Chapter 2 Contents of the Project

2-1 Basic Concept of the Project

Source: JICA Study Team

Figure 2-1-1 Previous Palu 4 Bridge

The earthquake that occurred on September 28, 2018 (epicentre: 80-km north of Palu City, the capital of Central Sulawesi Province, Indonesia; Mw 7.4) caused the collapse of the Palu 4 Bridge. The loss of the bridge at the mouth of the Palu River has been forcing west-bound traffic to detour via the Palu 3 Bridge (approximately 0.9 km south of the Palu 4 Bridge) and east-bound traffic to detour via the Palu 1 Bridge (approximately 1.6 km south of the Palu 4 Bridge). In this situation, the Government of Indonesia requested the Government of Japan for the construction of the Palu 4 Bridge for the purpose of improving physical distribution, expanding the traffic capacity in the east-west direction, enhancing the resilience of the road network, etc.

In addition, the Indonesian side has expressed its desire for early completion of the bridge as a symbol of recovery, and JICA and the Government of Indonesia have agreed that this request can be met appropriately through the implementation of a grant aid project rather than through the use of a sector loan. The present work develops the outline design of the Palu 4 Bridge in response to this request.

2-2 Outline Design of the Japanese Assistance

2-2-1 Design Policy

2-2-1-1 Basic policy

While this project essentially replaces the collapsed Palu 4 Bridge, the new bridge will be located to the south of the present bridge site in order to avoid the landslide zone produced by the earthquake. In addition, because the bridge is planned to form a segment of the tsunami dike, it must take into consideration the horizontal and vertical alignment and cross-sectional structure of the tsunami dike. As requested by the Government of Indonesia, it is important to select the bridge location so that the number of relocations of properties will be minimized, and the decision will be made based on comprehensive judgment in consideration of spatial planning.

2-2-1-2 Design Conditions

(1) Bridge Design

The bridge design should be carried out in accordance with "Specifications for Highway Bridges (Part I – V)" and should be checked according to "Standard National Indonesia (hereinafter referred to as "SNI")". The standards for bridge design are described below.

- Specifications for Highway Bridges (Part I – V): Japan Road Association (JRA)
- Bridge Management System: Directorate General of Highways (DGH)
- SNI 12-2004 Perencanaan struktur beton untuk jembatan: Badan Standardisasi Nasional (BSN)
- SNI 1725-2016 Pembebanan untuk jembatan: Badan Standardisasi Nasional (BSN)
- SNI 2833-2016 Earthquake Map 2017: Badan Standardisasi Nasional (BSN)
- SNI 8460-2017 Persyaratan perancangan geoteknik: Badan Standardisasi Nasional (BSN)

(2) Road Design

The road design should be carried out in accordance with the following standards:

- Persyaratan teknis jalan dan kriteria perencanaan teknis jalan: Peraturan Menteri Pekerjaan Umum (Nomor: 19/PRT/M/2011)
- SNI T-14-2004 Geometri Jalan Perkotaan: Badan Standardisasi Nasional (BSN)
- Geometric Design of Highways and Streets (2018 7th Edition): AASHTO

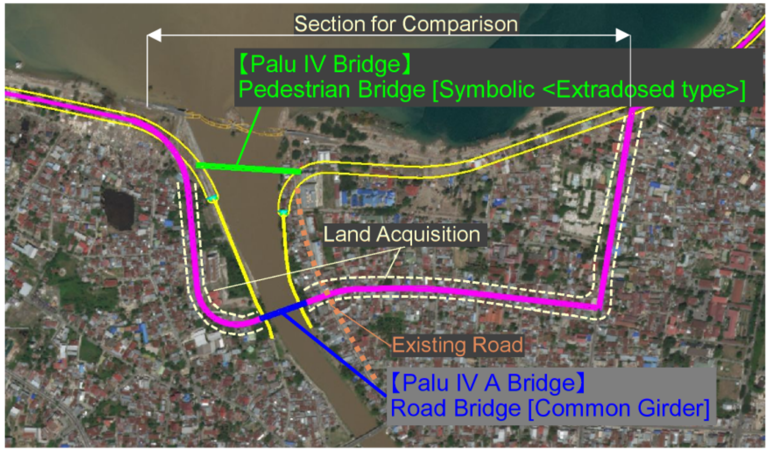
2-2-2 Basic Plan

2-2-2-1 Overall Plan

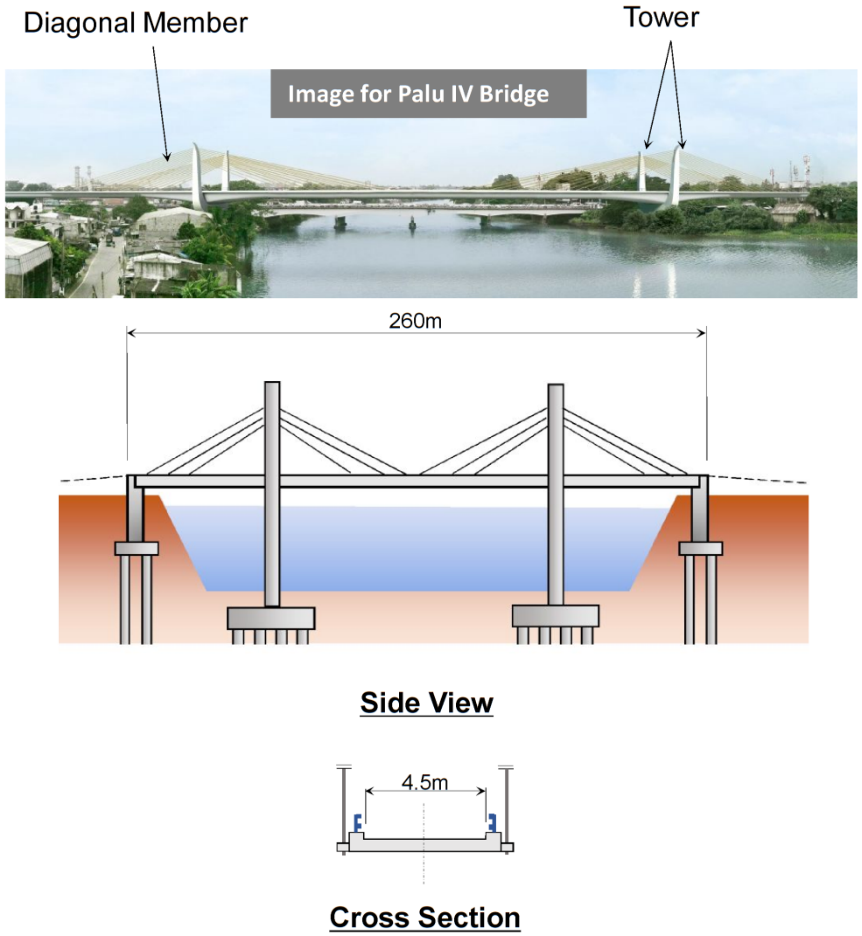
The Palu River runs through the central part of Palu City, and this river was spanned by four bridges (from the Palu 1 Bridge to the Palu 4 Bridge) constructed to provide east-west traffic. The earthquake that occurred on September 28, 2018 caused the collapse of the Palu 4 Bridge, resulting in a decrease in traffic capacity in the east-west direction. Therefore, for the purpose of securing traffic capacity in Palu City and nearby areas and also improving physical distribution, we consulted with Directorate General of Highways (Direktorat Jenderal Bina Marga; herein referred to as Bina Marga) about the objective of the grant aid project and the bridge location.

The comparison table for the objective grant project is shown in Figure 2-2-4 from Figure 2-2-1.

Alternative1: The construction of the multipurpose pedestrian bridge considering aesthetic (Palu IV)



■Completion : Palu IV: Jul. 2022 Others: N/A
■Road Alignment : Not smooth
■Land Acquisition : Approx.150 houses
■Cost : Total 490 bil. IDR
- Palu IV (Pedestrian) : 321 bil. IDR (2.50 bil. JPY) [Grant]
- Palu IV A (Road) : 100 bil. IDR [Indonesia]
- Road : 69 bil. IDR [Indonesia]
■Bridge Maintenance : Coastal area and many members (tower, diagonal member, girder)
■Remarks (on Palu IV)
・Special design such as main tower, diagonal member (cable), dynamic analysis for anti-seismic, wind resistant, etc., are required.

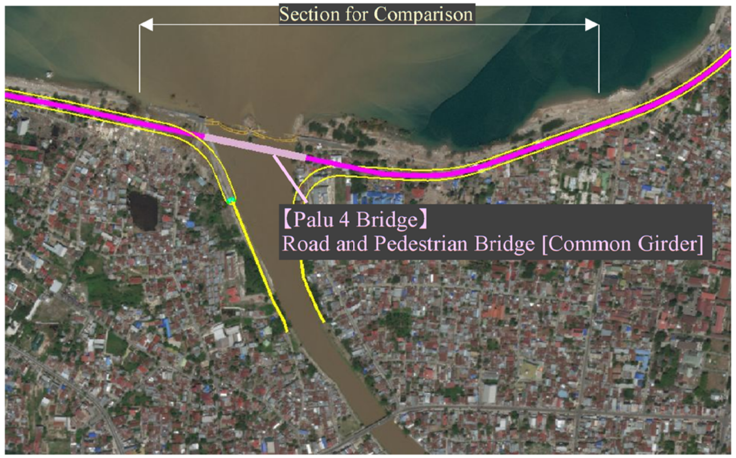


* Expected Commencement of Construction: Aug. 2020
* Cost of tsunami dike is not included in construction cost above.

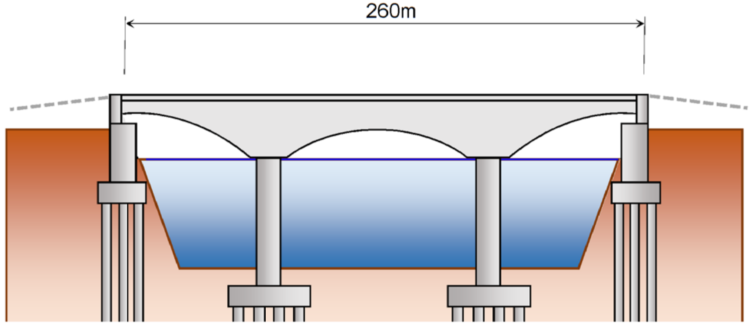
Source: JICA Study Team

Figure 2-2-1 Alternative 1

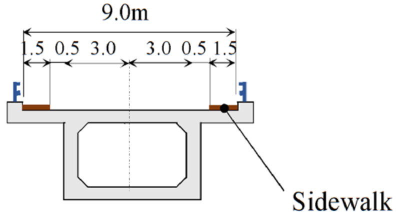
Alternative2: The construction of the roadway bridge with sidewalk considering aesthetic (Palu IV)



■Completion : 2020
■Road Alignment : Smooth
■Land Acquisition : <u>0 houses</u>
■Cost : Total: 359 bil. IDR (2.76 bil. JPY)
Road and Pedestrian Bridge : 325 bil. IDR (2.50 bil. JPY) [Grant]
Road on Dike : 34 bil. IDR (0.26 bil. JPY) [Grant or Loan]
■Bridge Maintenance : Concrete Structure
■Remarks (on Palu IV)
・Special design and analysis are not required.
・Symbolic landscape plan will be implemented.
・Consider rapid construction measures for superstructure construction.



