The State Agency of Automobile Roads of Ukraine
(Ukravtodor)

ADDITIONAL STUDY ON THE PROJECT FOR CONSTRUCTION OF MYKOLAIV BRIDGE IN UKRAINE

Final Report

December 2019

Japan International Cooperation Agency (JICA)

Central Consultant Inc.
Nippon Koei Co., Ltd.

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Project Location Map

Outline of the Project

1.Country： Ukraine

2.Project Name： Additional Study on the Project for Construction of Mykolaiv Bridge in Ukraine

3.ExecutionAgency： The State Agency of Automobile Roads of Ukraine (Ukravtodor)

4.Survey Objective： Considering the time elapsed since the feasibility study for a Japanese ODA Loan project in 2011, the main objectives of this Study are as follows:

- ・Reassessment of the project cost (including land compensation and O&M costs), reanalysis of cost benefits, and reexamination of the implementation method (procurement and construction);
- ・Reconsideration of the applicability of the latest technologies; and
- ・Confirmation of the environmental and social considerations and other matters related to project implementation under the latest conditions.

5.Survey Contents：

(1)Background
(2)Implementation Flow and Work Process
(3)Project Approval Procedure in Ukraine
(4)Supplementing Surveys of Natural Conditions
(5)Review of Routes and Locations of Bridges
(6)Review of Road Plans
(7)Review of Bridge Plans
(8)Traffic Demand Forecast
(9)Study on the Slope Stability at the Bridge Construction Site
(10)Environmental and Social Considerations
(11)Review of the Construction and Procurement Plans
(12)The Safety Measures during the Construction
(13)Project Operation and Maintenance Plans
(14)Recalculation of Estimated Project Cost
(15)Review of Project Risk Analysis
(16)Consideration of Cost Reduction Effects
(17)Economic and Financial Analysis
(18)Survey of Obstructions and Partner Country Responsibilities

6.Conclusion and Recommendations：

(1)Conclusion

1) The Project is technically and economically feasible.

2) Bypass route and the location of Mykolaiv Bridge are changed due to the following reasons.
   - ・The newly selected route has the best economic benefits (B / C), and the location of the interchange at its terminus is the best from the viewpoint of the ring road concept.
   - ・River channel alignment where the bridge crosses is close to straight, therefore it is superior in river condition and inland waterway condition.
   - ・Although there is a possibility of landslide, the range is narrow and the location of the abutment is outside of the landslide area.

3) The cable-stayed bridge with center span length of 420m is the most appropriate for the main bridge based on comprehensive evaluation of construction cost, navigation safety, merits for Ukraine (less environmental impact, possibility of technical transfer), aesthetic feature, construction difficulty and maintenance cost. Steel pipe sheet pile foundation is adopted for foundation based on the same evaluation except aesthetic feature.
   The center span length is determined from the minimum navigation width of 280m and an additional width (distance from the edge of the navigation channel to the main tower) of 140m. The minimum navigation width is determined with Ukrainian standard based on the maximum size of the vessels; the additional width based on the relationship between the navigation channel width and center span length of cable-stayed bridges in Japan (half of the minimum navigation width).

4) Precast PC slab and steel small number girder bridge with maximum span length of 60m is the most appropriate for the approach bridge based on comprehensive evaluation of construction cost, merits for Ukraine (less environmental impact, possibility of technical transfer), construction difficulty and maintenance cost. PC well method is adopted based on the same evaluation.

5) The Road Width which includes Lane width, Shoulder, Median and Pedestrian walkway and so on is changed to 25.5m for road section and 26.3m for bridge section due to the revision of Ukrainian standards. Maximum longitudinal gradient at bridge section is 2.5%, considering prevention of slipping by cross wind and winter freeze.

6) Cloverleaf type is the most appropriate for the interchange at the origin, considering drivability, safety, impact on farmland, involuntary resettlement, workability, and economy. Half-clover type is the most appropriate for the interchange at the terminus, considering the ring road concept.

7) Since the new route is selected, it is required to conduct the feasibility study by Ukraine again. The necessity of reapproval from the Cabinet of Ministers of Ukraine is currently being confirmed.

8) The execution agency for this project will be the State Agency of Automobile Roads of Ukraine (Ukravtodor). In case of applying for Japanese ODA Loan, the procurement of consultants for detailed design, preparation of tender documents, construction supervision and detailed design including procurement of contractor for construction are expected to take approx. three and half years after signing L/A. The estimated schedule is based on general process and cooperation from Ukravtodor and related organization is required.

(2)Recommendations

1) It is necessary to consider the impact of the project on the natural, social, and living environments. Especially, efforts must be made to prevent river contamination, to protect fishery resources and to mitigate impacts along the access roads during the bridge construction work. The construction schedule for bridge section must reflect aspects of measures against impacts on the natural, social, and living environments as well as river freeze in winter. In addition, JICA's Guidelines for Environmental and Social Considerations have been updated since the previous feasibility study and the latest version was published in 2010.

2) The newly selected route passes through the residential area on the right bank of the Southern Bug River and would require demolition of dozens of houses and relocation of their inhabitants. Therefore, the selection of this route would result in environmental and social impacts not discussed in the feasibility study conducted by Ukraine in 2012. In light of this fact, new approval for the Project is required.

3) The project contains the cable-stayed bridge with the longest maximum center span in Ukraine and application of Japanese technology on superstructure, substructure, and foundation works to envision project cost reduction. Therefore it is recommended to prepare documents for project approval to fully utilize the result of this study. In addition, it is important to select consultants and contractors with advanced technical capabilities and experiences in basic design, detailed design, construction supervision and management.

4) It is recommended that Ukraine continues the landslide monitoring implemented in this Study.

Executive Summary
1 Background

1-1 Background

Mykolaiv City is the capital of Mykolaiv Oblast, which developed mainly around the shipbuilding industry. The city is located in the southern Ukraine and acts as a key hub of the Black Sea coast connecting Europe and Asia. The city is a transport hub uniting the P-06, H-14 and H-11, which run north and south and the M-14 that runs east and west within the major road network. It extends from the granary of inland areas to the ports of Odesa, Yuzhny and Ilichevsk. As the junction of the said road network, the city suffers from high traffic volumes. Around 35,000 vehicles, both large and of other types, are forced into the city center every day, causing serious traffic jams and declines in the quality of life for citizens.

There are two bridges constructed in 1964 over the rivers that traverse the city: the Vavarovsky Bridge over the Southern Bug River and the Ingul Bridge over the Ingul River. However, Since both of the bridges are deteriorating, loaded vehicles weighing more than 24 tons are not permitted to cross them. The loading weight restriction has increased the cost of road transport via Mykolaiv City, exacerbating congestion and hindering smooth logistics. To streamline and expand the distribution network for grain and other products, the city expects a new bridge and an approach road that bypass the downtown area of the city immediately. It is worth noting that the importance of this work has been recognized for quite some time; the first feasibility study dealing with Mykolaiv Bridge Construction Project (hereinafter referred to as “the Project”) was conducted in 1989 by Kyivsoiuzshliakhproekt, which was assigned the study by the Government of Soviet Union.

Based on the Ukraine-European Union Association Agreement signed in June 2014, the Government of Ukraine (hereinafter referred as “GOU”) established “the Strategic Plan for Development of Road Transport and Road Infrastructure of Ukraine up to 2020” in December 2015, which highlights the importance of improving and modernizing road networks that take safety and the environment into consideration as a means of boosting the economy in Ukraine. The Project ensures smooth vehicle transportation in line with the plan and improves the road transport network in southern Ukraine. The Project is recognized as one of the priority projects among the five bypass projects under “The State Target Economic Program for Development of Automobile Roads of the Public (General) Use of State Importance for the Period of 2018-2022” (hereinafter referred to as “New Program”) that was formulated in 2018.

In response to the application the GOU presented to the Government of Japan (hereinafter referred as “GOJ”) for a Japanese ODA Loan for the Project in July 2005, the Japan International Cooperation Agency (hereinafter referred to as “JICA”) implemented a preparatory survey from October 2010 to October 2011 (hereinafter referred to as “the 2011F/S”). Based on the 2011F/S, GOU created a Feasibility Study (TEO) in 2012 (hereinafter referred to as “the 2012F/S (TEO)”). Subsequently, the Project described in the 2012F/S(TEO) was approved at a cabinet meeting of 2013. The change in the political situation in 2014, however, prevented the implementation of the Project at that time.

Considering continuous request for the Project from GOU after political change in 2014, JICA conducted a “Data Collection Survey on the Logistics and Transport System in Southern Ukraine” from October 2016 to June 2017 (hereinafter referred to as “the 2017 Survey”) under the latest situation, which was reflected drastic drop in trade with Russia. As a result, the need for the Project was reconfirmed as a means for facilitating logistics in the southern region of Ukraine.

1-2 Study Objectives

Considering that approximately six years have elapsed since the 2011F/S, the main objectives of the Additional Study on the Project for the Construction of Mykolaiv Bridge in Ukraine (hereinafter referred to as “this Study”) are as follows:

(1) Reassessment of the project cost (including land compensation and O&M costs) and reexamination of the implementation method (procurement and construction);
(2) Reconsideration of the applicability of the latest technologies; and
(3) Confirmation of the environmental and social considerations and other matters related to project implementation under the latest conditions.

1-3 Economic Conditions

In 2014, with the situation in the eastern part of the country growing worse, the value of trade and mining and industrial production decreased steeply, severely impacting the economy and resulting in negative economic growth. In addition, the unemployment rate rose from roughly 7% in the first half of the previous year to 9% in the same period in 2014. Concurrently, increasing foreign debt, decreasing foreign reserves and other factors contributed to progressing macroeconomic imbalances, and starting in April 2014, Ukraine received substantial support from the IMF, World Bank and other international financial institutions as well as the Western nations. In March 2015, the IMF approved a new economic program that included grants to GOU of roughly 17.5 billion dollars over four years. The government used four installments of those funds to increase its foreign reserves, but in order to fulfill the conditions of the program, it is required to produce further results through reforms in the sectors of finance, taxation, national pension, energy, public service and more.

Although economic growth turned positive in 2016 after another negative year in 2015, the repercussions from the previous year's growth rate were significant; thus, Ukraine still requires support from donor countries and organizations. In December 2018, IMF announced that the IMF Executive Board approved a 14-month USD 3.9 billion Stand-By Arrangement for Ukraine.

1-4 Transport Sector Policy and Plans

The "State Target Economic Program for the development of public roads for 2013-2018" was formulated in 2013 as transport sector policy for Ukraine, but budget shortfalls ultimately prevented the achievement of the project's initial objectives. In light of this, GOU formulated the New Program and the Cabinet of Ministers approved the program (Cabinet of Ministers of Ukraine Resolution (hereinafter referred to as "Cabinet Resolution"), March 21, 2018, No. 382) in March 2018. Based on reflections about problems with the previous program, a budget of 298,349 million UAH for the five years from 2018 to 2022 has been secured for the New Program.

The stated purposes of New Program are to repair and improve existing state roads for their integration into the European transport system, and to increase the level of traffic safety, speed, comfort and cost effectiveness of transportation.

1-5 Present State of Road Network

There are three major road categories in Ukraine: State Roads (State Importance), Local Roads (Local Importance), and Streets. In particular, State Roads (State Importance) are defined in a Cabinet Resolution (August 9, 2017, No. 654). Until 2018, Ukravtodor was in charge of State and Local Roads. However, since 2018, based on the Law of Ukraine (November 17, 2016, No. 1762-VIII, No. 1763-VIII, No. 1764-VIII), the scope of Ukravtodor was changed and it is in charge of State Roads only, and the management for Local Roads was transferred to Regional State Administrations.

State and Local Roads are further separated into the categories shown in the table below. The total length of these roads in Mykolaiv Oblast, in which the target area of the Project locates, accounts for roughly 3% of all such roads in Ukraine.

Table 1-1. Road Categories

Category		Whole Nation		Mykolaiv Oblast	
		Distance (km)	Ratio (%)	Distance (km)	Ratio (%)
The State Roads (State Importance)		51,700	31	1,487	31
International	(M-network)	8,600	5	200	4
National	(H-network)	4,800	3	407	8
Regional	(P-network)	10,000	6	368	8
Territorial State Roads	(T-network)	28,300	17	512	11
The Local Roads (Local Importance)		117,900	69	3,314	69
Regional Local Roads	(O-network)	50,000	29	2,669	56
District Local Roads	(C-network)	67,900	40	645	13
Total		169,600	100	4,801	100

Source: Ukravtodor

2 Implementation Flow and Work Process

2-1 Study Implementation Flow

The following is implementation flow for this Study.

【01】Prepare and discuss an inception report
Explain and discuss the inception report

↓

【02】Confirm the project approval procedures

↓

【03】Review the route and bridge locations
【04】Review the road plan
【05】Review the bridge plan
【06】Supplement the survey on natural conditions
【07】Demand Forecast
【08】Obstacle survey
【09】Update of safety measures during construction
【10】Review of the basic, construction and procurement plans
【11】Update the implementation and operation plans
【12】Plan additional policy to take environmental and social considerations into account
【13】Recalculate rough project cost

↓ ← Comments/Opinions from Ukraine

【14】Prepare and discuss an interim report

↓

【15】Review the project risk analysis
【16】Consider the cost-reduction effect
【17】Update the economic and financial analysis and the operational and outcome indicators
【18】Compile the burdens borne by the recipient country

↓

【19】Prepare an interim report 2

↓

【20】Prepare explanatory material

↓

【21】Complementary geological survey

↓

【22】Prepare and discuss an interim report 3

↓ ← Comments/Opinions from Ukraine

【23】Prepare and discuss a draft final report

↓ ← Comments/Opinions from Ukraine

【24】Prepare and submit the final report

3 Project Approval Procedure in Ukraine

3-1 Project Classification and Required Documents

The procedure leading to project implementation (commencement of construction work) in Ukraine previously depended on five levels of complexity categorized from I to V (The Project was categorized as level V in the 2012F/S(TEO)).

In 2017, however, The Law of Ukraine (Bulletin of the Verkhovna Rada (BP), 2017, No. 9, p.68) was established for better compliance with EU standards. With regard to the law in 2017, the procedure has depended on the degree of damage (consequences) likely to occur during disasters, instead. Three consequence classes are defined under this system: CC1 (Insignificant consequence class), CC2 (Medium consequence class) and CC3 (Significant consequence class) .

As the bypass road is related to international highways of state importance, the level of the "Functioning termination of engineering and transport infrastructure facilities" is National. Therefore, this Project is categorized as CC3.

To implement CC3 projects (to commence construction work), three documents are required: Feasibility Study (TEO: Техніко-економічне обґрунтування), Project (P), and Working Documentation (WD). The project implementation organization must prepare each of these documents, and the contents of each must be guaranteed by the Ministry of Regional Development, Building and Housing of Ukraine (hereinafter referred to as "MRDBH"), the Ministry of Economic Development and Trade of Ukraine, and the Ministry of Finance of Ukraine , and also must be approved by the Cabinet. The required content (structure) of each document is set out in "SCN A.2.2-3-2014 Structure and Content of Project Documentation on Construction."

3-2 Procedure Related to Cabinet Approval

The Cabinet approval procedure for bridge and road construction projects in Ukraine is set out in a Cabinet Resolution (11 May 2011 No. 560) and the project content must be reviewed by an expert organization officially authorized by MRDBH prior to Cabinet approval.

Before the review in practice, another approval must also be obtained from relevant organizations (the Ukravtodor Technical Committee and the Ministry of Ecology and Natural Resources of Ukraine) ; to obtain this approval, documents must be prepared according to the relevant standards and rules of the respective organizations.

Based on the 2011F/S, Ukravtodor conducted a Feasibility Study (the 2012F/S TEO) in 2012; the Cabinet approved the 2012F/S (TEO) in 2013.

According to relevant personnel in Ukraine, there are no expiration dates on Cabinet approvals. In general, however, all documents must be newly prepared if the Feasibility Study (TEO) is to be prepared anew. The necessity of reapproval from the Cabinet of Ministers of Ukraine is currently being confirmed.

3-3 Project Implementation Procedure and Timing of Document Submission

Figure 3-1 shows the procedures for normal project implementation (implementation of construction work) and the timing of submission of required documents.

For Project (P), relevant documents including an outline design will be prepared. Then, a tender based on the outline design will be held to determine the construction contractor to use for the project. (Feasibility Study (TEO) and Project (P) processes are combined and referred to as so-called "Stage P") Later, in general, the contractor will prepare the Working Documentation (hereinafter referred to as "WD"). The period from the WD preparation to the project completion is referred to as "Stage R".

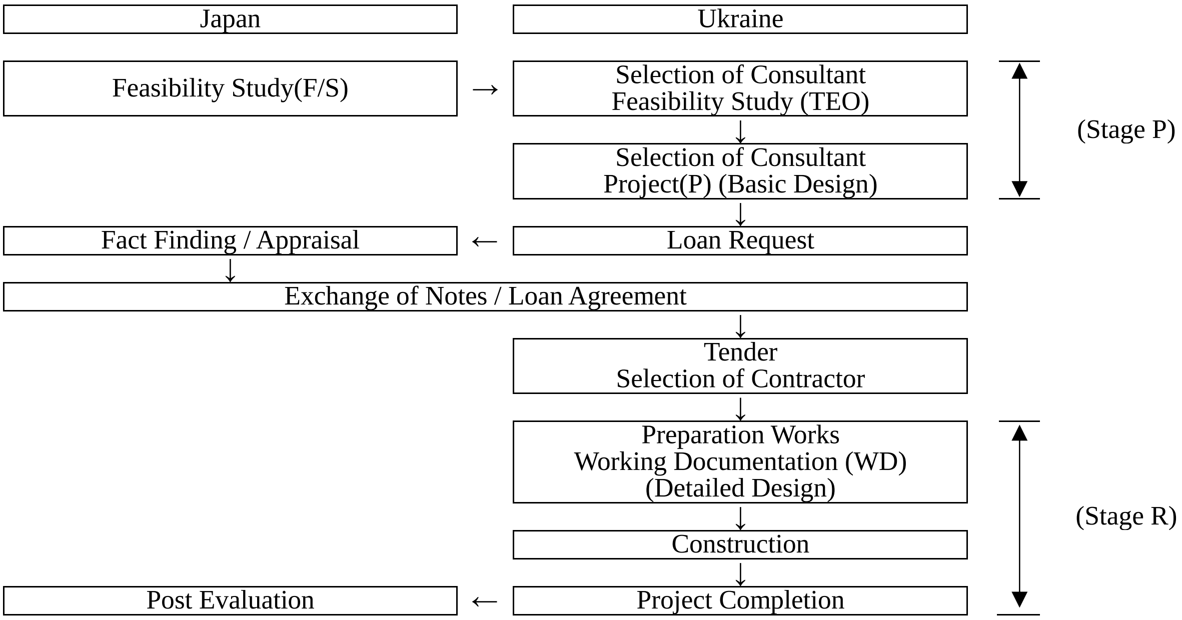


Figure 3-1. Period for Submission of Project Documentation

4 Supplementing Surveys of Natural Conditions

4-1 Meteorological Surveys and Hydrological Surveys

Table 4-1 shows the results of the meteorological surveys and hydrological surveys.

Table 4-1.Excerpt of Results of the Meteorological Surveys and Hydrological Surveys

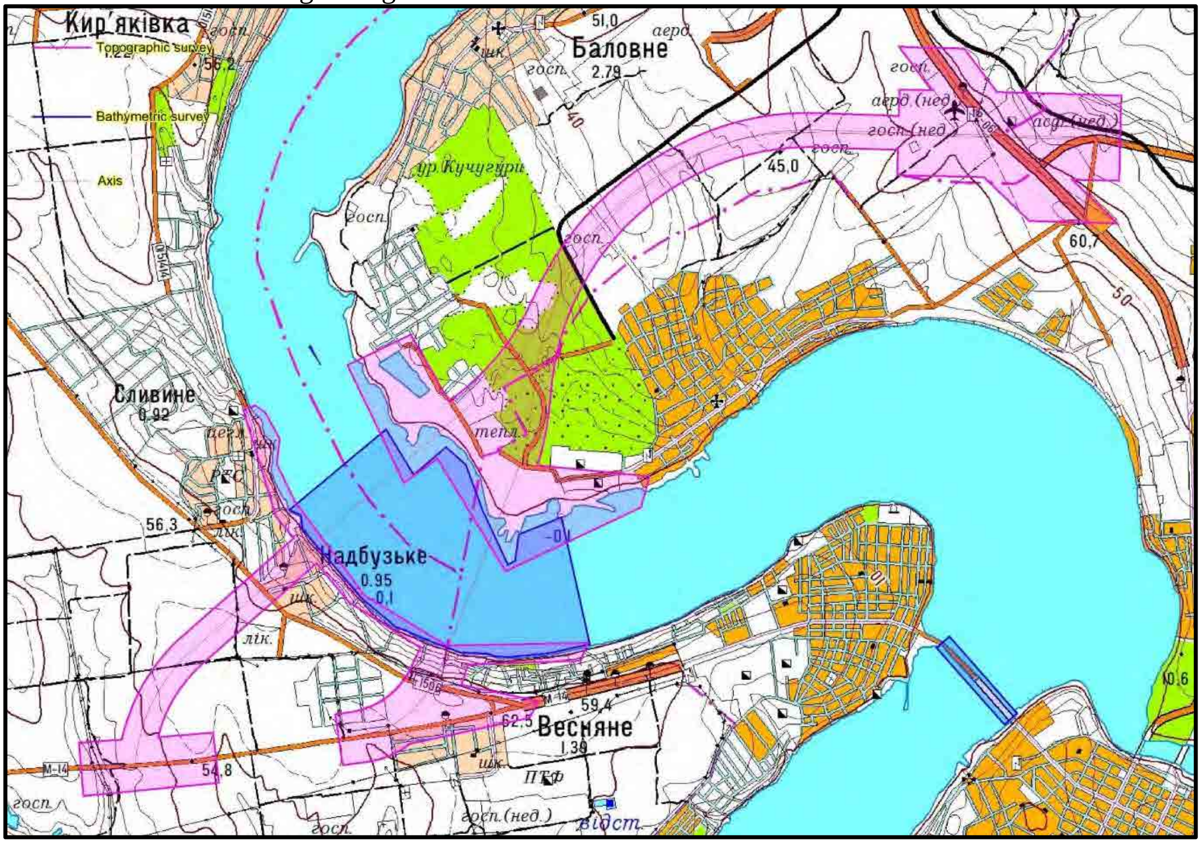
Observation Items	Observation Values	Observation Period	Observation Station
Temperature	Maximum of Average Monthly Maximum: 37.3°C (August) Minimum of Average Monthly Minimum: -18.5°C (January) Maximum: 39.7°C (August 2017) Minimum: -24.5°C (January 2010)	2008-2017	(1)
Humidity	Maximum Average Monthly: 86.5% (January) Minimum Average Monthly: 51.3% (August)	2008-2017	(1)
Rainfall	Average Annual: 413mm Maximum Annual: 651.9mm (2010) Maximum Average Monthly: 50.8mm (May) Minimum Average Monthly: 15.7mm (August) Maximum Daily: 42.7mm (September 2008)	2008-2017	(1)
Depth of snow	Average Annual Maximum: 12cm Maximum Annual: 34cm (1985)	1966-2017	(1)
Thickness of ice	Average Annual Maximum: 22cm Maximum Annual: 54cm (1984)	1956-2017	(2)
Wind	Wind speed is 7m/s or lower over 90% of the time Wind direction is North Maximum Instantaneous Wind Speed: 40m/s (WNW, 1969)	2011-2017	(1)
Water levels	Average Annual Maximum: BS +0.417 m Average Annual Minimum: BS -0.924 m Maximum: BS +0.900 m (1981) Minimum: BS -1.470 m (1984, 1991)	1917-2017	(2)
Discharge	Average Annual Maximum: 720 m3/s Average Annual Minimum: 19 m3/s Maximum: 5,320 m3/s (1932) Minimum: 2.6 m3/s (1954)	1914-2017	(3)

* Observation stations: (1) Aviation Meteorological Center Mykolaiv (Hydrometeorological Station)
(2) Mykolaiv (Sea Hydrometeorological Station)
(3) Oleksandrivka (Hydrological Station)

Annual maximum water levels at the Mykolaiv are influenced by the discharge from upstream, as well as water levels downstream and in the Black Sea because it is in tidal reaches.

4-2 Measurement Surveys

The topographic survey for this Study was carried out from July 2018 to the end of October 2018. The survey comprises a topographic survey and a sounding survey. Their areas are shown in Figure 4-1. The result of the topographic survey is three-dimensional data of the topographic map. These results are used for road and bridge design.



Source: JICA Survey Team

🟪 : Topographic Surveying Area　15km^2

🟦 : Sounding surveying　5.5km^2

Figure 4-1. Location Map of Topographic Survey

4-3 Geological Surveys

The geological survey was carried out for a road and a bridge design. The main contents of the geological survey are 1) borehole drilling at the proposed bridge (on land), 2) borehole drilling at the proposed bridge (in the river), 3) Cone Penetration Test at the proposed interchange, 4) material test at the approach road, and 5) material test at the borrow pit. Table 4-2 shows the detailed items and quantity.

Table 4-2. Scope of the Geological Survey

Item	Unit	Quantity
1)Borehole drilling at the proposed bridge (on land)		
･Boring site	number	4
･Boring	m	118.2
･Standard Penetration Test (SPT)	Set	156
2)Borehole drilling at the proposed bridge (in the river)		
･Boring site	number	6
･Boring	m	203.5
･Standard Penetration Test (SPT)	Set	131
3)Core Penetration Test (CPT) at the proposed interchange		
･Core Penetration Test (CPT)	number	4
4)Material test for the approach road		
･Sampling	number	23
･Laboratory test	Set	23
5)Material test at the borrow pit		
･Sampling	number	5
･CBR test	Set	9

Source: JICA Survey Team

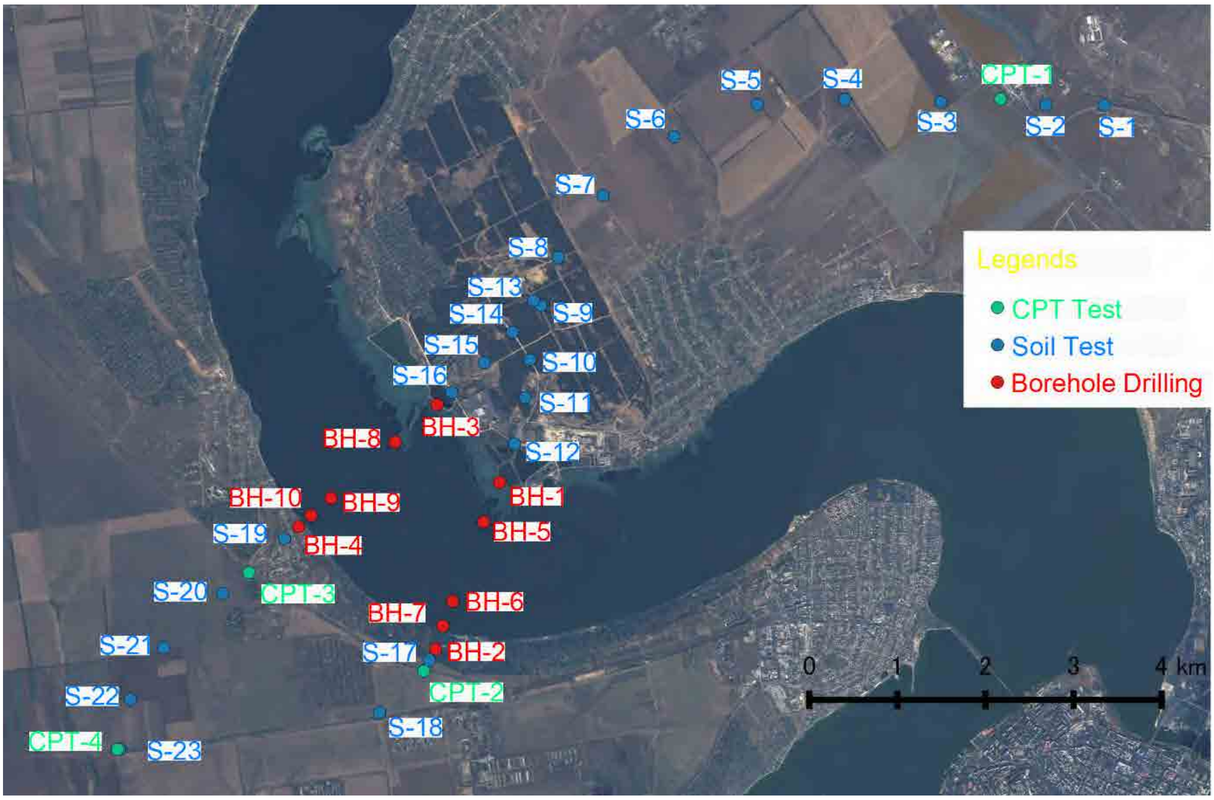


Figure 4-2.Location of Geological Survey

The ground layers studied in this survey are divided into 14 layers, and comprise arable soil, embankment, and river sedimentation from the modern period, and Quaternary (alluvium deposits and deluvial deposits) and Neogene layers.

The supporting layers for the bridge from the left bank and through the river are envisioned to be those including and deeper than Ground Layer No. 11, which is a Neogene clay layer, or Ground Layer No. 12, which comprises limestone. The supporting layers for the abutment on the right bank are envisioned to be those including and deeper than Ground Layer No. 8, a clay layer formed from the Quaternary period to the Neogene period.

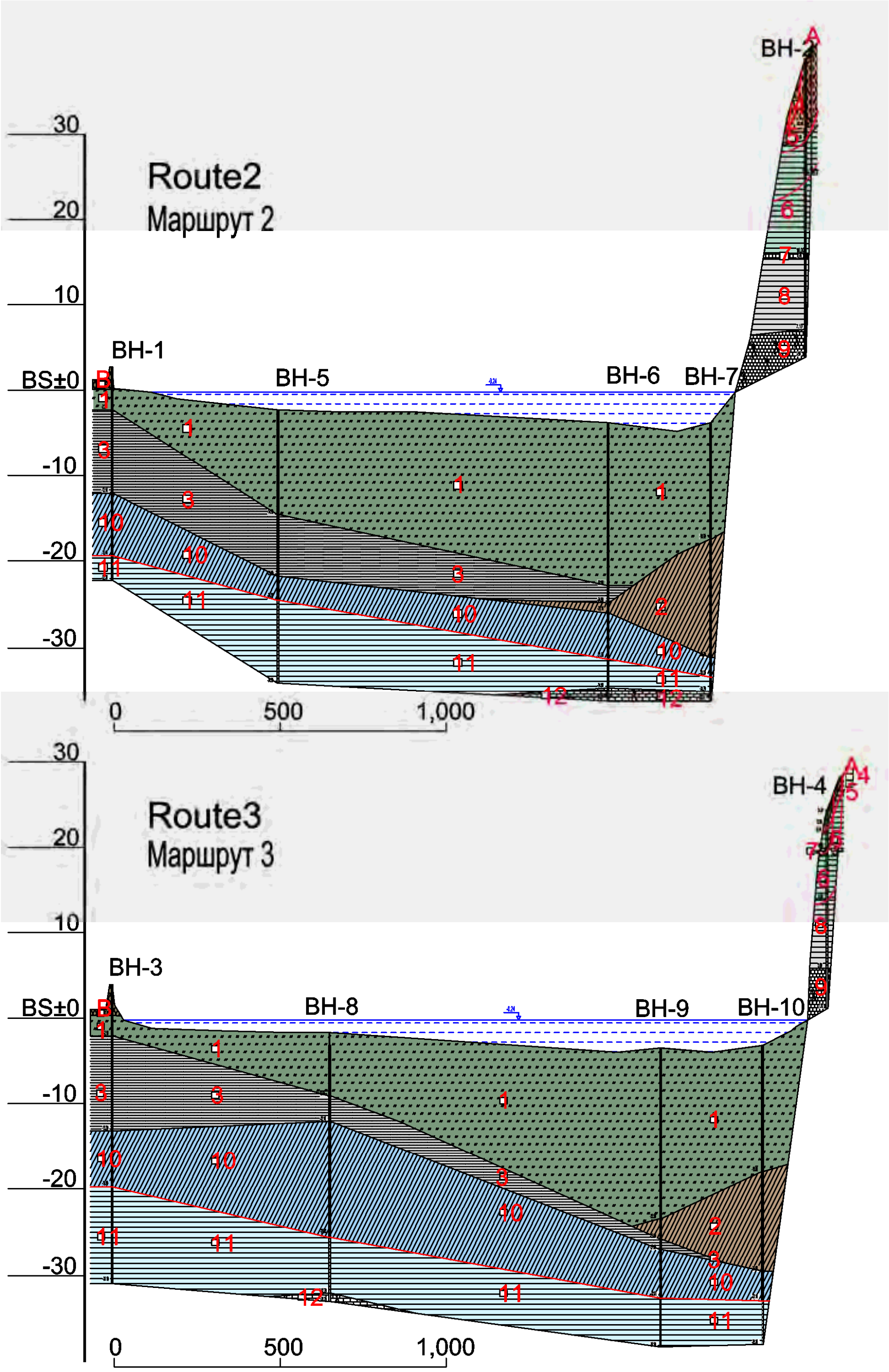


Figure 4-3.Assumed Geological Profile

5 Review of Routes and Locations of Bridges

5-1 Routes Overview

4 bypass routes and bridge locations shown in Figure 5-1 have been compared in the past six studies shown in Table 5-1. All of the studies selected Route 2.

Table 5-1. List of Past Feasibility Study

Year	Implementation Country	Counterpart	Survey Company
1989	Soviet-Union	No Information	Kievsoyuizdorproject
2000	Japan	Mykolaiv City	Japan Consulting Institute
2003	Japan	Mykolaiv City	Pacific Consultants International
2004	Ukraine	Mykolaiv Region	Kievsoyuizdorproject
2011	Japan	Ukravtodor	The Consortium of Oriental Consultants Co., Ltd. and Chodai Co., Ltd.
2012	Ukraine	Ukravtodor	Kievsoyuizdorproject

To account for present land use conditions, the alignments of the routes being compared in this report have been adjusted slightly from the alignments set in the past feasibility studies. The criteria in Tables 5-4 and 5-5 are compared to quantitatively evaluate the routes as extensively as possible.

Table 5-2 shows the characteristics of each route.

Note that Routes 1, 2 and 3 are referred to as “Northern Routes”, because they connect M14 on the north side of Mykolaiv City to M14 on the west side of the city. On the other hand, Route 4 is referred to as the “Southern Route”, because it connects M14 on the south side of the city to M14 on the west side.

Table 5-2. Route Characteristics

Route	Characteristics
Route 1	Route 1 is the longest among the Northern Routes, crossing the Southern Bug River at a point further north than the other routes. The river, however, is the narrowest at its crossing point, so the length of the bridge is the shortest, which may help reduce the total cost of construction. On the other hand, factors such as vessel navigation, flood control safety, airspace for Mykolaiv Airport, and resettlement shall be taken into account when considering this route. Significantly, the scale of involuntary resettlement is the biggest among the Northern Routes.
Route 2	Route 2 is the shortest among the Northern Routes, crossing the Southern Bug River at a point further south than the other routes. This route has two advantages: no involuntary resettlement is required and the route is reflected in the 2009 Mykolaiv City Planning. On the other hand, the bridge crosses over a bend in the river, which makes it necessary to consider vessel navigation and flood control safety. Attention must also be paid to slope stability at the right riverbank. The right riverbank is a colliding front, with the nearby slope marked as a landslide zone. The slope spread at the right riverbank is subject to relatively middle-scale landslides, with a series of minor landslides having actually occurred in the area in the past. A series of gullies has also developed around the said landslides, and there may be a groundwater concentration at a certain level underground.
Route 3	Route 3 is proposed as an alternative to Route 2, which crosses over a bend in the Southern Bug River. Route 3 crosses over a nearly straight section of the river in consideration of vessel navigation and flood control safety. The route is also intended to extend the ring roads already in service in the northeastern segment of the Mykolaiv to the northwestern segment. Thus, in terms of benefits, this is an advantageous route. The route, however, would require some degree of involuntary resettlement on a limited scale. The stability of the slope at the right riverbank must also be carefully watched: the slope near the right riverbank is subject to relatively small-scale landslides, with some minor landslides having actually occurred in the area recently.
Route 4	Route 4, the only Southern Route, is the longest of all. This route is also intended to extend the ring roads already in service at the northeastern segment of the Mykolaiv to the southwestern segment by avoiding the heavily populated residential areas along the Southern Bug River. Because the route crosses over a nearly straight section of the river, considerations can be made for vessel navigation and flood control safety, but the bridge would have to be longer because the river is wide at that point. In addition, because this route is located downstream of the Mykolaiv Port, the design vessels are larger than those for the Northern Routes, and the navigation clearance can also be increased.

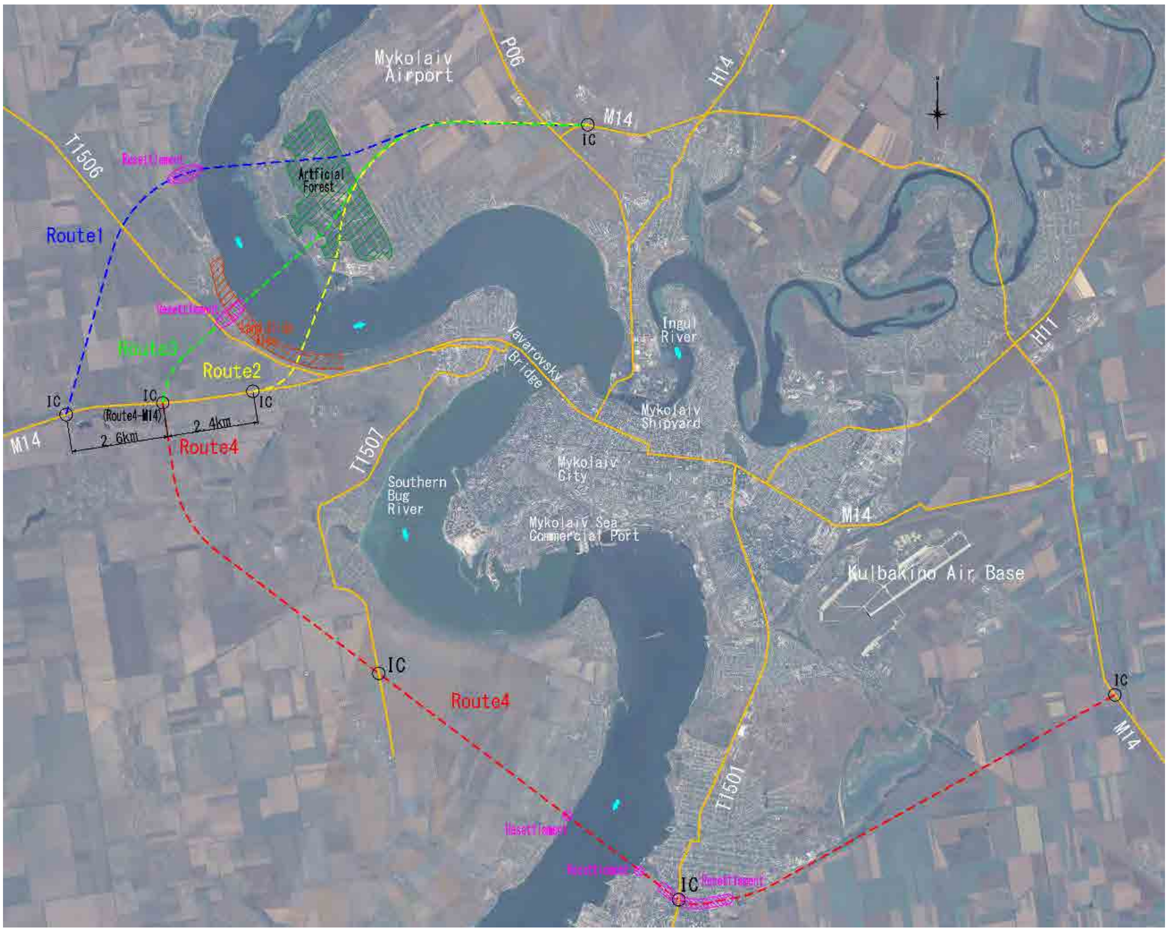


Figure 5-1. Location of Routes

Table 5-3. Rough Lengths of the Routes

Work Type	Route 1	Route 2	Route 3	Route 4
Route length	18,400m	13,200m	14,600m	32,500m
Bridge length of Bypass	1,500m	2,120m	2,180m	3,200m
(Main bridge length)	(840m)	(930m)	(840m)	(840m)
(Approach bridge length)	(660m)	(1,190m)	(1,340m)	(2,360m)
Road length	16,900m	11,080m	12,420m	29,300m

Table 5-4. List of Criteria (1/2)

Categories	Subcategories	Sub-subcategories	Reason for Selection	Evaluation Index
Project Effects	Improved VCR in the city	-	Elimination of congestion in the city is an important objective of the Project.	VCR (Volume/Capacity Ratio)
	Project Costs	-	It is important to fully understand the initial investment amount required for bypass road construction.	Initial Costs
	Project Benefits	-	It is important to quantitatively evaluate the effects of the Project.	TTC (Travel Time Cost) VOC (Vehicle Operation Cost)
Impact Factors	Social Environment	Reduction in the Scale of Involuntary Resettlement	Resettlement involves substantial changes to social and living environments. Thus, it is often impossible to obtain consent from all Project-Affected Persons (PAPs). A higher number of required relocations carries a major risk that the efficacy of a project will be undermined. In addition, the scale of involuntary resettlement was treated as a critical criterion in the 2011 F/S.	Number of Residential Buildings to Relocate

Table 5-5. List of Criteria (2/2)

Categories	Subcategories	Sub-subcategories	Reason for Selection	Evaluation Index
Impact Factors	Social Environment	Reduction in the Area of Agricultural Land Lost	The main industry around the project site is agriculture, so most of the land that the bypass road will pass through is farmland. The area of land lost indicates some degree of change in land use from the present situation, and is a factor in determining whether the main industry is preserved.	Area of Agricultural Land Lost
		Coherence with Mykolaiv City Planning	The Mykolaiv City planning was finalized on the premise that the bypass road to be constructed would pass through the city. If the route planned in the current city planning is not selected, the city planning will have to be revised.	Coherence with City Planning as formulated in 2009
		Coherence with the Ring Road Concept	Ukrainian cities with populations of over 300,000 tend to have semicircular or full ring roads established to allow vehicles to avoid traffic in downtown areas. Mykolaiv City has a population of 500,000, so a ring road is preferable.	Connectivity between Routes 1-3 and Route 4 (positional relationship of terminus interchange)
	Natural Environment	Reduction in Artificial Forest Clearing	There is a sizable artificial forest of roughly 570 ha near the left riverbank between the Southern Bug River and Mykolaiv Airport. The land surrounding the project site is flat, and there are no other forests; the artificial forest is important in preserving the natural environment.	Area of Artificial Forest Clearing
		Ecosystem Conservation	The conservation of ecosystems is important in a project of any type. Also, the bypass road may be adjacent to a no-fishing zone designated by the Fisheries Agency Mykolaiv Office.	Positional relationship with Especially Important Areas for Ecosystem Conservation Positional Relationship with No-Fishing Zones
	Living Environment	Impact of Vibrations/Noise on Residents in the Area	Most of the land around the project site is agricultural land; therefore, present noise and vibration levels are assumed to be low. Constructing a bypass road will significantly increase noise and vibration levels and substantially impact the living environment.	Number of Residential Buildings Impacted by Noise
		Impact of Vibrations/Noise on Public Facilities in the Area		Number of Public Facilities Impacted by Noise
Project Implementation Environment	Ground Conditions	Slope Failure	The slope near the right riverbank of Routes 2 and 3 has long been susceptible to landslides. For Route 2 in particular, it is highly likely that bridge piers and abutments will be built on the slope.	Scale and Safety of Landslides
	Inland Waterway Conditions	Probability of Vessel Collisions	Since the Southern Bug River is used as a navigation channel for inland waterways, there is a possibility that vessels will collide with the bridge piers, thus affecting the safety of both the vessels and bridge.	Relative Probability of Vessel Collisions
	River Conditions	Impact on Flood Control Safety	The construction of a bridge and the relationship between the location of the bridge and river channel conditions (narrow stretches, bends, water colliding fronts, confluences, places where flow conditions change, etc.) affect flood control safety.	Degree of River area Blockage by Bridge Pier Corresponding Number of River Channel Conditions that have a Negative Impact on Flood Control Safety
	Airspace Conditions	Restrictions Regarding Bridge Construction	Mykolaiv City has airports both to the north and south of town. Thus, in any construction on routes where the main bridge is built in the same direction used for runways, the bridge (particularly the main tower and diagonals), as well as any heavy machinery and materials used during construction, must be kept from entering the obstacle limitation surfaces of either airport.	Presence/Absence of Airspace Restrictions

5-2 Selecting Locations of Routes and Bridges

The Analytic Hierarchy Process (hereinafter referred to as “AHP”) is selected as the method for route selection for this Study.

Figure 5-2 shows process of route selection by AHP.

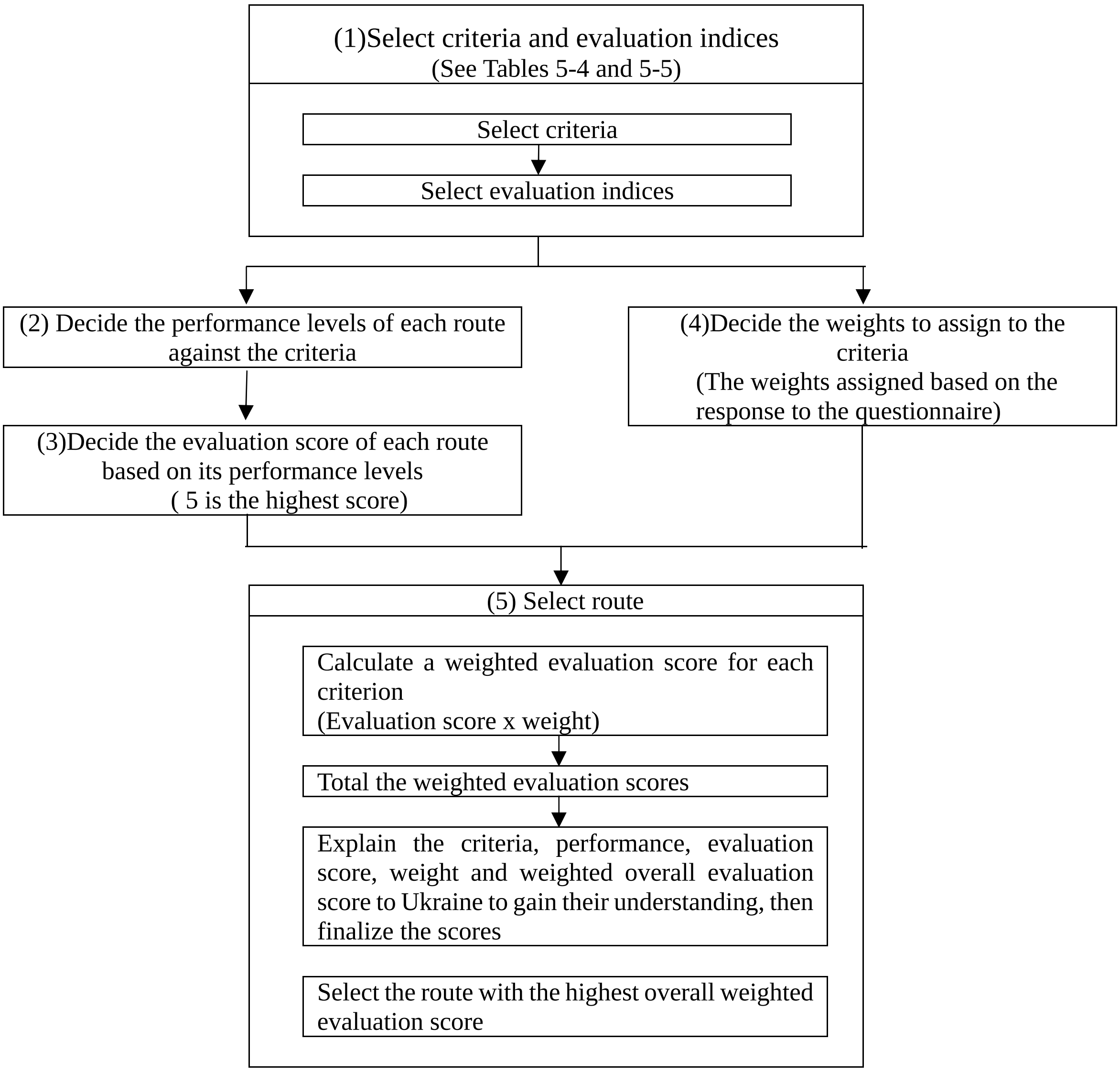


Figure 5-2. Route Selection Process

Table 5-6 shows a comparison of routes considering above.

As shown in the table, Route 3 has the highest weighted-evaluation-score.

The result of route selection including the criteria, performance, evaluation score, weight and weighted overall evaluation score were explained to Mykolaiv Oblast and Mykolaiv City on July 31st, Ukravtodor on September 17th and MoI on September 18th; and gained their understanding.

From the above, Route 3 is selected.

In addition, both Routes 2 and 3 have been studied for detailed comparison in the following chapters.

Table 5-6. Comparison of Routes

							Route 1			Route 2			Route 3			Route 4		
Categories	Weight W1	Subcategories	Sub-subcategories	Weight W2	A Total Weight (W1× W2/100)	Evaluation Index	Evaluation Results	B Evaluation Scores	A×B Weighted Overall Evaluation Scores	Evaluation Results	B Evaluation Scores	A×B Weighted Overall Evaluation Scores	Evaluation Results	B Evaluation Scores	A×B Weighted Overall Evaluation Scores	Evaluation Results	B Evaluation Scores	A×B Weighted Overall Evaluation Scores
Project Effects	58.4	Project Costs		42.9	25.054	Initial Cost	1.00	5.000	125.270	1.08 times of Route1	4.629	115.975	1.12 times of Route1	4.471	112.016	1.83 times of Route1	2.737	68.573
		Project Benefits		42.9	25.054	TTC(Travel Time Cost) VOC(Vehicle Operation Cost)	619Million USD	4.275	107.106	639Million USD	4.413	110.563	694Million USD	4.793	120.084	724Million USD	5.000	125.270
		Improved VCR in the City		14.2	8.293	VCR(Volume/Capacity Ratio) of Vavarovsky Bridge	Year2025：1.63 Year2040：2.43 Year2055：3.66	4.740	39.309	Year2025：1.54 Year2040：2.30 Year2055：3.47	5.000	41.465	Year2025：1.58 Year2040：2.35 Year2055：3.54	4.901	40.644	Year2025：1.71 Year2040：2.55 Year2055：3.83	4.530	37.567
		Subtotal		100	58.40	-	-	-	271.68	-	-	268.00	-	-	272.74	-	-	231.41
Impact Factors	28.1	Social Environment	Reduction in the Scale of Involuntary Resettlement	35.3	9.919	Number of Residential Buildings to Relocate	Roughly 50	3.000	29.757	None	5.000	49.595	3	4.500	44.636	Roughly 40	3.000	29.757
			Coherence with Mykolaiv City Planning	13.5	3.794	Coherence with City Planning	No coherence	3.000	11.382	Coherent	5.000	18.970	No coherence	3.000	11.382	No coherence	3.000	11.382
			Coherence with the Ring Road Concept	13.5	3.794	Connectivity between Routes 1-3 and Route 4 (Positional Relationship of Terminus Interchange)	2.6km	3.000	11.382	2.4km	4.000	15.176	Same Location	5.000	18.970	-	5.000	18.970
			Reduction in the Area of Agricultural Land Lost	2.9	0.815	Area of Agricultural Land Lost	119ha	2.000	1.630	77ha	4.000	3.260	93ha	3.000	2.445	198ha	1.000	0.815
		Natural Environment	Ecosystem Conservation	4.9	1.377	Positional Relationship with Especially Important Areas for Ecosystem Conservation and No-Fishing Areas	Possibly close to a no-fishing area	3.000	4.131	Possibly close to a no-fishing area	3.000	4.131	Possibly close to a no-fishing area	3.000	4.131	No restrictions	5.000	6.885
			Reduction in Artificial Forest Clearing	2.9	0.815	Area of Artificial Forest Clearing	11ha	4.000	3.260	15ha	3.000	2.445	10ha	4.000	3.260	None	5.000	4.075
		Living Environment	Impact of Vibrations/Noise on Residents in the Area	13.5	3.794	Number of Residential Buildings Impacted by Noise(Lr：Noise Level)	Lr≧65dB：Roughly110 Lr≧55dB：Roughly640 Lr≧45dB：Roughly3350	1.000	3.794	Lr≧65dB：Roughly10 Lr≧55dB：Roughly140 Lr≧45dB：Roughly1220	3.000	11.382	Lr≧65dB：Roughly30 Lr≧55dB：Roughly400 Lr≧45dB：Roughly1530	2.000	7.588	Lr≧65dB：Roughly90 Lr≧55dB：Roughly680 Lr≧45dB：Roughly3340	1.000	3.794
			Impact of Vibrations/Noise on Public Facilities in the Area	13.5	3.794	Number of Public Facilities Impacted by Noise(Lr：Noise Level)	Lr≧65dB：0 Lr≧55dB：0 Lr≧45dB：1	4.000	15.176	Lr≧65dB：0 Lr≧55dB：0 Lr≧45dB：1	4.000	15.176	Lr≧65dB：0 Lr≧55dB：2 Lr≧45dB：3	3.500	13.279	Lr≧65dB：2 Lr≧55dB：4 Lr≧45dB：Roughly20	2.500	9.485
		Subtotal		100	28.10	-	-	-	80.51	-	-	120.14	-	-	105.69	-	-	85.16
Project Implementation Environment	13.5	Ground Conditions		25.0	3.375	Scale and Safety of Landslides	No possibility of landslid	5.000	16.875	Possibility of landslide and the area is wide	3.000	10.125	Possibility of landslide and the area is narrow	4.000	13.500	No possibility of landslid	5.000	16.875
		Inland Waterway Conditions		25.0	3.375	Relative Probability of Vessel Collisions	Collision probability 2.1 times greater than Straight Region	2.400	8.100	Collision probability 2.5 times greater than Straight Region	2.000	6.750	Collision probability 1.8 times greater than Straight Region	2.800	9.450	Collision probability 1.2 times greater than Straight Region	4.200	14.175
		River Conditions		25.0	3.375	Presence/Absence of River Channel Conditions that have a Negative Impact on Flood Control Safety Degree of Blockage of Flow Area by Bridge Pier	Bend, Water colliding front Degree of blockage of flow area is big	2.000	6.750	Bend, Water colliding front Degree of blockage of flow area is big	2.000	6.750	Straight section Degree of blockage of flow area is small	4.500	15.188	Straight section Degree of blockage of flow area is small	4.500	15.188
		Airspace Conditions		25.0	3.375	Presence/Absence of Airspace Restrictions	Close to Mykolaiv Airport	3.000	10.125	No restrictions	5.000	16.875	No restrictions	5.000	16.875	No restrictions	5.000	16.875
		Subtotal		100	13.50	-	-	-	41.85	-	-	40.50	-	-	55.01	-	-	63.11
Total Weighted Overall Evaluation Score								394.04			428.64			433.44			379.68	

6 Road Plan

6-1 Overview of Previous Feasibility Studies

A total of six F/S were conducted for the Project between 1989 and 2012. The 2012 F/S (TEO) conducted by Ukrain in 2012 was approved by the Cabinet on July 11, 2013. Table 6-1 and Table 6-2 are overviews of the previous F/S.

Table 6-1. Overview of Previous F/S (1)

	1989 F/S	**2000 F/S**	**2003 F/S**	**2004 F/S**
Implementation Country	Soviet-Union	Japan	Japan	Ukraine
Counterpart	No information	Mikolaiv City	Mikolaiv City	Mykolaiv Region
Survey Company	Kievsoyuizdorproject	Japan Consulting Institute	Pacific Consultants International	Kievsoyuizdorproject
Reason for Survey		This project was identified as a key national project by the Ukrainian government.	Design Condition for Bridge was changed (aviation and navigation clearance)	The two F/S's executed by Japan reported that the Government of Japan had expressed interest in providing a loan for this project.
Outline of Survey Result	[Road Alignment Selection] 4 routes (different crossing points on Southern Bug river) were proposed and compared. The Bridge position selected by this F/S is the same as that for the current design stage.	[Comparison of Bridge Types] Comparison of Bridge types involved 3 types. A cable-stayed bridge was recommended.	[Comparison of Bridge Types] Comparison of Bridge types involved 3 Types. A suspension bridge was recommended.	[Road Alignment Selection] Comparison of Road alignment on the left-bank was implemented. It recommended "Route 1", which is located far from the city boundary line, as the best route. [Comparison of Bridge Types] Comparison of Bridge types involved 3 Types. A steel box-girder bridge was recommended.
Design Standard	SNiP[1]	SNiP	SNiP	DBN[2](and SNiP)

Source: 2011 F/S

Table 6-2. Overview of Previous F/S (2)

	2011 F/S	2012 F/S (TEO)
Implementation Country	Japan	Ukraine
Counterpart	Ukravtodor	Ukravtodor
Survey Company	Oriental Consultants Co., Ltd. Chodai Co., Ltd.	Kyivsoiuzshliakhproekt
Reason for Survey	To review and update the Feasibility Study conducted in 2003 (hereinafter referred to as "2003 F/S")	Conducted to obtain Cabinet approval in light of the 2011 F/S
Outline of Survey Results	[Road Alignment Selection] The same as the route proposed by Ukrain in the 2004 F/S [Comparison of Bridge Types] Three bridge types over the Southern Bug River were compared, and a suspension bridge was recommended.	[Road Alignment Selection] The same as the route selected in the 2004 F/S and the 2011 F/S [Comparison of Bridge Types] As in the 2011 F/S, a suspension bridge was recommended as the type of bridge for crossing the Southern Bug River.
Design Standard	DBN V.2.3-4 2007	DBN V.2.3-4 2007

Source: JICA Survey Team

6-2 Review of Road Structure

6-2-1 Design Standards and Road Categories

1) Design Standards

The Ukrainian standard known as DBN[1] was established based on SNiP[2], the Russian design standard. At the time of the 2011 F/S and 2012 F/S (TEO), the 2007 revised standard (DBN V.2.3-4 2007) was used to create plans. A new revised standard came out in 2015; therefore, this Study uses DBN V.2.3-4 2015 to review.

2) Road Categories

There are six road categories under DBN V.2.3-4 2015. The road category was I-a until the 2011 F/S was conducted; in the 2011 F/S, it was changed to I-b, and the road category remained the same in the 2012 F/S (TEO). This road category is still applicable in this Study; thus, the road is treated as a I-b road.

3) Design Speed

Given the road category at the time of the 2011 F/S, a design speed of 140 km/h was selected. The design speed was revised to match the road category that changed due to the update of DBN V.2.3-4; therefore, for this Study, a design speed of 110 km/h is used to conform to the updated standard.

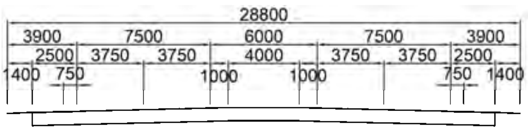
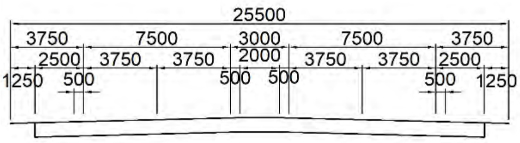
6-2-2 Transverse Structures

1) Cross-Sections

(1) Road Section

The result of road width review is shown in Table6-3.

Table 6-3. Results of Road Width Review

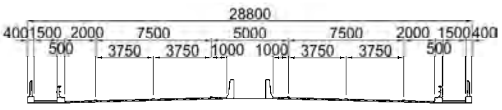
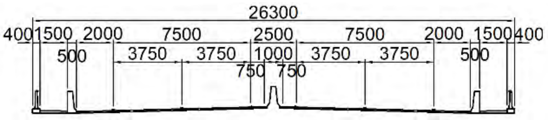
Standard width		

Source: JICA Survey Team

(2) Mykolaiv Bridge Section

The result of Mykolaiv Bridge width review is shown in Table6-4.

Table 6-4. Results of Bridge Width Review

Standard width		

Source: JICA Survey Team

2) Vertical Clearance Limit

Clearance of at least 5.5 m is secured to conform to DBN V.2.3-4 2015.

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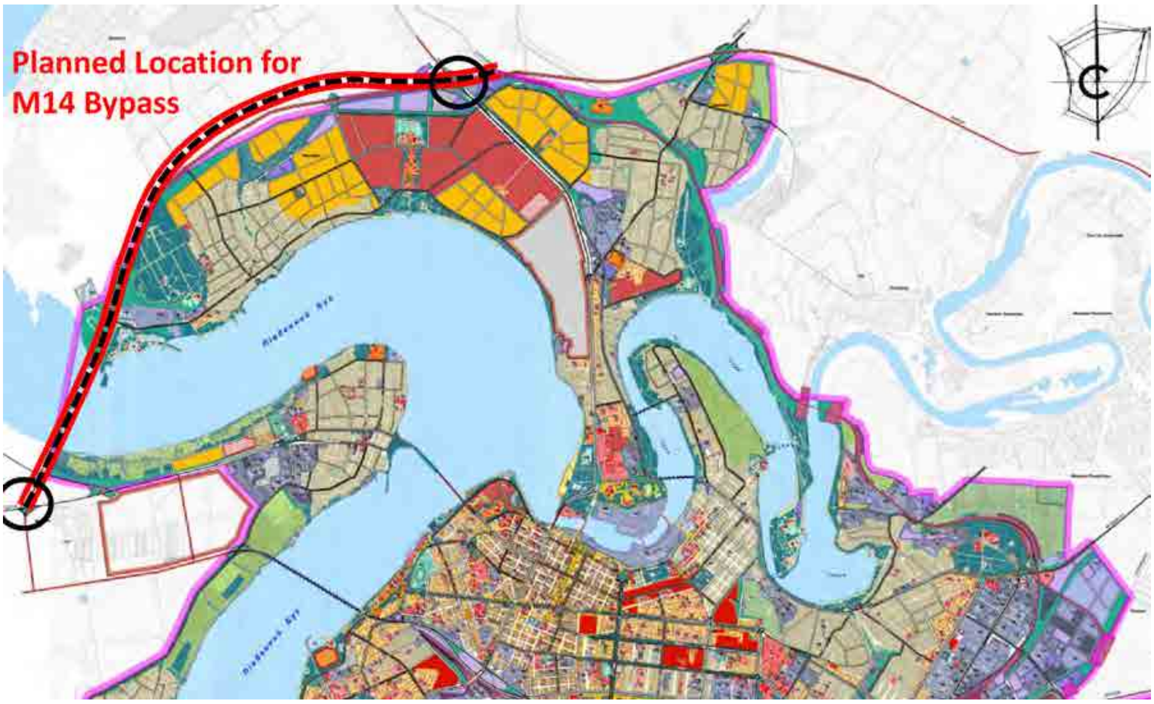
[1] ДБН:ДЕРЖ АВНІ БУДІВЕЛЬНІ НОРМИ УКРАЇНИ

[2] СНиП: Строительные Нормы и Правила

6-3 Review of Main Route Plan

6-3-1 Plan view

The M14 Bypass is a planned 4-lane road with a total approximate length of 13.2 km. As seen in Figure 6-1, the planned route will pass near the northern limits of Mykolaiv city, with its origin at the east end and terminus at the west end both connecting to existing arterial highways. The Survey plan view basically emulates Route 2, which was selected as the best option in the 2011 F/S. This route requires no resettlement as there is no housing in its path and it conforms with the 2015 revision of the Ukrainian Road Design Standards (DBN V.2.3-4 2015).



Source: Excerpt from Mykolaiv City Plans

Figure 6-1. Planned Location for M14 Bypass

6-3-2 Longitudinal plan

1) Controls for longitudinal plan

The roads, railways, and navigation channel crossing the planned road are listed in Table 6-5. Note that these have been treated as controls for the longitudinal plan.

Table 6-5. Controls on the Longitudinal Plan (Cross Traffic)

Survey point		Crossing traffic	Notes
Route 2	Route 3		
No. 12+0	- ditto -	Highway P06	Crosses overhead of main route
No. 32+0	- ditto -	City road	Crossed overhead by main route
No. 49+93	- ditto -	City road	Crossed overhead by main route
No. 60+88	- ditto -	City road	Crossed overhead by main route
No. 90+83	No. 88+87	City road	Crossed overhead by main route
No. 111+60	No. 108+67	Navigation channel (Southern Bug River)	Crossed overhead by main route
No. 118+60	No. 119+65	Highway T1506	Crosses overhead of main route
n/a	No. 132+18	City road	Crossed overhead by main route
No. 122+18	n/a	Road (interchange ramps)	Crosses overhead of main route
n/a	No. 144+0	Highway M14	Crossed overhead by main route

Source: JICA Survey Team

6-3-3 Routes in the Basic Plan

In Chapter 5: Review of Road and Bridge Locations, four route alternatives were compared and reviewed. Of these, Route 2 and Route 3 are the routes selected for the basic plan. An overview of these two routes is given in Table 6-6.

Table 6-6. Route Overview

Item	Route 2	Route 3
Planned locations	Same as planned location in the 2011 F/S (near the northern limits of Mykolaiv city)	Same line as Route 2 from the origin to near km 7.1. Terminates at M14 connection, approx. 3 km west of Route 2.
Route extension length	Approx. 13.2 km	Approx. 14.6 km
Length of bridge across the Southern Bug	2,115 m	2,180 m
Resettlement (Building with residents)	0	3
Obstructive Buildings (Garage, Warehouse etc)	26	60
Connection to P06 (connecting road at origin)	Cloverleaf interchange	Same
Connection to M14 (connecting road at terminus)	Trumpet interchange	Half-clover interchange

Source: JICA Survey Team

The planned locations for the two routes are shown in Figure 6-2. To the extent possible, the routes avoid residential areas, hospitals, graveyards, high-voltage lines, and other structures to minimize socioeconomic impact. Also, the bridge alignment is planned perpendicular to the river flow of the Southern Bug River as much as possible and the bridge length is planned as short as possible.

Source: JICA Survey Team

Figure 6-2. Planned Route Locations

6-4 Review of Connection Types

6-4-1 Interchange at Origin (same for Route 2 and Route 3)

This Survey recommends the same type as proposed in the 2011 and 2012 F/S: the cloverleaf.

6-4-2 Interchange at the Terminus (Route 2)

This Survey recommends the same type as proposed in the 2011 and 2012 F/S: Trumpet.

6-4-3 Interchange at Terminus (Route 3)

As there are close to no critical right-of-way limitations near the site for this interchange, a cloverleaf is recommended as it will be the easiest to convert from a 3-way to a 4-way interchange.

6-4-4 Connections at Intermediate Crossroads (same for Route 2 and Route 3)

A city road connecting residential areas on the north and south sides of the M14 Bypass pass under the bypass near Survey point No. 61. An exit is planned at this city road, which will also be convenient given that Survey point No. 61 is nearly the halfway mark of the M14 Bypass. (See Figure 6-3)

Source: JICA Survey Team

Figure 6-3. Intermediate Crossroad Connection Point (near Survey point No. 61)

6-5 Basic Interchange Structure

6-5-1 Ramp Design Speeds

- Design speeds for ramps on grade separated interchanges are set in accordance with DBN V.2.3-4 2015. The traffic volume used for calculating the ramp design speed was the future peak hourly volume for 2036 (vehicles/hour), found by calculating the traffic volume shares (%) for left- and right-turning vehicles entering the interchange from the main route during peak hours.

6-5-2 Number of Ramp Lanes

- For ramps on grade-separated interchanges, the number of ramp lanes used will be based on the traffic capacity ratio, calculated as the peak hour volume (PCU/h) over the ramp traffic capacity

(PCU/h). One lane will be used when the capacity ratio is 0.8 or lower and 2 lanes will be used when it is over 0.8.

6-5-3 Ramp Width

Ramp widths will be as follows in accordance with DBN V.2.3-4 2015:

- 1-lane ramps: 6.0 m lane width, 2.0 m shoulder width
- 2-lane ramps: 7.5 m lane width (3.75 m x 2), 2.0 m shoulder width

6-6 Discussion of Pavement Configuration

6-6-1 Conditions for Consideration

1) Design conditions

The basic design conditions are shown in Table 6-7.

Table 6-7. Basic Design Conditions

Item	Selected values	Notes	Source
Road category	I-b	See 6-2-1 Applied Standards and Road Categories above	DBN V.2.3-4 2015
Pavement design period	10 years	Based on values for I-b roads (pavement material: crushed stone mastic asphalt)	DBN V.2.3-4 2015
Design target year	2039	10 years from start of service (2030)	—
Confidence factor	0.95	Based on values for I-b roads	DBN V.2.3-4 2015
Climate category	III	Climate category for road area	DBN V.2.3-4 2015
Drainage condition category	I	Drainage condition category for road area	DBN V.2.3-4 2015
Standard frost penetration depth	60 cm	Standard frost penetration depth for road area	VBN V.2.3-218-186-2004

Source: DBN V.2.3-4 2015

2) Load conditions

The load conditions for I-b road are shown in Table 6-8.

Table 6-8. Load Conditions

Standard axle load kN	Standard wheel load kN	Tire inflation pressure MPa	Tire contact patch diameter (static) m	Tire contact patch diameter (dynamic) m
115	57.5	0.8	0.303	0.345

Source: DBN V.2.3-4 2015

6-6-2 Pavement Configuration

The proposed pavement configuration for the M14 Bypass is shown in Table 6-9.

Table 6-9. Pavement Configuration

Layer	Pavement configuration	Specifications	Layer thickness
1	Surface course (crushed stone-mastic asphalt mixture)	60/90[3]	5 cm
2	Intermediate course (hot asphalt mixture)	60/90	8 cm
3	Binder course (hot asphalt mixture)	60/90	10 cm
4	Cement stabilized base course	M40[4]	15 cm
5	Base course (crusher run)	C7[5]	20 cm
6	Base course (sand)	—	25 cm

Source: JICA Survey Team

6-7 Other ancillary facilities

1) Service roads

- If any existing facilities or farmland is made inaccessible due to construction of the route or interchanges, service roads (Class IV or equivalent) will be considered to restore access.

2) Street lighting

- In order to improve visibility for the merging and diverging vehicles at the interchanges, it is recommended to install street lighting from the start of the deceleration lane to the end of the acceleration lane.
- Street lighting is also recommended on the interchange ramp roads.
- Because Mykolaiv Bridge is constantly exposed to wind, there is a risk that lighting equipment will be toppled by wind during storms if typical pole-type lighting equipment is installed. There are also maintenance issues to be considered, such as the need for high-elevation work to perform regular maintenance. To address these concerns, it is recommended that low-position lighting, which offers easier maintenance and is effective in providing visual guidance, be used.
  In addition, lighting that could be mistaken for navigation light is prohibited to construct in approach surface by Japanese aviation laws and low-position lighting is usually constructed instead. Since Mykolaiv Bridge is located near Mykolaiv airport, it is important to take it into consideration.

3) Protective barrier

- In accordance with DBN V.2.3-4 2015, protective barriers are to be installed at the edge of shoulders on sections at embankment heights of 2 m or higher.

4) Noise barrier

- In order to satisfy the environmental standards of Ukraine, sound barriers will be constructed in sections that run close to residential areas. At the detailed design stage, the scope of sound barrier installation will be determined based on evaluating the impact of noise while also factoring in the impact of cutting and embankment.

5) Tollplaza

- If tolls are to be collected from traffic crossing the Southern Bug River, the candidate area for installation of tollgates is near the bridge on the left bank.
- The section on the left bank side has a straight plane alignment, a profile gradient of 0.5-2.1%, and embankment height of about 5 m and thus should have no hindering factors.

Because the terminus interchange extends to the bridge, installation of tollgates on the right bank is not recommended.

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[3] Penetration grade

[4] Crushesd stone for mechanical stabilization (Maximum particle size 40mm)

[5] The class of crushesd stone (Maximum particle size 40mm)

7 Bridge Plan Review

7-1 Policies for Setting Facility Grades

The bridge grades are set based on the following strategy:

a. Bridge profile gradient and width comply with Ukrainian standards. Measures to be considered include relaxing the profile gradient to account for the cold climate and minimizing bridge width to reduce costs. Note that, given the prospects of communities forming around the bridge, it is equipped with a walkway of sufficient width.
b. In accordance with Japanese standards for bridge durability, the bridge is designed selecting materials and methods to last at least 100 years.
c. In terms of bridge operation and maintenace, the bridge is designed selecting materials and methods for easy maintenance to avoid operation and maintenance cost increase and deferred maintenance.
d. The bridge's design live load is determined by comparing Japanese standards and Ukrainian standards and is adopted heavier one.
e. Given the extreme rarity of earthquakes in this region, there is no need to follow Japanese bridge standards for seismic reinforcement. Ukraine standards is followed instead.
f. For flooding measures, outside of navigable sections, bridge under clearance is higher than the water level for a 100-year flood, accounting for swell height.
g. For navigating vessels, bridge under clearance in navigable sections is at least the navigable water depth and channel height, and span length is at least the channel width with an added margin.

7-2 Consideration of Hydraulic Conditions

The hydraulic conditions required for the bridge plans are shown in Table 7-1. The river area blockage rate is the proportion of the width of the river area occupied by the total width of all bridge piers at the design high water level. The Japanese River Construction Ordinance sets out a target value of 5% or lower as standard, and 7% or lower for special cases such as expressways and/or bullet train. As shown in the table, the original pier layout plan for route 2 exceeds the above target value of 7% for the expressway case. Therefore, the modified pier layout plan shall be applied to meet the above target value by skewing the approach bridge piers 15 degrees from perpendicular to the longitudinal axis of the bridge in order to align the pier direction with the river flow direction as much as possible.

Table 7-1. Hydraulic Conditions Required for Bridge Plans

Hydraulic conditions	Route2	Route3
Design Discharge	4,600m3/s	same as on the left
Design high water level	BS+1.4m	BS+1.5m
Vertical bridge clearance	Inside the Navigation Channel: BS+15.8m Outside the Navigation Channel: BS+2.9m	Inside the Navigation Channel: BS+15.8m Outside the Navigation Channel: BS+3.0m
Flow speed	Left Bank Side: 0.8m/s Right Bank Side: 1.2m/s	Left Bank Side: 0.7m/s Right Bank Side: 1.1m/s
Scour depth	Left Bank Side: 4.3m (Modified* 3.3m) Right Bank Side: 5.6m	Left Bank Side: 2.3m Right Bank Side: 4.4m
River area blockage rate	9.9% (Modified* 6.8%)	4.1%
Navigation Vessel	Width:36m, Length:220m	same as on the left
Minimum Required Span Length	420m (Require Channel Width:280m)	same as on the left
Location of centerline of navigation channel	Approx.230m from the right bank	Approx.290m from the right bank

*: The value when the direction of the approach bridge piers is skewed by 15 degrees from perpendicular to the longitudinal axis of the bridge.

7-3 Obstacle Limitation Surfaces

When constructing a bypass road near an airport, bridge height is determined based on a Cabinet resolution (December 6, 2017, No. 954) and an order from the Ministry of Infrastructure (hereinafter referred as “MoI”) (Ministry of Infrastructure of Ukraine Order, November 30, 2012, No. 721).

As a result of confirmation with Mykolaiv Airport, the elevation of the construction space and top of main tower are confirmed to be lower than the obstacle limitation surface height.

Therefore, there is no limitation regarding the airspace condition.

7-4 Load Conditions

7-4-1 Seismic Load

According to "DBN V.1.2-15:2009", "DBN V.1.1-12:2006" and "DBN V.2.3-22:2009," the target area corresponds to a seismic level of "6" in the MSK seismic scale. This level seismic loads can be excluded from bridge design calculations. However, since the AASHOTO standard defines a minimum seismic load for design lateral seismic force (Kh=0.1), the Seismic Performance Level 1 is verified with the minimum seismic load for small-scale structures. On the other hand, since a long-term structure such as a cable-stayed bridge would be overdesigned even at Kh=0.1, the earthquake response spectrum for MSK seismic level 7 from "DBN V.1.1-12:2006" is used for the verification of Seismic Performance Level 1.

7-4-2 Live Load

A 'B live load' is adopted in accordance with “Specification for Highway Bridges, Part 1 Common (Japan Road Association, November 2017).” This load is much larger than the Russian standard AK11 (which is the same as the Ukrainian standard).

7-5 Basic Plan for the Route 2 Bridge

7-5-1 Main Bridge

.The main bridge is laid out with the navigation channel center and with the minimum center span length (420 m) that ensures the navigation channel widthas its minimum necessary span length. The left bank main tower position is 420/2 m from the channel center. For the position of left bank end-section piers, since the side spans of a cable-stayed bridge need to maintain a balance in a cantilevered construction method, in general, the length is the same as the center span cantilevered construction length. In this case, that position is 210 m, which is 1/2 the minimum required span length (420 m) of the center span. The right bank fulcrum (abutment) is positioned 510 m from the waterway center to avoid placing the substructure in a landslide area, thus the right bank main tower position is set to 1/2 of this 510 m. Based on this, the cable-stayed bridge's center span is 465 m (210 m+255 m) while the right bank side span is 255 m.

1) Bridge Type

Considering the central span length of 465 m, the comparative review considers the following 3 proposals with reference to bridges constructed in the past.

Proposal 1: Steel cable-stayed bridge
Proposal 2: Steel suspension bridge
Proposal 3: PC cable-stayed bridge

Figure 7-1 shows the structures of each proposals. Considering the characteristics and evaluations shown in Table7-2, "Proposal 1, steel cable-stayed bridge (PC slab composite edge-girder type)" is adopted on the ground of its superiority in all aspects of structural characteristics, technology transfer, workability, operation and maintenance, and economic feasibility.

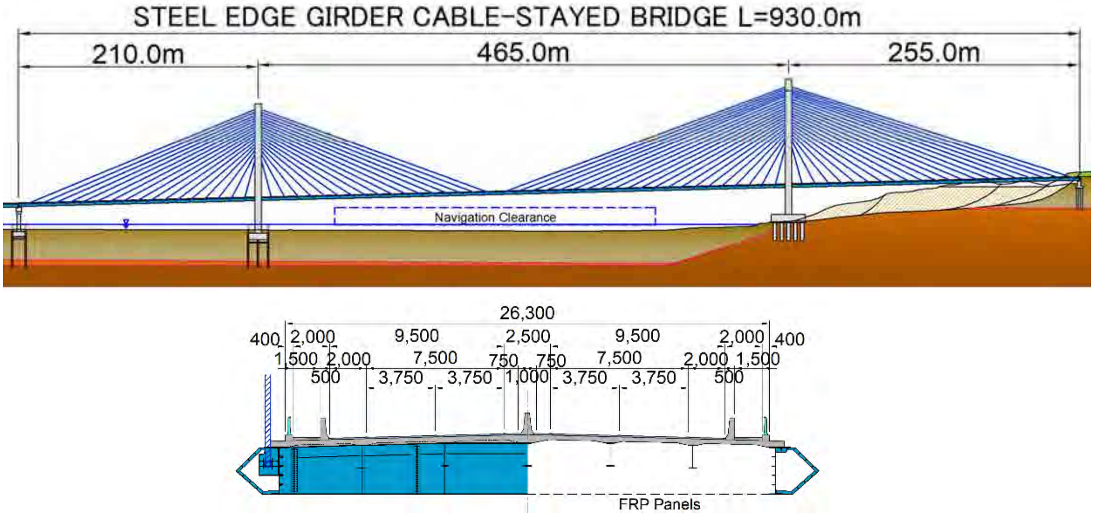
Table 7-2. Characteristics and Evaluations of Steel Cable-stayed Bridge

Structural characteristics	・ By adopting a highly durable concrete deck slab, surface freezing in the winter is mitigated better than Proposal 2, making this proposal more effective in preventing slipping accidents. ・ Wind tunnel experiments to date suggests that installation of FRP panels on the girder underside sufficiently resolves the issue of wind-resistant stability of the superstructure. ・ Although the right bank side is in a landslide zone, the bridge's long side span length makes it possible to install piers in locations that avoid the steep slopes near the riverbank. Thus, this proposal is less affected by landslides than Proposal 2.
Technology Transfer	・ This type of bridge is increasingly replacing Proposal 2 type bridges. There is also excellent potential for technology transfer due to the target country's thriving steel industry.
Workability	・ Steel girder construction of the superstructure is a piece-by-piece cantilever erection method using a traveler crane. There are no problems with regard to ensuring a navigable waterway during construction. The simple repetitive operation used in this method also makes it easier to manage construction.
Operation and maintenance	・ By installing FRP panels on the girder underside, which do not require painting, there would be few exposed metal parts, making repainting costs less than Proposal 2.
Economic feasibility	Most Economical

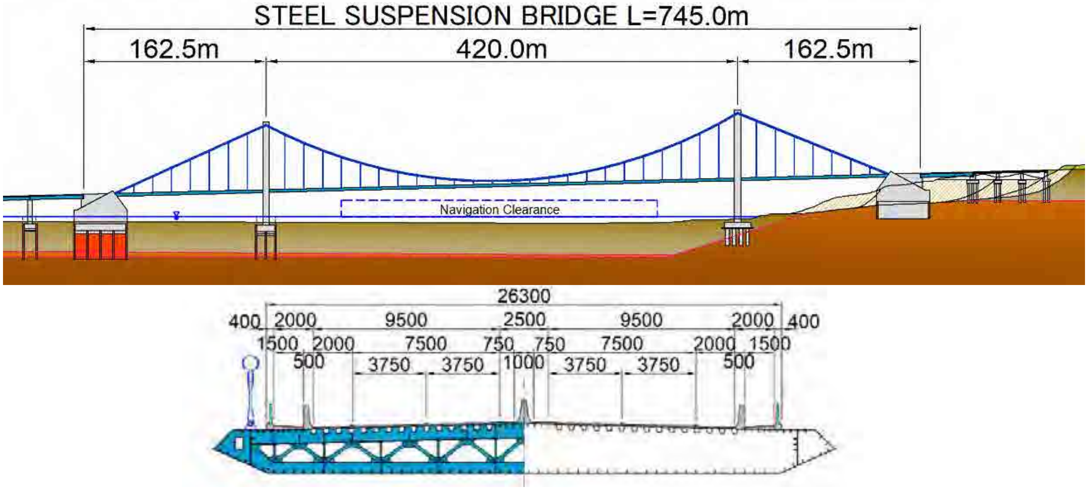
2) Main Tower Frame Type

Main tower frame types are broadly categorized into either steel tower or RC tower. In this project, an RC tower structure is adopted on the ground of its superior cost efficiency and many instances of use in recently built cable-stayed bridges.

Proposal 1: Steel cable-stayed bridge (PC slab composite edge-girder type)



Proposal 2: Steel suspension bridge (steel deck with box girders type) <Recommended proposal in 2011F/S>



Proposal 3: Steel cable-stayed bridge (corrugated steel web box girder bridge with struts)

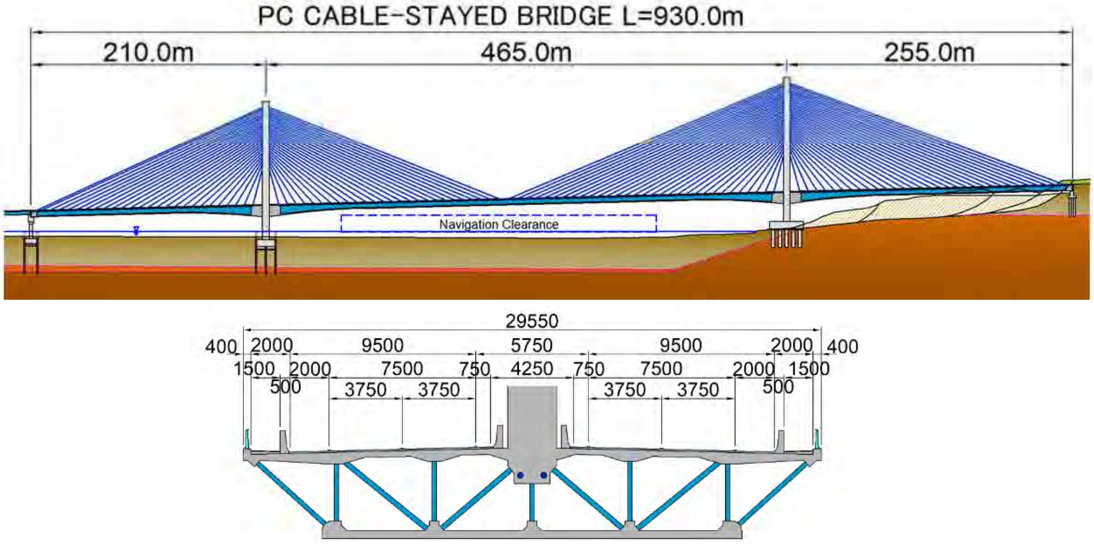


Figure 7-1.Structures of Main Bridges

3) Foundation Type

(1) Left Bank Main Bridge Main Tower

The left bank main tower foundation is constructed in a river roughly 4 m deep. As for ground conditions, the ground is composed of soft ground from the surface layer to intermediate layer, and its bearing layer contains a layer of soft rock at about 35 m below the water surface.

Considering the ground condition, the comparative review considers the following 3 proposals.

Proposal 1: Steel pipe sheet pile foundation (self-standing method)
Proposal 2: Cast-in-place pile foundation (multi pile-bent method),
Proposal 3: Steel pipe sheet pile foundation (temporary cofferdam method)

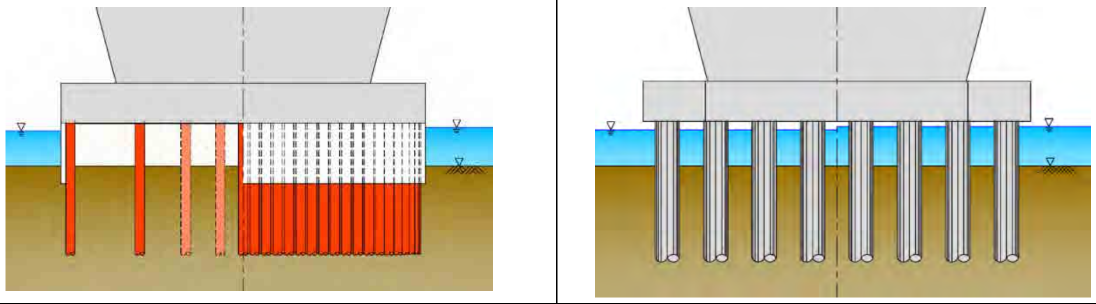
Figure7-2 shows the structures of each proposals. Considering the characteristics and evaluations shown in Table7-3, "Proposal 3: Steel pipe sheet pile foundation (temporary cofferdam method)" is adopted on the grounds of its superior workability and safety.

Table 7-3.Characteristics and Evaluations of Steel pipe sheet pile foundation (temporary cofferdam method)

Structural characteristics	・Because all steel pipes are underground, there is no need to implement anti-corrosion measures.
Impact on Rivers	・There is little impact on the river as the river flow is not significantly obstructed.
Workability	・This plan requires in-river excavation. However, it also has a proven history of use in many projects and its construction techniques are well-established. Viewed collectively, it is no better than the other proposals.
Landscape Aesthetics	・Because only the piers are exposed above the waterway, this plan is favorable from a landscape aesthetics perspective.
Economic feasibility	Almost the same as other proposals

Proposal 1: Steel pipe sheet pile foundation (self-standing method)

Proposal 2: Cast-in-place pile foundation (multi pile-bent method)



Proposal 3: Steel pipe sheet pile foundation (temporary cofferdam method)

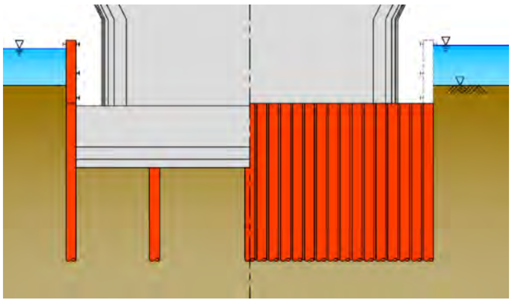


Figure 7-2. Structure of Foundations for Left Bank Main Bridge Main Tower

(2) Right Bank Main Bridge Main Tower

Right bank of main tower foundation is constructed on land in this Study. Geologically, a layer of soft ground continues for roughly 10 m from the surface layer, followed by a bearing layer composed of soft rock.

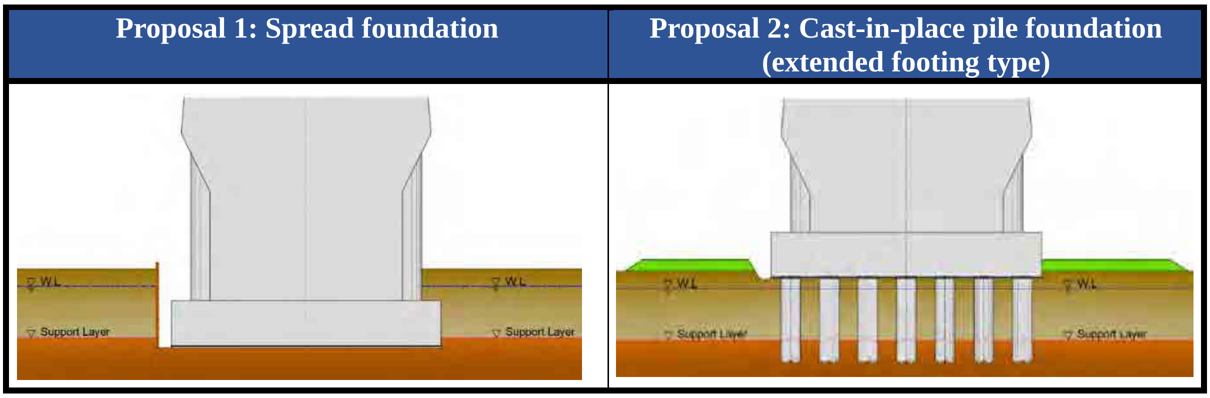
Considering the ground condition, the comparative review considers the following 2 proposals.

Proposal 1: Spread foundation
Proposal 2: Cast-in-place pile foundation (extended footing type)

Figure7-3 shows the structures of each proposals. Considering the characteristics and evaluations shown in Table 7-4, Proposal 2: Cast-in-place pile foundation (extended footing type) is adopted.

Table 7-4. Characteristics and Evaluations of Cast-in-place pile foundation (extended footing type)

Structural characteristics	・This type of structure is susceptible to horizontal force during an earthquake, but has no significant issues when used in non-earthquake areas.
Impact on Landslide	・As this plan greatly reduces excavation of the lower section of landslide-prone soil mass, it is better than Proposal 1 regarding landslide impact
Workability	・Since excavation work is shallow and some can be carried out as open excavation, this plan has better workability then Proposal 1. ・Although this plan requires cast-in-place pile work, it has a proven history of use in many projects and little compromise in workability.
Landscape Aesthetics	・Because of the massive footing protruding from the ground, this plan is inferior from a landscape aesthetics perspective.
Economic feasibility	Most Economical



Proposal 1: Spread foundation

Proposal 2: Cast-in-place pile foundation (extended footing type)

Figure 7-3. Structure of Foundations for Right Bank Main Bridge Main Tower

7-5-2 Approach Bridge

Between the left bank side abutment and main bridge left bank end-section (left bank approach bridge), a continuous girder structure is used as much as possible to promote cost-effectiveness and smoother surface drivability. Based on a value of around 400 m, which is the maximum length of a continuous girder when using a high-surface-pressure fixed-support structure, which has excellent economic efficiency, three runs of continuous girder are constructed within this length. Since the possible continuous girder length grows longer as pier heights increase, continuous girders are arranged (from shortest to longest) at 335 m, 395 m, and 455 m. With regard to the span layout for continuous girders, the optimal span length is set in principle to 60 m. With regard to span length of the end-section continuous girder, to avoid lower cost efficiency from concentrated sectional force, a ratio of 1.25:1.00, considered the most rational ratio for mid-section to end-section span lengths, is used to improve cost efficiency. This sets the length of the end-section span to 47.5 m.

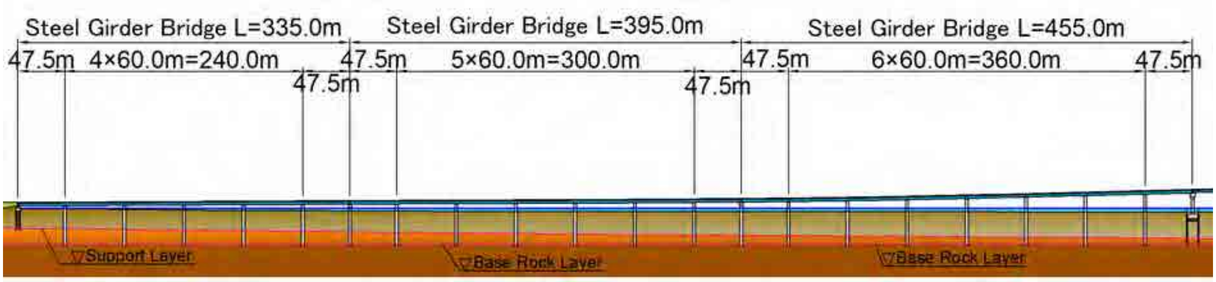


Figure 7-4. Layout of the Left Bank Approach Bridge (Route2)

(1) Deck Structure Type

As there are three types of deck structures for steel dual-main-girder structures: PC slab, precast PC slab, and steel/concrete composite deck, these three types are compared.

As the results of this comparative study, Precast PC Slab, is adopted on the grounds of its superior workability and safety.

(2) Substructure and Foundation Type

Substructure and foundation type were selected in consideration of the load scale (cost-effective span: 30-60 m girder bridge), construction conditions (construction site water depth: approx. 1-3 m; cold weather construction, etc.), and ground conditions (bearing layer depth: approx. 35 m from the riverbed).

Considering these conditions, the comparative review considers the following three proposals.

Proposal 1: Steel pipe pile foundation (multi pile-bent method)
Proposal 2: Cast-in-place pile foundation (multi pile-bent method)
Proposal 3: PC well foundation (single pile-bent method)

Figure 7-5 shows the image of each proposals. Considering the characteristics and evaluations shown in Table 7-5, “Proposal 3: PC well foundation (single pile-bent method)” was adopted on the ground of its superiority in most aspects including structural characteristics, impact on the river, and landscape aesthetics.

Table 7-5. Characteristics and Evaluations of Cast-in-place pile foundation (extended footing type)

Structural characteristics	・As the piles are high quality concrete fabricated at a nearby casting yard, there are no issues regarding anti-corrosion measures.
Impact on rivers	・There is little impact on the waterway as the river flow is not significantly obstructed.
Workability	・Since the PC well sinking work requires a relatively diverse range of types of work and also requires several setup changes, this proposal as inferior workability compared with other proposals based on machine excavation. ・Since footings and piers can be omitted and the structure can be completed easier than piers by stacking PC wells, this method has favorable workability for that portion of the work.
Landscape aesthetics	・Because the structural elements exposed above the waterway are slimmer, this plan is favorable from a landscape aesthetics perspective.
Economic feasibility	Most Economical

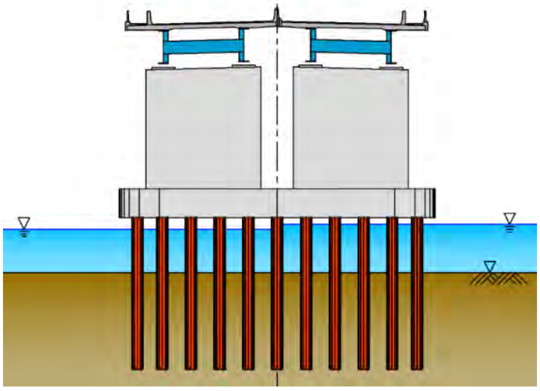
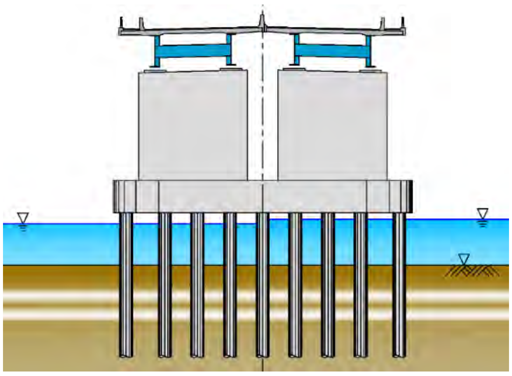
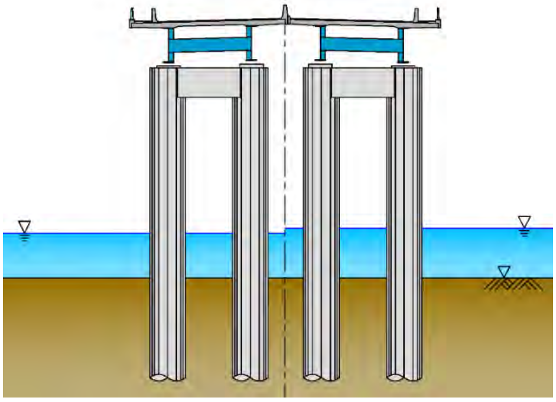
Proposal 1: Steel pipe pile foundation (multi pile-bent method)	**Proposal 2: Cast-in-place pile foundation (multi pile-bent method)**
	
Proposal 3: PC well foundation (single pile-bent method)	
	

Figure 7-5. Structure of Foundation for Approach Bridge

7-6 Basic Plan of the Route 3 Bridge

7-6-1 Main Bridge

The main bridge shall be a cable-stayed bridge with a center-span center that is aligned with the waterway center, and has a center span length (420 m) that ensures the navigation channel width. Because this bridge uses a cantilever construction method, side span length of the cable-stayed bridge shall be 210 m, basically set at about 1/2 the length of the center span.

1) Bridge Type

Considering the central span length of 420m, the comparative review considers the following 3 proposals with reference to bridges constructed in the past.

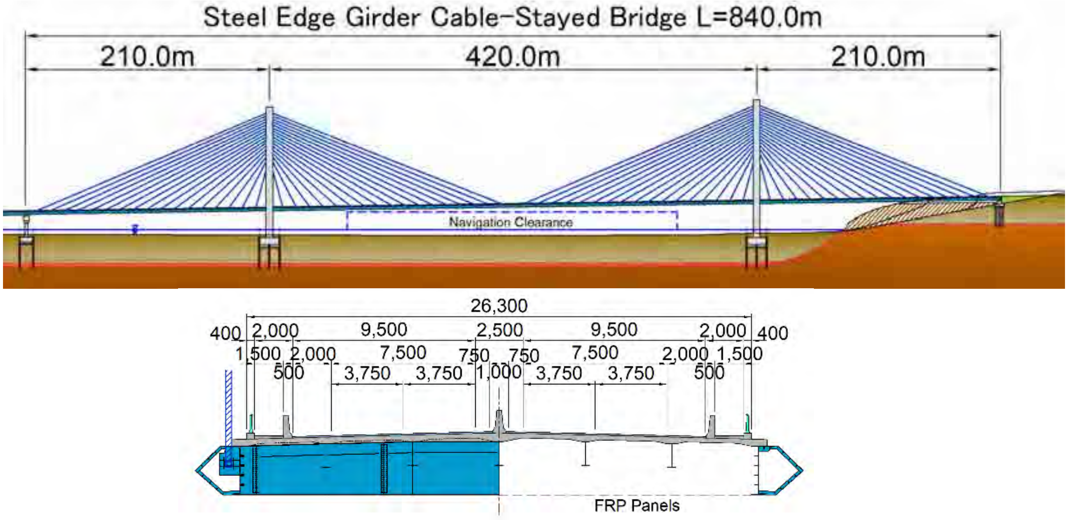
Proposal 1: Steel cable-stayed bridge
Proposal 2: Steel suspension bridge
Proposal 3: PC cable-stayed bridge

Figure7-6 shows the structure of each proposals. Considering the characteristics and evaluations shown in Table 7-6, “Proposal 1, steel cable-stayed bridge (PC slab composite edge-girder type)”, is adopted on the ground of its superiority in all aspects of structural characteristics, technology transfer, workability, maintenance, and economic feasibility.

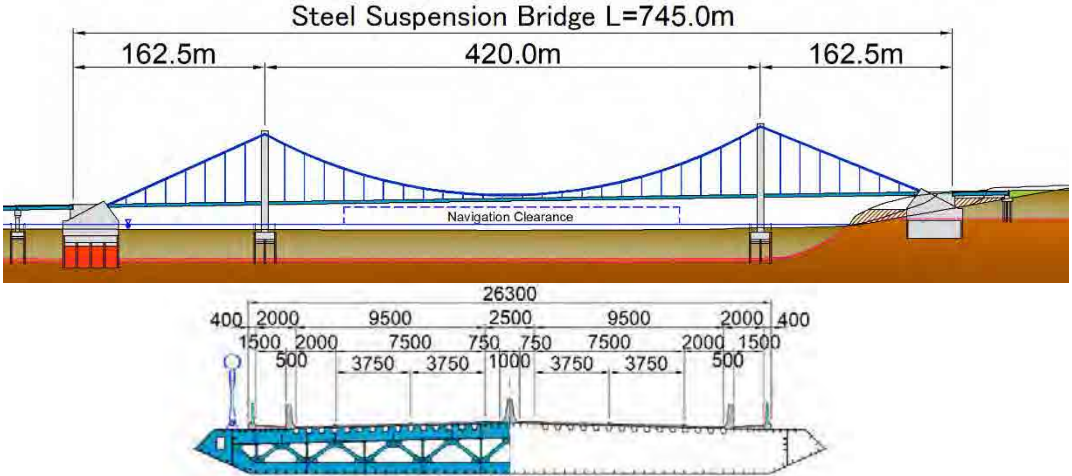
Table 7-6. Characteristics and Evaluations of Steel Cable-stayed Bridge

Structural characteristics	・By adopting a highly durable concrete deck slab, surface freezing in the winter is mitigated better than Proposal 2, making this proposal more effective in preventing slipping accidents. ・Wind tunnel experiments to date suggests that the installation of FRP panels on the girder underside sufficiently resolves the issue of wind-resistant stability of the superstructure. ・Although the right bank side is in a landslide zone, it is possible to avoid placing piers and abutments in the landslide area. Therefore, there is basically no negative impact from landslides.
Technology Transfer	・This type of bridge is increasingly replacing Proposal 2 type bridges. There is also excellent potential for technology transfer due to the target country's thriving steel industry.
Workability	・Steel girder construction of the superstructure is a piece-by-piece cantilever erection method using a traveler crane. There are no problems with regard to ensuring a navigable waterway during construction. The simple repetitive operation used in this method also makes it easier to manage construction.
Operation and maintenance	・By installing FRP panels on the girder underside, which do not require painting, there would be few exposed metal parts, making repainting costs less than Proposal 2.
Economic feasibility	Most Economical

Proposal 1: Steel cable-stayed bridge (PC slab composite edge-girder type)



Proposal 2: Steel suspension bridge (steel deck with box girders type) <Recommended proposal in 2011F/S>



Proposal 3: Steel cable-stayed bridge (corrugated steel web box girder bridge with struts)

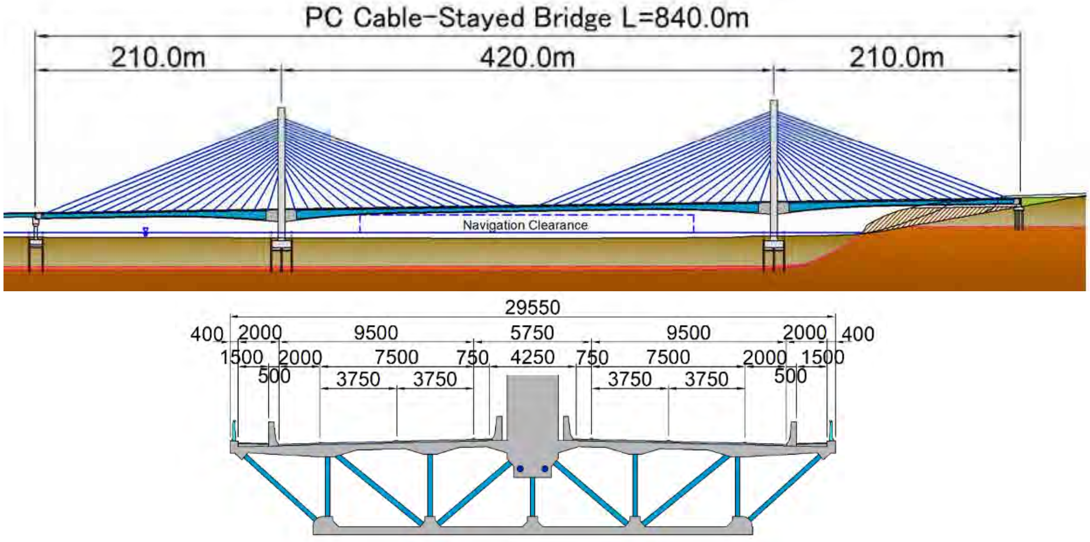


Figure 7-6. Structures of Main Bridges (Route2)

2) Main Tower Frame Type

An RC tower structure is adopted for the main tower frame type for Route 3, just as it is for Route 2.

3) Foundation Type

Since the conditions of both the left and right sides of the main tower foundation for Route 3 are essentially the same as those of the left side of the main tower foundation for Route 2, a steel pipe sheet pile foundation (temporary cofferdam method) is likewise adopted for the main tower foundation.

7-6-2 Approach Bridge

Between the left bank side abutment and main bridge (cable-stayed bridge) left bank end-section (left bank approach bridge), a continuous girder structure is used as much as possible to promote cost-effectiveness and smoother surface drivability. Based on a value of around 400 m, the maximum length of a continuous girder when using a high-surface-pressure fixed-support structure, a structure with excellent economic efficiency, three runs of continuous girder are constructed within this length. Since the possible continuous girder length grows longer as the pier heights increase, continuous girders are arranged (from shortest to longest) at 275 m, 335 m, 335 m, and 395 m. With regard to the span layout for continuous girders, the optimal span length is set in principle to 60 m. With regard to the span length of the end-section continuous girder, a ratio of 1.25:1.00, the most rational ratio for mid-section to end-section span lengths, is used to improve the cost efficiency by eliminating the efficiency reductions from the concentrated sectional force. This sets the length of the end-section span to 47.5 m.

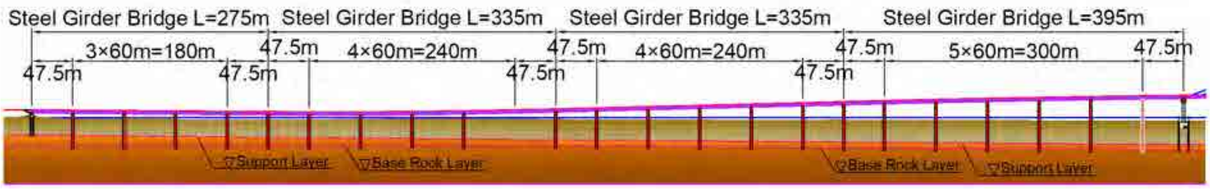


Figure 7-7. Layout of the Left Bank Approach Bridge (Route3)

1) Deck Structure Type

Since the conditions of Route 3 are essentially the same as those of Route 2, precast PC slab is likewise adopted for the deck structure.

2) Substructure and Foundation Type

Since the conditions of Route 3 are essentially the same as those of Route 2, a PC well foundation (single pile-bent method) is likewise adopted for the left bank approach bridge pier foundation.

7-7 Reviewing the Application of Japanese Technology

The purpose of this Study is to determine a bridge and road design that realizes high quality and economic efficiency by effectively utilizing Japanese technology. The table below shows a list of proposed Japanese technologies and their procurement ratios, which have exceeded the STEP criteria of 30%. In calculating these procurement ratios, expenses related to the procurement and use of Japanese technology have been excluded from the calculation. If these factors were included, the procurement ratio could be even higher.

Table 7-7. Japanese Technology Procurement Ratio

(Unit: million JPY)

Japaneses Technology	Main Bridge	Other Bridges	Sub Total	Procurement Ratio
High-durability Slab	1,125	1,785	2,910	6.1%
SBHS steel	289	1,102	1,391	2.9%
Stay Cable	1,645		1,645	3.5%
FRP Panel	680		680	1.4%
PC Pretensioned Slab Girder		1,041	1,041	2.2%
High-surface-pressure Support Structure	106	563	669	1.4%
Rotary All Casing Cast-in-place Pile Method		242	242	0.5%
PC Wells Foundation		4,302	4,302	9.1%
Steel Pipe Sheet Pile Foundation	2,370		2,370	5.0%
Aluminum Railing	118	188	306	0.6%
Sub Total (Japanese Technology)	6,333	9,223	15,556	32.7%
Construction Cost Total			47,516	100.0%

8 Traffic Demand Forecast

8-1 Review of Traffic Demand Forecasts Carried out as Part of 2011F/S and 2017 Survey

1) Demand Forecast in 2011F/S

(1) Methodology (2011)

The traffic demand forecast in 2011F/S was estimated by focusing on river crossing traffic, while river crossing traffic in future is estimated by adding induced traffic based on the Ochakiv Port Development Plan to future traffic volume at river crossings, as forecast from traffic survey results and socioeconomic indicators (Basic Traffic). By applying a conversion ratio model to the estimated river crossing traffic, the traffic volume traversing Mykolaiv Bridge can be forecast.

The flow of future demand forecast in 2011F/S is shown as follows:

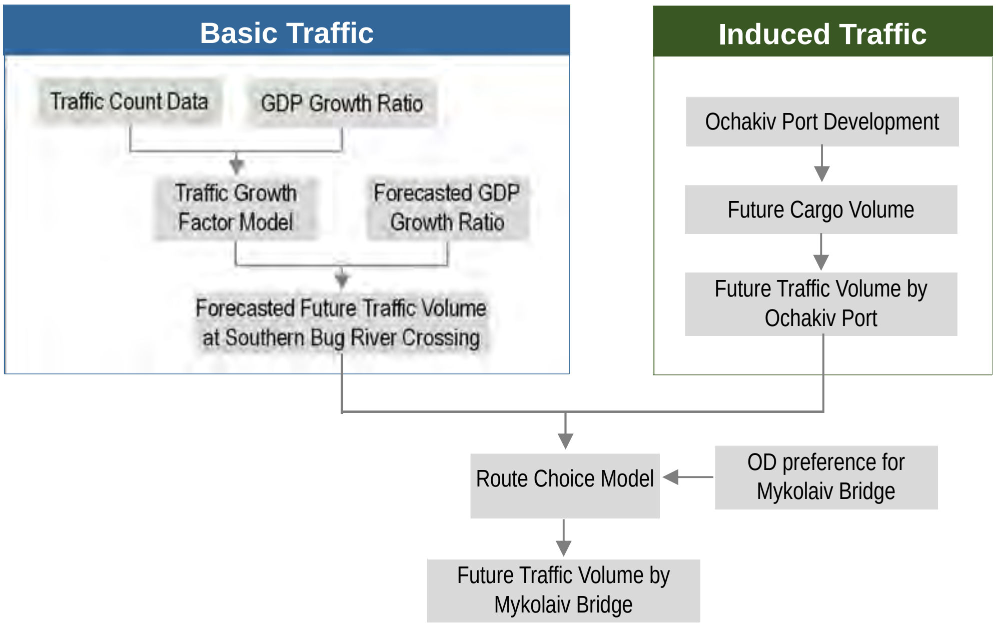


Figure 8-1. A flow of Future Demand Forecast in 2011F/S

(2) Result of the Estimation (2011)

Traffic demand for Mykolaiv Bridge can be forecast from the travel hours between the main sections and the route choice model based on the conversion ratio to Mykolaiv Bridge by the OD pair using the following tolls.

For buses, including intercity models, their OD or transit points are expected to remain in the center of the Mykolaiv region, which means demand for bus traffic using Mykolaiv Bridge located on the bypass route is not included in this future demand.

Table 8-1. PCU and Toll Systems (2011F/S)

Vehicle types	PCU	Toll setting cases（UAH/vehicle）			
		Free	Toll-1	Toll-2	Toll-3
Passenger cars	1.0	0	10	20	30
2-axle trucks	2.0	0	15	30	45
3+ axle trucks	2.5	0	20	40	60
Trailers	3.0	0	30	60	90

Source: 2011F/S

Table 8-2. Conversion Ratio to Mykolaiv Bridge (2011F/S)

Base Toll (UAH)	Passenger cars	2-axle trucks	3+ axle trucks	Trailers
Free	47.4%	50.2%	53.1%	54.5%
Toll-1	31.5%	38.8%	49.3%	43.2%
Toll-2	18.9%	28.4%	45.6%	32.5%
Toll-3	10.6%	19.8%	41.6%	23.3%

Source: 2011F/S

The estimated future traffic volume per day on Mykolaiv Bridge by demand cases related to the Ochakiv Port development is shown as follows:

Table 8-3. Future Traffic Volume on Mykolaiv Bridge (PCU/day)

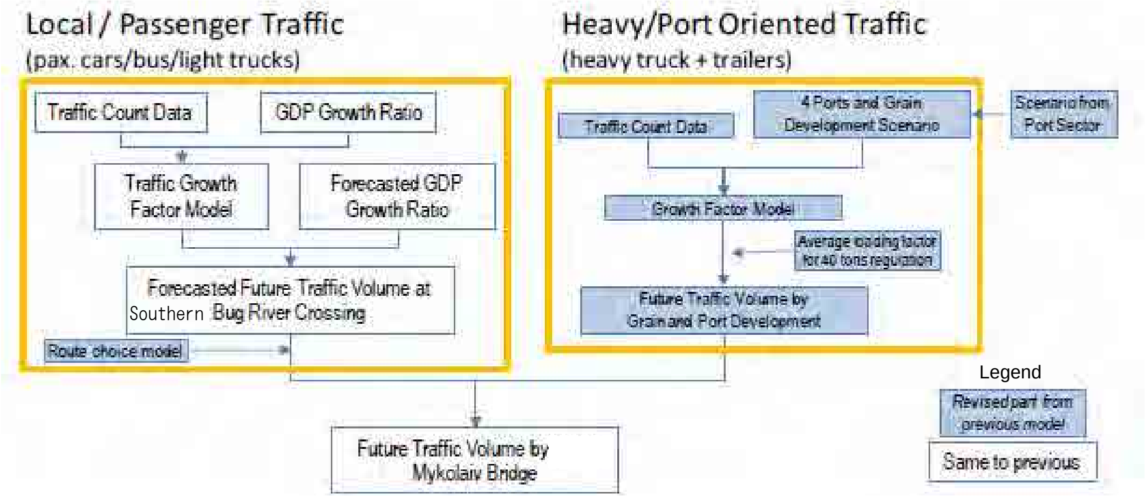
Year	Demand case	Free	Toll-1	Toll-2	Toll-3
2015	100%	18,300	13,300	9,200	6,000
	75%	18,300	13,300	8,900	5,700
	50%	18,000	13,000	8,600	5,700
	0	17,400	12,700	8,600	5,500
2025	100%	26,900	19,600	13,600	9,200
	75%	26,400	19,000	13,000	8,700
	50%	25,200	18,200	12,500	8,100
	0	23,300	16,800	11,100	7,000
2035	100%	37,600	27,300	18,800	12,400
	75%	36,800	26,400	18,300	12,100
	50%	35,100	25,300	17,200	11,000
	0	31,700	22,500	14,700	9,400
2045	100%	49,400	35,200	23,800	15,500
	75%	49,400	35,200	23,800	15,500
	50%	48,000	34,100	23,000	14,700
	0	43,500	30,500	19,900	12,500

Source: 2011F/S

2) Traffic Demand Forecast in 2017 Survey

(1) Methodology (2017)

Similar to the traffic demand forecast in 2011F/S, future traffic demand was estimated by focusing on river crossing traffic. The methodology applied in 2011F/S added induced traffic to the river crossing traffic but focused solely on the import/export volume in Odesa Port, excluding the volume in the other ports. From this perspective, 2017 Survey, in turn, categorized passenger cars, buses and 2-axle trucks as Local/Passenger Traffic and large trucks and trailers as Heavy/Port Oriented Traffic and estimated each demand respectively. Accordingly, the methodology applied in 2017 Survey is deemed more appropriate than that of 2011F/S as the former takes freight traffic in the major ports into consideration.



Source: 2017 Survey

Figure 8-2. Flow of Traffic Demand Forecast in 2017 Survey

(2) Local/Passenger Traffic

The future traffic volume at river crossings of Mykolaiv Bridge, calculated based on the future traffic volume at the river crossing volume and the conversion ratio.

(3) Heavy/Port Oriented Traffic

The river crossing traffic for large trucks and trailers is assumed to increase proportionally to the import/export volume at the main ports in the Southern Region, such as Odesa, Mykolaiv and Kherson Ports. Therefore, the river crossing traffic was estimated from cargo volume with two cases. Case 1 shows the volume of coals, minerals, metals, grains and containers while Case 2 adds the other cargo to Case 1, resulting in a 15% larger volume than Case 1.

(4) Result of Estimating Future Traffic Volume at River Crossings (2017 Survey)

The following table shows the results of estimating future traffic volume at river crossings in Cases 1 and 2.

Table 8-4. Estimation of Future Traffic Volume at River Crossing (Case 1)

	Passenger Cars	**Buses**	**2 Axle Trucks**	**Heavy Vehicles**	**Total**	**Total in PCU**
2017 Present Situation	24,564	3,688	3,941	3,270	**35,463**	49,632
2030 Case 1 with Bridge						
Crossing traffic at new birdge	14,890	963	1,792	2,878	**20,523**	29,035
Crossing traffic at existing birdge	21,189	3,965	2,550	0	**27,704**	34,219
2030 Case 1 without Bridge						
Crossing traffic at existing birdge	36,079	4,928	4,342	4,797	**51,891**	69,012

PCU: 1,0 for passenger cars, 2,0 for buses, 2,0 for 2 axle trucks and 3,0 for heavy vehicles

Source: 2017 Survey

Table 8-5. Estimation of Future Traffic Volume at River Crossing (Case 2)

	Passenger Cars	**Buses**	**2 Axle Trucks**	**Heavy Vehicles**	**Total**	**Total in PCU**
2017 Present Situation	24,564	3,688	3,941	3,270	**35,463**	49,632
2030 Case 2 with Bridge						
Crossing traffic at new birdge	14,890	963	1,792	3,520	**21,165**	30,960
Crossing traffic at existing birdge	21,189	3,965	2,550	0	**27,704**	34,219
2030 Case 2 without Bridge						
Crossing traffic at existing birdge	36,079	4,928	4,342	5,500	**50,850**	71,120

Source: 2017 Survey

8-2 Traffic Demand Forecast in Additional Study

8-2-1 Overview

The fast part of 8-2 is to show preconditions such as target sections, road conditions, zoning including OD and current traffic volume. Thereafter, the OD of river crossing, converted traffic volume, traffic volume in the road network and future traffic volume are shown.

1) Target Sections

The four routes are shown in Figure 8-3.

The traffic demand forecast in this survey will target the four routes passing the cross-section of Mykolaiv Bridge and Vavarovsky Bridge and road sections in the city.

Figure 8-3. Target Sections and Road Networks

2) Road Conditions

The type and class of vehicles and the number of lanes on the road networks as defined in the previous section are set based on the existing data and a current condition survey.

3) Zoning and OD Traffic Volume

The same zoning is applied as 2011F/S. The following values - as estimated in the previous section - are used for the attracted traffic volume generated, which is also applied for the estimation.

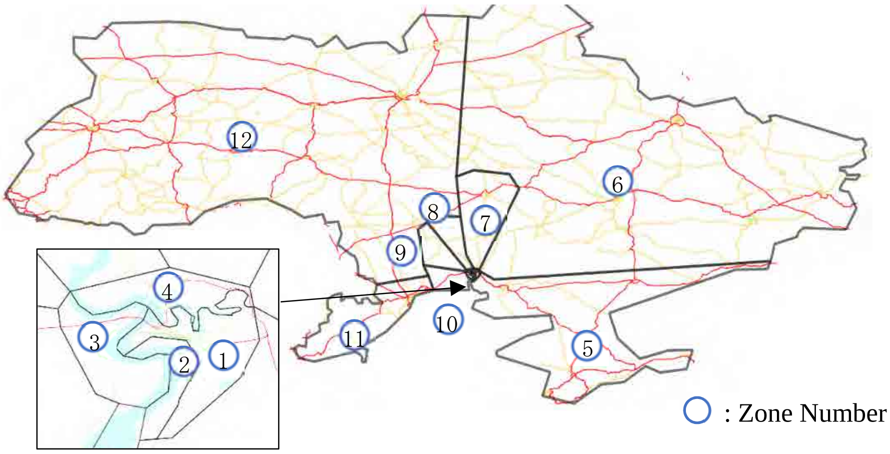


Figure 8-4. Zoning (Left: Narrow area; Right: Wide area)

4) Current Traffic Volume

The current traffic volume is estimated based on the following three different traffic surveys were conducted in the survey area:

- A traffic survey conducted in September 2016 (24-hours, four vehicle types)
- A traffic survey conducted in January 2017 (24-hours, five vehicle types) and a monthly variation survey on the cross-section of Vavarovsky Bridge (24-hours, five vehicle types)
- A traffic survey conducted in October 2018 (an hour, one vehicle type)

8-2-2 Adjustment of OD Traffic Volume to OD of River Crossing

Despite the distribution of the traffic volume as shown in the previous section as the OD of the Southern Bug River crossing (prepared based on the interview survey in the cross-section of Vavarovsky Bridge), it includes OD pairs that need not pass the bridge. Setting an appropriate OD of the Southern Bug River crossing is calculated in accordance with the following procedure. As described below, because it was felt that trip generation and attraction in the original OD table were not adequately balanced, efforts were taken in this Study to average the OD generation and attraction.

8-2-3 Estimation of Traffic Volume Converted from Vavarovsky Bridge to Mykolaiv Bridge

1) Travel Time Required between ODs

The free speed at each link on the road network is set based on the travel speed survey (2011) as well as their function as a trunk road.

In addition, the traffic origins in each zone are set.

2) Converted Traffic Volume

The following conversion ratio is applied to the difference in travel time between Mykolaiv Bridge and Vavarovsky Bridge as obtained in the previous section. In so doing, the traffic volume for each route crossing Mykolaiv Bridge is calculated as follows.

Table 8-6. Traffic Volumes of Mykolaiv Bridge and Vavarovsky Bridge after Traffic Conversion

Unit: veh./day

Bridges	Route	Pax	Bus	2-axle trucks	3+ axle trucks	Trailer	All
Mykolaiv Bridge	Route1	9,785	1,566	1,351	104	707	13,512
	Route2	10,714	1,742	1,563	106	804	14,929
	Route3	10,358	1,671	1,480	106	808	14,423
	Route4	9,032	1,383	1,201	100	842	12,558
Vavarovsky Bridge	Route1	15,303	2,636	2,671	88	1,255	21,954
	Route2	14,374	2,460	2,459	86	1,158	20,537
	Route3	14,730	2,531	2,542	86	1,154	21,043
	Route4	16,056	2,819	2,821	92	1,120	22,908

Unit: pcu/day

Bridges	Route	Pax	Bus	2-axle trucks	3+ axle trucks	Trailer	All
Mykolaiv Bridge	Route1	9,785	4,698	2,701	352	3,536	21,072
	Route2	10,714	5,227	3,125	359	4,020	23,445
	Route3	10,358	5,013	2,960	360	4,038	22,729
	Route4	9,032	4,150	2,402	338	4,208	20,130
Vavarovsky Bridge	Route1	15,303	7,908	5,343	298	6,274	35,126
	Route2	14,374	7,379	4,919	291	5,790	32,753
	Route3	14,730	7,593	5,084	290	5,772	33,469
	Route4	16,056	8,456	5,642	312	5,602	36,068

Bridge	Route	Conversion / Unconversion Rate
Mykolaiv Bridge	Route1	39.1%
	Route2	42.9%
	Route3	41.5%
	Route4	36.1%
Vavarovsky Bridge	Route1	60.9%
	Route2	57.1%
	Route3	58.5%
	Route4	63.9%

8-2-4 Estimation of Traffic Volume in the Road Network

1) Capacity

The road network capacity is set based on the road conditions (vehicle type and class and the number of lanes) for each section in the network.

2) Quantity-Velocity (QV)

To define the travel speed based on the converted traffic volume, the Quantity-Velocity (QV) conditions in each section are set.

3) Current Traffic Volume

The current traffic volume as of 2017 is estimated by compounding the traffic count data. Based on the traffic volume, the congestion level and travel speed (average and final) are estimated.

4) Traffic Volume after a Traffic Conversion

The traffic volume after a traffic conversion is estimated by adjusting the current traffic volume of the road network with the traffic volume of each route after the conversion.

8-2-5 Future Traffic Volume

1) Growth Ratio of Future Traffic Volume

It understands that little time has elapsed between 2017 Survey and this Study, and the latest situation around Mykolaiv City has remained largely unchanged. Accordingly, the growth ratio of future traffic used in 2017 Survey is also applied in this Study. As with 2011F/S, this growth ratio was estimated by a regression model using traffic count data and socioeconomic indicators. The GDP growth ratio, one of the socioeconomic indicators, was set between 2.5% and 3.5%. Based on this precondition, the growth ratios of future traffic volume are calculated and shown as follows:

Table 8-7. Growth Ratio of Future Traffic Volume

	Passenger cars	Buses	2-axle trucks	3+ axle trucks	Trailers
Annual average growth ratio	3.2%	2.0%	0.9%	3.0%	3.0%

2) Future Traffic Volume

The future traffic volume for each route are calculated from AADT and the growth ratio as follows:

Table 8-8. Future Traffic Volume (Vehicle Basis)

Route	Year	Bridge	Traffic volume (veh./day)					
			Pax	Bus	2-axle truck	3+ axle truck	Trailer	Total
Route1	2025	Vavarovsky	19,200	2,464	2,722	212	2,431	27,029
		Mykolaiv	12,555	1,840	1,446	124	1,367	17,332
	2040	Vavarovsky	30,647	3,333	3,100	330	3,782	41,192
		Mykolaiv	20,041	2,488	1,646	192	2,127	26,495
	2055	Vavarovsky	48,916	4,500	3,528	513	5,885	63,342
		Mykolaiv	31,987	3,359	1,873	299	3,310	40,830
Route2	2025	Vavarovsky	18,002	2,255	2,493	210	2,395	25,354
		Mykolaiv	13,754	2,049	1,675	126	1,403	19,006
	2040	Vavarovsky	28,734	3,049	2,839	326	3,727	38,676
		Mykolaiv	21,954	2,771	1,907	196	2,183	29,011
	2055	Vavarovsky	45,862	4,117	3,231	508	5,799	59,518
		Mykolaiv	35,041	3,741	2,170	305	3,396	44,654
Route3	2025	Vavarovsky	18,466	2,339	2,581	210	2,400	25,997
		Mykolaiv	13,289	1,964	1,587	126	1,398	18,364
	2040	Vavarovsky	29,475	3,164	2,939	326	3,735	39,640
		Mykolaiv	21,212	2,657	1,807	196	2,175	28,047
	2055	Vavarovsky	47,046	4,272	3,344	508	5,812	60,982
		Mykolaiv	33,857	3,587	2,057	305	3,384	43,190
Route4	2025	Vavarovsky	20,098	2,678	2,868	216	2,496	28,357
		Mykolaiv	11,657	1,625	1,300	120	1,301	16,004
	2040	Vavarovsky	32,081	3,622	3,266	336	3,885	43,189
		Mykolaiv	18,607	2,198	1,481	186	2,025	24,497
	2055	Vavarovsky	51,205	4,891	3,716	522	6,045	66,378
		Mykolaiv	29,699	2,968	1,685	290	3,151	37,793

Table 8-9. Future Traffic Volume (PCU basis)

Route	Year	Bridge	PCU						Capacity	VCR
			Pax	Bus	2-axle truck	3+ axle truck	Trailer	Total		
Route1	2025	Vavarovsky	19,200	7,392	5,445	717	12,153	44,907	27,500	1.63
		Mykolaiv	12,555	5,519	2,892	418	6,836	28,220	70,000	0.40
	2040	Vavarovsky	30,647	9,998	6,200	1,115	18,911	66,871	27,500	2.43
		Mykolaiv	20,041	7,464	3,293	650	10,637	42,085	70,000	0.60
	2055	Vavarovsky	48,916	13,499	7,055	1,735	29,426	100,631	70,000	3.66
		Mykolaiv	31,987	10,077	3,747	1,012	16,552	63,376	70,000	0.91
Route2	2025	Vavarovsky	18,002	6,764	4,987	709	11,976	42,437	27,500	1.54
		Mykolaiv	13,754	6,147	3,350	425	7,013	30,689	70,000	0.44
	2040	Vavarovsky	28,734	9,148	5,678	1,103	18,635	63,298	27,500	2.30
		Mykolaiv	21,954	8,313	3,815	662	10,913	45,657	70,000	0.65
	2055	Vavarovsky	45,862	12,352	6,461	1,717	28,997	95,389	27,500	3.47
		Mykolaiv	35,041	11,224	4,341	1,030	16,981	68,617	70,000	0.98
Route3	2025	Vavarovsky	18,466	7,018	5,162	709	12,001	43,357	27,500	1.58
		Mykolaiv	13,289	5,893	3,174	425	6,988	29,770	70,000	0.43
	2040	Vavarovsky	29,475	9,492	5,878	1,103	18,674	64,623	27,500	2.35
		Mykolaiv	21,212	7,970	3,615	662	10,874	44,332	70,000	0.63
	2055	Vavarovsky	47,046	12,816	6,689	1,717	29,058	97,326	27,500	3.54
		Mykolaiv	33,857	10,760	4,113	1,030	16,920	66,681	70,000	0.95
Route4	2025	Vavarovsky	20,098	8,034	5,736	729	12,482	47,080	27,500	1.71
		Mykolaiv	11,657	4,876	2,600	405	6,507	26,046	70,000	0.37
	2040	Vavarovsky	32,081	10,866	6,532	1,135	19,423	70,037	27,500	2.55
		Mykolaiv	18,607	6,595	2,961	630	10,125	38,919	70,000	0.56
	2055	Vavarovsky	51,205	14,672	7,433	1,766	30,223	105,298	27,500	3.83
		Mykolaiv	29,699	8,905	3,369	981	15,755	58,709	70,000	0.84

9 Study on the Slope Stability at the Bridge Construction Site

9-1 Overview

The JICA Survey Team focuses on the slope stability at the bridge construction site on Routes 2 and 3, the more promising choices compared with the other Routes. The thoughts of the JICA Survey Team are based on additional information obtained from the geological survey conducted during the 2011 F/S and this Study in 2018, as well as a joint field survey conducted with the Public Works Research Institute of Japan in February 2019 ("the 2019 Survey").

