example of Evaluation of liquefaction resistance)



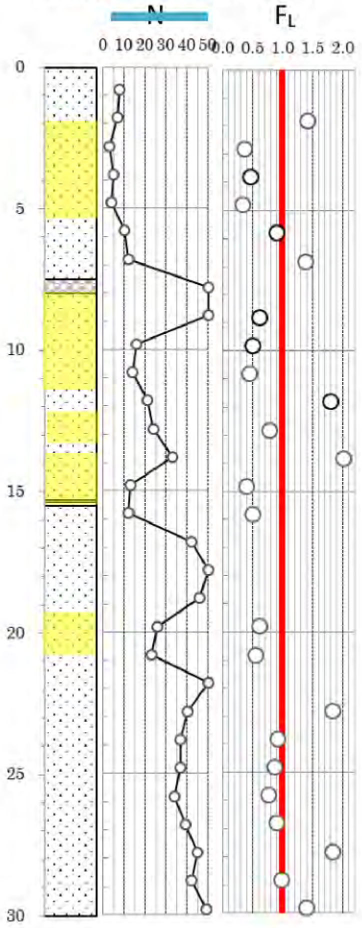
No.	1	Name	B−1	Location	Baraloa	LNG;	0816138 m E	LAT;	9899701 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	-1.95m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion: Type2 / 0.00m

Depth	Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
			kN/m³																		26.59		
				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
				8	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
				7	Sandy Soil	28.5	-	0.331	35.1	-2.4	17.6	30.0	0.784	2.000	1.568	35.1	17.1	0.905	1.114	1.407	9.10	1.000	0.000
				3	Sandy Soil	36.1	-	0.149	54.6	7.1	6.6	14.5	0.258	1.521	0.392	54.6	26.6	0.890	1.096	0.358	8.60	0.358	5.524
				5	Sandy Soil	32.8	-	0.266	74.1	16.6	9.8	19.1	0.299	1.655	0.494	74.1	36.1	0.875	1.077	0.459	8.10	0.459	4.384
				4	Sandy Soil	24.4	-	0.378	93.6	26.1	7.1	11.7	0.235	1.444	0.339	93.6	45.6	0.860	1.059	0.320	7.60	0.320	5.170
				10	Sandy Soil	26.2	-	0.339	113.1	35.6	16.1	26.2	0.468	2.000	0.936	113.1	55.1	0.845	1.040	0.899	7.10	0.899	0.716
	7.50	Sand	19.5	12	Sandy Soil	27.1	-	0.317	132.6	45.1	17.7	29.3	0.705	2.000	1.411	132.6	64.6	0.830	1.022	1.380	6.60	1.000	0.000
	8.00	Sand and Gravel	21.0	68	Gravelly Soil	12.5	-	8.419	152.6	55.1	92.4	71.7	134.97	2.000	269.9	152.6	74.6	0.815	1.000	269.8	6.10	1.000	0.000
				12	Sandy Soil	22.0	-	0.364	172.4	64.9	15.1	22.2	0.339	1.787	0.605	172.4	84.4	0.800	0.980	0.617	5.60	0.617	2.143
				16	Sandy Soil				191.9	74.4	18.8	18.8	0.296	1.645	0.486	191.9	93.9	0.785	0.963	0.505	5.10	0.505	2.523
				14	Sandy Soil				211.4	83.9	15.5	15.5	0.266	1.548	0.412	211.4	103.4	0.770	0.944	0.436	4.60	0.436	2.594
				21	Sandy Soil	20.5	-	0.358	230.9	93.4	21.9	30.4	0.839	2.000	1.677	230.9	112.9	0.755	0.926	1.811	4.10	1.000	0.000
				24	Sandy Soil				250.4	102.9	23.6	23.6	0.371	1.894	0.702	250.4	122.4	0.740	0.908	0.773	3.60	0.773	0.816
				33	Sandy Soil				269.9	112.4	30.8	30.8	0.893	2.000	1.785	269.9	131.9	0.725	0.890	2.006	3.10	1.000	0.000
	15.30	Sand	19.5	13	Sandy Soil				289.4	121.9	11.5	11.5	0.233	1.440	0.336	289.4	141.4	0.710	0.872	0.385	2.60	0.385	1.598
	15.50	Silt	17.5	12	Sandy Soil	22.9	-	0.339	308.5	131.0	10.2	15.6	0.267	1.551	0.414	308.5	150.5	0.695	0.855	0.484	2.10	0.484	1.083
				42	Sandy Soil				328.0	140.5	33.9	33.9	1.520	2.000	3.041	328.0	160.0	0.680	0.836	3.636	1.60	1.000	0.000
				51	Sandy Soil				347.5	150.0	39.4	39.4	3.792	2.000	7.584	347.5	169.5	0.665	0.818	9.273	1.10	1.000	0.000
				46	Sandy Soil	24.9	-	0.338	367.0	159.5	34.1	52.3	21.74	2.000	43.47	367.0	179.0	0.650	0.799	54.38	0.60	1.000	0.000
				26	Sandy Soil				386.5	169.0	18.5	18.5	0.292	1.635	0.478	386.5	188.5	0.635	0.781	0.612	0.10	0.612	0.039
				23	Sandy Soil				406.0	178.5	15.7	15.7	0.268	1.556	0.417	406.0	198.0	0.620	0.763	0.547		0.547	
				500	Sandy Soil				425.5	188.0	329.5	329.5	281676.41	2.000	563352.8	425.5	207.5	0.605	0.744	757039		1.000	
				40	Sandy Soil	13.7	-	0.817	445.0	197.5	25.4	28.8	0.662	2.000	1.323	445.0	217.0	0.590	0.726	1.824		1.000	
				37	Sandy Soil				464.5	207.0	22.7	22.7	0.350	1.824	0.638	464.5	226.5	0.575	0.707	0.901		0.901	
				37	Sandy Soil				484.0	216.5	22.0	22.0	0.335	1.776	0.595	484.0	236.0	0.560	0.689	0.864		0.864	
				34	Sandy Soil				503.5	226.0	19.5	19.5	0.302	1.668	0.505	503.5	245.5	0.545	0.670	0.753		0.753	
				39	Sandy Soil				523.0	235.5	21.7	21.7	0.331	1.762	0.583	523.0	255.0	0.530	0.652	0.894		0.894	
				45	Sandy Soil	14.1	-	0.738	542.5	245.0	24.3	27.9	0.580	2.000	1.160	542.5	264.5	0.515	0.634	1.832		1.000	
				42	Sandy Soil				562.0	254.5	22.0	22.0	0.336	1.779	0.598	562.0	274.0	0.500	0.615	0.971		0.971	
	30.00	Sand	19.5	49	Sandy Soil				581.5	264.0	24.9	24.9	0.414	2.000	0.828	581.5	283.5	0.485	0.597	1.387		1.000	

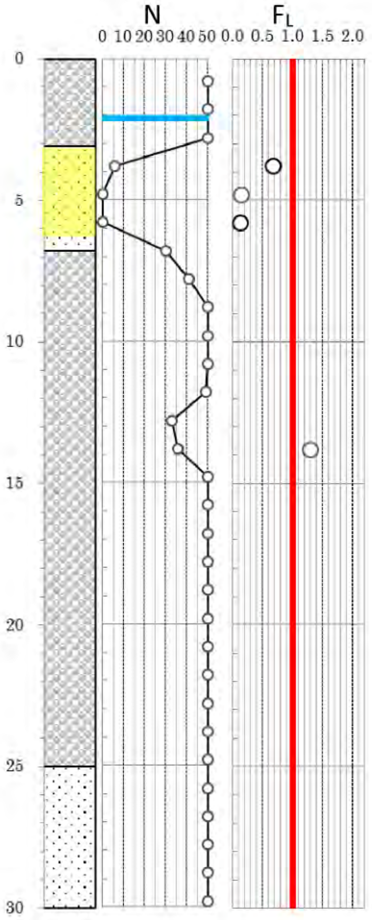
Remark

B-1 Inside of landslide area

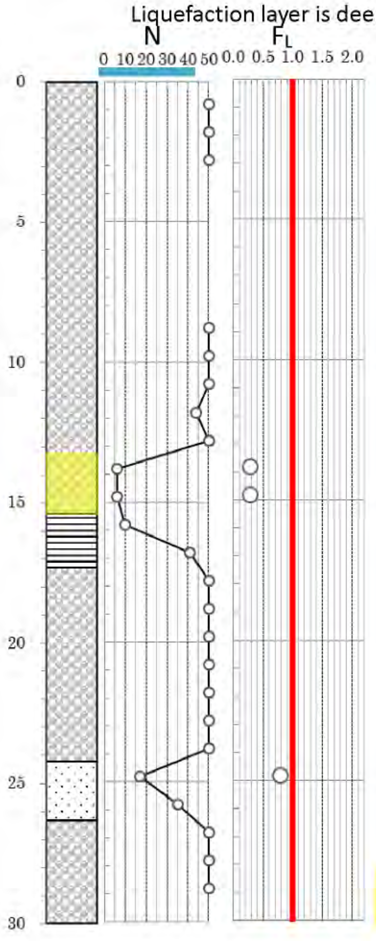
GL raised +1.95m after boring



B-2 Near landslide are

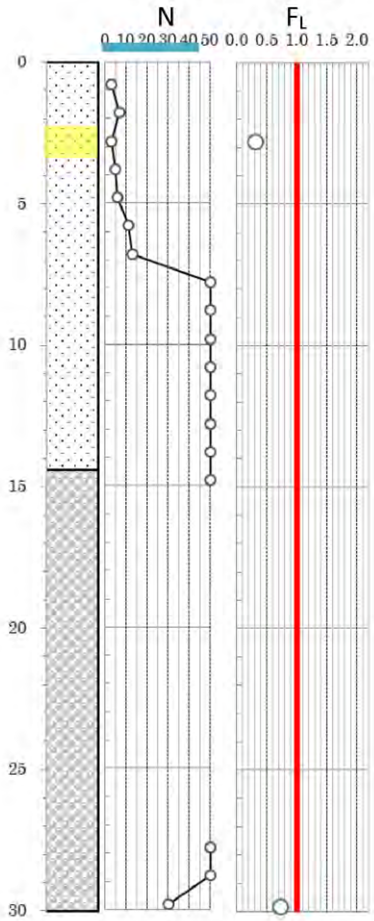


B-3 Far north side of landslide area
(No deformation)
Liquefaction layer is deep

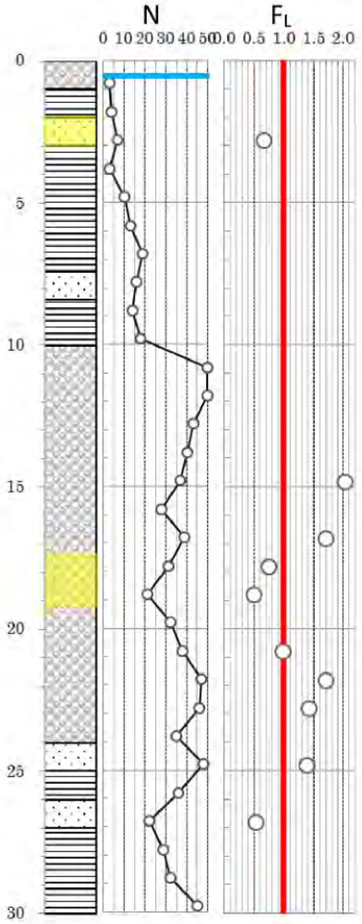


🟨 Liquefaction layer

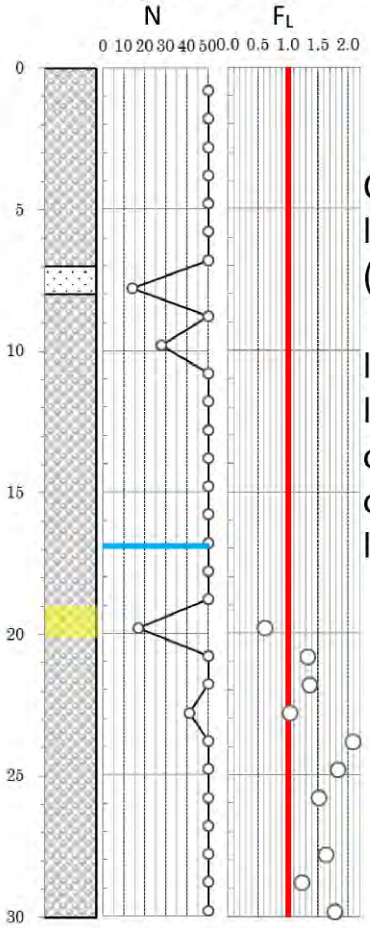
B-4 Far south side of landslide area
(No deformation)
Liquefaction layer is limited



B-5 End of the deposited area
Liquefaction layer is limited



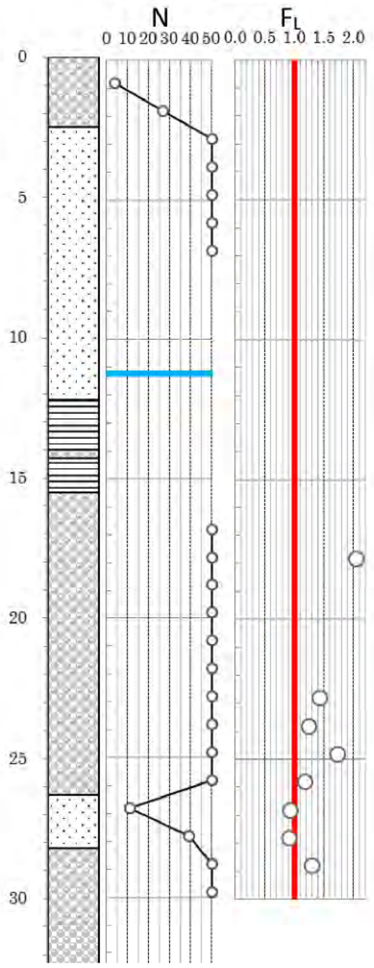
B-6 Far south side of landslide area
(No deformation)
Liquefaction layer is limited



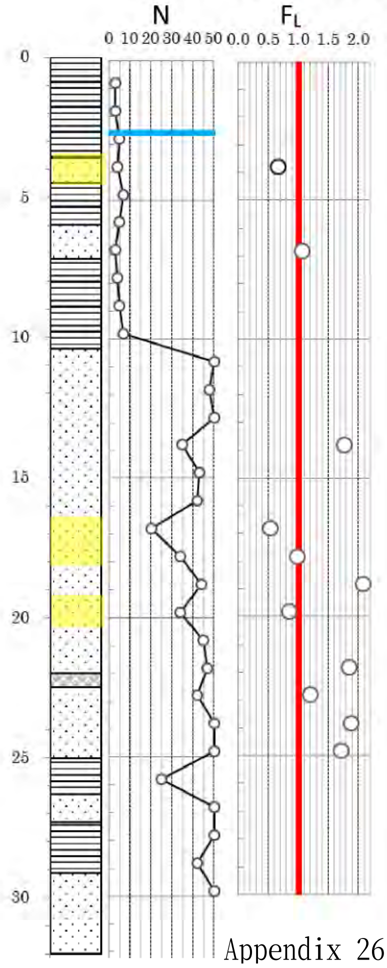
Outside of landslide area (B-3, B-4, B-5, B-6)
→ It seems that liquefaction landslide did not occurred because of thick non-liquefaction layer

🟨 Liquefaction layer

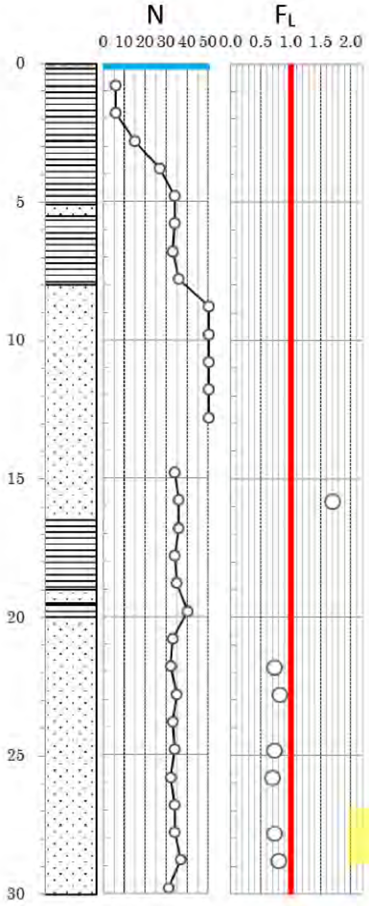
LP-1 Inside of landslide area
/ Cracks area on top
Groundwater level reduced
after the disaster



LP-2 At the south-end of Inside
of landslide area
Moved deposition is
identified up to approx. 2m

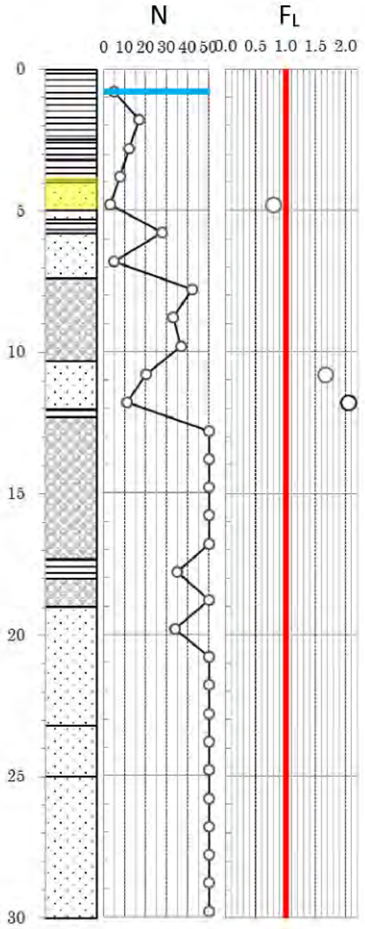


LP-3 Outside of landslide area
End of the deposition area
No liquefaction layer

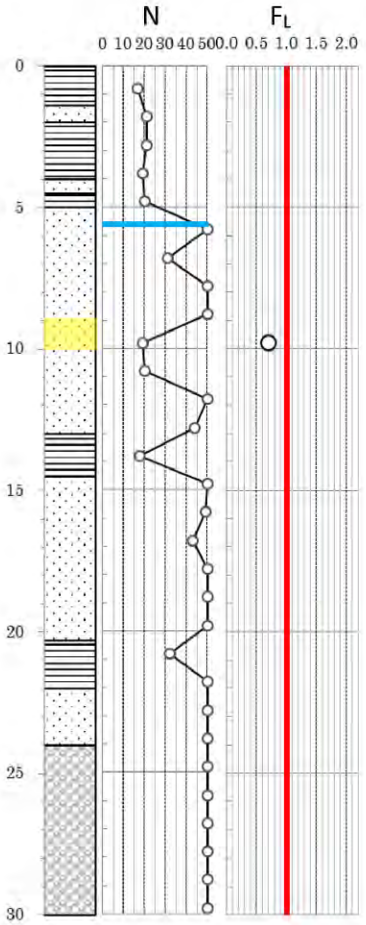


🟨 Liquefaction layer

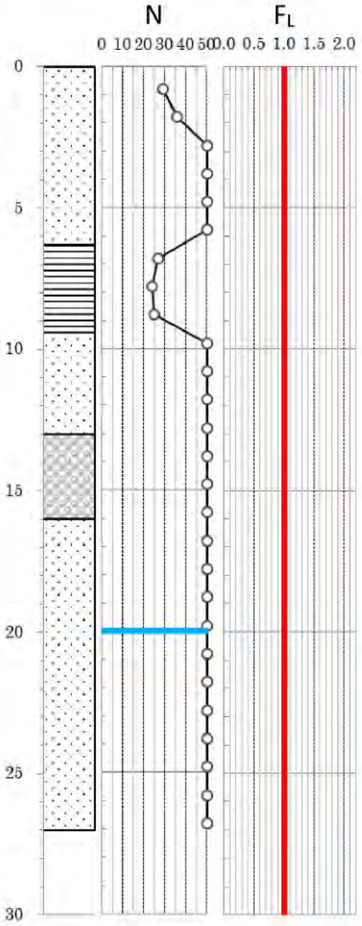
LP-4 Near the north end of landslide area



LP-5 Outside of landslide area / southwest of the airport

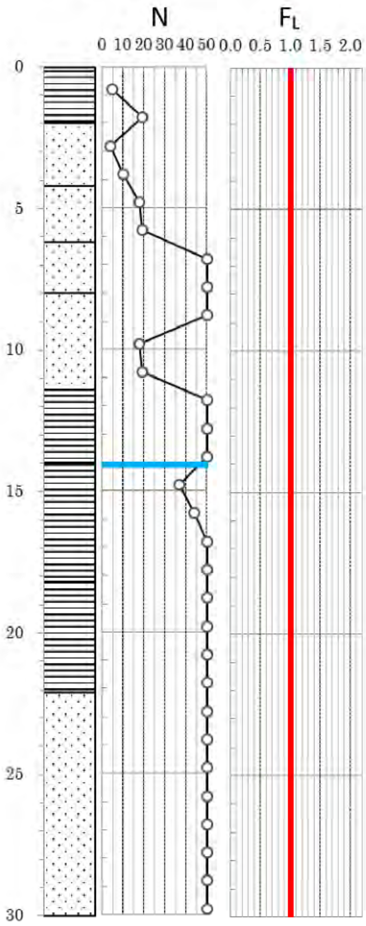


LP-6 Outside of landslide area / northeast of the airport

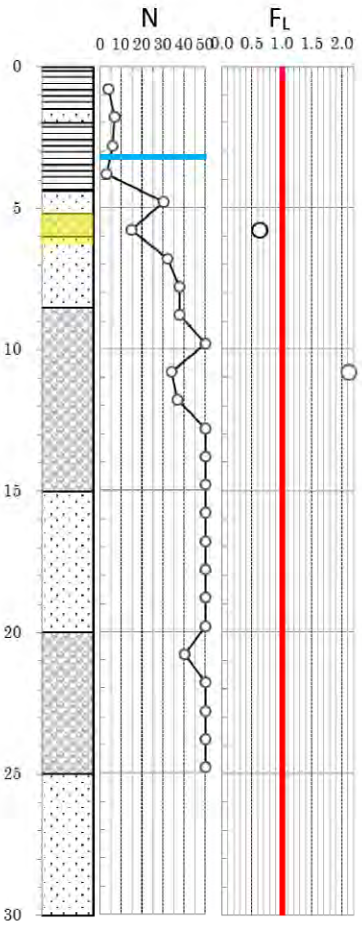


🟨 Liquefaction layer

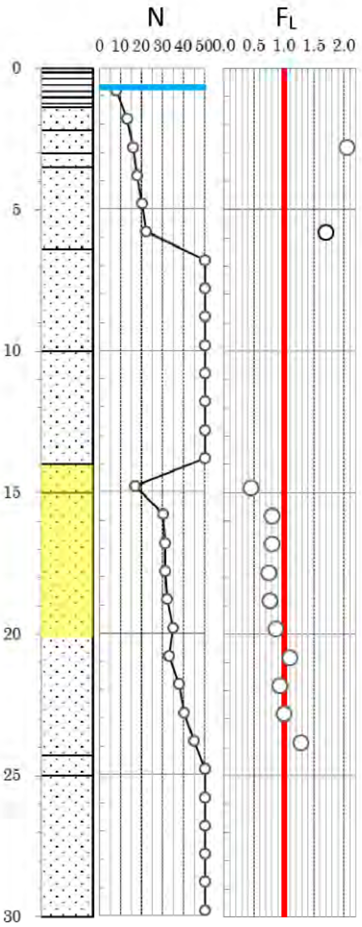
J-1 Inside of landslide area / Cracks area on top Groundwater level reduced after the disaster



J-2 Inside of landslide area

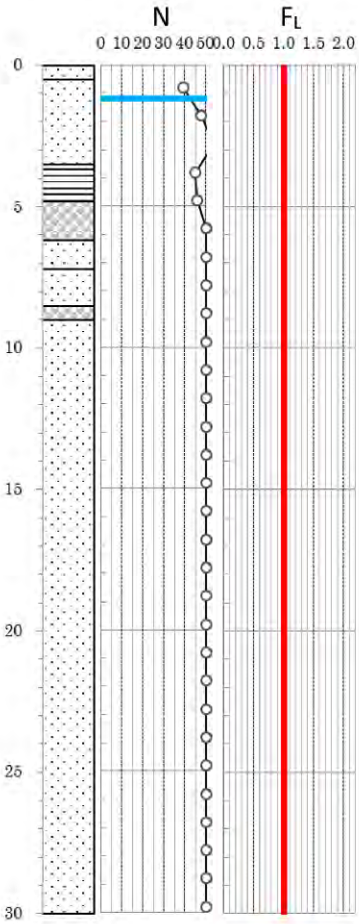


J-3 Inside of landslide area / End of the deposited area

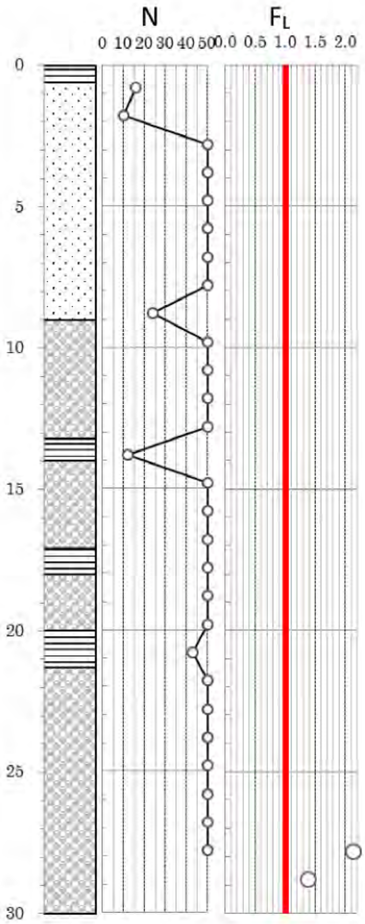


🟨 Liquefaction layer

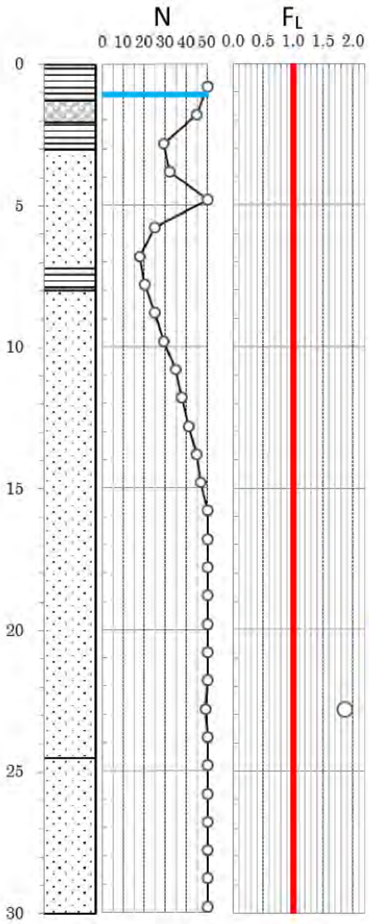
J-4 Outside of landslide area



J-5 Outside of landslide area
Cracks are identified (ZRB3)

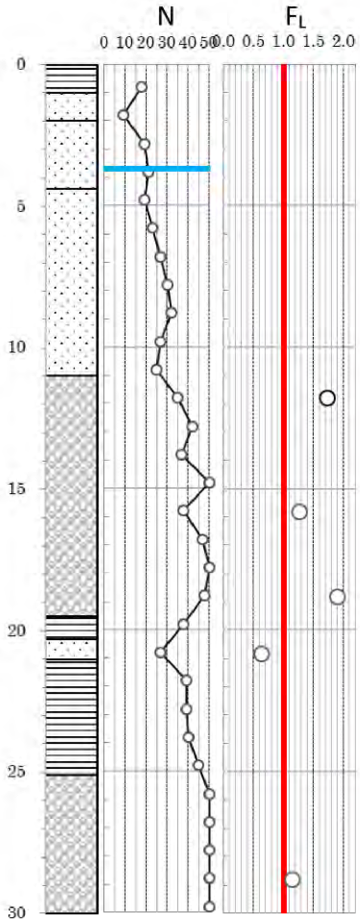


J-6 Outside of landslide area

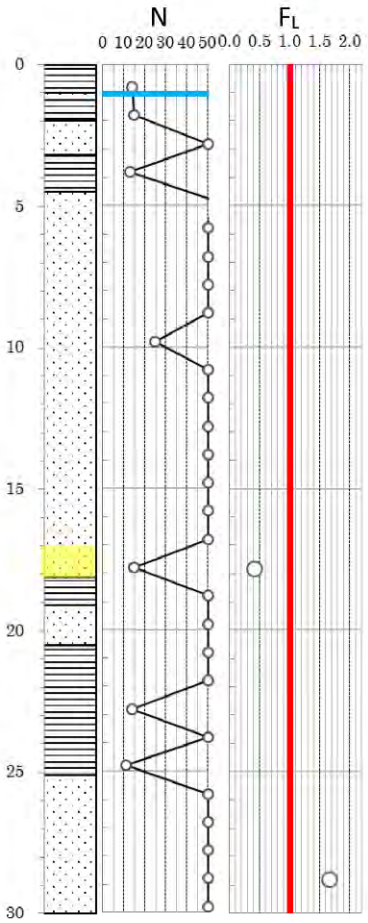


🟨 Liquefaction layer

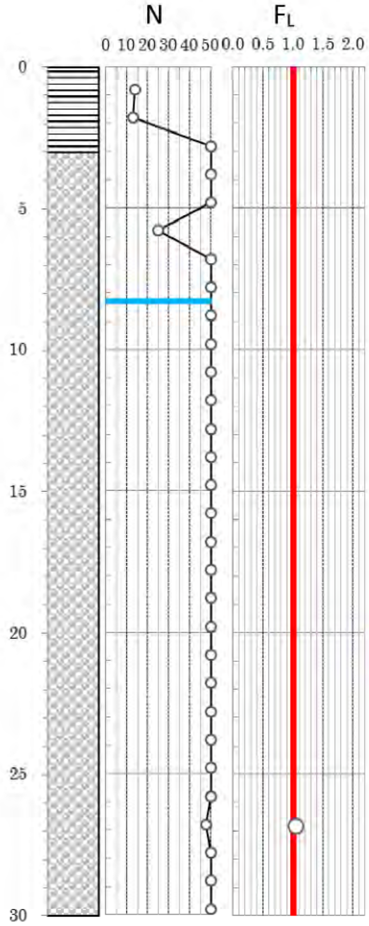
J-7 Outside of landslide area
Cracks are identified (ZRB3)



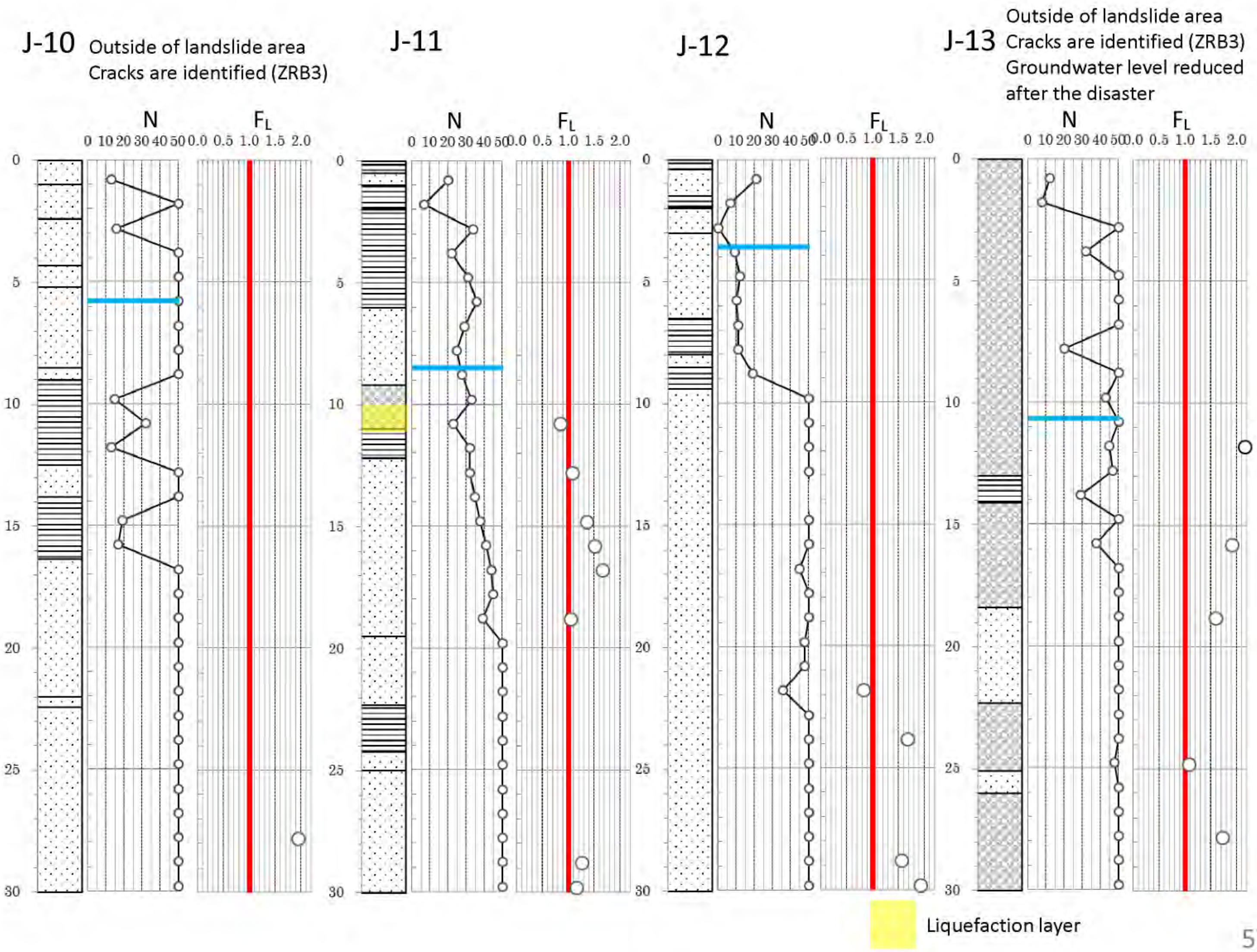
J-8



J-9 Outside of landslide area
Cracks are identified (ZRB3)



🟨 Liquefaction layer



5-(3) Evaluation of liquefaction resistance (FL)

Issues on evaluation of liquefaction resistance

1. Condition of liquefaction landslide

- Alternation of new sandy mudflow, which is provided by the flood, and sand & gravel deposition are identified at a lower slope at the end of alluvial fan. Moreover, thin silty clay and humus soil layers are existing in-between the alternation.
- Nalodo is occurred where the small new alluvial fan at the upper slope was created and the boundary of old wide alluvial fan. This place is relatively gentle slope and concave-shape. Moreover, new deposition which N-value is less than 10 is identified in Baralao, Petobo, Jono Oge by the boring survey.

2. Relation between liquefaction resistance and liquefaction landslide

- There is a distribution of “FL < 1” even outside of Nalodo (B-3, 4, 5, 6) in Balaroa. Evaluation of Nalodo requires to consider gradient, thickness of upper non-liquefaction layer, existence of cap and so on. → Refer to the following page

3. Issues on evaluation of liquefaction resistance

- FL might be evaluated as a dangerous side, especially for a sample of standard penetration test (penetration length 30 – 50cm) of drill hole at an alternation of sand & silt layers because the thickness of each layer is few centimeters to 1m (maximum)
- Evaluation using the sampling at an outcrop is required for the evaluation of thin layer because thin sand layers might exist between the layers especially at the silt layer, which is identified by the boring
- In case the liquefaction is evaluated by the groundwater level after the landslide, it might not be evaluated properly especially at the place where groundwater level decreased

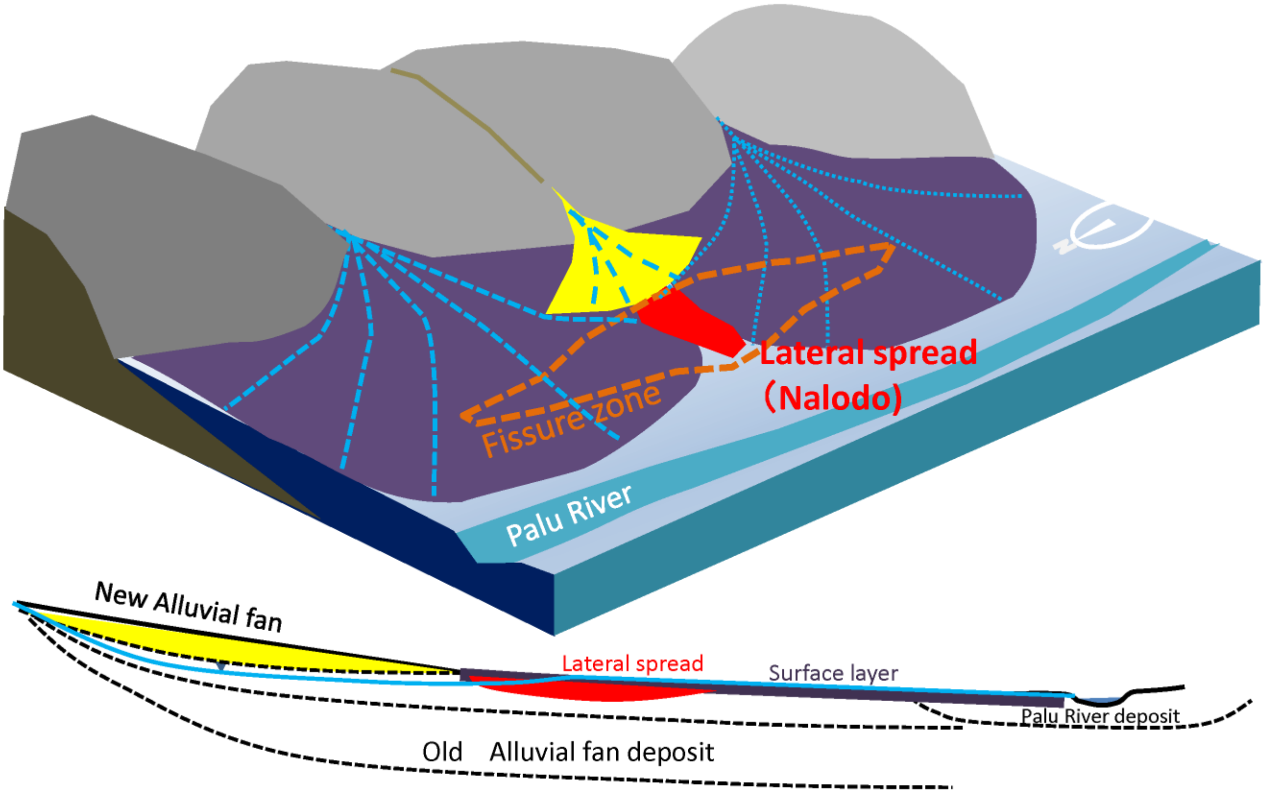
5-(4) Evaluation of Occurrence of Liquefaction landslide

Analysis of the Nalodo

It is assumed that the Nalodo is occurred when the condition meets the following factors

		Slope / Gradient	Thickness of upper non-liquefaction layer	With / without of cap	Liquefaction resistance (FL)		Existence of Liquefaction landslide
					Soil characteristics (N-value, gradation)	Groundwater level	
Upper slope including alluvial fan		More than 5%		Without	N>30-50	GL-20〜50m	Not occurred
Lower slope including the end of alluvial fan	New deposition is distributed	1 – 4%	Less than a couple of meters	With	FL < 1		**Occurred**
				Without			**Not occurred**
			More than a couple of meters				Large-scale liquefaction landslide is not occurred
	New deposition is NOT distributed	1 – 4%			FL > 1		Not occurred
		Less than 1%					Large-scale liquefaction landslide is not occurred

5-(5) Geological model

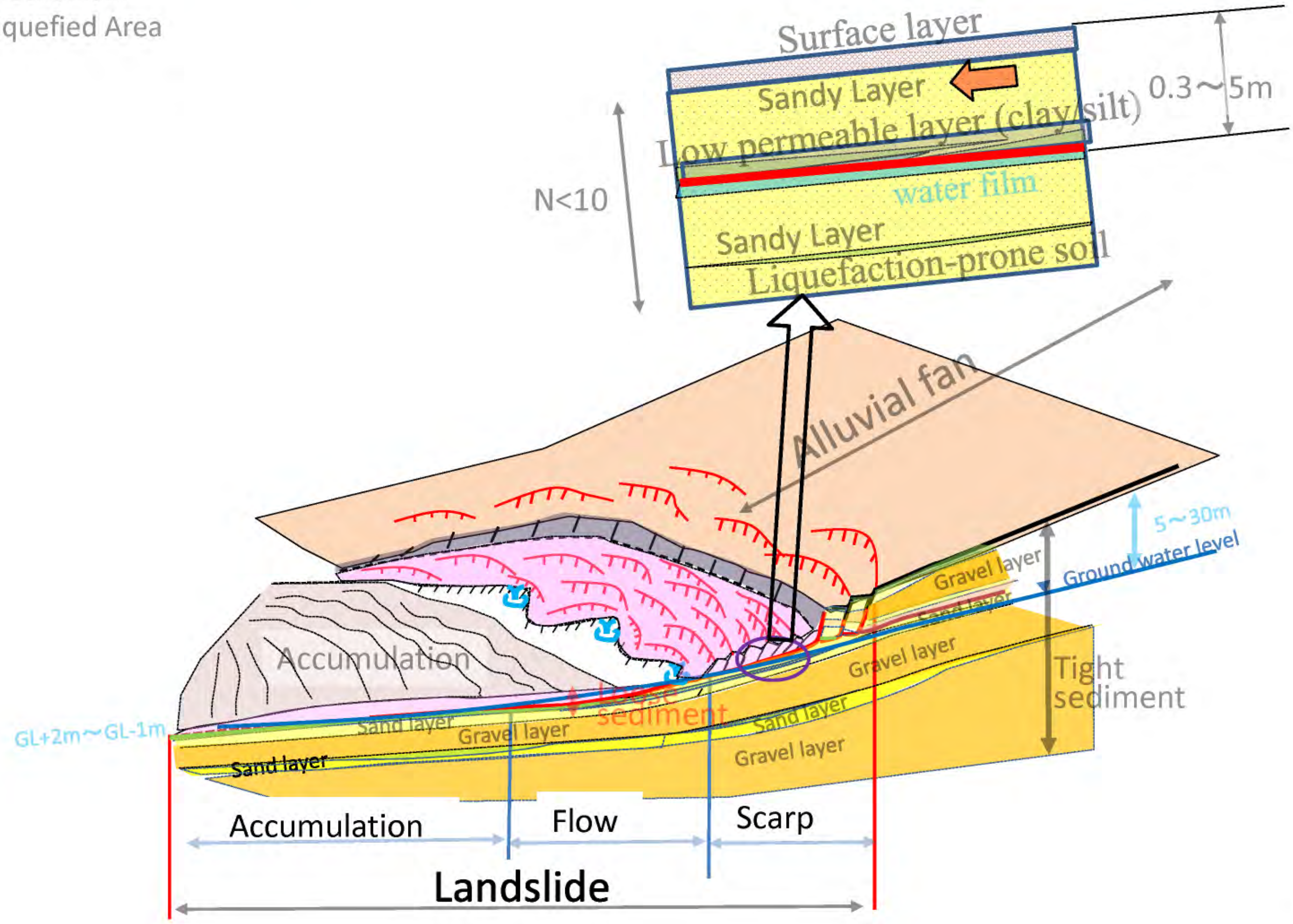


	New Alluvial fan area	**Land slide area**	Paddy field area	Palu River
Geology	Gravel/Course Sand	Fine Sand/Thin Silt layer (Weakest layer)	Fine Sand//Silt	Sand/Silt/Gravel
Ground water level	Deep(more than10m)	Shallow (confined aquifer)	Shallow	Shallow

5-(5) Geological model

Mechanism

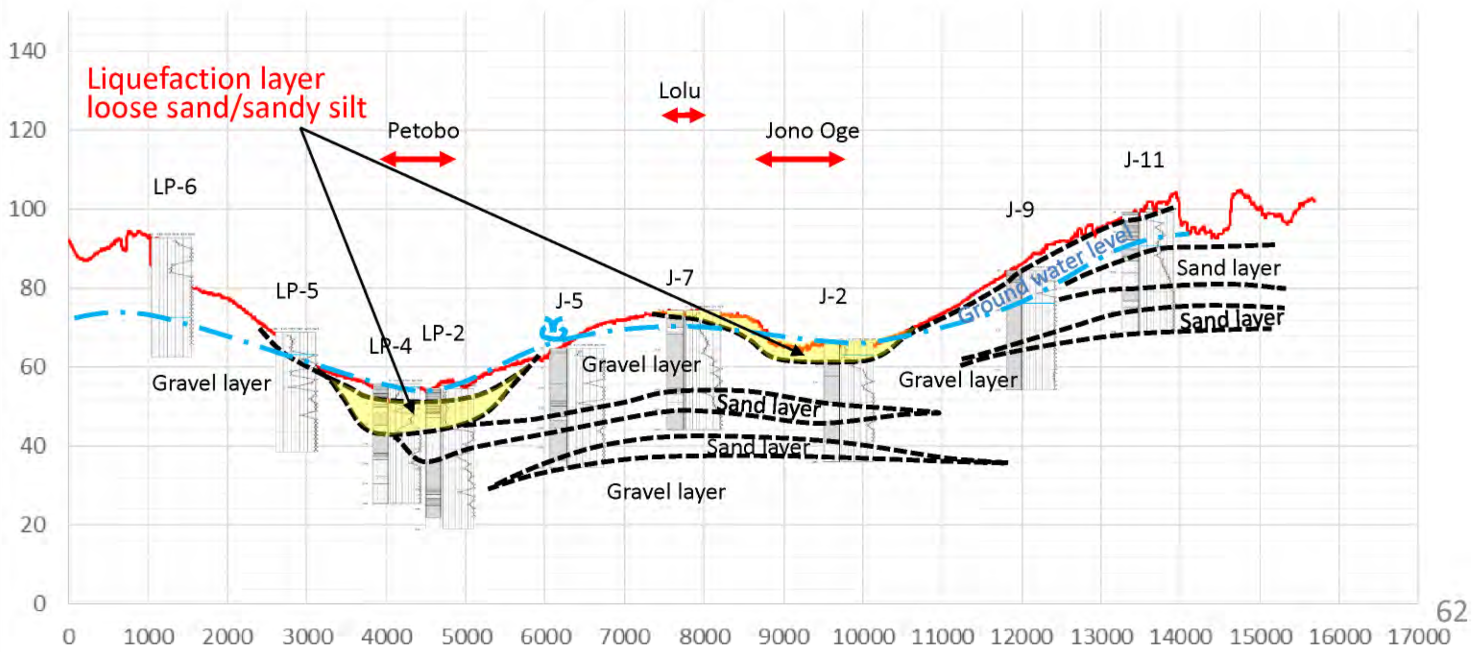
Liquefied Area



5-(5) Geological model

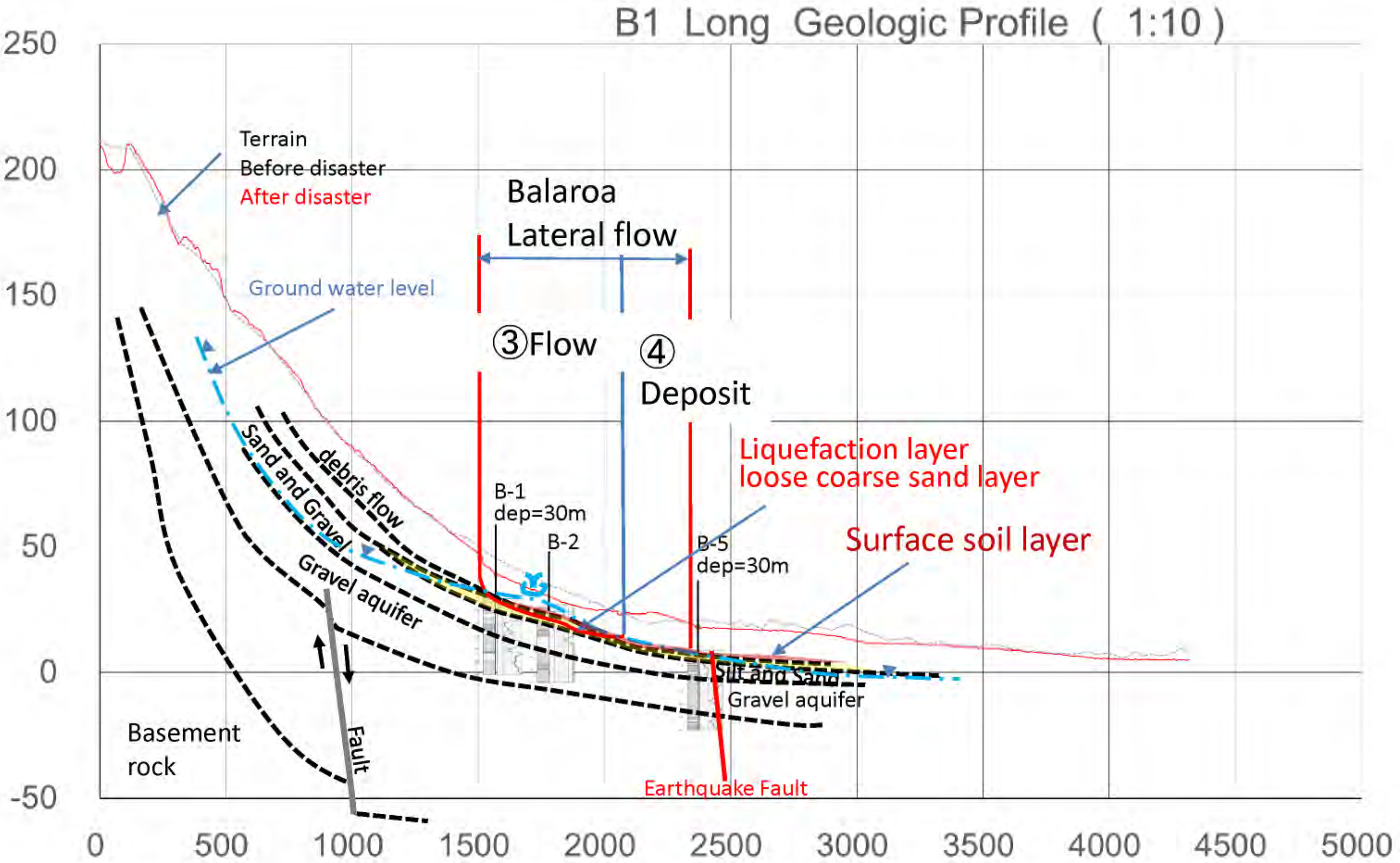
South-North Geologic Profile

J7 Long Geologic Profile 1:50



5-(5) Geological model

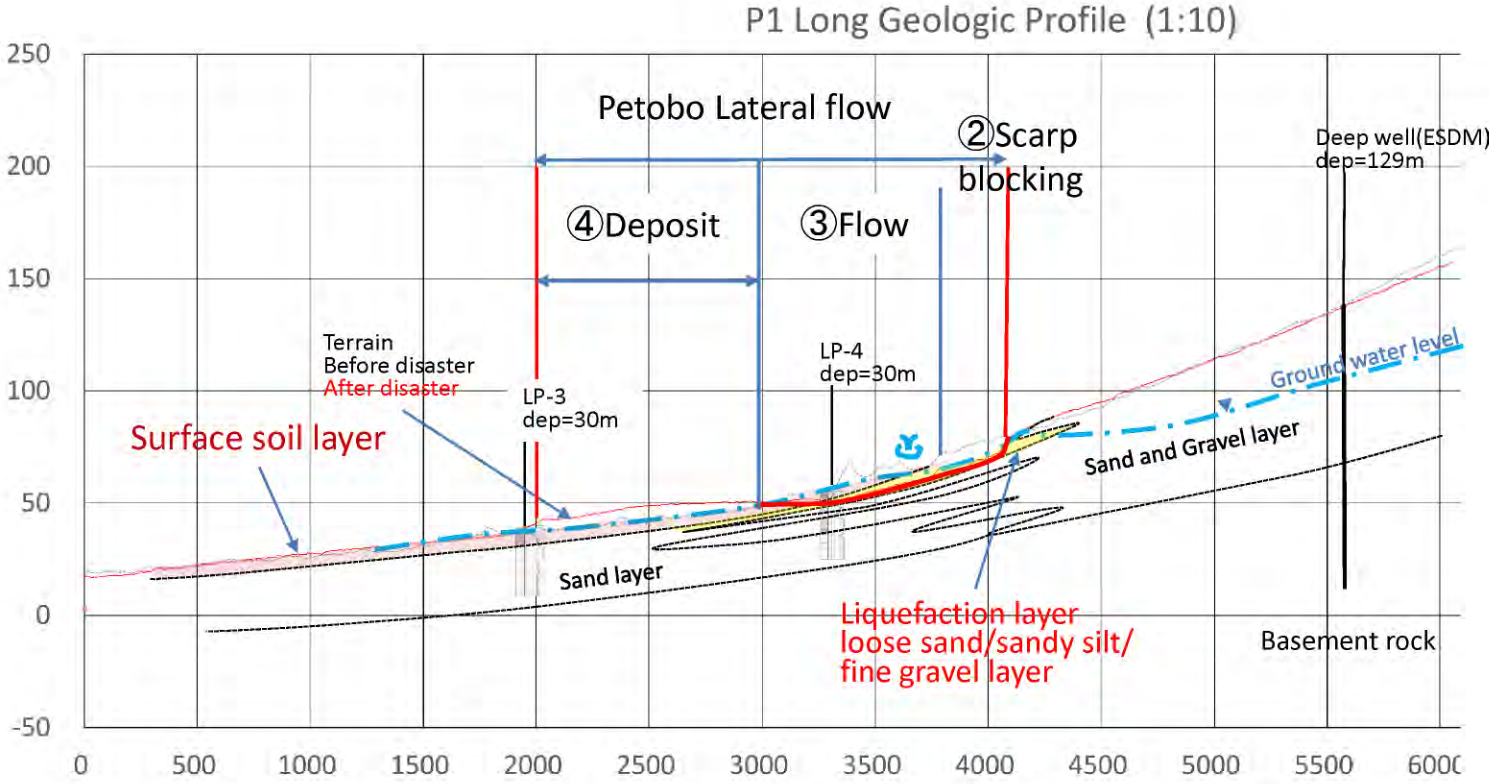
Balaroa



B1 Long Geologic Profile (1:10)