Side View

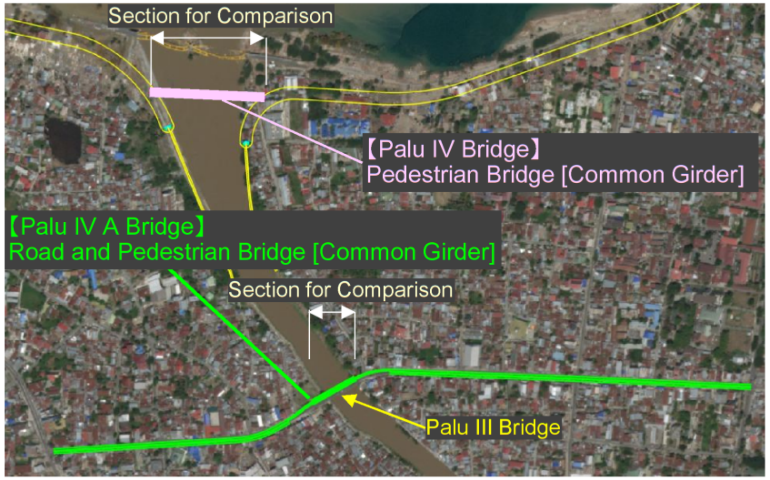


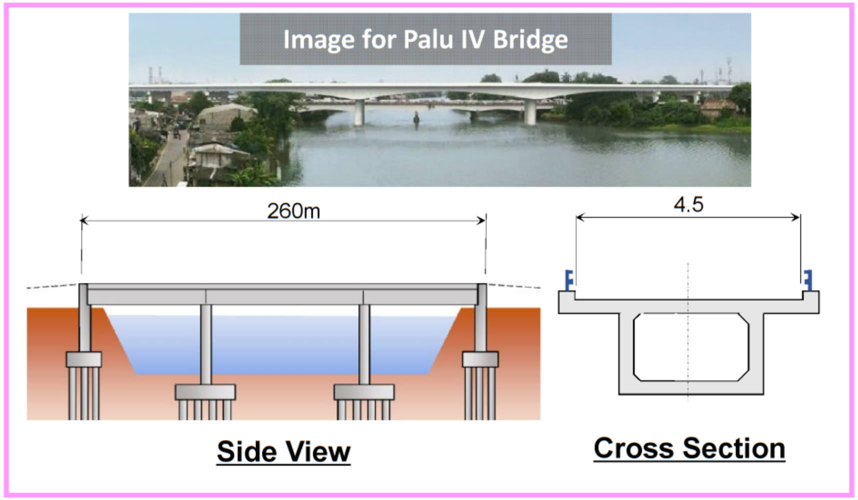
Cross Section

Source: JICA Study Team

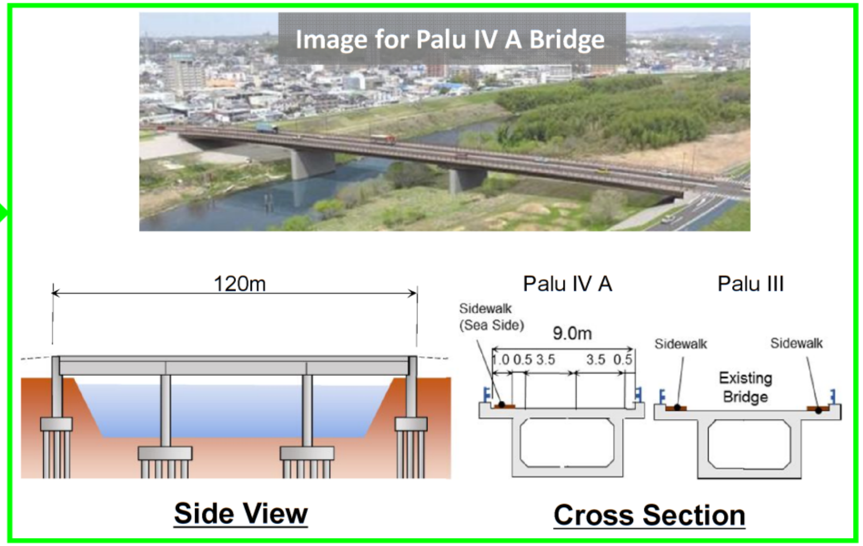
Figure 2-2-2 Alternative 2

Alternative3: The construction of the multipurpose pedestrian bridge (Palu IV)
The construction of the bridge for the improvement of the traffic network (Palu IV A)





■Completion : Palu IV: May 2022
Palu IV A: Oct. 2022
(When it stats at the same time of Palu IV)
■Road Alignment : Smooth
■Land Acquisition : Palu IV: - , Palu IV A: Approx. 5 houses
■Cost : Total 372 ~ 384 bil. IDR
- Palu IV (Pedestrian) : 172 bil. IDR (1.34 bil. JPY) [Grant]
- Palu IV A (Road and Pedestrian):142 bil. IDR (1.11 bil. JPY) [Grant]
- Improvement of the existing Palu III Bridge: 39 ~ 51 bil. IDR (It's necessary to carry out the detailed inspections) [Indonesia]
- Road: 19 bil. IDR [Indonesia]
■Bridge Maintenance : Concrete structure
■Remarks (on Palu IV & IV A)
・Dynamic analysis are required.
・Bridge type shall be determined based on discussion with GOI.

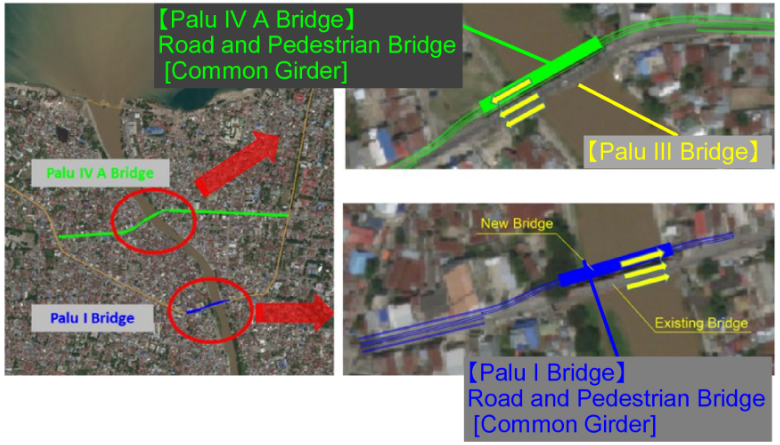


* When the bridge should be constructed by Dec. 2022, one-bridge can be constructed because the construction cost will be increased due to rapid construction.
* Expected Commencement of Construction: Aug. 2020
* Cost of tsunami dike is not included in construction cost above.

Source: JICA Study Team

Figure 2-2-3 Alternative 3

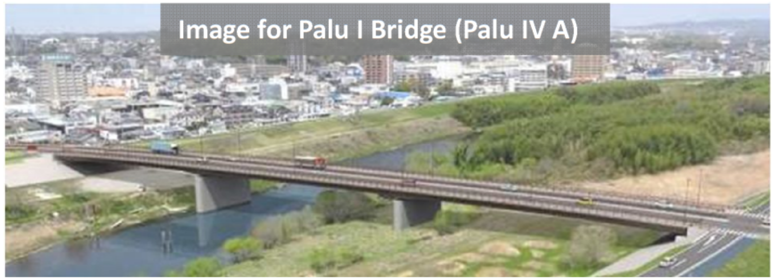
Alternative 4: The construction of the bridge for the improvement of the traffic network (Palu IV A) (Palu I) The improvement of the Palu I and Palu III bridges

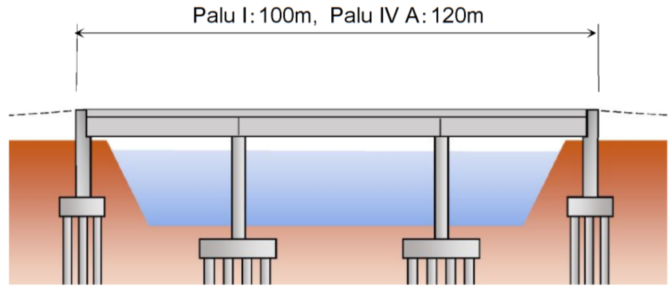


■Completion : Palu IV A: Oct. 2022
Palu I: Oct. 2022
(When it stats at the same time of Palu IV A)
■Road Alignment : Smooth
■Land Acquisition : Palu IV Approx. 5 houses, Palu I: Approx. 5 houses
■Cost : Total 321 ~ 340 bil. IDR
- Palu IV A (Road and Pedestrian): 142 bil. IDR (1.11 bil. JPY) [Grant]
- Palu I (Road and Pedestrian) : 112 bil. IDR (0.87 bil. JPY) [Grant]
- Improvement of the Palu III and Palu I Bridge: 45 ~ 64 bil. IDR (It's necessary to carry out the detailed inspections) (0.35 ~ 0.50 bil. JPY) [Grant]
- Road: 22 bil. IDR [Indonesia]
■Bridge Maintenance: Concrete structure
■Remarks (on Palu IV A & I)
・Dynamic analysis are required.
・Bridge type shall be determined based on discussion with GOI.

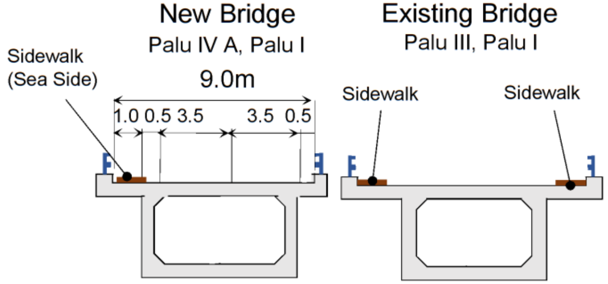
* When the bridge should be constructed by Dec. 2022, one-bridge can be constructed because the construction cost will be increased due to rapid construction.
* Expected Commencement of Construction: Aug. 2020

* The multipurpose pedestrian bridge will be constructed by sector loan.





Side View



Cross Section

Source: JICA Study Team

Figure 2-2-4 Alternative 4

At the meeting of related organizations held on February 18, 2019 in Palu City, the Government of Indonesia requested the adoption of Alternative 2, and the Japanese side accepted this request. In addition, requests were also made for consideration of aesthetic aspects and early completion as a symbol of recovery from the disaster.

2-2-2-2 Road Plan

(1) Geometric Design Criteria

The geometric design criteria of road plan is shown in Table 2-2-1.

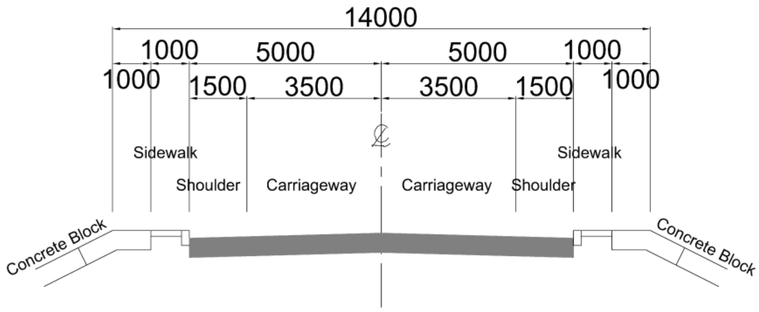
Table 2-2-1 Geometric Design Criteria

Item		Unit	Criteria	Adopted Value	Remarks
Design Speed		km/hr	60	60	
Cross Section					
- Carriageway		m	3.50	3.50	
- Left Shoulder		m	1.50	1.50	
- Sidewalk	Bridge	m	1.00	1.00	
	Road	m	1.00	1.00	
- Frontage Road		m	4.00	4.00	If necessary
- Shoulder of Frontage Road		m	0.50	0.50	If necessary
Horizontal Alignment					
- Standard Minimum Radius		m	150	TBD	
- Desirable Minimum Radius		m	200	TBD	
- Minimum Radius for Normal Cross-fall (i=2.0%)		m	2,000	TBD	
- Minimum Curve Length		m	100	TBD	
- Standard Minimum of Transition Sections		m	50	TBD	
- Standard Minimum Radius not Requiring Transition Section		m	600	TBD	
- Widening of Lanes		m	0.25	TBD	- less than R=160 - per lane
Vertical Alignment					
- Maximum Grade		%	5.0	4.0	as requested by Balai
- Critical Length of Grade		%	6 % - 500m 7% - 400m 8% - 300m	TBD	
- Standard Minimum Radius		m	Crest – 1,400 Sag – 1,000	TBD	
- Desirable Minimum radius		m	Crest – 2,000 Sag – 1,500	TBD	
- Standard Minimum Length		m	50	TBD	
Super-elevation					
- Maximum Super-elevation		%	8.0	TBD	
- Minimum Length of Super-elevation Runoff		-	1/175	TBD	

Source: JICA Study Team

(2) Typical Cross Section

The typical cross section is shown in Figure 2-2-5.