As a result of the 2019 Survey, both routes contain active and potential areas in which landslide activity does or may occur. Therefore, the complementary survey (shown in the Table 9-1) were carried out in order to study the stability of the slope and countermeasures.

In addition, the result of the 2019 Survey also adopts a policy of excluding active areas highly susceptible to landslides from the locations in which to build bridge piers and abutments.

Table 9-1. Quantity of Complementary Survey

Survey item	Route 2	Route 3	Remarks
Boring survey	3 holes (25m × 3 holes) Hole No.1 ℓ=25 m Hole No.2 ℓ=25 m Hole No.3 ℓ=25 m	3 holes (25m × 3 holes) Hole No.4 ℓ=25 m Hole No.5 ℓ=25 m Hole No.6 ℓ=25 m	✓ All core boring ✓ The boring depth should be the level achieving the expected supporting layers ✓ Inserting groundwater level monitoring hole and pipe strain gauge after drilling
Groundwater level measurement	3 holes × 12 months	3 holes × 12 months	✓ Including six months after the snow-melting season
Pipe strain gauge measurement	3 holes × 12 months	3 holes × 12 months	✓ Including six months after the snow-melting season
Measurement of the movement between two points	4 points × 12 months	4 points × 12 months	✓ Including six months after the snow-melting season ✓ Measuring by a ground extensometer or two-point measurement pile ✓ Using a continuous pile for the section with uncertain deformation
Moving pile measurement	2 traverse lines × 12 months	1 traverse line × 12 months	✓ Including six months after the snow-melting season

9-2 Complementary Survey Results and Landslide Countermeasures

Necessary measures for preserving road structures were examined based on the complementary survey (geological survey and monitoring) results. Basic design policy of the countermeasures based on the present landslide analysis and the slope stability analysis in each route are shown below.

9-2-1 Route 2

1) Landslide analysis

・As a result of geological survey, the sand layer observed at about GL 24 to 27 m of Br-11, BR-8, Br-2 and Br-12 has a layer thickness of about 3 m and a horizontally continuous sedimentary layer. This layer is continuously observed till the plateau on the upper slope.

・The geologic layer above this sand layer is the loam and clay layer, and no disorder was found due to the secondary movement.

・Therefore, the ground higher than the horizontal sand layer is likely to be a geologically stable ground, since there is no history of landslide movement.

・On the lower slope, the sand layer mentioned above is not confirmed from the topographical position.

・Landslide activity may become apparent in the future in the range of landslide block A with a width of about 60m. This landslide block has step topography on the head area and spring water from the side area affected by gully erosion.

・In the monitoring results, remarkable change which showed signs of landslide movement was not recognized.

Table 9-2. Monitoring result of Landslide(Route 2)

Devive	№	Location	Value of movement	Tendency of movement	Class
Extesometer	S-1	Upper	Accumulation +5.3mm Ave.1.5mm/month	Temporary tension moving – tension moving	c
	S-2	Upper	Accumulation -0.4mm	Compression→tension, theft in July 2019	d
Pipe Strain Gauge	Br-11	Lower	363μ-s (-14m)	Cumulative deformation only at the beginning of monitoring but subsequently calms down	c - d
	Br-12	Upper	440μ-s (-23m)		
	Br-13	Plateau	139μ-s (-22m)		
Ground water	Br-11	Lower	Around GL-19m	Constant depth	d
	Br-12	Upper	Around GL-24m	Constant depth	
	Br-13	Plateau	No water	-	
Moving pile	P-1	Center	No moving	-	d
	P-2	Upper	No moving	-	

・Considering comprehensively, no clear landslide moving has occurred as of July 2019. In terms of comprehensive evaluation, this is equivalent to a landslide with a latent moving of class “c”, and it is evaluated as “continuous observation is necessary”.

・Bridge structures are planned outside the assumed landslide block. However, it is better to take preventive measures for landslide areas that may affect bridge structures for the future.

2) Design policy of the countermeasure work

When landslide block A is activated, extrusion of soil mass to the pier (main tower) is expected. In addition, although the groundwater level has not been confirmed in the landslide mass on the main survey line, spring water is recognized from the sand layer on the side of this landslide block. Therefore, it is better to stabilize by combining drainage water method. From the result of geological survey, it is assumed that landslide is not existed from the middle to upper slopes However, in consideration of the long-term stability of the ground during and after construction of the abutment, it is better to set a structure that protects the abutment on the valley side. As other small scale landslide blocks are expected to have little impact on this route, it is considered that there is no need for countermeasures. For the longtime stability, it is necessary to consider the prevention of erosion of Gully and the riverbank.

3) Countermeasure works

Countermeasure works are shown in Figure 9-1.

The steel pipe pile work and groundwater drainage work will secure a predetermined planned safety factor Fs> 1.2 for the landslide block A. In addition, gabion works will have the function for prevent the gully erosion. And the sheet pile at the front ground of the abutment will keep the stability of the ground around the abutment structures.

9-2-2 Route 3

1) Landslide analysis

・As a result of geological survey, it was confirmed that there is a possibility of moving of several landslide blocks with different head positions in the soil above the limestone basement layer.

・Monitoring result of the case of pipe strain gauges, some ground movements were identified at specific depths. In particular, GL-15m of Br-14 matches the depth of the assumed slip surface, and GL-6m of Br-15 has accumulated ground deformation exceeding 1600μs. This movement is match to the Type "c" as presence of a slip surface not confirmed and continuous observation necessary. The possibility of a sliding surface connecting these two points was assumed. In addition, this landslide surface is corresponded to the assumed third-order slide, and it calls it "landslide block B" hereafter.

・The measuring instruments other than pipe strain gauges did not measure clear data indicating signs of landslides, but distortion occurred at an unexpected depth in July-September at a depth of 12 m at Br-16. Depending on the progress of the project, it is suggested to excavate Br-17 on the flat surface behind Br-16 and check for any changes related to the same period.

・ In terms of comprehensive evaluation, this is equivalent to a landslide with a latent moving of class “c”, and it is evaluated as “continuous observation is necessary”.

Table 9-3. Monitoring result of Landslide(Route 3)

Device	№	Location	Value of movement	Tendency of movement	Class
Extesometer	S-3	Upper	Accumulation -4.6mm Ave.-1.3mm/month	Accumulation only June	c
	S-4	Lower	Accumulation -10.7mm Ave.-2.7mm/month	Tension→No moving →Compression	b
Pipe Strain Gauge	Br-14	Center	824μ-s(-15m)	Cumulative moving is up to early June. Later the moving was subsided.	c
	Br-15	Upper	1593μ-s(-6m)		
	Br-16	Plateau	1545μ-s(-12m)	The accumulation strain from July to September is remarkable.	
Ground water	Br-14	Center	Around GL-20m	Constant depth	d
	Br-15	Upper	No water	-	
	Br-16	Plateau	Around GL-15 m	Constant depth	
Moving pile	P-3	Center	No moving	-	d

・The data of pipe strain gauge indicate the possibility of minor landslide moving. However, the bridge structure is not planned the point which is directly affected by landslides.

・It is necessary to consider long-term stabilization measures for landslide areas, including the areas where deformation has been occurred.

・In addition, as explained in Chapter7,river bank erosion is progression both Route 2 and 3. And it is considered to be an immediate cause of landslides. To account for that, riprap and river bank protection shall be installed on river banks within the maximum landslide block.

2) Design policy of the countermeasure work

・The largest landslide block C of width 150m, and the other landslide blocks are included in the block C.

・On the cross-sectional view, first, second, third(Block B), and fourth-order slips(Block C) are continuous in a positional relationship.

・The countermeasure construction should consider for the fourth-order slip which is the most influential when the scale is large activity.

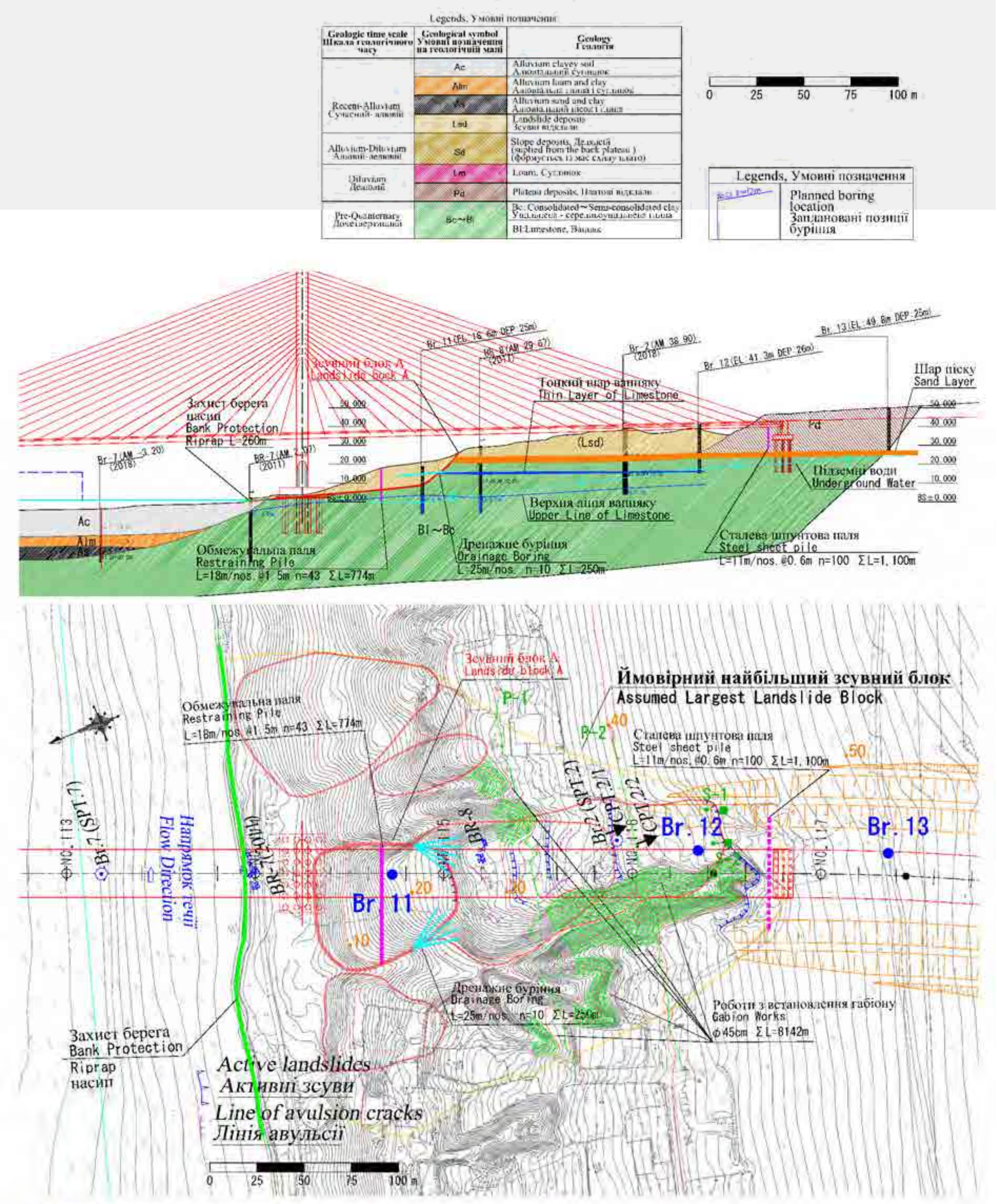
・And the check work of the countermeasure effect is needed. The effect to the third-order landslide which is currently moving should be checked.

・The main countermeasure work is steel pipe piling work. Groundwater level is not observed in landslide block, but groundwater drainage work should be considered for drainage effect for during excess water in rainfall.

3) Countermeasure works

Countermeasure works are shown in Figure 9-2.

The steel pipe pile work and groundwater drainage work will secure a predetermined planned safety factor Fs> 1.2 for the landslide block C. In addition, it was confirmed that the safety factor Fs> 1.2 can be secured by this measures also for the landslide block B.



Legends, Умовні позначення

● :Boring locations (Nos. 11 - 13)
позиції буріння (№11 - 13)

● ● :Observation of Displacement Stake（P-1,2）
Спостереження зміщення палі（P-1,2）

■ :Observation of Extensometer（S-1～4）
Спостереження екстензометра（S-1～4）

:Restraining Pile Обмежувальна паля

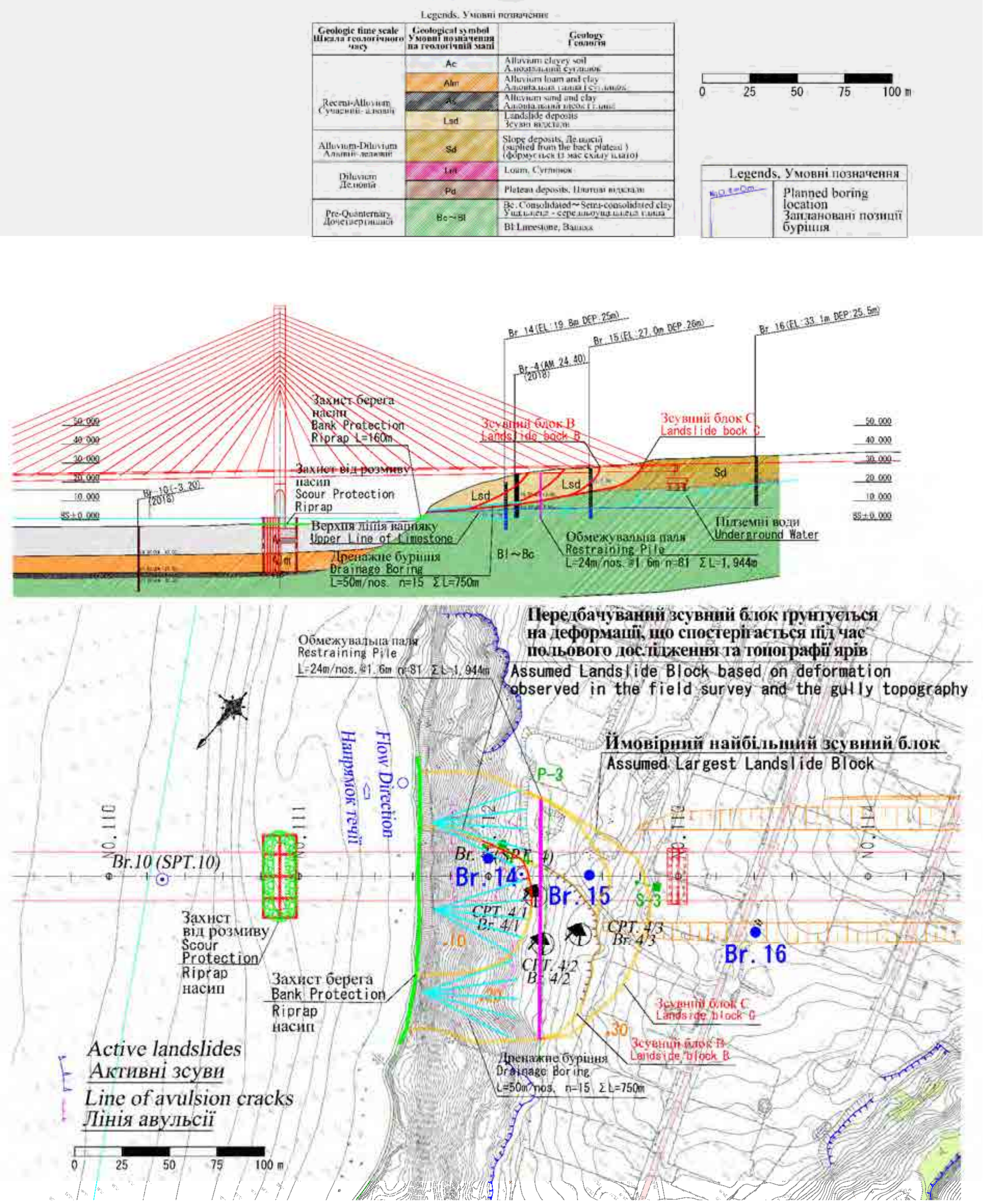
:Steel Sheet Pile Сталева шпунтова паля

:Drainage Boring Дренажне буріння

▨ **:Gabion Works Роботи з встановлення габіону**

:Bank Protection(Riprap) Захист берега (насип)

Figure 9-1. Map of Landslide Countermeasures for Route 2



Legends, Умовні позначення

● **:Boring locations (Nos. 14 - 16)**
позиції буріння (№14 - 16)

:Observation of Displacement Stake（P-3）
Спостереження зміщення палі（P-3）

:Observation of Extensometer（S-5～8）
Спостереження екстензометра（S-5～8）

:Restraining Pile Обмежувальна паля

:Drainage Boring Дренажне буріння

:Bank Protection(Riprap) Захист берега (насип)

Figure 9-2. Map of Landslide Countermeasures for Route 3

10 Environmental and Social Considerations

Policies for additional studies of environmental and social considerations are shown below.

10-1 Additional Survey Policy for Route 2

For Route 2, the Cabinet of Ministers of Ukraine approved the 2012 F/S (TEO) in 2013, and the need to conduct the study again depends on the types of changes as shown in Section 3-2. The procedure for conducting the studies again is the same as those for the case of Route 3, which is explained later, so the policy here is for the case in which studies do not need to be conducted again. If the studies do not need to be conducted again, then the Law of Ukraine on Environmental Impact Assessment (2017) does not apply, and the procedure required by Ukraine is for Ukravtodor to create documents related to environmental and social considerations based on project plans, designs and the like from the Project (P) stage. The items to be discussed in Project (P) are essentially the same as those from the 2012 F/S (TEO), but because the Project (P) stage requires more highly precise discussion than the F/S (TEO) stage, an impact assessment must be conducted in line with the most updated laws and regulations about the environment, mitigation measures, environmental management plans and environmental monitoring plans must be drafted. In addition, because the roles of relevant organizations were not clarified in EIA 2011 and EIA 2012, and because seven years have passed since the last stakeholder meetings were held, it is important to hold stakeholder meetings again to clarify the scope of responsibilities for relevant organizations.

These actions are also necessary to satisfy the requirements in JICA Guidelines for Environmental and Social Considerations (2010).

10-2 Additional Survey Policy for Route 3

Although the origin of Route 3 is the same as that for Route 2, which was approved by the Cabinet of Ministers in 2013, the route of the bypass and the location of Mykolaiv Bridge are different. In addition, Route 3 passes through the residential area on the right bank of the Southern Bug River and would require the demolition of dozens of houses and the relocation of their inhabitants; significantly, the 2012 F/S (TEO) makes no mention of this. Therefore, the selection of Route 3 would result in environmental and social impacts not discussed in the 2012 F/S (TEO). In light of this fact, the possibility of undergoing the F/S (TEO) procedure again has been suggested, and in that case, the new F/S (TEO) procedure is subject to the Law of Ukraine on Environmental Impact Assessment (2017).

The requirements of the Law of Ukraine on Environmental Impact Assessment, which are generally equivalent to the requirements of JICA Guidelines for Environmental and Social Considerations (2010); the requirements of the JICA guidelines are more comprehensive. Therefore, most of the additional survey policy for Route 2 created to comply with JICA Guidelines for Environmental and Social Considerations also applies to Route 3. However, the following differences in additional survey policy must be noted.

- EIA based on the Law on Environmental Impact Assessment must be conducted in addition to F/S (TEO). Submit the Letter of Intent and the EIA Study Report to NENR.
- Compensation for loss of residence facilities will be added to the resettlement action plan (RAP), which will result in the diversification and increase in the scale of PAPs. In addition, there is likely a definite number of landowners and residents who will unexpectedly become PAPs. Suddenly publicizing a Letter of Intent could cause confusion in communities; therefore, it is necessary to proceed carefully with meetings with local stakeholders in an effort to create an understanding of the need for the construction of Route 3.
- Changing from Route 2 to Route 3 will have an impact on the development plan for Mykolaiv City; therefore, the required procedures and the schedule for them must be confirmed.

11 Review of the Construction and Procurement Plans

11-1 Policy for Construction Conditions

Ukraine has constructed a number of track records of concrete and steel bridges, which are constructed mainly by the local companies and seems to be capable of constructing them. Accordingly, this project will actively make use of the local technologies of the country.

11-2 Policies for Construction Methods and Schedule

1) Policy for construction methods

Methods based on Japanese technology will be actively adopted to build infrastructures with high quality up to Ukrainian standards. Where multiple Japanese technologies are applicable, methods that optimally exploit local equipment and materials will be adopted for effective transfer of technology.

The Southern Bug River is used as an inland waterway route, with barges and hydrofoils navigating the waters daily throughout most of the year, except in winter, when the river is frozen. Therefore, the construction method allows to keep the navigation clearance at all times will be adopted.

2) Policy for construction schedule

The construction schedule will take factors such as the individual workloads, construction procedures, critical paths and local weather conditions into consideration. In terms of weather conditions, the period with temperatures below freezing in winter will render outside work infeasible. From 2013 to 2018, notices of freezing in Mykolaiv Port lasted roughly three months from January to March. Also, with regard to safety measures, the 2011 F/S mentions that the Ukrainian labor law prohibits any work outside and/or in the river when the snow exceeds a prescribed depth. However, since it is currently unclear when construction will start, the construction period will be calculated as year-round and 3 months of work period will be added to the annual work schedule. On the other hand, member fabrication using the Japanese PCa method will take place indoors and thus be deemed year-round work.

11-3 Construction Plan for Route2

11-3-1 Temporary Construction Work

For the left bank approach, a temporary bridge is installed to facilitate construction of the substructure and steel girders. The structure of the temporary bridge at the main tower position must take into account the weight of the pile driver as well as the SPSP as its maximum weight. The temporary bridge must also be reinforced with diagonal or corner bracing to ensure stability under vibration when the SPSP construction is underway. The temporary bridge on the left bank approach will extend to P22. The barge is also used for constructing pile foundations and material carry-in.

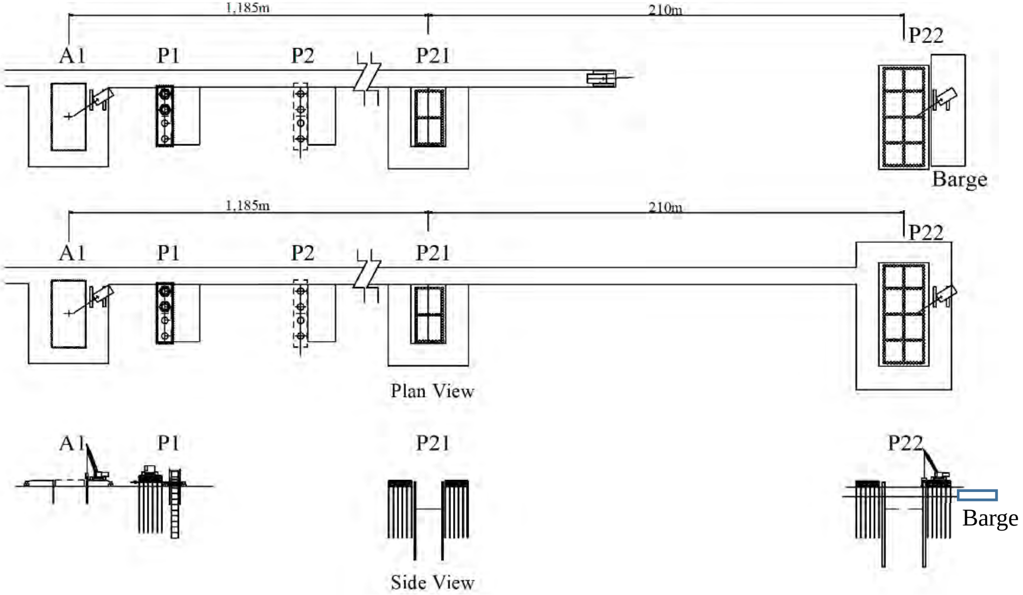


Figure 11-1. Reference Drawing for Temporary Construction on the Left Bank

Figure 11-2 shows the construction access road for transporting equipment/materials and ready-mixed concrete. As the A2 abutment is located at the top of a landslide, the landslide countermeasures (restraining pile, drainage pipe) determined based on the survey must be put in place before the start of construction in order to ensure construction safety.

Since the inclination of temporary load is about 12%, the temporary pavement needs for stable transportation.

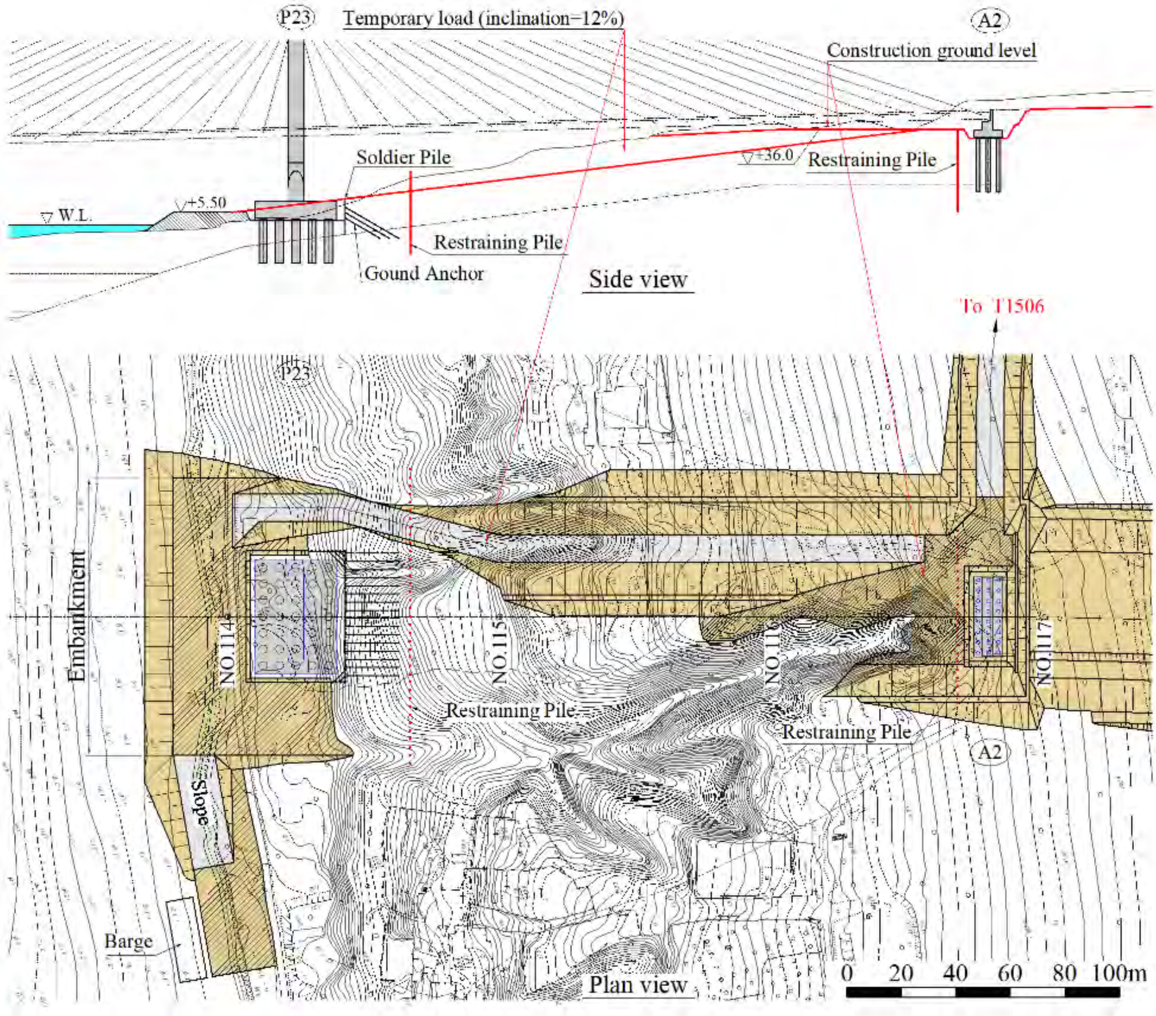


Figure 11-2. Reference Drawing for Temporary Construction on the Right Bank

11-3-2 Construction Procedure for Steel Girder and PC Slabs

Two proposals of PC slab construction were compared: a proposal to construct both girders and PC slabs simultaneously and a proposal to construct girders and PC slabs separately. As a result of the study, the proposal to construct girders and PC slabs separately, is selected as it is superior in terms of workability and safety.

11-3-3 Girder Election Method

The construction of cable-stayed bridges can be generally categorized into three types: piece-by-piece erection, medium-block erection, and large-block erection. Among these choices, large-block erection requires a large floating crane, which is not practical for application at the target site due to the massive costs for floating operation, etc. As a result of a comparative study on piece-by-piece erection versus medium-block erection, piece-by-piece erection (by traveler crane), is selected as it is superior in terms of workability, safety, and economic feasibility.

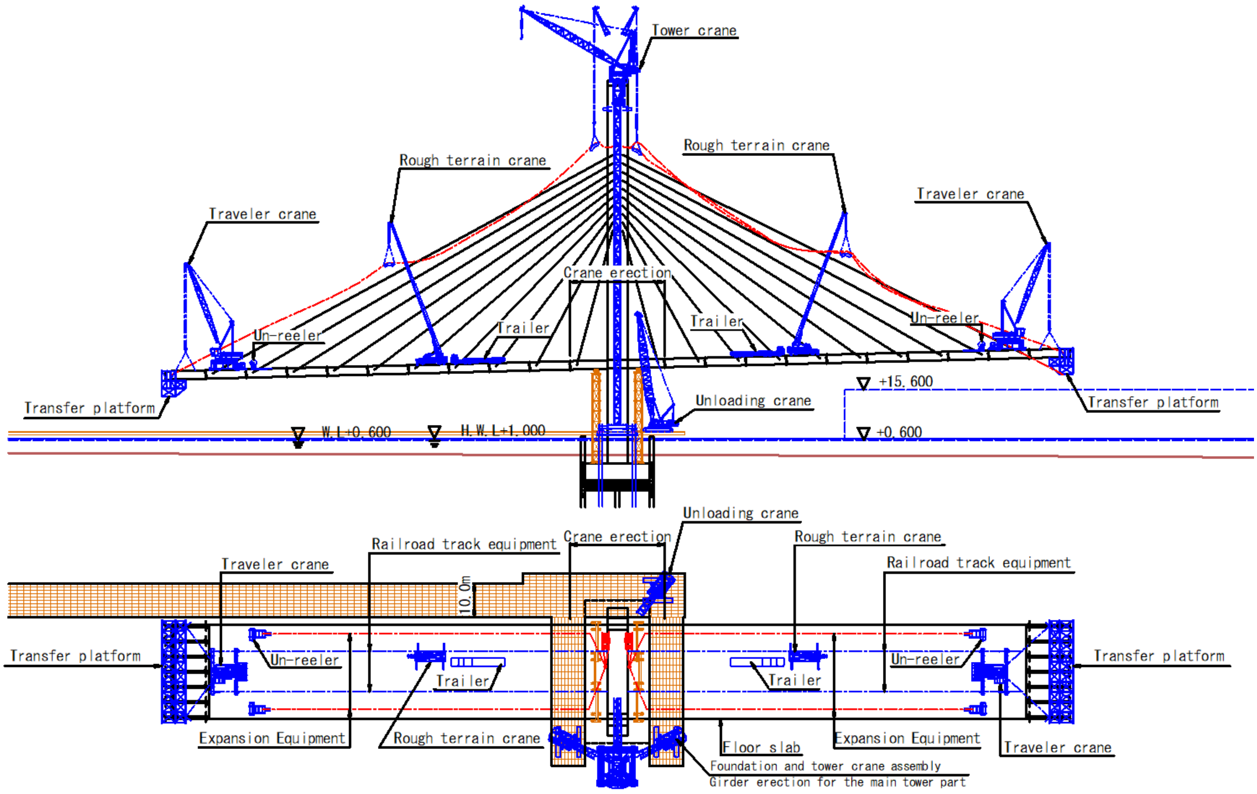


Figure 11-3.Girder Election Method (Piece-by-piece Erection)

11-3-4 Production of PC Well Members

The methods, equipment, and supervision of the PC Well Member production are all sufficient to satisfy the design strength and dimensional accuracy requirements. Fabrication by the match-casting method is adopted in order to prevent tension cracks when the PC wells are joined.

Since the temperature at the construction site can potentially fall to around -20°C between November and March, the construction period is scheduled for the seven months from April to October. Therefore, PCa members with high quality and durability (against salt/frost damage) is fabricated and stockpiled on site by setting up a simple factory near the bridge location in order to effective use of winter months.

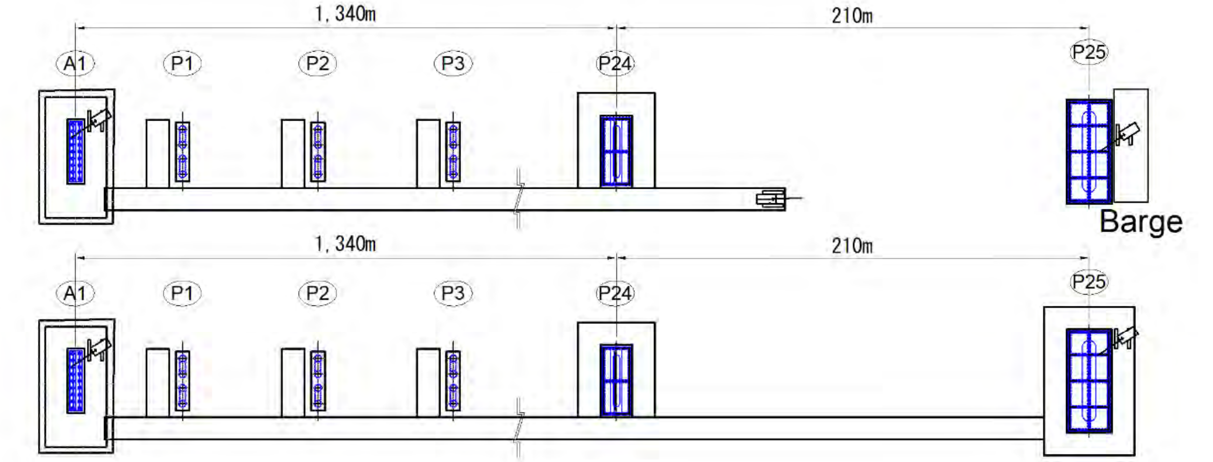
11-4 Construction Plan of Route 3

For the construction plan of Route 3, only contents that differ from Route 2 is described.

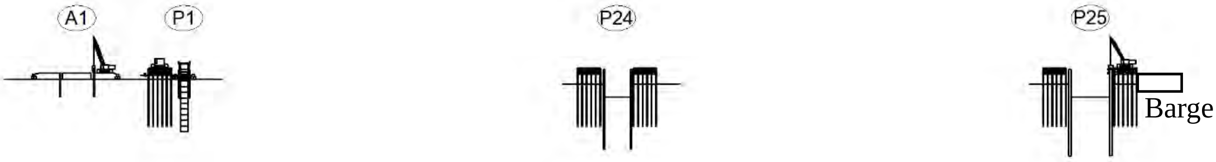
11-4-1 Temporary Construction Work

For the left bank approach, a temporary bridge will be installed to facilitate construction of the substructure and steel girders. The temporary bridge on the left bank approach will extend to the left bank main tower position (P25).

On the right bank, the riverbank has a steep slope and there is a large gully on the rear side. If a construction access road is set straight and perpendicular to the river bank, the gradient would be about 30%. For this reason, the construction access road will detour to a location upstream side where inclination is about 9%, and the temporary bridge will be built at P26. The barge is also used for constructing pile foundations and material carry-in.



Plan View



Side View

Figure 11-4. Left Bank Temporary Bridge

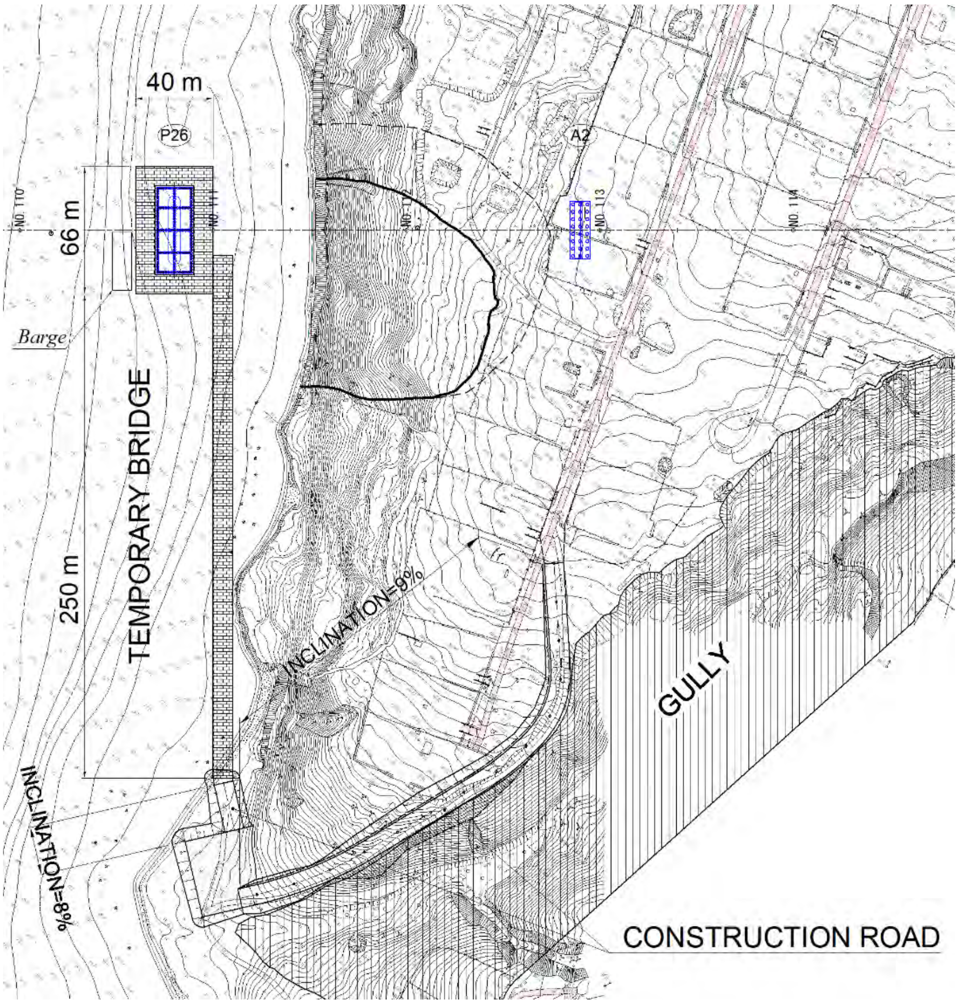


Figure 11-5. Right Bank Temporary Bridge and Construction Road

12 The Safety Measures during the Construction

12-1 Construction during the Freezing Period in Winter (December to February)

Since the construction in winter is done under the very severe conditions which are the low temperature and the strong wind. Ukrainian labor laws and regulations prohibit outdoor workers from continuing to work when the snowfall exceeds the standard volume. Work on frozen rivers is also prohibited. In this plan, it is necessary to prioritize the safety of workers under such severe weather conditions, and to develop the construction process with a margin that allows for a three-month winter outage.

12-2 Safety Measures in Construction of the Main Bridge (Superstructure and Substructure)

Because the construction of steel cable-stayed bridges, the main bridge in this project, typically involves aerial work at some 40 m above ground level at the present design, it is necessary to take sufficient measures to prevent serious disasters caused by a worker’s fall, falling of a building member itself or other dangers. In particular, to prevent third-party damage to ships navigating the river, shipping companies and construction officials should conduct discussions on river-passage planning and construction to promote understanding between them. It is also necessary to assign a patrol boat near the temporary bridge to prevent collisions. Because equipment specific to each construction method are operated, it is also essential to fully understand their unique characteristics, ensure that regular maintenance of all the construction equipment has to be performed, and be mindful to prevent equipment from being involved in any type of accident.

12-3 Safety Measures for Constructing the Approach Bridge (Substructure and Deck Slabs)

The PC well method of the precast (hereinafter PCa) method is applied for approach bridge substructures. PCa members were selected for the Project for two reasons: first, the members can be produced at a temporary factory during the winter season, when outdoor work is prohibited; second, the method is effective toward ensuring quality and shortening the construction period. First, the PCa members are to be brought on site and press-fitted using push-in frames by excavating the ground with a large crane and hammer grab. It is a special construction method that is being applied in Ukraine for the first time; therefore, safety should be taken into consideration for each process.

12-4 Safety Measures for Landslide Prevention Work

Based on the additional survey, the possibility of landslides cannot be ruled out. Therefore, it is proposed to take measures to prevent landslides prior to construction, considering the safety of workers during construction.

13 Project Operation and Maintenance Plans

13-1 Organization

Ukravtodor is a central executive agency that implements national road policy in the field of road transportation. Its activities are managed and coordinated by the Cabinet of Ministers of Ukraine through MoI. Ukravtodor locates its Head Office in Kyiv and has 24 branch offices, one in each oblast. The Head Office plans and manages international corridors; each branch office manages state roads within its oblast.

13-2 Technical Level

Ukravtodor itself is not such a large organization; it comprises numerous state-owned enterprises and operates in an environment in which it can assign the work of design, construction, construction supervision, and maintenance to these organizations and the other State Enterprises.

Regarding technical standards, proactive efforts have been made to establish Ukrainian standards by switching from SNiP and GOST used during the Soviet era to DBN design and construction standards after gaining independence, and the standards are updated as necessary.

Ukraine therefore seems to fulfill the technical standards necessary to implement normal road development projects. However, appropriate technical assistance is required for the Project because it includes a cable-stayed bridge with 420-m spans, and Ukraine has no experience with cable-stayed bridges with spans longer than 312 m.

13-3 Operation/Maintenance System

Since 2018, Ukravtodor only maintains State Roads and the bypass road of this Project belongs to State Road. The maintenance of State Roads is divided into daily maintenance and other maintenance.

Tenders are used to determine the subcontractors who actually perform both types of maintenance, but essentially all the daily maintenance are performed by PJSC (PUBLIC JOINT STOCK COMPANY) "DAK" Automobile roads of Ukraine, a subordinate organization of Ukravtodor.

The company performs maintenance totaling 4 billion UAH (equivalent to 3,000 km) each year, and performs maintenance on roads of general use of state and local importance in the length of for 170,000 km throughout Ukraine. The company has 24 branches (Oblastvodor) throughout Ukraine, and employs 19,000 skilled engineers, including over 5,000 engineers with both experience and skills.

However, at present, only eight of the company’s branch offices are stably managed, and although "Mykolayiv Oblastvodor," the Subsidiary Enterprise in the jurisdiction of Mykolaiv Oblast, has 24 management offices and 800 employees throughout the oblast, it outsources maintenance work because it does not have the materials and machinery required to perform the maintenance. In fact, it is facing management difficulties, as are many other branch offices.

Therefore, it cannot be said that Ukravtodor has developed the system of daily maintenance required after bypass road construction, and must restructure to make the following improvements in particular:

- Integration of workforce, funds and financial resources
- Optimization of network of production facilities
- Stabilization of financial situation and financial reconstruction
- Improvement of the quality and competitiveness of construction and services
- Improvement of the effectiveness of internal control and internal management
- Introduction of effective methods of corporate management

Nonetheless, Ukravtodor is directly outsourcing daily maintenance to private companies on a trial basis using financial support from the International Financial Institution (IFI) in an effort to reduce costs and streamline work, and should be able to use that system for bypass road maintenance.

14 Recalculation of Estimated Project Cost

14-1 Conditions for cost estimation

The following are the conditions for cost estimation.

- Base year/month for cost estimation: The unit price used in this estimation are as of June 2018.
- Exchange rates: The exchange rates used in this estimate are as shown below
  US$1.0＝108.06 JPY
  US$1.0＝26.50 UAH
  UAH1.0= 4.08 JPY
- Price escalation: Foreign currency: 0%, Local currency: 5.0%
- Physical contingency: Physical contingency is 10.0% of construction costs and 5% of engineering costs.
- Rate of interest during construction: Interest during construction is 0.1% of construction costs and 0.01% of engineering costs.
- Value added tax (VAT[6]): VAT is 20% as of June 2018.
- Import tax[7]: Since import tax for iron and cast iron products ranges from 0% to 5.0%, an import tax of 5.0% was used for calculation.
- Rate of administration cost: Administration cost of the project implementor is set at 5% of construction costs.
- Rate of Front end fee: Set at 0.2% of the ODA loan covered amount
- Scope of loans

Within scope	Outside scope
● Civil works ➢ Construction of the bridge over the Southern Bug River ➢ Construction of bypass road and Interchanges ➢ Construction of main route bridges ➢ Construction of overbridge at T1506 ➢ Construction of overbridge at P06 ➢ Construction of ramp bridge ➢ Construction of temporary yards ● Price escalation ● Physical contingency ● Engineering cost	● Land acquisition and resettlement ● Leasing construction yards ● Relocating utilities ● VAT (Value Added Tax) ● Import tax ● Other taxs

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[6] Tax Code of Ukraine; Article 193

[7] State Fiscal Service of Ukraine - http://sfs.gov.ua/baneryi/mitne-oformlennya/subektam-zed/stavki-vviznogo-ta-viviznogo-mita/eksportne-mito/

14-2 Expenses Borne by the Partner Country

14-2-1 Costs related to land acquisition and resettlement

The following tables show the costs related to land acquisition and resettlement.

Table 14-1. Summary of Land Acquisition Cost by Land use type

Land use type	Cost (UAH)	
	Route 2	Route 3
Agriculture	3,846,000	4,650,360
Artificial Forest	3,697,627	2,618,426
Road[*1]		
Residential	15,544	53,269
Others[*2]	5,712	70,918
Unknown[*3]	1,434,920	1,518,799
Total	8,999,803	8,911,771

*1: No compensation will be paid because the government owns the land

*2: Applied unit price of agricultural land

*3: Government-owned land not included

Table 14-2. Summary of Compensation Cost

Category	Unit	Route 2	Route 3
Number of affected buildings	bldgs.	26	60
Compensation cost	UAH	105,680,425	154,772,958

14-2-2 Cost of leasing construction yards and cost of relocating utilities

The Administration Cost includes the cost of leasing construction yards and the cost of relocating utilities.

14-3 Package

The Project was packaged in the following way and the cost estimation was carried out accordingly.

Package	Section
Package 1	Highyway & Interchange
Package 2	Main Bridge (Steel stayed-cable bridge)
Package 3	Approach Bridge

14-4 Route 2 cost estimation results and project schedule

1) Cost estimation results

Table 14-3 shows the total Project cost for Route 2, and Table 14-4 to Table 14-6 show the breakdown of estimated construction cost for each Package.

Table 14-3. Cost estimation result

Breakdown of Cost	Foreign Currency Portion (million JPY)			Local Currency Portion (million JPY)			Amount (million JPY)			Amount (million USD)		
	Total Cost	JICA Portion	Others	Total Cost	JICA Portion	Others	Total Cost	JICA Portion	Others	Total Cost	JICA Portion	Others
Package 1 / Highway & Interchange	4,323	4,323	0	7,642	7,642	0	11,965	11,965	0	111	111	0
Package 2 / Bridge-1 / Main Bridge	13,240	13,240	0	4,858	4,858	0	18,098	18,098	0	167	167	0
Package 3 / Bridge-2 / Approach bridge	10,071	10,071	0	6,098	6,098	0	16,169	16,169	0	150	150	0
Civil Works Sub Total	**27,634**	**27,634**	**0**	**18,598**	**18,598**	**0**	**46,232**	**46,232**	**0**	**428**	**428**	**0**
Price Escalation	0	0	0	8,632	8,632	0	8,632	8,632	0	80	80	0
Physical Contingency	2,763	2,763	0	2,723	2,723	0	5,486	5,486	0	51	51	0
Consulting Services	3,079	3,079	0	2,119	2,119	0	5,199	5,199	0	48	48	0
Interest during Construction	256	256	0	0	0	0	256	256	0	2	2	0
Front End Fee	132	132	0	0	0	0	132	132	0	1	1	0
Land Acquisition	0	0	0	596	0	596	596	0	596	6	0	6
Administration Cost	0	0	0	3,307	0	3,307	3,307	0	3,307	31	0	31
VAT	0	0	0	6,415	0	6,415	6,415	0	6,415	59	0	59
Import Tax	0	0	0	1,520	0	1,520	1,520	0	1,520	14	0	14
Other Taxes	0	0	0	0	0	0	0	0	0	0	0	0
Total	**33,864**	**33,864**	**0**	**43,911**	**32,073**	**11,838**	**77,775**	**65,937**	**11,838**	**720**	**610**	**110**

Table 14-4. Cost Breakdown of Package 1/ Highway & Interchange

Package 1 / Highway & Interchange Loan Coverage Ratio 100

Item	Unit	Q'ty	Unit Price		Cost		Amount
			Foreign	Local	Foreign	Local	
			JPY	UAH	JPY	UAH	JPY
Road works	LS	1	383,536,000	1,050,938,599	383,536,000	1,050,938,599	4,668,986,000
Accessory works	LS	1	26,690,000	230,219,179	26,690,000	230,219,179	965,463,000
Main route bridge L=25m	LS	4	81,258,000	37,124,278	325,032,000	148,497,113	930,564,000
T1506 Bridge	LS	1	386,995,000	42,567,250	386,995,000	42,567,250	560,573,000
P06 Bridge	LS	1	150,300,000	73,556,506	150,300,000	73,556,506	450,244,000
Ramp Bridge	LS	1	153,761,000	82,657,389	153,761,000	82,657,389	490,816,000
Main route bridge (Culvert)	LS	1	0	6,964,159	0	6,964,159	28,398,000
Landslide countermeasures	LS	1	81,571,000	17,956,779	81,571,000	17,956,779	154,794,000
Bank protection	LS	1	0	3,340,089	0	3,340,089	13,620,000
Indirect cost	LS	1	1,933,550,750	209,842,737	1,933,550,750	209,842,737	2,789,234,000
General Expense	LS	1	850,406,000	0	850,406,000	0	850,406,000
Dispute Board	LS	1	30,878,145	7,572,375	30,878,145	7,572,375	61,756,290
Total					4,322,719,895	1,874,112,173	11,964,854,290

Table 14-5. Cost Breakdown of Package 2/ Main Bridge

Package 2 / Bridge-1 / Main Bridge Loan Coverage Ratio 100

Item	Unit	Q'ty	Unit Price		Cost		Amount
			Foreign	Local	Foreign	Local	
			JPY	UAH	JPY	UAH	JPY
Factory fabrication (Girder, cable, bearing)	LS	1	4,215,446,000	0	4,215,446,000	0	4,215,446,000
Material transportation	LS	1	630,021,000	0	630,021,000	0	630,021,000
Main girder erection	LS	1	399,964,000	98,084,578	399,964,000	98,084,578	799,927,000
On-site painting	LS	1	7,090,000	745,021	7,090,000	745,021	10,128,000
Cable installation	LS	1	323,062,000	184,859,939	323,062,000	184,859,939	1,076,872,000
Bridge surface	LS	1	321,351,000	56,838,159	321,351,000	56,838,159	553,122,000
Bearing installation	LS	1	1,200,000	294,281	1,200,000	294,281	2,400,000
Equipment consumption cost of transportation priod	LS	1	195,262,000	0	195,262,000	0	195,262,000
Main tower works	LS	1	1,653,930,000	284,728,840	1,653,930,000	284,728,840	2,814,979,000
Deck slab	LS	1	1,425,244,000	140,644,716	1,425,244,000	140,644,716	1,998,756,000
Substructure	LS	1	348,948,000	72,320,035	348,948,000	72,320,035	643,850,000
Scour protection	LS	1	0	2,120,049	0	2,120,049	8,645,000
Temporary bridge	LS	1	114,504,000	112,321,155	114,504,000	112,321,155	572,520,000
Indirect cost	LS	1	2,284,104,000	230,872,238	2,284,104,000	230,872,238	3,225,540,000
General Expense	LS	1	1,288,567,000	0	1,288,567,000	0	1,288,567,000
Dispute Board	LS	1	30,878,145	7,572,375	30,878,145	7,572,375	61,756,290
Total					13,239,571,145	1,191,401,387	18,097,791,290

Table 14-6. Cost Breakdown of Package 3/ Approach Bridge

Package 3 / Bridge-2 / Approach bridge Loan Coverage Ratio 100

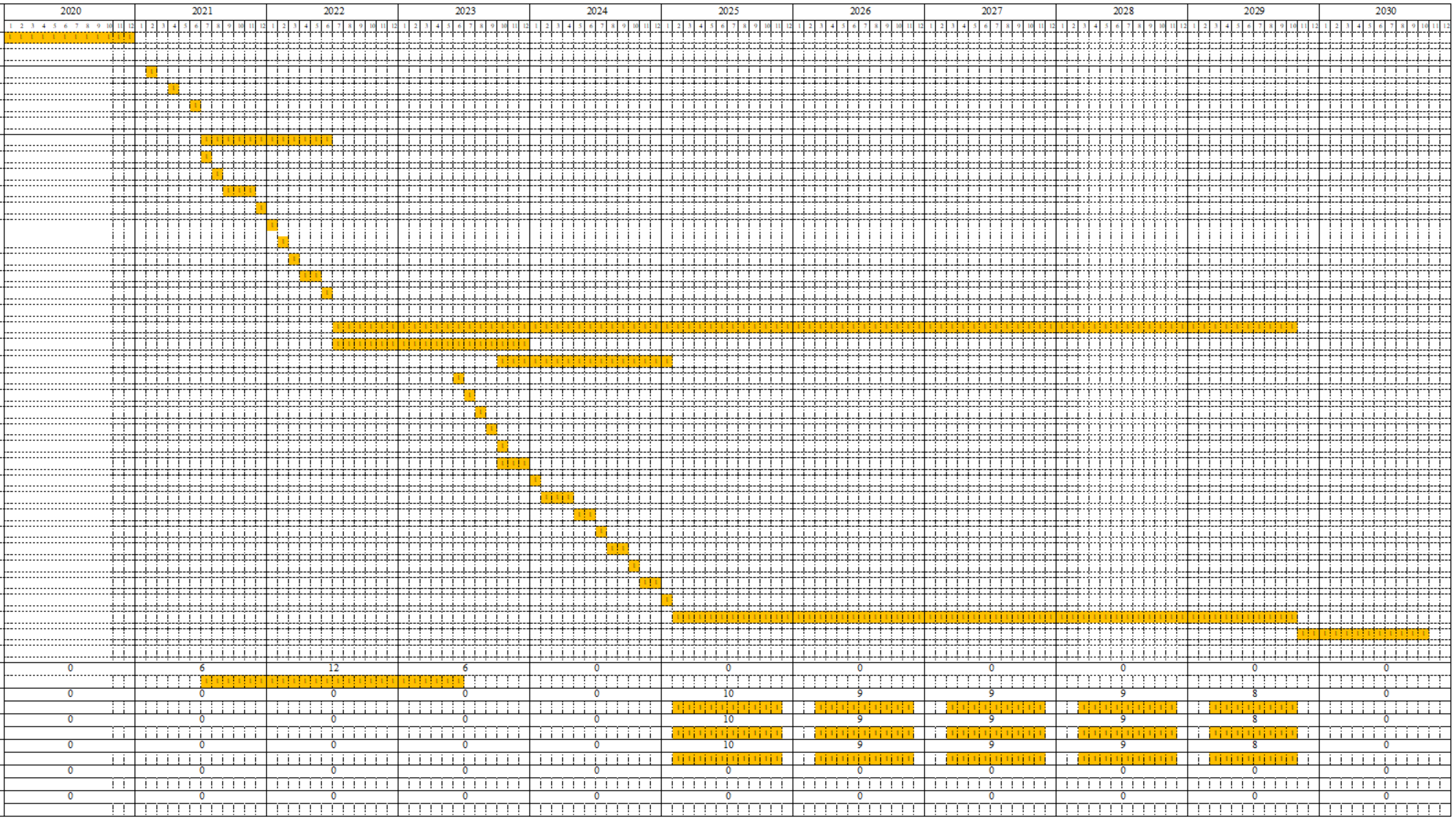
Item	Unit	Q'ty	Unit Price		Cost		Amount
			Foreign	Local	Foreign	Local	
			JPY	UAH	JPY	UAH	JPY
Factory fabrication (Girder, bearing)	LS	1	2,438,520,000	0	2,438,520,000	0	2,438,520,000
Material transportation	LS	1	524,037,000	0	524,037,000	0	524,037,000
Main girder erection	LS	1	184,340,000	105,481,575	184,340,000	105,481,575	614,466,000
On-site painting	LS	1	41,819,000	23,929,456	41,819,000	23,929,456	139,397,000
Bridge surface	LS	1	408,303,000	72,390,908	408,303,000	72,390,908	703,494,000
Bearing installation	LS	1	5,700,000	1,397,835	5,700,000	1,397,835	11,400,000
Deck slab	LS	1	747,972,000	183,428,262	747,972,000	183,428,262	1,495,944,000
Substructure	LS	1	1,857,220,000	455,453,729	1,857,220,000	455,453,729	3,714,440,000
Temporary bridge	LS	1	423,096,000	415,030,316	423,096,000	415,030,316	2,115,480,000
Indirect cost	LS	1	2,258,536,000	230,785,180	2,258,536,000	230,785,180	3,199,617,000
General Expense	LS	1	1,150,791,000	0	1,150,791,000	0	1,150,791,000
Dispute Board	LS	1	30,878,145	7,572,375	30,878,145	7,572,375	61,756,290
Total					10,071,212,145	1,495,469,636	16,169,342,290

2) Project schedule

Table 14-7 shows the Project schedule for Route 2.

Table 14-7. Project Schedule

Implementation Schedule



	Month	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Preparation of Feasibility Study (TEO)	12											
	0											
Appreisal	1											
Pledge	1											
Signing of Loan Agreement	1											
	0											
Procurement of Consultant	12											
- Preparation of RFP	1											
- No Objection by JICA	1											
- Advertising	3											
- Technical Bid Evaluation	1											
- No Objection by JICA	1											
- Price Bid Evaluation	1											
- No Objection by JICA	1											
- Contract Negotiation	2											
- No Objection by JICA	1											
	0											
Consulting Services	88											
Detailed Design	18											
Tender Assistance	16											
- Preparation of PQ Documents	1											
- No Objection by JICA	1											
- PQ Advertising	1											
- PQ Evaluation	1											
- No Objection by JICA	1											
- Preparation of Bid Documents	3											
- No Objection by JICA	1											
- Advertising	3											
- Technical Bid Evaluation	2											
- No Objection by JICA	1											
- Price Bid Evaluation	2											
- No Objection by JICA	1											
- Contract Negotiation. Preoration for Contract/Commencement of works	2											
- No Objection by JICA	1											
Construction Supervision	57											
Defect Notification Period (DNP)	12											
	0											
Land Acquisition/ Utility relocation	24	0	6	12	6	0	0	0	0	0	0	0
Package 1 / Highway & Interchange	45	0	0	0	0	0	10	9	9	9	8	0
Package 2 / Bridge-1 / Main Bridge	45	0	0	0	0	0	10	9	9	9	8	0
Package 3 / Bridge-2 / Right bank side approach bridge	45	0	0	0	0	0	10	9	9	9	8	0
Package 4	0	0	0	0	0	0	0	0	0	0	0	0
Package 5	0	0	0	0	0	0	0	0	0	0	0	0

14-5 Route 3 cost estimation results and project schedule

1) Cost estimation results

Table 14-8 shows the total Project cost for Route 3, Table14-9 to Table 14-11 show the breakdown of estimated construction cost for each Package.

Table 14-8. Cost estimation result

Breakdown of Cost	Foreign Currency Portion (million JPY)			Local Currency Portion (million JPY)			Amount (million JPY)			Amount (million USD)		
	Total Cost	JICA Portion	Others	Total Cost	JICA Portion	Others	Total Cost	JICA Portion	Others	Total Cost	JICA Portion	Others
Package 1 / Highway & Interchange	4,999	4,999	0	8,393	8,393	0	13,392	13,392	0	124	124	0
Package 2 / Main Bridge	11,693	11,693	0	4,783	4,783	0	16,476	16,476	0	152	152	0
Package 3 / Approach bridge	11,719	11,719	0	6,114	6,114	0	17,834	17,834	0	165	165	0
Civil Works Sub Total	**28,411**	**28,411**	**0**	**19,290**	**19,290**	**0**	**47,701**	**47,701**	**0**	**441**	**441**	**0**
Price Escalation	0	0	0	8,953	8,953	0	8,953	8,953	0	83	83	0
Physical Contingency	2,841	2,841	0	2,824	2,824	0	5,665	5,665	0	52	52	0
Consulting Services	3,079	3,079	0	2,119	2,119	0	5,199	5,199	0	48	48	0
Interest during Construction	264	264	0	0	0	0	264	264	0	2	2	0
Front End Fee	136	136	0	0	0	0	136	136	0	1	1	0
Land Acquisition	0	0	0	851	0	851	851	0	851	8	0	8
Administration Cost	0	0	0	3,418	0	3,418	3,418	0	3,418	32	0	32
VAT	0	0	0	6,637	0	6,637	6,637	0	6,637	61	0	61
Import Tax	0	0	0	1,563	0	1,563	1,563	0	1,563	14	0	14
Other Taxes	0	0	0	0	0	0	0	0	0	0	0	0
Total	**34,732**	**34,732**	**0**	**45,656**	**33,187**	**12,469**	**80,388**	**67,919**	**12,469**	**744**	**629**	**115**

Table 14-9. Cost Breakdown of Package 1/ Highway & Interchange

Package 1 / Highway & Interchange Loan Coverage Ratio 100

Item	Unit	Q'ty	Unit Price		Cost		Amount
			Foreign	Local	Foreign	Local	
			JPY	UAH	JPY	UAH	JPY
Road and interchange	LS	1	400,061,000	1,211,010,763	400,061,000	1,211,010,763	5,338,243,000
Accessory works	LS	1	26,957,000	238,036,753	26,957,000	238,036,753	997,608,000
Main route bridge L=25m	LS	5	81,258,000	37,124,278	406,290,000	185,621,391	1,163,205,000
T1506 Bridge	LS	1	386,995,000	42,567,250	386,995,000	42,567,250	560,573,000
P06 Bridge	LS	1	150,300,000	73,556,506	150,300,000	73,556,506	450,244,000
Main route bridge L=50m	LS	1	131,328,000	61,433,847	131,328,000	61,433,847	381,839,000
Landslide countermeasures	LS	1	345,363,000	1,246,770	345,363,000	1,246,770	350,447,000
Bank protection	LS	1	0	2,059,967	0	2,059,967	8,400,000
Indirect cost	LS	1	2,168,226,000	235,196,942	2,168,226,000	235,196,942	3,127,297,000
General Expense	LS	1	952,366,000	0	952,366,000	0	952,366,000
Dispute Board	LS	1	30,878,145	7,572,375	30,878,145	7,572,375	61,756,290
Total					4,998,764,145	2,058,302,562	13,391,978,290

Table 14-10. Cost Breakdown of Package 2/ Main Bridge

Package 2 / Main Bridge Loan Coverage Ratio 100

Item	Unit	Q'ty	Unit Price		Cost		Amount
			Foreign	Local	Foreign	Local	
			JPY	UAH	JPY	UAH	JPY
Factory fabrication (Girder, cable, bearing)	LS	1	3,143,631,000	0	3,143,631,000	0	3,143,631,000
Material transportation	LS	1	500,131,000	0	500,131,000	0	500,131,000
Main girder erection	LS	1	326,592,000	80,091,259	326,592,000	80,091,259	653,183,000
On-site painting	LS	1	5,789,000	608,426	5,789,000	608,426	8,270,000
Cable installation	LS	1	205,637,000	117,667,995	205,637,000	117,667,995	685,456,000
Bridge surface	LS	1	294,654,000	51,457,723	294,654,000	51,457,723	504,485,000
Bearing installation	LS	1	1,200,000	294,281	1,200,000	294,281	2,400,000
Equipment consumption cost of transportation priod	LS	1	195,262,000	0	195,262,000	0	195,262,000
Main tower	LS	1	1,764,300,000	289,447,881	1,764,300,000	289,447,881	2,944,592,000
Deck slab	LS	1	1,287,317,000	127,033,976	1,287,317,000	127,033,976	1,805,328,000
Substructure	LS	1	358,345,000	73,856,427	358,345,000	73,856,427	659,512,000
Scour protection	LS	1	0	4,240,098	0	4,240,098	17,290,000
Temporary bridge	LS	1	201,576,000	197,733,259	201,576,000	197,733,259	1,007,880,000
Indirect cost	LS	1	2,205,653,000	222,877,360	2,205,653,000	222,877,360	3,114,488,000
General Expense	LS	1	1,172,103,000	0	1,172,103,000	0	1,172,103,000
Dispute Board	LS	1	30,878,145	7,572,375	30,878,145	7,572,375	61,756,290
Total					11,693,068,145	1,172,881,060	16,475,767,290

Table 14-11. Cost Breakdown of Package 3/ Approach Bridge

Package 3 / Approach bridge Loan Coverage Ratio 100

Item	Unit	Q'ty	Unit Price		Cost		Amount
			Foreign	Local	Foreign	Local	
			JPY	UAH	JPY	UAH	JPY
Factory fabrication (Girder, bearing)	LS	1	2,670,509,000	0	2,670,509,000	0	2,670,509,000
Material transportation	LS	1	560,037,000	0	560,037,000	0	560,037,000
Main girder erection	LS	1	195,752,000	112,011,915	195,752,000	112,011,915	652,507,000
On-site painting	LS	1	47,338,000	27,087,336	47,338,000	27,087,336	157,793,000
Bridge surface	LS	1	444,811,000	81,399,338	444,811,000	81,399,338	776,736,000
Bearing installation	LS	1	8,400,000	2,059,967	8,400,000	2,059,967	16,800,000
Deck slab	LS	1	1,014,970,000	165,936,693	1,014,970,000	165,936,693	1,691,616,000
Substructure	LS	1	2,547,219,000	422,455,270	2,547,219,000	422,455,270	4,269,880,000
Temporary bridge	LS	1	434,184,000	425,906,941	434,184,000	425,906,941	2,170,920,000
Indirect cost	LS	1	2,495,481,000	254,997,145	2,495,481,000	254,997,145	3,535,292,000
General Expense	LS	1	1,269,687,000	0	1,269,687,000	0	1,269,687,000
Dispute Board	LS	1	30,878,145	7,572,375	30,878,145	7,572,375	61,756,290
Total					11,719,266,145	1,499,426,979	17,833,533,290

2) Project schedule

Table 14-12 shows the Project schedule for Route 3.

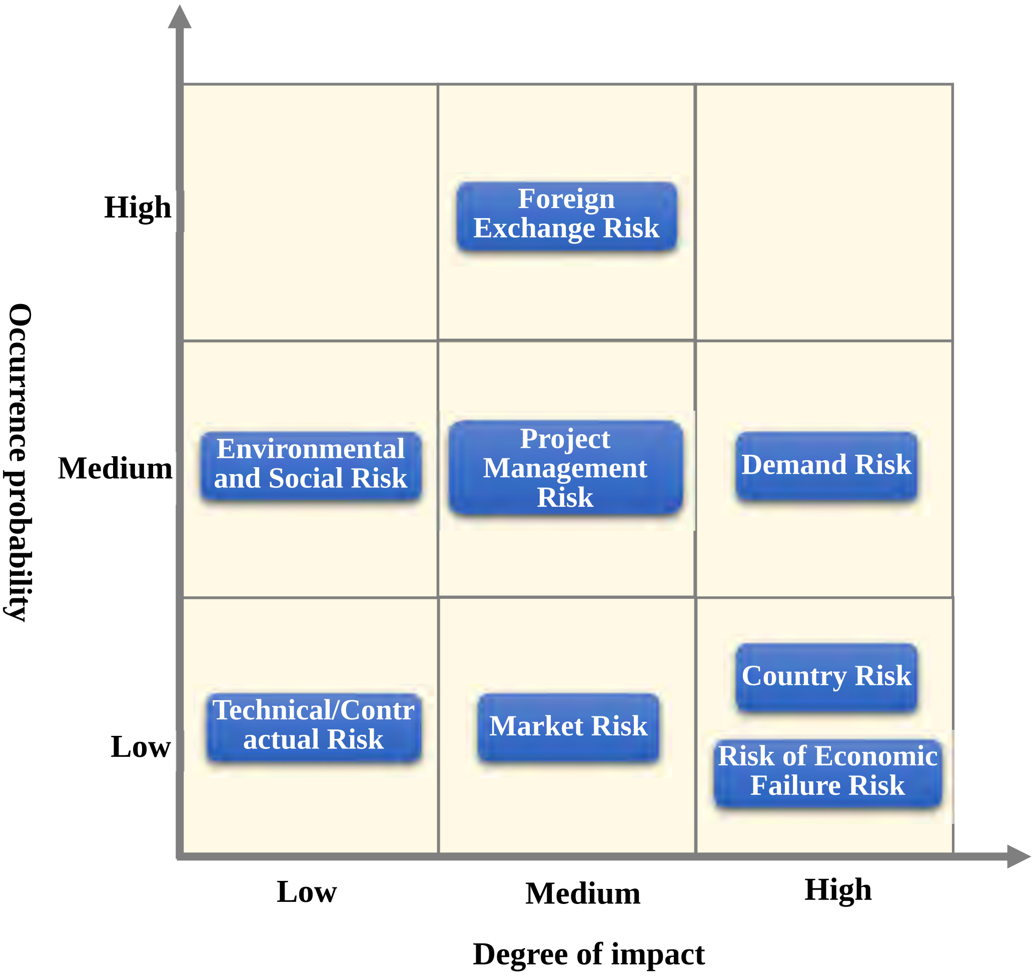
Table 14-12. Project Schedule

Implementation Schedule

	Month	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Preparation of Feasibility Study (TEO)	12											
	0											
Appreisal	1											
Pledge	1											
Signing of Loan Agreement	1											
	0											
Procurement of Consultant	12											
- Preparation of RFP	1											
- No Objection by JICA	1											
- Advertising	3											
- Technical Bid Evaluation	1											
- No Objection by JICA	1											
- Price Bid Evaluation	1											
- No Objection by JICA	1											
- Contract Negotiation	2											
- No Objection by JICA	1											
	0											
Consulting Services	88											
Detailed Design	18											
Tender Assistance	16											
- Preparation of PQ Documents	1											
- No Objection by JICA	1											
- PQ Advertising	1											
- PQ Evaluation	1											
- No Objection by JICA	1											
- Preparation of Bid Documents	3											
- No Objection by JICA	1											
- Advertising	3											
- Technical Bid Evaluation	2											
- No Objection by JICA	1											
- Price Bid Evaluation	2											
- No Objection by JICA	1											
- Contract Negotiation. Preoration for Contract/Commencement of works	2											
- No Objection by JICA	1											
Construction Supervision	57											
Defect Notification Period (DNP)	12											
	0											
Land Acquisition/ Utility relocation	24	0	6	12	6	0	0	0	0	0	0	0
Package 1 / Highway & Interchange	45	0	0	0	0	0	10	9	9	9	8	0
Package 2 / Bridge-1 / Main Bridge	45	0	0	0	0	0	10	9	9	9	8	0
Package 3 / Bridge-2 / Right bank side approach bridge	45	0	0	0	0	0	10	9	9	9	8	0
Package 4	0	0	0	0	0	0	0	0	0	0	0	0
Package 5	0	0	0	0	0	0	0	0	0	0	0	0

15 Review of Project Risk Analysis

This is a review of the risk analysis conducted for the 2011F/S. The risk analysis will be updated in response to the results of investigations during this study.



Source: Figure was modified by reference to "Project Management Handbook, JICA, 2007".

Figure 15-1. Risk Occurrence Probability/Impact Matrix

16 Consideration of Cost Reduction Effects

Tables 16-1 and 16-2 show the cost reductions obtained by reviewing the road cross-section of bridge and structure types adopted in the 2011F/S.

Conditions for the cost estimation are shown in 14-1.

The condtions are significantly different from the one in 2011. For example, Ukrainian Hryvnia's exchange rate against U.S. dollar was approx. 8 UAH compared with the current rate of 26.5 UAH.

Therefore, the costs under 2011F/S shown in the table below are not those calculated in the 2011F/S; instead, they are the costs recaluculated in this Study.

As shown in the tables, cost reductions are 83 million USD for Route2 and 75 million USD for Route3.

Main factors of cost reduction regarding road cross-section of bridge, main bridge type and foundation type of approach bridge are reduction in the width of the median, change of bridge type and change of foundation type respectively.

Table 16-1.Cost Reduction of Route2

Item	Result of Study and Cost		Cost Reduction
	2011F/S*	Route2	
Road Cross-section of Bridge	Approach Bridge Section L=1,230m, W=28.8m 178 Million USD	Approach Bridge Section L=1,185m, W=26.3m 156 Million USD	22 Million USD
Main Bridge Type	Steel Suspension Bridge L=820m,W=28.8m 211 Million USD	Steel Cable-stayed Bridge L=930m, W=26.3m 158 Million USD	53 Million USD
Foundation Type Of Approach Bridge	Steel Pipe Pile Foundation (Multi Pile-bent Method) L=1,230m 57 Million USD	PC Well Foundation (Single Pile-bent Method) L=1,185m 49 Million USD	8 Million USD
Total of Cost Reduction	-	-	83 Million USD

*: The Costs are not those calculated in the 2011F/S; instead, they are the costs recaluculated in this Study.

Table 16-2.Cost Reduction of Route3

Item	Result of Study and Cost		Cost Reduction
	2011F/S*	Route3	
Road Cross-section of Bridge	Approach Road Section L=1,230m, W=28.8m 178 Million USD	Approach Road Section L=1,340m, W=26.3m 177 Million USD	1 Million USD
Main Bridge Type	Steel Suspension Bridge L=820m, W=28.8m 211 Million USD	Steel Cable-stayed Bridge L=840m, W=26.3m 138 Million USD	73 Million USD
Foundation Type Of Approach Bridge	Steel Pipe Pile Foundation (Multi Pile-bent Method) L=1,230m 58 Million USD	PC Well Foundation (Single Pile-bent Method) L=1,340m 57 Million USD	1 Million USD
Total of Cost Reduction	-	-	75 Million USD

*: The Costs are not those calculated in the 2011F/S; instead, they are the costs recaluculated in this Study.

17 Economic and Financial Analysis

17-1 Financial Analysis

17-1-1 Basic Policy

In this Study, it is not determined that toll collection is applied or not as of June 30 2019, therefore, financial analysis is implemented under the assumption that toll collection is applied.

As the evaluation indexes of the Project, Financial Internal Rate of Return (FIRR) on the Project is calculated to judge the viability to carry out commercial undertaking.

17-1-2 Financial Costs (Construction Cost, Maintenance Cost)

As with the economic costs, the financial costs are calculated based on the construction cost and maintenance cost described in Chapter 14. The basic precondition for financial costs are as follows:

- Implementation schedule: Year 2020-2029 for construction period, operation start from year 2030
- VAT and import tax: Included
- Inflation: Not considered.
- Resettlement and compensation costs: Considered.
- Standard conversion factor: Not applicable.

17-1-3 Revenue

Revenue is calculated from the number of vehicles passing through Mykolaiv Bridge multiplying by toll by the type of vehicles.

1) Toll by the Type of Vehicles

The following table shows PCU and toll structure defined in 2011F/S.

Table 17-1. PCU and Assumed Toll Structure (2011F/S)

Vehicle type	PCU	Toll structure（UAH/vehicle）			
		Free	Toll-1	Toll-2	Toll-3
Passenger cars	1.0	0	10	20	30
2ax-trucks	2.0	0	15	30	45
3ax + trucks	2.5	0	20	40	60
Trailers	3.0	0	30	60	90

In the table shown above, there is poor correlation between PCU and toll structure for 3+ trucks. The PCU of 3+ trucks are the median value of 2-axle trucks and trailers, however the tolls are not the median value. Other vehicle types such as passenger cars, 2-axle trucks and trailers are correlated between PCU and toll structure. In this Study, the toll structure for the type of vehicles is corrected to correlate with PCU. PCU is also revised for this Study.

When conducting the financial analysis, it is required to determine the most appropriate toll structure considering suitable traffic demand and maximizing the revenue.

The following toll structures were examined based on the equation of conversion rate applied to estimate future traffic demand in Chapter 8.

The revenue was maximum when the case of toll-3 was applied. Therefore, the toll-3 was adopted for this Study.

Table 17-2. PCU and Toll Structures

Vehicle type	PCU	Toll structure（UAH/vehicle）				
		Toll-1	Toll-2	Toll-3	Toll-4	Toll-5
Passenger cars	1.0	5	10	15	20	25
2-axle trucks	2.0	10	20	30	40	50
3-axle + trucks	3.0	15	30	45	60	75
Trailers	4.0	20	40	60	80	100

17-1-4 Financial Internal Rate of Return (FIRR)

If estimated FIRR exceed the weighted average capital cost (WACC), it is evaluated that the Project is feasible.

The WACC of the Project is 4.0 percent for Route 2 and Route 3.

17-1-5 Financial Analysis Case

In this Study, the financial analysis was conducted for the following cases that varied in the cost to be considered. The setting of revenue was same for all cases.

Case 1: Total cost for the financial analysis is included.
Case 2: Cost for the loan potion such as construction and consultant cost and cost for the borrower finance portion such as land acquisition and tax are not included. However, the operation and maintenance cost is included.

17-1-6 Financial Analysis Result

1) Financial Analysis Result for Route 2

(1) Estimation of FIRR for Route 2

FIRR was estimated based on revenue and financial costs for Route 2.

a) Case 1

The financial analysis was evaluated to compare with the estimated FIRR and the social discount rate. The estimated FIRR of -9.4% was substantially below the WACC of 4%, therefore, the project is concluded as financially unfeasible.

b) Case 2

The estimated FIRR 5.3% for Case 2 was exceed the WACC. Therefore, the project is concluded as financially feasible.

2) Financial Analysis Result for Route 3

(1) Estimation of FIRR for Route 3

a) Case 1

The results of the financial analysis for Case 1 of Route 3 was almost same compare with those of Route 2. The estimated FIRR of -9.8% was substantially below the WACC of 4%, therefore, the project is concluded as financially unfeasible.

b) Case 2

For the financial analysis for Case 2 of Route 3, the project is concluded as financially unfeasible. The estimated FIRR of 4.7% was substantially below the WACC of 4%.

3) Sensitivity Analysis for Case 2

Table 17-3. Sensitivity Analysis (Route 2)

FIRR		Revenue		
		100%	90%	80%
Costs	100%	5.3%	4.4%	3.4%
	110%	4.5%	3.6%	2.6%
	120%	3.8%	2.9%	1.8%

Table 17-4. Sensitivity Analysis (Route 3)

FIRR		Revenue		
		100%	90%	80%
Costs	100%	4.7%	3.9%	2.8%
	110%	3.9%	3.0%	2.0%
	120%	3.2%	2.3%	1.2%

17-2 Economic Analysis

17-2-1 Basic Policy

Overall goal of the Project is to secure the function of the M-14 as a part of the Europe-Asia Corridor (Eurasian Corridor) and to improve the civil life of Mykolaiv. Considering the goal, this Study conducts Economic Analysis of the Project is examined by comparing two cases: the case in which the Project is implemented ("With Project"), and the case in which the Project is not implemented ("Without Project"). "With Project" is the case that Mykolaiv Bridge is constructed and "Without Project" is the case that Mykolaiv Bridge is not constructed.

17-2-2 Economic Costs (Construction Cost, Maintenance Cost)

Economic costs are calculated based on the construction cost and maintenance cost described in Chapter 14. The basic precondition for economic costs are as follows:

- Implementation schedule: Year 2020-2029 for construction period, operation start from year 2030
- VAT and import tax: Not included
- Inflation: Not considered.
- Resettlement and compensation costs: Considered.
- Opportunity cost: Considered (It is assumed that the land which is currently used for agriculture, artificial forest, etc. will be developed as residential area.)
- Standard conversion factor (SCF): 0.97 for nontraded commodity. SCF is estimated based on total amount of import and export (past 5 years data) and total amount of import duty (5% of total amount of import which is set in Chapter 14).

17-2-3 Economic Benefits

The basic units were estimated based on updated data obtained from corrected information at the site survey in this Study and web search, etc.

1) Types of Benefits

Implementing the Project should deliver the following quantitative benefits:

- Reduction of vehicle operation cost (VOC)
- Reduction of travel time cost (TTC)

The non-quantifiable indirect benefits are presented below:

Benefit due to reduce traffic jam (improvement of VCR)

With securing altenate route, the taraffic jam in the city will be reduced.

Benefit due to increase an oppotunitiy of larage-scale maintenance and repair for Vavarovsky Bridge.

It is also increased an oppotunity of large-scale maintenance and repair for Vavarovsky Bridge due to secure altenate route.

Benefit due to improve roadside enviroment in the city (air pollusion, noise and vibration, etc.)

The roadside einviroment such as air pollusion, noise and vibration is improved in CBD because the traffic flow is ditributed, however those indicators might be worsend along newly developed corridor.

Benefit due to an increased inter-regional economic exchange

Mykolaiv Bridge will provide a stable transport route, which will thus boost transport and help extend inter-regional exchanges by not only faster and safer alternate route but also load limit of up to 54 metric ton against 24 metric ton on Vavalofsky Bridge.

Benefit through reduced traffic accidents

Once Mykolaiv Bridge is constructed and the vehicular travel environment is correspondingly improved, it will help users cross bridges more safely and thus reduce the number of traffic accidents.

2) Reduction of Vehicle Operation Cost (VOC)

(1) Calculating Reduction of VOC

The reduction of VOC is calculated by subtracting the operation cost in the Without Project case from the operation cost in the With Project case.

(2) Basic Units of Operation Cost by Vehicle Type

The basic units of operation cost were calculated from the costs of fuel, oil consumption and change, tires, maintenance and cost depreciation and general administrative expenses per kilometer driven by each type of vehicle.

Table 17-5. Basic Units of VOC

Unit: UAH/km

VOC	Passenger cars	Buses	2-axle truck	3+ axle Trucks	Trailers
Fuel cost	1.75	4.43	2.20	5.42	7.55
Oil cost	0.10	0.11	0.10	0.10	0.10
Tire cost	0.20	0.75	0.75	1.32	2.04
Insurance cost	0.14	0.04	0.07	0.04	0.04
Maintenance cost	0.61	0.68	0.68	1.52	1.52
Spare parts cost	0.20	0.20	0.24	0.16	0.19
Depreciation cost	2.80	1.50	3.49	2.53	4.07
Sub-total	5.79	7.72	7.54	11.09	15.52
Overhead cost	0.58	0.77	0.75	1.11	1.55
Total	6.37	8.49	8.29	12.20	17.07

3) Reduction of Travel Time Cost (TTC)

The reduction of TTC is calculated by converting into money the value of the vehicle operation time saved in the With Project case compared to the Without Project case.

The table below shows the basic units of TTC for each type of vehicle.

Table 17-6. Basic Units of TTC

(Unit: USD/veh.· time)

Vehicle type	Basic units of TTC
Passenger cars	2.58
Buses	32.62
2-axle trucks	26.55
3+ axle trucks	117.73
Trailers	64.03

4) Calculating Benefits

Benefits of the Project were calculated based on the results of calculations of the benefits delivered by the reduction of TTC and VOC.

(1) Establishing Overall Benefits for the Analysis Period

The total benefit was calculated for each year, with the operation start year for the Project as the starting point, and an analysis period of 30 years starting from that point.

(2) Social Discount Rate

The economic evaluation of the Project was conducted using the social discount rate of 8%.

(3) Calculating Present Value of Benefits

A social discount rate is used to convert various benefits throughout the analysis period into present values in the base year.

(4) Total Benefit

The total benefit is the total of the present values of all benefits.

(5) Economic Internal Rate of Return (EIRR)

EIRR is the discount rate where the economic costs and the benefit calculated into the net present value (NPV) become equal.

17-2-4 Economic Analysis Result

1) Economic Analysis Result for Route 2

(1) Estimation of EIRR for Route 2

The Project is concluded as economically feasible, because the estimated EIRR of 13.4% exceed the social discount rate of 8%.

(2) Sensitivity Analysis for Route 2

Table 17-7. Sensitivity Analysis (Route 2)

EIRR		Benefits		
		100%	90%	80%
Costs	100%	13.4%	12.5%	11.7%
	110%	12.6%	11.8%	11.0%
	120%	12.0%	11.2%	10.3%

2) Economic Analysis Result for Route 3

(1) Estimation of EIRR for Route 3

The project is concluded as economically feasible, because the estimated EIRR of 13.8% exceed the social discount rate of 8%.

(2) Sensitivity Analysis for Route 3

Table 17-8. Sensitivity Analysis (Route 3)

EIRR		Benefits		
		100%	90%	80%
Costs	100%	13.8%	12.9%	12.0%
	110%	13.0%	12.2%	11.3%
	120%	12.4%	11.6%	10.7%

When comparing Route 3 with Route 2 for the economic analysis, Route 3 is slightly more feasible than Route 2.

Both the benefits and cost of Route 3 exceed those of Route 2. However, in the case of the analysis for this Study, the difference in benefits between Routes 2 and 3 has a greater impact than the difference in costs, which renders Route 3 more feasible than Route 2.

17-3 Operation and Effect Indicators

In order to evaluate the achievements of the Project quantitatively, operation and effect are selected based on available data, validity and reliability in both the baseline year (year 2018) and two years after the completion of the Project.

Selected operation and effect indicators are summarized as follows.

17-3-1 AADT and Travel Time

AADT and travel time for 2018 (baseline year) and 2032 (two years after the completion of the Project) are shown in the following table.

Table 17-9. AADT and Travel Time (Proposal)

Year			2018	2032
AADT (Veh./day)	Vavarovsky Bridge	Passenger cars	40,046	23,512
		Bus	5,696	3,431
		2-axle trucks	4,574	2,891
		3-axle + trucks	299	134
		Trailers	3,053	1,337
	Mykolaiv Bridge	Passenger cars	-	16,534
		Bus	-	2,265
		2-axle trucks	-	1,683
		3-axle + trucks	-	165
		Trailers	-	1,716
Estimated Access Time (minutes)		Route A	37	30
		Route B	-	10

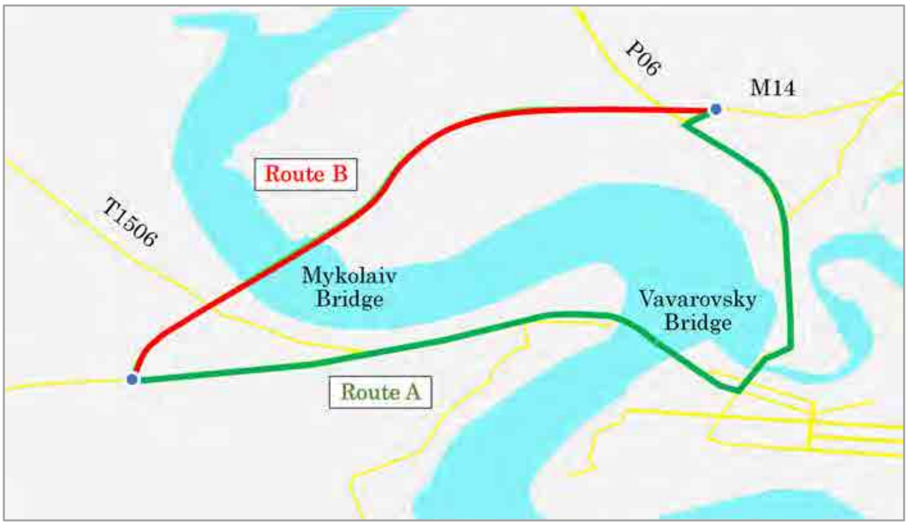


Figure 17-1. Selected Routes to Compare Access Time

17-3-2 Annual Passenger and Freight Volume

Annual passenger and freight volume for 2018 (baseline year) and 2032 (two years after the completion of the Project) are shown in the following table.

Table 17-10. Annual Passenger and Freight Volume (Proposal)

Year			2018	2032
Passenger Traffic Volume (thousand person/year)	Vavarovsky Bridge	Passenger cars	30,695	18,022
		Bus	41,581	25,046
		Total	72,276	43,068
	Mykolaiv Bridge	Passenger cars	-	12,673
		Bus	-	16,535
		Total	-	29,208
Freight Traffic Volume (thousand ton/year)	Vavarovsky Bridge	2-axle trucks	6,678	4,221
		3-axle + trucks	1,091	489
		Trailers	22,287	9,760
		Total	30,056	14,470
	Mykolaiv Bridge	2-axle trucks	-	2,457
		3-axle + trucks	-	602
		Trailers	-	12,527
		Total	-	15,586

Note)
- Assume the number of car passengers was 2.1 per a car
- Assume the number of bus passengers was 20.0 per a bus
- Annual passenger volume = AADT × car/bus passengers × 365 days

- Assume average load for one way trip of 2-axle trucks was 2.0 ton (50% of load capacity)
- Assume average load for one way trip of 3-axle + trucks was 4.0 ton (50% of load capacity)
- Assume average load for one way trip of Trailers was 10.0 ton (50% of load capacity)
- Annual freight volume = AADT × freight volume for one way trip × 2 (round trip)× 365 days

18 Survey of Obstructions and Partner Country Responsibilities

18-1 Buried Objects and Overhead Lines

The following obstructive buried objects and overhead lines will have to be relocated before the construction begins as one of partner country responsibilities.

Table 18-1. List of Obstructive Buried Objects and Overhead Lines

Obstructive Buried Objects	Sewerage Pipe, Gas Pipe, Communication Cable, Drainage Pipe, High-Voltage Electric Cable Low-Voltage Electric Cable
Overhead Lines	High-Voltage Power Line, Low-Voltage Power Line

18-2 Partner Country Responsibilities

The table below is a list required to implement Mykolaiv Bridge and Bypass Road, which should be coordinated under the responsibilities of Ukravtodor and the relevant authorities.

Table 18-2. List of Ukravtodor's Responsibilities

Responsibility	Description	Implementation Deadline
1.Provide and grade land for construction yards	Provide land for construction yards.	Announcement of P/Q
2. Select candidate locations for borrow areas and quarries	Select appropriate candidate locations for borrow areas and quarries.	Announcement of P/Q, or start of construction
3. Select candidate locations for waste disposal areas	Select appropriate candidate locations for waste disposal areas.	Announcement of P/Q
4.Land acquisition	Pay compensation or support money to parties impacted by bypass road construction according to the Resettlement Action Plan (RAP), and faithfully implement the required acquisition of land.	Announcement of P/Q
5.Relocation of obstacles	Relocate the obstacles	Announcement of P/Q
6.Obtain approval for the EIA, supervision of environmental management, etc.	Obtain approval for the EIA from MENR.	At least 120 days before signing the L/A
	Supervise the creation and implementation of environmental management plans by the construction contractor.	Plan: Before construction starts Implementation: During construction period
	Obtain the environmental monitoring report from the construction contractor and monitor that the environmental management plan is being implemented appropriately.	During construction period
7.Tax exemption process	Provide support so that tax exemption measures for customs, product service taxes (value added taxes (VAT)), income taxes and corporate taxes are implemented faithfully. The scope of tax exemption is defined by E/N	During detailed design period During construction period
8.Acquire construction permits, etc.	Provide support for registration of Permanent Establishment (PE) required by the MENR and the Ukrainian Tax Authority.	Start of construction work
	Acquire construction permits, etc. required to start construction work.	Announcement of P/Q
	Provide support for acquiring construction permits, etc. required during the construction period.	During construction period
9.Maintenance work	Perform maintenance work on the bypass roads.	After completion of construction (after handover)

ADDITIONAL STUDY
ON
THE PROJECT
FOR
CONSTRUCTION OF MYKOLAIV BRIDGE
IN UKRAINE

Final Report

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ABBREVIATIONS and ACRONYMS

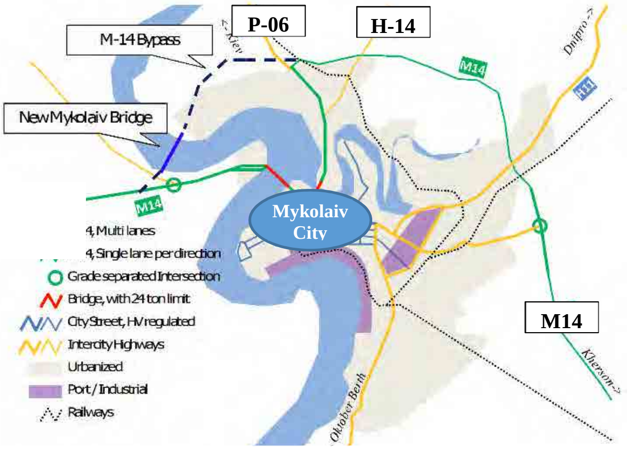
Organizations	
AASHTO	American Association of State Highway and Transportation Officials
C/P	Counterparts
EU	European Union
GOJ	Government of Japan
GOU	Government of Ukraine
IFI	International Financial Institution
IMF	International Monetary Fund
JICA	Japan International Cooperation Agency
MEDT	Ministry of Economic Development and Trade of Ukraine
MENR	Ministry of Ecology and Natural Resources of Ukraine
MoF	Ministry of Finance of Ukraine
MoI	Ministry of Infrastructure of Ukraine
MRA	Mykolaiv Region Administration
MRDBH	Ministry of Regional Development, Building and Housing of Ukraine
NGO	Non-Governmental Organization
Nibulon	Nibulon Ltd.
OSCE	Organization for Security and Co-operation in Europe
RCM	Regional Climate Models
SLC	State Land Committee
Ukravtodor	The State Agency of Automobile Roads of Ukraine
Ukrdiprodor	State Enterprise- Ukrainian State Institute for Design of Road Facilities
USSR	Union of Soviet Socialist Republics
WB	Word Bank
Technical Terms	
1989 F/S	The first feasibility study for the project conducted by Soviet Union in 1989
2000 F/S	The feasibility study for the project conducted by Japan in 2000
2003 F/S	The feasibility study for the project conducted by Japan in 2003
2004 F/S	The feasibility study for the project conducted by Ukraine in 2004
AADT	Annual Average Daily Traffic
AESUM	Analytical Expertise Bridge Management System
AHP	Analytic Hierarchy Process
B/C	Benefit/Cost
BS	Baltic System
Cabinet Resolution	Cabinet of Ministers of Ukraine Resolution

CBEs	Commercial and Business Enterprises
CBR	California Bearing Ratio
COD	Cut-Off Date
CPT	Cone Penetration Test
DBN, DSTU	Ukrainian Standard
DCFTA	Deep and Comprehensive Free Trade Agreement
EHS	Environmental, Health, and Safety
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
F/F	Fact Finding
F/S	Feasibility Study
FIDIC	International Federation of Consulting Engineers
FIRR	Financial Internal Rate of Return
FRP	Fiber Reinforced Plastics
G.L	Ground Level
GDP	Gross Domestic Product
GIS	Geographic Information System
GOST, SNiP	Russian Design Standard
GPS	Global Positioning System
GRM	Grievance Redress Mechanism
H.W.L	High Water Level
HCM	Highway Capacity Manual
HH	House Hold
IBA	Important Bird Area
IRI	International Roughness Index
IRP	Income Restoration Program
JBIC	Japan Bank for International Cooperation
JIS	Japanese Industrial Standards
L/A	Loan Agreement
M/D	Minutes of Discussion
MAC	Maximum Allowable Concentrations
MAL	Maximum Allowable Level
MSK	Medvedev-Sponheuer-Karnik
N/A	Not Applicable
NETIS	New Technology Information System
New Program	The State Target Economic Program for Development of Automobile Roads of the Public (General) Use of State Importance for the Period of 2018-2022
NPV	Net Present Value

O&M	Operation and Maintenance
OD	Origin-Destination
ODA	Official Development Assistance
OP	Operational Policies
P/Q	Prequalification
PAC	Public Cadastre Card
PAPs	Project Affected Persons
PAUs(PAHs)	Project Affected Units (Project Affected Households)
PC	Prestressed Concrete
PCa	Precast Concrete
PCU	Passenger Car Unit
PDCA	Plan-Do-Check-Action
PHC	Pretensioned Spun High Strength Concrete
Q&A	Question and Answer
QV	Quantity-Velocity
RAP	Resettlement Action Plan
RC	Reinforced Concrete
SBHS	Steels for Bridge High Performance Structure
SCF	Standard Conversion Factor
SEA	Strategic Environmental Assessment
SLSC	Standard Least Squares Criterion
SPSP	Steel Pipe Sheet Pile
SPT	Standard Penetration Test
STEP	Special Terms for Economic Partnership
TEM	Trans-European Motorway
The 2011F/S	Preparatory Survey on the Project for Construction of Mykolaiv Bridge in Ukraine, November 2011, JICA
The 2012F/S(TEO)	Feasibility study (TEO) created by Ukraine and approved by the cabinet of ministers of Ukraine in 2012
The 2017 Survey	Data Collection Survey on Logistics and Transport System in Southern Ukraine, June 2017, JICA
The 2019 Survey	A joint field survey conducted with the Public Works Research Institute of Japan in February 2019
The Project	The Project for Construction of Mykolaiv Bridge in Ukraine
This Study	Additional Study on the Project for the Construction of Mykolaiv Bridge in Ukraine
TMCP	Thermo-Mechanical Control Process
TOR	Terms of Reference
TTC	Travel Time Cost

UTM	Universal Transverse Mercator
VAT	Value Added Tax
VCR	Volume/Capacity Ratio
VOC	Vehicle Operation Cost
W/C	Water/Cement Ratio
WACC	Weighted Average Capital Cost
WD	Working Documentation
WGS	World Geodetic System
WL	Water Level
Currency	
JPY	Japanese Yen
UAH	Ukrainian Hryvnia
USD,US$	United States Dollar

Chapter 1 Background



Source: JICA Survey Team of the 2011F/S

1-1 Background

Mykolaiv City is the capital of Mykolaiv Oblast, which developed mainly around the shipbuilding industry. The city is located in the southern Ukraine and acts as a key hub of the Black Sea coast connecting Europe and Asia. The city is a transport hub uniting the P-06, H-14 and H-11, which run north and south and the M-14 that runs east and west within the major road network. It extends from the granary of inland areas to the ports of Odesa, Yuzhny and Ilichevsk. As the junction of the said road network, the city suffers from high traffic volumes. Around 35,000 vehicles, both large and of other types, are forced into the city center every day, causing serious traffic jams and declines in the quality of life for citizens.

There are two bridges constructed in 1964 over the rivers that traverse the city: the Vavarovsky Bridge over the Southern Bug River and the Ingul Bridge over the Ingul River. However, since both of the bridges are deteriorating, loaded vehicles weighing more than 24 tons are not permitted to cross them. The loading weight restriction has increased the cost of road transport via Mykolaiv City, exacerbating congestion and hindering smooth logistics. To streamline and expand the distribution network for grain and other products, the city expects a new bridge and an approach road that bypass the downtown area of the city immediately. It is worth noting that the importance of this work has been recognized for quite some time; the first feasibility study dealing with Mykolaiv Bridge Construction Project (hereinafter referred to as “the Project”) was conducted in 1989 by Kyivsoiuzshliakhproekt, which was assigned the study by the Government of Soviet Union.

Based on the Ukraine-European Union Association Agreement signed in June 2014, the Government of Ukraine (hereinafter referred as “GOU”) established “the Strategic Plan for Development of Road Transport and Road Infrastructure of Ukraine up to 2020” in December 2015, which highlights the importance of improving and modernizing road networks that take safety and the environment into consideration as a means of boosting the economy in Ukraine. The Project ensures smooth vehicle transportation in line with the plan and improves the road transport network in southern Ukraine. The Project is recognized as one of the priority projects among the five bypass projects under “The State Target Economic Program for Development of Automobile Roads of the Public (General) Use of State Importance for the Period of 2018-2022” (hereinafter referred to as “New Program”) that was formulated in 2018.

In response to the application the GOU presented to the Government of Japan (hereinafter referred as “GOJ”) for a Japanese ODA Loan for the Project in July 2005, the Japan International Cooperation Agency (hereinafter referred to as “JICA”) implemented a preparatory survey from October 2010 to October 2011 (hereinafter referred to as “the 2011F/S”). Based on the 2011F/S, GOU created a Feasibility Study (TEO) in 2012 (hereinafter referred to as “the 2012F/S (TEO)”). Subsequently, the Project described in the 2012F/S(TEO) was approved at a cabinet meeting of 2013. The change in the political situation in 2014, however, prevented the implementation of the Project at that time.

Considering continuous request for the Project from GOU after political change in 2014, JICA conducted a “Data Collection Survey on the Logistics and Transport System in Southern Ukraine” from October 2016 to June 2017 (hereinafter referred to as “the 2017 Survey”) under the latest situation, which was reflected drastic drop in trade with Russia. As a result, the need for the Project was reconfirmed as a means for facilitating logistics in the southern region of Ukraine.

1-2 Contents of the request by Ukraine

Construction of a bridge and approach road that bypass the downtown area of Mykolaiv City in Ukraine under a Japanese ODA Loan Project.

1-3 Study Objectives

Considering that approximately six years have elapsed since the 2011F/S, the main objectives of the Additional Study on the Project for the Construction of Mykolaiv Bridge in Ukraine (hereinafter referred to as "this Study") are as follows:

(1) Reassessment of the project cost (including land compensation and O&M costs) and reexamination of the implementation method (procurement and construction);
(2) Reconsideration of the applicability of the latest technologies; and
(3) Confirmation of the environmental and social considerations and other matters related to project implementation under the latest conditions.

1-4 Social and Economic Conditions

1-4-1 Social Conditions

1) Internal Affairs

The November 2013 decision to suspend negotiations for the Ukraine-European Union Association Agreement incited massive antigovernment and/or pro-European demonstrations. Clashes from February 18-20, 2014 claimed over 100 lives and resulted in the exile of President Viktor Yanukovych to Russia and the establishment of a new regime under Prime Minister Arseniy Yatsenyuk. In March of that year, Russia "annexed" the Autonomous Republic of Crimea in response to the illegal "referendum" carried out by "the government of the republic", but GOU announced its disapproval of Russia's actions as illegal occupation by military force. The situation became more unstable in the eastern part of the country as well, and armed insurgents and other groups occupied various facilities of regional governments. This ignited conflict between the Armed Forces of Ukraine and the armed insurgents. On May 25, 2014, a presidential election was held earlier than originally scheduled, and on June 7, Petro Poroshenko, former Minister of Economic Development and Trade, assumed the presidency. On October 27, an early election of the Verkhovna Rada (parliament) was held, and resulted in a pro-European ruling coalition consisting of five parties: Petro Poroshenko Bloc, People's Front, Self-Reliance, Radical Party and Fatherland. In December, the second Yatsenyuk Cabinet was formed. In April 2016, at the end of protracted negotiations over Cabinet formation, Prime Minister Yatsenyuk announced his intent to resign and was dismissed at the Cabinet of Ministers meeting. Volodymyr Groysman, the Chairman of the Cabinet of Ministers, became the new Prime Minister and established a new Cabinet. The 2019 presidential election was held on March 31 and Volodymyr Zelensky was inaugurated on May 20.

In the parliamentary election held on July 21, President Zelensky's "Servant of the People" party won 254 seats, achieving the first substantial single-party majority in the history of Ukraine's parliamentary election since its independence (as of July 26).

2) Diplomatic Relations

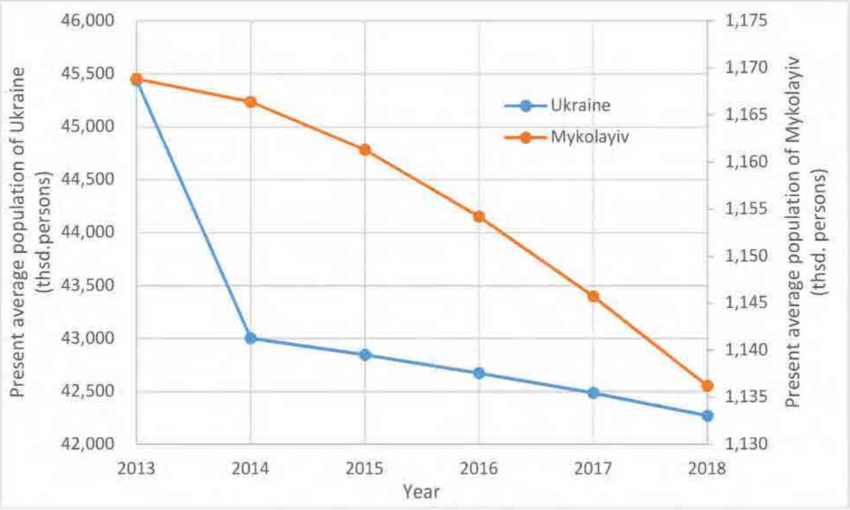
Following the establishment of a new government in February 2014 and the assumption of President Poroshenko in June of that year, GOU drove harder down the path toward joining the European Union, and eventually signed the Ukraine-European Union Association Agreement. The agreement went into effect in November 2014, and in January 2016, the provisional application of the Deep and Comprehensive Free Trade Agreement (DCFTA) between the EU and Ukraine began in January 2016. The current administration is aiming to apply to join the EU by 2020.

However, relations with Russia have deteriorated rapidly due to the "annexation" of Crimea and growing instability in the eastern part of the country. As for the situation in eastern Ukraine, on September 5 and September 19, 2014 and February 12, 2015, the Trilateral Contact Group on Ukraine that comprises Ukraine, Russia and OSCE signed the Minsk Protocol and Minsk II, which aimed to bring a resolution to the war and political issues. However, these agreements have not been completely fulfilled and Ukraine's instability continues. While following the Poroshenko administration's pro-European approach, the Zelensky administration also expressed the willingness for a dialogue with Russia, aiming to resolve the challenges that the country faces.

3) Population

The population estimates for both the entire country of Ukraine and the Mykolaiv Oblast show gradual decreases (see Figure 1-4-1). The United States Census estimates an increase in emigration, which is likely to cause further decreases. It is worth noting that the working-age population (people 15-64 years of age) of Ukraine has slowly decreased from around 70% of the entire population in 2013 to around 68% in 2017. (Note: The sharp decline between 2013 and 2014 in the figure below can be explained by the exclusion of the data on the Autonomous Republic of Crimea and the city of Sevastopol from the population statistics of Ukraine in 2014.)

Despite projections of future population decreases, GDP growth is expected to be roughly 3% per year as explained later in this report, and GOU continues to emphasize the export of agricultural products that is one of the key sectors in the Ukrainian economy. Furthermore, Southern Ukraine possesses ports that exports to the Middle East and northern Africa, the area growing population and economy. Based on this background, the increase in the volume of exports from Southern Ukraine is expected to continue.



Source : State Statistics Service of Ukraine (2018)

Figure 1-4-1. Population Trends

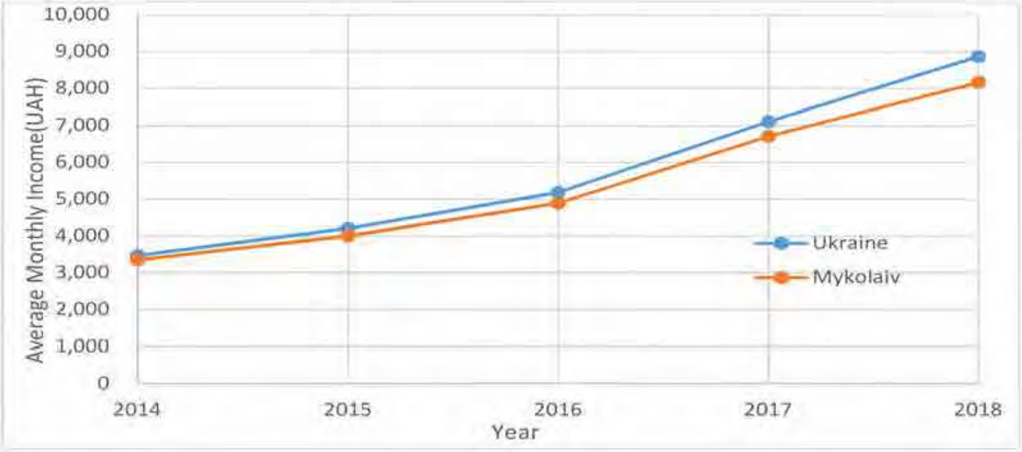
4) Education

Ukraine has a 4-5-2-5 (elementary school-junior high school-high school-university) system, and compulsory education lasts from age 6-7 to age 16-17 (first grade through 11th grade). Elementary, junior high and high schools are convened at the same school; barring transfers, students can stay at one school through high school.

In 2014, roughly 83% of high school students continued on to university.

5) Income

The figure below shows actual trends in average monthly incomes in Ukraine. The income level is increasing as a whole. However, as the table below shows, Adjusted Net National Income per Capita of Ukraine is still lower that the average of EU countries and neighboring countries.



Note:Excluding the temporarily occupied territories of the Autonomous Republic of Crimea, the city of Sevastopol and a part of temporarily occupied territories in the Donetsk and Luhansk regions.

Source : Ministry of Finance of Ukraine (2018)

Figure 1-4-2. Average Monthly Income Trends

Table 1-4-1. Adjusted Net National Income per Capita of Ukraine and Neighbor Country

Country	Adjusted Net National Income per Capita (2017)
Ukraine	2,333USD
European Union	28,096USD
Belarus	4,979USD
Poland	11,650USD
Romania	8,433USD
Moldova	2,302USD
Russian Federation	8,519USD

Source：World Bank

1-4-2 Economic Conditions

President Yanukovych, who assumed office in 2010, utilized the support from the IMF to reform the tax code, the national pension system and the land system in addition to implementing other economic reforms. In June 2012, Ukraine co-hosted the 2012 UEFA European championship with Poland, and the development of roads, airports and other infrastructure to capitalize on the event helped support the nation’s economy. Unfortunately, steel production—the nation’s leading industry—decreased that year, and decreased exports and other factors caused GDP growth to stagnate at 0.2%. In 2013, exports of steel, railways and the like to Russia flagged, and the growth rate was 0%.

In 2014, with the situation in the eastern part of the country growing worse, the value of trade and mining and industrial production decreased steeply, severely impacting the economy and resulting in negative economic growth. In addition, the unemployment rate rose from roughly 7% in the first half of the previous year to 9% in the same period in 2014. Concurrently, increasing foreign debt, decreasing foreign reserves and other factors contributed to progressing macroeconomic imbalances, and starting in April 2014, Ukraine received substantial support from the IMF, World Bank (hereinafter referred to as “WB”) and other international financial institutions as well as the Western nations. In March 2015, the IMF approved a new economic program that included grants to GOU of roughly 17.5 billion dollars over four years. The government used four installments of those funds to increase its foreign reserves, but in order to fulfill the conditions of the program, it is required to produce further results through reforms in the sectors of finance, taxation, national pension, energy, public service and more.

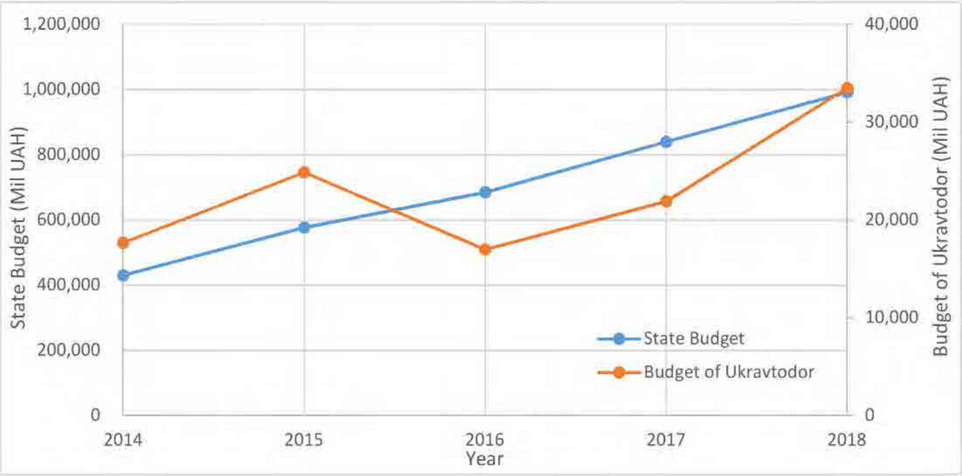
Although economic growth turned positive in 2016 after another negative year in 2015, the repercussions from the previous year's growth rate were significant; thus, Ukraine still requires support from donor countries and organizations. In December 2018, IMF announced that the IMF Executive Board approved a 14-month USD 3.9 billion Stand-By Arrangement for Ukraine.

1) Government Expenditure in Ukraine

The figure below shows expenditures by GOU and the State Agency of Automobile Roads of Ukraine (hereinafter referred to as "Ukravtodor"), subordinate to the Ministry of Infrastructure of Ukraine (hereinafter referred to as "MoI") that may serve as the Ukrainian Executing Agency for the Project.

The fiscal expenditure by GOU has increased in recent years, possibly as a result of efforts to institute foreign currency controls, banking system improvement, public finance improvement, energy and structural reforms with support from international financial institutions, Western nations, and others.

Expenditure by Ukravtodor stood at around 2.5% to 4.3% of that by GOU in every year except 2016, when it temporarily fell due to a reallocation of resources by GOU to social security and national defense. Since then, however, Ukravtodor's expenditure has increased at a greater pace than the government's because GOU has channeled funds into road improvements based on the aforementioned plan and program designed in 2015 and 2018, respectively.



*2014-2017: Actual Expenditure, 2018: Plan

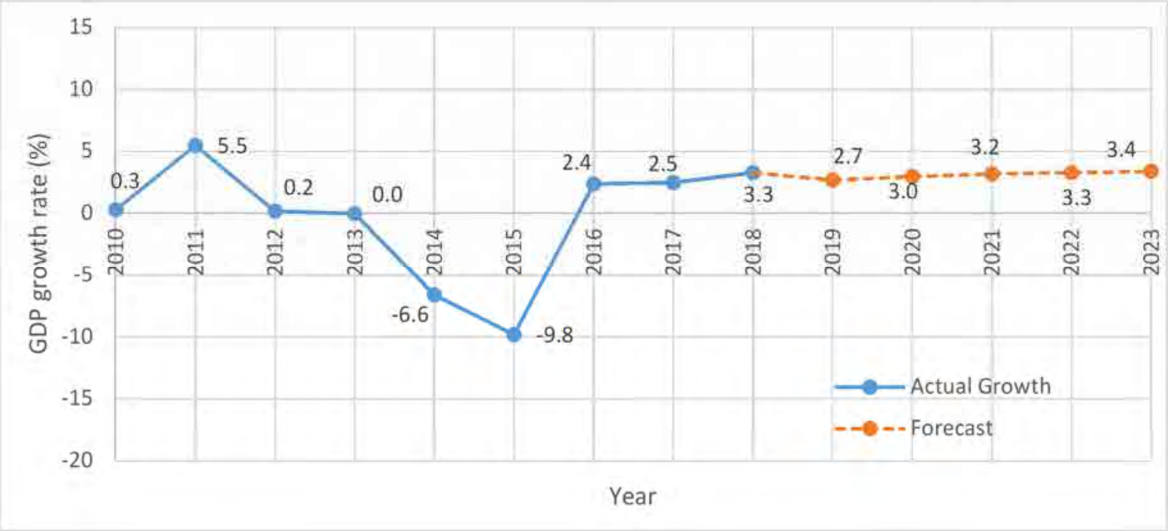
Source : Ministry of Finance of Ukraine (2018), Ukravtodor

Figure 1-4-3. Expenditures by GOU and the Ukraine State Road Agency

2) GDP (gross domestic product)

The real GDP in 2018 was 113,000 million USD, which constitutes growth of roughly 3.3% as shown in the figure below.

The agricultural sector, retail trade, passenger transportation have been the main economic drivers in recent years.



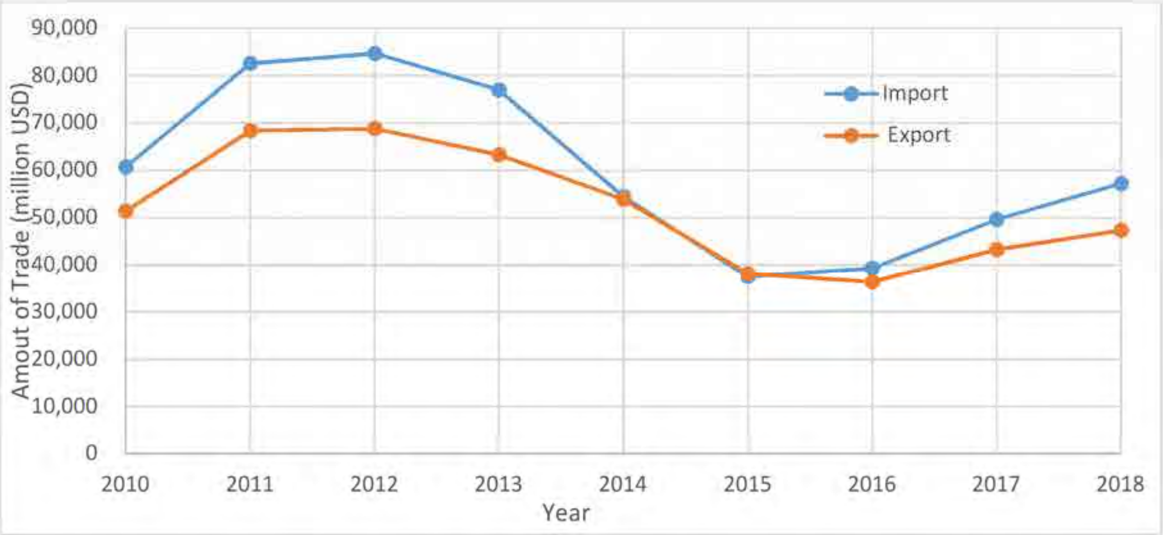
Note:From 2014, Excluding the temporarily occupied territories of the Autonomous Republic of Crimea, the city of Sevastopol and a part of temporarily occupied territories in the Donetsk and Luhansk regions.

Source : IMF(International Monetary Fund) (2018), State Statistics Service of Ukraine (2019)

Figure 1-4-4. GDP Growth Rate Trends

3) Trade

The figure below shows trends in the trade value of Ukraine.

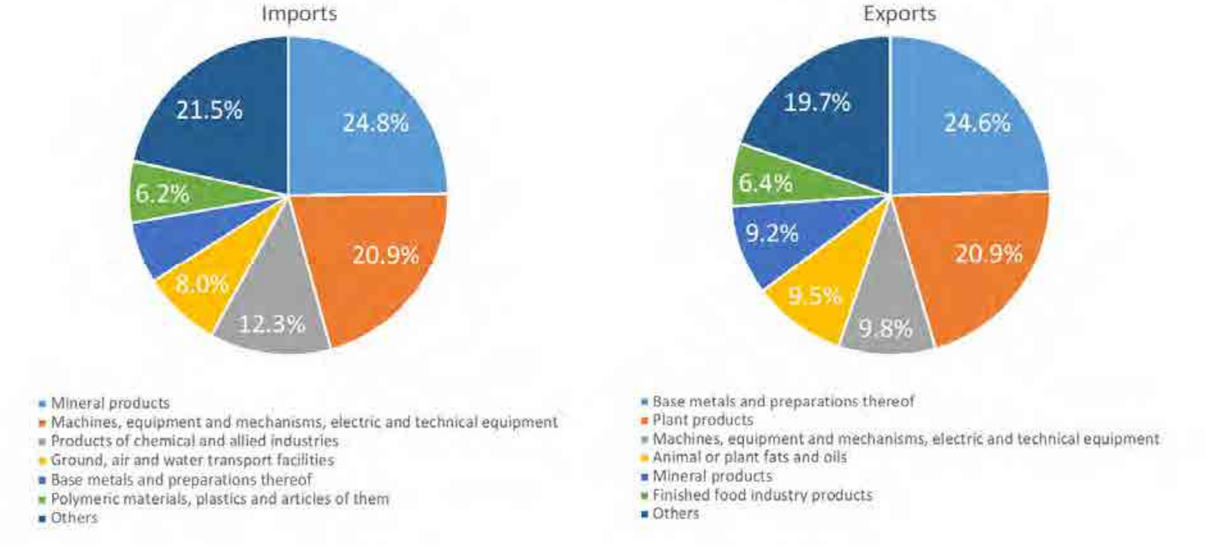


Note:From 2014, Excluding the temporarily occupied territories of the Autonomous Republic of Crimea, the city of Sevastopol and a part of temporarily occupied territories in the Donetsk and Luhansk regions.

Source : State Statistics Service of Ukraine (2019)

Figure 1-4-5. Trade Value Trends

Turning to trends in trade, the figures below show the percentage values of primary trade goods relative to the overall trade value. The information available to identify the routes of transportation for the respective export items is limited. It can be assumed, however, that the road network continues to be an essential infrastructure for trading in Ukraine, given that motor vehicles and railways respectively account for roughly 60% and 30% of the transportation volume in Ukraine (2018 actual figures, Source: Volume of freight transportation by type of carrier, State Statistics Service of Ukraine).



Note:Excluding the temporarily occupied territories of the Autonomous Republic of Crimea, the city of Sevastopol and a part of temporarily occupied territories in the Donetsk and Luhansk regions.

Source : State Statistics Service of Ukraine (2019)

Figure 1-4-6. Primary Trade Goods

1-5 Transport Sector Policy and Plans

The “State Target Economic Program for the development of public roads for 2013-2018” was formulated in 2013 as transport sector policy for Ukraine, but budget shortfalls ultimately prevented the achievement of the project’s initial objectives. In light of this, GOU formulated the New Program and the Cabinet of Ministers approved the program (Cabinet of Ministers of Ukraine Resolution (hereinafter referred to as “Cabinet Resolution”), March 21, 2018, No. 382) in March 2018. Based on reflections about problems with the previous program, a budget of 298,349 million UAH for the five years from 2018 to 2022 has been secured for the New Program.

The stated purposes of New Program are to repair and improve existing state roads for their integration into the European transport system, and to increase the level of traffic safety, speed, comfort and cost effectiveness of transportation.

The following sections describe the key program implementation aspects and expected results.

1-5-1 Key Program Implementation Aspects (Excerpt)

Key program implementation aspects are as follows:

- Introduction of long-term maintenance contracts (for five or seven years)
- Introduction of an independent quality control system
- Phased transition to the organization of the implementation of road construction works involving the consulting engineers based on the internationally recognized standard forms of contracts, including "FIDIC" contracts
- Introduction of a geographic information system for the management of highways
- Introduction of a traffic safety audit as a systematic, detailed, technical, independent process
- Introduction of automatic dimensional and weight control

1-5-2 Key Expected Results and Objectives (Excerpt)

Key expected results and objectives to achieve in each year are as follows:

- Improvement of the transport and operational condition of public highway roads of state importance on the main routes; new construction and reconstruction of highways in accordance with modern European standards with appropriate road infrastructure;
- Wider use of export and logistics potential of Ukraine;
- Reduction of the cost of transportation of goods and passengers and increase of profits on road transport in connection with improved conditions for the operation of motor transport;
- Reduction of traffic accident losses due to the unsatisfactory conditions of highways;
- Stable demand in the domestic market for production by the mining and processing industry, metallurgy industry, and other industries;
- Strengthened quality control and financing of roads by users;
- Creation of conditions for the development of public roads of state importance in accordance with the requirements of European and world standards;
- Warranty period for the operation for the new construction, reconstruction, and overhaul of public roads of state importance for at least 10 years.

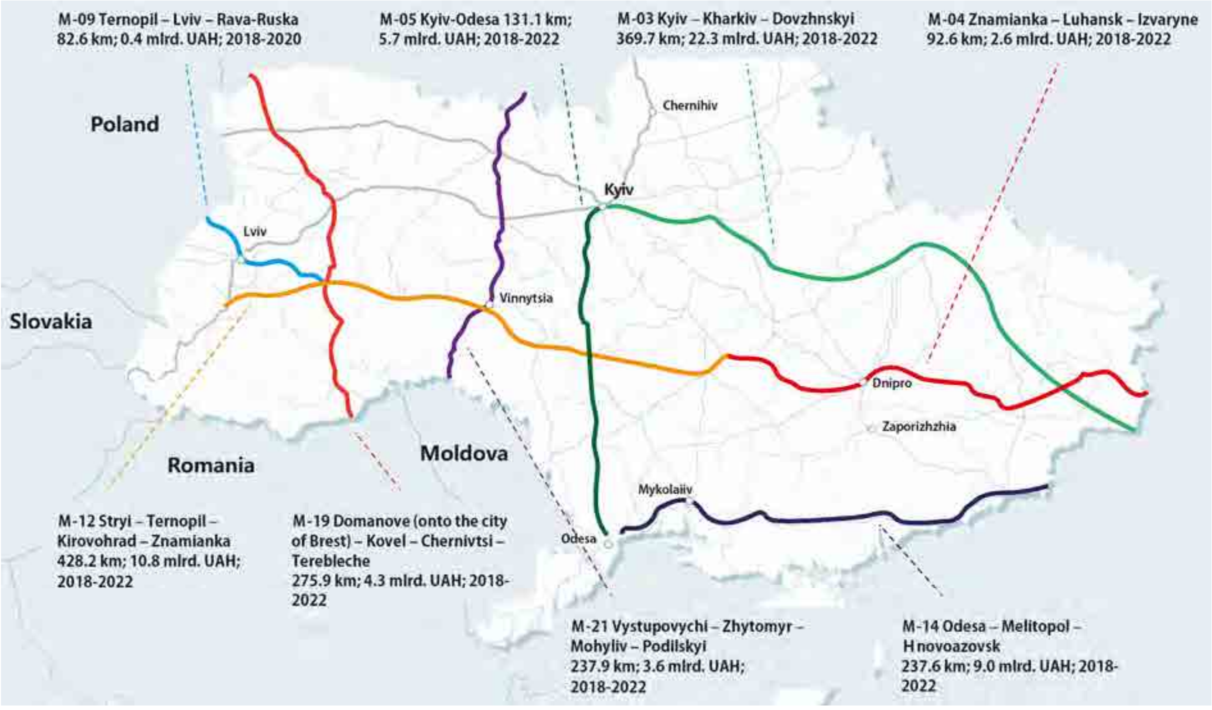
Table 1-5-1. Expected Outcomes of the Program Implementation

Unit: km

Name of objective	Name of objective completion indicator	Total	Year				
			2018	2019	2020	2021	2022
New construction of public roads of state importance	The length of the built public roads of state importance	325.46	24.29	42.88	44.40	12.32	201.57
Reconstruction of public roads of state importance	The length of the reconstructed public roads of state importance	431.15	20.56	81.26	106.16	105.24	117.93
Capital repairs of public roads of state importance	The length of repaired roads of general use of state importance	4,347.70	77.94	306.43	1,400.55	1.198.62	1,364.16
Current average repair of public roads of state importance	The length of repaired roads of general use of state importance	1,588.41	950.23	638.19	-	-	-
Total		6,692.73	1,073.02	1,068.75	1,551.11	1,316.19	1,683.66

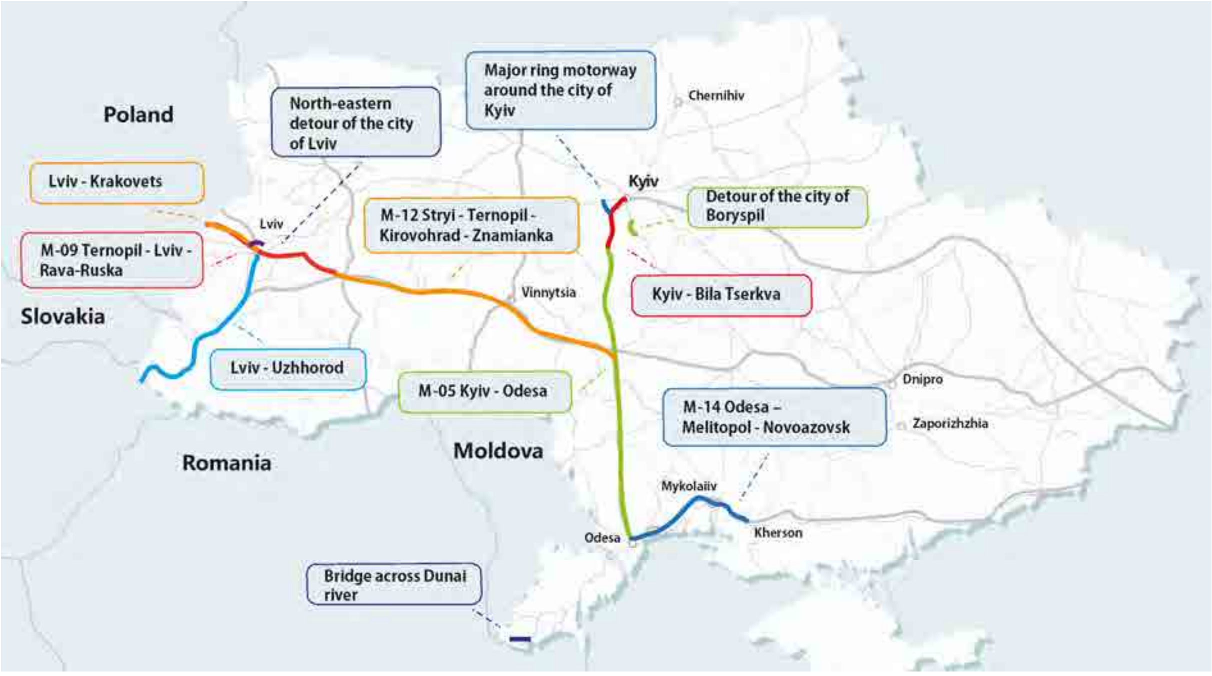
Source: Cabinet of Ministers of Ukraine

Figure 1-5-1 shows the international corridors that GOU plans to establish under the New Program. Given the limited funding sources of GOU, however, funding needs to be secured from several of the corridors described in Figure 1-5-2, including M14 from Odesa to Kherson, via Mykolaiv.