5-(5) Geological model

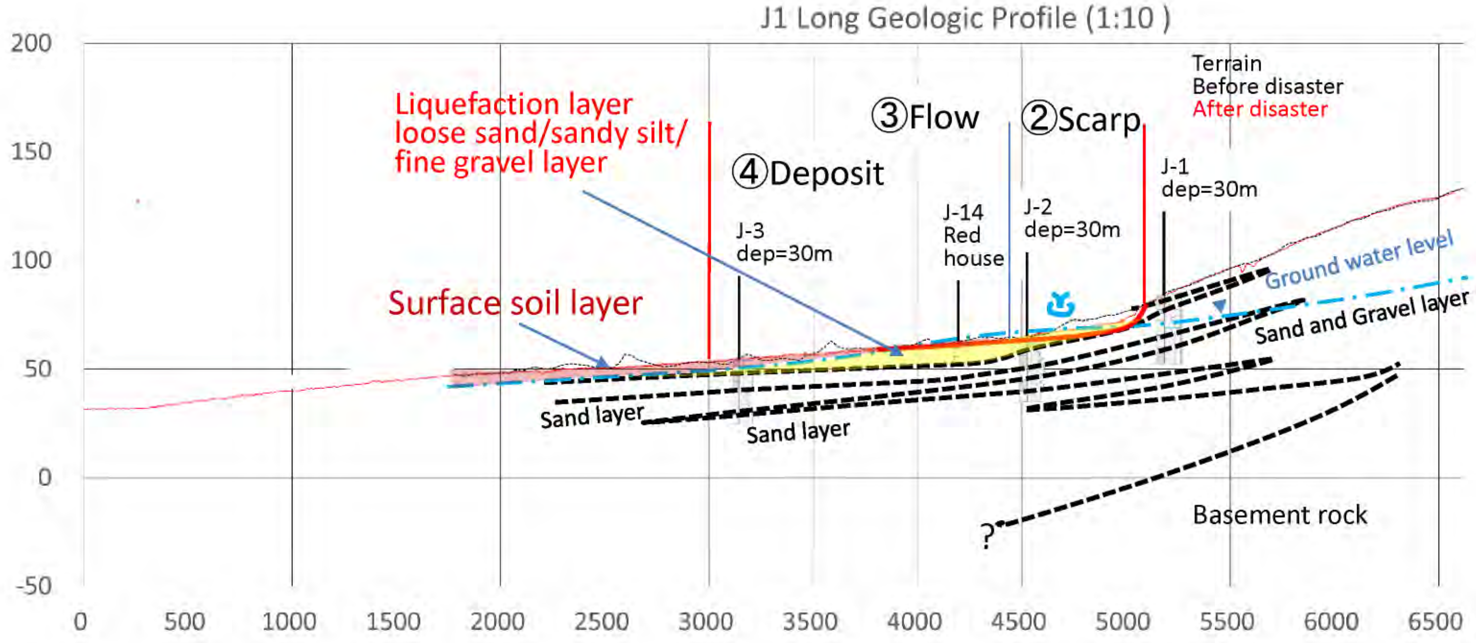
Petobo



P1 Long Geologic Profile (1:10)

5-(5) Geological model

Jono Oge



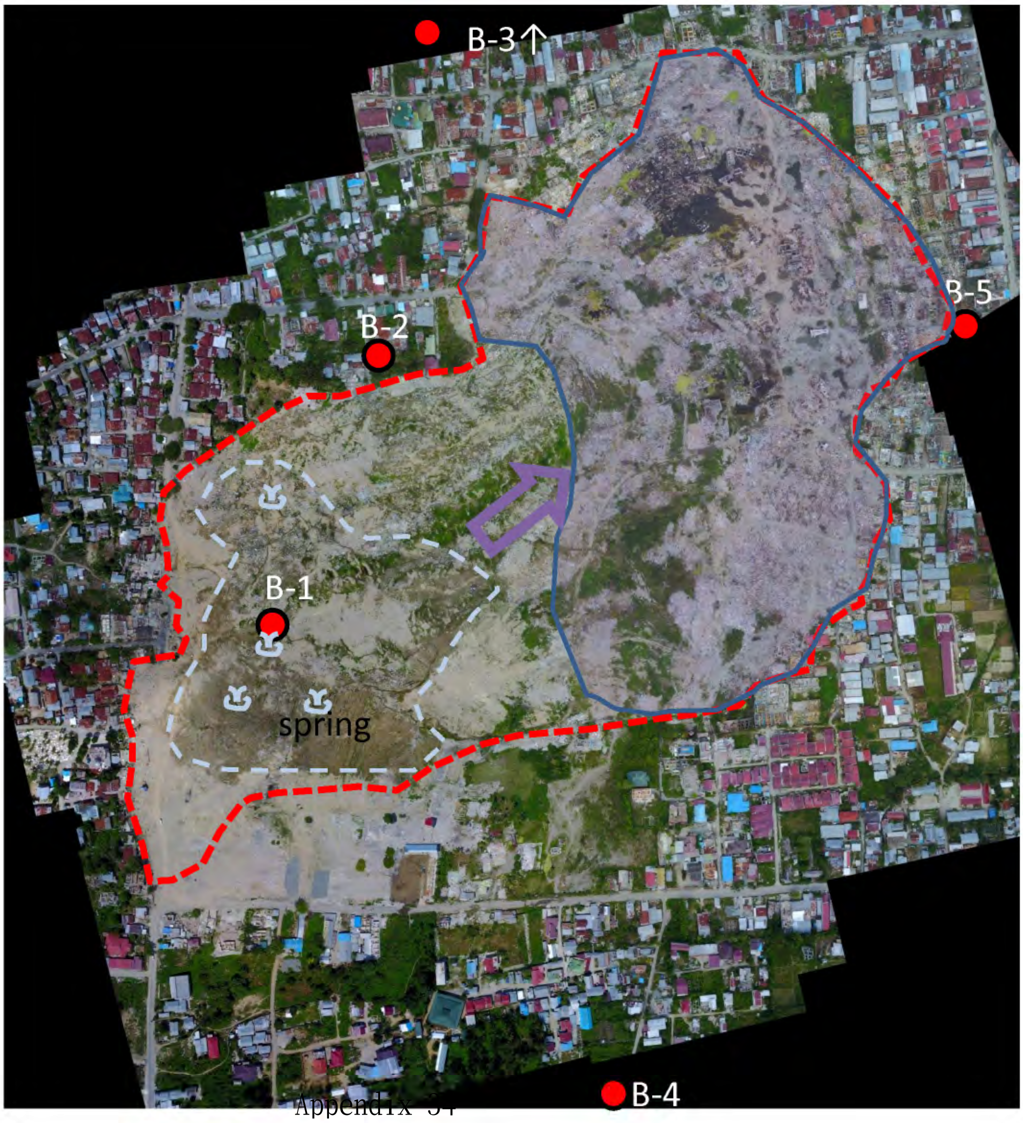
5-(6) Future soil / groundwater survey

Future survey and analysis

- Maximum depth of fluidization is less than 10m. It is approximately 1 -3m from the present ground
- Additional trench survey
  (Trench survey is effective to confirm the Liquefaction / fluidization layer and mechanism of large-scale fluidization)
- Additional drawing of geologic profile reflecting the boring survey result
- Trial of 3D geological model using 2m grid topography data
- Additional survey for drain location and confirming the efficacy of groundwater reduction （permeability, supplied amount of groundwater from the top of the alluvial fan)

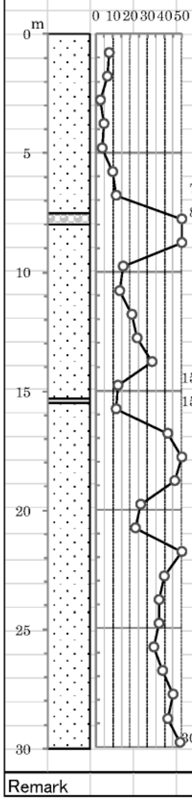
- Reference data

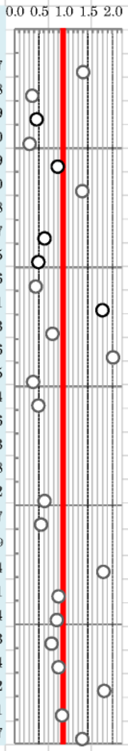
Balaroa



B-1

No.	1	Name	B-1	Location	Baraloa	LNG;	0816138 m E	LAT;	9899701 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	-1.95m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m





Drilling Log		Unit Weight kN/m³	N Value	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L 26.59		
			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
			8	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
			7	Sandy Soil	28.5	-	0.331	35.1	-2.4	17.6	30.0	0.784	2.000	1.568	35.1	17.1	0.905	1.114	1.407	9.10	1.000	0.000
			3	Sandy Soil	36.1	-	0.149	54.6	7.1	6.6	14.5	0.258	1.521	0.392	54.6	26.6	0.890	1.096	0.358	8.60	0.358	5.524
			5	Sandy Soil	32.8	-	0.266	74.1	16.6	9.8	19.1	0.299	1.655	0.494	74.1	36.1	0.875	1.077	0.459	8.10	0.459	4.384
			4	Sandy Soil	24.4	-	0.378	93.6	26.1	7.1	11.7	0.235	1.444	0.339	93.6	45.6	0.860	1.059	0.320	7.60	0.320	5.170
			10	Sandy Soil	26.2	-	0.339	113.1	35.6	16.1	26.2	0.468	2.000	0.936	113.1	55.1	0.845	1.040	0.899	7.10	0.899	0.716
7.50	Sand	19.5	12	Sandy Soil	27.1	-	0.317	132.6	45.1	17.7	29.3	0.705	2.000	1.411	132.6	64.6	0.830	1.022	1.380	6.60	1.000	0.000
8.00	Sand and Gravel	21.0	68	Gravelly Soil	12.5	-	8.419	152.6	55.1	92.4	71.7	134.97	2.000	269.9	152.6	74.6	0.815	1.000	269.8	6.10	1.000	0.000
			12	Sandy Soil	22.0	-	0.364	172.4	64.9	15.1	22.2	0.339	1.787	0.605	172.4	84.4	0.800	0.980	0.617	5.60	0.617	2.143
			16	Sandy Soil				191.9	74.4	18.8	18.8	0.296	1.645	0.486	191.9	93.9	0.785	0.963	0.505	5.10	0.505	2.523
			14	Sandy Soil				211.4	83.9	15.5	15.5	0.266	1.548	0.412	211.4	103.4	0.770	0.944	0.436	4.60	0.436	2.594
			21	Sandy Soil	20.5	-	0.358	230.9	93.4	21.9	30.4	0.839	2.000	1.677	230.9	112.9	0.755	0.926	1.811	4.10	1.000	0.000
			24	Sandy Soil				250.4	102.9	23.6	23.6	0.371	1.894	0.702	250.4	122.4	0.740	0.908	0.773	3.60	0.773	0.816
			33	Sandy Soil				269.9	112.4	30.8	30.8	0.893	2.000	1.785	269.9	131.9	0.725	0.890	2.006	3.10	1.000	0.000
15.30	Sand	19.5	13	Sandy Soil				289.4	121.9	11.5	11.5	0.233	1.440	0.336	289.4	141.4	0.710	0.872	0.385	2.60	0.385	1.598
15.50	Silt	17.5	12	Sandy Soil	22.9	-	0.339	308.5	131.0	10.2	15.6	0.267	1.551	0.414	308.5	150.5	0.695	0.855	0.484	2.10	0.484	1.083
			42	Sandy Soil				328.0	140.5	33.9	33.9	1.520	2.000	3.041	328.0	160.0	0.680	0.836	3.636	1.60	1.000	0.000
			51	Sandy Soil				347.5	150.0	39.4	39.4	3.792	2.000	7.584	347.5	169.5	0.665	0.818	9.273	1.10	1.000	0.000
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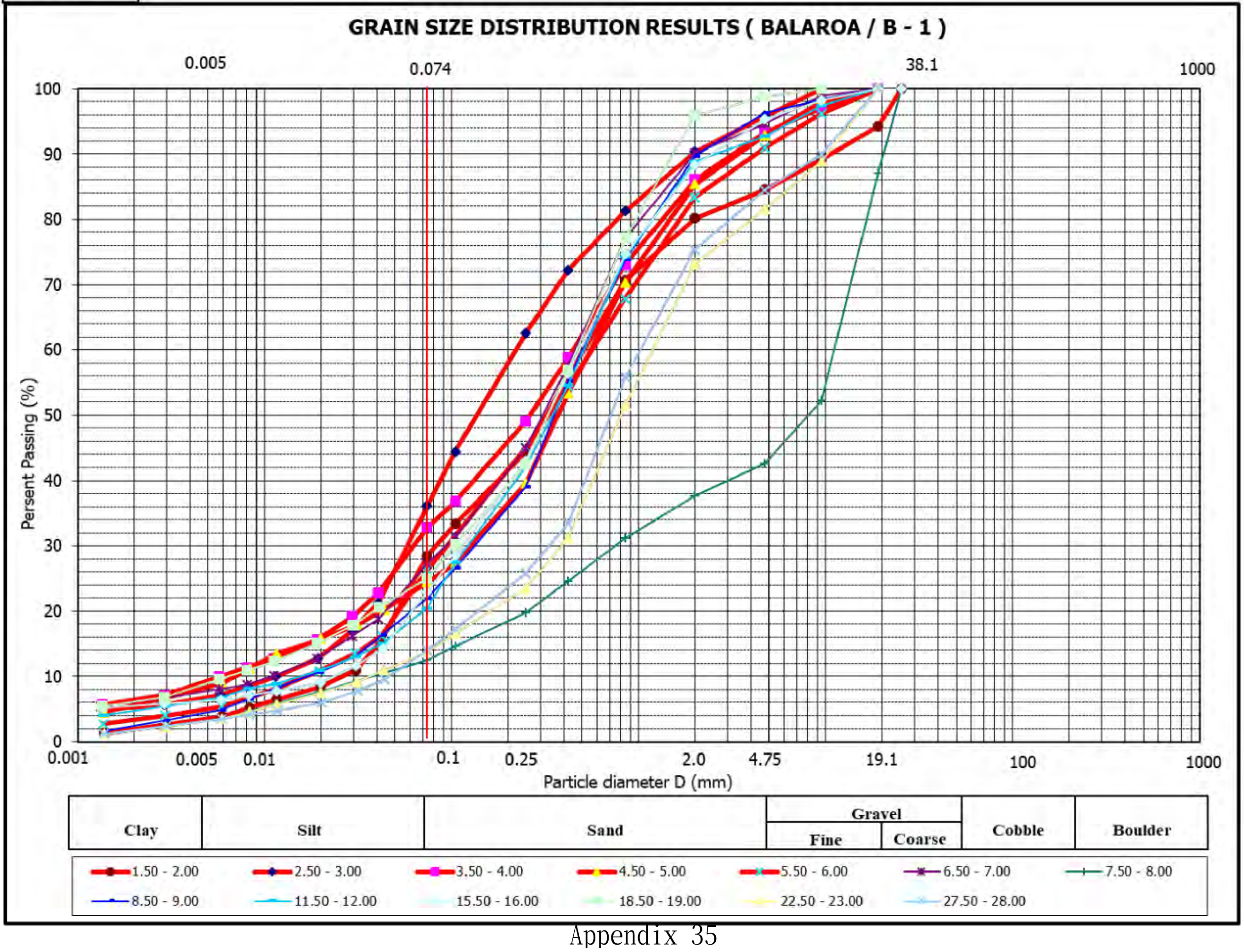
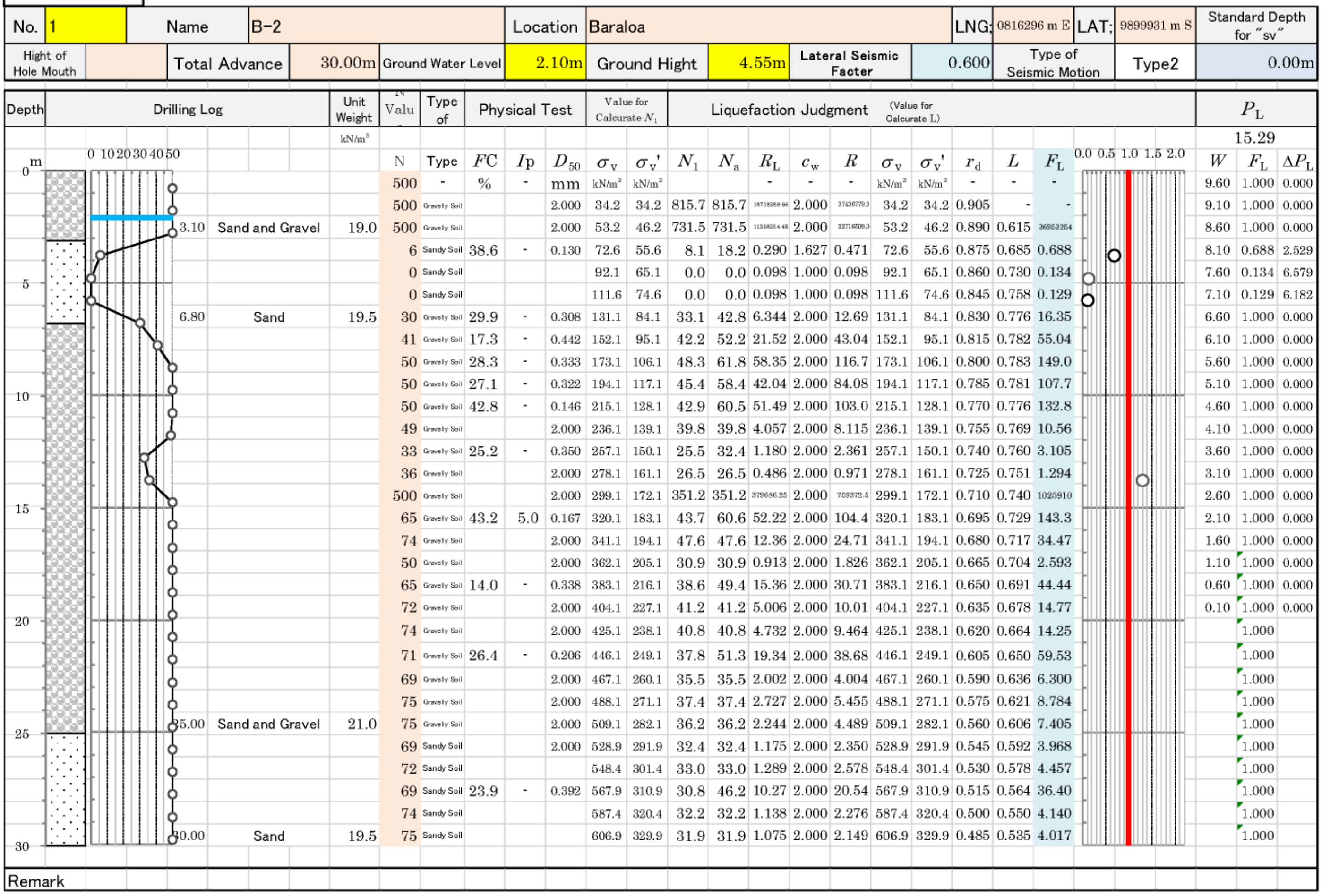
			26	Sandy Soil				386.5	169.0	18.5	18.5	0.292	1.635	0.478	386.5	188.5	0.635	0.781	0.612	0.10	0.612	0.039
			23	Sandy Soil				406.0	178.5	15.7	15.7	0.268	1.556	0.417	406.0	198.0	0.620	0.763	0.547		0.547	
			500	Sandy Soil				425.5	188.0	329.5	329.5	281676.41	2.000	563352.8	425.5	207.5	0.605	0.744	757039		1.000	
			40	Sandy Soil	13.7	-	0.817	445.0	197.5	25.4	28.8	0.662	2.000	1.323	445.0	217.0	0.590	0.726	1.824		1.000	
			37	Sandy Soil				464.5	207.0	22.7	22.7	0.350	1.824	0.638	464.5	226.5	0.575	0.707	0.901		0.901	
			37	Sandy Soil				484.0	216.5	22.0	22.0	0.335	1.776	0.595	484.0	236.0	0.560	0.689	0.864		0.864	
			34	Sandy Soil				503.5	226.0	19.5	19.5	0.302	1.668	0.505	503.5	245.5	0.545	0.670	0.753		0.753	
			39	Sandy Soil				523.0	235.5	21.7	21.7	0.331	1.762	0.583	523.0	255.0	0.530	0.652	0.894		0.894	
			45	Sandy Soil	14.1	-	0.738	542.5	245.0	24.3	27.9	0.580	2.000	1.160	542.5	264.5	0.515	0.634	1.832		1.000	
			42	Sandy Soil				562.0	254.5	22.0	22.0	0.336	1.779	0.598	562.0	274.0	0.500	0.615	0.971		0.971	
30.00	Sand	19.5	49	Sandy Soil				581.5	264.0	24.9	24.9	0.414	2.000	0.828	581.5	283.5	0.485	0.597	1.387		1.000	

Remark

B-1



B-2

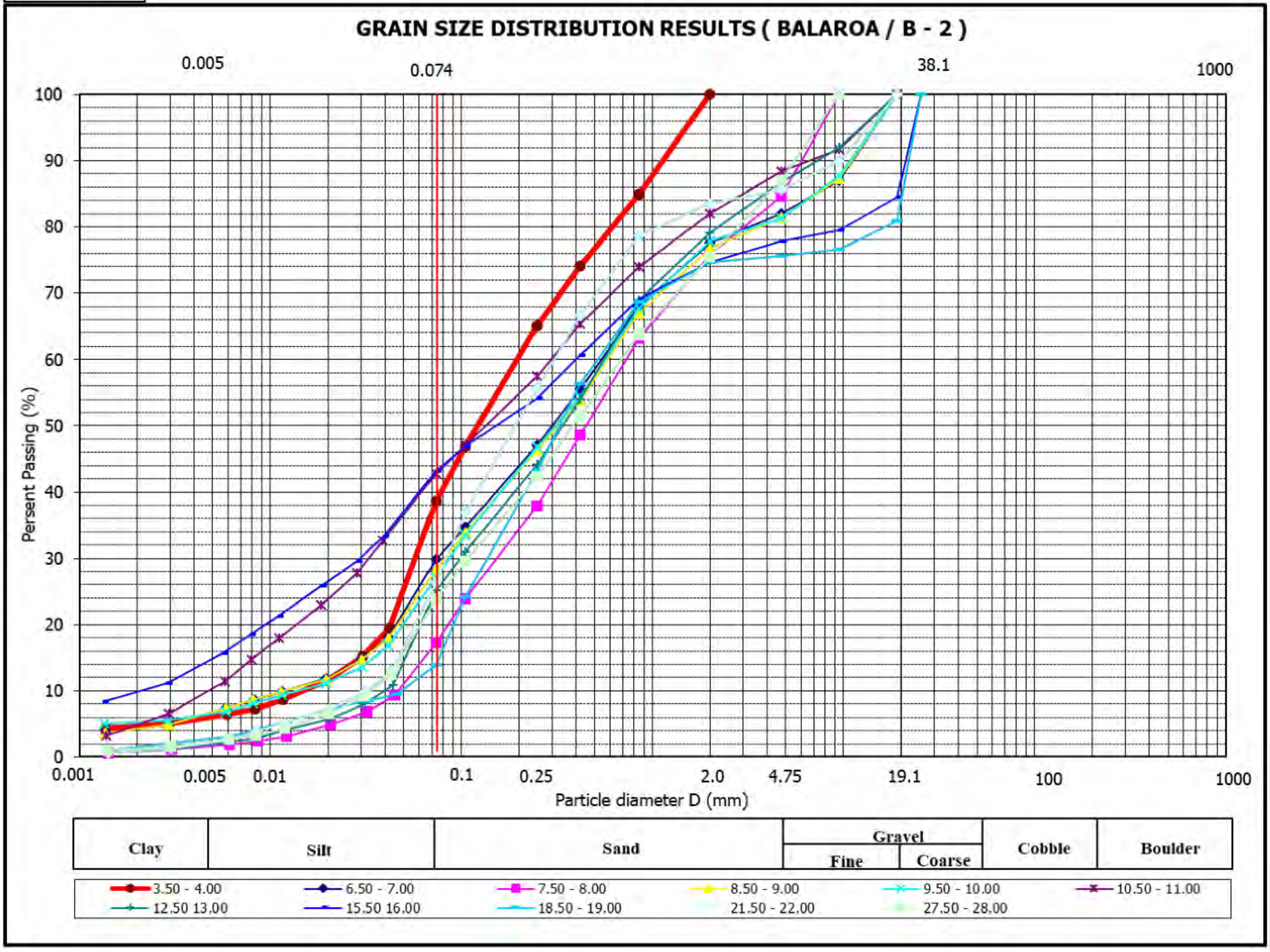


No.	1	Name	B-2	Location	Baraloa	LNG;	0816296 m E	LAT;	9899931 m S	Standard Depth for ″sv″		
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	2.10m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m

Depth	Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
			kN/m³																		15.29		
				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
				500	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
				500	Gravely Soil			2.000	34.2	34.2	815.7	815.7	18718389.66	2.000	37436779.3	34.2	34.2	0.905	-	-	9.10	1.000	0.000
	3.10	Sand and Gravel	19.0	500	Gravely Soil			2.000	53.2	46.2	731.5	731.5	11358254.48	2.000	22716509.0	53.2	46.2	0.890	0.615	36952254	8.60	1.000	0.000
				6	Sandy Soil	38.6	-	0.130	72.6	55.6	8.1	18.2	0.290	1.627	0.471	72.6	55.6	0.875	0.685	0.688	8.10	0.688	2.529
				0	Sandy Soil				92.1	65.1	0.0	0.0	0.098	1.000	0.098	92.1	65.1	0.860	0.730	0.134	7.60	0.134	6.579
				0	Sandy Soil				111.6	74.6	0.0	0.0	0.098	1.000	0.098	111.6	74.6	0.845	0.758	0.129	7.10	0.129	6.182
	6.80	Sand	19.5	30	Gravely Soil	29.9	-	0.308	131.1	84.1	33.1	42.8	6.344	2.000	12.69	131.1	84.1	0.830	0.776	16.35	6.60	1.000	0.000
				41	Gravely Soil	17.3	-	0.442	152.1	95.1	42.2	52.2	21.52	2.000	43.04	152.1	95.1	0.815	0.782	55.04	6.10	1.000	0.000
				50	Gravely Soil	28.3	-	0.333	173.1	106.1	48.3	61.8	58.35	2.000	116.7	173.1	106.1	0.800	0.783	149.0	5.60	1.000	0.000
				50	Gravely Soil	27.1	-	0.322	194.1	117.1	45.4	58.4	42.04	2.000	84.08	194.1	117.1	0.785	0.781	107.7	5.10	1.000	0.000
				50	Gravely Soil	42.8	-	0.146	215.1	128.1	42.9	60.5	51.49	2.000	103.0	215.1	128.1	0.770	0.776	132.8	4.60	1.000	0.000
				49	Gravely Soil			2.000	236.1	139.1	39.8	39.8	4.057	2.000	8.115	236.1	139.1	0.755	0.769	10.56	4.10	1.000	0.000
				33	Gravely Soil	25.2	-	0.350	257.1	150.1	25.5	32.4	1.180	2.000	2.361	257.1	150.1	0.740	0.760	3.105	3.60	1.000	0.000
				36	Gravely Soil			2.000	278.1	161.1	26.5	26.5	0.486	2.000	0.971	278.1	161.1	0.725	0.751	1.294	3.10	1.000	0.000
				500	Gravely Soil			2.000	299.1	172.1	351.2	351.2	379686.25	2.000	759372.5	299.1	172.1	0.710	0.740	1025910	2.60	1.000	0.000
				65	Gravely Soil	43.2	5.0	0.167	320.1	183.1	43.7	60.6	52.22	2.000	104.4	320.1	183.1	0.695	0.729	143.3	2.10	1.000	0.000
				74	Gravely Soil			2.000	341.1	194.1	47.6	47.6	12.36	2.000	24.71	341.1	194.1	0.680	0.717	34.47	1.60	1.000	0.000
				50	Gravely Soil			2.000	362.1	205.1	30.9	30.9	0.913	2.000	1.826	362.1	205.1	0.665	0.704	2.593	1.10	1.000	0.000
				65	Gravely Soil	14.0	-	0.338	383.1	216.1	38.6	49.4	15.36	2.000	30.71	383.1	216.1	0.650	0.691	44.44	0.60	1.000	0.000
				72	Gravely Soil			2.000	404.1	227.1	41.2	41.2	5.006	2.000	10.01	404.1	227.1	0.635	0.678	14.77	0.10	1.000	0.000
				74	Gravely Soil			2.000	425.1	238.1	40.8	40.8	4.732	2.000	9.464	425.1	238.1	0.620	0.664	14.25		1.000	
				71	Gravely Soil	26.4	-	0.206	446.1	249.1	37.8	51.3	19.34	2.000	38.68	446.1	249.1	0.605	0.650	59.53		1.000	
				69	Gravely Soil			2.000	467.1	260.1	35.5	35.5	2.002	2.000	4.004	467.1	260.1	0.590	0.636	6.300		1.000	
				75	Gravely Soil			2.000	488.1	271.1	37.4	37.4	2.727	2.000	5.455	488.1	271.1	0.575	0.621	8.784		1.000	
	25.00	Sand and Gravel	21.0	75	Gravely Soil			2.000	509.1	282.1	36.2	36.2	2.244	2.000	4.489	509.1	282.1	0.560	0.606	7.405		1.000	
				69	Sandy Soil			2.000	528.9	291.9	32.4	32.4	1.175	2.000	2.350	528.9	291.9	0.545	0.592	3.968		1.000	
				72	Sandy Soil				548.4	301.4	33.0	33.0	1.289	2.000	2.578	548.4	301.4	0.530	0.578	4.457		1.000	
				69	Sandy Soil	23.9	-	0.392	567.9	310.9	30.8	46.2	10.27	2.000	20.54	567.9	310.9	0.515	0.564	36.40		1.000	
				74	Sandy Soil				587.4	320.4	32.2	32.2	1.138	2.000	2.276	587.4	320.4	0.500	0.550	4.140		1.000	
	30.00	Sand	19.5	75	Sandy Soil				606.9	329.9	31.9	31.9	1.075	2.000	2.149	606.9	329.9	0.485	0.535	4.017		1.000	

Remark

B-2

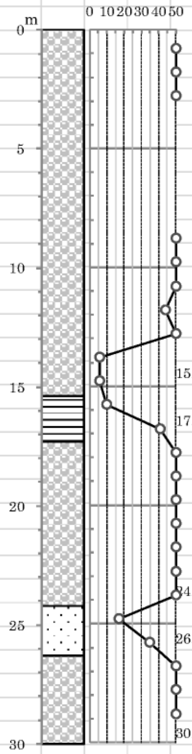


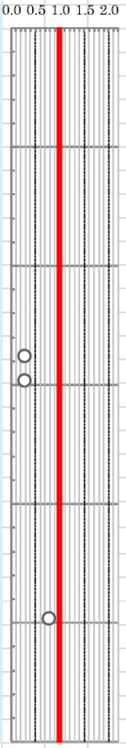
GRAIN SIZE DISTRIBUTION RESULTS (BALAROA / B - 2)

Appendix 36

B-3

No.	1	Name	B-3	Location	Baraloa	LNG;	0816347 m E	LAT;	9900455 m S	Standard Depth for "sv"		
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	-0.30m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m

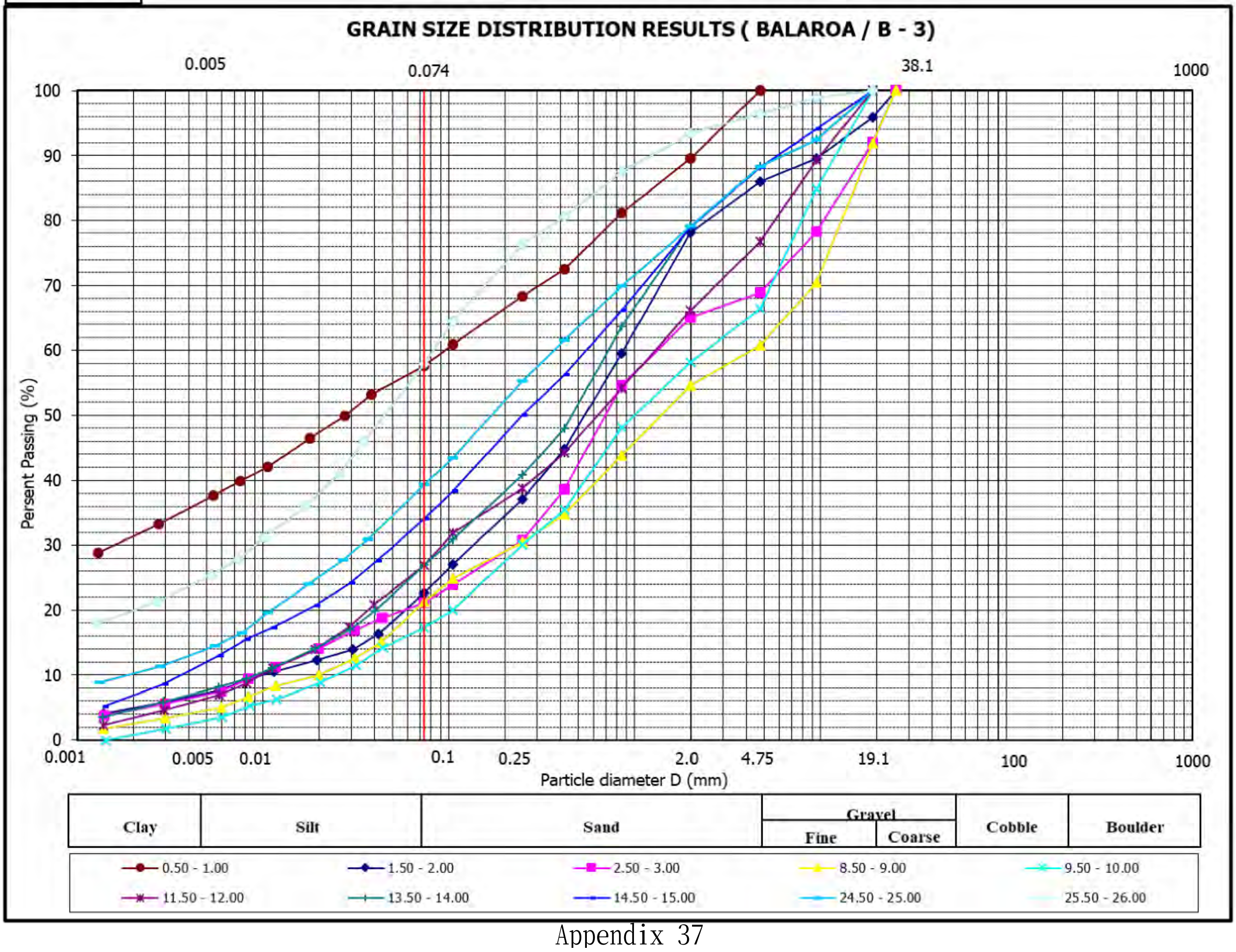




Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
		kN/m³																		4.13		
			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
			150	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
			150	Gravelly Soil	22.7	-	0.571	37.8	16.8	293.8	351.3	380503.84	2.000	761007.7	37.8	19.8	0.905	1.036	734315	9.10	1.000	0.000
			150	Gravelly Soil	21.2	-	0.726	58.8	27.8	260.7	302.0	186908.03	2.000	373816.1	58.8	30.8	0.890	1.019	366785	8.60	1.000	0.000
			500	Gravelly Soil	21.3	-	1.505	79.8	38.8	781.3	816.0	1874332.06	2.000	3748664.1	79.8	41.8	0.875	1.002	37412330	8.10	1.000	0.000
				Gravelly Soil	17.3	-	1.064	100.8	49.8	-	-	-	-	-	100.8	52.8	0.860	-	-	7.60	1.000	0.000
				Gravelly Soil				121.8	60.8	-	-	-	-	-	121.8	63.8	0.845	-	-	7.10	1.000	0.000
				Gravelly Soil				142.8	71.8	-	-	-	-	-	142.8	74.8	0.830	-	-	6.60	1.000	0.000
				Gravelly Soil				163.8	82.8	-	-	-	-	-	163.8	85.8	0.815	-	-	6.10	1.000	0.000
			61	Gravelly Soil			2.000	184.8	93.8	63.3	63.3	66.96	2.000	133.9	184.8	96.8	0.800	0.916	146.2	5.60	1.000	0.000
			56	Gravelly Soil			2.000	205.8	104.8	54.5	54.5	27.78	2.000	55.56	205.8	107.8	0.785	0.899	61.81	5.10	1.000	0.000
			150	Gravelly Soil			2.000	226.8	115.8	137.2	137.2	4098.79	2.000	8197.6	226.8	118.8	0.770	0.882	9297	4.60	1.000	0.000
			44	Gravelly Soil	27.0	-	0.668	247.8	126.8	38.0	44.5	8.127	2.000	16.25	247.8	129.8	0.755	0.865	18.80	4.10	1.000	0.000
			150	Gravelly Soil			2.000	268.8	137.8	122.7	122.7	2331.02	2.000	4662.0	268.8	140.8	0.740	0.847	5502	3.60	1.000	0.000
			6	Gravelly Soil	26.9	-	0.476	289.8	148.8	4.7	5.7	0.178	1.259	0.224	289.8	151.8	0.725	0.830	0.270	3.10	0.270	2.262
15.40	Sand and Gravel	21.0	6	Gravelly Soil	34.1	-	0.249	310.8	159.8	4.4	5.9	0.180	1.265	0.228	310.8	162.8	0.710	0.813	0.281	2.60	0.281	1.871
			10	-			2.000	330.4	169.4	7.1	-	-	-	-	330.4	172.4	0.695	0.799	-	2.10	1.000	0.000
17.30	Silt	17.5	41	-				347.9	176.9	28.2	-	-	-	-	347.9	179.9	0.680	0.789	-	1.60	1.000	0.000
			150	Gravelly Soil			2.000	367.2	186.2	99.6	99.6	793.42	2.000	1586.8	367.2	189.2	0.665	0.774	2050	1.10	1.000	0.000
			150	Gravelly Soil			2.000	388.2	197.2	95.5	95.5	636.25	2.000	1272.5	388.2	200.2	0.650	0.756	1683	0.60	1.000	0.000
			150	Gravelly Soil			2.000	409.2	208.2	91.7	91.7	514.03	2.000	1028.1	409.2	211.2	0.635	0.738	1393	0.10	1.000	0.000
			300	Gravelly Soil			2.000	430.2	219.2	176.4	176.4	14175.30	2.000	28350.6	430.2	222.2	0.620	0.720	39375		1.000	
			120	Gravelly Soil			2.000	451.2	230.2	68.0	68.0	100.25	2.000	200.5	451.2	233.2	0.605	0.702	285.6		1.000	
			115	Gravelly Soil			2.000	472.2	241.2	62.8	62.8	64.11	2.000	128.2	472.2	244.2	0.590	0.684	187.4		1.000	
24.20	Sand and Gravel	21.0	120	Gravelly Soil			2.000	493.2	252.2	63.3	63.3	67.05	2.000	134.1	493.2	255.2	0.575	0.667	201.2		1.000	
			17	Sandy Soil	39.3	-	0.186	513.3	262.3	8.7	19.6	0.303	1.671	0.507	513.3	265.3	0.560	0.650	0.780		0.780	
26.30	Sand	19.5	35	Sandy Soil	57.9	6.7	0.048	532.8	271.8	17.4	66.9	92.07	2.000	184.1	532.8	274.8	0.545	0.634	290.5		1.000	
			100	Gravelly Soil			2.000	553.0	282.0	48.3	48.3	13.43	2.000	26.86	553.0	285.0	0.530	0.617	43.56		1.000	
			150	Gravelly Soil			2.000	574.0	293.0	70.2	70.2	120.68	2.000	241.4	574.0	296.0	0.515	0.599	403.0		1.000	
			300	Gravelly Soil			2.000	595.0	304.0	136.4	136.4	3968.64	2.000	7937.3	595.0	307.0	0.500	0.581	13658		1.000	
30.00	Sand and Gravel	21.0	200	Gravelly Soil			2.000	616.0	315.0	88.3	88.3	421.24	2.000	842.5	616.0	318.0	0.485	0.563	1495		1.000	

Remark

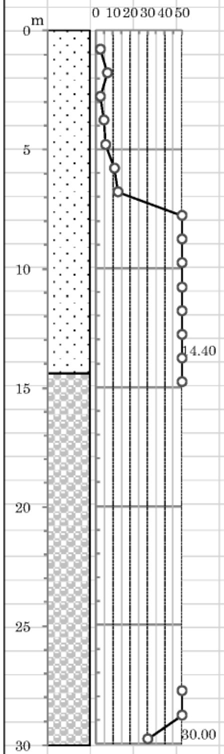
B-3



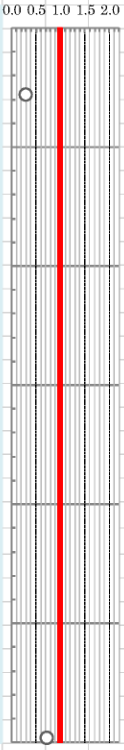
B-4

No.	1	Name	B-4	Location	Baraloa	LNG;	0816423 m E	LAT;	9899102 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	-0.60m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m