Source: JICA Study Team

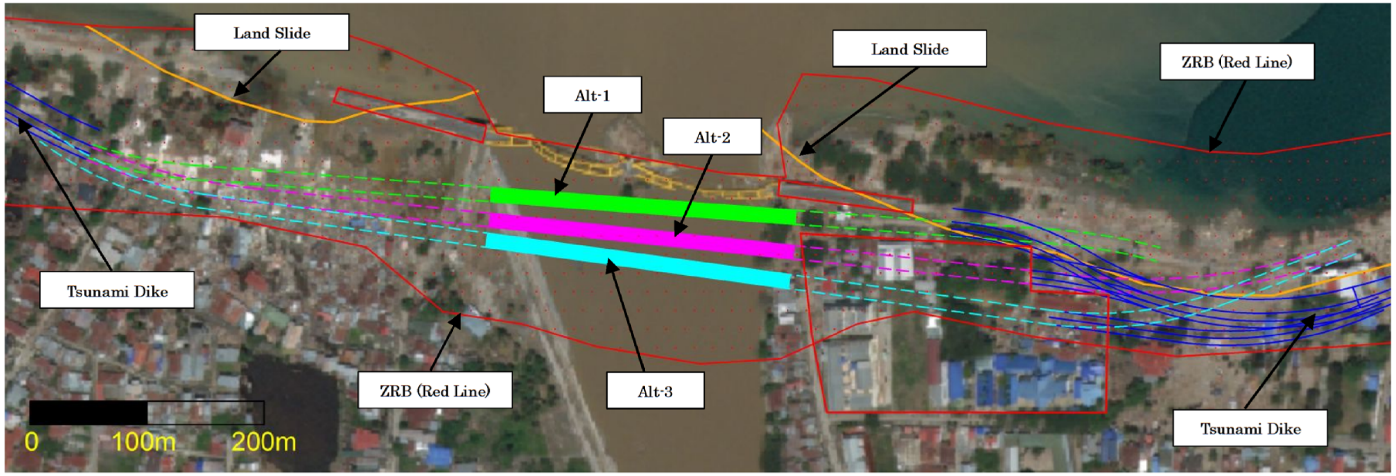
Figure 2-2-5 Typical Cross Section

(3) Road Horizontal Alignment

Because the reconstruction of the collapsed Palu 4 Bridge at the mouth of the Palu River has been agreed upon with the Government of Indonesia, as mentioned above, we examine the positioning of the route in the vicinity of the river mouth, considering spatial planning and other factors. Because there is a landslide zone near the river mouth, the route will be selected basically avoiding this zone. However, since Bina Marga and related organizations expect difficulty in relocation of properties, they requested us to include comparison with an alternative route that passes through the landslide-affected zone and requires less relocations of properties. The comparison table for road horizontal alignment is shown in Table 2-2-2.

As a result of consultation with related organizations, Alternative 1 was adopted instead of Alternative 2 recommended by the JICA Study Team. Despite of joint field surveys and a number of discussions, the Indonesian side concluded that the negotiations for the relocation of properties was difficult and within the limitation of the budget of Palu City, Alternative 1 was realistic from the viewpoint of social and environmental consideration.

Table 2-2-2 Comparison Table for Road Horizontal Alignment

Image			
Alternatives	Alternative -1	Alternative -2	Alternative -3
Outline	The route of right bank side avoids the housing area.	The approach road except for access road of right bank side avoids the land slide area.	The route is planned along the ZRB according to the spatial planning.
Bridge Length *	approx. 260m	approx. 260m	approx. 260m
Approach Road Length *	approx. 170m (Both sides)	approx. 170m (Both sides)	approx. 170m (Both sides)
Access Road Length* – Left bank	approx. 170m	approx. 170m	approx. 220m
Access Road Length* – Right bank	approx. 140m	approx. 300m	approx. 320m
Impact to housing *	nil (0)	3 housings	3 housings, 1 big facility
Existing bridge	When it is judged to disturb the construction, the existing bridge must be demolished by Indonesian Government before the commencement of the construction.	No influence	No influence
Recommendation	Although the impact to housing is nil, the demolition of the existing bridge on right bank might be necessary. -	Although there are impacted housings by the project, it is unnecessary to demolish the existing bridge on right bank. Recommended	The big facility is impacted by the project. -

* Subject to change according to the result of outline design (Only recommended alternative)

Source: JICA Study Team

2-2-2-3 Bridge Plan

(1) Design Conditions

1) Hydrological Condition

(a) Return Period

Return period of the Palu River is instituted in a 25-year return period. According to the maximum records, the highest water level surveyed by visual observation and hearing of the previous Palu 4 Bridge area has flown several times over the existing bank so far. Therefore, a 25-return period is applied for Palu 4 Bridge.

(b) Estimated High-water Discharge Volume

Estimated high-water discharge volume of Palu 4 Bridge calculated by a 25-year return period is shown in Table 2-2-3.

Table 2-2-3 Estimated High-water Discharge Volume

Return Period	Estimated Highest Water Level (m)	Estimated High-water Discharge Volume (m^3/s)
1/25	EL. +1.230	1,000*

*Note: The high water discharge volume estimated by BWS in 2017 is 800 m^3/s (756.024 m^3/s). However, the JICA Study Team is considering river and basin countermeasures targeting the 2016 floods. Even if the considerations to determine the scale of both river and basin countermeasures are on-going, the estimated design flood discharge in the downstream of Palu River is supposed to not exceed 1,000m^3/s, because of the difficulties to widen the river..

Source: JICA Study Team

(c) Design Flow Velocity

Design flow velocity in the 25-year return period for bridge planning is shown in Table 2-2-4.

Table 2-2-4 Design Flow Velocity

Return Period	Design Flow Velocity (m/s)
1/25	1.210

Source: BWS (2017), "Investigation and Design Survey on the Palu River Boundary in Palu City of 2017"

(d) Highest Water Level

The highest water level should be set considering a calculation result by a 25-year return period, a record of the high tide and the maximum wave height generated by tsunami as shown in Table 2-2-5.

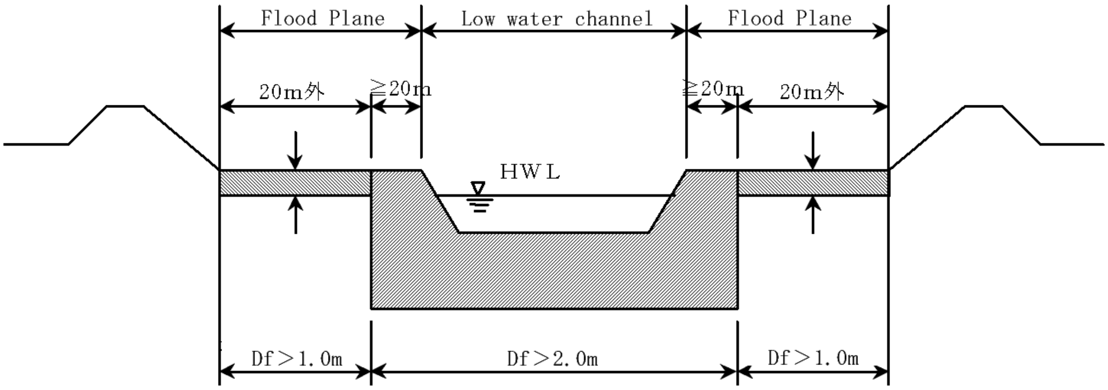
Table 2-2-5 Highest Water Level

Source	Highest water Level (m)
25-year return period	1.230
Record of high tide (Mean High Water Spring)	2.316
Record of tsunami	6.500

Source: JICA Study Team

(e) Embedment Depth

Embedment depth of the foundation in the main stream of the river should at least be kept more than 2 m depth shown in Figure 2-2-6.



Source: MLIT (Ministry of Land, Infrastructure, Transport and Tourism)

Figure 2-2-6 Embedment Depth

(f) Blockade Ratio Caused by Structures in the River

Palu 4 Bridge is located on an important ring road connecting east and west furthermore north and south roads. The blockade rati caused by structures in the river is kept at less than 5% in the Standard of MLIT in Japan. The blockade ratio is calculated using the following formula.

$$\text{Blockade Ratio} = \frac{\text{Sum of structure width}}{\text{River Width}} \times 100\ (\%) < 5\ \%$$

Accordingly, width of the Palu River is now 230m long at the point, so that sum of structure width should be kept less than 11.5m long.

(g) Requested Span Length

Requested span length is calculated using the following formula as shown in Figure 2-2-7 based on the Standard of MLIT.

$L = 20 + 0.005Q$

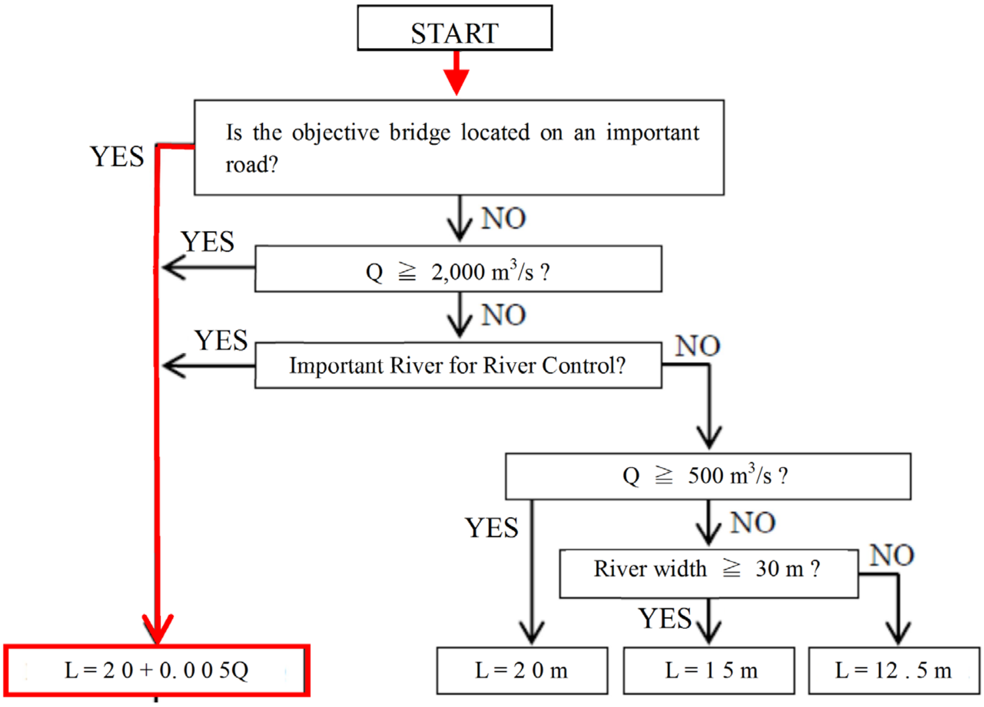
Here,

L: Requested span length (m)

Q: Estimated High-water Discharge Volume (m^3/s)

Estimated High-water Discharge Volume (m^3/s): 1,000

Requested Span Length (m): more than 25.0



Source: MLIT (Ministry of Land, Infrastructure, Transport and Tourism)

Figure 2-2-7 Calculation Flowchart of Requested Span Length

2) Load Condition

(a) Dead Load

Dead load of each material is shown in Table 2-2-6 stipulated in the Japanese Standard.

Table 2-2-6 Unit Weight

Material Content	Unit weight (kN/m^3)
Steel	77.0
Reinforced concrete	24.5
Plain (Non-reinforced) concrete	23.0
Cement mortar	21.0
Asphalt concrete	22.5
Sand, gravel	20.0
Sandy soil	19.0
Clay soil	18.0

Source: MLIT (Ministry of Land, Infrastructure, Transport and Tourism)

(b) Live Load

Live load applies two (2) types such as L type (uniform load) and T type (concentrated load) of JRA. Moreover, each element of the bridge structure shall be verified by applying D type (uniform load) and T type (concentrated load) of SNI.

(c) Impact

The impact of the live load shall be considered. Calculation of the impact shall apply the Japanese Standard. And then the impact of the live load should not be applied to the design of the sub-structure.

(d) Influence of Creep for Concrete and dry Shrinkage for Concrete

The creep strain and drying shrinkage related to the age of concrete material shall be calculated according to Specifications for Highway Bridges (Part III), and the creep coefficient after the completion of structural elements shall be 1.50 for main girder concrete. The drying shrinkage rate of main girder concrete shall be 15.00×10^{-5}.

(e) Thermal Load

An annual average highest temperature is approximately 30.7 degrees (monthly average highest temperature: 32.1 degrees in October) and an annual average lowest temperature is approximately 23.0 degrees (monthly average lowest temperature: 22.0 degrees in July) along the objective area. As the result of each temperature, an annual average temperature is 26.8 degrees. Therefore, the thermal force shall be considered as ±15 degrees as an annual average temperature in consideration with the difference of a monthly average highest temperature and a monthly average lowest temperature.

(f) Static/Dynamic Earth Pressure

Earth pressure shall appropriately consider the type of structure and the earth conditions based on the Japanese Standard.

(g) Static/Dynamic Water Pressure

The pressure of the water shall appropriately consider the change of the water level, flow velocity, scouring, and shape/measurement size of the pier based on the Japanese Standard.

(h) Tsunami Load

The pressure of tsunami shall be the largest of the values calculated from the formulas proposed in the following standards:

- Technical Standards and Commentaries for Coastal Facilities, August 2018.
- The Principles of Parapet Design Considering Tsunamis (Provisional Version), November 2015.
- An Experimental Study on Wave Force Acting on On-shore Structures Due to Overflowing Tsunamis (Asakura et al., Coastal Engineering Proceedings Vol. 47, 2000).