Source: New Program

Figure 1-5-1. International Corridor Locations and Construction Schedules



Source: New Program

Figure 1-5-2. International Corridors for which Funding must be Secured

1-6 Present State of Road Network

There are three major road categories in Ukraine: State Roads (State Importance), Local Roads (Local Importance), and Streets. In particular, State Roads (State Importance) are defined in a Cabinet Resolution (August 9, 2017, No. 654). Until 2018, Ukravtodor was in charge of State and Local Roads. However, since 2018, based on the Law of Ukraine (November 17, 2016, No. 1762-VIII, No. 1763-VIII, No. 1764-VIII), the scope of Ukravtodor was changed and it is in charge of State Roads only, and the management for Local Roads was transferred to Regional State Administrations.

State and Local Roads are further separated into the categories shown in the table below. The total length of these roads in Mykolaiv Oblast, in which the target area of the Project locates, accounts for roughly 3% of all such roads in Ukraine.

Table 1-6-1. Road Categories

Category		Whole Nation		Mykolaiv Oblast	
		Distance (km)	Ratio (%)	Distance (km)	Ratio (%)
The State Roads (State Importance)		51,700	31	1,487	31
International	(M-network)	8,600	5	200	4
National	(H-network)	4,800	3	407	8
Regional	(P-network)	10,000	6	368	8
Territorial State Roads	(T-network)	28,300	17	512	11
The Local Roads (Local Importance)		117,900	69	3,314	69
Regional Local Roads	(O-network)	50,000	29	2,669	56
District Local Roads	(C-network)	67,900	40	645	13
Total		169,600	100	4,801	100

Source: Ukravtodor

The figure below shows the network of the State Roads throughout Ukraine.
The network of the State Roads in Mykolaiv Oblast is shown in Figure 1-6-3.

Source: Strategy for Prioritization of Investments, Funding and Modernization of Ukraine's Road Sector (WB)

Figure 1-6-1. The State Roads Network in Ukraine

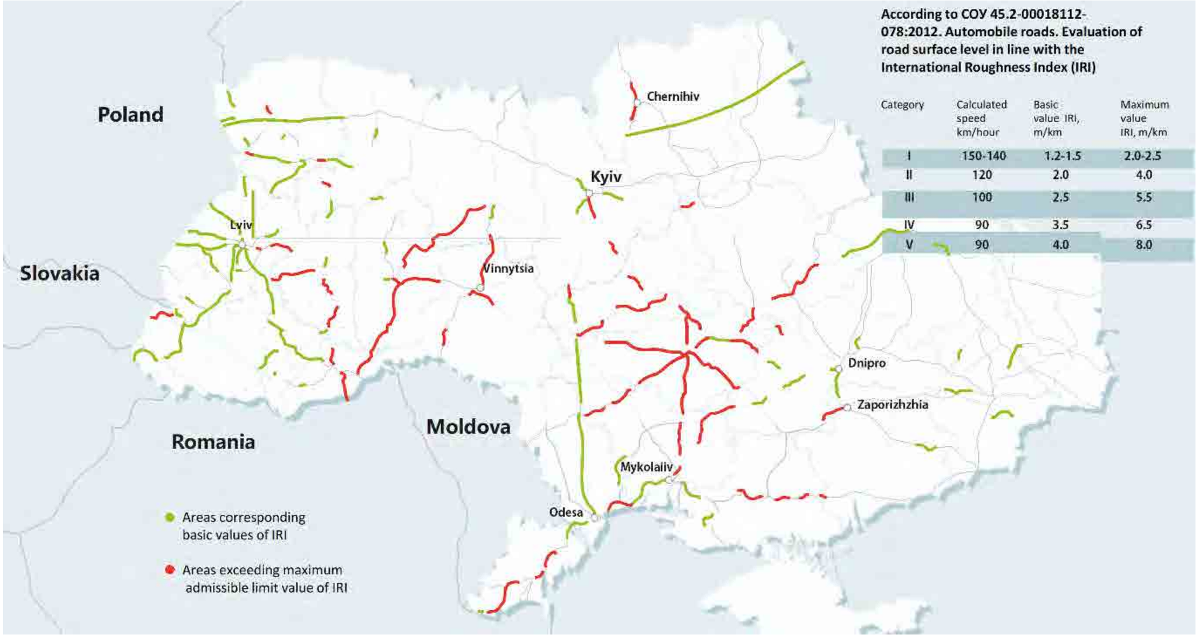
Table 1-6-2 and Figure1-6-2 show the International Roughness Index (IRI) in Ukraine as of the end of 2017. IRI was advocated by WB in 1986 as a way to evaluate the structural deterioration of paved surfaces. It serves as an index linking the state of paved surfaces to motorists' comfort when driving over them. (Note that "calculated speed" values on the table below are basic design speed values in flat areas.)

Given the maximum values of IRI exceeding the basic values, shown on the Table 1-6-2 and Figure 1-6-2, many roads in Ukraine clearly need urgent repairs.

Table 1-6-2. Evaluation of Road Surface Levels Using the International Roughness Index (IRI)

Category	Calculated speed km/hour	Basic value IRI, m/km	Maximum value IRI, m/km
I	150-140	1.2-1.5	2.0-2.5
II	120	2.0	4.0
III	100	2.5	5.5
IV	90	3.5	6.5
V	90	4.0	8.0

*According to СОУ 45.2-00018112-078:2012. Automobile roads. Source: Ukravtodor



According to СОУ 45.2-00018112-078:2012. Automobile roads. Evaluation of road surface level in line with the International Roughness Index (IRI)

Category	Calculated speed km/hour	Basic value IRI, m/km	Maximum value IRI, m/km
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II	120	2.0	4.0
III	100	2.5	5.5
IV	90	3.5	6.5
V	90	4.0	8.0

Source: Ukravtodor

Figure 1-6-2. Evaluation of Road Surface Levels Using the International Roughness Index (IRI)

Note that road categories are determined according to daily traffic volume as shown in the table below.

Table 1-6-3. Road Categories According to Daily Traffic Volume

Category	Daily Traffic Volume (Number of Vehicles)	
I	10,000 or more	(14,000 or more)
II	3,000-10,000	(5,000-14,000)
III	1,000-3,000	(2,500-5,000)
IV	150-1,000	(300-2,500)
V	Less than 150	(Less than 300)

*Figures in parentheses are conversions for PCU (Passenger Car Unit)

The figure below shows the network of the State Roads in Mykolaiv Oblast.

In Mykolaiv Oblast, there are 98 bridges and crossovers with a cumulative length of 3,696 m on State Roads (State Importance), and 159 bridges and crossovers with a cumulative length of 2,770 m on Local Roads (Local Importance).

The State Roads (State Importance)		Legends
International	(M-network)	—
National	(H-network)	—
Regional	(P-network)	—
Territorial State Roads	(T-network)	—

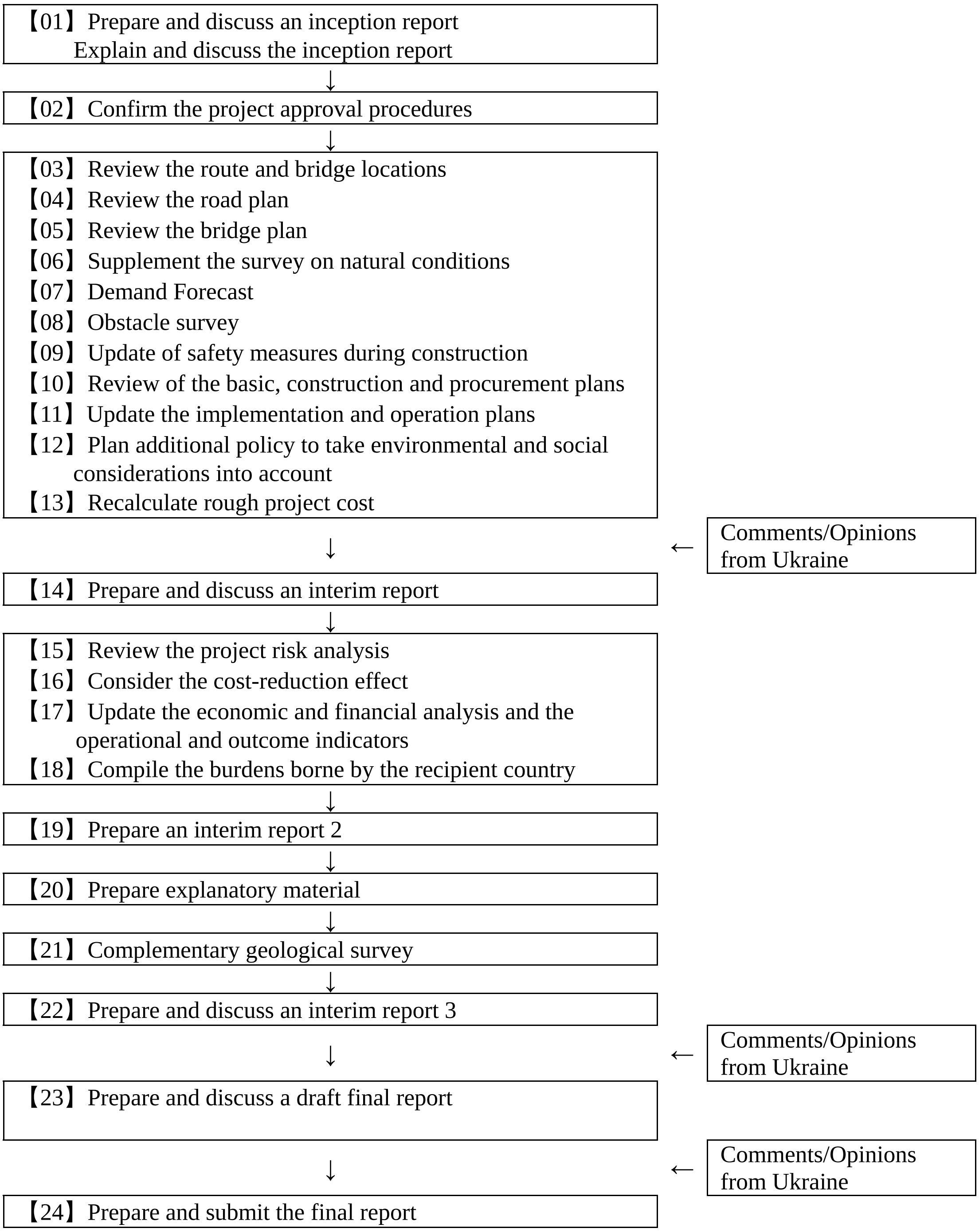
Source: Mykolaiv Branch of Ukravtodor

Figure 1-6-3. The State Roads Network in Mykolaiv Oblast

Chapter 2 Implementation Flow and Work Process

2-1 Study Implementation Flow

The following is implementation flow for this Study.



2-2 Work Process

The following is the work process for this Study.

2-3 Matters to be confirmed by item

The following are matters to be confirmed by item for this Study.

Item	Description	Matters to be discussed and confirmed in Ukraine
【01】Prepare and discuss an inception report	Summarize an inception report and discuss and confirm the policy, plan, implementation schedule and other matters related to this Study.	➢ Confirm and discuss any excess and deficiency and demands regarding the work process and method. ➢ Confirm the availability of arrangement and matters requested for this Study. ➢ Introduce the focal point of JICA Survey Team and request prior communication.
【02】Confirm the project approval procedures	Although the feasibility study of the Project was approved in 2013, the F/S should be changed and re-approved if this Study will involve any change in the bridge type or route. Therefore, this Study will fully discuss and confirm the validity of the approved F/S, the process of changing and reapproving F/S, Stages P and R and other matters and procedures required before implementing the project with the executing agency.	➢ Confirm the need to change and reapprove the F/S. ➢ As required, confirm the procedures.
【03】Review the route and bridge locations	Considering the latest land use trend and urban planning, the potential to form a city in future, sea-route limitations, aviation restrictions and other matters in Mykolaiv City, the most suitable plan for route and bridge locations will be selected as an outcome of this Study based on economic efficiency, project effect, resettlement and other environmental and social considerations, construction period, safety, workability, maintenance and management and alignment with urban planning, etc. after comparing and fully discussing details of plans, including those that will not be implemented.	➢ Confirm and discuss conditions such as the alignment with the urban planning of Mykolaiv City, laws and regulations related to the environmental and social considerations, land use, the existence of unique terrain and natural conditions, linking to other roads and roadside facilities, sea-route limitations and the marine navigation status and aviation restrictions at Mykolaiv Airport. ➢ If a significant alternative route and bridge location are available, discuss the best plan.
【04】Review the road plan	Review the road structure defined by the existing survey and the method of linking existing roads with the bypass to be constructed under the Project from the perspectives of economic efficiency, workability, convenience, construction period, safety and other factors to confirm the relevance of the existing survey results. In case alternatives are available, new plans will be proposed after comparing with such results and the most suitable plan will be selected as a survey outcome after fully discussing the proposals.	➢ Confirm and discuss the relevance of the number of lanes (demand forecast), design conditions (normative requirements and load conditions), topographical conditions (land use status), soil conditions (existence of unusual soils), etc. required when considering the road structure, linking method and other elements. ➢ If a significant alternative road structure and linking method are available, discuss the best plan.
【05】Review the bridge plan	Review the bridge type defined by the existing survey from the perspectives of economic efficiency, workability, convenience, construction period, safety and other factors to confirm the relevance of existing survey results. In case alternatives are available, new plans will be proposed upon comparing with such results and the most suitable plan will be selected as an outcome of this Study after fully discussing the proposals. Moreover, cost reduction measures and scope to apply the latest technologies which will help boost quality will be considered and proposed.	➢ Confirm and discuss the relevance of the number of lanes (demand forecast), external forces (meteorological conditions, etc.), design conditions (normative requirements and load conditions), topographical conditions (land use status), soil conditions (existence of unusual soils), etc. required when considering the bridge type and other components. ➢ If a significant alternative bridge type is available, discuss the best plan. ➢ Explain details of the efficiency of applying latest technologies and confirm their adoption.
【06】Supplement the survey on natural conditions	Review existing survey results related to the natural conditions required to plan and design road and bridge structures to identify matters to be further investigated and confirm the relevance of this Study. In case such matters are identified, an additional survey will be conducted on the same.	➢ Confirm proper collection methods, sources and matters to be noted in the survey while collecting meteorological, hydrological/water quality, topographical and soil data.
【07】Demand Forecast	Review the results of the traffic count survey and demand forecast conducted in the 2011F/S and the 2017 Survey and leverage their data to forecast demand. The number of lanes on the bridge will be reconsidered and proposed, taking into account the inadequate traffic handling capacity, feasibility, convenience, cost reduction and other factors based on the demand forecast results reviewed.	➢ Confirm the existence of a traffic count survey results other than the 2011F/S and the 2017 Survey. ➢ Confirm the intention to introduce a user charge system.
【08】obstacle survey	Investigate utilities that will hinder efforts to plan and design road and bridge structures by reviewing existing survey results, site reconnaissance and hearing survey. If such utilities are identified, their relocation method will be investigated and confirmed.	➢ Confirm the existence of overhead lines, underground facilities and other utilities deemed to hinder the Project, their administrators, relocation method and other relevant matters.
【09】Update safety measures during construction	Confirm any deficiency in safety measures during the construction period by reviewing the existing survey results. If such measures are deemed insufficient, measures will be added based on the Guidance to Manage Safety for Construction Works in Japanese ODA Projects and any costs incurred will be reflected in the overall project cost.	➢ Confirm the existence of laws and standards concerning construction and work safety, their outlines and compliance matters to be noted for the same. ➢ Confirm matters to be noted in safety measures derived from natural conditions.
【10】Review of the basic, construction and procurement plan	Confirm the relevance of the basic plan, method statement and procurement plan for the work by reviewing the existing survey results and identifying matters to be noted in the plans. In case the road or bridge structures, etc. are changed compared to the previous item, the plans should be changed and optimized appropriately.	➢ Confirm the procurement conditions of local materials and equipment and their survey guidelines, subjects of the survey and other relevant matters.
【11】Update the implementation and operation plans	Review existing survey results related to implementing the Project and operation plans and confirm their relevance. In addition, confirm and identify the latest status of the technical capacity of human resources, including equipment owned, financial situation and other aspects of the executing agency. If the organizational, personnel, budgetary, technical and other levels are constrained due to change in such factors, consider and propose a proper project implementation system.	➢ Confirm the current operational and management system, including the organization, authority, personnel structure, budgetary condition, technical level and other elements.
【12】Plan additional policy to take environmental and social considerations into account	Plan the additional survey policy mainly by reviewing the Environmental and Impact Assessment (EIA) and Resettlement Action Plan (RAP) formulated in the 2011F/S. As for the EIA review, confirm the need to conduct various environmental measurements (air, noise, vibration, water and ecosystem), which will complement the previous survey results, particularly in the planned bridge construction field amid the broad investigation points defined in the previous survey. The relevance of the measurement survey should be carefully considered, particularly for wetlands and adjacent resort facilities in the planned area where the Project may cause an adverse impact. As for the RAP review, the viability of the compensation policy is fully analyzed by confirming a survey on the present and past market prices. The review should be basically conducted to ensure the future executing capacity by clarifying the executing agency and their roles following discussion with counterparts (C/P).	➢ For both EIA and RAP: confirm the latest relevant laws in Ukraine, the need to revise EIA and RAP reports prepared in 2011, the process and period needed for required procedures, past land acquisitions or residential meetings after 2011 and additional survey policy and its specific implementation method, cost and other matters. Anticipating an additional survey conducted by the local subcontractor and confirm EIA/RAP cases in similar projects and a short list of local consultants for subcontracting works related to EIA/RAP. ➢ For EIA: particularly confirm the distance to the nearest residence and resort facility, countermeasures for water pollution, distribution of species included in the Red List,

Item	Description	Matters to be discussed and confirmed in Ukraine
		other conditions at the project site and other matters necessary for formulating additional survey policy. ➢ For RAP: particularly confirm past land acquisitions and resettlement based on the updated cadastral map and their size/scale and basic compensation policy (including the use of residual land).
【13】Recalculate rough project cost	Following considerations of the previous items, the project cost is approximately calculated based on the latest foreign exchange rate, material and equipment costs and labour costs referring to the Design and Calculation Manual for the Preparatory Survey (trial version).	➢ Confirm the availability and source of information on the construction price of materials as well as the cost of equipment and labour. ➢ Confirm where to request a quote for the cost of materials, equipment and labour.
【14】Prepare and discuss an interim report	Compile an interim report including a comparative analysis of alternative routes and plans for the bridge type, project cost estimation, demand forecast, the applicability of Japanese technologies, the result of the documented review of existing environmental and social considerations (EIA and RAP) and additional survey policy to take such environmental and social considerations into account and discuss and confirm their contents.	➢ Discuss and confirm the contents.
【15】Review the project risk analysis	Review existing survey results related to project risks and their countermeasures and confirm their relevance. The latest situation of Ukraine is also surveyed to confirm whether such risks have changed and whether any new risk has been observed and optimize countermeasures accordingly.	➢ Confirm the current status of the country risk, economic risk, exchange risk, market risk, risk in project management and in demand forecast and other risks.
【16】Consider the cost reduction effect	Review and update the cost reduction effect of the Project examined in the 2011F/S as required, based on the result of this Study.	-
【17】Update the economic and financial analysis and the operational and outcome indicators	Review the demand forecast, quantitative outcomes/indicators (operational and outcome indicators) and qualitative outcomes examined in the past survey as well as the target value over the two years after the project completion.	➢ Confirm and redefine the primary unit of each facility (personnel expense, fuel cost, etc.) as defined in the 2017 Survey. ➢ Confirm the intention to introduce a user charge system.
【18】 Compile the burdens borne by the recipient country	Summarize the burdens to be borne by the recipient country. Regarding the construction works borne by the recipient country, the work schedule is considered after fully confirming their organizational structure, budget and other executing capacities.	➢ Summarize the procedures and other duties involved in securing land, requesting arrangements, obtaining a range of construction permits, relocating road utilities (obstacles), traffic regulations and environmental and social considerations. ➢ Confirm the current operational and management system, including the organization, authority, personnel structure, budgetary condition, technical level and other elements.
【19】Prepare an interim report 2	Add the results of field surveys about the impact of landslides conducted in early February to the interim report, and consolidate.	-
【20】Prepare an explanatory material	Regarding the prominent route proposals, consolidate revised versions of the basic design, the initial cost estimation, landslide countermeasures, route selection, and any other comparison items into an explanatory material, and then discuss and confirm the details.	-
【21】Complementary geological survey	Regarding the prominent route proposals, conduct complementary geological surveys and monitoring to confirm safety with respect to landslides.	➢ Confirm the status of deformations of river banks, gullies and landslides.
【22】Prepare and discuss an interim report 3	Regarding the prominent route proposals, consolidate revised versions of the basic design, the initial cost estimation, landslide countermeasures, and route selection, and any other comparison items into Interim Report 3, and then discuss and confirm the details.	➢ Confirm comments from Ukraine.
【23】Prepare and discuss a draft final report	Compile a draft final report and discuss and confirm their contents.	➢ Confirm comments from Ukraine.
【24】Prepare and submit the final report	Based on the comments on the draft final report from Ukraine, determine the final contents and outcome of this Study and compile and submit the final report.	-

Chapter 3 Project Approval Procedure in Ukraine

3-1 Project Classification and Required Documents

The procedure leading to project implementation (commencement of construction work) in Ukraine previously depended on five levels of complexity categorized from I to V (The Project was categorized as level V in the 2012F/S(TEO)).

In 2017, however, The Law of Ukraine (Bulletin of the Verkhovna Rada (BP), 2017, No. 9, p.68) was established for better compliance with EU standards. With regard to the law in 2017, the procedure has depended on the degree of damage (consequences) likely to occur during disasters, instead. Three consequence classes are defined under this system: CC1 (Insignificant consequence class), CC2 (Medium consequence class) and CC3 (Significant consequence class) as shown in the table below.

As the bypass road is related to international highways of state importance, the level of the "Functioning termination of engineering and transport infrastructure facilities" is National. Therefore, this Project is categorized as CC3.

Table 3-1-1. Consequences Class of Houses, Buildings, Structures, Linear Facilities of Engineering and Transport Infrastructure

Categories of Complexity *1	Consequences class (responsibility) *2	Possible consequences characteristics of failure of houses, buildings, structures, linear facilities of engineering and transport infrastructure					
		Possible danger to health and lives of people, the number of people			Amount of possible economic damage, the minimum wage (mr.z.p)	Loss of cultural heritage objects, category of objects (level)	Functioning termination of engineering and transport infrastructure facilities (level)
		who are constantly inside the facility (persons)	who are periodically inside the facility (persons)	who are outside the facility (persons)			
V	CC3 (Significant consequence class)	Over 400	Over 1000	Over 50,000	Over 150,000	National Significance	National
III, IV	CC2 (Medium consequence class)	from 50 to 400	from 100 to 1000	from 100 to 50,000	from 2,000 to 150,000	Local Significance	Regional, Local
I, II	CC1 (Insignificant consequence class)	up to 50	up to 100	up to 100	up to 2,000	–	–

*1 : Former Standard as of 2012F/S(TEO)*2 : Standard Since 2017

To implement CC3 projects (to commence construction work), three documents are required: Feasibility Study (TEO: Техніко-економічне обґрунтування), Project (P), and Working Documentation (WD). The project implementation organization must prepare each of these documents, and the contents of each must be guaranteed by the Ministry of Regional Development, Building and Housing of Ukraine (hereinafter referred to as "MRDBH"), the Ministry of Economic Development and Trade of Ukraine (hereinafter referred to as "MEDT"), and the Ministry of Finance of Ukraine (hereinafter referred to as "MoF"), and also must be approved by the Cabinet. The required content (structure) of each document is set out in "SCN A.2.2-3-2014 Structure and Content of Project Documentation on Construction."

The required content (structure) of each document is shown in Tables 3-1-2 to 3-1-4.

Table 3-1-2. Structure of Feasibility Study (TEO)

Structure of Feasibility Study (TEO)	
1.	Basic provisions, which indicate the technical and economic feasibility of construction of the facility in full, upon stages and start-up facilities.
2.	Justification of the design capacity of the construction object, the expected range of products planned for release, as well as considerations for its sale.
3.	Justification for the number of new or additional workplaces of production personnel.
4.	Data on the availability of the raw material base, on the provision with basic materials, energy resources, semi-finished products, labour resources justifying the possibility of their use or receipt.
5.	Data of engineering surveys
6.	Environmental Impact Assessment (EIA).
7.	General layout and Transport Schemes.
8.	Scheme of utilities summary plan.
9.	Basic solutions on the land development and protection of the object from hazardous natural or man-made factors.
10.	Basic technological, construction and architectural and planning solutions.
11.	Basic solutions and indicators for energy efficiency, comparison of options, accounting and use of secondary and renewable resources, and safety and labour protection.
12.	Basic provisions for the organization of construction.
13.	Measures for technical protection of information.
14.	Basic solutions on sanitary and household servicing of workers.
15.	Basic solutions on fire and explosion safety of production.
16.	Basic solutions on implementation of engineering and technical measures of civil defense.
17.	Identification and declaration of safety of extra-hazardous objects.
18.	Accessibility of the site for the disabled people (except for production objects).
19.	Justification of investment efficiency.
20.	Conclusions with the definition of the selected option of the proposed solutions and suggestions.
21.	Project duration of construction.
22.	Technical and economic indicators.
23.	Estimate documentation, structure, volume and content of which shall be determined in accordance with DSTU B D.1.1-1.[*1]
24.	Calculation of the class of consequences (liability) and complexity categories according to DSTU-N B V.1.2-16.[*2]

*1: Rules for Construction Cost Calculation

*2: Determination of the class of consequences (responsibilities) and complexity categories of construction objects

Source : SCN A.2.2-3-2014 Structure and Content of Project Documentation on Construction Appendix C

Table 3-1-3. Structure of the Project (P)

Structure of the Project		
F.1. Explanatory Note		
1.	Initial data for design.	
2.	Brief description of the construction object and its structure:	
	1)	Data on project capacity, nomenclature, quality and technical level of production, raw material base;
	2)	The results of calculations of numerical and vocational and qualification structure of the personnel;
	3)	Quantity and equipment of workplaces;
	4)	Information on organization, specialization and co-operation of the main and auxiliary industries.
3.	Data of engineering surveys.	
4.	Information on fuel, water, heat and electricity requirements, energy saving measures, etc., separately for own needs and technology.	
5.	Information on the stages of the construction and start-up facilities.	
6.	Data on the capital investments efficiency (if necessary).	
7.	Basic solutions and indicators for the general layout, engineering networks and communications.	
8.	Solutions on the land development and protection of the object.	
9.	Occupational health and safety.	
	The section contains the following information:	
	1)	A list of basic regulatory documents;
	2)	Measures to ensure the safety of processes and products;
	3)	Toxicological, fire-hazardous characteristics of materials, products, semi-finished products, waste products; control over safety requirements;
	4)	The characteristics of the production premises, calculations or justification of the categories of explosive fire hazard, classes of PBE;
	5)	Determination of the energy potential of explosive blocks, radius of zones of possible destruction; measures to protect personnel from injuries, safe evacuation of workers at possible accidents and fires;
	6)	Data on lighting of workplaces, noise, vibration, methods of extracting and neutralizing waste with hazardous properties;
	7)	Means of preventing fires, explosions, storing and transporting materials, semi-finished products with dangerous and harmful properties, carrying out loading and unloading work;
	8)	Measures to protect workers from external and internal factors; availability of sanitary facilities, medical services;
	9)	Data on benefits, admissibility of women labour and adolescents.
10.	Section for engineering and technical measures of civil defense.	
11.	Section for provision of Reliability and Safety.	
12.	Identification and declaration of safety of extra-hazardous objects.	
13.	Environmental Impact Assessment (EIA).	
14.	Assessment of the effectiveness of the decisions taken and comparing the technical and economic indicators of the project with the indicators approved in the feasibility study (TEO).	
15.	Assessment of economy, received on the results of implementation of energy saving measures.	
16.	Section for scientific and technical support (if necessary).	
17.	Information on the scope of work.	
18.	Calculation of the class of consequences (liability) and complexity categories in accordance with DSTU-N B V.1.2-16.[*1]	
F.2 General Layout and Transport		
·	Brief description of the construction area and the construction site.	
·	Solutions and indicators upon the general layout, internal onsite and external transport.	
·	Basic design solutions, measures for improvement and maintenance of territories.	
·	Solution on the location of engineering utilities. Organization of enterprise protection (buildings, structures).	
F.3 Basic Drawings		
·	Site layout plan of an enterprise, building or structure with indication of external utility lines, networks (existing and designed), and territories designated for construction using one of these scales of 1:2 000, 1:5 000 or 1:10 000. The plan of the route is given for linear structures (if necessary, the longitudinal profile of the route).	

• The general layout, which is applied to houses and buildings (existing and designed ones, those reconstructed and subject to demolition), objects of environmental protection and land improvement, landscaping and special solutions for placing onsite engineering utilities and transport communications, grade elevation for the territory and networks that are part of start-up facilities on a scale of 1:500 or 1:1000.
• Cartography of earthworks.
F.4. Technological Part
Data on production and calculation programs:
1) Brief description and justification of the solutions regarding the accepted technology of production;
2) Allocation of production units;
3) Solutions for the use of low-waste and non-waste processes and industries;
4) Data on the complexity (machining content) of production, mechanization and automation of technological processes;
5) Structure and justification of the equipment used (including imported), start-up and adjustment works; number of jobs and their equipment;
6) Total number of employees, including by category and qualification;
7) Solutions on the organization of the maintenance facility;
8) Data on the amount and composition of harmful emissions into the atmosphere and water sources (given upon separate production workshops, facilities);
9) Characteristics of workshop and interdepartmental communications;
10) Solutions for heat supply, electricity supply and electrical equipment;
11) Suggestions for the operation of electrical installations;
12) Fuel and energy and material balances of technological processes;
13) Engineering solutions for fire protection measures;
14) Solutions on energy saving and application of energy-saving technologies.
F.5. (1) Basic Drawings
• Principal schemes of technological processes;
• Technological layout or planning upon buildings (workshops) with instructions for the placement of large, unique equipment and vehicles.
• Traffic flow diagrams for large enterprises.
• Principal power supply schemes of the enterprise.
• Schemes of trunk route and distributive heating networks.
F.5. (2) Architectural and Construction Solutions
• Brief description of the area of the construction site.
• A brief description and justification of the architectural and construction solutions of the construction site, erection diagram, categories of responsibility of structures and their elements. Calculations of main bearing elements.
• Principal solutions from the adopted structural scheme of objects (materials and characteristics of elements of bearing structures).
• Justification of principle solutions for lighting of workplaces, reduction of production noise and vibration, domestic, sanitary servicing of workers.
• Measures concerning electrical, explosion and fire safety, protection of building structures, networks and structures from corrosion.
• Basic solutions for water supply, sewerage, heating, ventilation and air conditioning.
• Solution to energy saving.
• Lists of individual projects and typical projects (design solutions).
• Solutions on the accessibility of the facility for the disabled people.
F.6. Basic Drawings
• Layout of foundations, floor plans, facades and sections of buildings and structures with a schematic representation of the main bearing and enclosing structures using one of these scales of 1:50, 1:100 or 1:200; main connecting nodes of structural elements, schemes for in-situ reinforced concrete structures, details of fencing structures at a scale of 1:25.
• Lists of buildings and structures that indicate the design solutions used or reused (main drawings) for typical projects
• Plan of routes for external and transport utility system, onsite networks (for all enterprises and structures) and data profiles (for large enterprises and facilities).

• For production structures with sophisticated ventilation and air conditioning systems, plans and sections of these buildings can be developed with the application of the mentioned systems, as well as plans for the main structures of the water supply and sewage system, the principal schemes for the installation of engineering equipment for industrial building as well as buildings for administrative and household and laboratory purposes.
• For large complex production objects it should be noted: Schemes of trunk route and distribution of engineering networks; structural schemes of power supply of the enterprise (workshop).
F.7. Organization of Construction
• The structure, volume and content of the design documentation of the section are established in accordance with the requirements and recommendations of the SCN A.3.1-5.[*2]
F.8 Estimate Documentation
• The structure, volume and content of the estimate documentation are determined in accordance with DSTU B D.1.1-1.[*3]

*1: Determination of the class of consequences (responsibilities) and complexity categories of construction objects

*2: Organization of Construction Manufacturing

*3: Rules for Construction Cost Calculation

Source : SCN A.2.2-3-2014 Structure and Content of Project Documentation on Construction Appendix F

Table 3-1-4. Structure of Working Documentation (WD)

Structure of Working Documentation
The working documentation consists of:
1. Work Drawings;
2. Passport of finishing works;
3. Estimate documents;
4. Specifications of equipment, products and materials;
5. Data sheet and dimensional Drawings for the relevant types of equipment and products;
6. Working documentation for construction products;
7. Design Drawings of general types of untypical products.
Note. Structure of WD can be specified and supplemented by project implementation organization

Source : SCN A.2.2-3-2014 Structure and Content of Project Documentation on Construction Appendix G

3-2 Procedure Related to Cabinet Approval

The Cabinet approval procedure for bridge and road construction projects in Ukraine is set out in a Cabinet Resolution (11 May 2011 No. 560) and the project content must be reviewed by an expert organization officially authorized by MRDBH prior to Cabinet approval.

Before the review in practice, another approval must also be obtained from relevant organizations (the Ukravtodor Technical Committee and the Ministry of Ecology and Natural Resources of Ukraine (hereinafter referred to as “MENR”)) ; to obtain this approval, documents must be prepared according to the relevant standards and rules of the respective organizations.

Ukravtodor has experience preparing Feasibility Study (TEO) and Project (P) documents for the design of roads and bridges in cooperation with Ukrdiprodor, which is a subordinate enterprise of Ukravtodor. Therefore, it is possible that Ukravtodor will prepare the documents required for the internal procedures for the Project in Ukraine.

The table below shows the procedure leading to Cabinet approval of bridge and road construction projects, using Feasibility Study (TEO) documents as an example.

Table 3-2-1. Approval Procedure of Feasibility Study (TEO) for Bridge and Road Construction Projects

Preparation of Feasibility Study (TEO)
(Ukravtodor contracts a consultant to prepare Feasibility Study (TEO) documents)

↓

Submission to Related Organizations (The consultant submit TEO to related organizations)
・Ukravtodor Technical Committee
・MENR

↓

Expert Reviews by Expert Organizations (The consultant submit TEO to expert assessment)
(Expert reviews shall be performed by expert organizations of any form of ownership that comply with criteria determined by MRDBH)

↓

Submission to Ukravtodor (The consultant submit TEO to Ukravtodor)

↓

Submission to Cabinet of Ministers (Ukravtodor submit TEO to Cabinet of Ministers)
(Endorsements from MRDBH, MEDT and MoI are required)

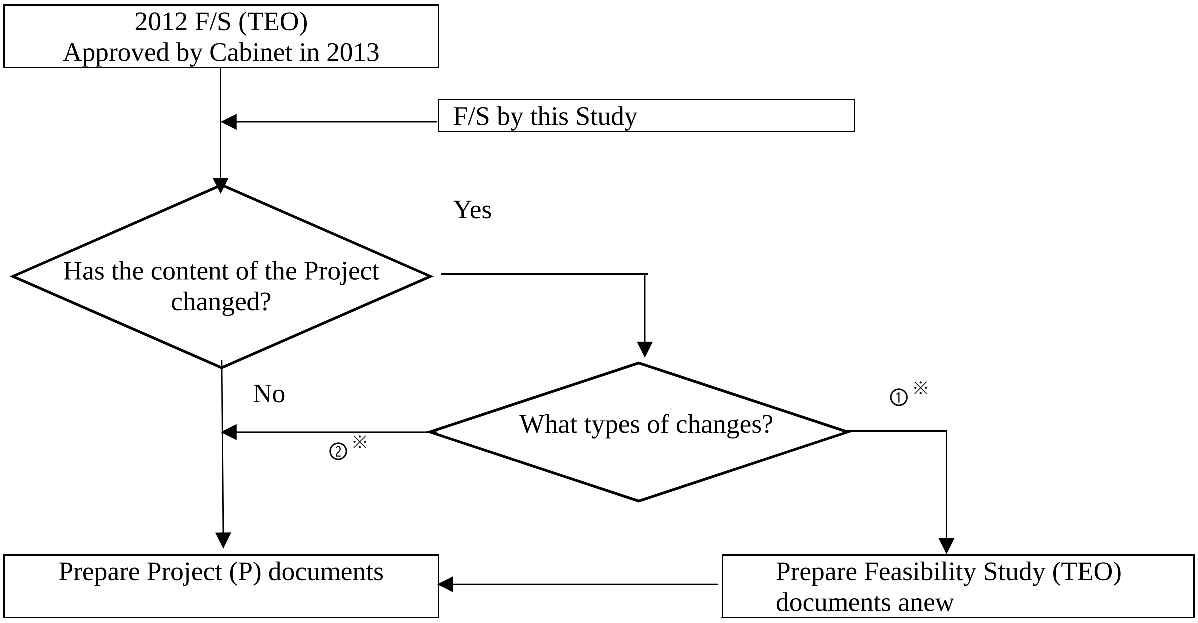
↓

Obtaining the approval of the Cabinet of Ministers

Based on the 2011F/S, Ukravtodor conducted a Feasibility Study (the 2012F/S TEO) in 2012; the Cabinet approved the 2012F/S (TEO) in 2013.

According to relevant personnel in Ukraine, there are no expiration dates on Cabinet approvals. In general, however, all documents must be newly prepared if the Feasibility Study (TEO) is to be prepared anew. The necessity of reapproval from the Cabinet of Ministers of Ukraine is currently being confirmed.

The Figure 3-2-1 shows the relationship between the procedure leading to preparation and approval of Project (P) documents and the details of changes to the 2012F/S (TEO).



*See Table 3-2-2. Types of Changes

Figure 3-2-1. Flow Leading to Preparation of Project (P) Documents

Table 3-2-2. Types of Changes

Type	Description of Changes
①	When the following changes have been made to the content set out in the Feasibility Study (TEO): ・The route has been changed ・The total length has been changed at least 10% in either direction ・Total bridge length has been changed at least 2% in either direction (changes to the breakdown of the lengths of approach and main bridges do not count) ・The number of lanes has been changed ・The type of pavement has been changed ・The number of interchanges has been increased (or reduced) ・The scope of land acquisition has been increased (changes to interchange types, etc.) *The above are the result of interviews with the chief engineer of Ukrdiprodor; no actual document that clearly specifies thresholds used for determining whether to accept or reject changes has been confirmed.
②	When changes have been made to the content not set out in the Feasibility Study (TEO): Examples: Bridge type, project cost, EIA, updated standards

3-3 Project Implementation Procedure and Timing of Document Submission

The figure below shows the procedures for normal project implementation (implementation of construction work) and the timing of submission of required documents.

For Project (P), relevant documents including an outline design will be prepared. Then, a tender based on the outline design will be held to determine the construction contractor to use for the project. (Feasibility Study (TEO) and Project (P) processes are combined and referred to as so-called “Stage P”) Later, in general, the contractor will prepare the Working Documentation (hereinafter referred to as “WD”). The period from the WD preparation to the project completion is referred to as “Stage R”. The WD corresponds to the detailed designs, but the drawings and figures normally included in detailed designs prepared in Japan can differ widely from those required for WD.

There are also cases where, after Stage P but before the tender, a consultant is hired to implement the detailed design (equivalent to detailed designing in Japan, but WD). In these cases, either the consultant or the contractor prepares the WD. The desires of the providers or the project implementation organization of capital assistance can be used to determine whether to hire a consultant before the tender, and whether to have the consultant or the contractor prepare the WD.

Note that, even when there are no detailed designs, a consultant is normally hired for the construction supervision.

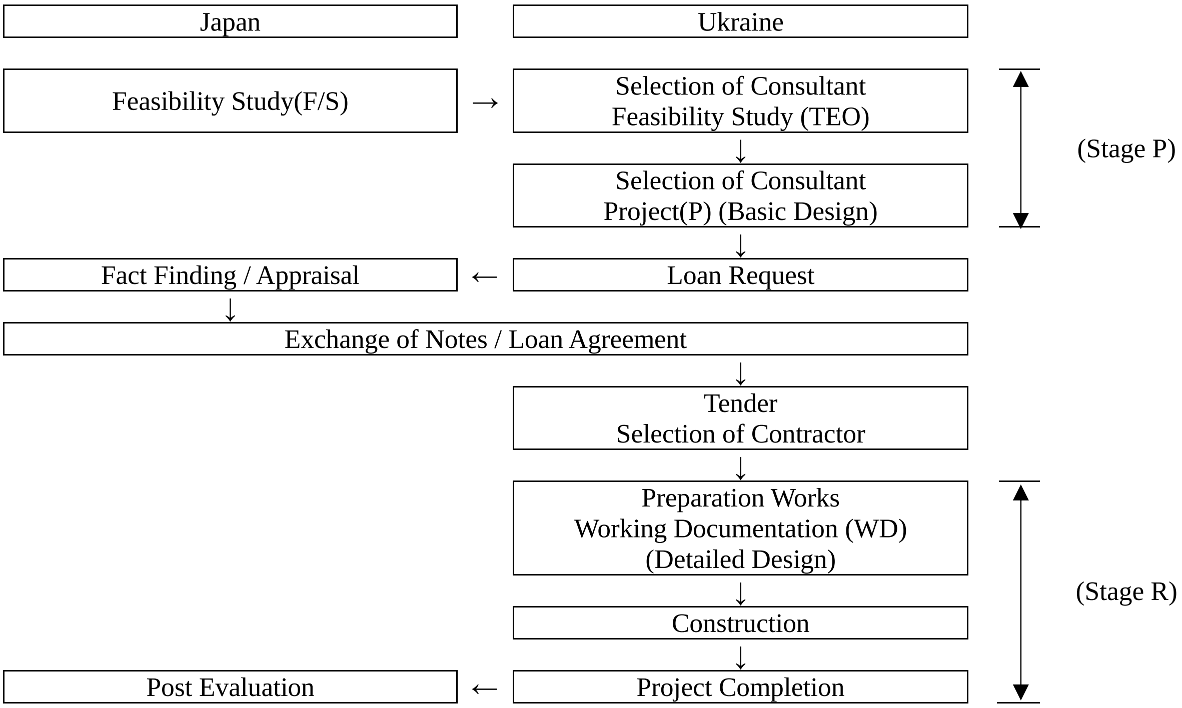


Figure 3-3-1. Period for Submission of Project Documentation

Chapter 4 Supplementing Surveys of Natural Conditions

Surveys of natural conditions (meteorological surveys and hydrological surveys, measurement surveys, and geological surveys) were conducted during the 2011F/S, but the following supplemental information is provided for the purposes stated therein.

Table 4-1. Purpose of Supplementing the Surveys

Surveys of Natural Conditions	Purpose of Supplementing the Surveys
Meteorological surveys and hydrological surveys	Updating observation data obtained during the 2011F/S. Reviewing the meteorological/hydrological conditions determined for the 2011F/S.
Measurement surveys	Confirming changes to land use conditions. Obtaining a wide range of data for comparing routes.
Geological surveys	Re-confirming soil constants used for SPT testing (CPT only in the 2011F/S). Obtaining a wide range of data for comparing routes.

4-1 Meteorological Surveys and Hydrological Surveys

4-1-1 The 2011 F/S Results and Purpose of These Surveys

The table below shows the results of the meteorological survey from the 2011F/S.

Table 4-1-1. Results of The 2011F/S Meteorological Survey (1876-2009)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Yearly
Temperature (℃)													
Mean Max.	0.3	1.6	6.6	15.5	22.2	26.1	28.1	27.9	22.7	15.3	7.8	2.8	14.7
Mean Min.	-5.8	-4.6	-0.5	5.8	11.5	15.2	17.0	16.3	12.0	6.2	1.7	-2.6	6.0
Ave.	-3.3	-2.5	2.3	9.5	16.7	20.8	23.6	22.6	17.3	10.7	4.1	0.9	10.1
Max.	14.0	18.1	24.1	29.5	35.1	36.6	40.0	40.1	34.1	32.9	23.4	15.6	40.1
Min.	-29.7	-28.7	-20.8	-7.9	-1.2	4.2	9	7.5	-1.4	-13.7	-18.2	-24.6	-29.7
Relative Humidity (%)													
Ave.	85	82	77	69	64	64	61	60	68	75	84	86	73
Wind Speed (m/s)													
Max.	30	24	28	40	20	20	28	20	21	40	27	34	40
Mean	4.1	4.2	4.1	3.9	3.6	3.3	3.1	3.0	3.2	3.4	3.8	4.0	3.6
Days with Wind Speed over 15m/s													
Ave.	1.9	2.2	2.1	1.7	1.2	1.4	1.1	0.6	0.6	1.2	1.5	1.8	17.3
Rainfall (mm)													
Mean	26	27	25	27	44	51	39	36	46	32	32	31	416
Daily Max.	28	35	41	34	71	144	75	138	90	63	40	33	144
Rainy Days over 10mm/day													
Ave.	0.5	0.7	0.7	0.6	1.2	1.3	1.5	1.1	1.2	1.0	1.1	0.7	11.6

Hydrological study results were also obtained for the 2011F/S. They included water level data from the Mykolaiv (Sea Hydro-meteorological Station) from 1917 to 2009, and discharge rate data from Oleksandrivka (Hydrological Station) from 1914 to 2009.

In light of this fact, JICA Survey Team obtained and organized the latest observation data from the Mykolaiv Regional Center of Hydrometeorology for areas around the planned locations of Mykolaiv Bridge. This was done to fully understand the meteorological and hydrological conditions for and in which the bridge and other facilities would be planned, designed, constructed and maintained.

Table 4-1-2 shows the purpose of obtaining observation values, as well as whether they were obtained or not, and the observation stations from which they were obtained.

Table 4-1-2. Purpose of Obtaining Observation Values

Type	Observation Values	Purpose of Obtaining	Obtained		Observation Station
			2011F/S	This Study	
Meteorological Phenomena	Temperature	Consideration of appropriate quality of concrete, construction plans	Yes	Yes	(1)
	Humidity	Consideration of appropriate quality of concrete, coating consideration	Yes	Yes	(1)
	Rainfall	Construction plans	Yes	Yes	(1)
	Depth of snow	Consideration of external forces, construction plans	No	Yes	(1)
	Thickness of ice	Consideration of external forces, construction plans	Yes	Yes	(2)
	Wind	Consideration of design water levels, consideration of external forces	Yes	Yes	(1)
Hydrology	Water levels	Consideration of design water levels, consideration of external forces	Yes	Yes	(2)
	Discharge rates	Consideration of external forces	Yes	Yes	(3)

* Observation stations: (1) Aviation Meteorological Center Mykolaiv (Hydrometeorological Station)
(2) Mykolaiv (Sea Hydro-meteorological Station)
(3) Oleksandrivka (Hydrological Station)

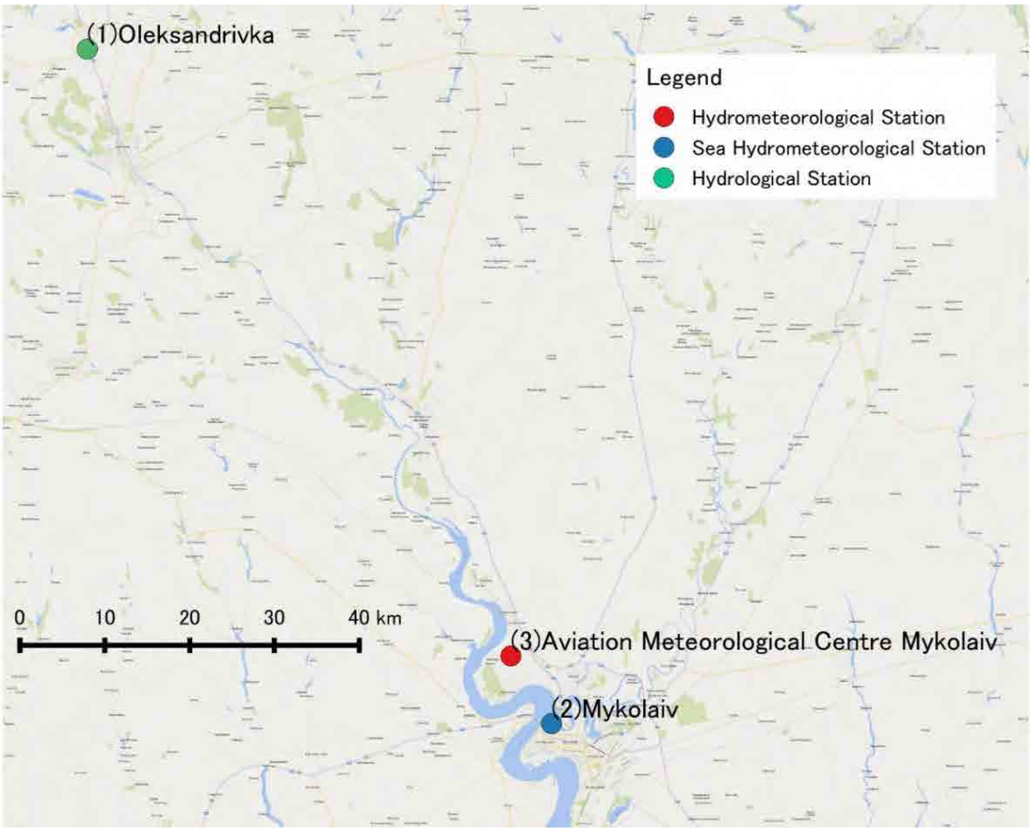
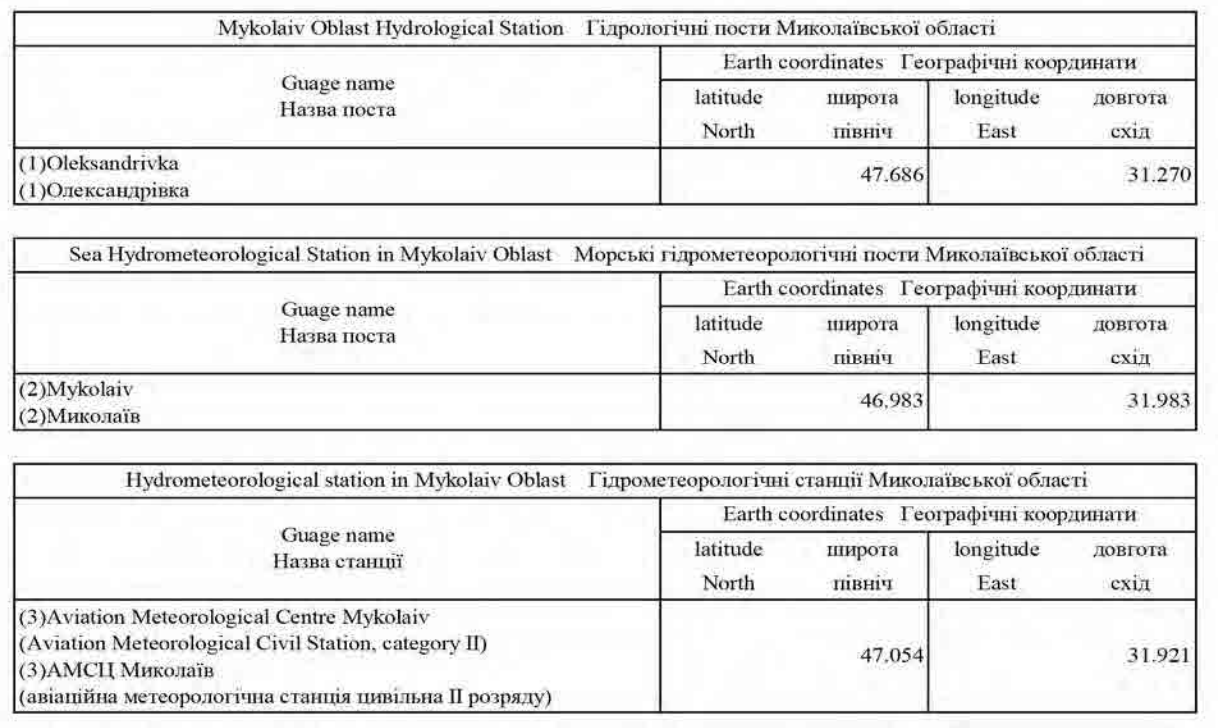


Figure 4-1-1. Observation Station Location Map

Table 4-1-3. Observation Station Location Coordinates



Mykolaiv Oblast Hydrological Station Гідрологічні пости Миколаївської області		
Guage name Назва поста	Earth coordinates Географічні координати	
	latitude широта North північ	longitude довгота East схід
(1)Oleksandrivka (1)Олександрівка	47.686	31.270

Sea Hydrometeorological Station in Mykolaiv Oblast Морські гідрометеорологічні пости Миколаївської області		
Guage name Назва поста	Earth coordinates Географічні координати	
	latitude широта North північ	longitude довгота East схід
(2)Mykolaiv (2)Миколаїв	46.983	31.983

Hydrometeorological station in Mykolaiv Oblast Гідрометеорологічні станції Миколаївської області		
Guage name Назва станції	Earth coordinates Географічні координати	
	latitude широта North північ	longitude довгота East схід
(3)Aviation Meteorological Centre Mykolaiv (Aviation Meteorological Civil Station, category II) (3)АМСЦ Миколаїв (авіаційна метеорологічна станція цивільна II розряду)	47.054	31.921

4-1-2 Meteorological Surveys

The table below shows the observation stations and timing of observation for the measured meteorological data.

Table 4-1-4. List of Meteorological Observation Data

Observation Values	Data Type	Observation Period	Observation Station*
Temperature	Daily average temperature Daily maximum temperature Daily minimum temperature	2008-2017	(1)
Humidity	Daily average relative humidity	2008-2017	(1)
Rainfall	Daily rainfall	2008-2017	(1)
Depth of snow	Annual maximum depth of snow	1966-2017	(1)
Thickness of ice	Annual maximum thickness of ice	1956-2017	(2)
Wind	Monthly wind speed/direction	2011-2017	(1)
	Record monthly maximum instantaneous wind speed	Observed since 1927	(1)

*Observation stations: (1) Aviation Meteorological Centre Mykolaiv (Hydrometeorological Station)
(2) Mykolaiv (Sea Hydro-meteorological Station)

1) Temperature

The table and the figure below show average monthly, average monthly maximum, and average monthly minimum temperatures over the past 10 years (2008-2017), measured at the Aviation Meteorological Centre Mykolaiv. The Average monthly maximum and average monthly minimum temperatures fluctuate widely (roughly 30°C) throughout the year.

Table 4-1-5. Average Monthly, Average Monthly Maximum, and Average Monthly Minimum Temperatures

Unit : ℃

Month	Average Monthly Temperature		Average Monthly Maximum Temperature		Average Monthly Minimum Temperature	
	Value	Standard Deviation	Value	Standard Deviation	Value	Standard Deviation
Jan	-2.7	1.4	9.0	2.0	-18.5	3.1
Feb	-0.6	3.2	12.4	2.8	-12.5	5.6
Mar	4.8	1.8	18.1	2.1	-6.4	3.5
Apr	11.0	1.1	25.9	2.9	-0.5	2.2
May	17.4	1.8	29.9	1.9	5.7	2.5
Jun	21.8	0.8	34.1	1.9	10.7	1.5
Jul	24.1	1.1	36.1	1.5	13.4	1.4
Aug	24.0	1.1	37.3	2.1	11.3	1.2
Sep	18.1	1.6	31.8	2.6	5.6	1.7
Oct	10.3	1.9	23.9	2.6	-1.4	2.4
Nov	5.8	2.3	17.3	2.3	-5.2	2.6
Dec	0.9	2.0	13.6	1.7	-13.1	5.1

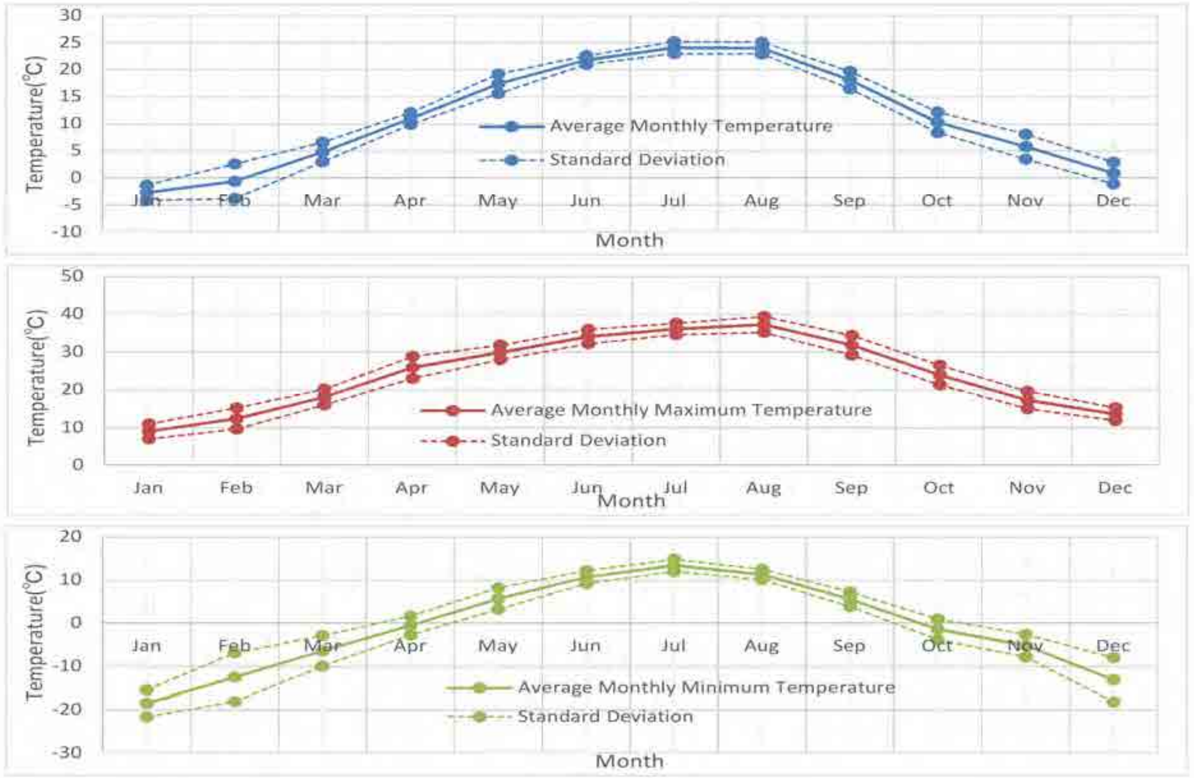


Figure 4-1-2. Average Monthly, Average Monthly Maximum, and Average Monthly Minimum Temperatures

The maximum and minimum temperatures from the 10-year period are shown below.

Maximum temperature: 39.7°C (August 2017)
Minimum temperature: -24.5°C (January 2010)

2) Humidity

The table and figure below show average monthly relative humidity of the past 10 years (2008-2017), measured at the Aviation Meteorological Centre Mykolaiv. Relative humidity fluctuates widely (roughly 35%) throughout the year.

Table 4-1-6. Average Monthly Relative Humidity

Unit : %

Month	Average Monthly Relative Humidity	
	Value	Standard Deviation
Jan	86.5	3.6
Feb	82.2	3.1
Mar	72.8	3.3
Apr	65.2	6.6
May	66.0	5.2
Jun	62.6	4.3
Jul	59.3	5.6
Aug	51.3	2.9
Sep	61.1	6.1
Oct	74.7	5.9
Nov	82.8	4.1
Dec	86.0	2.9

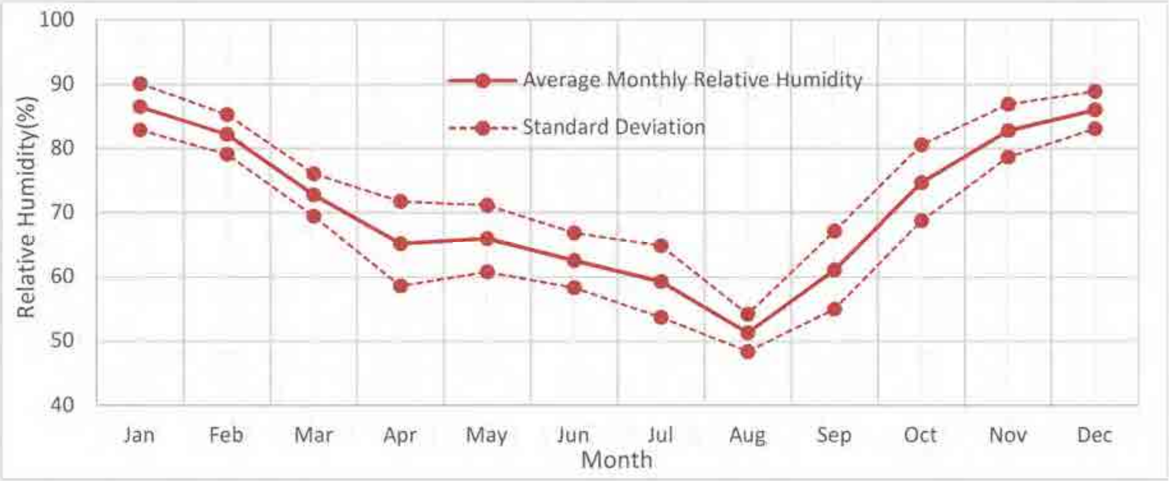


Figure 4-1-3. Average Monthly Relative Humidity

3) Rainfall

The table and the figure below show monthly and annual rainfall for each of the past 10 years (2008-2017), measured at the Aviation Meteorological Centre Mykolaiv. As mentioned above, Mykolaiv City is located in the southeastern part of Ukraine, which has a dry steppe climate; average annual rainfall is roughly 413 mm (Standard Deviation : 111mm), which is relatively lower than the global average. Summer is considered rainy season in almost all areas of Ukraine except the southern coast of Crimea. As far as historical records, while there is no significant difference in the monthly rainfall, slightly more rainfall is recorded from May to July. However, in the coastal regions of the Black Sea and Azov Sea, hot winds blow from the steppe climate zone of the Lower Volga Region during summer months, sometimes causing droughts. The maximum daily rainfall for the 10-year period occurred in September 2008 at 42.7 mm.

Table 4-1-7. Average Monthly Precipitation

Unit : mm

Month	Average Monthly Precipitation	
	Value	Standard Deviation
Jan	38.5	21.1
Feb	26.8	17.5
Mar	23.6	16.5
Apr	28.8	19.9
May	50.8	26.7
Jun	49.2	26.0
Jul	47.9	36.2
Aug	15.7	12.2
Sep	34.6	33.0
Oct	39.8	23.4
Nov	23.7	15.0
Dec	34.0	20.9

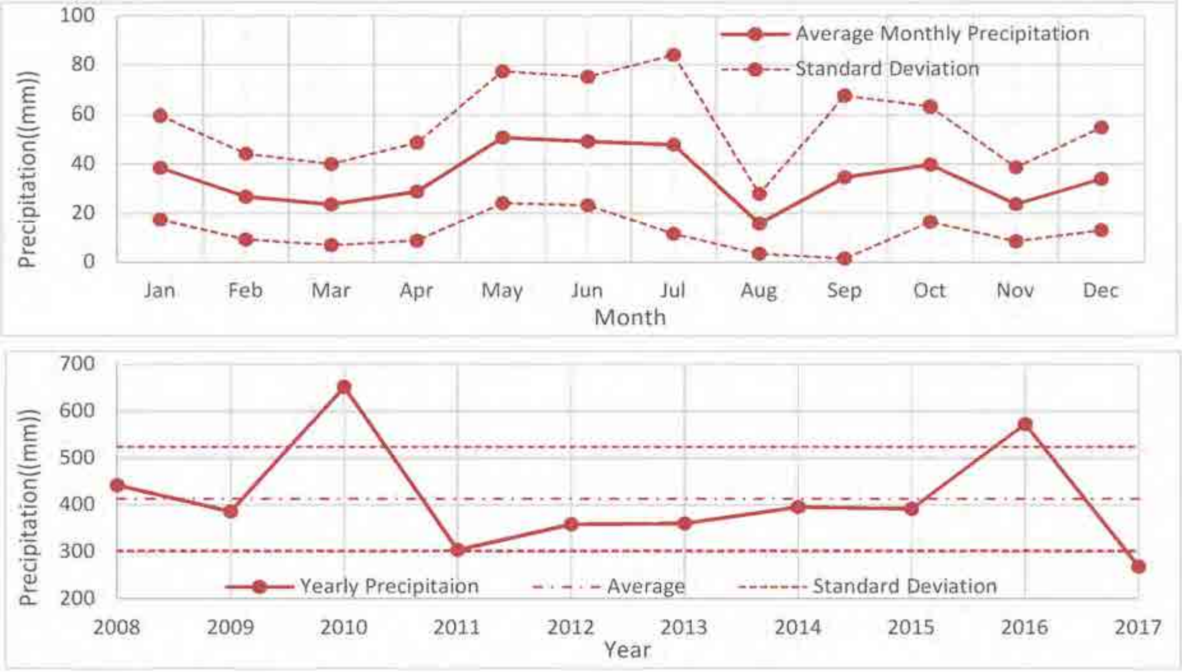


Figure 4-1-4. Monthly and Yearly Precipitation

In addition, the table below shows average rainfall days (at least 10 mm) for each month over the past 10 years.

Table 4-1-8. Average Rainfall Days (at least 10 mm) in Each Month

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Yearly
Rainy Days over 10mm/day	0.5	0.7	0.7	0.6	1.2	1.3	1.5	1.1	1.2	1.0	1.1	0.7	11.6

4) Depth of snow

The figure below shows annual maximum depth of snow for each of the past 52 years (1966-2017), measured at the Aviation Meteorological Centre Mykolaiv. The average annual maximum depth of snow is 12 cm (Standard Deviation : 8cm).

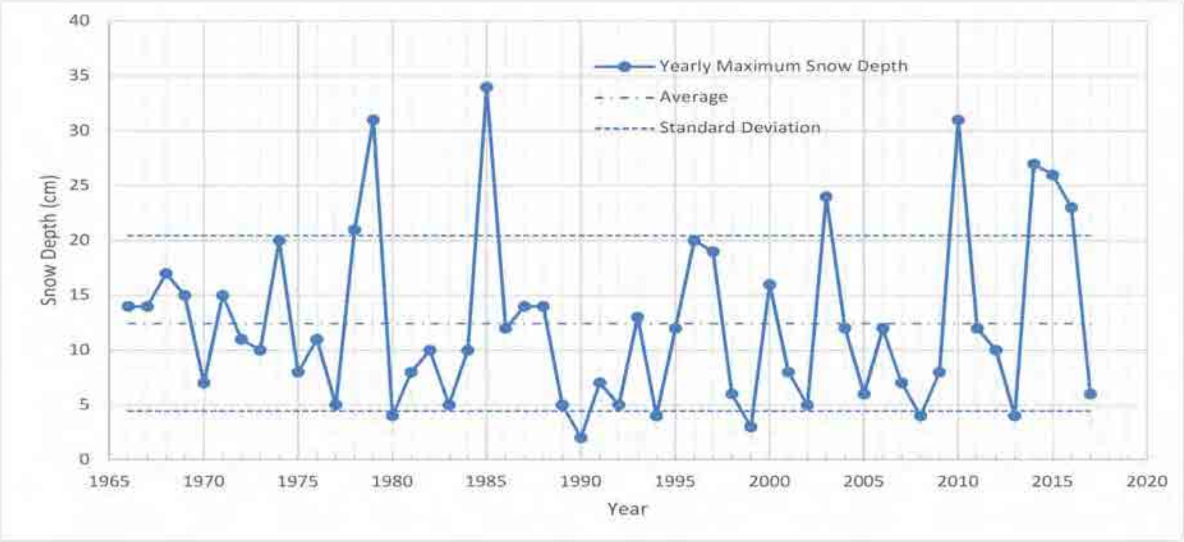


Figure 4-1-5. Annual Maximum Depth of Snow

5) Thickness of ice

The figure below shows annual maximum thickness of ice on the Southern Bug River for each of the past 62 years (1956-2017), measured at Mykolaiv (Sea Hydro-meteorological Station). The average annual maximum thickness of ice is 12 cm (Standard Deviation : 10cm), and the maximum thickness of ice is 54 cm.

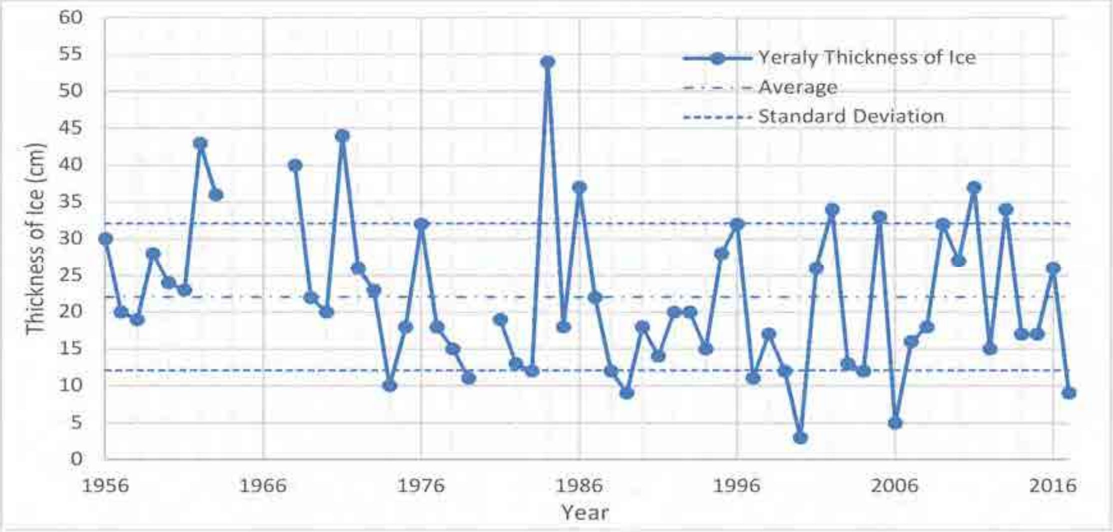
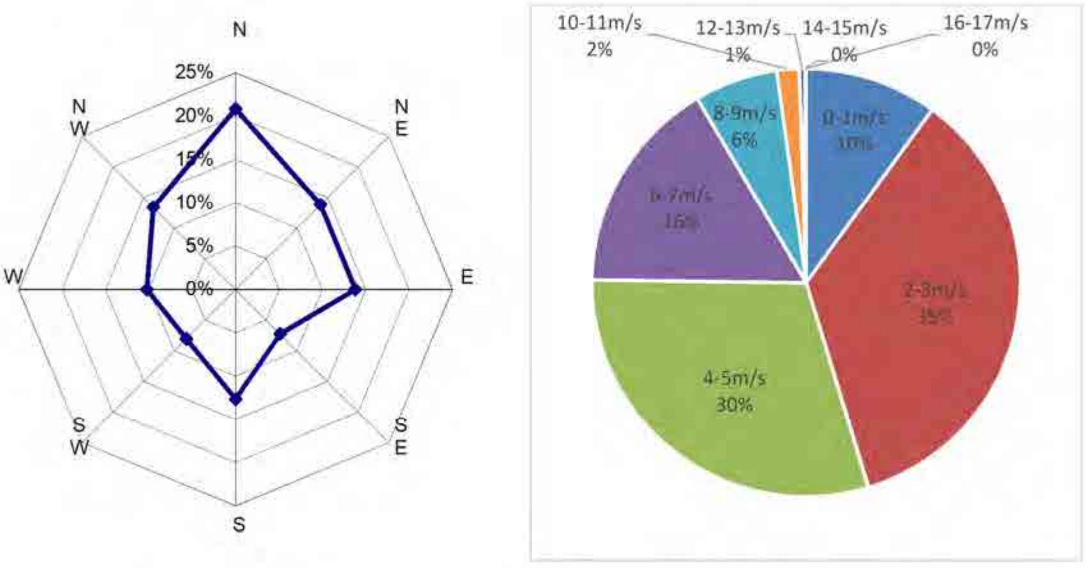


Figure 4-1-6. Annual Maximum Thickness of Ice

6) Wind Direction and Speed

The figure below shows the distribution of average wind direction and speed over the past seven years (2011-2017), measured at the Aviation Meteorological Centre Mykolaiv. The height of the observation point is 10 m above ground level with wind that predominantly blows from the north. From those limited data, it seems that the wind speed is 7 m/s or lower over 90% of the time.



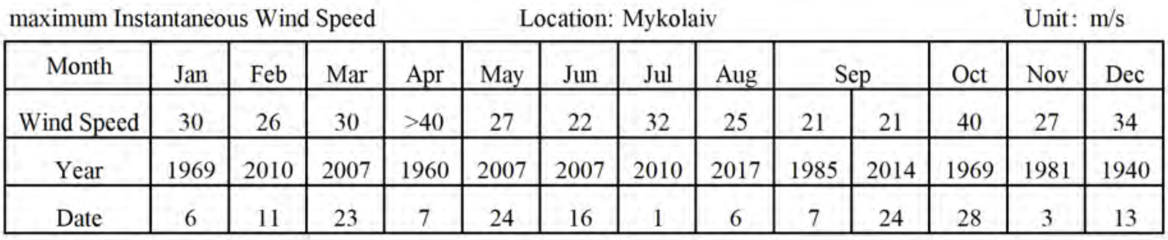
Wind Direction

Wind Speed

Figure 4-1-7. Wind Direction/Speed Frequency Distribution (2011-2017 Average)

The table below shows the maximum instantaneous wind speed on record for each month. According to interviews with the Mykolaiv Regional Center of Hydrometeorology, strong winds blow from the northwest, and the highest instantaneous wind speed on record is 40 m/s from 290° (West Northwest).

Table 4-1-9. Monthly Maximum Instantaneous Wind Speed



maximum Instantaneous Wind Speed   Location: Mykolaiv   Unit: m/s

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep		Oct	Nov	Dec
Wind Speed	30	26	30	>40	27	22	32	25	21	21	40	27	34
Year	1969	2010	2007	1960	2007	2007	2010	2017	1985	2014	1969	1981	1940
Date	6	11	23	7	24	16	1	6	7	24	28	3	13

4-1-3 Hydrological Surveys

The table below shows the observation stations and timing of observation for the obtained hydrological data.

Table 4-1-10. List of Hydrological Observation Data

Survey Item	Data Type	Observation Period	Observation Station*
Water levels	Annual maximum water levels Annual minimum water levels	1917-2017 (incomplete data)	(2)
	Hourly water levels	2000-2017	(2)
Discharge rates	Annual maximum discharge Annual minimum discharge	1914-2017 (incomplete data)	(1)

*Observation stations: (1) Oleksandrivka (Hydrological Station)
(2) Mykolaiv (Sea Hydro-meteorological Station)

1) Water Levels

Figure 4-1-8 shows annual maximum and minimum water levels over the past 101 years (1917-2017), measured at Mykolaiv (Sea Hydro-meteorological Station).

The values are as follows:

Average annual maximum water level: BS* +0.417 m (Standard Deviation:0.16m)
Average annual minimum water level: BS* -0.924 m (Standard Deviation:0.19m)
Highest water level on record: BS* +0.900 m
Lowest water level on record: BS* -1.470 m

* : BS is the abbreviation for "Baltic System", meaning in relation to average sea water level of the Baltic Sea.

The result of the observation data review is shown in Appendix 6.

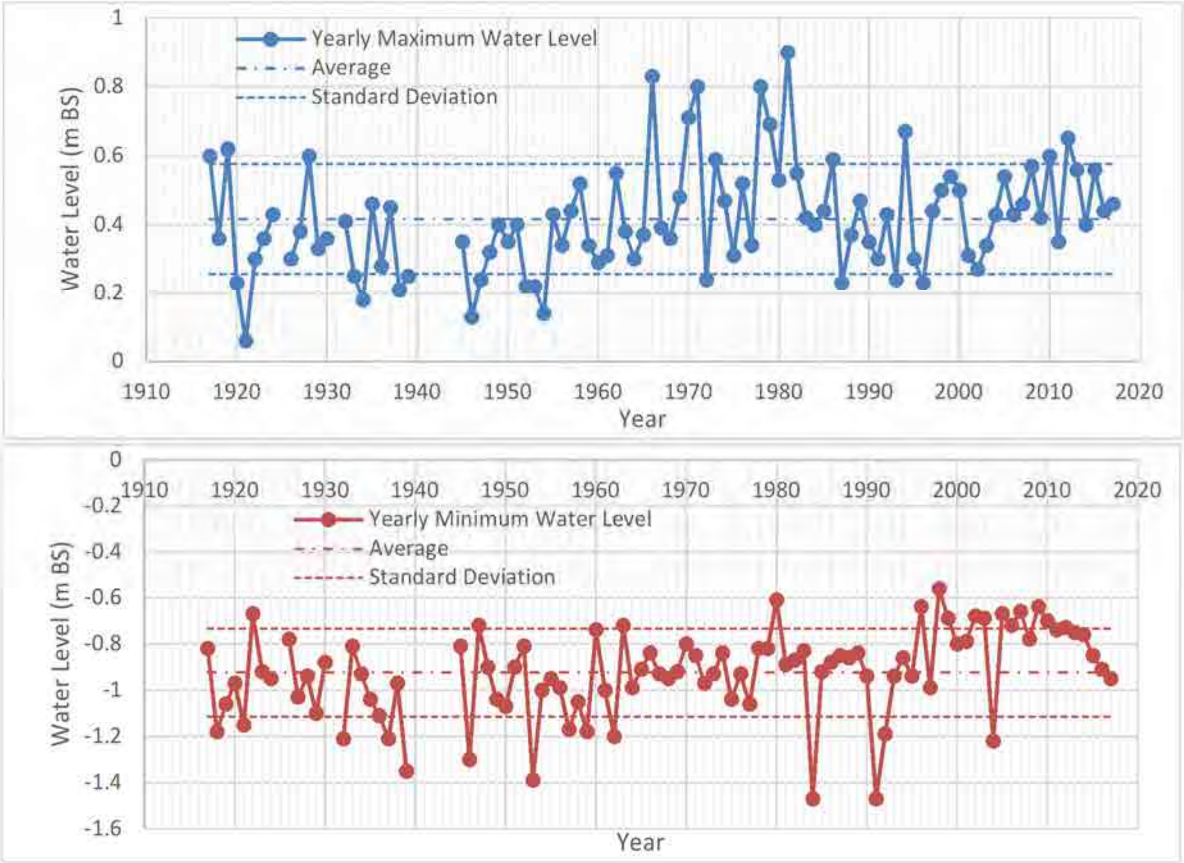


Figure 4-1-8. Annual Maximum and Minimum Water Levels at Mykolaiv
(Sea Hydro-meteorological Station)

Annual maximum water levels at the Mykolaiv (Sea Hydro-meteorological Station) are influenced by the discharge from upstream, as well as water levels downstream (the Black Sea) because it is in tidal reaches.

Figure 4-1-8 indicates that the average annual maximum water level since 1965 tends to be about 13 cm higher than the same of the years before then.

There are many factors that cause changes in the water level, and they are mutually interacting with each other. So it is difficult to quantitatively indicate the degree of influence of each factor. However, the main factors are considered as follows.

(1) Artificial Factors

Main artificial factor could be the impact of Vavarovsky Bridge (construction began in 1957, and completed in 1964). The bridge is built on an embankment that takes up roughly half of the 1,300-m width of the river; therefore, there may be a possibility that the bridge affected water levels directly upstream at Mykolaiv (Sea Hydro-meteorological Station).

Another artficial factor that may affect water levels is the fact that the present discharge of the Southern Bug River is regulated by a hydroelectric power plant (Oleksandrivskaya HES) located upstream in Oleksandrivka.

(2) Natural Factors

According to “Tide in the Black Sea: Observation and Numerical Modeling (May 2018, Pure and Applied Geophysics)”,the maximum tidal range in the Black Sea varies from 1.1 cm near Crimiean Peninsula to 19 cm in the Dnieper-Bug Estuary, which includes Mykolaiv. In addition, its main occurrence factors are amplification of diurnal radiational harmonic due to the combined effect of the shallow water, the estuary isolation and strong sea breezes, and astronomical tide.

Furthermore, storm surges in the Black Sea due to low atmospheric pressure have a major influence on the sea level and it is considered to be the main occurrence factor of the historical highest water level.

2) Discharge

The figure below shows annual maximum and minimum discharge over the past 104 years (1914-2017), measured at Oleksandrivka (Hydrological Station).

The values are as follows:

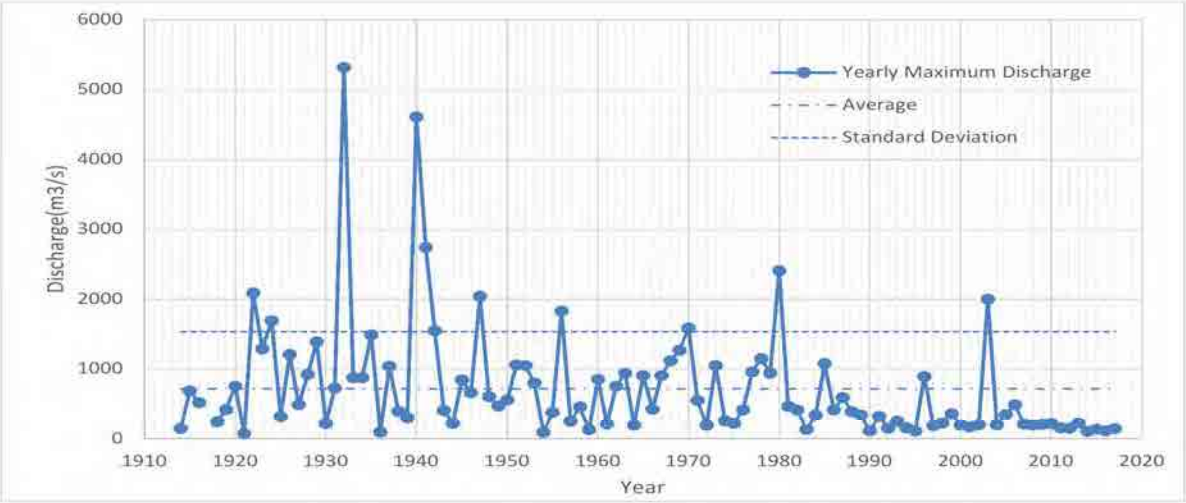
Average annual maximum discharge: 720 m^3/s (Standard Deviation:816m^3/s)
Average annual minimum discharge: 19 m^3/s (Standard Deviation:12m^3/s)
Highest discharge on record: 5,320 m^3/s
Lowest discharge on record: 2.6 m^3/s

The result of the observation data review is shown in Appendix 6.

The annual average discharge is roughly 91 m^3/s at Oleksandrivka (Hydrological Station), and roughly 102 m^3/s near Mykolaiv Bridge location (Source: River Basin Management Plan for Pivdenny Bug, river basin analysis and measures, Kyiv 2014).

A dam-type hydroelectric power plant, Oleksandrivskaya HES, is located directly upstream of the Oleksandrivka (Hydrological Station), and according to the South Ukrainian Energy Complex's official website, the power plant has the capacity to control flood discharge, although details of the unregulated amounts are not clear.

Oleksandrivskaya HES was built in 1927 originally. Although this hydroelectric plant was destroyed by Germany in 1944, it was rebuilt in 1956. In addition, construction of a new hydroelectric power station directly upstream of the old hydroelectric power station began in 1984 and was completed in 1999.



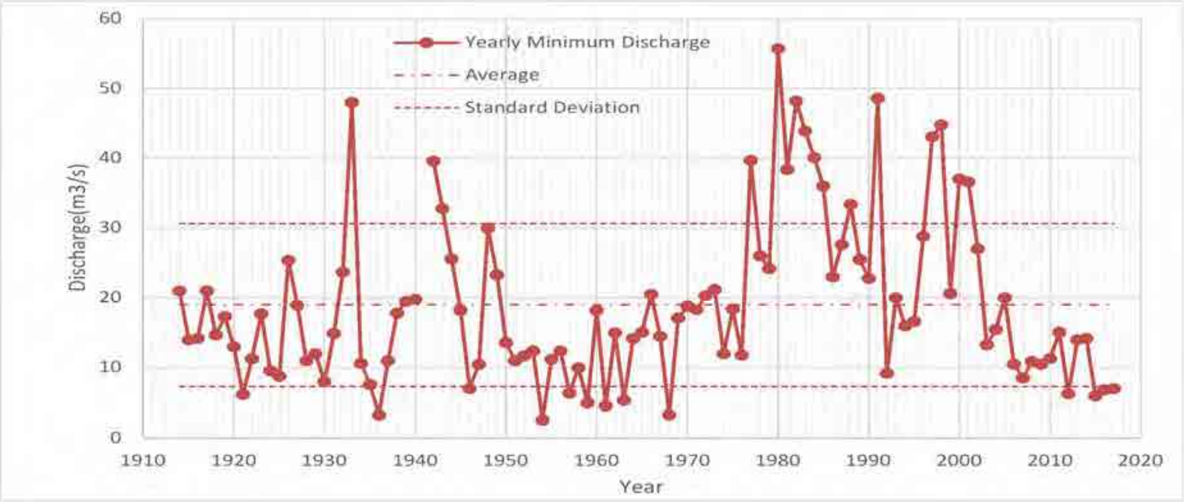


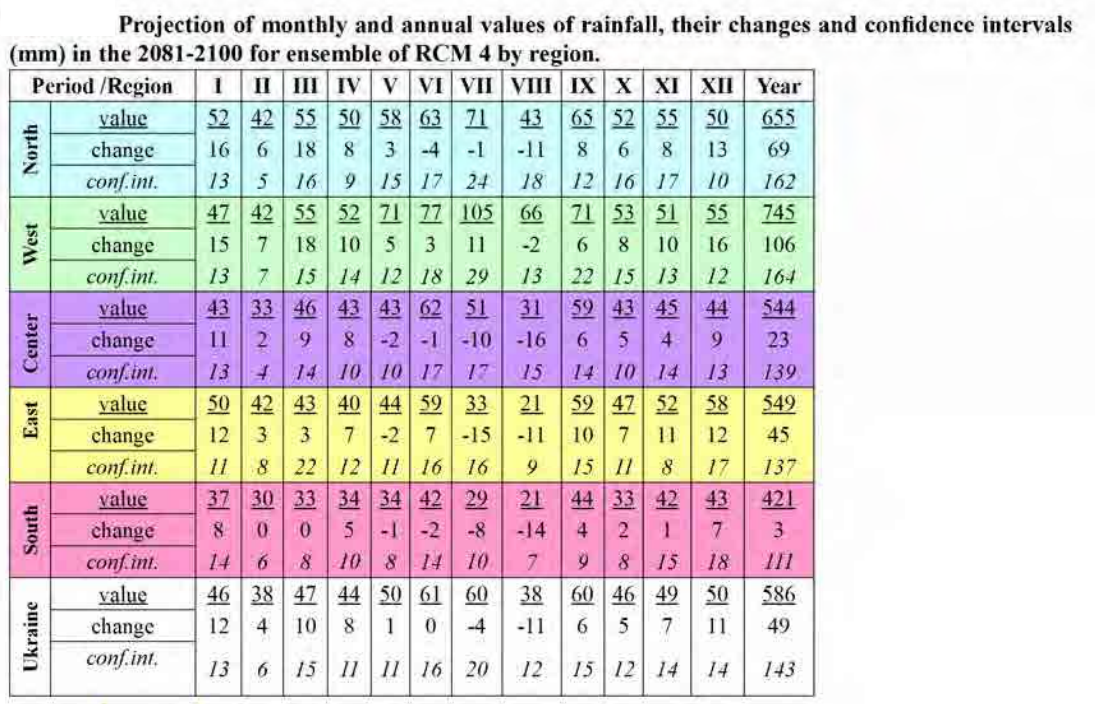
Figure 4-1-9. Annual Maximum and Minimum Discharge Rates at Oleksandrivskaya (Hydrological Station)

4-1-4 Climate Change

1) Changes in Rainfall

Rainfall in Mykolaiv Oblast (South region), the target area of the Project, is expected to increase by a total of 3 mm per year, with the greatest increase of 8 mm in January as shown in the table below.

Table 4-1-11. Variation in Rainfall due to Climate Change



Projection of monthly and annual values of rainfall, their changes and confidence intervals (mm) in the 2081-2100 for ensemble of RCM 4 by region.

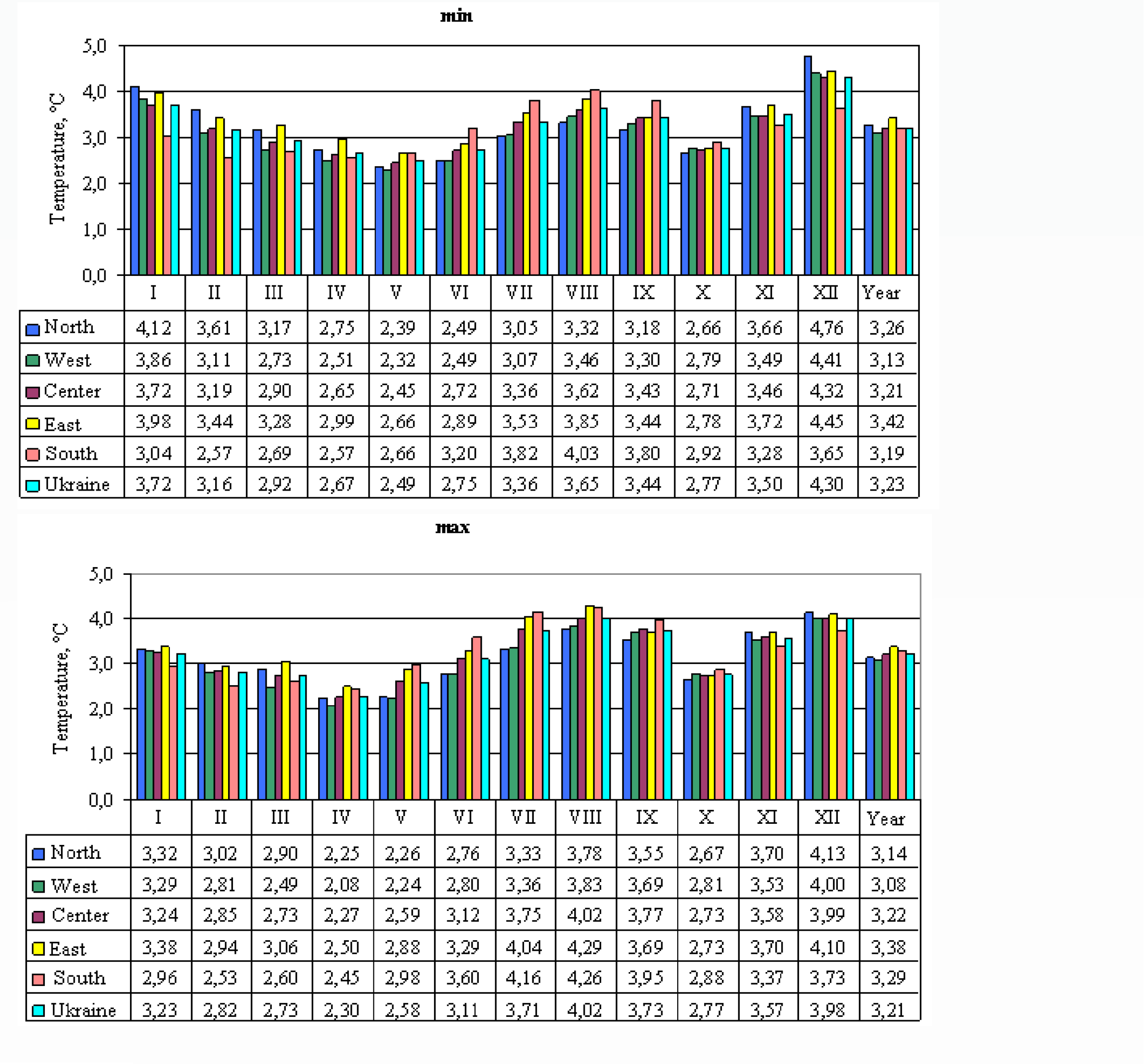
Period /Region		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
North	value	52	42	55	50	58	63	71	43	65	52	55	50	655
	change	16	6	18	8	3	-4	-1	-11	8	6	8	13	69
	conf.int.	*13*	*5*	*16*	*9*	*15*	*17*	*24*	*18*	*12*	*16*	*17*	*10*	*162*
West	value	47	42	55	52	71	77	105	66	71	53	51	55	745
	change	15	7	18	10	5	3	11	-2	6	8	10	16	106
	conf.int.	*13*	*7*	*15*	*14*	*12*	*18*	*29*	*13*	*22*	*15*	*13*	*12*	*164*
Center	value	43	33	46	43	43	62	51	31	59	43	45	44	544
	change	11	2	9	8	-2	-1	-10	-16	6	5	4	9	23
	conf.int.	*13*	*4*	*14*	*10*	*10*	*17*	*17*	*15*	*14*	*10*	*14*	*13*	*139*
East	value	50	42	43	40	44	59	33	21	59	47	52	58	549
	change	12	3	3	7	-2	7	-15	-11	10	7	11	12	45
	conf.int.	*11*	*8*	*22*	*12*	*11*	*16*	*16*	*9*	*15*	*11*	*8*	*17*	*137*
South	value	37	30	33	34	34	42	29	21	44	33	42	43	421
	change	8	0	0	5	-1	-2	-8	-14	4	2	1	7	3
	conf.int.	*14*	*6*	*8*	*10*	*8*	*14*	*10*	*7*	*9*	*8*	*15*	*18*	*111*
Ukraine	value	46	38	47	44	50	61	60	38	60	46	49	50	586
	change	12	4	10	8	1	0	-4	-11	6	5	7	11	49
	conf.int.	*13*	*6*	*15*	*11*	*11*	*16*	*20*	*12*	*15*	*12*	*14*	*14*	*143*

Source: National Communication of Ukraine on Climate Change (2013)

Figure 4-1-10. Definition of the Region

2) Changes in Temperature

The maximum temperature in Mykolaiv Oblast (South region), the target area of the Project, is expected to rise by 3.2°C, and the minimum temperature is expected to rise by 3.3°C as shown in the figure below.



min

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
■ North	4,12	3,61	3,17	2,75	2,39	2,49	3,05	3,32	3,18	2,66	3,66	4,76	3,26
■ West	3,86	3,11	2,73	2,51	2,32	2,49	3,07	3,46	3,30	2,79	3,49	4,41	3,13
■ Center	3,72	3,19	2,90	2,65	2,45	2,72	3,36	3,62	3,43	2,71	3,46	4,32	3,21
■ East	3,98	3,44	3,28	2,99	2,66	2,89	3,53	3,85	3,44	2,78	3,72	4,45	3,42
■ South	3,04	2,57	2,69	2,57	2,66	3,20	3,82	4,03	3,80	2,92	3,28	3,65	3,19
■ Ukraine	3,72	3,16	2,92	2,67	2,49	2,75	3,36	3,65	3,44	2,77	3,50	4,30	3,23

max

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
■ North	3,32	3,02	2,90	2,25	2,26	2,76	3,33	3,78	3,55	2,67	3,70	4,13	3,14
■ West	3,29	2,81	2,49	2,08	2,24	2,80	3,36	3,83	3,69	2,81	3,53	4,00	3,08
■ Center	3,24	2,85	2,73	2,27	2,59	3,12	3,75	4,02	3,77	2,73	3,58	3,99	3,22
■ East	3,38	2,94	3,06	2,50	2,88	3,29	4,04	4,29	3,69	2,73	3,70	4,10	3,38
■ South	2,96	2,53	2,60	2,45	2,98	3,60	4,16	4,26	3,95	2,88	3,37	3,73	3,29
■ Ukraine	3,23	2,82	2,73	2,30	2,58	3,11	3,71	4,02	3,73	2,77	3,57	3,98	3,21

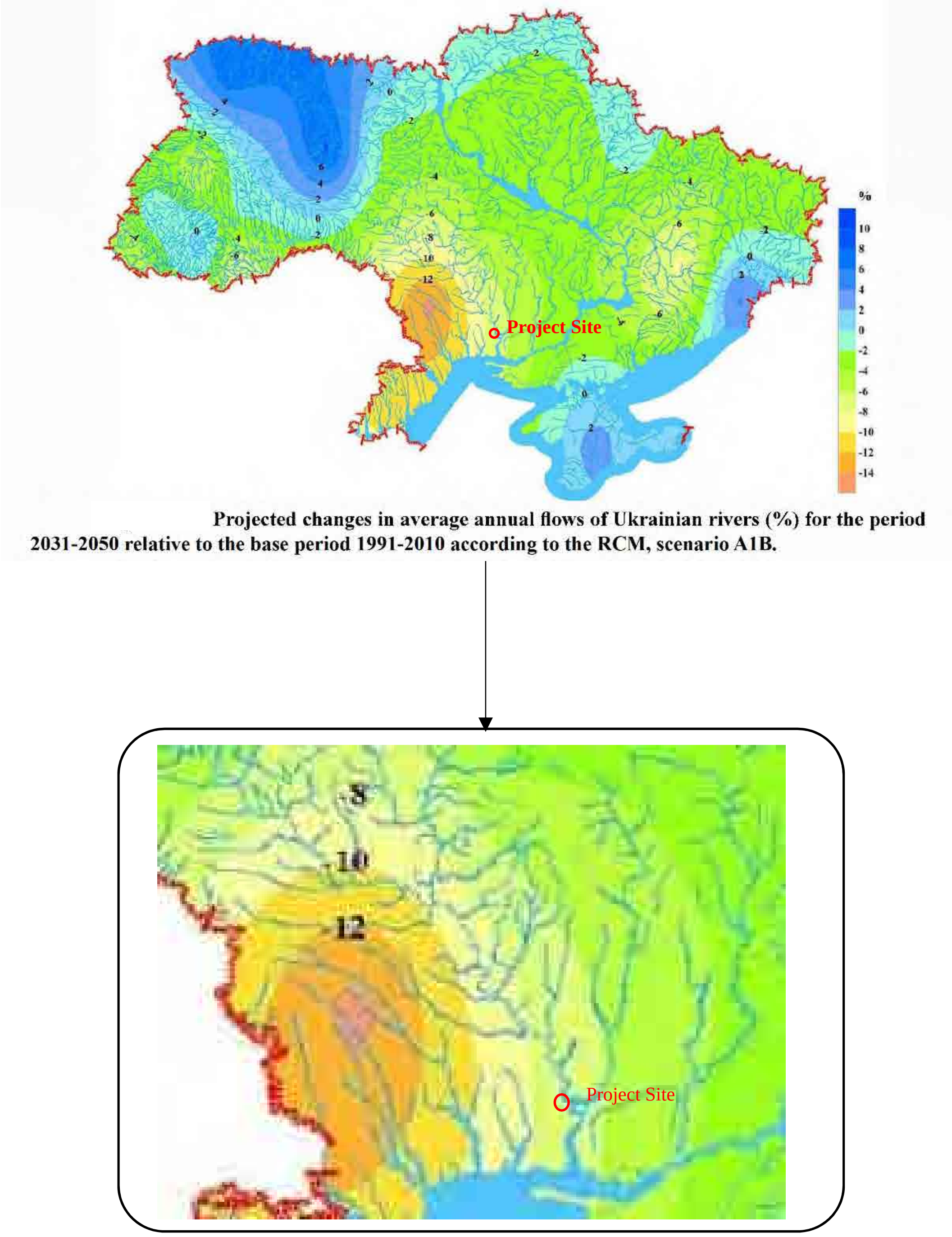
Changes in the average minimum and maximum air temperatures in 2081-2100 relative to 1991-2010.

Source: National Communication of Ukraine on Climate Change (2013)

Figure 4-1-11. Variation in Maximum/Minimum Temperature due to Climate Change

3) Changes in Discharge

By 2081-2100, the average annual discharge of the South Bug River around the Project Site is projected to decrease by 6%-8% from 1991-2010 levels.



Projected changes in average annual flows of Ukrainian rivers (%) for the period 2031-2050 relative to the base period 1991-2010 according to the RCM, scenario A1B.

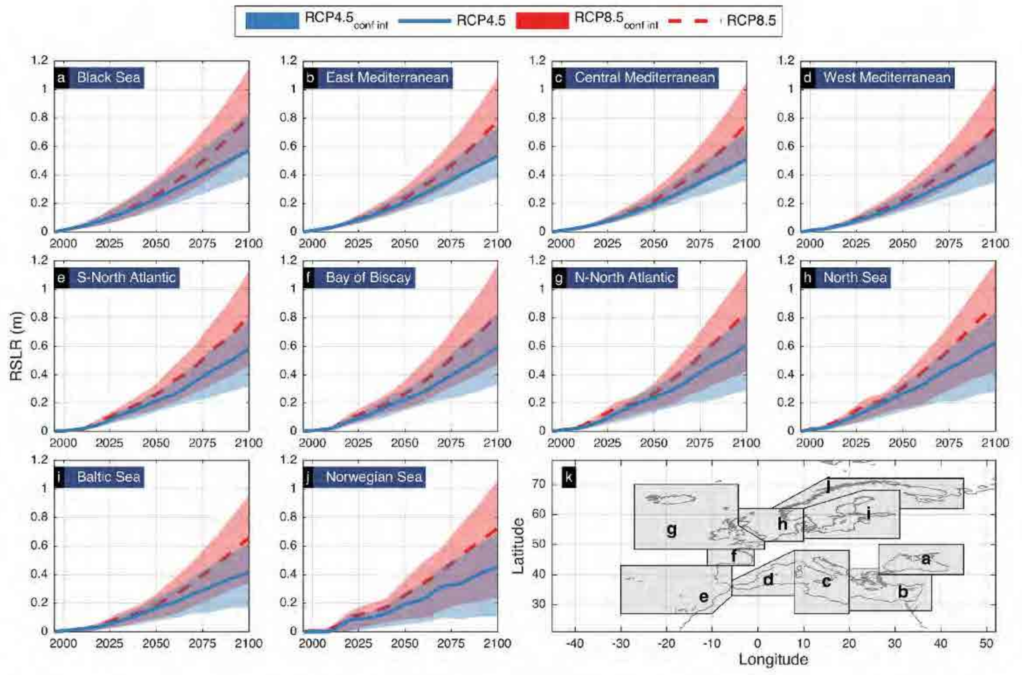
*RCM: Regional Climate Models
Scenario A1B: Moderate Scenario of Society Development

Source: National Communication of Ukraine on Climate Change (2013)

Figure 4-1-12. Variation in Annual Average Discharge due to Climate Change

4) Changes in Sea Level

According to "Extreme sea levels on the rise along Europe's coasts" (Michalis I. Vousdoukas, Lorenzo Mentaschi, Evangelos Voukouvalas, Martin Verlaan and Luc Feyen, AGU Publications, 2017), an analysis of sea level rises caused by global warming, the sea level of the Black Sea is expected to rise by 0.8 m by 2100 (the median worst case; the maximum rise is roughly 1.1 m).



Time evolution of relative sea level rise (RSLR) under Representative Concentration Pathway (RCP)4.5 and RCP8.5. Lines express the ensemble mean and colored patches the intermodel range (defined by the best and worst case scenario). Europe is divided in 10 geographical regions (see k) in order to better reflect the spatial variations of RSLR, where the values shown in (a–j) are averages for each region.

Source: Extreme Sea Levels on the Rise along Europe's Coasts AGU Publication (2017)

Figure 4-1-13. Sea Level Rise due to Climate Change

5) Conclusion

Due to the reasons below, design discharge rates are not expected to increase as a result of climate change; still, in view of the sea level changes noted later in this document, there is a possibility of a 0.8 m sea level rise by the year 2100.

Climate Change Considerations

- Based on Figure4-1-11, rise in both maximum and minimum temperatures is projected. However, as seen in the table below, the annual maximum discharge of the Southern Bug River occurs from February to April, presumably as a result of snow melting. Therefore, the discharge is expected to decrease alongside the future decrease in snowfall.

Table 4-1-12. Months when Annual Maximum Discharge Occur

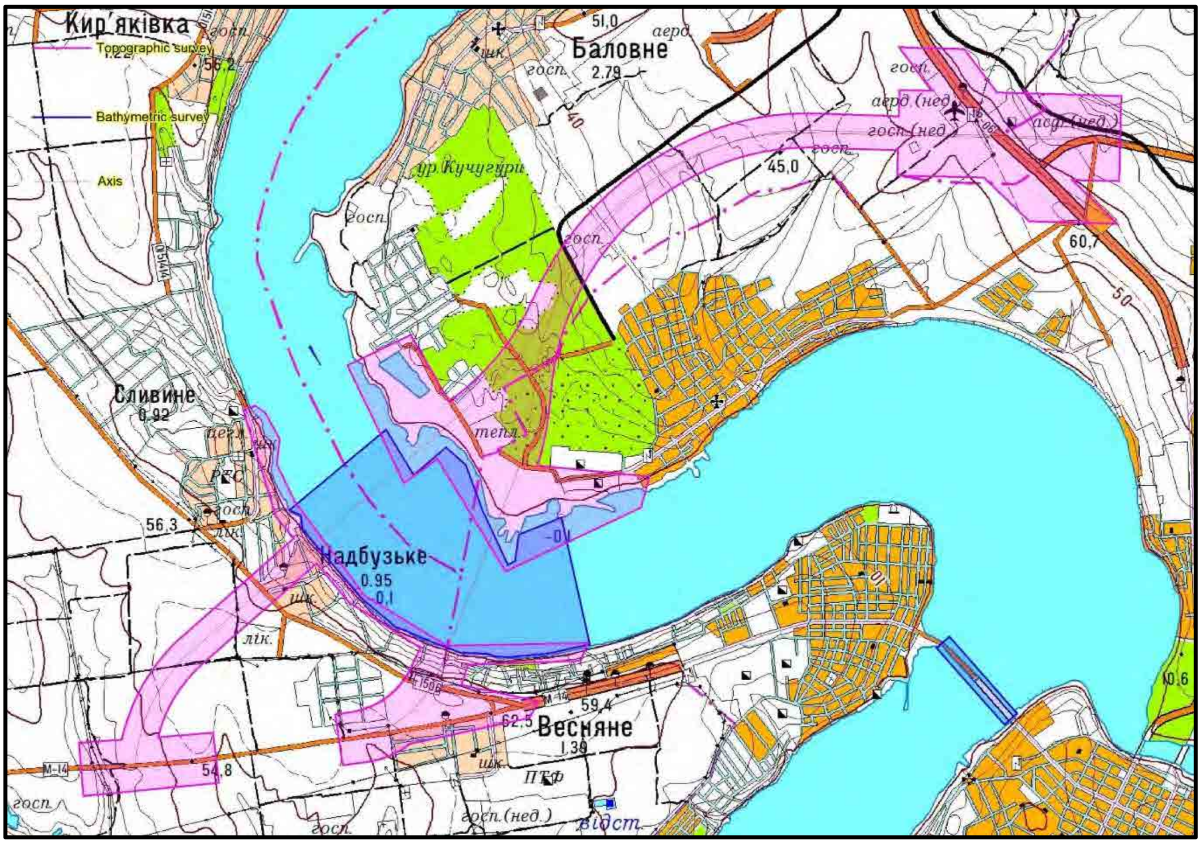
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of Occurrence	4	14	46	20	3	3	6	2	1	2	1	1

- As seen in Table4-1-11, changes in the amount of rainfall are negligible at just 3 mm total per year, and even on a monthly basis this would only add 8 mm. Additionally, as seen in Figure4-1-12, the annual maximum discharge is expected to decrease by 6-8%. Given these conditions, no significant changes are expected in maximum discharge.
- Because Mykolaiv Bridge is located in an estuary zone, they are influenced by rises in sea level.

4-2 Measurement Surveys

4-2-1 Overview of Topographic Survey

The topographic survey for this Study was carried out from July 2018 to the end of October 2018. The survey comprises a topographic survey and a sounding survey. Their areas are shown in Figure4-2-1. The result of the topographic survey is three-dimensional data of the topographic map. These results are used for road and bridge design.



Source: JICA Survey Team

🟪 : Topographic Surveying Area 15km^2

🟦 : Sounding surveying Area 5.5km^2

Figure 4-2-1. Location Map of Topographic Survey

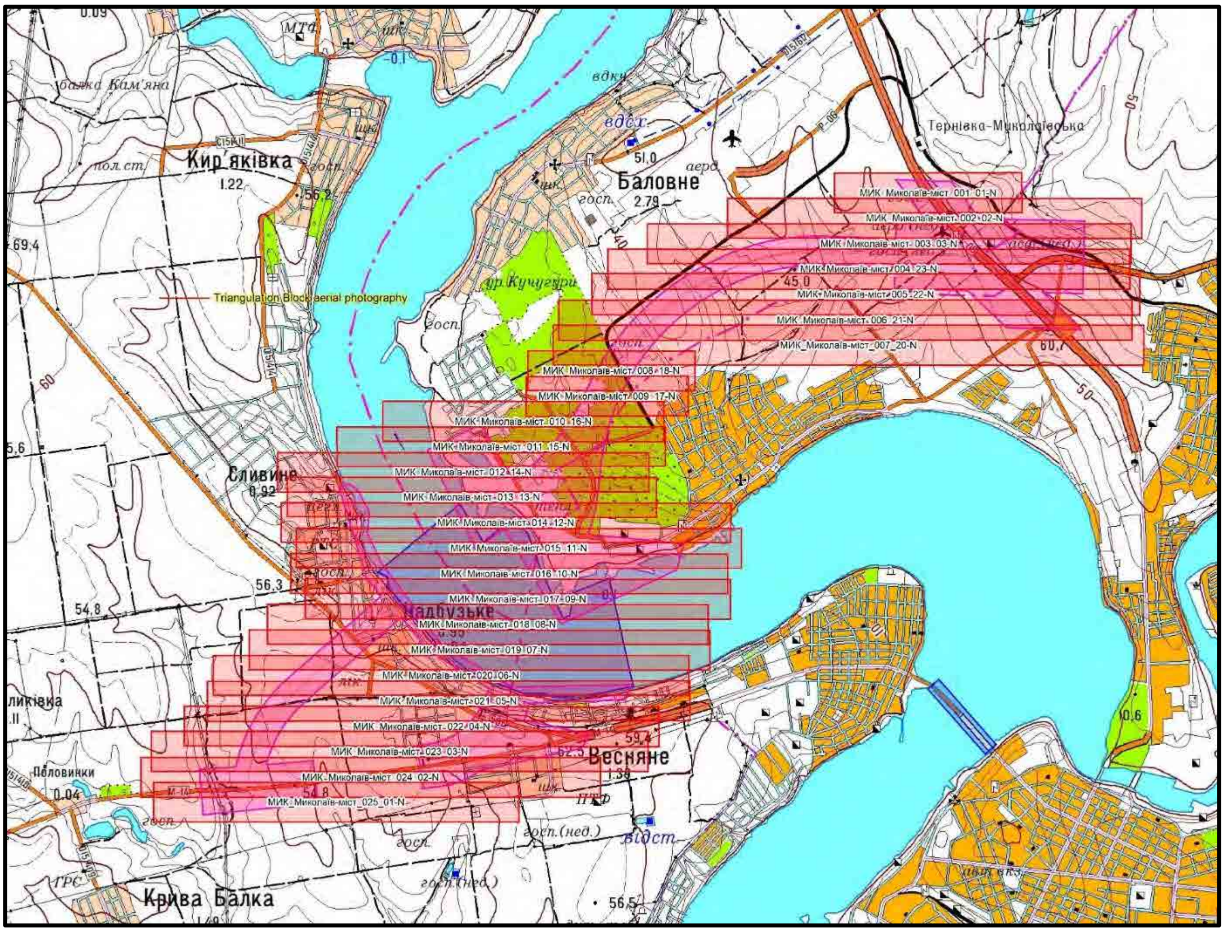
4-2-2 Topographic Surveying

The digital aerial photographs to create the topographic map carried out by certified photographic survey airplane AN-2 (the airline "V-Avia", airplane No. 40437). The locations of digital aerial photographs are shown in the Figure4-2-2 (aerial photography was performed over the areas in the shaded red boxes). The conditions of the topographic map are as follows.

(1) Aerial survey area: 27.77 km^2
(2) Mapping area: 15 km^2
(3) Scale: 1/1,000
(4) Contour interval: 0.5m
(5) Coordinate system: Longitude/latitude, WGS 84/UTM zone 36N
(6) Reference plane: the Baltic Sea Level Datum of 1977 (Baltic elevation system)

The network of control points within the survey area in Mykolaiv Oblast and Mykolaiv City was used for the reference points for the topographic surveying.

The geodetic network points for this survey are shown in Table4-2-1 and Figure4-2-3.



Source: JICA Survey Team

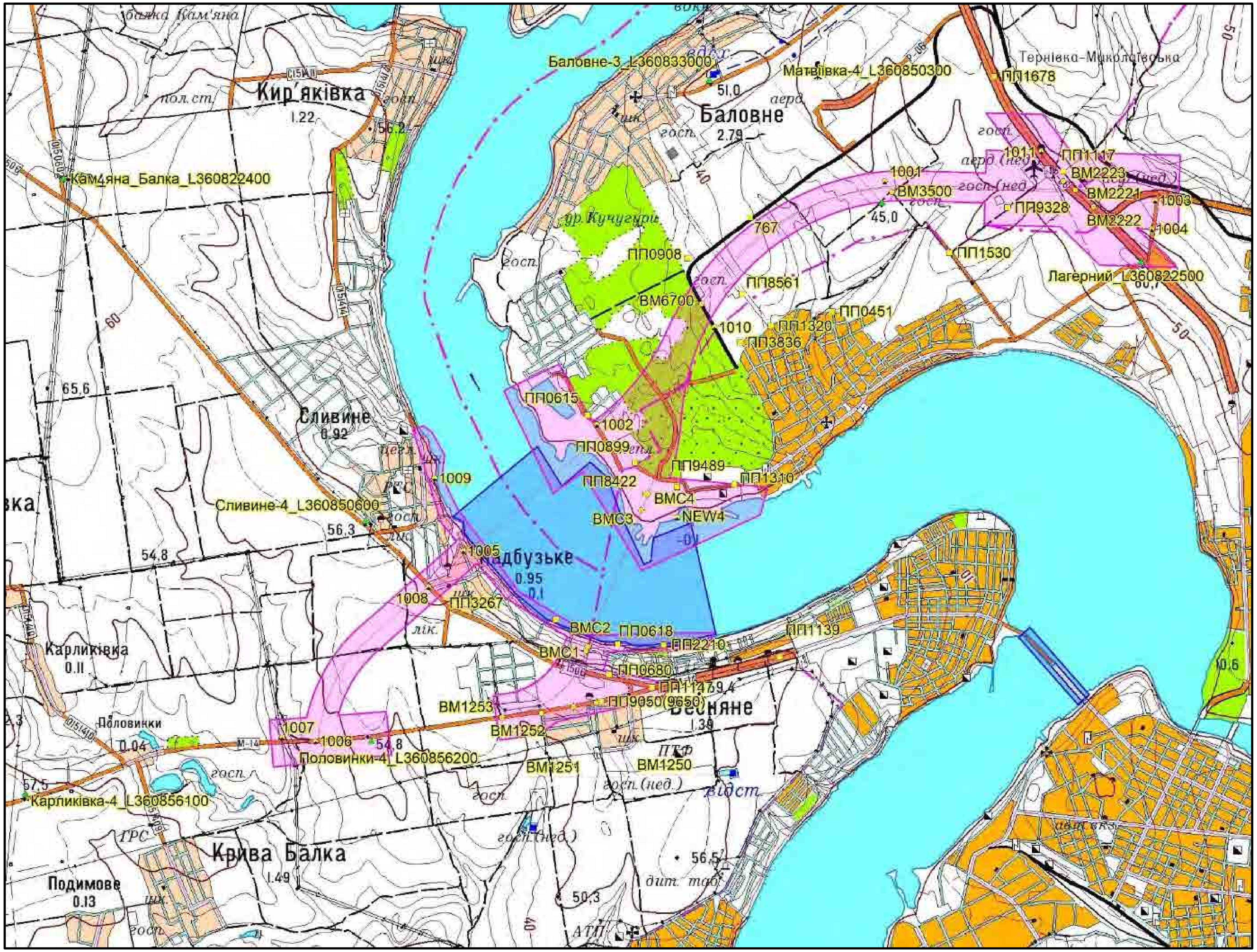
Figure 4-2-2. Location of Aerial Photographs

Table 4-2-1. List of Coordinates and Altitudes of the Geodetic Network Points (Topographic Surveying)

No.	Point No.	Latitude	Longitude	E*	N*	H(m)
1	ПП0451	47°01'44"	31°55'27"	418253.581	5208936.023	19.000
2	ПП0615	47°00'57"	31°52'53"	414982.444	5207530.771	6.175
3	ПП0680	46°59'05"	31°53'09"	415271.057	5204068.735	54.977
4	ПП0899	47°00'37"	31°53'24"	415628.157	5206904.097	3.932
5	ПП0908	47°02'06"	31°53'55"	416321.330	5209642.122	35.532
6	ПП1117	47°02'46"	31°57'53"	421360.450	5210808.313	56.450
7	ПП1139	46°59'14"	31°54'57"	417556.290	5204314.542	52.318
8	ПП1147	46°59'00"	31°53'36"	415839.224	5203906.312	58.167
9	ПП1310	47°00'28"	31°54'27"	416954.457	5206607.580	5.918
10	ПП1320	47°01'37"	31°54'48"	417427.425	5208731.313	33.128
11	ПП1530	47°02'10"	31°56'41"	419826.285	5209717.341	46.238
12	ПП1678	47°03'27"	31°57'08"	420427.902	5212086.550	53.169
13	ПП2210	46°59'18"	31°53'43"	415994.930	5204459.849	0.509
14	ПП3267	46°59'28"	31°52'34"	414541.903	5204789.258	1.347
15	ПП3836	47°01'30"	31°54'29"	417023.373	5208520.816	36.431
16	ПП8422	47°00'23"	31°53'30"	415748.725	5206470.149	2.441
17	ПП8561	47°01'51"	31°54'30"	417053.518	5209168.753	38.211
18	ПП9050 (9650)	46°58'53"	31°53'04"	415160.163	5203699.823	58.267
19	ПП9328	47°02'30"	31°57'18"	420615.364	5210324.234	50.914
20	ПП9489	47°00'26"	31°53'50"	416172.337	5206556.792	4.717
21	ПП0618	46°59'18"	31°53'14"	415382.376	5204468.517	1.118
22	767	47°02'24"	31°54'34"	417152.132	5210186.229	40.347
23	BM2221	47°02'38"	31°58'01"	421525.989	5210559.136	56.236
24	BM2222	47°02'31"	31°58'12"	421755.254	5210339.999	52.919
25	BM2223	47°02'42"	31°57'53"	421358.817	5210684.840	57.90
26	BM3500	47°02'36"	31°56'04"	419056.371	5210530.493	(45.398)
27	BM6700	47°01'46"	31°54'04"	416502.602	5209022.089	35.727
28	BMS4	47°00'23"	31°53'32"	415790.956	5206469.552	2.312
29	BMS3	47°00'16"	31°53'28"	415703.435	5206254.670	2.664
30	BMS2	46°59'17"	31°52'55"	414980.607	5204443.364	29.407
31	BMS1	46°59'15"	31°52'54"	414958.604	5204381.929	36.559
32	BM1250	46°58'53"	31°53'01"	415096.788	5203700.725	58.116
33	BM1251	46°58'51"	31°52'47"	414800.151	5203643.210	56.916
34	BM1252	46°58'48"	31°52'27"	414376.311	5203556.662	52.70
35	BM1253	46°58'45"	31°52'01"	413825.700	5203471.976	53.067

*: WGS 84/UTM zone 36N

Source: JICA Survey Team



Source: JICA Survey Team

Figure 4-2-3. Location of Coordinates and Altitudes of the Geodetic Network Points (Topographic Surveying)

A digital scanner Aerial camera 3 DAS-1-80 was used for the aerial photography. While the images were being captured, an Applanix navigation system POS AV 510 was used to measure the coordinates and elevation of the flightpath at a recording frequency of 200 Hz, and a GPS receiver (GPS Trimble 5700) programmed with the network of control points (survey reference points) was used to convert the flightpath into a frame of reference.
In addition, GPS surveying using GNSS RTK South S660P was used to supplement (adjust the planar height of the aerial photographs) the photographing positions.

The following is a summary of the aerial photogrammetry specifications.

[Surveying Equipment]

・Digital scanner: Aerial camera 3 DAS-1-80 (with built-in POS AV 510)
Focal length: 80 mm
Pixel size: 9.0 microns
Number of pixels: 8,000 pixels

・GPS receiver: GPS Trimble 5700
Measurement error: Horizontal RMS: 10 mm + 1 ppm
Vertical RMS: 20 mm + 1 ppm
GNSS RTK South S660P
Measurement error: Horizontal RMS: 15 mm; Vertical RMS: 20 mm

Table 4-2-2. Aerial Photogrammetry Specifications

Scale	Altitude m	Output resolution cm	Photograph width m	Maximum flight speed km/h	Overlap		Error (RMS)	
					Vertical %	Horizontal %	Horizontal cm	Vertical cm
1/7,500	600	6.75	540	152	100	25	10.1	13.5

[Measurement Error]

The following are the results of the confirmation of the precision of the aerial photography after image processing.

Measurement error: Horizontal (XY) RMS: 5 cm; Vertical (Z) RMS: 14 cm

4-2-3 Sounding Surveying

The sounding survey was carried out by using echo sounding machine (Echosounder Bathy 500 df) and GPS (GNSS R4 Trimble, Built in GPRS modem and antenna).

The following are the final specifications for sounding surveying.

The network of control points in Mykolaiv Oblast and Mykolaiv City was used for the reference points for the sounding surveying.

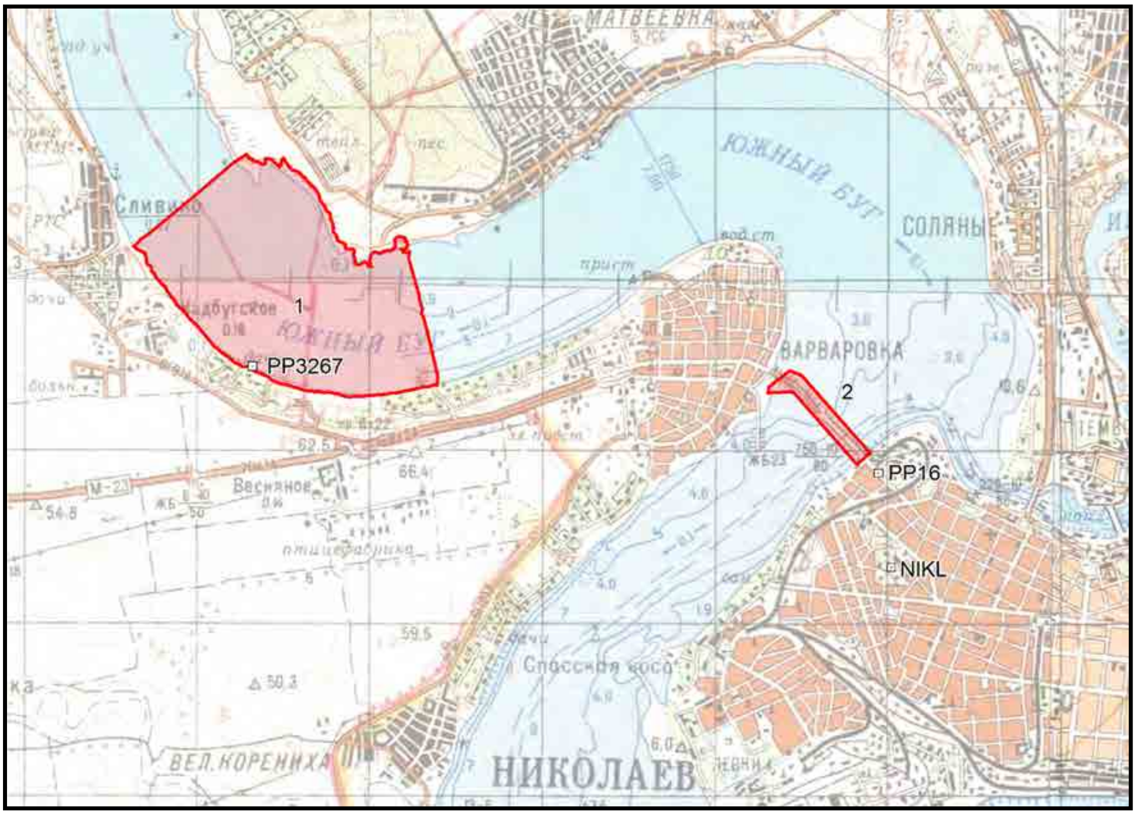
The geodetic network points for this survey are shown in Table 4-2-3 and Figure4-2-4.

(1) Target area: 5.5 km^2
(2) Scale: 1/1,000
(3) Contour interval: 0.5m
(4) Coordinate system: Longitude/latitude, WGS 84/UTM zone 36N
(5) Reference plane: the Baltic Sea Level Datum of 1977 (Baltic elevation system)

Table 4-2-3. List of Coordinates and Altitudes of the Geodetic Network Points (Sounding Surveying)

No.	Latitude	Longitude	E*	N*	H
PP3267	46° 59' 28.31"	31° 52' 34.44"	414551.333	5204798.693	1.347
NIKL	46° 58' 16.08"	31° 58' 26.25"	421952.869	5202467.146	58.419
PP16	46° 58' 46.01"	31° 58' 26.52"	421970.669	5203390.949	40.790

*: WGS 84/UTM zone 36N Source: JICA Survey Team



Source: JICA Survey Team

Figure 4-2-4. Location of Coordinates and Altitudes of the Geodetic Network Points (Sounding Surveying)

The following is a summary of sounding surveying specifications.

[Surveying Equipment]

- Echo sounder: Echosounder Bathy 500 df
  (manufactured by Ocean Data Equipment Corporation)
  Frequency: 33/210 kHz
  Measurement error (Z): ±0.5% (3-4 cm)
  Acoustic wave velocity: 1,400-1,600 m/sec
- GPS receiver: GNSS R4 Trimble
  Measurement error: Horizontal (XY) RMS: 15 mm; Vertical (Z) RMS: 20 mm

[Survey Conditions]

Survey side lines were planned perpendicular to the coastline, and measurements were taken with survey line spacing of 20 m and survey point spacing of 1-6 m (roughly one survey point per 100 m^2). Figure 4-2-5 shows the layout of the survey side lines.