Depth | Drilling Log

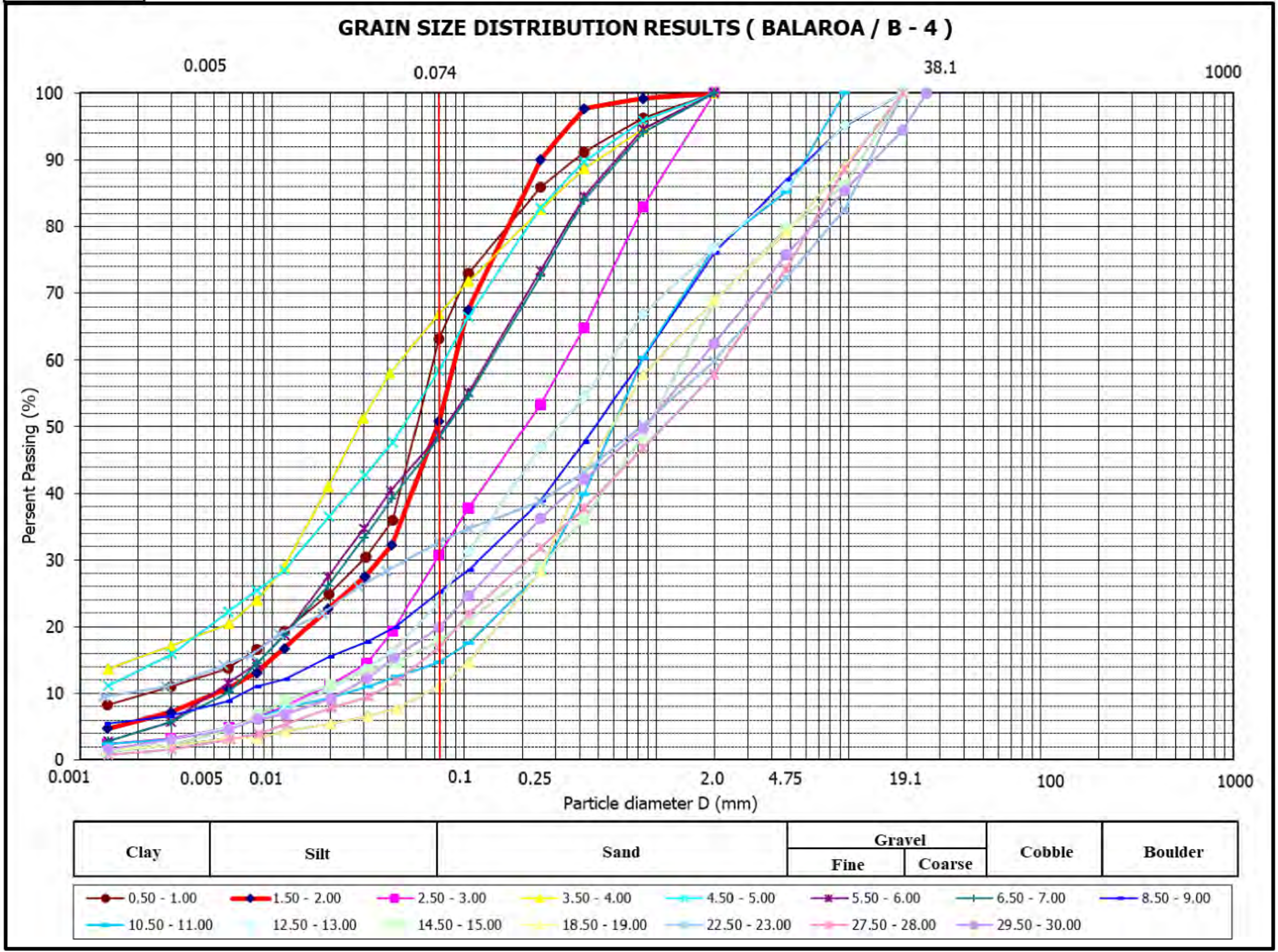


Unit Weight kN/m³	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment					(Value for Calcurate L)					P_L 6.01		
	N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
	3	-	%	-	mm	kN/m³	kN/m³			-	-	-	kN/m³	kN/m³	-	-	-	9.60	1.000	0.000
	7	Sandy Soil	50.9	-	0.073	35.1	11.1	14.7	47.3	11.86	2.000	23.72	35.1	17.1	0.905	1.114	21.28	9.10	1.000	0.000
	3	Sandy Soil	30.8	-	0.220	54.6	20.6	5.6	11.2	0.231	1.432	0.331	54.6	26.6	0.890	1.096	0.302	8.60	0.302	6.006
	5	Sandy Soil	66.9	20.2	0.029	74.1	30.1	8.5	44.0	7.575	2.000	15.15	74.1	36.1	0.875	1.077	14.06	8.10	1.000	0.000
	6	Sandy Soil	58.5	18.7	0.049	93.6	39.6	9.3	39.3	3.692	2.000	7.385	93.6	45.6	0.860	1.059	6.974	7.60	1.000	0.000
	11	Sandy Soil	48.8	7.1	0.080	113.1	49.1	15.7	47.2	11.60	2.000	23.19	113.1	55.1	0.845	1.040	22.29	7.10	1.000	0.000
	13	Sandy Soil	48.3	6.9	0.082	132.6	58.6	17.2	50.4	17.45	2.000	34.90	132.6	64.6	0.830	1.022	34.15	6.60	1.000	0.000
	141	Sandy Soil				152.1	68.1	173.6	173.6	13104.75	2.000	26209.5	152.1	74.1	0.815	1.003	26120	6.10	1.000	0.000
	90	Sandy Soil	25.1	-	0.502	171.6	77.6	103.7	157.2	8040.05	2.000	16080.1	171.6	83.6	0.800	0.985	16326	5.60	1.000	0.000
	61	Sandy Soil				191.1	87.1	66.0	66.0	84.97	2.000	169.9	191.1	93.1	0.785	0.966	175.8	5.10	1.000	0.000
	50	Sandy Soil	14.7	-	0.633	210.6	96.6	51.0	59.4	46.24	2.000	92.48	210.6	102.6	0.770	0.948	97.55	4.60	1.000	0.000
	69	Sandy Soil				230.1	106.1	66.6	66.6	89.46	2.000	178.9	230.1	112.1	0.755	0.930	192.5	4.10	1.000	0.000
	84	Sandy Soil	23.6	-	0.319	249.6	115.6	76.9	113.0	1530.40	2.000	3060.8	249.6	121.6	0.740	0.911	3360	3.60	1.000	0.000
19.5	70	Sandy Soil				269.1	125.1	61.0	61.0	54.02	2.000	108.0	269.1	131.1	0.725	0.893	121.1	3.10	1.000	0.000
	135	Gravely Soil	17.8	-	0.931	289.2	135.2	111.8	125.2	2582.64	2.000	5165.3	289.2	141.2	0.710	0.872	5922	2.60	1.000	0.000
		Gravely Soil			2.000	310.2	146.2	-	-	-	-	-	310.2	152.2	0.695	-	-	2.10	1.000	0.000
		Gravely Soil				331.2	157.2	-	-	-	-	-	331.2	163.2	0.680	-	-	1.60	1.000	0.000
		Gravely Soil				352.2	168.2	-	-	-	-	-	352.2	174.2	0.665	-	-	1.10	1.000	0.000
		Gravely Soil	11.0	-	0.623	373.2	179.2	-	-	-	-	-	373.2	185.2	0.650	-	-	0.60	1.000	0.000
		Gravely Soil				394.2	190.2	-	-	-	-	-	394.2	196.2	0.635	-	-	0.10	1.000	0.000
		Gravely Soil				415.2	201.2	-	-	-	-	-	415.2	207.2	0.620	-	-		1.000	
		Gravely Soil				436.2	212.2	-	-	-	-	-	436.2	218.2	0.605	-	-		1.000	
		Gravely Soil	32.7	-	0.834	457.2	223.2	-	-	-	-	-	457.2	229.2	0.590	-	-		1.000	
		Gravely Soil				478.2	234.2	-	-	-	-	-	478.2	240.2	0.575	-	-		1.000	
		Gravely Soil				499.2	245.2	-	-	-	-	-	499.2	251.2	0.560	-	-		1.000	
		Gravely Soil				520.2	256.2	-	-	-	-	-	520.2	262.2	0.545	-	-		1.000	
		Gravely Soil				541.2	267.2	-	-	-	-	-	541.2	273.2	0.530	-	-		1.000	
	75	Gravely Soil	16.9	-	1.182	562.2	278.2	36.6	39.6	3.919	2.000	7.838	562.2	284.2	0.515	0.611	12.83		1.000	
	120	Gravely Soil			2.000	583.2	289.2	56.8	56.8	35.61	2.000	71.22	583.2	295.2	0.500	0.592	120.2		1.000	
21.0	30	Gravely Soil	19.8	-	0.872	604.2	300.2	13.8	15.6	0.267	1.551	0.414	604.2	306.2	0.485	0.574	0.721		0.721	



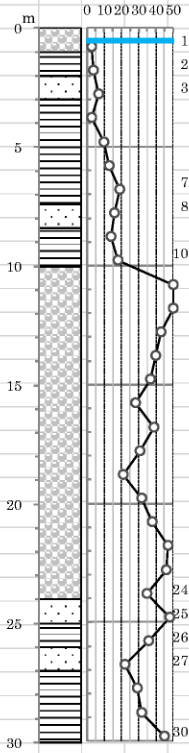
Remark

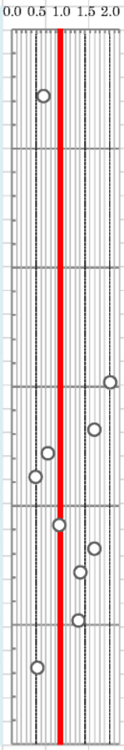
B-4



B-5

No.	1	Name	B-5	Location	Baraloa	LNG;	0816912 m E	LAT;	9899918 m S	Standard Depth for "sv"	
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	0.55m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2
											0.00m

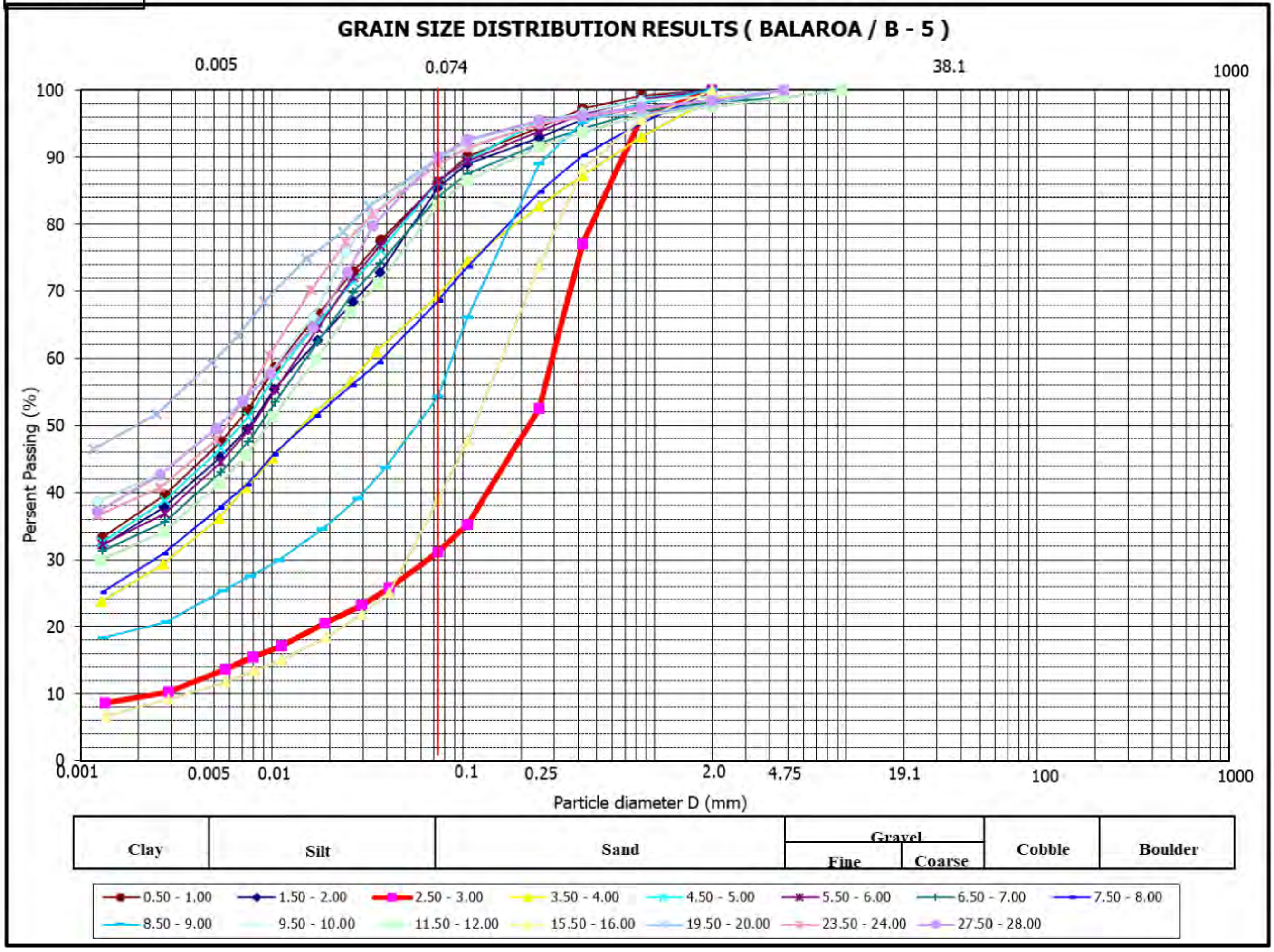




Depth	Drilling Log	Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
		kN/m³																		3.59		
			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
1.00	Top Soil or Back-fill	15.0	3	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
2.00	Silt	17.5	4	-	85.4	22.8	0.008	29.0	16.5	7.9	-	-	-	-	29.0	16.5	0.905	0.954	-	9.10	1.000	0.000
3.00	Sand	19.5	7	Sandy Soil	31.1	-	0.229	48.1	25.6	12.4	22.9	0.354	1.839	0.652	48.1	25.6	0.890	1.003	0.650	8.60	0.650	3.011
			3	-	69.4	12.2	0.015	66.0	33.5	4.9	-	-	-	-	66.0	33.5	0.875	1.034	-	8.10	1.000	0.000
			10	-	86.3	24.1	0.007	83.5	41.0	15.3	-	-	-	-	83.5	41.0	0.860	1.051	-	7.60	1.000	0.000
			13	-	86.4	23.6	0.008	101.0	48.5	18.6	-	-	-	-	101.0	48.5	0.845	1.056	-	7.10	1.000	0.000
7.40	Silt	17.5	19	-	84.1	22.1	0.009	118.5	56.0	25.6	-	-	-	-	118.5	56.0	0.830	1.053	-	6.60	1.000	0.000
8.40	Sand	19.5	16	Sandy Soil	68.7	12.2	0.015	136.8	64.3	20.3	97.2	701.24	2.000	1402.5	136.8	64.3	0.815	1.040	1348	6.10	1.000	0.000
			14	-	54.3	-	0.020	155.5	73.0	16.6	-	-	-	-	155.5	73.0	0.800	1.022	-	5.60	1.000	0.000
10.00	Silt	17.5	18	-	90.0	22.6	0.005	173.0	80.5	20.3	-	-	-	-	173.0	80.5	0.785	1.012	-	5.10	1.000	0.000
			50	Gravely Soil			2.000	193.3	90.8	52.9	52.9	23.24	2.000	46.48	193.3	90.8	0.770	0.983	47.27	4.60	1.000	0.000
			57	Gravely Soil	82.8	23.5	0.010	214.3	101.8	56.4	103.6	975.36	2.000	1950.7	214.3	101.8	0.755	0.953	2046	4.10	1.000	0.000
			43	Gravely Soil			2.000	235.3	112.8	40.0	40.0	4.149	2.000	8.298	235.3	112.8	0.740	0.926	8.962	3.60	1.000	0.000
			40	Gravely Soil			2.000	256.3	123.8	35.1	35.1	1.854	2.000	3.707	256.3	123.8	0.725	0.900	4.118	3.10	1.000	0.000
			37	Gravely Soil			2.000	277.3	134.8	30.7	30.7	0.885	2.000	1.770	277.3	134.8	0.710	0.876	2.021	2.60	1.000	0.000
			28	Gravely Soil	38.9	-	0.119	298.3	145.8	22.1	31.8	1.059	2.000	2.118	298.3	145.8	0.695	0.853	2.484	2.10	1.000	0.000
			39	Gravely Soil			2.000	319.3	156.8	29.2	29.2	0.702	2.000	1.404	319.3	156.8	0.680	0.831	1.690	1.60	1.000	0.000
			31	Gravely Soil			2.000	340.3	167.8	22.2	22.2	0.339	1.788	0.606	340.3	167.8	0.665	0.809	0.749	1.10	0.749	0.276
			21	Gravely Soil			2.000	361.3	178.8	14.3	14.3	0.256	1.516	0.388	361.3	178.8	0.650	0.788	0.493	0.60	0.493	0.304
			32	Gravely Soil	89.9	23.3	0.002	382.3	189.8	20.9	43.6	7.136	2.000	14.27	382.3	189.8	0.635	0.767	18.60	0.10	1.000	0.000
			38	Gravely Soil			2.000	403.3	200.8	23.9	23.9	0.378	1.917	0.724	403.3	200.8	0.620	0.747	0.970		0.970	
			47	Gravely Soil			2.000	424.3	211.8	28.4	28.4	0.617	2.000	1.235	424.3	211.8	0.605	0.727	1.699		1.000	
			46	Gravely Soil			2.000	445.3	222.8	26.7	26.7	0.498	2.000	0.997	445.3	222.8	0.590	0.707	1.409		1.000	
24.00	Sand and Gravel	21.0	35	Gravely Soil	88.9	23.5	0.006	466.3	233.8	19.6	37.4	2.746	2.000	5.491	466.3	233.8	0.575	0.688	7.984		1.000	
25.00	Sand	19.5	48	Sandy Soil				486.1	243.6	26.0	26.0	0.461	2.000	0.922	486.1	243.6	0.560	0.670	1.375		1.000	
26.00	Silt	17.5	36	-				504.0	251.5	19.0	-	-	-	-	504.0	251.5	0.545	0.655	-		1.000	
27.00	Sand	19.5	22	Sandy Soil				523.1	260.6	11.3	11.3	0.232	1.434	0.332	523.1	260.6	0.530	0.638	0.520		0.520	
			29	-	90.1	23.4	0.005	541.0	268.5	14.6	-	-	-	-	541.0	268.5	0.515	0.622	-		1.000	
			32	-				558.5	276.0	15.7	-	-	-	-	558.5	276.0	0.500	0.607	-		1.000	
30.00	Silt	17.5	45	-				576.0	283.5	21.6	-	-	-	-	576.0	283.5	0.485	0.591	-		1.000	

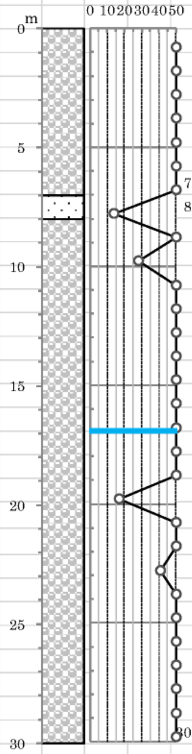
Remark

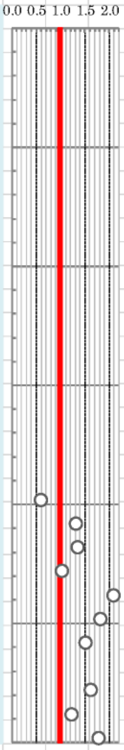
B-5



B-6

No.	1	Name	B-6	Location	Baraloa	LNG;	0816235 m E	LAT;	9897507 m S	Standard Depth for "sv"		
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	16.91m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m

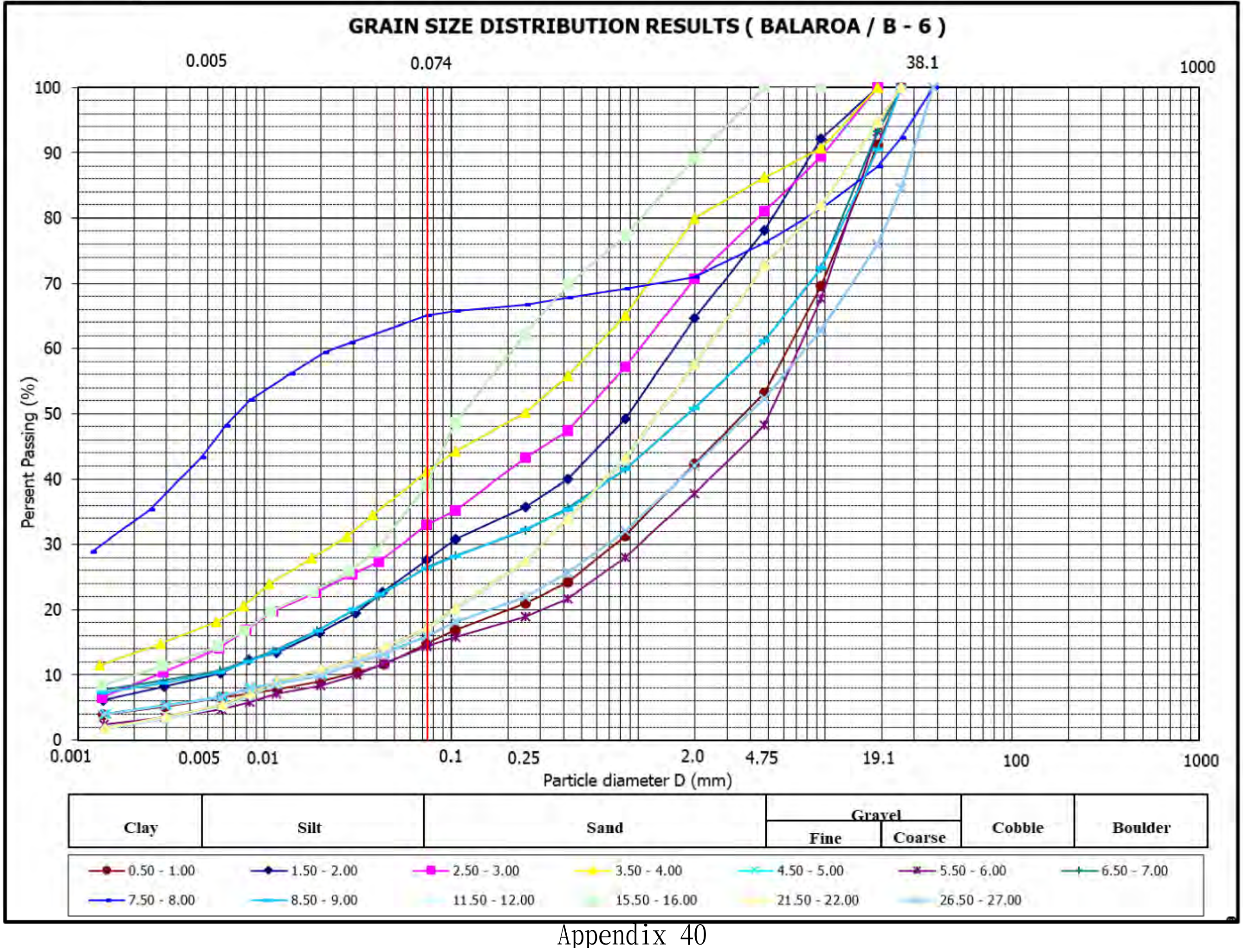




Depth	Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)									P_L		
			kN/m³																	0.04		
				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
				150	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
				150	Gravelly Soil	27.6	-	0.911	34.2	34.2	244.7	274.8	119526.66	2.000	239053.3	34.2	34.2	0.905	-	-	9.10	1.000	0.000
				150	Gravelly Soil	32.9	-	0.532	53.2	53.2	207.0	249.8	75972.18	2.000	151944.4	53.2	53.2	0.890	-	-	8.60	1.000	0.000
				150	Gravelly Soil	41.1	8.1	0.245	72.2	72.2	179.3	238.2	60488.92	2.000	120977.8	72.2	72.2	0.875	-	-	8.10	1.000	0.000
				105	Gravelly Soil	15.9	-	4.117	91.2	91.2	110.7	98.2	739.91	2.000	1479.8	91.2	91.2	0.860	-	-	7.60	1.000	0.000
				75	Gravelly Soil	14.3	-	5.179	110.2	110.2	70.8	60.2	50.21	2.000	100.4	110.2	110.2	0.845	-	-	7.10	1.000	0.000
	7.00	Sand and Gravel	19.0	54	Gravelly Soil	26.4	-	1.891	129.2	129.2	46.1	46.5	10.62	2.000	21.24	129.2	129.2	0.830	-	-	6.60	1.000	0.000
	8.00	Sand	17.5	14	Sandy Soil	65.1	19.5	0.007	147.0	147.0	11.0	52.5	22.22	2.000	44.44	147.0	147.0	0.815	-	-	6.10	1.000	0.000
				150	Gravelly Soil	26.3	-	1.890	165.7	165.7	108.2	109.1	1279.83	2.000	2559.7	165.7	165.7	0.800	-	-	5.60	1.000	0.000
				28	Gravelly Soil			2.000	184.7	184.7	18.7	18.7	0.294	1.641	0.483	184.7	184.7	0.785	-	-	5.10	1.000	0.000
				150	Gravelly Soil			2.000	203.7	203.7	93.2	93.2	559.88	2.000	1119.8	203.7	203.7	0.770	-	-	4.60	1.000	0.000
				53	Gravelly Soil	16.9	-	1.407	222.7	222.7	30.8	32.5	1.187	2.000	2.374	222.7	222.7	0.755	-	-	4.10	1.000	0.000
				51	Gravelly Soil			2.000	241.7	241.7	27.8	27.8	0.573	2.000	1.147	241.7	241.7	0.740	-	-	3.60	1.000	0.000
				150	Gravelly Soil			2.000	260.7	260.7	77.1	77.1	202.22	2.000	404.4	260.7	260.7	0.725	-	-	3.10	1.000	0.000
				61	Gravelly Soil			2.000	279.7	279.7	29.7	29.7	0.749	2.000	1.497	279.7	279.7	0.710	-	-	2.60	1.000	0.000
				50	Gravelly Soil	39.2	-	0.120	298.7	298.7	23.1	33.2	1.344	2.000	2.688	298.7	298.7	0.695	-	-	2.10	1.000	0.000
				68	Gravelly Soil			2.000	317.7	317.7	29.8	29.8	0.768	2.000	1.535	317.7	317.7	0.680	-	-	1.60	1.000	0.000
				72	Gravelly Soil			2.000	336.7	327.8	30.8	30.8	0.893	2.000	1.787	336.7	327.8	0.665	0.410	4.361	1.10	1.000	0.000
				85	Gravelly Soil			2.000	355.7	336.8	35.5	35.5	1.995	2.000	3.991	355.7	336.8	0.650	0.412	9.693	0.60	1.000	0.000
				17	Gravelly Soil			2.000	374.7	345.8	7.0	7.0	0.191	1.302	0.249	374.7	345.8	0.635	0.413	0.604	0.10	0.604	0.040
				52	Gravelly Soil			2.000	393.7	354.8	20.8	20.8	0.318	1.718	0.546	393.7	354.8	0.620	0.413	1.322		1.000	
				51	Gravelly Soil	17.1	-	1.391	412.7	363.8	20.0	21.1	0.322	1.732	0.558	412.7	363.8	0.605	0.412	1.355		1.000	
				41	Gravelly Soil			2.000	431.7	372.8	15.7	15.7	0.268	1.556	0.418	431.7	372.8	0.590	0.410	1.019		1.000	
				67	Gravelly Soil			2.000	450.7	381.8	25.2	25.2	0.424	2.000	0.849	450.7	381.8	0.575	0.407	2.084		1.000	
				65	Gravelly Soil			2.000	469.7	390.8	24.0	24.0	0.381	1.929	0.736	469.7	390.8	0.560	0.404	1.822		1.000	
				61	Gravelly Soil			2.000	488.7	399.8	22.1	22.1	0.337	1.783	0.601	488.7	399.8	0.545	0.400	1.504		1.000	
				270	Gravelly Soil	15.9	-	4.117	507.7	408.8	95.9	85.0	344.19	2.000	688.4	507.7	408.8	0.530	0.395	1744		1.000	
				65	Gravelly Soil			2.000	526.7	417.8	22.7	22.7	0.348	1.820	0.634	526.7	417.8	0.515	0.389	1.628		1.000	
				53	Gravelly Soil			2.000	545.7	426.8	18.1	18.1	0.289	1.624	0.469	545.7	426.8	0.500	0.383	1.224		1.000	
	30.00	Sand and Gravel	19.0	69	Gravelly Soil			2.000	564.7	435.8	23.2	23.2	0.360	1.859	0.670	564.7	435.8	0.485	0.377	1.778		1.000	

Remark

B-6



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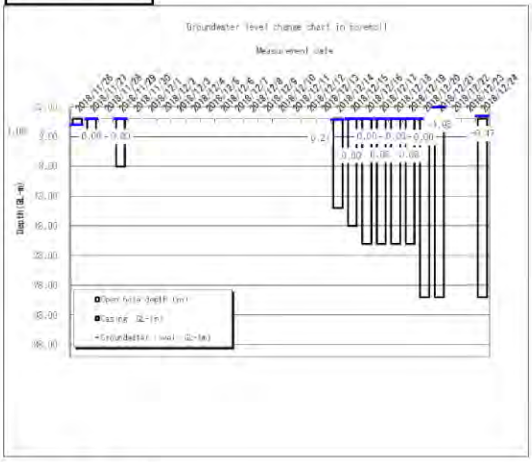

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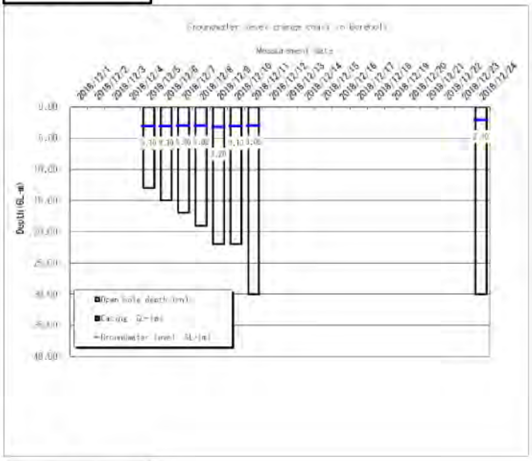

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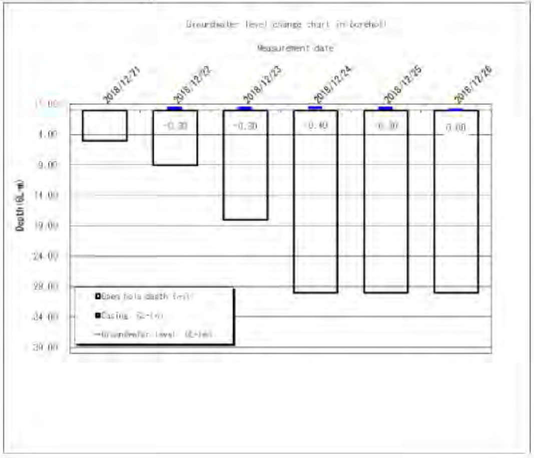
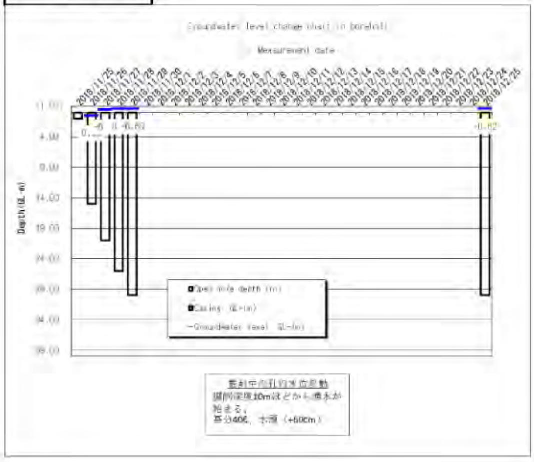


B-4



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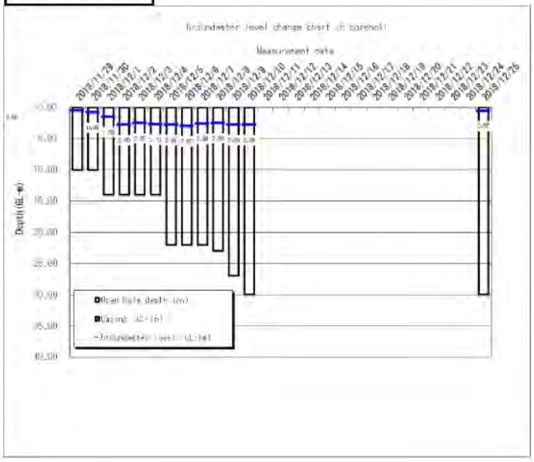

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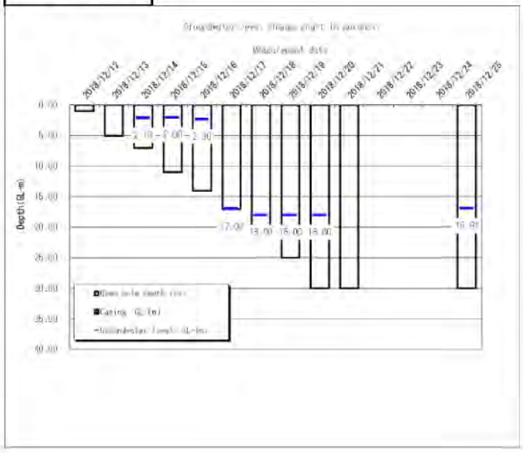
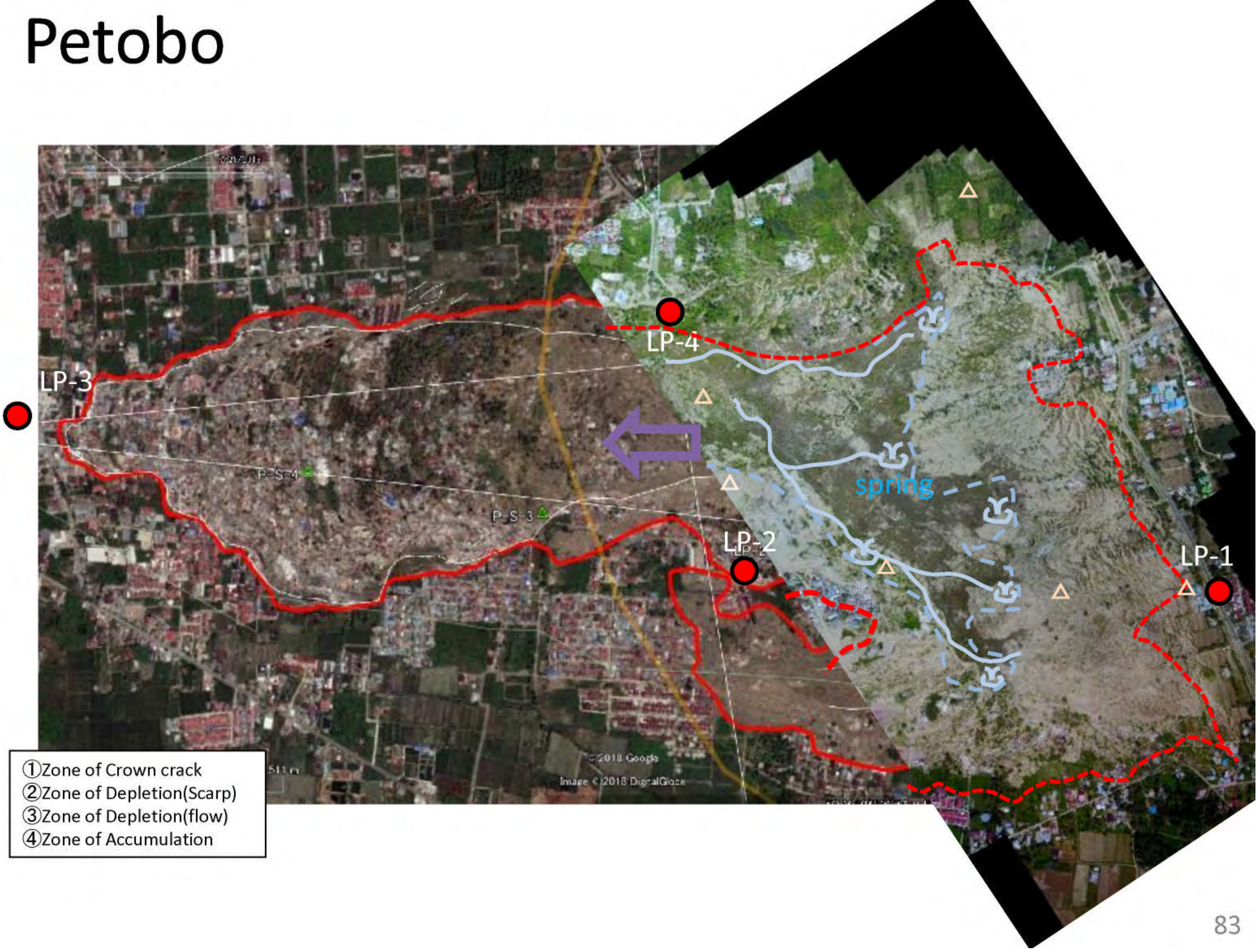
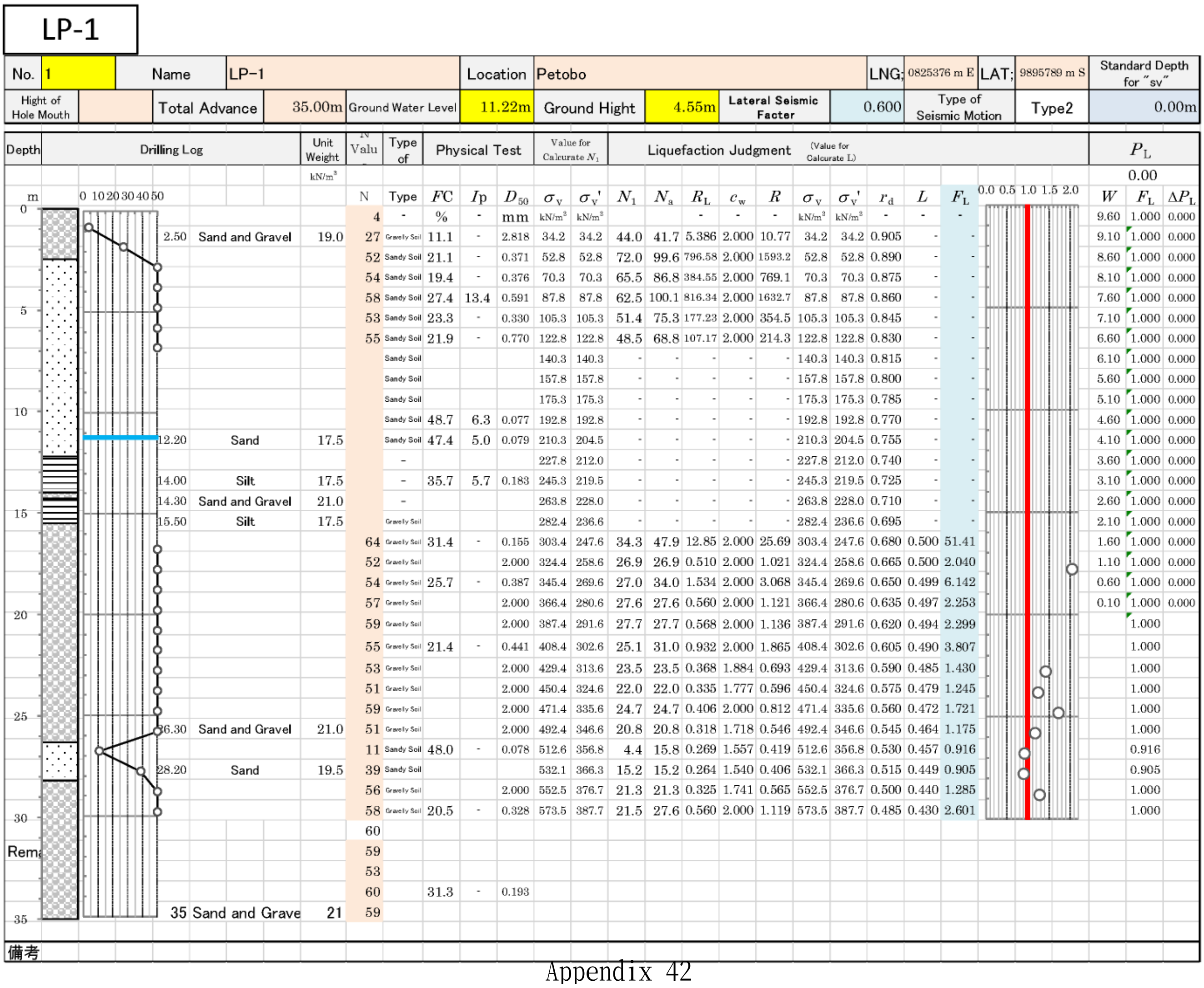


Petobo



LP-1

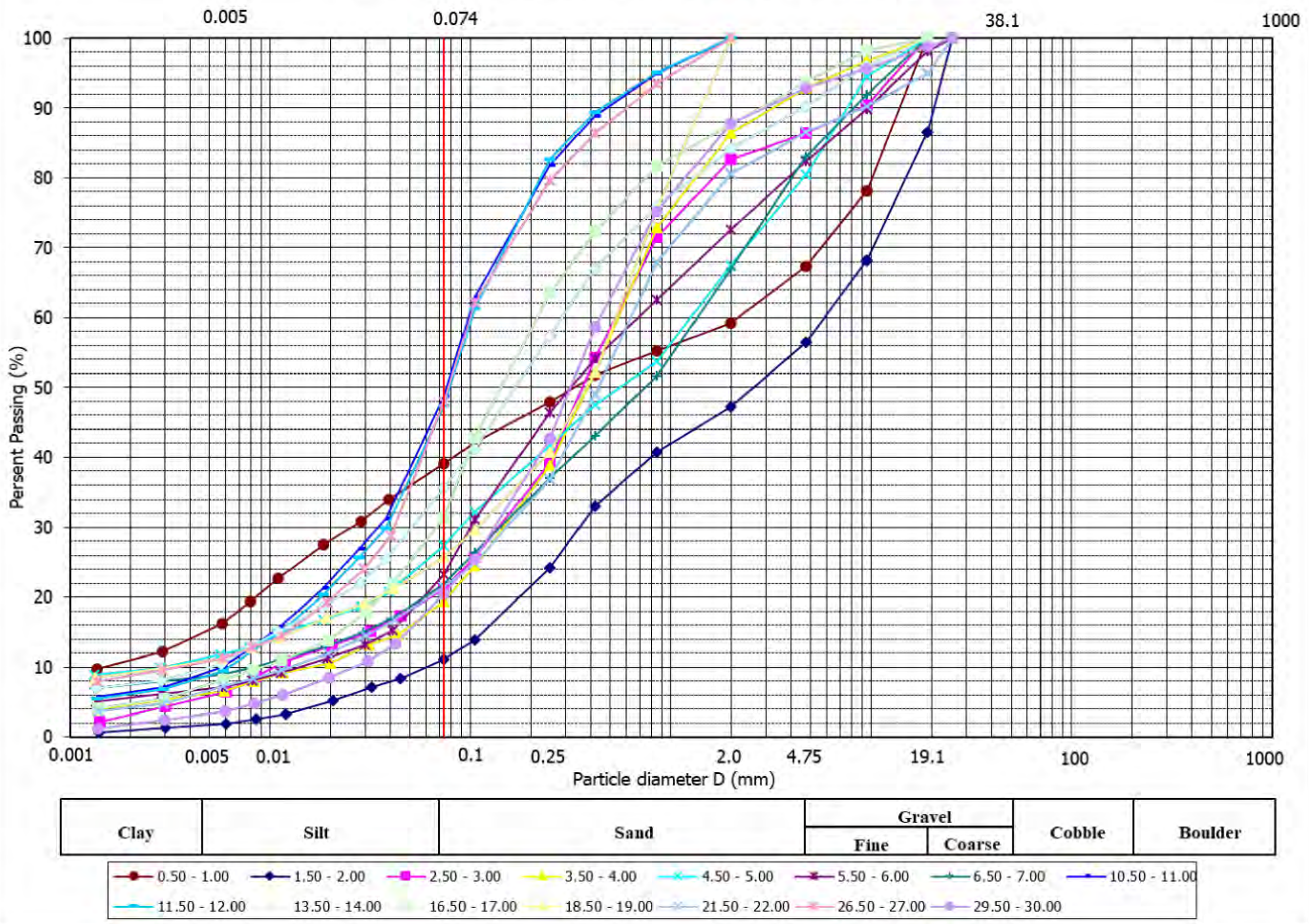


No.	1	Name	LP−1	Location	Petobo			LNG;	0825376 m E	LAT;	9895789 m S
Hight of Hole Mouth		Total Advance	35.00m	Ground Water Level	11.22m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2
Standard Depth for "sv"	0.00m										

Depth	Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment					(Value for Calcurate L)					P_L		
			kN/m³																		0.00		
m				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
				4	-	%	-	mm	kN/m³	kN/m³			-	-	-	kN/m³	kN/m³	-	-	-	9.60	1.000	0.000
	2.50	Sand and Gravel	19.0	27	Gravelly Soil	11.1	-	2.818	34.2	34.2	44.0	41.7	5.386	2.000	10.77	34.2	34.2	0.905	-	-	9.10	1.000	0.000
				52	Sandy Soil	21.1	-	0.371	52.8	52.8	72.0	99.6	796.58	2.000	1593.2	52.8	52.8	0.890	-	-	8.60	1.000	0.000
				54	Sandy Soil	19.4	-	0.376	70.3	70.3	65.5	86.8	384.55	2.000	769.1	70.3	70.3	0.875	-	-	8.10	1.000	0.000
				58	Sandy Soil	27.4	13.4	0.591	87.8	87.8	62.5	100.1	816.34	2.000	1632.7	87.8	87.8	0.860	-	-	7.60	1.000	0.000
				53	Sandy Soil	23.3	-	0.330	105.3	105.3	51.4	75.3	177.23	2.000	354.5	105.3	105.3	0.845	-	-	7.10	1.000	0.000
				55	Sandy Soil	21.9	-	0.770	122.8	122.8	48.5	68.8	107.17	2.000	214.3	122.8	122.8	0.830	-	-	6.60	1.000	0.000
					Sandy Soil				140.3	140.3	-	-	-	-	-	140.3	140.3	0.815	-	-	6.10	1.000	0.000
					Sandy Soil				157.8	157.8	-	-	-	-	-	157.8	157.8	0.800	-	-	5.60	1.000	0.000
					Sandy Soil				175.3	175.3	-	-	-	-	-	175.3	175.3	0.785	-	-	5.10	1.000	0.000
					Sandy Soil	48.7	6.3	0.077	192.8	192.8	-	-	-	-	-	192.8	192.8	0.770	-	-	4.60	1.000	0.000
	12.20	Sand	17.5		Sandy Soil	47.4	5.0	0.079	210.3	204.5	-	-	-	-	-	210.3	204.5	0.755	-	-	4.10	1.000	0.000
					-				227.8	212.0	-	-	-	-	-	227.8	212.0	0.740	-	-	3.60	1.000	0.000
	14.00	Silt	17.5		-	35.7	5.7	0.183	245.3	219.5	-	-	-	-	-	245.3	219.5	0.725	-	-	3.10	1.000	0.000
	14.30	Sand and Gravel	21.0		-				263.8	228.0	-	-	-	-	-	263.8	228.0	0.710	-	-	2.60	1.000	0.000
	15.50	Silt	17.5		Gravelly Soil				282.4	236.6	-	-	-	-	-	282.4	236.6	0.695	-	-	2.10	1.000	0.000
				64	Gravelly Soil	31.4	-	0.155	303.4	247.6	34.3	47.9	12.85	2.000	25.69	303.4	247.6	0.680	0.500	51.41	1.60	1.000	0.000
				52	Gravelly Soil			2.000	324.4	258.6	26.9	26.9	0.510	2.000	1.021	324.4	258.6	0.665	0.500	2.040	1.10	1.000	0.000
				54	Gravelly Soil	25.7	-	0.387	345.4	269.6	27.0	34.0	1.534	2.000	3.068	345.4	269.6	0.650	0.499	6.142	0.60	1.000	0.000
				57	Gravelly Soil			2.000	366.4	280.6	27.6	27.6	0.560	2.000	1.121	366.4	280.6	0.635	0.497	2.253	0.10	1.000	0.000
				59	Gravelly Soil			2.000	387.4	291.6	27.7	27.7	0.568	2.000	1.136	387.4	291.6	0.620	0.494	2.299		1.000	
				55	Gravelly Soil	21.4	-	0.441	408.4	302.6	25.1	31.0	0.932	2.000	1.865	408.4	302.6	0.605	0.490	3.807		1.000	
				53	Gravelly Soil			2.000	429.4	313.6	23.5	23.5	0.368	1.884	0.693	429.4	313.6	0.590	0.485	1.430		1.000	
				51	Gravelly Soil			2.000	450.4	324.6	22.0	22.0	0.335	1.777	0.596	450.4	324.6	0.575	0.479	1.245		1.000	
				59	Gravelly Soil			2.000	471.4	335.6	24.7	24.7	0.406	2.000	0.812	471.4	335.6	0.560	0.472	1.721		1.000	
	26.30	Sand and Gravel	21.0	51	Gravelly Soil			2.000	492.4	346.6	20.8	20.8	0.318	1.718	0.546	492.4	346.6	0.545	0.464	1.175		1.000	
				11	Sandy Soil	48.0	-	0.078	512.6	356.8	4.4	15.8	0.269	1.557	0.419	512.6	356.8	0.530	0.457	0.916		0.916	
	28.20	Sand	19.5	39	Sandy Soil				532.1	366.3	15.2	15.2	0.264	1.540	0.406	532.1	366.3	0.515	0.449	0.905		0.905	
				56	Gravelly Soil			2.000	552.5	376.7	21.3	21.3	0.325	1.741	0.565	552.5	376.7	0.500	0.440	1.285		1.000	
				58	Gravelly Soil	20.5	-	0.328	573.5	387.7	21.5	27.6	0.560	2.000	1.119	573.5	387.7	0.485	0.430	2.601		1.000	
				60																			
				59																			
				53																			
				60		31.3	-	0.193															
	35	Sand and Grave	21	59																			
備考																							

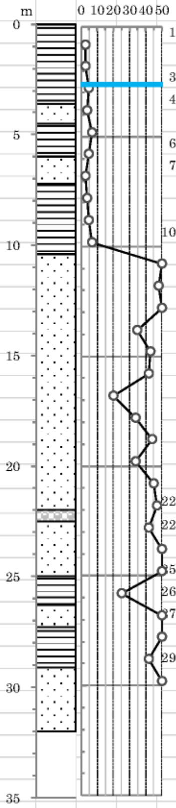
LP-1

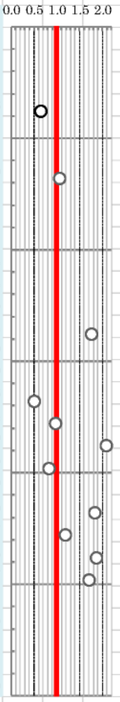
GRAIN SIZE DISTRIBUTION RESULTS (PETOBO / LP - 1)