(i) Buoyancy and Uplift

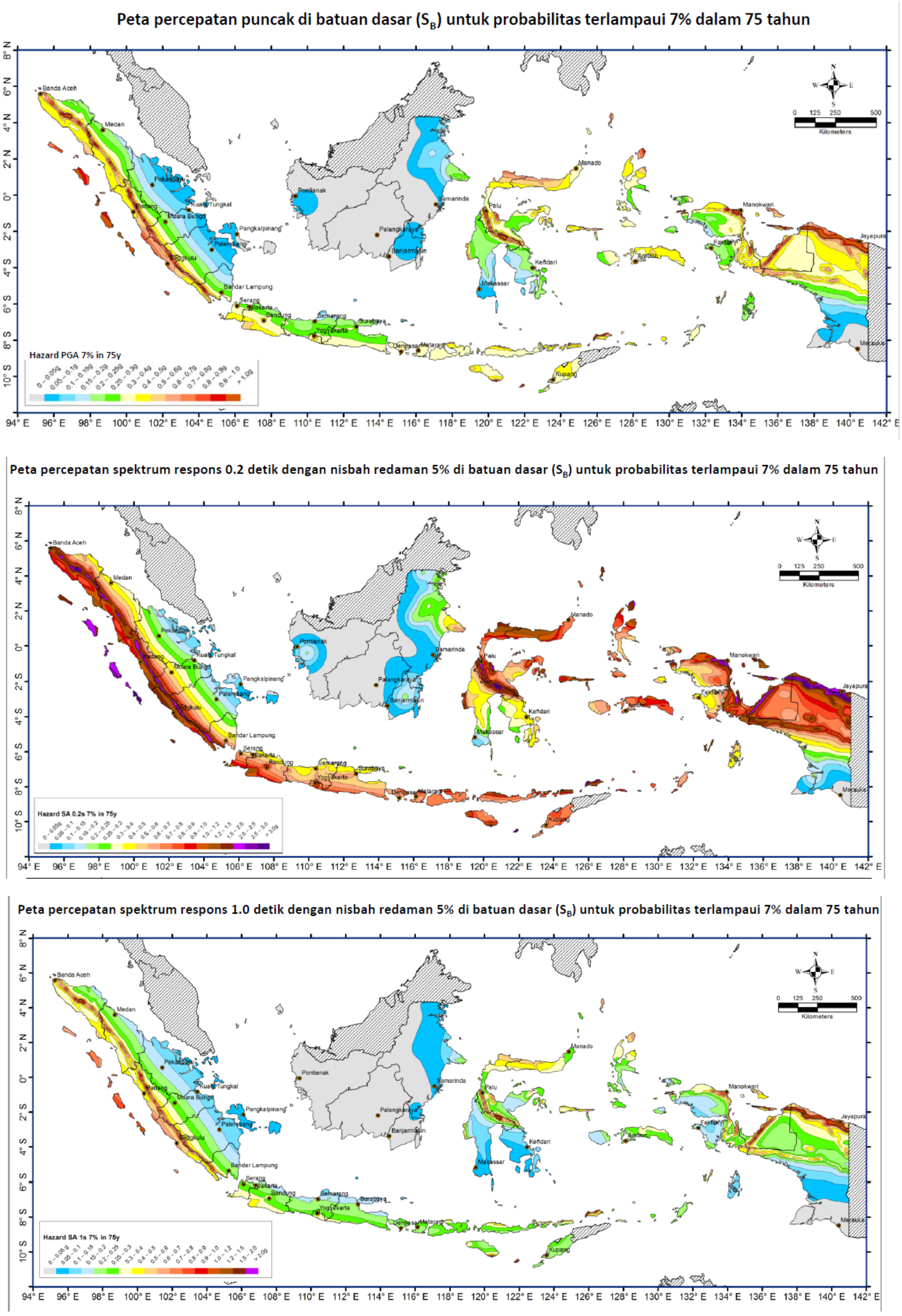
Buoyancy and uplift shall appropriately consider the pore water and the change of the water level.

(j) Wind Load

Wind load shall be considered on this Project because there is influence along Palu Bay to the objective bridges.

(k) Seismic Load

Seismic load including liquefaction prediction applies JRA based on the geological result surveyed at the new location of the Palu 4 Bridge site. Moreover, the whole structure and each element of the bridge shall also be verified by applying SNI and site seismic hazard analysis. Distribution map of Earthquakes in Sulawesi island is shown in Figure 2-2-8. And the estimated fault in the Palu Bay is shown in Figure 2-2-9. Moreover, magnitude and earthquakes are classified in Table 2-2-7. Frequency of the occurrence in Japan is sampled as the relationship of the earthquake scale and the magnitude in Table 2-2-8.



Source: SNI- INDONESIA EARTHQUAKE SOURCES AND EARTHQUAKE 2017 MAP

Figure 2-2-8 Distribution map of Earthquakes in Sulawesi island

Source: JICA Study Team

Figure 2-2-9 Estimated Fault in the Palu Bay Area

Table 2-2-7 Classification of Earthquakes by Magnitude (M)

Mega Earthquake	8 ≤ M
Great Earthquake	7 ≤ M
Moderate Earthquake	5 ≤ M < 7
Minor Earthquake	3 ≤ M < 5
Micro Earthquake	1 ≤ M < 3
Ultra-micro Earthquake	1 < M

Source: National Research Institute for Earth Science and Disaster Prevention

Table 2-2-8 Relationship of Earthquake Scale and Magnitude (M)

Scale		M	Outline of Earthquake (in case of earthquake occurred at shallow depth)	Earthquake Occurrence in around Japan
Great Earthquake	Mega Earthquake	9	occurrence mega diastrophism in around several hundred kilometer or 1,000 kilometer, catastrophe and/or giant tsunami in wide area	once a several hundred years
		8	catastrophe in wide area if earthquake occurred in land, large tsunami if earthquake occurred at seabed	once a ten years
		7	large damage in wide area if earthquake occurred in land, tsunami if earthquake occurred at seabed	around once or twice a year
Moderate Earthquake		6	small damage around the epicenter, large damage in case of ground condition if the area is near M7	around 10～15 times a year
		5	minor damage or some damage in case of ground condition if the area is near around epicenter	around 10 times a month
Minor Earthquake		4	macroseismic area at the epicenter, macro damage at the epicenter if the hypocenter is very shallow	around 10 times a day
			rarely macroseismic area at the epicenter	around several times a day
Micro earthquake		3	rarely macroseismic area if the hypocenter is very shallow	around 10 times a hour
		2	insensitive to quake to the people	around once or twice a minute
Ultra-micro Earthquake		1	insensitive to quake to the people	occurrence in countless
		0	insensitive to quake to the people	
		-1	insensitive to quake to the people	

Source: National Research Institute for Earth Science and Disaster Prevention

(I) Collision Load

Since there is some possibility of collisions with the piers during flooding, a collision load shall be appropriately considered based on the Japanese Standard.

(2) Basic Plan for Bridge

1) Basic Policy

The basic policy and its contents are described in Table 2-2-9. The objective bridges shall be planned based on the basic policy. The scale and type of the objective bridges are decided in this chapter.

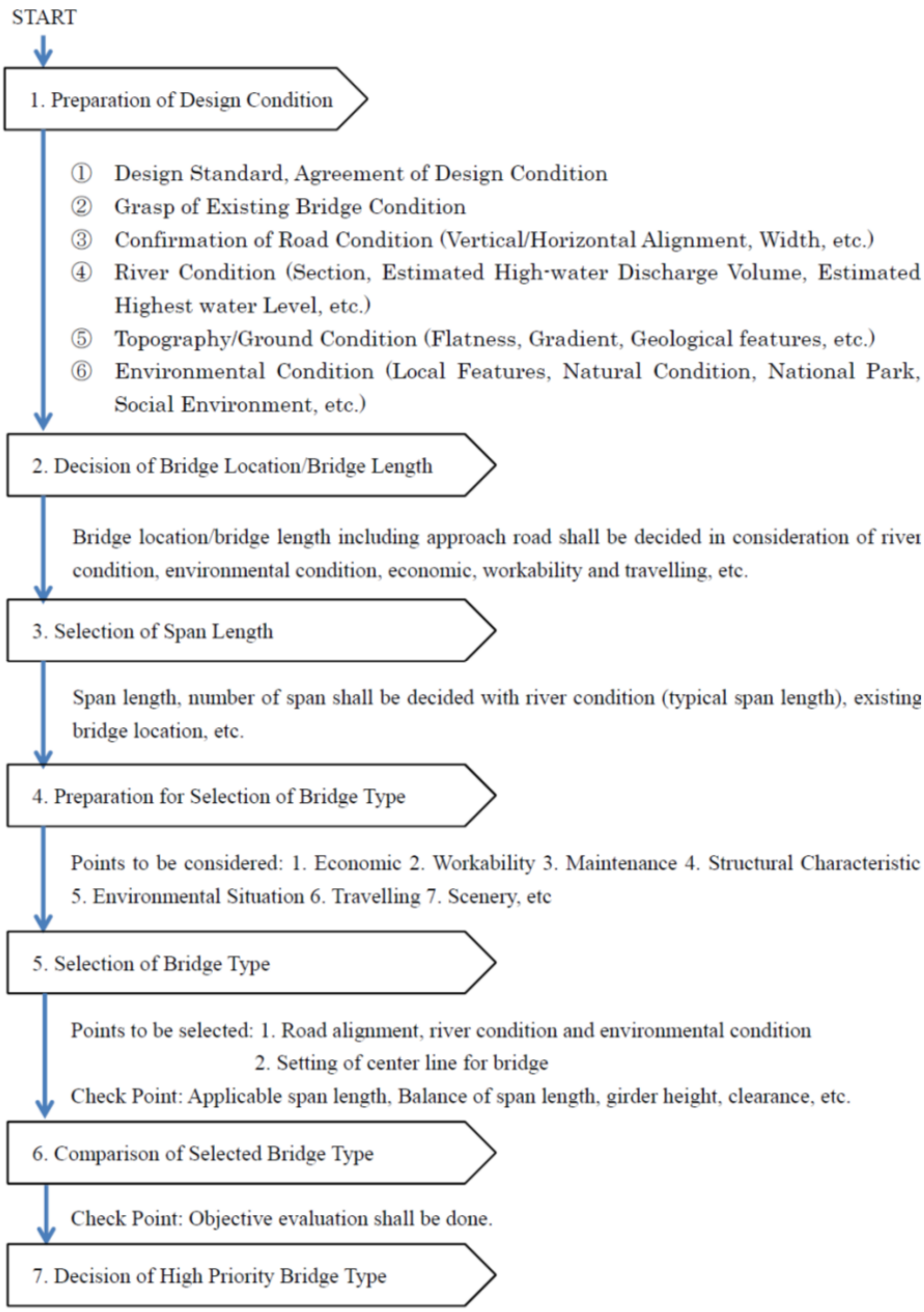
Table 2-2-9 Basic Policy of Bridge Plan

Policy of the Planning	Contents of the Policy
① Suitable Alignment and Bridge Location	In order to keep an economical bridge length and safe and comfortable travelling, a suitable road alignment and bridge location shall be considered.
② Economy	Selection of the bridge material/type shall consider not only the economy of construction costs but also the life cycle cost spent for maintenance.
③ Workability	The bridge plan shall prioritize safety first and select the bridge type of exact erection method. Furthermore, the bridge plan shall consider the road users and surrounding people.
④ Scenery	The bridge plan shall be considered in harmony with the surrounding environmental situation.
⑤ Aseismicity	The bridge plan shall adequately consider the aseismatic design based on the past seismic records.
⑥ Clearance	The bridge plan shall consider the influence of flooding and debris in the river. Therefore, clearance shall be analyzed based on rainfall and hydrological data. Furthermore, high tide and influence of tsunami should be also considered.
⑦ Seasonal Changes	The bridge plan shall be studied in consideration with both rainy and dry seasons for the plan of road elevation and erection method.
⑧ Construction Space	The bridge plan shall be studied in consideration with no affect to road users for the limited construction yard.
⑨ Transportation for Construction	Transportation issues restrict length, height, and weight of bridge; members and materials shall be surveyed on the bridge plan.
⑩ Traffic safety during Construction	The bridge plan shall consider road users during construction work, erection of temporary bridge, and preparation of temporary yard.
⑪ Social Vulnerability	Based on the results of a social condition survey, a bridge plan shall decide the sidewalk on the bridge and bridge composition with enough discussion with Indonesian side.