Survey Point 1: Number of side lines: 203; Number of survey points: 53,052
Survey Point 2: Number of side lines: 30; Number of survey points: 4,138

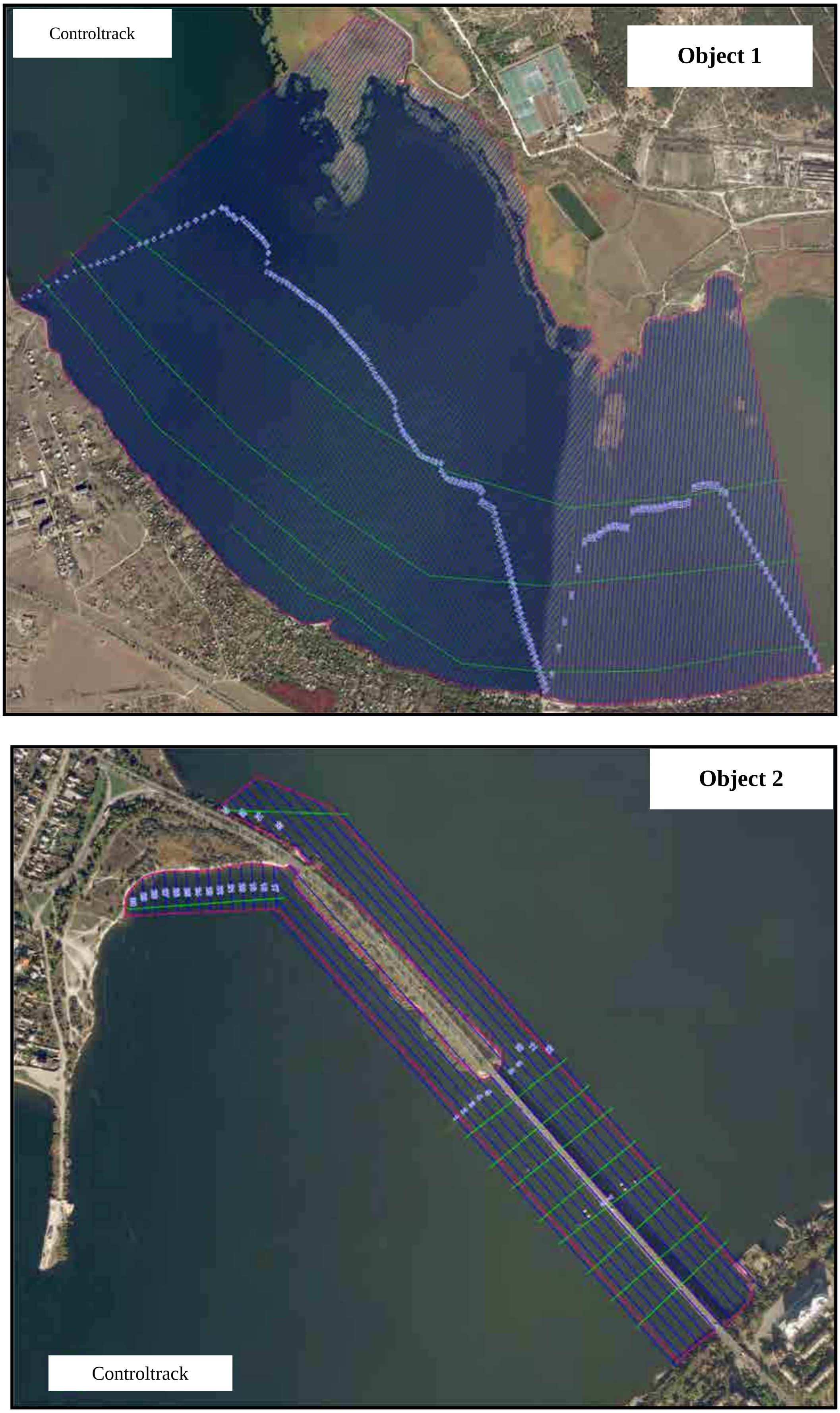
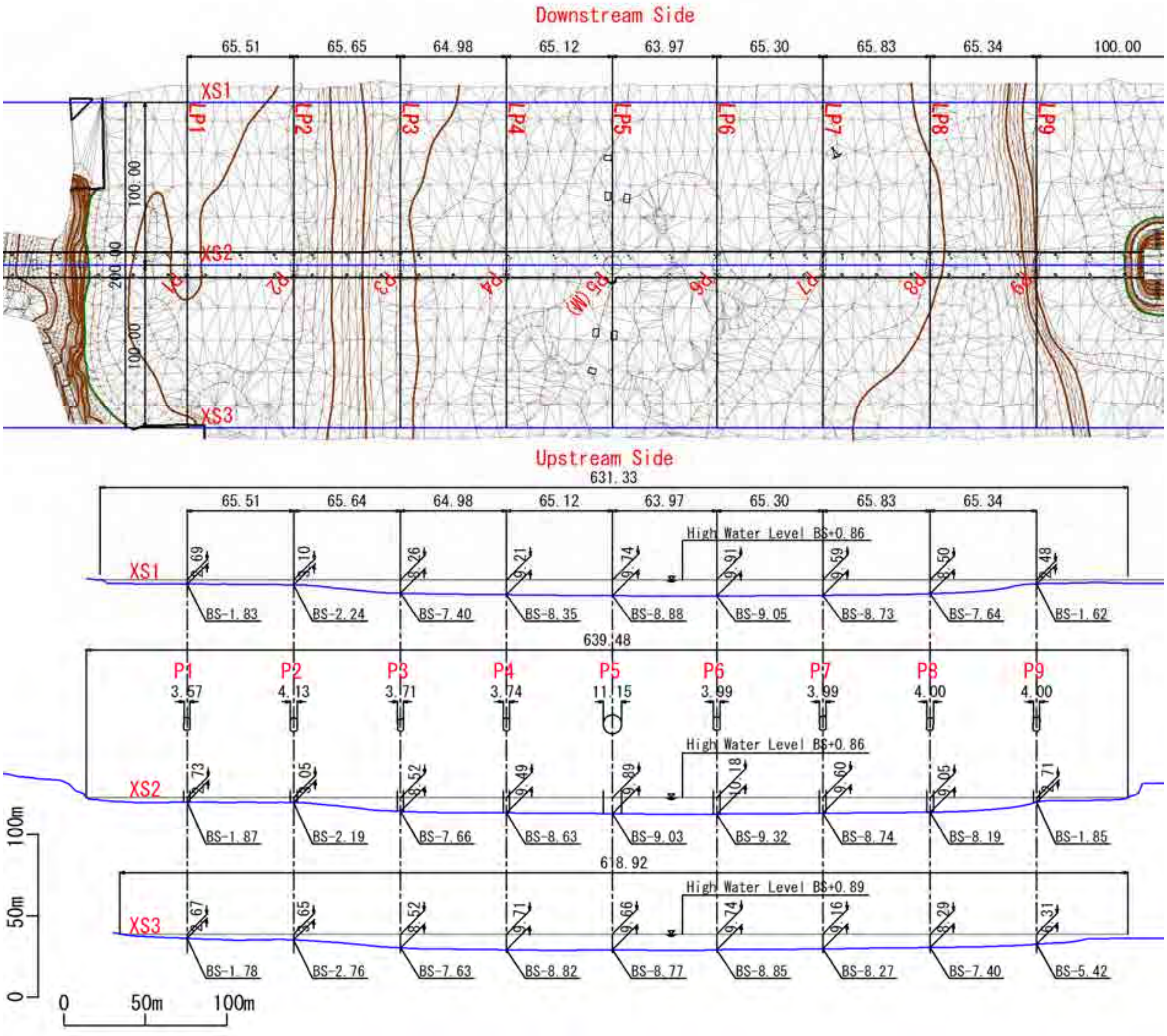


Figure 4-2-5. Layout of Survey Track Lines (Sounding Surveying)

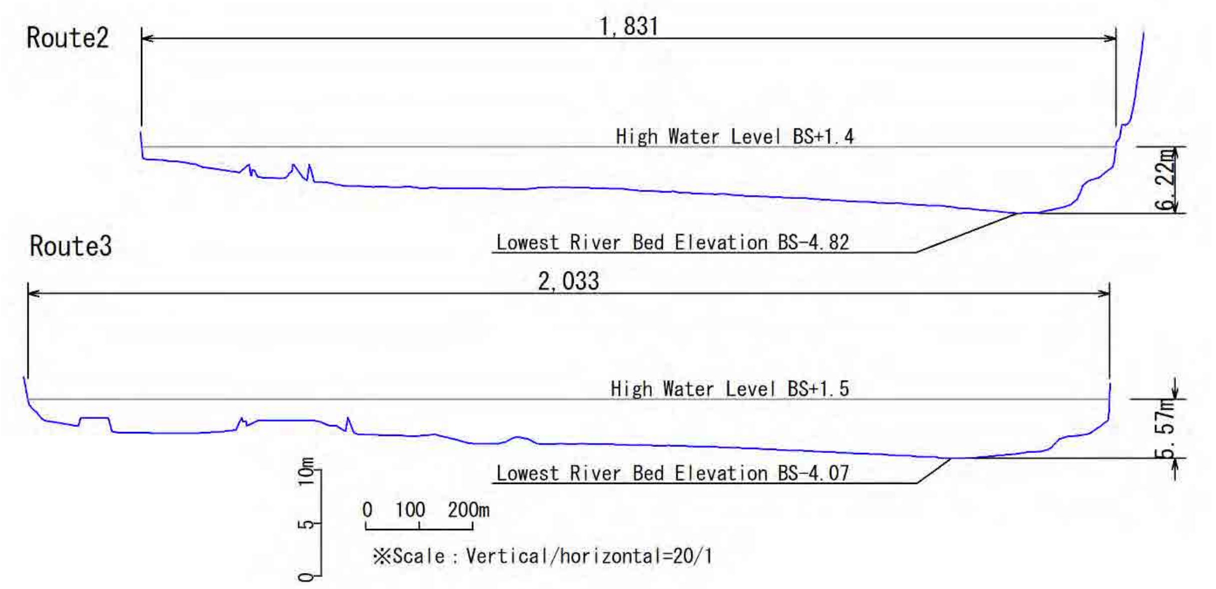
The following figures are part of the sounding surveying results.
High water levels in the cross sections shown in Figures 4-2-6 and 4-2-7 are calculated water levels in 7-2-2 1).
It is occurred by design discharge (1/100-year discharge) and 1/100-year high water level (BS+1.0m) at Mykolaiv (Sea Hydro-meteorological Station).



Cross Section	Average Depth from High Water Level
XS1	6.8m
XS2	6.9m
XS3	7.2m

※Bed slope between XS1 and XS3 is approx. 0.00026 (1/3,846).

Figure 4-2-6. Cross Section of Southern Bug River at Vavarovsky Bridge



Cross Section	Average Depth from High Water Level
Route2	4.0m
Route3	3.8m

※Bed slope of the survey area is approx. 0.00022 (1/4,545).

Figure 4-2-7. Cross Section of Southern Bug River at Route2 and Route3

Table 4-2-4. Result of One-dimensional steady flow Calculation

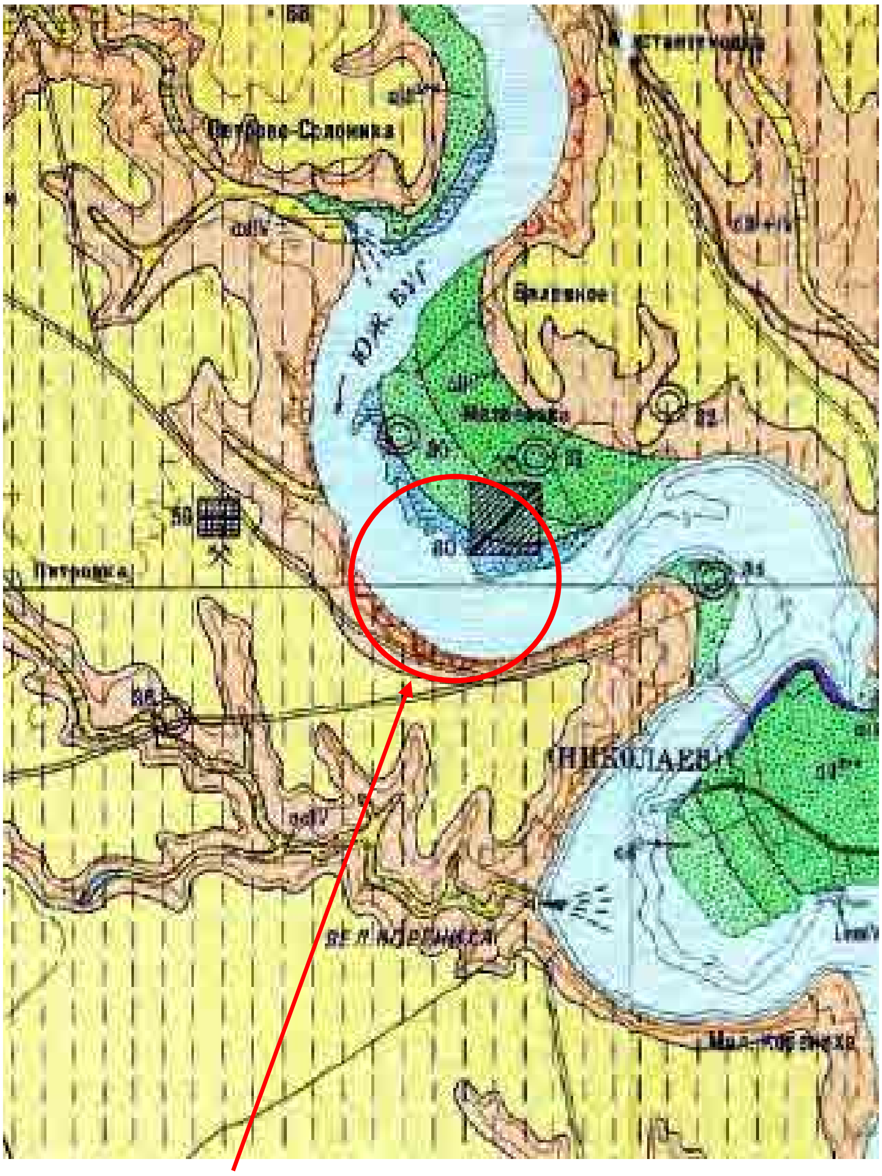
Name of Bridge	Design High Water Level (m)	Design Discharge (m^3/s)	Velocity (m/s)	Average Depth (m)	Top Width (m)	Flow Area (m^2)	Bed Slope	Distance (km)
Vavarovsky Bridge, XS1	BS+0.86	5,430	1.3	6.8	631	4,265	0.00026 (1/3,846)	-0.1
Vavarovsky Bridge, XS2	BS+0.86	5,430	1.3	6.9	597	4,112	0.00026 (1/3,846)	0.0
Vavarovsky Bridge, XS3	BS+0.89	5,430	1.2	7.2	619	4,483	0.00026 (1/3,846)	0.1
Mykolaiv Bridge (Route 2)	BS+1.4	4,600	0.7	4.0	1,762	7,063	0.00022 (1/4,545)	10.9
Mykolaiv Bridge (Route 3)	BS+1.5	4,600	0.6	3.8	1,949	7,301	0.00022 (1/4,545)	12.9

4-3 Geological Surveys

4-3-1 Overview

The Ukrainian Shield spreads out southwest of the Eurasian plate and East Europe Craton in Ukraine. The Ukrainian Shield is old bedrock that extends from the northwest of Ukraine to the southeast (Azov sea) and formed on last Cambrian period (roughly 4.5-5.0 billion years ago). It is formed by granite, gneiss, quartzite, sandstone and is divided into two plateaus: the Dnieper Plateau and the Azov Plateau.

The targeted area of this Study is located along the Southern Bug River upstream of the Ukrainian Shield. Also, most of this area is mainly composed of a wide range of sedimentary layers of sand, sandy loam, loamy clay, limestone, marl and the like formed during the Neogene (roughly 2.6-23 million years ago) and Quaternary (as early as roughly 2.6 million years ago, as late as the modern period) periods. The Quaternary sediment layers comprise sand and clay, and the Neogene sediment layers comprise a Meotis layer of clay and limestone with a Sarmatian layer of clay above it, and the distribution of clay and limestone has been confirmed in all places in the target area of the survey.



Proposed Bridge Location
Пропоноване місцезнаходження моста

Recent deposits (until roughly 100,000 years ago)	a IV	Alluvial floodplain deposits. Sands, sandy clay, silt
	Lmn IV	Firth deposits in modern and ancient Black Sea layers. Sands, sand clay, silt
	ad IV	Alluvial and deluvial deposits in riverbeds. Sands, sandy clay, silt, loam
Upper quaternary and modern deposits (until roughly 120,000 years ago)	d III+IV	Deluvial deposits of the slopes at the rivers' and cloughs' valleys. Loam, sandy clay with spots of rocks
Upper quaternary deposits (roughly 100,000-120,000 years ago)	vd,L III	Aeolian and lake deposits. Loess-like loam.
	vd III	Aeolian and deluvial deposits and deluvial deposits. Loess-like loam with fossil soil
	a III^{3+4}	Aeolian deposits I of upland fringe terraces. Sands with silt
	a III^{1+2}	Aeolian deposits II of upland fringe terraces. Sands with silt
Middle quaternary deposits (roughly 120,000-780,000 years ago)	vd II	Aeolian and deluvial deposits. Broan loess-like loam with fossil soil (only on a cut)
	a II^{3+4}	Aeolian deposits III of upland fringe terraces, sands with loam and silt layers
Lower quaternary deposits (roughly 780,000-2,600,000 years ago)	vd I	Aeolian and deluvial deposits. Loess-like loam, red and brown, with fossil soil (only on a cut)

Source: Ministry of Geology of the USSR (Quaternary Deposits Map) L-36-VIII (1967)

Figure 4-3-1. Subsurface Geological Map of the Survey Area

4-3-2 Geological Survey

The geological survey was carried out for a road and a bridge design. The main contents of the geological survey are 1) borehole drilling at the proposed bridge (on land), 2) borehole drilling at the proposed bridge (in the river), 3) Cone Penetration Test at the proposed interchange, 4) material test at the approach road, and 5) material test at the borrow pit. Table4-3-1 shows the detailed items and quantity.

Table 4-3-1. Scope of the Geological Survey

Item	Unit	Quantity
1)Borehole drilling at the proposed bridge (on land)		
･Boring site	number	4
･Boring	m	118.2
･Standard Penetration Test (SPT)	Set	156
2)Borehole drilling at the proposed bridge (in the river)		
･Boring site	number	6
･Boring	m	203.5
･Standard Penetration Test (SPT)	Set	131
3)Core Penetration Test (CPT) at the proposed interchange		
･Core Penetration Test (CPT)	number	4
4)Material test for the approach road		
･Sampling	number	23
･Laboratory test	Set	23
5)Material test at the borrow pit		
･Sampling	number	5
･CBR test	Set	9

Source: JICA Survey Team

1) Borehole Drilling at the Proposed Bridge

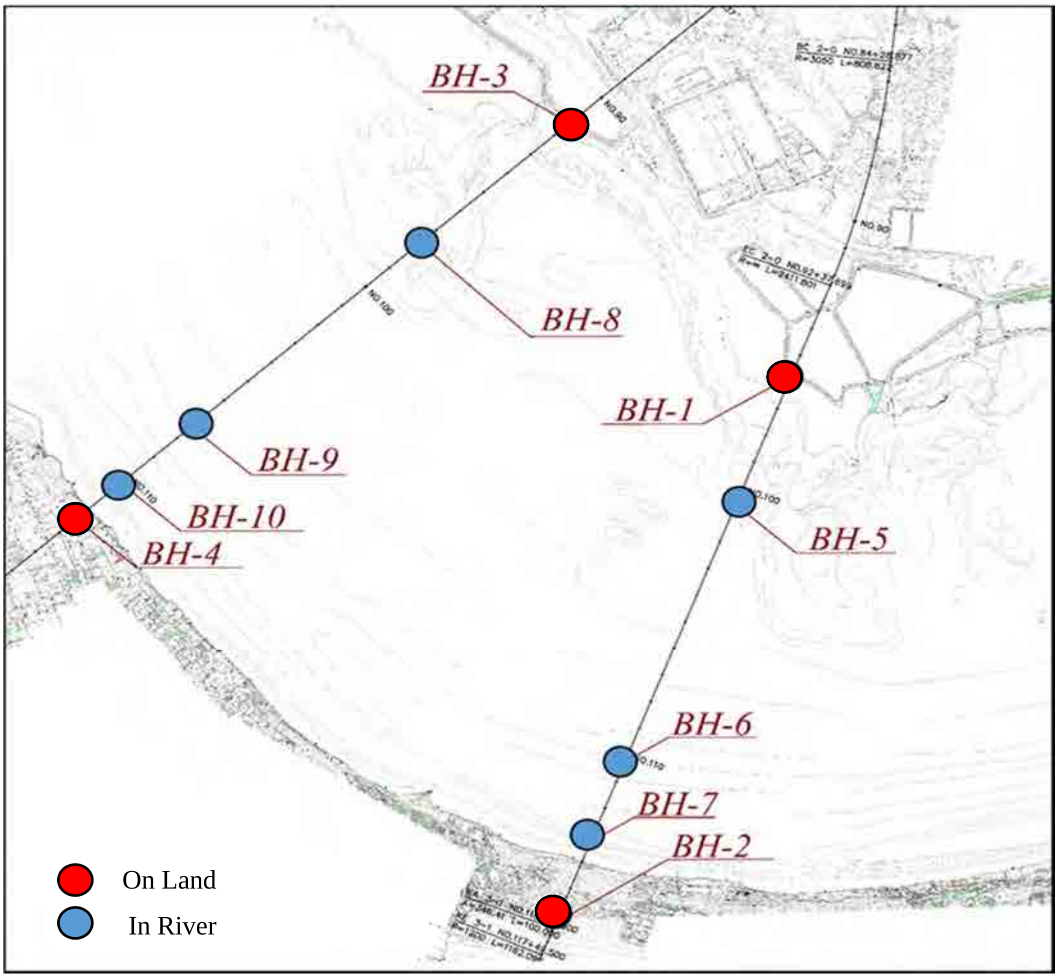
The locations of borehole drilling are shown in the Table4-3-2 and Figure4-3-2.

Table 4-3-2. Locations of Borehole Drilling

Route	No.	Coordinates				H (m)	Depth (m)	Remarks
		Latitude	Longitude	E*	N*			
Route2	BH-1	47° 0' 16.01"	31° 53' 28.13"	415706.184	5206254.940	2.7	25.0	on Land
	BH-2	46° 59' 14.28"	31° 52' 54.98"	414978.987	5204359.409	38.9	35.0	
	BH-5	47° 0' 1.32"	31° 53' 19.85"	415524.910	5205803.967	-2.3	32.0	In River
	BH-6	46° 59' 31.98"	31° 53' 3.75"	415172.015	5204903.132	-3.8	35.0	
	BH-7	46° 59' 22.89"	31° 52' 58.73"	415061.988	5204624.052	-3.2	35.0	
Route3	BH-3	47° 0' 44.28"	31° 52' 54.02"	414998.371	5207137.821	3.9	35.0	on Land
	BH-4	46° 59' 58.68"	31° 51' 40.55"	413426.728	5205752.590	24.4	23.2	
	BH-8	47° 0' 30.43"	31° 52' 31.65"	414519.933	5206717.061	-1.7	31.5	In River
	BH-9	47° 0' 9.33"	31° 51' 57.62"	413791.973	5206076.106	-3.5	35.0	
	BH-10	47° 0' 2.87"	31° 51' 47.11"	413567.140	5205879.915	-3.2	35.0	

*: WGS 84/UTM zone 36N

Source: JICA Survey Team



Source: JICA Survey Team

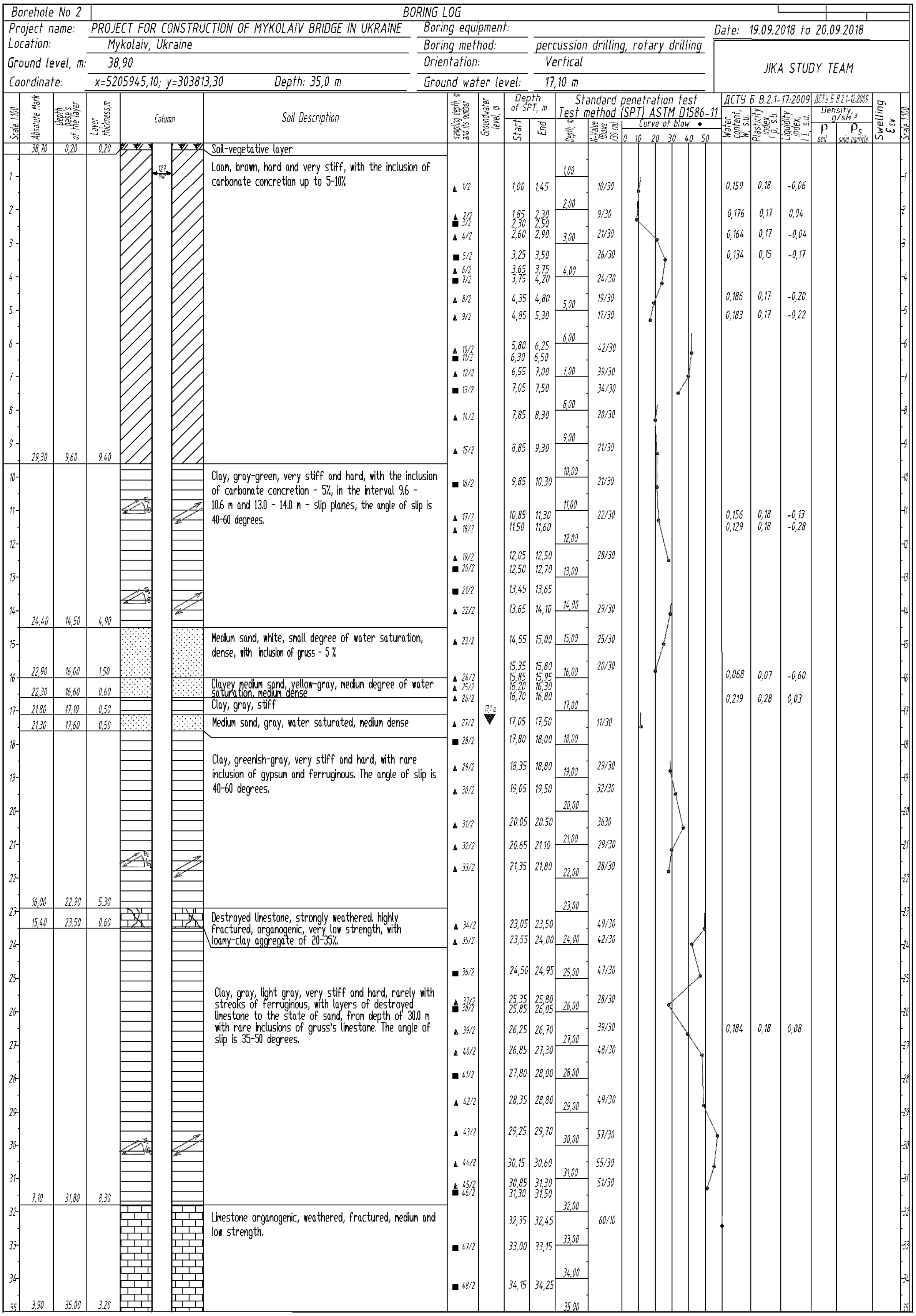
Figure 4-3-2. Location of Borehole Drilling

Figure4-3-7 and Figure4-3-8 show the assumed soil profile of the Project area based on the boring logs of BH-1 to BH-10 (samples logs are shown from Figure4-3-3 to Figure4-3-6). Based on the survey results, fourteen different layers observed in the Project area are described from top to bottom as shown in Table 4-3-3.

Table 4-3-3. Soil Property

Layer		Characteristic
Name	Number	
eH	A	Soil-vegetative layer with roots of plant
tH	B	Made layer - different granular composition sands, yellow-gray, gray, grayish-brown, medium dense, small degree of water saturation, rumpled, loose in the roof, with the inclusion of crushed stone and stones, with inclusion of limestone fragments, with rare smears of loam
lm, ln P_{IV}	1	Clayey silt, dark gray, greenish gray, black, unstable and stable consistency, soft and very soft. Limans and lagoons deposits
p, ad P_{IV}	2	Loams and clays, dark gray, dark brown, from soft to stiff, with sand interlayers. Proluvial and alluvial-deluvial deposits. The layer was formed from the remains of landslides, soils of ravine cone, and the alluvium of the river
a P_{III}	3	Fine and medium sands, light and dark gray, blue-gray, yellow-gray, water saturated, medium dense and dense. Alluvial deposits
d, vd P_{III-IV}	4	Loam, brown, reddish, hard and very stiff, non-sinking, non-swelling. Postglacial deluvial and aeolian-deluvial deposits. In the case of development it can be used for the construction of embankments.
	5	Clay, light brown, hard and very stiff, weakly swelling. Postglacial diluvial and eolian-diluvial deposits
N_1m+P_{III}	6	Clay, gray-green, light gray, hard and very stiff, weakly and strongly swelling. Sliding planes are traced throughout the entire thickness. Neogene and Quaternary deposits. In the case of development it is not recommended as a material for the construction of embankments.
	7	Limestone, destroyed, highly weathered, strongly fractured, organogenic, of very low strength, with loamy-clayey filler 20-35%. Neogene and Quaternary deposits
	8	Clay, gray, light gray, hard and very stiff. Medium swelling to heavily swelling. Neogene and Quaternary deposits
	9	Limestone, weathered, fractured, organogenic, medium and low strength. The actual thickness of the layer according to the results of drilling is uncertain. Neogene and Quaternary deposits
N_1s	10	Clay, loam, bluish-gray, greenish-gray, gray, from very stiff to stiff. Alternate with tiles and layers of sandstone, limestone, and the weathering crust of sandstone and limestone. Clays from non-swelling to weakly swelling. Neogene deposits. This layer is heterogeneous in composition and properties, therefore it is not recommended as a base for support
	11	Marley clay, light bluish-gray, greenish-gray, very stiff, very dense, with tiles and interlayers of gray sandstone, strongly weathered limestone, with layers of shattered argillite, sandstone and dolomitized limestone. Non-swelling and rarely weakly swelling. Neogene deposits. This layer is recommended as a base for the bridge supports.
	12	Dolomitic limestone, grayish-white, strongly weathered, strongly fractured, low-strength with interlayers of medium strength, with layers of weathering crust and ruined argillite, sandstone. Neogene deposits. This layer can be considered as a base for the supports of the bridge, but the final thickness at this stage is uncertain.

Source: JICA Survey Team



Borehole No 2

BORING LOG

Project name:	PROJECT FOR CONSTRUCTION OF MYKOLAIV BRIDGE IN UKRAINE	Boring equipment:	
Location:	Mykolaiv, Ukraine	Boring method:	percussion drilling, rotary drilling
Ground level, m:	38,90	Orientation:	Vertical
Coordinate:	x=5205945,10; y=303813,30 Depth: 35,0 m	Ground water level:	17,10 m

Date: 19.09.2018 to 20.09.2018

JIKA STUDY TEAM

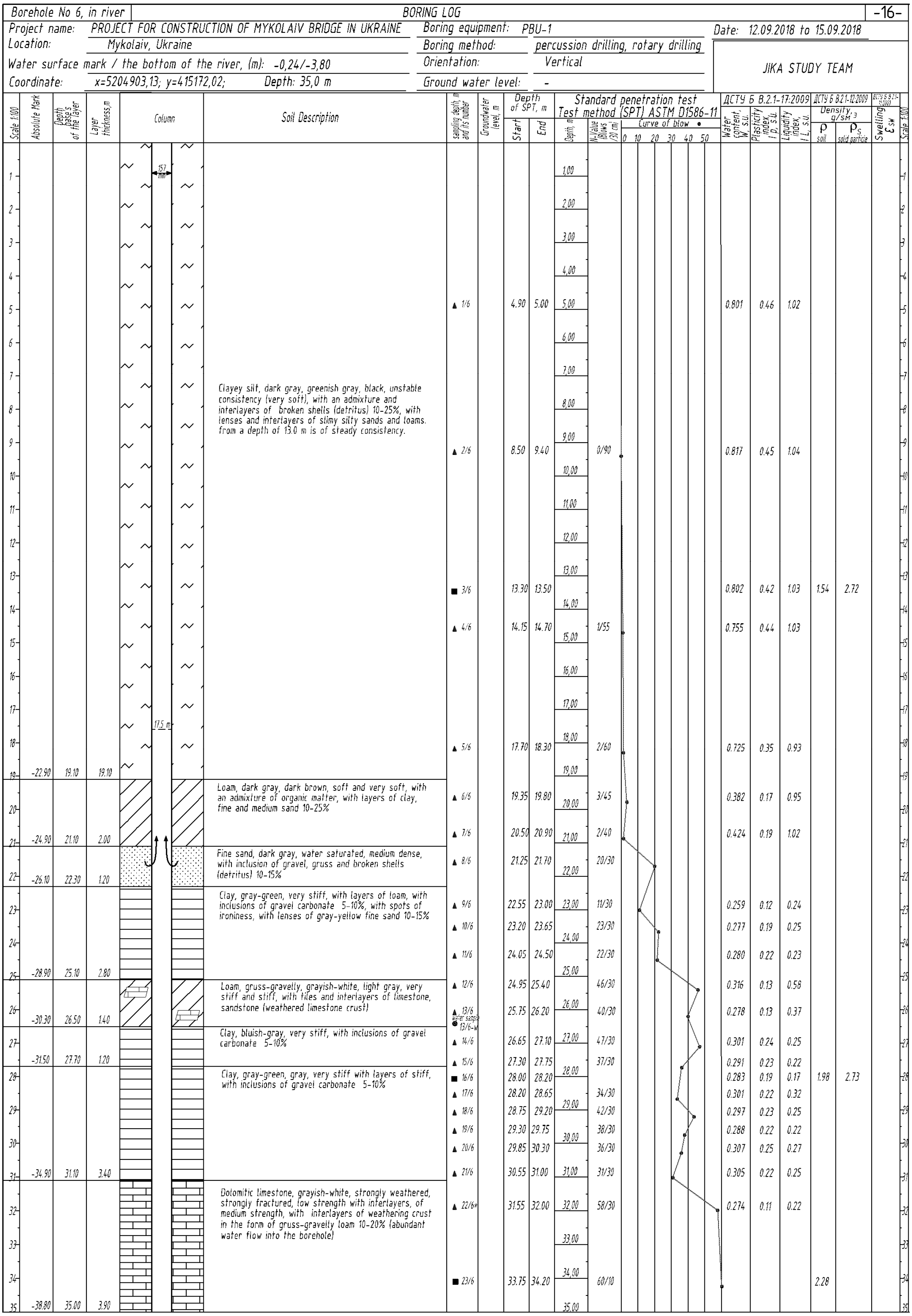
Absolute Mark	Depth base's of the layer	Layer thickness, m	Soil Description
38,70	0,20	0,20	Soil-vegetative layer
29,30	9,60	9,40	Loam, brown, hard and very stiff, with the inclusion of carbonate concretion up to 5-10%
24,40	14,50	4,90	Clay, gray-green, very stiff and hard, with the inclusion of carbonate concretion - 5%, in the interval 9.6 - 10.6 m and 13.0 - 14.0 m - slip planes, the angle of slip is 40-60 degrees.
22,90	16,00	1,50	Medium sand, white, small degree of water saturation, dense, with inclusion of gruss - 5 %
22,30	16,60	0,60	Clayey medium sand, yellow-gray, medium degree of water saturation, medium dense
21,80	17,10	0,50	Clay, gray, stiff
21,30	17,60	0,50	Medium sand, gray, water saturated, medium dense
16,00	22,90	5,30	Clay, greenish-gray, very stiff and hard, with rare inclusion of gypsum and ferruginous. The angle of slip is 40-60 degrees.
15,40	23,50	0,60	Destroyed limestone, strongly weathered. highly fractured, organogenic, very low strength, with loamy-clay aggregate of 20-35%.
7,10	31,80	8,30	Clay, gray, light gray, very stiff and hard, rarely with streaks of ferruginous, with layers of destroyed limestone to the state of sand, from depth of 30.0 m with rare inclusions of gruss's limestone. The angle of slip is 35-50 degrees.
3,90	35,00	3,20	Limestone organogenic, weathered, fractured, medium and low strength.

Groundwater level, m: 17,1 m

sampling depth, m and its number	Depth of SPT, m Start	End	N-Value (Blows /30 cm)	Water content, W, s.u.	Plasticity index, I p, s.u.	Liquidity index, I L, s.u.
▲ 1/2	1,00	1,45	10/30	0,159	0,18	-0,06
▲ 2/2	1,85	2,30	9/30	0,176	0,17	0,04
■ 3/2	2,30	2,50				
▲ 4/2	2,60	2,90	21/30	0,164	0,17	-0,04
■ 5/2	3,25	3,50	26/30	0,134	0,15	-0,17
▲ 6/2	3,65	3,75				
■ 7/2	3,75	4,20	24/30			
▲ 8/2	4,35	4,80	19/30	0,186	0,17	-0,20
▲ 9/2	4,85	5,30	17/30	0,183	0,17	-0,22
▲ 10/2	5,80	6,25	42/30			
■ 11/2	6,30	6,50				
▲ 12/2	6,55	7,00	39/30			
■ 13/2	7,05	7,50	34/30			
▲ 14/2	7,85	8,30	20/30			
▲ 15/2	8,85	9,30	21/30			
■ 16/2	9,85	10,30	21/30			
▲ 17/2	10,85	11,30	22/30	0,156	0,18	-0,13
▲ 18/2	11.50	11,60		0,129	0,18	-0,28
▲ 19/2	12,05	12,50	28/30			
■ 20/2	12,50	12,70				
■ 21/2	13,45	13,65				
▲ 22/2	13,65	14,10	29/30			
▲ 23/2	14,55	15,00	25/30			
	15,35	15,80	20/30			
▲ 24/2	15,85	15,95		0,068	0,07	-0,60
▲ 25/2	16,20	16,30				
▲ 26/2	16,70	16,80		0,219	0,28	0,03
▲ 27/2	17,05	17,50	11/30			
■ 28/2	17,80	18,00				
▲ 29/2	18,35	18,80	29/30			
▲ 30/2	19,05	19,50	32/30			
▲ 31/2	20.05	20.50	3630			
▲ 32/2	20.65	21.10	29/30			
▲ 33/2	21,35	21,80	28/30			
▲ 34/2	23,05	23,50	49/30			
▲ 35/2	23,55	24,00	42/30			
■ 36/2	24,50	24,95	47/30			
▲ 37/2	25,35	25,80	28/30			
■ 38/2	25,85	26,05				
▲ 39/2	26,25	26,70	39/30	0,184	0,18	0,08
▲ 40/2	26,85	27,30	48/30			
■ 41/2	27,80	28,00				
▲ 42/2	28,35	28,80	49/30			
▲ 43/2	29,25	29,70	57/30			
▲ 44/2	30,15	30,60	55/30			
▲ 45/2	30,85	31,30	51/30			
■ 46/2	31,30	31,50				
	32,35	32,45	60/10			
■ 47/2	33,00	33,15				
■ 48/2	34,15	34,25				

Source: JICA Survey Team

Figure 4-3-3. Borehole Log (BH-2 at Route2)



Borehole No 6, in river

BORING LOG

-16-

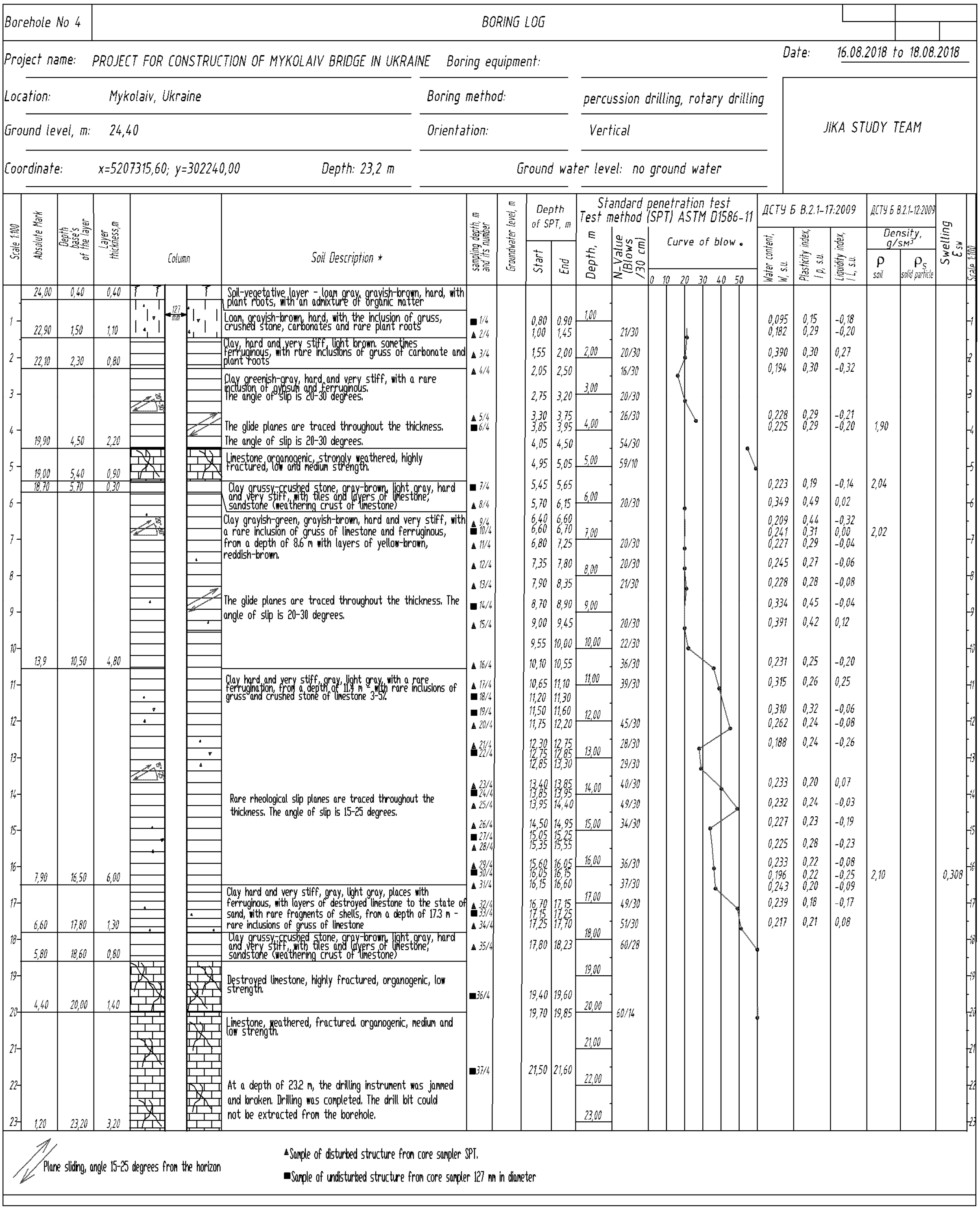
Project name: PROJECT FOR CONSTRUCTION OF MYKOLAIV BRIDGE IN UKRAINE
Location: Mykolaiv, Ukraine
Water surface mark / the bottom of the river, (m): -0,24/-3,80
Coordinate: x=5204903,13; y=415172,02; Depth: 35,0 m
Boring equipment: PBU-1
Boring method: percussion drilling, rotary drilling
Orientation: Vertical
Ground water level: -
Date: 12.09.2018 to 15.09.2018
JIKA STUDY TEAM

Absolute Mark	Depth base's of the layer	Layer thickness,m	Soil Description
-22.90	19.10	19.10	Clayey silt, dark gray, greenish gray, black, unstable consistency (very soft), with an admixture and interlayers of broken shells (detritus) 10-25%, with lenses and interlayers of slimy silty sands and loams. from a depth of 13.0 m is of steady consistency.
-24.90	21.10	2.00	Loam, dark gray, dark brown, soft and very soft, with an admixture of organic matter, with layers of clay, fine and medium sand 10-25%
-26.10	22.30	1.20	Fine sand, dark gray, water saturated, medium dense, with inclusion of gravel, gruss and broken shells (detritus) 10-15%
-28.90	25.10	2.80	Clay, gray-green, very stiff, with layers of loam, with inclusions of gravel carbonate 5-10%, with spots of ironiness, with lenses of gray-yellow fine sand 10-15%
-30.30	26.50	1.40	Loam, gruss-gravelly, grayish-white, light gray, very stiff and stiff, with tiles and interlayers of limestone, sandstone (weathered limestone crust)
-31.50	27.70	1.20	Clay, bluish-gray, very stiff, with inclusions of gravel carbonate 5-10%
-34.90	31.10	3.40	Clay, gray-green, gray, very stiff with layers of stiff, with inclusions of gravel carbonate 5-10%
-38.80	35.00	3.90	Dolomitic limestone, grayish-white, strongly weathered, strongly fractured, low strength with interlayers, of medium strength, with interlayers of weathering crust in the form of gruss-gravelly loam 10-20% (abundant water flow into the borehole)

sampling depth, m and its number	Groundwater level, m	Depth of SPT, m Start	Depth of SPT, m End	Standard penetration test Test method (SPT) ASTM D1586-11 N-Value (Blows /30 cm)	ДСТУ Б В.2.1-17:2009 Water content, W, s.u.	Plasticity index, I P, s.u.	Liquidity index, I L, s.u.	ДСТУ Б В.2.1-12:2009 Density, g/sм³ ρ soil	ρs solid particle	Swelling εsw
▲ 1/6		4.90	5.00		0.801	0.46	1.02			
▲ 2/6		8.50	9.40	0/90	0.817	0.45	1.04			
■ 3/6		13.30	13.50		0.802	0.42	1.03	1.54	2.72	
▲ 4/6		14.15	14.70	1/55	0.755	0.44	1.03			
▲ 5/6		17.70	18.30	2/60	0.725	0.35	0.93			
▲ 6/6		19.35	19.80	3/45	0.382	0.17	0.95			
▲ 7/6		20.50	20.90	2/40	0.424	0.19	1.02			
▲ 8/6		21.25	21.70	20/30						
▲ 9/6		22.55	23.00	11/30	0.259	0.12	0.24			
▲ 10/6		23.20	23.65	23/30	0.277	0.19	0.25			
▲ 11/6		24.05	24.50	22/30	0.280	0.22	0.23			
▲ 12/6		24.95	25.40	46/30	0.316	0.13	0.58			
▲ 13/6 water sample ● 13/6-w		25.75	26.20	40/30	0.278	0.13	0.37			
▲ 14/6		26.65	27.10	47/30	0.301	0.24	0.25			
▲ 15/6		27.30	27.75	37/30	0.291	0.23	0.22			
■ 16/6		28.00	28.20		0.283	0.19	0.17	1.98	2.73	
▲ 17/6		28.20	28.65	34/30	0.301	0.22	0.32			
▲ 18/6		28.75	29.20	42/30	0.297	0.23	0.25			
▲ 19/6		29.30	29.75	38/30	0.288	0.22	0.22			
▲ 20/6		29.85	30.30	36/30	0.307	0.25	0.27			
▲ 21/6		30.55	31.00	31/30	0.305	0.22	0.25			
▲ 22/6*		31.55	32.00	58/30	0.274	0.11	0.22			
■ 23/6		33.75	34.20	60/10				2.28		

Source: JICA Survey Team

Figure 4-3-4. Borehole Log (BH-6 at Route2)



Borehole No 4

BORING LOG

Project name: PROJECT FOR CONSTRUCTION OF MYKOLAIV BRIDGE IN UKRAINE

Boring equipment:

Date: 16.08.2018 to 18.08.2018

Location: Mykolaiv, Ukraine

Boring method: percussion drilling, rotary drilling

Ground level, m: 24,40

Orientation: Vertical

Coordinate: x=5207315,60; y=302240,00

Depth: 23,2 m

Ground water level: no ground water

JIKA STUDY TEAM

Absolute Mark	Depth base's of the layer	Layer thickness,m	Soil Description *
24,00	0,40	0,40	Soil-vegetative layer - loam gray, grayish-brown, hard, with plant roots, with an admixture of organic matter
22,90	1,50	1,10	Loam, grayish-brown, hard, with the inclusion of gruss, crushed stone, carbonates and rare plant roots
22,10	2,30	0,80	Clay, hard and very stiff, light brown. sometimes ferruginous, with rare inclusions of gruss of carbonate and plant roots
19,90	4,50	2,20	Clay greenish-gray, hard and very stiff, with a rare inclusion of gypsum and ferruginous. The angle of slip is 20-30 degrees. The glide planes are traced throughout the thickness. The angle of slip is 20-30 degrees.
19,00	5,40	0,90	Limestone organogenic, strongly weathered, highly fractured, low and medium strength.
18,70	5,70	0,30	Clay grussy-crushed stone, gray-brown, light gray, hard and very stiff, with tiles and layers of limestone, sandstone (weathering crust of limestone)
13,9	10,50	4,80	Clay grayish-green, grayish-brown, hard and very stiff, with a rare inclusion of gruss of limestone and ferruginous, from a depth of 8.6 m with layers of yellow-brown, reddish-brown. The glide planes are traced throughout the thickness. The angle of slip is 20-30 degrees.
7,90	16,50	6,00	Clay hard and very stiff, gray, light gray, with a rare ferrugination, from a depth of 11.4 m - with rare inclusions of gruss and crushed stone of limestone 3-5%. Rare rheological slip planes are traced throughout the thickness. The angle of slip is 15-25 degrees.
6,60	17,80	1,30	Clay hard and very stiff, gray, light gray, places with ferruginous, with layers of destroyed limestone to the state of sand, with rare fragments of shells, from a depth of 17.3 m - rare inclusions of gruss of limestone
5,80	18,60	0,80	Clay grussy-crushed stone, gray-brown, light gray, hard and very stiff, with tiles and layers of limestone, sandstone (weathering crust of limestone)
4,40	20,00	1,40	Destroyed limestone, highly fractured, organogenic, low strength.
1,20	23,20	3,20	Limestone, weathered, fractured. organogenic, medium and low strength. At a depth of 23.2 m, the drilling instrument was jammed and broken. Drilling was completed. The drill bit could not be extracted from the borehole.

sampling depth, m and its number	Groundwater level, m	Depth of SPT, m Start	Depth of SPT, m End	Standard penetration test Test method (SPT) ASTM D1586-11 N_Value (Blows /30 cm)	ДСТУ Б В.2.1-17:2009 Water content, W, s.u.	ДСТУ Б В.2.1-17:2009 Plasticity index, I p, s.u.	ДСТУ Б В.2.1-17:2009 Liquidity index, I L, s.u.	ДСТУ Б В.2.1-12:2009 Density, g/sм³ ρ soil	ДСТУ Б В.2.1-12:2009 Density, g/sм³ ρs solid particle	Swelling ε_{sw}
■ 1/4		0,80	0,90		0,095	0,15	-0,18			
▲ 2/4		1,00	1,45	21/30	0,182	0,29	-0,20			
▲ 3/4		1,55	2,00	20/30	0,390	0,30	0,27			
▲ 4/4		2,05	2,50	16/30	0,194	0,30	-0,32			
		2,75	3,20	20/30						
▲ 5/4		3,30	3,75	26/30	0,228	0,29	-0,21			
■ 6/4		3,85	3,95		0,225	0,29	-0,20	1,90		
		4,05	4,50	54/30						
		4,95	5,05	59/10						
■ 7/4		5,45	5,65		0,223	0,19	-0,14	2,04		
▲ 8/4		5,70	6,15	20/30	0,349	0,49	0,02			
▲ 9/4		6,40	6,60		0,209	0,44	-0,32			
■ 10/4		6,60	6,70		0,241	0,31	0,00	2,02		
▲ 11/4		6,80	7,25	20/30	0,227	0,29	-0,04			
▲ 12/4		7,35	7,80	20/30	0,245	0,27	-0,06			
▲ 13/4		7,90	8,35	21/30	0,228	0,28	-0,08			
■ 14/4		8,70	8,90		0,334	0,45	-0,04			
▲ 15/4		9,00	9,45	20/30	0,391	0,42	0,12			
		9,55	10,00	22/30						
▲ 16/4		10,10	10,55	36/30	0,231	0,25	-0,20			
▲ 17/4		10,65	11,10	39/30	0,315	0,26	0,25			
■ 18/4		11,20	11,30							
■ 19/4		11,50	11,60		0,310	0,32	-0,06			
▲ 20/4		11,75	12,20	45/30	0,262	0,24	-0,08			
▲ 21/4		12,30	12,75	28/30	0,188	0,24	-0,26			
■ 22/4		12,75	12,85							
		12,85	13,30	29/30						
▲ 23/4		13,40	13,85	40/30	0,233	0,20	0,07			
■ 24/4		13,85	13,95							
▲ 25/4		13,95	14,40	49/30	0,232	0,24	-0,03			
▲ 26/4		14,50	14,95	34/30	0,227	0,23	-0,19			
■ 27/4		15,05	15,25							
▲ 28/4		15,35	15,55		0,225	0,28	-0,23			
▲ 29/4		15,60	16,05	36/30	0,233	0,22	-0,08			
■ 30/4		16,05	16,15		0,196	0,22	-0,25	2,10		0,308
▲ 31/4		16,15	16,60	37/30	0,243	0,20	-0,09			
▲ 32/4		16,70	17,15	49/30	0,239	0,18	-0,17			
■ 33/4		17,15	17,25							
▲ 34/4		17,25	17,70	51/30	0,217	0,21	0,08			
▲ 35/4		17,80	18,23	60/28						
■ 36/4		19,40	19,60							
		19,70	19,85	60/14						
■ 37/4		21,50	21,60							

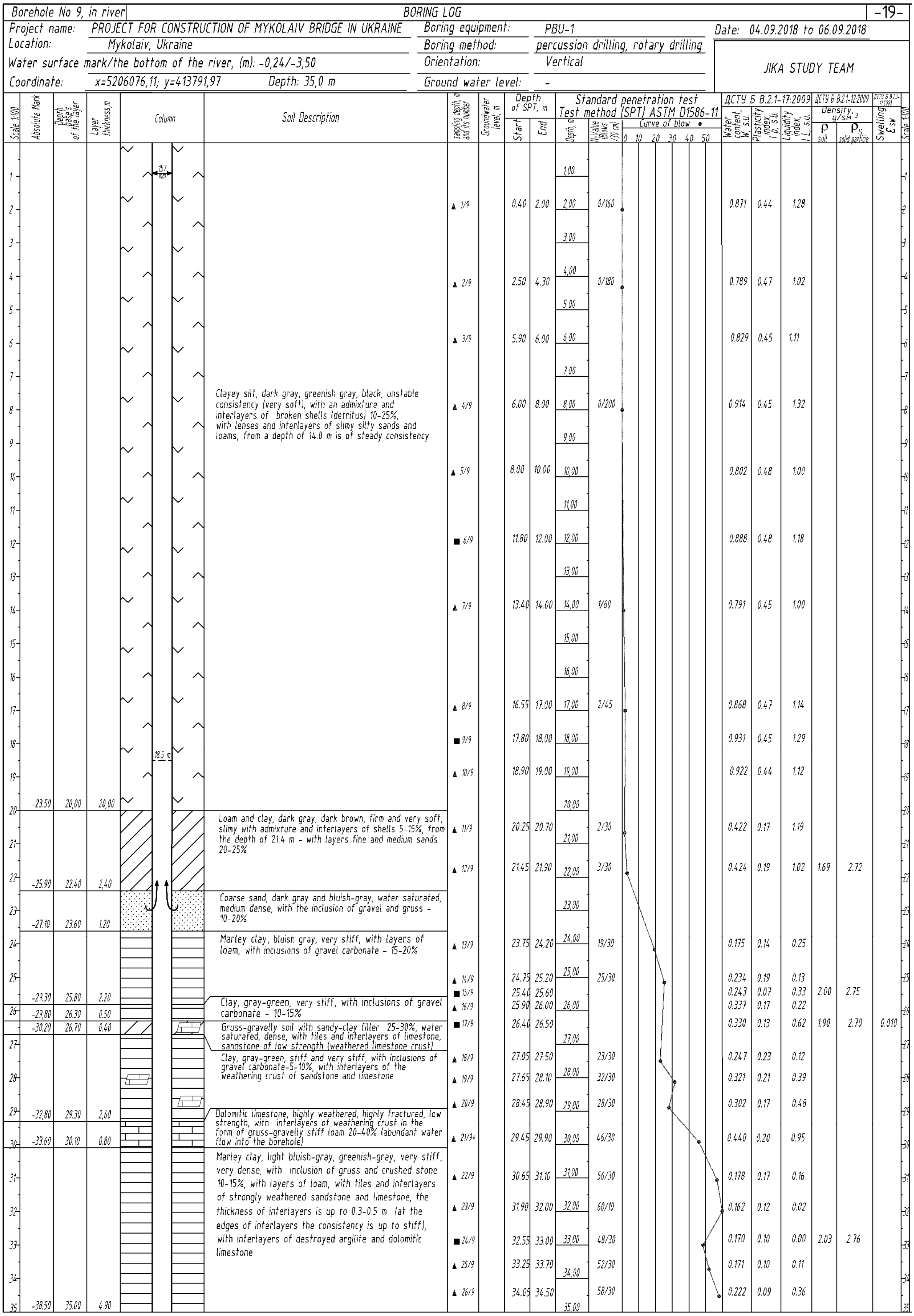
Plane sliding, angle 15-25 degrees from the horizon

▲Sample of disturbed structure from core sampler SPT.

■Sample of undisturbed structure from core sampler 127 mm in diameter

Source: JICA Survey Team

Figure 4-3-5. Borehole Log (BH-4 at Route3)



Borehole No 9, in river | BORING LOG | -19-

Project name: PROJECT FOR CONSTRUCTION OF MYKOLAIV BRIDGE IN UKRAINE

Location: Mykolaiv, Ukraine

Water surface mark/the bottom of the river, (m): -0,24/-3,50

Coordinate: x=5206076,11; y=413791,97 Depth: 35,0 m

Boring equipment: PBU-1

Boring method: percussion drilling, rotary drilling

Orientation: Vertical

Ground water level: -

Date: 04.09.2018 to 06.09.2018

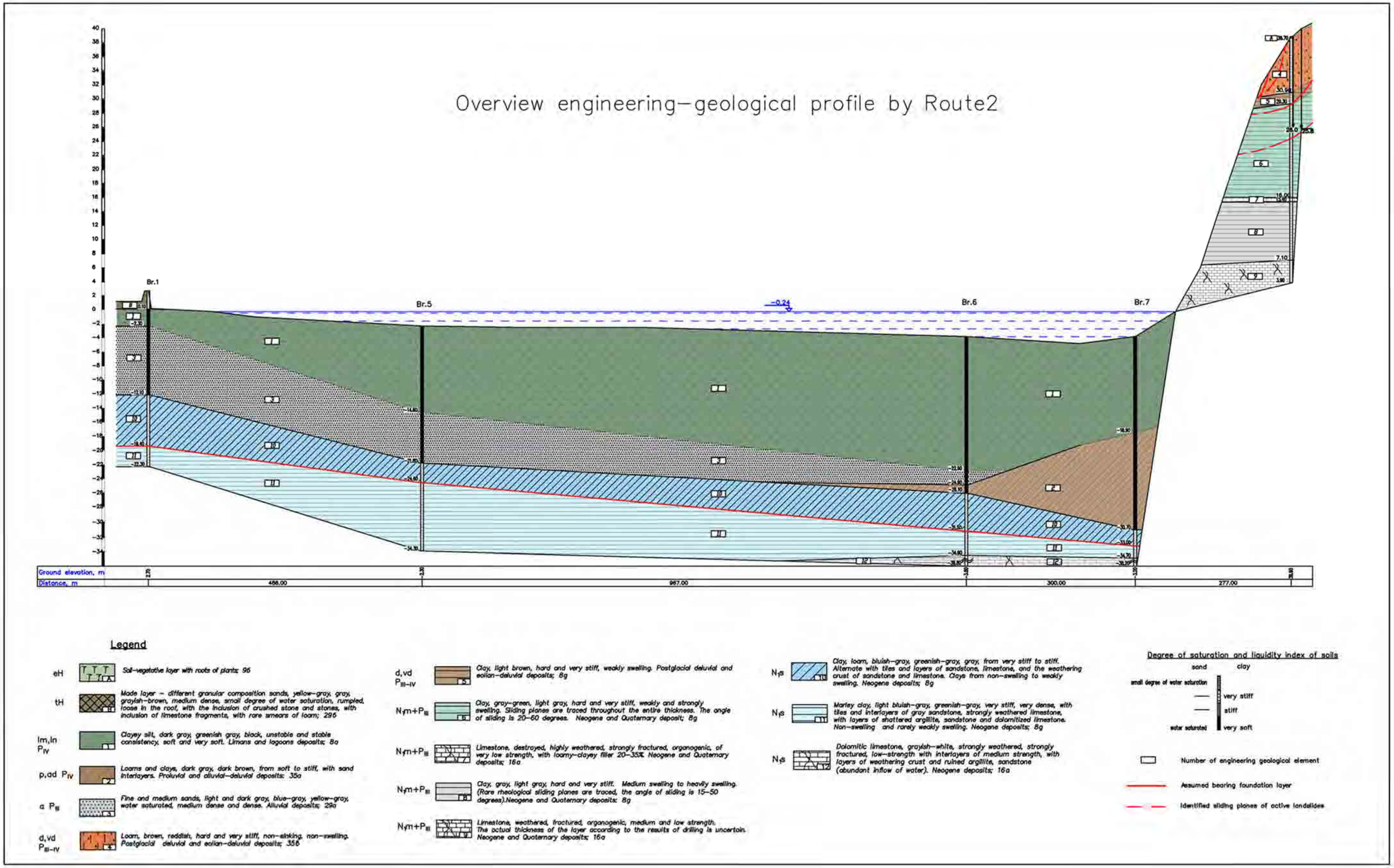
JIKA STUDY TEAM

Absolute Mark	Depth base's of the layer	Layer thickness,m	Soil Description
-23.50	20,00	20,00	Clayey silt, dark gray, greenish gray, black, unstable consistency (very soft), with an admixture and interlayers of broken shells (detritus) 10-25%, with lenses and interlayers of slimy silty sands and loams, from a depth of 14.0 m is of steady consistency
-25.90	22.40	2,40	Loam and clay, dark gray, dark brown, firm and very soft, slimy with admixture and interlayers of shells 5-15%, from the depth of 21.4 m - with layers fine and medium sands 20-25%
-27.10	23.60	1.20	Coarse sand, dark gray and bluish-gray, water saturated, medium dense, with the inclusion of gravel and gruss - 10-20%
-29.30	25.80	2.20	Marley clay, bluish gray, very stiff, with layers of loam, with inclusions of gravel carbonate - 15-20%
-29,80	26.30	0.50	Clay, gray-green, very stiff, with inclusions of gravel carbonate - 10-15%
-30.20	26.70	0.40	Gruss-gravelly soil with sandy-clay filler 25-30%, water saturated, dense, with tiles and interlayers of limestone, sandstone of low strength (weathered limestone crust)
-32,80	29.30	2,60	Clay, gray-green, stiff and very stiff, with inclusions of gravel carbonate-5-10%, with interlayers of the weathering crust of sandstone and limestone
-33.60	30.10	0.80	Dolomitic limestone, highly weathered, highly fractured, low strength, with interlayers of weathering crust in the form of gruss-gravelly stiff loam 20-40% (abundant water flow into the borehole)
-38.50	35.00	4.90	Marley clay, light bluish-gray, greenish-gray, very stiff, very dense, with inclusion of gruss and crushed stone 10-15%, with layers of loam, with tiles and interlayers of strongly weathered sandstone and limestone, the thickness of interlayers is up to 0.3-0.5 m (at the edges of interlayers the consistency is up to stiff), with interlayers of destroyed argilite and dolomitic limestone

sampling depth, m and its number	Groundwater level, m	Depth of SPT, m		Standard penetration test Test method (SPT) ASTM D1586-11	ДСТУ Б В.2.1-17:2009			ДСТУ Б В.2.1-12:2009 Density, g/sм³		ДСТУ Б В.2.1-17:2009
		Start	End	N-Value (Blows /30 cm)	Water content, W, s.u.	Plasticity index, I P, s.u.	Liquidity index, I L, s.u.	ρ soil	ρs solid particle	Swelling εsw
▲ 1/9		0.40	2.00	0/160	0.871	0.44	1.28			
▲ 2/9		2.50	4.30	0/180	0.789	0.47	1.02			
▲ 3/9		5.90	6.00		0.829	0.45	1.11			
▲ 4/9		6.00	8.00	0/200	0.914	0.45	1.32			
▲ 5/9		8.00	10.00		0.802	0.48	1.00			
■ 6/9		11.80	12.00		0.888	0.48	1.18			
▲ 7/9		13.40	14.00	1/60	0.791	0.45	1.00			
▲ 8/9		16.55	17.00	2/45	0.868	0.47	1.14			
■ 9/9		17.80	18.00		0.931	0.45	1.29			
▲ 10/9		18.90	19.00		0.922	0.44	1.12			
▲ 11/9		20.25	20.70	2/30	0.422	0.17	1.19			
▲ 12/9		21.45	21.90	3/30	0.424	0.19	1.02	1.69	2.72	
▲ 13/9		23.75	24.20	19/30	0.175	0.14	0.25			
▲ 14/9		24.75	25.20	25/30	0.234	0.19	0.13			
■ 15/9		25.40	25.60		0.243	0.07	0.33	2.00	2.75	
▲ 16/9		25.90	26.00		0.337	0.17	0.22			
■ 17/9		26.40	26.50		0.330	0.13	0.62	1.90	2.70	0.010
▲ 18/9		27.05	27.50	23/30	0.247	0.23	0.12			
▲ 19/9		27.65	28.10	32/30	0.321	0.21	0.39			
▲ 20/9		28.45	28.90	28/30	0.302	0.17	0.48			
▲ 21/9*		29.45	29.90	46/30	0.440	0.20	0.95			
▲ 22/9		30.65	31.10	56/30	0.178	0.17	0.16			
▲ 23/9		31.90	32.00	60/10	0.162	0.12	0.02			
■ 24/9		32.55	33.00	48/30	0.170	0.10	0.00	2.03	2.76	
▲ 25/9		33.25	33.70	52/30	0.171	0.10	0.11			
▲ 26/9		34.05	34.50	58/30	0.222	0.09	0.36			

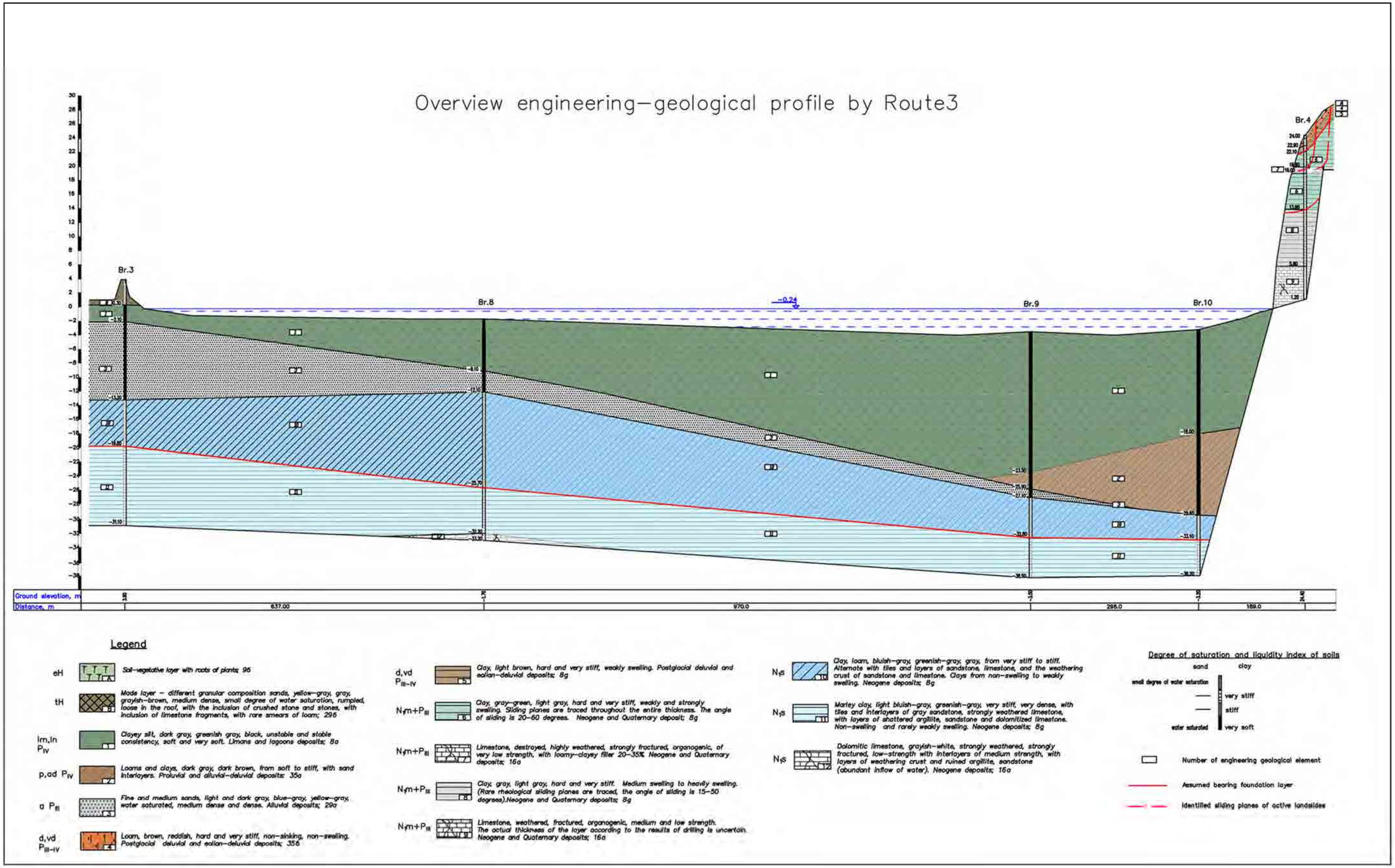
Source: JICA Survey Team

Figure 4-3-6. Borehole Log (BH-9 at Route3)



Source: JICA Survey Team

Figure 4-3-7. Assumed Geological Profile (Route 2)



Legend

eH	A	Soil–vegetative layer with roots of plants; 9б
tH	B	Made layer – different granular composition sands, yellow–gray, gray, grayish–brown, medium dense, small degree of water saturation, rumpled, loose in the roof, with the inclusion of crushed stone and stones, with inclusion of limestone fragments, with rare smears of loam; 29б
lm,ln P_{IV}	1	Clayey silt, dark gray, greenish gray, black, unstable and stable consistency, soft and very soft. Limans and lagoons deposits; 8a
p,ad P_{IV}	2	Loams and clays, dark gray, dark brown, from soft to stiff, with sand interlayers. Proluvial and alluvial–deluvial deposits: 35a
a P_{III}	3	Fine and medium sands, light and dark gray, blue–gray, yellow–gray, water saturated, medium dense and dense. Alluvial deposits; 29a
d,vd P_{III-IV}	4	Loam, brown, reddish, hard and very stiff, non–sinking, non–swelling. Postglacial deluvial and eolian–deluvial deposits; 35б
d,vd P_{III-IV}	5	Clay, light brown, hard and very stiff, weakly swelling. Postglacial deluvial and eolian–deluvial deposits; 8g
N_1m+P_{III}	6	Clay, gray–green, light gray, hard and very stiff, weakly and strongly swelling. Sliding planes are traced throughout the entire thickness. The angle of sliding is 20–60 degrees. Neogene and Quaternary deposit; 8g
N_1m+P_{III}	7	Limestone, destroyed, highly weathered, strongly fractured, organogenic, of very low strength, with loamy–clayey filler 20–35%. Neogene and Quaternary deposits; 16a
N_1m+P_{III}	8	Clay, gray, light gray, hard and very stiff. Medium swelling to heavily swelling. (Rare rheological sliding planes are traced, the angle of sliding is 15–50 degrees).Neogene and Quaternary deposits; 8g
N_1m+P_{III}	9	Limestone, weathered, fractured, organogenic, medium and low strength. The actual thickness of the layer according to the results of drilling is uncertain. Neogene and Quaternary deposits; 16a
N_1s	10	Clay, loam, bluish–gray, greenish–gray, gray, from very stiff to stiff. Alternate with tiles and layers of sandstone, limestone, and the weathering crust of sandstone and limestone. Clays from non–swelling to weakly swelling. Neogene deposits; 8g
N_1s	11	Marley clay, light bluish–gray, greenish–gray, very stiff, very dense, with tiles and interlayers of gray sandstone, strongly weathered limestone, with layers of shattered argillite, sandstone and dolomitized limestone. Non–swelling and rarely weakly swelling. Neogene deposits; 8g
N_1s	12	Dolomitic limestone, grayish–white, strongly weathered, strongly fractured, low–strength with interlayers of medium strength, with layers of weathering crust and ruined argillite, sandstone (abundant inflow of water). Neogene deposits; 16a

Degree of saturation and liquidity index of soils

☐ Number of engineering geological element

— Assumed bearing foundation layer

– – Identified sliding planes of active landslides

Source: JICA Survey Team

Figure 4-3-8. Assumed Geological Profile (Route 3)

2) Cone Penetration Test (CPT) at the Proposed Interchange

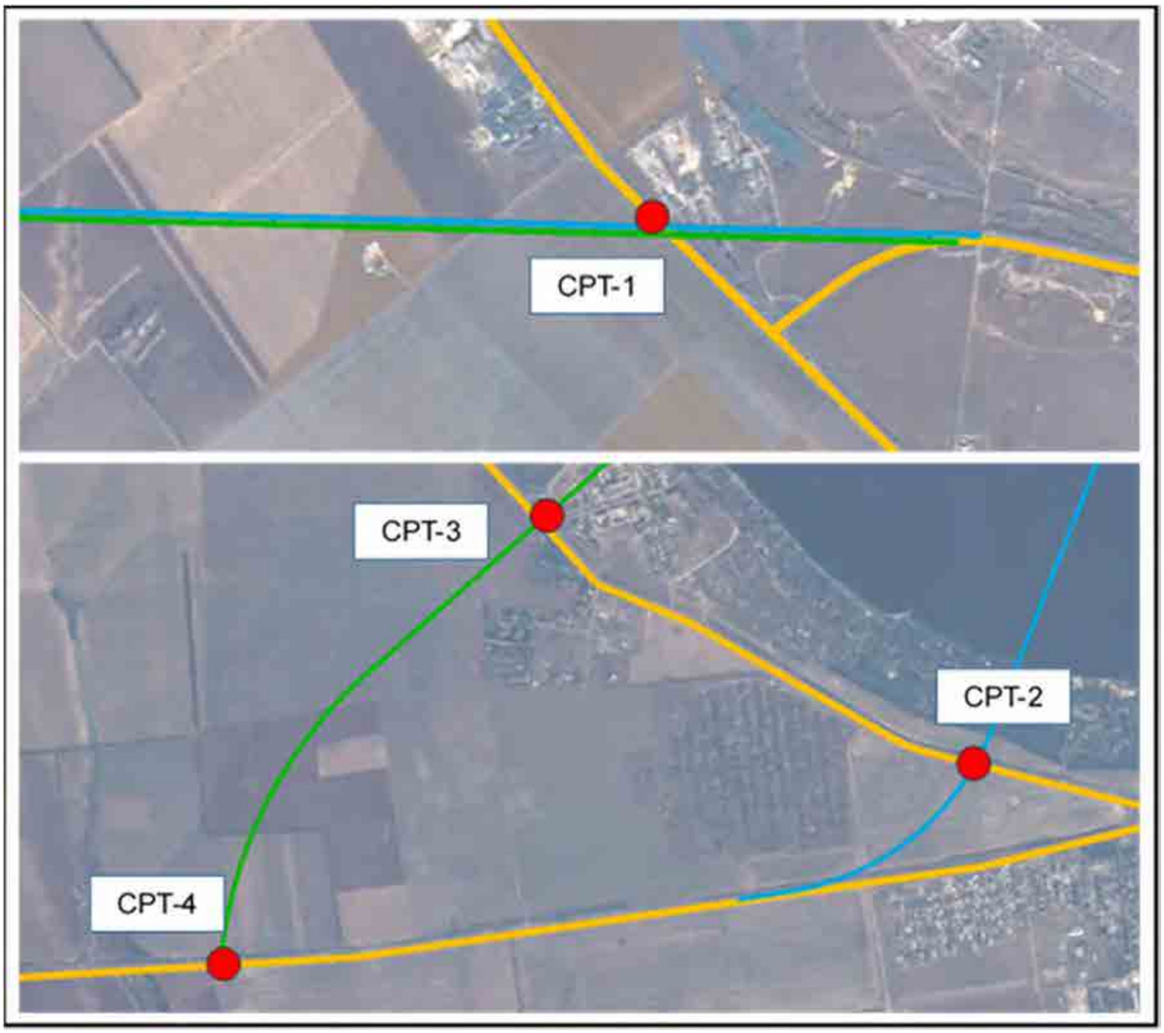
CPT tests were carried out in order to study the geological structure of the points where the interchange is planned. The locations of CPT tests are shown in Table4-3-4 and Figure4-3-9.

Table 4-3-4. Location of CPT Tests at the Proposed Interchange

No.	Coordinates				H (m)	Depth (m)	Target route
	Latitude	Longitude	E*	N*			
CPT-1	47° 2' 39.56"	31° 57' 54.71"	421393.903	5210609.044	56.4	7.4	Route 2, Route 3
CPT-2	46° 59' 6.27"	31° 52' 48.80"	414844.913	5204114.020	56.8	14.0	Route 2
CPT-3	46° 59' 41.49"	31° 51' 14.13"	412861.026	5205230.106	46.1	5.0	Route 3
CPT-4	46° 58' 35.54"	31° 50' 4.92"	411369.036	5203215.931	46.5	12.8	Route 3

*: WGS 84/UTM zone 36N

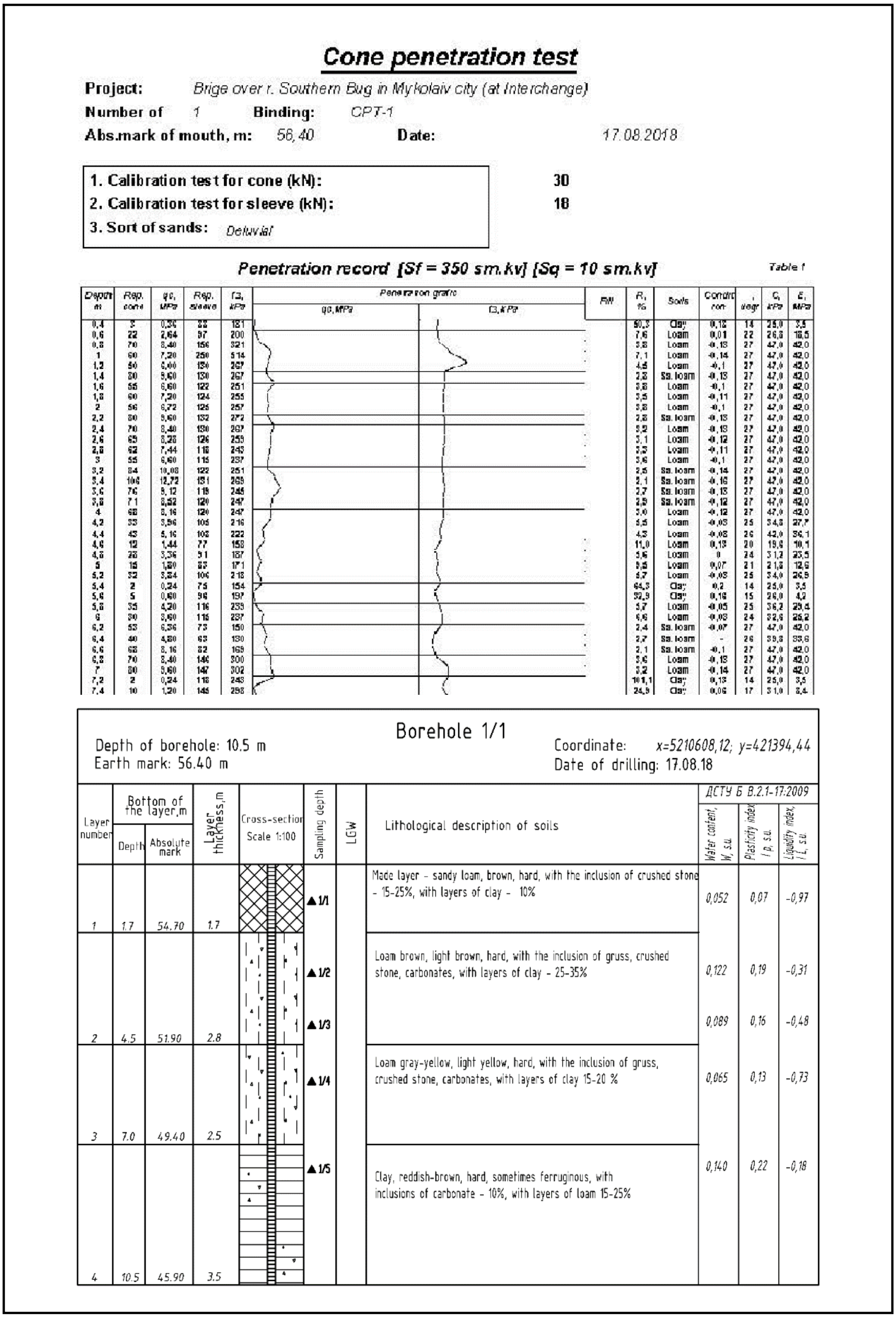
Source: JICA Survey Team



Source: JICA Survey Team

Figure 4-3-9. Location of Coordinates and Altitudes of the Geodetic Network Points

It shows a graph of depth and the ground resistance as a result of Corn Penetration Test (samples logs are shown in Figure4-3-10).



Cone penetration test

Project: Brige over r. Southern Bug in Mykolaiv city (at Interchange)
Number of 1 **Binding:** CPT-1
Abs.mark of mouth, m: 56,40 **Date:** 17.08.2018

1. **Calibration test for cone (kN):** 30
2. **Calibration test for sleeve (kN):** 18
3. **Sort of sands:** Deluvial

Penetration record [Sf = 350 sm.kv] [Sq = 10 sm.kv]

Table 1

Depth m	Rep. cone	qc, MPa	Rep. sleeve	fs, kPa	PW	R, %	Soils	Condition	, degr	C, kPa	E, MPa
0,4	3	0,36	88	181		50,3	Clay	0,12	14	25,0	3,5
0,6	22	2,64	97	200		7,6	Loam	0,01	22	26,8	18,5
0,8	70	8,40	156	321		3,8	Loam	-0,13	27	47,0	42,0
1	60	7,20	250	514		7,1	Loam	-0,14	27	47,0	42,0
1,2	50	6,00	130	267		4,5	Loam	-0,1	27	47,0	42,0
1,4	80	9,60	130	267		2,8	Sa. loam	-0,13	27	47,0	42,0
1,6	55	6,60	122	251		3,8	Loam	-0,1	27	47,0	42,0
1,8	60	7,20	124	255		3,5	Loam	-0,11	27	47,0	42,0
2	56	6,72	125	257		3,8	Loam	-0,1	27	47,0	42,0
2,2	80	9,60	132	272		2,8	Sa. loam	-0,13	27	47,0	42,0
2,4	70	8,40	130	267		3,2	Loam	-0,13	27	47,0	42,0
2,6	65	8,28	126	259		3,1	Loam	-0,12	27	47,0	42,0
2,8	62	7,44	118	243		3,3	Loam	-0,11	27	47,0	42,0
3	55	6,60	115	237		3,6	Loam	-0,1	27	47,0	42,0
3,2	84	10,08	122	251		2,5	Sa. loam	-0,14	27	47,0	42,0
3,4	106	12,72	131	269		2,1	Sa. loam	-0,16	27	47,0	42,0
3,6	76	9,12	119	245		2,7	Sa. loam	-0,13	27	47,0	42,0
3,8	71	8,52	120	247		2,9	Sa. loam	-0,12	27	47,0	42,0
4	68	8,16	120	247		3,0	Loam	-0,12	27	47,0	42,0
4,2	33	3,96	105	216		5,5	Loam	-0,05	25	34,8	27,7
4,4	43	5,16	108	222		4,3	Loam	-0,08	26	42,0	36,1
4,6	12	1,44	77	158		11,0	Loam	0,19	20	19,6	10,1
4,8	28	3,36	91	187		5,6	Loam	0	24	31,2	23,5
5	15	1,80	83	171		9,5	Loam	0,07	21	21,8	12,6
5,2	32	3,84	106	218		5,7	Loam	-0,03	25	34,0	26,9
5,4	2	0,24	75	154		64,3	Clay	0,2	14	25,0	3,5
5,6	5	0,60	96	197		32,9	Clay	0,16	15	26,0	4,2
5,8	35	4,20	116	239		5,7	Loam	-0,05	25	36,2	29,4
6	30	3,60	115	237		6,6	Loam	-0,08	24	32,6	25,2
6,2	53	6,36	73	150		2,4	Sa. loam	-0,07	27	47,0	42,0
6,4	40	4,80	63	130		2,7	Sa. loam	-	26	39,8	33,6
6,6	68	8,16	82	169		2,1	Sa. loam	-0,1	27	47,0	42,0
6,8	70	8,40	146	300		3,6	Loam	-0,13	27	47,0	42,0
7	80	9,60	147	302		3,2	Loam	-0,14	27	47,0	42,0
7,2	2	0,24	118	243		101,1	Clay	0,13	14	25,0	3,5
7,4	10	1,20	145	298		24,9	Clay	0,06	17	31,0	8,4

Borehole 1/1

Depth of borehole: 10.5 m
Earth mark: 56.40 m
Coordinate: x=5210608,12; y=421394,44
Date of drilling: 17.08.18

Layer number	Bottom of the layer,m		Layer thickness,m	Cross-section Scale 1:100	Sampling depth	LGW	Lithological description of soils	ДСТУ Б В.2.1-17:2009		
	Depth	Absolute mark						Water content, W, s.u.	Plasticity index I p, s.u.	Liquidity index, I L, s.u.
1	1.7	54.70	1.7		▲1/1		Made layer - sandy loam, brown, hard, with the inclusion of crushed stone - 15-25%, with layers of clay - 10%	0,052	0,07	-0,97
2	4.5	51.90	2.8		▲1/2 ▲1/3		Loam brown, light brown, hard, with the inclusion of gruss, crushed stone, carbonates, with layers of clay - 25-35%	0,122 0,089	0,19 0,16	-0,31 -0,48
3	7.0	49.40	2.5		▲1/4		Loam gray-yellow, light yellow, hard, with the inclusion of gruss, crushed stone, carbonates, with layers of clay 15-20 %	0,065	0,13	-0,73
4	10.5	45.90	3.5		▲1/5		Clay, reddish-brown, hard, sometimes ferruginous, with inclusions of carbonate - 10%, with layers of loam 15-25%	0,140	0,22	-0,18

Source: JICA Survey Team

Figure 4-3-10. Result of CPT

3) Soil Testing at the Approach Road

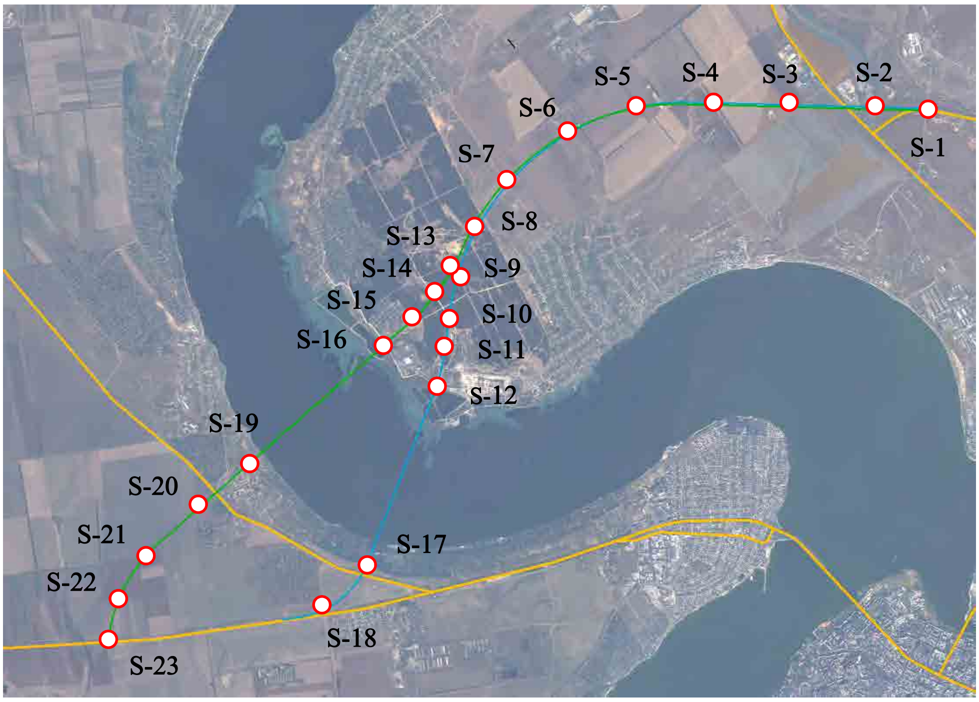
23 pits were excavated from the surface on the section of the approach road in order to study the physical properties, swell index of soil particle and others. The survey locations are shown in Table 4-3-5 and Figure 4-3-11.

Table 4-3-5. Soil Testing Locations

No.	Coordinates				Target Route
	Latitude	Longitude	E*	N*	
S-1	47°02'37.90"	31°58'50.59"	422572.332	5210542.332	Route 2, Route 3
S-2	47°02'37.72"	31°58'19.19"	421909.697	5210545.440	Route 2, Route 3
S-3	47°02'38.22"	31°57'22.48"	420713.282	5210576.710	Route 2, Route 3
S-4	47°02'38.67"	31°56'30.98"	419626.787	5210605.190	Route 2, Route 3
S-5	47°02'36.48"	31°55'44.05"	418635.612	5210551.056	Route 2, Route 3
S-6	47°02'24.10"	31°54'59.47"	417689.647	5210181.852	Route 2, Route 3
S-7	47°02'01.99"	31°54'21.53"	416879.493	5209510.490	Route 2, Route 3
S-8	47°01'38.99"	31°53'58.05"	416373.977	5208807.467	Route 2, Route 3
S-9	47°01'21.30"	31°53'49.17"	416178.854	5208264.046	Route 2
S-10	47°01'01.20"	31°53'43.60"	416052.525	5207645.254	Route 2
S-11	47°00'47.30"	31°53'41.36"	415999.181	5207216.854	Route 2
S-12	47°00'30.41"	31°53'35.89"	415876.327	5206697.123	Route 2
S-13	47°01'23.14"	31°53'44.89"	416089.309	5208322.117	Route 3
S-14	47°01'11.37"	31°53'33.98"	415853.873	5207962.051	Route 3
S-15	47°00'59.87"	31°53'18.99"	415532.394	5207611.551	Route 3
S-16	47°00'48.86"	31°53'01.67"	415161.901	5207276.892	Route 2
S-17	46°59'10.23"	31°52'51.72"	414908.340	5204235.376	Route 2
S-18	46°58'50.75"	31°52'25.38"	414343.307	5203642.041	Route 2
S-19	46°59'54.15"	31°51'32.96"	413264.406	5205615.090	Route 3
S-20	46°59'33.56"	31°51'00.17"	412562.598	5204989.644	Route 3
S-21	46°59'13.29"	31°50'28.71"	411888.883	5204373.741	Route 3
S-22	46°58'54.27"	31°50'11.41"	411514.736	5203792.049	Route 3
S-23	46°58'35.65"	31°50'06.14"	411394.862	5203218.942	Route 3

*: WGS 84/UTM zone 36N

Source: JICA Survey Team



Source: JICA Survey Team

Figure 4-3-11. Soil Testing Locations

The results of the swelling tests are shown in the table below.

Table 4-3-6. Result of Swelling Test

No.	Name of Layer	Degree of Swelling	Target Route
S-1	Loam	Strong Swelling	Route2, Route3
S-2	Loam	Strong Swelling	Route2, Route3
S-3	Loam	Not Swelling Soil	Route2, Route3
S-4	Loam	Not Swelling Soil	Route2, Route3
S-5	Loam	Moderate Swelling	Route2, Route3
S-6	Loam	Moderate Swelling	Route2, Route3
S-7	Loam	Moderate Swelling	Route2, Route3
S-8	Sandy loam	No Swelling	Route2, Route3
S-17	Loam	Weakly Swelling	Route2
S-18	Loam	Not Swelling Soil	Route2
S-19	Loam	Not Swelling Soil	Route3
S-20	Loam	Moderate Swelling	Route3
S-21	Loam	Not Swelling Soil	Route3
S-22	Loam	Weak Swelling	Route3
S-23	Loam	Not Swelling Soil	Route3

Source: JICA Survey Team

4) Material Test at the Borrow Pit

As shown in Figure 4-3-12, the borrow pit is located on the right bank of the Ingul River as it flows into the Southern Bug River.

At present, the borrow pit area is four hectares.

The soil of the borrow pit is separated into the following three layers, which are listed from top to bottom.

Layer 1: Arable soil, loam: Layer which shall not be sold.
This soil shall be stored on the property for use in agriculture.
Layer 2: Loam: Layer which shall not be sold. This soil shall be stored on the property.
Layer 3: Sandy soil: Layer which shall be sold. The target layer for the embankment material.

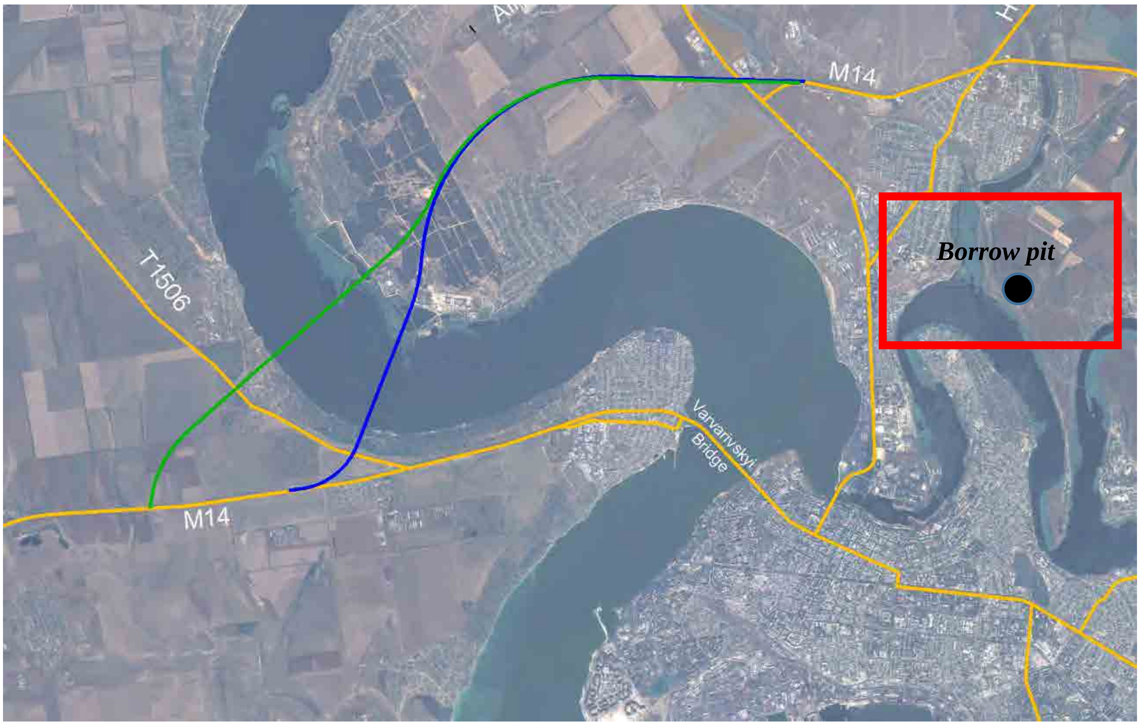
CBR tests were conducted on Layer 3. The table below shows the results of the tests.

Any CBR value that exceeds the standard deviation is rejected.

Table 4-3-7. Results of Soil Tests

Site	CBR Value (%)	Remark
1	5.33	Rejection
2	7.71	
3	7.14	
4	9.43	
5	9.81	
6	7.33	
7	6.48	
8	13.05	Rejection
9	8.00	
Average	8.25	
Standard Deviation	2.26	

Source: JICA Survey Team



Source: JICA Survey Team

Figure 4-3-12. Location of Borrow Pit

In addition, the borrow pit is expected to expand to roughly 12 hectares in the future; at present, this process is in the registration application stage. Therefore, at the construction implementation stage, the status of acquisition of permits in terms of aspects of natural and social environments must be confirmed. In addition, during the detailed design stage, it is best to conduct surveys of the volume of buried soil at the borrow pit in order to investigate the volume of soil used for construction embankments.

4-3-3 Overview of Geological Survey Results, and Recommendations

The ground layers studied in this survey are divided into 14 layers shown in Table4-3-3, and comprise arable soil, embankment, and river sedimentation from the modern period, and Quaternary (alluvium deposits and deluvial deposits) and Neogene layers. The following is a summary of the geological survey results. Note that landslide is discussed in Chapter 9 thus omitted here.

1) The supporting layers for the bridge from the left bank and through the river are envisioned to be those including and deeper than Ground Layer No. 11, which is a Neogene clay layer, or Ground Layer No. 12, which comprises limestone. The supporting layers for the abutment on the right bank are envisioned to be those including and deeper than Ground Layer No. 8, a clay layer formed from the Quaternary period to the Neogene period.
2) Wide survey spacing during the boring surveys at bridge locations conducted this time prevented sufficient confirmation of the continuity of ground layers; thus, there is concern over the deterioration of strength due to weathering near the boundary between Ground Layer No. 12, which is limestone, and Ground Layer No. 11. Therefore, for the detailed design, it is best to conduct appropriate surveys in consideration of the locations of piers and abutments.
3) A distribution of soft soil (Ground Layer No. 1) at and shallower than BS-2.1 to BS-2.3 m was confirmed in the left bank floodplain; thus, there is concern that construction work for embankments may cause consolidation settlement. Because the distribution depth in the floodplain is shallow, response by replacement or the like is possible; however, care must be taken during bridge construction because the 25-m to 30-m sediment layer in the river bed is extremely soft.
4) Artesian water was confirmed in Ground Layer No. 3, an alluvial sand layer; thus, care must be taken during construction.

5) The swelling of the deluvial deposit of loam (Ground Layer No. 4), which is distributed throughout the upper part of the bridge plan area on the right bank (earth cut section), has not been confirmed. However, the Neogene clay (Ground Layers No. 6 and 8) is swellable, and, per Ukraine standards, cannot be used for embankments unless it undergoes special treatment; therefore, care must be taken.

6) Material surveys for the approach road confirmed the distribution of an expansible loam layer on the surface layer. In cases when construction is performed in areas in which these swelling soils have been confirmed, measures must be taken to prevent surface water from seeping into the ground. Therefore, when preparing the detailed design, it is best to conduct additional surveys along the selected routes.

Chapter 5 Review of Routes and Locations of Bridges

5-1 Routes Overview

4 bypass routes and bridge locations shown in Figure 5-1-1 have been compared in the past six studies shown in Table 5-1-1. All of the studies selected Route 2.

Table 5-1-1. List of Past Feasibility Study

Year	Implementation Country	Counterpart	Survey Company
1989	Soviet-Union	No Information	Kievsoyuizdorproject
2000	Japan	Mykolaiv City	Japan Consulting Institute
2003	Japan	Mykolaiv City	Pacific Consultants International
2004	Ukraine	Mykolaiv Region	Kievsoyuizdorproject
2011	Japan	Ukravtodor	The Consortium of Oriental Consultants Co., Ltd. and Chodai Co., Ltd.
2012	Ukraine	Ukravtodor	Kievsoyuizdorproject

To account for present land use conditions, the alignments of the routes being compared in this report have been adjusted slightly from the alignments set in the past feasibility studies. The criteria in Table5-4-6 are compared to quantitatively evaluate the routes as extensively as possible.

Table 5-1-2shows the characteristics of each route.

Note that Routes 1, 2 and 3 are referred to as “Northern Routes”, because they connect M14 on the north side of Mykolaiv City to M14 on the west side of the city. On the other hand, Route 4 is referred to as the “Southern Route”, because it connects M14 on the south side of the city to M14 on the west side.

Table 5-1-2. Route Characteristics

Route	Characteristics
Route 1	Route 1 is the longest among the Northern Routes, crossing the Southern Bug River at a point further north than the other routes. The river, however, is the narrowest at its crossing point, so the length of the bridge is the shortest, which may help reduce the total cost of construction. On the other hand, factors such as vessel navigation, flood control safety, airspace for Mykolaiv Airport, and resettlement shall be taken into account when considering this route. Significantly, the scale of involuntary resettlement is the biggest among the Northern Routes.
Route 2	Route 2 is the shortest among the Northern Routes, crossing the Southern Bug River at a point further south than the other routes. This route has two advantages: no involuntary resettlement is required and the route is reflected in the 2009 Mykolaiv City Planning. On the other hand, the bridge crosses over a bend in the river, which makes it necessary to consider vessel navigation and flood control safety. Attention must also be paid to slope stability at the right riverbank. The right riverbank is a colliding front, with the nearby slope marked as a landslide zone. The slope spread at the right riverbank is subject to relatively middle-scale landslides, with a series of minor landslides having actually occurred in the area in the past. A series of gullies has also developed around the said landslides, and there may be a groundwater concentration at a certain level underground.
Route 3	Route 3 is proposed as an alternative to Route 2, which crosses over a bend in the Southern Bug River. Route 3 crosses over a nearly straight section of the river in consideration of vessel navigation and flood control safety. The route is also intended to extend the ring roads already in service in the northeastern segment of the Mykolaiv to the northwestern segment. Thus, in terms of benefits, this is an advantageous route. The route, however, would require some degree of involuntary resettlement on a limited scale. The stability of the slope at the right riverbank must also be carefully watched: the slope near the right riverbank is subject to relatively small-scale landslides, with some minor landslides having actually occurred in the area recently.
Route 4	Route 4, the only Southern Route, is the longest of all. This route is also intended to extend the ring roads already in service at the northeastern segment of the Mykolaiv to the southwestern segment by avoiding the heavily populated residential areas along the Southern Bug River. Because the route crosses over a nearly straight section of the river, considerations can be made for vessel navigation and flood control safety, but the bridge would have to be longer because the river is wide at that point. In addition, because this route is located downstream of the Mykolaiv Port, the design vessels are larger than those for the Northern Routes, and the navigation clearance can also be increased.

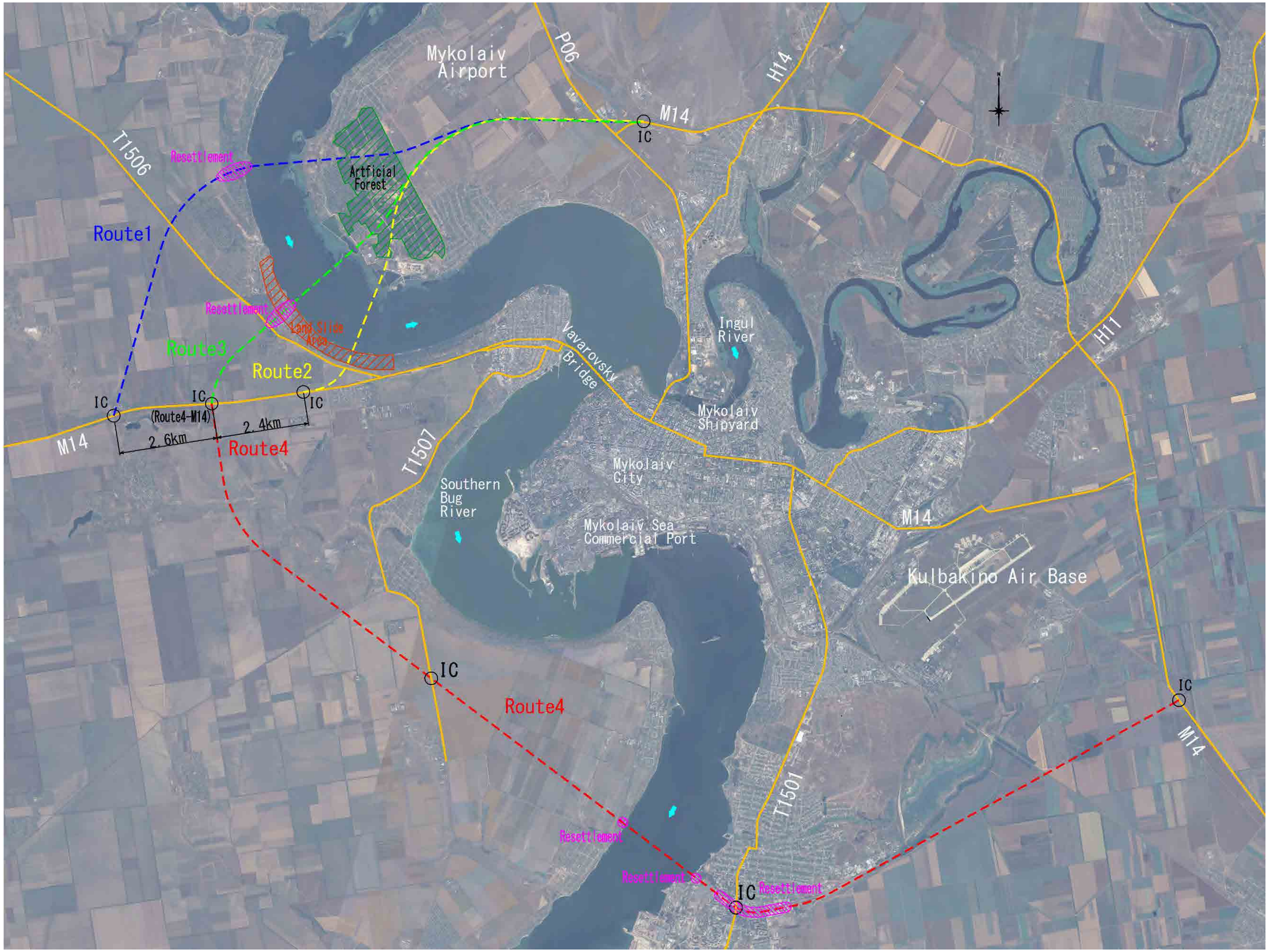
<table>
<tr><th>Item</th><th>Route-1</th><th>Route-2 (Selected in the 2011 F/S)</th><th>Route-3</th><th>Route-4</th></tr>
<tr><td>Map of
Proposed
Routes</td><td colspan="4"></td></tr>
</table>

Figure 5-1-1. Map of Proposed Routes

Table 5-1-3. Rough Lengths of the Routes

Work Type	Route 1	Route 2	Route 3	Route 4*
Route length	18,400m	13,200m	14,600m	32,500m
Bridge length of Bypass	1,500m	2,120m	2,180m	3,200m
(Main bridge length)	(840m)	(930m)	(840m)	(840m)
(Approach bridge length)	(660m)	(1,190m)	(1,340m)	(2,360m)
Road length	16,900m	11,080m	12,420m	29,300m

*River traffic conditions and vessel specifications differ depending on whether the route is upstream or downstream of Mykolaiv Port; larger target vessels and a longer bridge length may be applicable with Route 4, which is downstream of the port, than with Routes 1, 2 and 3, which are upstream of the port. However, for the purposes of this Study, the same target vessel specifications and conditions were used for all four routes.

5-2 Method of Route Selection

The Analytic Hierarchy Process (hereinafter referred to as “AHP”), a stratified decision-making process with a good track record, is more suitable for this Study than the other methods. This method provides a comprehensive and objective framework for evaluating multiple criteria. Weights can be assigned to the respective criteria without applying external standards. The AHP can also be performed without relying on large sample sizes. In light of these features, the AHP has been selected as the method for route selection for this Study.

In general, route selection requires a multi-criteria analysis, a comprehensive method to evaluate a large number of criteria. Many methods of multi-criteria analyses have been developed, such as the Checklist Method, Scoring Method, Factor Profile Method, Gold Achievement Matrix Method, and AHP. In all of these methods, each criterion is comprehensively organized and evaluated independently from the others. Although a multi-criteria analysis often deals with subjective factors, evaluations are expected to be rational, persuasive, and convincing to a third party. Thus, the evaluations must be as quantitative as possible to maintain objectivity.

As for the criteria, guidelines developed in Japan, e.g., “Guideline on Evaluation of Road Investments” were referenced to set general criteria and those on which the Project is considered to have significant impacts in terms of the environment and the project implementation.

5-3 Procedure of Route Selection

According to standard AHP procedures, the route selection for this Study proceeds in the following steps:

Step 1: Select the criteria and evaluation indices

Select the criteria based on the positive and negative effects of the Project. For each criterion, select evaluation indices to compare alternatives (See 5-4 for details).

Step 2: Decide the performance levels of each route against the criteria

Assess the performance of each route against each of the criteria with respect to the evaluation indices (See 5-5 for details).

Step 3: Decide the evaluation score of each route based on its performance levels

Score each route based on its performance levels on the criteria with respect to the evaluation indices (See 5-5 for details).

Because the scales of measurement vary in scoring the evaluation indices, consistent numerical scales are applied to translate the performance levels, such that the highest performance level on each criterion is assigned the same evaluation score as the others.

The table below shows an example of evaluation scores (5 is the highest score).

Table 5-3-1. Conversion of Performance Levels to Evaluation Scores (Example)

Example

Unit: Points

Criteria	Performance					Evaluation Scores			
	R1	R2	R3	R4		R1	R2	R3	R4
Initial Cost (million USD)	409	415	444	577		5.0	4.9	4.6	3.5
Number of Affected Structures to be Relocated (Houses)	50	None	3	40	⇨	3.0	5.0	4.5	3.0
※Vessel Collision Probability	2.1 times	2.5 times	1.8 times	1.2 times		2.4	2.0	2.8	4.2

*Increase in vessel collision probability with bridge piers compared to collision probability in straight sections

Step 4: Decide the weights to assign to the criteria

Criteria are compared and assigned weights based on the relative importance to the decision (called “Weighting”) (See 5-6 for details).

Step 5: Select the route

Calculate the weighted evaluation score by multiplying the evaluation score of each route on a criterion from Step 3 by the weights from Step 4. Next, select the route with the highest overall weighted evaluation score (See 5-7 for details).

The figure below shows Steps 1-5 described above.

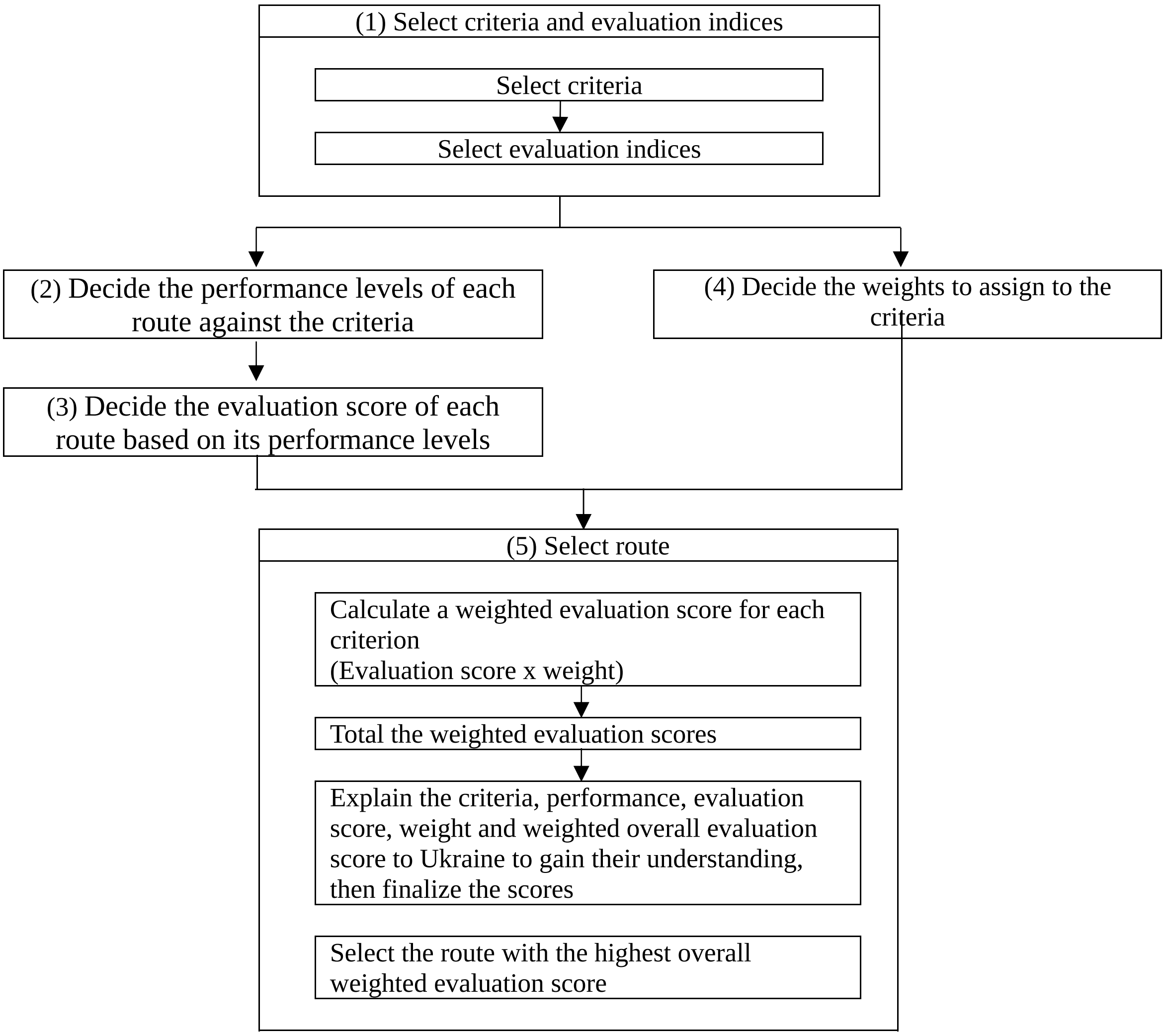


Figure 5-3-1. Route Selection Process

5-4 Criteria and Evaluation Indices

The following points are considered when selecting the criteria:

- Cover general criteria such as the cost, benefit, environmental impact, etc.
- Cover key criteria to evaluate project objectives
- Cover criteria for conditions requiring special consideration in project implementation
- Select quantitatively measurable criteria, insofar as possible
- Include criteria emphasized in the 2011F/S

Tables of the general criteria for road construction in Japan (Source: Guideline on Evaluation of Road Investments, Chapter 2 Overall Evaluation, pp. 6-8, Table 1-2) are given for reference (see Tables 5-4-1 to 5-4-5).

The list of criteria, the reasons for their selection, and the evaluation indices set for this Study are presented in Table5-4-6.

Table 5-4-1. General Criteria for Road Construction in Japan (1/5)

Beneficiary	Category	Subcategory	Sub-subcategory	Focus of Evaluation	Example of Evaluation Index (Reference)	Effects of the Project		Criteria (Draft)		
						Yes/ No	Reasoning	JICA Survey Team & JICA Selection Yes: Selected	Ukraine Selection	Final Decision
Cost: ✔Construction Cost (Initial Cost), ✓Bridge Construction Cost						-	-	Yes		
Road users	Effects on road use	✔Project Benefits (travel time reduction)	Increase in production time due to reduced travel time	・Increased production in the transportation industry ・Increased production in the manufacturing industry ・Increased production in the commercial/service industries	・TTC (Travel Time Cost) is used to evaluate	Yes	Increased production in the transportation industry, etc. through efforts to facilitate distribution of grain crops, etc.	Yes		
			Increased leisure time due to reduced travel time	・More fulfilling recreation ・Improved self-studying ・More fulfilling rest		Yes	Reduced commuting time and increased free time due to alleviation of traffic congestion in the Mykolaiv City area			
		✔Project Benefits (reduction in operation costs)	Saving on fuel costs	・Saving on gasoline and diesel fuel	・VOC (Vehicle Operation Cost) is used to evaluate	Yes	Saving on fuel costs through reduced idling and optimal driving speeds achieved through alleviation of traffic congestion in the Mykolaiv City area	Yes		
			Saving on vehicle consumption costs	・Saving on oil consumption ・Saving on tire/inner tube consumption						
			Saving on vehicle maintenance costs	・Saving on vehicle maintenance costs ・Saving on vehicle repair costs						
			Saving on vehicle depreciation costs	・Saving on depreciation						
		Reduction in traffic accidents	Reduction in personal loss	・Reduced loss due to physical injuries, etc. ・Reduced material loss ・Reduced cost of dealing with accidents	・Depends on the extent to which trucks, etc. use each route; uncertain at present, so assuming conversion rate of heavy vehicles is 100% in previous F/S ・Need data on the number of accidents in Ukraine	Yes	Fewer accidents due to fewer trucks passing through the Mykolaiv City area.	Will use VCR to decide		
			Reduction in societal loss	・Reduced material loss ・Reduced cost of dealing with accidents						
		Improvement of comfort on the road	Reduction in fatigue	・Reduced driver fatigue ・Reduced passenger fatigue	・✔Improved VCR (Volume Capacity Ratio) in the city ・Elimination of sites with minimum radius ・Higher design speed ・Pavement of unpaved areas	Yes	Reduced fatigue for drivers of trucks and passenger vehicles due to the reduction of traffic congestion in the Mykolaiv City area	Yes Will use VCR to decide		
			Creation of scenery from the road	・Scenery to be viewed from inside vehicles ・Scenery to be viewed from the road	・Establish SA (Service Area), PA (Parking Area) and parks on sites with good views	Yes	New scenery can be created as the lack of skyscrapers, hills or mountains in the area make long-distance views possible	Same evaluation for each route		
		Improvement of pedestrian safety /comfort	Improvement of pedestrian safety	・Improved safety for pedestrians ・Improved safety for cyclists	・Installation of sidewalks ・Establishment of traffic safety facilities	Yes	Improved safety by reducing the number of trucks traveling through the Mykolaiv City area	Same evaluation for each route		
			Improvement of pedestrian comfort	・Improved comfort by enabling pedestrians to walk without worrying about bicycles ・Improved comfort by enabling cyclists to ride without worrying about motor vehicles	・Greening of sidewalks ・Establishment of rest facilities ・Sidewalk width of at least 3 m ・Separation of pedestrians and bicycles ・Universally accessible	Yes	Increased comfort through reduction of dust and noise due to fewer trucks passing through the Mykolaiv City area	Same evaluation for each route		

Table 5-4-2. General Criteria for Road Construction in Japan (2/5)

Beneficiary	Category	Subcategory	Sub-subcategory	Focus of Evaluation	Example of Evaluation Index (Reference)	Effects of the Project		Criteria (Draft)		
						Yes/ No	Reasoning	JICA Survey Team & JICA Selection Yes: Selected	Ukraine Selection	Final Decision
Areas and communities along the route	Environ-mental effects	Air pollution	Impact on people	・Impact of NO_x on people ・Impact of SO_x on people ・Impact of SPM on people	・Difficult to accurately calculate at present; need frequency distribution of hourly average wind speed and direction. It is unlikely that there are any differences between routes	Yes	Fewer pollutants in the city area due to fewer trucks passing through the Mykolaiv City area More bypass routes	Same evaluation for each route		
			Impact on materials							
		✓Noise/vibrations	Impact on communication	・Impact on people living along the route ・Impact on facilities along the route	・Relationship between noise levels and number of households affected	Yes	People/facilities along the route will be affected	Yes		
			Impact on comfort							
			Impact on physical and mental health							
		Global warming	Environmental impact of CO_2 emissions from motor vehicles		・Evaluation of the scale of emissions suggests no difference between routes. ・Impossible to accurately calculate at present; need frequency distribution of hourly average wind speed and direction.	Yes	Completion of the bypass route will cause CO_2 to increase due to increased traffic flow. Reduced impact with optimal driving speeds. Reduced CO_2 due to alleviation of traffic congestion in the Mykolaiv City area	Same evaluation for each route		
		Scenery	Harmony with surrounding area	・Harmony with natural scenery ・Harmony with urban scenery ・Protect along with cultural resources, investigate	・Harmony with surrounding area ・No impact on cultural assets	Yes	The long bridge will create new scenery as a landmark. Nighttime illumination and other efforts will make it a tourist attraction	Same evaluation for each route		
			Creation of new regional scenery	・Creation of new scenery with road structures	・Bridge will have structural beauty	Yes		Same evaluation for each route		
		Ecosystem	Impact on regional ecosystems along the route	・Impact of motor vehicle traffic ・Impact of road structures	・The route will/will not pass through protected areas for rare species designated by law or regulations. ・Evaluate the positional relationship with protected areas, world heritage sites and no-fishing areas for ✓ecosystem conservation.	Yes	This item must be evaluated, regardless of presence/absence of effects.	Yes		
			Impact on rare species							
			Impact on soil / riparian environment / topography	・Impact of road structures	・No impact on soil/riparian environment (environmental assessment has/has not been implemented) ・✓Evaluate the extent of artificial forest clearing and the area of agricultural land that will be lost.	Yes	This item must be evaluated, regardless of presence/absence of effects.	Yes		

Table 5-4-3. General Criteria for Road Construction in Japan (3/5)

Beneficiary	Category	Subcategory	Sub-subcategory	Focus of Evaluation	Example of Evaluation Index (Reference)	Effects of the Project		Criteria (Draft)		
						Yes/ No	Reasoning	JICA Survey Team & JICA Selection Yes: Selected	Ukraine Selection	Final Decision
Areas and communities along the route	Effects on people's lives	Use of road space	Consolidation of lifelines	・Increased convenience due to consolidation of electric power lines ・Increased convenience due to consolidation of water supply and wastewater pipes ・Increased convenience due to consolidation of gas lines	・Will/won't run alongside bridges	Yes	Increased convenience if lifelines run alongside bridges	Difficult to evaluate		
			Provision of space for disaster prevention	・Reduced damage due to function as a firebreak gap ・Reduced damage due to function as space for evacuation during disasters	・Increased space for firebreaks (at least 25 m in densely populated urban areas)	Yes	Route 4 passes through the city area, so these effects can be expected.	Difficult to evaluate		
		Securing of alternate routes during disasters	Securing the functionality of transportation during disasters	・Elimination of inconvenience of detours ・Reduced psychological anxiety		Yes	The alleviation of traffic congestion reduces psychological anxiety toward disasters	Same evaluation for each route		
			Reduction of damage to the flow of people	・Elimination of traffic restrictions during extreme weather events ・Elimination of dangerous places		Yes	Completion of the bypass will make it possible to conduct maintenance on Vavarovsky Bridge, which will eliminate dangerous places	Same evaluation for each route		
		Expansion of opportunities for life/exchange	Improvement of access to recreation facilities	・Improved access to recreation facilities ・Improved access to tourist attractions	・Reduced travel time (at least 30 minutes) between primary tourist attractions ・Increased number of municipalities with access to comprehensive resort areas within 90 minutes	Yes	Route 4 will improve access to the city area from areas along T1501	Slight effects		
			Increase of nonresident population	・Increased population within day-travel range ・Increased access to urban areas	・Increased number of municipalities with access to each other within 90 minutes	Yes	Route 4 will improve access to the city area from areas along T1501	Slight effects		
			Improvement of access to arterial roads	・Improved access to high-speed railway/express train stations ・Improved access to airports/ports and harbors	・Increased number of towns/villages with access to airports within 60 minutes	Yes	Routes 1-3 will improve access to the airport.	Slight effects		
		Improvement of public services	Improvement of access to public facilities/lifestyle convenience facilities	・Improved access to city/town offices ・Improved access to high schools ・Improved access to large-scale retail outlets ・Improved access to sports/cultural facilities	・Increased number of towns/villages with access to designated facilities (libraries, community centers, high schools, large-scale retail outlets) within one hour ・Access to municipal offices within 30 minutes in all municipalities	Yes	Alleviation of traffic congestion in the city area improves access to the suburbs of Mykolaiv	Slight effects		
			Improvement of access to emergency facilities	・Improved access to acute care hospitals ・Improved access to fire departments ・Improved access to police departments	・Increased number of municipalities with access to emergency facilities (acute care hospitals, fire departments, police departments) within 30 minutes	Yes	Alleviation of traffic congestion improves access for suburban residents to various facilities in Mykolaiv City	Slight effects		
			Improvement of public transportation	・Improved convenience by enabling passage of large buses	・At least 20 buses are planned. ・Passage of large buses made possible	No	No change in types of vehicles that can pass through.			

Table 5-4-4. General Criteria for Road Construction in Japan (4/5)

Beneficiary	Category	Subcategory	Sub-subcategory	Focus of Evaluation	Example of Evaluation Index (Reference)	Effects of the Project		Criteria (Draft)		
						Yes/ No	Reasoning	JICA Survey Team & JICA Selection Yes: Selected	Ukraine Selection	Final Decision
Areas and communities along the route	Effects on regional economy/ public finances	Creation of demand due to construction projects	Increase in sales in relevant industries	・Increased sales in the construction industry ・Increased sales in the construction materials industry ・Increased sales in regional services industries	Consolidated into a single item (“industry promotion”) to facilitate the model analysis required for measurement. ・Access road to wholesale markets. ・Industrial parks are located or planned along the route ・Large-scale resort facilities are located along the route. ・Large-scale shopping centers are located or planned along the route		Included in city planning.			
			Increase in employment in relevant industries	・Increased sales in the construction industry ・Increased sales in the construction materials industry ・Increased sales in regional services industries						
			Environmental impact of CO₂ emissions generated by road construction							
		Increase in production due to arrival of businesses to the area	Relocation/moving to the area to reduce transportation costs	・Increased production by relocation/moving of the construction industry ・Increased production by relocation/moving of the commercial/services industries ・Increased production by relocation/moving of the shipping/transportation industry						
					・Access road to specified important ports and harbors/important ports and harbors. ・✓Evaluate collaboration with Ochakov Port.	No	No interchange at the intersection with T1507.			
					・Access road to logistics/distribution zones. ・✔Evaluate coherence with the Ring Road Concept.	Yes	There are preferable routes with respect to the Ring Road Concept.	Yes		
			Relocation/moving to the area due to market expansion	・Increased production by relocation/moving of the commercial/services industries ・Increased productivity due to relocation/moving of leisure industries	・There are plans to establish residential zones along the route. ・This is a designated area or a road in a designated area in a disadvantaged area (regional revitalization legislation, etc.).		Included in city planning			
		Increased employment opportunities/ income	Increase in employment due to expansion of production in existing industries	・Increased employment in the agriculture, forestry and fisheries industries ・Increased employment in the manufacturing industry ・Increased employment in the commercial/services industries ・Increased employment in the shipping/transportation industry						
			Increase in income due to expansion of production in existing industries		・Viewed as significant in land readjustment projects and redevelopment projects. ・✓Evaluate coherence with Mykolaiv City planning. ・✔Evaluate coherence with Mykolaiv City planning.	Yes	There are routes mentioned in city planning.	Yes		
			Increase in employment generated by production in relocation industry	・Increased employment in the manufacturing industry ・Increased employment in the commercial/services industries ・Increased employment in the shipping/transportation industry						
			Increase in income generated by production in relocation industry					Effects unclear		

Table 5-4-5. General Criteria for Road Construction in Japan (5/5)

Beneficiary	Category	Subcategory	Sub-subcategory	Focus of Evaluation	Example of Evaluation Index (Reference)	Effects of the Project		Criteria (Draft)		
						Yes/ No	Reasoning	JICA Survey Team & JICA Selection Yes: Selected	Ukraine Selection	Final Decision
Areas and communities along the route	Effects on regional economy/ public finances	Population stabilization	Settling of population					Effects unclear		
		Decrease in the price of financing/services	Decrease in the price of financing/services due to reduced production costs	・Decreased prices in the construction industry ・Decreased prices in the commercial/services industries ・Decreased prices in the shipping/transportation industry						
			Decrease in the price of financing/services due to streamlining of distribution system							
		Increase in property values	Increase in land values due to improved convenience	・Increased residential land values ・Increased industrial land values						
			Increase in land values due to market expansion	・Increased commercial land values ・Increased industrial land values						
		Stable public finances	Saving of financial expenditures	・Saving on public facility establishment costs						
			Increase in tax revenue	・Increased local tax revenue ・Increased national tax revenue						
-	Other	✔Resettlement, ✓Resettlement			Evaluate the scale of involuntary resettlement.			Yes		
		✔Ground conditions, ✓Ground conditions	✔Slope failure		Evaluate the scale of landslides, safety, etc.			Yes		
		✔Inland Waterway conditions	✔Probability of vessel collisions		Evaluate the relative probability of vessel collisions			Yes		
		✔River conditions	✔Impact on flood control safety		Evaluate the number of cases in which river conditions (bends, water colliding fronts, narrow stretches, confluences, etc.) adversely affect flood control safety			Yes		
		✔Airspace conditions	✔Restrictions regarding bridge construction		Evaluate the presence/absence of airspace restrictions			Yes		
	✓Location of road as one section of the East-West Corridor							Use other items to evaluate		

Note 1: Criteria used in the 2011 F/S are marked with ✓.
Note 2: Criteria proposed for the Project are marked with ✔.
Note 3: Sub-subcategory items were selected in consideration of factors such as the potential objectivity of evaluations, the ease with which evaluators can evaluate them, and the existence of data and other information. Generally, brainstorming by experts and people involved in roadway administration is part of the process for selecting criteria.
Note 4: "Other" does not include general criteria within Japan, but comprises criteria that require special consideration in the implementation of the Project.

Table 5-4-6. List of Criteria

Categories	Subcategories	Sub-subcategories	Reason for Selection	Evaluation Index
Project Effects	Improved VCR in the city	-	Elimination of congestion in the city is an important objective of the Project.	VCR (Volume/Capacity Ratio) of Vavarovsky Bridge
	Project Costs	-	It is important to fully understand the initial investment amount required for bypass road construction.	Initial Costs
	Project Benefits	-	It is important to quantitatively evaluate the effects of the Project.	TTC (Travel Time Cost) VOC (Vehicle Operation Cost)
Impact Factors	Social Environment	Reduction in the Scale of Involuntary Resettlement	Resettlement involves substantial changes to social and living environments. Thus, it is often impossible to obtain consent from all Project-Affected Persons (PAPs). A higher number of required relocations carries a major risk that the efficacy of a project will be undermined. In addition, the scale of involuntary resettlement was treated as a critical criterion in the 2011 F/S.	Number of Residential Buildings to Relocate
		Reduction in the Area of Agricultural Land Lost	The main industry around the project site is agriculture, so most of the land that the bypass road will pass through is farmland. The area of land lost indicates some degree of change in land use from the present situation, and is a factor in determining whether the main industry is preserved.	Area of Agricultural Land Lost
		Coherence with Mykolaiv City Planning	The Mykolaiv City planning was finalized on the premise that the bypass road to be constructed would pass through the city. If the route planned in the current city planning is not selected, the city planning will have to be revised.	Coherence with City Planning as formulated in 2009
		Coherence with the Ring Road Concept	Ukrainian cities with populations of over 300,000 tend to have semicircular or full ring roads established to allow vehicles to avoid traffic in downtown areas. Mykolaiv City has a population of 500,000, so a ring road is preferable.	Connectivity between Routes 1-3 and Route 4 (positional relationship of terminus interchange)
	Natural Environment	Reduction in Artificial Forest Clearing	There is a sizable artificial forest of roughly 570 ha near the left riverbank between the Southern Bug River and Mykolaiv Airport. The land surrounding the project site is flat, and there are no other forests; the artificial forest is important in preserving the natural environment.	Area of Artificial Forest Clearing
		Ecosystem Conservation	The conservation of ecosystems is important in a project of any type. Also, the bypass road may be adjacent to a no-fishing zone designated by the Fisheries Agency Mykolaiv Office.	Positional relationship with Especially Important Areas for Ecosystem Conservation Positional Relationship with No-Fishing Zones
	Living Environment	Impact of Vibrations/Noise on Residents in the Area	Most of the land around the project site is agricultural land; therefore, present noise and vibration levels are assumed to be low. Constructing a bypass road will significantly increase noise and vibration levels and substantially impact the living environment.	Number of Residential Buildings Impacted by Noise
		Impact of Vibrations/Noise on Public Facilities in the Area		Number of Public Facilities Impacted by Noise
Project Implementation Environment	Ground Conditions	Slope Failure	The slope near the right riverbank of Routes 2 and 3 has long been susceptible to landslides. For Route 2 in particular, it is highly likely that bridge piers and abutments will be built on the slope.	Scale and Safety of Landslides
	Inland Waterway Conditions	Probability of Vessel Collisions	Since the Southern Bug River is used as a navigation channel for inland waterways, there is a possibility that vessels will collide with the bridge piers, thus affecting the safety of both the vessels and bridge.	Relative Probability of Vessel Collisions
	River Conditions	Impact on Flood Control Safety	The construction of a bridge and the relationship between the location of the bridge and river channel conditions (narrow stretches, bends, water colliding fronts, confluences, places where flow conditions change, etc.) affect flood control safety.	Degree of River area Blockage by Bridge Pier Corresponding Number of River Channel Conditions (Bends, Water Colliding Fronts, Narrow Stretches, Confluences, Etc.) that have a Negative Impact on Flood Control Safety
	Airspace Conditions	Restrictions Regarding Bridge Construction	Mykolaiv City has airports both to the north and south of town. Thus, in any construction on routes where the main bridge is built in the same direction used for runways, the bridge (particularly the main tower and diagonals), as well as any heavy machinery and materials used during construction, must be kept from entering the obstacle limitation surfaces of either airport.	Presence/Absence of Airspace Restrictions

5-5 Review and Scoring of Performance on the Criteria

The performance of each route on each of the criteria with respect to the evaluation indices were reviewed and scored on a 5-point scale. The following section describes how the evaluation scores for each evaluation index were obtained.