LP-2

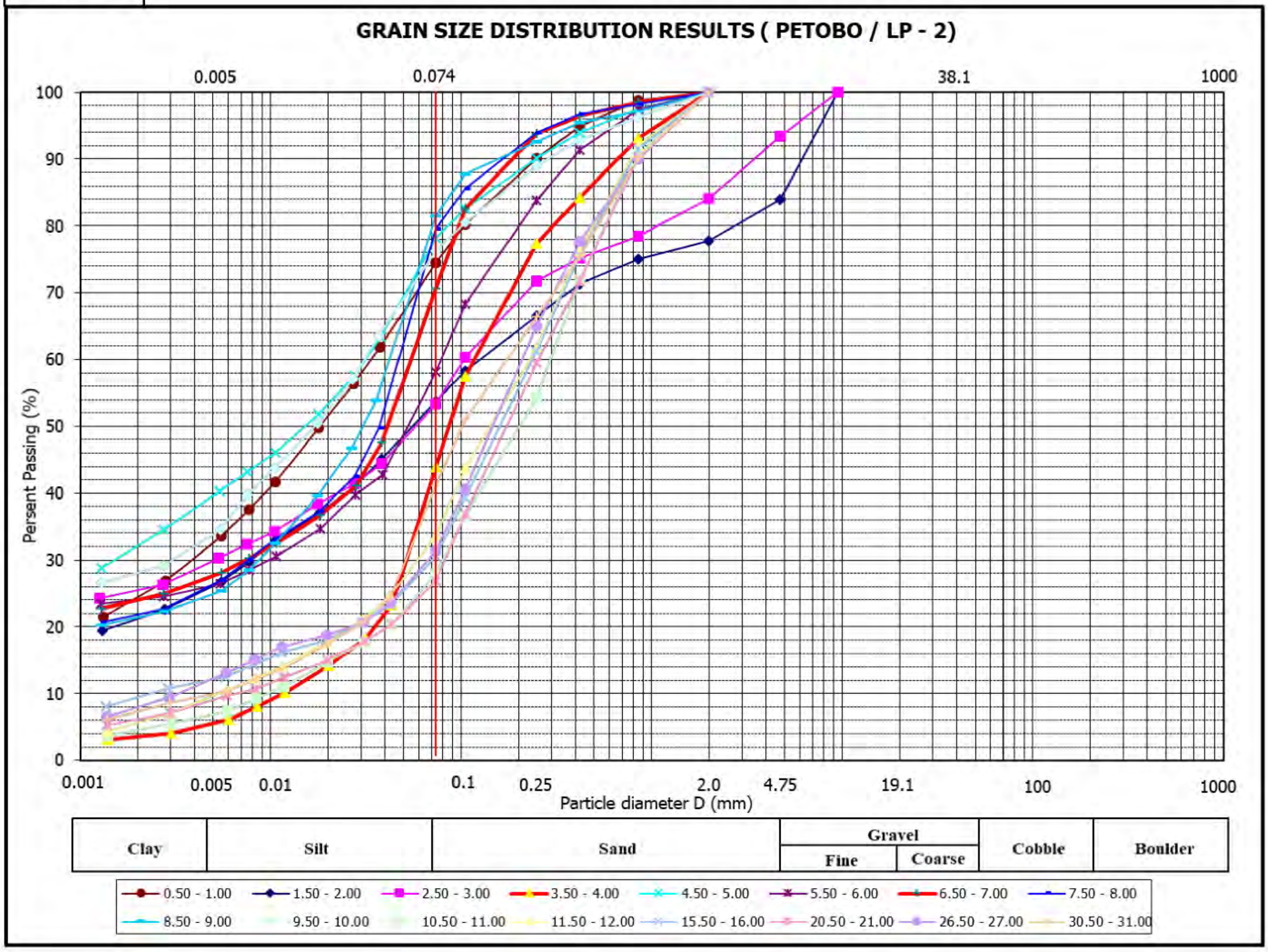
No.	1	Name	LP−2	Location	Petobo	LNG;	0824472 m E	LAT;	9895841 m S	Standard Depth for "sv"			
Hight of Hole Mouth		Total Advance	32.00m	Ground Water Level	2.60m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2		0.00m





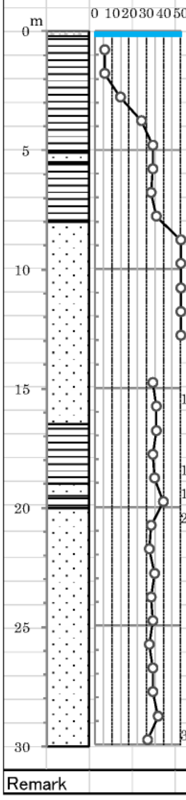
Depth	Drilling Log		Unit Weight	N Value	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
			kN/m³																			3.53	
m				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
	1.10	Landslide Dep.	15.5	3	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
				3	-	53.8	8.7	0.058	27.9	27.9	5.2	-	-	-	-	27.9	27.9	0.905	-	-	9.10	1.000	0.000
	3.60	Silt	15.5	5	-	53.3	11.3	0.061	43.4	41.4	7.6	-	-	-	-	43.4	41.4	0.890	0.560	-	8.60	1.000	0.000
	4.50	Sand	19.5	4	Sandy Soil	43.9	7.0	0.088	59.7	47.7	5.8	16.7	0.276	1.582	0.437	59.7	47.7	0.875	0.657	0.666	8.10	0.666	2.709
				7	-	78.1	15.6	0.016	78.6	56.6	9.4	-	-	-	-	78.6	56.6	0.860	0.716	-	7.60	1.000	0.000
	6.00	Silt	17.5	5	-	58.2	11.7	0.055	96.1	64.1	6.3	-	-	-	-	96.1	64.1	0.845	0.760	-	7.10	1.000	0.000
	7.20	Sand	19.5	3	Sandy Soil	70.6	10.2	0.042	115.2	73.2	3.6	25.0	0.415	2.000	0.830	115.2	73.2	0.830	0.784	1.060	6.60	1.000	0.000
				4	-	79.5	9.1	0.037	133.5	81.5	4.5	-	-	-	-	133.5	81.5	0.815	0.801	-	6.10	1.000	0.000
				5	-	81.5	7.9	0.031	151.0	89.0	5.3	-	-	-	-	151.0	89.0	0.800	0.814	-	5.60	1.000	0.000
	10.40	Silt	17.5	7	-	76.3	13.4	0.017	168.5	96.5	7.1	-	-	-	-	168.5	96.5	0.785	0.822	-	5.10	1.000	0.000
				50	Sandy Soil	27.9	-	0.215	186.8	104.8	48.6	79.2	233.98	2.000	468.0	186.8	104.8	0.770	0.823	568.4	4.60	1.000	0.000
				48	Sandy Soil	33.6	-	0.155	206.3	114.3	44.3	81.0	265.00	2.000	530.0	206.3	114.3	0.755	0.817	648.4	4.10	1.000	0.000
				50	Sandy Soil				225.8	123.8	43.9	43.9	7.398	2.000	14.80	225.8	123.8	0.740	0.810	18.28	3.60	1.000	0.000
				35	Sandy Soil				245.3	133.3	29.3	29.3	0.706	2.000	1.411	245.3	133.3	0.725	0.800	1.764	3.10	1.000	0.000
				43	Sandy Soil				264.8	142.8	34.4	34.4	1.635	2.000	3.269	264.8	142.8	0.710	0.790	4.140	2.60	1.000	0.000
				42	Sandy Soil	30.6	-	0.166	284.3	152.3	32.1	55.8	32.25	2.000	64.50	284.3	152.3	0.695	0.778	82.89	2.10	1.000	0.000
				20	Sandy Soil				303.8	161.8	14.7	14.7	0.259	1.525	0.395	303.8	161.8	0.680	0.766	0.516	1.60	0.516	0.775
				34	Sandy Soil				323.3	171.3	24.0	24.0	0.381	1.926	0.733	323.3	171.3	0.665	0.753	0.974	1.10	0.974	0.029
				44	Sandy Soil				342.8	180.8	29.8	29.8	0.769	2.000	1.537	342.8	180.8	0.650	0.739	2.080	0.60	1.000	0.000
				34	Sandy Soil				362.3	190.3	22.2	22.2	0.340	1.790	0.608	362.3	190.3	0.635	0.725	0.838	0.10	0.838	0.016
				45	Sandy Soil	26.9	-	0.189	381.8	199.8	28.4	45.7	9.590	2.000	19.18	381.8	199.8	0.620	0.711	26.99		1.000	
	22.00	Sand	19.5	47	Sandy Soil				401.3	209.3	28.6	28.6	0.640	2.000	1.280	401.3	209.3	0.605	0.696	1.840		1.000	
	22.50	Sand and Gravel	21.0	42	Sandy Soil				421.6	219.6	24.7	24.7	0.403	2.000	0.807	421.6	219.6	0.590	0.679	1.187		1.000	
				50	Sandy Soil				441.1	229.1	28.4	28.4	0.624	2.000	1.247	441.1	229.1	0.575	0.664	1.878		1.000	
	25.00	Sand	19.5	50	Sandy Soil				460.6	238.6	27.5	27.5	0.553	2.000	1.107	460.6	238.6	0.560	0.648	1.707		1.000	
	26.30	Silt	17.5	25	-				478.5	246.5	13.4	-	-	-	-	478.5	246.5	0.545	0.635	-		1.000	
	27.30	Sand	19.5	50	Sandy Soil	31.4	-	0.161	497.0	255.0	26.2	46.6	10.74	2.000	21.49	497.0	255.0	0.530	0.620	34.68		1.000	
				50	-				515.5	263.5	25.5	-	-	-	-	515.5	263.5	0.515	0.604	-		1.000	
	29.10	Silt	17.5	42	-				533.0	271.0	20.9	-	-	-	-	533.0	271.0	0.500	0.590	-		1.000	
				81	Sandy Soil				551.9	279.9	39.4	39.4	3.757	2.000	7.514	551.9	279.9	0.485	0.574	13.10		1.000	
				90		41.1	-	0.102															
	32	Sand	19.5	98																			
				50																			
Remark				50																			

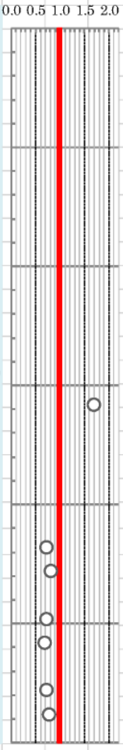
LP-2



LP-3

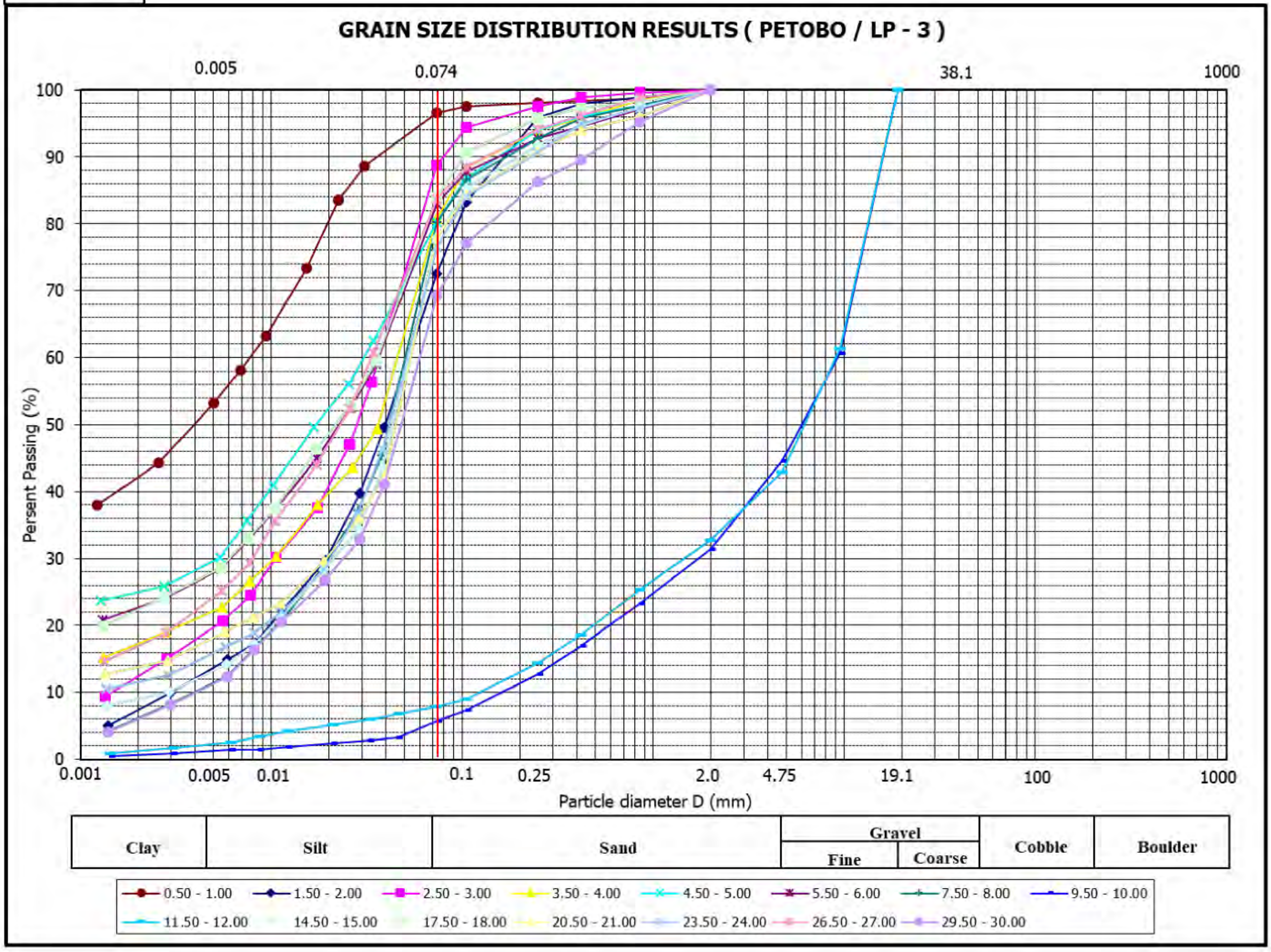
No.	1	Name	LP-3	Location	Petobo	LNG;	0822721 m E	LAT;	9896233 m S	Standard Depth for "sv"		
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	0.13m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m





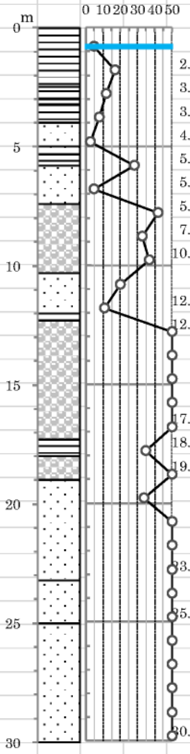
Depth	Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
			kN/m³																		0.00		
				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
	0.20	Top Soil or Back-fill	15.0	6	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
				6	-	72.5	12.9	0.040	31.0	14.3	12.1	-	-	-	-	31.0	14.3	0.905	1.177	-	9.10	1.000	0.000
				15	-	88.7	13.5	0.026	48.5	21.8	27.8	-	-	-	-	48.5	21.8	0.890	1.188	-	8.60	1.000	0.000
				27	-	80.7	22.4	0.037	66.0	29.3	46.2	-	-	-	-	66.0	29.3	0.875	1.182	-	8.10	1.000	0.000
	5.10	Silt	17.5	34	-	80.2	20.2	0.017	83.5	36.8	54.1	-	-	-	-	83.5	36.8	0.860	1.170	-	7.60	1.000	0.000
	5.50	Sand	19.5	34	-	82.9	17.2	0.023	101.8	45.1	50.2	-	-	-	-	101.8	45.1	0.845	1.144	-	7.10	1.000	0.000
				33	-				119.3	52.6	45.8	-	-	-	-	119.3	52.6	0.830	1.129	-	6.60	1.000	0.000
	8.00	Silt	17.5	36	-	80.2	11.3	0.043	136.8	60.1	47.0	-	-	-	-	136.8	60.1	0.815	1.113	-	6.10	1.000	0.000
				55	Sandy Soil				155.9	69.2	67.2	67.2	93.79	2.000	187.6	155.9	69.2	0.800	1.081	173.5	5.60	1.000	0.000
				64	Sandy Soil	5.7	-	6.372	175.4	78.7	73.2	73.2	151.41	2.000	302.8	175.4	78.7	0.785	1.049	288.6	5.10	1.000	0.000
				65	Sandy Soil				194.9	88.2	69.8	69.8	116.89	2.000	233.8	194.9	88.2	0.770	1.021	229.1	4.60	1.000	0.000
				99	Sandy Soil	7.9	-	6.583	214.4	97.7	100.4	100.4	827.62	2.000	1655.2	214.4	97.7	0.755	0.994	1666	4.10	1.000	0.000
				67	Sandy Soil				233.9	107.2	64.3	64.3	73.04	2.000	146.1	233.9	107.2	0.740	0.968	150.8	3.60	1.000	0.000
					Sandy Soil				253.4	116.7	-	-	-	-	-	253.4	116.7	0.725	-	-	3.10	1.000	0.000
				34	Sandy Soil	78.0	11.8	0.045	272.9	126.2	29.5	162.4	9457.29	2.000	18914.6	272.9	126.2	0.710	0.921	20540	2.60	1.000	0.000
	16.50	Sand	19.5	36	Sandy Soil				292.4	135.7	29.8	29.8	0.760	2.000	1.520	292.4	135.7	0.695	0.898	1.692	2.10	1.000	0.000
				36	-				311.3	144.6	28.5	-	-	-	-	311.3	144.6	0.680	0.878	-	1.60	1.000	0.000
				34	-	84.0	17.1	0.022	328.8	152.1	26.0	-	-	-	-	328.8	152.1	0.665	0.862	-	1.10	1.000	0.000
	19.00	Silt	17.5	35	-				346.3	159.6	25.9	-	-	-	-	346.3	159.6	0.650	0.846	-	0.60	1.000	0.000
	19.50	Sand	19.5	40	-				364.8	168.1	28.6	-	-	-	-	364.8	168.1	0.635	0.826	-	0.10	1.000	0.000
	20.00	Silt	17.5	33	Sandy Soil	77.9	11.9	0.047	383.9	177.2	22.7	127.4	2815.85	2.000	5631.7	383.9	177.2	0.620	0.806	6991		1.000	
				32	Sandy Soil				403.4	186.7	21.2	21.2	0.323	1.736	0.560	403.4	186.7	0.605	0.784	0.715		0.715	
				35	Sandy Soil				422.9	196.2	22.4	22.4	0.342	1.800	0.616	422.9	196.2	0.590	0.763	0.808		0.808	
				33	Sandy Soil	76.5	11.5	0.043	442.4	205.7	20.3	112.7	1506.87	2.000	3013.7	442.4	205.7	0.575	0.742	4063		1.000	
				34	Sandy Soil				461.9	215.2	20.3	20.3	0.311	1.695	0.527	461.9	215.2	0.560	0.721	0.731		0.731	
				32	Sandy Soil				481.4	224.7	18.5	18.5	0.292	1.634	0.477	481.4	224.7	0.545	0.700	0.681		0.681	
				34	Sandy Soil	83.6	17.3	0.023	500.9	234.2	19.0	118.6	1956.97	2.000	3913.9	500.9	234.2	0.530	0.680	5757		1.000	
				34	Sandy Soil				520.4	243.7	18.4	18.4	0.292	1.632	0.476	520.4	243.7	0.515	0.660	0.722		0.722	
				37	Sandy Soil				539.9	253.2	19.5	19.5	0.302	1.666	0.503	539.9	253.2	0.500	0.639	0.786		0.786	
	30.00	Sand	19.5	31	Sandy Soil	69.2	10.2	0.050	559.4	262.7	15.8	78.7	226.83	2.000	453.7	559.4	262.7	0.485	0.619	732.5		1.000	
Remark																							

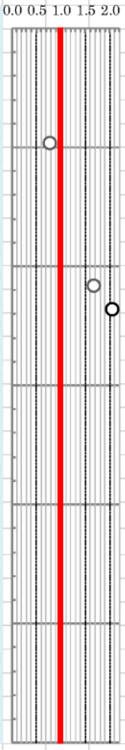
LP-3



LP-4

No.	1	Name	LP−4	Location	Petobo	LNG;	0824246 m E	LAT;	9896370 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	0.80m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion: Type2 — 0.00m

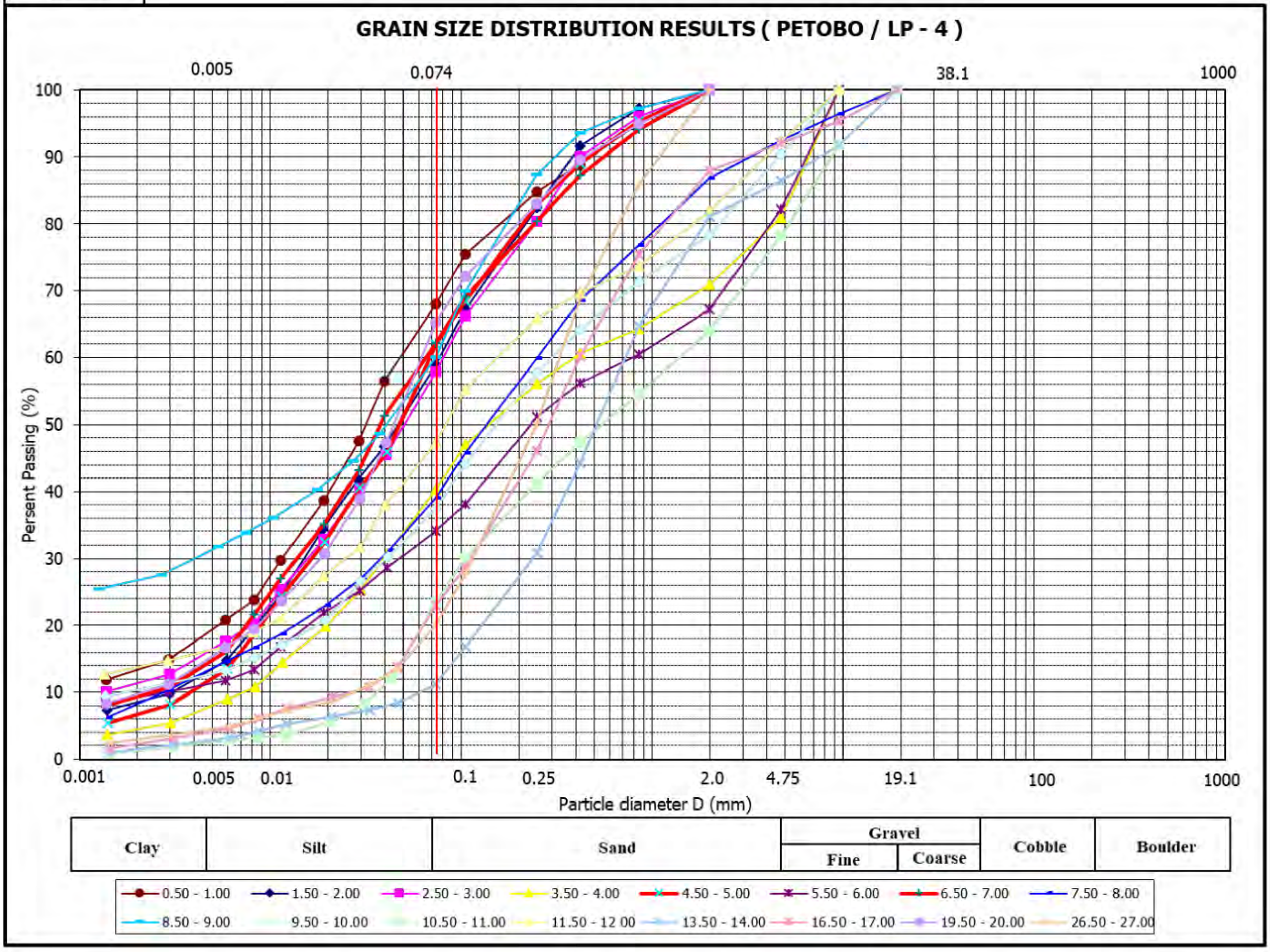




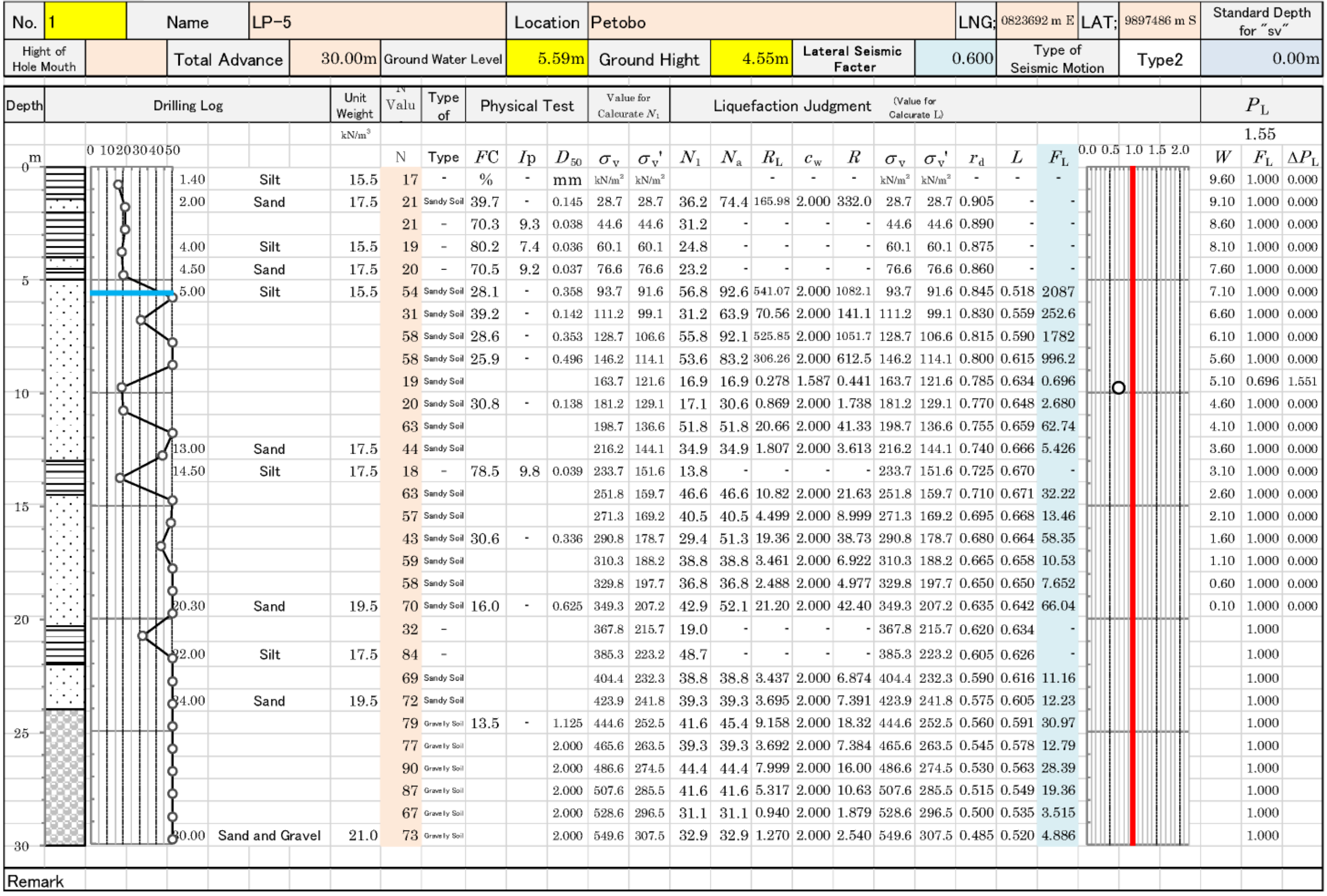
Depth	Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment				(Value for Calcurate L)						P_L		
			kN/m³																			1.63	
m				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
				5	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
	2.50	Silt	15.5	17	-	59.0	13.1	0.049	27.9	17.9	32.9	-	-	-	-	27.9	17.9	0.905	0.846	-	9.10	1.000	0.000
	3.00	Silt	17.5	12	-	57.9	13.7	0.052	44.0	24.0	21.7	-	-	-	-	44.0	24.0	0.890	0.979	-	8.60	1.000	0.000
	3.20	Sand	19.5	8	-	40.3	12.5	0.153	61.9	31.9	13.3	-	-	-	-	61.9	31.9	0.875	1.018	-	8.10	1.000	0.000
	4.00	Silt	17.5	3	Sandy Soil	61.9	12.7	0.055	81.0	41.0	4.6	24.6	0.400	2.000	0.801	81.0	41.0	0.860	1.019	0.786	7.60	0.786	1.628
5	5.00	Sand	19.5	28	Sandy Soil	34.1	5.2	0.237	99.5	49.5	39.8	73.8	158.73	2.000	317.5	99.5	49.5	0.845	1.019	311.6	7.10	1.000	0.000
	5.30	Sand	19.5	5	Sandy Soil	62.2	12.6	0.038	119.0	59.0	6.6	32.4	1.167	2.000	2.334	119.0	59.0	0.830	1.004	2.325	6.60	1.000	0.000
	5.80	Silt	17.5	42	Gravelly Soil	39.0	6.8	0.148	139.1	69.1	51.3	72.2	140.91	2.000	281.8	139.1	69.1	0.815	0.984	286.4	6.10	1.000	0.000
	7.40	Sand	19.5	33	Gravelly Soil	60.0	29.0	0.041	160.1	80.1	37.4	60.0	49.22	2.000	98.45	160.1	80.1	0.800	0.959	102.6	5.60	1.000	0.000
	10.30	Sand and Gravel	21.0	37	Gravelly Soil	37.4	4.5	0.168	181.1	91.1	39.0	54.2	26.90	2.000	53.81	181.1	91.1	0.785	0.936	57.49	5.10	1.000	0.000
10				20	Sandy Soil	23.4	-	0.578	201.4	101.4	19.8	29.8	0.766	2.000	1.532	201.4	101.4	0.770	0.918	1.669	4.60	1.000	0.000
	12.00	Sand	19.5	11	Sandy Soil	47.4	5.1	0.084	220.9	110.9	10.3	31.0	0.928	2.000	1.857	220.9	110.9	0.755	0.902	2.058	4.10	1.000	0.000
	12.30	Silt	17.5	57	Gravelly Soil			2.000	240.5	120.5	50.9	50.9	18.43	2.000	36.86	240.5	120.5	0.740	0.886	41.60	3.60	1.000	0.000
				65	Gravelly Soil	11.2	-	0.474	261.5	131.5	54.8	67.2	93.94	2.000	187.9	261.5	131.5	0.725	0.865	217.3	3.10	1.000	0.000
				63	Gravelly Soil			2.000	282.5	142.5	50.4	50.4	17.43	2.000	34.85	282.5	142.5	0.710	0.844	41.28	2.60	1.000	0.000
15				61	Gravelly Soil			2.000	303.5	153.5	46.4	46.4	10.49	2.000	20.99	303.5	153.5	0.695	0.824	25.47	2.10	1.000	0.000
	17.30	Sand and Gravel	21.0	60	Gravelly Soil	23.0	-	0.297	324.5	164.5	43.5	56.5	34.41	2.000	68.82	324.5	164.5	0.680	0.805	85.54	1.60	1.000	0.000
	18.00	Silt	17.5	35	-				343.8	173.8	24.4	-	-	-	-	343.8	173.8	0.665	0.789	-	1.10	1.000	0.000
	19.00	Sand and Gravel	21.0	57	Gravelly Soil			2.000	364.1	184.1	38.1	38.1	3.088	2.000	6.177	364.1	184.1	0.650	0.771	8.010	0.60	1.000	0.000
				34	Sandy Soil	65.3	9.9	0.045	383.9	193.9	21.9	97.7	719.67	2.000	1439.3	383.9	193.9	0.635	0.754	1909	0.10	1.000	0.000
20				59	Sandy Soil				403.4	203.4	36.7	36.7	2.431	2.000	4.862	403.4	203.4	0.620	0.738	6.592		1.000	
				62	Sandy Soil				422.9	212.9	37.3	37.3	2.673	2.000	5.346	422.9	212.9	0.605	0.721	7.417		1.000	
	23.20	Sand	19.5	58	Sandy Soil				442.4	222.4	33.7	33.7	1.469	2.000	2.938	442.4	222.4	0.590	0.704	4.173		1.000	
				59	Sandy Soil				461.9	231.9	33.2	33.2	1.349	2.000	2.698	461.9	231.9	0.575	0.687	3.928		1.000	
	25.00	Sand	19.5	66	Sandy Soil				481.4	241.4	36.0	36.0	2.177	2.000	4.355	481.4	241.4	0.560	0.670	6.501		1.000	
25				63	Sandy Soil				500.9	250.9	33.4	33.4	1.384	2.000	2.769	500.9	250.9	0.545	0.653	4.243		1.000	
				66	Sandy Soil	20.1	-	0.249	520.4	260.4	34.0	46.3	10.32	2.000	20.64	520.4	260.4	0.530	0.635	32.49		1.000	
				66	Sandy Soil				539.9	269.9	33.0	33.0	1.301	2.000	2.601	539.9	269.9	0.515	0.618	4.210		1.000	
				63	Sandy Soil				559.4	279.4	30.7	30.7	0.877	2.000	1.754	559.4	279.4	0.500	0.600	2.922		1.000	
30	30.00	Sand	19.5	64	Sandy Soil				578.9	288.9	30.3	30.3	0.831	2.000	1.662	578.9	288.9	0.485	0.583	2.851		1.000	

Remark

LP-4



LP-5

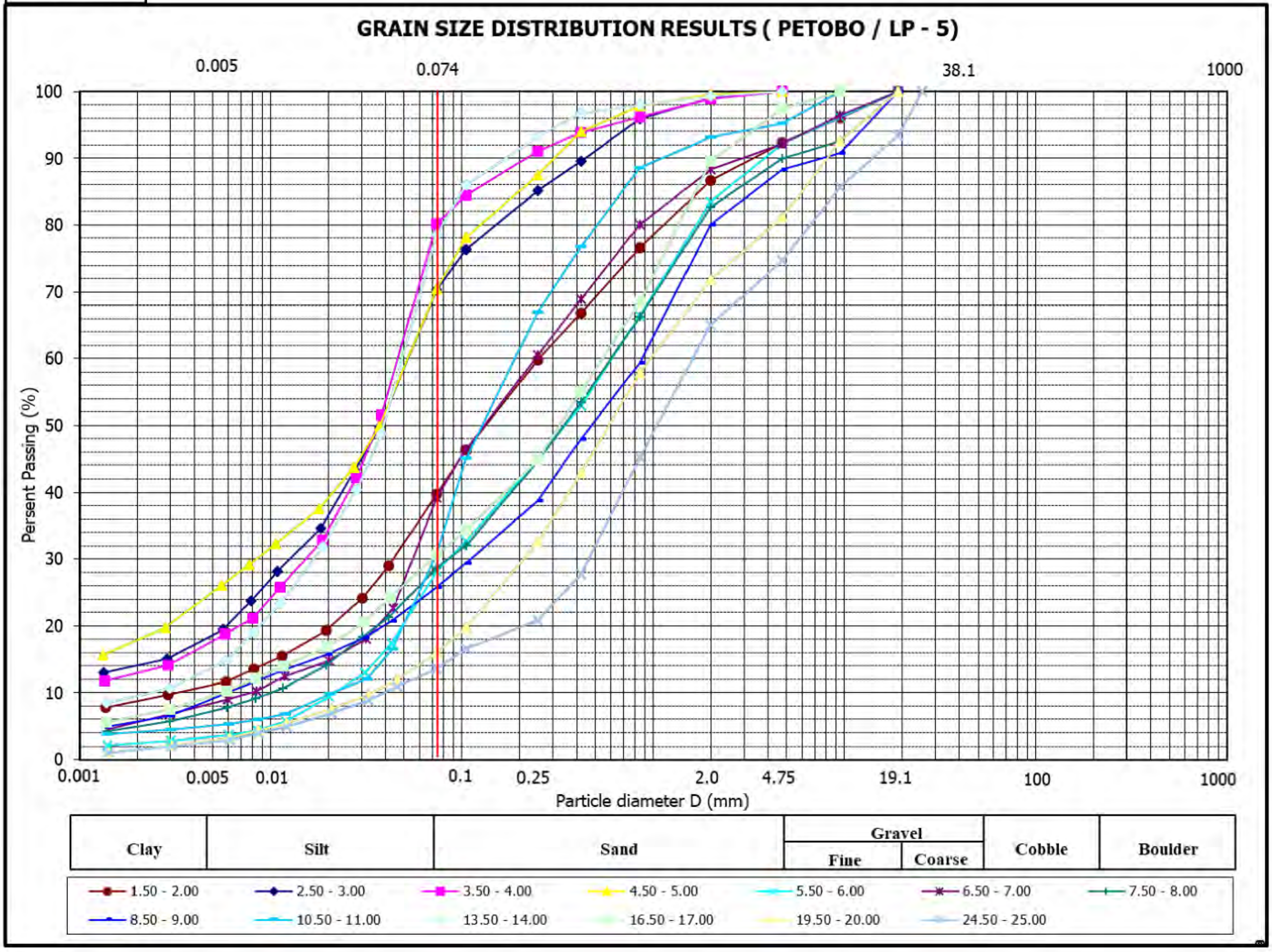


No.	1	Name	LP−5	Location	Petobo	LNG;	0823692 m E	LAT;	9897486 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	5.59m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion
									Type2	0.00m

Depth	Drilling Log	Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
		kN/m³																		1.55		
m			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
1.40	Silt	15.5	17	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
2.00	Sand	17.5	21	Sandy Soil	39.7	-	0.145	28.7	28.7	36.2	74.4	165.98	2.000	332.0	28.7	28.7	0.905	-	-	9.10	1.000	0.000
			21	-	70.3	9.3	0.038	44.6	44.6	31.2	-	-	-	-	44.6	44.6	0.890	-	-	8.60	1.000	0.000
4.00	Silt	15.5	19	-	80.2	7.4	0.036	60.1	60.1	24.8	-	-	-	-	60.1	60.1	0.875	-	-	8.10	1.000	0.000
4.50	Sand	17.5	20	-	70.5	9.2	0.037	76.6	76.6	23.2	-	-	-	-	76.6	76.6	0.860	-	-	7.60	1.000	0.000
5.00	Silt	15.5	54	Sandy Soil	28.1	-	0.358	93.7	91.6	56.8	92.6	541.07	2.000	1082.1	93.7	91.6	0.845	0.518	2087	7.10	1.000	0.000
			31	Sandy Soil	39.2	-	0.142	111.2	99.1	31.2	63.9	70.56	2.000	141.1	111.2	99.1	0.830	0.559	252.6	6.60	1.000	0.000
			58	Sandy Soil	28.6	-	0.353	128.7	106.6	55.8	92.1	525.85	2.000	1051.7	128.7	106.6	0.815	0.590	1782	6.10	1.000	0.000
			58	Sandy Soil	25.9	-	0.496	146.2	114.1	53.6	83.2	306.26	2.000	612.5	146.2	114.1	0.800	0.615	996.2	5.60	1.000	0.000
			19	Sandy Soil				163.7	121.6	16.9	16.9	0.278	1.587	0.441	163.7	121.6	0.785	0.634	0.696	5.10	0.696	1.551
			20	Sandy Soil	30.8	-	0.138	181.2	129.1	17.1	30.6	0.869	2.000	1.738	181.2	129.1	0.770	0.648	2.680	4.60	1.000	0.000
			63	Sandy Soil				198.7	136.6	51.8	51.8	20.66	2.000	41.33	198.7	136.6	0.755	0.659	62.74	4.10	1.000	0.000
13.00	Sand	17.5	44	Sandy Soil				216.2	144.1	34.9	34.9	1.807	2.000	3.613	216.2	144.1	0.740	0.666	5.426	3.60	1.000	0.000
14.50	Silt	17.5	18	-	78.5	9.8	0.039	233.7	151.6	13.8	-	-	-	-	233.7	151.6	0.725	0.670	-	3.10	1.000	0.000
			63	Sandy Soil				251.8	159.7	46.6	46.6	10.82	2.000	21.63	251.8	159.7	0.710	0.671	32.22	2.60	1.000	0.000
			57	Sandy Soil				271.3	169.2	40.5	40.5	4.499	2.000	8.999	271.3	169.2	0.695	0.668	13.46	2.10	1.000	0.000
			43	Sandy Soil	30.6	-	0.336	290.8	178.7	29.4	51.3	19.36	2.000	38.73	290.8	178.7	0.680	0.664	58.35	1.60	1.000	0.000
			59	Sandy Soil				310.3	188.2	38.8	38.8	3.461	2.000	6.922	310.3	188.2	0.665	0.658	10.53	1.10	1.000	0.000
			58	Sandy Soil				329.8	197.7	36.8	36.8	2.488	2.000	4.977	329.8	197.7	0.650	0.650	7.652	0.60	1.000	0.000
20.30	Sand	19.5	70	Sandy Soil	16.0	-	0.625	349.3	207.2	42.9	52.1	21.20	2.000	42.40	349.3	207.2	0.635	0.642	66.04	0.10	1.000	0.000
			32	-				367.8	215.7	19.0	-	-	-	-	367.8	215.7	0.620	0.634	-		1.000	
22.00	Silt	17.5	84	-				385.3	223.2	48.7	-	-	-	-	385.3	223.2	0.605	0.626	-		1.000	
			69	Sandy Soil				404.4	232.3	38.8	38.8	3.437	2.000	6.874	404.4	232.3	0.590	0.616	11.16		1.000	
24.00	Sand	19.5	72	Sandy Soil				423.9	241.8	39.3	39.3	3.695	2.000	7.391	423.9	241.8	0.575	0.605	12.23		1.000	
			79	Gravelly Soil	13.5	-	1.125	444.6	252.5	41.6	45.4	9.158	2.000	18.32	444.6	252.5	0.560	0.591	30.97		1.000	
			77	Gravelly Soil			2.000	465.6	263.5	39.3	39.3	3.692	2.000	7.384	465.6	263.5	0.545	0.578	12.79		1.000	
			90	Gravelly Soil			2.000	486.6	274.5	44.4	44.4	7.999	2.000	16.00	486.6	274.5	0.530	0.563	28.39		1.000	
			87	Gravelly Soil			2.000	507.6	285.5	41.6	41.6	5.317	2.000	10.63	507.6	285.5	0.515	0.549	19.36		1.000	
			67	Gravelly Soil			2.000	528.6	296.5	31.1	31.1	0.940	2.000	1.879	528.6	296.5	0.500	0.535	3.515		1.000	
30.00	Sand and Gravel	21.0	73	Gravelly Soil			2.000	549.6	307.5	32.9	32.9	1.270	2.000	2.540	549.6	307.5	0.485	0.520	4.886		1.000	

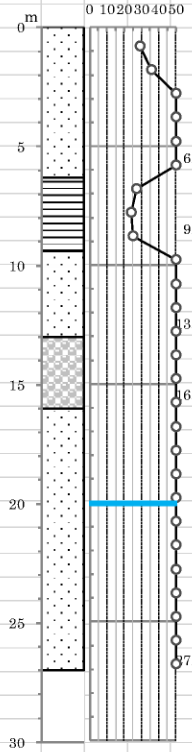
Remark

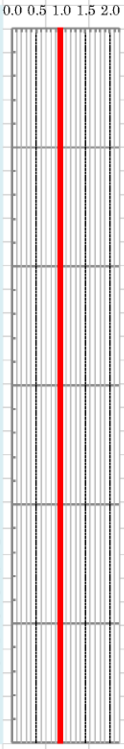
LP-5



LP-6

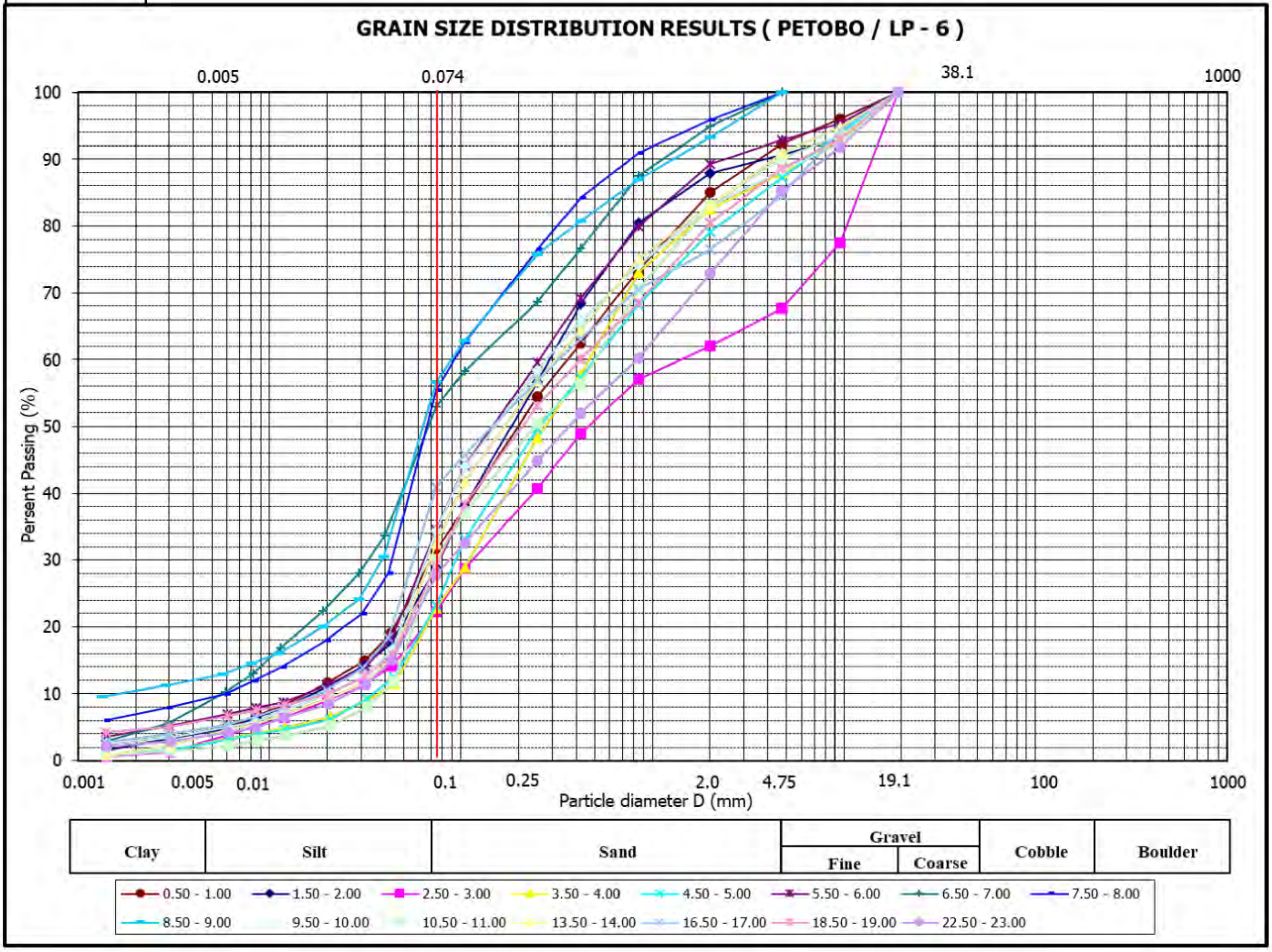
No.	1	Name	LP-6	Location	Petobo	LNG;	0823903 m E	LAT;	9899203 m S	Standard Depth for ″sv″		
Hight of Hole Mouth		Total Advance	27.00m	Ground Water Level	20.00m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m