Source: JICA Study Team

2) Flowchart of Bridge Plan

The selection process for the bridge type is shown in Figure 2-2-10.



Source: JICA Study Team

Figure 2-2-10 Flowchart for Selection Process for Bridge Type

3) Plan for Selection of Bridge Location

(a) Selection Policy

The plan for the bridge location shall be selected based on the following policies:

Basic item:

- Location considers approach road alignment for safe and smooth traffic.
- Location allows construction space that does not disturb road users.

Item considered objective area:

- Location does not require the removal of residences and buildings surrounding the previous Palu 4 Bridge.
- Location does not hinder ZRB area.
- Location considers a future tsunami dike alignment for the approach road.

(b) Study for Bridge Location

As the result of route selection (see Table 2-2-2), the alternative 1 has been selected. Thus, the bridge plan is carried out at the location.

(c) Study for Abutment Location and Bridge Length

There are no records of overflow in the vicinity of the pre-collapse positions of bridge piers. Therefore, the positions of the new abutments that will be constructed on both banks should be in the same positions as the former bridge piers or on the landward side of these positions from a safety standpoint, and the bridge length is set at 260m.

4) Study for Bridge Material and Bridge Type

(a) Bridge Type of Superstructure and Span Length

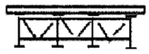
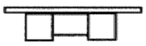
As mentioned above, the bridge length has been planned in 260 meters and span length is necessary to ensure more than 25 meters. Regarding the span in 260 meters, it is desirable that the span length is ensured more than 40 meters considering the flood-wood, other bulk trash and span length of existing bridge during monsoon.

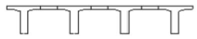
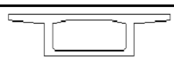
The applicable bridge type under conditions of the circumstances is described below.

- 3-span: 2 x 75.0m + 110.0m = 260.0m (Box-type/deck-box-type Steel-girder bridge, Box-type PC-girder bridge)
- 5-span: 5 x 52.0m = 260.0m (I-type Steel-girder bridge, Box-type/deck-box-type Steel-girder bridge, Box-type PC-girder bridge)

The bridge type of superstructure and span length are shown in Table 2-2-10.

Table 2-2-10 Bridge Type of Superstructure and Span Length

Type			Shape	Election Method	Span (20 40 60 80 100)	Ratio
Steel Bridge	Girder Type	I-typed		Truck Crane/ Launching		1/16～1/22
		Box typed		Truck Crane/ Launching Launching		1/20～1/30
		Steel deck box typed		Truck Crane/ Launching Launching		1/22～1/28
	Truss Type			Tower Crane		1/7.0～10.0
	Arch Type			Tower Crane		1/5.3～76.3

Type			Shape	Election Method	Span (20 40 60 80 100)	Ratio
Concrete Bridge	RC	T-typed		Fix typed support		1/8～1/11
	Pre-tension	Slab typed		Truck crane		1/14～1/25
	Post-tension (site product)	Connected T-typed		Gantry crane/ erectiongirder		1/13～1/17
		Slab typed		Fix typed support		1/20～1/24
		Box typed		Fixed typed support/Launching		1/16～1/22

Source: Bridge Hand Manual

According to Table 2-2-10, steel I-typed girder and steel box-typed girder should be adopted the track crane or the launching girder as erection method. On the other hand, PC Bridge can be adopted the launching girder or the fixed typed support, however, the balanced cantilever method should be adopted considering erection equipment and economic efficiency.

(b) Span Type

As mentioned above, the objective bridge is studied for 3-span or 5-span. The comparison table for the span is shown in Table 2-2-11.

Table 2-2-11 Comparison Table for Span

Item		3-Span Type	5-Span Type
Span length (m)		75.0, 110.0, 75.0	5 x 52.0
Girder height (m)	Steel I-type*	-	3.0 (1/17)
	Steel box-type*	-	-
	PC box-type*	3.0 (1/25), 72 (1/18), 3.0	3.5 (1/15)
Number of piers (No.)		2	4
Influence on the vertical road alignment		PC type is much longer than Steel type because of much higher girder height △	Steel type is much shorter than PC type ○
Influence on the substructure/construction period		Two large size piers, but not much influence on the construction period because of lesser piers than 5-Span Type ○	There are four piers and pier size is smaller than 3-Span Type, but much influence on the construction period because of more piers than 3-Span Type △
Total cost		Almost similar cost with 5-Span Type ○	Almost similar cost with 3-Span Type ○
Total evaluation		○	○

○: Highly effective, △: Effective, ×: Ineffective

*: Steel I type: Ratio of Girder Height/Span Length, PC box type: Ratio of Girder Height/Span Length

As a result of comparison, 3-span and 5-span are competitive, thus, comprehensive study including bridge type should be carried out. The comparison for the span is described below.

(c) Selection of Bridge Type

The following bridge type has been selected by reference to Table 2-2-10.

Alternative 1:	3-span box-type PC-girder bridge	75.0m+110.0m+75.0m = 260.0 m
Alternative 2:	5-span box-type PC-girder bridge	5 x 52.0 m = 260.0 m
Alternative 3:	5-span I-type Steel-girder bridge	5 x 52.0 m = 260.0 m

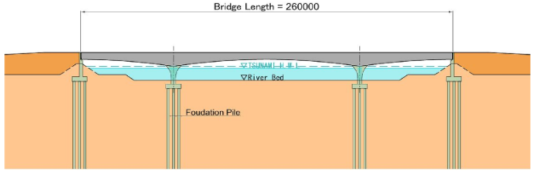
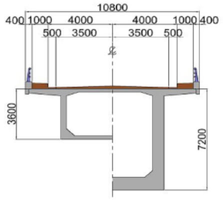
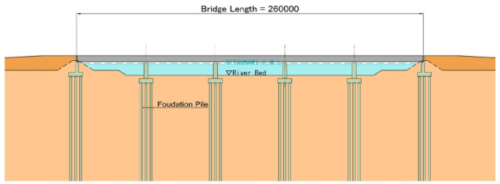
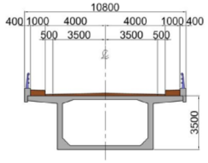
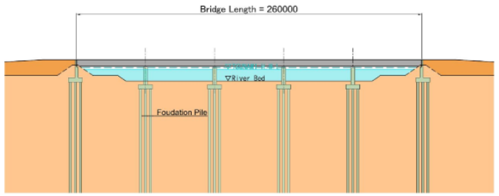
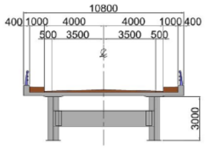
(d) Comparison for Bridge Type

The comparison for selected bridge type is shown in Table 2-2-12.

As a result, alternative 1 (PC-Box Girder Bridge with variable depth) has been adopted from the viewpoint of the following reasons.

- Aesthetic and symbolic views because of the wide center span and the variation of the girder height of the bridge
- Separate construction work of the superstructure without approach roads
- Cheapest maintenance cost
- Possibility for using Japanese technology

Table 2-2-12 Comparison Table for Bridge Type

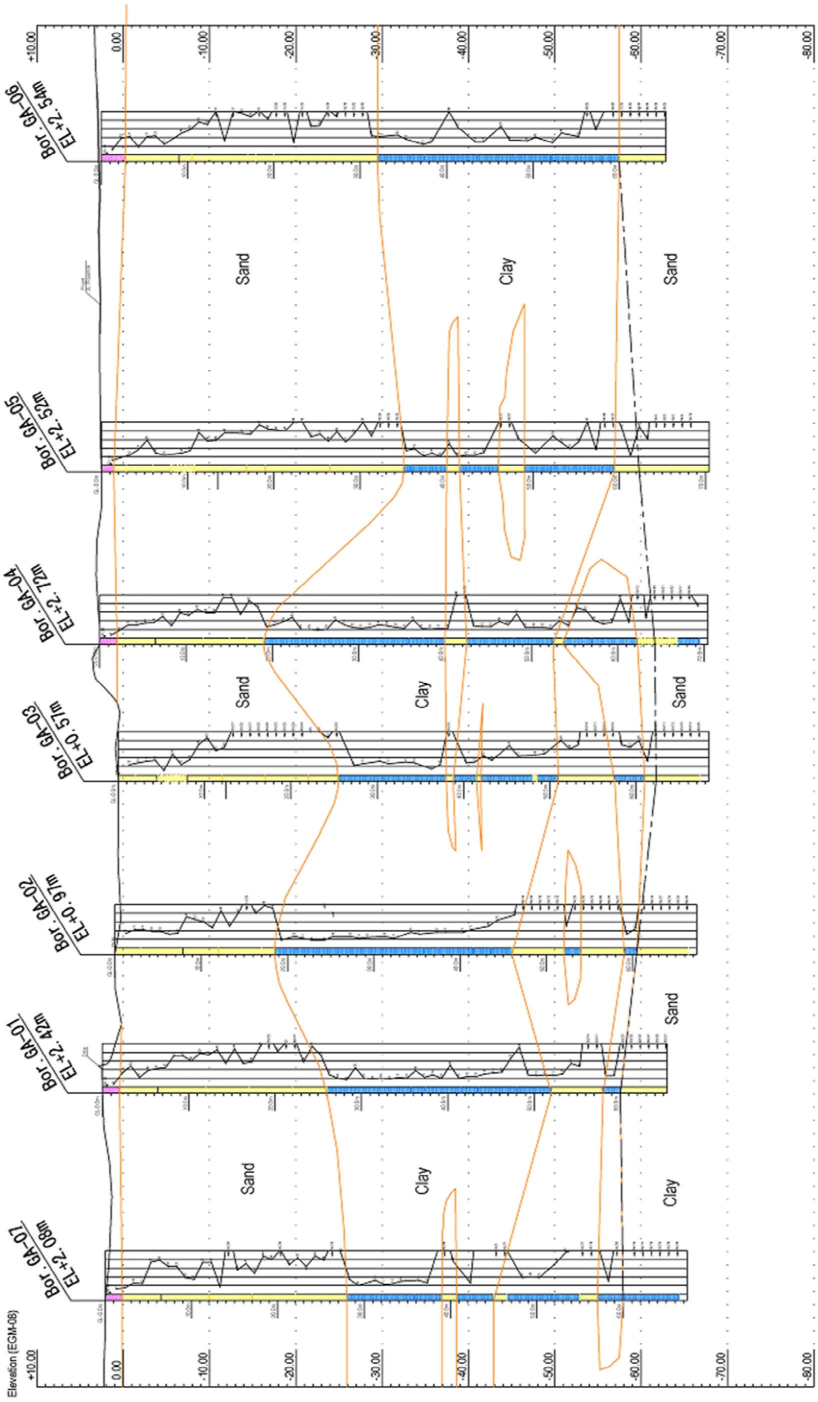
	Side View	Cross Section	Image	Cost	Recommendation
Alternative-1 PC-Box Girder (Balanced Cantilever Method)				<u>1) Total</u> - 321 bil. Rp - 2.5 bil. JPY <u>2) Superstructure</u> - 154 Rp <u>3) Substructure</u> - 62 Rp 4) Others - 65 Rp 5) Consultant(DD,CS) - 40Rp	The number of piers in the Palu River is the fewest among alternatives. From the viewpoints of river inhibition, Alt-1 is the most advantageous among alternatives. **Recommendation**
Alternative-2 PC-Box Girder (Launching Girder Method)				<u>1) Total</u> - 290 bil. Rp - 2.3 bil. JPY <u>2) Superstructure</u> - 110 Rp <u>3) Substructure</u> - 80 Rp 4) Others - 64 Rp 5) Consultant(DD,CS) - 36Rp	From the viewpoints of river inhibition, it is inferior to Alt-1 because 4 piers will be constructed in the river.
Alternative-3 Steel-I Girder (Launching Girder Method)				<u>1) Total</u> - 311 bil. Rp - 2.4 bil. JPY <u>2) Superstructure</u> - 130 Rp <u>3) Substructure</u> - 78 Rp 4) Others - 65 Rp 5) Consultant(DD,CS) - 39Rp	Ditto

Source: JICA Study Team

5) Study for Type of Substructure and Foundation

(a) Depth of Bearing Layer

The formation level of the footing is especially important to keep from the scouring in the river. The N value of each abutment and pier is as below. The bearing layer is approximately 60m from the ground surface as shown in Figure 2-2-11.