5-5-1 Project Effects

1) Improvements to VCR in the City

The volume capacity ratio (VCR) is defined as the ratio of a road's traffic volume to its traffic capacity and it is generally used to evaluate the project effects on congestion. For each year compared, a route with a lower value can better alleviate traffic congestion. The following table presents the calculated VCRs in the city and the evaluation scores for Vavarovsky Bridge for two cases: if Mykolaiv Bridge with an extension of the bypass road is constructed ("With Project"), and if Mykolaiv Bridge with an extension of the bypass road is not constructed ("Without Project").

The route with the lowest VCR in 2055 was assigned 5 points; other routes were scored as shown below.

Evaluation scores = 5 x Lowest VCR in 2055 / VCR of each route for 2055

Table 5-5-1. Calculated VCRs and Evaluation Scores in the "With Project" and "Without Project" Cases

	VCR				
	Without Project	With Project			
		Route 1	Route 2	Route 3	Route 4
Present state (2017)	2.54	-	-	-	-
2025	2.66	1.63	1.54	1.58	1.71
2040	3.96	2.43	2.30	2.35	2.55
2055	5.96	3.66	3.47	3.54	3.83
Evaluation Scores	-	4.74	5.00	4.90	4.53

2) Project Costs

Generally, road and bridge construction projects require construction costs (Initial Costs) and operation and maintenance costs (Running Costs). As the main parts of Project Costs here, however, the JICA Survey Team calculated and compared the Initial Costs of Routes 1, 2, 3, and 4. Table5-5-2 shows the main work types figured into the calculations for the initial costs. Note that the calculations do not include environmental mitigation work. While the need for environmental mitigation remains unclear at this point, such work would be unlikely to increase the overall cost of construction substantially.

The studies conducted to date have revealed concerns about landslides occurring on Routes 2 and 3. The costs for these routes thus include landslide countermeasures (including river bank protection). The results of future complementary geological surveys, however, may affect the type and scale of the countermeasures necessary.

A physical contingency was estimated at 10% of the Initial Costs to cover measures for any design changes, accidents, natural disasters or other unforeseen circumstances. A consulting fee of 6% was estimated to cover the Consultant's work in performing the detailed design, assisting with the procurement, and supervising the construction. A price escalation of 20% was used as the estimation to account for construction requiring multiple years to complete. (Note: The rates above are subject to change, depending on the results of further studies. Approximately 20% is equivalent to the cost for 10 years at annual rate of 5%.)

Table 5-5-2. Main Work Types Figured into the Calculations for Initial Costs

Type of Project Cost	Main Work Types
Initial Costs*	Earthwork, pavement, drainage, ancillary works, landslide countermeasures, river bank protection, scour protection, bridge construction (superstructure, substructure, foundations), physical contingency, price slide, consulting fee, price escalation

*Environmental mitigation work, facilities for toll road, etc. are NOT included.

The calculated Initial Costs and evaluation scores are given in the table below. The route with the lowest Initial Costs was assigned 5 points; the other routes were assigned the scores shown below.

Evaluation Scores = 5 x lowest Initial Costs / Initial Costs of each route

Table 5-5-3. Initial Costs and Evaluation Scores

Unit: Million USD

	Route 1	Route 2	Route 3	Route 4
Initial Costs Total	549	593	614	1,003
(Physical Contingency)	(47)	(51)	(53)	(87)
(Price Escalation)	(79)	(86)	(90)	(144)
(Consulting Service)	(24)	(25)	(26)	(43)
Evaluation Scores	5.00	4.66	4.48	2.74

3) Project Benefits

In traffic demand analysis, Reduction in Vehicle Operation Cost (VOC) and Reduction in Travel Time Cost (TTC) can be used to quantitatively evaluate the project benefits. Especially in this Study, the project benefits are defined as the differences in the above measurements between the “With Project” and “Without Project” cases.

The calculated benefits and evaluation scores are given in the table below. The route with the highest benefit was assigned 5 points; the other routes were assigned the scores shown below.

Evaluation Scores = 5 x route benefit / highest benefit

Table 5-5-4. Project Benefit Calculations and Evaluation Scores

Unit: Million USD

Type of Benefit	Route 1	Route 2	Route 3	Route 4
TTC reduction	532	550	585	676
VOC reduction	87	89	109	48
Total	619	639	694	724
Evaluation Scores	4.27	4.41	4.79	5.00

5-5-2 Impact Factors

1) Social Environment

(1) Reduction in the Scale of Involuntary Resettlement

The number of residential buildings subject to relocation was counted to evaluate the scale of involuntary resettlement. The results and evaluation scores are given in the table below. The routes were scored based on qualitative judgments, with “no relocation” assigned 5 points.

Table 5-5-5. Number of Residential Buildings to Relocate and Evaluation Scores

Route	Number of Residential Buildings to Relocate	Evaluation Scores
Route 1	Roughly 50 houses	3.0
Route 2	None	5.0
Route 3	3 houses	4.5
Route 4	Roughly 40 houses	3.0

(2) Reduction in the Area of Agricultural Land Lost

The area of agricultural land lost was calculated for each route to evaluate the imapact on the agricultural land. The results and evaluation scores are given in the table below. The routes were scored based on qualitative judgments, with “no agricultural land lost” assigned 5 points.

Table 5-5-6. Area of Agricultural Land Lost and Evaluation Scores

Route	Area of Agricultural Land Lost	Evaluation Scores
Route 1	119ha	2.0
Route 2	77ha	4.0
Route 3	93ha	3.0
Route 4	198ha	1.0

(3) Coherence with Mykolaiv City Planning

Coherence with Mykolaiv City Planning was evaluated for each route. With the Route 2 bridge location assumed in the current Mykolaiv City Planning, as formulated in 2009, only Route 2 was considered coherent with the plan.

The results and evaluation scores are given in the table below. The routes coherent with city planning were assigned 5 points. All other routes were assigned a median of 3 points.

Table 5-5-7. Coherence with City Planning and Evaluation Scores

Route	Coherence with City Planning	Evaluation Scores
Route 1	No coherence with city planning.	3.0
Route 2	Coherence with city planning is assured.	5.0
Route 3	No coherence with city planning.	3.0
Route 4	No coherence with city planning.	3.0

(4) Coherence with the Ring Road Concept

When a ring road is considered in the near future, M14 serves the east-to-north portion; Route 1, 2, or 3 the north-to-west portion; and Route 4 the west-to-south-to-east portion.

Since the only option for the southern route is Route 4, an interchange connecting Route 4 and M14 (west side) is necessary. Similarly, an interchange is necessary to connect the north-to-west route and M14 (west side). Considering the function of a ring road, the closer the latter interchange is to the former interchange, the better its functionality. The best option is when the two meet at the same location.

Therefore, the distance between the Route 4 interchange on M14 (west side) and the interchanges of each of other three routes on M14 (west side) was evaluated.

The results and evaluation scores are shown in the table below. Route 4 was assigned an evaluation score of 5 points. Route 3 was also assigned 5 points, because its interchange coincided with that of Route 4. The other two routes were scored based on qualitative judgments.

Table 5-5-8. Distance to the Route 4 Interchange and Evaluation Scores

Route	Distance between the Route 4 interchange and the Route 1/2/3 interchanges	Evaluation Scores
Route 1	2.6 km to the Route 4 interchange	3.0
Route 2	2.4 km to the Route 4 interchange	4.0
Route 3	Same location as the Route 4 interchange	5.0
Route 4	-	5.0

2) Natural Environment

(1) Reduction in Artificial Forests Clearing

The area of artificial forests subject to clearing for each route was calculated to evaluate the impact on the natural environment. The results and evaluation scores are given in the table below. The routes were scored based on qualitative decisions, with "no artificial forest clearing required" assigned 5 points.

Table 5-5-9. Area of Artificial Forests Subject to Clearing and Evaluation Scores

Route	Area of Artificial Forests Subject to Clearing	Evaluation Scores
Route 1	11 ha	4.0
Route 2	15 ha	3.0
Route 3	10 ha	4.0
Route 4	None	5.0

(2) Ecosystem Conservation

In evaluating the impact on ecosystem conservation, the JICA Study Team focused on (1) ecologically important areas such as protected areas, World Heritage sites (both natural and cultural), Ramsar wetlands, and IBAs, and (2) the seasonal no-fishing zones specified by the Fisheries Agency Mykolaiv Office. The proximity to these areas was evaluated for each route.

The results and evaluation scores are given in the table below. Route 4, with no impact on ecosystem conservation, was assigned an evaluation score of 5 points. While the other routes may be adjacent to no-fishing zones, none of them are adjacent to any other protected areas, World Heritage sites, or the like. As such, Routes 1, 2, and 3 are assigned median evaluation scores of 3.

Table 5-5-10. Impact on Ecosystem Conservation and Evaluation Scores

Route	Impact on Ecosystem Conservation	Evaluation Scores
Route 1	Could run adjacent to seasonal no-fishing zones as specified by the Fisheries Agency Mykolaiv Office, but not adjacent to any other protected areas or World Heritage sites. Considerations needed for dredging period, turbid water removal, etc.	3.0
Route 2	Same as above	3.0
Route 3	Same as above	3.0
Route 4	Not adjacent to any protected areas, World Heritage sites, or seasonal no-fishing zones specified by the Fisheries Agency Mykolaiv Office.	5.0

3) Living Environment

Noise and vibrations levels were evaluated to measure the impact on the living environment. As noise generally impacts a wider area than vibration, noise levels and the number of affected residential buildings and public facilities were calculated.

Ukraine noise regulation standards stipulate the average and maximum allowable noise levels for different building types and for day and night, as shown in the table below. This evaluation counted the numbers of residential buildings and public facilities that would be exposed to the applicable noise level. Referencing the Ukraine noise regulation standards, the maximum allowable noise levels are set to 65 dB, 55 dB, and 45 dB.

Note here that noise impacts in the actual road project differ slightly by section: embankments, earth cutting works, and other earth works create differences in elevation between roads and buildings. Still, two assumptions are made: 1) there are no great differences in cut-and-fill shapes of sections near buildings between routes, and 2) conservatively, there are no noise barriers near the calculated areas of influence. Since the calculated noise levels only represent theoretical noise levels based on constant assumptions, each noise level per se was not evaluated. Instead, the evaluations were performed by comparing the calculated levels for the respective routes.

Table 5-5-11. Ukraine Noise Regulation Standards (MAL: Maximum Allowable Level)

(dB(A))

Classification	Average Value		Maximum		Regulations
	Day	Night	Day	Night	
Residential buildings	55	45	70	60	SN 3077-84, SBN 360-92, SBN 2.4-1-94, SBN V. 1.1-31:2013
Public facilities	55	55	70	70	SBN V. 1.1-31:2013
General buildings	60	50	75	65	SN 3077-84
	60	50	75	60	DBN 360-92
First floor of buildings affected by traffic noise	65	55	80	70	SN 3077-84, annex No,16 DSP 173-96
11th floor of buildings affected by traffic noise	70	60	85	75	SN 3077-84, annex No. 16 DSP 173-96

Note: “Day” covers the period from 8 AM to 10 PM, and “Night” covers the period from 10 PM to 8 AM.

The following formula is used to calculate the range of impact for each noise level.

$$Lr = Lw - 8 - 20 \times \log10 (r)$$

where: Lr : Noise level at distance (dB)
Lw : Source power level (dB)
r : Distance from the source (m)

Although trailer trucks and dump trucks are likely sources of noise, the details on vehicle noise restrictions in Ukraine are unclear. Therefore, the following formula for large vehicles (regular cargo trucks with the gross vehicle weight of more than 8 tons or maximum loading capacity of 5 tons and buses with 30 or more seating capacity), taken from the Japanese standard (Technical Methods for Environmental Impact Assessment of Roads), is used to calculate source power levels.

$$Lw = 53.2 + 30 \times \log10 (V)$$

where: Lw : Source power level (dB)
V : Average vehicle speed in sections where vehicles travel at a constant speed ($40 \leqq V \leqq 140$ km/h)

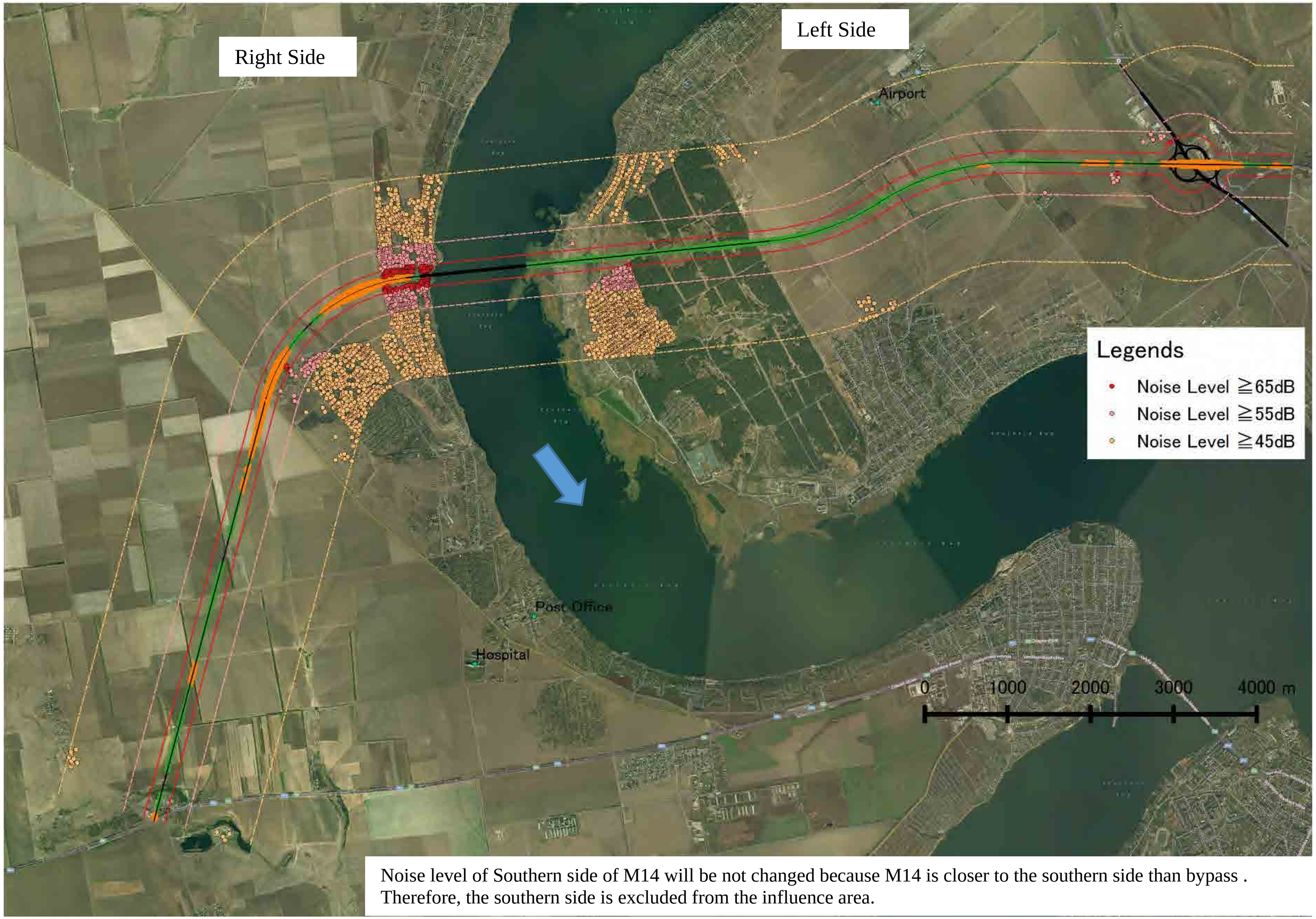
The results and evaluation scores are given in the table below. The routes were scored based on qualitative judgments, with “no structures affected” assigned 5 points.

Table 5-5-12. Number of Residential Buildings and Public Facilities Affected for Each Noise Level Range and Evaluation Scores

Route		Number of Structures Affected for Each Noise Level Range (Unit : Houses)						Evaluation Scores
		65 dB and Over		55 dB and Over		45 dB and Over		
		Left*	Right*	Left*	Right*	Left*	Right*	
1	Residential	3	Roughly 110	Roughly 150	Roughly 490	Roughly 1,470	Roughly 1,880	1.0
	Public Facilities	0	0	0	0	1	0	4.0
2	Residential	2	Roughly 10	Roughly 20	Roughly 120	Roughly 510	Roughly 710	3.0
	Public Facilities	0	0	0	0	1	0	4.0
3	Residential	4	Roughly 30	Roughly 200	Roughly 200	Roughly 730	Roughly 800	2.0
	Public Facilities	0	0	0	2	1	2	3.5
4	Residential	Roughly 80	Roughly 10	Roughly 600	Roughly 80	Roughly 2,940	Roughly 400	1.0
	Public Facilities	2	0	4	0	Roughly 20	1	2.5

*Note: “Right” and “Left” refer to the right and left sides of the riverbank, respectively.

The number of affected structures were calculated based on Figures 5-5-1 to 5-5-4.



Noise level of Southern side of M14 will be not changed because M14 is closer to the southern side than bypass . Therefore, the southern side is excluded from the influence area.

Figure 5-5-1. Affected Households of Route 1

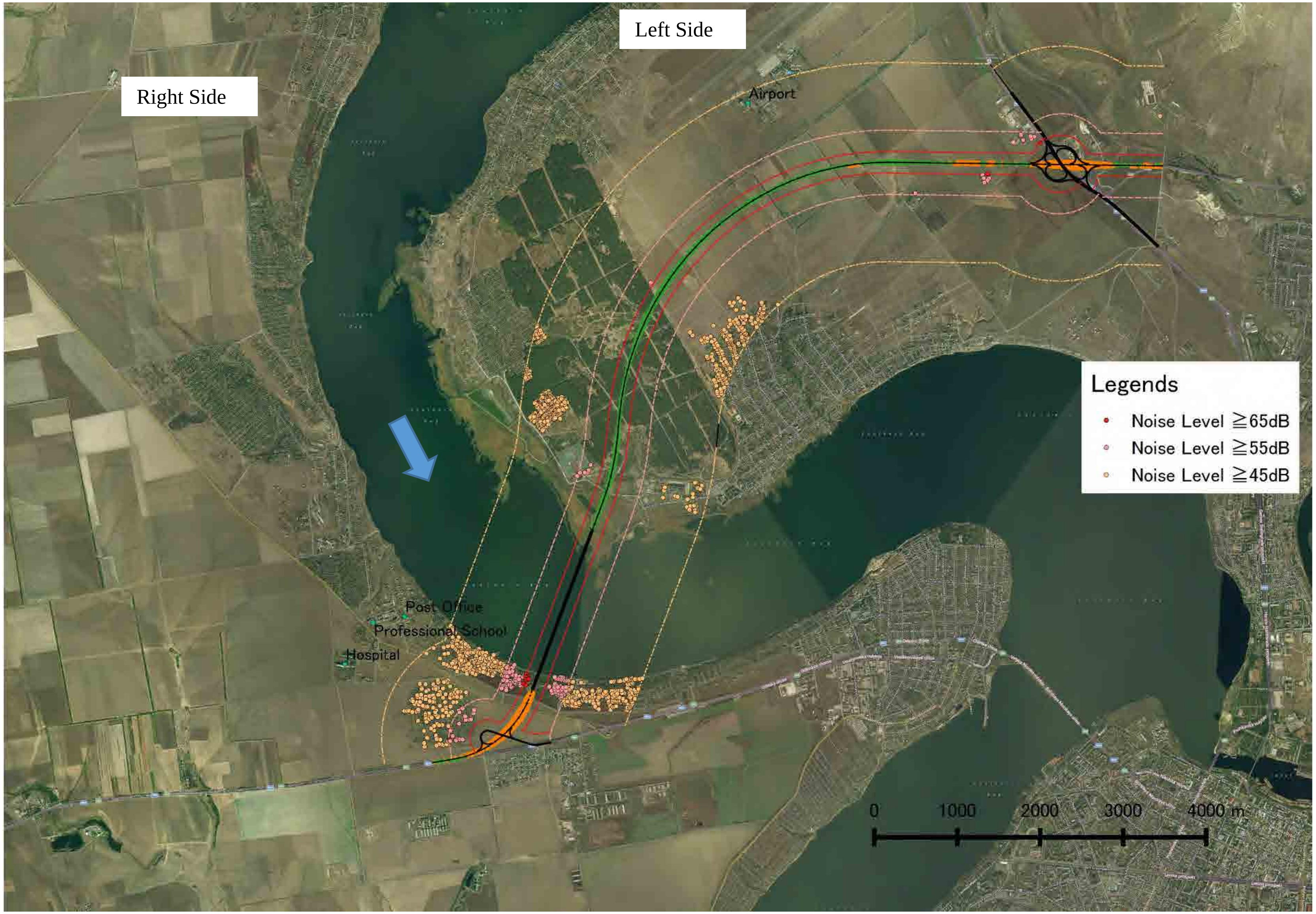


Figure 5-5-2. Affected Households of Route 2

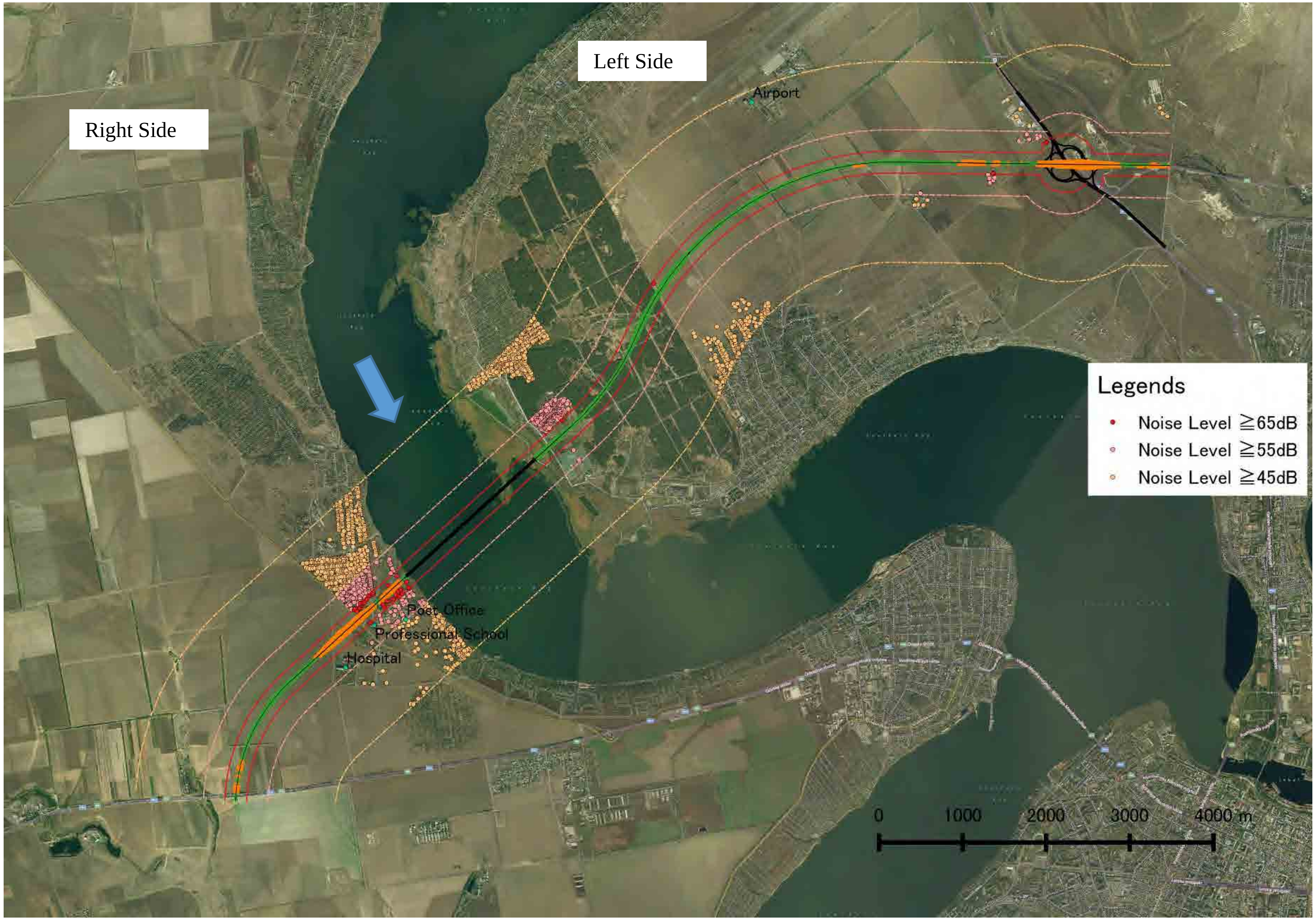


Figure 5-5-3. Affected Households of Route 3

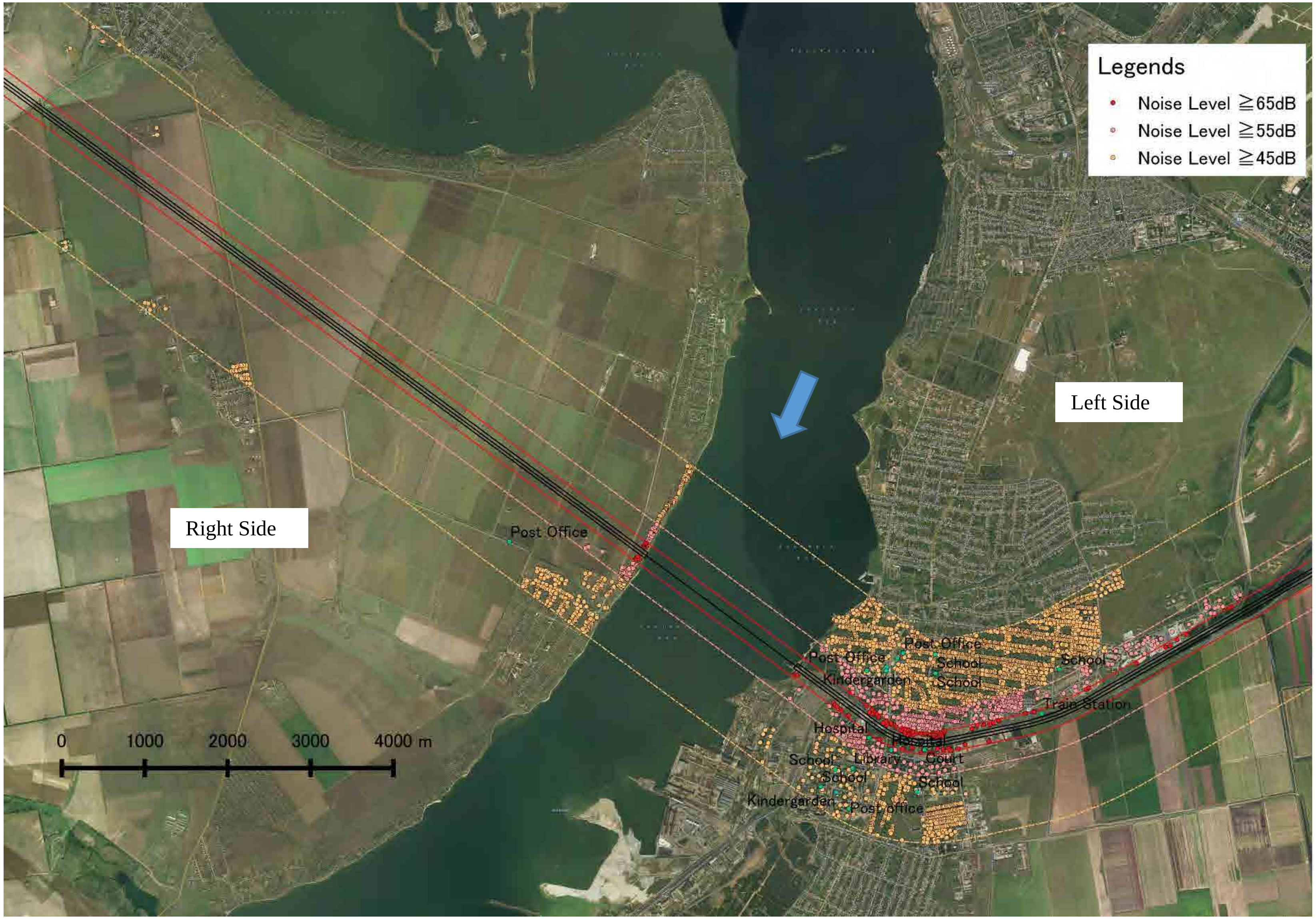


Figure 5-5-4. Affected Households of Route 4

5-5-3 Project Implementation Environment

1) Ground Conditions

As mentioned previously, the Southern Bug River meanders continuously over a widening area from upstream to downstream. The right banks of the river along Route 2 are located in river bends, which makes them water colliding fronts. Geological surveys conducted to date have also revealed evidence of past landslides and the potential occurrence of more landslides in the future. Safety from landslides should therefore be evaluated for the ground conditions.

The table below shows the results of considerations and evaluation scores. Routes 1 and 4 were assigned evaluation scores of 5 points because landslides do not occur on those routes. As for Routes 2 and 3, given that the cost of landslide countermeasures were evaluated as part of the cost of construction described previously, points were scored based on qualitative judgments that focused on geography and the scale of landslides as elements of safety against landslides.

See Chapter 9 for details about landslides on Routes 2 and 3.

Table 5-5-13. Safety against Landslides and Evaluation Scores

Route	Safety Against Landslides	Evaluation Scores
Route 1	Landslides will not occur because the route does not pass through prone areas of landslides.	5.0
Route 2	With the landslide surfaces gently sloped, the probability of major movement in the future is low. However, the range of possible landslides is wide because the landform facilitates the accumulation of water around the proposed bridge abutment.	3.0
Route 3	The probability of landslides occurring in the future is higher than that for Route 2, however the range is still narrow. Gullies formed on the land side of the route prevent underground and/or surface water to accumulate around the proposed bridge abutment.	4.0
Route 4	Landslides will not occur because the route does not pass through prone areas of landslides.	5.0

2) Inland Waterway Conditions

The Southern Bug River is used as an inland waterway route, with barges and hydrofoils navigating the waters daily throughout the year except in winter, when the river freezes. The probability of vessel collision with bridge piers is therefore evaluated for inland waterway conditions.

The specific method used in this Study for calculating collision probability is part of the following formulas for collapse probability used in “AASHTO LRFD Bridge Design Specifications (AASHTO, November 2017). These formulas are:

$AF=(N)(PA)(PG)(PC)(PF)$

where:
AF : Annual frequency of bridge component collapse due to vessel collision
N : The annual number of vessels, classified by type, size, and loading condition, that utilize the channel
PA : The probability of vessel aberrancy
PG : The geometric probability of a collision between an aberrant vessel and a bridge pier or span
PC : The probability of bridge collapse due to a collision with an aberrant vessel
PF : Adjustment factor to account for potential protection of the piers from vessel collision due to upstream or downstream land masses or other structures that look the vessel

$PA=(B_R)(R_B)(Rc)(Rxc)(R_D)$

where: B_R : Aberrancy base rate
R_B : Correction factor for bridge location
Rc : Correction factor for current acting parallel to vessel transit path
Rxc : Correction factor for cross-currents acting perpendicular to vessel transit path
R_D : Correction factor vessel traffic density

PG=1 – A1 – A2
where: A1 : The area from average to the deviation x1 in the normal distribution with standard deviation of Vessel Length. x1=Navigation Channel width/4 + additional width– pier width – vessel width.
A2 : The area from average to the deviation x2 in the normal distribution with standard deviation of Vessel Length. x2=Navigation Channel widthx3/4 + additional width– pier width – vessel width

Calculation Results of Main Factors are shown in Table 5-5-15.

The bridge is theoretically designed to withstand collision with the vessels expected to navigate the river, with no risk of bridge collapse. In calculating the collapse probability in this Study, two conditions were set: the PC and PF were set at 1 respectively for convenience sake, and a vessel navigated outside the span length. Accordingly, given that the collapse probability from this simplified calculation includes a hypothetical value, the calculated values themselves are not evaluated; instead, the numerical values for each route are only compared relative to one another.

Here, "outside the span length" refers to the area shown in red in the figure below.

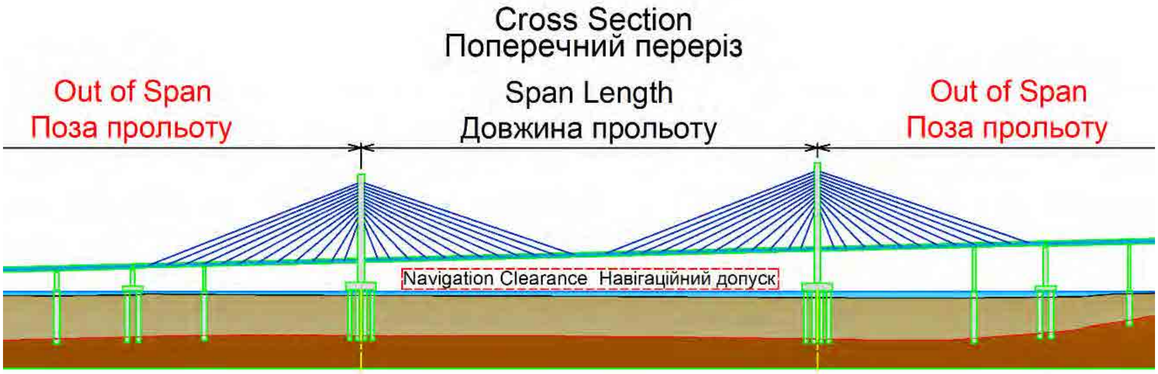


Figure 5-5-5. Image of Out of Span

The calculated collision probabilities and evaluation scores are given in the table below. The collision probability in straight regions was assigned an evaluation score of 5 points. Each route was scored by the equation given below.

Evaluation Scores = 5 x Collision probability of Straight Region / Collision probability for each route

Table 5-5-14. Collision Probabilities and Evaluation Scores

Route	Collision Probabilities	Evaluation Scores
Route 1	Bend Region, Angle of Bend is 47° Collision probability 2.1 times greater than Straight Region	2.4
Route 2	Bend Region, Angle of Bend is 69° Collision probability 2.5 times greater than Straight Region	2.0
Route 3	Transition Region of Bend Region, Angle of Bend is 69° Collision probability 1.8 times greater than Straight Region	2.8
Route 4	Transition Region of Turn Region, Angle of Turn is 19° Collision probability 1.2 times greater than Straight Region	4.2

The tables below show the main results and conditions for calculating collision probabilities. River traffic conditions and vessel specifications are different depending on whether the route is upstream or downstream of Mykolaiv Port. In actuality, calculation conditions for Route 4 differ from those for Routes 1, 2 and 3. However, for the purposes of this Study, the same conditions were used for all four routes.

Table 5-5-15. Calculation Result of Main Factors

Route	AF	N (times)	PA	PG	PC	PF
Straight	2.981×10^{-2}	250	5.620×10^{-4}	4.244×10^{-1}	1	1
Route 1	6.153×10^{-2}	250	1.126×10^{-3}	4.372×10^{-1}	1	1
Route 2	7.536×10^{-2}	250	1.408×10^{-3}	4.282×10^{-1}	1	1
Route 3	5.379×10^{-2}	250	1.014×10^{-3}	4.244×10^{-1}	1	1
Route 4	3.586×10^{-2}	250	6.760×10^{-4}	4.244×10^{-1}	1	1

Table 5-5-16. Collision Probability Calculation Conditions 1

Route	Navigation Channel Width (m)	Extra Space (m)	Span Length (m)
Straight and Route 1--4	280	140	420

Table 5-5-17. Collision Probability Calculation Conditions 2

Route	Pier Width (axial) (m)	Pier Length (transverse) (m)	Vessel Specifications		
			Type	Length (m)	Width (m)
Straight and Route 1--4	21	35	Barge	217	34

Table 5-5-18. Collision Probability Calculation Conditions 3

Route	River Channel Conditions			
	Section Type	Curve/Bend Angle θ (°)	Flow Speed (m/s)	Angle of Deviation between Navigation Direction and Transverse Axis φ (°)
Straight	Straight	0	1.0	0
Route 1	Bend	47	1.0	18
Route 2	Bend	69	1.0	5
Route 3	Transition	69	1.0	0
Route 4	Transition	19	1.0	0

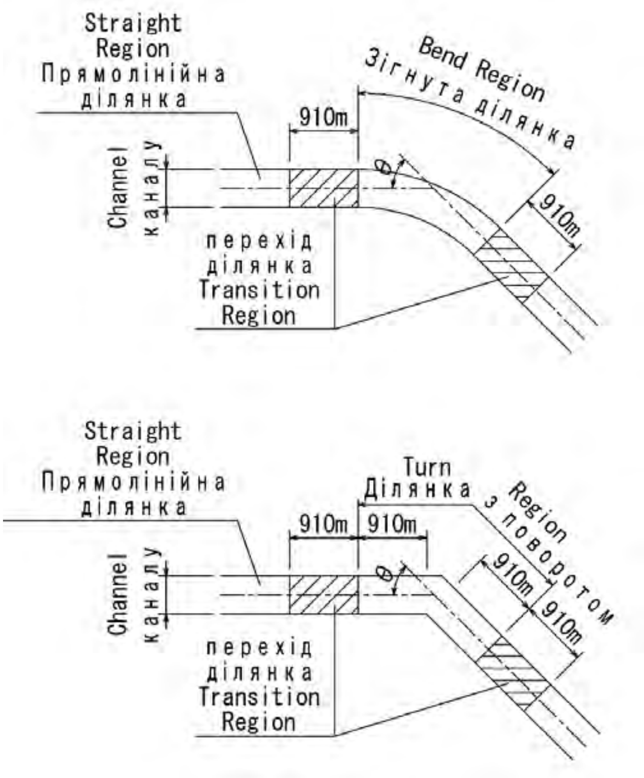


Figure 5-5-6. Images of Sections by Type

Calculation conditions were based on the figures below.

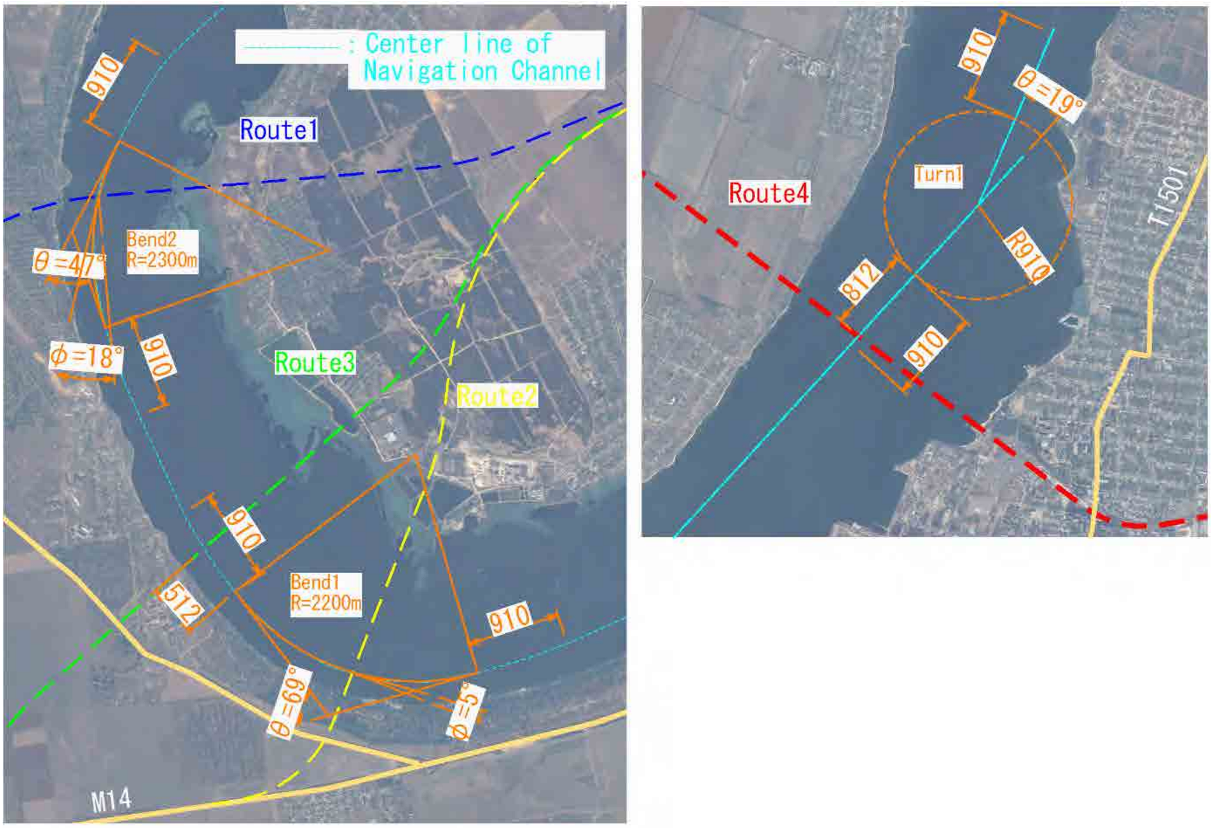


Figure 5-5-7. Basis for Collision Probability Calculation Conditions

3) River Conditions

In Japan, bridge locations are determined with reference to “Guidelines for Plans for Bridges that Cross Rivers (Japan Institute of Construction Engineering (JICE), July 2009)” These guidelines advise against selecting bridges in locations where river channel conditions negatively affect flood control safety (narrow stretches, bends, water colliding fronts, confluences, places where flow conditions change, etc.).

In addition, Government Ordinance for Structural Standard for River Administration Facilities in Japan sets out target values for river area blockage rates, and considerations have been taken such that bridge piers do not inhibit the flow of flood water.

Therefore, points that correspond to negative effects of river channel conditions on flood control safety, and the degree of river area blockage by bridge piers are considered for river conditions.

The results and evaluation scores are given in the table below.

Straight sections were assigned evaluation scores of 5 points. Points were subtracted in line with the number of points that correspond to negative effects of river channel conditions on flood control safety, and the number of points that correspond to the degree of river area blockage.

Table 5-5-19. River Conditions

Route	River conditions (Figures inside parentheses are the number of points subtracted)	Degree of river area blockage (Figures inside parentheses are the number of points subtracted)	Evaluation Scores
Route 1	Bend (1), Water colliding front (1)	There is a large degree of river area blockage because the direction of the bridge pier is not perpendicular to the flow direction (1)	2.0
Route 2	Bend (1), Water colliding front (1)	There is a large degree of river area blockage because the direction of the bridge pier is not perpendicular to the flow direction (1)	2.0
Route 3	Straight section (no negative effects)	There is a small degree of river area blockage because the direction of the bridge pier is perpendicular to the flow direction (0.5)	4.5
Route 4	Straight section (no negative effects)	There is a small degree of river area blockage because the direction of the bridge pier is perpendicular to the flow direction (0.5)	4.5

4) Airspace Conditions

With downtown Mykolaiv City flanked by airports to its north and south, the relative position of each route to obstacle limitation surfaces must be evaluated. The obstacle limitation surfaces for Kulbakino Air Base to the south were not identified. For convenience, therefore, the same obstacle limitation surfaces values used for Mykolaiv International Airport to the north are used for this evaluation, as well.

The results and evaluation scores are given in the table below.

Routes 2, 3 and 4 were assigned 5 points for being outside the obstacle limitation surfaces. Route 1 may be slightly within the obstacle limitation surfaces during construction, but is sufficiently removed by distance and, with adaptations, should effectively pose no issues to construction. Route 1 was assigned a median evaluation score of 3 points.

Table 5-5-20. Airspace Restrictions and Evaluation Scores

Route	Airport Name	Runway Length	Runway No.	Elevation	Positional Relationship with Obstacle limitation surfaces	Evaluation Scores
Route1	Mykolaiv International Airport	Roughly 2,500 m	04/22	56 m Above Sea Level	Within obstacle limitation surfaces	3.0
Route 2					Outside obstacle limitation surfaces	5.0
Route 3					Outside obstacle limitation surfaces	5.0
Route 4	Kulbakino Air Base	Roughly 3,200 m	05/23	52 m Above Sea Level	Outside obstacle limitation surfaces	5.0

5-6 Criteria Weighting

The following details the procedure for weighting items in the AHP with examples, followed by the weighting itself.

5-6-1 Weighting Procedure Using AHP

When using AHP to determine weights for criteria, the final objective and criteria are viewed in a hierarchical relationship. Next, the hierarchical structure is used to determine the weights (importance) of criteria in terms of the final objective based on pairwise comparisons (comparisons of two criteria). The basic approach of AHP is to repeat primitive pairwise comparisons and integrate their calculations to help make complicated decisions.

AHP involves the following tasks:

(1) Describe the hierarchical structure of the final objective and criteria.
(2) Perform pairwise comparisons between criteria based on the hierarchical structure.
(3) Calculate the weights based on the results of the pairwise comparisons.
(4) Check for coherence with pairwise comparisons.

5-6-2 Example of Weight Determination

The following is an example of determining the weights of three criteria.

1) Hierarchical Structure of the Final Objective and Criteria

The figure below is an example of the hierarchy of the final objective and criteria. This figure illustrates the nature of relationships between the final objective and criteria. It is acceptable to elaborate on criteria by using further detailed criteria.

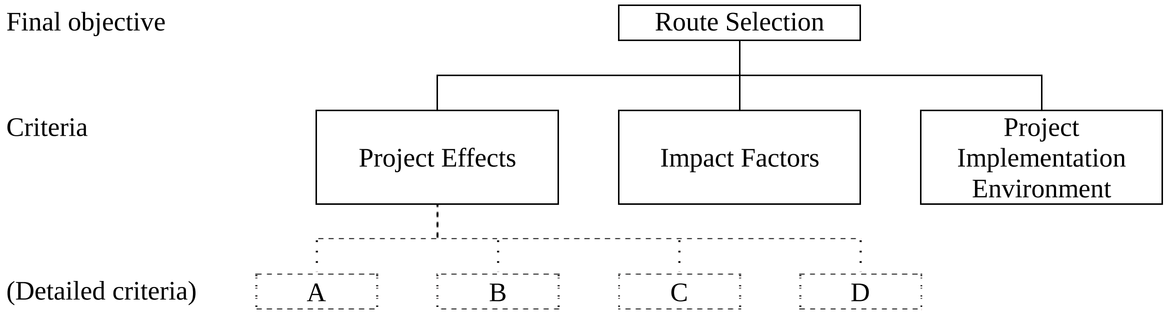


Figure 5-6-1. Hierarchical Structure of an Issue

2) Pairwise Comparisons

Items located lower in the hierarchical structure are evaluated in terms of higher items. As for items to evaluate, pairwise comparisons of criteria are performed in terms of the final objective.

In the example, a pair of the criteria (“Project Effects”, “Impact Factors”, and “Project Implementation Environment”) are selected for comparison and evaluation in terms of the final objective (“Route Selection”). For example, “Project Effects” and “Impact Factors” are compared against the final objective to see which to emphasize over the other, and the criteria in Table 5-6-1 are used to express that emphasis numerically. Since there are three criteria in the example, three pairwise comparisons are performed.

Table 5-6-1. Pairwise Comparison Values

Pairwise Comparison Value	Interpretation
1	The two criteria have the same importance.
3	The first criterion is slightly more important than the second one.
5	The first criterion is more important than the second one.
7	The first criterion is much more important than the second one.
9	The first criterion is immensely more important than the second one.
2, 4, 6, 8	Used for interpolation.
Reciprocals of above values	Used when viewing the second criterion in terms of the first one.

In the evaluations using pairwise comparison, the evaluator subjectively considers only the pair in question; the evaluator does not consider criteria outside the pair. The results of pairwise comparisons are expressed on a pairwise comparison matrix like the one below.

Table 5-6-2. Example of a Pairwise Comparison Matrix

	Project Effects	Impact Factors	Project Implementation Environment
Project Effects	1	3	4
Impact Factors	1/3	1	3
Project Implementation Environment	1/4	1/3	1

On the pairwise comparison matrix, the evaluator enters the values that express the importance of the criteria in the rows compared to the importance of those in the columns. In the example, "Project Effects" are evaluated as "slightly more important (3)" than "Impact Factors." Since the pairwise comparison value of a criterion against itself is the same, the evaluator enters "1." In addition, the rule is to enter the reciprocal pairwise comparison value when the relationship is viewed in terms of the opposite criterion; therefore, the reciprocal must be entered in the symmetrical location (the location where the row and column are switched). This means that when evaluations are performed for one side of the table, the values for the other side are determined automatically.

3) Calculating Weights

The most important criterion in the example is "Project Effects." Weights for each of the criteria are calculated in order to quantify the degree to which "Project Effects" are to be emphasized over the other criteria, as well as the degree to which the other criteria are to be emphasized.

The geometric mean method (shown below) is used to calculate the weights.

$G = (X1xX2\cdots Xn)$^(1/n)

where: G : Geometric mean value
Xn : Pairwise comparison value
n : Number of criteria

In the geometric mean method, the geometric mean of the pairwise comparison values of each criterion is determined and weighted such that the sum of the geometric means of all criteria equals 1. Specifically, weights are determined by calculating the geometric means from each row, and dividing them by the sum of the geometric means from each row.

Table 5-6-3. Example Calculation of Geometric Means and Weights

	Project Effects	Impact Factors	Project Implementation Environment	Geometric Mean	Weight
Project Effects	1	3	4	2.289	0.614
Impact Factors	1/3	1	3	1.000	0.268
Project Implementation Environment	1/4	1/3	1	0.437	0.118
Total				3.726	1.000

*Geometric mean value for Project Effects: G = (1x3x4)^(1/3) = 2.289, Weight for Project Effects = 2.289/3.726 = 0.614

4) Calculation of Coherence

Because pairwise comparisons are limited to two criteria at a time, it is possible that the overall results of the pairwise comparison matrix are not coherent. For example, if “Project Effects” > “Impact Factors,” and “Impact Factors” > “Project Implantation Environment,” it would not make sense if “Project Implementation Environment” > “Project Effects.” Even when there is no logical inconsistency, pairwise comparison matrix can lack coherence if pairwise comparison values are skewed too far in one direction. Therefore, coherence is confirmed by setting coherence equal to the degree of coherence of the pairwise comparative matrix.

Suppose n is the number of criteria on the pairwise comparison matrix, and λ is the largest eigenvalue of the rows and columns of the matrix. In this case, $\lambda \geqq n$, and if the pairwise evaluation is performed with complete coherence, then, logically, λ and n should be equal.

Coherence is an indicator that expresses divergence from the ideal value of λ. It is calculated using the following formula. The upper limit is set to 0.1, but there are cases where there is tolerance of roughly 0.15. (Source: Information Processing with Excel for Economic and Management Sectors III: Making Decisions with AHP [2013])

$CI = (\lambda - n) / (n-1)$

where: CI : Coherence
λ : Largest eigenvalue of pairwise comparison matrix rows and columns
n : Number of criteria

The following steps show the calculation procedure using the example.

Step 1: Multiply the weights of each of the criteria from the pairwise comparison matrix by the values in their respective columns.

	Project Effects	Impact Factors	Project Implementation Environment
Weight	0.614	0.268	0.118
Project Effects	0.614*1	0.268*3	0.118*4
Impact Factors	0.614*1/3	0.268*1	0.118*3
Project Implementation Environment	0.614*1/4	0.268*1/3	0.118*1

Step 2: Divide the totals of each row by the respective weights.

	Project Effects	Impact Factors	Project Implementation Environment	Total	Total/Weight
Weight	0.614	0.268	0.118		
Project Effects	0.614	0.804	0.472	1.890	3.078
Impact Factors	0.205	0.268	0.354	0.827	3.085
Project Implementation Environment	0.154	0.089	0.118	0.361	3.058

*Total/Weight for Project Effects = 1.890/0.614 = 3.078

Step 3: Calculate λ as the average value of total/weight. Then, calculate coherence.

$\lambda = (3.078 + 3.085 + 3.058) / 3 = 3.074$

$CI = (\lambda - n) / (n-1) = (3.074 – 3) / (3-1) = 0.037$

In the example, CI ≦ 0.1; the values are sufficiently coherent.

5-6-3 Weighting

Questionnaires are prepared and used for this Study, as is the general practice to simplify pairwise comparisons. With questionnaires, the categories, sub-categories, and sub-subcategories can be created at any stage. Thus, 4 questionnaires were prepared in this Study from the aforementioned criteria, following the hierarchy shown in Figure 5-6-2.

The tables 5-6-4 to 5-6-10 show JICA and the Survey Team’s responses to the questionnaire survey, and the weights assigned based on those responses.

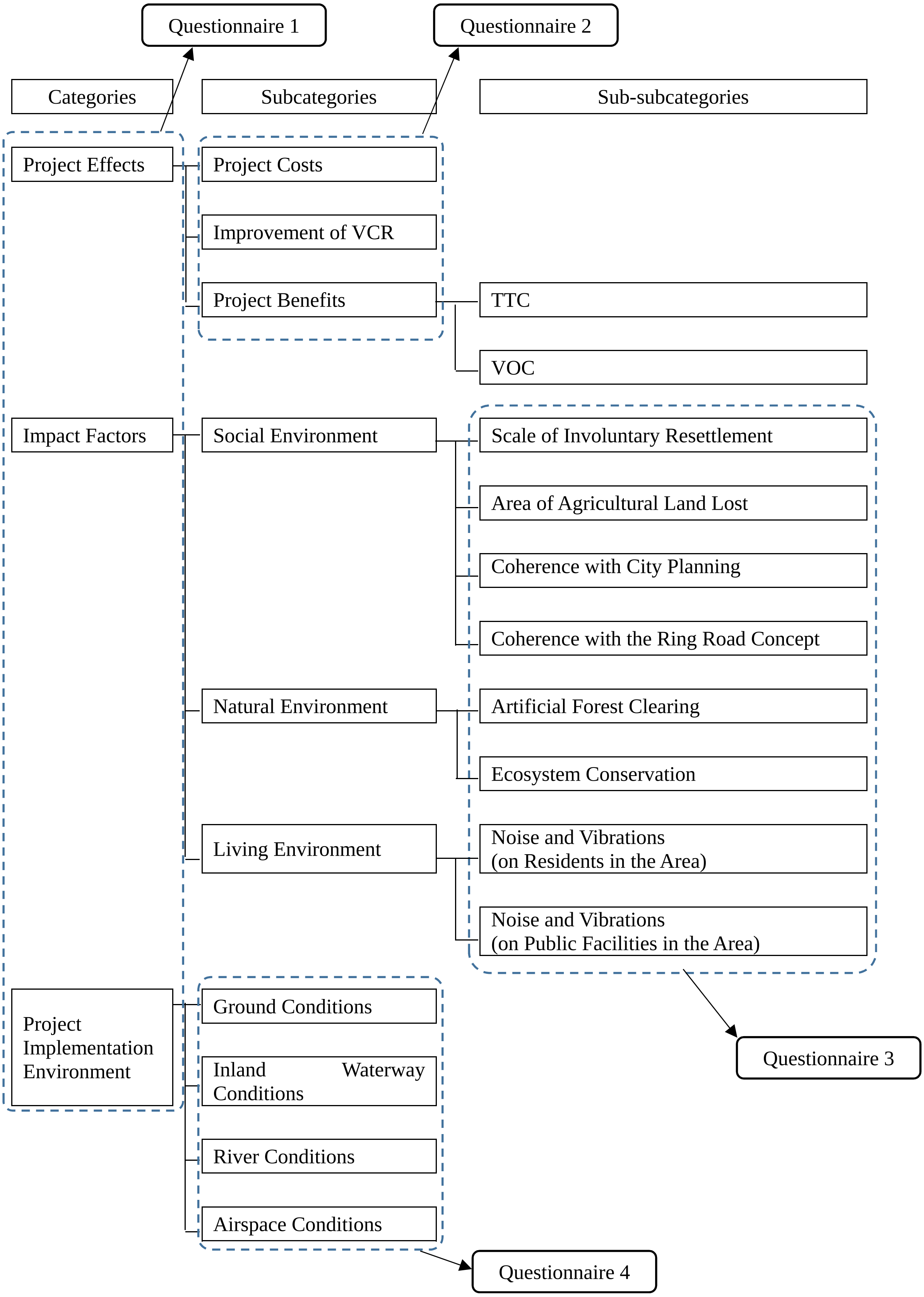


Figure 5-6-2. Questionnaire Hierarchy

Table 5-6-4. Questionnaire Survey Responses by JICA and the Survey Team (1/3)

Question 1: Overall comparison (comparison of categories)
Which of the items shown in the table below do you consider important for route selection?
In the table below, please put a "+" in the cells that most closely describe your thoughts on each item.

Left	The One on the Left is Extremely Important 9	8	The One on the Left is Very Important 7	6	The One on the Left is Important 5	4	The One on the Left is Somewhat Important 3	2	Same 1	2	The One on the Right is Somewhat Important 3	4	The One on the Right is Important 5	6	The One on the Right is Very Important 7	8	The One on the Right is Extremely Important 9	Right
A: Project Effects							+											B: Impact Factors
A: Project Effects							+											C: Project Implementation Environment
B: Impact Factors							+											C: Project Implementation Environment

※2,4,6,8 are Used for interpolation.

Question 2: Evaluation items regarding project effects (comparison of subcategories/sub-subcategories)
Which of the items in each left-right pair shown in the table below is more important for route selection?
In the table below, please put a "+" in the cells that most closely describe your thoughts on each item.

Left	The One on the Left is Extremely Important 9	8	The One on the Left is Very Important 7	6	The One on the Left is Important 5	4	The One on the Left is Somewhat Important 3	2	Same 1	2	The One on the Right is Somewhat Important 3	4	The One on the Right is Important 5	6	The One on the Right is Very Important 7	8	The One on the Right is Extremely Important 9	Right
A1: Project Costs									+									A2: Project Benefits
A1: Project Costs							+											A3: Improved VCR in the City
A2: Project Benefits							+											A3: Improved VCR in the City

※2,4,6,8 are Used for interpolation.

Table 5-6-5. Questionnaire Survey Responses by JICA and the Survey Team (2/3)

Question 3: Evaluation items regarding impact factors (comparison of subcategories/sub-subcategories)
The “environment item” in impact factors is a consolidation of social, natural and living environments.
Which of the items in each left-right pair shown in the table below is more important for route selection?
In the table below, please put a "+" in the cells that most closely describe your thoughts on each item.

Left	The One on the Left is Extremely Important 9	8	The One on the Left is Very Important 7	6	The One on the Left is Important 5	4	The One on the Left is Somewhat Important 3	2	Same 1	2	The One on the Right is Somewhat Important 3	4	The One on the Right is Important 5	6	The One on the Right is Very Important 7	8	The One on the Right is Extremely Important 9	Right
B11: Reduction in the scale of involuntary resettlement			+															B12: Reduction in the area of agricultural land lost
B11: Reduction in the scale of involuntary resettlement							+											B13: Coherence with Mykolaiv City Planning
B11: Reduction in the scale of involuntary resettlement							+											B14: Coherence with the Ring Road Concept
B11: Reduction in the scale of involuntary resettlement			+															B21: Reduction in artificial forest clearing
B11: Reduction in the scale of involuntary resettlement					+													B22: Ecosystem Conservation
B11: Reduction in the scale of involuntary resettlement					+													B31: Impact of vibrations/noise on residents in the area
B11: Reduction in the scale of involuntary resettlement					+													B32: Impact of vibrations/noise on public facilities in the area
B12: Reduction in the area of agricultural land lost													+					B13: Coherence with Mykolaiv City Planning
B12: Reduction in the area of agricultural land lost													+					B14: Coherence with the Ring Road Concept
B12: Reduction in the area of agricultural land lost									+									B21: Reduction in artificial forest clearing
B12: Reduction in the area of agricultural land lost											+							B22: Ecosystem Conservation
B12: Reduction in the area of agricultural land lost													+					B31: Impact of vibrations/noise on residents in the area
B12: Reduction in the area of agricultural land lost													+					B32: Impact of vibrations/noise on public facilities in the area
B13: Coherence with Mykolaiv City Planning									+									B14: Coherence with the Ring Road Concept
B13: Coherence with Mykolaiv City Planning					+													B21: Reduction in artificial forest clearing
B13: Coherence with Mykolaiv City Planning							+											B22: Ecosystem Conservation
B13: Coherence with Mykolaiv City Planning									+									B31: Impact of vibrations/noise on residents in the area
B13: Coherence with Mykolaiv City Planning									+									B32: Impact of vibrations/noise on public facilities in the area
B14: Coherence with the Ring Road Concept					+													B21: Reduction in artificial forest clearing
B14: Coherence with the Ring Road Concept							+											B22: Ecosystem Conservation
B14: Coherence with the Ring Road Concept									+									B31: Impact of vibrations/noise on residents in the area

Table 5-6-6. Questionnaire Survey Responses by JICA and the Survey Team (3/3)

Left	The One on the Left is Extremely Important 9	8	The One on the Left is Very Important 7	6	The One on the Left is Important 5	4	The One on the Left is Somewhat Important 3	2	Same 1	2	The One on the Right is Somewhat Important 3	4	The One on the Right is Important 5	6	The One on the Right is Very Important 7	8	The One on the Right is Extremely Important 9	Right
B14: Coherence with the Ring Road Concept									+									B32: Impact of vibrations/noise on public facilities in the area
B21: Reduction in artificial forests clearing											+							B22: Ecosystem Conservation
B21: Reduction in artificial forest clearing													+					B31: Impact of vibrations/noise on residents in the area
B21: Reduction in artificial forest clearing													+					B32: Impact of vibrations/noise on public facilities in the area
B22: Ecosystem Conservation													+					B31: Impact of vibrations/noise on residents in the area
B22: Ecosystem Conservation													+					B32: Impact of vibrations/noise on public facilities in the area
B31: Impact of vibrations/noise on residents in the area									+									B32: Impact of vibrations/noise on public facilities in the area

※2,4,6,8 are Used for interpolation.

Question 4: Evaluation items regarding the project implementation environment (comparison of subcategories/sub-subcategories)
Which of the items in each left-right pair shown in the table below is more important for route selection?
In the table below, please put a "+" in the cells that most closely describe your thoughts on each item.

Left	The One on the Left is Extremely Important 9	8	The One on the Left is Very Important 7	6	The One on the Left is Important 5	4	The One on the Left is Somewhat Important 3	2	Same 1	2	The One on the Right is Somewhat Important 3	4	The One on the Right is Important 5	6	The One on the Right is Very Important 7	8	The One on the Right is Extremely Important 9	Right
C1: Ground Conditions									+									C2: Inland waterway Conditions
C1: Ground Conditions									+									C3: River Conditions
C1: Ground Conditions									+									C4: Airspace Conditions
C2: Inland waterway Conditions									+									C3: River Conditions
C2: Inland waterway Conditions									+									C4: Airspace Conditions
C3: River Conditions									+									C4: Airspace Conditions

※2,4,6,8 are Used for interpolation.

Table 5-6-7. Results of Weight Setting by JICA and the Survey Team (1/4)

Overall Comparison (Comparison of Categories)

	A: Project Effects	B: Impact Factors	C: Project Implementation Environment	Cumulative	Geometric Mean	Weight
A: Project Effects	1	3	3	9.0000	2.0801	0.584
B: Impact Factors	1/3	1	3	1.0000	1.0000	0.281
C: Project Implementation Environment	1/3	1/3	1	0.1111	0.4807	0.135
				Total	3.5608	1.00

Coherence

	A: Project Effects	B: Impact Factors	C: Project Implementation Environment	Total	Total/Weight
A: Project Effects	0.5840	0.8430	0.4050	1.8320	3.137
B: Impact Factors	0.1947	0.2810	0.4050	0.8807	3.134
C: Project Implementation Environment	0.1947	0.0937	0.1350	0.4234	3.136

λ = 3.136

CI= 0.068 ≦ 0.1 -O.K-

Table 5-6-8. Results of Weight Setting by JICA and the Survey Team (2/4)

Evaluation Items Regarding Project Effects (Comparison of Subcategories/Sub-subcategories)

	A1: Project Costs	A2: Project Benefits	A3: Improved VCR in the City	Cumulative	Geometric Mean	Weight
A1: Project Costs	1	1	3	3.0000	1.4422	0.429
A2: Project Benefits	1	1	3	3.0000	1.4422	0.429
A3: Improved VCR in the City	1/3	1/3	1	0.1111	0.4807	0.142
				Total	3.3651	1.00

Coherence

	A1: Project Costs	A2: Project Benefits	A3: Improved VCR in the City	Total	Total/Weight
A1: Project Costs	0.4290	0.4290	0.4260	1.2840	2.993
A2: Project Benefits	0.4290	0.4290	0.4260	1.2840	2.993
A3: Improved VCR in the City	0.1430	0.1430	0.1420	0.4280	3.014

$\lambda =$ 3.000

CI= 0.000 ≦ 0.1 -O.K-

Table 5-6-9. Results of Weight Setting by JICA and the Survey Team (3/4)

Evaluation Items Regarding Impact Factors (Comparison of Subcategories/Sub-subcategories)

	B11: Reduction in the scale of involuntary resettlement	B12: Reduction in the area of agricultural land lost	B13: Coherence with Mykolaiv City Planning	B14: Coherence with the Ring Road Concept	B21: Reduction in artificial forest clearing	B22: Ecosystem Conservation	B31: Impact of vibrations/noise on residents in the area	B32: Impact of vibrations/noise on public facilities in the area	Cumulative	Geometric Mean	Weight
B11: Reduction in the scale of involuntary resettlement	1	7	3	3	7	5	5	5	55125.0000	3.9144	0.353
B12: Reduction in the area of agricultural land lost	1/7	1	1/5	1/5	1	1/3	1/5	1/5	0.0001	0.3162	0.029
B13: Coherence with Mykolaiv City Planning	1/3	5	1	1	5	3	1	1	25.0000	1.4953	0.135
B14: Coherence with the Ring Road Concept	1/3	5	1	1	5	3	1	1	25.0000	1.4953	0.135
B21: Reduction in artificial forest clearing	1/7	1	1/5	1/5	1	1/3	1/5	1/5	0.0001	0.3162	0.029
B22: Ecosystem Conservation	1/5	3	1/3	1/3	3	1	1/5	1/5	0.0080	0.5469	0.049
B31: Impact of vibrations/noise on residents in the area	1/5	5	1	1	5	5	1	1	25.0000	1.4953	0.135
B32: Impact of vibrations/noise on public facilities in the area	1/5	5	1	1	5	5	1	1	25.0000	1.4953	0.135
									Total	11.0749	1.00

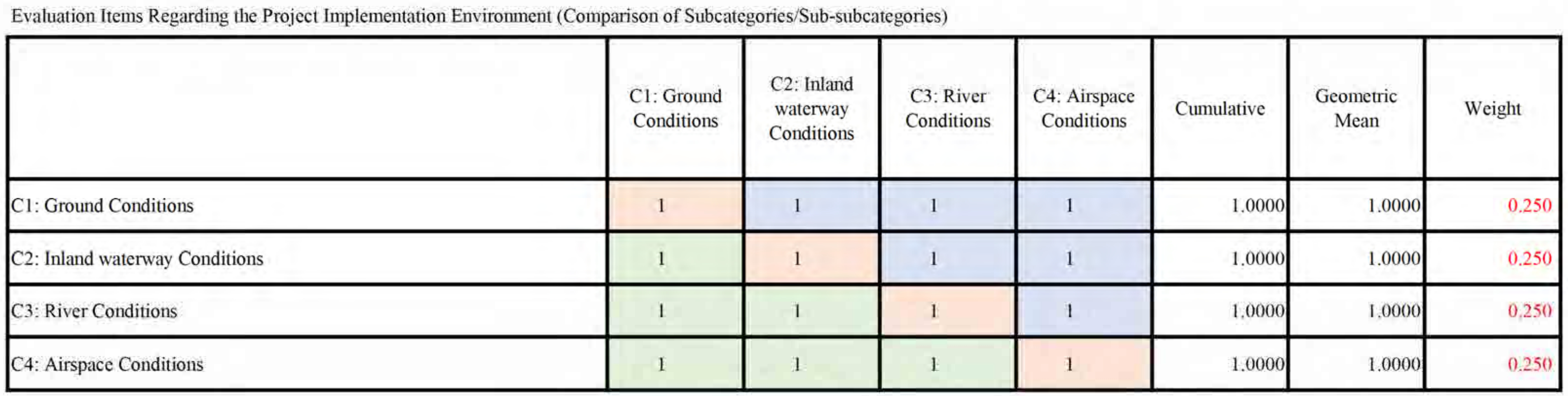
Coherence

	B11: Reduction in the scale of involuntary resettlement	B12: Reduction in the area of agricultural land lost	B13: Coherence with Mykolaiv City Planning	B14: Coherence with the Ring Road Concept	B21: Reduction in artificial forest clearing	B22: Ecosystem Conservation	B31: Impact of vibrations/noise on residents in the area	B32: Impact of vibrations/noise on public facilities in the area	Total	Total/Weight
B11: Reduction in the scale of involuntary resettlement	0.3530	0.2030	0.4050	0.4050	0.2030	0.2450	0.6750	0.6750	3.1640	8.963
B12: Reduction in the area of agricultural land lost	0.0504	0.0290	0.0270	0.0270	0.0290	0.0163	0.0270	0.0270	0.2327	8.024
B13: Coherence with Mykolaiv City Planning	0.1177	0.1450	0.1350	0.1350	0.1450	0.1470	0.1350	0.1350	1.0947	8.109
B14: Coherence with the Ring Road Concept	0.1177	0.1450	0.1350	0.1350	0.1450	0.1470	0.1350	0.1350	1.0947	8.109
B21: Reduction in artificial forest clearing	0.0504	0.0290	0.0270	0.0270	0.0290	0.0163	0.0270	0.0270	0.2327	8.024
B22: Ecosystem Conservation	0.0706	0.0871	0.0450	0.0450	0.0871	0.0490	0.0270	0.0270	0.4378	8.935
B31: Impact of vibrations/noise on residents in the area	0.0706	0.1450	0.1350	0.1350	0.1450	0.2450	0.1350	0.1350	1.1456	8.486
B32: Impact of vibrations/noise on public facilities in the area	0.0706	0.1450	0.1350	0.1350	0.1450	0.2450	0.1350	0.1350	1.1456	8.486

λ = 8.392

CI= 0.056 ≦ 0.1 -O.K-

Table 5-6-10. Results of Weight Setting by JICA and the Survey Team (4/4)



Evaluation Items Regarding the Project Implementation Environment (Comparison of Subcategories/Sub-subcategories)

	C1: Ground Conditions	C2: Inland waterway Conditions	C3: River Conditions	C4: Airspace Conditions	Cumulative	Geometric Mean	Weight
C1: Ground Conditions	1	1	1	1	1.0000	1.0000	0.250
C2: Inland waterway Conditions	1	1	1	1	1.0000	1.0000	0.250
C3: River Conditions	1	1	1	1	1.0000	1.0000	0.250
C4: Airspace Conditions	1	1	1	1	1.0000	1.0000	0.250

Total	4.0000	1.00

Coherence

	C1: Ground Conditions	C2: Inland waterway Conditions	C3: River Conditions	C4: Airspace Conditions	Total	Total/Weight
C1: Ground Conditions	0.2500	0.2500	0.2500	0.2500	1.0000	4.000
C2: Inland waterway Conditions	0.2500	0.2500	0.2500	0.2500	1.0000	4.000
C3: River Conditions	0.2500	0.2500	0.2500	0.2500	1.0000	4.000
C4: Airspace Conditions	0.2500	0.2500	0.2500	0.2500	1.0000	4.000

λ = 4.000

CI= 0.000 ≦ 0.1 -O.K-

5-7 Selecting Locations of Routes and Bridges

Table 5-7-1 shows a comparison of routes by JICA and the Survey Team.

As shown in the table, Route 3 has the highest weighted-evaluation-score. As mentioned in 5-3 (Figure 5-3-1), weighted-evaluation-score is calculated by multiplying the evaluation score and the weight of each comparison item.

The result of route selection including the criteria, performance, evaluation score, weight and weighted overall evaluation score were explained to Mykolaiv Oblast and Mykolaiv City on July 31st, Ukravtodor on September 17th and MoI on September 18th; and gained their understanding.

From the above, Route 3 is selected.

In addition, both Routes 2 and 3 have been studied for detailed comparison in the following chapters.

Table 5-7-1. Comparison of Routes by JICA and the Survey Team

							Route 1			Route 2			Route 3			Route 4		
Categories	Weight W1	Subcategories	Sub-subcategories	Weight W2	A Total Weight (W1× W2/100)	Evaluation Index	Evaluation Results	B Evaluation Scores	A×B Weighted Overall Evaluation Scores	Evaluation Results	B Evaluation Scores	A×B Weighted Overall Evaluation Scores	Evaluation Results	B Evaluation Scores	A×B Weighted Overall Evaluation Scores	Evaluation Results	B Evaluation Scores	A×B Weighted Overall Evaluation Scores
Project Effects	58.4	Project Costs		42.9	25.054	Initial Cost	1.00	5.000	125.270	1.08 times of Route1	4.629	115.975	1.12 times of Route1	4.471	112.016	1.83 times of Route1	2.737	68.573
		Project Benefits		42.9	25.054	TTC(Travel Time Cost) VOC(Vehicle Operation Cost)	619Million USD	4.275	107.106	639Million USD	4.413	110.563	694Million USD	4.793	120.084	724Million USD	5.000	125.270
		Improved VCR in the City		14.2	8.293	VCR(Volume/Capacity Ratio) of Vavarovsky Bridge	Year2025：1.63 Year2040：2.43 Year2055：3.66	4.740	39.309	Year2025：1.54 Year2040：2.30 Year2055：3.47	5.000	41.465	Year2025：1.58 Year2040：2.35 Year2055：3.54	4.901	40.644	Year2025：1.71 Year2040：2.55 Year2055：3.83	4.530	37.567
		Subtotal		100	58.40	-	-	-	271.68	-	-	268.00	-	-	272.74	-	-	231.41
Impact Factors	28.1	Social Environment	Reduction in the Scale of Involuntary Resettlement	35.3	9.919	Number of Residential Buildings to Relocate	Roughly 50	3.000	29.757	None	5.000	49.595	3	4.500	44.636	Roughly 40	3.000	29.757
			Coherence with Mykolaiv City Planning	13.5	3.794	Coherence with City Planning as formulated in 2009	No coherence	3.000	11.382	Coherent	5.000	18.970	No coherence	3.000	11.382	No coherence	3.000	11.382
			Coherence with the Ring Road Concept	13.5	3.794	Connectivity between Routes 1-3 and Route 4 (Positional Relationship of Terminus Interchange)	2.6km	3.000	11.382	2.4km	4.000	15.176	Same Location	5.000	18.970	-	5.000	18.970
			Reduction in the Area of Agricultural Land Lost	2.9	0.815	Area of Agricultural Land Lost	119ha	2.000	1.630	77ha	4.000	3.260	93ha	3.000	2.445	198ha	1.000	0.815
		Natural Environment	Ecosystem Conservation	4.9	1.377	Positional Relationship with Especially Important Areas for Ecosystem Conservation and No-Fishing Zones	Possibly close to a no-fishing area	3.000	4.131	Possibly close to a no-fishing area	3.000	4.131	Possibly close to a no-fishing area	3.000	4.131	No restrictions	5.000	6.885
			Reduction in Artificial Forest Clearing	2.9	0.815	Area of Artificial Forest Clearing	11ha	4.000	3.260	15ha	3.000	2.445	10ha	4.000	3.260	None	5.000	4.075
		Living Environment	Impact of Vibrations/Noise on Residents in the Area	13.5	3.794	Number of Residential Buildings Impacted by Noise(Lr: Noise Level)	Lr≧65dB：Roughly110 Lr≧55dB：Roughly640 Lr≧45dB：Roughly3350	1.000	3.794	Lr≧65dB：Roughly10 Lr≧55dB：Roughly140 Lr≧45dB：Roughly1220	3.000	11.382	Lr≧65dB：Roughly30 Lr≧55dB：Roughly400 Lr≧45dB：Roughly1530	2.000	7.588	Lr≧65dB：Roughly90 Lr≧55dB：Roughly680 Lr≧45dB：Roughly3340	1.000	3.794
			Impact of Vibrations/Noise on Public Facilities in the Area	13.5	3.794	Number of Public Facilities Impacted by Noise(Lr: Noise Level)	Lr≧65dB：0 Lr≧55dB：0 Lr≧45dB：1	4.000	15.176	Lr≧65dB：0 Lr≧55dB：0 Lr≧45dB：1	4.000	15.176	Lr≧65dB：0 Lr≧55dB：2 Lr≧45dB：3	3.500	13.279	Lr≧65dB：2 Lr≧55dB：4 Lr≧45dB：Roughly20	2.500	9.485
		Subtotal		100	28.10	-	-	-	80.51	-	-	120.14	-	-	105.69	-	-	85.16
Project Implementation Environment	13.5	Ground Conditions		25.0	3.375	Scale and Safety of Landslides	No possibility of landslide	5.000	16.875	Possibility of landslide and the area is wide	3.000	10.125	Possibility of landslide and the area is narrow	4.000	13.500	No possibility of landslide	5.000	16.875
		Inland Waterway Conditions		25.0	3.375	Relative Probability of Vessel Collisions	Collision probability 2.1 times greater than Straight Region	2.400	8.100	Collision probability 2.5 times greater than Straight Region	2.000	6.750	Collision probability 1.8 times greater than Straight Region	2.800	9.450	Collision probability 1.2 times greater than Straight Region	4.200	14.175
		River Conditions		25.0	3.375	Degree of River area Blockage by Bridge Pier Corresponding Number of River Channel Conditions (Bends, Water Colliding Fronts, Narrow Stretches, Confluences, Etc.) that have a Negative Impact on Flood Control Safety Degree of Blockage of Flow Area by Bridge Pier	Bend, Water colliding front Degree of blockage of flow area is big	2.000	6.750	Bend, Water colliding front Degree of blockage of flow area is big	2.000	6.750	Straight section Degree of blockage of flow area is small	4.500	15.188	Straight section Degree of blockage of flow area is small	4.500	15.188
		Airspace Conditions		25.0	3.375	Presence/Absence of Airspace Restrictions	Close to Mykolaiv Airport	3.000	10.125	No restrictions	5.000	16.875	No restrictions	5.000	16.875	No restrictions	5.000	16.875
		Subtotal		100	13.50	-	-	-	41.85	-	-	40.50	-	-	55.01	-	-	63.11
Total Weighted Overall Evaluation Score								394.04			428.64			433.44			379.68	

Chapter 6 Review of Road Plans

6-1 Overview of Previous Feasibility Studies

A total of six F/S were conducted for the Project between 1989 and 2012. The 2012 F/S (TEO) conducted by Ukrain in 2012 was approved by the Cabinet on July 11, 2013. Table6-1-1 and Table6-1-2 are overviews of the previous F/S.

1) Road Alignment Selection

The area of the route has not changed substantially since the first F/S was conducted in 1989 (hereinafter referred to as “1989 F/S”). As for the river-crossing location and the right bank, the proposal in which the route passes roughly 6 km northwest of Vavarovsky Bridge was selected in light of the construction cost and impact on the social environment (the proposal requires no resettlement). The left bank of the river-crossing location has not significantly changed since it was revised slightly in the F/S conducted in 2004 (hereinafter referred to as “2004 F/S”) to accommodate Mykolaiv city planning.

2) Mykolaiv Bridge Plan

Various F/S recommended a cable-stayed bridge, a suspension bridge and a box girder bridge over the Southern Bug River. In the 2011 F/S and 2012 F/S, a suspension bridge was recommended.

Table 6-1-1. Overview of Previous F/S (1)

	1989 F/S	2000 F/S	2003 F/S	2004 F/S
Implementation Country	Soviet-Union	Japan	Japan	Ukraine
Counterpart	No information	Mikolaiv City	Mikolaiv City	Mykolaiv Region
Survey Company	Kievsoyuizdorproject	Japan Consulting Institute	Pacific Consultants International	Kievsoyuizdorproject
Reason for Survey		This project was identified as a key national project by the Ukrainian government.	Design Condition for Bridge was changed (aviation and navigation clearance)	The two F/S’s executed by Japan reported that the Government of Japan had expressed interest in providing a loan for this project.
Outline of Survey Result	[Road Alignment Selection] 4 routes (different crossing points on Southern Bug river) were proposed and compared. The Bridge position selected by this F/S is the same as that for the current design stage.	[Comparison of Bridge Types] Comparison of Bridge types involved 3 types. A cable-stayed bridge was recommended.	[Comparison of Bridge Types] Comparison of Bridge types involved 3 Types. A suspension bridge was recommended.	[Road Alignment Selection] Comparison of Road alignment on the left-bank was implemented. It recommended “Route 1”, which is located far from the city boundary line, as the best route. [Comparison of Bridge Types] Comparison of Bridge types involved 3 Types. A steel box-girder bridge was recommended.
Design Standard	SNiP[1]	SNiP	SNiP	DBN[2](and SNiP)

Source: 2011 F/S

Table 6-1-2. Overview of Previous F/S (2)

	2011 F/S	2012 F/S (TEO)
Implementation Country	Japan	Ukraine
Counterpart	Ukravtodor	Ukravtodor
Survey Company	Oriental Consultants Co., Ltd. Chodai Co., Ltd.	Kyivsoiuzshliakhproekt
Reason for Survey	To review and update the Feasibility Study conducted in 2003 (hereinafter referred to as "2003 F/S")	Conducted to obtain Cabinet approval in light of the 2011 F/S
Outline of Survey Results	[Road Alignment Selection] The same as the route proposed by Ukrain in the 2004 F/S [Comparison of Bridge Types] Three bridge types over the Southern Bug River were compared, and a suspension bridge was recommended.	[Road Alignment Selection] The same as the route selected in the 2004 F/S and the 2011 F/S [Comparison of Bridge Types] As in the 2011 F/S, a suspension bridge was recommended as the type of bridge for crossing the Southern Bug River.
Design Standard	DBN V.2.3-4 2007	DBN V.2.3-4 2007

Source: JICA Survey Team

6-2 Review of Road Structure

6-2-1 Design Standards and Road Categories

1) Design Standards

The Ukrainian standard known as DBN[1] was established based on SNiP[2], the Russian design standard. At the time of the 2011 F/S and 2012 F/S (TEO), the 2007 revised standard (DBN V.2.3-4 2007) was used to create plans. A new revised standard came out in 2015; therefore, this Study uses DBN V.2.3-4 2015 to review.

2) Road Categories

There are six road categories under DBN V.2.3-4 2015. The road category was I-a until the 2011 F/S was conducted; in the 2011 F/S, it was changed to I-b, and the road category remained the same in the 2012 F/S (TEO). This road category is still applicable in this Study; thus, the road is treated as a I-b road.

Table 6-2-1. Road Categories and Spot Traffic Volume

Road Categories	Traffic Volume per Day	
	Traffic Volume (Number of Vehicles)	Traffic Volume (PCU)
I-a – I-b	10,000 or more	14,000 or more
II	3,000-10,000	5,000-14,000
III	1,000-3,000	2,500-5,000
IV	150-1,000	300-2,500
V	Less than 150	Less than 300

Note: The requirements for both I-a and I-b roads are the same; both roads are categorized as Category I roads.

Source: DBN V.2.3-4 2015

3) Design Speed

Given the road category at the time of the 2011 F/S, a design speed of 140 km/h was selected. The design speed was revised to the figure shown in Table6-2-2 to match the road category that changed due

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[1] ДБН:ДЕРЖ АВНІ БУДІВЕЛЬНІ НОРМИ УКРАЇНИ

[2] СНиП: Строительные Нормы и Правила

to the update of DBN V.2.3-4; therefore, for this Study, a design speed of 110 km/h is used to conform to the updated standard.

Table 6-2-2. Design Speed

No.	Road Categories	Design Speed (km/h)		
		Basic Value for Flat Areas	Topographic restrictions	
			Hilly Areas	Mountainous Areas
1	I-a	130	100	80
2	I-b	110	90	70
3	II	90	70	60
4	III	90	60	50
5	IV	90	50	30
6	V	90	40	30

Note 1: Hilly areas are deep valleys with an elevation difference of 50 m or more, over a 0.5-km stretch, or topography that results from open-cut excavation of valleys with unstable slopes and tributaries running in the foothills.

Note 2: Mountainous areas are road sections (1-km stretches of road in each direction) on ridges or in ravines with complex, intensely indented or unstable slopes, and areas with distributions of ductile soil through which streams branch out.

Source: DBN V.2.3-4 2015

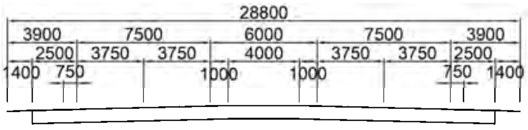
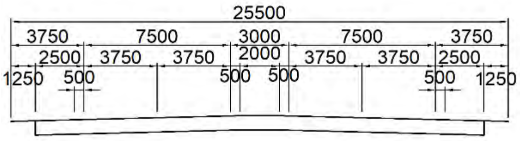
6-2-2 Transverse Structures

1) Cross-Sections

(1) Road Sections

The widths of the median and median shoulders were revised due to the update of DBN. Therefore, road cross-sections is revised from the 2011 F/S onward as shown in Table6-2-3.

Table 6-2-3. Results of Road Width Review

	2011 F/S	This Study
Standard width		

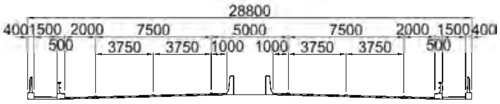
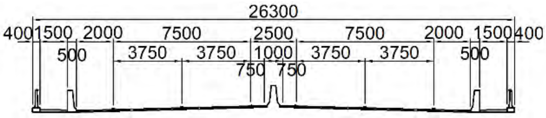
Cross-Section	Width	Notes
Number of lanes	4 lanes	
Lanes (both sides)	3.75 m	I-b standard width
Parking lane (including shoulder)	2.5 m	I-b standard width
Soft shoulder	1.25 m	I-b standard width
Median	3.0 m	I-b standard width (includes median shoulders)
Median shoulder	0.5 m	I-b standard width
Total width	25.5 m	I-b standard width

Source: JICA Survey Team

(2) Mykolaiv Bridge Section

The bridge selected in the 2011 F/S has a substantial impact on the project cost because it is longer than 2 km and has an extremely wide median (5.0 m). According to DBN, the width of a median may include the widths of safety barriers and the shoulders on each side. Therefore, a median width of 2.5 m—consisting of the widest possible rigid safety barrier (1.0 m) and two median shoulders (0.75 m each)—is selected in an effort to reduce costs. The standard median shoulder width for I-b roads is 0.5 m, but EU and USA standards result in the selection of widths wider than 0.5 m (Table6-2-5). Since safety barriers installed on the bridge sides could easily create oppressive feeling of enclosure, the width for road category I-a (0.75 m) is selected. As for other widths, the widths from the 2011 F/S are selected.

Table 6-2-4. Results of Bridge Width Review

	2011F/S	**This Study**
Standard width		

Cross-sections	Width	Notes
Number of lanes	4 lanes	
Lane width	3.75 m	Same as 2011 F/S, I-b standard width
Shoulder	2.0 m	Same as 2011 F/S, enough width for vehicle to park
Median	2.5 m	
Median barrier	1.0 m	Widest possible rigid safety barrier
Median shoulder	0.75 m	I-a median shoulders
Pedestrian walkway	1.5 m	Same as 2011 F/S, enough width for people to pass one another
Width of safety barrier on pedestrian walkway/roadway boundary	0.5 m	Same as 2011 F/S
Total width	26.3 m	

Table 6-2-5. Road Width Standards

Cross-sections	DBN-2.3-4:2015		TEM *1	AASHTO	Japanese Road Structure Ordinance
Road Categories	I-a	I-b	4 lanes	Freeway 4 lanes	Type 1, Class 1
Design Speed	130km/h	110km/h	100,120km/h	110km/h	120km/h
Lanes	3.75m	3.75m	3.75m	3.6m	3.50m
Shoulder	2.5m	2.5m	2.5m	3.0m	2.5m
Soft shoulder	1.25m	1.25m	0.5m	-	-
Median (including median shoulder)	6.0m *2	3.0m *2	3.0m	3.0m	4.5m
Median shoulder	0.75m	0.5m	1.0m	1.2m	0.75m

*1: Trans-European Motorway (TEM), which was developed as a standard to apply to European expressways that cross international borders.

*2: If a safety barrier is to be installed, the total width may include the widths of the safety barrier and the shoulders on each side.

Source: JICA Survey Team

2) Vertical Clearance Limit

Clearance of at least 5.5 m is secured to conform to DBN V.2.3-4 2015.

3) Slope Gradient

(1) Embankment Slope

DBN V.2.3-4 2015 sets out slope gradients in line with embankment material properties, climatic classifications and embankment heights. (Table 6-2-7) Mykolaiv City falls under climatic classification III (Southern Region), and the embankment material is loam (cut earth) or sandy soil (from a borrow pit). Therefore, slopes are set as shown in Table 6-2-6.

Table 6-2-6. Embankment Slope Gradient

Embankment Height	Slope Gradient	Notes
Less than 2 m	1:3	DBN sets out a gentle gradient to enable the passage of emergency vehicles.
2-6 m	1:1.75	Climatic classification III, sandy soil slope
6 m or more	1:1.75 (upper part 0-6 m)	Climatic classification III, sandy soil slope
	1:2.0 (lower part 6 m or more)	Climatic classification III, sandy soil slope

Source: JICA Survey Team

Table 6-2-7. Standard Values for Embankment Slope Gradient

Embankment Material Properties	Embankment Height (m)*Note 2		
	2-6 m	6-12 m	
		Lower part (6-12 m)	Upper part (0-6 m)
Soft rock soil	1:1-1:1.3	1:1.3-1:1.5	1:1.3-1:1.5
Gravelly soil	1:1.5	1:1.5	1:1.5
Sandy soil, clayey soil *Note 1	1:1.5 1:1.75	1:1.75 1:1.2	1:1.5 1:1.75

Note 1: The numbers below the lines are the figures for climatic classifications I-III.

Note 2: Embankment heights are the difference between the upper and lower edges of the embankments.

Source: DBN V.2.3-4 2015

(2) Cut Slopes

DBN V.2.3-4 2015 sets out the cut slope heights according to the soil properties of the cut earth as shown in Table 6-2-9. Geological surveys revealed that the area in question comprises loam and clayey soil. Therefore, the cut slope gradients are set as shown on Table 6-2-8.

Table 6-2-8. Cut Slope Gradient

Cut Earth Height	Slope Gradient	Notes
1m or less	1:5	DBN calls for the selection of gentle slopes (1:5) to prevent snowdrifts.
More than 1m	1:2.0	Selected a gentle slope of 1:2.0, even though the clayey soil.

Source: JICA Survey Team

Table 6-2-9. Standard Values for Cut Slope Gradient

Number	Type of Soil	Cut Height (m)	Maximum Slope Gradient
1	Soft rock	Maximum 16	1:0.5
	Somewhat weathered, but not soft rock	Maximum 16	1:1 - 1:1.5
	Weathered soft rock	Maximum 6	1:1 - 1:2
2	Gravelly soil	Maximum 12	1:1-1:1.5
3	Sandy soil (coarse sand, medium sand)	Maximum 12	1:1.5
4	Clayey soil, homogeneous (hard, semisolid)	Maximum 12	1:1.5
5	Sand (fine sand, very fine sand)	Maximum 12	1:2
6	Clayey soil, homogeneous, high plasticity	Maximum 12	1:2
7	Forest soil	Maximum 12	1:1-1:1.5

Note 1: Perpendicular slopes may be installed in soft rock and weathered soil.

Note 2: Cut heights are the difference between the slope heights of the upper and the lower edges of the gradient.

Source: DBN V.2.3-4 2015

6-2-3 Elements of Alignment

(1) Main Route

DBN V.2.3-4 2015 sets out two different values for planning horizontal and vertical alignments: ideal values that generally satisfy requirements without regard for design speed, and allowable values that depend on design speeds. Design speeds were decreased due to the update of DBN; accordingly, allowable values are reduced. Table 6-2-10 shows the elements of alignment set out in DBN V.2.3-4 2015 and the adopted values for Route 2 and 3 in this Study. The sight distance is set at 250 m; if necessary for safety, widening of road width is desirable to secure 250m sight distance.

It is best for motorists on the main route to be able to identify interchanges from as far away as possible. Table 6-2-11 is provided as a reference for elements of route alignment near interchanges in Japanese standards for road design.

Table 6-2-10. Elements of Alignment

Elements of Alignment	DBN V.2.3-4 2015		Selected values	
	Ideal Value	Allowable Value at Design Speed 110 km/h	Route 2	Route 3
Curve radius	3,000 m or more	700 m	1,200m	1,300m
Gradient	3% or lower	5%	2.5%	2.5%
Radius of vertical curves (convex)	70,000 m or more	11,000 m	25,100m	25,600m
Length of vertical curves (convex)	300 m or more	-	330m	300m
Radius of vertical curves (concave)	8,000 m or more	3,200 m	8,000m	8,000m
Length of vertical curves (concave)	100 m or more	-	100m	100m
Sight distance	450 m or more	250 m	250m	250m

Source: JICA Survey Team

Table 6-2-11. Elements of Main Route Alignment Near Interchanges in Japan

Design speed	120 km/h		100 km/h	
	Standard Value	Special Cases*	Standard Value	Special Cases*
Curve radius	2,000 m or more	1,500 m or more	1,500 m or more	1,000 m or more
Gradient	2.0% or lower	2.0% or lower	2.0% or lower	3.0% or lower
Radius of vertical curves (convex)	45,000 m or more	23,000 m or more	25,000 m or more	15,000 m or more
Radius of vertical curves (concave)	16,000 m or more	12,000 m or more	12,000 m or more	8,000 m or more

* Cases where standard values are difficult to satisfy due to conditions with the topography, natural features of the landscape, economic conditions, etc. or for technical reasons.

Source: JICA Survey Team

2) Interchange ramps

In DBN V.2.3-4 2015, ramp design speeds are set separately for left-turn and right-turn ramps onto the crossroad. As left-turn ramps are often loop ramps, their design speeds are set lower than those for right-turn ramps. The reference values for each of the elements of alignment are shown in Table 6-2-12. In addition, the values selected for the elements of alignment on the origin interchange and terminal interchange are shown in Tablse 6-2-13 and Table 6-2-14, respectively.

Table 6-2-12 Reference Values for Elements of Ramp Alignment

Elements of alignment	DBN V.2.3-4 2015			
	Right-turn ramps		Left-turn ramps	
Design speed	70 km/h	60 km/h	50 km/h	40 km/h
Minimum curve radius	225 m	150 m	100 m	65 m
Maximum gradient	7.0%	7.5%	8.0%	9.0%
Radius of vertical curves (convex)	5,500 m	3,500 m	2,000 m	1,000 m
Radius of vertical curves (concave)	1,300 m	1,000 m	700 m	500 m
Sight distance	115 m	90 m	70 m	50 m

Source: JICA Survey Team

Table 6-2-13. Selected Values for Elements of Ramp Alignment for Origin Interchange

Elements of alignment	Selected values			
	Routes 2/3 (same)			
Design speed	70 km/h	60 km/h	50 km/h	40 km/h
Minimum curve radius	225 m	180 m	100 m	65 m
Maximum gradient	2.6%	6.0%	2.2%	5.6%
Radius of vertical curves (convex)	5,800 m	3,600 m	2,200 m	2,100 m
Radius of vertical curves (concave)	4,800 m	1,100 m	1,100 m	700 m
Sight distance	115 m	90 m	70 m	50 m

Source: JICA Survey Team

Table 6-2-14. Selected Values for Elements of Ramp Alignment for Terminal Interchange

Elements of alignment	Selected values			
	Route 2		Route 3	
Design speed	70 km/h	50 km/h	70 km/h	50 km/h
Minimum curve radius	225 m	100 m	225 m	100 m
Maximum gradient	5.2%	4.8%	4.5%	4.0%
Radius of vertical curves (convex)	5,500 m	4,000 m	5,700 m	2,000 m
Radius of vertical curves (concave)	2,100 m	1,200 m	1,300 m	1,100 m
Sight distance	115 m	70 m	115 m	70 m

Source: JICA Survey Team

6-3 Review of Main Route Plan

6-3-1 Plan view

The M14 Bypass is a planned 4-lane road with a total approximate length of 13.2 km. As seen in Figure 6-3-1, the planned route will pass near the northern limits of Mykolaiv city, with its origin at the east end and terminus at the west end both connecting to existing arterial highways. The Survey plan view basically emulates Route 2, which was selected as the best option in the 2011 F/S. This route requires no resettlement as there is no housing in its path and it conforms with the 2015 revision of the Ukrainian Road Design Standards (DBN V.2.3-4 2015). However, careful study of the alignment elements from the 2011 F/S revealed a broken back curve[3] near Survey point No. 47+40. To correct this, the curves will be connected to eliminate the short straightaway.

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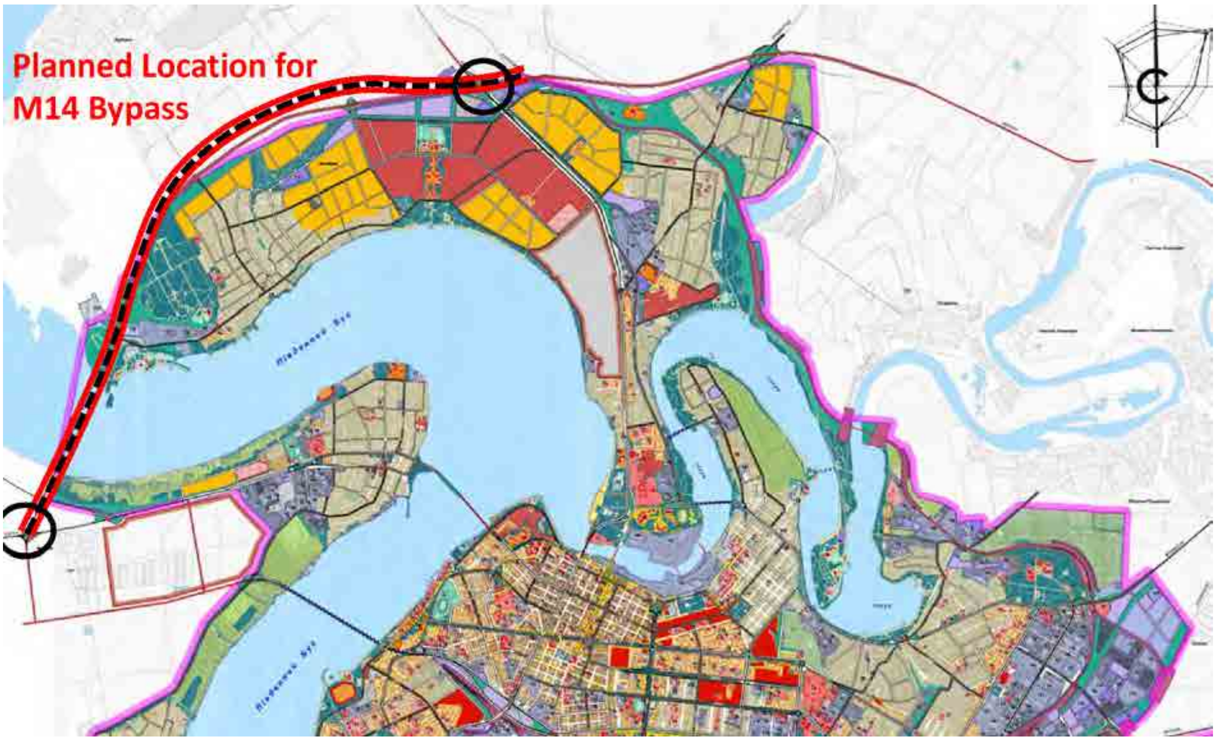
[3] Broken back curve: An arrangement with two curves with a short tangent deflecting in the same direction. This is not visually smooth; the straight section appears as if curved in the opposite direction of the two curved sections.



Source: Excerpt from Mykolaiv City Plans

Figure 6-3-1. Planned Location for M14 Bypass

6-3-2 Longitudinal plan

1) Controls for longitudinal plan

The roads, railways, and navigation channel crossing the planned road are listed in Table 6-3-1. Note that these have been treated as controls for the longitudinal plan.

Table 6-3-1. Controls on the Longitudinal Plan (Cross Traffic)

Survey point		Crossing traffic	Notes
Route 2	Route 3		
No. 12+0	- ditto -	Highway P06	Crosses overhead of main route
No. 32+0	- ditto -	City road	Crossed overhead by main route
No. 49+93	- ditto -	City road	Crossed overhead by main route
No. 60+88	- ditto -	City road	Crossed overhead by main route
No. 90+83	No. 88+87	City road	Crossed overhead by main route
No. 111+60	No. 108+67	Navigation channel (Southern Bug River)	Crossed overhead by main route
No. 118+60	No. 119+65	Highway T1506	Crosses overhead of main route
n/a	No. 132+18	City road	Crossed overhead by main route
No. 122+18	n/a	Road (interchange ramps)	Crosses overhead of main route
n/a	No. 144+0	Highway M14	Crossed overhead by main route

Source: JICA Survey Team

2) Railway branch line, near Survey point No. 8+80 (discontinued)

On the origin side of the main route, there are an in-service railway and a discontinued branch line. The main route crosses the discontinued branch line near Survey point No. 8+80 (see Figure 6-3-2). According to the discussion with the Mykolaiv mayor, the branch line is discontinued, and no plans for a branch line are specified in any of the latest Mykolaiv city plans. Based on these facts, the branch line will not be treated as a control in the longitudinal plan for this Survey.

 		
Location of branch line (discontinued) near the planned interchange site	State of the discontinued railway branch line	State of the discontinued railway branch line

Source: JICA Survey Team

Figure 6-3-2. Railway Branch Line (Discontinued) at Planned Interchange Site

The average elevation near Survey point No. 8+80 is 55 m, which is roughly 17 m higher than that at the origin (Survey point No. 0-5) of 38 m. This difference in elevation makes the profile gradient of the planned road relatively steep. Also, in the 2011 F/S, a grade separation was planned with the branch line passing over the planned road, clearing the planned road overhead by 5.5 m.

The advantages of not treating the branch line as a control in the longitudinal plan are as follows:

- The area in question is at an interchange section, and thus, adopting the gentlest gradient possible is preferable in the interest of both vehicle safety and smoothness. While no profile gradients for a main route near an interchange are stipulated in DBN V.2.3-4 2015, a standard gradient of 2.0% or less is stipulated in Japanese Road Structure Ordinance. At 1.5%, the profile gradient for this Survey is greatly improved from the 2.5% in the 2011 F/S.
- The planned elevation for the road at the interchange section is higher than in the 2011 F/S. This makes for shorter connection ramps at the crossing with P06 than in the 2011 F/S and will cut construction costs by reducing the overall scale of earthwork needed for the interchange.
- According to the geological survey, this area has a stratum of highly expansive clay[4] at a depth of 7-10.5 m below the surface. If expansive soil is exposed during excavation, swelling and shrinkage could cause displacement and reduce ground strength, making the slope less stable. In this Survey, excavation depth for the interchange section will be approximately 7 m, which is less likely to expose expansive soil on the slope than the depth of nearly 10 m in the 2011 F/S.
-

3) Railway branch line, near Survey point No. 66+60 (discontinued)

As depicted in Figure 6-3-3, an area near Survey point No. 66+60 appears to be a road site elevated about 1.5 m above the surrounding ground. The local residents say that this was an old rail line servicing a former silica plant near the Southern Bug River. An inspection of the area, however, revealed no tracks. The rail line is discontinued, and the silica plant has been demolished. With no plans for a branch line specified in any of the Mykolaiv city plans, the branch line will not be treated as a control in the longitudinal plan for this Survey.

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[4] Swelling factor from sample testing: $E_{SW} = 0.131$ (>0.12). Standards (GOST 25100-95): Non-swelling: E_{SW} <0.04, Low swelling:0.04< E_{SW} <0.08, Middle swelling 0.08< E_{SW} <0.12, High swelling E_{SW} >0.12.

<table>
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<tr>
<td>Location of branch line (discontinued), near Survey point No. 66+60</td>
<td>State of the discontinued railway branch line (no tracks)</td>
<td>State of the discontinued railway branch line (no tracks)</td>
</tr>
</table>

Source: JICA Survey Team

Figure 6-3-3. Railway Branch Line Remains, near Survey point No. 66+60

The elevation near Survey point No. 66+60 is 34 m, sloping down to an elevation of 20 m for the ground toward the road terminus on the Southern Bug River side. In the 2011 F/S, a grade separation was planned at this point, with the planned road passing over the branch line and clearing the branch line overhead by 5.5 m.

The advantages of not treating the branch line as a control in the longitudinal plan are as follows:

- In the 2011 F/S, a profile gradient of 3% was planned to restrict the embankment height from near Survey point No. 66+60 to the road terminus. At 2.1%, the profile gradient for this Survey is an improvement over that in the 2011 F/S.
- In the 2011 F/S, a 10-meter-high embankment stretching approximately 400 m was planned toward the road terminus side. In contrast, this Survey has the embankment at an average height of 3 m, greatly reducing the amount of earthwork. This will reduce construction costs.
-

4) Excavation on the right bank of the Southern Bug River

Given the elevation difference of 55-60 m between the Southern Bug River and its right bank, there will be relatively large-scale excavation from near Survey point No. 117 to the terminus interchange. Upon a close review of the 2011 F/S to see if excavation can be scaled down, changing the plane alignment could impact residences, and raising the profile alignment would increase construction costs for the bridge across the river. Neither of these options is optimal. Thus, excavation depth was left at approximately 12 m, similar to the 2011 F/S. From the geological survey, the soil is loam and not very expansive from the surface down to a depth of 12 m. Accordingly, no special measures will be required for the cut slope.

6-3-3 Standard Cross Section

The standard cross section for the main route is depicted below.

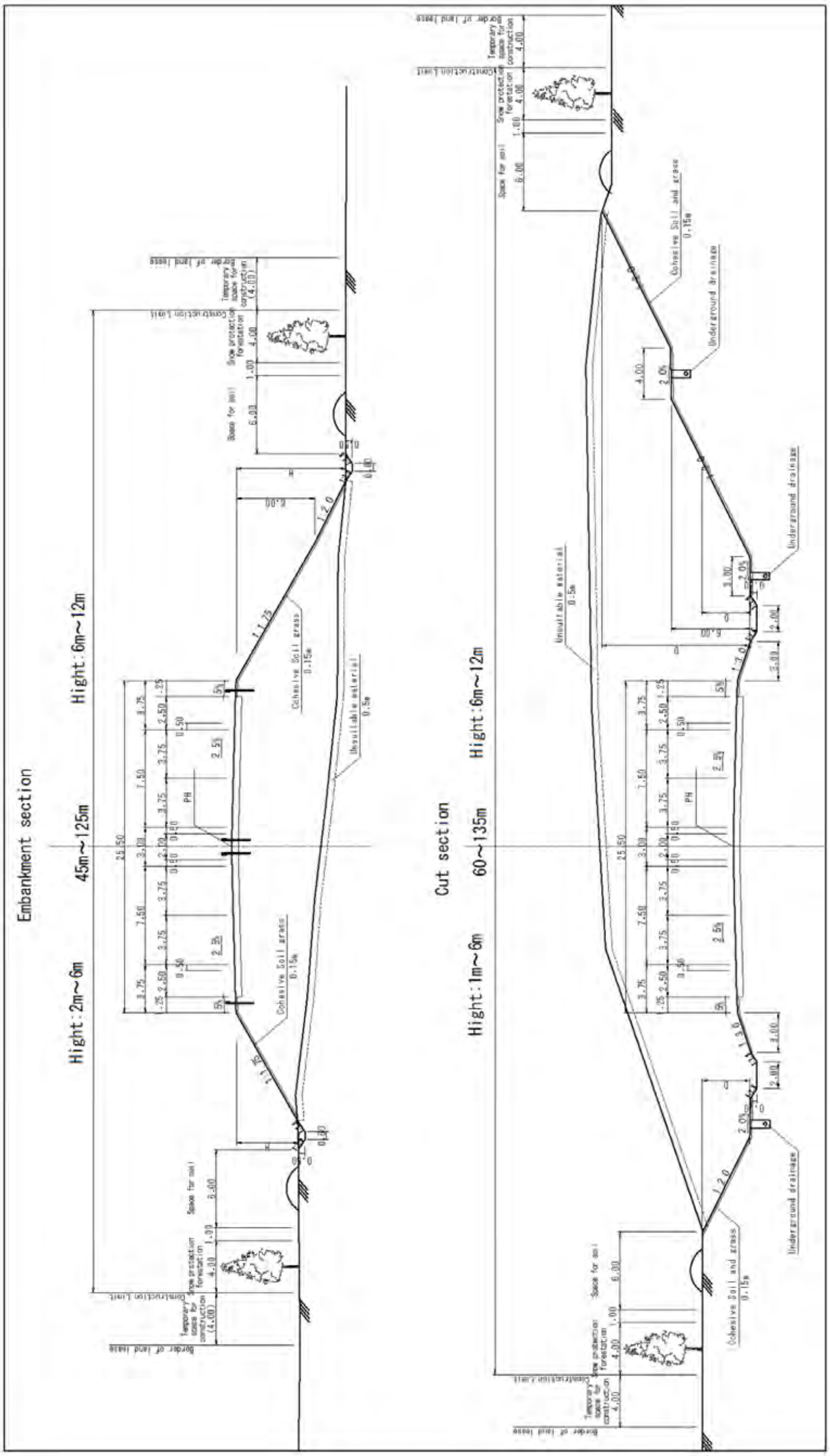


Figure 6-3-4. Width Configuration for the Main Route

Source: JICA Survey Team

6-3-4 Routes in the Basic Plan

In Chapter 5: Review of Road and Bridge Locations, four route alternatives were compared and reviewed. Of these, Route 2 and Route 3 are the routes selected for the basic plan. An overview of these two routes is given in Table 6-3-2.

Table 6-3-2. Route Overview

Item	Route 2	Route 3
Planned locations	Same as planned location in the 2011 F/S (near the northern limits of Mykolaiv city)	Same line as Route 2 from the origin to near km 7.1. Terminates at M14 connection, approx. 3 km west of Route 2.
Route extension length	Approx. 13.2 km	Approx. 14.6 km
Length of bridge across the Southern Bug	2,115 m	2,180 m
Resettlement (Building with residents)	0	3
Obstructive Buildings (Garage, Warehouse etc)	26	60
Connection to P06 (connecting road at origin)	Cloverleaf interchange	Same
Connection to M14 (connecting road at terminus)	Trumpet interchange	Half-clover interchange

Source: JICA Survey Team

The planned locations for the two routes are shown in Figure 6-3-5. To the extent possible, the routes avoid residential areas, hospitals, graveyards, high-voltage lines, and other structures to minimize socioeconomic impact. Also, the bridge alignment is planned perpendicular to the river flow of the Southern Bug River as much as possible and the bridge length is planned as short as possible.

Source: JICA Survey Team

Figure 6-3-5. Planned Route Locations

6-4 Review of Connection Types

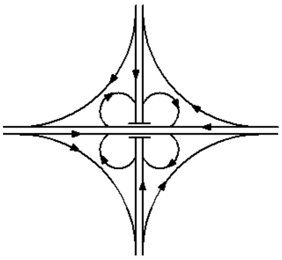
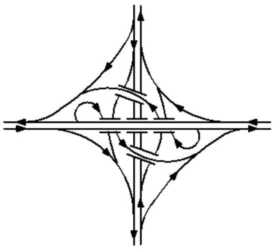
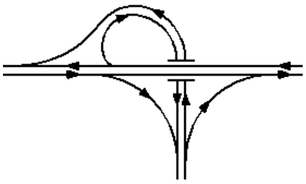
6-4-1 Interchange at Origin (same for Route 2 and Route 3)

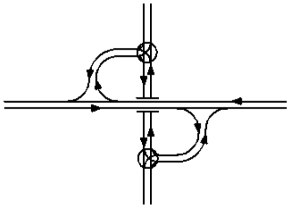
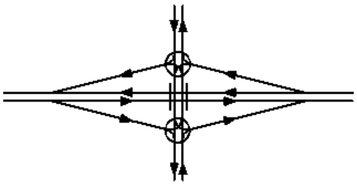
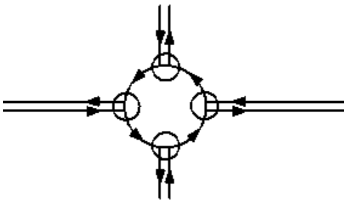
1) Interchanges proposed in the past surveys

At the origin, the M14 Bypass will form a 4-way junction with P06, which runs in the north-south direction. Route P06 is a high-traffic I-b class arterial highway, the same class as the M14 Bypass. In the 2011 F/S, a fully-separated cloverleaf interchange was proposed as the connection at this location. In the 2012 F/S, Ukraine compared the cloverleaf interchange to a cloverstack interchange, eventually selecting the same cloverleaf interchange as in the 2011 F/S.

Other than the cloverleaf and cloverstack interchanges given above, another possible type of connection commonly built in Ukraine is the trumpet interchange. The general characteristics of the cloverleaf, cloverstack and trumpet interchanges are organized in Table 6-4-1 below.

Table 6-4-1. Interchange Characteristics

Cloverleaf	Cloverstack	Trumpet
This was proposed in the 2011 and 2012 F/S	A hybrid interchange, taking a cloverleaf and replacing one pair of loop ramps with semi-directional ramps	A typical 3-way junction
		
• Common in Ukraine • Economical, but weaving affects all traffic (degree of impact will depend on traffic volume and the distance between ramp noses)	• Not common in Ukraine • Shifting the ramp positions as in the figure above can eliminate the weave of traffic, but this involves more structures and is more expensive than a cloverleaf	• Common in Ukraine • Economical and saves space. When used in a 4-way junction, another trumpet is added on the crossroad side for a double trumpet.

Partial cloverleaf	Diamond	Roundabout
Partial cloverleaf has at-grade intewrchange.	Diamond has at at-grade intewrchange.	Roundabout has at-grade interchange.
 ○At-grade intersections	 ○At-grade intersections	 ○At-grade intersections
• As this produces at-grade intersections, it is not suited for connections between two 4-lane arterial highways. • Economical and suited for connections between an arterial highway and a low-traffic local road	• As this produces at-grade intersections, it is not suited for connections between two 4-lane arterial highways. • Economical and suited for connections between an arterial highway and a low-traffic local road. • Land acquisition is narrow.	• As this produces at-grade intersections, it is not suited for connections between two 4-lane arterial highways. • In case one of roads has heavy traffic, it is possible to reduce the number of grade intersections by chaning it to grade separation.

Source: JICA Survey Team

2) Location of the planned interchange site

There is a privately-owned and active asphalt plant to the north of the interchange. This plant will be treated as a control in the plans. If interchange construction blocks off the plant access road, a diversion road will be planned to restore access. Mykolaiv Oblast also has a state-owned asphalt plant next to the private plant, however, the Mykolaiv mayor has stated that this plant can be relocated. Thus, the public plant will not be an obstacle.

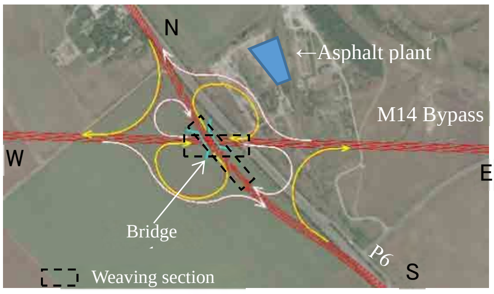
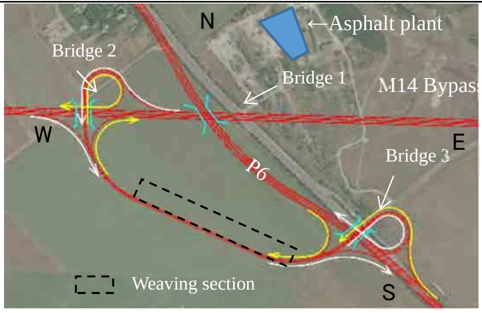
3) Comparison of interchange types

Of the interchange types proposed for the route origin shown in Table 6-4-1, the cloverleaf and double trumpet types will be compared as both are common in Ukraine and economical.

Table 6-4-2 is a comparison table of these two types.

Upon review of their drivability, safety, impact on farmland, involuntary resettlement, workability, and economy, this Survey recommends the same type as proposed in the 2011 and 2012 F/S: the cloverleaf. With the double trumpet, left-turn traffic in two directions is directed through loop ramps. Meanwhile, whereas the clover is slightly inferior in that left-turn traffic in all four directions must pass through loop ramps, it reduces the area of impacted farmland and is more economical. Further, the clover is more common as 4-way interchange in Ukraine, making it the best choice overall.

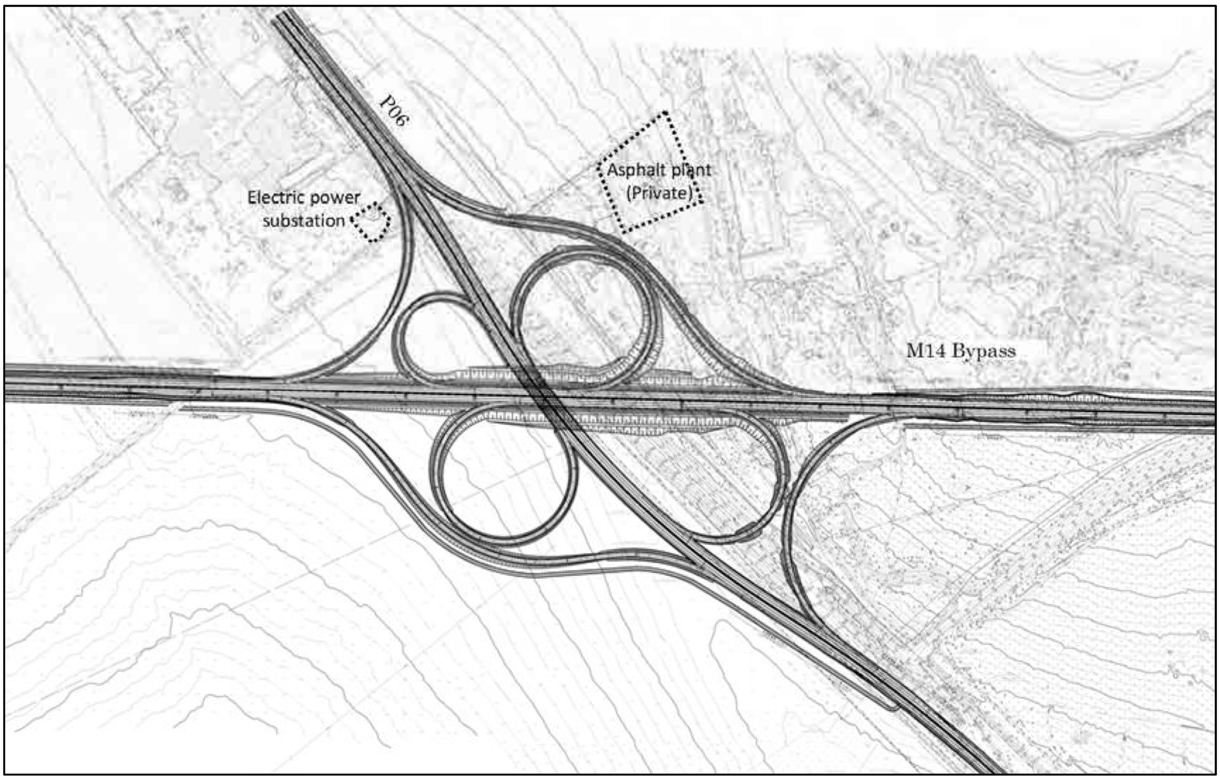
Table 6-4-2. Comparison of Interchange Types at the Route Origin

Interchange Type	Option 1: Cloverleaf (2011 F/S)		Option 2: Trumpet	
Interchange layout				
Drivability	• Ramps for left turns in all four directions (S-W, E-S, N-E, W-N) are loops • Traffic weaves between entrance and exit ramps; all left turns traffic must weave each other (impact: high)	- -	• Ramps for left turns in two directions (S-W, W-N) are loops • Traffic weaves between the two trumpet interchanges; all traffic in left and right turns must weave (impact: low)	++ +
Safety	• Common type in Ukraine; risk can be reduced if distribution lane is provided separately from main carriageway.	-	• Not so common type in Ukraine, risk can be less than that of cloverleaf since weaving section is only one and much longer than that of cloverleaf.	+
Impact to farmland	• Impacted area: 15 ha	++	• Impacted area: 33 ha (2.2x that of Option 1)	-
Resettlement	• None	+	• None	+
Workability	• No issues; at most 10 m of excavation	+	• No issues; approximately 2 m of excavation	+
Economy	• More cost effective: short ramps, only 1 bridge • As the interchange will involve excavation, the resulting excavated soil can be recycled as material for embankment sections	++ ++	• Less cost effective: long ramps (approx. 1.7x those in Option 1) and 3 bridges • The interchange will involve embankments, increasing the shortage of soil for the overall work	- -
Evaluation	Recommended option			

++: Superior, +: Roughly equivalent, -: Inferior

Source: JICA Survey Team

4) Interchange Layout



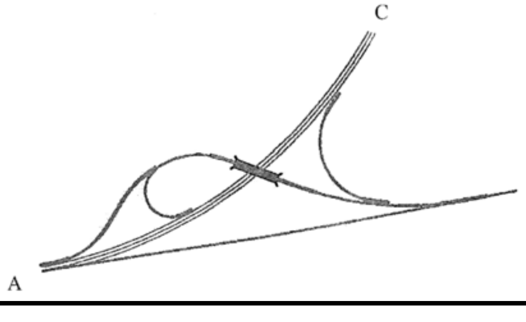
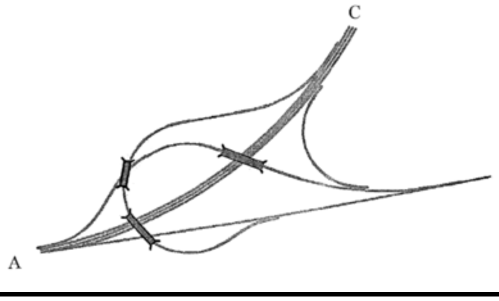
Source: JICA Survey Team

Figure 6-4-1. Layout of the Interchange at the Origin (same for Route 2 and Route 3)

6-4-2 Interchange at the Terminus (Route 2)

1) Interchanges proposed in past surveys

At the terminus, the M14 Bypass will form a 3-way junction with M14, which runs in the east-west direction. Route M14 is a high-traffic I-b class arterial highway, the same class as the M14 Bypass. In the 2011 F/S a trumpet was the recommended interchange type for this location. In the 2012 F/S prepared by Ukraine, a trumpet was selected upon comparing the trumpet with a semi-directional Y interchange. For reference, an overview of the semi-directional Y format is given in Figure 6-4-2.

Trumpet	Semi-directional Y
The type proposed in the 2011 and 2012 F/S	Merges without loop ramps and uses semi-directional connections for both splits. More costly than a trumpet interchange as it involves more grade separations.
	

Source: JICA Survey Team

Figure 6-4-2. Overview of Trumpet and Semi-Directional Y Interchanges

2) Location of the planned interchange site

The planned interchange site is a farmland surrounded by M14, T1506, and two residential lands and has no obstacles (see Figure 6-4-3).

Land use near the planned interchange site

Farmland

Source: JICA Survey Team

Figure 6-4-3. Land Use at the Planned Interchange Site

3) Comparison of interchange types

A comparison is made between two types of trumpet interchanges (Type 1 and Type 2) that the 2011 and 2012 F/S recommended for the route terminus. Table 6-4-3 compares the two types.Upon review of their drivability, safety, impact on farmland, involuntary resettlement, workability, and economy, this Survey recommends Type 1 (Option 1). Type 1 has better drivability in the M14 east-west direction (outbound and inbound in relation to Mykolaiv) and maintains the current M14 transportation capacity.

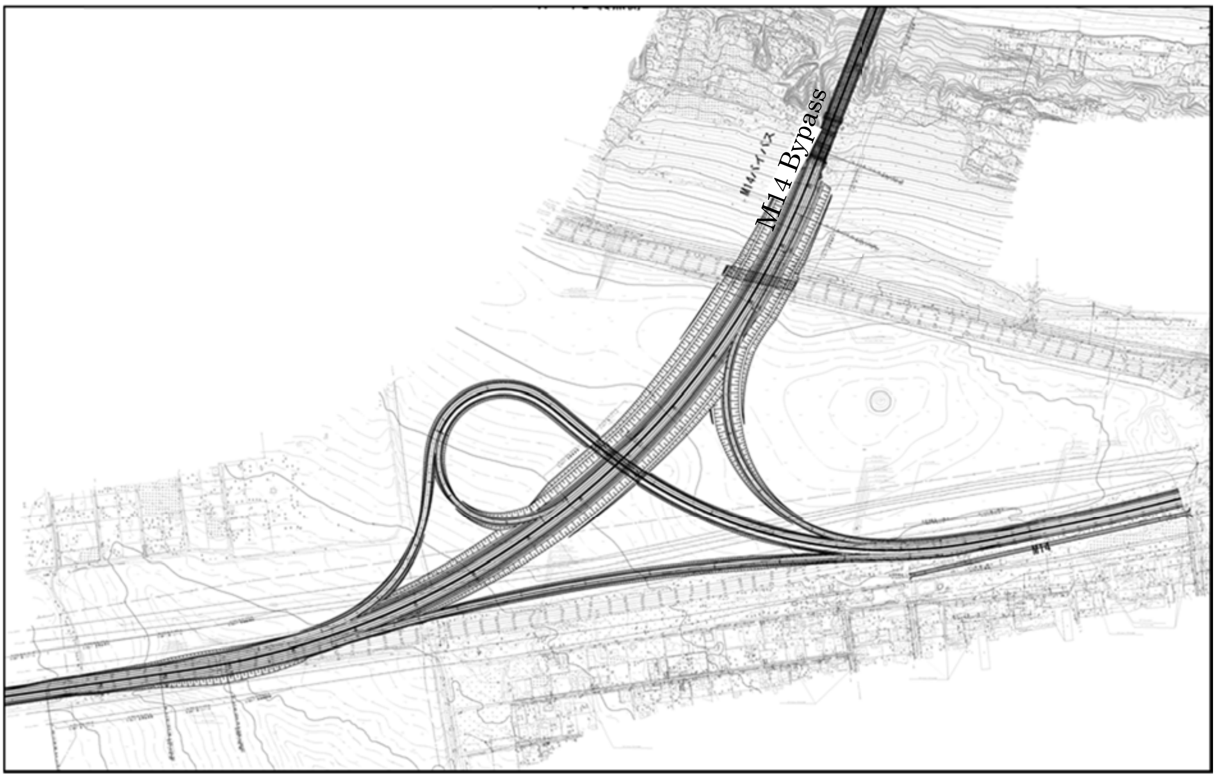
Table 6-4-3. Comparison of Interchange Types at the Route Terminus

Interchange type	Option 1: Trumpet (Type 1)		Option 2: Trumpet (Type 2)	
Interchange Layout				
Drivability	• Southbound traffic heading downtown on the M14 Bypass passes over the Southern Bug River and takes a loop ramp onto the M14 (ramp traffic volume: 690 vehicles/h.) • Better drivability for east-west M14 traffic (inbound-outbound) than Option 2, and maintains current M14 transportation capacity	+ ++	• Outbound M14 traffic for the suburbs takes a loop ramp onto the westbound M14 Bypass (ramp traffic volume: 680 vehicles/h.) • M14 transportation capacity is decreased as both east and west M14 traffic (inbound-outbound) pass through loop ramps	+ -
Safety	• Common type in Ukraine; risk can be reduced with the normal safety measures	+	• Same	+

Impact to farmland	• No difference	+	• No difference	+
Resettlement	• None	+	• None	+
Workability	• As the interchange will involve excavation, the resulting excavated soil can be recycled as material for embankment sections	+	• Same	+
Economy	• Ramp length is almost equal. One ramp bridge.	++	• More costly than Option 1 due to widening from the exit ramp where Route T1506 crosses the M14 Bypass	-
Evaluation	Recommended option			

Note: ++: Superior, +: Roughly equivalent, -: Inferior

4) Interchange layout



Source: JICA Survey Team

Figure 6-4-4. Layout of the Interchange at the Terminus (Route 2)

6-4-3 Interchange at Terminus (Route 3)

1) Location of the planned interchange site

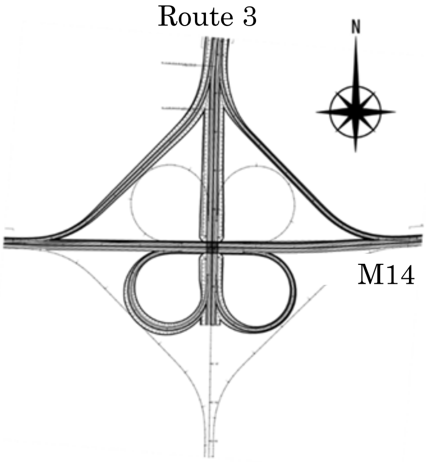
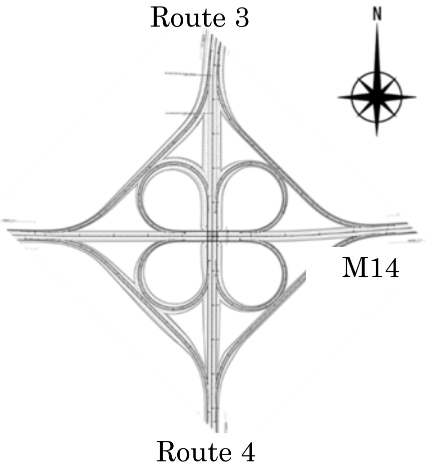
The planned interchange site is flat farmland with no affected houses or other structures.