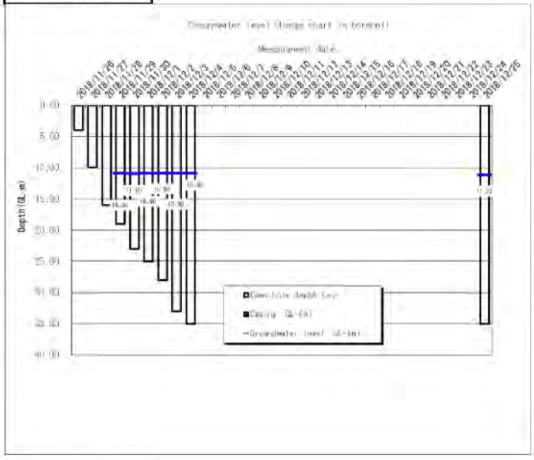


Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
		kN/m³																			0.00	
			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
			29	-	%	-	mm	kN/m³	kN/m³			-	-	-	kN/m³	kN/m³	-	-	-	9.60	1.000	0.000
			36	Sandy Soil	28.9	-	0.198	31.5	31.5	60.3	99.8	802.10	2.000	1604.2	31.5	31.5	0.905	-	-	9.10	1.000	0.000
			60	Sandy Soil	22.3	-	0.475	49.0	49.0	85.7	121.8	2248.05	2.000	4496.1	49.0	49.0	0.890	-	-	8.60	1.000	0.000
			62	Sandy Soil	22.8	-	0.281	66.5	66.5	77.2	111.2	1405.53	2.000	2811.1	66.5	66.5	0.875	-	-	8.10	1.000	0.000
			64	Sandy Soil	23.2	-	0.258	84.0	84.0	70.6	102.9	943.40	2.000	1886.8	84.0	84.0	0.860	-	-	7.60	1.000	0.000
6.30	Sand	17.5	60	Sandy Soil	34.6	-	0.160	101.5	101.5	59.5	110.2	1342.68	2.000	2685.4	101.5	101.5	0.845	-	-	7.10	1.000	0.000
			27	-	53.0	-	0.069	118.0	118.0	24.4	-	-	-	-	118.0	118.0	0.830	-	-	6.60	1.000	0.000
			24	-	55.4	-	0.068	133.5	133.5	20.0	-	-	-	-	133.5	133.5	0.815	-	-	6.10	1.000	0.000
9.40	Silt	15.5	25	-	56.6	-	0.065	149.0	149.0	19.4	-	-	-	-	149.0	149.0	0.800	-	-	5.60	1.000	0.000
			62	Sandy Soil	34.4	-	0.165	165.3	165.3	44.8	83.2	305.56	2.000	611.1	165.3	165.3	0.785	-	-	5.10	1.000	0.000
			60	Sandy Soil	30.1	-	0.246	182.8	182.8	40.3	69.0	109.52	2.000	219.0	182.8	182.8	0.770	-	-	4.60	1.000	0.000
			61	Sandy Soil				200.3	200.3	38.4	38.4	3.202	2.000	6.404	200.3	200.3	0.755	-	-	4.10	1.000	0.000
13.00	Sand	17.5	64	Sandy Soil				217.8	217.8	37.8	37.8	2.922	2.000	5.845	217.8	217.8	0.740	-	-	3.60	1.000	0.000
			59	Gravely Soil	32.4	-	0.153	236.5	236.5	32.7	45.9	9.791	2.000	19.58	236.5	236.5	0.725	-	-	3.10	1.000	0.000
			60	Gravely Soil			2.000	255.5	255.5	31.3	31.3	0.980	2.000	1.961	255.5	255.5	0.710	-	-	2.60	1.000	0.000
16.00	Sand and Gravel	19.0	500	Gravely Soil			2.000	274.5	274.5	246.7	246.7	71614.18	2.000	143228.4	274.5	274.5	0.695	-	-	2.10	1.000	0.000
			63	Sandy Soil	41.0	-	0.077	292.3	292.3	29.6	64.1	72.18	2.000	144.4	292.3	292.3	0.680	-	-	1.60	1.000	0.000
			64	Sandy Soil				309.8	309.8	28.6	28.6	0.644	2.000	1.288	309.8	309.8	0.665	-	-	1.10	1.000	0.000
			60	Sandy Soil	29.1	-	0.172	327.3	327.3	25.7	43.6	7.124	2.000	14.25	327.3	327.3	0.650	-	-	0.60	1.000	0.000
			55	Sandy Soil				344.8	344.8	22.5	22.5	0.346	1.812	0.627	344.8	344.8	0.635	-	-	0.10	1.000	0.000
			66	Sandy Soil				362.3	354.3	26.4	26.4	0.483	2.000	0.966	362.3	354.3	0.620	0.380	2.541		1.000	
			66	Sandy Soil				379.8	361.8	26.0	26.0	0.459	2.000	0.918	379.8	361.8	0.605	0.381	2.410		1.000	
			69	Sandy Soil	27.7	-	0.108	397.3	369.3	26.7	43.9	7.488	2.000	14.98	397.3	369.3	0.590	0.381	39.34		1.000	
			67	Sandy Soil				414.8	376.8	25.5	25.5	0.436	2.000	0.872	414.8	376.8	0.575	0.380	2.298		1.000	
			68	Sandy Soil				432.3	384.3	25.4	25.4	0.434	2.000	0.868	432.3	384.3	0.560	0.378	2.298		1.000	
			69	Sandy Soil				449.8	391.8	25.4	25.4	0.432	2.000	0.864	449.8	391.8	0.545	0.375	2.304		1.000	
27.00	Sand	17.5	69	Sandy Soil				467.3	399.3	25.0	25.0	0.416	2.000	0.831	467.3	399.3	0.530	0.372	2.235		1.000	
				Sandy Soil				484.8	406.8	-	-	-	-	-	484.8	406.8	0.515	-	-		1.000	
				–				502.3	414.3	-	-	-	-	-	502.3	414.3	0.500	-	-		1.000	
				–				519.8	421.8	-	-	-	-	-	519.8	421.8	0.485	-	-		1.000	
Remark																						

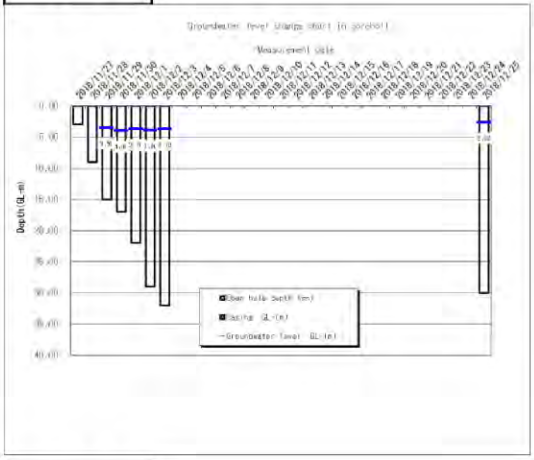
LP-6



LP-1



LP-2



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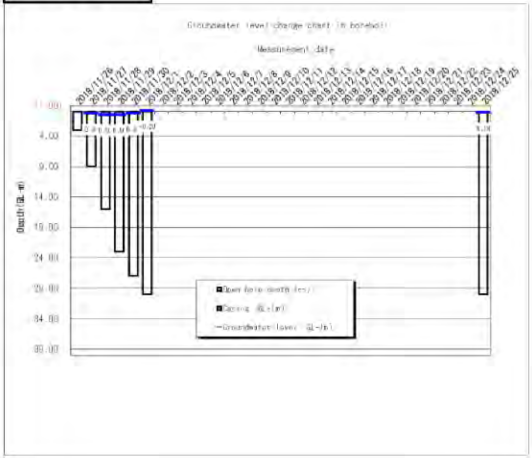
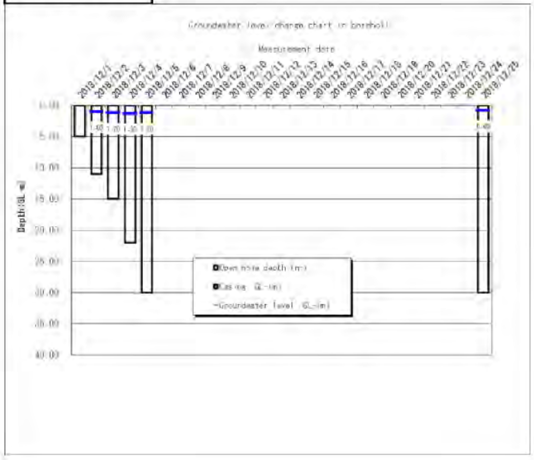


LP-4



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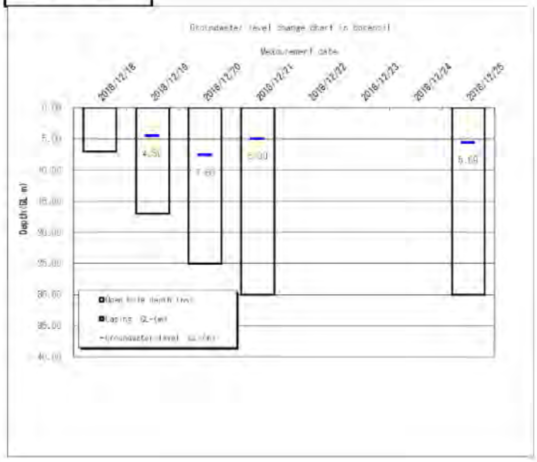

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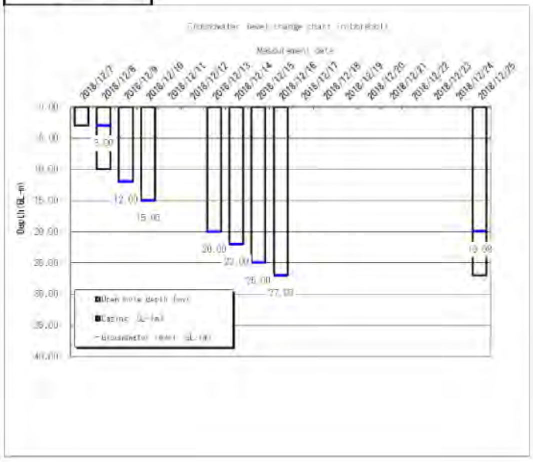
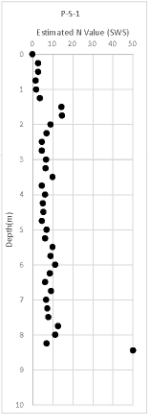


Swedish weight sounding test

Petobo

P-S-1



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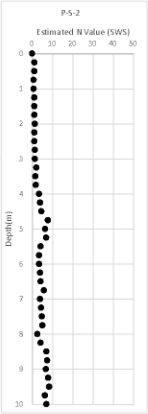

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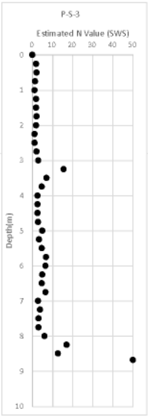

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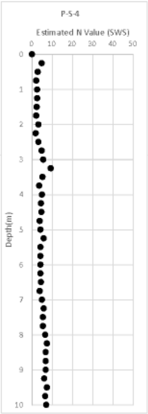

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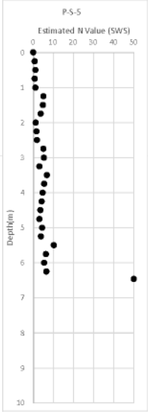

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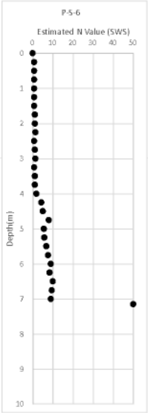

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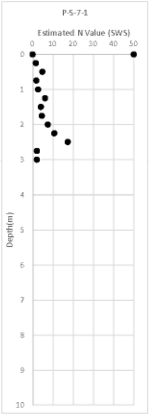
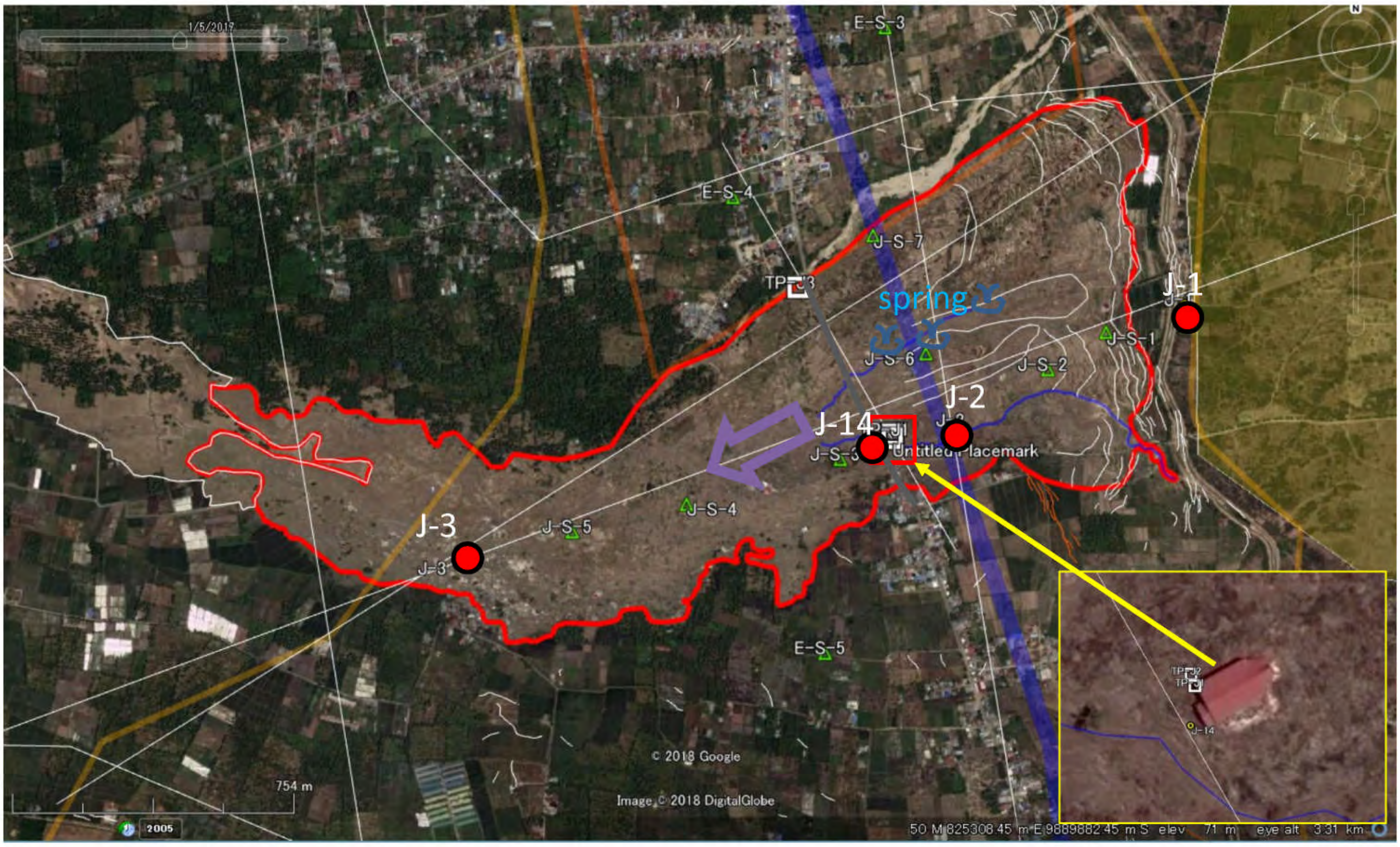
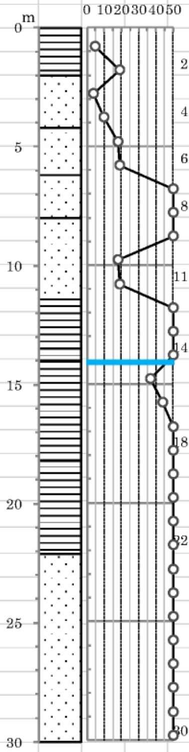


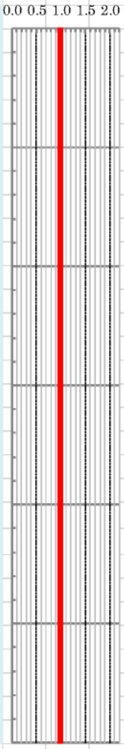
Jono Oge



J-1

No.	1	Name	J-1	Location	Jono Oge	LNG;	825742.00 m E	LAT;	9891240.00 m S	Standard Depth for ″sv″		
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	14.08m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m

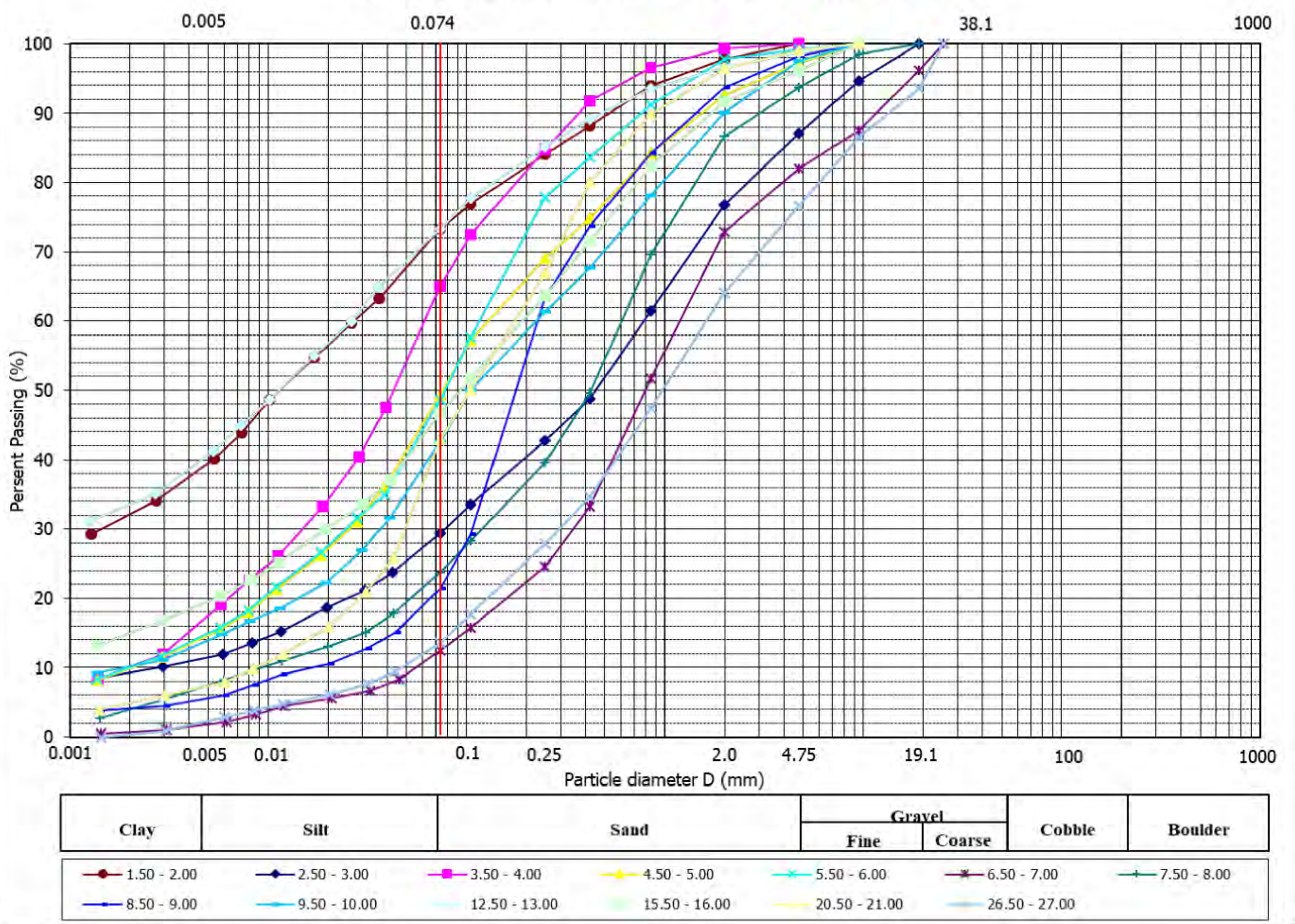




Depth	Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
			kN/m³																		0.00		
m				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
				5	-	%	-	mm	kN/m³	kN/m³			-	-	-	kN/m³	kN/m³	-	-	-	9.60	1.000	0.000
	2.00	Silt	15.5	19	-	73.4	21.7	0.012	27.9	27.9	33.0	-	-	-	-	27.9	27.9	0.905	-	-	9.10	1.000	0.000
				4	Sandy Soil	29.4	-	0.459	45.0	45.0	5.9	11.3	0.232	1.435	0.332	45.0	45.0	0.890	-	-	8.60	1.000	0.000
	4.20	Sand	17.5	10	Sandy Soil	65.1	5.8	0.044	62.5	62.5	12.8	60.1	49.72	2.000	99.44	62.5	62.5	0.875	-	-	8.10	1.000	0.000
				18	Sandy Soil	49.3	5.2	0.077	80.0	80.0	20.4	61.0	54.31	2.000	108.6	80.0	80.0	0.860	-	-	7.60	1.000	0.000
	6.20	Sand	17.5	19	Sandy Soil	48.7	5.0	0.079	97.5	97.5	19.3	56.8	35.53	2.000	71.07	97.5	97.5	0.845	-	-	7.10	1.000	0.000
				73	Sandy Soil	12.5	-	0.811	115.0	115.0	67.1	72.8	147.77	2.000	295.5	115.0	115.0	0.830	-	-	6.60	1.000	0.000
	8.00	Sand	17.5	129	Sandy Soil	23.7	-	0.426	132.5	132.5	108.3	159.0	8507.00	2.000	17014.0	132.5	132.5	0.815	-	-	6.10	1.000	0.000
				92	Sandy Soil	21.4	-	0.193	150.0	150.0	71.1	99.1	774.85	2.000	1549.7	150.0	150.0	0.800	-	-	5.60	1.000	0.000
				18	Sandy Soil	42.6	-	0.105	167.5	167.5	12.9	31.6	1.028	2.000	2.056	167.5	167.5	0.785	-	-	5.10	1.000	0.000
	11.40	Sand	17.5	19	Sandy Soil				185.0	185.0	12.7	12.7	0.243	1.471	0.357	185.0	185.0	0.770	-	-	4.60	1.000	0.000
				75	-				201.7	201.7	46.9	-	-	-	-	201.7	201.7	0.755	-	-	4.10	1.000	0.000
				99	-	73.4	22.2	0.012	217.2	217.2	58.6	-	-	-	-	217.2	217.2	0.740	-	-	3.60	1.000	0.000
	14.00	Silt	15.5	75	-				232.7	232.7	42.1	-	-	-	-	232.7	232.7	0.725	-	-	3.10	1.000	0.000
				37	-				248.2	241.0	20.2	-	-	-	-	248.2	241.0	0.710	0.439	-	2.60	1.000	0.000
				44	-	46.8	5.9	0.094	263.7	246.5	23.6	-	-	-	-	263.7	246.5	0.695	0.446	-	2.10	1.000	0.000
				150	-				279.2	252.0	79.2	-	-	-	-	279.2	252.0	0.680	0.452	-	1.60	1.000	0.000
	18.20	red silt	15.5	80	-				294.7	257.5	41.5	-	-	-	-	294.7	257.5	0.665	0.456	-	1.10	1.000	0.000
				113	-				311.4	264.2	57.5	-	-	-	-	311.4	264.2	0.650	0.459	-	0.60	1.000	0.000
				150	-				328.9	271.7	74.6	-	-	-	-	328.9	271.7	0.635	0.461	-	0.10	1.000	0.000
				75	-	42.9	-	0.105	346.4	279.2	36.5	-	-	-	-	346.4	279.2	0.620	0.461	-		1.000	
	22.10	Silt	17.5	125	-				363.9	286.7	59.6	-	-	-	-	363.9	286.7	0.605	0.461	-		1.000	
				150	Sandy Soil				382.8	295.6	69.7	69.7	115.95	2.000	231.9	382.8	295.6	0.590	0.458	506.1		1.000	
				90	Sandy Soil				402.3	305.1	40.8	40.8	4.697	2.000	9.394	402.3	305.1	0.575	0.455	20.66		1.000	
				150	Sandy Soil				421.8	314.6	66.3	66.3	87.14	2.000	174.3	421.8	314.6	0.560	0.450	387.1		1.000	
				150	Sandy Soil				441.3	324.1	64.7	64.7	75.85	2.000	151.7	441.3	324.1	0.545	0.445	340.9		1.000	
				150	Sandy Soil	13.6	-	1.028	460.8	333.6	63.2	71.1	129.09	2.000	258.2	460.8	333.6	0.530	0.439	588.0		1.000	
				150	Sandy Soil				480.3	343.1	61.7	61.7	57.89	2.000	115.8	480.3	343.1	0.515	0.432	267.8		1.000	
				150	Sandy Soil				499.8	352.6	60.3	60.3	50.75	2.000	101.5	499.8	352.6	0.500	0.425	238.8		1.000	
	30.00	Sand	19.5	150	Sandy Soil				519.3	362.1	59.0	59.0	44.59	2.000	89.19	519.3	362.1	0.485	0.417	213.8		1.000	
Remark																							

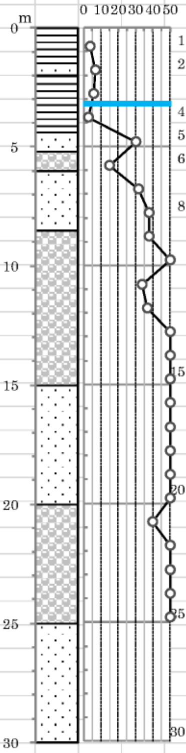
J-1

GRAIN SIZE DISTRIBUTION RESULTS (JONO OGE /J - 1)



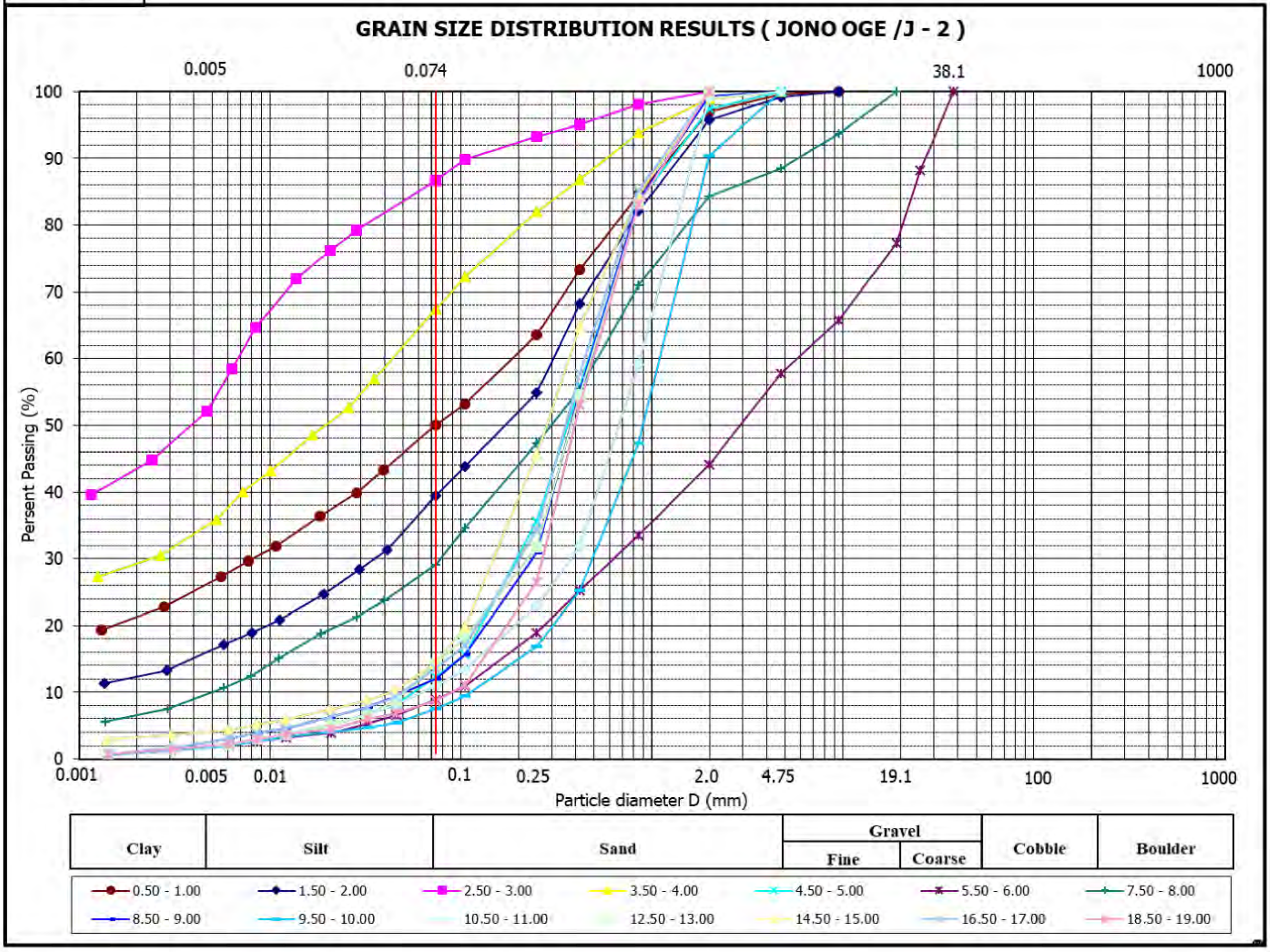
J-2

No.	1	Name	J-2	Location	Jono Oge	LNG;	825140.52 m E	LAT;	9890923.74 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	25.00m	Ground Water Level	3.20m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m



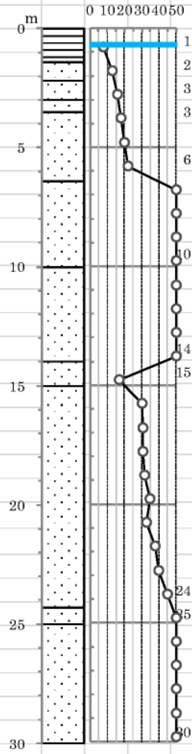
Depth	Drilling Log		Unit Weight	N Value	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
			kN/m³																		2.60		
				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
	1.50	Silt	15.5	4	-	%	-	mm	kN/m³	kN/m³			-	-	-	kN/m³	kN/m³	-	-	-	9.60	1.000	0.000
	2.00	Sand	17.5	7	Sandy Soil	39.4	5.7	0.186	28.5	28.5	12.1	26.4	0.478	2.000	0.956	28.5	28.5	0.905	-	-	9.10	1.000	0.000
				6	-	86.7	29.0	0.004	44.4	44.4	8.9	-	-	-	-	44.4	44.4	0.890	-	-	8.60	1.000	0.000
	4.40	Silt	15.5	3	-	67.5	15.3	0.020	59.9	53.9	4.1	-	-	-	-	59.9	53.9	0.875	0.583	-	8.10	1.000	0.000
	5.20	Sand	19.5	30	Sandy Soil	12.4	-	0.370	77.0	61.0	38.9	42.2	5.841	2.000	11.68	77.0	61.0	0.860	0.651	17.94	7.60	1.000	0.000
	6.00	Sand and Gravel	21.0	15	Gravelly Soil	8.9	-	3.171	97.4	71.4	18.0	16.7	0.277	1.584	0.438	97.4	71.4	0.845	0.691	0.634	7.10	0.634	2.597
				32	Sandy Soil	29.1	-	0.306	117.2	81.2	36.0	60.4	51.18	2.000	102.4	117.2	81.2	0.830	0.719	142.4	6.60	1.000	0.000
	8.50	Sand	19.5	38	Sandy Soil	12.0	-	0.384	136.7	90.7	40.2	43.1	6.618	2.000	13.24	136.7	90.7	0.815	0.737	17.97	6.10	1.000	0.000
				38	Gravelly Soil	7.5	-	0.923	156.7	100.7	37.9	42.4	6.018	2.000	12.04	156.7	100.7	0.800	0.747	16.12	5.60	1.000	0.000
				67	Gravelly Soil	10.9	-	0.705	177.7	111.7	62.7	72.9	148.61	2.000	297.2	177.7	111.7	0.785	0.749	396.7	5.10	1.000	0.000
				34	Gravelly Soil			2.000	198.7	122.7	30.0	30.0	0.790	2.000	1.581	198.7	122.7	0.770	0.748	2.113	4.60	1.000	0.000
				37	Gravelly Soil			2.000	219.7	133.7	30.9	30.9	0.911	2.000	1.821	219.7	133.7	0.755	0.744	2.447	4.10	1.000	0.000
				50	Gravelly Soil	14.3	-	0.386	240.7	144.7	39.6	49.8	16.18	2.000	32.36	240.7	144.7	0.740	0.738	43.82	3.60	1.000	0.000
				50	Gravelly Soil			2.000	261.7	155.7	37.7	37.7	2.858	2.000	5.716	261.7	155.7	0.725	0.731	7.820	3.10	1.000	0.000
	15.00	Sand and Gravel	21.0	50	Gravelly Soil	14.4	-	0.288	282.7	166.7	35.9	46.8	11.06	2.000	22.12	282.7	166.7	0.710	0.722	30.63	2.60	1.000	0.000
				52	Sandy Soil			2.000	302.5	176.5	35.9	35.9	2.117	2.000	4.233	302.5	176.5	0.695	0.715	5.925	2.10	1.000	0.000
				52	Sandy Soil	13.6	-	0.364	322.0	186.0	34.5	38.9	3.515	2.000	7.030	322.0	186.0	0.680	0.706	9.955	1.60	1.000	0.000
				54	Sandy Soil				341.5	195.5	34.6	34.6	1.701	2.000	3.401	341.5	195.5	0.665	0.697	4.881	1.10	1.000	0.000
				50	Sandy Soil	8.7	-	0.400	361.0	205.0	30.9	30.9	0.915	2.000	1.830	361.0	205.0	0.650	0.687	2.665	0.60	1.000	0.000
	20.00	Sand	19.5	50	Sandy Soil				380.5	214.5	29.9	29.9	0.776	2.000	1.551	380.5	214.5	0.635	0.676	2.296	0.10	1.000	0.000
				60	Gravelly Soil			2.000	401.2	225.2	34.6	34.6	1.694	2.000	3.387	401.2	225.2	0.620	0.663	5.113		1.000	
				300	Gravelly Soil			2.000	422.2	236.2	166.6	166.6	10714.18	2.000	21428.4	422.2	236.2	0.605	0.649	33036		1.000	
				214	Gravelly Soil			2.000	443.2	247.2	114.7	114.7	1652.42	2.000	3304.8	443.2	247.2	0.590	0.634	5209		1.000	
				750	Gravelly Soil			2.000	464.2	258.2	388.5	388.5	609357.82	2.000	1218715.6	464.2	258.2	0.575	0.620	1965558		1.000	
	25.00	Sand and Gravel	21.0	375	Gravelly Soil			2.000	485.2	269.2	188.0	188.0	19331.90	2.000	38663.8	485.2	269.2	0.560	0.605	63867		1.000	
					Sandy Soil				505.0	279.0	-	-	-	-	-	505.0	279.0	0.545	-	-		1.000	
					Sandy Soil				524.5	288.5	-	-	-	-	-	524.5	288.5	0.530	-	-		1.000	
					Sandy Soil				544.0	298.0	-	-	-	-	-	544.0	298.0	0.515	-	-		1.000	
					Sandy Soil				563.5	307.5	-	-	-	-	-	563.5	307.5	0.500	-	-		1.000	
	30.00	Sand	19.5		Sandy Soil				583.0	317.0	-	-	-	-	-	583.0	317.0	0.485	-	-		1.000	
Remark																							

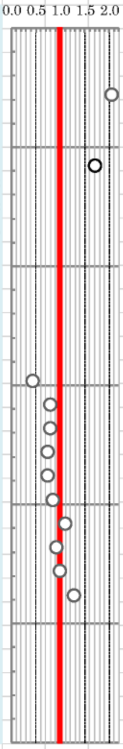
J-2



J-3

No.	1	Name	J-3	Location	Jono Oge	LNG;	823812.00 m E	LAT;	9890557.00 m S
Standard Depth for "sv"	0.00m								
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	0.70m	Ground Hight	4.55m	Lateral Seismic Facter	0.600
Type of Seismic Motion	Type2								

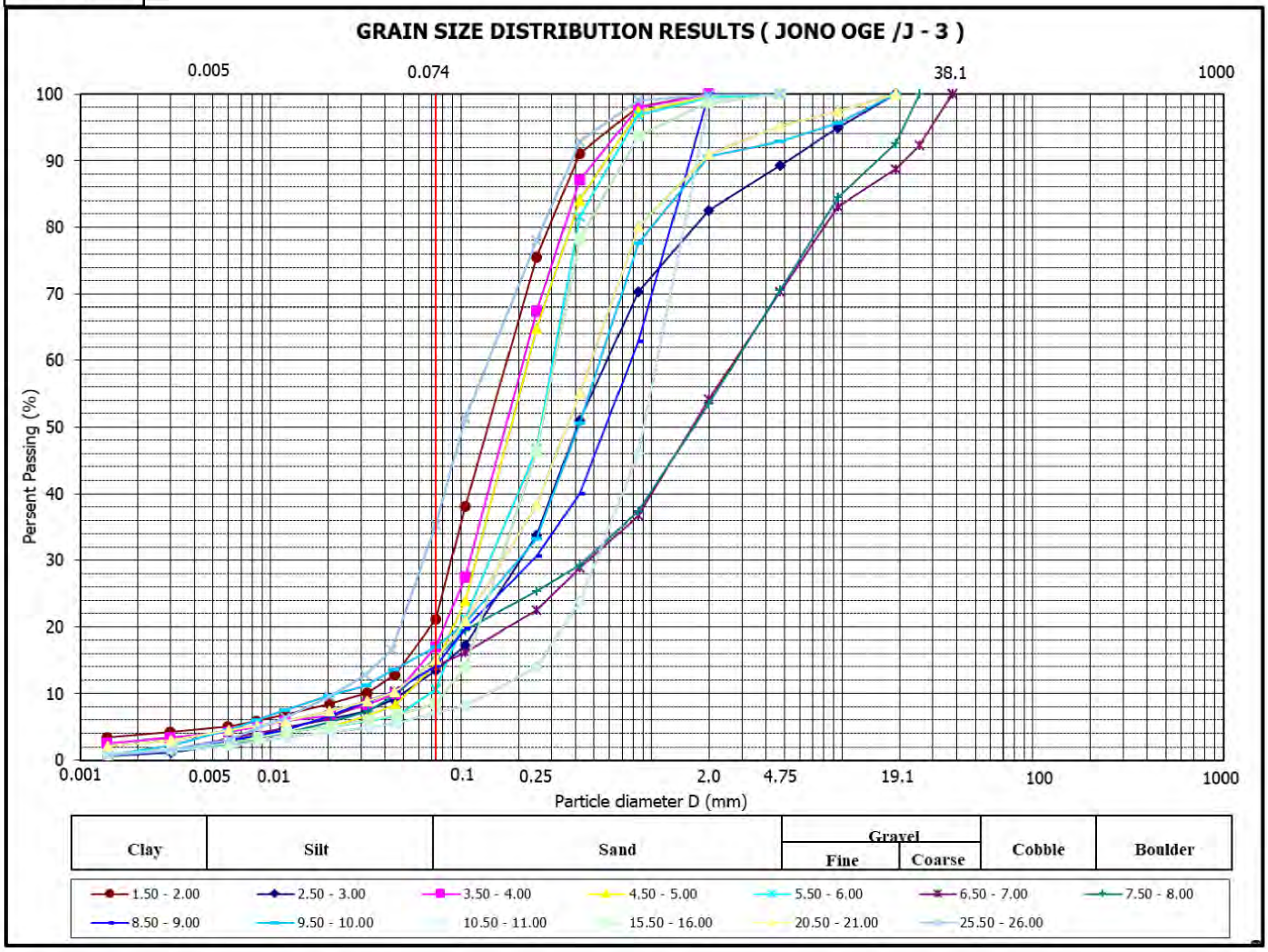




Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment					(Value for Calcurate L)					P_L		
		kN/m³																		2.68		
			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
1.40	Silt	15.5	8	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
2.20	Sand	19.5	13	Sandy Soil	21.2	-	0.151	29.5	18.5	25.0	35.2	1.886	2.000	3.772	29.5	18.5	0.905	0.866	4.357	9.10	1.000	0.000
3.00	Sand	19.5	16	Sandy Soil	13.4	-	0.410	49.0	28.0	27.8	31.2	0.955	2.000	1.910	49.0	28.0	0.890	0.934	2.045	8.60	1.000	0.000
3.50	Sand	19.5	18	Sandy Soil	17.0	-	0.187	68.5	37.5	28.5	35.6	2.039	2.000	4.077	68.5	37.5	0.875	0.959	4.253	8.10	1.000	0.000
			20	Sandy Soil	14.3	-	0.198	88.0	47.0	29.1	33.6	1.444	2.000	2.888	88.0	47.0	0.860	0.966	2.990	7.60	1.000	0.000
6.40	Sand	19.5	22	Sandy Soil	10.7	-	0.266	107.5	56.5	29.6	30.3	0.825	2.000	1.649	107.5	56.5	0.845	0.964	1.710	7.10	1.000	0.000
			135	Sandy Soil	14.1	-	1.724	127.0	66.0	168.8	192.0	21450.76	2.000	42901.5	127.0	66.0	0.830	0.958	44783	6.60	1.000	0.000
			222	Sandy Soil	15.4	-	1.746	146.5	75.5	259.4	306.6	200461.01	2.000	400922.0	146.5	75.5	0.815	0.949	422662	6.10	1.000	0.000
			175	Sandy Soil	14.2	-	0.609	166.0	85.0	191.9	218.9	40406.22	2.000	80812.4	166.0	85.0	0.800	0.937	86235	5.60	1.000	0.000
10.00	Sand	19.5	163	Sandy Soil	17.1	-	0.414	185.5	94.5	168.4	208.7	32072.12	2.000	64144.2	185.5	94.5	0.785	0.924	69401	5.10	1.000	0.000
			93	Sandy Soil	7.1	-	0.937	205.0	104.0	90.9	90.9	490.23	2.000	980.5	205.0	104.0	0.770	0.910	1077	4.60	1.000	0.000
			102	Sandy Soil				224.5	113.5	94.5	94.5	603.36	2.000	1206.7	224.5	113.5	0.755	0.896	1347	4.10	1.000	0.000
			96	Sandy Soil				244.0	123.0	84.6	84.6	333.76	2.000	667.5	244.0	123.0	0.740	0.880	758.1	3.60	1.000	0.000
14.00	Sand	19.5	111	Sandy Soil				263.5	132.5	93.2	93.2	560.43	2.000	1120.9	263.5	132.5	0.725	0.865	1296	3.10	1.000	0.000
15.00	Sand	19.5	17	Sandy Soil				283.0	142.0	13.6	13.6	0.250	1.496	0.374	283.0	142.0	0.710	0.849	0.441	2.60	0.441	1.453
			30	Sandy Soil	8.5	-	0.270	302.5	151.5	23.0	23.0	0.356	1.846	0.658	302.5	151.5	0.695	0.832	0.791	2.10	0.791	0.439
			31	Sandy Soil				322.0	161.0	22.8	22.8	0.352	1.831	0.644	322.0	161.0	0.680	0.816	0.790	1.60	0.790	0.337
			31	Sandy Soil				341.5	170.5	21.9	21.9	0.334	1.773	0.593	341.5	170.5	0.665	0.799	0.742	1.10	0.742	0.284
			32	Sandy Soil				361.0	180.0	21.8	21.8	0.332	1.765	0.585	361.0	180.0	0.650	0.782	0.749	0.60	0.749	0.151
			35	Sandy Soil				380.5	189.5	22.9	22.9	0.354	1.839	0.652	380.5	189.5	0.635	0.765	0.852	0.10	0.852	0.015
			33	Sandy Soil	15.1	-	0.369	400.0	199.0	20.9	24.8	0.410	2.000	0.820	400.0	199.0	0.620	0.747	1.097		1.000	
			38	Sandy Soil				419.5	208.5	23.2	23.2	0.360	1.860	0.670	419.5	208.5	0.605	0.730	0.918		0.918	
			40	Sandy Soil				439.0	218.0	23.6	23.6	0.371	1.894	0.703	439.0	218.0	0.590	0.713	0.986		0.986	
24.30	Sand	19.5	45	Sandy Soil				458.5	227.5	25.7	25.7	0.446	2.000	0.892	458.5	227.5	0.575	0.695	1.284		1.000	
25.00	Sand	19.5	81	Sandy Soil				478.0	237.0	44.9	44.9	8.507	2.000	17.01	478.0	237.0	0.560	0.677	25.12		1.000	
			122	Sandy Soil	35.4	-	0.103	497.5	246.5	65.5	123.0	2362.08	2.000	4724.2	497.5	246.5	0.545	0.660	7161		1.000	
			120	Sandy Soil				517.0	256.0	62.6	62.6	62.63	2.000	125.3	517.0	256.0	0.530	0.642	195.1		1.000	
			135	Sandy Soil				536.5	265.5	68.4	68.4	103.96	2.000	207.9	536.5	265.5	0.515	0.624	333.1		1.000	
			107	Sandy Soil				556.0	275.0	52.7	52.7	22.88	2.000	45.76	556.0	275.0	0.500	0.606	75.49		1.000	
30.00	Sand	19.5	210	Sandy Soil				575.5	284.5	100.7	100.7	842.70	2.000	1685.4	575.5	284.5	0.485	0.588	2865		1.000	

Remark

J-3

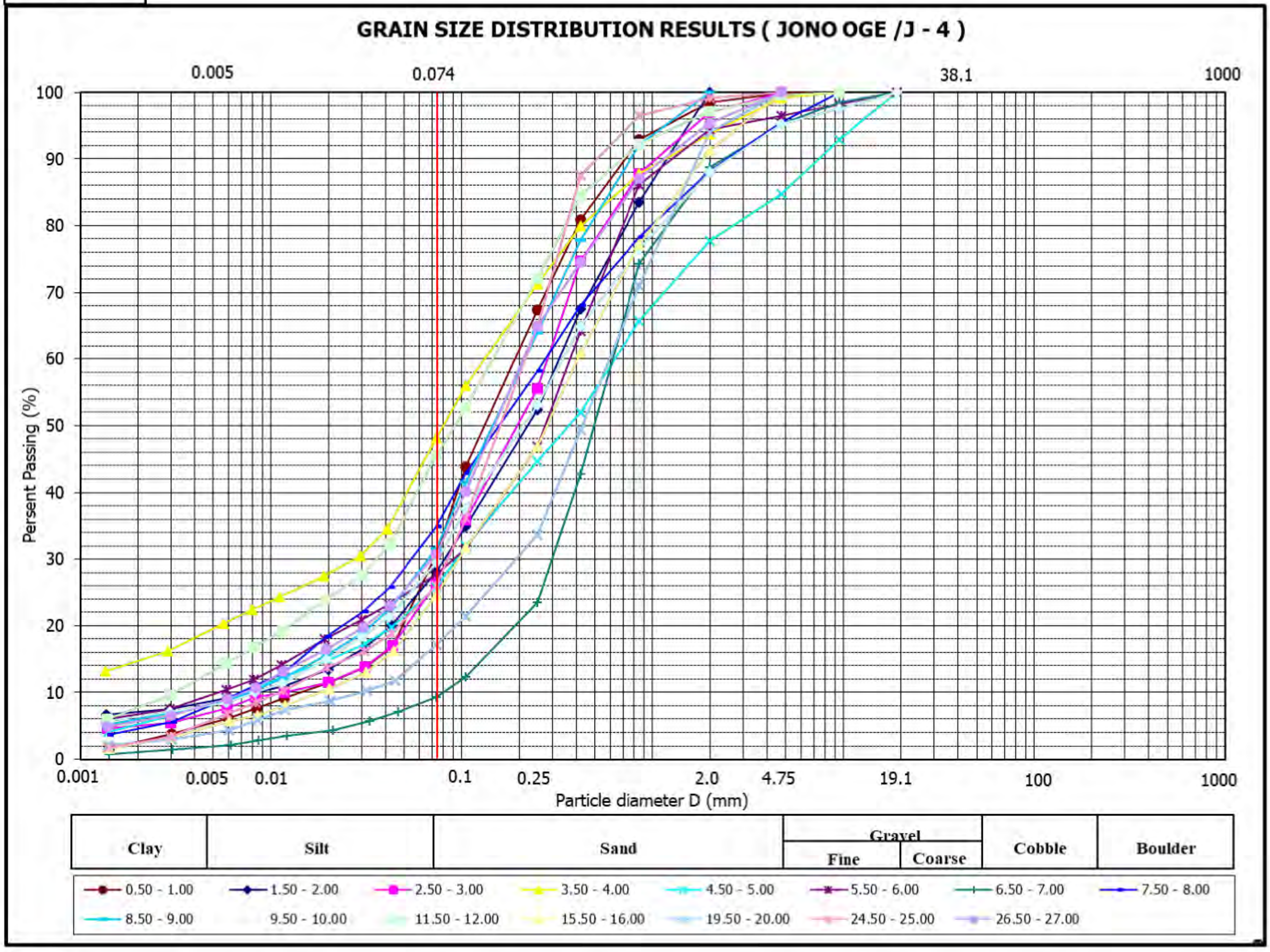


J-4

No.	1	Name	J-4	Location	Jono Oge	LNG;	822542.00 m E	LAT;	9891390.00 m S
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	1.20m	Ground Hight	4.55m	Lateral Seismic Facter	0.600
Type of Seismic Motion	Type2	Standard Depth for "sv"	0.00m						