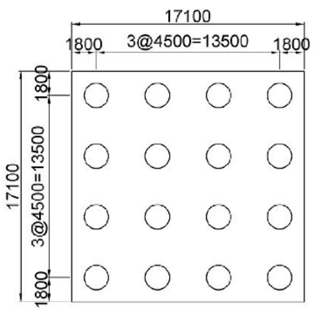
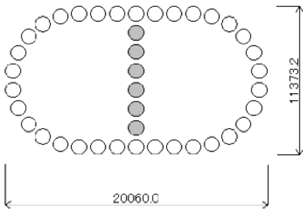
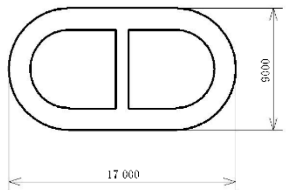
Source: JICA Study Team

Figure 2-2-11 Boring Log

(b) Selection of Foundation Type

The results of geological survey indicated that a type of deep foundation must be selected to reach the bearing layer. The possible types of deep foundation include pile foundation, caisson foundation, and steel pipe sheet pile well foundation, and all of these types are appropriate for technology transfer from Japan.

Table 2-2-13 Comparison Table for Foundation Type

Item / Alternatives	Alternative-1: Cast-in-place RC Pile (D=1.8m)		Alternative-2: Steel Pipe Sheet Pile (D=1.2m)		Alternative-3: Open Caisson	
Schematic View						
	4x4=16 Nos, L=58.5m		40 Nos, L=62.50m+7.00m=69.50m		L=62.50m	
Construction Cost	Ratio = 1.00	◎	Ratio = 1.76	△	Ratio = 1.91	×
Construction Period	44 days	◎	223 days	△	409 days	×
Evaluation	**Recommended**		—		—	

◎: Excellent, ○Good, ×Poor

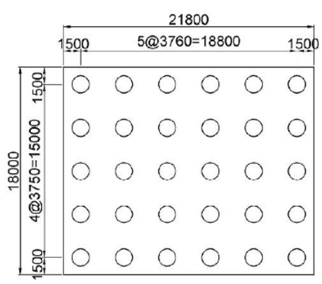
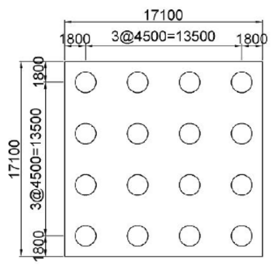
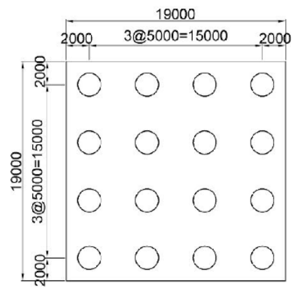
Source: JICA Study Team

The results of the comparisons, the pile foundation has been selected from the viewpoint of the economic efficiency and construction period. The bridge type has been selected Box Girder and center span has been planned 110m, thus, the load on the substructure is heavy.

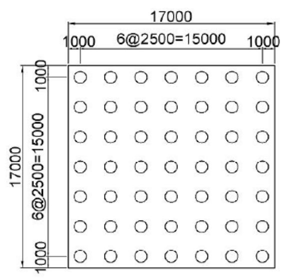
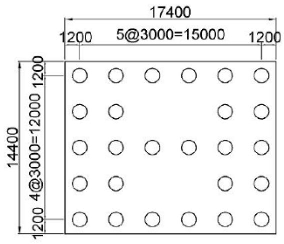
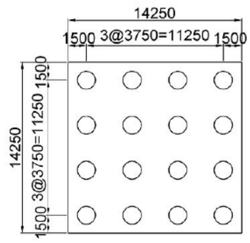
Regarding the comparison for the pile type and diameter, the comparison tables are shown in Table 2-2-13 and Table 2-2-14.

The result of the comparison, the Cast-in-Place Concrete Pile dia.1800 is adopted considering the conditions such as the economic efficiency and construction period.

Table 2-2-14 Comparison Table for Pile Type and Diameter

Item / Alternatives	Alternative 1: Cast-in-Place Concrete Pile (φ1500)		Alternative 2: Cast-in-Place Concrete Pile (φ1800)		Alternative 3: Cast-in-Place Concrete Pile (φ2000)	
Schematic View						
	6x5=30 Nos, L=58.50m		4x4=16 Nos, L=58.50m		4x4=16 Nos, L=58.50m	
Construction Cost	Ratio = 1.34	×	Ratio = 1.00	◎	Ratio = 1.23	△
Construction Period	69 days	△	44 days	◎	48 days	◎
Evaluation	—		**Recommended**		—	

◎ : Excellent, ○Good, △Moderate, ×Poor

Item / Alternatives	Alternative 4: Steel Pile (φ1000)		Alternative 5: Steel Pile (φ1200)		Alternative 6: Steel Pile (φ1500)	
Schematic View						
	7x7=49 Nos, L=58.00m		6x5=26 Nos, L=58.50m		4x4=16 Nos, L=58.50m	
Construction Cost	Ratio = 1.24	△	Ratio = 1.05	○	Ratio = 1.07	○
Construction Period	114 days	×	73 days	○	56 days	○
Evaluation	—		—		—	

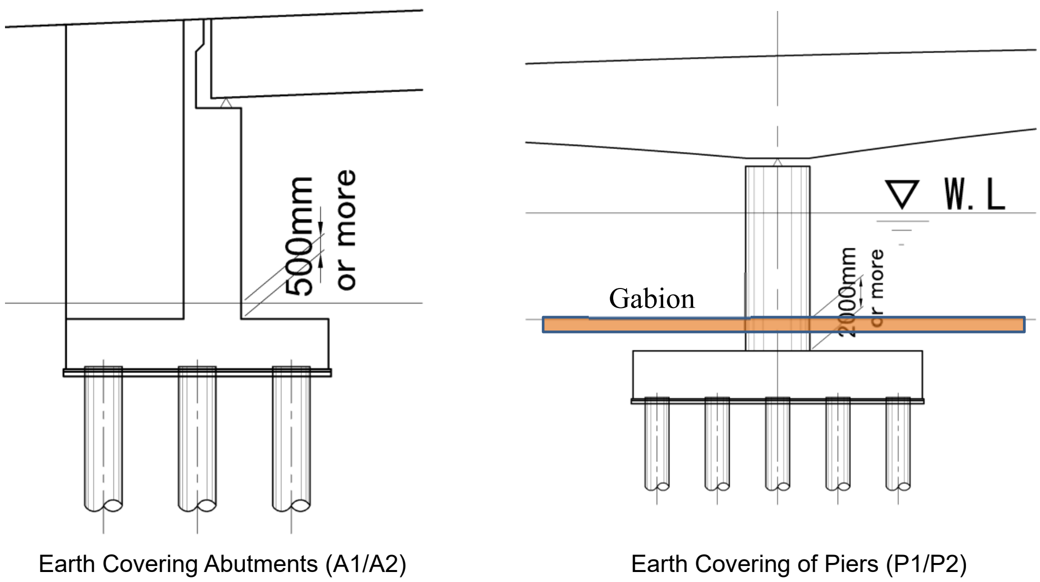
◎ : Excellent, ○Good, △Moderate, ×Poor

Source: JICA Study Team

(c) Installation Surface of Abutments and Piers

The footing installation surfaces for abutments and piers shall be determined based on the results of topographic survey, paying attention to future plans for the riverbed surface.

The height of installation surface of substructure is shown in Figure 2-2-12.



Source: JICA Study Team

Figure 2-2-12 Height for Installation Surface of Substructure

A1 Abutment

The abutment height will be approximately 14.0 m, and the use of inverted T-type abutments will be possible. The embedment in the top face of footings shall be 0.5 m below the planned ground surface.

P1Pier

The embedment in the top face of footings shall be 2.0 m below the planned riverbed surface, considering the effect of rivered souring, and protection with wire mats shall be used.

P2 Pier

The embedment in the top face of footings shall be 2.0 m below the planned riverbed surface, considering the effect of riverbed scouring, and protection with wire mats shall be used.

A2 Abutment

The abutment height will be approximately 13.0 m, and the use of invert T-type abutments will be possible. The embedment in the top face of footings shall be 0.5 m below the planned ground surface.

(d) Selection of Substructure Type

The substructure type should be selected by reference to Table 2-2-15 and Table 2-2-16. For the type of abutments, we select inverted T-type abutments because the abutment height is in the range from 10.0 to 15.0 m. For the type of piers, we select wall-type piers with little influence on water flow, because all piers will be located within the river.

Table 2-2-15 Selection of Abutment

Abutment Type	Height (m) 10 20 30	Remarks
T-Type	6 15 ( )	
Rigid Frame Type	15	
Box Type	15	
Earth Pressure Relieved Type h H	5 7	H h

Source: MLIT (Ministry of Land, Infrastructure, Transport and Tourism)

Table 2-2-16 Selection of Pier

Type	Height (m) 10 20 30	Remarks
Column Type Wall Type		(Including hollow Type)
Rigid Frame Type (1 layer)		
Rigid Frame Type (2 layers)		
2 Columns Type		

Source: MLIT (Ministry of Land, Infrastructure, Transport and Tourism)

(3) Bridge Design

Previous Palu 4 Bridge had been as symbol of the Palu city before the disaster. However, the symbol has been lost due to the disaster. Besides, the logistics have been affected because the previous traffic mast detour the Palu I Bridge and the Palu III Bridge. Under the circumstances, Indonesian Government has requested to introduce the aesthetic of bridge as symbol of reconstruction. The study for the aesthetic of the bridge has been carried out considering the characteristics of Japanese Grant Project as shown in Table 2-2-17.

Alternative 1: The special form is proposed in order to mitigate the oppressive feeling and bring harmony with the natural environment.

Alternative 2: The statue is proposed in order to improve the bridge space as a landmark.

Alternative 3: The balcony is proposed in order to ensure the space for scenery. Besides, the design will be improved by the balcony considering the aesthetic.

Alternative 4: The light up is proposed in order to beautify the bridge for night.

Table 2-2-17 Study for the esthetic of the bridge

Alternative 1: Retaining Wall for Approach Road	Alternative 3: Balcony
Image:   General Form: approx. 2.6 bii. Rp, Special Form: approx. 6.6 bil. Rp	Image:   4 places: approx. 1.6 bii. Rp
Alternative 2: Statue	**Alternative 4: Light Up**
Image:   4 places: approx. 2.1 bii. Rp	Image:   Bridge in Sumatra Bridge in Jakarta Construction Cost of Light Up: approx. 18.5 bil. Rp [Reference] Electricity Expense: approx. 2.8 mil. Rp / night (Japan)

Source: JICA Study Team

As a result of the discussion in Japan, the alternative 3 has been selected among four alternatives. Thus, JICA Study Team will discuss the adoption of alternative 3 with Indonesian Government.

2-2-3 Outline Design Drawings

Outline design drawings including plan, profile, typical cross section, and general view of bridge are provided as below.

Figure 2-2-13 Plan (1)