2) Comparison of interchange types

As the M14 Bypass terminus intersects with the M14, which runs in the east-west direction, the basic connection type will be the same trumpet interchange as recommended for Route 2 if it is a 3-way interchange. That said, given a possibility that a Route 4 be added as part of a ring road in the future, it is preferable to simplify the connection of Routes 3 and 4 from an infrastructural investment perspective and the user perspective. Therefore, the 3-way interchange types considered for this location will account for a future Route 3 extension to the south (which would make this a 4-way interchange).

As there are close to no critical right-of-way limitations near the site for this interchange, a cloverleaf is recommended as it will be the easiest to convert from a 3-way to a 4-way interchange.

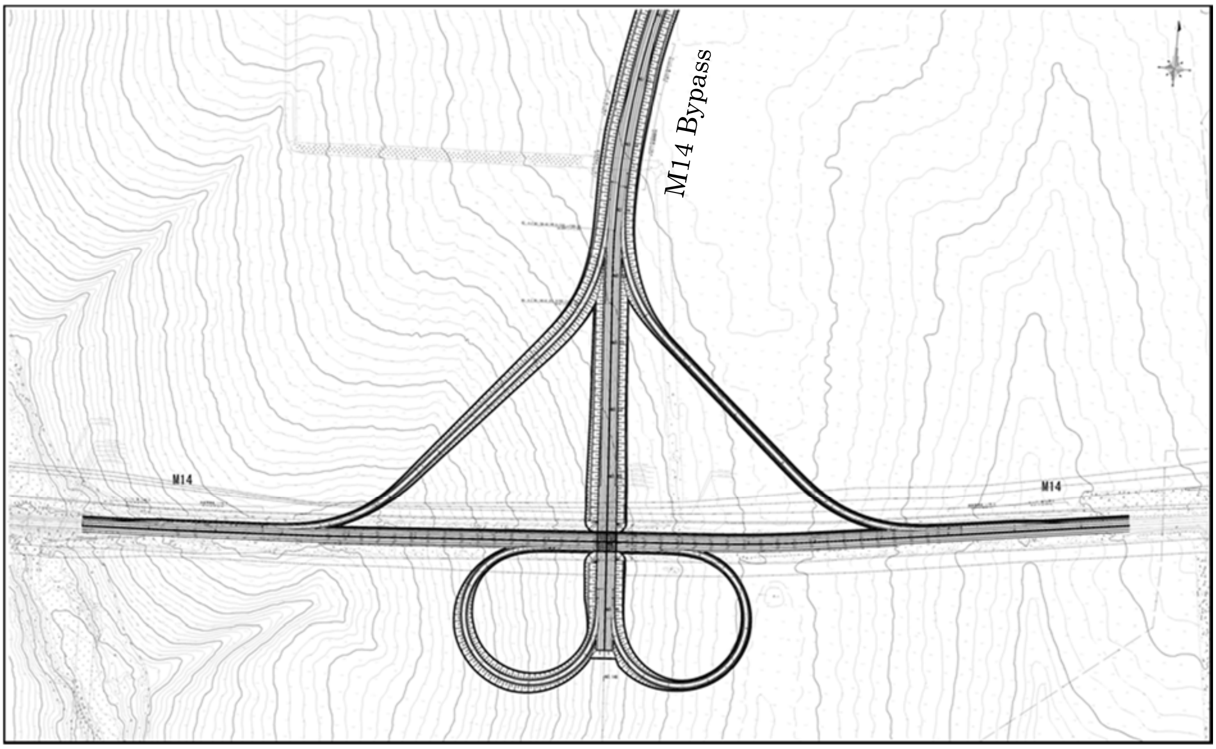
Figure 6-4-5 shows outline maps for the initial construction (the 3-way interchange) and the future construction (4-way interchange).

Initial construction (3-way interchange)	**Future construction (4-way interchange)**
Half-clover	Cloverleaf
	

Source: JICA Survey Team

Figure 6-4-5. Overview of Route 3 Interchange Types

3) Interhcange layout



Source: JICA Survey Team

Figure 6-4-6. Layout of the Interchange at the Terminus (Route 3)

6-4-4 Connections at Intermediate Crossroads (same for Route 2 and Route 3)

A city road connecting residential areas on the north and south sides of the M14 Bypass pass under the bypass near Survey point No. 61. An exit is planned at this city road, which will also be convenient given that Survey point No. 61 is nearly the halfway mark of the M14 Bypass. (See Figure 6-4-7)

A connection with the city road at Survey point No. 61 was also planned in the 2011 F/S using an at-grade intersection on the main route side. In this type, left-turning traffic on the main route must turn across the oncoming lanes in a central opening. While the impact on traffic flow on the main route should be minimal when connection road traffic is light, in terms of safety, it would be highly preferable to avoid an at-grade intersection on a road with a design speed of 110 km/h.

In the 2011 F/S, another at-grade intersection was planned at another city road near Survey point No. 32. For this Survey, the recommendation is to combine the connection points for Survey point No. 61 and No. 32 at Survey point No. 61 and install a diamond type at-grade intersection on the connecting road side.

Source: JICA Survey Team

Figure 6-4-7. Intermediate Crossroad Connection Point (near Survey point No. 61)

6-5 Basic Interchange Structure

6-5-1 Ramp Design Speeds

1) Setting of design speeds

- Design speeds for ramps on grade separated interchanges are set in accordance with DBN V.2.3-4 2015. (See Table 6-5-1)

Table 6-5-1. Ramp Design Speed Standards for Grade Separated Interchanges

	Right-turn ramps			Left-turn ramps		
Volume share (%)	15 or lower	15-30	30 and up	15 or lower	15-30	30 and up
Design speed (km/h)	60	65	70	40	45	50

Source: DBN V.2.3-4 2015

- The traffic volume used for calculating the ramp design speed was the future peak hourly volume for 2036 (vehicles/hour), found by calculating the traffic volume shares (%) for left- and right-turning vehicles entering the interchange from the main route during peak hours.
- The interchange types proposed for the route origin and terminus are those given in 6-5. Review of Connection Types above. (See Table 6-5-2)

Table 6-5-2. Interchange Types at Route Origin and Terminus

	Route 2	Route 3
Interchange at origin	Cloverleaf	Trumpet
Interchange at terminus	Cloverleaf	Half-clover

Source: JICA Survey Team

2) Interchange at Origin (same for Route 2 and Route 3)

The ramp design speeds for the cloverleaf interchange at the origin for Route 2 and Route 3 are shown below.

Table 6-5-3. Ramp Design Speeds for Interchange at Origin (Same for Route 2 and Route 3)

Entering interchange from	Daily traffic volume (2036) (Veh./day)	Peak hour traffic* (Veh./h.)			Vehicle traveling direction	Volume share	Ramp design speed (km/h)
M14 Bypass (W-E)	12,947	971	A	144	Straight	15%	Main route
			B	808	Right	83%	70
			C	19	Left	2%	40
M14 Bypass (E-W)	6,278	471	D	144	Straight	31%	Main route
			E	296	Right	63%	70
			F	32	Left	7%	40
P06 (N-S)	11,712	878	G	564	Straight	64%	Main route
			H	19	Right	2%	60
			I	296	Left	34%	50
P06 (S-N)	18,707	1,403	J	564	Straight	40%	Main route
			K	32	Right	2%	60
			L	808	Left	58%	50

*See Figure 6-5-1

Source: JICA Survey Team

3) Interchange at terminus (Route 2)

The ramp design speeds for the trumpet interchange at the terminus for Route 2 are shown below.

Table 6-5-4. Ramp Design Speeds for Interchange at Terminus (Route 2)

Entering interchange from	Daily traffic volume (2036) (Veh./day)	Peak hour traffic* (Veh./h.)			Vehicle traveling direction	Volume share	Ramp design speed (km/h)
M14 Bypass (N-E)	12,947	971	M	291	Straight	30%	Main route
			N	680	Left	70%	50
M14 Bypass (E-N)	13,088	982	O	291	Straight	30%	Main route
			P	690	Right	70%	70
Route M14 (E-M14 Bypass)	18,266	1,370	Q	690	Left	50%	50
			R	680	Right	50%	70

*See Figure 6-5-1

Source: JICA Survey Team

4) Interchange at terminus (Route 3)

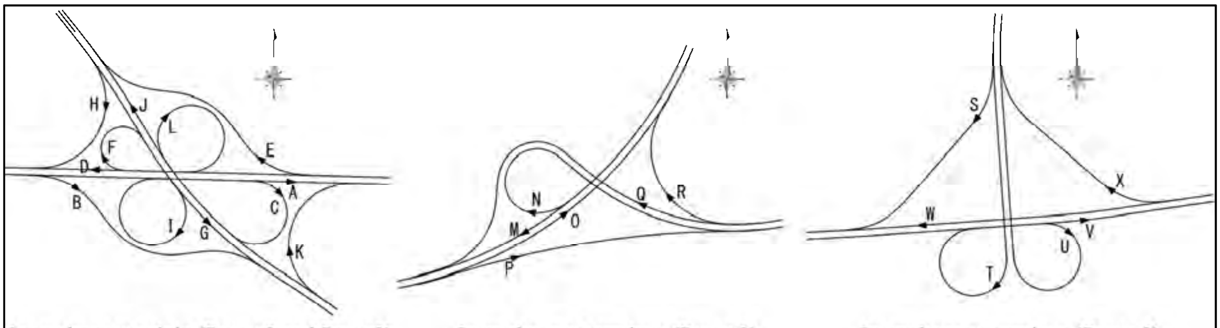
The ramp design speeds for the half-clover interchange at the terminus for Route 3 are shown below.

Table 6-5-5. Ramp Design Speeds for Interchange at Terminus (Route 3)

Entering interchange from	Daily traffic volume (2036) (Veh./day)	Peak hour traffic[*] (Veh./h.)			Vehicle traveling direction	Volume share	Ramp design speed (km/h)
M14 Bypass (N-S)	12,505	938	S	296	Right	32%	70
			T	642	Left	68%	50
Route M14 (W-E)	13,088	982	U	296	Left	30%	50
			V	685	Straight	70%	Main route
Route M14 (E-W)	17,695	1,327	W	685	Straight	52%	Main route
			X	642	Right	48%	70

[*] See Figure 6-5-1

Source: JICA Survey Team



Intertchage at origin (Route 2 and Route3)

Intertchage at terminus (Route 2)

Intertchage at terminus (Route 3)

Source: JICA Survey Team

Figure 6-5-1 Note of Peak hour traffic

6-5-2 Number of Ramp Lanes

1) Setting number of lanes

- For ramps on grade-separated interchanges, the number of ramp lanes used will be based on the traffic capacity ratio, calculated as the peak hour volume (PCU/h) over the ramp traffic capacity (PCU/h). One lane will be used when the capacity ratio is 0.8 or lower and 2 lanes will be used when it is over 0.8.[5]
- The ramp traffic capacities are the basic traffic capacities given in Table 6-5-6 adjusted for impact from heavy vehicles.[6]

Table 6-5-6. Basic Capacity of Ramps

Design speed km/h	1-lane ramp PCU/h	2-lane ramp PCU/h
>80	2,200	4,400
64-80	2,100	4,200
48-64	2,000	4,000
32-48	1,900	3,800
<32	1,800	3,600

Source: Highway Capacity Manual 2010

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[5] See design level of service for the interchange, mentioned below

[6] Based on heavy vehicle traffic of 25% on the M14 Bypass, the adjustment value for heavy vehicle impact was set to 0.8, referencing Traffic Capacity of Roads (Japan Road Association).

- The design level of service for the interchange was set to 0.8, considering levels at which there would be no congestion in the urban area year round (design level of service of 1).

Table 6-5-7. Design Level of Service and Capacity Ratios

Design level of service	Capacity ratio	
	Rural	Urban
1	0.75	0.80
2	0.85	0.90
3	1.00	1.00

Source: Traffic Capacity of Roads (Japan Road Association)

2) Interchange at Origin (same for Route 2 and Route 3)

The table below shows the number of lanes for the ramps on the cloverleaf interchange at the origin for Route 2 and Route 3.

Table 6-5-8. Number of Lanes for Ramps on Interchange at Origin (Same for Route 2 and Route 3)

Entering interchange from	Vehicle traveling direction	Ramp design speeds km/h	Basic capacity PCU/h	Capacity C PCU/h	Peak hour traffic[7] V PCU/h	Capacity ratio V/C	Assessment 0.8≧V/C 1 lane	Lanes
M14 Bypass (W-E)	Straight	Main route	-	-	351	-	-	-
	Right	70	2,100	1,680	1,184	0.70	Yes	1
	Left	40	1,900	1,520	55	0.04	Yes	1
M14 Bypass (E-W)	Straight	Main route	-	-	351	-	-	-
	Right	70	2,100	1,680	985	0.59	Yes	1
	Left	40	1,900	1,520	89	0.06	Yes	1
P06 (N-S)	Straight	Main route	-	-	982	-	-	-
	Right	60	2,000	1,600	55	0.03	Yes	1
	Left	50	1,900	1,520	985	0.65	Yes	1
P06 (S-N)	Straight	Main route	-	-	982	-	-	-
	Right	60	2,000	1,600	89	0.06	Yes	1
	Left	50	2,000	1,600	1,184	0.74	Yes	1

Source: JICA Survey Team

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[7] PCU/h converted from peak hour traffic of Table 6-5-3. PCU refer to Table 17-1-2.

3) Interchange at terminus (Route 2)

The number of lanes for the ramps on the trumpet interchange at the terminus for Route 2 are shown below.

Table 6-5-9. Number of Lanes for Ramps on Interchange at Terminus (Route 2)

Entering interchange from	Vehicle traveling direction	Ramp design speeds km/h	Basic capacity PCU/h	Capacity C PCU/h	Peak hour traffic[8] V PCU/h	Capacity ratio V/C	Assessment 0.8≧V/C 1 lane	Lanes
M14 Bypass (N-E)	Straight	Main route	-	-	606	-	-	-
	Left	50	2,000	1,600	935	0.58	Yes	1
M14 Bypass (E-N)	Straight	Main route	-	-	606	-	-	-
	Right	70	2,100	1,680	1,370	0.82	No	2
Route M14 (E-M14 Bypass)	Left	50	2,000	1,600	1,370	0.86	No	2
	Right	70	2,100	1,680	935	0.56	Yes	1

Source: JICA Survey Team

4) Interchange at Terminus (Route 3)

The number of lanes for the ramps on the half-clover interchange at the terminus for Route 3 are shown below.

Table 6-5-10. Number of Lanes for Ramps on Interchange at Terminus (Route 3)

Entering interchange from	Vehicle traveling direction	Ramp design speeds km/h	Basic capacity PCU/h	Capacity C PCU/h	Peak hour traffic[9] V PCU/h	Capacity ratio V/C	Assessment 0.8≧V/C 1 lane	Lanes
M14 Bypass (N-S)	Right	70	2,100	1,680	606	0.36	Yes	1
	Left	50	2,000	1,600	935	0.58	Yes	1
Route M14 (W-E)	Left	50	2,000	1,600	606	0.38	Yes	1
	Straight	Main route	-	-	1,370	-	-	-
Route M14 (E-W)	Straight	Main route	-	-	1,370	-	-	-
	Right	70	2,100	1,680	935	0.56	Yes	1

Source: JICA Survey Team

6-5-3 Ramp Width

Ramp widths will be as follows in accordance with DBN V.2.3-4 2015:

- 1-lane ramps: 6.0 m lane width, 2.0 m shoulder width
- 2-lane ramps: 7.5 m lane width (3.75 m x 2), 2.0 m shoulder width

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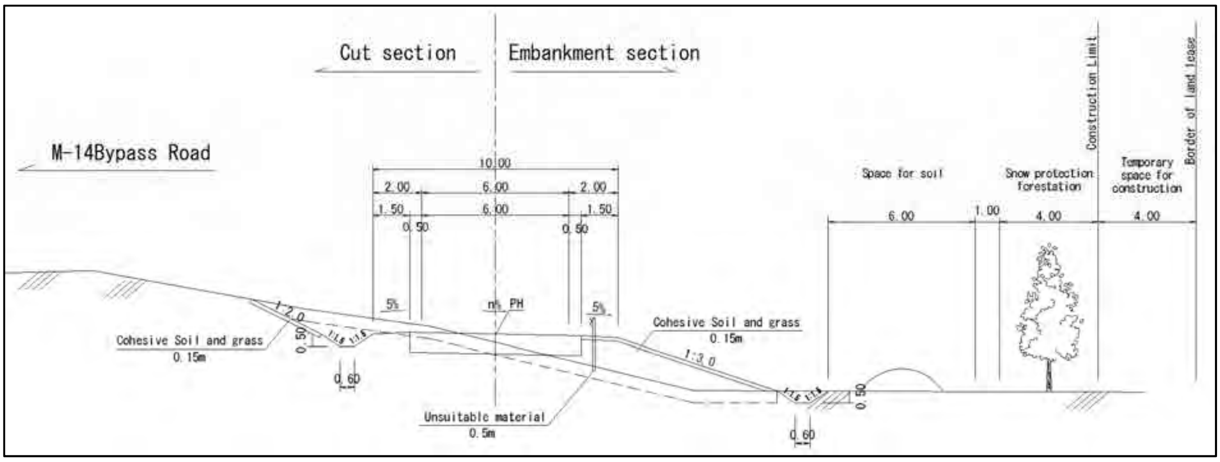
[8] PCU/h converted from peak hour traffic of Table 6-5-4. PCU refer to Table17-1-2.

[9] PCU/h converted from peak hour traffic of Table 6-5-5. PCU refer to Table17-1-2.



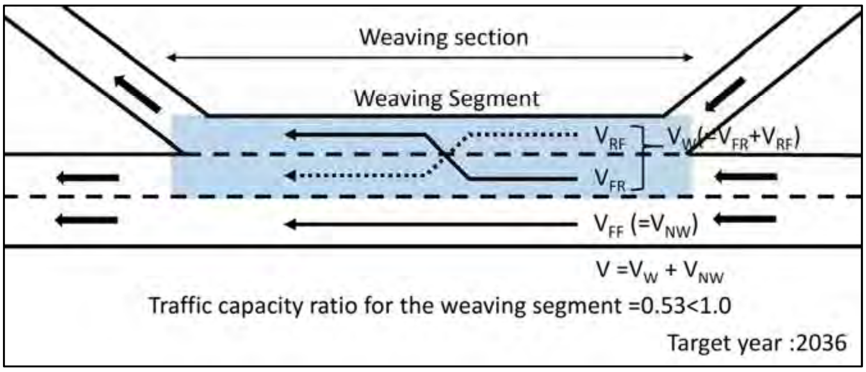
Source: JICA Survey Team

Figure 6-5-2. Ramp Width Configuration

6-5-4 Traffic Capacity for Weaving Sections

1) Sections considered

On the cloverleaf interchange at the origin, there will be weaving between traffic from the M14 entrance and exit ramps. Of the weaving sections, most of the weaving traffic will congregate in two sections: where the left lane of the northbound Route P06 merges with the M14 Bypass (1,184 PCU/h), and where the left lane of the westbound M14 Bypass diverges (89 PCU/h; see Figure 6-5-3). The traffic capacity of these weaving segments are considered below.



Source: JICA Survey Team

Figure 6-5-3. Weaving Segments (Shaded)

2) Traffic conditions

Traffic conditions for the merging segments are as follows:

V_{FF}	: Segment traffic (main route through traffic)	176	PCU/h
V_{FR}	: Segment traffic (main route to ramp)	89	PCU/h
V_{RF}	: Segment traffic (ramp onto main route)	1,184	PCU/h
V_W	: Total weaving traffic (V_{FR} + V_{RF})	1,273	PCU/h
V_{NW}	: Total non-weaving traffic (V_{FF})	176	PCU/h
V	: Total segment traffic (V_W + V_{NW})	1,449	PCU/h
VR	: Ratio of segment traffic that is weaving traffic (Vw/V)	0.88	

3) Traffic capacity

The Highway Capacity Manual 2010 (HCM2010) was referenced in calculating the traffic capacity for the weaving segments. According to the HCM2010, the smaller of the following values is taken for weaving segment traffic capacity (veh/h): 1) traffic capacity based on maximum traffic density (27 PCU/km/lane), or 2) traffic capacity based on weaving traffic demand.

As will be described below, the result for 1) was calculated as 3,156 veh/h, and that for 2) was 1,909 veh/h. Therefore, the traffic capacity for the weaving segments is 1,909 veh/h.

With total traffic of 1,449 PCU/h for the weaving segments (1,449 * 0.7 = 1,014 veh/h), the capacity ratio of 1,014/1,909 = 0.53 is less than 1.0. Thus, the number of lanes and distance between noses for the weaving sections are deemed appropriate.

(1) Traffic capacity based on traffic density

The traffic capacity for the weaving segment (C_W) is 3,156 veh/h, calculated using the following formula:

$$C_W = C_{IWL} N f_{HV},$$

where

C_{IWL} : Traffic capacity per lane for weaving segments 1,503 PCU/h/ln
$C_{IFL} - [438.2(1 + VR)^{1.6}] + [0.0765L_S] + [119.8N_{WL}]$
VR : Ratio of segment traffic that is weaving traffic 0.88
L_S : Design distance between noses (260 m / 0.3 = 866 ft) 866 ft
N_{WL} : Lanes in weaving segments 2 lanes
N : Lanes in weaving sections 3 lanes
f_{HV} : Conversion factor for heavy vehicles 0.7
(25.2% heavy vehicle traffic, car conversion factor: 3)

(2) Traffic capacity based on weaving traffic demand

The traffic capacity for the weaving segment (C_W) is 1,909 veh/h, calculated using the following formula:

$$C_W = C_{IW} f_{HV},$$

$$C_{IW} = \frac{2{,}400}{VR} \quad (For\ 2 - lane\ weaving\ segment),$$

where

VR : Ratio of segment traffic that is weaving traffic 0.88

6-6 Discussion of Pavement Configuration

6-6-1 Conditions for Consideration

1) Design conditions

The basic design conditions are described below.

Table 6-6-1. Basic Design Conditions

Item	Selected values	Notes	Source
Road category	I-b	See 6-2-1 Applied Standards and Road Categories above	DBN V.2.3-4 2015
Pavement design period	10 years	Based on values for I-b roads (pavement material: crushed stone mastic asphalt)	DBN V.2.3-4 2015
Design target year	2039	10 years from start of service (2030)	—
Confidence factor $_{н}$	0.95	Based on values for I-b roads	DBN V.2.3-4 2015
Climate category	III	Climate category for road area	DBN V.2.3-4 2015
Drainage condition category	I	Drainage condition category for road area	DBN V.2.3-4 2015
Standard frost penetration depth	60 cm	Standard frost penetration depth for road area	VBN V.2.3-218-186-2004

2) Load conditions

The load conditions for I-b road are as follows.

Table 6-6-2. Load Conditions

Standard axle load kN	Standard wheel load kN	Tire inflation pressure MPa	Tire contact patch diameter (static) m	Tire contact patch diameter (dynamic) m
115	57.5	0.8	0.303	0.345

Source: DBN V.2.3-4 2015

3) Future traffic volume

Future traffic volume for the years starting with the year the road is opened to traffic are as follows. The growth ratio of future traffic volume refer to Table 8-2-7.

Table 6-6-3. Future Traffic Volume

	Year	Passenger vehicles	Buses	Trucks (2-axle)	Trucks (3+ axles)	Trailer trucks	Total
1	2030	16,074	2,265	1,749	146	1,625	21,860
2	2031	16,583	2,311	1,764	150	1,674	22,483
3	2032	17,108	2,358	1,780	155	1,724	23,125
4	2033	17,650	2,406	1,795	159	1,776	23,786
5	2034	18,209	2,455	1,811	164	1,829	24,468
6	2035	18,786	2,505	1,826	169	1,884	25,170
7	2036	19,380	2,556	1,842	174	1,940	25,893
8	2037	19,994	2,608	1,858	179	1,998	26,637
9	2038	20,627	2,662	1,875	185	2,058	27,407
10	2039	21,280	2,716	1,891	190	2,119	28,196

Source: JICA Survey Team

4) Minimum pavement thickness

The minimum pavement thicknesses by pavement type are as follows.

Table 6-6-4. Minimum Pavement Thickness

Pavement type	Maximum dimensions	Minimum pavement thickness
Crushed stone-mastic asphalt mixture	20 mm	5 cm
Hot asphalt mixture (dense-graded)	20 mm	5 cm
Hot asphalt mixture (coarse-graded)	—	10 cm
Cement stabilized base course	40 mm	10 cm
Base course (crusher run)	—	15 cm
Base course (sand)	—	15 cm

Source: DBN V.2.3-4 2015

6-6-2 Pavement Configuration

The proposed pavement configuration for the M14 Bypass is shown below in Table 6-6-5.

Table 6-6-5. Pavement Configuration

Layer	Pavement configuration	Specifications	Layer thickness
1	Surface course (crushed stone-mastic asphalt mixture)	60/90[10]	5 cm

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[10] Penetration grade

2	Intermediate course (hot asphalt mixture)	60/90	8 cm
3	Binder course (hot asphalt mixture)	60/90	10 cm
4	Cement stabilized base course	M40[11]	15 cm
5	Base course (crusher run)	C7[12]	20 cm
6	Base course (sand)	—	25 cm

Source: JICA Survey Team

6-6-3 Pavement Structure

1) Review procedure

The pavement structure for the M14 Bypass pavement configuration described in 6-6-2 Pavement Configuration above was reviewed for compliance with the Ukraine pavement design standards in VBN V.2.3-218-186-2004. The steps in this review follow below.

1. The 3 evaluation indicators for pavement configuration are: 1) elastic deformation of pavement structure, 2) shear stress on the roadbed, and 3) bending tensile stress on bottom surface of asphalt mixture courses.
2. Design target year traffic load is set from the average daily traffic volume by vehicle class to calculate the cumulative design traffic load for the pavement design period (10 years).
3. Using this cumulative design traffic load, the required elastic modulus is calculated for evaluating elastic deformation of the pavement structure.
4. Using the design specifications for the pavement material and a monogram, the elastic modulus ratio (design elastic modulus/required elastic modulus), shear stress ratio (design shear stress/limit dynamic shear stress), and tensile stress ratio (design bending tensile stress/allowable tensile stress) are calculated.
5. Calculations are reiterated until all evaluation standards of elastic modulus ratio, shear stress ratio, and bending tensile stresss ratio are satisfied.

2) Cumulative design traffic load

The traffic loads (Np) for the design target year are as follows.

Table 6-6-6. Traffic Lload for Design Target Year

Vehicle classes	Future average daily traffic volume N	Load equivalence factor[13] Sn	Traffic load N*Sn
Passenger vehicles	21,280	—	—
Buses	2,716	1.11255	3,022
Trucks (2-axle)	1,891	0.03407	64
Trucks (3+ axles)	190	2.26521	430
Trailer trucks	2,119	1.93893	4,109
Total (both directions)			7,625
Traffic load for design target year (Np)	7,625*0.5		3,813

Source: JICA Survey Team

The cumulative design traffic load (ΣN_P) is 4,580,226 as calculated with the following formula:

$$\sum N_P = 0.7 * N_P * \frac{K_C}{q^{(T_d-1)}} * T_P * K_n,$$

where

Np : Traffic load for design target year 3,813 (Listed above)

K_C : Coefficient calculated using: $\frac{q^{T_d-1}}{q-1}$ 11.359

q : Annual growth of traffic volume 1.028

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[11] Crushesd stone for mechanical stabilization (Maximum particle size 40mm)

[12] The class of crushesd stone (Maximum particle size 40mm)

[13] Conversion factor for each vechicle type

T_d	: Design period	10	years
T_P	: Cumulative days per year of residual deformation	130	days
K_n	: Coefficient based on highway class I	1.49	

3) Required elastic modulus

The required elastic modulus for the pavement (E_n) is 341 MPa as calculated with the following formula:

$$E_n = 42.843 * \ln\left(\sum N_p\right) - 315.68$$

4) Design specifications for pavement materials

The design specifications for pavement materials are as follows.

Table 6-6-7. Design Specifications for Pavement Materials

	Design specifications for pavement materials					
	Elastic deformation	Shear resistance	Bending tensile resistance			
	Elastic modulus E (MPa)	Elastic modulus E (MPa)	Elastic modulus E (MPa)	Bending tensile strength R (MPa)	Fatigue modulus m	Modulus of impact of cyclic loading Knp
Crushed stone-mastic asphalt mixture	2,700	1,100	3,700	3.4	6.5	2.9
Hot asphalt mixture	3,200	1,080	4,500	9.8	5.5	4.0
Cement stabilized base course	700	700	-	-	-	-
Base course (crusher run)	240	240	-	-	-	-
Base course (sand)	100	100	-	-	-	-
Roadbed (loam) CBR=6%	60	60	-	-	-	-

Sources: 1) VBN V.2.3-218-186-2004
2) Handbook of Design Characteristics of Soils and Materials for Road Pavement 2017

5) Evaluation criteria for pavement configuration

The coefficients and reference values for pavement configuration are as follows.

Table 6-6-8. Evaluation Criteria for Pavement Structure (for Class I-b Road with Confidence Level 0.95)

Coefficients	Elastic deformation of pavement structure	Shear stress on roadbed	Bending tensile stress on bottom surface of asphalt mixture courses
	Elastic modulus ratio	Shear stress ratio	Bending tensile stress ratio
Reference value	1.43	1.48	1.35

Source: VBN V.2.3-218-186-2004

6) Evaluation of pavement composition

- Results for the proposed pavement composition exceeded all 3 evaluation indicators.
- As the total pavement thickness of 83 cm exceeds the standard frost penetration depth of 60 cm, no special frost measures appear to be necessary at this time.
- As evaluated using Japanese pavement design methods, at 40.25, the design equivalence conversion factor of the pavement composition surpasses the required equivalence conversion factor of 37.07 (incremented for design load consideration).

(1) Elastic deformation of pavement composition

- Design elastic modulus: 648 MPa
- Required elastic modulus: 341 MPa

- Elastic modulus ratio: 1.90
- Reference: 1.43 < 1.90 (exceeds the reference value)

(2) Shear stress on roadbed

- Design shear stress: 0.01184 MPa
- Limit dynamic shear stress: 0.01834 MPa
- Shear stress ratio: 1.55
- Reference: 1.48 < 1.55 (exceeds the reference value)

(3) Bending tensile stress on bottom surface of asphalt mixture courses

- Design bending tensile stress: 0.8020 MPa
- Allowable bending tensile stress: 1.7360 MPa
- Bending tensile stress ratio: 2.16
- Reference: 1.35 < 2.16 (exceeds the reference value)

6-7 Other ancillary facilities

1) Service roads

- If any existing facilities or farmland is made inaccessible due to construction of the route or interchanges, servise roads (Class IV or equivalent) will be considered to restore access.

2) Street lighting

- In order to improve visibility for the merging and diverging vehicles at the interchanges, it is recommended to install street lighting from the start of the deceleration lane to the end of the acceleration lane.
- Street lighting is also recommended on the interchange ramp roads.
- Because Mykolaiv Bridge is constantly exposed to wind, there is a risk that lighting equipment will be toppled by wind during storms if typical pole-type lighting equipment is installed. There are also maintenance issues to be considered, such as the need for high-elevation work to perform regular maintenance. To address these concerns, it is recommended that low-position lighting, which offers easier maintenance and is effective in providing visual guidance, be used.
  In addition, lighting that could be mistaken for navigation light is prohibited to construct in approach surface by Japanese aviation laws and low-position lighting is usually constructed instead. Since Mykolaiv Bridge is located near Mykolaiv airport, it is important to take it into consideration.

3) Protective barrier

- In accordance with DBN V.2.3-4 2015, protective barriers are to be installed at the edge of shoulders on sections at embankment heights of 2 m or higher.

4) Noise barrier

- In order to satisfy the environmental standards of Ukraine, sound barriers will be installed the verges located outside of the edge of outer shouleder in sections that run close to residential areas. This survey will determine the installation scope using Figures 5-5-2 and 5-5-3 as points of reference. At the detailed design stage, the scope of sound barrier installation will be determined based on evaluating the impact of noise while also factoring in the impact of cutting and embankment.

5) Tollplaza

- If tolls are to be collected from traffic crossing the Southern Bug River, the candidate area for installation of tollgates is near the bridge on the left bank.
- The section on the left bank side has a straight plane alignment, a profile gradient of 0.5-2.1%, and embankment height of about 5 m and thus should have no hindering factors.
- Because the terminus interchange extends to the bridge, installation of tollgates on the right bank is not recommended.

Chapter 7 Bridge Plan Review

7-1 Policies for Setting Facility Grades

The bridge grades are set based on the following strategy:

a. Bridge profile gradient and width comply with Ukrainian standards. Measures to be considered include relaxing the profile gradient to account for the cold climate and minimizing bridge width to reduce costs. Note that, given the prospects of communities forming around the bridge, it is equipped with a walkway of sufficient width.
b. In accordance with Japanese standards for bridge durability, the bridge is designed selecting materials and methods to last at least 100 years.
c. In terms of bridge operation and maintenace, the bridge is designed selecting materials and methods for easy maintenance to avoid operation and maintenance cost increase and deferred maintenance.
d. The bridge's design live load is determined by comparing Japanese standards and Ukrainian standards and is adopted heavier one.
e. Given the extreme rarity of earthquakes in this region, there is no need to follow Japanese bridge standards for seismic reinforcement. Ukraine standards is followed instead.
f. For flooding measures, outside of navigable sections, bridge under clearance is higher than the water level for a 100-year flood, accounting for swell height.
g. For navigating vessels, bridge under clearance in navigable sections is at least the navigable water depth and channel height, and span length is at least the channel width with an added margin.

7-2 Consideration of Hydraulic Conditions

This chapter aims to check the hydraulic conditions required for the bridge plans proposed in the 2011F/S by analyzing the updated hydrogical data summarized in Chapter 4.

The table below shows the hydraulic conditions required for bridge plans; descriptions and purposes of hydraulic considerations; and whether surveys include such considerations.

As explained in Chapter 5-5-3 3), the bridge on Route 2 is on a bend in the river at a water colliding front. This means that the bridge pier is not positioned perpendicularly to the river flow. Therefore, the suitability of its hydraulic properties must be included among the hydraulic considerations, as shown in the table below.

Table 7-2-1. Hydraulic Conditions Required for Bridge Plans; Descriptions and Purposes of Hydraulic Considerations; and Inclusion of Considerations in Surveys

Hydraulic conditions required for bridge plans	Purpose	Inclusion of considerations in surveys	
		2011F/S	This Study
Design high water level	Determining vertical bridge clearance, determining locations of effects of outside forces	Yes	Yes
Vertical bridge clearance	Determining location of superstructure	Yes	Yes
Design discharge	Determining flow speed	Yes	Yes
Flow speed	Determining scour depth Determining external forces	Yes	Yes
Scour depth	Determining design ground surface Determining scour protection work	No	Yes
River area blockage rate	Evaluation of impact on water level	No	Yes
Location of bridge construction	Evaluation of impact on river bank	No	Yes
Appropriateness of hydraulic properties	Evaluating impact when erecting a bridge in river conditions that negatively impact flood control safety (narrow stretches, water colliding fronts, confluences, bends, places where flow conditions change, etc.)	No	Yes

*External forces: Vessel impact loads, ice loads

Source: Guidelines for Plans for Bridges that Cross Rivers, Japan Institute of Construction Engineering (JICE), July 2009 modified by JICA Survey Team

The following points are included in considerations of the appropriateness of hydraulic properties.

After two-dimensional (quasi-three-dimensional) analysis of flood water flow and hydraulic model experiments are used to evaluate the impact of bridge piers, the economic efficiency, maintainability, construction work schedule, and impact on the environment and scenery must be considered.

- Are the bridge piers located in areas where the main stream of the river flows quickly?
- Do the bridge piers cause the water level to rise on the river banks?
- Does the construction of the bridge piers create an area where the river flow accelerates?
- Do the areas where the flow accelerates due to bridge piers extend to levees or river banks in shallow areas?
- Does the scale of discharge influence the impact of bridge piers?

On the other hand, according to the rough analysis under this Study which is still the basic plan phase, the flow speed is a maximum of roughly 1.2 m/s even in fast sections on the right bank, and the river is shallower than fast sections near the river banks on the right side. Thus, the points indicated above will not be so critical, howerver futher investigation shall be highly recommended during the course of detailed design stage.

7-2-1 Design Discharge

In general, the design discharge, set at a 1/100-year discharge event, should be calculated based on a statistical analysis of observation data (annual maximums) at the the bridge location. In this Study, however, because of the limitation of the data at the bridge location, JICA Study Team collects the data of the Oleksandrivka (Hydrological Station), which is located about 90 km directly upstream from the bridge location and calcurates the discharge at the bridge location by using the specific discharge at the Oleksandrivka.

The specific discharge is obtained by dividing the discharge by the catchment area. Therefore, the design discharge at the bridge location is calculated by the following formulas.

Specific Discharge = Design Discharge at Oleksandrivka / Catchment Area at Oleksandrivka
Design Discharge at Bridge Location = Specific Discharge x Catchement at Bridge Location

1) Design Discharge at Oleksandrika

The statistical analysis method is used is based on "Technical Criteria for River Works: Practical Guide for Investigation (Ministry of Land, Infrastructure, Transport and Tourism, Japan, Water and Disaster Management Bureau, April 2014)" and "Guidelines for Planning for Small and Medium-Sized Rivers (Commission for Planning for Small and Medium-Sized Rivers, September 1999)."

The following shows the results of calculating discharge recurrence probability (in years) at the Oleksandrivka (Hydrological Station) based on statistical analysis.

Design discharge at Oleksandrivka (1/100-year discharge event) is 3,940 m^3/s

Table 7-2-2.Discharge for Each Recurrence Probability

ecurrence probability (in years)	2	3	5	10	20	30	50	80	100	150	200	400
Discharge (m3/s)	460	685	1,001	1,503	2,101	2,501	3,063	3,640	3,936	4,511	4,950	6,122

LSC (99%): 0.03, Applicable distribution: Logarithmic normal distribution, 2-parameter (Slade I, moment method)

Source: JICA Survey Team

2) Design Discharge at the Bridge Location

Table 7-2-3 shows the calculation results of the discharge at the bridge location.

From the table, the design discharge at the bridge location (1/100-year discharge event) is 4,590 m^3/s ≈ 4,600 m^3/s.

Although the method of calculating design discharge in the 2011F/S is unclear, the same 1/100-year discharge as this Study was used, and the result of 4,500 m^3/s is close, so it was probably calculated using the same method.

Table 7-2-3. Design Discharge at the Bridge Location

River/Station	Catchment Area (km^2)	Length (km)	Design Discharge (m^3/s)		
			1/10	1/50	1/100
Oleksandrivske Water Storage Reservoir	46,200	671	1,510	3,070	3,940
New Mykolaiv Bridge Location	53,810	796	1,760	3,570	4,590
Vavarovsky Bridge Location	63,700	806	2,080	4,230	5,430

Source: JICA Survey Team

7-2-2 Design High Water Level and Vertical Bridge Clearance (excluding Navigation Channel)

The design discharges (1/100-year discharge) is shown in Table 7-2-3. It is generally adopted to consider the design high water level by using one-dimensional non-uniform flow calculations at each station except Oleksandirvske Water Storage Reservoir.

JICA Study Team compares (1) these high water levels above mentioned at each station and (2) historical data at Mykolaiv (Sea Hydro-meteorological Station) for the reassurance of adaptability of preconditions set forth in the preceding paragraph and the comparison reveals (1) is obviously lower. The gap between (1) calculated data and (2) historical data caused by several factors, such as tide, strong breeze and storm surge, raisings by construction of Vavarovsky Bridge, etc (refer to 4-1-3), which is not included as preconditions for (1) calculated data. Thus, just to be on the safe side, the 1/100-year high water level at Mykolaiv (Sea Hydro-meteorological Station) is obtained from the statistical analysis of observation data (annual maximums).

The statistical analysis method is same as one described in 7-2-1.

Vertical bridge clearances, excluding those in navigation channels, are determined as design high water levels plus the freeboard or wind wave heights.

Vertical bridge clearance over the navigation channel, which is equal to the design navigable water level plus the navigation channel clearance height, is also considered separately.

1) Design High Water Level

The following shows calculations results on the water level recurrence probability (in years) according to the statistical analysis.

1/100-year high water level at Mykolaiv (Sea Hydro-meteorological Station) is calculated as BS+0.988 m ≈ BS+1.0 m

Table 7-2-4. Water Levels for Each Recurrence Probability

Recurrence probability (in years)	2	3	5	10	20	30	50	80	100	150	200	400
Water level (BS+m)	0.446	0.515	0.591	0.687	0.779	0.832	0.898	0.959	0.988	1.040	1.076	1.165

SLSC (Standard Least Squares Criterion, 99%): 0.021 / Applicable Distribution: Gumbel

Source: JICA Survey Team

The water levels occurred by design discharge at New Mykolaiv bridge locations are calculated for each route and for the presence and absence of a bridge and are shown in Table 7-2-5.

The start point of calculation is 800m downstream from Vavarovsky Bridge to consider the influence of backwater developed by shrinkage of river width at Vavarovsky Bridge.

Since the gut of the Southern Bug River around the bridge location is on the right bank side, the flow conditions of the left and right bank side differ. Therefore, the river section is divided into two sections.

The table shows that the design high water levels for Route 2 and Route 3 are BS+1.4m and BS+1.5m respectively due to infuluence of backwater developed by shrinkage of river width at Vavarovsky Bridge

Table 7-2-5. Calculations of High Water Level by Route

Route2

Bridge Present/Absent		Absent		Present	
Section		Left Bank Side (Shallow)	Right Bank Side (Deep)	Left Bank Side (Shallow)	Right Bank Side (Deep)
Top Width	(m)	1,045	786	991	771
Average Depth	(m)	3.2	5.0	3.3	5.0
Design High Water Level	(m)	BS+1.4		BS+1.4	
Discharge	(m^3/s)	1,756	2,844	1,667	2,933
Velocity	(m/s)	0.5	0.7	0.5	0.8

※Roughness Factor (Manning's N value) = 0.03

Route3

Bridge Present/Absent		Absent		Present	
Section		Left Bank Side (Shallow)	Right Bank Side (Deep)	Left Bank Side (Shallow)	Right Bank Side (Deep)
Top Width	(m)	1,259	774	1,193	756
Average Depth	(m)	3.2	4.7	3.2	4.7
Design High Water Level	(m)	BS+1.5		BS+1.5	
Discharge	(m^3/s)	1,916	2,684	1,830	2,770
Velocity	(m/s)	0.5	0.7	0.5	0.8

※Roughness Factor (Manning's N value) = 0.03 Source: JICA Survey Team

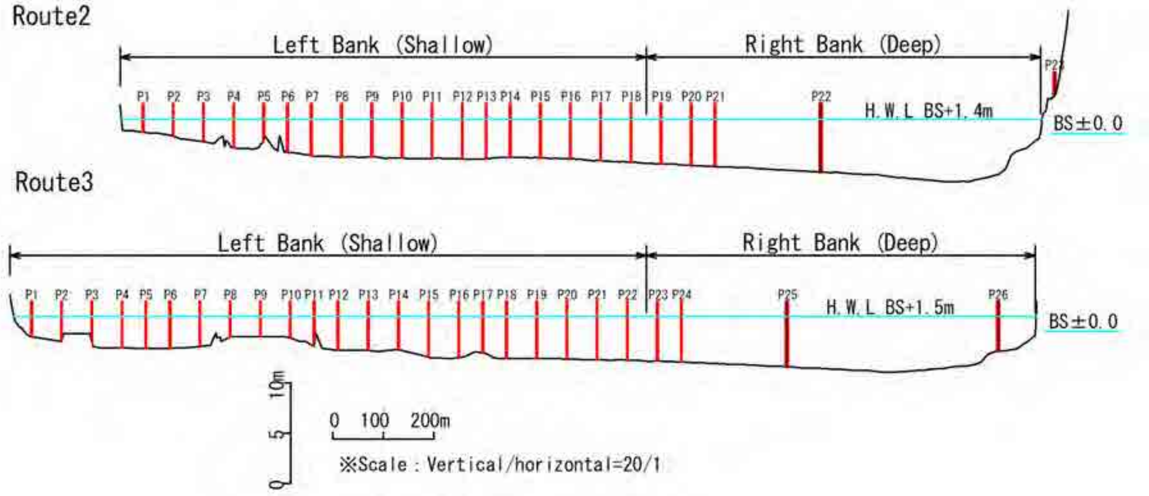


Figure 7-2-1. River Section at Bridge Erection Location

Table 7-2-6. Route 2 Bridge Pier Dimensions

Section	Left Bank Side (Shallow)	Right Bank Side (Deep)	
Pier No.	P1-P18	P19-P21	P22, P23
Length*	3m×4 cylinders＝12m	3m×4 cylinders＝12m	36
Width**	3	3	6

*Length: Length in bridge-axial rectangular direction (m) , **Width: length in bridge-axial direction (m)

Table 7-2-7. Route 3 Bridge Pier Dimensions

Section	Left Bank Side (Shallow)	Right Bank Side(Deep)	
Pier No.	P1～P22	P23,P24	P25, P26
Length*	3m×4 cylinders＝12m	3m×4 cylinders＝12m	36
Width**	3	3	6

*Length: Length in bridge-axial rectangular direction (m) , **Width: length in bridge-axial direction (m)

2) Vertical Bridge Clearance (excluding navigation channel)

On normal rivers, vertical bridge clearance (minimum height of bottom of girder) must exceed clearance for design high water levels with freeboard added. However, the bridge location in this case is in an area where the river is wide, and in an environment where wind waves develop; therefore, the wind wave level must be added to the design high water level and considered, and the higher of the two values must be selected for the vertical bridge clearance. As the Southern Bug River may encounter accumulations of drifting ice, freeboard is 1.0 m in accordance with the standard in Ukraine (DBN V.2.3-22:2009 Bridges and Pipes, General Requirements for Design). Therefore, the vertical bridge clearances (minimum heights of bottom of girder) for Route 2 and Route 3 are set as BS+1.4 m+1.0 m = BS+2.4 m and BS+1.5m+1.0m = BS+2.5m respectively.

On the other hand, according to the calculations below, the wind waves are 1.5 m high, and the vertical bridge clearances (minimum heights of bottom of girder) for Route 2 and Route 3 are reset as BS+1.4 m+1.5 m = BS+2.9 m and BS+1.5m+1.5m = BS+3.0m respectively.

For reference, the design high water level of BS+1.58m including afflux by wind plus the freeboard of 1.40m was proposed, therefore vertical bridge clearance (mimimum height of bottom of girder) became BS+3.0m in the 2011F/S.

Note that the vertical bridge clearance determined here is the minimum requirement and may differ from the value actually used in plans for the bridge and road.

It is recommended to investigate futher about the relationships between discharge, water level and wind speed during the course of detailed design stage. Because the possibility of coincidence of 1/100-year discharge ,1/100-year high water level, and maximum historic wind speed can be happened theoretically however chance of such occurence is considered relatively very low; and vertical bridge clearance may be lowered.

Additional sounding surveying from Vavalofsky Bridge through Mykolaiv Sea Hydro-meteorological Station to the downstream end of this Study’s sounding surveying area is also recommended for accuracy improvements of the calculated high water levels.

Two-dimensional (quasi-three-dimensional) analysis is recommended to evaluate the infuluence of backwater and the impact of bridge piers.

[Calculations of Height of Wind Waves]

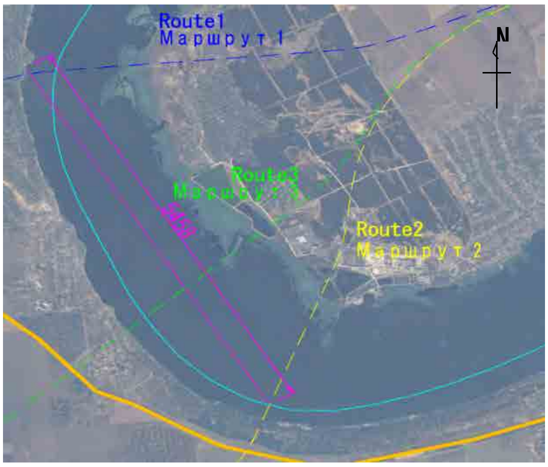
According to the following calculations, wind waves are 1.5 m high.

Items	Value				Remarks
Peak instantaneous wind gust	Ug	:	40	m/s	(maximum historic value in observation period: 1927-2017)
Peak wind gust	U	:	27	m/s	(Ug/1.5)
Fetch length	x	:	6	km	(From Figure7-2-2)
Water depth	D	:	3	m	
	gx/U^2	:	81		
	gD/U^2	:	0.04		
	gH/U^2	:	0.0129		(According to the following formula)
Significant wave height	H	:	0.96	m	
1/100-year maximum wave height	H1%	:	1.63	m	(H×1.7)
H1% of maximum wave height	h	:	1.22	m	(H1%×0.75)
Freeboard	FB	:	0.25	m	(From DBN V.2.3-22:2009)
Wind wave height	WL	:	1.5	m	(h+FB)

$$\frac{gH}{U^2} = \alpha \tanh\left[k_3\left(\frac{gD}{U^2}\right)^{3/4}\right] \cdot \tanh\left[\frac{k_1\left(\frac{gx}{U^2}\right)^{1/2}}{\tanh k_3\left(\frac{gD}{U^2}\right)^{3/4}}\right]$$

$$\alpha=0.26\ ,\ k_1=10^{-2}\ ,\ k_3=0.578$$

Source: Calculation of Figures for Wind Waves in Shallow Seas, Proceedings from the 12th Coastal Engineering Committee Seminar (1965)



Because strong winds blow from the northwest, distance is measured where it is longest near the center of the river channel in the North to West range.

Figure 7-2-2. Rationale Diagram for Fetch Length

7-2-3 Flow Speed

Flow speeds at bridge locations are calculated for each route and for the presence and absence of a bridge using one-dimensional steady flow calculations.

As mentioned in 4-1-3 1), the water level at the bridge location varies with floods as well as other factors. As the water level gets higher, the flow speed gets slower. Thus, the flow speed is the slowest at the design high-water level.

Since the objective of calculating the flow speed here is to calculate the scour depth, faster flow speed would be assumed to be on the safe side. In calculating the flow speed, the water level of the downstream end of the calculated area was obtained by an uniform flow calculation with the mean slope of the riverbed (≒0.00022 or 1/4,545) in the calculated area. This water level is the highest water level when there are no influences other than floods.

Since the gut of the Southern Bug River around the bridge location is on the right bank side, the flow conditions of the left and right bank side differ. Therefore, the river section is divided into two sections.

The table below shows the calculation results at the design discharge (1/100-year discharge of 4,600 m^3/s).

Table 7-2-8. Calculations of Flow Speed by Route

Route2

Bridge Present/Absent	Absent		Present	
Section	Left Bank Side (Shallow)	Right Bank Side (Deep)	Left Bank Side (Shallow)	Right Bank Side (Deep)
Top Width (m)	981	783	928	768
Average Depth (m)	2.1	3.8	2.1	3.8
Water Level (m)	BS+0.1		BS+0.1	
Discharge (m^3/s)	1,511	3,089	1,447	3,153
Velocity (m/s)	0.8	1.1	0.8	1.2

※Roughness Factor (Manning's N value) = 0.03

Route3

Bridge Present/Absent	Absent		Present	
Section	Left Bank Side (Shallow)	Right Bank Side (Deep)	Left Bank Side (Shallow)	Right Bank Side (Deep)
Top Width (m)	1,243	773	1,180	755
Average Depth (m)	2.1	3.6	2.1	3.6
Water Level (m)	BS+0.3		BS+0.3	
Discharge (m^3/s)	1,721	2,879	1,661	2,939
Velocity (m/s)	0.7	1.1	0.7	1.1

※Roughness Factor (Manning's N value) = 0.03

Source: JICA Survey Team

7-2-4 Scour Depth and Scour Protection Work

The scour depth and specifications (diameter and range) of the riprap required for the scour protection work are calculated for the locations of the bridge piers for each route.

According to the results of geological surveys, the riverbed material is clayey silt; therefore, the scour depth is calculated with "NCHRP REPORT516 Pier and Contraction Scour in Cohesive Soils (Transportation Reseach Board, 2004)." The specifications of the riprap are determined based on "Bridge Scour (Water Resources Publications LLC, 2000)".

The river is divided into two sections for calculation, as with the flow speed.

The table below shows the calculation results at the design discharge (1/100-year discharge of 4,600 m^3/s).

Scour protection work is required for the piers of the cable-stayed bridge to prevent further scouring, as the scour depth exceeds the embedment of the footings.

On the other hand, the piers of the approach bridge are single pile bents, and thus do not have footings. In addition, due to the soft ground (N = 0) comprising the stratum of the riverbed, the design ground surface is deeper than the range (depth) in which scour occurs. Therefore, scour prevention work is not required for the piers of the approach bridges.

Riprap should be used for the scour protection work for the piers of the cable-stayed bridge. The range of scour protection work for both Routes 2 and 3 should be twice the width of the piers in all directions around the piers, and the thickness should be three times the diameter of the riprap.

Note that the depth sounding revealed that the contraction of the Vavarovsky Bridge resulted in a scour of roughly 0.5 m; hence, no major localized scouring is occurring there. It is therefore estimated that these calculation results are safer than the actual conditions.

Table 7-2-9. Results of Scour Depth Calculations by Route

Route		Route2		Route3	
Section		Left Bank Side (Shallow)	Right Bank Side (Deep)	Left Bank Side (Shallow)	Right Bank Side Deep
Pier Width	(m)	3	6	3	6
Pier Length	(m)	12	36	12	36
Attack Angle	(°)	Max: 35 Average: 27 Modified*: 12	5	0	0
Pier Projection Width	(m)	Max: 9.4 Average: 8.2 Modified*: 5.5	9.2	3	6
Mean Grain Size	(mm)	0.005	0.005	0.005	0.005
Average Depth	(m)	2.1	3.8	2.1	3.6
Velocity	(m/s)	0.8	1.2	0.7	1.1
Contruction Scour	(m)	0.9	1.8	0.8	1.6
Pier Scour	(m)	Max: 3.4 Ave: 3.1 Modified*: 2.4	3.8	1.5	2.8
Total Scour	(m)	Max: 4.3 Ave: 4.0 Modified*: 3.3	5.6	2.3	4.4
Required Riprap Size	(m)	0.10	0.20	0.10	0.20

*: The value when the direction of the approach bridge piers is skewed by 15 degrees from perpendicular to the longitudinal axis of the bridge.

Source: JICA Survey Team

7-2-5 River Area Blockage Rate

The river area blockage rate is the proportion of the width of the river area occupied by the total width of all bridge piers at the design high water level. The Japanese River Construction Ordinance sets out a target value of 5% or lower as standard, and 7% or lower for special cases such as expressways and/or bullet train.

The table below shows the river area blockage rates for each route.

As shown in the table, the original pier layout plan for route 2 exceeds the above target value of 7% for the expressway case. Therefore, the modified pier layout plan shall be applied to meet the above target value by skewing the approach bridge piers 15 degrees from perpendicular to the longitudinal axis of the bridge in order to align the pier direction with the river flow direction as much as possible.

Table 7-2-10. River Area Blockage Rates

Route		River Area Blockage Rate
Route 2	Original	(21 x 8.2 + 9.2) / 1,831 x 100 = 9.9%
	Modified*	(21 x 5.5 + 9.2) / 1,831 x 100 = 6.8%
Route 3		(24 x 3.0+ 2 x 6.0) / 2,033 x 100 = 4.1%

*: The value when the direction of the approach bridge piers is skewed by 15 degrees from perpendicular to the longitudinal axis of the bridge.

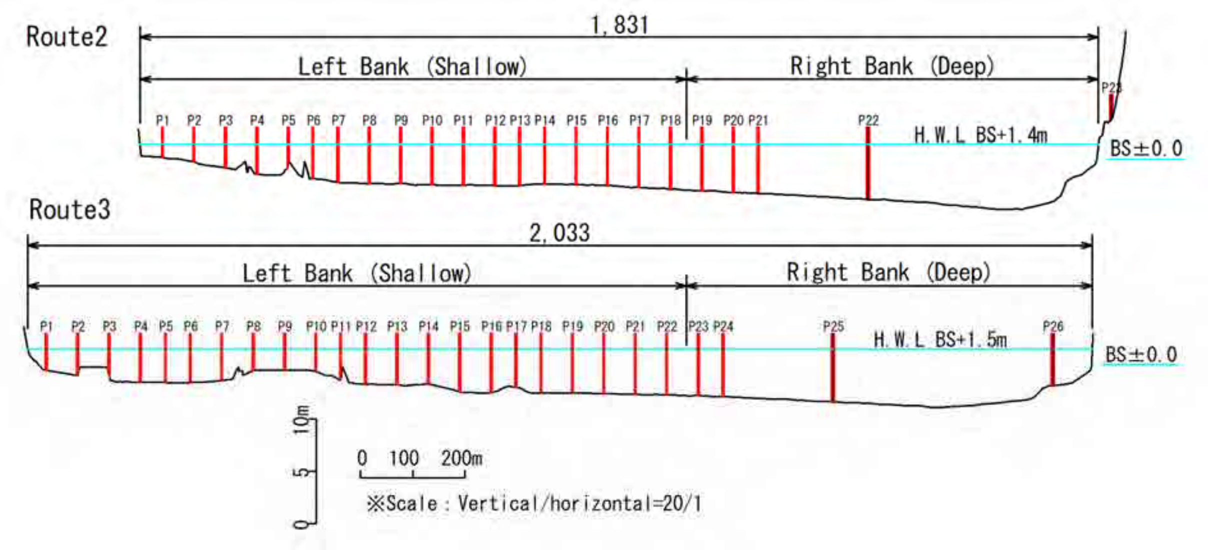


Figure 7-2-3. Basis for Calculations of River Area Blockage Rates

For reference, the flow areas at Vavarovsky Bridge and Mykolaiv Bridge are shown in the table below.

The flow area at Mykolaiv Bridge is approximatly 1.7 times larger than the flow area at Vavarovsky Bridge.

Note that the values in the table represent when the discharge is set at the design discharge and the water level at the design high-water level.

Table 7-2-11. Comparison of Flow Areas

Name of Bridge	Design High Water Level (m)	Design Discharge (m^3/s)	Velocity (m/s)	Average Depth (m)	Top Width*1 (m)	Flow Area*2 (m^2)	Area Ratio	Bed Slope	Distance (km)
Vavarovsky Bridge	BS+0.9	5,430	1.3	6.9	597	4,112	1.00	0.00026 (1/3,846)	0.0
Mykolaiv Bridge (Route 2)	BS+1.4	4,600	0.7	4.0	1,762	7,063	1.72	0.00022 (1/4,545)	10.9
Mykolaiv Bridge (Route 3)	BS+1.5	4,600	0.6	3.8	1,949	7,301	1.78	0.00022 (1/4,545)	12.9

※Roughness Factor (Manning's N value) = 0.03

*1:width of piers is excluded

*2:Area of piers is excluded

7-2-6 Location of Bridge Pier

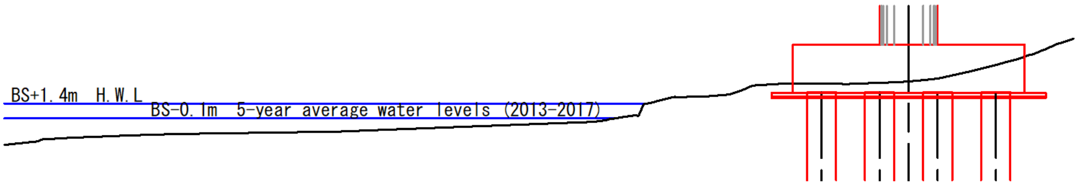
The Ukrainian standards do not specify a required distance between a pier and the top of a river bank. However, a river bank becomes more susceptible to scouring if a pier is located close to the top of a river bank. Thus, it is necessary to secure a safe distance between them against scouring.

The Japanese Cabinet Order Concerning Structural Standards for River Management Facilities, etc. requires that bridge piers be located at least 10 m from the tops of river banks.

As shown in the figure below, the right bank bridge pier for Route 2 is outside the river, and the corresponding pier for Route 3 is at least 10 m from the top of the river bank.

Therefore, both routes meet the requirement.

Route2



Route3

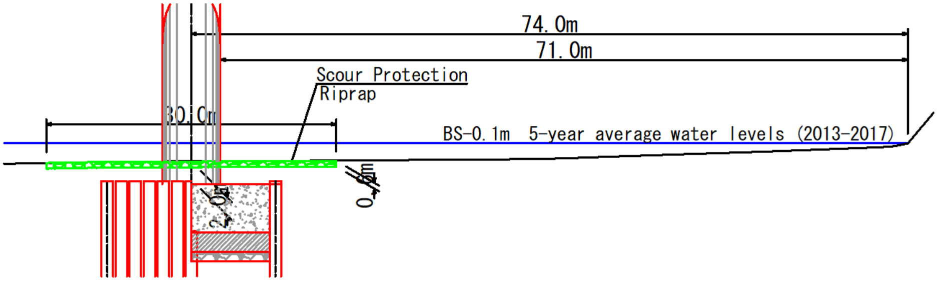


Figure 7-2-4. Positional Relationship of Bridge Piers and River Bank

7-2-7 River Bank Control Work

As explained previously, the flow speed is a maximum of roughly 1.2 m/s even in fast sections on the right bank side.

On the other hand, according to the “Guidelines for the Structural Study of River Embankments (Japan Institute of Construction Engineering, Feburuary 2012),” vegetation can withstand speeds of up to 2 m/s. Thus, river bank control work is unlikely to be necessary for major protection against floods.

However, the impacts of wind waves and the like are causing progressive erosion on the river banks of both Routes 2 and 3. In general, erosion may become a factor leading to landslides. With regard to the situation, the riprap is selected as river bank control work.

The table below shows the diameter of the riprap and range of river bank control work.

Table 7-2-12. Riprap Diameter and Range of River Bank Control Work

River Bank Control Location	Riprap Diameter	Embankment Height	Range
Right bank	0.5m	The lower of the existing river bank height or BS+3.0 m	The maximum envisioned slide range from Chapter 9 +20 m (extended 10 m on each side)
Left bank	0.5m	Embankment crown height	Superstructure width +20 m (extended 10 m on each side)

7-3 Navigation Clearance

The navigation clearance proposed in the 2011F/S is based on the “Clearances of Navigable Bridge Spans in The Inland Water Ways Norms and Technical Requirements DSTU B.2.3-1-95” (shown below).

Table 7-3-1. Conditions related to Navigation Clearance in the 2011F/S

Type	Value	Notes
Navigation vessels	Width: 21 m Length: 180 m	Waterway Class*: State (1)
Channel width	240 m	Waterway Class*: State (1) Letter of approval received from Ukrainian Water Ways
Channel height	13.5 m	Waterway Class*: State (1)
Design navigation water level	BS+0.78m	Basis for calculation unclear
Minimum Required Span length	510 m	Proposed based on a comprehensive judgment of the width required for construction, position of anchorage on the right bank, and comparison of side spans
Additional width	120 m	Proposed based on the width required for construction

*: The classification of waterway classes is shown in Table 7-2-4 and Table 7-2-5.

To re-calculate the navigation clearance, this Study adopts the same standards as the 2011F/S. However, because of the different design of the bridge plan, etc., the span length and additional width are planned based on the designs and past records of cable-stayed bridges in Japan, respectively.

7-3-1 Navigation Vessels

To clarify the latest situation of the navigation vessels, the JICA Survey Team interviewed Nibulon Ltd. (hereinafter referred to as “Nibulon”). According to Mykolaiv City, Delta-Lotsman which is a branch of state company "Ukrainian Sea Ports Authority", and the others, currently Nibulon is the only company that regularly has large vessels traveling from the Port of Mykolaiv on the Southern Bug River.

Now Nibulon owns several terminals, such as the River Terminal in Nova Odesa and Voznesensk, and is mainly engaged in transporting grain via pusher barge. In addition, the company began providing passenger transport via hydrofoil in 2017. The table below shows the company’s 2018 figures for the service.

Table 7-3-2. Hydrofoil Vessel Operation Figures

Day of Week	Origin and Destination		
Friday	Mykolaiv	--->	Voznesensk
Saturday* & Sunday*	Mykolaiv	<--->	Voznesensk
Monday	Mykolaiv	<---	Voznesensk

Duration：May 18 ~ September 15

* The hydrofoil vessel makes two round trips daily on Saturday and Sunday.

Figure 7-3-1 and Table 7-3-3 show the specifications and navigation clearance required for pusher barges obtained from interviews with Nibulon.

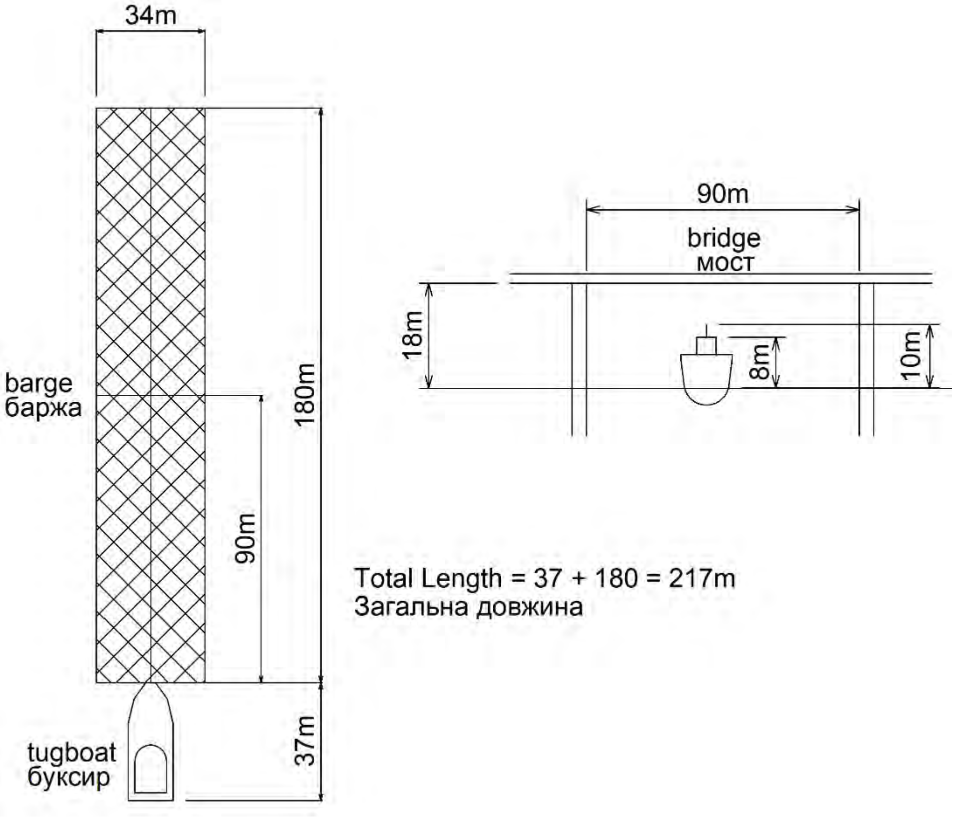


Figure 7-3-1. Pusher Barge Specifications & Required Navigation Clearance

Table 7-3-3. Vessel Specifications & Required Navigation Clearance

Type		Barge	Hydrofoil
Length (LOA)	(m)	217	28
Width	(m)	34	6
Weight (DWT)	(t)	12,000	-
Maximum Draft	(m)	3.56	2.0
Speed	(km/hour) (Knot)	7.4 4.0	65 35
Frequency	(round trips)	125[*1]	105[*2]
Required Navigation Clearance			
Height	(m)	18[*3]	-
Width	(m)	90	-

*1: Total for the nine month period from March to November
*2: 2018 actual figures (18 May - 15 September)
*3: Nibulon’s desired values in consideration of future cargo use

7-3-2 Navigation Width and Height

The 2011F/S explains that the navigation width and height are 240 m (dual channel, 120 m each) and 13.5 m, respectively, because the maximum dimensions of vessels in the 2011F/S correspond to category “3. State (1)” under the local rule in Ukraine, as shown in Table 7-3-5.

However, the maximum dimensions (width/length) of Nibulon's vessels are 34/217, which should correspond to category "2. Cross-State (2)" as determined by the Designed Width/Length of Fleet shown in Table 7-3-4.

Therefore, the larger value is adopted to be on the safe side, resulting in a navigation width of 140 × 2=280 m (dual channel), and navigation height of 15.0 m, as shown in "2. Cross-State (2)" of Table 7-3-5.

Table 7-3-4. Main Characteristics of Navigation Clearance and Cargo Fleet

Unit: Meters

Waterway (Stretches) Class	Long Term Navigable Pass Depth		Designed Width/Length of Fleet		Designed Free Board Height
	Controlling	Average Navigation	Ship	Float	
1. Cross-State(1)	Over 3.2	Over 3.4	36/220 or 29/280	110/830 or 75/950	15.2
2. Cross-State(2)	Over 2.5 to 3.2	Over 2.9 to 3.4	36/220	75/950	13.7
3. State(1)	Over 1.9 to 2.5	Over 2.3 to 2.9	21/180	75/680	12.8
4. State(2)	Over 1.5 to 1.9	Over 1.7 to 2.3	16/160	50/590	10.4
5. Local(1)	Over 1.1 to 1.5	Over 1.3 to 1.7	16/160	50 /590	9.6
6. Local(2)	Over 0.7 to 1.1	Over 0.9 to 1.3	14/140	30/470	9.0
7. Local(3)	0.7 and Less	From 0.6 to 0.9	10/100	20/300	6.6

Source: DSTU B V.2.3-1-95

Table 7-3-5. Bridge Clearance for Navigable Bridge Spans

Unit: Meters

Waterway (Stretches) Class	Height of Bridge Clearance h, min	Width of Bridge Clearance B, min for a Span	
		Non-Movable	Movable
1. Cross-State (1)	17.0	140	60
2. Cross-State (2)	15.0	140	60
3. State (1)	13.5	120	50
4. State (2)	12.0	120	40
5. Local (1)	10.5	100/60	30
6. Local (2)	9.5	60/40	-
7. Local (3)	7.0	40/30	-

* Following article should be described in the ‘4.9, DSTU B V.2.3-1-95’.

"Non-movable bridges should have, as a rule, at least two courses of waterways...."

Source: DSTU B V.2.3-1-95

7-3-3 Design Navigable Water Level and Vertical Bridge Clearance (Navigation Channel)

The design navigable water level is a navigable water level with an occurrence probability of 3%. It is calculated based on a statistical analysis of annual navigable water level data. BS+0.78m was proposed as the design navigable water level in the 2011F/S. Unfortunately, however, the calculation methods are unclear in 2011F/S so that JICA Study Team re-caluculates as mentions below to verify the proposal of 2011 F/S (BS+0.78m) by mentions below in this Study.

1) Days of Continuous Water Level

Days of continuous water level is calculated based on the formula below.

$t = K \times T / 100$,

where t : Days of continuous water level (in days)

K : Allowable reduction factor (6 in the case of '2. Cross-state (2))

T : Annual navigable days (in days)

Because of the river freezes from December to February, the 9 months annual naivigable days from March to November are adopted. It seems appropriate because Nibulon’s navigation period is the same. The year-round navigable days are also considered for reference.

2) Annual Navigable Water Levels

Annual navigable water levels is the maximum water levels among those that can be maintained for “t” days each year. It is calculated as shown below.

(1) Calculate the lowest water level for “t” consecutive days. The number of the water levels are T-t+1 items per year.

(2) The maximum water level among T-t+1 items is set as that year's navigable water level.

(3) Calculate the navigable water level for years with observation data.

Although daily water level data is required to calculate annual navigable water levels, this data has only been compiled since 2000. Therefore, only data for the 18 years of 2000-2017 is used for this Study. Calculation results are shown in Table 7-3-6.

The table shows that the navigable water level using the 9-month annual navigable days from March to November and that using the year-round navigable days. As shown in the table, the former is higher value than the latter and is thus on the safe side.

Table 7-3-6. Annual Navigable Water Levels

Annual Navigable Days (in days)	T	365	270
Allowable Reduction Factor	K	6	6
Days of Maintained Water Level (in days)	t	22	16
Annual Navigable Water Levels (m)	Year	BS+m	BS+m
	2000	-0.04	-0.04
	2001	0.01	0.02
	2002	-0.09	-0.09
	2003	-0.11	-0.11
	2004	0.03	0.03
	2005	0.13	0.13
	2006	0.08	0.11
	2007	-0.04	-0.01
	2008	0.00	0.02
	2009	0.00	0.00
	2010	0.15	0.15
	2011	-0.02	0.00
	2012	0.03	0.08
	2013	0.21	0.21
	2014	0.05	0.05
	2015	-0.02	0.02
	2016	0.09	0.11
	2017	-0.02	-0.02

3) Design Navigable Water Level

The design navigable water level is the water level with an occurrence probability Pd%. Pd in the case of "2. Cross-State (2)" is defined as 3%.

Based on the calculation results on the occurrence probability based on statistical analysis, the navigable water level (design navigable water level) corresponding to an occurrence probability of 3% is BS+0.237 ≈ BS+0.24 m.

Table 7-3-7. Navigable Water Level for each Occurrence Probability

Probability (%)	50	33.333	20	10	5	3.333	3	2	1.25	1
Water Level (BS+m)	0.022	0.059	0.1	0.152	0.201	0.23	0.237	0.266	0.298	0.314

SLSC (99%): 0.035 / Applicable distribution: Gumbel

However, given that (i) this water level is lower than the average annual maximum water levels (BS+0.45 m) of 1945-2017, (ii) data covers only 18 years of 2000-2017, and (iii) the high water level period of 1965-1985 is not taken into account, the obtained navigable water level is not a safe figure to rely on.

Therefore, navigable water level is calculated using the maximum water levels of 1965-2017 as described below.

(1) Calculate occurrence probability by conducting statistical analysis on the maximum water levels of 1965-2017.
(2) Calculate the maximum water level (Hmax3%) corresponding to a probability of 3%.
(3) Calculate the difference between maximum water level and navigable water level by year (⊿h) for 2007-2017.
(4) Hmax3% minus ⊿h is used as the design navigable water level.

The relationship between the occurrence probability and maximum water level is shown in the table below.

From the table, the maximum water level (Hmax3%) corresponding to an occurrence probability of 3% is BS+0.846 m ≈ BS+0.85 m.

Table 7-3-8. Maximum Water Level for each Occurrence Probability

Probability (%)	50	33.333	20	10	5	3.333	3	2	1.25	1
Water Level (BS+m)	0.446	0.515	0.591	0.687	0.779	0.832	0.846	0.898	0.959	0.988

SLSC(99%): 0.022 / Applicable distribution: Gumbel

On the other hand, the table below shows that the difference between maximum water level and navigable water level (⊿h) by year for 2007-2017 is at least 0.29 m.

Table 7-3-9. Difference between the Maximum Water Level and Navigable Water Level

Annual navigable days (in days)	T	270	Annual Maximum Water Level	Difference
Factor	K	6		
Days of maintained water level (in days)	t	16		
Navigable water level by year (m)	Year	BS+m		
	2000	-0.04	0.50	0.54
	2001	0.02	0.31	0.29
	2002	-0.09	0.27	0.36
	2003	-0.11	0.34	0.45
	2004	0.03	0.43	0.40
	2005	0.13	0.54	0.41
	2006	0.11	0.43	0.32
	2007	-0.01	0.46	0.47
	2008	0.02	0.57	0.55
	2009	0.00	0.42	0.42
	2010	0.15	0.60	0.45
	2011	0.00	0.35	0.35
	2012	0.08	0.65	0.57
	2013	0.21	0.56	0.35
	2014	0.05	0.40	0.35
	2015	0.02	0.56	0.54
	2016	0.11	0.44	0.33
	2017	-0.02	0.46	0.48
		Smallest difference:		0.29

Based on the situation above, the design navigable water level is calculated to BS+0.85-0.29 m =0.56 ≈ BS+0.6 m. Based on this result, BS+0.8 m, which is proposed in 2011F/S, meets the requirement in this Study or stays on more safe side. Therefore, the BS+0.8 m value proposed in the 2011F/S has been adopted in this Study.

In addition, Considering above mentioned, the required vertical clearance is BS+0.80 m +15.0 m = BS+15.8 m. Note that the vertical bridge clearance determined here is the minimum requirement, and may differ from the value actually used in plans for the bridge and road.

7-3-4 Minimum Required Span Length and Additional Width

This section considers the minimum required span length as determined by the navigation channel width and additional width.

No international standards or regulations under the local laws and rules of Ukraine specify a minimum span length or additional width. For this Study, therefore, the minimum required span length and additional width are calculated based on past records of cable-stayed bridges in Japan as an alternative. The “domestic cable-stayed bridges with spans of 300 m or more” are selected from the database provided by the Japan Bridge Association Inc.

Table 7-3-10 shows the relationship between the channel width and span lengths of cable-stayed bridges in Japan.

The average ratio between the channel width and span length is calculated from 15 of the bridges (excluding the Maizuru Crane Bridge and Ikina Bridge) shown in the table.

As a result, the minimum required span length is 1.5 times the channel width (280 m x 1.5 = 420 m). Accordingly, the additional width for a single channel is the channel width divided in half, and then in half again (280 m x 0.5/2 = 70 m).

Note that this is for setting the necessary additional width in a straight line; this substantial additional width is insufficient for Route 2, since its bridging position is in a river bend section and vessels do not traverse the bridge at a 90° angle to the bridge. Specifically, this reduces the clearance from 70 m to 64 m as shown in the figure below; each side is lacking 6 m of additional width.

However, when factoring in 'average value - standard deviation', the 'span length/the channel width' is about 1.2. This means that an additional width (single channel) of up to 30 m should be acceptable.

Therefore, the additional width for the river bend section of Route 2 is provisionally set identical to the 70-m width on the river side of Route 3 (a straight section).

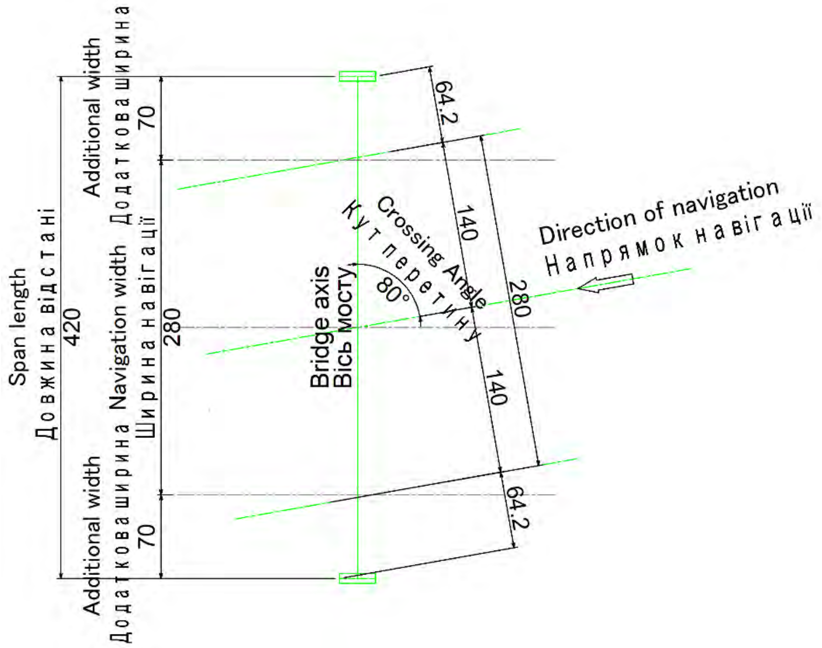


Figure 7-3-2. Relationship between Navigation Direction and Bridge Axis Orientation

Table 7-3-10. Span Length and Clearance Figures for Cable-Stayed Bridges in Japan

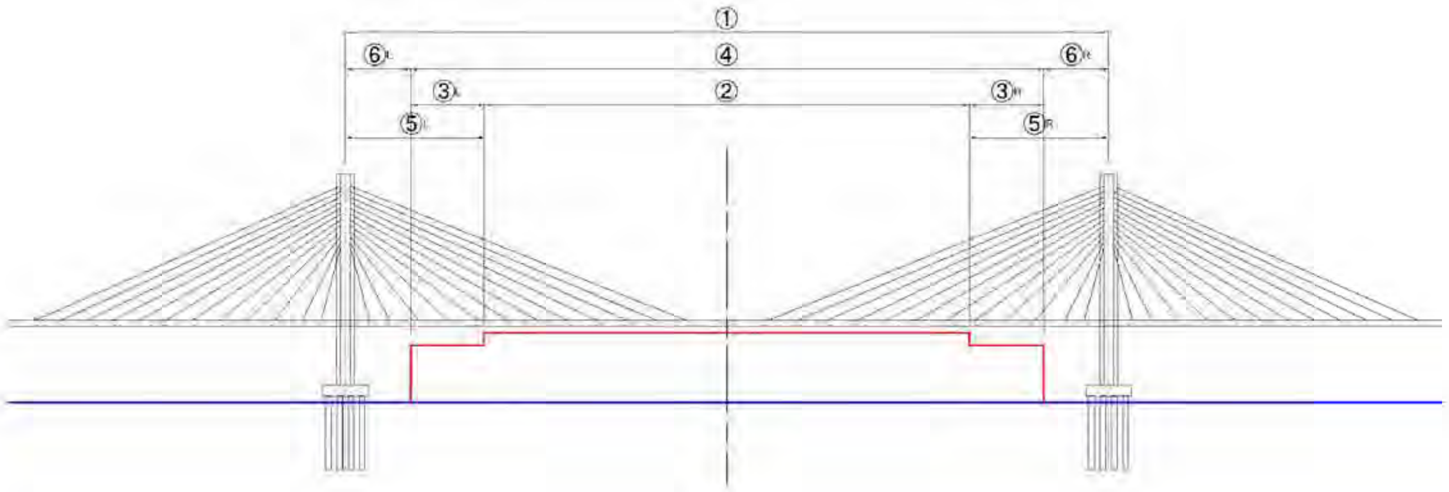
Past Record of Cable-Stayed Bridges in Japan

Bridges are domestic cable-stayed bridges with a span length of at least 300m, which were extracted from the Japan Bridge Association database.

			①	②	③	④	⑤	⑥	⑦	⑧	
No	Data No	Bridge Name	Span Length	Main Navigation Channel Width	Secondary Navigation Channel Width $③_L+③_R$	Navigation Channel Width ②+③	Additional width 1 ①-②	Additional width 2 ①-④	Ratio 1 ①/②	Ratio 2 ①/④	Barrier※
1	1	Tatara Bridge	890	680	-	-	210	-	1.309	-	-
2	2	Meiko Chuo Bridge	590	300	190	490	290	100	1.967	1.204	present
3	3	Tsurumi Tsubasa Bridge	510	300	150	450	210	60	1.700	1.133	absent
4	4	Ikuchi Bridge	490	280	-	-	210	-	1.750	-	-
5	5	Higashi Kobe Bridge	485	455	0	455	30	30	1.066	1.066	absent
6	6	Megami Bridge	480	375	0	375	105	105	1.280	1.280	absent river side outside river
7	7	Yokohama Bay Bridge	460	270	130	400	190	60	1.704	1.150	absent
8	8	Iwakurojima Bridge	420	260	-	-	160	-	1.615	-	-
9	9	Hitsuichijima Bridge	420	185	-	-	235	-	2.270	-	-
10	10	Meiko Higashi Bridge	410	340	0	340	70	70	1.206	1.206	present
11	11	Meiko Nishi Bridge	405	270	70	340	135	65	1.500	1.191	present
12	12	Takashima Hizen Bridge	400	240	0	240	160	160	1.667	1.667	absent
13	13	Shin-Minato Bridge	360	270	0	270	90	90	1.333	1.333	absent
14		Yamato River	355	unclear	-	-	-	-	-	-	-
15	14	Oshima Bridge	350	320	0	320	30	30	1.094	1.094	absent
16	15	Maizuru Crane Bridge	350	100	0	100	250	250	3.500	3.500	absent
17	16	Ajikawa Bridge	350	190	50	240	160	110	1.842	1.458	absent river side outside river
18		Ishikario Bridge	340	unclear	-	-	-	-	-	-	-
19	17	Ikina Bridge	315	100	0	100	215	215	3.15	3.15	absent
Average							162	103	1.762	1.572	
				Excluding the Maizuru Crane Bridge and the Ikina Bridge			152	80	1.554	1.253	
Standard Deviation							74	65	0.652	0.767	
				Excluding the Maizuru Crane Bridge and the Ikina Bridge			73	36	0.329	0.169	

※ : Bridge piers are independently constructed, presence/absence of items in navigation channel. Judge based on photo.

Average value for Ratio 1, excluding the Maizuru Crane Bridge and Ikina Bridge:	1.554	≒	1.5
Span length for 280m wide navigation channel:			420m
Clearance for 280m wide navigation channel (single channel):			70m
Average value ± standard deviation for Ratio 1, exluding the Maizuru Crane Bridge and Ikina B	1.225	~	1.883
Span length for 280m wide navigation channel:	343m	~	527m
Clearance for 280m wide navigation channel (single channel):	32m	~	124m



7-3-5 Navigation Channel Center

In the course of investigating the navigation channel center in this Study, the JICA Survey Team has obtained the four varying sets of data presented in Figure 7-3-3 and Figure 7-3-4. The riverbed rarely changed between the 2011F/S and the present, and the reasons for the variations remain unclear (see Figure 7-3-4).

Out of the alternatives given, this Study adopts the centerline from State Hydrographic Service of Ukraine (shown as line (4) in the Figures) because it matches the gut of the river and reflects the latest information from Ukrainian officials. This means that the alignment of the navigation channel is closer to the right bank than in the 2011F/S, and that the location of the piers of the main bridge may be shifted near the right bank. Since the right bank is a landslide area, as stated in Chapter 9, the locations of the piers should be determined with care.

As a supplement, Nibulon said in an interview that their vessel–pass-line (shown as (2)) was set further to the left than the centerline (4) in an effort to reduce fuel costs.

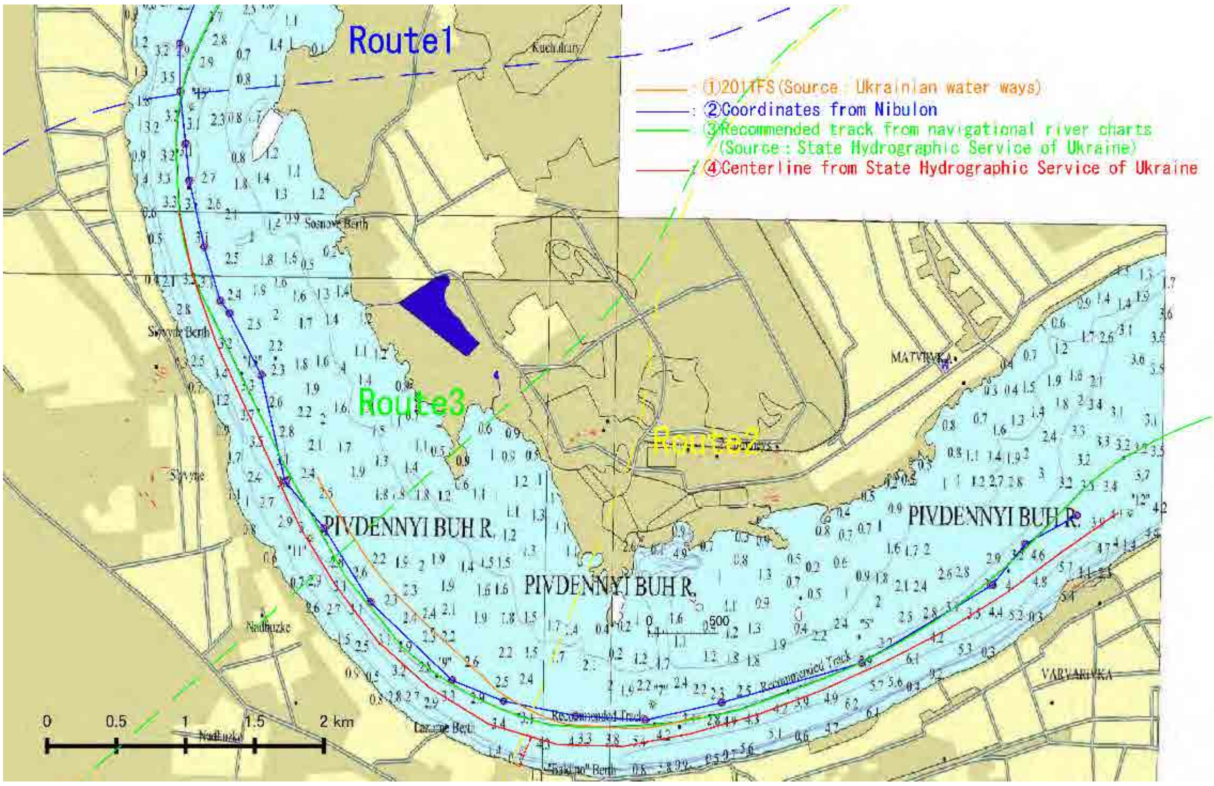


Figure 7-3-3. Lines Showing the Navigation Channel Center

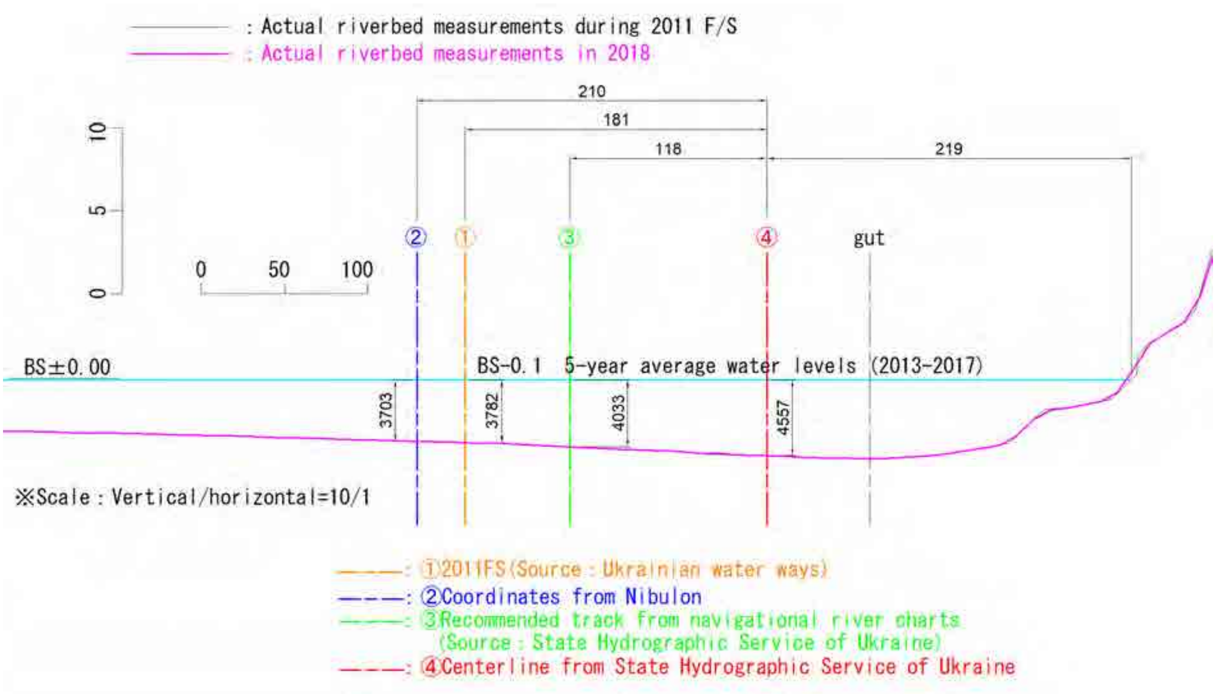


Figure 7-3-4. Relationship between Navigation Channel Center and River Flow Channel/River Bed Shape Comparison for Route 2

7-4 Obstacle Limitation Surfaces

When constructing a bypass road near an airport, bridge height is determined based on a Cabinet resolution (December 6, 2017, No. 954) and an order from MoI (Ministry of Infrastructure of Ukraine Order, November 30, 2012, No. 721).

As a result of confirmation with Mykolaiv Airport, the elevation of the construction space and top of main tower are confirmed to be lower than the obstacle limitation surface height, as shown in the table below.

Therefore, there is no limitation regarding the airspace condition.

Table 7-4-1 Relationship between Elevation of Construction Space and Top of Main Tower, and the Obstacle Limitation Surface Height

Route	Elevation of Construction Space Z1	Elevation of Top of Main Tower Z2	Obstacle Limitation Surface Height
Route 2	BS+140m	BS+120m	BS+206.3m
Route 3	BS+135m	BS+115m	BS+206.3m

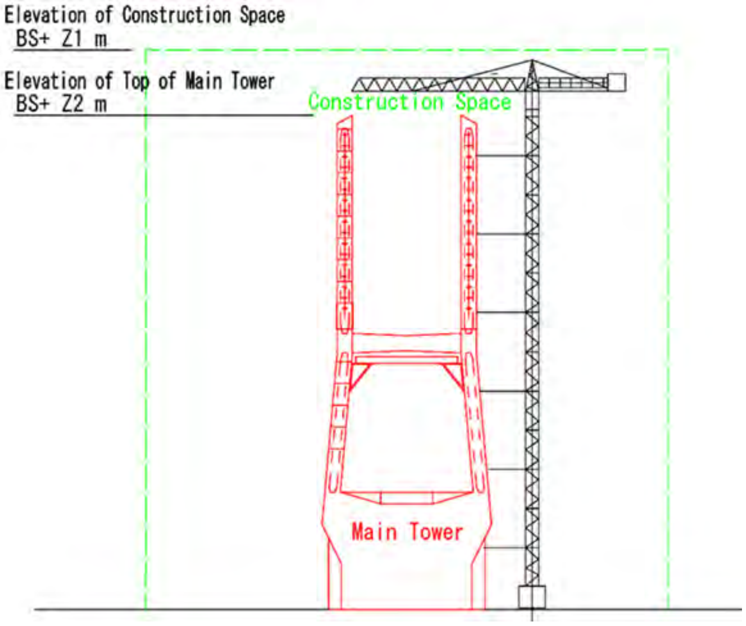


Figure 7-4-1. Explanatory Drawing of the Elevation of the Construction Space and Top of the Main Tower

The obstacle limitation surface is shown in Figure 7-4-2.

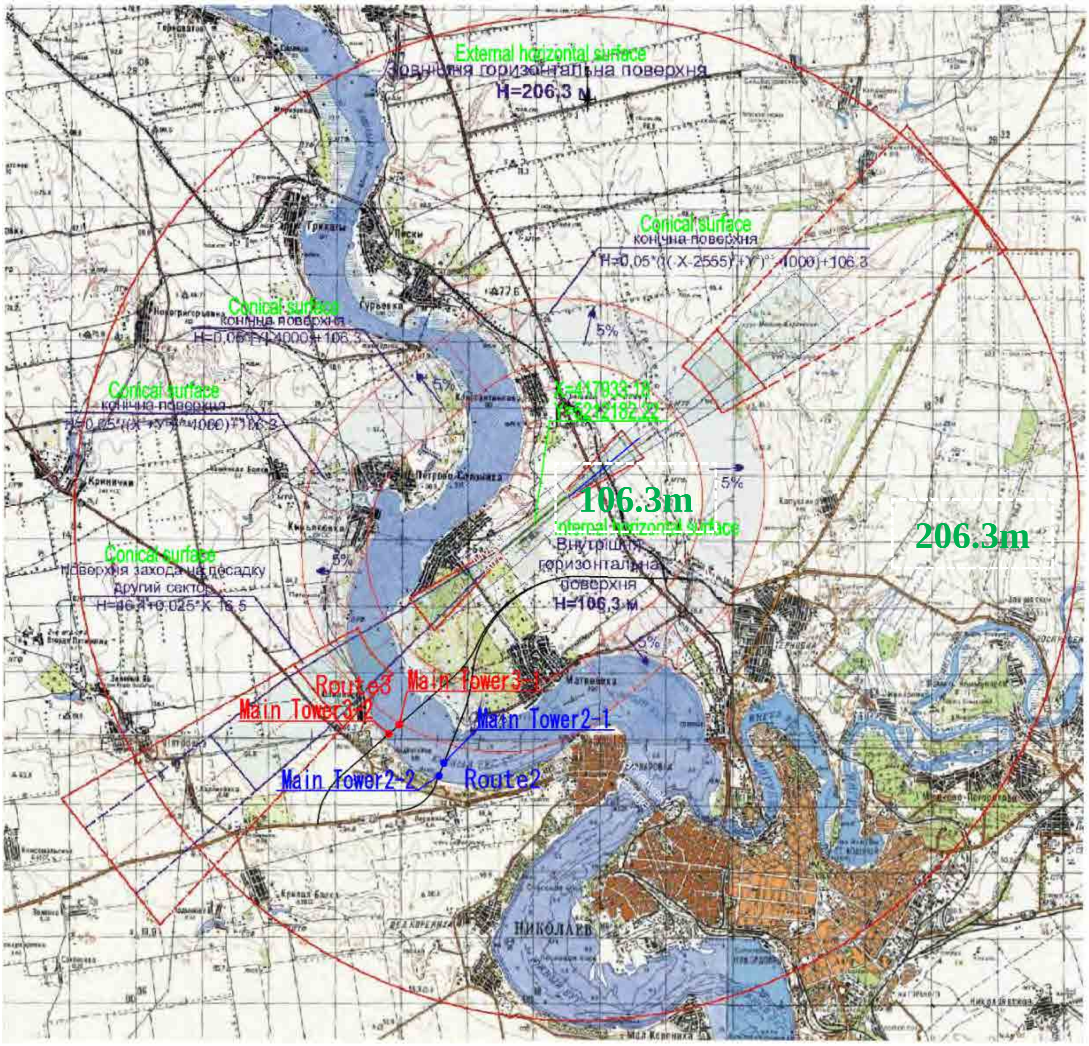


Figure 7-4-2. Obstacle Limitation Surface Diagram

7-5 Load Conditions

7-5-1 Ship Collision Load

Considering the case of category "2. Cross-State (2)" as above mentioned, "DBN V.1.2-15:2009 Bridges and pipes. Load and Impact" states that the ship collision load is 1,130kN parallel to, and 1,420kN perpendicular to, the longitudinal axis of the bridge.

This value, however, is constant regardless of the ship size, and is considered to be too small for the applicable ships in this Study, considering the design vessel displacement tonnage is 120,000kN (12,000 tonne). The load is therefore calculated here according to the formula given in "AASHOTO's LRFD Bridge Design Specification 2017," the specification for bridge design in the USA.

This results in a collision load of 2,768kip=12,312kN perpendicular to the longitudinal axis and half that at 6,156kN parallel to the longitudinal axis.

$P_B = 1{,}349 + 110a_{B,}$
where P_B : Equivalent static barge impact force(kip)
a_B : Barge bow damage length(ft)

$a_B = 10.2[(1+KE/5{,}672)^{0.5}-1]$,
where KE : Vessel collision energy(kip-ft)

$KE = C_H \cdot W \cdot V^2 / 29.2$,
where C_H : Hydrodynamic mass coefficient
W : Vessel displacement tonnage(tonne)
V : Vessel impact velocity(ft/s)

The table below shows the calculation results and criteria for major coefficients.

Table 7-5-1. Calculation Results and Criteria for Major Coefficients

P_B (kip)	a_B (ft)	KE (kip-ft)	C_H	W (tonne)	V (ft/s)
2,768	12.9	23,405.4	1.25	12,000	6.75

7-5-2 Ice Load

The smaller of the two types of ice loads from "DBN V.1.2-15:2009 Bridges and pipes. Load and Impact" is adopted here. Note, however, this Study only calculates F_1 since the speed and area of the ice sheet are unknown.

$F_1 = \psi_1 \cdot Rzn \cdot b \cdot t$,
where F_1 : Load when ice breaks on a pier (kN)
ψ_1 : Pier shape coefficient =1.0
Rzn : Ice strength (kN / m^2) =735kN/m^2
b : Pier width (m)
t : Ice thickness (m) just before it begins to move 0.46m at 80% of maximum ice thickness

$F_2 = 1.253 \cdot v \cdot t \cdot (\psi 2 \cdot A \cdot Rzn)^{0.5}$,
where F_2 : Load when ice remains on pier (kN)
v : Ice sheet speed (m/s)
ψ_2 : Pier shape coefficient
A : Ice sheet area (m^2)

In accordance with "AASHTO LRFD Bridge Design Specifications (AASHTO, November 2017)," ice load is calculated with the following formula and the largest value is adopted.

$F= Ca \cdot P \cdot t \cdot w$,

where

F : Ice Load (kN)

Ca : Coefficient accounting for pier width and ice thickness
$Ca=(5 \cdot t/w+1)^{0.5}$

P : Ice strength (kN / m2)
$P=766kN/m^2$

t : Ice thickness (m)
t=0.57m

w : Pier width (m)

As a result of the calculation below, the ice loads calculated according to AASHTO are adopted.

Table 7-5-2. Ice Load Calculation Result

DBN V.1.2-15

b (m)	ψ1	Rzn (kN/m^2)	t (m)	F1 (kN)
1	1	735	0.46	338
2	1	735	0.46	676
3	1	735	0.46	1,014
4	1	735	0.46	1,352
5	1	735	0.46	1,691
6	1	735	0.46	2,029
7	1	735	0.46	2,367
8	1	735	0.46	2,705
9	1	735	0.46	3,043
10	1	735	0.46	3,381

AASHOTO

w (m)	Ca	P (kN/m^2)	t (m)	F (kN)
1	1.96	766	0.57	856
2	1.56	766	0.57	1,362
3	1.4	766	0.57	1,834
4	1.31	766	0.57	2,288
5	1.25	766	0.57	2,729
6	1.21	766	0.57	3,170
7	1.19	766	0.57	3,637
8	1.16	766	0.57	4,052
9	1.15	766	0.57	4,519
10	1.13	766	0.57	4,934

Ice thickness, set at a 1/100-year ice thickness event, is calculated based on a statistical analysis of observation data (annual maximums) from Mykolaiv (Sea Hydro-meteorological Station). From this, the calculated result is 57 cm.

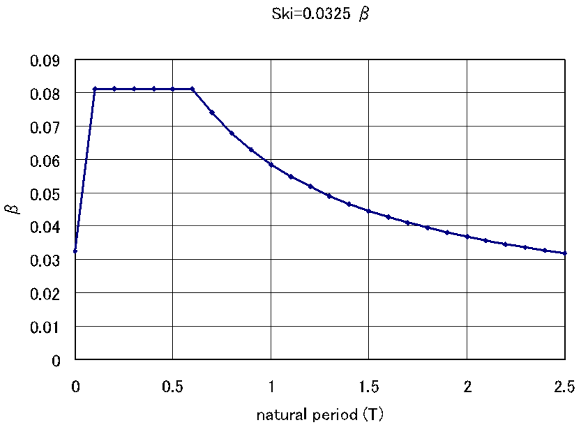
Table 7-5-3. Ice Thickness for Each Recurrence Probability

Recurrence probability (in years)	2	3	5	10	20	30	50	80	100	150	200	400
Ice thickness (cm)	21	25	30	37	43	46	51	55	57	60	63	69

SLSC (99%): 0.020 / Applicable distribution: Gumbel

7-5-3 Seismic Load

According to "DBN V.1.2-15:2009", "DBN V.1.1-12:2006" and "DBN V.2.3-22:2009," the target area corresponds to a seismic level of "6" in the MSK seismic scale. This level seismic loads can be excluded from bridge design calculations. However, since the AASHOTO standard defines a minimum seismic load for design lateral seismic force (Kh=0.1), the Seismic Performance Level 1 is verified with the minimum seismic load for small-scale structures. On the other hand, since a long-term structure such as a cable-stayed bridge would be overdesigned even at Kh=0.1, the earthquake response spectrum for MSK seismic level 7 (see the figure below) from "DBN V.1.1-12:2006" is used for the verification of Seismic Performance Level 1.

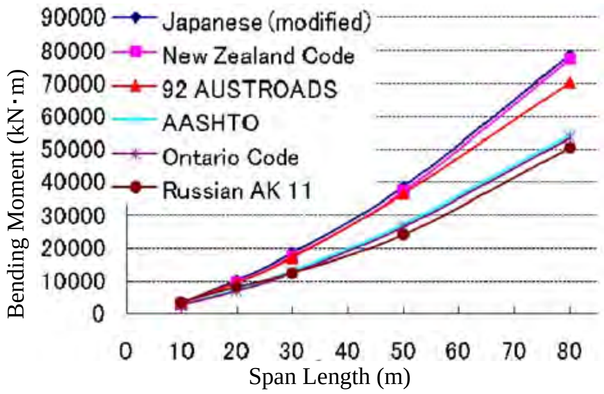


Source: 2011F/S

Figure 7-5-1. MSK7 Acceleration Response Spectrum

7-5-4 Live Load

A 'B live load' is adopted in accordance with “Specification for Highway Bridges, Part 1 Common (Japan Road Association, November 2017).” As shown in the figure below, this load is much larger than the Russian standard AK11 (which is the same as the Ukrainian standard).



Source: Research on Design Load versus Actual Load of Bridges in Cambodia.
Japan Society of Civil Engineers Bridge and Annual Conference

Figure 7-5-2. Comparison of Generated Bending Moment

7-5-5 Wind Load

1) Approach Bridge

The limit state below is considered based on "DBN. V.1.2-2:2006 System Reliability and Safety of Construction Projects."

Load intensity: Wm=γf x W_0 x C,

- Limit tolerance =1.15 x 51.0 x (1.65 x 2.25 x 1.2) = 261 kgf／m^2,
- Usage value =0.50 x 51.0 x (1.65 x 2.25 x 1.2) = 114 kgf／m^2,

where

γf : Calculations are made based on coefficients of 1.15 for limit tolerance value and 0.5 for usage value.
W_0 : Wind speed (1 in 50-year event), in Region 3 of Mykolaiv: V =29 m/s, P =500 Pa
C : Height correction and friction coefficients

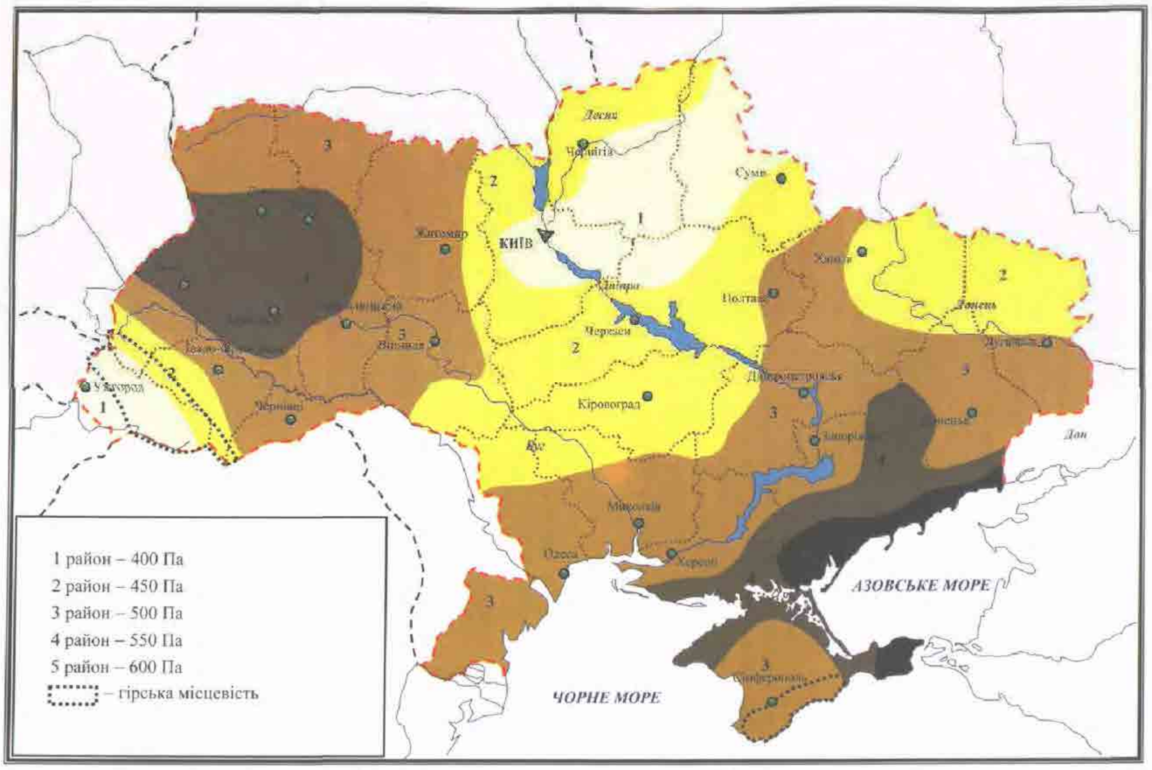


Figure 7-5-3. Regional Map of Wind Speeds

2) Main Bridge

For the Main Bridge, dynamic stability is considered. The design basis wind speed is set at 40m/s in accordance with “Wing Resistant Design Manual for Highway Bridges (Japan Road Association, December 2007), a manual compiled based on a proved history of large-scale bridge design in Japan.

7-5-6 Temperature Load

The maximum and minimum temperatures from 1876 to 2017 in the area were +40.1°C and -29.7°C respectively.

Given the similar condition, +37.8°C and -41.0°C, in Hokkaido, Japan, the cold region temperature fluctuation range from Japan's highway bridge specifications, -30°C to +50°C (steel structures), is adopted. The plus temperature is set somewhat higher, but this value takes into account the effect of direct sunlight.

7-6 Basic Plan for the Route 2 Bridge

Based on the various conditions established thus far, a layout plan is prepared for the Southern Bug River waterway-crossing section of the bridge. The arrangement procedure is as follows.

(1)The left bank side abutment is placed at the edge of the right bank river flow area to avoid any reduction of the current river width.

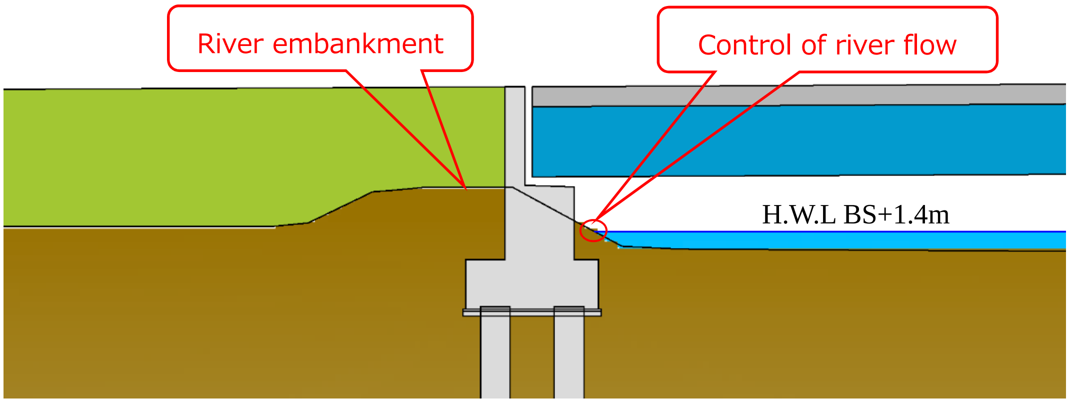


Figure 7-6-1. The Left Bank Side Abutment Layout (Route2)

(2)The main bridge (cable-stayed bridge) is laid out with the navigation channel center stipulated in 7-3-5 and with the minimum center span length (420 m) that ensures the navigation channel width stipulated in 7-3-4 as its minimum necessary span length. The left bank main tower position is 420/2 m from the channel center. For the position of left bank end-section piers, since the side spans of a cable-stayed bridge need to maintain a balance in a cantilevered construction method, in general, the length is the same as the center span cantilevered construction length. In this case, that position is 210 m, which is 1/2 the minimum required span length (420 m) of the center span. The right bank fulcrum (abutment) is positioned 510 m from the waterway center to avoid placing the substructure in a landslide area, thus the right bank main tower position is set to 1/2 of this 510 m. Based on this, the cable-stayed bridge's center span is 465 m (210 m+255 m) while the right bank side span is 255 m.

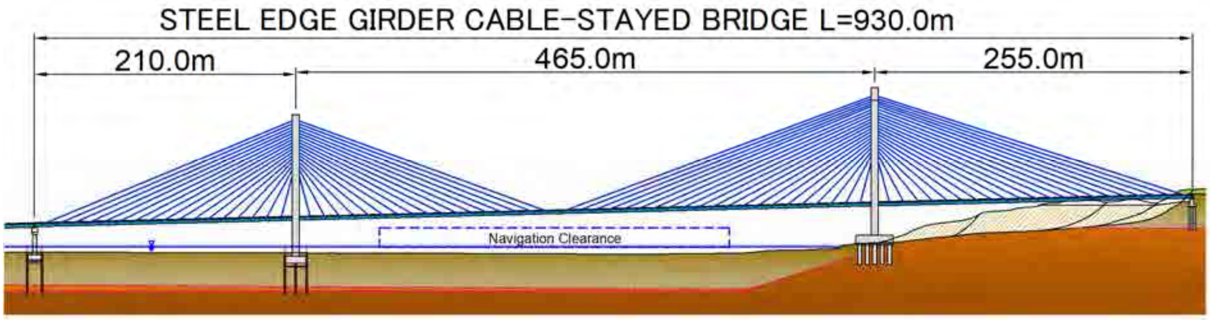


Figure 7-6-2. Main Bridge Layout (Route2)

(3)Between the left bank side abutment and main bridge (cable-stayed bridge) left bank end-section (left bank approach bridge), a continuous girder structure is used as much as possible to promote cost-effectiveness and smoother surface drivability. Based on a value of around 400 m, which is the maximum length of a continuous girder when using a high-surface-pressure fixed-support structure, which has excellent economic efficiency, three runs of continuous girder are constructed within this length. Since the possible continuous girder length grows longer as pier heights increase, continuous girders are arranged (from shortest to longest) at 335 m, 395 m, and 455 m. With regard to the span layout for continuous girders, the optimal span length is set in principle to 60 m, as stipulated in 7-7-2 3) item (3). With regard to span length of the end-section continuous girder, to avoid lower cost efficiency from concentrated sectional force, a ratio of 1.25:1.00, considered the most rational ratio for mid-section to end-section span lengths, is used to improve cost efficiency. This sets the length of the end-section span to 47.5 m.

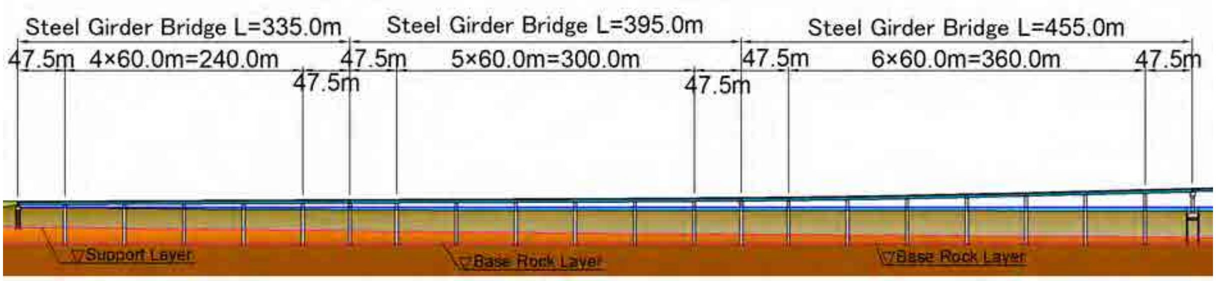


Figure 7-6-3. Layout of the Left Bank Approach Bridge (Route2)

7-7 Reviewing Bridge Type for Route 2

7-7-1 List of Target Bridges

The target bridges in this Study can be broadly categorized into bridges that cross the Southern Bug River, and short-span bridges that are part of a roadway such as an interchange. The structural specifications of each bridge are as shown in the tables below.

Table 7-7-1. Structural Specifications of the Bridge that Crosses the Southern Bug River (Route2)

	Superstructure		Substructure		
	Bridge length	Span length		Pier, Main tower height	Abutment height
Left bank approach bridges	1,185m = 335m + 395m + 455m	(47.5 + 4@60 + 47.5) + (47.5 + 5@60 + 47.5) + (47.5 + 6@60 + 47.5)	Abutment	-	9m
			Pier	3-18 m	-
Main bridge	930m	210m + 465m + 255m	Left bank end-section piers	20m	-
			Left bank main tower	113.5m	-
			Right bank main tower	121.5m	-
			Right bank end-section abutment	-	10m

Table 7-7-2. Structural Specifications of Short-span Bridges on Interchanges, etc. (Route2)

	Main route survey point	Width	Bridge length	Span length	Pier height	Abutment height
Main route bridge	32+0	W=26.3m	25m	24m	-	12m
Main route bridge	50+0	W=26.3m	25m	24m	-	12m
Main route bridge	61+0	W=26.3m	25m	24m	-	12m
Main route bridge	90+80	W=26.3m	25m	24m	-	12m
Main route bridge	129+15	W=37.8m	10m	10m	-	5m
T1506 bridge	118+60	W=15.8m	130m	56m	15m	5m
P06 bridge	12+0	W=30.3m	56m	27m	6m	12m
Ramp bridge	122+80	W=21.3m	112m	27m	6m	5m

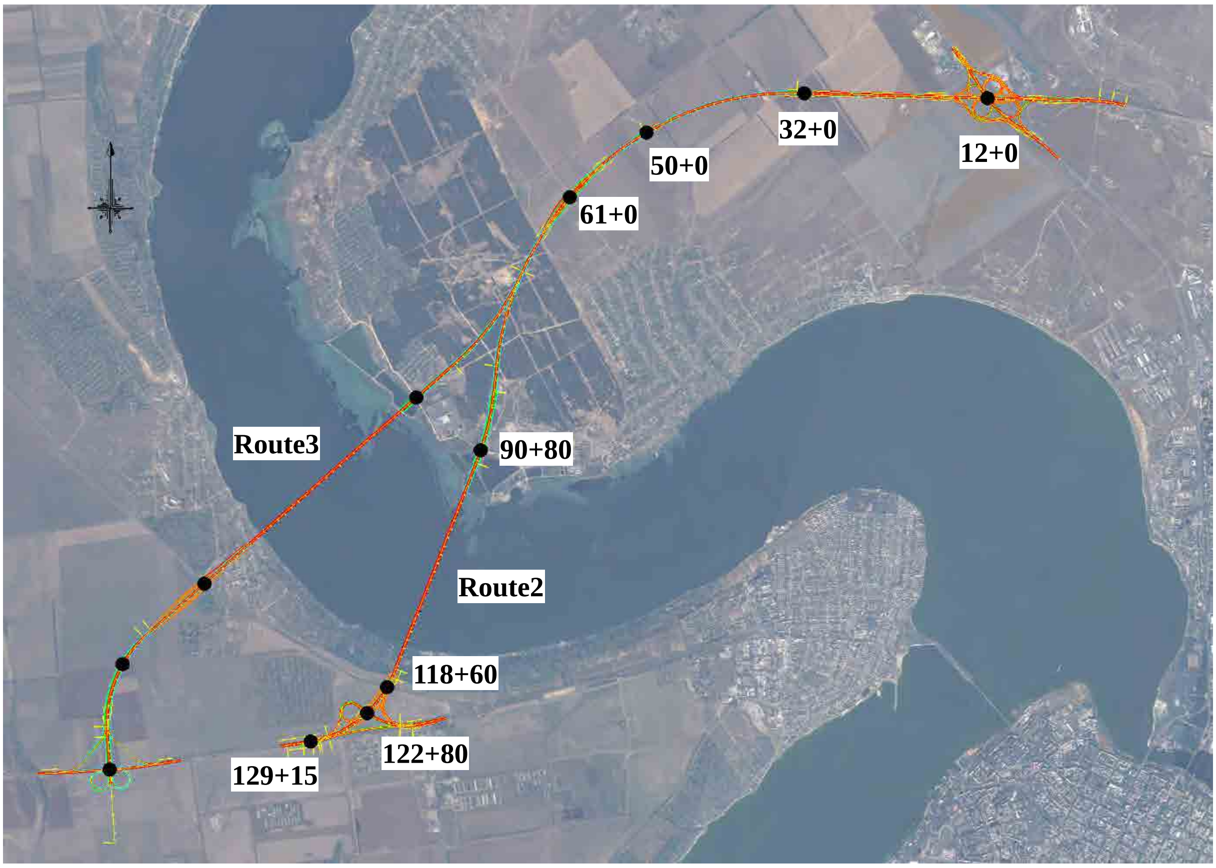


Figure 7-7-1. Main Route Survey Point (Route2)

7-7-2 Review of Superstructure Type Selection

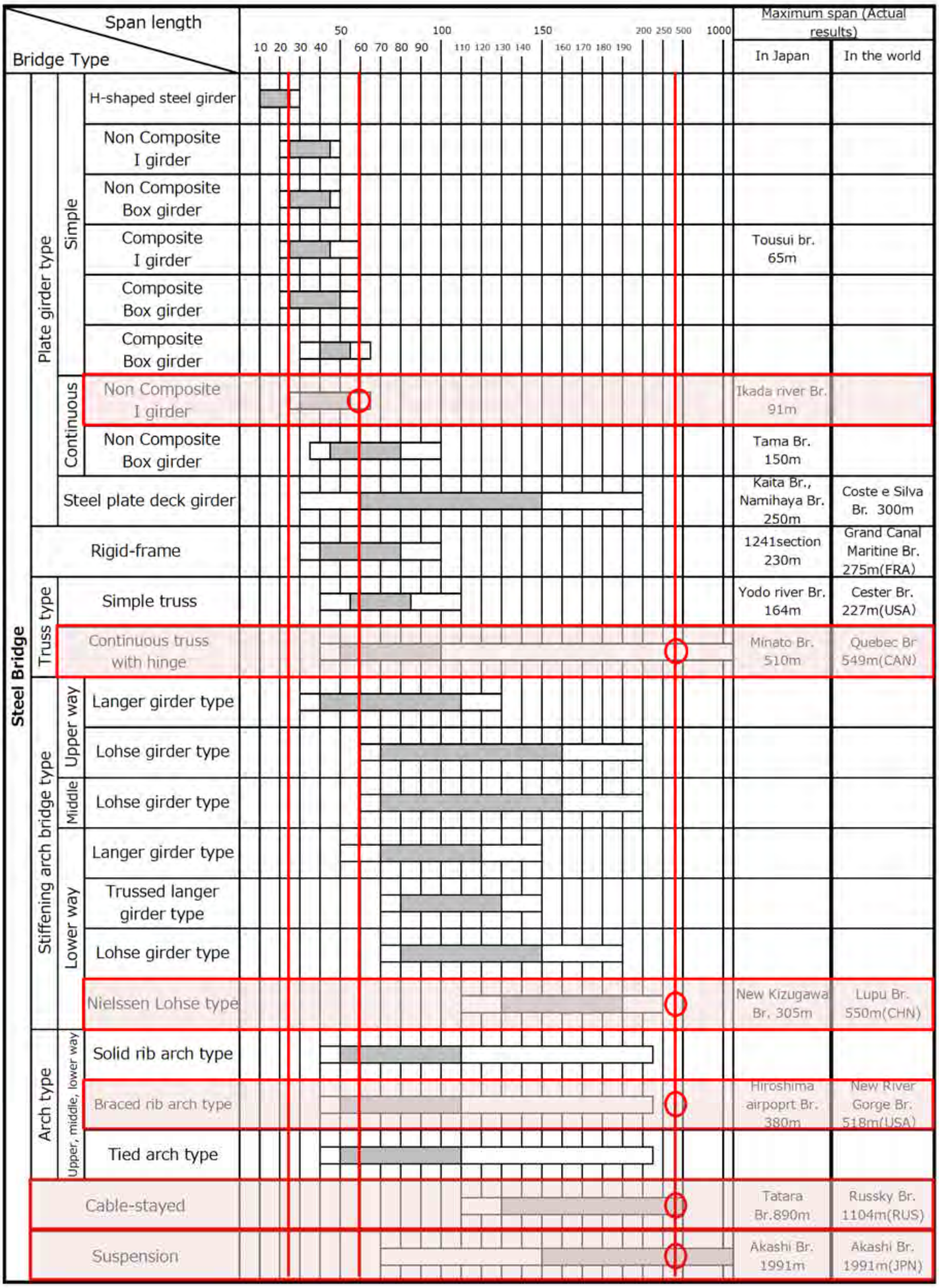
1) Selection Policy for Superstructure Type

As shown in Table 7-7-4 and Table 7-7-5, the type of superstructure is generally chosen based on the required span length, and the structural types are reviewed using these tables as reference. In addition, the span length required for each bridge is roughly classified into the three types shown in the table below according to topographical conditions and cost-efficiency, as generally summarized in Table 7-7-1 and Table 7-7-2. Each types are examined.

Table 7-7-3. Span Classification for Bridges (Route 2)

Span Classification	Applicable Bridges
Span Classification 1 (210 m +465 m +255 m)	Main Bridge
Span Classification 2 (average span of about 60 m)	Left Bank Approach Bridge, T1506 Bridge
Span Classification 3 (average span of about 25 m)	Short-span Bridges such as an Main Route Bridge, P06 Bridge, or Ramp Bridge

Table 7-7-4. Standard Applied Spans (Steel Bridges) (Route2)

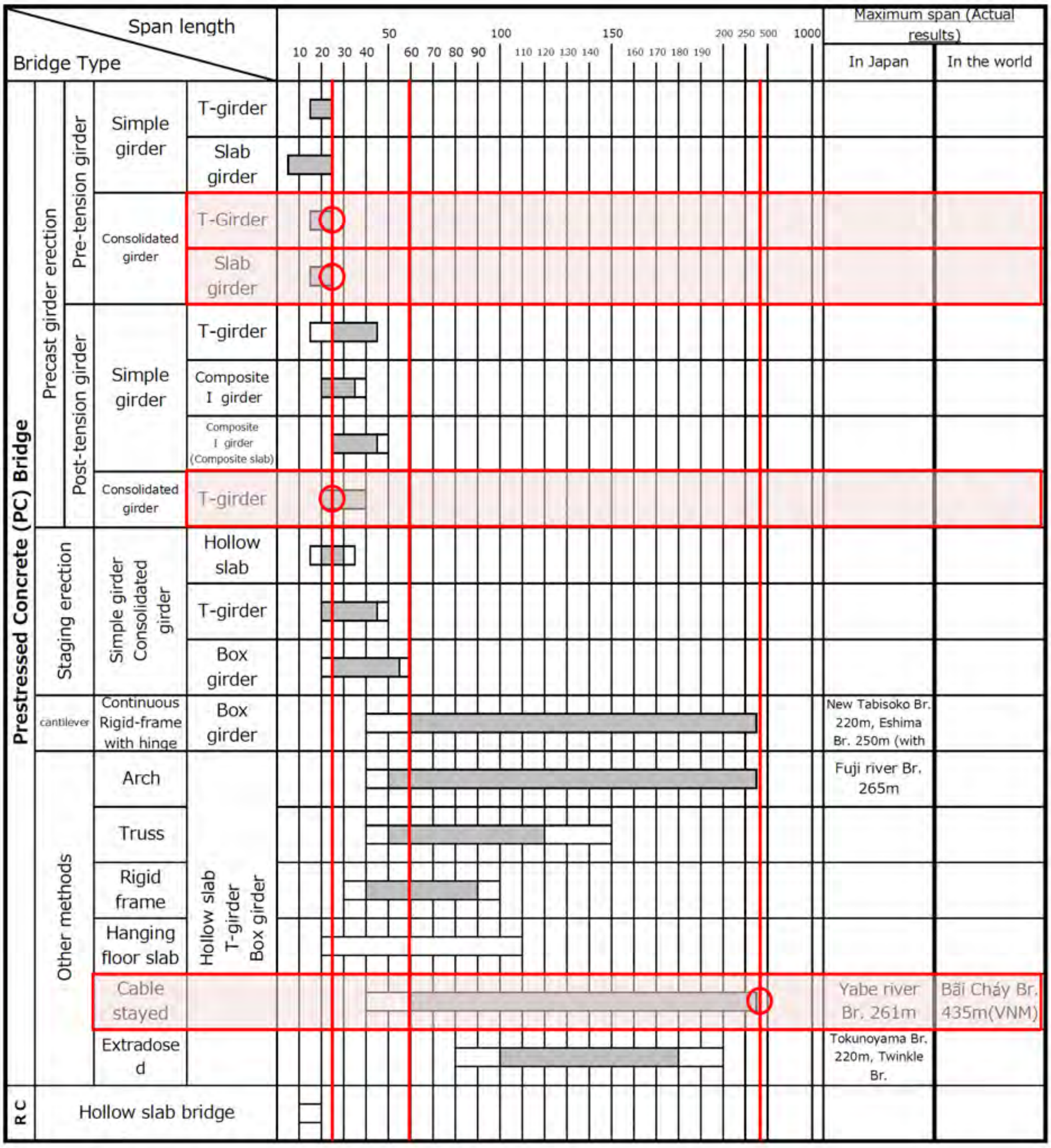


			Bridge Type	Maximum span (Actual results)	
				In Japan	In the world
Steel Bridge	Plate girder type	Simple	H-shaped steel girder		
			Non Composite I girder		
			Non Composite Box girder		
			Composite I girder	Tousui br. 65m	
			Composite Box girder		
			Composite Box girder		
		Continuous	Non Composite I girder	Ikada river Br. 91m	
			Non Composite Box girder	Tama Br. 150m	
			Steel plate deck girder	Kaita Br., Namihaya Br. 250m	Coste e Silva Br. 300m
	Rigid-frame			1241section 230m	Grand Canal Maritine Br. 275m(FRA)
	Truss type		Simple truss	Yodo river Br. 164m	Cester Br. 227m(USA)
			Continuous truss with hinge	Minato Br. 510m	Quebec Br 549m(CAN)
	Stiffening arch bridge type	Upper way	Langer girder type		
			Lohse girder type		
		Middle	Lohse girder type		
		Lower way	Langer girder type		
			Trussed langer girder type		
			Lohse girder type		
			Nielssen Lohse type	New Kizugawa Br. 305m	Lupu Br. 550m(CHN)
	Arch type	Upper, middle, lower way	Solid rib arch type		
			Braced rib arch type	Hiroshima airpoprt Br. 380m	New River Gorge Br. 518m(USA)
			Tied arch type		
	Cable-stayed			Tatara Br.890m	Russky Br. 1104m(RUS)
	Suspension			Akashi Br. 1991m	Akashi Br. 1991m(JPN)

Note) ▨ : Generally applied range ☐ : Relatively applicable range

Source: Design Manual, Chubu Regional Development Bureau (April 2000)

Table 7-7-5. Standard Applied Spans (Concrete Bridges) (Route2)



Bridge Type					Maximum span (Actual results)	
					In Japan	In the world
Prestressed Concrete (PC) Bridge	Precast girder erection	Pre-tension girder	Simple girder	T-girder		
				Slab girder		
			Consolidated girder	T-Girder		
				Slab girder		
		Post-tension girder	Simple girder	T-girder		
				Composite I girder		
				Composite I girder (Composite slab)		
			Consolidated girder	T-girder		
	Staging erection		Simple girder Consolidated girder	Hollow slab		
				T-girder		
				Box girder		
	cantilever		Continuous Rigid-frame with hinge	Box girder	New Tabisoko Br. 220m, Eshima Br. 250m (with	
	Other methods		Arch	Hollow slab T-girder Box girder	Fuji river Br. 265m	
			Truss			
			Rigid frame			
			Hanging floor slab			
			Cable stayed		Yabe river Br. 261m	Bãi Cháy Br. 435m(VNM)
			Extradosed		Tokunoyama Br. 220m, Twinkle Br.	
RC	Hollow slab bridge					

Note) ▨ : Generally applied range ☐ : Relatively applicable range

Source: Design Manual, Chubu Regional Development Bureau (April 2000)

2) Span Classification 1: Main Bridge

A steel suspension bridge was selected for the main bridge's superstructure in the 2011F/S. This Study compares and re-examines it by reviewing relevant factors such as waterway bounds.