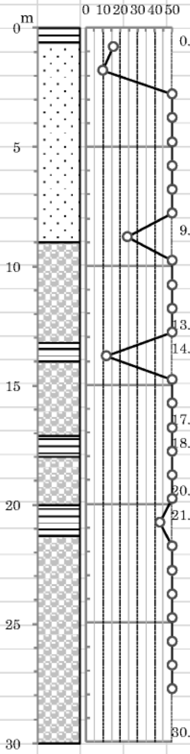
Depth	Drilling Log	Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)											P_L		
		kN/m³																			0.00		
0 m	0 10 20 30 40 50		N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	0.0 0.5 1.0 1.5 2.0	W	F_L	ΔP_L
0.50	Sand	17.5	39	-	%	-	mm	kN/m³	kN/m³			-	-	-	kN/m³	kN/m³	-	-	-		9.60	1.000	0.000
			48	Sandy Soil	28.1	-	0.230	31.5	25.5	85.4	138.5	4297.62	2.000	8595.2	31.5	25.5	0.905	0.671	12818		9.10	1.000	0.000
3.50	Sand	17.5	54	Sandy Soil	26.4	-	0.209	49.0	33.0	89.1	139.1	4385.52	2.000	8771.0	49.0	33.0	0.890	0.793	11065		8.60	1.000	0.000
			45	-	48.1	5.6	0.082	66.5	40.5	69.2	-	-	-	-	66.5	40.5	0.875	0.862	-		8.10	1.000	0.000
4.80	Silt	17.5	46	Gravelly Soil	25.9	-	0.374	84.0	48.0	66.3	83.6	314.69	2.000	629.4	84.0	48.0	0.860	0.903	697.2		7.60	1.000	0.000
6.20	Sand and Gravel	21.0	58	Gravelly Soil	27.7	-	0.280	105.0	59.0	76.4	99.9	808.49	2.000	1617.0	105.0	59.0	0.845	0.902	1793		7.10	1.000	0.000
7.20	Sand	19.5	56	Sandy Soil	9.3	-	0.519	125.1	69.1	68.4	68.4	104.25	2.000	208.5	125.1	69.1	0.830	0.901	231.3		6.60	1.000	0.000
8.50	Sand	19.5	56	Sandy Soil	35.0	-	0.172	144.6	78.6	64.1	119.4	2028.73	2.000	4057.5	144.6	78.6	0.815	0.899	4512		6.10	1.000	0.000
9.00	Sand and Gravel	21.0	56	Gravelly Soil	31.7	-	0.160	164.6	88.6	60.0	83.8	317.16	2.000	634.3	164.6	88.6	0.800	0.892	711.4		5.60	1.000	0.000
			72	Sandy Soil	29.5	-	0.221	184.4	98.4	72.7	121.7	2231.27	2.000	4462.5	184.4	98.4	0.785	0.883	5056		5.10	1.000	0.000
			62	Sandy Soil				203.9	107.9	59.3	59.3	45.70	2.000	91.41	203.9	107.9	0.770	0.873	104.7		4.60	1.000	0.000
			59	Sandy Soil	45.5	-	0.094	223.4	117.4	53.5	135.1	3783.61	2.000	7567.2	223.4	117.4	0.755	0.862	8780		4.10	1.000	0.000
			61	Sandy Soil				242.9	126.9	52.7	52.7	22.76	2.000	45.53	242.9	126.9	0.740	0.850	53.58		3.60	1.000	0.000
			63	Sandy Soil				262.4	136.4	51.9	51.9	20.82	2.000	41.63	262.4	136.4	0.725	0.837	49.76		3.10	1.000	0.000
			73	Sandy Soil				281.9	145.9	57.5	57.5	38.27	2.000	76.55	281.9	145.9	0.710	0.823	93.02		2.60	1.000	0.000
			71	Sandy Soil	24.6	-	0.288	301.4	155.4	53.6	80.9	262.73	2.000	525.5	301.4	155.4	0.695	0.809	649.8		2.10	1.000	0.000
			80	Sandy Soil				320.9	164.9	57.9	57.9	39.93	2.000	79.85	320.9	164.9	0.680	0.794	100.6		1.60	1.000	0.000
			73	Sandy Soil				340.4	174.4	50.8	50.8	18.26	2.000	36.51	340.4	174.4	0.665	0.779	46.89		1.10	1.000	0.000
			78	Sandy Soil				359.9	183.9	52.2	52.2	21.63	2.000	43.27	359.9	183.9	0.650	0.763	56.71		0.60	1.000	0.000
			76	Sandy Soil	17.2	-	0.433	379.4	193.4	49.1	61.4	56.28	2.000	112.6	379.4	193.4	0.635	0.747	150.6		0.10	1.000	0.000
			80	Sandy Soil				398.9	202.9	49.8	49.8	16.29	2.000	32.58	398.9	202.9	0.620	0.731	44.56			1.000	
			70	Sandy Soil				418.4	212.4	42.1	42.1	5.767	2.000	11.53	418.4	212.4	0.605	0.715	16.13			1.000	
			76	Sandy Soil				437.9	221.9	44.3	44.3	7.840	2.000	15.68	437.9	221.9	0.590	0.698	22.45			1.000	
			74	Sandy Soil				457.4	231.4	41.7	41.7	5.431	2.000	10.86	457.4	231.4	0.575	0.682	15.93			1.000	
			72	Sandy Soil	26.1	-	0.175	476.9	240.9	39.4	61.8	58.33	2.000	116.7	476.9	240.9	0.560	0.665	175.4			1.000	
			72	Sandy Soil				496.4	250.4	38.2	38.2	3.122	2.000	6.244	496.4	250.4	0.545	0.648	9.635			1.000	
			68	Sandy Soil	30.7	-	0.162	515.9	259.9	35.0	61.0	53.91	2.000	107.8	515.9	259.9	0.530	0.631	170.9			1.000	
			67	Sandy Soil				535.4	269.4	33.6	33.6	1.429	2.000	2.857	535.4	269.4	0.515	0.614	4.655			1.000	
			76	Sandy Soil				554.9	278.9	37.0	37.0	2.574	2.000	5.148	554.9	278.9	0.500	0.597	8.629			1.000	
30.00	Sand	19.5	70	Sandy Soil				574.4	288.4	33.2	33.2	1.344	2.000	2.689	574.4	288.4	0.485	0.579	4.641			1.000	
Remark																							

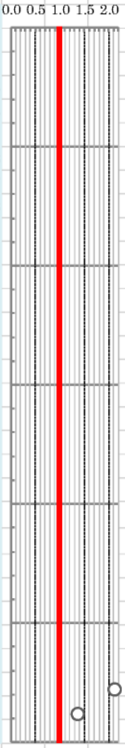
J-4



J-5

No.	1	Name	J-5	Location	Jono Oge	LNG;	824476.00 m E	LAT;	9894166.00 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	28.00m	Ground Water Level	-1.95m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion
									Type2	0.00m

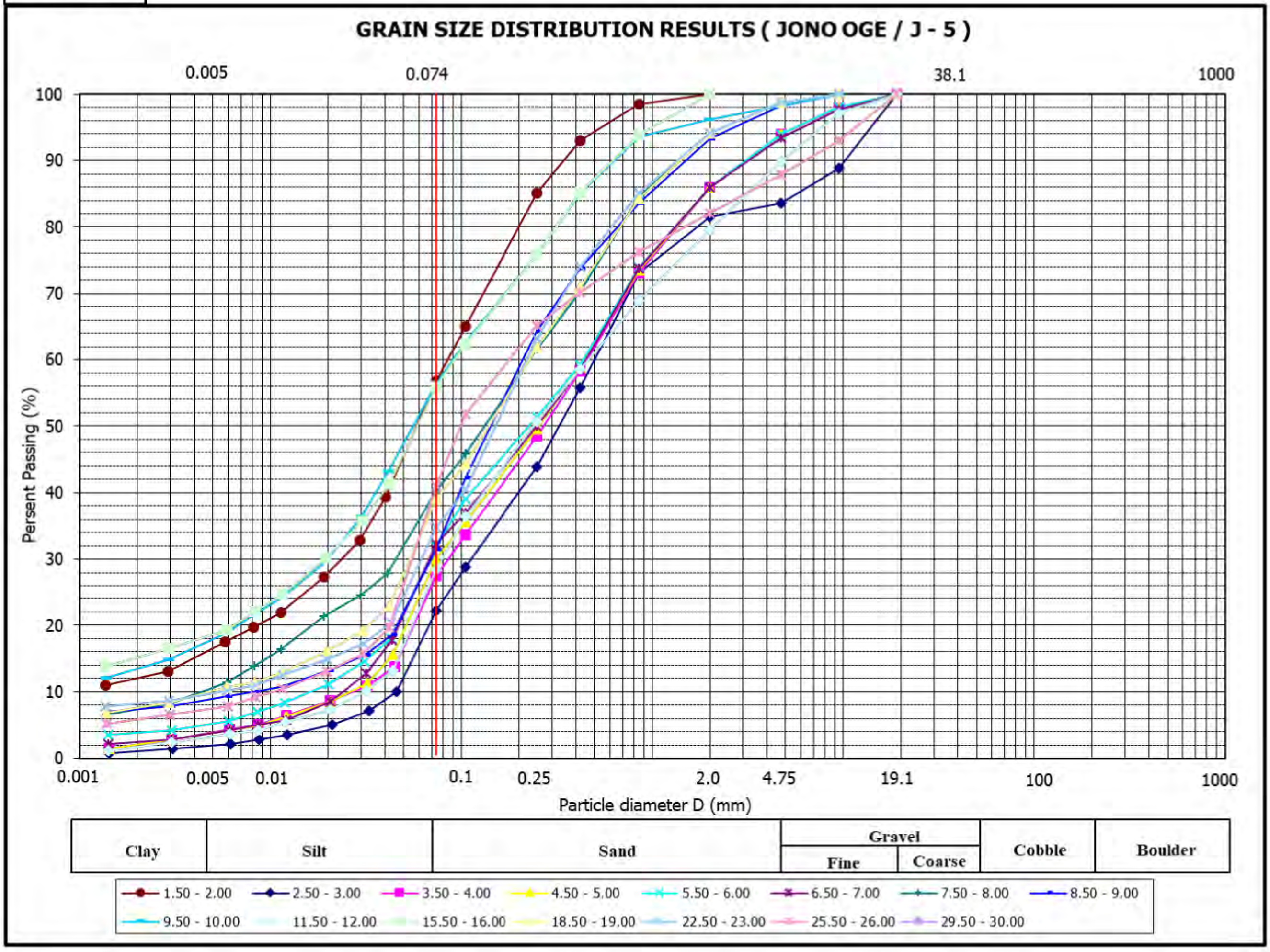




Depth	Drilling Log	Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
		kN/m³																		0.00		
m			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
0.60	Silt	17.5	16	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
			10	Sandy Soil	56.8	4.9	0.061	33.9	-3.6	25.6	92.9	551.98	2.000	1104.0	33.9	15.9	0.905	1.157	953.8	9.10	1.000	0.000
			63	Sandy Soil	22.2	-	0.337	53.4	5.9	141.1	199.5	25828.00	2.000	51656.0	53.4	25.4	0.890	1.122	46025	8.60	1.000	0.000
			58	Sandy Soil	27.5	-	0.277	72.9	15.4	115.5	184.3	17542.90	2.000	35085.8	72.9	34.9	0.875	1.096	32003	8.10	1.000	0.000
			53	Sandy Soil	30.1	-	0.257	92.4	24.9	94.9	160.1	8808.67	2.000	17617.3	92.4	44.4	0.860	1.074	16411	7.60	1.000	0.000
			57	Sandy Soil	32.0	-	0.211	111.9	34.4	92.8	162.8	9578.78	2.000	19157.6	111.9	53.9	0.845	1.052	18206	7.10	1.000	0.000
			57	Sandy Soil	32.2	-	0.250	131.4	43.9	85.1	150.0	6374.88	2.000	12749.8	131.4	63.4	0.830	1.032	12357	6.60	1.000	0.000
			54	Sandy Soil	40.2	-	0.144	150.9	53.4	74.4	152.8	6996.49	2.000	13993.0	150.9	72.9	0.815	1.012	13828	6.10	1.000	0.000
9.00	Gravelly silty sand	19.5	24	Sandy Soil	31.4	-	0.156	170.4	62.9	30.7	54.4	27.52	2.000	55.04	170.4	82.4	0.800	0.992	55.47	5.60	1.000	0.000
			65	Gravelly Soil	56.3	7.0	0.058	191.1	73.6	76.9	119.5	2033.76	2.000	4067.5	191.1	93.1	0.785	0.966	4209	5.10	1.000	0.000
			59	Gravelly Soil			2.000	212.1	84.6	64.9	64.9	77.01	2.000	154.0	212.1	104.1	0.770	0.941	163.7	4.60	1.000	0.000
			58	Gravelly Soil	28.4	-	0.243	233.1	95.6	59.5	79.2	233.48	2.000	467.0	233.1	115.1	0.755	0.917	509.2	4.10	1.000	0.000
13.20	Sand and Gravel	21.0	55	Gravelly Soil			2.000	254.1	106.6	52.9	52.9	23.46	2.000	46.92	254.1	126.1	0.740	0.894	52.46	3.60	1.000	0.000
14.00	Silt	17.5	12	-				273.0	115.5	11.0	-	-	-	-	273.0	135.0	0.725	0.879	-	3.10	1.000	0.000
			64	Gravelly Soil			2.000	293.3	125.8	55.6	55.6	31.30	2.000	62.60	293.3	145.3	0.710	0.860	72.82	2.60	1.000	0.000
			51	Gravelly Soil	56.0	6.5	0.058	314.3	136.8	41.9	65.2	78.93	2.000	157.9	314.3	156.3	0.695	0.838	188.3	2.10	1.000	0.000
17.10	Sand and Gravel	21.0	55	Gravelly Soil			2.000	335.3	147.8	42.9	42.9	6.471	2.000	12.94	335.3	167.3	0.680	0.817	15.83	1.60	1.000	0.000
18.00	Silt	17.5	67	-				353.9	156.4	50.3	-	-	-	-	353.9	175.9	0.665	0.803	-	1.10	1.000	0.000
			74	Gravelly Soil	39.1	-	0.152	374.2	166.7	53.2	74.6	168.21	2.000	336.4	374.2	186.2	0.650	0.784	429.3	0.60	1.000	0.000
20.00	Sand and Gravel	21.0	50	Gravelly Soil			2.000	395.2	177.7	34.3	34.3	1.627	2.000	3.253	395.2	197.2	0.635	0.763	4.262	0.10	1.000	0.000
21.30	Silt	17.5	43	-				413.4	185.9	28.6	-	-	-	-	413.4	205.4	0.620	0.748	-		1.000	
			55	Gravelly Soil			2.000	432.6	195.1	35.3	35.3	1.912	2.000	3.824	432.6	214.6	0.605	0.731	5.228		1.000	
			64	Gravelly Soil	34.8	-	0.166	453.6	206.1	39.4	54.8	28.67	2.000	57.34	453.6	225.6	0.590	0.711	80.60		1.000	
			69	Gravelly Soil			2.000	474.6	217.1	40.9	40.9	4.746	2.000	9.493	474.6	236.6	0.575	0.692	13.72		1.000	
			56	Gravelly Soil			2.000	495.6	228.1	31.9	31.9	1.083	2.000	2.167	495.6	247.6	0.560	0.672	3.223		1.000	
			62	Gravelly Soil	40.9	-	0.100	516.6	239.1	34.1	50.1	16.74	2.000	33.49	516.6	258.6	0.545	0.653	51.29		1.000	
			58	Gravelly Soil			2.000	537.6	250.1	30.8	30.8	0.898	2.000	1.797	537.6	269.6	0.530	0.634	2.834		1.000	
			56	Gravelly Soil			2.000	558.6	261.1	28.8	28.8	0.654	2.000	1.308	558.6	280.6	0.515	0.615	2.127		1.000	
			50	Gravelly Soil			2.000	579.6	272.1	24.8	24.8	0.410	2.000	0.820	579.6	291.6	0.500	0.596	1.376		1.000	
30.00	Sand and Gravel	21.0		Gravelly Soil			2.000	600.6	283.1	-	-	-	-	-	600.6	302.6	0.485	-	-		1.000	

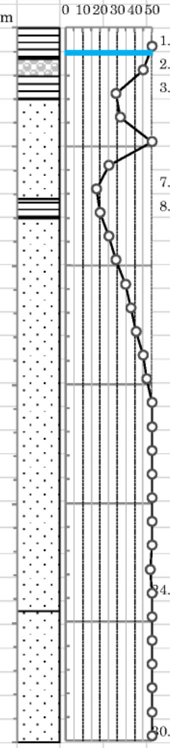
Remark

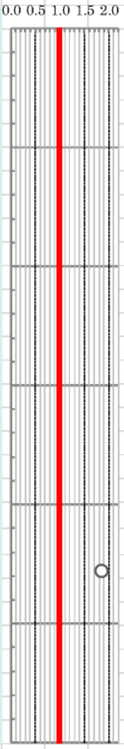
J-5



J-6

No.	1	Name	J-6	Location	Jono Oge	LNG;	822628.00 m E	LAT;	9894199.00 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	1.07m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m

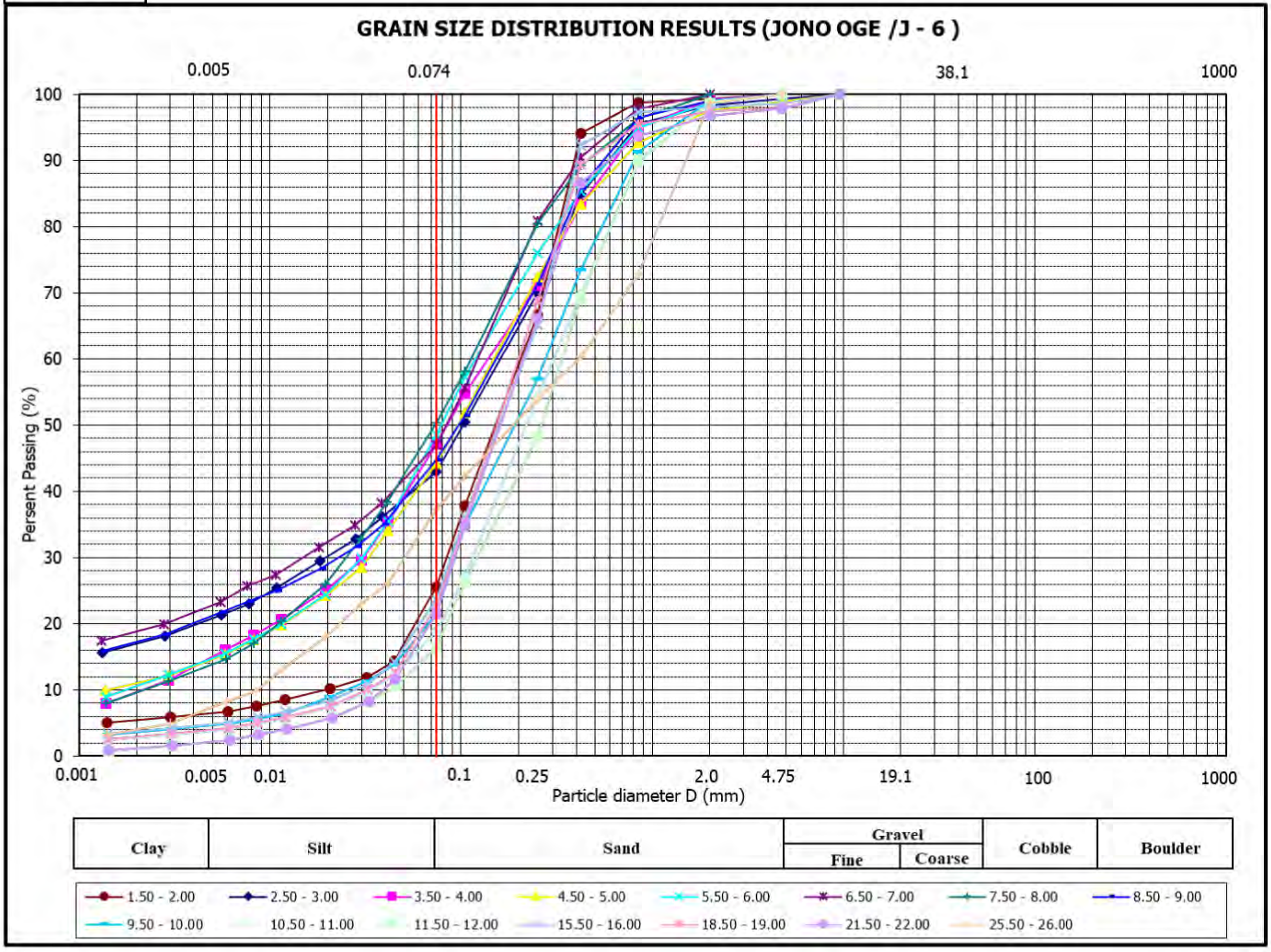




Depth	Drilling Log	Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment					(Value for Calcurate L)					P_L		
		kN/m³																		0.00		
m			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
1.30	Silt	15.5	51	-	%	-	mm	kN/m³	kN/m³			-	-	-	kN/m³	kN/m³	-	-	-	9.60	1.000	0.000
2.05	Sand and Gravel	21.0	45	Gravelly Soil	25.6	-	0.166	30.7	23.4	81.9	113.8	1589.04	2.000	3178.1	30.7	23.4	0.905	0.713	4460	9.10	1.000	0.000
3.00	Silt	17.5	29	-	43.0	10.5	0.103	49.0	31.7	48.5	-	-	-	-	49.0	31.7	0.890	0.825	-	8.60	1.000	0.000
			32	Sandy Soil	47.1	6.9	0.086	68.1	40.8	49.1	131.1	3259.79	2.000	6519.6	68.1	40.8	0.875	0.876	7444	8.10	1.000	0.000
			50	Sandy Soil	44.2	-	0.097	87.6	50.3	70.6	169.1	11538.00	2.000	23076.0	87.6	50.3	0.860	0.898	25692	7.60	1.000	0.000
			25	Sandy Soil	48.5	6.5	0.079	107.1	59.8	32.7	93.0	554.63	2.000	1109.3	107.1	59.8	0.845	0.908	1222	7.10	1.000	0.000
7.20	Sand	19.5	18	Sandy Soil	47.0	11.6	0.085	126.6	69.3	22.0	60.7	52.45	2.000	104.9	126.6	69.3	0.830	0.909	115.4	6.60	1.000	0.000
8.00	Silt	17.5	20	-	50.3	6.4	0.073	144.9	77.6	23.0	-	-	-	-	144.9	77.6	0.815	0.913	-	6.10	1.000	0.000
			25	Sandy Soil	44.8	10.6	0.099	164.0	86.7	27.1	68.5	104.41	2.000	208.8	164.0	86.7	0.800	0.908	230.1	5.60	1.000	0.000
			29	Sandy Soil	21.5	-	0.179	183.5	96.2	29.7	42.0	5.601	2.000	11.20	183.5	96.2	0.785	0.898	12.47	5.10	1.000	0.000
			35	Sandy Soil	18.8	-	0.203	203.0	105.7	33.9	44.5	8.137	2.000	16.27	203.0	105.7	0.770	0.887	18.35	4.60	1.000	0.000
			38	Sandy Soil	16.5	-	0.264	222.5	115.2	34.9	42.9	6.457	2.000	12.91	222.5	115.2	0.755	0.875	14.77	4.10	1.000	0.000
			41	Sandy Soil				242.0	124.7	35.8	35.8	2.090	2.000	4.180	242.0	124.7	0.740	0.861	4.853	3.60	1.000	0.000
			45	Sandy Soil				261.5	134.2	37.5	37.5	2.761	2.000	5.522	261.5	134.2	0.725	0.847	6.517	3.10	1.000	0.000
			47	Sandy Soil				281.0	143.7	37.4	37.4	2.727	2.000	5.454	281.0	143.7	0.710	0.833	6.551	2.60	1.000	0.000
			50	Sandy Soil	23.6	-	0.174	300.5	153.2	38.1	56.5	34.56	2.000	69.11	300.5	153.2	0.695	0.818	84.53	2.10	1.000	0.000
			56	Sandy Soil				320.0	162.7	40.9	40.9	4.783	2.000	9.565	320.0	162.7	0.680	0.802	11.93	1.60	1.000	0.000
			58	Sandy Soil				339.5	172.2	40.7	40.7	4.637	2.000	9.275	339.5	172.2	0.665	0.786	11.80	1.10	1.000	0.000
			63	Sandy Soil	22.8	-	0.169	359.0	181.7	42.5	61.7	57.66	2.000	115.3	359.0	181.7	0.650	0.770	149.7	0.60	1.000	0.000
			69	Sandy Soil				378.5	191.2	44.9	44.9	8.566	2.000	17.13	378.5	191.2	0.635	0.754	22.73	0.10	1.000	0.000
			71	Sandy Soil				398.0	200.7	44.6	44.6	8.194	2.000	16.39	398.0	200.7	0.620	0.737	22.22		1.000	
			69	Sandy Soil	21.4	-	0.175	417.5	210.2	41.9	58.7	43.40	2.000	86.79	417.5	210.2	0.605	0.721	120.4		1.000	
			49	Sandy Soil				437.0	219.7	28.8	28.8	0.654	2.000	1.307	437.0	219.7	0.590	0.704	1.858		1.000	
24.50	Sand	19.5	54	Sandy Soil				456.5	229.2	30.7	30.7	0.880	2.000	1.761	456.5	229.2	0.575	0.687	2.564		1.000	
			75	Sandy Soil				476.0	238.7	41.3	41.3	5.077	2.000	10.15	476.0	238.7	0.560	0.670	15.16		1.000	
			75	Sandy Soil	37.3	-	0.202	495.5	248.2	40.1	78.8	227.94	2.000	455.9	495.5	248.2	0.545	0.652	698.7		1.000	
			75	Sandy Soil				515.0	257.7	38.9	38.9	3.494	2.000	6.987	515.0	257.7	0.530	0.635	11.00		1.000	
			78	Sandy Soil				534.5	267.2	39.3	39.3	3.734	2.000	7.468	534.5	267.2	0.515	0.618	12.09		1.000	
			74	Sandy Soil				554.0	276.7	36.3	36.3	2.269	2.000	4.539	554.0	276.7	0.500	0.600	7.560		1.000	
30.00	Gravelly silty sand	19.5	71	Sandy Soil				573.5	286.2	33.9	33.9	1.509	2.000	3.018	573.5	286.2	0.485	0.583	5.178		1.000	

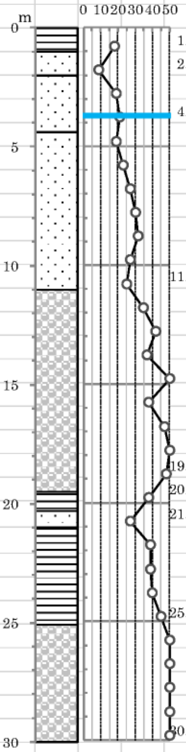
Remark

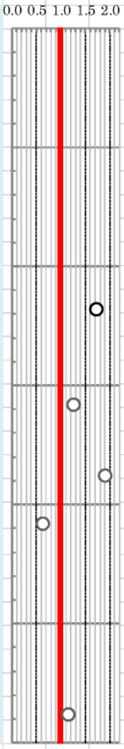
J-6



J-7

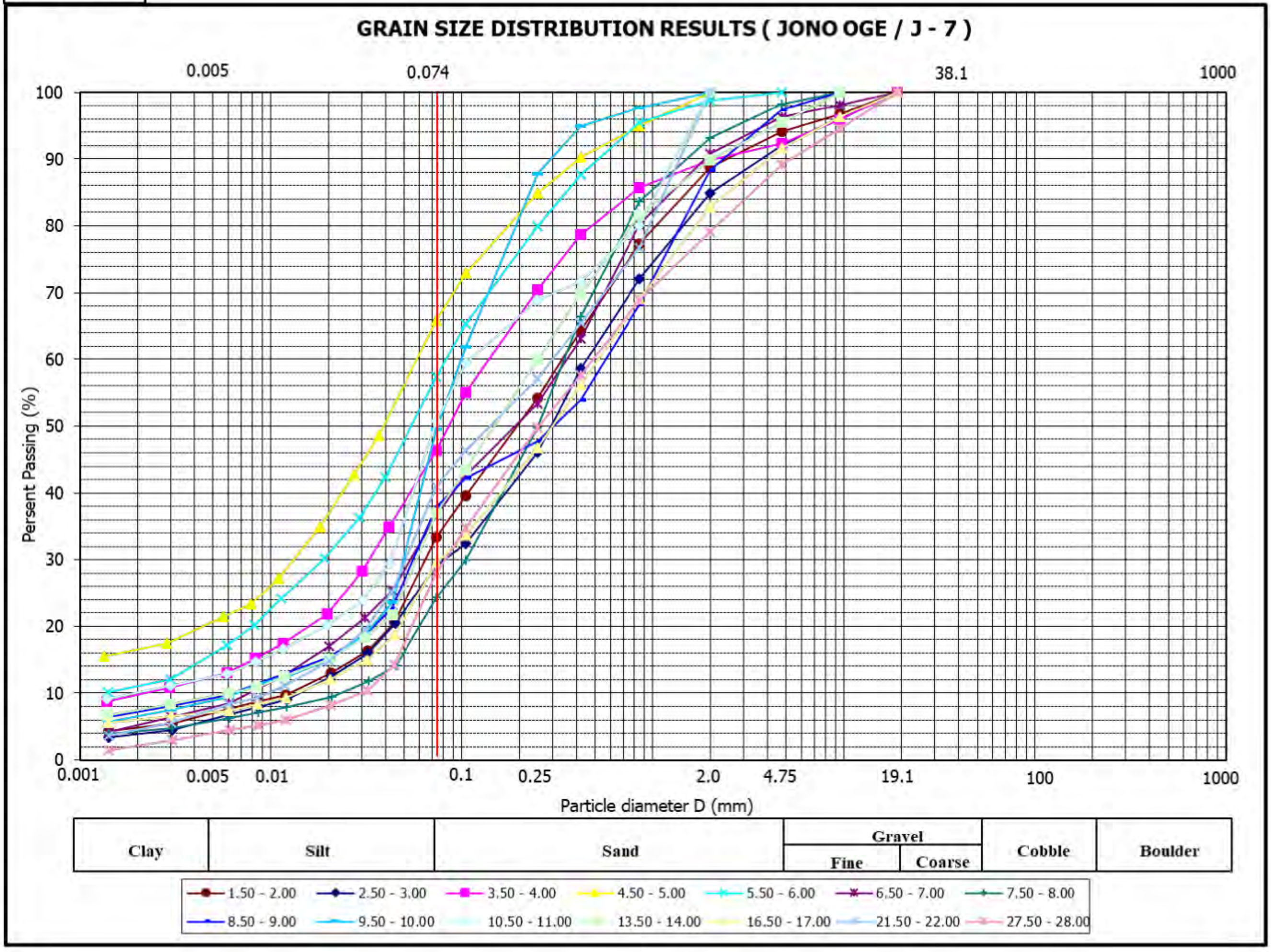
No.	1	Name	J−7	Location	Jono Oge	LNG;	824564.00 m E	LAT;	9892721.00 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	3.71m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m





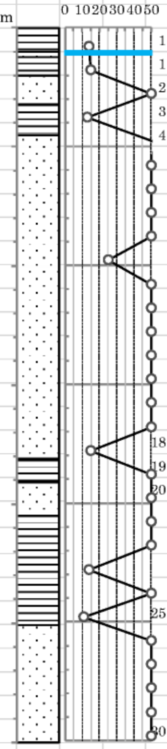
Drilling Log		Unit Weight	N Value	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
		kN/m³																		0.00		
			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
1.00	Silt	15.5	18	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
2.00	Sand	17.5	9	Sandy Soil	33.4	-	0.208	29.5	29.5	15.4	29.3	0.710	2.000	1.420	29.5	29.5	0.905	-	-	9.10	1.000	0.000
			19	Sandy Soil	29.1	-	0.303	47.0	47.0	27.6	46.8	11.05	2.000	22.11	47.0	47.0	0.890	-	-	8.60	1.000	0.000
4.40	Gravelly sand	17.5	21	Sandy Soil	46.4	-	0.087	64.5	63.6	26.7	71.4	131.97	2.000	263.9	64.5	63.6	0.875	0.532	495.9	8.10	1.000	0.000
			19	Sandy Soil	65.9	8.9	0.040	82.8	71.9	22.8	102.4	918.43	2.000	1836.9	82.8	71.9	0.860	0.594	3092	7.60	1.000	0.000
			23	Sandy Soil	57.4	7.6	0.057	102.3	81.4	25.8	95.1	624.72	2.000	1249.4	102.3	81.4	0.845	0.637	1961	7.10	1.000	0.000
			27	Sandy Soil	36.7	-	0.204	121.8	90.9	28.5	56.1	33.14	2.000	66.28	121.8	90.9	0.830	0.667	99.36	6.60	1.000	0.000
			30	Sandy Soil	24.4	-	0.252	141.3	100.4	29.9	45.4	9.227	2.000	18.45	141.3	100.4	0.815	0.688	26.82	6.10	1.000	0.000
			32	Sandy Soil	38.0	-	0.314	160.8	109.9	30.2	60.8	52.82	2.000	105.6	160.8	109.9	0.800	0.702	150.5	5.60	1.000	0.000
			27	Sandy Soil	49.6	-	0.075	180.3	119.4	24.2	72.2	140.96	2.000	281.9	180.3	119.4	0.785	0.711	396.5	5.10	1.000	0.000
11.00	Sand	19.5	25	Sandy Soil	50.7	-	0.073	199.8	128.9	21.4	66.5	88.78	2.000	177.6	199.8	128.9	0.770	0.716	248.0	4.60	1.000	0.000
			35	Gravelly Soil			2.000	220.5	139.6	28.4	28.4	0.620	2.000	1.241	220.5	139.6	0.755	0.715	1.735	4.10	1.000	0.000
			42	Gravelly Soil			2.000	241.5	150.6	32.4	32.4	1.165	2.000	2.330	241.5	150.6	0.740	0.712	3.274	3.60	1.000	0.000
			37	Gravelly Soil	37.0	-	0.163	262.5	161.6	27.2	37.8	2.928	2.000	5.856	262.5	161.6	0.725	0.706	8.290	3.10	1.000	0.000
			150	Gravelly Soil			2.000	283.5	172.6	105.1	105.1	1053.13	2.000	2106.3	283.5	172.6	0.710	0.699	3011	2.60	1.000	0.000
			38	Gravelly Soil			2.000	304.5	183.6	25.5	25.5	0.435	2.000	0.871	304.5	183.6	0.695	0.691	1.259	2.10	1.000	0.000
			47	Gravelly Soil	29.6	-	0.309	325.5	194.6	30.2	39.0	3.553	2.000	7.107	325.5	194.6	0.680	0.682	10.42	1.60	1.000	0.000
			150	Gravelly Soil			2.000	346.5	205.6	92.5	92.5	539.75	2.000	1079.5	346.5	205.6	0.665	0.672	1606	1.10	1.000	0.000
19.50	Sand and Gravel	21.0	48	Gravelly Soil			2.000	367.5	216.6	28.5	28.5	0.628	2.000	1.256	367.5	216.6	0.650	0.661	1.899	0.60	1.000	0.000
20.30	Silt	17.5	38	-				387.5	226.6	21.8	-	-	-	-	387.5	226.6	0.635	0.651	-	0.10	1.000	0.000
21.00	Sand	19.5	27	Sandy Soil				406.0	235.1	15.0	15.0	0.262	1.536	0.403	406.0	235.1	0.620	0.642	0.628		0.628	
			39	-	41.0	-	0.154	423.9	243.0	21.2	-	-	-	-	423.9	243.0	0.605	0.633	-		1.000	
			39	-				441.4	250.5	20.7	-	-	-	-	441.4	250.5	0.590	0.624	-		1.000	
			40	-				458.9	258.0	20.7	-	-	-	-	458.9	258.0	0.575	0.613	-		1.000	
25.10	Silt	17.5	45	-				476.4	265.5	22.8	-	-	-	-	476.4	265.5	0.560	0.603	-		1.000	
			150	Gravelly Soil			2.000	496.3	275.4	73.8	73.8	159.13	2.000	318.3	496.3	275.4	0.545	0.589	540.3		1.000	
			87	Gravelly Soil			2.000	517.3	286.4	41.5	41.5	5.233	2.000	10.47	517.3	286.4	0.530	0.574	18.23		1.000	
			150	Gravelly Soil	28.0	-	0.254	538.3	297.4	69.4	91.8	517.36	2.000	1034.7	538.3	297.4	0.515	0.559	1851		1.000	
			50	Gravelly Soil			2.000	559.3	308.4	22.5	22.5	0.344	1.807	0.622	559.3	308.4	0.500	0.544	1.145		1.000	
30.00	Sand and Gravel	21.0	150	Gravelly Soil			2.000	580.3	319.4	65.5	65.5	81.21	2.000	162.4	580.3	319.4	0.485	0.528	307.4		1.000	
Remark																						

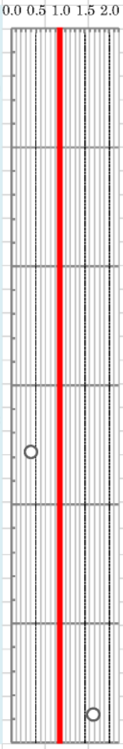
J-7



J-8

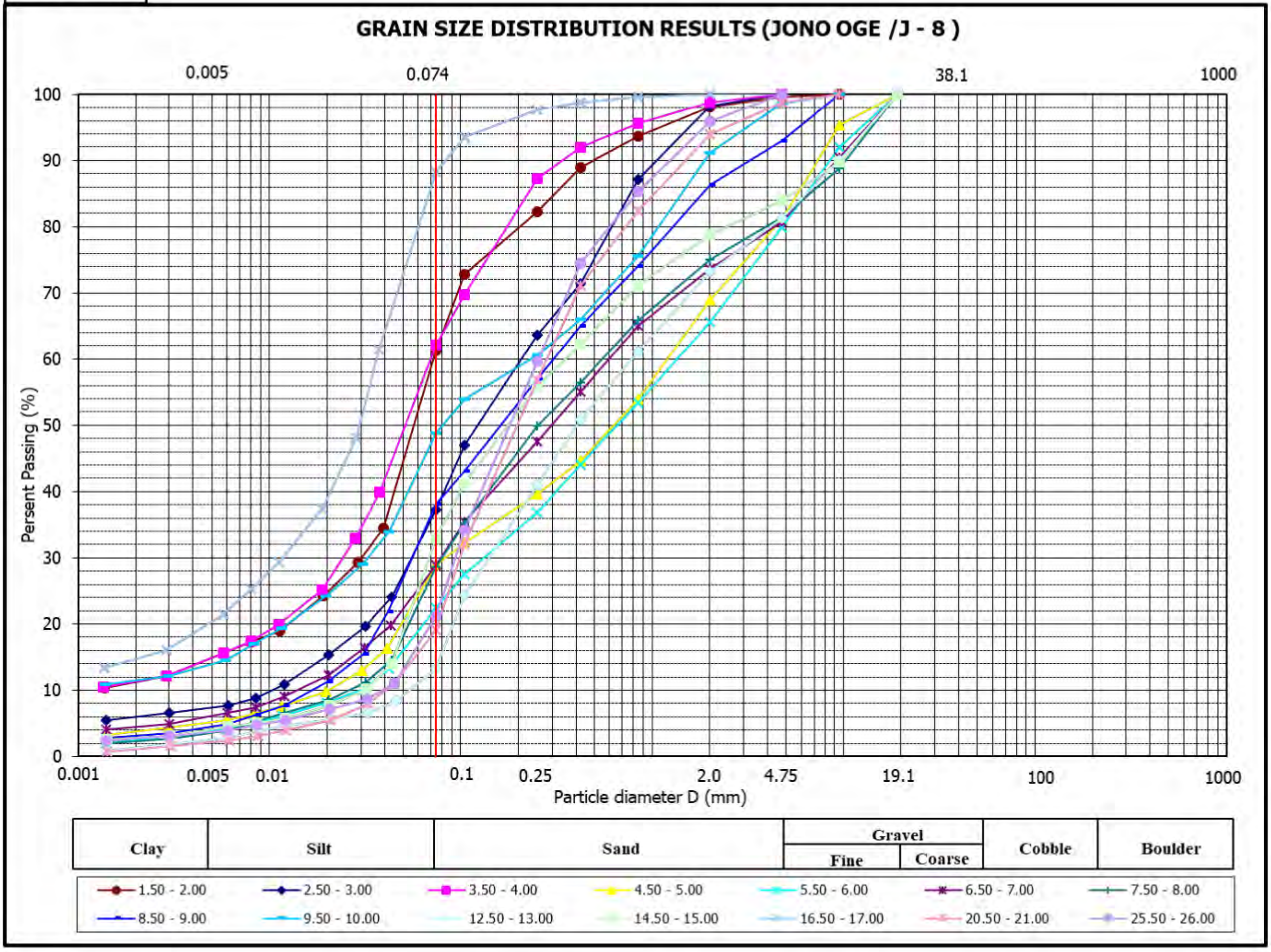
No.	1	Name	J-8	Location	Jono Oge	LNG;	823337.00 m E	LAT;	9892345.00 m S	Standard Depth for "sv"		
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	1.05m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m





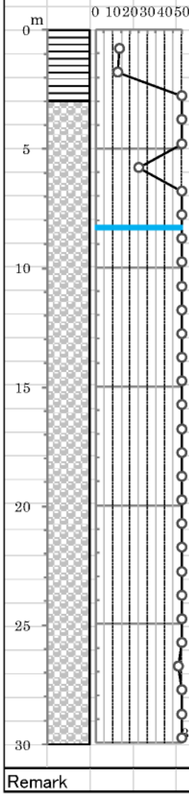
Depth	Drilling Log	Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment					(Value for Calcurate L)					P_L		
		kN/m³																		0.66		
			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
1.00	Silt	15.5	14	-	%	-	mm	kN/m³	kN/m³			-	-	-	kN/m³	kN/m³	-	-	-	9.60	1.000	0.000
1.25	Sand	17.5	15	-	61.2	6.5	0.059	29.5	22.0	27.7	-	-	-	-	29.5	22.0	0.905	0.728	-	9.10	1.000	0.000
2.00	Silt	17.5	53	Sandy Soil	37.3	-	0.131	48.6	31.1	89.1	172.5	12730.27	2.000	25460.5	48.6	31.1	0.890	0.834	30519	8.60	1.000	0.000
3.20	Sand	19.5	13	-	62.1	6.3	0.054	66.9	39.4	20.2	-	-	-	-	66.9	39.4	0.875	0.891	-	8.10	1.000	0.000
4.50	Silt	17.5	52	Sandy Soil	28.9	-	0.668	85.0	47.5	75.2	124.2	2472.85	2.000	4945.7	85.0	47.5	0.860	0.923	5358	7.60	1.000	0.000
			64	Sandy Soil	22.4	-	0.695	104.5	57.0	85.7	122.0	2266.83	2.000	4533.7	104.5	57.0	0.845	0.929	4879	7.10	1.000	0.000
			64	Sandy Soil	29.0	-	0.306	124.0	66.5	79.7	131.7	3334.50	2.000	6669.0	124.0	66.5	0.830	0.928	7184	6.60	1.000	0.000
			65	Sandy Soil	28.7	-	0.252	143.5	76.0	75.7	124.4	2496.81	2.000	4993.6	143.5	76.0	0.815	0.923	5410	6.10	1.000	0.000
			59	Sandy Soil	38.1	-	0.177	163.0	85.5	64.5	127.2	2798.13	2.000	5596.3	163.0	85.5	0.800	0.915	6117	5.60	1.000	0.000
			25	Sandy Soil	48.8	6.6	0.081	182.5	95.0	25.8	74.7	170.44	2.000	340.9	182.5	95.0	0.785	0.905	376.8	5.10	1.000	0.000
			56	Sandy Soil				202.0	104.5	54.6	54.6	28.06	2.000	56.13	202.0	104.5	0.770	0.893	62.87	4.60	1.000	0.000
			68	Sandy Soil				221.5	114.0	62.8	62.8	64.08	2.000	128.2	221.5	114.0	0.755	0.880	145.6	4.10	1.000	0.000
			65	Sandy Soil	13.2	-	0.404	241.0	123.5	57.1	63.5	68.13	2.000	136.3	241.0	123.5	0.740	0.866	157.3	3.60	1.000	0.000
			68	Sandy Soil				260.5	133.0	56.9	56.9	36.18	2.000	72.35	260.5	133.0	0.725	0.852	84.95	3.10	1.000	0.000
			62	Sandy Soil	32.9	-	0.191	280.0	142.5	49.6	89.4	449.94	2.000	899.9	280.0	142.5	0.710	0.837	1075	2.60	1.000	0.000
			61	Sandy Soil				299.5	152.0	46.7	46.7	10.94	2.000	21.88	299.5	152.0	0.695	0.821	26.64	2.10	1.000	0.000
			67	Sandy Soil	88.2	9.4	0.030	319.0	161.5	49.2	308.5	206483.58	2.000	412967.2	319.0	161.5	0.680	0.806	512622	1.60	1.000	0.000
18.10	Sand	19.5	15	Sandy Soil				338.5	171.0	10.6	10.6	0.225	1.414	0.318	338.5	171.0	0.665	0.790	0.403	1.10	0.403	0.656
19.10	Silt	17.5	58	-				356.6	179.1	39.6	-	-	-	-	356.6	179.1	0.650	0.776	-	0.60	1.000	0.000
20.50	Sand	19.5	64	Sandy Soil				375.5	188.0	42.2	42.2	5.787	2.000	11.57	375.5	188.0	0.635	0.761	15.22	0.10	1.000	0.000
			66	-	19.1	-	0.210	394.4	196.9	42.0	-	-	-	-	394.4	196.9	0.620	0.745	-		1.000	
			53	-				411.9	204.4	32.8	-	-	-	-	411.9	204.4	0.605	0.731	-		1.000	
			14	-				429.4	211.9	8.4	-	-	-	-	429.4	211.9	0.590	0.717	-		1.000	
			59	-				446.9	219.4	34.7	-	-	-	-	446.9	219.4	0.575	0.702	-		1.000	
25.10	Silt	17.5	11	-				464.4	226.9	6.3	-	-	-	-	464.4	226.9	0.560	0.687	-		1.000	
			52	Sandy Soil	21.2	-	0.195	483.3	235.8	28.9	40.6	4.582	2.000	9.164	483.3	235.8	0.545	0.670	13.68		1.000	
			64	Sandy Soil				502.8	245.3	34.5	34.5	1.679	2.000	3.357	502.8	245.3	0.530	0.652	5.153		1.000	
			62	Sandy Soil				522.3	254.8	32.5	32.5	1.182	2.000	2.364	522.3	254.8	0.515	0.633	3.734		1.000	
			53	Sandy Soil				541.8	264.3	27.0	27.0	0.513	2.000	1.026	541.8	264.3	0.500	0.615	1.670		1.000	
30.00	Sand	19.5	67	Sandy Soil				561.3	273.8	33.1	33.1	1.327	2.000	2.653	561.3	273.8	0.485	0.596	4.449		1.000	
Remark																						

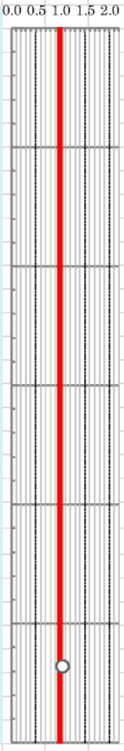
J-8



J-9

No.	1	Name	J-9	Location	Jono Oge	LNG;	825484.00 m E	LAT;	9888633.00 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	8.30m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion: Type2	0.00m