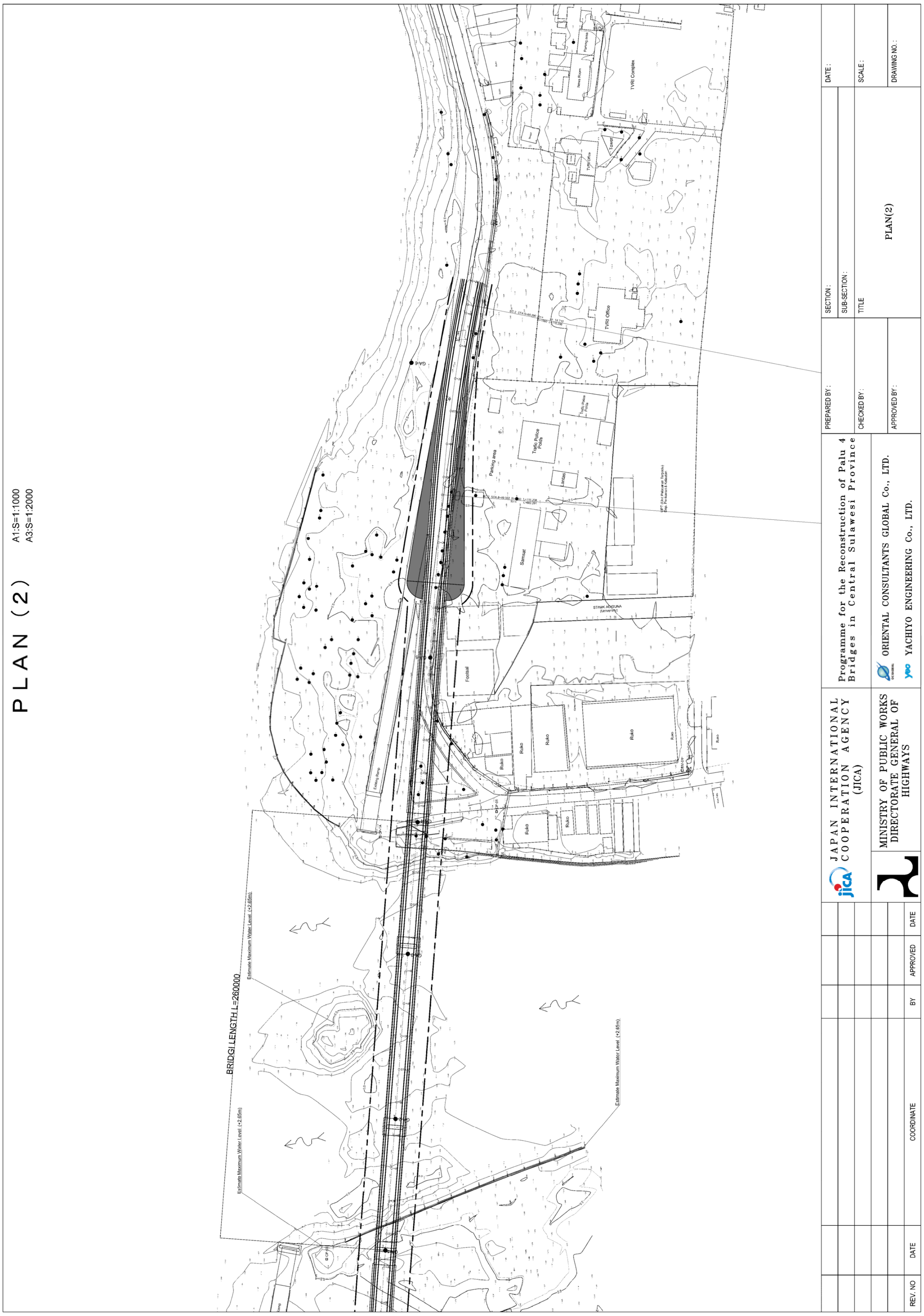


Figure 2-2-14 Plan (2)

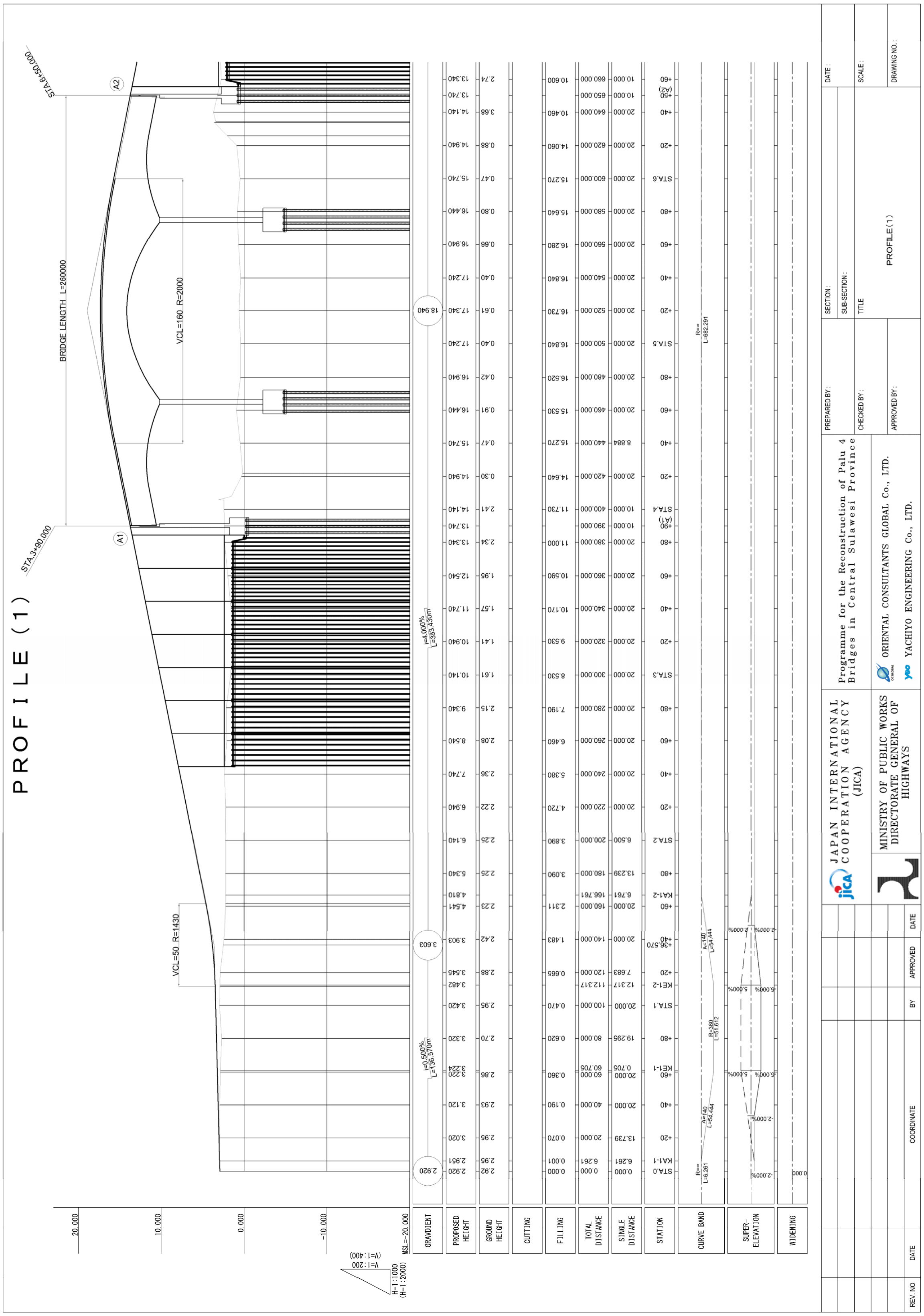


Figure 2-2-15 Profile (1)

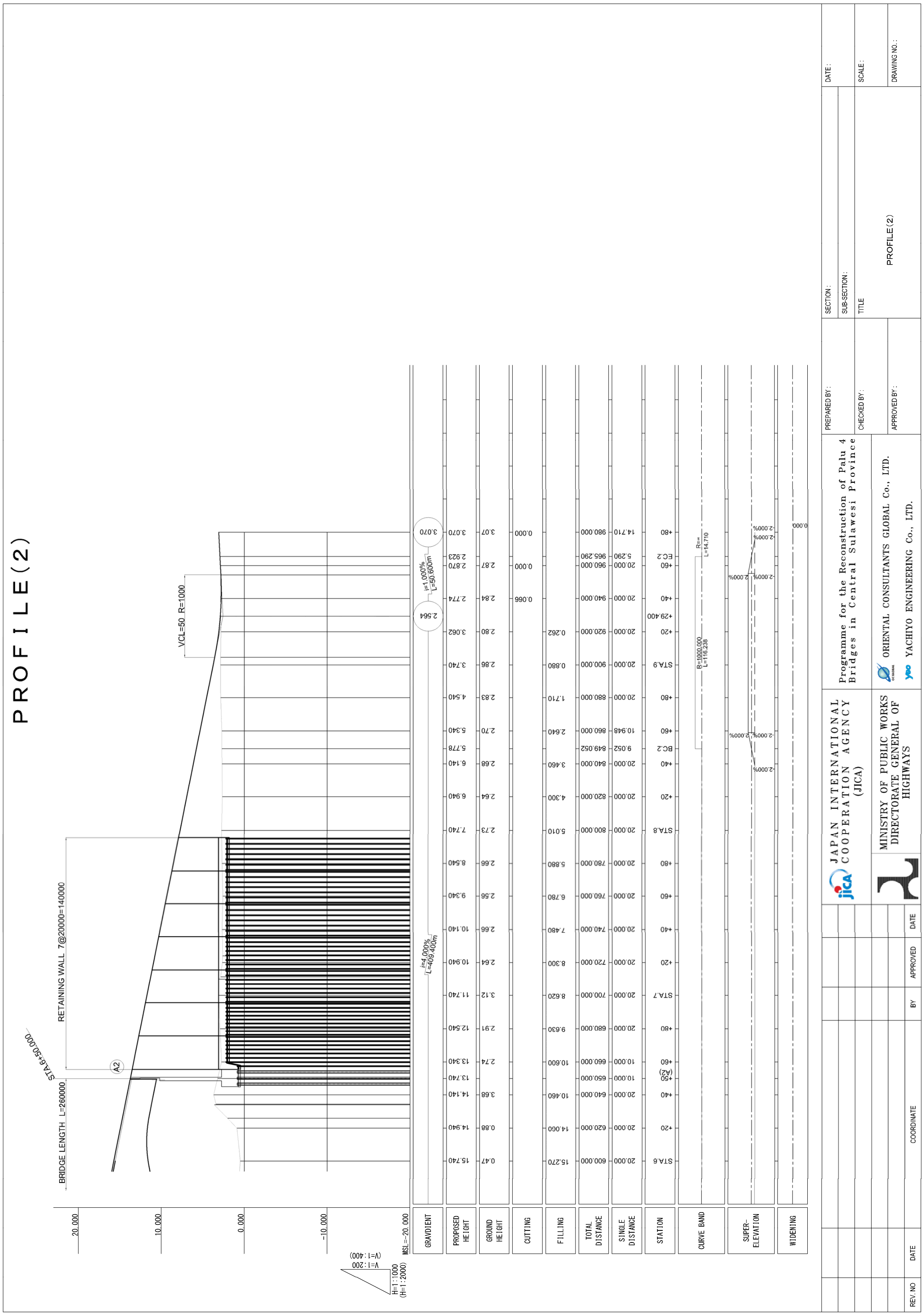


Figure 2-2-16 Profile (2)

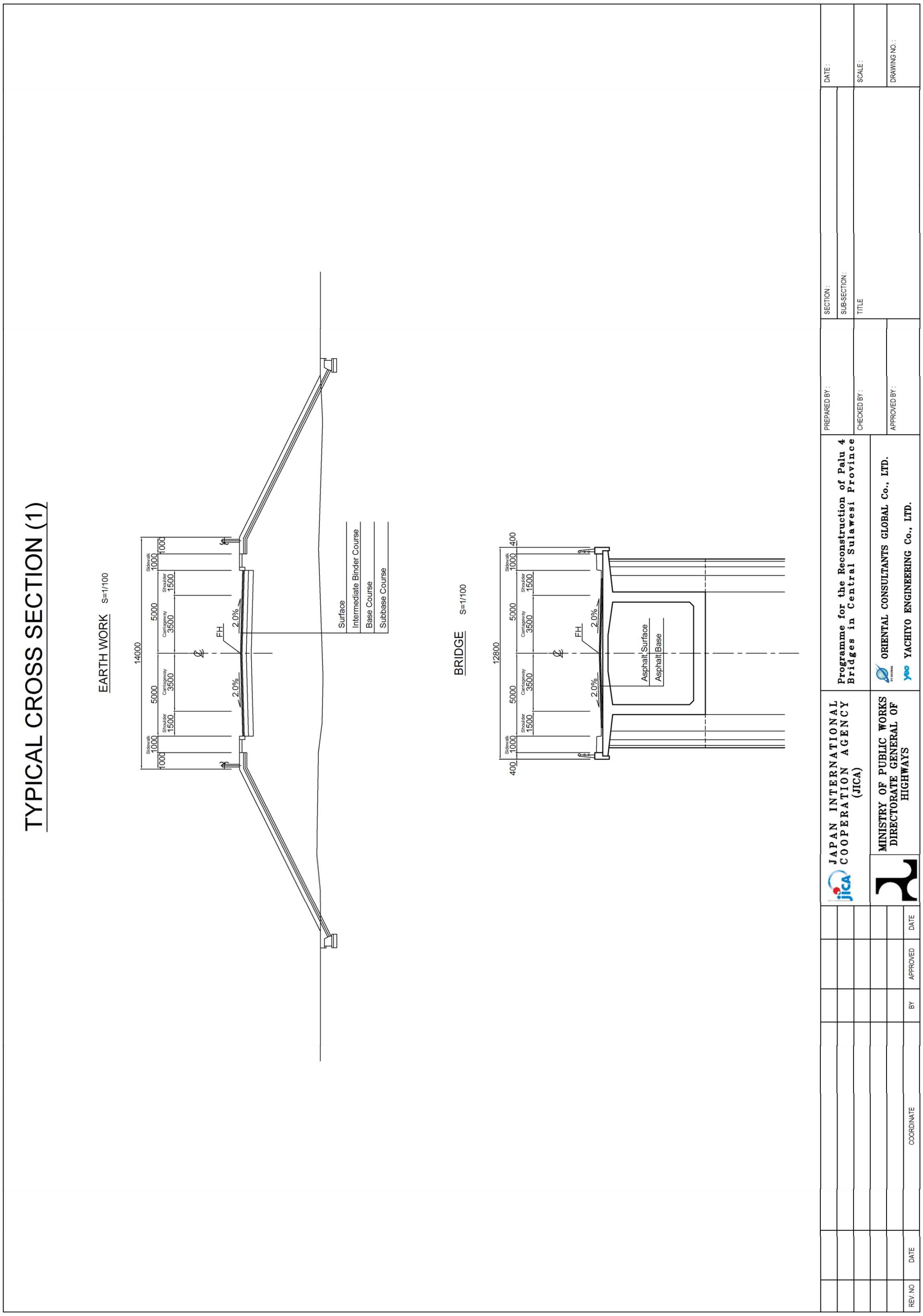


Figure 2-2-17 Typical Cross Section (1)