(1) Primary Comparative Rreview of Proposals

In line with 7-6, the central span of this bridge has a length of 465 m. Table 7-7-6 shows six proposals for appropriate bridge types for this case, with reference to bridges constructed in the past. Considering the characteristics and evaluations shown in the table, proposals 4, 5, and 6 are chosen for a secondary comparative review of the proposals.

Table 7-7-6. Primary Selection Chart of Main Bridge Types (Route2)

	Characteristics	Evaluation
<Steel girder>		
Proposal 1: Continuous truss with hinge bridge	Is within range concerning track record, but also the largest type. A bridge of the scale has economical disadvantages, and in recent years has only been adopted to satisfy unique circumstances.	**Poor**
Proposal 2: Nielsen Lohse type bridge	Its track record of 400 m plus span lengths are all half-through bridges, and their arch rib design would block some of the waterway.	**Fair**
Proposal 3: Braced rib arch type bridge	Its track record of 400 m plus span lengths are all half-through bridges, and their arch rib design would block some of the waterway.	**Fair**
Proposal 4: Steel cable-stayed bridge	Applicable and within range concerning track record.	**Good**
Proposal 5: Steel suspension bridge	Applicable and within range concerning track record.	**Good**
<PC girder>		
Proposal 6: PC cable-stayed bridge	Is within range concerning track record, but also the world's largest type.	**Good**

(2) Secondary Comparative Review of the Proposals

For each proposal selected in the primary comparative review, the following have been set as preconditions for the secondary comparative review after optimizing the structure of each based on track record of recent years, etc.

Table 7-7-7. Comparison of Proposals 4, 5, and 6

Items		Proposal 4 Steel-calbe stayed bridge	Proposal 5 Steel suspension bridge	Proposal 6 PC cable-stayed bridge
Main girder (stiffening girder)	Type	Edge-girder configuration	Full-box structure	Corrugated steel web box girder with inner and outer struts
	Note	Cost effective	Proven history of use in many projects, e.g., the Kurushima-Kaikyo Bridge	Lower costs by reducing dead load
Deck slab	Type	Precast PC slab	Steel plate deck	PC slab
	Note	Highly durable in a cold region	Proven history of use in many projects, e.g., the Kurushima-Kaikyo Bridge (no history of concrete deck slabs in a bridge of this scale)	N/A
Wind stabilization measures	Type	FRP panels and wind fairings	Full-box structure and wind fairings	Highly-rigid box girder structure and concrete in the main structure
	Note	Shield the girder underside	N/A	Improve damping coefficient

Tables 7-7-8 to 7-7-10 show results of the comparative study of the above three proposals. "Proposal 4, steel cable-stayed bridge' (PC slab composite edge-girder type)" is adopted on the ground of its superiority in all aspects of structural characteristics, technology transfer, workability, operation and maintenance, and economic feasibility.

Table 7-7-8. Main Bridge Section: Bridge Type Comparison Table (1/3) (Route2)

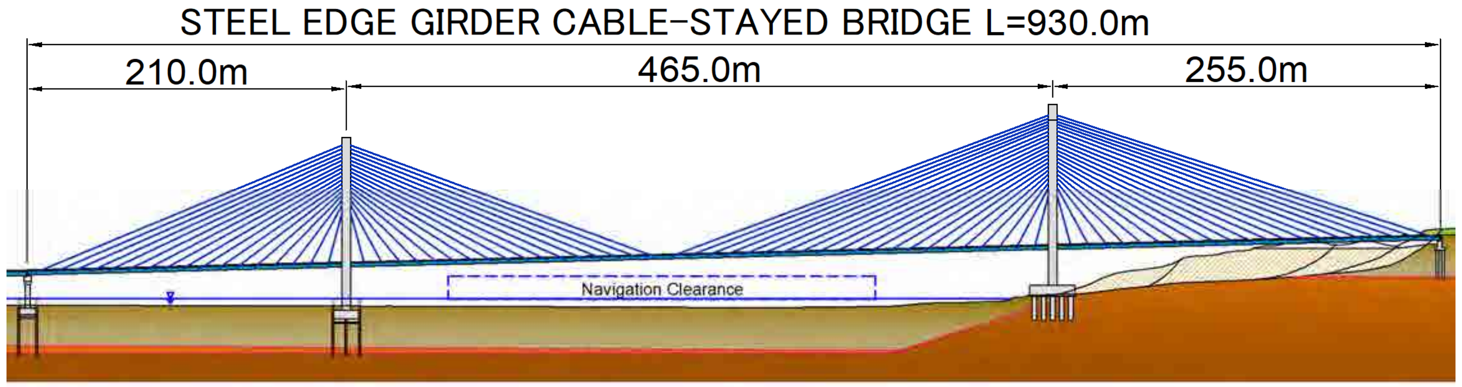
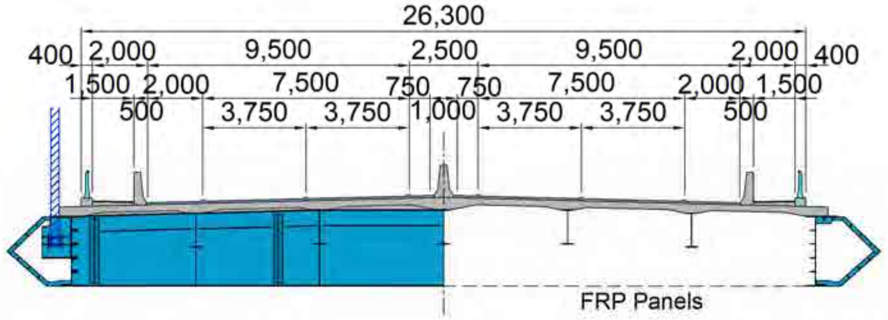
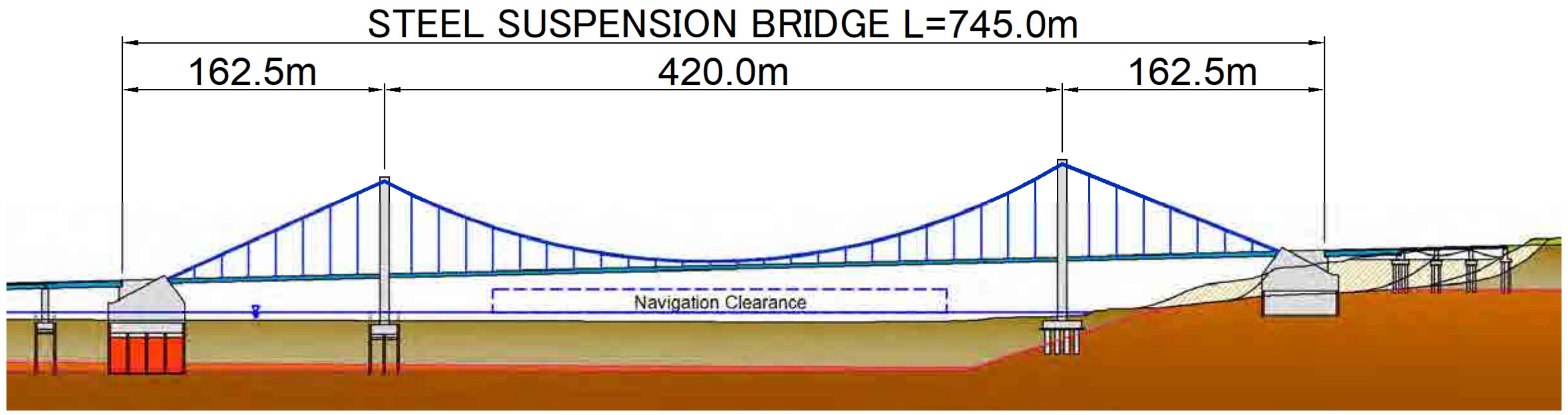
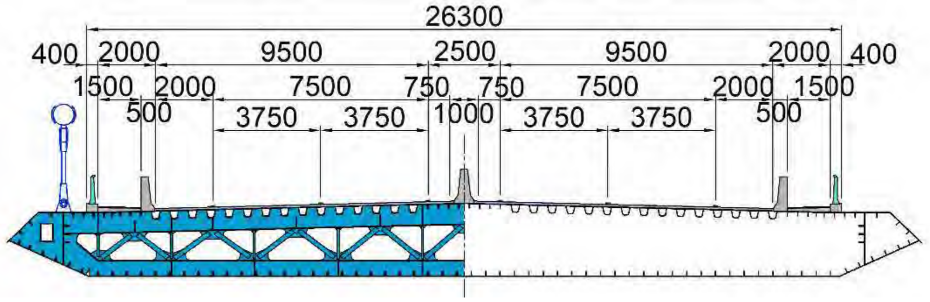
Proposal 4: Steel cable-stayed bridge (PC slab composite edge-girder type)		
 		
Structural characteristics	・ By adopting a highly durable concrete deck slab, surface freezing in the winter is mitigated better than Proposal 5, making this proposal more effective in preventing slipping accidents. ・ Wind tunnel experiments to date suggests that installation of FRP panels on the girder underside sufficiently resolves the issue of wind-resistant stability of the superstructure. ・ Although the right bank side is in a landslide zone, the bridge's long side span length makes it possible to install piers in locations that avoid the steep slopes near the riverbank. Thus, this proposal is less affected by landslides than Proposal 5.	Very good
Technology Transfer	・ This type of bridge is increasingly replacing Proposal 5 type bridges. There is also excellent potential for technology transfer due to the target country's thriving steel industry.	Very good
Workability	・ Steel girder construction of the superstructure is a piece-by-piece cantilever erection method using a traveler crane. There are no problems with regard to ensuring a navigable waterway during construction. The simple repetitive operation used in this method also makes it easier to manage construction.	Very good
Operation and maintenance	・ By installing FRP panels on the girder underside, which do not require painting, there would be few exposed metal parts, making repainting costs less than Proposal 5.	Very good
Economic feasibility	Main bridge only: ratio of 1.00	Very good
Evaluation	**Adopt**	

Table 7-7-9. Main Bridge Section: Bridge Type Comparison Table (2/3) (Route2)

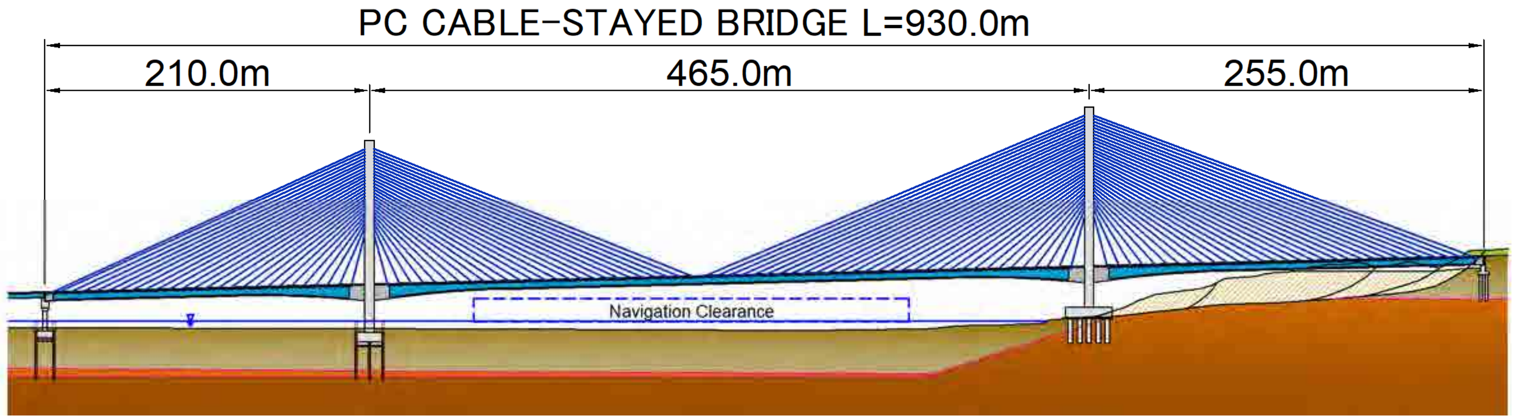
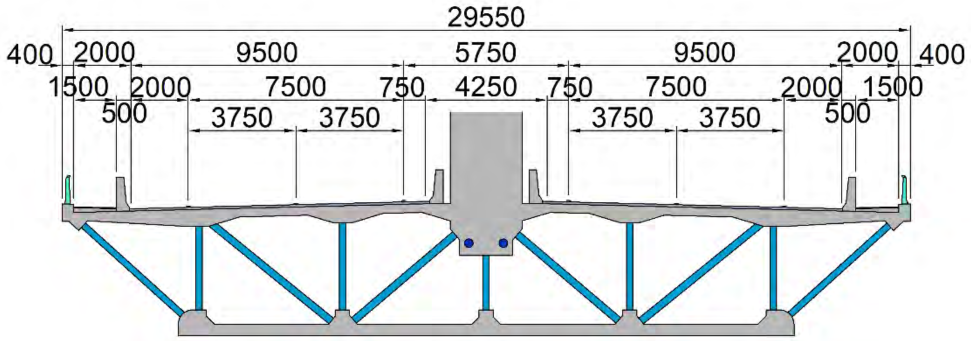
Proposal 5: Steel suspension bridge (steel deck with box girders type) <Recommended proposal in 2011F/S>





Structural characteristics	・ Based on its track record, a steel deck plate is the standard structure used. Thus, there are concerns over slip accidents due to winter road freezing with this structure. ・ Wind-resistant stability of its superstructure is provided by a box girder structure which has been proven in Kurushima-Kaikyo Bridge. Thus there are no problems with regard to wind resistance. ・ Since anchorage and piers must be installed in the landslide zone on the right bank, this proposal is more affected by landslides than proposals 4 and 6.	Fair
Technology Transfer	・ Since the construction method is generally used for oversized bridges, there is limited scope for technological reuse and thus low potential for technology transfer.	Fair
Workability	・ Since a medium-block lifting erection is used to erect the superstructure's girders, restrictions are placed on the navigation channel underneath. Managing construction is also more complex as block loading and other work locations are disjointed. ・ Constructing anchorage on the right bank in the landslide zone is also extremely dangerous.	Fair
Operation and maintenance	・ Paint must be applied over a large area of the outer surface on the underside of box girders, making this proposal costlier than the others.	Fair
Economic feasibility	Main bridge only: ratio of 1.45	Fair
Evaluation		

Table 7-7-10. Main Bridge Section: Bridge Type Comparison Table (3/3) (Route2)

Proposal 6: Steel cable-stayed bridge (corrugated steel web box girder bridge with struts)		
		
Structural characteristics	・ By adopting a concrete deck slab, surface freezing in the winter is mitigated better than Proposal 5, making this proposal more effective in preventing slipping accidents. ・ Due to being a concrete bridge, there are no problems with regard to wind-resistant stability. ・ Although the right bank side is in a landslide zone, the bridge's long side span length makes it possible to install piers in locations that avoid the steep slopes near the riverbank. Thus, this proposal is less affected by landslides than Proposal 5.	Very good
Technology Transfer	・ This type of bridge is increasingly being adopted in recent years. However, given the country's low level of maturity in technologies related to PC bridges, there is less potential for technology transfer than Proposal 4.	Good
Workability	・ There is a high level of technical difficulty in the superstructure work. ・The target area is a cold climate with minimum temperatures below 0 degrees for up to 7 months a year. Due to the long construction time required to implement fully covered winter concreting, this construction method is not realistic.	Fair
Operation and maintenance	・ With few exposed metal sections, repainting cost is lower than Proposal 5.	Very good
Economic feasibility	Main bridge only: ratio of 1.07	Good
Evaluation		

3) Span Classification 2: Left Bank Approach Bridge, T1506 Bridge

(1) Review of Superstructure's Basic Structure

Construction conditions for the left bank approach bridge are similar to the plan in the 2011F/S. Thus, the 2011F/S is used as the basis of consideration. With the optimal span length in the 2011F/S set at 50m, the 2011F/S selected the steel small number girder method for superstructure over several other types, namely, steel box girder, PC composite girder (composite type), and PC-box girder. The steel small number girder method has been used in several projects in Japan, including the Tokyo Metropolitan Expressway and the Shin-Tomei Expressway connecting Tokyo and Nagoya. It has proven cost effectiveness and has been set as the basic structure for this project, as well.

The superstructure type of the 56 m long T1506 bridge has a span arrangement that is essentially the same as the left bank approach. Therefore, the superstructure construction adopts the same construction type as the left bank approach in view of its advantages, which include a consistent set of engineers and construction equipment due to a uniform structure, as well as cost-effectiveness and quality improvements.

(2) Comparative Study of Deck Structures

As there are three types of deck structures for steel dual-main-girder structures: PC slab, precast PC slab, and steel/concrete composite deck, these three types are compared.

Table 7-7-12 shows the results of this comparative study. Proposal 2, Precast PC Slab, is adopted on the grounds of its superior workability and safety.

(3) Review of Optimal Span Length

In bridge planning, while substructure costs vary significantly depending on topography and ground conditions, the superstructure costs are relatively constant. Therefore, it is necessary to consider the most economical span length. As mentioned above, the 2011F/S selected 50 m as the optimal span length. However, in more recent years, application of high-strength S14T bolts etc. enabled splicing of high-strength SBHS 500 steel plate and thick plate. Thus it has become possible to improve the cost-efficiency of long spans. In light of this development, the span length is reconsidered.

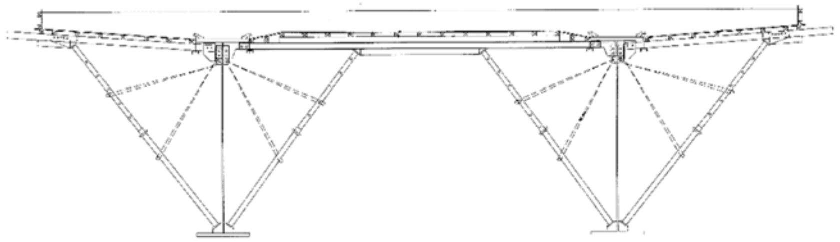
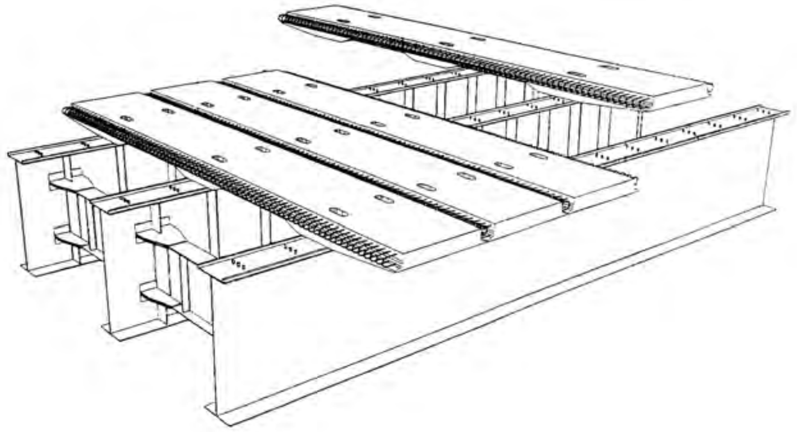
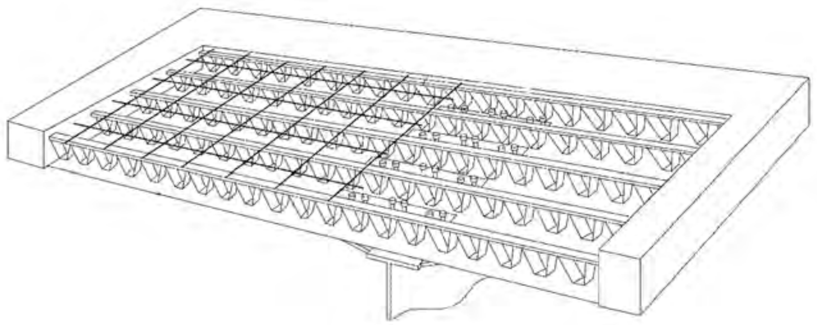
The girder length under review is set to 300 m, the range in which fixed support can be economically applied to the bearing structure. This span is divided into equal lengths.

Table 7-7-11 shows the results of the review, in which an optimal span length of 60 m is selected.

Table 7-7-11. Review of optimal span length

	Proposal 1: 50 m average span （6@50=300m）	**Proposal 2: 60 m average span （5@60=300m）**	**Proposal 3: 75 m average span （4@75=300）**
Superstructure cost	Steel girder 0.30 Deck slab 0.14	Steel girder 0.36 Deck slab 0.14	Steel girder 0.46 Deck slab 0.14
Substructure cost	Substructure 0.40 Abutment 0.18	Substructure 0.34 Abutment 0.16	Substructure 0.30 Abutment 0.13
Total	1.02	1.00	1.03
Evaluation		Adopt	

Table 7-7-12. Comparative Study of Deck Structures in Steel Dual Main Girder Structures

	Proposal 1: Cast-in-place PC slab	**Proposal 2: Precast PC slab**	**Proposal 3: Steel/Concrete Composite Deck**
Overview			
Structural characteristics	● Because all work is performed in the field, it is difficult to ensure quality. Even in Japan, the application of this method is limited. For overseas application, this method brings a high level of risk. （Fair）	● Due to the fact that most structural members are manufactured in a simple plant near the site, and technology acquisition is fast due to the simple, repetitive work, this method makes it easy to ensure quality and high structural reliability. ● This method adopts a looped joint developed in Japan as its connection method. Fatigue loading tests of this method have been conducted. Therefore, this method has no structural drawbacks. （Very good）	● With non-concrete components manufactured at a factory, quality is easy to secure. ● This method has a track record of use in many projects and no structural issues. However, the potential for deterioration from water accumulating on steel plates under the deck surface has been pointed out. （Good）
Workability	● Safety is difficult to control due to all work being performed at a highly-elevated work position. ● This method has inferior workability due to long periods of construction under cold weather conditions and the need to implement winter concreting measures. （Fair）	● Indoor fabrication as well as fabrication during winter months are both possible. The simple repetitive operations used in this method also makes it easier to control safety and quality. ● Adopting a loop joint allows work from under the deck slab to be eliminated, providing excellent workability in the field. （Very good）	● Quality is easy to control as steel members are manufactured in a fully equipped factory. ● Work from under the deck slab is eliminated due to the presence of a bottom plate, providing excellent workability in the field. ● Fabricated members need to be transported from the production factory to work site. （Good）
Economic feasibility	1.07 （Good）	1.00 （Very good）	1.80 （Fair）
Evaluation		**Adopt**	

4) Span Classification 3: Short-span Bridges such as Main Route Bridges, P06 Bridges, and Ramp Bridges

Because many of the existing short-span bridges (e.g., main route bridges, P06 bridges, and ramp bridges) have span lengths of around 25 m, the adoption of PC precast girders, etc. help to ensure better economic feasibility and workability.

Aside from the span length, the number of expansion joints is another point to consider in setting the selection criteria. Because the P06 bridge at the survey point 12+0 and ramp bridge at the survey point 122+80 are multi-span continuous bridges, the number of expansion joints will be reduced to lower maintenance costs. Therefore, a bridge type able to provide either a continuous or connected structure is adopted.

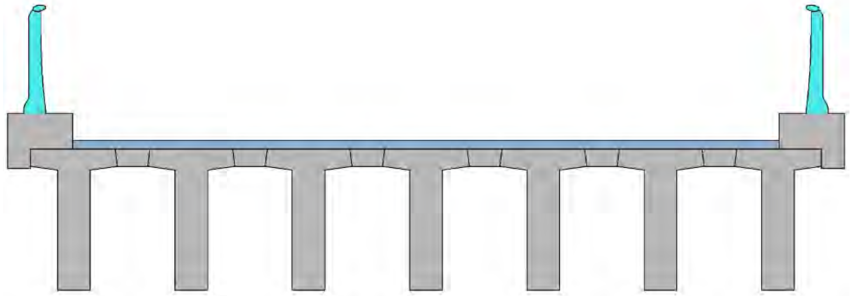
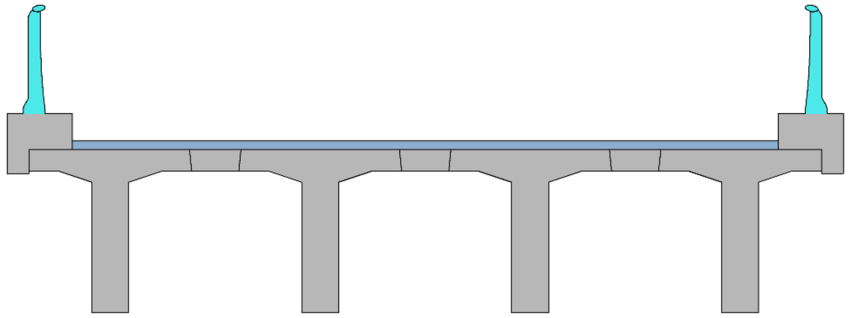
Girders for staging work have seen a fewer number of use in recent years due to its difficulty ensuring quality and inferior workability and cost-effectiveness compared with precast girders. Given above, it is not included in the consideration.

Therefore, the following three types are compared:

Proposal 1: PC precast, pretensioned continuous (simple) T-girder
Proposal 2: PC precast, pretensioned continuous (simple) slab girder
Proposal 3: PC precast, post-tensioned continuous (simple) T-girder

As the result of the study, as shown in Table 7-7-13, "Proposal 2: PC precast, pretensioned continuous (simple) slab girder" was adopted on the ground of its superiority in all aspects of structural characteristics, technology transfer, workability, operation and maintenance, and economic feasibility.

Table 7-7-13. Comparative Study of Bridge Types with Span Lengths of Approx. 25 m

	Proposal 1: PC precast Pretensioned continuous (simple) T-girder	**Proposal 2: PC precast Pretensioned continuous (simple) slab girder**	**Proposal 3: PC precast Post-tensioned continuous (simple) T-girder**
Overview			
Structural characteristics	● Since many components are fabricated in simple, repetitive work in a simple factory, this method makes it easy to ensure the production of high-quality girders. ● This method is prone to structural defects in work carried out at the bridge site, especially the concrete filled between slabs. （Good）	● Since many components are fabricated in simple, repetitive work in a simple factory, this method makes it easy to ensure the production of high-quality girders. ● It is difficult for structural defects to occur as almost no components are fabricated at the bridge site. （Very good）	● Compared with Proposal 1 and Proposal 2, it is more difficult to ensure girder quality as they are fabricated near the building site. ● This method is prone to structural defects in work carried out at the bridge site, especially in the concrete filled between slabs and grouting in the sheathing pipe after PC slabs are tensioned. （Fair）
Technology Transfer	● Although this plan is designed and constructed to JIS equivalent standards, due to being old technology and structures, there is little potential for technology transfer. （Good）	● This plan is not only designed and constructed to JIS equivalent standards, but also features a unique structure that eliminates fabrication work at the bridge location. This has high potential for technology transfer as a powerful structural form for small-scale bridges. （Very good）	● Due to being old technology and structure, there is little potential for technology transfer. （Fair）
Workability	● The precast girder can be fabricated at a single simple factory, then transported and installed to a variety of locations, realizing efficient construction. ● Some work must be performed at the bridge from under the girder structure, such as crossbeams and concrete filling between slabs. Compared to Proposal 2, this proposal is inferior in workability and safety due to the large amount of high-elevation work that requires scaffolding and such in all work. （Good）	● The precast girder can be fabricated at a single simple factory, then transported and installed to a variety of locations, realizing efficient construction. ● This method does not require work to be performed at the bridge from under the girder structure. All work can be carried out using only bridge scaffolding that is set up when girders are erected. Due to the minimal amount of high-elevation work, this is the best proposal in terms of workability and safety. （Very good）	● This proposal requires fabrication yards near each bridge position to fabricate and erect precast girders on site. Compared with the other proposals, this proposal requires significant resources to go into temporary facilities/equipment. ● Some work must be performed at the bridge from under the girder structure, such as crossbeams and concrete filling between slabs. Compared with Proposal 2, this proposal is inferior in workability and safety due to the large amount of high-elevation work that requires scaffolding and such in all work. （Fair）
Operation and maintenance	● As all proposals use concrete girders, the differences are negligible. (Good)	● As all proposals use concrete girders, the differences are negligible. (Good)	● As all proposals use concrete girders, the differences are negligible. (Good)
Economic feasibility	1.0 (Good)	1.0 (Good)	1.3 (Fair)
Evaluation		**Adopt**	

7-7-3 Review of Substructure Type Selection

1) Selection Policy for Substructure Type

(1) Main Tower Frame Type

Main tower frame types are broadly categorized into either steel tower or RC tower. In this project, an RC tower structure is adopted on the ground of its superior cost efficiency and many instances of use in recently built cable-stayed bridges.

(2) Pier Structure Type

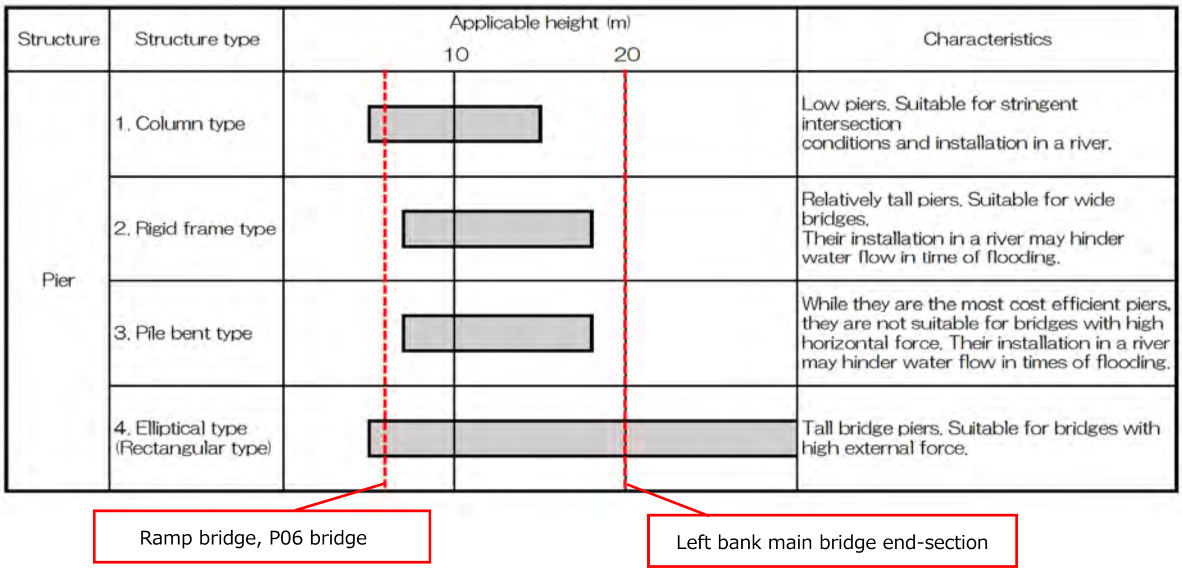
With regard to general RC pier structure types, as shown in Table 7-7-15, the applicable type is generally determined by the required structural height. For this reason, structural types are considered using this table as reference. As for pier height, although the height required for each bridge differs depending on topography, road alignment, construction limitations, etc., pier height is broadly classified into the three types shown in Table 7-7-14, each of which is investigated.

Pier classification 3 bridges, namely the left bank approach bridge and T1506 bridge, are considered separately from Table 7-7-15 because PC wells (single pile-bent method) is considered desirable for these bridges for the following reasons: in the case of the left bank approach bridge, to avoid the increased costs of building over the waterway; and in the case of the T1506 bridge, for construction procedure.

Table 7-7-14. Pier Classification for Bridges (Route 2)

Pier Classification	Applicable Bridges
Pier Classification 1 (RC pier height of about 6 m)	Ramp Bridge Pier, P06 Bridge Pier
Pier Classification 2 (RC pier height of about 20 m)	Left Bank Main Bridge End-section Pier
Pier Classification 3 (pier that uses a PC well)	Left Bank Approach Bridge Pier, T1506 Bridge Pier, Right Bank Main Bridge End-section Pier

Table 7-7-15. Relationship between the Typical RC Pier Structure Type and Height (Route2)



Structure	Structure type	Applicable height (m) 10 20	Characteristics
Pier	1. Column type		Low piers. Suitable for stringent intersection conditions and installation in a river.
	2. Rigid frame type		Relatively tall piers. Suitable for wide bridges. Their installation in a river may hinder water flow in time of flooding.
	3. Pile bent type		While they are the most cost efficient piers, they are not suitable for bridges with high horizontal force. Their installation in a river may hinder water flow in times of flooding.
	4. Elliptical type (Rectangular type)		Tall bridge piers. Suitable for bridges with high external force.

Source: Design Manual, Chubu Regional Development Bureau (April 2000)

a) Pier Classification 1: Ramp Bridge Pier, P06 Bridge Pier

Piers of the ramp bridge and P06 bridge are short at only around 6 m in height. Based on Table 7-7-15, shows that "1. Column type" and "4. Elliptical type (Rectangular type)” can be chosen. However, since the bridge is quite wide at 25.5 m in width and beams cannot be built with the "1. Colum type," the "4. Elliptical type (Rectangular type)" is chosen. Note that since the target piers are outside the waterway and an elliptical shape is not required, the simpler construction, a rectangular pier, is adopted here.

b) Pier Classification 2: Left Bank Main Bridge End-section Pier

Because the pier height of the left bank main bridge end-section reaches 20 m, construction over the waterway is necessary. However, the single pile-bent PC well pier structure adopted for the left bank approach bridge pier cannot be adopted. Therefore, an appropriate structure is selected from among the available general RC pier structures.

Since pier height is 20 m, "4. Elliptical type" is selected as per Table 7-7-15.

c) Pier Classification 3: Left Bank Approach Bridge Pier, T1506 Bridge Pier

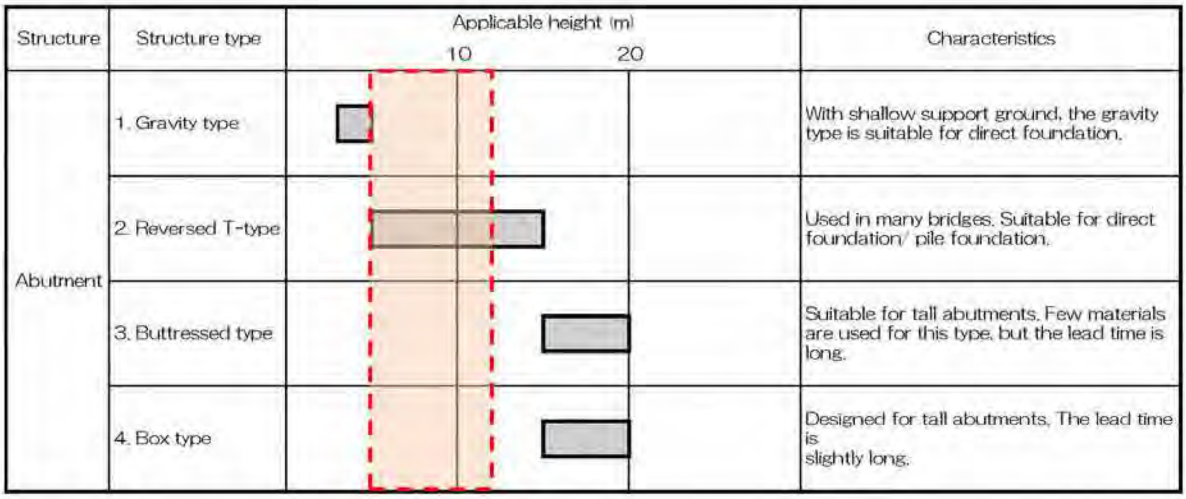
Since the left bank approach bridge piers require construction over the waterway and on extremely soft ground, eliminating cofferdamming work is important to reduce costs. Pile bent structures that eliminate cofferdamming work are broadly classified into two types: multi pile bent and single pile bent, and their pier structure varies depending on the type. With this in mind, selection of the pier structure for the left bank approach bridge is considered together with the foundation structure in the next section.

For the T1506 bridge, an approximate 15 m deep cutting is necessary to construct the main road, and must be cut while road T1506 is in service. In an ordinary bridge structure, large-scale excavation must be performed before the frame structure can be constructed. This would result in major challenges in economic efficiency, workability, arrangement of temporary bypass roads, etc. However, in multi pile-bent pier column structures that use PC wells, the PC well itself also serves as the pier structure. This means that piers can be constructed without implementing large-scale excavation, thereby solving many of the problems mentioned above. For this reason, a PC well foundation (single pile-bent method) is adopted for the main bridge’s pier structure.

(3) Abutment Structure Type

With regard to general RC abutment structure types, as shown in Table 7-7-16, the applicable type is generally determined by the required height. For this reason, structure types are considered while using this table as reference. Abutment heights vary from roughly 5 to 12 m, and since the optimal configuration for all abutments in this range is a reversed T-type abutment, this type is adopted for all abutments of the bridge.

Table 7-7-16. Relationship between the Typical Abutment Structure Type and Height (Route2)



Structure	Structure type	Applicable height (m) 10 20	Characteristics
Abutment	1. Gravity type		With shallow support ground, the gravity type is suitable for direct foundation.
	2. Reversed T-type		Used in many bridges. Suitable for direct foundation/ pile foundation.
	3. Buttressed type		Suitable for tall abutments. Few materials are used for this type, but the lead time is long.
	4. Box type		Designed for tall abutments. The lead time is slightly long.

Source: Design Manual, Chubu Regional Development Bureau (April 2000)

7-7-4 Review of Foundation Type Selection

1) Selection Policy for Foundation Type

The construction conditions, ground conditions, and structural scale of the upper structure all have to be considered when selecting the type of foundation. Further, in view of advantages such as a consistent set of engineers and construction equipment by having a uniform structure, as well as cost-effectiveness and quality improvement, there is no benefit in needlessly increasing structural formats. With this in mind, this Study classifies the alternatives in to the three types shown in the table below and investigates each.

Table 7-7-17. Foundation Classification for Bridges (Route 2)

Foundation Classification	Target Foundations
Foundation Classification 1 (a foundation that bears a major superstructure counterforce from the main bridge)	Main Bridge Main Tower, Left Bank Main Bridge End-section Pier
Foundation Classification 2 (a foundation that is constructed over a waterway on soft ground and has special construction requirements)	Left Bank Approach Bridge Piers, T1506 Bridge Piers
Foundation Classification 3 (a basic land foundation without special construction requirements)	Main Route Bridge Abutment, P06 Bridge Abutment/Pier, Ramp Bridge Abutment/Pier, Left Bank Approach Bridge Abutment, Right Bank Main Bridge End-section Abutment

2) Foundation Classification 1: Main Bridge Main Tower, Left Bank Main Bridge End-section Pier

Because a major counterforce from the superstructure is exerted onto the main bridge's foundation, its structure varies widely depending on ground conditions. Therefore, this section re-examines foundation types based on data that includes the results of the complementary geological surveys and changes in counterforce size from the superstructure.

(1) Left Bank Main Bridge Main Tower

The left bank main tower foundation is constructed in a river roughly 4 m deep. As for ground conditions, the ground is composed of soft ground from the surface layer to intermediate layer, and its bearing layer contains a layer of soft rock at about 35 m below the water surface.

The 2011F/S made a comparative study of several foundations types including cast-in-place pile foundation (multi pile-bent method), open caisson foundation (self-standing method), and steel pipe sheet pile foundation (self-standing method). Of which, the steel pipe sheet pile foundation (self-standing method) method was selected.

The open caisson foundation method (self-standing method) is inferior in economic feasibility as not adopted in the 2011F/S; thus it is not included in the comparative review in this Study.As the steel pipe sheet pile foundation (self-standing method) method does not require cofferdamming work, it is included in the comparative review again in this Study. However, since the steel pipe sheet pile on the exterior portion of the well is in constant direct contact with water, anti-corrosive measures are an issue with this method. Althout not adopted in the 2011F/S, the cast-in-place pile foundation (multi pile-bent method) requires no cofferdamming work, and its mainly concrete construction reduces anti-corrosive issues. Therefore, it is included in the comparative review again in this Study. Furthermore, since these two proposals have the same issue, namely, that the foundation needs to bear a significant reaction load from the weight of the footing, a steel pipe sheet pile foundation (temporary cofferdam method), a structure that may reduce reaction load by placing footings underwater, will also be reviewed as a new proposal. Since the steel pipe sheet pile can be used as a cofferdam, excavation is possible even in soft ground such as that in this foundation.

Based on the above, the comparative review considers the following three proposals.

Proposal 1: Steel pipe sheet pile foundation (self-standing method)
Proposal 2: Cast-in-place pile foundation (multi pile-bent method),
Proposal 3: Steel pipe sheet pile foundation (temporary cofferdam method)

Table 7-7-18 shows the results of this comparative study. Since there is little difference in economic feasibility between the three proposals, "Proposal 3: Steel pipe sheet pile foundation (temporary cofferdam method)" is adopted on the grounds of its superior workability and safety.

(2) Right Bank Main Bridge Main Tower

Unlike the 2011F/S, right bank of main tower foundation is constructed on land in this Study. Geologically, a layer of soft ground continues for roughly 10 m from the surface layer, followed by a bearing layer composed of soft rock.

As the bearing layer is found in a relatively shallow depth for a foundation, the spread foundation of Proposal 1 is a promising alternative; however, being located in the landslide zone, the large-scale excavation work when constructing the foundation may trigger a landslide. Because of this, it is compared with Proposal 2, Cast-in-place pile (extended footing type), in which the footings protrude above ground to eliminate the need for large-scale excavation, and a cast-in-place pile is constructed under the footings to provide support. The steel pipe sheet pile foundation (self-standing method) method chosen in the 2011F/S is disadvantageous in the case of land construction in terms of cost effectiveness and workability due to its spread foundation and cast-in-place pile, and thus rejected as inadequate.

Based on the above, the comparative review considers the following two proposals.

Proposal 1: Spread foundation
Proposal 2: Cast-in-place pile foundation (extended footing type)

Based on the result of this comparative study, shown in Table 7-7-19, Proposal 2: Cast-in-place pile foundation (extended footing type) is adopted.

(3) Left Bank Main Bridge End-section Pier

For the left bank end-section pier foundation, since the pier height reaches 20 m and will be subjected to significant horizontal counterforce from the main bridge side span, the PC well (single pile-bent method) method used on the neighboring left bank approach bridge cannot be adopted.

Since ground and topographic conditions are the same as the left bank main tower foundation, the applicable structural types are steel pipe sheet pile foundation (self-standing method), cast-in-place pile foundation (multi pile-bent method), and steel pipe sheet pile foundation (temporary cofferdam method). However, in considering the advantage of reusing the same equipment, the 'steel pipe sheet pile foundation (temporary cofferdam method)' is adopted as the foundation for the left bank main tower.

Table 7-7-18. Comparative Review of Left Bank Main Tower Foundations

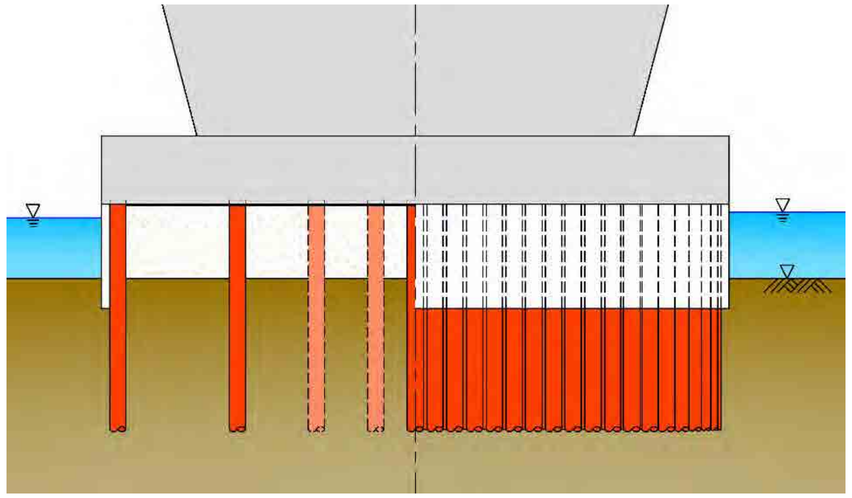
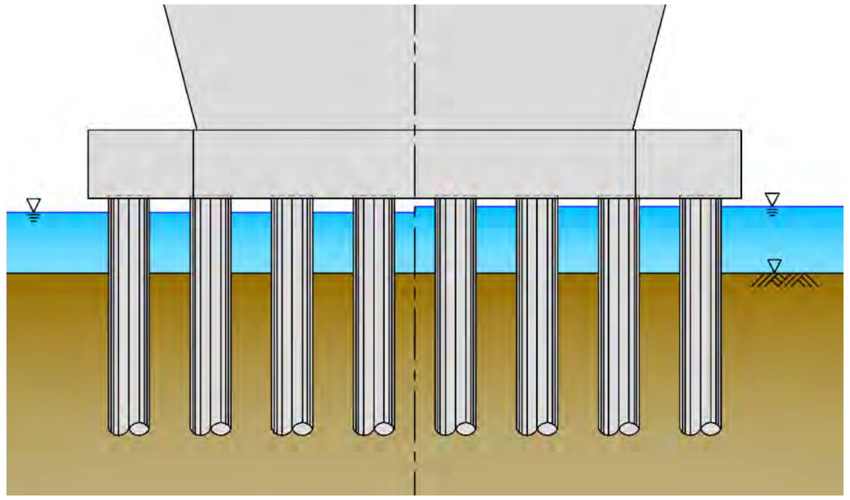
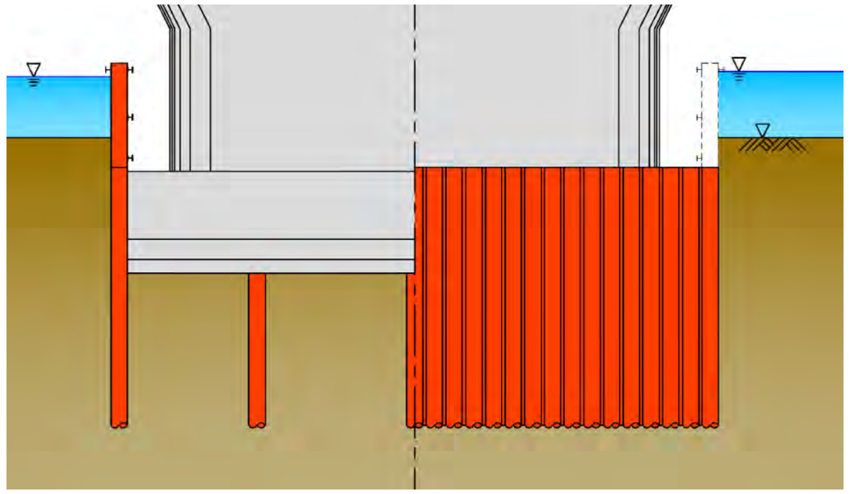
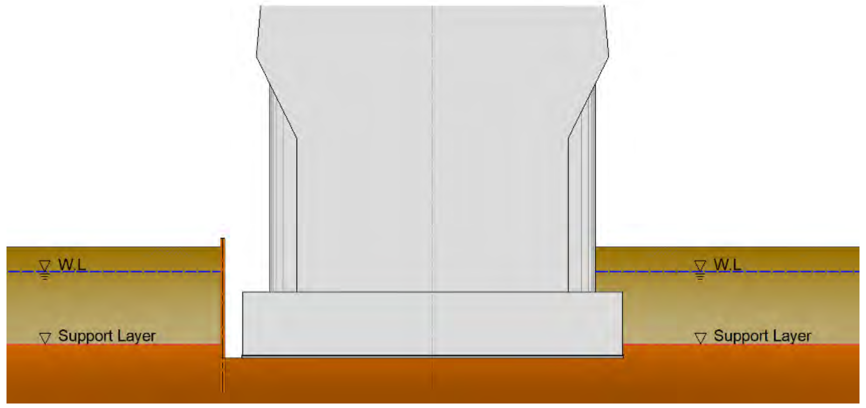
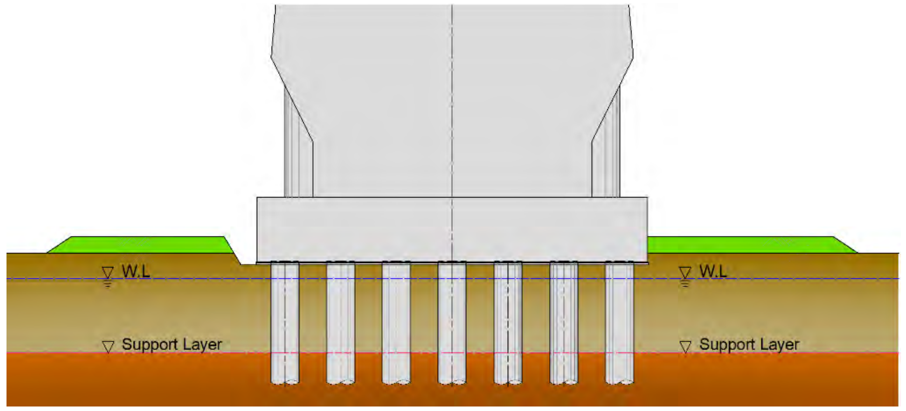
	Proposal 1: Steel pipe sheet pile foundation (self-standing method)	**Proposal 2: Cast-in-place pile foundation (multi pile-bent method)**	**Proposal 3: Steel pipe sheet pile foundation (temporary cofferdam method)**
Overview			
Structural characteristics	●Exterior metal pipes protruding above ground require anti-corrosion measures due to them having direct contact with water. However, such measures is a cause for concern as it is extremely difficult to achieve long-term durability. （Fair）	● Since the piles protruding above ground are concrete, there are no issues regarding anti-corrosion measures. ● This type of structure is susceptible to horizontal force during an earthquake, but has no significant issues when used in non-earthquake areas. （Very good）	● Because all steel pipes are underground, there is no need to implement anti-corrosion measures. （Very good）
Impact on rivers	●With this method, there is concern over impact on rivers such as scouring caused by major river flow obstruction. （Fair）	● With this method, there is concern over impact on rivers such as scouring caused by major river flow obstruction. （Fair）	● There is little impact on the river as the river flow is not significantly obstructed. （Very good）
Workability	●The workability is good since in-river excavation is unnecessary. Howver, because it requires cofferdamming work to perform anti-corrosive measures on protruding steel pipes and also involves complicated staging work to pour concrete footings over the waterway, it is no better than the other proposals when viewed collectively. （Good）	● The workability is good since in-river excavation is unnecessary. However, because it requires caisson cast-in-place pile work on the waterway and also involves complicated staging work to pour concrete footings over the waterway, it is no better than the other proposals when viewed collectively. （Good）	● This plan requires in-river excavation. However, it also has a proven history of use in many projects and its construction techniques are well-established. Viewed collectively, it is no better than the other proposals. （Good）
Landscape aesthetics	●Because of the massive footing protruding from the water, this plan is inferior from a landscape aesthetics perspective. （Fair）	●Because of the massive footing protruding from the water, this plan is inferior from a landscape aesthetics perspective. （Fair）	● Because only the piers are exposed above the waterway, this plan is favorable from a landscape aesthetics perspective. （Very good）
Economic feasibility	1.05 （Good）	1.00 （Very good）	1.01 （Very good）
Evaluation			**Adopt**

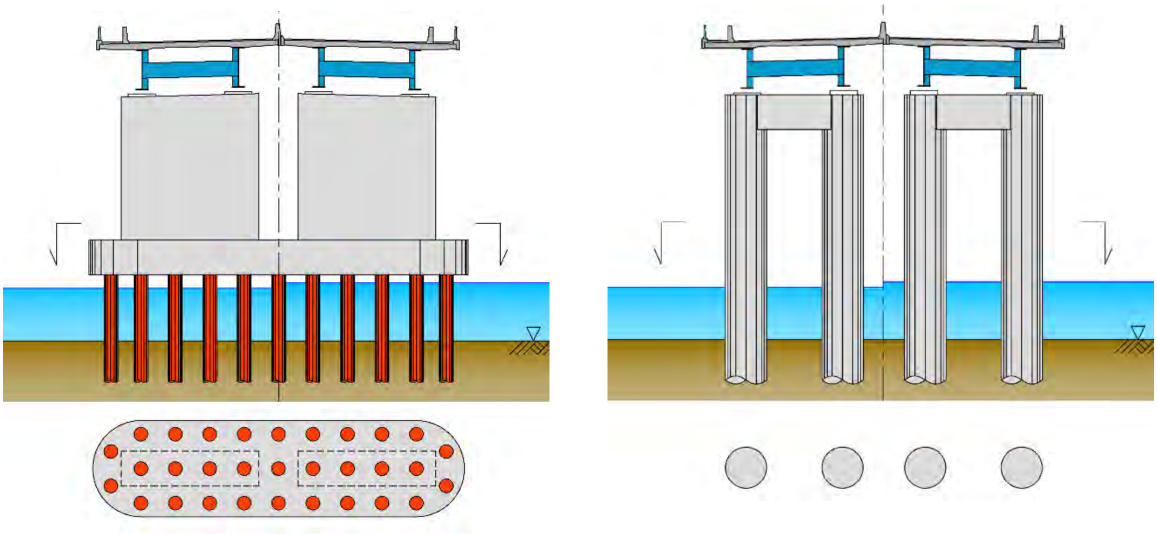
Table 7-7-19. Comparative Review of Right Bank Main Tower Foundations

	Proposal 1: Spread foundation	**Proposal 2: Cast-in-place pile foundation (extended footing type)**
Overview		
Structural characteristics	● As this configuration dates back for generations, there are no problems regarding structural soundness. （Very good）	● This type of structure is susceptible to horizontal force during an earthquake, but has no significant issues when used in non-earthquake areas. （Very good）
Landslide impact	●Large-scale excavation of the lower section of landslide-prone soil mass has high potential to trigger movement of the soil mass. （Fair）	● As this plan greatly reduces excavation of the lower section of landslide-prone soil mass, it is better than Proposal 1 regarding landslide impact. （Very good）
Workability	● Since excavation work requires at least 10 m of major excavation and open excavation is not possible, the workability of this plan is inferior to Proposal 2. ● Due to a foundation structure composed only of footings, this plan has better workability than Proposal 2. （Good）	● Since excavation work is shallow and some can be carried out as open excavation, this plan has better workability then Proposal 1. ● Although this plan requires cast-in-place pile work, it has a proven history of use in many projects and little compromise in workability. （Good）
Landscape aesthetics	●Because only piers are exposed over land, this plan is favorable from a landscape aesthetics perspective. （Very good）	●Because of the massive footing protruding from the ground, this plan is inferior from a landscape aesthetics perspective. （Good）
Economic feasibility	1.12 （Very good）	1.00 （Good）
Evaluation		Adopt

3) Foundation Classification 2: Left Bank Approach Bridge Pier, T1506 Bridge Pier

(1) Left Bank Approach Bridge Pier

Because construction over the waterway is necessary, there are two applicable configurations for the left bank approach bridge pier structure and foundation type: multi pile-bent method and single pile-bent method (see the figure below). Of these, since the single pile-bent method has no clear boundary between the pier structure and foundation, the pier structure and foundation are reviewed here as a single entity.



Multi pile-bent method Single pile-bent method

Figure 7-7-2. Variations of Piers Using the Pile-bent Method

The 2011F/S compared several approach bridge substructures, including a cast-in-place pile foundation (multi pile-bent method), steel pipe pile foundation (multi pile-bent method), and steel pipe sheet pile foundation (self-standing method). Of these, the steel pipe pile foundation (multi pile-bent method) was selected in consideration of the load scale (cost-effective span: 30-60 m girder bridge), construction conditions (construction site water depth: approx. 1-3 m; cold weather construction, etc.), and ground conditions (bearing layer depth: approx. 35 m from the riverbed).

A 'steel pipe pile foundation (multi pile-bent method)' has been used in over-water construction in almost all cases. Though it has good workability and superior cost-effectiveness, there is concern over the durability of the steel pipe as it is difficult to prevent it from corroding. This method has rarely been used for bridge substructures in Japan in recent years. Although this method is included in a comparative study, other structural types are considered for this reason.

Though not adopted in the 2011F/S because of the high cost, the cast-in-place pile foundation (multi pile-bent method), a method that eliminates the need for anti-corrosion measures, is also considered as an alternative. Also, the single pile-bent method eliminates the need for anti-corrosion and offers high rigidity. Therefore, the PC well foundation (single pile-bent method) is added as a new proposal. This method is superior in reducing impact on rivers and maintaining landscape aesthetics.

Based on the above, the comparative review considers the following three proposals.

Proposal 1: Steel pipe pile foundation (multi pile-bent method)
Proposal 2: Cast-in-place pile foundation (multi pile-bent method)
Proposal 3: PC well foundation (single pile-bent method)

Table 7-7-20 shows the results of this comparative study. “Proposal 3: PC well foundation (single pile-bent method)” was adopted on the ground of its superiority in most aspects including structural characteristics, impact on the river, and landscape aesthetics.

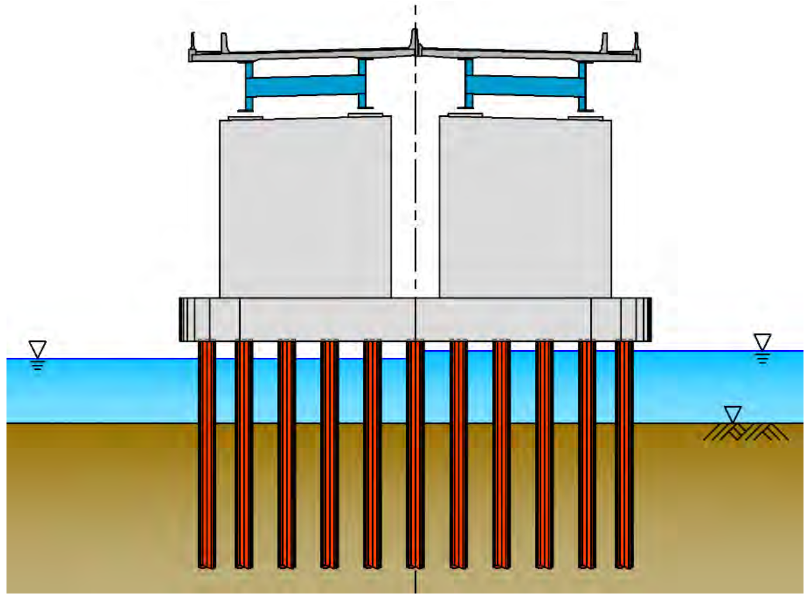
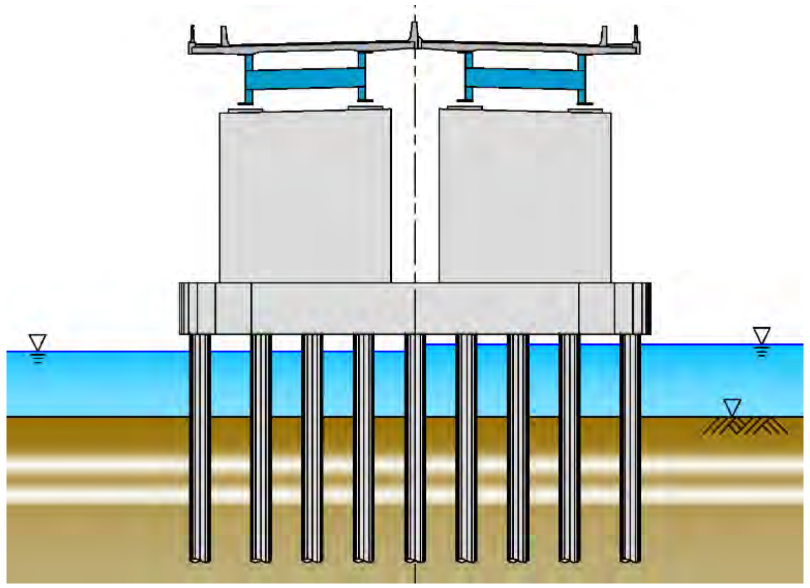
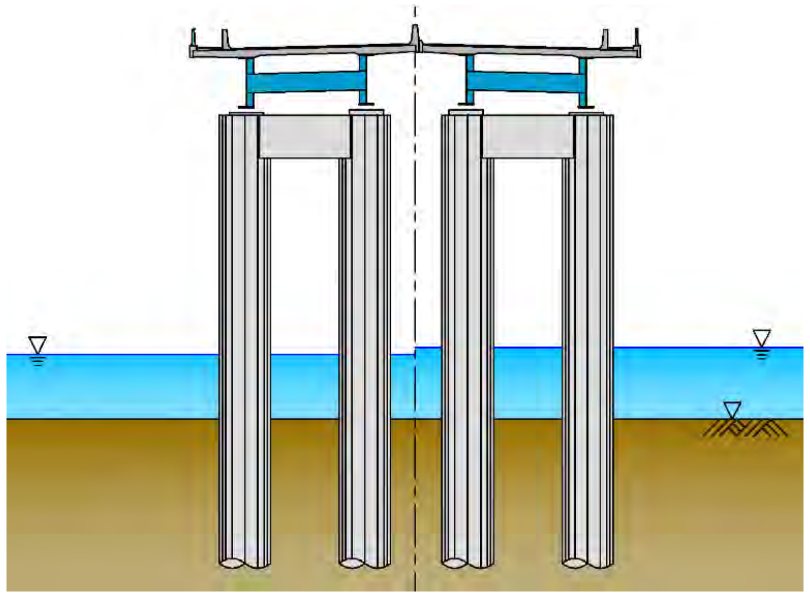
(2) T1506 Bridge Pier

As mentioned in the review of T1506 bridge pier structures, the 'PC well foundation (single pile-bent method)' is adopted due to special construction requirements for the piers.

4) Span Classification 3: Main Route Bridge Abutment, P06 Bridge Abutment/Pier, Ramp Bridge Abutment/Pier, Left Bank Approach Bridge Abutment, and Right Bank Main Bridge End-section Abutment

Since the foundation can be constructed on land, a typical pile foundation would be most economical. Types of pile foundations are roughly categorized into cast-in-place pile, steel pipe pile, and PHC pile. Of these, steel pipe pile and PHC pile require sections to be transported from a factory, and have almost no history of previous implementation in work outside Japan except for special situations due to this method's economical disadvantages. Therefore, cast-in-place piles are adopted for the foundation work.

Table 7-7-20. Comparative Review of Approach Bridge Foundations

	Proposal 1: Steel pipe pile foundation (multi pile-bent method)	**Proposal 2: Cast-in-place pile foundation (multi pile-bent method),**	**Proposal 3: PC well foundation (single pile-bent method)**
Overview			
Structural characteristics	●Due to the presence of moisture and oxygen around the water surface where the steel pipes protrude outside the water, severe rusting may occur. Steel pipes with linings and such have been developed, however, they are not perfect as there is concern over corrosion spreading from corroded sections on the exterior. There are doubts over the durability of foundations using this configuration. （Fair）	● Since the piles protruding from the water surface are made of concrete, and the temporary steel pipe used to pour the concrete is on the outside, there are no issues regarding anti-corrosion measures. （Very good）	● As the piles are high quality concrete fabricated at a nearby casting yard, there are no issues regarding anti-corrosion measures. （Very good）
Impact on rivers	●With this method, there is concern over impact on rivers such as scouring caused by major river flow obstruction. （Fair）	●With this method, there is concern over impact on rivers such as scouring caused by major river flow obstruction. （Fair）	● There is little impact on the waterway as the river flow is not significantly obstructed. （Very good）
Workability	●Since the steel pipe pile can be efficiently driven in using a flying hammer etc., workability is good. ●Because the heavy weight of the concrete requires complicated staging work to pour concrete footings over the waterway, this plan has inferior workability. （Good）	● Since pouring work for cast-in-place pile requires lining the entire surface of the upper pile, requiring significant effort for temporary work, this plan has inferior workability. ● Because the heavy weight of the concrete requires complicated staging work to pour concrete footings over the waterway, this plan has inferior workability. （Fair）	● Since the PC well sinking work requires a relatively diverse range of types of work and also requires several setup changes, this proposal as inferior workability compared with other proposals based on machine excavation. ● Since footings and piers can be omitted and the structure can be completed easier than piers by stacking PC wells, this method has favorable workability for that portion of the work. （Good）
Landscape aesthetics	●Because of the massive footing protruding from the water, this plan is inferior from a landscape aesthetics perspective. （Fair）	●Because of the massive footing protruding from the water, this plan is inferior from a landscape aesthetics perspective. （Fair）	● Because the structural elements exposed above the waterway are slimmer, this plan is favorable from a landscape aesthetics perspective. （Very good）
Economic feasibility	1.12 （Good）	1.12 （Fair）	1.00 （Very good）
Evaluation			**Adopt**

7-8 Basic Plan of the Route 3 Bridge

Based on the various conditions established thus far, a layout plan has been prepared for the Southern Bug River waterway-crossing section of the bridge. The arrangement procedure is as follows.

(1)The left bank side abutment is placed at the edge of the right bank river flow area to avoid any reduction of the current river width.

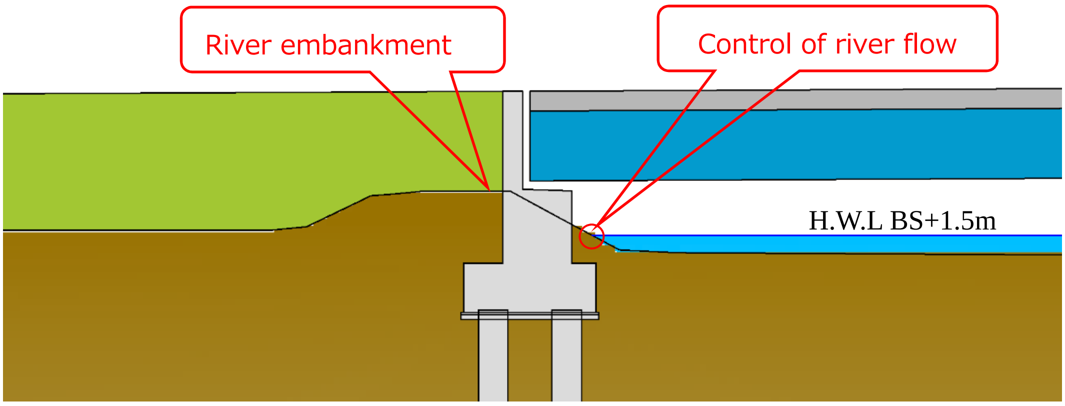


Figure 7-8-1. The Left Bank Side Abutment Layout (Route3)

(2)The main bridge (cable-stayed bridge) shall be a cable-stayed bridge with a center-span center that is aligned with the waterway center stipulated in 7-3-5, and has a center span length (420 m) that ensures the navigation channel width stipulated in 7-3-4. Because this bridge uses a cantilever construction method, side span length of the cable-stayed bridge shall be 210 m, basically set at about 1/2 the length of the center span.

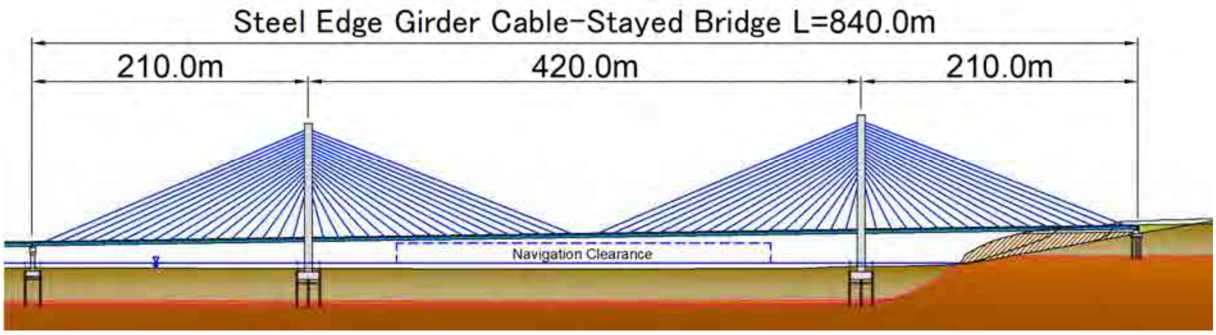


Figure 7-8-2. Main Bridge Layout (Route3)

(3)Between the left bank side abutment and main bridge (cable-stayed bridge) left bank end-section (left bank approach bridge), a continuous girder structure is used as much as possible to promote cost-effectiveness and smoother surface drivability. Based on a value of around 400 m, the maximum length of a continuous girder when using a high-surface-pressure fixed-support structure, a structure with excellent economic efficiency, three runs of continuous girder are constructed within this length. Since the possible continuous girder length grows longer as the pier heights increase, continuous girders are arranged (from shortest to longest) at 275 m, 335 m, 335 m, and 395 m. With regard to the span layout for continuous girders, the optimal span length is set in principle to 60 m, as stipulated in 7-9-2 3) item (3). With regard to the span length of the end-section continuous girder, a ratio of 1.25:1.00, the most rational ratio for mid-section to end-section span lengths, is used to improve the cost efficiency by eliminating the efficiency reductions from the concentrated sectional force. This sets the length of the end-section span to 47.5 m.

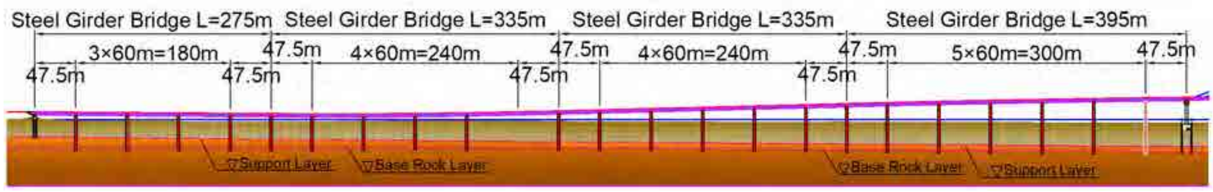


Figure 7-8-3. Layout of the Left Bank Approach Bridge (Route3)

(4)As the right bank side abutment is outside the assumed landslide line in the cable-stayed bridge's right bank end-section, an abutment is placed at this position.

7-9 Reviewing Bridge Type for Route 3

7-9-1 List of Target Bridges

The target bridges in this Study can be broadly classified into bridges that cross the Southern Bug River, and short-span bridges that are part of a roadway such as an interchange. The structural specifications of each bridge are as shown in the tables below.

Table 7-9-1. Structural specifications of the Bridge that Crosses the Southern Bug River (Route3)

	Superstructure		Substructure		
	Bridge length	Span length		Pier, Main tower height	Abutment height
Left bank approach	1,340m = 275m + 335m + 335m + 395m	(47.5 + 3@60 + 47.5) + (47.5 + 4@60 + 47.5) + (47.5 + 4@60 + 47.5) + (47.5 + 5@60 + 47.5)	Abutment	-	9m
			Pier	3-18 m	-
Main bridge	840m	210m+420m+210m	End-section Pier	20m	-
			Main Tower	116.0m	-
			Main Tower	117.5m	-
			Abutment	-	10m

Table 7-9-2. Structural Specifications of Short-span Bridges on Interchanges etc. (Route3)

	Main route survey point	Width	Bridge length	Span length	Pier height	Abutment height
Main route bridge	32+0	W=26.3m	25m	24m	—	12m
Main route bridge	50+0	W=26.3m	25m	24m	—	12m
Main route bridge	61+0	W=26.3m	25m	24m	—	12m
Main route bridge	88+80	W=26.3m	25m	24m	—	12m
Main route bridge	132+10	W=26.3m	25m	24m	—	12m
Main route bridge	143+90	W=26.3m	50m	24m	6m	12m
T1506 bridge	118+60	W=15.8m	130m	56m	15m	5m
P06 bridge	12+0	W=30.3m	56m	27m	6m	12m

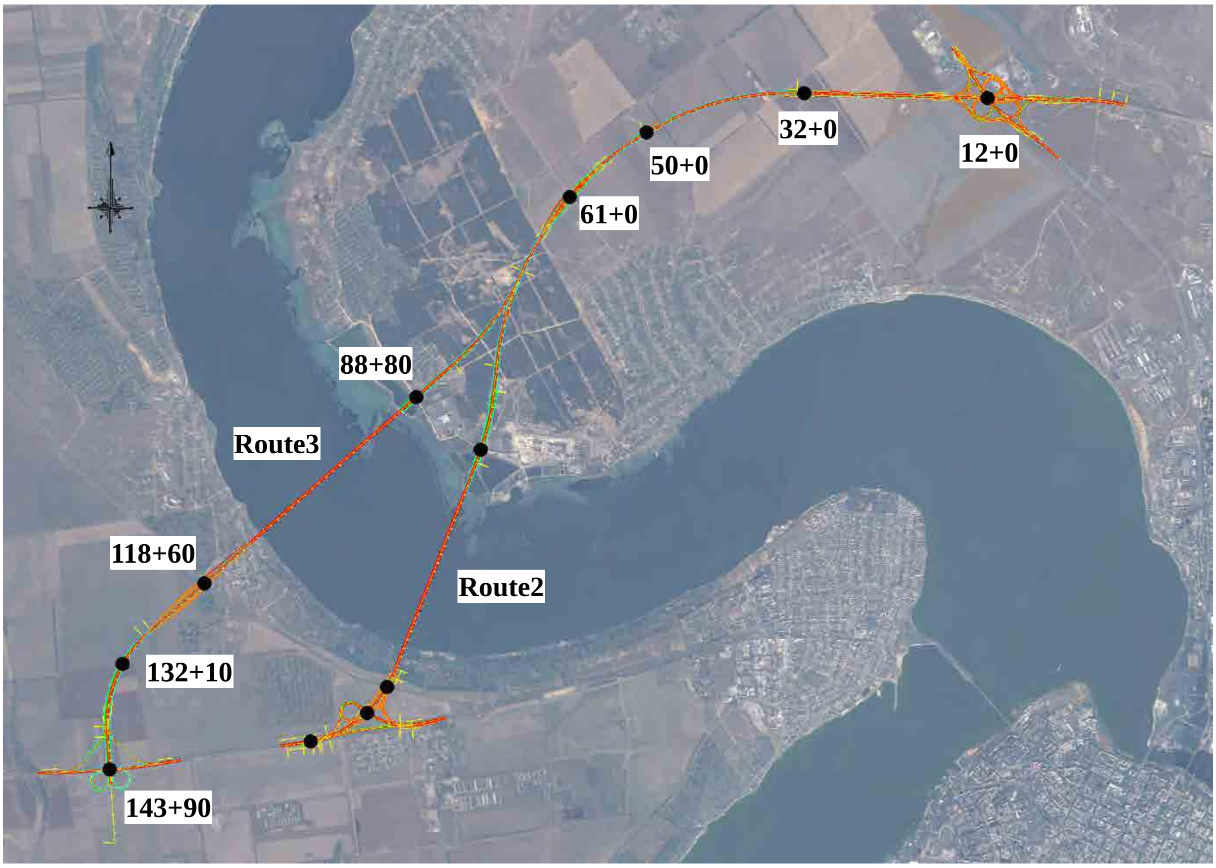


Figure 7-9-1. Main Route Survey Point (Route3)

7-9-2 Review of Superstructure Type Selection

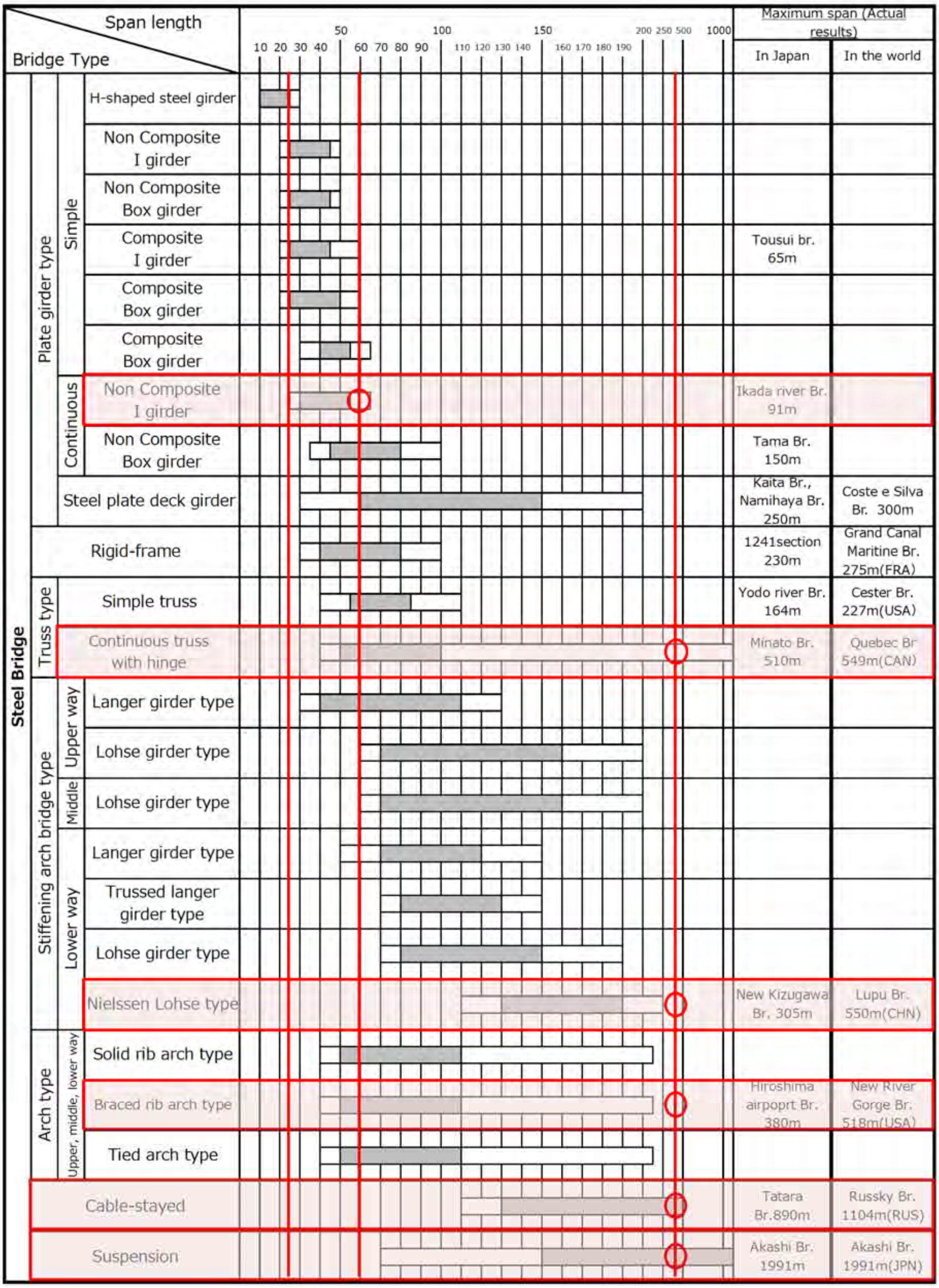
1) Selection Policy for Superstructure Type

As shown in Table 7-9-4 and Table 7-9-5, the type of superstructure is generally chosen based on the required span length, and the structural types are reviewed using these tables as reference. Also, the span length required for each bridge is roughly classified into the three types shown in the table below according to topographical conditions and cost-efficiency as generally summarized in Table 7-9-1 and Table 7-9-2. Each types are examined.

Table 7-9-3. Span Classification for Bridges (Route 3)

Span Classification	Applicable Bridges
Span Classification 1 (210 m +420 m +210 m)	Main Bridge
Span Classification 2 (average span of about 60 m)	Left Bank Approach Bridge, T1506 Bridge
Span Classification 3 (average span of about 25 m)	Main Route Bridge, P06 Bridge

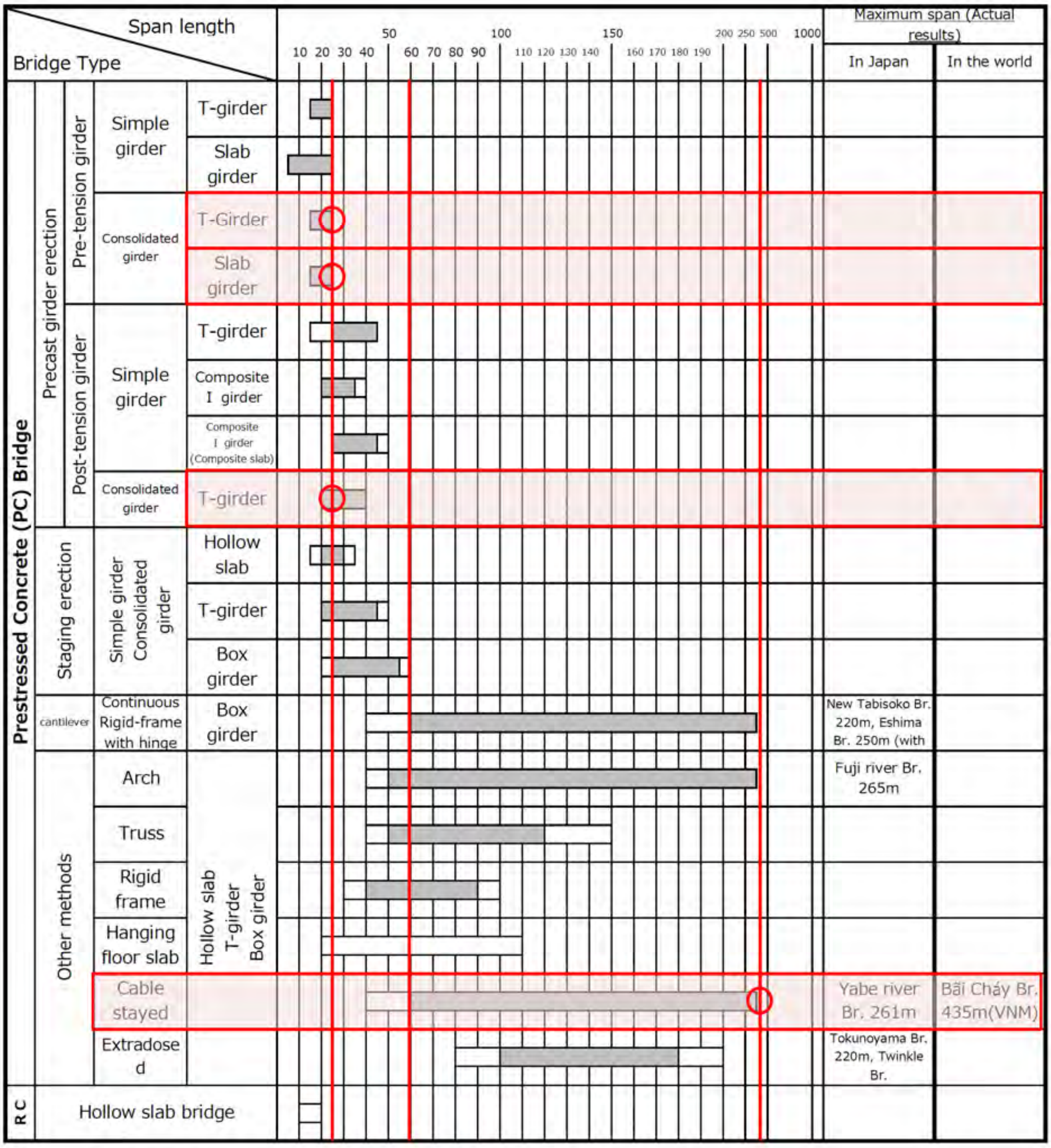
Table 7-9-4. Standard Applied Spans (Steel Bridges) (Route3)



Bridge Type				Maximum span (Actual results)	
				In Japan	In the world
Steel Bridge	Plate girder type	Simple	H-shaped steel girder		
			Non Composite I girder		
			Non Composite Box girder		
			Composite I girder	Tousui br. 65m	
			Composite Box girder		
			Composite Box girder		
		Continuous	Non Composite I girder	Ikada river Br. 91m	
			Non Composite Box girder	Tama Br. 150m	
		Steel plate deck girder		Kaita Br., Namihaya Br. 250m	Coste e Silva Br. 300m
	Rigid-frame			1241section 230m	Grand Canal Maritine Br. 275m(FRA)
	Truss type	Simple truss		Yodo river Br. 164m	Cester Br. 227m(USA)
		Continuous truss with hinge		Minato Br. 510m	Quebec Br 549m(CAN)
	Stiffening arch bridge type	Upper way	Langer girder type		
			Lohse girder type		
		Middle	Lohse girder type		
		Lower way	Langer girder type		
			Trussed langer girder type		
			Lohse girder type		
			Nielssen Lohse type	New Kizugawa Br. 305m	Lupu Br. 550m(CHN)
	Arch type	Upper, middle, lower way	Solid rib arch type		
			Braced rib arch type	Hiroshima airpoprt Br. 380m	New River Gorge Br. 518m(USA)
			Tied arch type		
	Cable-stayed			Tatara Br.890m	Russky Br. 1104m(RUS)
	Suspension			Akashi Br. 1991m	Akashi Br. 1991m(JPN)

Note) ▨ : Generally applied range ☐ : Relatively applicable range

Table 7-9-5. Standard Applied Spans (Concrete Bridges) (Route3)



Bridge Type					In Japan	In the world
Prestressed Concrete (PC) Bridge	Precast girder erection	Pre-tension girder	Simple girder	T-girder		
				Slab girder		
			Consolidated girder	T-Girder		
				Slab girder		
		Post-tension girder	Simple girder	T-girder		
				Composite I girder		
				Composite I girder (Composite slab)		
			Consolidated girder	T-girder		
	Staging erection		Simple girder Consolidated girder	Hollow slab		
				T-girder		
				Box girder		
	cantilever		Continuous Rigid-frame with hinge	Box girder	New Tabisoko Br. 220m, Eshima Br. 250m (with	
	Other methods		Arch	Hollow slab T-girder Box girder	Fuji river Br. 265m	
			Truss			
			Rigid frame			
			Hanging floor slab			
			Cable stayed		Yabe river Br. 261m	Bãi Cháy Br. 435m(VNM)
			Extradosed		Tokunoyama Br. 220m, Twinkle Br.	
RC	Hollow slab bridge					

Note) ▨ : Generally applied range ☐ : Relatively applicable range

Source: Design Manual, Chubu Regional Development Bureau (April 2000)

2) Span Classification 1: Main Bridge Superstructure Construction

A steel suspension bridge was selected for the main bridge's superstructure in the 2011F/S. This Study compares and re-examines the selection by reviewing relevant factors such as waterway bounds.

(1) Primary Comparative Review of Proposals

By ensuring a channel width of 280 m plus a clearance width of 70 m, values based on a reassessment of the waterway bounds, the center span of this bridge becomes 420 m (see 7-3-4).

Based on past constructed bridges, the appropriate bridge types for this span of bridge are the six proposals shown in Table 7-9-6. Considering the characteristics and evaluations shown in the table, proposal 4, 5, and 6 are chosen for a comparative review of the proposals.

Table 7-9-6. Primary Selection Chart of Main Bridge Types (Route 3)

	Characteristics	Evaluation
<Steel girder>		
Proposal 1: Continuous truss with hinge bridge	Is within range concerning track record, but also the largest type. A bridge of the scale has economical disadvantages, and in recent years has only been adopted to satisfy unique circumstances.	**Poor**
Proposal 2: Nielsen Lohse type bridge	Its track record of 400 m plus span lengths are all half-through bridges, and their arch rib design would block some of the waterway.	**Fair**
Proposal 3: Braced rib arch type bridge	Its track record of 400 m plus span lengths are all half-through bridges, and their arch rib design would block some of the waterway.	**Fair**
Proposal 4: Cable-stayed bridge	Applicable and within range concerning track record.	**Good**
Proposal 5: Suspension bridge	Applicable and within range concerning track record.	**Good**
<PC girder>		
Proposal 6: Cable-stayed bridge	Is within range concerning track record, but also the world's largest type.	**Good**

(2) Secondary Comparative Review of Proposals

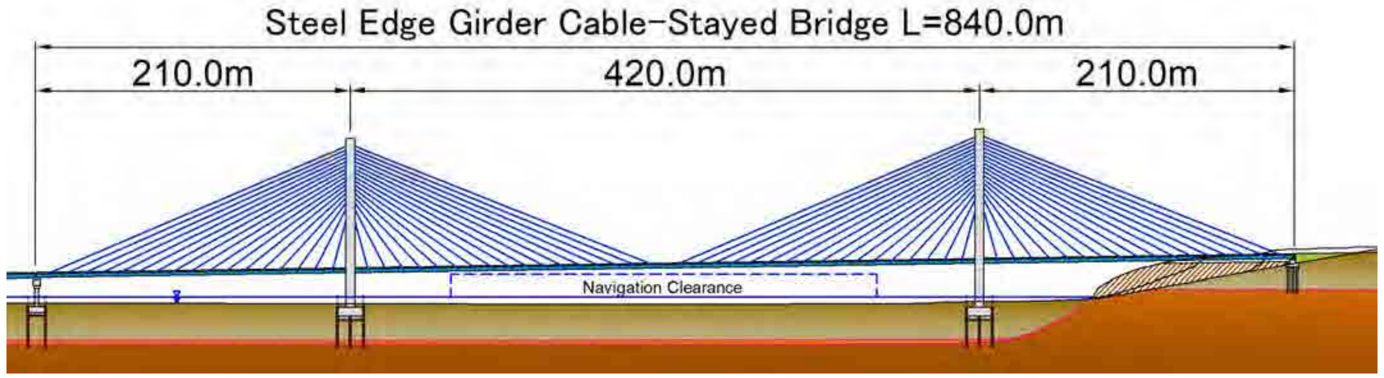
For each proposal selected in the primary comparative review, the following have been set as preconditions for the secondary comparative review after optimizing the structure of each based on track record of recent years, etc.

Table 7-9-7. Comparison of Proposals 4, 5, and 6

Items		Proposal 4 Steel-calbe stayed bridge	Proposal 5 Steel suspension bridge	Proposal 6 PC cable-stayed bridge
Main girder (stiffening girder)	Type	Edge-girder onfiguration	Full-box structure	Corrugated steel web box girder with inner and outer struts
	Note	Cost effective	Proven history of use in many projects, e.g., the Kurushima-Kaikyo Bridge	Lower costs by reducing dead load
Deck slab	Type	Precast PC slab	Steel plate deck	PC slab
	Note	Highly durable in a cold region	Proven history of use in many projects, e.g., the Kurushima-Kaikyo Bridge (no history of concrete deck slabs in a bridge of this scale)	N/A
Wind stabilization measures	Type	FRP panels and wind fairings	Full-box structure and wind fairings	Highly-rigid box girder structure and concrete in the main structure
	Note	Shield the girder underside	N/A	Improve damping coefficient

Tables 7-9-8 to 7-9-10 show results of the comparative study of the above three proposals. Proposal 4, steel cable-stayed bridge' (PC slab composite edge-girder type), was adopted on the ground of its superiority in all aspects of structural characteristics, technology transfer, workability, maintenance, and cost-effectiveness.

Table 7-9-8. Main Bridge Section: Bridge Type Comparison Table (1/3) (Route 3)

<table>
<tr><th colspan="3">Proposal 4 : Steel cable-stayed bridge (PC slab composite edge-girder type)</th></tr>
<tr><td colspan="3">

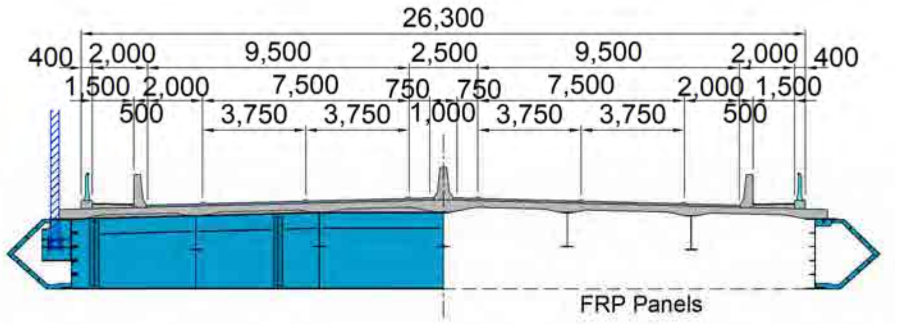
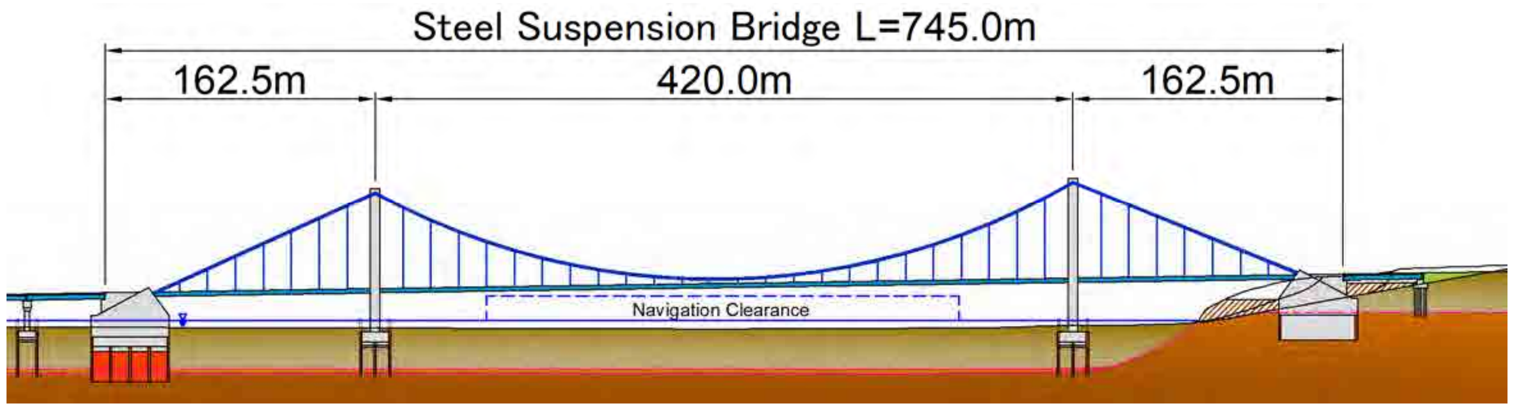

</td></tr>
<tr><td>Structural characteristics</td><td>・ By adopting a highly durable concrete deck slab, surface freezing in the winter is mitigated better than Proposal 5, making this proposal more effective in preventing slipping accidents.
・ Wind tunnel experiments to date suggests that the installation of FRP panels on the girder underside sufficiently resolves the issue of wind-resistant stability of the superstructure.
・ Although the right bank side is in a landslide zone, it is possible to avoid placing piers and abutments in the landslide area. Therefore, there is basically no negative impact from landslides.</td><td>Very good</td></tr>
<tr><td>Technology Transfer</td><td>・ This type of bridge is increasingly replacing Proposal 5 type bridges. There is also excellent potential for technology transfer due to the target country's thriving steel industry.</td><td>Very good</td></tr>
<tr><td>Workability</td><td>・ Steel girder construction of the superstructure is a piece-by-piece cantilever erection method using a traveler crane. There are no problems with regard to ensuring a navigable waterway during construction. The simple repetitive operation used in this method also makes it easier to manage construction.</td><td>Very good</td></tr>
<tr><td>Operation and maintenance</td><td>・ By installing FRP panels on the girder underside, which do not require painting, there would be few exposed metal parts, making repainting costs less than Proposal 5.</td><td>Very good</td></tr>
<tr><td>Economic feasibility</td><td>Main bridge only: ratio of 1.00</td><td>Very good</td></tr>
<tr><td>Evaluation</td><td colspan="2">Adopt</td></tr>
</table>

Table 7-9-9. Main Bridge Section: Bridge Type Comparison Table (2/3) (Route 3)

<table>
<tr><th colspan="3">Proposal 5: Steel suspension bridge (steel deck with box girders type) <Recommended proposal in 2011F/S></th></tr>
<tr><td colspan="3">

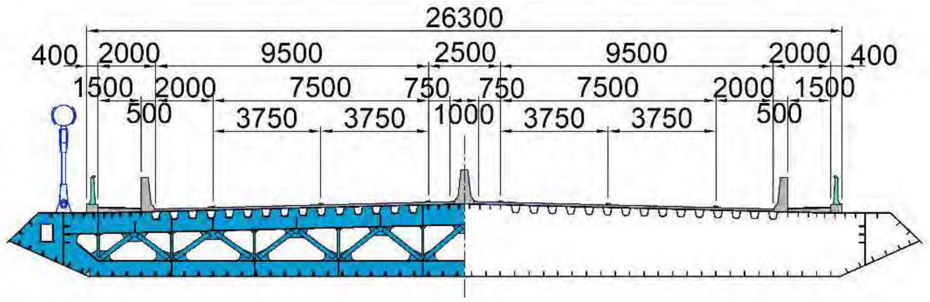
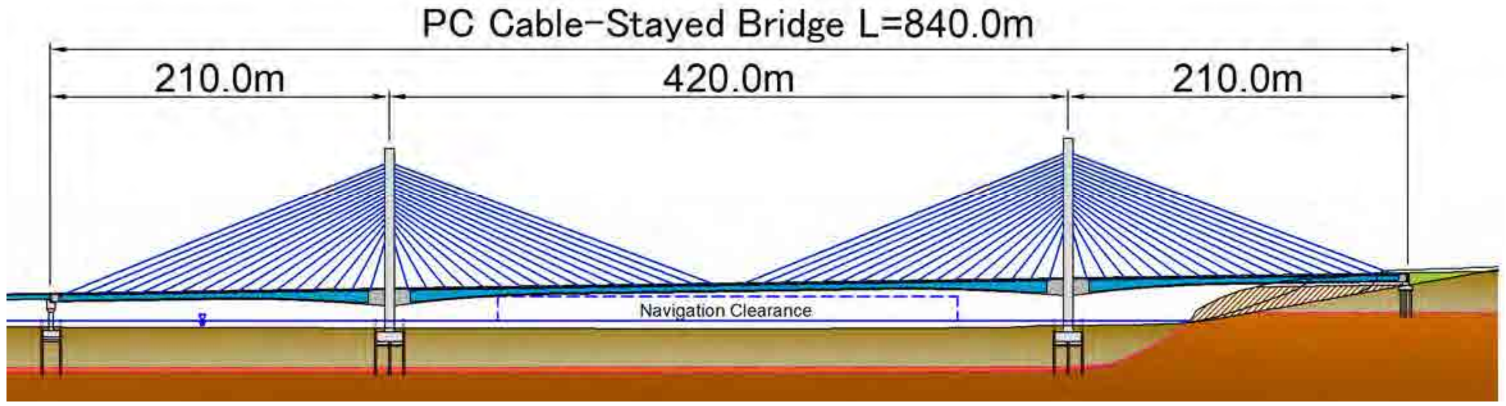
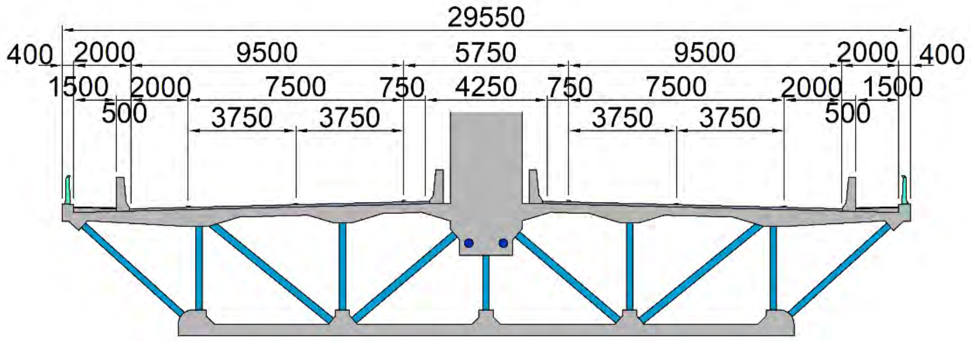

</td></tr>
<tr><td>Structural characteristics</td><td>・ Based on its track record, a steel deck plate is the standard structure used. Thus, there are concerns over slip accidents due to winter road freezing with this structure.
・ Wind-resistant stability of its superstructure is provided by a box girder structure which has been proven in Kurushima-Kaikyo Bridge. Thus there are no problems with regard to wind resistance.
・ Since anchorage must be installed near the center of the landslide zone on the right bank, this proposal is more affected by landslides than proposals 4 and 6.</td><td>Fair</td></tr>
<tr><td>Technology Transfer</td><td>・ Since the construction method is generally used for oversized bridges, there is limited scope for technological reuse and thus low potential for technology transfer.</td><td>Fair</td></tr>
<tr><td>Workability</td><td>・ Since a medium-block lifting erection is used to erect the superstructure's girders, restrictions are placed on the navigation channel underneath. Managing construction is also more complex as block loading and other work locations are disjointed.
・ Constructing anchorage on the right bank in the landslide zone is also extremely dangerous.</td><td>Fair</td></tr>
<tr><td>Operation and maintenance</td><td>・ Paint must be applied over a large area of the outer surface on the underside of box girders, making this proposal costlier than the others.</td><td>Fair</td></tr>
<tr><td>Economic feasibility</td><td>Main bridge only: ratio of 1.45</td><td>Fair</td></tr>
<tr><td>Evaluation</td><td colspan="2"></td></tr>
</table>

Table 7-9-10. Main Bridge Section: Bridge Type Comparison Table (3/3) (Route 3)

<table>
<tr><th colspan="3">Proposal ６: Steel cable-stayed bridge (corrugated steel web box girder bridge with struts)</th></tr>
<tr><td colspan="3">




</td></tr>
<tr><td>Structural characteristics</td><td>・ By adopting a concrete deck slab, surface freezing in the winter is mitigated better than Proposal 5, making this proposal more effective in preventing slipping accidents.
・ Due to being a concrete bridge, there are no problems with regard to wind-resistant stability.
・ Although the right bank side is in a landslide zone, it is possible to avoid placing piers and abutments in the landslide area. Therefore, there is basically no negative impact from landslides.</td><td>Very good</td></tr>
<tr><td>Technology Transfer</td><td>・ This type of bridge is increasingly being adopted in recent years. However, given the country's low level of maturity in technologies related to PC bridges, there is less potential for technology transfer than Proposal 4.</td><td>Good</td></tr>
<tr><td>Workability</td><td>・ There is a high level of technical difficulty in the superstructure work.
・ The target area is a cold climate with minimum temperatures below 0 degrees for up to 7 months a year. Due to the long construction time required to implement fully covered winter concreting, this construction method is not realistic.</td><td>Fair</td></tr>
<tr><td>Operation and maintenance</td><td>・ With few exposed metal sections, repainting cost is lower than Proposal 5.</td><td>Very good</td></tr>
<tr><td>Economic feasibility</td><td>Main bridge only: ratio of 1.07</td><td>Good</td></tr>
<tr><td>Evaluation</td><td colspan="2"></td></tr>
</table>

3) Span Classification 2: Left Bank Approach Bridge, T1506 Bridge

(1) Review of Superstructure's Basic Structure

Since the conditions of Route 3 are essentially the same as those of Route 2, the steel small number girder method is likewise adopted for the superstructure's basic structure.

(2) Comparative Study of Deck Structures

Since the conditions of Route 3 are essentially the same as those of Route 2, precast PC slab is likewise adopted for the deck structure.

(3) Review of Optimal Span Length

Since the conditions of Route 3 are essentially the same as those of Route 2, an optimal span length of 60 m is likewise adopted.

4) Span Classification 3: Short-span Bridges such as an Main Route Bridge, P06 Bridge

Since the conditions for short-span bridges of Route 3 are essentially the same as those of Route 2, PC precast, pretensioned continuous (simple) slab girders are likewise adopted as the superstructure type.

7-9-3 Review of Substructure Type Selection

1) Selection Policy for Substructure Type

(1) Main Tower Frame Type

An RC tower structure is adopted for the main tower frame type for Route 3, just as it is for Route 2.

(2) Pier Structure Type

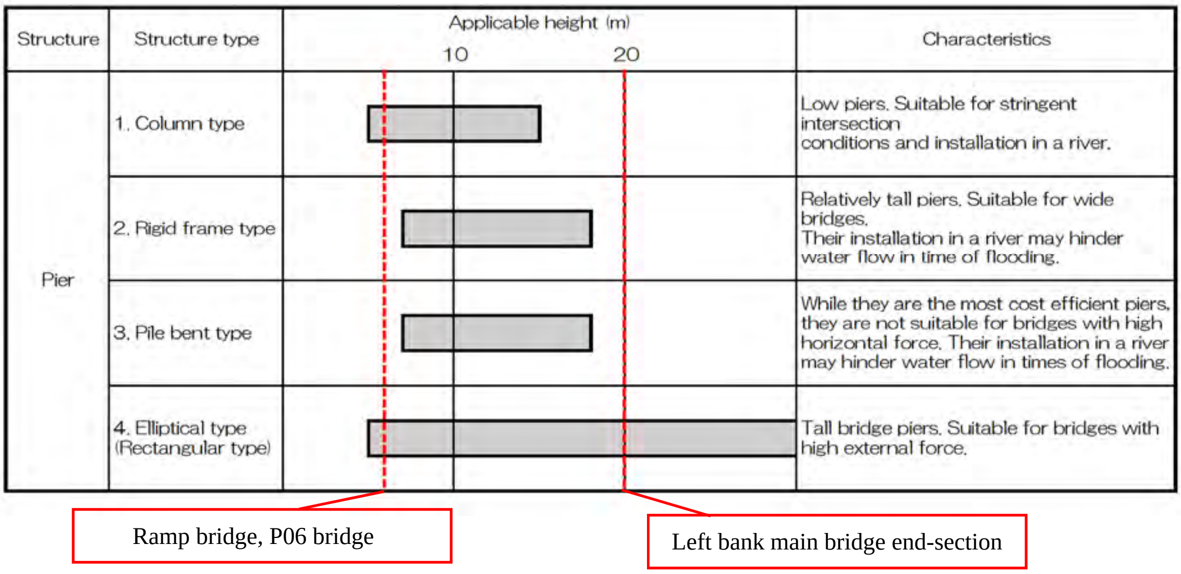
With regard to general RC pier structure types, as shown in Table 7-9-12, the applicable type is generally determined by the required structural height. For this reason, structural types are considered using this table as reference. As for pier height, although the height required for each bridge differs depending on topography, road alignment, construction limitations, etc., pier height is broadly classified into the three types shown in Table 7-9-11, each of which were investigated.

Pier classification 3 bridges, namely the left bank approach bridge and T1506 bridge, are considered separately from Table 7-9-12 because PC wells (single pile-bent method) is considered desirable for these bridges for the following reasons: in the case of the left bank approach bridge, to avoid the increased costs of building over the waterway; and in the case of the T1506 bridge, for construction procedure.

Table 7-9-11. Pier Classification for Bridges (Route 3)

Pier Classification	Applicable Bridges
Pier Classification 1 (RC pier height of about 6 m)	P06 Bridge Pier, Main Route Bridge Pier at 143+90
Pier Classification 2 (RC pier height of about 20 m)	Left Bank Main Bridge End-section Pier
Pier Classification 3 (pier that use a PC well)	Left Bank Approach Bridge Pier, T1506 Bridge Pier

Table 7-9-12. Relationship between Typical RC Pier Type and Height (Route 3)



Structure	Structure type	Applicable height (m) 10 20	Characteristics
Pier	1. Column type		Low piers. Suitable for stringent intersection conditions and installation in a river.
	2. Rigid frame type		Relatively tall piers. Suitable for wide bridges. Their installation in a river may hinder water flow in time of flooding.
	3. Pile bent type		While they are the most cost efficient piers, they are not suitable for bridges with high horizontal force. Their installation in a river may hinder water flow in times of flooding.
	4. Elliptical type (Rectangular type)		Tall bridge piers. Suitable for bridges with high external force.

Ramp bridge, P06 bridge

Left bank main bridge end-section

Source: Design Manual, Chubu Regional Development Bureau (April 2000)

a) Pier Classification 1: P06 Bridge Pier, Main Route Bridge Pier at 143+90 m

Since the conditions for the P06 bridge pier and main route bridge pier at 143+90 m of Route 3 are essentially the same as those for the ramp bridge pier and P06 bridge pier of Route 2, a rectangular pier is likewise adopted as the pier type.

b) Pier Classification 2: Left Bank Main Bridge End-Section Pier

Since the conditions of Route 3 are essentially the same as those of Route 2, an elliptical pier is likewise adopted as the pier type.

c) Pier Classification 3: Left Bank Approach Bridge Pier and T1506 Bridge Pier

The selection of the pier structure type for the left bank approach bridge is considered together with the foundation structure in the next section, just as it is for Route 2.

Since the conditions of the T1506 bridge for Route 3 are essentially the same as those for Route 2, a PC well foundation (single pile-bent method) is likewise adopted as the pier type.

(3) Abutment Structure Type

Since the conditions of Route 3 are essentially the same as those of Route 2, a reversed T-type abutment is likewise adopted as the abutment structure type.

7-9-4 Review of Foundation Type Selection

1) Selection Policy for Foundation Type

The type of foundation is selected based on construction conditions, ground conditions, and structural scale of the upper structure. Further, in view of advantages such as a consistent set of in engineers and construction equipment by having a uniform structure, as well as cost-effectiveness and quality improvement, there is no benefit in needlessly increasing structural formats. With this in mind, this Study classifies the alternatives into the three types shown in the table below and investigates each.

Table 7-9-13. Foundation Classification for Bridges (Route 3)

Foundation Classification	Target Foundations
Foundation Classification 1 (a foundation that bears major superstructure counterforce from the main bridge)	Main Bridge Main Tower pier, Left Bank Main Bridge End-section Pier
Foundation Classification 2 (a foundation that is constructed over a waterway on soft ground and has special construction requirements)	Left Bank Approach Bridge pier, T1506 Bridge Pier
Foundation Classification 3 (a basic land foundation without special construction requirements)	Main Route Bridge Abutment, P06 Bridge Abutment/Pier, Ramp Bridge Abutment/Pier, Left Bank Approach Bridge Abutment, Right Bank Main Bridge End-section Abutment

2) Foundation Classification 1: Main Bridge Main Tower, Left Bank Main Bridge End-section Pier

Because a major counterforce from the superstructure is exerted onto the main bridge's foundation, its structure varies widely depending on ground conditions. Therefore, this section re-examines foundation types based on data that includes the results of the complementary geological surveys and changes in counterforce size from the superstructure.

(1) Main Bridge Main Tower

Since the conditions of both the left and right sides of the main tower foundation for Route 3 are essentially the same as those of the left side of the main tower foundation for Route 2, a steel pipe sheet pile foundation (temporary cofferdam method) is likewise adopted for the main tower foundation.

(2) Left Bank Main Bridge End-section Pier

Since the conditions of Route 3 are essentially the same as those of Route 2, a steel pipe sheet pile foundation (temporary cofferdam method) is likewishe adopted for the main bridge left bank end-section pier foundation.

3) Foundation Classification 2: Left Bank Approach Bridge Pier, T1506 Bridge Pier

(1) Left Bank Approach Bridge Pier

Since the conditions of Route 3 are essentially the same as those of Route 2, a PC well foundation (single pile-bent method) is likewise adopted for the left bank approach bridge pier foundation.

(2) T1506 Bridge Pier

Since the conditions of Route 3 are essentially the same as those of Route 2, a PC well foundation (single pile-bent method) is likewise adopted for the T1506 bridge pier foundation.

4) Foundation Classification 3: Main Route Bridge Abutment/Pier, P06 Bridge Abutment/Pier, T1506 Bridge Abutment, Left Bank Approach Bridge Abutment, Right Bank Main Bridge End-section Abutment

Since the conditions of Route 3 are essentially the same as those of Route 2, cast-in-place piles are likewise adopted for the foundations in span classification 3.

7-10 Reviewing the Applicatin of Japanese Technology

7-10-1 Basic Policy

The purpose of this Study is to determine a bridge and road design that realizes high quality and economic efficiency by effectively utilizing Japanese technology. The table below shows a list of proposed Japanese technologies and their procurement ratios, which have exceeded the STEP criteria of 30%. In calculating these procurement ratios, expenses related to the procurement and use of Japanese technology have been excluded from the calculation. If these factors were included, the procurement ratio could be even higher.

Below provides a summary of each Japanese technology.

Table 7-10-1. Japanese Technology Procurement Ratio (Route 3)

(Unit: million JPY)

Japaneses Technology	Main Bridge	Other Bridges	Sub Total	Procurement Ratio
High-durability Slab	1,125	1,785	2,910	6.1%
SBHS steel	289	1,102	1,391	2.9%
Stay Cable	1,645		1,645	3.5%
FRP Panel	680		680	1.4%
PC Pretensioned Slab Girder		1,041	1,041	2.2%
High-surface-pressure Support Structure	106	563	669	1.4%
Rotary All Casing Cast-in-place Pile Method		242	242	0.5%
PC Wells Foundation		4,302	4,302	9.1%
Steel Pipe Sheet Pile Foundation	2,370		2,370	5.0%
Aluminum Railing	118	188	306	0.6%
Sub Total (Japanese Technology)	6,333	9,223	15,556	32.7%
Construction Cost Total			47,516	100.0%

7-10-2 Adoption of a Precast PC Slab Structure that Combines Road Surface Anti-freezing Properties with Durability

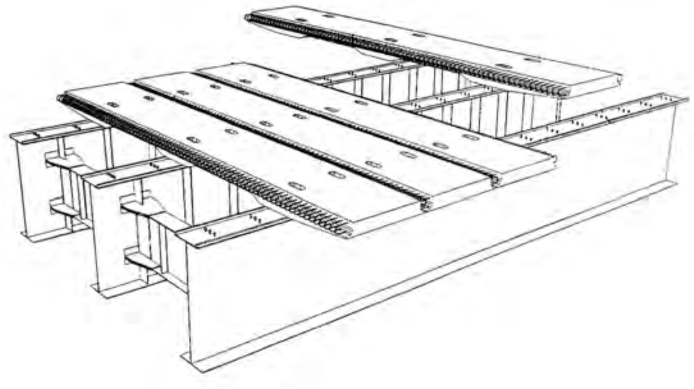
Many large bridges, such as suspension and cable-stayed bridges, have been using steel plate decking to lower costs by reducing the weight of the bridge. However, the low heat capacity of steel deck causes drastic temperature changes on the road surface which, as shown in the figure below, make these bridges prone to forming ice overnight as surface snow is slow to melt. As this is a cause of many accidents, in general, they are not used in Japan. This bridge has a relatively steep incline of 2.5% (the 2011F/S) and design speed of 110 km/h, which makes it all the more dangerous; therefore, a concrete slab structure is used in lieu of a steel deck.

Source: Reducing steel deck surface freezing by embedding heat storing material

Figure 7-10-1. Freezing Status of Bridge Pavement Using Steel Deck

RC deck slab of a type that has been widely used as decking on steel bridges has resulted in numerous cases of deterioration damage such as cracking and falling of broken pieces since around 1965 in Japan. To respond, equipment to test moving loads was developed to suitably reproduce floor slab deterioration to analyze deterioration of RC deck slab, while highly durable slabs were developed to replace RC deck slab. As a result, it was found that a PC slab structure that applies prestress to the deck slab and a composite slab constructed from steel and concrete were able to greatly improve decks durability. The fabrication and design standards of each structure have been established and registered with JIS and NETIS, realizing a leading Japanese technology that has been applied to past STEP projects. In this Study, as a result of comparative study described in 7-7-2 3) item(2), a precast PC slab configuration was selected on the ground of its cost-effectiveness and workability. This structure is adopted as a Japanese technology capable of achieving high durability while reducing road surface freezing in cold regions.

As for locations, the precast PC slab structure is adopted for the main bridge, the left bank approach bridge, and T1506 bridge. All structures having steel girders as their main girder use it.



Source: Japan Prestressed Concrete Contractors Association website

Figure 7-10-2. Precast PC Slab Concept Image

7-10-3 Adoption of Edge-girder type Cable-Stayed Bridges

Following their adoption in the Alex Fraser Bridge (Canada), cable-stayed bridges with RC decks and composite edge-girders have been proven in many bridge projects around the world. Their structure, which uses simple I-section girders on both sides of the main girder, achieves significant cost savings by reducing the steel weight. Compared with steel deck with box girders type cable-stayed bridges used in many projects in Japan, the Nhat Tan Bridge (Vietnam), built through Japanese ODA, had about 1/3 less steel weight per square meter, which is typically used to estimate the cost of steel bridges. That being said, while this structural format offers cost savings, it also involves some structural issues. By applying the technologies of Japan, such issues can be resolved, allowing it to be applied to the construction of superstructures to combine the benefits of cost-effectiveness and high quality. The following describes the structural issues and Japanese technologies that solve them.

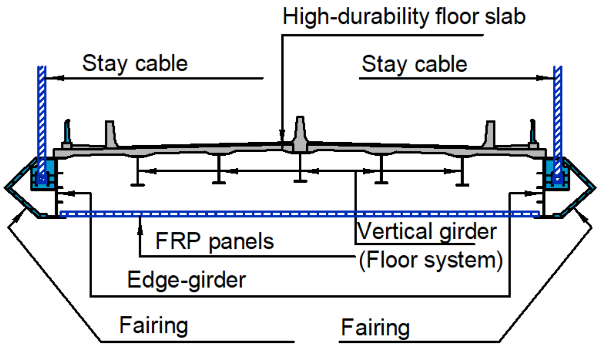


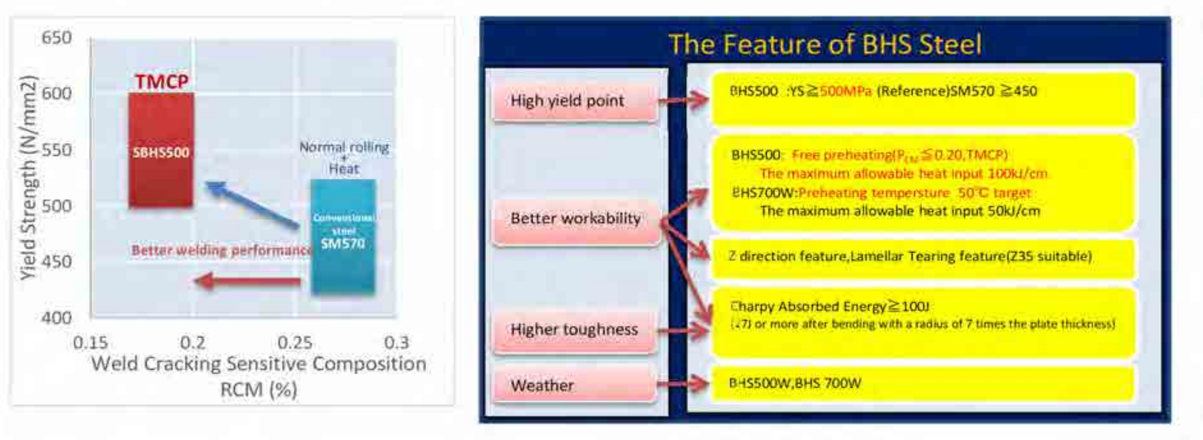
Figure 7-10-3. Edge-girder Type Overview

1) Adoption of High-durability Slabs

The precast PC slab version described above will be adopted to improve the durability of edge-girder cable-stayed bridges and reduce the freezing of bridge road surfaces in cold regions.

2) Adoption of SBHS 400 & 500 Steel

Since edge-girder type cable-stayed bridges involve a minimum size and number of main girders, the steel plates for the main girders must be thicker and stronger to withstand the sectional forces they are subjected to. However, using thicker and stronger steel plates reduces workability for welding and other tasks, which makes it crucial to select a high-quality steel material. It is also essential to be vigilant about preventing low-temperature brittle fractures that weaken welded sections due to low temperatures, especially in cold regions. SBHS steel is a material developed with Japan's unique TMCP (thermo-mechanical control process) technology. As shown in the figure below, this steel material has improved strength, weldability and Charpy absorbed energy value, an indicator of strength against low-temperature brittle fractures. This is a leading Japanese technology, and has been adopted in this Study not only for the cable-stayed bridge, but also left bank approach bridge superstructure and T1506 bridge in an aim to reduce costs and prevent damage from low-temperature brittle fractures.



The Feature of BHS Steel

High yield point → BHS500 :YS≧500MPa (Reference)SM570 ≧450

Better workability → BHS500: Free preheating(P_{CM}≦0.20,TMCP)
The maximum allowable heat input 100kJ/cm
BHS700W:Preheating tempersture 50℃ target
The maximum allowable heat input 50kJ/cm

Z direction feature,Lamellar Tearing feature(Z35 suitable)

Higher toughness → Charpy Absorbed Energy≧100J
(≥7) or more after bending with a radius of 7 times the plate thickness)

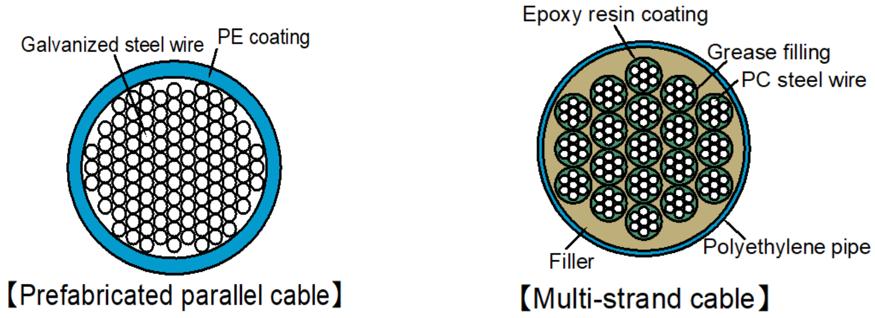
Weather → BHS500W,BHS 700W

Source: Pamphlet on high performance steel for bridges

Figure 7-10-4. SBHS Steel Characteristics (formerly called "BHS" steel)

3) Adoption of High-quality Diagonal Cable with Superior Rust-prevention, Fatigue Durability and Low-temperature Brittleness Resistance

As shown in the figure below, cables for cable-stayed bridges are broadly categorized into the following types: 'prefabricated parallel cable', wherein all wires are bundled into a single cable at a factory and transported to the worksite for construction; and 'multi-strand cable', wherein a strand that bundles together seven wires is fabricated at the factory, transported to the worksite, and several of these strands are combined one-by-one during construction.



【Prefabricated parallel cable】 【Multi-strand cable】

Figure 7-10-5. High Quality Diagonal Cable

Prefabricated diagonal cable uses state-of-the-art technology developed in Japan and are factory-manufactured, thereby offering excellent rust-prevention performance and fatigue durability.

Since multi-strand cables are usually constructed on site, they have been generally regarded as having rust-related issues. However, an epoxy strand cable, wherein the strand is completely coated with epoxy resin, has been developed in Japan in recent years which has dramatically improved anticorrosive properties and is a remarkable Japanese technology. In terms of cost, both cables are essentially equal, and although this Study basically considers prefabricated parallel cable of a type proven in many projects, appended material specifications will allow the use of either cable when ordered.

4) Adoption of FRP Panels

The edge-girder type cable-stayed bridges use an open-cross-section structure similar to the Tacoma Narrows Bridge which collapsed under wind load. For this bridge type, it is essential to take sufficient measures to ensure resilience against wind. Further, despite a fast vehicle design speed of 110 km/h, the bridge accommodates both vehicle and pedestrian paths on the same deck, thus requiring a concrete barrier between vehicle and pedestrian lanes to reliably prevent vehicles from deviating into the footpath. This makes ensuring wind resistant stability more difficult due to the increased surface area exposed to wind. To address this issue, the FRP panel shown in the figure below is installed on the girder undersurface to streamline the wind flow and achieve wind stability.

Source: Kurimoto, Ltd. Website

Figure 7-10-6. FRP Hollow Panel

The FRP panels' stabilizing effect against winds has been verified by wind tunnel testing of cable-stayed bridges in the past. Also note that the construction of this FRP panel incorporates JIS materials designed to ensure strength, durability and weight reduction, and takes full advantage of Japan's latest technologies.

7-10-4 PC Pretensioned Slab Girders

A comparison of the actual costs of different girder types in Japan as shown in Figure 7-10-7 indicates that a PC pretensioned slab bridge is by far the most cost effective at the span of 20-25 m.

PC pretensioned slab bridges aim to improve cost-effectiveness by mass producing multiple girders at one time at a purpose-equipped factory using the heavy-duty jack shown in Figure 7-10-8. From a cost perspective, however, it would be unrealistic to use the equipment located in Japan for the bridge in this project. Therefore, the simplified pretensioning equipment shown in Figure 7-10-9 is used to reduce equipment costs, allowing a pretensioned slab bridge to be achieved practically in Ukraine.

The above equipment consists of a U-shaped RC member and metal abutments on both ends. The RC member is used to bear the counterforce from the abutments and the girder is fabricated on the tension abutment inside. Prestressing is applied by using a single strand jack to apply and set tension on cables one-by-one with the abutments. A concrete girder is fabricated while in this tensioned state, and then the cable ends are cut. Because special equipment such as large jacks is not required, the construction cost for a girder fabrication facility can be drastically reduced.

With a unique construction detail, this girder fabrication method is a technology of Japan that achieves a rationalized structure that eliminates as much bridge-site work as possible, and has been standardized under JIS (Japanese Industrial Standards).