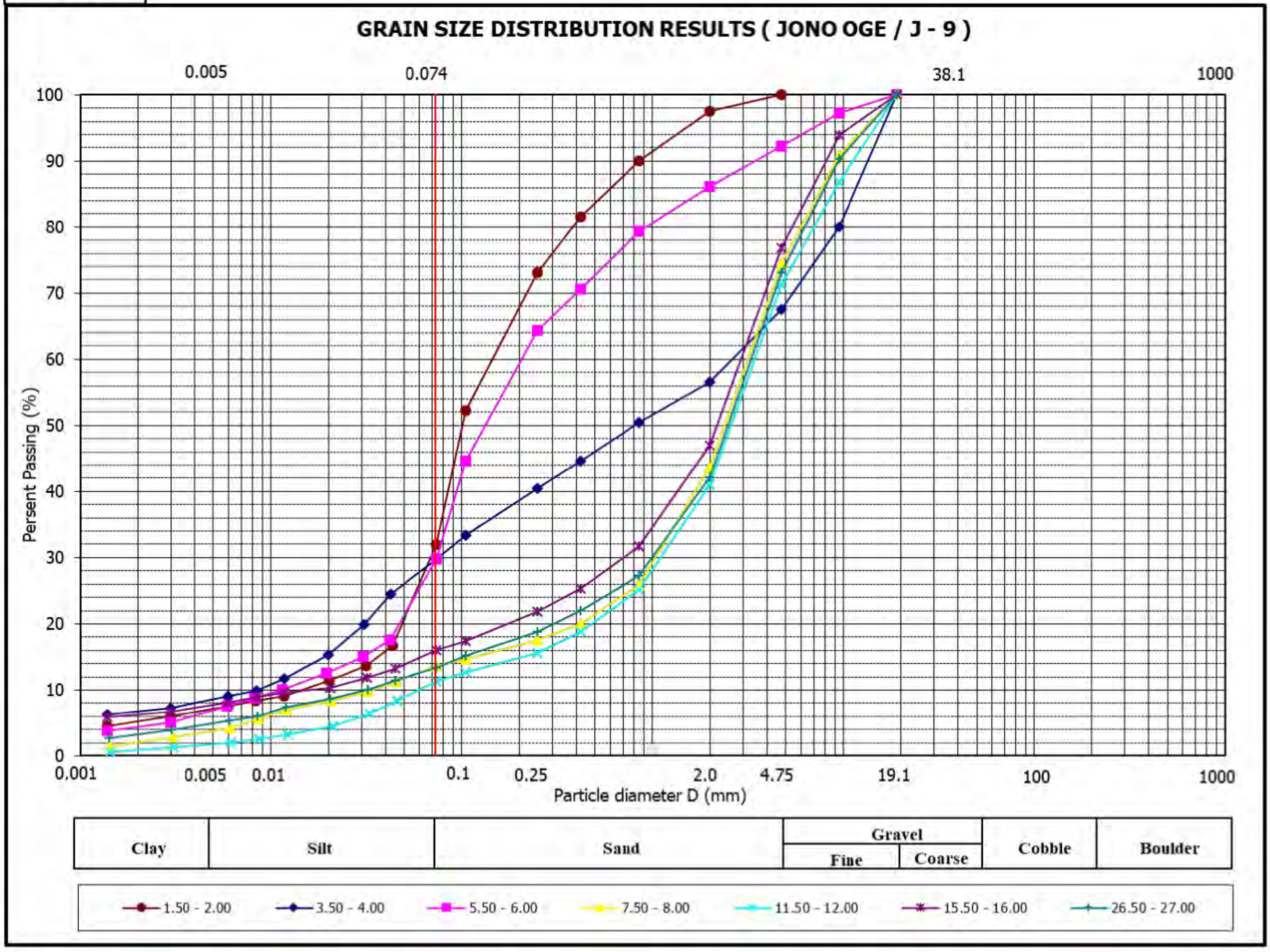




Depth	Drilling Log	Unit Weight kN/m³	N Value N	Type of Type	Physical Test FC	Ip	D_{50}	Value for Calcurate N_1 σ_v	σ_v'	Liquefaction Judgment N_1	N_a	R_L	c_w	R	(Value for Calcurate L) σ_v	σ_v'	r_d	L	F_L	P_L 0.00 W	F_L	ΔP_L
			14	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
			13	-	32.1	-	0.101	27.9	27.9	22.6	-	-	-	-	27.9	27.9	0.905	-	-	9.10	1.000	0.000
3.00	Silt	15.5	94	-				43.4	43.4	140.9	-	-	-	-	43.4	43.4	0.890	-	-	8.60	1.000	0.000
			375	Gravelly Soil	29.8	-	0.814	61.7	61.7	484.1	552.1	3111085.94	2.000	6222171.9	61.7	61.7	0.875	-	-	8.10	1.000	0.000
			375	Gravelly Soil			2.000	80.7	80.7	423.0	423.0	905730.91	2.000	1811461.8	80.7	80.7	0.860	-	-	7.60	1.000	0.000
			25	Gravelly Soil	29.7	-	0.144	99.7	99.7	25.0	35.3	1.934	2.000	3.867	99.7	99.7	0.845	-	-	7.10	1.000	0.000
			300	Gravelly Soil			2.000	118.7	118.7	270.3	270.3	110475.60	2.000	220951.2	118.7	118.7	0.830	-	-	6.60	1.000	0.000
			375	Gravelly Soil	13.7	-	2.560	137.7	137.7	306.9	295.1	167440.82	2.000	334881.6	137.7	137.7	0.815	-	-	6.10	1.000	0.000
			250	Gravelly Soil			2.000	156.7	151.7	191.7	191.7	21268.56	2.000	42537.1	156.7	151.7	0.800	0.496	85818	5.60	1.000	0.000
			300	Gravelly Soil			2.000	175.7	160.7	221.1	221.1	42327.53	2.000	84655.1	175.7	160.7	0.785	0.515	164443	5.10	1.000	0.000
			144	Gravelly Soil			2.000	194.7	169.7	102.1	102.1	906.68	2.000	1813.4	194.7	169.7	0.770	0.530	3422	4.60	1.000	0.000
			120	Gravelly Soil	11.3	-	2.819	213.7	178.7	82.0	77.6	209.72	2.000	419.4	213.7	178.7	0.755	0.542	774.5	4.10	1.000	0.000
			214	Gravelly Soil			2.000	232.7	187.7	141.2	141.2	4720.13	2.000	9440.3	232.7	187.7	0.740	0.550	17156	3.60	1.000	0.000
			102	Gravelly Soil			2.000	251.7	196.7	65.0	65.0	77.96	2.000	155.9	251.7	196.7	0.725	0.556	280.2	3.10	1.000	0.000
			500	Gravelly Soil			2.000	270.7	205.7	308.3	308.3	205929.88	2.000	411859.8	270.7	205.7	0.710	0.560	734918	2.60	1.000	0.000
			75	Gravelly Soil	16.0	-	2.274	289.7	214.7	44.8	43.9	7.424	2.000	14.85	289.7	214.7	0.695	0.562	26.40	2.10	1.000	0.000
			500	Gravelly Soil			2.000	308.7	223.7	289.4	289.4	152770.24	2.000	305540.5	308.7	223.7	0.680	0.563	542872	1.60	1.000	0.000
			500	Gravelly Soil			2.000	327.7	232.7	280.8	280.8	132435.51	2.000	264871.0	327.7	232.7	0.665	0.562	471568	1.10	1.000	0.000
			500	Gravelly Soil			2.000	346.7	241.7	272.7	272.7	115264.04	2.000	230528.1	346.7	241.7	0.650	0.559	412239	0.60	1.000	0.000
			500	Gravelly Soil			2.000	365.7	250.7	265.0	265.0	100695.13	2.000	201390.3	365.7	250.7	0.635	0.556	362505	0.10	1.000	0.000
			500	Gravelly Soil			2.000	384.7	259.7	257.8	257.8	88279.16	2.000	176558.3	384.7	259.7	0.620	0.551	320531		1.000	
			500	Gravelly Soil			2.000	403.7	268.7	251.0	251.0	77653.31	2.000	155306.6	403.7	268.7	0.605	0.545	284886		1.000	
			500	Gravelly Soil			2.000	422.7	277.7	244.5	244.5	68523.16	2.000	137046.3	422.7	277.7	0.590	0.539	254444		1.000	
			500	Gravelly Soil			2.000	441.7	286.7	238.3	238.3	60648.47	2.000	121296.9	441.7	286.7	0.575	0.531	228307		1.000	
			63	Gravelly Soil			2.000	460.7	295.7	29.3	29.3	0.708	2.000	1.415	460.7	295.7	0.560	0.523	2.705		1.000	
			500	Gravelly Soil			2.000	479.7	304.7	226.8	226.8	47911.93	2.000	95823.9	479.7	304.7	0.545	0.515	186221		1.000	
			48	Gravelly Soil	13.5	-	2.701	498.7	313.7	21.3	20.3	0.311	1.695	0.527	498.7	313.7	0.530	0.505	1.043		1.000	
			500	Gravelly Soil			2.000	517.7	322.7	216.5	216.5	38244.01	2.000	76488.0	517.7	322.7	0.515	0.495	154371		1.000	
			75	Gravelly Soil			2.000	536.7	331.7	31.7	31.7	1.049	2.000	2.097	536.7	331.7	0.500	0.485	4.322		1.000	
30.00	Sand and Gravel	19.0	75	Gravelly Soil			2.000	555.7	340.7	31.0	31.0	0.934	2.000	1.869	555.7	340.7	0.485	0.474	3.939		1.000	

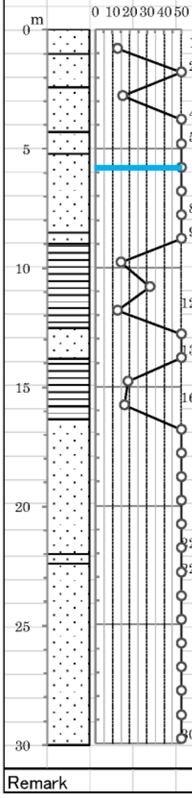
Remark

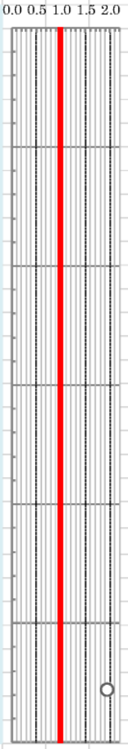
J-9



J-10

No.	1	Name	J-10	Location	Jono Oge	LNG;	823748.00 m E	LAT;	9888547.00 m S	Standard Depth for "sv"			
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	5.80m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m	

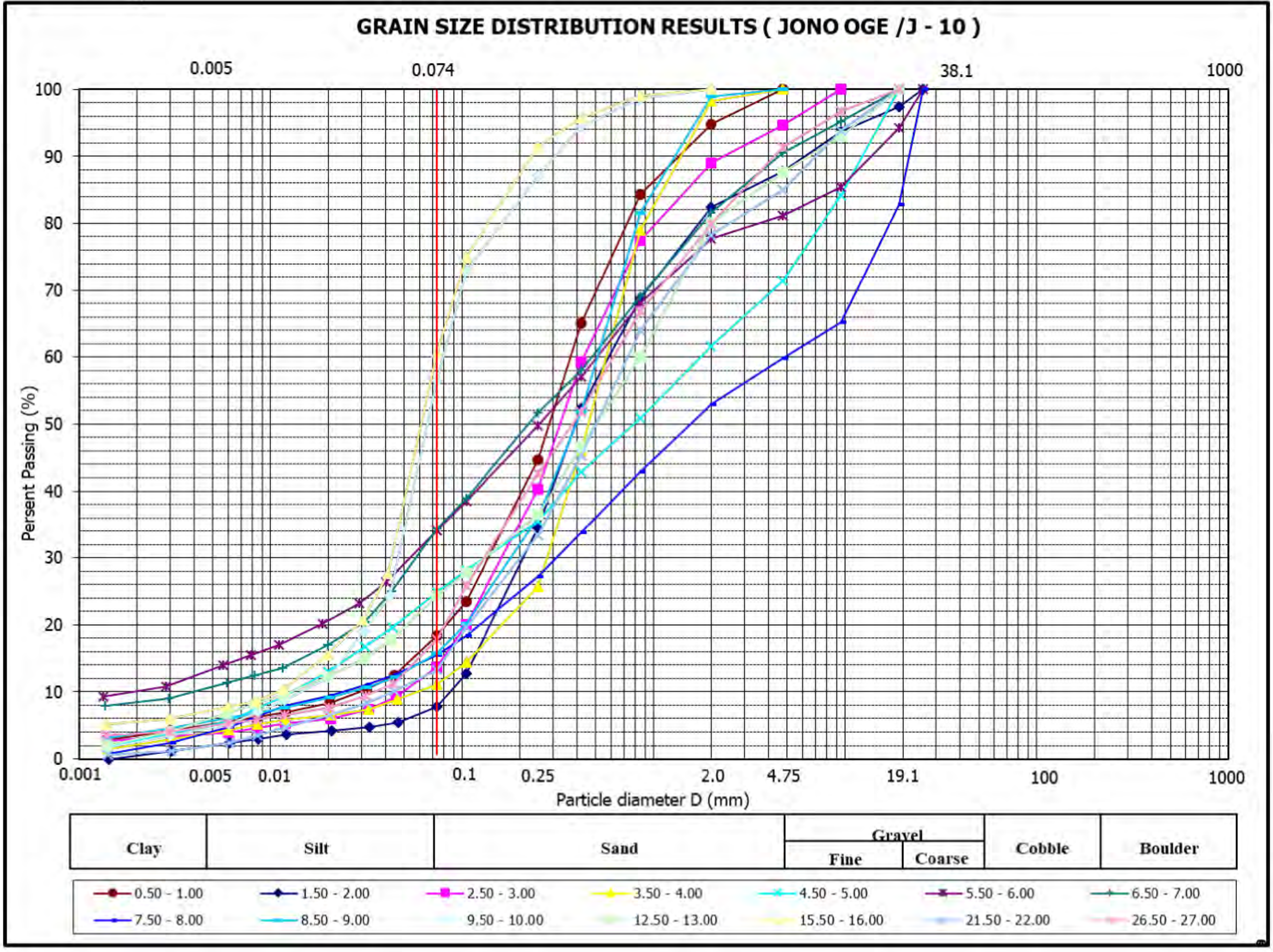




Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment					(Value for Calcurate L)					P_L		
		kN/m³																		0.00		
			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
1.00	Sand	17.5	13	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
2.40	Gravelly sand	17.5	56	Sandy Soil	7.8	-	0.397	31.5	31.5	93.8	93.8	580.04	2.000	1160.1	31.5	31.5	0.905	-	-	9.10	1.000	0.000
			16	Sandy Soil	13.8	-	0.337	49.0	49.0	22.9	26.0	0.461	2.000	0.922	49.0	49.0	0.890	-	-	8.60	1.000	0.000
4.30	Sand	17.5	58	Sandy Soil	11.1	-	0.471	66.5	66.5	72.2	75.0	173.58	2.000	347.2	66.5	66.5	0.875	-	-	8.10	1.000	0.000
5.20	Gravelly sand	17.5	64	Sandy Soil	24.8	-	0.803	84.0	84.0	70.6	106.8	1142.66	2.000	2285.3	84.0	84.0	0.860	-	-	7.60	1.000	0.000
			53	Sandy Soil	34.1	-	0.255	101.5	101.5	52.5	96.8	683.45	2.000	1366.9	101.5	101.5	0.845	-	-	7.10	1.000	0.000
			61	Sandy Soil	34.3	-	0.231	119.0	109.0	57.9	106.9	1148.96	2.000	2297.9	119.0	109.0	0.830	0.544	4228	6.60	1.000	0.000
8.50	Sand	17.5	57	Sandy Soil	15.5	-	1.664	136.5	116.5	52.0	61.9	58.83	2.000	117.7	136.5	116.5	0.815	0.573	205.4	6.10	1.000	0.000
9.00	Gravelly sand	19.5	50	Sandy Soil	15.8	-	0.400	154.6	124.6	43.7	52.6	22.55	2.000	45.10	154.6	124.6	0.800	0.595	75.74	5.60	1.000	0.000
			15	-	56.5	-	0.068	172.5	132.5	12.6	-	-	-	-	172.5	132.5	0.785	0.613	-	5.10	1.000	0.000
			32	-				190.0	140.0	25.9	-	-	-	-	190.0	140.0	0.770	0.627	-	4.60	1.000	0.000
12.50	Silt	17.5	13	-				207.5	147.5	10.2	-	-	-	-	207.5	147.5	0.755	0.637	-	4.10	1.000	0.000
			60	Sandy Soil	24.2	-	0.529	225.6	155.6	45.2	67.9	99.37	2.000	198.7	225.6	155.6	0.740	0.644	308.8	3.60	1.000	0.000
13.80	Sand	19.5	53	-				245.1	165.1	38.3	-	-	-	-	245.1	165.1	0.725	0.646	-	3.10	1.000	0.000
			19	-				262.6	172.6	13.3	-	-	-	-	262.6	172.6	0.710	0.648	-	2.60	1.000	0.000
16.35	Silt	17.5	17	-	60.7	-	0.063	280.1	180.1	11.6	-	-	-	-	280.1	180.1	0.695	0.648	-	2.10	1.000	0.000
			59	Sandy Soil				298.5	188.5	38.8	38.8	3.436	2.000	6.872	298.5	188.5	0.680	0.646	10.64	1.60	1.000	0.000
			67	Sandy Soil				318.0	198.0	42.5	42.5	6.076	2.000	12.15	318.0	198.0	0.665	0.641	18.97	1.10	1.000	0.000
			71	Sandy Soil				337.5	207.5	43.5	43.5	7.023	2.000	14.05	337.5	207.5	0.650	0.634	22.15	0.60	1.000	0.000
			61	Sandy Soil				357.0	217.0	36.1	36.1	2.213	2.000	4.426	357.0	217.0	0.635	0.627	7.063	0.10	1.000	0.000
			58	Sandy Soil				376.5	226.5	33.3	33.3	1.355	2.000	2.710	376.5	226.5	0.620	0.618	4.385		1.000	
22.00	Gravelly sand	19.5	63	Sandy Soil	13.2	-	0.528	396.0	236.0	35.0	39.1	3.581	2.000	7.162	396.0	236.0	0.605	0.609	11.76		1.000	
22.40	Sand	19.5	65	Sandy Soil				415.5	245.5	35.0	35.0	1.834	2.000	3.667	415.5	245.5	0.590	0.599	6.123		1.000	
			65	Sandy Soil				435.0	255.0	34.0	34.0	1.539	2.000	3.079	435.0	255.0	0.575	0.588	5.233		1.000	
			68	Sandy Soil				454.5	264.5	34.6	34.6	1.694	2.000	3.388	454.5	264.5	0.560	0.577	5.870		1.000	
			63	Sandy Soil				474.0	274.0	31.1	31.1	0.948	2.000	1.896	474.0	274.0	0.545	0.565	3.354		1.000	
			60	Sandy Soil	17.9	-	0.386	493.5	283.5	28.9	37.1	2.594	2.000	5.188	493.5	283.5	0.530	0.553	9.376		1.000	
			58	Sandy Soil				513.0	293.0	27.2	27.2	0.527	2.000	1.054	513.0	293.0	0.515	0.541	1.948		1.000	
			62	Sandy Soil				532.5	302.5	28.3	28.3	0.612	2.000	1.225	532.5	302.5	0.500	0.528	2.321		1.000	
30.00	Gravelly sand	19.5	67	Sandy Soil				552.0	312.0	29.8	29.8	0.768	2.000	1.535	552.0	312.0	0.485	0.515	2.983		1.000	

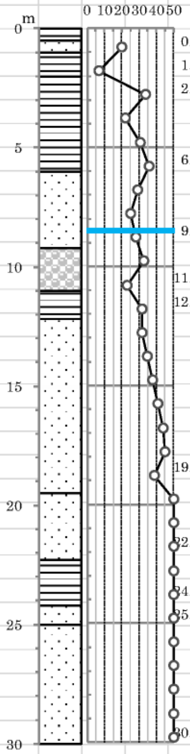
Remark

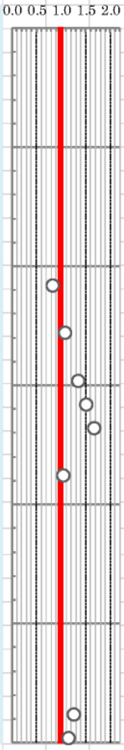
J-10



J-11

No.	1	Name	J–11	Location	Jono Oge	LNG; 825351.00 m E	LAT; 9887130.00 m S
Standard Depth for "sv"	0.00m						
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	8.50m	Ground Hight	4.55m
Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2				

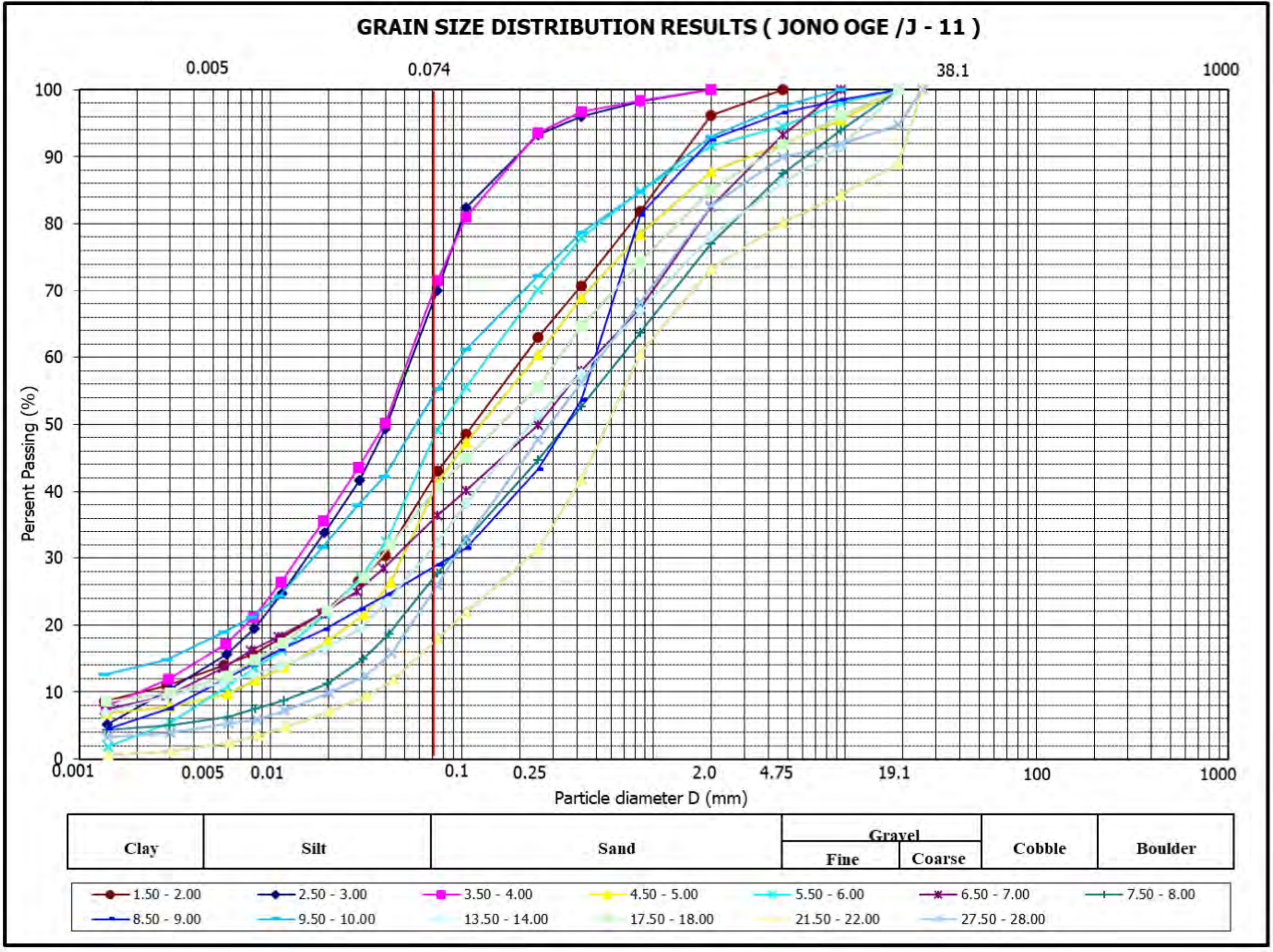




Depth	Drilling Log		Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
			kN/m³																		0.74		
m				N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
	0.50	Silt	15.5	20	-	%	-	mm	kN/m³	kN/m³			-	-	-	kN/m³	kN/m³	-	-	-	9.60	1.000	0.000
	1.00	Sand	17.5	7	-	43.0	-	0.119	28.9	28.9	12.0	-	-	-	-	28.9	28.9	0.905	-	-	9.10	1.000	0.000
	2.00	Silt	15.5	34	-	70.0	5.6	0.041	44.4	44.4	50.5	-	-	-	-	44.4	44.4	0.890	-	-	8.60	1.000	0.000
				22	-	71.6	6.6	0.039	59.9	59.9	28.8	-	-	-	-	59.9	59.9	0.875	-	-	8.10	1.000	0.000
				31	-	41.2	-	0.135	75.4	75.4	36.2	-	-	-	-	75.4	75.4	0.860	-	-	7.60	1.000	0.000
	6.00	Gravelly silt	15.5	36	-	49.3	-	0.049	90.9	90.9	38.0	-	-	-	-	90.9	90.9	0.845	-	-	7.10	1.000	0.000
				29	Sandy Soil	36.5	-	0.250	108.0	108.0	27.7	54.3	27.29	2.000	54.57	108.0	108.0	0.830	-	-	6.60	1.000	0.000
				25	Sandy Soil	27.8	-	0.363	125.5	125.5	21.7	36.1	2.192	2.000	4.384	125.5	125.5	0.815	-	-	6.10	1.000	0.000
	9.20	Sand	17.5	28	Sandy Soil	28.9	-	0.360	143.0	140.0	22.7	38.5	3.292	2.000	6.584	143.0	140.0	0.800	0.490	13.43	5.60	1.000	0.000
				33	Gravelly Soil	55.2	7.2	0.060	162.6	149.6	25.5	39.6	3.873	2.000	7.745	162.6	149.6	0.785	0.512	15.13	5.10	1.000	0.000
	11.00	Sand and Gravel	21.0	23	Gravelly Soil			2.000	183.6	160.6	17.0	17.0	0.279	1.590	0.443	183.6	160.6	0.770	0.528	0.839	4.60	0.839	0.739
	12.20	Silt	17.5	32	-				201.8	168.8	22.8	-	-	-	-	201.8	168.8	0.755	0.541	-	4.10	1.000	0.000
				32	Sandy Soil				220.5	177.5	22.0	22.0	0.335	1.777	0.596	220.5	177.5	0.740	0.551	1.081	3.60	1.000	0.000
				35	Sandy Soil	32.3	-	0.235	240.0	187.0	23.2	42.2	5.802	2.000	11.60	240.0	187.0	0.725	0.558	20.79	3.10	1.000	0.000
				38	Sandy Soil				259.5	196.5	24.2	24.2	0.389	1.955	0.761	259.5	196.5	0.710	0.562	1.353	2.60	1.000	0.000
				41	Sandy Soil				279.0	206.0	25.3	25.3	0.426	2.000	0.852	279.0	206.0	0.695	0.565	1.509	2.10	1.000	0.000
				44	Sandy Soil				298.5	215.5	26.2	26.2	0.470	2.000	0.940	298.5	215.5	0.680	0.565	1.664	1.60	1.000	0.000
				45	Sandy Soil	40.5	-	0.173	318.0	225.0	25.9	55.5	31.20	2.000	62.41	318.0	225.0	0.665	0.564	110.7	1.10	1.000	0.000
	19.50	Fine sand	19.5	39	Sandy Soil				337.5	234.5	21.8	21.8	0.332	1.765	0.586	337.5	234.5	0.650	0.561	1.044	0.60	1.000	0.000
				54	Sandy Soil				357.0	244.0	29.2	29.2	0.702	2.000	1.405	357.0	244.0	0.635	0.557	2.521	0.10	1.000	0.000
				56	Sandy Soil				376.5	253.5	29.4	29.4	0.723	2.000	1.446	376.5	253.5	0.620	0.552	2.618		1.000	
	22.30	Coarse sand	19.5	56	Sandy Soil	18.0	-	0.607	396.0	263.0	28.6	36.8	2.486	2.000	4.972	396.0	263.0	0.605	0.546	9.101		1.000	
				63	-				414.5	271.5	31.4	-	-	-	-	414.5	271.5	0.590	0.540	-		1.000	
	24.20	Silt	17.5	57	-				432.0	279.0	27.8	-	-	-	-	432.0	279.0	0.575	0.534	-		1.000	
	25.00	Coarse sand	19.5	59	Sandy Soil				450.7	287.7	28.0	28.0	0.591	2.000	1.182	450.7	287.7	0.560	0.526	2.247		1.000	
				65	Sandy Soil				470.2	297.2	30.1	30.1	0.802	2.000	1.603	470.2	297.2	0.545	0.517	3.100		1.000	
				68	Sandy Soil				489.7	306.7	30.7	30.7	0.882	2.000	1.763	489.7	306.7	0.530	0.508	3.474		1.000	
				58	Sandy Soil	26.0	-	0.195	509.2	316.2	25.5	40.4	4.440	2.000	8.880	509.2	316.2	0.515	0.497	17.85		1.000	
				52	Sandy Soil				528.7	325.7	22.3	22.3	0.342	1.799	0.615	528.7	325.7	0.500	0.487	1.264		1.000	
	30.00	Fine sand	19.5	50	Sandy Soil				548.2	335.2	21.0	21.0	0.320	1.725	0.552	548.2	335.2	0.485	0.476	1.160		1.000	

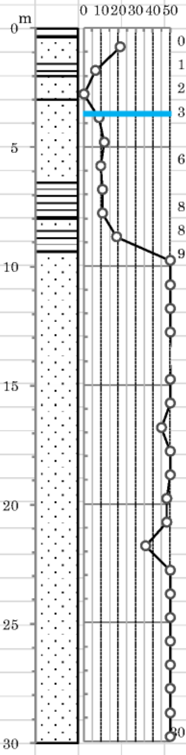
Remark

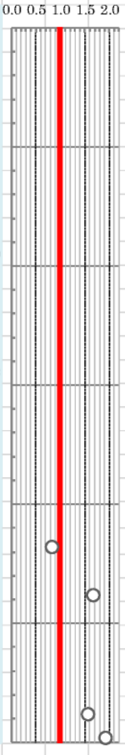
J-11



J-12

No.	1	Name	J−12	Location	Jono Oge	LNG;	823649.00 m E	LAT;	9887090.00 m S	Standard Depth for "sv"
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	3.60m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion
									Type2	0.00m

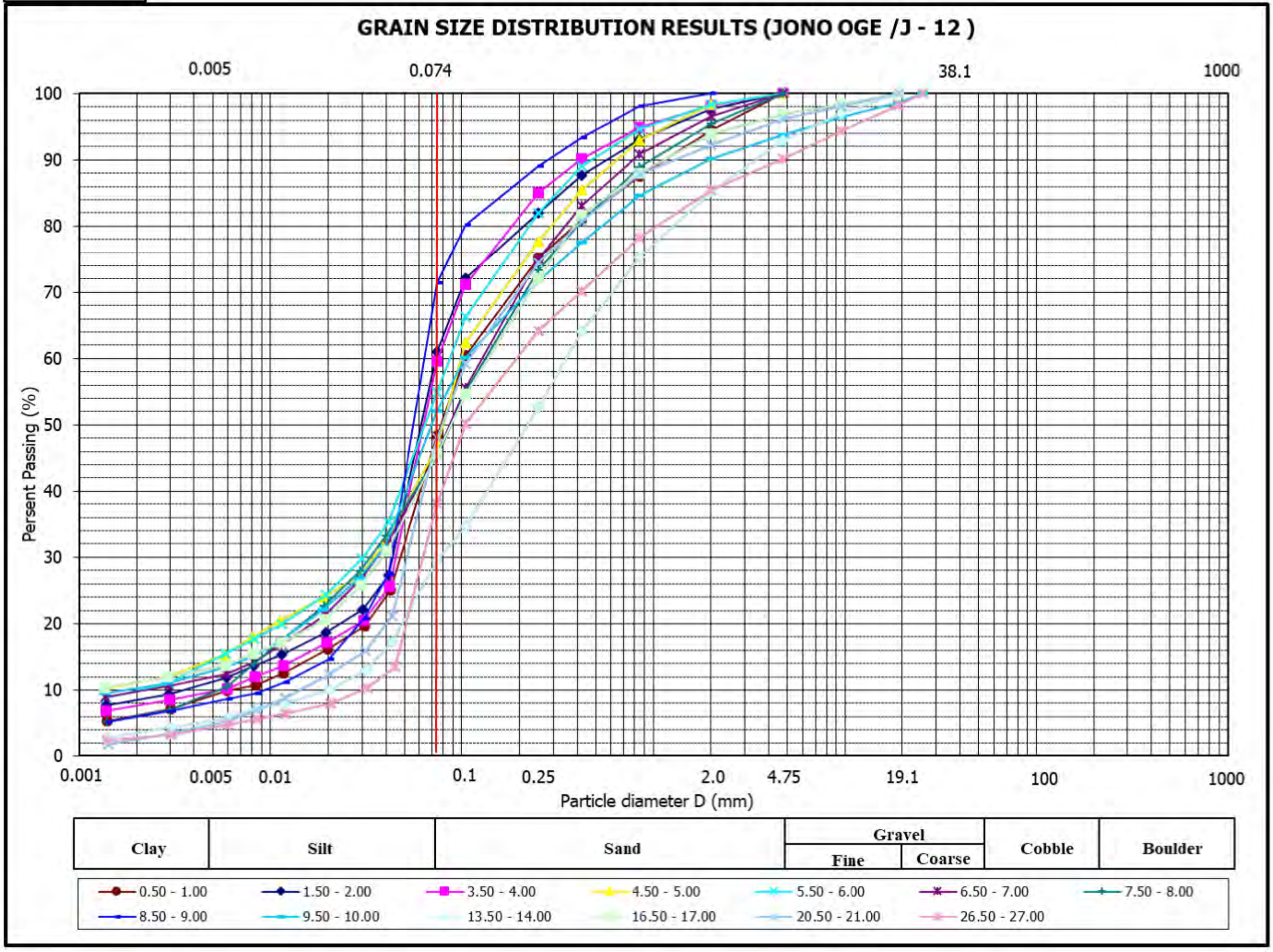




Depth	Drilling Log	Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)										P_L		
		kN/m³																			0.00	
m			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
0.40	Silt	15.5	21	-	%	-	mm	kN/m²	kN/m²			-	-	-	kN/m²	kN/m²	-	-	-	9.60	1.000	0.000
1.50	Sand	17.5	7	-	61.1	-	0.063	30.1	30.1	11.9	-	-	-	-	30.1	30.1	0.905	-	-	9.10	1.000	0.000
2.00	Silt	15.5	0	Sandy Soil				47.2	47.2	0.0	0.0	0.098	1.000	0.098	47.2	47.2	0.890	-	-	8.60	1.000	0.000
3.00	Sand	17.5	9	Sandy Soil	59.6	-	0.065	64.7	62.7	11.5	48.5	13.70	2.000	27.40	64.7	62.7	0.875	0.542	50.60	8.10	1.000	0.000
			12	Sandy Soil	46.7	6.3	0.080	82.2	70.2	14.6	41.1	4.912	2.000	9.824	82.2	70.2	0.860	0.604	16.26	7.60	1.000	0.000
6.50	Fine sand	17.5	10	Sandy Soil	54.9	5.8	0.066	99.7	77.7	11.5	42.8	6.396	2.000	12.79	99.7	77.7	0.845	0.650	19.67	7.10	1.000	0.000
			11	-	45.7	-	0.087	117.2	85.2	12.0	-	-	-	-	117.2	85.2	0.830	0.685	-	6.60	1.000	0.000
8.00	Silt	17.5	11	-	45.2	-	0.089	134.7	92.7	11.5	-	-	-	-	134.7	92.7	0.815	0.710	-	6.10	1.000	0.000
8.50	Sand	19.5	19	-	71.4	-	0.058	153.2	101.2	18.9	-	-	-	-	153.2	101.2	0.800	0.726	-	5.60	1.000	0.000
9.40	Silt	17.5	75	Sandy Soil	52.2	5.3	0.070	171.5	109.5	71.0	219.0	40430.61	2.000	80861.2	171.5	109.5	0.785	0.737	109650	5.10	1.000	0.000
			50	Sandy Soil				191.0	119.0	45.0	45.0	8.649	2.000	17.30	191.0	119.0	0.770	0.741	23.34	4.60	1.000	0.000
			68	Sandy Soil				210.5	128.5	58.2	58.2	41.27	2.000	82.54	210.5	128.5	0.755	0.742	111.3	4.10	1.000	0.000
			50	Sandy Soil				230.0	138.0	40.9	40.9	4.752	2.000	9.505	230.0	138.0	0.740	0.740	12.85	3.60	1.000	0.000
			74	Sandy Soil	29.5	-	0.229	249.5	147.5	57.8	97.0	691.11	2.000	1382.2	249.5	147.5	0.725	0.736	1879	3.10	1.000	0.000
			500	Sandy Soil				269.0	157.0	374.4	374.4	512767.09	2.000	1025534.2	269.0	157.0	0.710	0.730	1405532	2.60	1.000	0.000
			69	Sandy Soil				288.5	166.5	49.6	49.6	15.81	2.000	31.61	288.5	166.5	0.695	0.722	43.77	2.10	1.000	0.000
			45	Sandy Soil	45.6	5.7	0.089	308.0	176.0	31.1	80.4	253.31	2.000	506.6	308.0	176.0	0.680	0.714	709.8	1.60	1.000	0.000
			72	Sandy Soil				327.5	185.5	47.9	47.9	12.78	2.000	25.56	327.5	185.5	0.665	0.704	36.30	1.10	1.000	0.000
			56	Sandy Soil				347.0	195.0	35.9	35.9	2.136	2.000	4.273	347.0	195.0	0.650	0.694	6.159	0.60	1.000	0.000
			48	Sandy Soil				366.5	204.5	29.7	29.7	0.757	2.000	1.514	366.5	204.5	0.635	0.683	2.218	0.10	1.000	0.000
			48	Sandy Soil	48.1	-	0.079	386.0	214.0	28.7	81.1	265.46	2.000	530.9	386.0	214.0	0.620	0.671	791.6		1.000	
			36	Sandy Soil				405.5	223.5	20.9	20.9	0.318	1.720	0.547	405.5	223.5	0.605	0.658	0.831		0.831	
			56	Sandy Soil				425.0	233.0	31.4	31.4	0.994	2.000	1.988	425.0	233.0	0.590	0.645	3.080		1.000	
			50	Sandy Soil				444.5	242.5	27.2	27.2	0.529	2.000	1.059	444.5	242.5	0.575	0.632	1.675		1.000	
			60	Sandy Soil				464.0	252.0	31.7	31.7	1.038	2.000	2.075	464.0	252.0	0.560	0.618	3.356		1.000	
			63	Sandy Soil				483.5	261.5	32.3	32.3	1.154	2.000	2.307	483.5	261.5	0.545	0.604	3.818		1.000	
			56	Sandy Soil	38.2	-	0.088	503.0	271.0	27.9	56.5	34.38	2.000	68.75	503.0	271.0	0.530	0.590	116.5		1.000	
			63	Sandy Soil				522.5	280.5	30.6	30.6	0.863	2.000	1.726	522.5	280.5	0.515	0.575	3.000		1.000	
			54	Sandy Soil				542.0	290.0	25.5	25.5	0.436	2.000	0.873	542.0	290.0	0.500	0.560	1.558		1.000	
30.00	Sand	19.5	59	Sandy Soil				561.5	299.5	27.1	27.1	0.526	2.000	1.051	561.5	299.5	0.485	0.545	1.928		1.000	

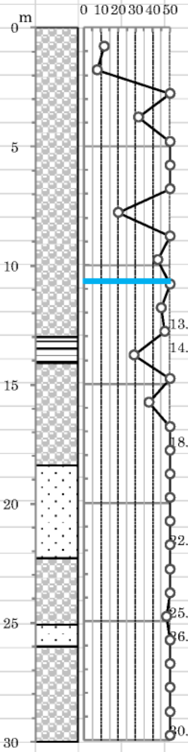
Remark

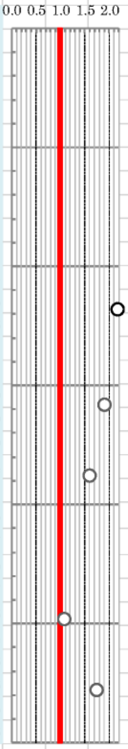
J-12



J-13

No.	1	Name	J-13	Location	Jono Oge	LNG;	825336.96 m E	LAT;	9892623.66 m S	Standard Depth for "sv"		
Hight of Hole Mouth		Total Advance	30.00m	Ground Water Level	10.66m	Ground Hight	4.55m	Lateral Seismic Facter	0.600	Type of Seismic Motion	Type2	0.00m

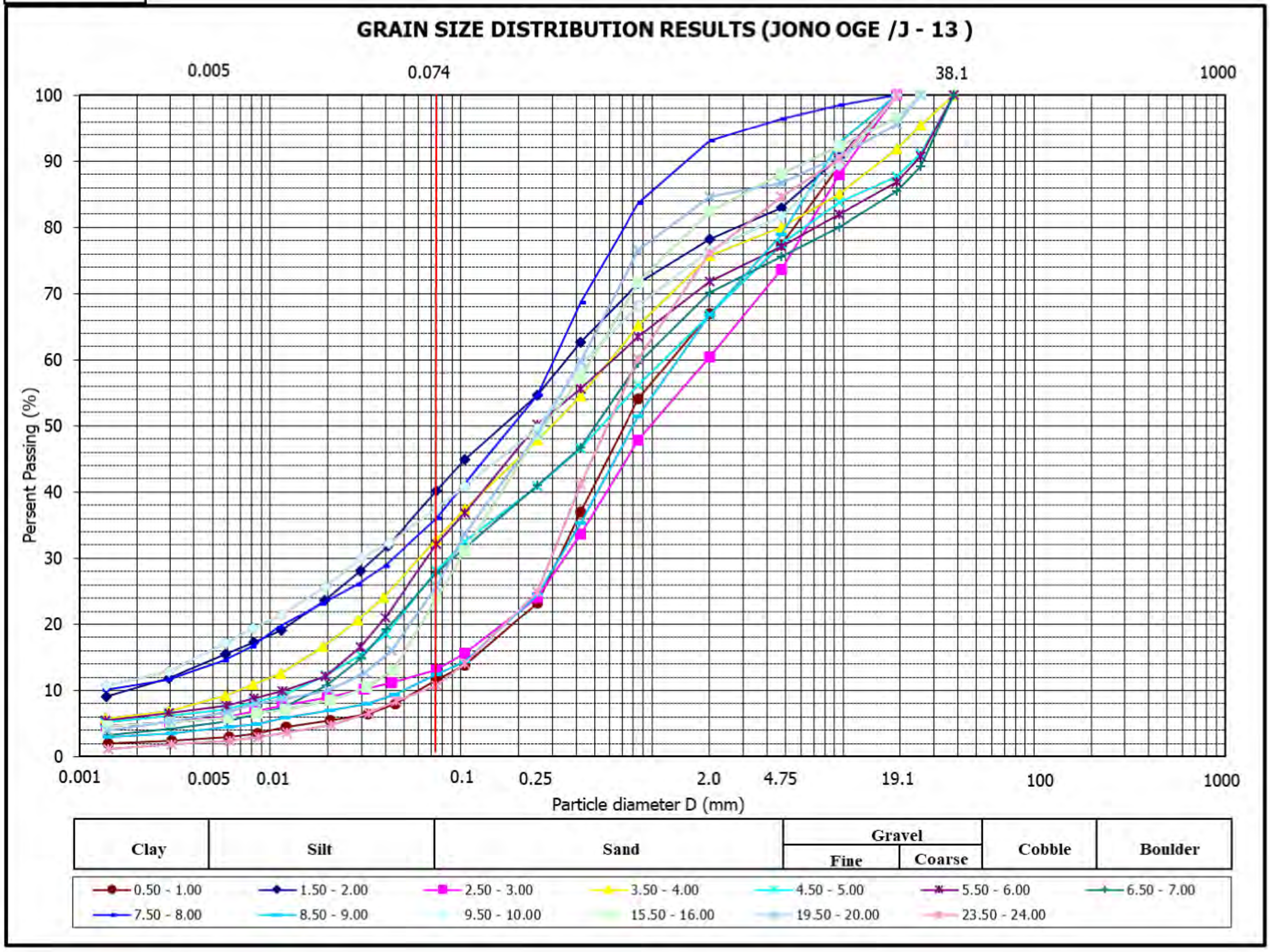




Depth	Drilling Log	Unit Weight	N Valu	Type of	Physical Test			Value for Calcurate N_1		Liquefaction Judgment (Value for Calcurate L)									P_L		
		kN/m^3																	0.00		
			N	Type	FC	Ip	D_{50}	σ_v	σ_v'	N_1	N_a	R_L	c_w	R	σ_v	σ_v'	r_d	L	F_L	W	F_L	ΔP_L
			12	-	%	-	mm	kN/m^3	kN/m^3			-	-	-	kN/m^3	kN/m^3	-	-	-	9.60	1.000	0.000
			8	Gravelly Soil	40.2	5.5	0.181	34.2	34.2	13.1	18.0	0.287	1.619	0.465	34.2	34.2	0.905	-	-	9.10	1.000	0.000
			150	Gravelly Soil	13.1	-	1.046	53.2	53.2	207.0	228.0	49055.64	2.000	98111.3	53.2	53.2	0.890	-	-	8.60	1.000	0.000
			32	Gravelly Soil	32.8	-	0.305	72.2	72.2	38.3	49.5	15.64	2.000	31.27	72.2	72.2	0.875	-	-	8.10	1.000	0.000
			50	Gravelly Soil	28.1	-	0.572	91.2	91.2	52.7	63.1	65.41	2.000	130.8	91.2	91.2	0.860	-	-	7.60	1.000	0.000
			150	Gravelly Soil	32.1	-	0.247	110.2	110.2	141.5	187.7	19217.41	2.000	38434.8	110.2	110.2	0.845	-	-	7.10	1.000	0.000
			150	Gravelly Soil	27.9	-	0.530	129.2	129.2	128.0	154.6	7413.91	2.000	14827.8	129.2	129.2	0.830	-	-	6.60	1.000	0.000
			20	Gravelly Soil	36.1	-	0.200	148.2	148.2	15.6	21.2	0.323	1.735	0.560	148.2	148.2	0.815	-	-	6.10	1.000	0.000
			150	Gravelly Soil	12.5	-	0.811	167.2	167.2	107.5	122.7	2327.21	2.000	4654.4	167.2	167.2	0.800	-	-	5.60	1.000	0.000
			43	Gravelly Soil	37.5	5.8	0.255	186.2	186.2	28.5	37.7	2.880	2.000	5.760	186.2	186.2	0.785	-	-	5.10	1.000	0.000
			90	Gravelly Soil			2.000	205.2	203.8	55.9	55.9	32.36	2.000	64.72	205.2	203.8	0.770	0.465	139.2	4.60	1.000	0.000
			45	Gravelly Soil			2.000	224.2	212.8	27.1	27.1	0.520	2.000	1.039	224.2	212.8	0.755	0.477	2.178	4.10	1.000	0.000
13.00	Sand and Gravel	19.0	47	Gravelly Soil			2.000	243.2	221.8	27.4	27.4	0.542	2.000	1.083	243.2	221.8	0.740	0.487	2.226	3.60	1.000	0.000
14.10	Silt	17.5	29	-				261.0	229.6	16.5	-	-	-	-	261.0	229.6	0.725	0.494	-	3.10	1.000	0.000
			150	Gravelly Soil			2.000	281.0	239.6	82.4	82.4	289.84	2.000	579.7	281.0	239.6	0.710	0.499	1161	2.60	1.000	0.000
			38	Gravelly Soil	23.8	-	0.277	302.0	250.6	20.2	26.4	0.480	2.000	0.959	302.0	250.6	0.695	0.502	1.909	2.10	1.000	0.000
			117	Gravelly Soil			2.000	323.0	261.6	60.0	60.0	49.07	2.000	98.14	323.0	261.6	0.680	0.504	194.9	1.60	1.000	0.000
18.40	Sand and Gravel	21.0	150	Gravelly Soil			2.000	344.0	272.6	74.4	74.4	166.59	2.000	333.2	344.0	272.6	0.665	0.503	662.0	1.10	1.000	0.000
			51	Sandy Soil				364.4	283.0	24.6	24.6	0.400	2.000	0.800	364.4	283.0	0.650	0.502	1.594	0.60	1.000	0.000
			150	Sandy Soil	25.8	-	0.262	383.9	292.5	70.4	108.7	1255.30	2.000	2510.6	383.9	292.5	0.635	0.500	5022	0.10	1.000	0.000
			150	Sandy Soil				403.4	302.0	68.6	68.6	105.27	2.000	210.5	403.4	302.0	0.620	0.497	423.8		1.000	
22.30	Sand	19.5	150	Sandy Soil				422.9	311.5	66.9	66.9	91.30	2.000	182.6	422.9	311.5	0.605	0.493	370.7		1.000	
			99	Gravelly Soil			2.000	443.1	321.7	43.0	43.0	6.506	2.000	13.01	443.1	321.7	0.590	0.487	26.70		1.000	
			150	Gravelly Soil	10.7	-	0.620	464.1	332.7	63.3	74.9	172.62	2.000	345.2	464.1	332.7	0.575	0.481	717.7		1.000	
25.10	Sand and Gravel	21.0	48	Gravelly Soil			2.000	485.1	343.7	19.7	19.7	0.305	1.675	0.510	485.1	343.7	0.560	0.474	1.076		1.000	
26.00	Sand	19.5	80	Sandy Soil				505.1	353.7	32.1	32.1	1.114	2.000	2.228	505.1	353.7	0.545	0.467	4.774		1.000	
			150	Gravelly Soil			2.000	525.8	364.4	58.7	58.7	43.26	2.000	86.52	525.8	364.4	0.530	0.459	188.6		1.000	
			64	Gravelly Soil			2.000	546.8	375.4	24.4	24.4	0.396	1.975	0.781	546.8	375.4	0.515	0.450	1.736		1.000	
			150	Gravelly Soil			2.000	567.8	386.4	55.9	55.9	32.35	2.000	64.70	567.8	386.4	0.500	0.441	146.8		1.000	
30.00	Sand and Gravel	21.0	99	Gravelly Soil			2.000	588.8	397.4	36.0	36.0	2.168	2.000	4.336	588.8	397.4	0.485	0.431	10.06		1.000	

Remark

J-13



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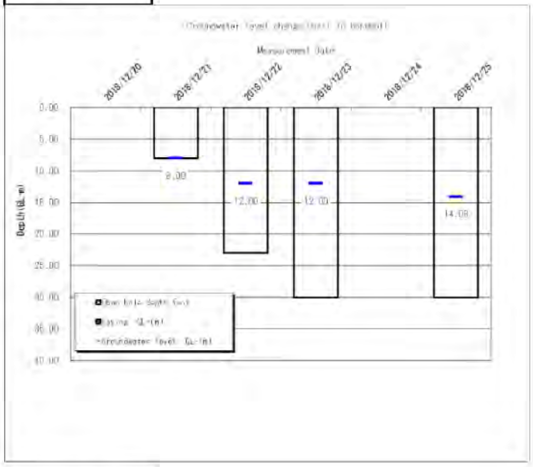

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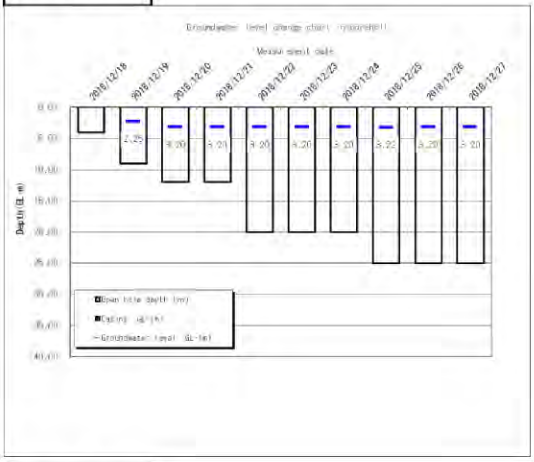

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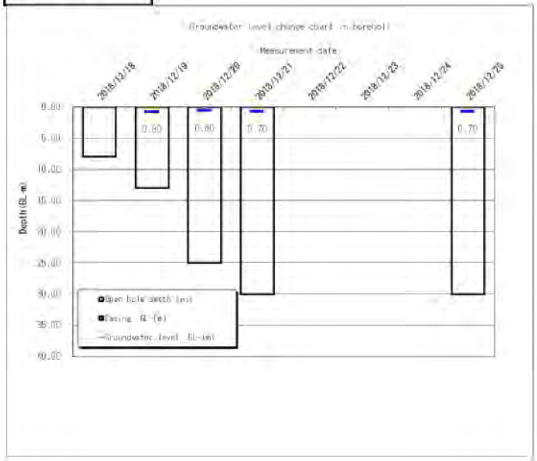