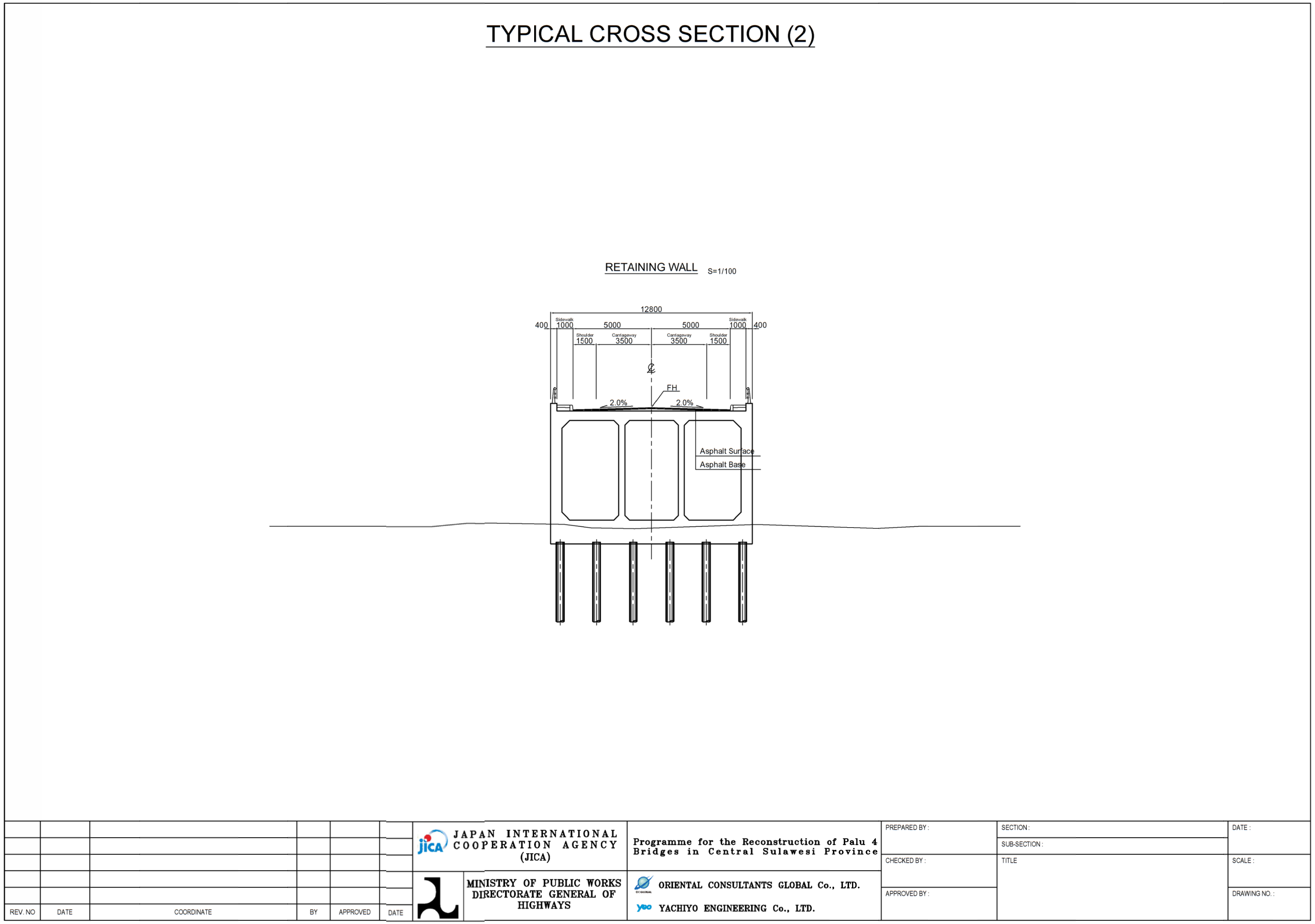


Figure 2-2-18 Typical Cross Section (2)

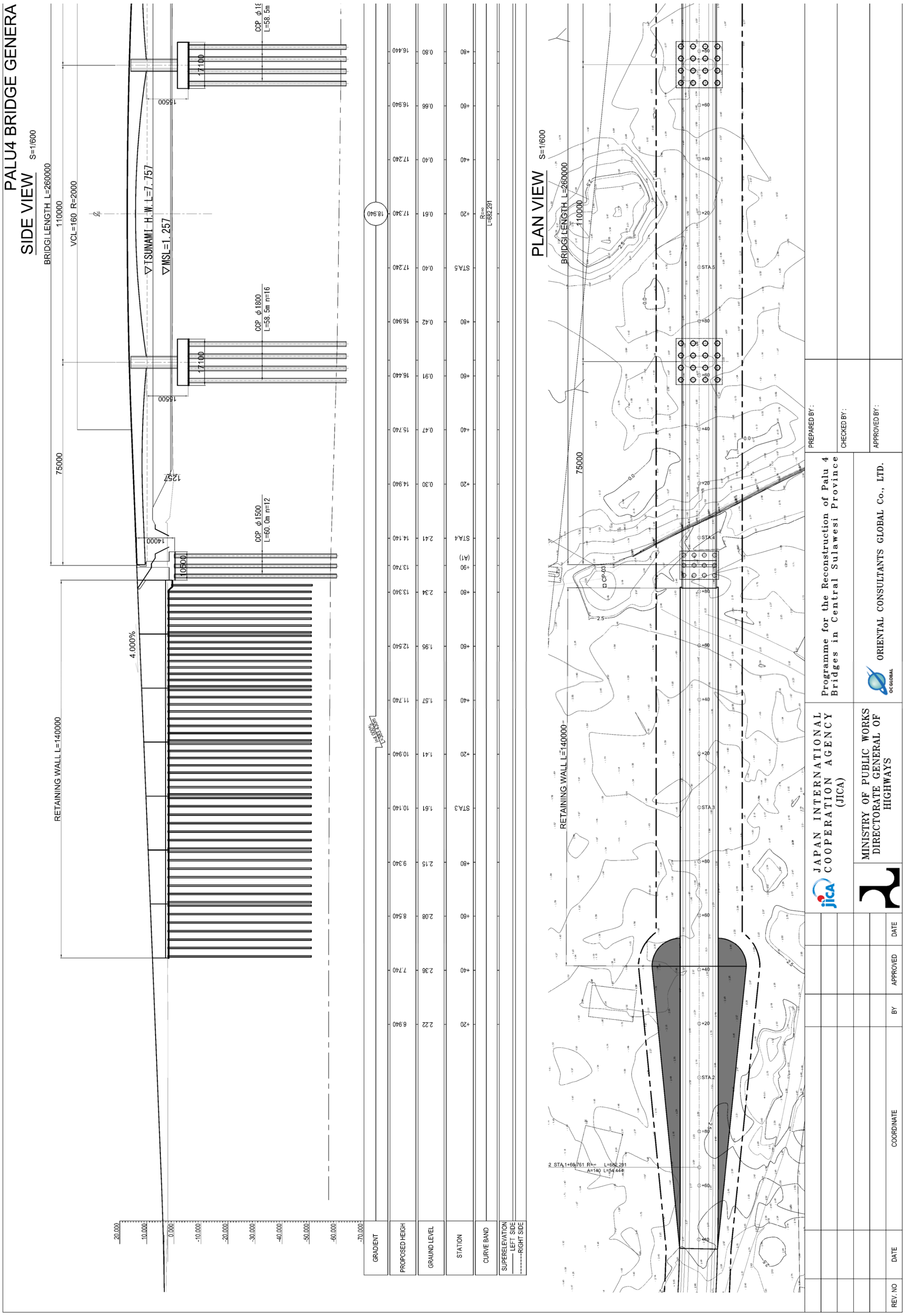


Figure 2-2-19 General View of Bridge (1)

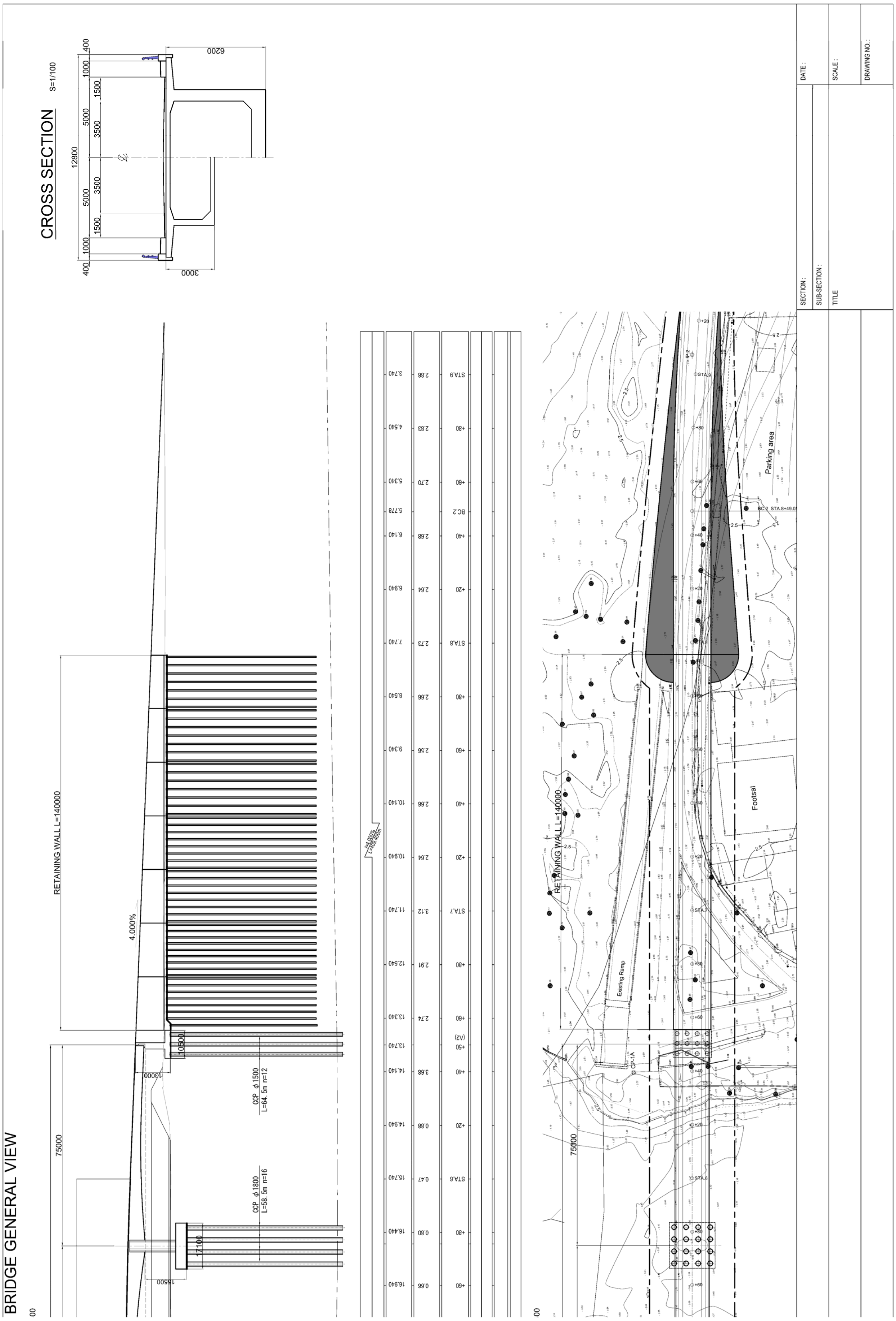


Figure 2-2-20 General View of Bridge (2)