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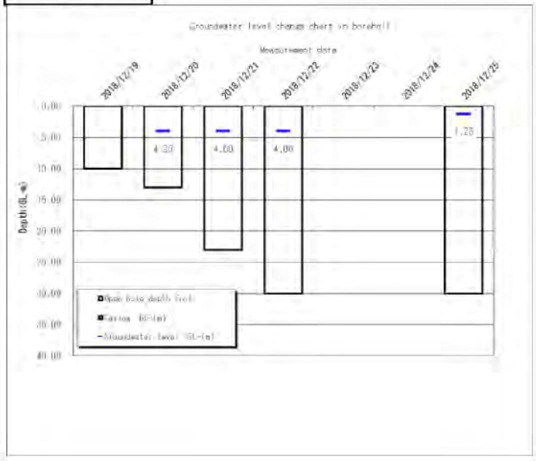

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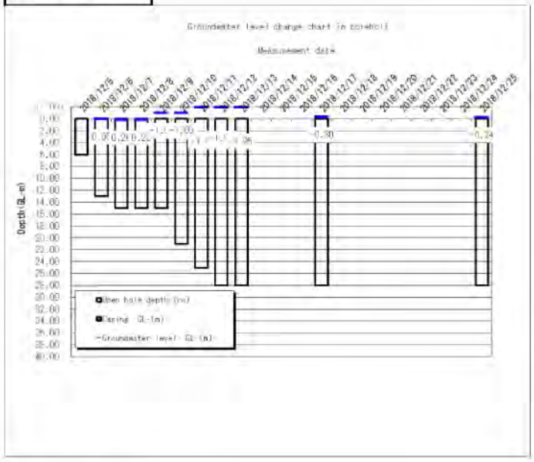

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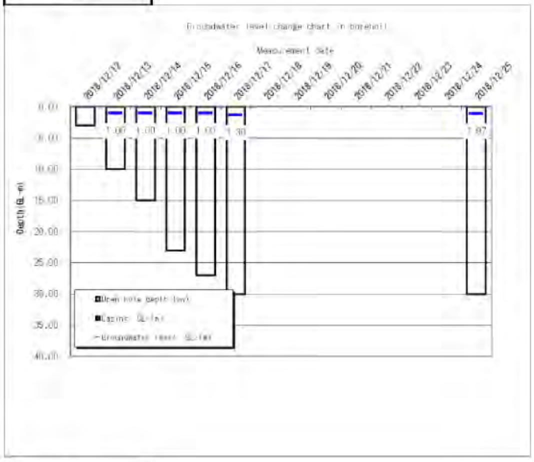

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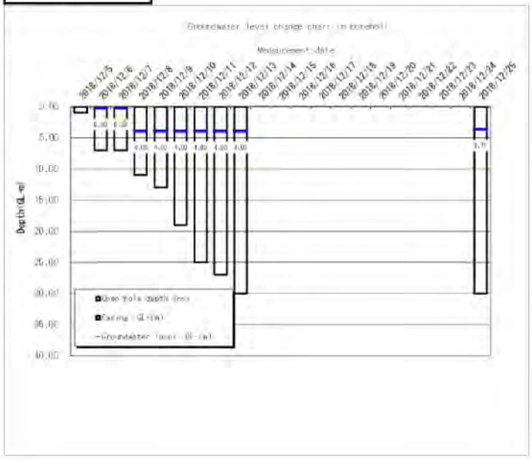

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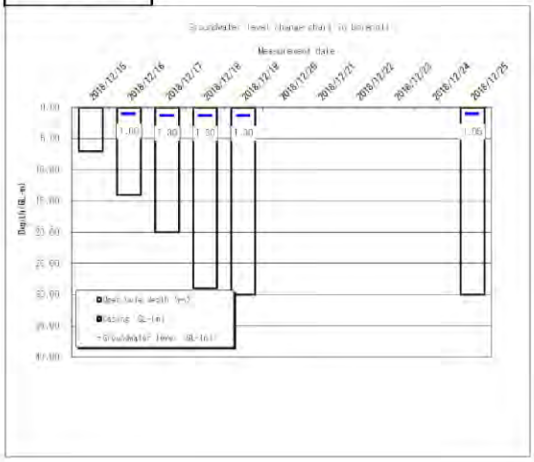

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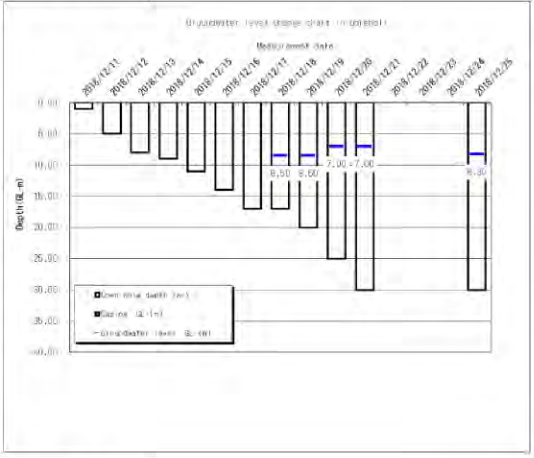

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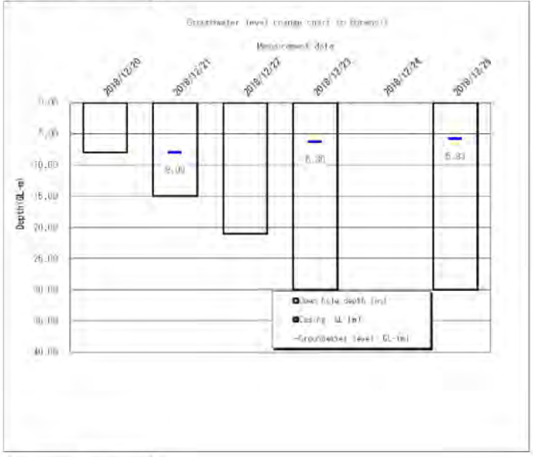

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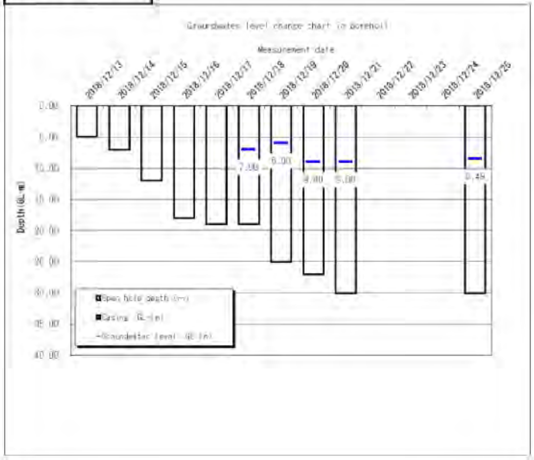

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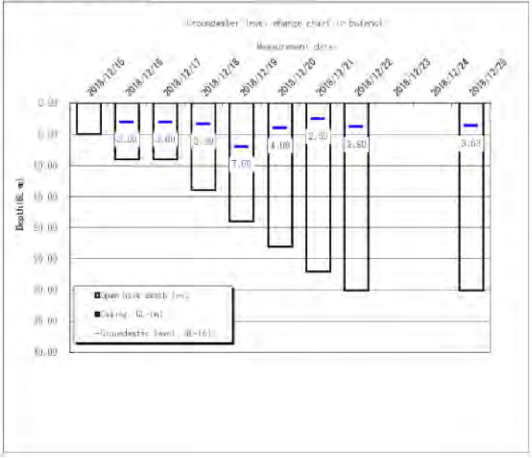

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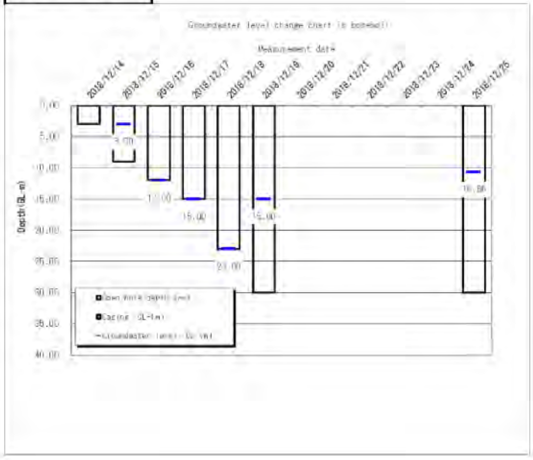

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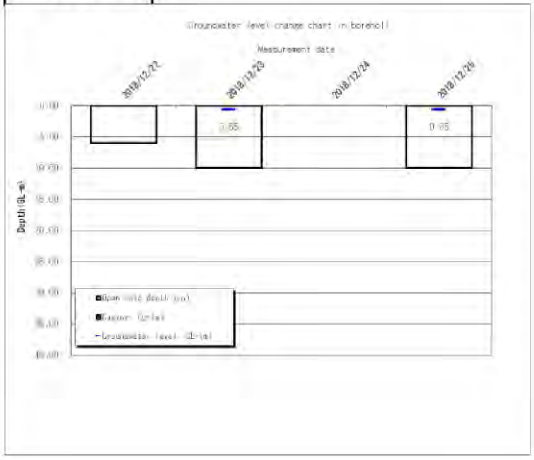
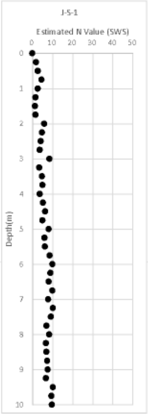


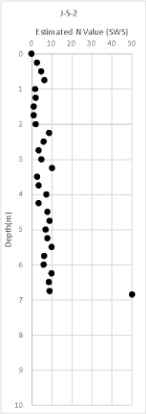
Swedish weight sounding test

Jono Oge

J-S-1



J-S-2



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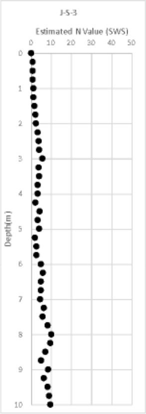
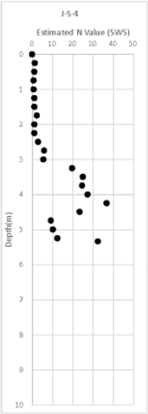
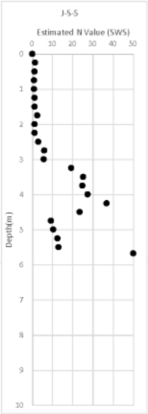


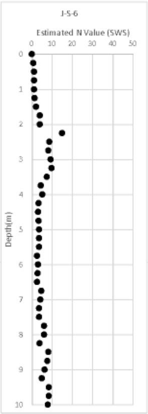
J-S-4



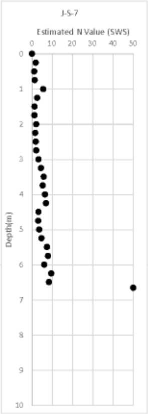
J-S-5



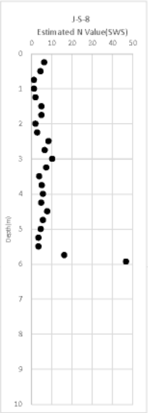
J-S-6



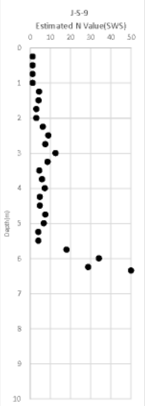
J-S-7



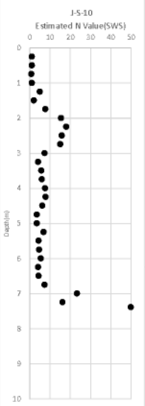
J-S-8



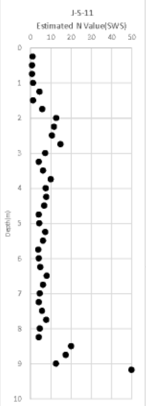
J-S-9



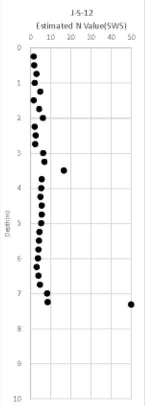
J-S-10



J-S-11



J-S-12



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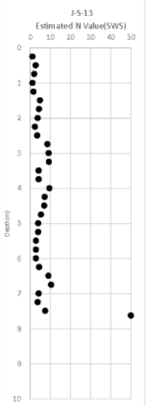
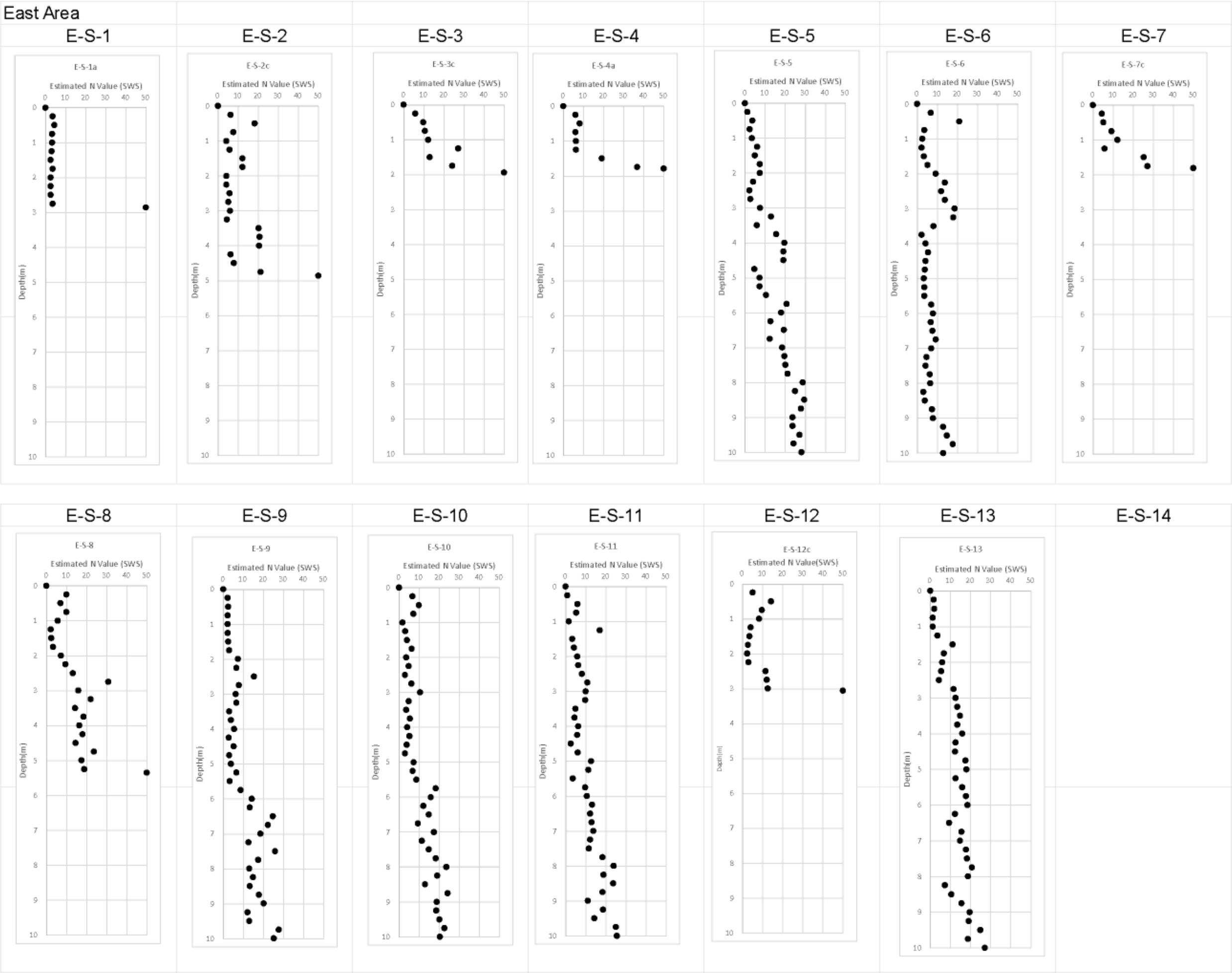
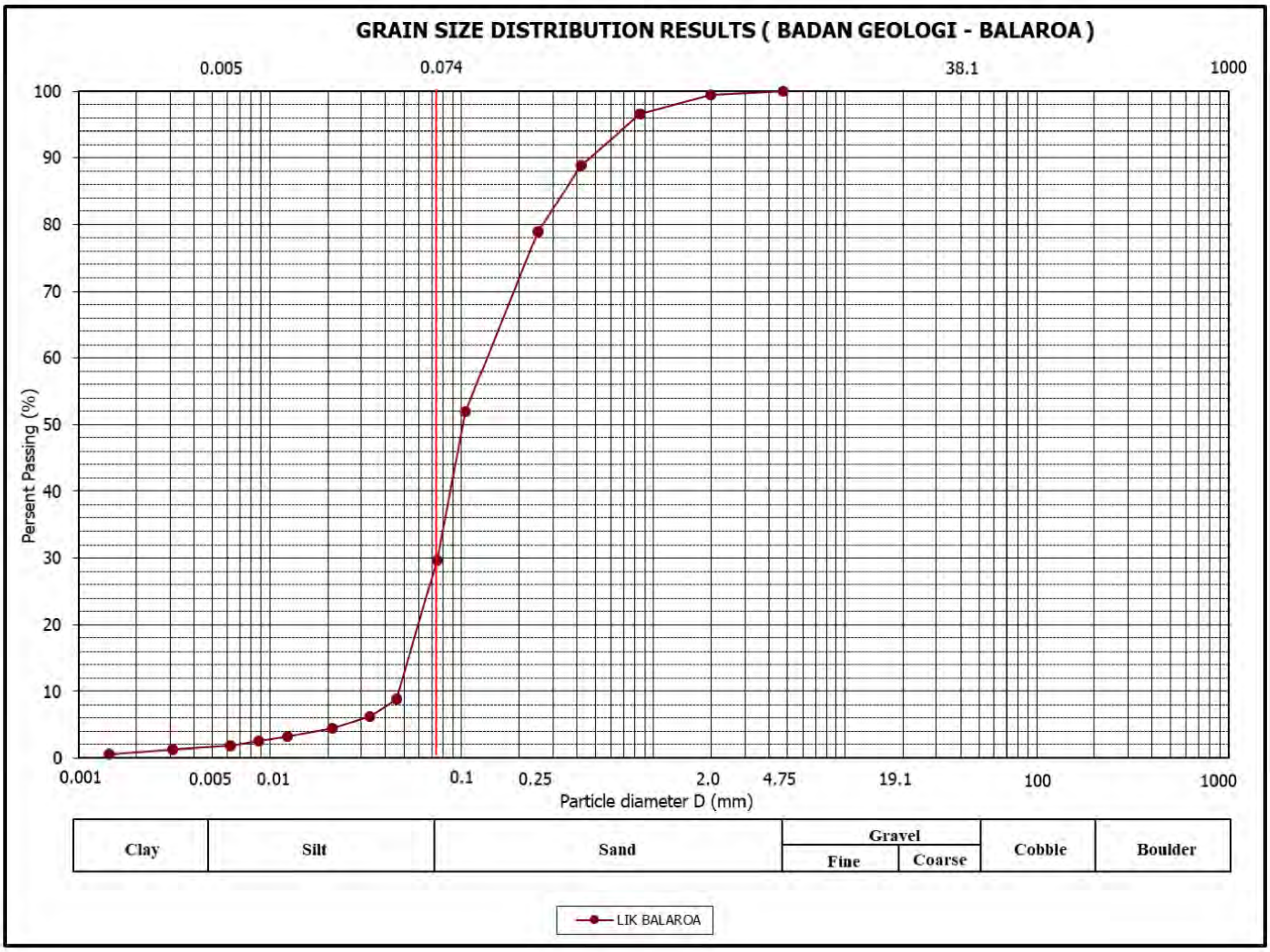
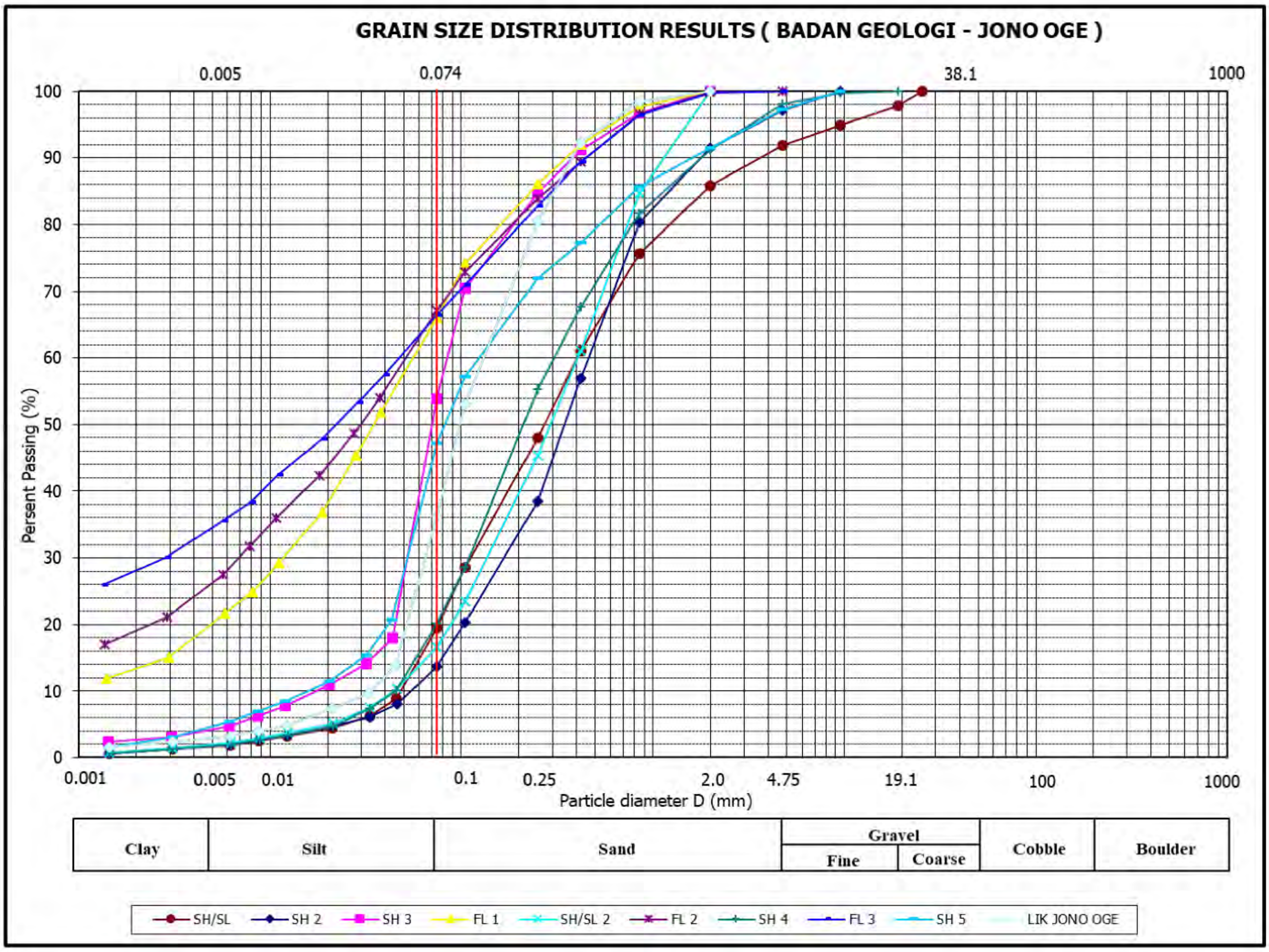
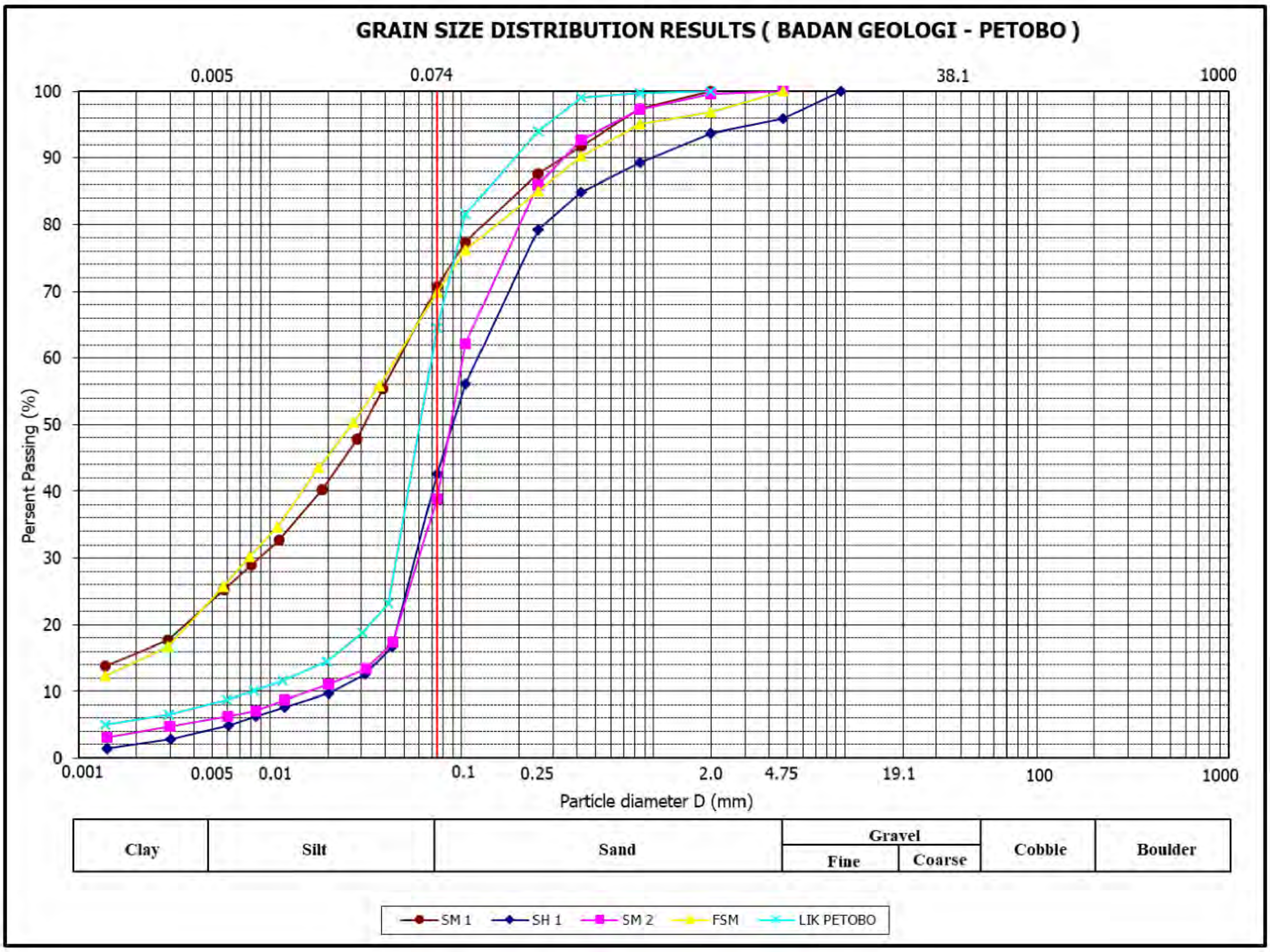


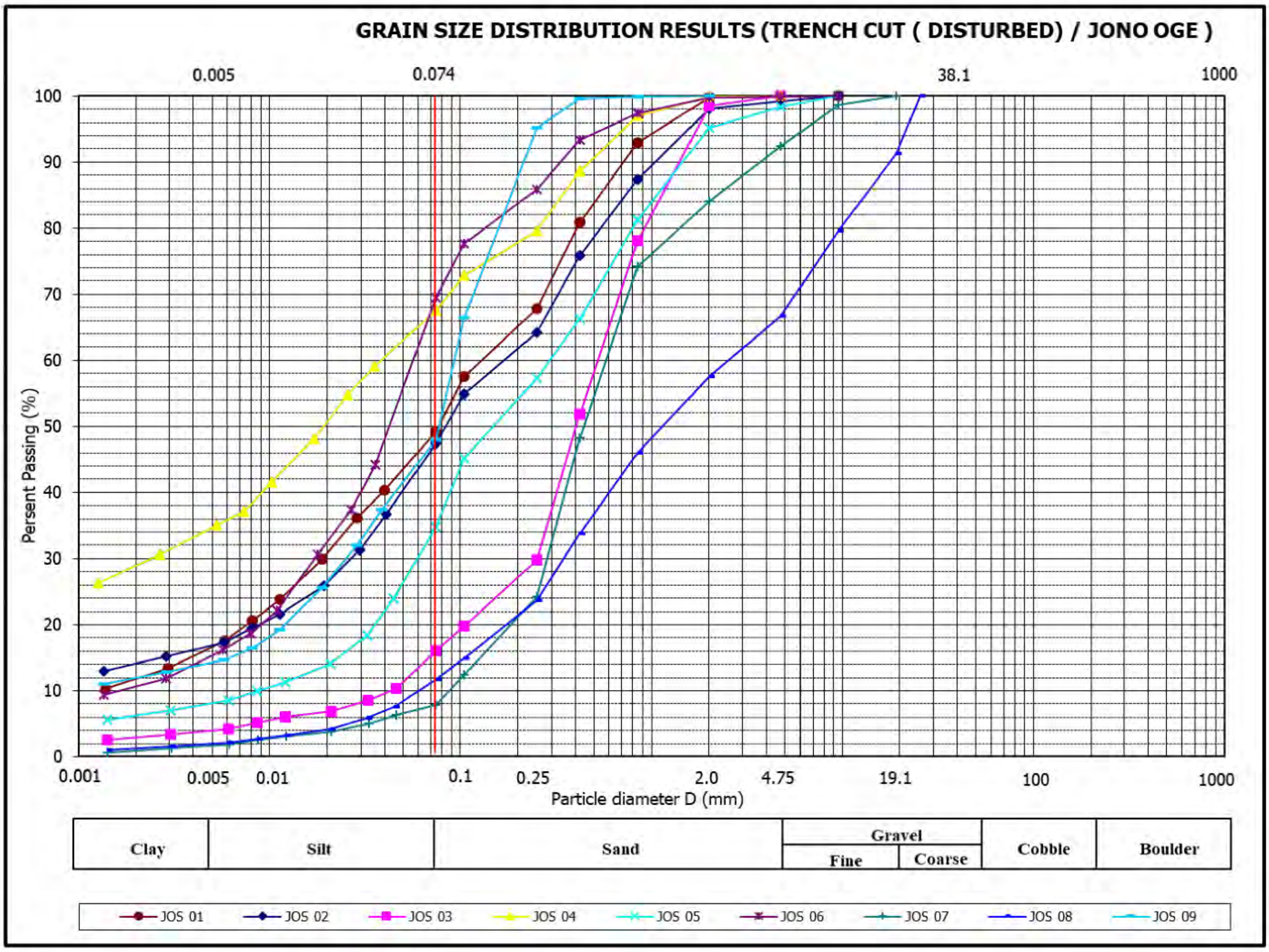
Swedish weight sounding test

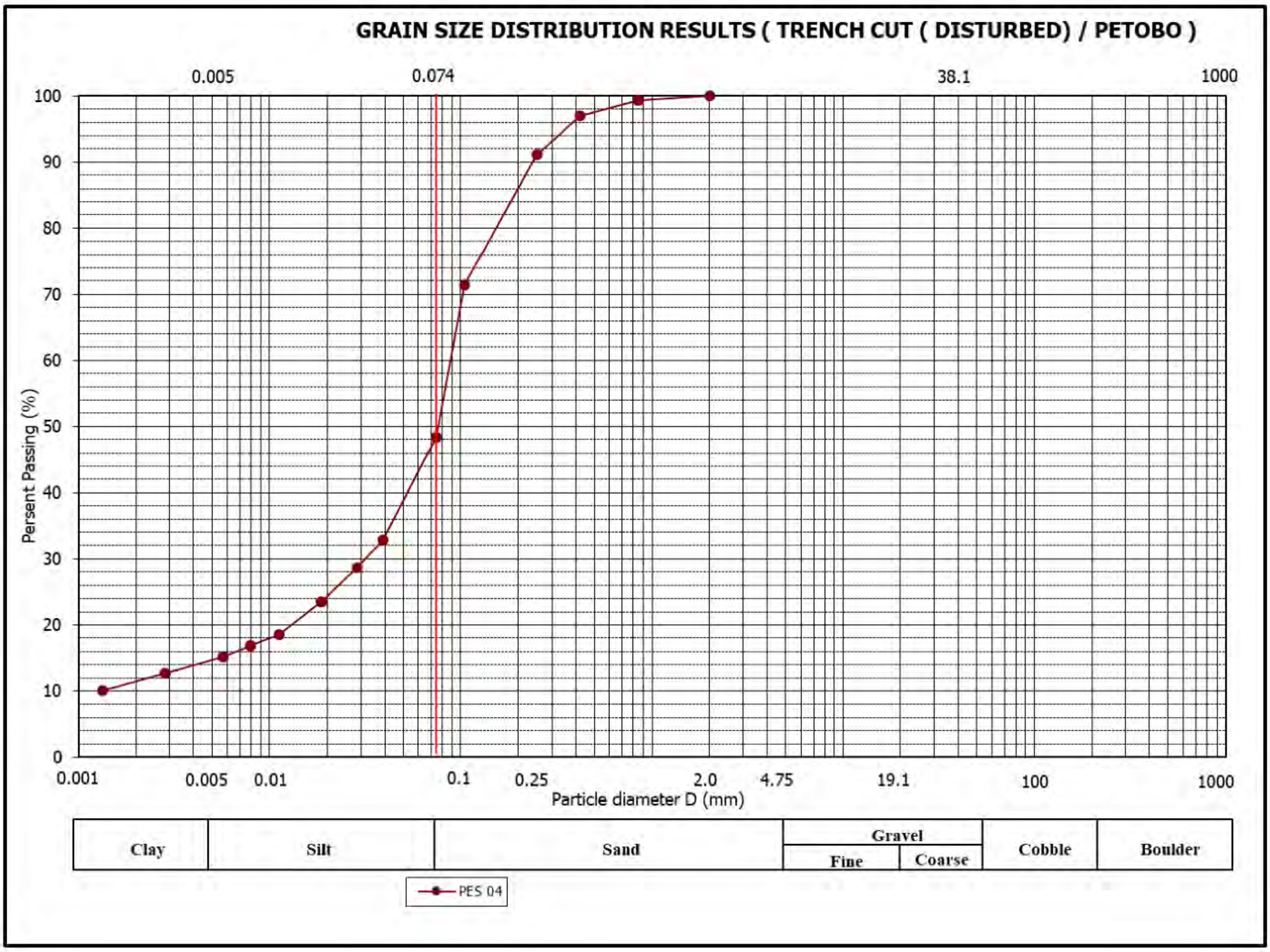


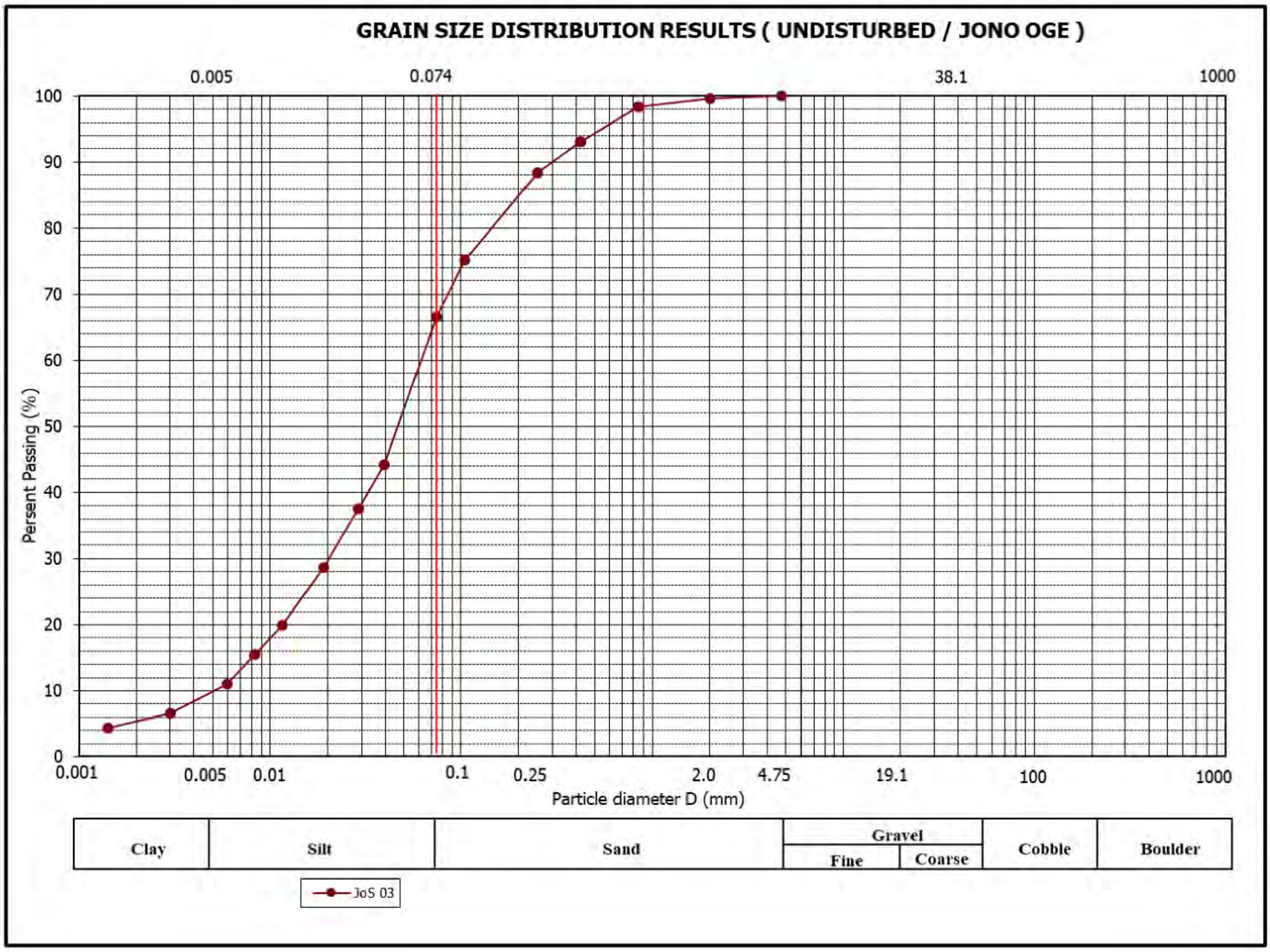


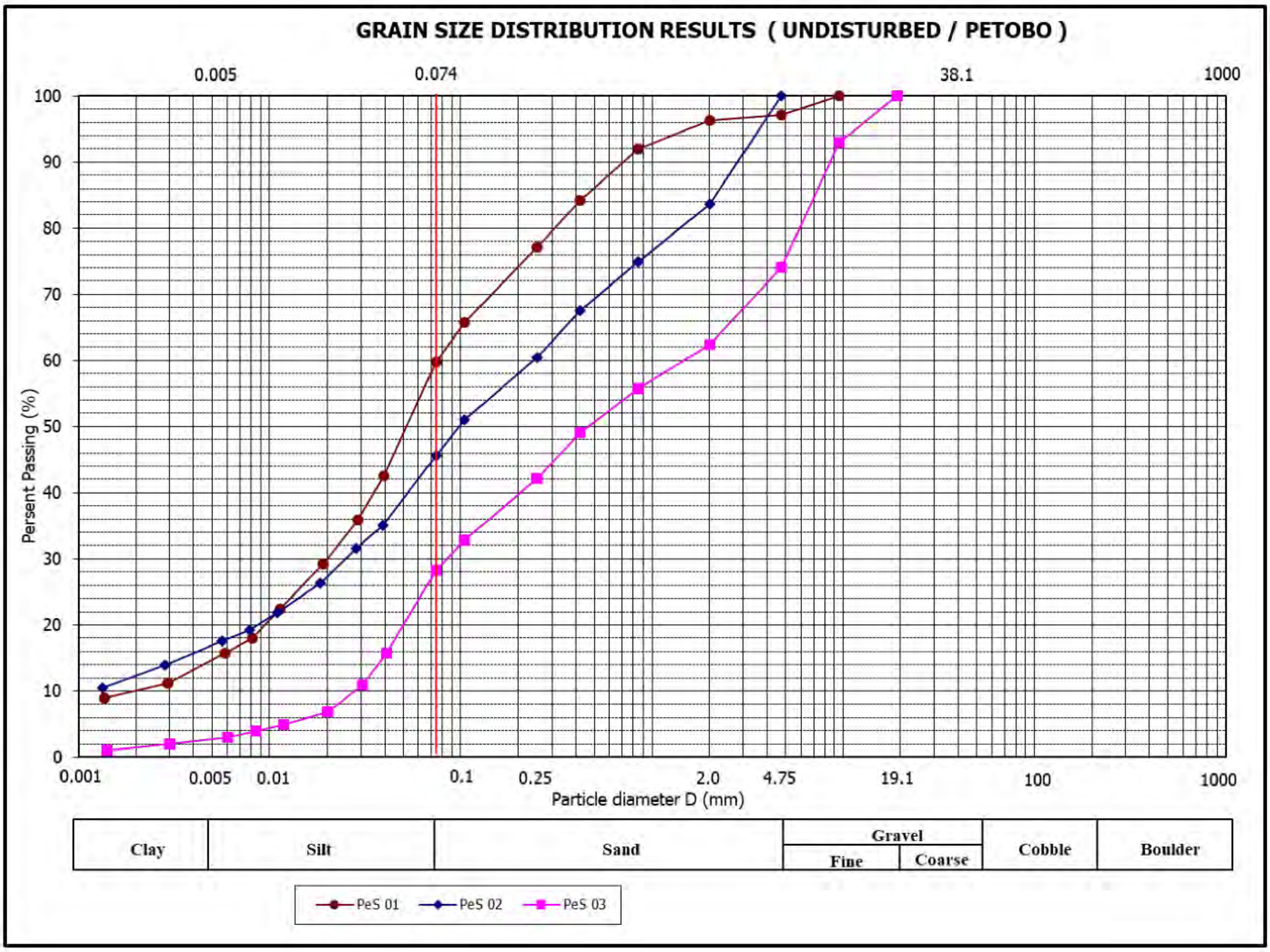

GRAIN SIZE DISTRIBUTION RESULTS (BADAN GEOLOGI - JONO OGE)
0.005
0.074
38.1
1000
Persent Passing (%)
100
90
80
70
60
50
40
30
20
10
0
0.001
0.005
0.01
0.1
0.25
2.0
4.75
19.1
100
1000
Particle diameter D (mm)
Clay
Silt
Sand
Gravel
Fine
Coarse
Cobble
Boulder
SH/SL
SH 2
SH 3
FL 1
SH/SL 2
FL 2
SH 4
FL 3
SH 5
LIK JONO OGE


GRAIN SIZE DISTRIBUTION RESULTS (BADAN GEOLOGI - PETOBO)
0.005
0.074
38.1
1000
Persent Passing (%)
100
90
80
70
60
50
40
30
20
10
0
0.001
0.005
0.01
0.1
0.25
2.0
4.75
19.1
100
1000
Particle diameter D (mm)
Clay
Silt
Sand
Gravel
Fine
Coarse
Cobble
Boulder
SM 1
SH 1
SM 2
FSM
LIK PETOBO


GRAIN SIZE DISTRIBUTION RESULTS (TRENCH CUT (DISTURBED) / JONO OGE)

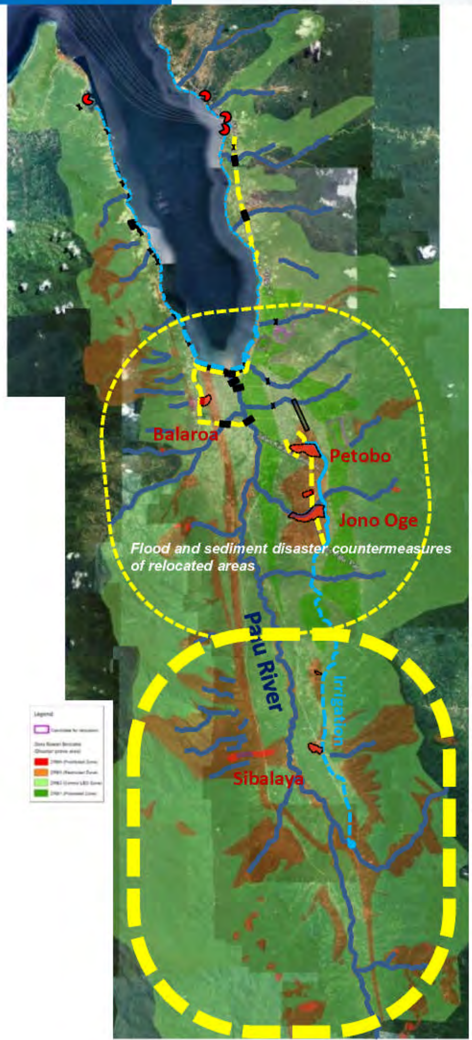

GRAIN SIZE DISTRIBUTION RESULTS (TRENCH CUT (DISTURBED) / PETOBO)


GRAIN SIZE DISTRIBUTION RESULTS (UNDISTURBED / JONO OGE)
0.005
0.074
38.1
1000
100
90
80
70
60
50
40
30
20
10
0
Persent Passing (%)
0.001
0.005
0.01
0.1
0.25
2.0
4.75
19.1
100
1000
Particle diameter D (mm)
Clay
Silt
Sand
Gravel
Fine
Coarse
Cobble
Boulder
JoS 03


GRAIN SIZE DISTRIBUTION RESULTS (UNDISTURBED / PETOBO)
0.005
0.074
38.1
1000
100
90
80
70
60
50
40
30
20
10
0
Persent Passing (%)
0.001
0.005
0.01
0.1
0.25
2.0
4.75
19.1
100
1000
Particle diameter D (mm)
Clay
Silt
Sand
Gravel
Fine
Coarse
Cobble
Boulder
PeS 01
PeS 02
PeS 03

SUNGAI 3c

Peningkatan Sungai dan kontrol Sedimen (Aliran Atas Sungai Palu dan DAS sungai lain)
(River Improvement and Sediment control (Up stream of Palu River)



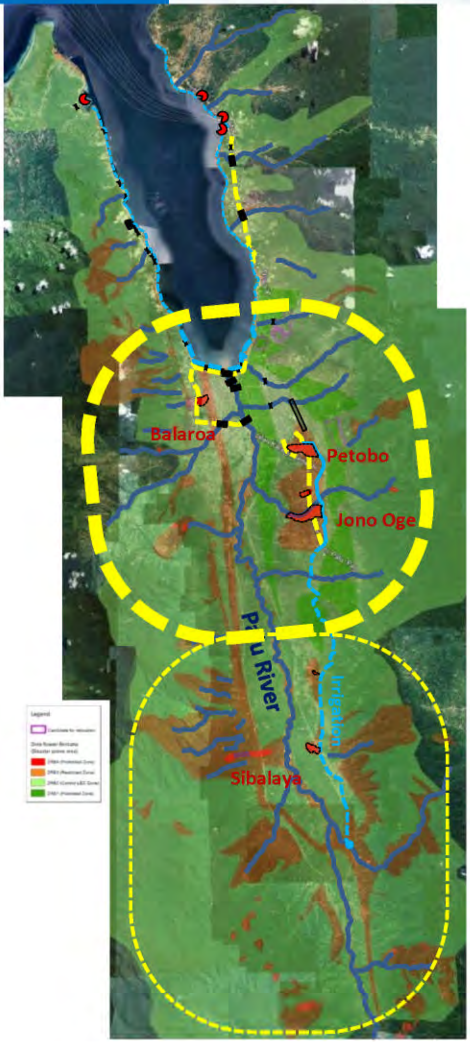
Hard measures
(Sabo Dam · Channel Works)

+

Soft measures
(Warning Warning System)

SUNGAI C-3d

Penanggulangan bencana banjir dan sedimen terhadap daerah yang direlokasi
(Flood and sediment disaster countermeasures for relocation areas)



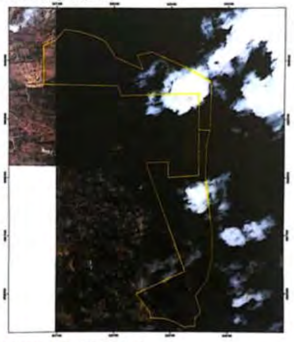
Relocation areas

Duyu

A. Kota Palu seluas 560,93 Ha yang meliputi :
1. Kecamatan Tatanga seluas 79,3 Ha terletak di Kelurahan Duyu

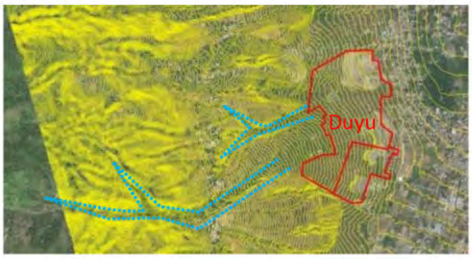
Pombewe/Oloboju

B. Kabupaten Sigi seluas 362 Ha terletak di Kecamatan Sigi Biromaru meliputi:
1. Desa Pombewe seluas 201,12 Ha;
2. Desa Oloboju 160,88 Ha;



Tondo/Talise

2. Kecamatan Mantikulore seluas 481,63 Ha terletak di Kelurahan Tondo dan Kelurahan Talise.



Hard measures
(Sabo Dam · Channel Works)

+

Soft measures
(Warning Evacuation System)