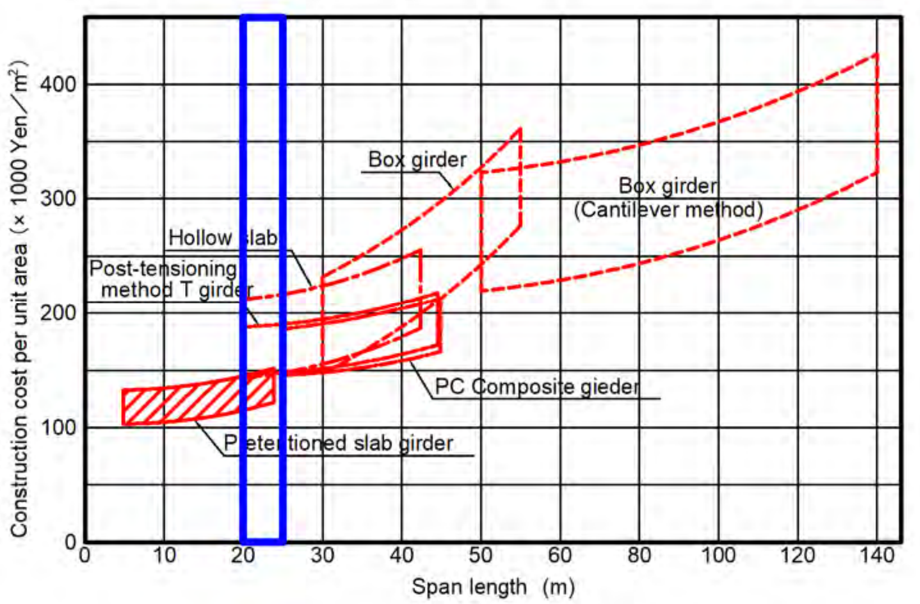


Figure 7-10-7. Relationship between the Estimated Cost of a Concrete Bridge and Span Lengths

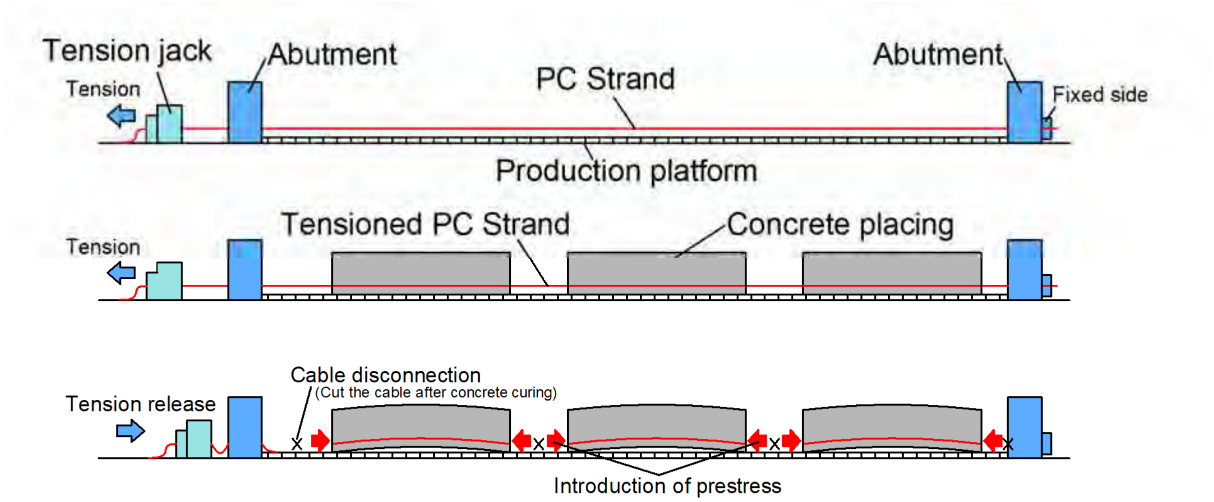


Figure 7-10-8. Pretensioned Girder Fabrication Method Using Large Jacks

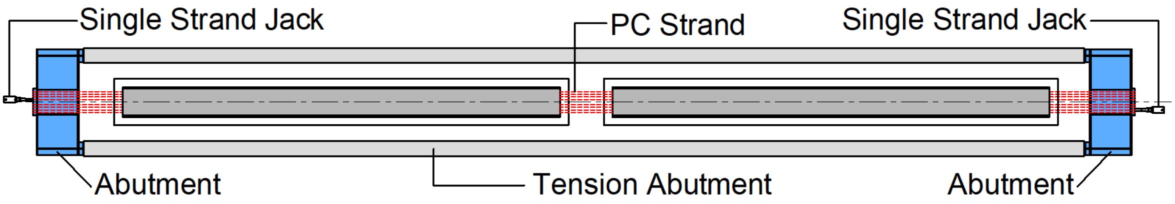
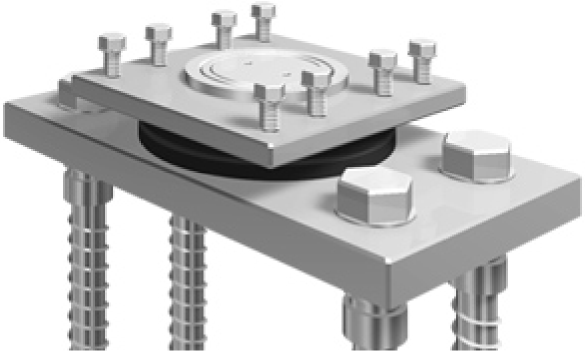


Figure 7-10-9. Simplified Fabrication Platform Using a Single Strand Jack

7-10-5 High Surface-Pressure Bearing Structure

Compared with the allowable bearing stress of 8N/mm² for ordinary laminated rubber bearings, using the unique rubber shape and reinforcing member shown in the figure below can improve allowable bearing stress to 25 N/mm². More compact rubber fittings that provide cost savings have been developed, and this cost-effective leading Japanese technology is adopted.

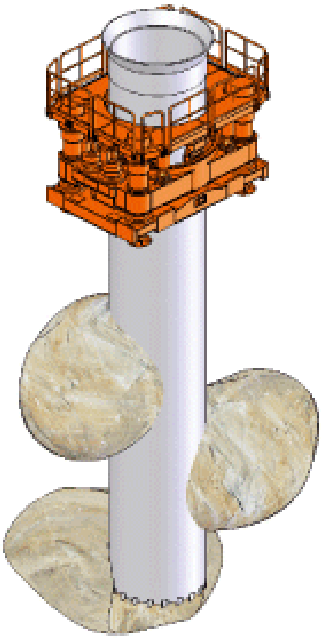


Source: BBM Co., Ltd. website

Figure 7-10-10. High Surface-Pressure Bearing Structure

7-10-6 Rotary All Casing Cast-In-Place Pile Method

The rotary all casing cast-in-place pile method is a superior technology that was developed in Japan. Other than the all-casing method, reverse method and earth drill method are used in the cast-in-place pile method. Both methods generally involve digging without earth retention, making pile walls in the inner layer prone to collapsing. It is more difficult with these methods to clean the slime that accumulates on the edge, which sometimes impairs edge bearing capacity. The bentonite used to prevent the collapse of pile walls when digging without earth retention also has potential to pollute the river water. The all casing method not only uses a casing to eliminate the need for bentonite to stabilize the pile wall, but is also able to penetrate into the bedrock layer, which is the bearing layer for the bridge's foundation, by using a strong cutting edge attached to the end of the casing with a mechanical system that holds, rotates, and pushes in the casing. This mechanical system has been patented in Japan.



Source: Nippon Sharyo, Ltd. website

Figure 7-10-11. Rotary All Casing Cast-In-Place Pile Method

7-10-7 Using PC Wells to Construct Pier, Foundation, and Prevent Landslide

The PC well construction method is a highly practical state-of-the-art Japanese technology. It allows wells to be sunk extremely quickly and with great vertical accuracy. In this method, members for bridge piers and foundations ("PCa members") are fabricated beforehand at a locally-established simple factory, stockpiled, later transferred to the construction site, and then connected with PC bar while pushed into the ground with compressive jacks. Developed in 1984 by the formerly called "Public Works Research Institute, Ministry of Construction", this method has an extensive track record of use in more than 2,400 foundations in Japan.

Since the temperature at the construction site can potentially fall to around -20°C between November and March, the construction period is scheduled for the seven months from April to October. However, if a simple factory is set up near the bridge location, PCa members with high quality and durability (against salt/frost damage) can be fabricated and stockpiled, thereby making effective use of winter months.

Furthermore, the locally procurable cement is similar to Japan's high-early-strength portland cement, making it possible to streamline the process by shortening the production cycle. The geology in the river at the bridge position consists of hard cohesive soil (bearing layer) under a loose sedimentary layer of about 20 m. This method has been proven in many projects with similar geology and includes mechanisms that can push PCa members into the soft ground while supporting them, and including equipment able to excavate the semi-hard rock. This system ensures that construction can be performed reliably.

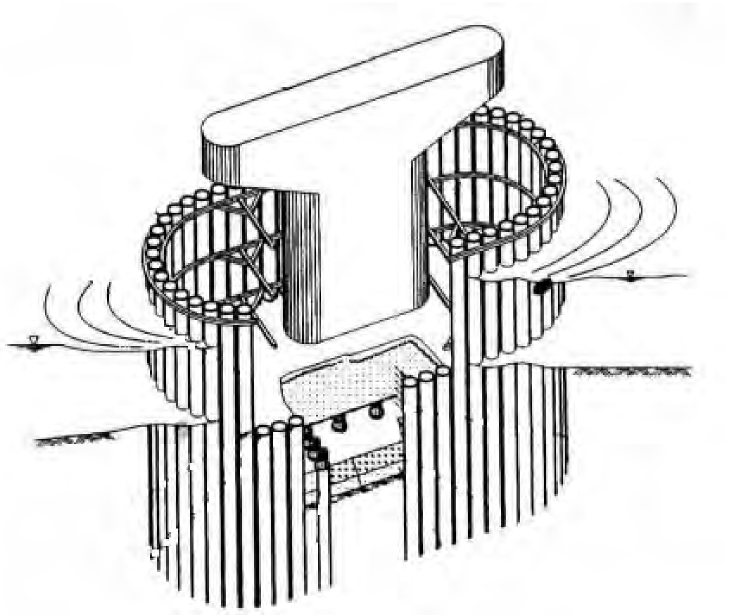
PC wells can be sunk into the ground from above the waterway. It is also possible to construct a pier structure in which the foundation and pier are integrated into one if the PC well is extended to the ground-section. This makes it possible to construct the piers economically by eliminating underwater construction work. Figure 7-10-12 shows the stages of manufacturing, transportation, construction and completion.

Manufacturing	Transportation
	
Construction	Completion
	

Figure 7-10-12. Stages of the PC Well Method

7-10-8 Steel Pipe Sheet Pile Well Foundation

This method is Japanese technology with a foundation structure developed in Japan. Joining steel pipe to each other with innovative sheet pile couplers ensures high rigidity. It can also be used as a cofferdam during construction. Because of this, this method has a track record of use in many projects where has been necessary to build a foundation on soft ground or perform construction underwater.



Source: Japanese Association for Steel Pipe Piles website

Figure 7-10-13. Concept Drawing of a Steel Pipe Sheet Pile Well Foundation

7-10-9 Scenery-friendly Aluminum Railings

Scenery-friendly aluminum railings use ellipsoidal balusters on a horizontal rail. Enhancing their cross-sectional performance realizes a structure that minimizes the use of expensive aluminum while also reducing costs through mass production. Their slim form is also effective for improving scenery-friendliness by achieving a less imposing structure. Additionally, the aluminum material itself does not degrade from rusting etc. which is an advantage in terms of durability and reducing maintenance costs. This is a Japanese technology that makes it possible to improve durability and landscape aesthetics at a relatively low cost by using the aluminum manufacturing technology of Japan.

Source: Sumikei-Nikkei Engineering Co.,Ltd. website

Figure 7-10-14. Scenery-friendly Aluminum Railings

Chapter 8 Traffic Demand Forecast

8-1 Review of Traffic Demand Forecasts Carried out as Part of 2011F/S and 2017 Survey

8-1-1 The Result of Traffic Surveys Conducted as Part of 2011F/S and 2017 Survey

The following is the results of traffic surveys conducted during 2011F/S and 2017 Survey.

1) Traffic Survey during 2011F/S

(1) Survey Contents

In 2011F/S, a 24-hour traffic count survey over two days and roadside driver interviews were conducted to identify current traffic conditions at foot on west side of Vavarovsky Bridge in December 2010.

The traffic count survey was conducted by vehicle categories, namely: motorcycles, passenger cars, buses, 2-axle trucks, 3- or more axle rigid trucks and trailers.

The interview questions included average passenger numbers, trip purpose, origin and destination and preference for using Mykolaiv Bridge.

(2) Survey Result (2011F/S)

a) Result of the Traffic Count Survey

The result of the traffic survey conducted on December 16 (Thu) and 20 (Mon), 2010, during the 2011F/S is shown as follows:

Table 8-1-1. Traffic Survey Result (2011F/S)

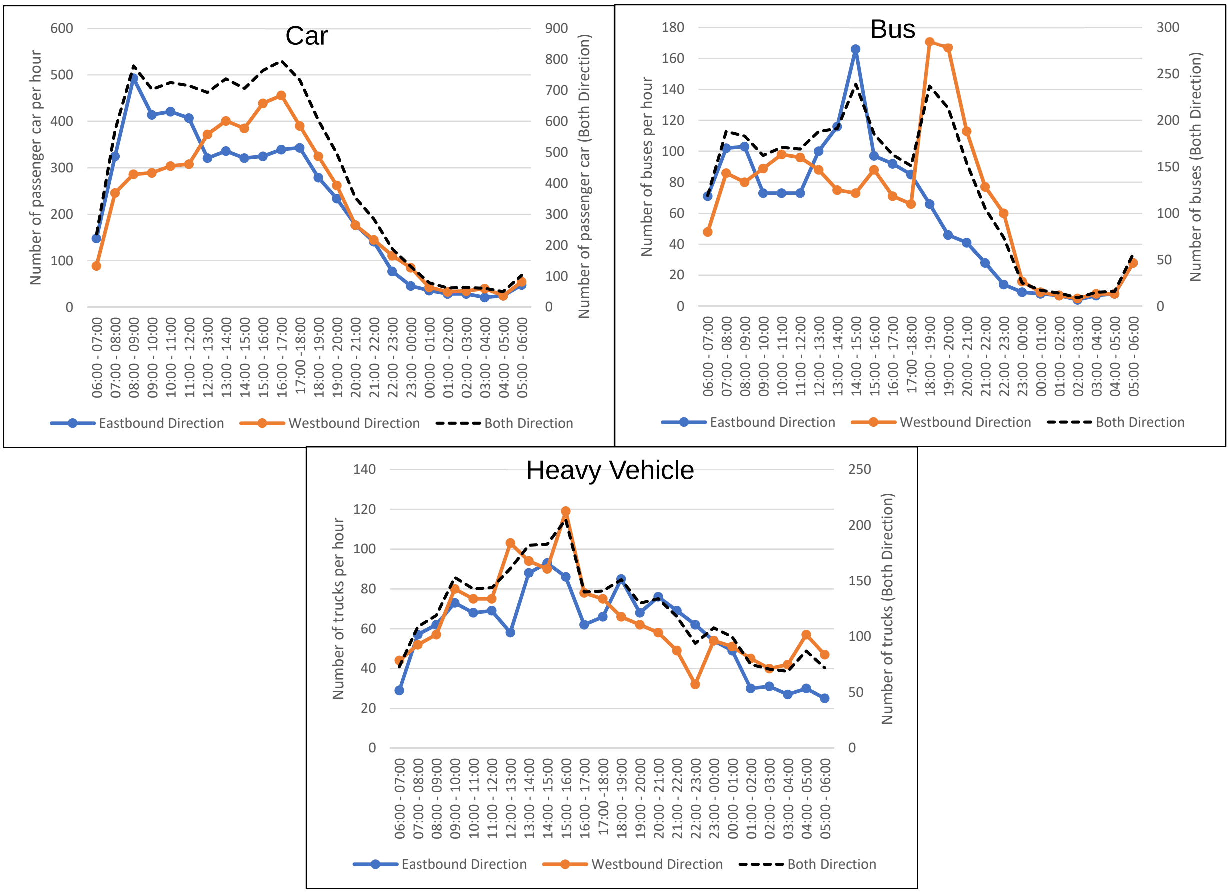
Unit: veh./day

	Motorcycles	Passenger cars	Buses	2-axle trucks	3+ axle trucks	Trailers	Total
Dec. 16 (Thu)	0	10,610	3,608	1,129	486	1,397	17,230
Dec. 20 (Mon)	0	10,680	2,423	1,175	510	1,207	15,995
Average	0	10,645	3,016	1,152	498	1,302	16,613

Source: 2011F/S

The average daily traffic volume was approximately 17,000 vehicles for both directions combined. Passenger cars comprised 64% of total traffic volume while buses and trailers comprised 18% each.

With regard to passenger cars, the morning peak period was observed for eastbound traffic to Mykolaiv city center between 8:00 a.m. to 9:00 a.m. (approx. 500 vehicle/hour), while the evening peak period was observed between 4:00 p.m. to 5:00 p.m for westbound traffic from the city center. The number of buses peaked in the afternoon, a 2:00 - 3:00 p.m. (approx. 170 vehicle/hour) for eastbound traffic and 6:00 - 7:00 p.m (approx. 170 vehicle/hour) for westbound traffic. For trucks, no particular characteristics were observed in terms of direction, while their peaks were observed at around 2:00 p.m.



* The Heavy Vehicles category includes 2- and 3+ axle trucks and trailers.

Figure 8-1-1. Transition of Traffic Volume over Time by Direction and Vehicle Type

b) Results of Roadside Driver Interviews (2011F/S)

The average number of passengers by vehicle type as calculated based on the interview result is shown as follows:

Table 8-1-2. Average Number of Passengers by Vehicle Type (2011F/S)

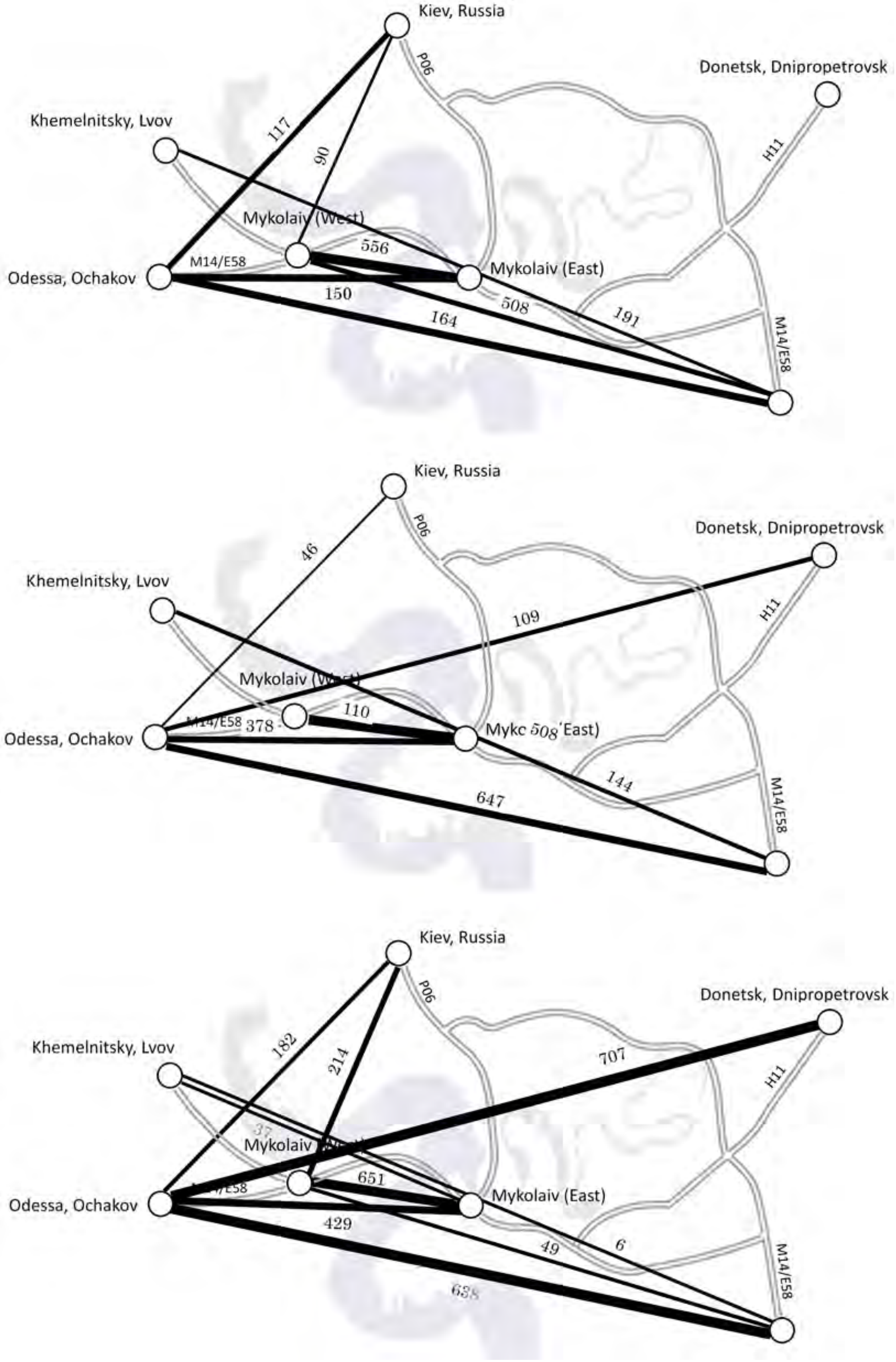
	Motorcycles	Passenger cars	Buses	2-axle trucks	3+ axle trucks	Trailers
Ave. No. of passengers	-	2.12	6.14	1.38	1.23	1.50

Source: 2011F/S

The interview survey on the Origin-Destination (hereinafter referred to as “OD”) of river crossing traffic was concluded as follows:

- Almost half of passenger car and bus traffic observed on west side of Vavarovsky Bridge is dominated by internal trips within the Mykolaiv city.
- The traffic volumes for passenger cars and buses between Odesa and other western regions and countries and Mykolaiv and the western region are also significant.
- Since Donetsk is an industrial city, a considerable number of trucks and trailers come and go between Donetsk and Odesa, where the main ports in Ukraine are located.

Desired lines as estimated based on the interview survey are shown as follows:



Unit: Vehicle/day
Source: 2011F/S

Figure 8-1-2. Desired Lines

2) Traffic Survey during 2017 Survey

(1) Survey Contents

The traffic survey during 2017 Survey focused on traffic counts conducted at six locations from January 24 (Tue.) – 25 (Wed.), 2017, while OD surveys were also conducted at Vavarovsky Bridge.

(2) Survey Results (2017)

a) Result of the Traffic Count Survey

The results of the traffic survey conducted during 2017 Survey are shown as follows:

Table 8-1-3. Traffic Survey Result (2017 Survey)

Unit: veh./day

	Passenger cars	Buses	2-axle trucks	3+ axle trucks	Trailers	Total
1. Vavarovsky Bridge West	13,363	1,976	1,401	143	1,620	18,502
2. M-14 125 km post	4,703	550	1,049	123	1,365	7,780
3. P06	4,466	665	503	115	1,416	7,164
4. H11	3,202	473	686	77	468	4,905
5. M-14 167 km post	3,688	510	1,192	104	1,769	7,262
6. Ingul Bridge North	18,638	3,204	1,833	123	1,515	25,312

Source: 2017 Survey

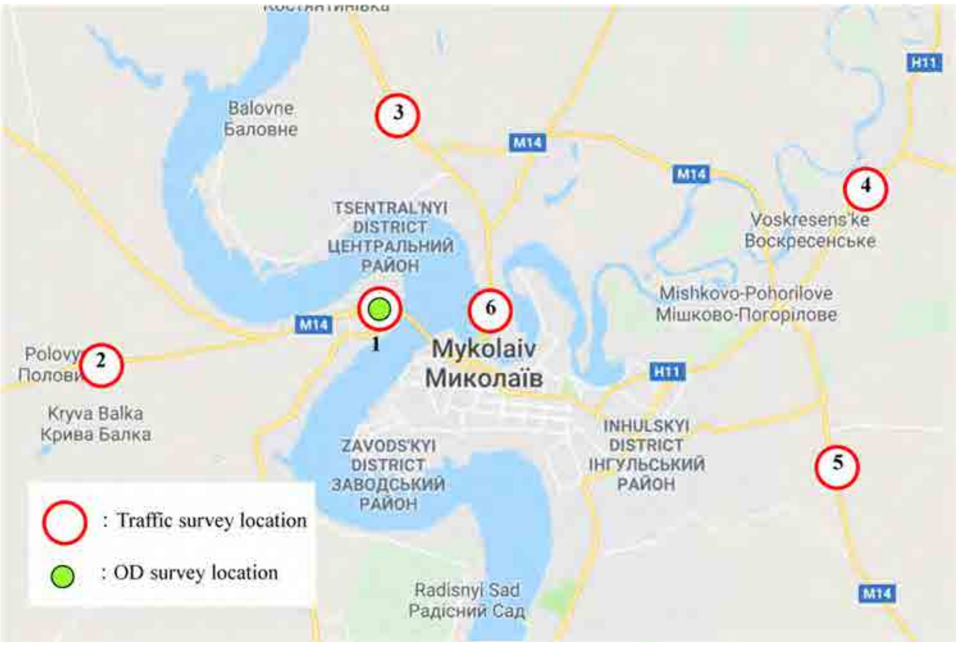


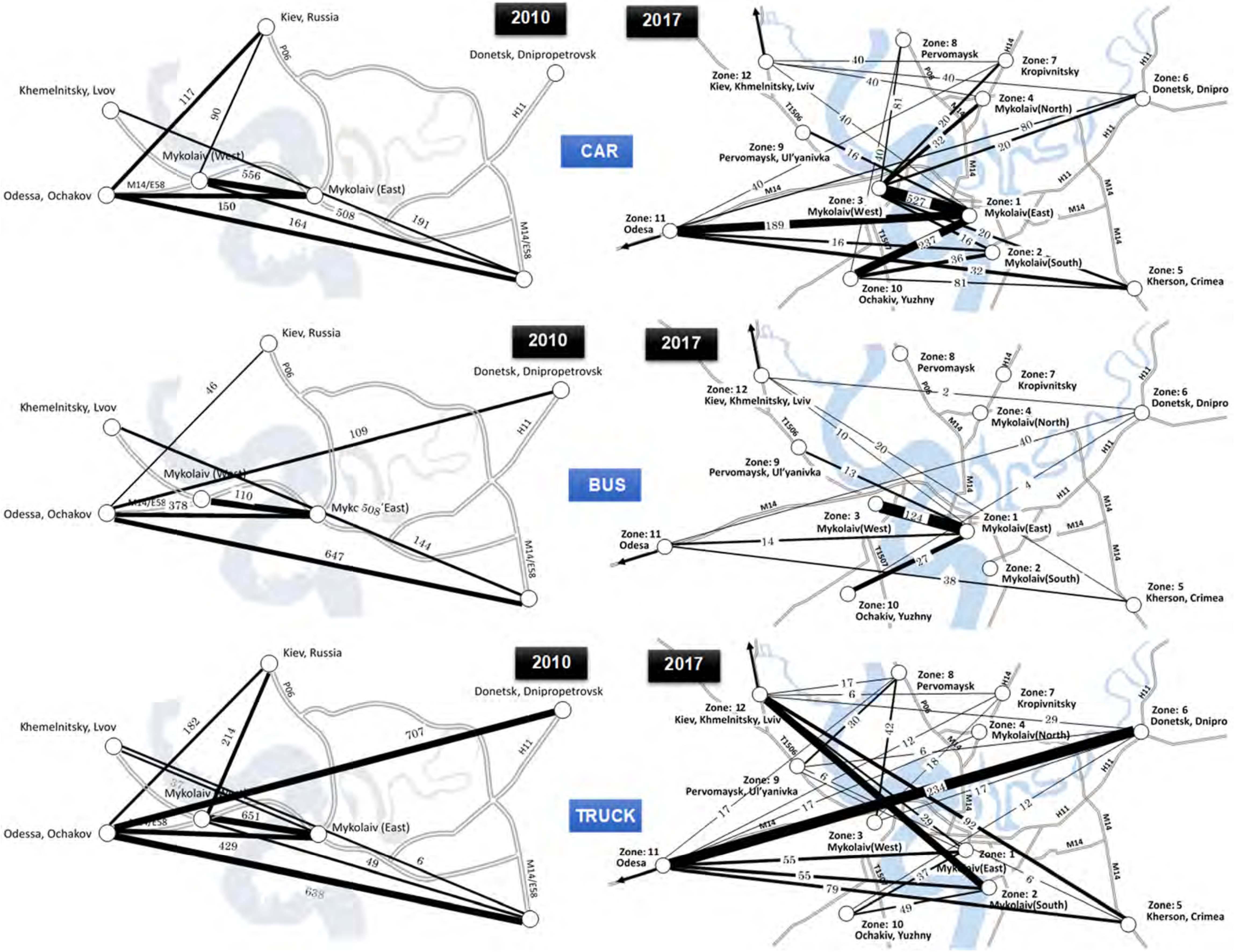
Figure 8-1-3. Traffic Survey Locations (2017 Survey)

b) Result of the OD Survey

The OD survey conducted during 2017 Survey is outlined as follows:

- Passenger cars: interviewed on the roadside from 8:00 a.m. until 4:00 p.m.
  A total of 333 samples were collected (sample rate: 5 to 6%).
- Buses: collected over 1,008 trips (in both directions combined) from route bus users, which comprises half of all bus traffic.
- Trucks and trailers: the survey originally planned to conduct roadside driver interviews but could not obtain permission from the relevant authority due to safety concerns. Instead, data was collected by interviewing the Transport Safety Agency (Ukrtransbezpeky) and port management companies.

The desired lines prepared during 2011F/S and 2017 Survey are shown below. Comparing with the lines for passenger cars, there are no changes in traffic volumes in the west and central areas of the Mykolaiv region emerge, while 2017 Survey result indicates more intercity traffic than before. Given the emergence of a similar trend for buses and trucks, Enhance the traffic network by construction of new bridge over South Bug River will make trips more convenient for users. Since the traffic volume of trucks and trailers between Odesa-Donetsk and Dnipro exceeds that of other regions, traffic in future is expected to avoid traversing the congested city and shift to Mykolaiv Bridge.



Unit: Vehicle/day

Figure 8-1-4. Comparison of Desired Lines

3) Annual Average Daily Traffic (AADT)

In 2011 F/S, the monthly traffic volume variation was calculated based on the existing traffic count data (2007), and the traffic count survey result of 2011F/S was used to estimate the annual average daily traffic (hereinafter referred to as “AADT”) in 2010.

On the other hand, 2017 Survey shows a new estimation of AADT by adjusting the monthly variation coefficients calculated in 2011F/S based on the traffic volume for different months, such as September 2016 and January 2017.

The monthly variation coefficients for each of the vehicle types in 2017 were adjusted to be lower than the value observed in 2011. As described in the 2017 Survey report, one of the reason for the adjustment of the value is trend change of monthly traffic flow. In addition, it is presumed that the value of 2011F/S is overestimated when considering current traffic condition and the opinion of local traffic engineer.

Table 8-1-4. Adjustment of Monthly Variation Coefficients (2017 Survey)

Monthly Variation 2010					
	Pax	Bus	2xT	3xT	Trail
Jan	1.00	1.00	1.00	1.00	1.00
Feb	1.00	1.00	1.00	1.00	1.00
Mar	1.30	1.97	1.85	1.79	1.76
Apr	1.43	2.16	3.29	2.14	2.11
May	2.51	3.33	4.65	3.36	3.32
Jun	4.25	4.49	6.02	4.61	4.54
Jul	4.67	4.95	5.90	4.79	4.74
Aug	4.25	4.49	6.02	4.61	4.54
Sep	2.84	3.33	4.65	3.36	3.32
Oct	1.43	2.16	3.29	2.14	2.11
Nov	1.33	1.93	2.23	1.82	1.81
Dec	1.30	1.97	1.86	1.78	1.76

Monthly Variation 2016-17					
	Pax	Bus	2xT	3xT	Trail
Jan	1.00	1.00	1.00	1.00	1.00
Feb	1.00	1.00	1.00	1.00	1.00
Mar	1.21	1.51	1.63	1.42	1.41
Apr	1.29	1.61	2.70	1.61	1.59
May	2.02	2.22	3.70	2.25	2.24
Jun	3.20	2.83	4.72	2.91	2.90
Jul	3.49	3.07	4.63	3.01	3.00
Aug	3.20	2.83	4.72	2.91	2.90
Sep	1.93	1.74	3.44	1.78	1.78
Oct	1.29	1.61	2.70	1.61	1.59
Nov	1.22	1.49	1.91	1.44	1.43
Dec	1.20	1.51	1.64	1.41	1.41

Source: 2017 Survey

The AADT of those crossing Vavarovsky Bridge estimated during 2011F/S and 2017 Survey are shown as follows

Table 8-1-5. AADT Calculated during 2011F/S and 2017 Survey

Unit: veh./day

	Passenger cars	Buses	2-axle trucks	3+ axle trucks	Trailers	Total
2017 Estimation in 2011F/S	24,675	4,279	2,278	839	2,039	34,110
2017 Survey (2017Actual)	24,564	3,688	3,941	266	3,004	35,463

The passenger car volume of 2011F/S and 2017 survey were almost same. However, bus and 3+ axle trucks volume of 2017 survey were much less than those of 2011F/S. On the other hand, 2-axle trucks and Trailers volume of 2017 survey were much more than those of 2011F/S.

This Study adopts the estimated AADT of 2017 survey because data for the estimation is updated and the characteristics of current traffic condition are represented.

8-1-2 Traffic Demand Forecast in Past Surveys

1) Demand Forecast in 2011F/S

(1) Methodology (2011)

The traffic demand forecast in 2011F/S was estimated by focusing on river crossing traffic, while river crossing traffic in future is estimated by adding induced traffic based on the Ochakiv Port Development Plan to future traffic volume at river crossings, as forecast from traffic survey results and socioeconomic indicators (Basic Traffic). By applying a conversion ratio model to the estimated river crossing traffic, the traffic volume traversing Mykolaiv Bridge can be forecast.

The flow of future demand forecast in 2011F/S is shown as follows:

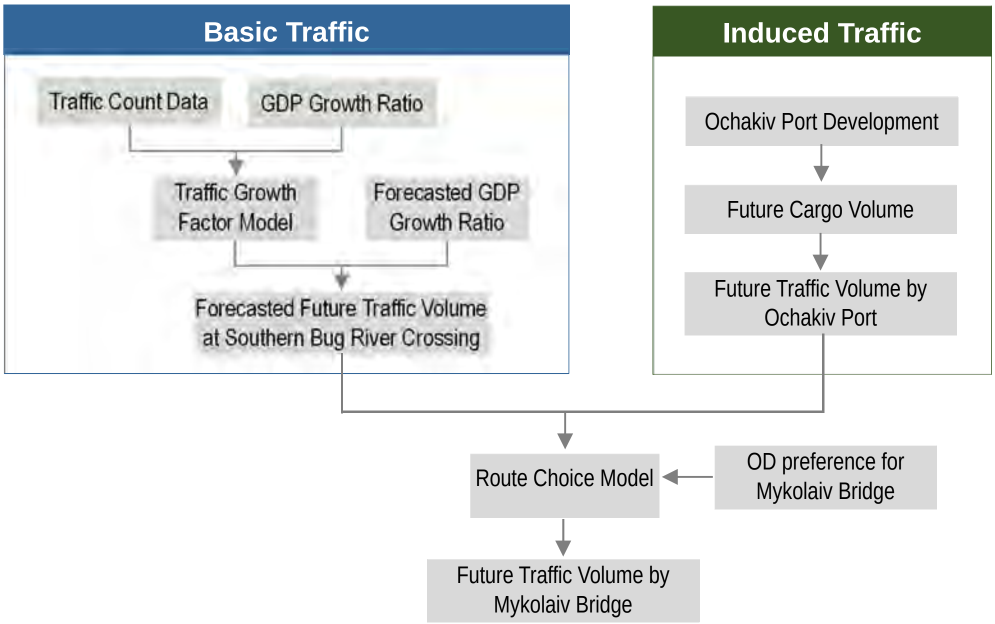


Figure 8-1-5. A flow of Future Demand Forecast in 2011F/S

(2) Result of the Estimation (2011)

a) Basic Traffic

The future traffic volume growth ratio was calculated by a linear regression model, which is based on traffic count data and socioeconomic indicators. Given the limited data source, the growth ratio of future traffic was assumed to be proportional to the GDP growth ratio in Ukraine in both 2011F/S and 2017 Survey. The GDP growth rate, one of the socioeconomic indicators, was set as 4.5%, IMF predictive value from 2010 to 2014 and 4.0% after 2015.

Table 8-1-6. Traffic Demand Growth Ratio (2011F/S)

	Passenger cars	Buses	Trucks	Trailers
Annual average growth ratio (2010 to 2045)	3.88%	0.82%	1.41%	1.20%

The following table shows future demand for basic traffic as forecast from AADT and the traffic demand growth ratio. AADT is estimated based on average of monthly traffice volume.

Table 8-1-7. Forecast River Crossing Traffic Demand (2011F/S)

Unit: AADT (veh./day)

Year	Passenger cars	Buses	2-axle trucks	3+ axle trucks	Trailers	Total
2010	18,600	4,180	2,160	760	1,970	27,670
2015f	22,900	4,200	2,200	800	2,000	32,100
2025f	33,300	4,700	2,600	1,000	2,200	43,800
2035f	48,500	5,300	3,000	1,200	2,600	60,600
2045f	70,600	5,900	3,400	1,400	3,000	84,300

Source: 2011F/S

b) Induced Traffic

The induced traffic can be forecast with the development scenario of Ochakiv Port in mind. This scenario is based on four cases of port demand: 100%, 75%, 50% and 0% demand respectively. The induced traffic comprises 3 to 5% of total demand.

Table 8-1-8. Future Traffic Demand Related to Development Port of Ochakiv (2011F/S)

Unit: veh./day

	100% demand		75% demand		50% demand	
	3+ axles	Trailers	3+ axles	Trailers	3+ axles	Trailers
2010	0	0	0	0	0	0
2011f	0	0	0	0	0	0
2012f	0	0	0	0	0	0
2013f	70	119	53	89	35	59
2014f	141	237	106	178	70	119
2015f	211	356	159	267	106	178
2020f	564	948	423	711	282	474
2025f	916	1,541	687	1,156	458	770
2030f	1,247	2,081	935	1,561	623	1,041
2035f	1,374	2,283	1,172	1,940	782	1,293
2040f	1,374	2,283	1,374	2,283	940	1,546
2045f	1,374	2,283	1,374	2,283	1,098	1,799

Source: 2011F/S

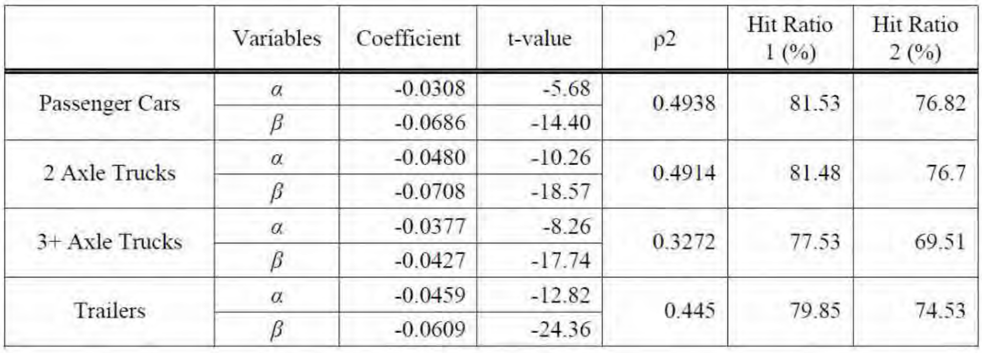
c) Route Choice Model

The conversion ratio formula in a route choice model is based on the interview survey; applying the difference in travel times and tolls by using Mykolaiv Bridge and Vavarovsky Bridge.

$$P_{new} = \frac{\exp(V_{new})}{\exp(V_{new}) + \exp(V_{old})}$$

where,

V_{new} = α (Travel Time by Mykolaiv Bridge) + β (Toll)
V_{old} = α (Travel Time by Vavarovsky Bridge)
P_{new}: Probability of Mykolaiv Bridge chosen (diversion ration)
α, β: Parameters shown in the following table



	Variables	Coefficient	t-value	ρ2	Hit Ratio 1 (%)	Hit Ratio 2 (%)
Passenger Cars	α	-0.0308	-5.68	0.4938	81.53	76.82
	β	-0.0686	-14.40			
2 Axle Trucks	α	-0.0480	-10.26	0.4914	81.48	76.7
	β	-0.0708	-18.57			
3+ Axle Trucks	α	-0.0377	-8.26	0.3272	77.53	69.51
	β	-0.0427	-17.74			
Trailers	α	-0.0459	-12.82	0.445	79.85	74.53
	β	-0.0609	-24.36			

Source: 2011F/S

Figure 8-1-6. A Conversion Ratio Model Formula in 2011F/S

d) Future Traffic Demand of Mykolaiv Bridge

Traffic demand for Mykolaiv Bridge can be forecast from the travel hours between the main sections and the route choice model based on the conversion ratio to Mykolaiv Bridge by the OD pair using the following tolls.

For buses, including intercity models, their OD or transit points are expected to remain in the center of the Mykolaiv region, which means demand for bus traffic using Mykolaiv Bridge located on the bypass route is not included in this future demand.

Table 8-1-9. PCU and Toll Systems (2011F/S)

Vehicle types	PCU	Toll setting cases（UAH/vehicle）			
		Free	Toll-1	Toll-2	Toll-3
Passenger cars	1.0	0	10	20	30
2-axle trucks	2.0	0	15	30	45
3+ axle trucks	2.5	0	20	40	60
Trailers	3.0	0	30	60	90

Source: 2011F/S

Table 8-1-10. Conversion Ratio to Mykolaiv Bridge (2011F/S)

Base Toll (UAH)	Passenger cars	2-axle trucks	3+ axle trucks	Trailers
Free	47.4%	50.2%	53.1%	54.5%
Toll-1	31.5%	38.8%	49.3%	43.2%
Toll-2	18.9%	28.4%	45.6%	32.5%
Toll-3	10.6%	19.8%	41.6%	23.3%

Source: 2011F/S

The estimated future traffic volume per day on Mykolaiv Bridge by demand cases related to the Ochakiv Port development is shown as follows:

Table 8-1-11. Future Traffic Volume on Mykolaiv Bridge (PCU/day)

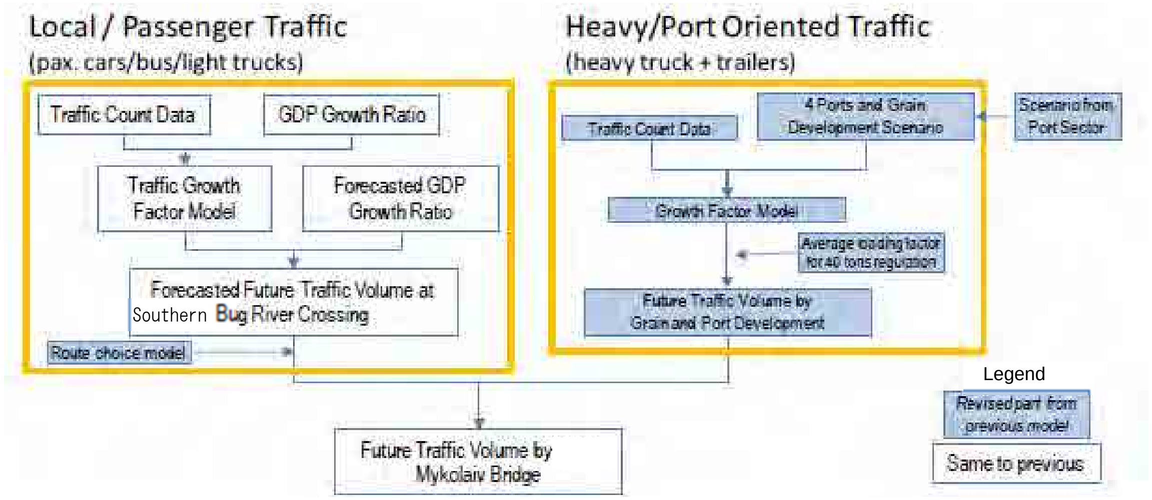
Year	Demand case	Free	Toll-1	Toll-2	Toll-3
2015	100%	18,300	13,300	9,200	6,000
	75%	18,300	13,300	8,900	5,700
	50%	18,000	13,000	8,600	5,700
	0	17,400	12,700	8,600	5,500
2025	100%	26,900	19,600	13,600	9,200
	75%	26,400	19,000	13,000	8,700
	50%	25,200	18,200	12,500	8,100
	0	23,300	16,800	11,100	7,000
2035	100%	37,600	27,300	18,800	12,400
	75%	36,800	26,400	18,300	12,100
	50%	35,100	25,300	17,200	11,000
	0	31,700	22,500	14,700	9,400
2045	100%	49,400	35,200	23,800	15,500
	75%	49,400	35,200	23,800	15,500
	50%	48,000	34,100	23,000	14,700
	0	43,500	30,500	19,900	12,500

Source: 2011F/S

2) Traffic Demand Forecast in 2017 Survey

(1) Methodology (2017）

Similar to the traffic demand forecast in 2011F/S, future traffic demand was estimated by focusing on river crossing traffic. The methodology applied in 2011F/S added induced traffic to the river crossing traffic but focused solely on the import/export volume in Odesa Port, excluding the volume in the other ports. From this perspective, 2017 Survey, in turn, categorized passenger cars, buses and 2-axle trucks as Local/Passenger Traffic and large trucks and trailers as Heavy/Port Oriented Traffic and estimated each demand respectively. Accordingly, the methodology applied in 2017 Survey is deemed more appropriate than that of 2011F/S as the former takes freight traffic in the major ports into consideration.



Source: 2017 Survey

Figure 8-1-7. Flow of Traffic Demand Forecast in 2017 Survey

(2) Local/Passenger Traffic

a) Future Traffic Volume Growth Ratio and Future Traffic Volume at River Crossing

The future traffic volume growth ratio is estimated by a regression model which is based on the traffic count data and socioeconomic indicators as in 2011F/S. The GDP growth ratio, one of the socioeconomic indicators, was set between 2.5% and 3.5% and the growth ratios calculated are shown as follows:

Table 8-1-12. Future Traffic Volume Growth Ratio (2017 Survey)

	Passenger cars	Buses	2-axle trucks
Annual average growth ratio	3.2%	2.0%	0.9%

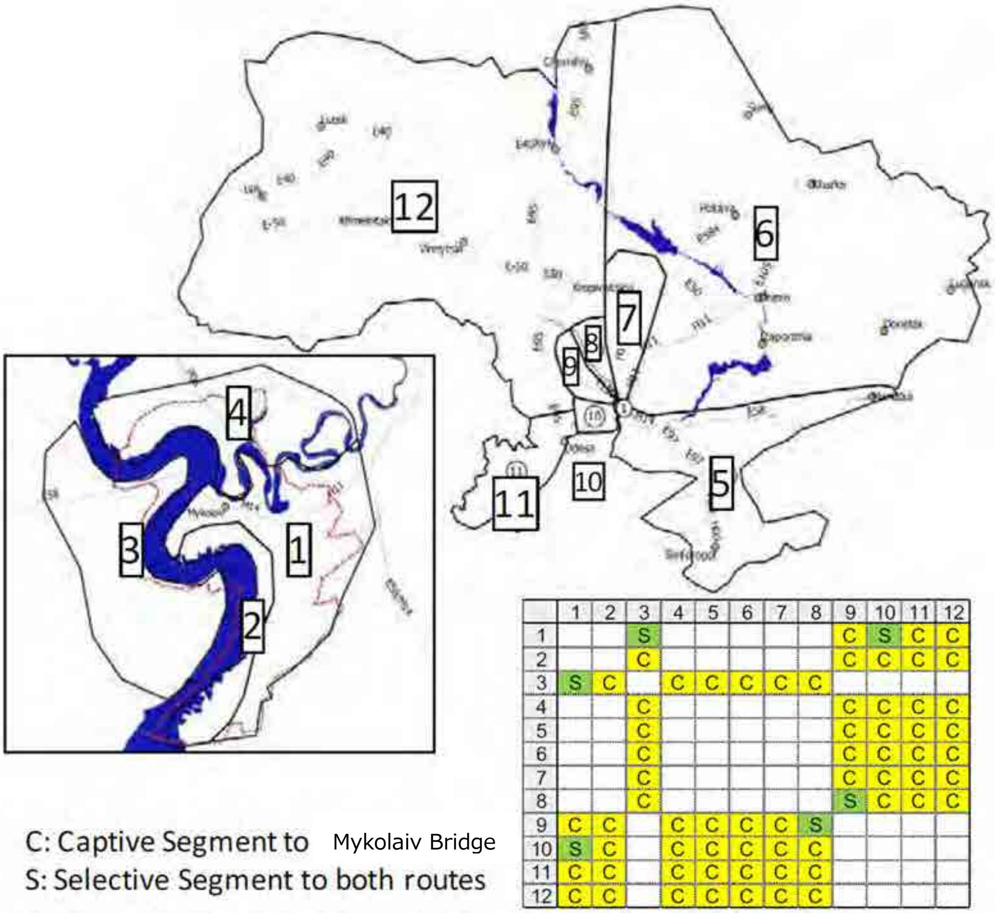
The table below shows the future traffic volume at river crossings calculated based on the future traffic volume growth ratio above and the AADT, which is estimated from the traffic count data and the monthly variations.

Table 8-1-13. Future traffic volume at river crossing (vehicles/day)

Year	Passenger cars	Buses	2-axle trucks
2017	24,564	3,688	3,941
2025	30,872	4,456	4,159
2035	42,165	5,450	4,534
2045	57,589	6,664	4,943

b) OD Patterns and Route Choice

2017 Survey conducted an interview survey again in the cross-section of Vavarovsky Bridge by dividing the traffic zone into 12 portions and applying a conversion ratio model identical to that of the 2011F/S. The ratio was adjusted based on the traffic characteristics by vehicle type and zone to forecast the traffic demand for Mykolaiv Bridge and Vavarovsky Bridge.



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

Source: 2017 Survey

Figure 8-1-8. Route Selectivity by Traffic Zone and OD pair

Selectivity by OD pair is classified into two segments: Captive and Selective. Captive is defined as "using Mykolaiv Bridge" while Selective refers to "using both Vavarovsky Bridge and Mykolaiv Bridge". Route selectivity was estimated by OD pattern.

Table 8-1-14. Conversion Ratio (2017 Survey)

	Passenger cars	Buses	2-axle trucks
Captive	29.82%	19.54%	29.82%
Selective	57.23%	76.59%	57.23%
Final	41.27%	19.54%	41.27%

Source: 2017 Survey

2017 Survey report omits a detailed explanation on the classification of the two segments, Captive and Selective, by an OD pair, making detailed analysis of the method difficult. That being said, whether or not their setting of each OD pair is appropriate remains questionable. For example, in the segment setting from Zone 3 to each zone by pair, the segment from Zones 3 to 1 is only set as "Selective" whereas that to the other Zones are set as "Collective" with no basis. Moreover, when setting the conversion ratio, although 20% of passenger cars traveling in the M14 area around Mykolaiv City are assumed to traverse Mykolaiv Bridge, no prerequisite or basis for calculating the final conversion ratio is specified. As for the conversion ratio for buses, for “Selective”, route buses are considered to maintain unchanged routes even after Mykolaiv Bridge services commence. Accordingly, the conversion ratio is only set for “Captive”. Due to the lack of data, the conversion ratio for passenger cars is also applied to large vehicles.

c) Future Traffic Volume at River Crossings in Mykolaiv Bridge (Local/Passenger Traffic)

The future traffic volume at river crossings of Mykolaiv Bridge, calculated based on the future traffic volume at the river crossing volume and the conversion ratio, is shown as follows:

Table 8-1-15. Future Traffic Volume at River Crossing of Mykolaiv Bridge (vehicles/day)

Year	Passenger cars	Buses	2-axle trucks
2017	10,138	721	1,626
2025	12,741	871	1,716
2035	17,402	1,065	1,871
2045	23,767	1,302	2,040

(3) Heavy/Port Oriented Traffic

The river crossing traffic for large trucks and trailers is assumed to increase proportionally to the import/export volume at the main ports in the Southern Region, such as Odesa, Mykolaiv and Kherson Ports. Therefore, the river crossing traffic was estimated from cargo volume with two cases. Case 1 shows the volume of coals, minerals, metals, grains and containers while Case 2 adds the other cargo to Case 1, resulting in a 15% larger volume than Case 1. The following shows a model estimating river crossing traffic of large trucks and trailers:

Table 8-1-16. Estimation Model of River Crossing Traffic of Large Trucks and Trailers

	Present	**Case 1 without bridge**	**Case 2 without bridge**	**Case 1 with bridge**	**Case 2 with bridge**
[**Input**] Total volume of Export & Import in Southern Region (million tons)	93.77	157	180	157	180
Variables					
1) Business days per year	300	300			
2) Road share	25%	25%	20%	25%	20%
3) Average ton per vehicle	12	12	12	24	24
4) roundtrip	2	2	2	2	2
5) crossing ratio at Mykolaiv	25%	25%	25%	30%	32%
[**Output**] Expected HV crossing per day (AADT of heavy vehicles)	3,256	4,797	5,500	2,878	3,520

Source: 2017 Survey

(4) Result of Estimating Future Traffic Volume at River Crossings (2017 Survey)

The following table shows the results of estimating future traffic volume at river crossings in Cases 1 and 2.

Table 8-1-17. Estimation of Future Traffic Volume at River Crossing (Case 1)

	Passenger Cars	**Buses**	**2 Axle Trucks**	**Heavy Vehicles**	**Total**	**Total in PCU**
2017 Present Situation	24,564	3,688	3,941	3,270	**35,463**	49,632
2030 Case 1 with Bridge						
Crossing traffic at new birdge	14,890	963	1,792	2,878	**20,523**	29,035
Crossing traffic at existing birdge	21,189	3,965	2,550	0	**27,704**	34,219
2030 Case 1 without Bridge						
Crossing traffic at existing birdge	36,079	4,928	4,342	4,797	**51,891**	69,012

PCU: 1,0 for passenger cars, 2,0 for buses, 2,0 for 2 axle trucks and 3,0 for heavy vehicles

Source: 2017 Survey

Table 8-1-18. Estimation of Future Traffic Volume at River Crossing (Case 2)

	Passenger Cars	**Buses**	**2 Axle Trucks**	**Heavy Vehicles**	**Total**	**Total in PCU**
2017 Present Situation	24,564	3,688	3,941	3,270	**35,463**	49,632
2030 Case 2 with Bridge						
Crossing traffic at new birdge	14,890	963	1,792	3,520	**21,165**	30,960
Crossing traffic at existing birdge	21,189	3,965	2,550	0	**27,704**	34,219
2030 Case 2 without Bridge						
Crossing traffic at existing birdge	36,079	4,928	4,342	5,500	**50,850**	71,120

Source: 2017 Survey

8-2 Traffic Demand Forecast in Additional Study

8-2-1 Overview

The fast part of Section 8.2 is to show preconditions such as target sections, road conditions, zoning including OD and current traffic volume. Thereafter, the OD of river crossing, converted traffic volume, traffic volume in the road network and future traffic volume are shown.

1) Target Sections

The four routes are shown in the following figure.

The traffic demand forecast in this survey will target the following four routes passing the cross-section of Mykolaiv Bridge and Vavarovsky Bridge and road sections in the city.

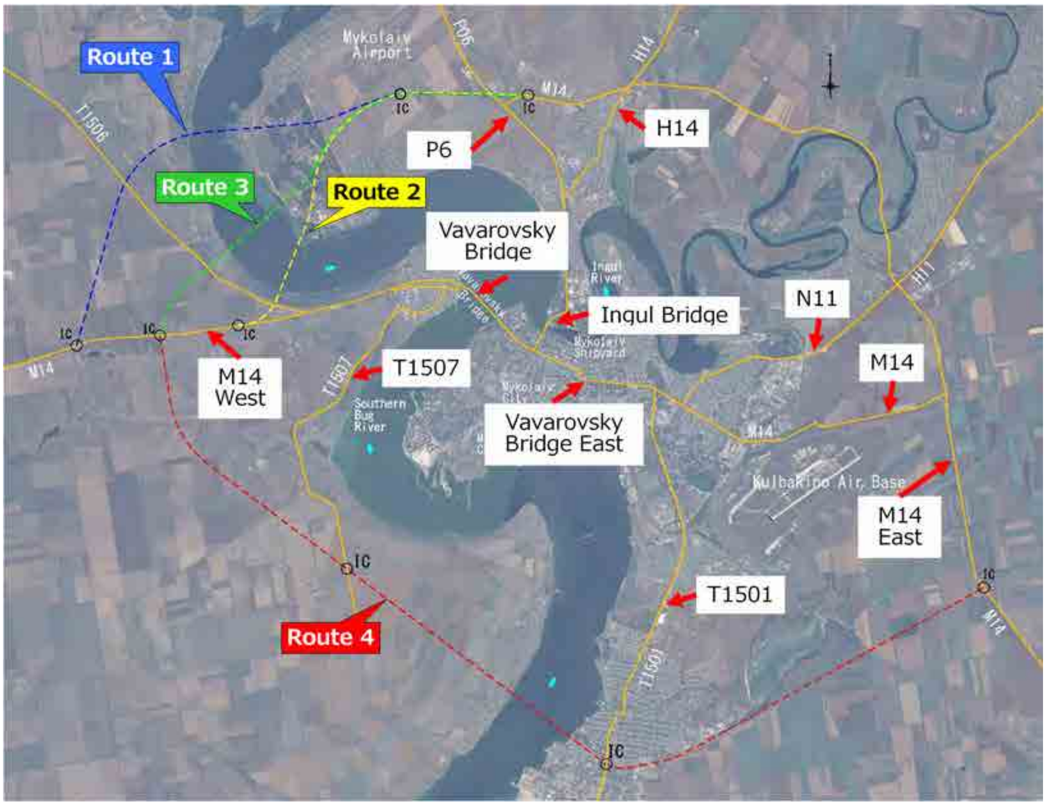


Figure 8-2-1. Target Sections and Road Networks

2) Road Conditions

The type and class of vehicles and the number of lanes on the road networks as defined in the previous section are set based on the existing data and a current condition survey as follows:

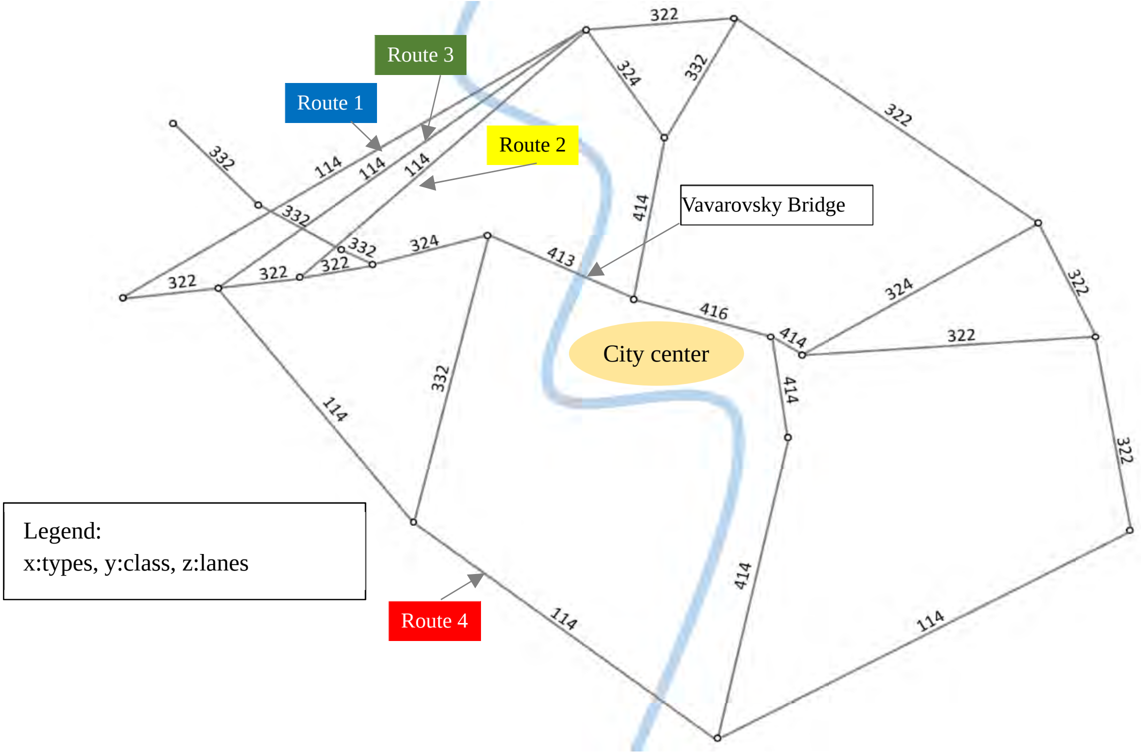


Figure 8-2-2. Vehicle Type and Class and the Number of Lanes in Each Link on the Road Network

Based on the existing data and a topographical map, the distance of each link on the road network is shown below:

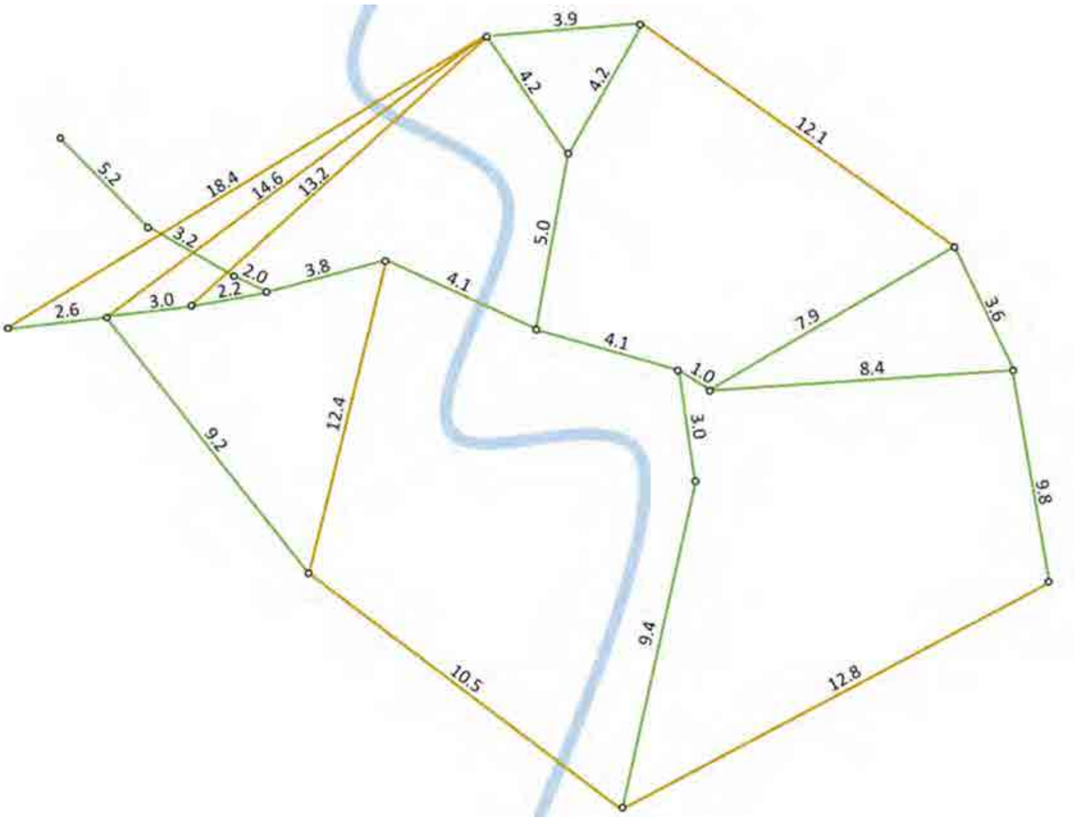


Figure 8-2-3. Distance of Each Link on the Road Network (km)

3) Zoning and OD Traffic Volume

The same zoning is applied as 2011F/S. The following values - as estimated in the previous section - are used for the attracted traffic volume generated, which is also applied for the estimation.

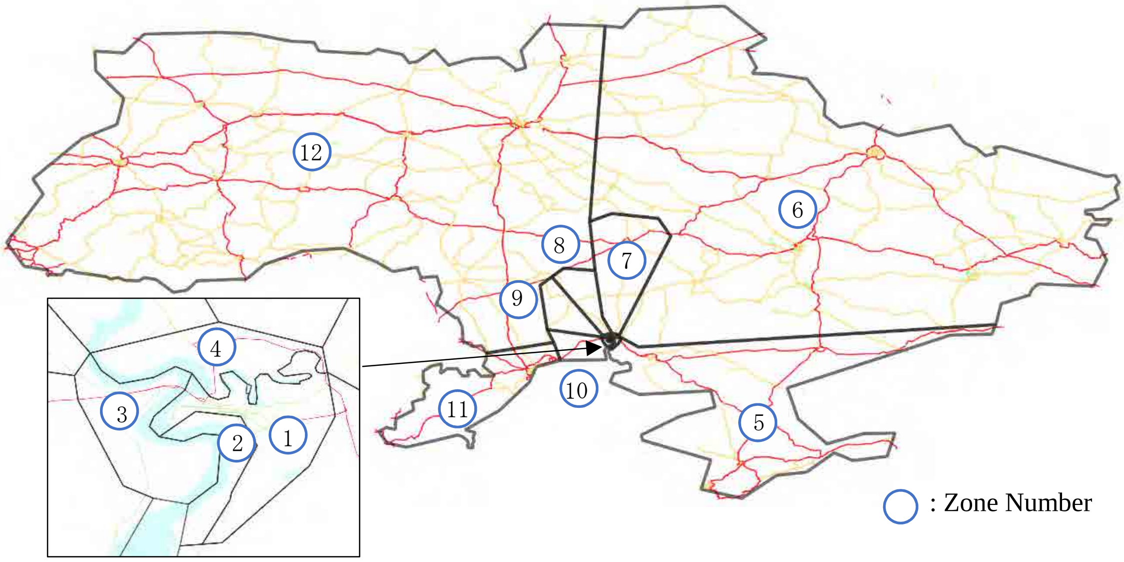


Figure 8-2-4. Zoning (Left: Narrow area; Right: Wide area)

The OD traffic volume in accordance with this zoning is shown in Table 8-2-1.

Table 8-2-1. The Original OD Traffic Volume (as of 2017)

Veh./day

Pax

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	0	3,847	74	369	74	222	888	222	3,774	3,404	0	12,874
2	0	0	74	0	222	0	0	0	0	74	222	0	592
3	5,845	222	0	369	0	222	149	149	74	592	0	149	7,771
4	0	0	222	0	0	0	0	0	0	0	0	74	296
5	74	0	149	0	0	0	0	0	0	149	592	0	963
6	74	0	149	0	74	0	0	0	0	0	74	0	369
7	222	0	0	0	0	0	0	0	0	0	74	74	369
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	74	0	0	0	0	0	0	0	0	0	0	0	74
10	592	0	222	0	0	0	0	74	0	0	0	0	888
11	74	0	74	0	0	74	0	0	0	0	0	0	221
12	74	0	0	0	0	74	0	0	0	0	0	0	147
Total	7,027	222	4,737	443	665	443	371	1,110	296	4,588	4,365	296	24,564

Veh./day

Bus

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	0	1,158	0	0	0	0	69	121	252	136	11	1,747
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1,158	0	0	0	0	0	0	0	0	0	0	0	1,158
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	4	0	0	0	0	34	22	60
6	0	0	0	0	0	0	0	0	0	4	37	0	41
7	0	0	0	0	0	0	0	0	0	0	0	0	0
8	69	0	0	0	0	0	0	0	0	0	0	0	69
9	121	0	0	0	0	0	0	0	0	0	0	0	121
10	252	0	0	0	0	4	0	0	0	0	0	0	255
11	136	0	0	0	37	37	0	0	0	0	0	0	211
12	7	0	0	0	15	4	0	0	0	0	0	0	26
Total	1,743	0	1,158	0	52	48	0	69	121	255	207	34	3,688

Veh./day

Trucks

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	0	617	12	59	12	36	142	36	605	546	0	2,065
2	0	0	12	0	36	0	0	0	0	12	36	0	95
3	938	36	0	59	0	36	24	24	12	95	0	24	1,247
4	0	0	36	0	0	0	0	0	0	0	0	12	47
5	12	0	24	0	0	0	0	0	0	24	95	0	155
6	12	0	24	0	12	0	0	0	0	0	12	0	59
7	36	0	0	0	0	0	0	0	0	0	12	12	59
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	12	0	0	0	0	0	0	0	0	0	0	0	12
10	95	0	36	0	0	0	0	12	0	0	0	0	142
11	12	0	12	0	0	12	0	0	0	0	0	0	35
12	12	0	0	0	0	12	0	0	0	0	0	0	24
Total	1,127	36	760	71	107	71	60	178	47	736	700	47	3,941

Veh./day

3ax

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	4	0	0	0	0	0	0	0	2	6	0	12
2	0	0	0	0	0	0	0	0	0	0	2	0	2
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0	1
5	0	20	0	0	8	0	0	1	0	0	0	0	29
6	1	16	3	0	2	0	0	0	0	0	12	1	34
7	0	4	3	0	1	1	0	5	0	0	0	0	13
8	11	13	7	0	17	6	1	2	5	0	3	1	65
9	1	0	2	0	1	1	0	0	0	0	0	0	5
10	4	8	0	0	0	2	0	0	0	0	4	0	18
11	3	7	0	3	12	25	2	0	1	4	0	0	57
12	5	18	0	0	15	4	1	2	0	0	0	0	44
Total	26	93	17	7	60	45	11	17	15	16	37	14	279

Veh./day

Tailer

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	42	0	0	0	0	0	0	0	20	63	0	125
2	0	0	0	0	0	0	0	0	0	0	20	0	20
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	10	0	0	0	0	0	0	0	0	0	0	0	10
5	0	218	0	0	83	0	0	10	0	0	0	0	311
6	10	176	29	0	19	0	0	0	0	0	125	10	369
7	0	42	30	0	10	10	0	51	0	0	0	0	144
8	117	142	71	0	181	68	10	19	51	0	29	10	697
9	10	0	20	0	10	10	0	0	0	0	0	0	51
10	42	83	0	0	0	20	0	0	0	0	42	0	188
11	30	73	0	29	134	271	20	0	10	42	0	0	609
12	49	195	0	0	156	39	10	19	0	0	0	0	467
Total	270	973	154	33	597	424	48	106	70	73	290	32	2,991

Veh./day

All

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	46	5,622	85	429	85	258	1,099	379	4,653	4,155	11	16,823
2	0	0	85	0	258	0	0	0	0	85	280	0	709
3	7,941	258	0	429	0	258	173	173	85	687	0	173	10,176
4	11	0	258	0	0	0	0	0	0	0	0	85	355
5	85	239	173	0	91	4	0	11	0	173	720	22	1,518
6	96	192	204	0	106	0	0	0	0	4	259	11	873
7	258	46	33	0	11	11	0	55	0	0	85	85	586
8	197	155	78	0	198	74	11	20	55	0	31	11	831
9	218	0	22	0	11	11	0	0	0	0	0	0	262
10	985	91	258	0	0	26	0	85	0	0	46	0	1,491
11	255	80	85	31	183	419	22	0	11	46	0	0	1,132
12	146	213	0	0	185	132	11	20	0	0	0	0	707
Total	10,192	1,320	6,819	545	1,472	1,019	475	1,465	531	5,648	5,578	399	35,463

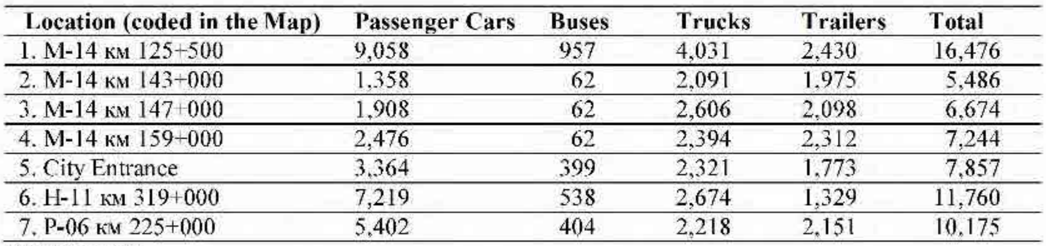
4) Current Traffic Volume

The following three different traffic surveys were conducted in the survey area:

- A traffic survey conducted in September 2016 (24-hours, four vehicle types)
- A traffic survey conducted in January 2017 (24-hours, five vehicle types) and a monthly variation survey on the cross-section of Vavarovsky Bridge (24-hours, five vehicle types)
- A traffic survey conducted in October 2018 (an hour, one vehicle type)

The outline of these surveys is shown as follows:

- A Traffic Survey in September 2016 (24-hours, Four Vehicle Types, Conducted by JICA)



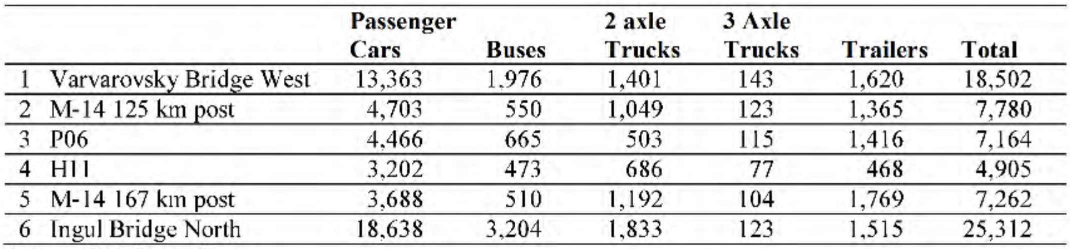
Location (coded in the Map)	Passenger Cars	Buses	Trucks	Trailers	Total
1. M-14 км 125+500	9,058	957	4,031	2,430	16,476
2. M-14 км 143+000	1,358	62	2,091	1,975	5,486
3. M-14 км 147+000	1,908	62	2,606	2,098	6,674
4. M-14 км 159+000	2,476	62	2,394	2,312	7,244
5. City Entrance	3,364	399	2,321	1,773	7,857
6. H-11 км 319+000	7,219	538	2,674	1,329	11,760
7. P-06 км 225+000	5,402	404	2,218	2,151	10,175

KM=kilometer

Source: Ukravtodor Office of Mykolaiv Oblast

Source: Ukravtodor Office of Mykolaiv Oblast

- A Traffic Survey in January 2017 (24-hours, Five Vehicle Types, Conducted by JICA)



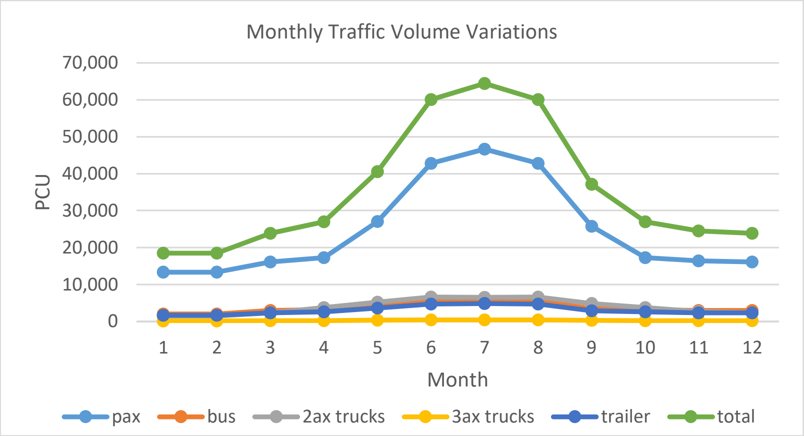
		Passenger Cars	Buses	2 axle Trucks	3 Axle Trucks	Trailers	Total
1	Varvarovsky Bridge West	13,363	1,976	1,401	143	1,620	18,502
2	M-14 125 km post	4,703	550	1,049	123	1,365	7,780
3	P06	4,466	665	503	115	1,416	7,164
4	H11	3,202	473	686	77	468	4,905
5	M-14 167 km post	3,688	510	1,192	104	1,769	7,262
6	Ingul Bridge North	18,638	3,204	1,833	123	1,515	25,312

Source: JICA Survey Team.

Source: JICA Survey Team

Table 8-2-2. Monthly Traffic Volume Variations on the Cross-Section of Vavarovsky Bridge (cited from 2017 Survey report)

	pax	bus	trucks	3ax	trailer	total	pax	bus	trucks	3ax	trailer	total
1	13,363	1,976	1,400	143	1,620	18,502	0.54	0.54	0.36	0.54	0.54	0.52
2	13,363	1,976	1,400	143	1,620	18,502	0.54	0.54	0.36	0.54	0.54	0.52
3	16,103	2,982	2,287	203	2,277	23,852	0.66	0.81	0.58	0.76	0.76	0.67
4	17,234	3,178	3,776	230	2,581	26,999	0.70	0.86	0.96	0.86	0.86	0.76
5	27,029	4,381	5,182	322	3,636	40,550	1.10	1.19	1.31	1.21	1.21	1.14
6	42,815	5,583	6,604	417	4,692	60,111	1.74	1.51	1.68	1.57	1.56	1.70
7	46,620	6,063	6,487	430	4,867	64,467	1.90	1.64	1.65	1.62	1.62	1.82
8	42,815	5,583	6,604	417	4,692	60,111	1.74	1.51	1.68	1.57	1.56	1.70
9	25,736	3,438	4,819	255	2,884	37,132	1.05	0.93	1.22	0.96	0.96	1.05
10	17,234	3,178	3,776	230	2,581	26,999	0.70	0.86	0.96	0.86	0.86	0.76
11	16,358	2,942	2,672	205	2,323	24,500	0.67	0.80	0.68	0.77	0.77	0.69
12	16,097	2,980	2,290	202	2,279	23,848	0.66	0.81	0.58	0.76	0.76	0.67
AADT	24,564	3,688	3,941	266	3,004	35,463	1.00	1.00	1.00	1.00	1.00	1.00



- A Traffic Survey in October 2018 (per one hour, one vehicle type, conducted during this survey)

Location No.	Time	Vehicle
1	10:27～11:27	449
2	13:14～14:14	2,100
3	13:00～14:00	1,863
4	13:12～14:12	2,150
5	10:14～11:14	1,424
6	10:14～11:14	279
7	10:13～11:13	841
8	10:23～11:23	279

Figure 8-2-5. Result and Locations of Traffic Counting (October 2018)

8-2-2 Adjustment of OD Traffic Volume to OD of River Crossing

Despite the distribution of the traffic volume as shown in the previous section as the OD of the Southern Bug River crossing (prepared based on the interview survey in the cross-section of Vavarovsky Bridge), it includes OD pairs that need not pass the bridge. Setting an appropriate OD of the Southern Bug River crossing is calculated in accordance with the following procedure. As described below, because it was felt that trip generation and attraction in the original OD table were not adequately balanced, efforts were taken in this Study to average the OD generation and attraction.

1) Issue of 2017 Survey's OD

In general, trip generation and attraction of traffic between zones should show about the same volume of traffic. In a full-day time period, most trips leave from, and return to, the same origin. In 2017 Survey, the current OD table was prepared by multiplying a roughly 2.5% sample size of sample data gathered from interview surveys (as long as it was a passenger vehicle). It is believed that the sample's differences in generated and attracted traffic volumes were magnified by multiplying these values. This imbalance may have been due to the time-period of the interview survey which was conducted between 8:00 to 16:00, omitting peak traffic in the evening, as well as the low sample rate (the standard sampling rate in Japan is about 7% based on a similar population parameter).

2) Result of 2017 Survey's OD

According to the 2017 OD table, the ratio of total traffic above and below the diagonal line is 66:34 (16% from the middle value) for passenger vehicles. The same trend is shown even for vehicle types except for buses.

There is no standard acceptable values concerning differences in trip generation/attraction values. However, when considering data reliability, this is considered a large gap from typical values of 5%

On the other hand, the bus OD table was the result of an interview survey with bus operators on the number of buses on scheduled bus routes. The ratio of total traffic volume above and below the diagonal line is 50:50, indicating no difference between these zones.

3) Method of Adjustment of this Study's OD

In general, there are two conceivable ways to correct this imbalance as follows.

Option 1: Average the trip generation and attraction volumes by assuming that the ratio of total distributed traffic on the generation side and attraction side obtained in interviews is reliable.

Option 2: Estimate based on existing data by, for example, using the rest of the poorly balanced distribution volume to estimate the cross-sectional traffic volume ratio of unobserved time zones.

In this Study, option 1 based on observed data to improve the balance is adopted because there is no interview data, and even if there was, the OD of unobserved time periods would be estimated from time period data with small sample sizes.

Furthermore, buses are averaged together with other vehicle types. Even when averaging, buses are believed to have no impact on accuracy as there are only a few buses in the traffic volume between the zones with differences in trip generation and attraction.

i) Extraction of OD of river crossing

ii) The extracted OD of river crossing is expanded and calculated as the total trip generation/attraction before extraction divided by the total trip generation/attraction after extraction.

The calculated OD is shown in Table 8-2-3.

Table 8-2-3. OD Traffic Volume after Adjustment of OD of River Crossing (as of 2017)

Pax

Veh./day

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	0	5,745	0	0	0	0	0	175	2,587	2,061	44	10,612
2	0	0	175	0	0	0	0	0	0	44	132	0	351
3	5,745	175	0	351	88	220	88	88	0	0	0	0	6,755
4	0	0	351	0	0	0	0	0	0	0	0	44	395
5	0	0	88	0	0	0	0	0	0	88	351	0	527
6	0	0	220	0	0	0	0	0	0	0	87	44	351
7	0	0	88	0	0	0	0	0	0	0	44	44	176
8	0	0	88	0	0	0	0	0	0	44	0	0	132
9	175	0	0	0	0	0	0	0	0	0	0	0	175
10	2,587	44	0	0	88	0	0	44	0	0	0	0	2,763
11	2,061	132	0	0	351	87	44	0	0	0	0	0	2,675
12	44	0	0	44	0	44	44	0	0	0	0	0	176
Total	10,612	351	6,755	395	527	351	176	132	175	2,763	2,675	176	25,088

Bus

Veh./day

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	0	1,373	0	0	0	0	0	144	298	161	11	1,987
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1,373	0	0	0	0	0	0	0	0	0	0	0	1,373
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	42	22	64
6	0	0	0	0	0	0	0	0	0	4	44	2	50
7	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	144	0	0	0	0	0	0	0	0	0	0	0	144
10	298	0	0	0	0	4	0	0	0	0	0	0	302
11	161	0	0	0	42	44	0	0	0	0	0	0	247
12	11	0	0	0	22	2	0	0	0	0	0	0	35
Total	1,987	0	1,373	0	64	50	0	0	144	302	247	35	4,202

Trucks

Veh./day

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	0	922	0	0	0	0	0	28	415	331	7	1,703
2	0	0	28	0	0	0	0	0	0	7	21	0	56
3	922	28	0	56	14	35	14	14	0	0	0	0	1,083
4	0	0	56	0	0	0	0	0	0	0	0	7	63
5	0	0	14	0	0	0	0	0	0	14	56	0	84
6	0	0	35	0	0	0	0	0	0	0	14	7	56
7	0	0	14	0	0	0	0	0	0	0	7	7	28
8	0	0	14	0	0	0	0	0	0	7	0	0	21
9	28	0	0	0	0	0	0	0	0	0	0	0	28
10	415	7	0	0	14	0	0	7	0	0	0	0	443
11	331	21	0	0	56	14	7	0	0	0	0	0	429
12	7	0	0	7	0	7	7	0	0	0	0	0	28
Total	1,703	56	1,083	63	84	56	28	21	28	443	429	28	4,022

3ax

Veh./day

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	0	0	0	0	0	0	0	1	3	5	3	12
2	0	0	0	0	0	0	0	0	0	5	5	11	21
3	0	0	0	0	0	2	2	4	0	0	0	0	8
4	0	0	0	0	0	0	0	0	0	0	2	0	2
5	0	0	0	0	0	0	0	0	1	0	7	9	17
6	0	0	2	0	0	0	0	0	1	1	22	3	29
7	0	0	2	0	0	0	0	0	0	0	1	1	4
8	0	0	4	0	0	0	0	0	3	0	2	2	11
9	1	0	0	0	1	1	0	3	0	0	0	0	6
10	3	5	0	0	0	1	0	0	0	0	0	0	9
11	5	5	0	2	7	22	1	2	0	0	0	0	44
12	3	11	0	0	9	3	1	2	0	0	0	0	29
Total	12	21	8	2	17	29	4	11	6	9	44	29	192

Tailer

Veh./day

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	0	0	0	0	0	0	0	6	37	55	29	127
2	0	0	0	0	0	0	0	0	0	49	55	115	219
3	0	0	0	0	0	17	18	42	0	0	0	0	77
4	0	0	0	0	0	0	0	0	0	0	17	0	17
5	0	0	0	0	0	0	0	0	6	0	79	92	177
6	0	0	17	0	0	0	0	0	6	12	235	29	299
7	0	0	18	0	0	0	0	0	0	0	12	6	36
8	0	0	42	0	0	0	0	0	30	0	17	17	106
9	6	0	0	0	6	6	0	30	0	0	0	0	48
10	37	49	0	0	0	12	0	0	0	0	0	0	98
11	55	55	0	17	79	235	12	17	0	0	0	0	470
12	29	115	0	0	92	29	6	17	0	0	0	0	288
Total	127	219	77	17	177	299	36	106	48	98	470	288	1,962

All

Veh./day

	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	0	0	8,040	0	0	0	0	0	354	3,340	2,613	94	14,441
2	0	0	203	0	0	0	0	0	0	105	213	126	647
3	8,040	203	0	407	102	274	122	148	0	0	0	0	9,296
4	0	0	407	0	0	0	0	0	0	0	19	51	477
5	0	0	102	0	0	0	0	0	7	102	535	123	869
6	0	0	274	0	0	0	0	0	7	17	402	85	785
7	0	0	122	0	0	0	0	0	0	0	64	58	244
8	0	0	148	0	0	0	0	0	33	51	19	19	270
9	354	0	0	0	7	7	0	33	0	0	0	0	401
10	3,340	105	0	0	102	17	0	51	0	0	0	0	3,615
11	2,613	213	0	19	535	402	64	19	0	0	0	0	3,865
12	94	126	0	51	123	85	58	19	0	0	0	0	556
Total	14,441	647	9,296	477	869	785	244	270	401	3,615	3,865	556	35,466

8-2-3 Estimation of Traffic Volume Converted from Vavarovsky Bridge to Mykolaiv Bridge

1) Travel Time Required between ODs

The free speed at each link on the road network is set as follows based on the travel speed survey (2011) as well as their function as a trunk road.

In addition, the traffic origins in each zone are set as follows:

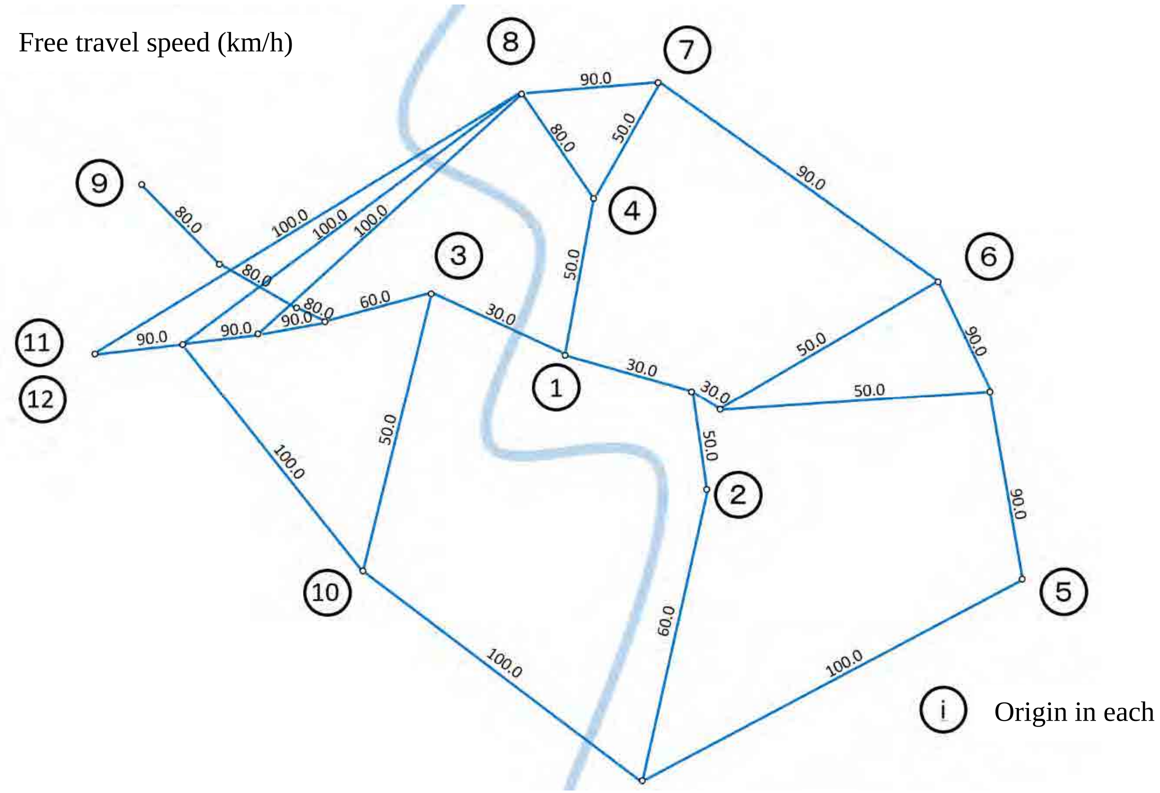


Figure 8-2-6. Free Travel Speed (km/h) and Traffic Origin in Each Link on the Road Network

With this free travel speed and the distance from each link, the travel time between zones are obtained as shown in Table 8-2-4.

Table 8-2-4. Estimation of Travel Time between Zones

When using Vavarovsky Bridge Minutes

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	11.82	8.22	6.00	26.82	19.08	11.04	9.18	19.80	23.10	17.22	347.22
2	11.82	0.00	19.98	17.82	22.20	15.06	22.86	20.94	31.62	34.86	28.98	358.98
3	8.22	19.98	0.00	14.22	35.04	27.30	19.26	17.34	11.58	14.88	9.00	339.00
4	6.00	17.82	14.22	0.00	22.02	13.08	5.04	3.12	25.80	29.10	23.22	353.22
5	26.82	22.20	35.04	22.02	0.00	8.94	16.98	19.62	46.62	49.92	44.04	374.04
6	19.08	15.06	27.30	13.08	8.94	0.00	8.04	10.68	38.88	42.18	36.30	366.30
7	11.04	22.86	19.26	5.04	16.98	8.04	0.00	2.58	30.84	34.14	28.26	358.26
8	9.18	20.94	17.34	3.12	19.62	10.68	2.58	0.00	28.92	32.22	26.34	356.34
9	19.80	31.62	11.58	25.80	46.62	38.88	30.84	28.98	0.00	26.46	13.02	343.02
10	23.10	34.86	14.88	29.10	49.92	42.18	34.14	32.22	26.46	0.00	23.88	353.88
11	17.22	28.98	9.00	23.22	44.04	36.30	28.26	26.34	13.02	23.88	0.00	330.00
12	347.22	358.98	339.00	353.22	374.04	366.30	358.26	356.34	343.02	353.88	330.00	330.00

When using Mykolaiv Bridge (Route 1) Minutes

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	11.82	29.16	6.00	26.82	19.08	11.04	9.18	33.18	44.04	20.16	350.16
2	11.82	0.00	40.98	17.82	22.20	15.06	22.86	20.94	45.00	55.86	31.98	361.98
3	29.16	40.98	0.00	23.16	39.66	30.72	22.62	20.04	11.58	14.88	9.00	339.00
4	6.00	17.82	23.22	0.00	22.02	13.08	5.04	3.12	27.18	38.04	14.16	344.16
5	26.82	22.20	39.66	22.02	0.00	8.94	16.98	19.62	43.62	54.54	30.66	360.66
6	19.08	15.06	30.72	13.08	8.94	0.00	8.04	10.68	34.68	45.60	21.72	351.72
7	11.04	22.86	22.62	5.04	16.98	8.04	0.00	2.58	26.64	37.50	13.62	343.62
8	9.18	20.94	20.04	3.12	19.62	10.68	2.58	0.00	24.06	34.92	11.04	341.04
9	33.18	45.00	11.58	27.18	43.62	34.68	26.64	24.06	0.00	26.46	13.02	343.02
10	44.04	55.86	14.88	38.04	54.54	45.60	37.50	34.92	26.46	0.00	23.88	353.88
11	20.16	31.98	9.00	14.16	30.66	21.72	13.62	11.04	13.02	23.88	0.00	330.00
12	350.16	361.98	339.00	344.16	360.66	351.72	343.62	341.04	343.02	353.88	330.00	330.00

When using Mykolaiv Bridge (Route 2) Minutes

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	11.82	22.32	6.00	26.82	19.08	11.04	9.18	26.34	37.20	20.82	350.16
2	11.82	0.00	34.14	17.82	22.20	15.06	22.86	20.94	38.16	49.02	32.58	361.98
3	22.32	34.14	0.00	16.32	32.76	23.88	15.78	13.20	11.58	14.88	9.00	339.00
4	6.00	17.82	16.32	0.00	22.02	13.08	5.04	3.12	20.34	31.20	14.82	344.16
5	26.82	22.20	32.76	22.02	0.00	8.94	16.98	19.62	36.78	47.64	31.26	360.66
6	19.08	15.06	23.88	13.08	8.94	0.00	8.04	10.68	27.84	38.76	22.32	351.72
7	11.04	22.86	15.78	5.04	16.98	8.04	0.00	2.58	19.80	30.66	14.28	343.62
8	9.18	20.94	13.20	3.12	19.62	10.68	2.58	0.00	17.16	28.08	11.64	341.04
9	26.34	38.16	11.58	20.34	36.78	27.84	19.80	17.16	0.00	26.46	13.02	343.02
10	37.20	49.02	14.88	31.20	47.64	38.76	30.66	28.08	26.46	0.00	23.88	353.88
11	20.82	32.58	9.00	14.82	31.26	22.32	14.28	11.64	13.02	23.88	0.00	330.00
12	350.16	361.98	339.00	344.16	360.66	351.72	343.62	341.04	343.02	353.88	330.00	330.00

When using Mykolaiv Bridge (Route 3) Minutes

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	11.82	25.20	6.00	26.82	19.08	11.04	9.18	29.16	40.08	19.62	350.16
2	11.82	0.00	36.96	17.82	22.20	15.06	22.86	20.94	40.98	51.84	31.44	361.98
3	25.20	36.96	0.00	19.20	35.64	26.70	18.60	16.02	11.58	14.88	9.00	339.00
4	6.00	17.82	19.20	0.00	22.02	13.08	5.04	3.12	23.16	34.08	13.62	344.16
5	26.82	22.20	35.64	22.02	0.00	8.94	16.98	19.62	39.60	50.52	30.12	360.66
6	19.08	15.06	26.70	13.08	8.94	0.00	8.04	10.68	30.72	41.58	21.18	351.72
7	11.04	22.86	18.60	5.04	16.98	8.04	0.00	2.58	22.62	33.48	13.08	343.62
8	9.18	20.94	16.02	3.12	19.62	10.68	2.58	0.00	20.04	30.90	10.50	341.04
9	29.16	40.98	11.58	23.16	39.60	30.72	22.62	20.04	0.00	26.46	13.02	343.02
10	40.08	51.84	14.88	34.08	50.52	41.58	33.48	30.90	26.46	0.00	23.88	353.88
11	19.62	31.44	9.00	13.62	30.12	21.18	13.08	10.50	13.02	23.88	0.00	330.00
12	350.16	361.98	339.00	344.16	360.66	351.72	343.62	341.04	343.02	353.88	330.00	330.00

When using Mykolaiv Bridge (Route 4) Minutes

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.00	11.82	40.26	6.00	26.82	19.08	11.04	9.18	44.28	27.48	34.74	350.16
2	11.82	0.00	28.50	17.82	17.10	15.06	22.86	20.94	32.46	15.72	22.98	361.98
3	40.26	28.50	0.00	46.26	26.76	35.70	43.74	46.38	11.58	12.78	9.00	339.00
4	6.00	17.82	46.26	0.00	22.02	13.08	5.04	3.12	50.28	33.48	40.74	344.16
5	26.82	17.10	26.76	22.02	0.00	8.94	16.98	19.62	30.78	13.98	21.24	360.66
6	19.08	15.06	35.70	13.08	8.94	0.00	8.04	10.68	39.72	22.92	30.18	351.72
7	11.04	22.86	43.74	5.04	16.98	8.04	0.00	2.58	47.76	30.96	38.22	343.62
8	9.18	20.94	46.38	3.12	19.62	10.68	2.58	0.00	50.34	33.60	40.86	341.04
9	44.28	32.46	11.58	50.28	30.78	39.72	47.76	50.34	0.00	16.80	13.02	343.02
10	27.48	15.72	12.78	33.48	13.98	22.92	30.96	33.60	16.80	0.00	7.26	353.88
11	34.74	22.98	9.00	40.74	21.24	30.18	38.22	40.86	13.02	7.26	0.00	330.00
12	350.16	361.98	339.00	344.16	360.66	351.72	343.62	341.04	343.02	353.88	330.00	330.00

2) Converted Traffic Volume

The following conversion ratio is applied to the difference in travel time between Mykolaiv Bridge and Vavarovsky Bridge as obtained in the previous section. In so doing, the traffic volume for each route crossing Mykolaiv Bridge is calculated as follows.

Table 8-2-5. Traffic Volumes of Mykolaiv Bridge and Vavarovsky Bridge after Traffic Conversion

Unit: veh./day

Bridges	Route	Pax	Bus	2-axle trucks	3+ axle trucks	Trailer	All
Mykolaiv Bridge	Route1	9,785	1,566	1,351	104	707	13,512
	Route2	10,714	1,742	1,563	106	804	14,929
	Route3	10,358	1,671	1,480	106	808	14,423
	Route4	9,032	1,383	1,201	100	842	12,558
Vavarovsky Bridge	Route1	15,303	2,636	2,671	88	1,255	21,954
	Route2	14,374	2,460	2,459	86	1,158	20,537
	Route3	14,730	2,531	2,542	86	1,154	21,043
	Route4	16,056	2,819	2,821	92	1,120	22,908

Unit: pcu/day

Bridges	Route	Pax	Bus	2-axle trucks	3+ axle trucks	Trailer	All
Mykolaiv Bridge	Route1	9,785	4,698	2,701	352	3,536	21,072
	Route2	10,714	5,227	3,125	359	4,020	23,445
	Route3	10,358	5,013	2,960	360	4,038	22,729
	Route4	9,032	4,150	2,402	338	4,208	20,130
Vavarovsky Bridge	Route1	15,303	7,908	5,343	298	6,274	35,126
	Route2	14,374	7,379	4,919	291	5,790	32,753
	Route3	14,730	7,593	5,084	290	5,772	33,469
	Route4	16,056	8,456	5,642	312	5,602	36,068

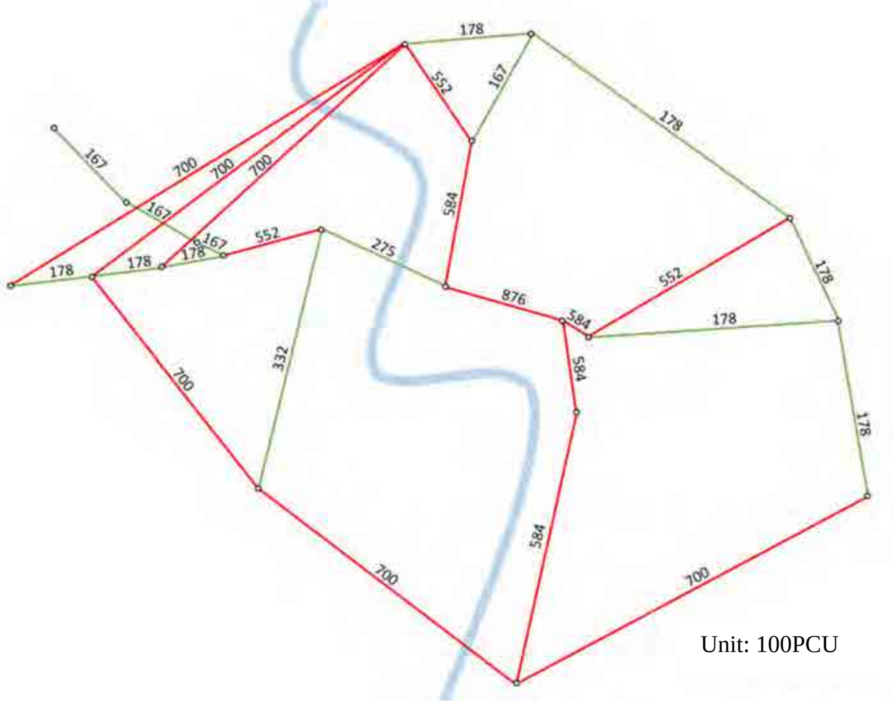
Bridge	Route	Conversion / Unconversion Rate
Mykolaiv Bridge	Route1	39.1%
	Route2	42.9%
	Route3	41.5%
	Route4	36.1%
Vavarovsky Bridge	Route1	60.9%
	Route2	57.1%
	Route3	58.5%
	Route4	63.9%

8-2-4 Estimation of Traffic Volume in the Road Network

1) Setting the Road Network Capacity and Quantity-Velocity conditions

(1) Capacity

The road network capacity is set as follows based on the road conditions (vehicle type and class and the number of lanes) for each section in the network.

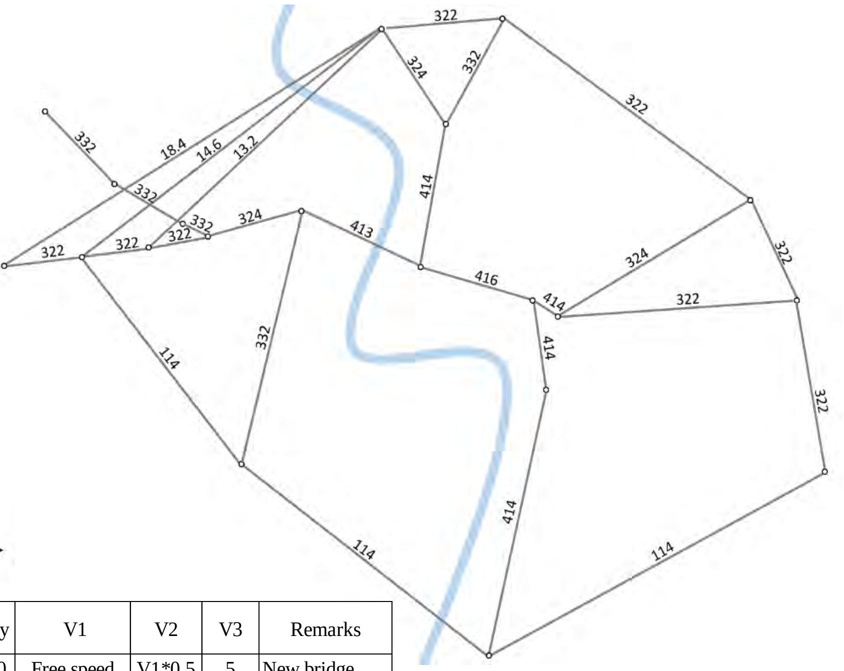


Unit: 100PCU

Figure 8-2-7. Road Network Capacity

(2) Quantity-Velocity (QV)

To define the travel speed based on the converted traffic volume, the Quantity-Velocity (QV) conditions in each section are set as follows:



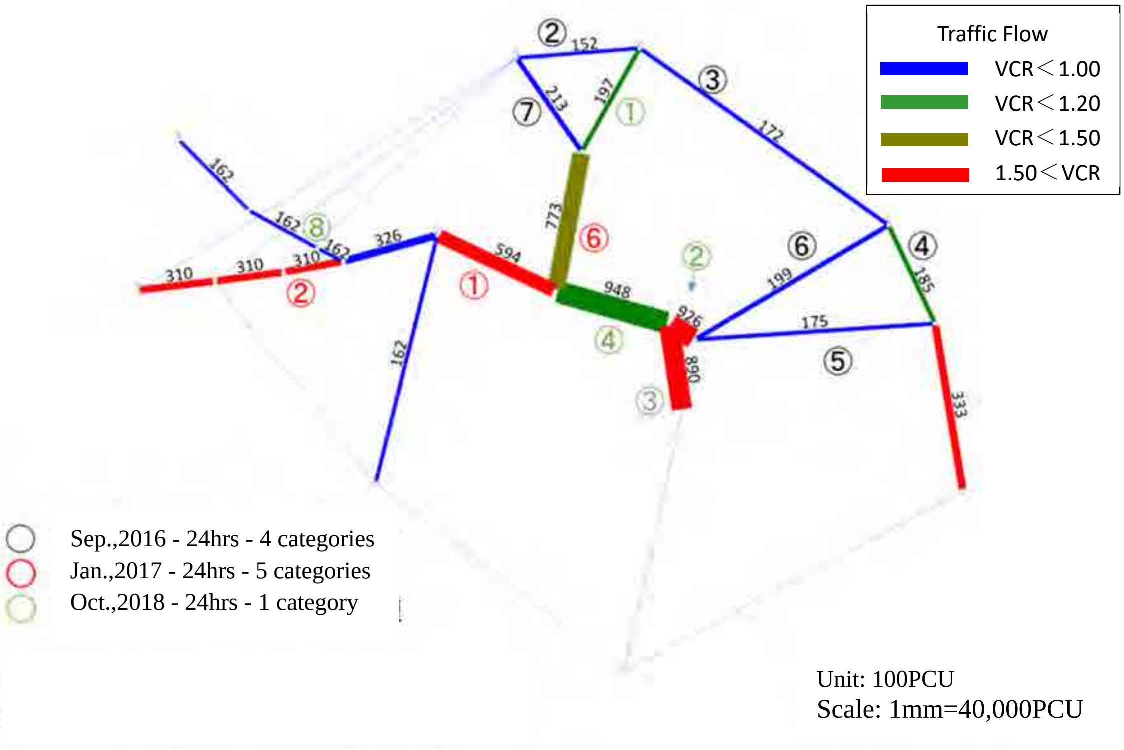
Qvno	Lanes	Q1	Q2	Capacity	V1	V2	V3	Remarks
114	4	54,000	93,200	70,000	Free speed	V1*0.5	5	New bridge
324	4	32,400	64,800	55,200	Free speed	V1*0.5	5	M14 suburb
322	2	10,500	20,900	17,800	Free speed	V1*0.5	5	M14 suburb
332	2	9,900	19,700	16,700	Free speed	V1*0.5	5	Other roads
416	6	49,200	97,800	87,600	Free speed	V1*0.5	5	Main area
414	4	32,800	65,200	58,400	Free speed	V1*0.5	5	Main area
413	3	15,450	30,900	27,500	Free speed	V1*0.5	5	Existing bridge

*New bridge: Mykolaiv Bridge, Existing bridge: Vavarovsky Bridge

Figure 8-2-8. Quantity-Velocity Setting

(3) Current Traffic Volume

The current traffic volume as of 2017 is estimated by compounding the traffic count data. Based on the traffic volume, the congestion level and travel speed (average and final) are estimated as follows:



Unit: 100PCU
Scale: 1mm=40,000PCU

Figure 8-2-9. Traffic Volume Estimation (Current Traffic Volume)

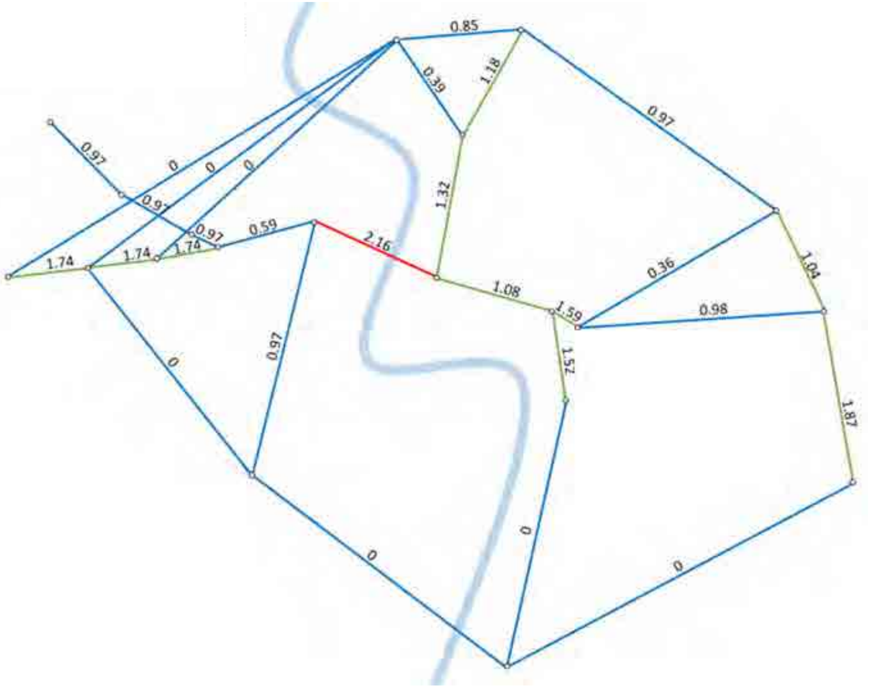
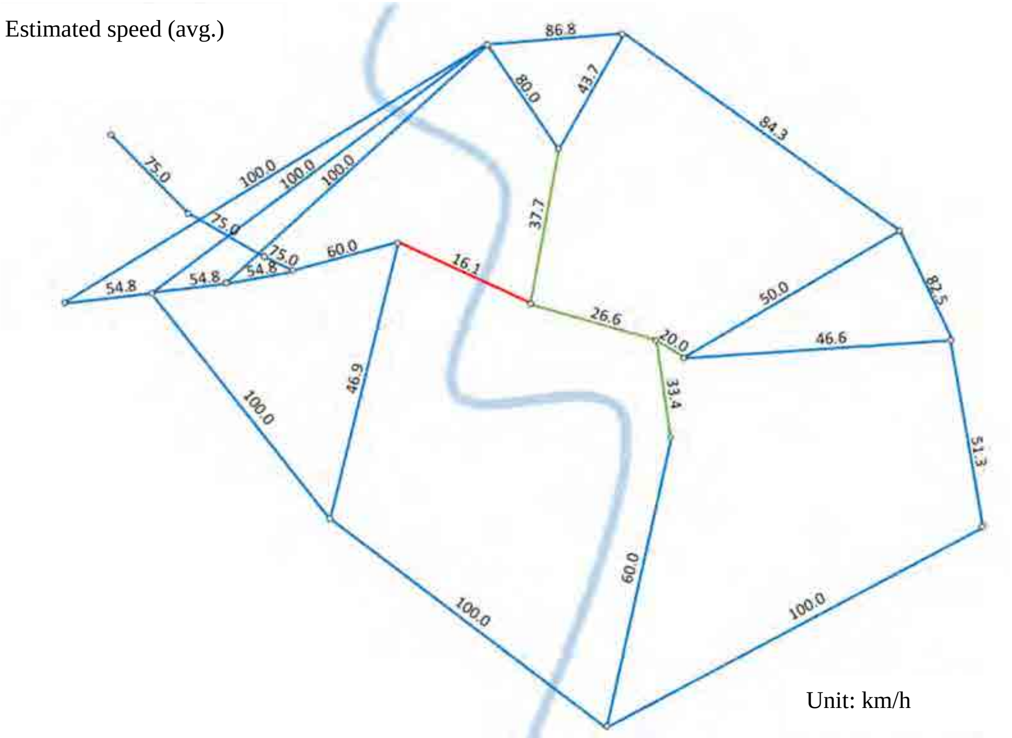


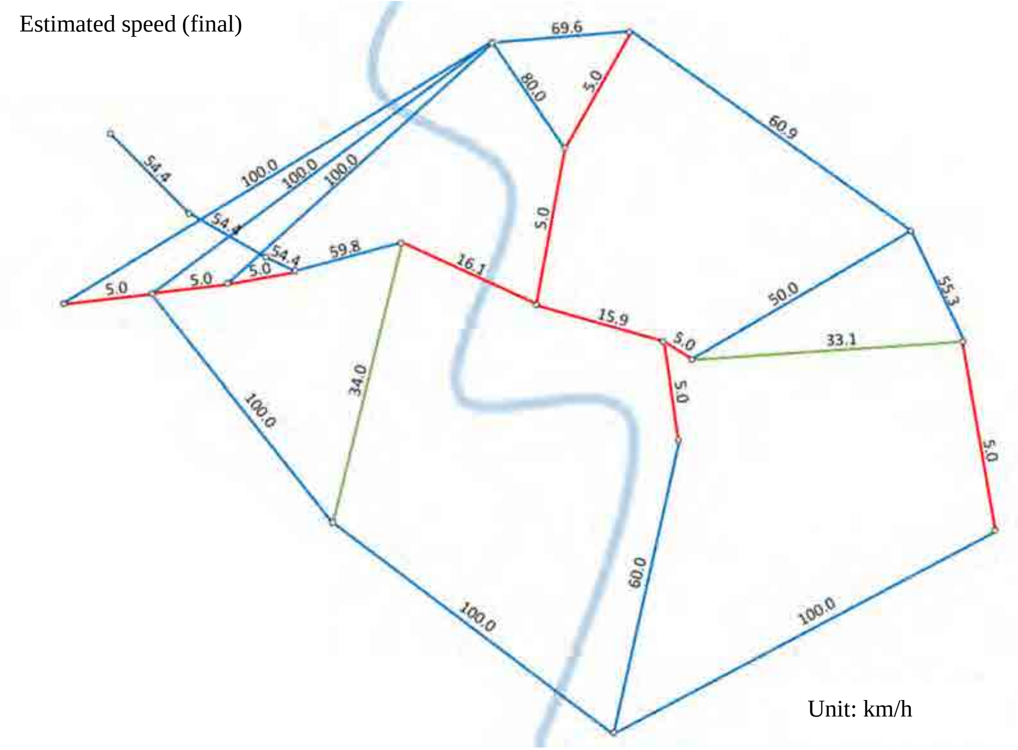
Figure 8-2-10. Traffic Volume Estimation (Current Congestion Level)

Estimated speed (avg.)



Unit: km/h

Estimated speed (final)



Unit: km/h

Figure 8-2-11. Traffic Volume Estimation (Current Travel Speed)

(4) Traffic Volume after a Traffic Conversion

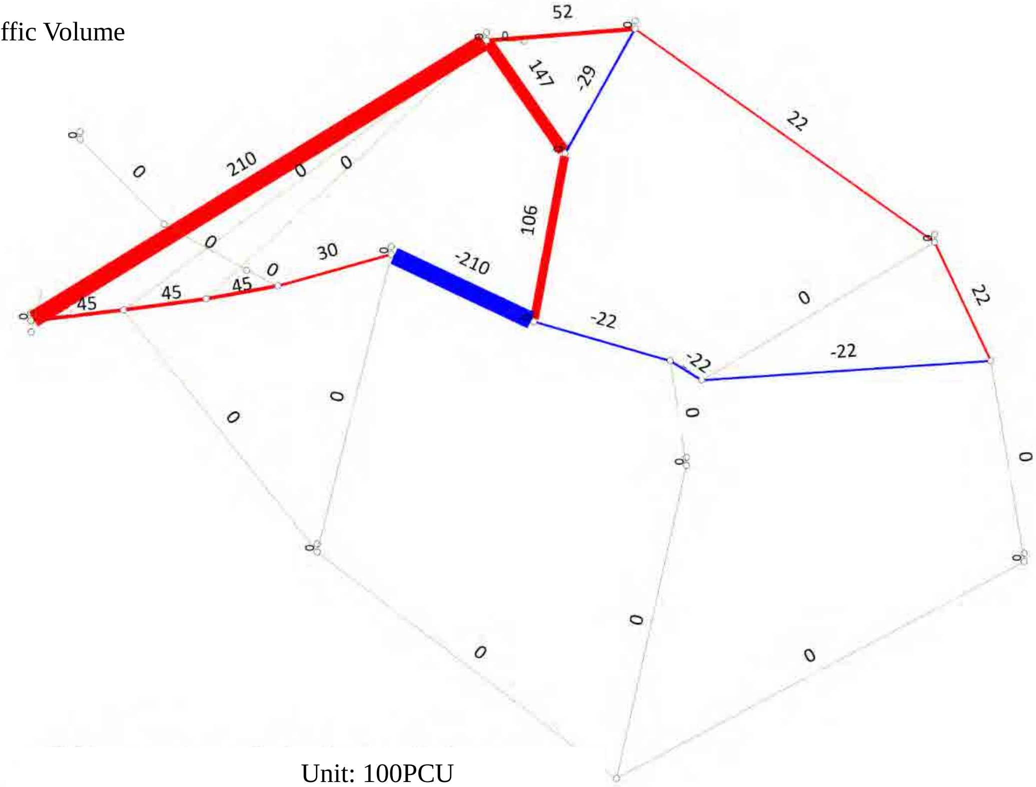
The traffic volume after a traffic conversion is estimated by adjusting the current traffic volume of the road network with the traffic volume of each route after the conversion.

The figures for the traffic volume of each route after the conversion as well as the traffic volume, congestion level and travel speed (average and final) between the main sections are shown as follows:

Table 8-2-6. Summary of the Traffic Volume Estimation in the Road Network

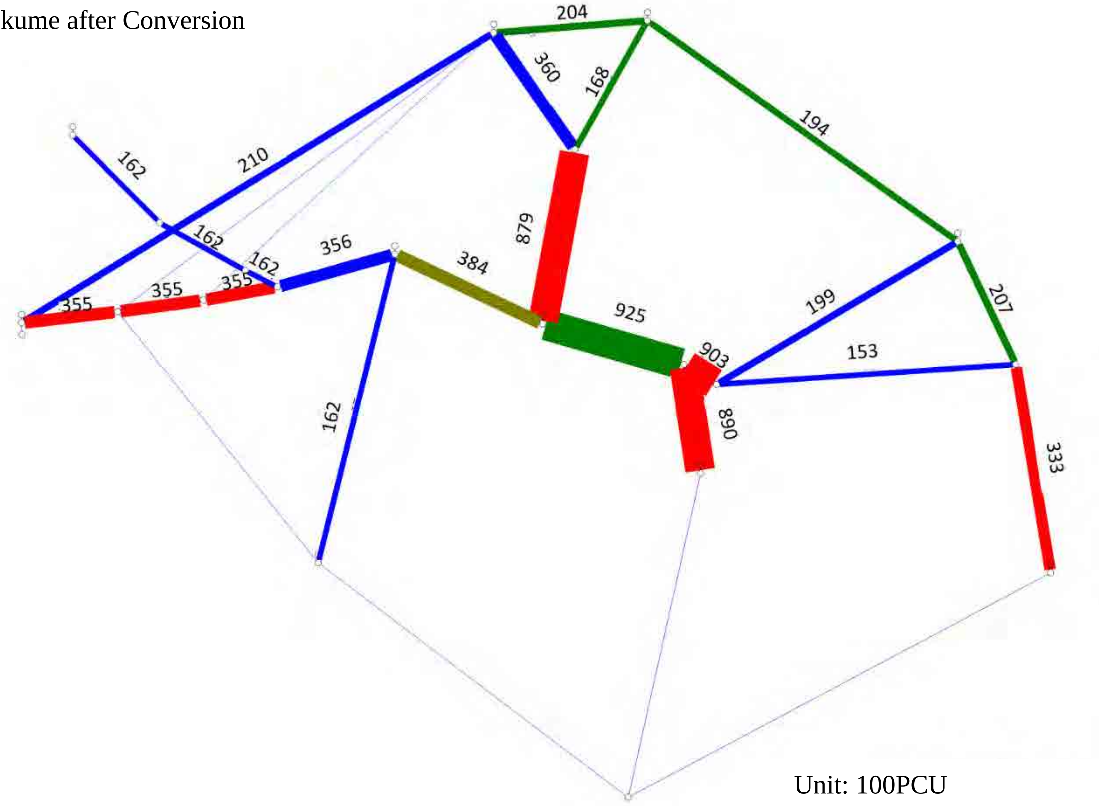
	Location	Capacity 100PCU/day	Total 100PCU/day	Pax 100PCU/day	Bus 100PCU/day	2ax 100PCU/day	3ax 100PCU/day	Trailer 100PCU/day	VCR	Speed(Avg.) km/h	Speed(Final) km/h
Current traffic	Vavarovsky Bridge	275	594	247	110	78	9	150	2.54	16.1	5.0
	Mykolaiv Bridge	700	0	0	0	0	0	0	0.00	100.0	100.0
	M-14 (west)	178	310	87	31	58	8	126	0.81	54.8	5.0
	P-6	552	213	51	13	36	0	112	0.07	80.0	80.0
	N-11	552	199	69	17	44	0	69	0.00	50.0	50.0
	N-14	167	197	92	47	18	2	37	0.33	43.7	5.0
	T-1501	584	890	267	94	119	24	387	0.05	33.4	5.0
	M-14	178	175	32	13	38	0	92	0.25	46.6	33.1
	T-1506	167	162	48	17	22	4	70	0.24	75.0	54.4
	T-1507	167	162	48	17	22	4	70	0.37	46.9	34.0
	M-14 (east)	178	333	68	28	66	7	164	0.25	51.3	5.0
	Ingul bridge	584	773	345	178	102	8	140	0.46	37.7	5.0
	Vavarovsky Bridge(east)	876	948	413	183	87	15	250	0.29	26.6	15.9
Route1	Vavarovsky Bridge	275	384	150	63	51	6	115	2.16	22.1	5.0
	Mykolaiv Bridge	700	210	98	47	27	3	35	0.00	100.0	100.0
	M-14 (west)	178	355	127	60	67	6	96	1.74	48.4	5.0
	P-6	552	360	135	56	59	1	109	0.39	79.8	75.6
	N-11	552	199	69	17	44	0	69	0.36	50.0	50.0
	N-14	167	168	87	46	16	1	19	1.18	46.4	32.4
	T-1501	584	890	267	94	119	24	387	1.52	33.4	5.0
	M-14	178	154	26	11	36	0	81	0.98	48.2	38.4
	T-1506	167	162	48	17	22	4	70	0.97	75.0	54.4
	T-1507	167	162	48	17	22	4	70	0.97	46.9	34.0
	M-14 (east)	178	333	68	28	66	7	164	1.87	51.3	5.0
	Ingul bridge	584	879	416	219	120	7	116	1.32	33.8	5.0
	Vavarovsky Bridge(east)	876	925	407	181	85	14	239	1.08	26.9	16.6
Route2	Vavarovsky Bridge	275	360	140	57	47	6	110	2.16	23.2	5.0
	Mykolaiv Bridge	700	234	107	52	31	3	40	0.00	100.0	100.0
	M-14 (west)	178	310	87	31	58	8	126	1.74	54.8	5.0
	P-6	552	375	144	61	63	1	107	0.39	79.6	73.7
	N-11	552	199	69	17	44	0	69	0.36	50.0	50.0
	N-14	167	165	86	46	16	1	16	1.18	46.6	33.2
	T-1501	584	890	267	94	119	24	387	1.52	33.4	5.0
	M-14	178	154	26	11	36	0	81	0.98	48.2	38.5
	T-1506	167	162	48	17	22	4	70	0.97	75.0	54.4
	T-1507	167	162	48	17	22	4	70	0.97	46.9	34.0
	M-14 (east)	178	333	68	28	66	7	164	1.87	51.3	5.0
	Ingul bridge	584	890	424	224	124	7	112	1.32	33.4	5.0
	Vavarovsky Bridge(east)	876	925	407	181	84	14	239	1.08	26.9	16.6
Route3	Vavarovsky Bridge	275	367	144	60	48	6	110	2.16	22.9	5.0
	Mykolaiv Bridge	700	227	104	50	30	3	40	0.00	100.0	100.0
	M-14 (west)	178	310	87	31	58	8	126	1.74	54.8	5.0
	P-6	552	368	141	59	61	1	107	0.39	79.7	74.5
	N-11	552	199	69	17	44	0	69	0.36	50.0	50.0
	N-14	167	165	86	46	16	1	16	1.18	46.6	33.2
	T-1501	584	890	267	94	119	24	387	1.52	33.4	5.0
	M-14	178	153	26	11	36	0	81	0.98	48.2	38.5
	T-1506	167	162	48	17	22	4	70	0.97	75.0	54.4
	T-1507	167	162	48	17	22	4	70	0.97	46.9	34.0
	M-14 (east)	178	333	68	28	66	7	164	1.87	51.3	5.0
	Ingul bridge	584	884	421	222	122	7	112	1.32	33.6	5.0
	Vavarovsky Bridge(east)	876	925	407	181	84	14	239	1.08	26.9	16.6
Route4	Vavarovsky Bridge	275	393	157	68	54	6	108	2.16	21.7	5.0
	Mykolaiv Bridge	700	201	90	42	24	3	42	0.00	100.0	100.0
	M-14 (west)	178	310	87	31	58	8	126	1.74	54.8	5.0
	P-6	552	212	51	13	36	0	112	0.39	80.0	80.0
	N-11	552	199	69	17	44	0	69	0.36	50.0	50.0
	N-14	167	173	87	46	17	1	22	1.18	46.0	31.2
	T-1501	584	1,002	337	131	137	23	374	1.52	30.2	5.0
	M-14	178	150	25	10	36	0	79	0.98	48.4	39.3
	T-1506	167	162	48	17	22	4	70	0.97	75.0	54.4
	T-1507	167	114	22	8	13	4	66	0.97	49.8	46.2
	M-14 (east)	178	333	67	27	65	7	167	1.87	51.3	5.0
	Ingul bridge	584	747	340	176	100	6	124	1.32	38.9	5.0
	Vavarovsky Bridge(east)	876	1,034	476	218	102	14	224	1.08	25.1	5.0

Route 1
Converted Traffic Volume



Unit: 100PCU
Red: Plus, Blue: Minus
Scale: 1mm=10,000PCU

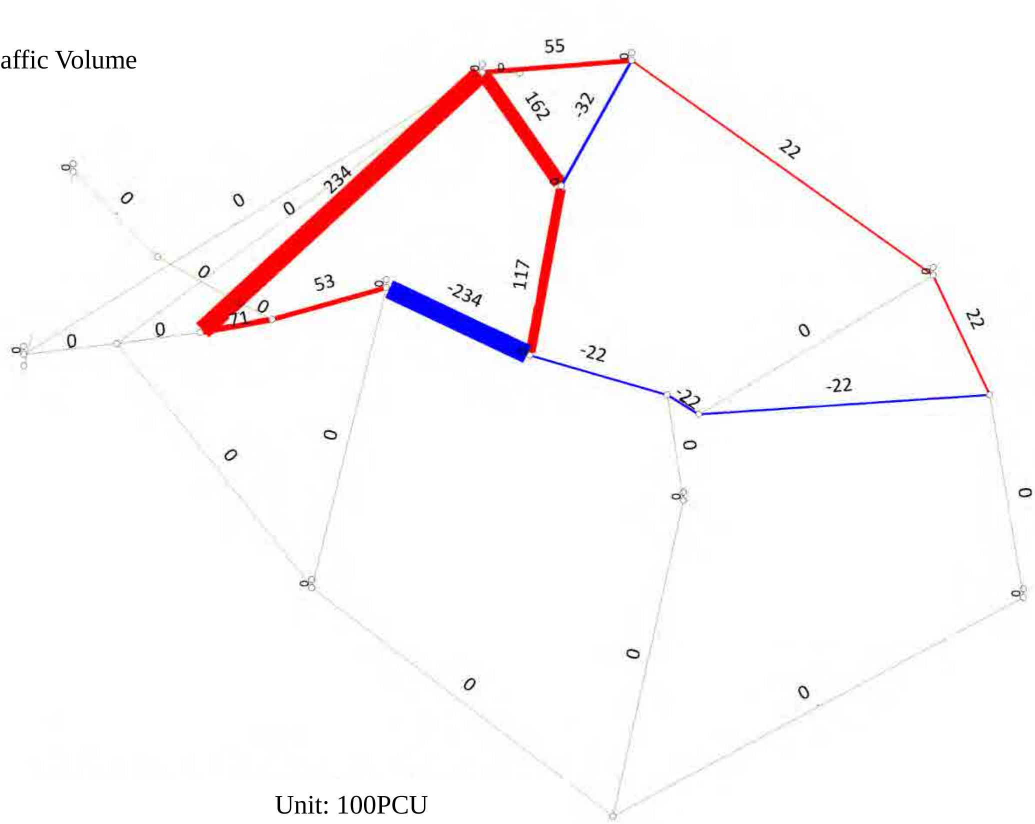
Route 1
Traffic Vokume after Conversion



Unit: 100PCU
Scale: 1mm=30,000PCU

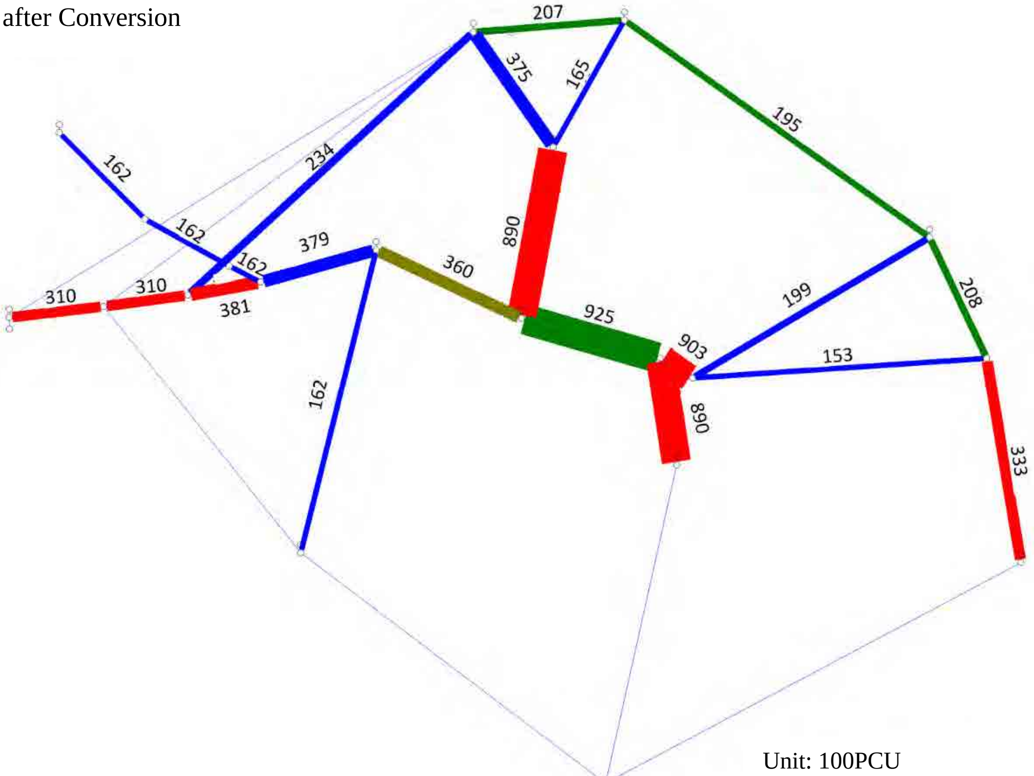
Figure 8-2-12. Traffic Volume Estimation (Route 1)

Route 2
Converted Traffic Volume



Unit: 100PCU
Red: Plus, Blue: Minus
Scale: 1mm=10,000PCU

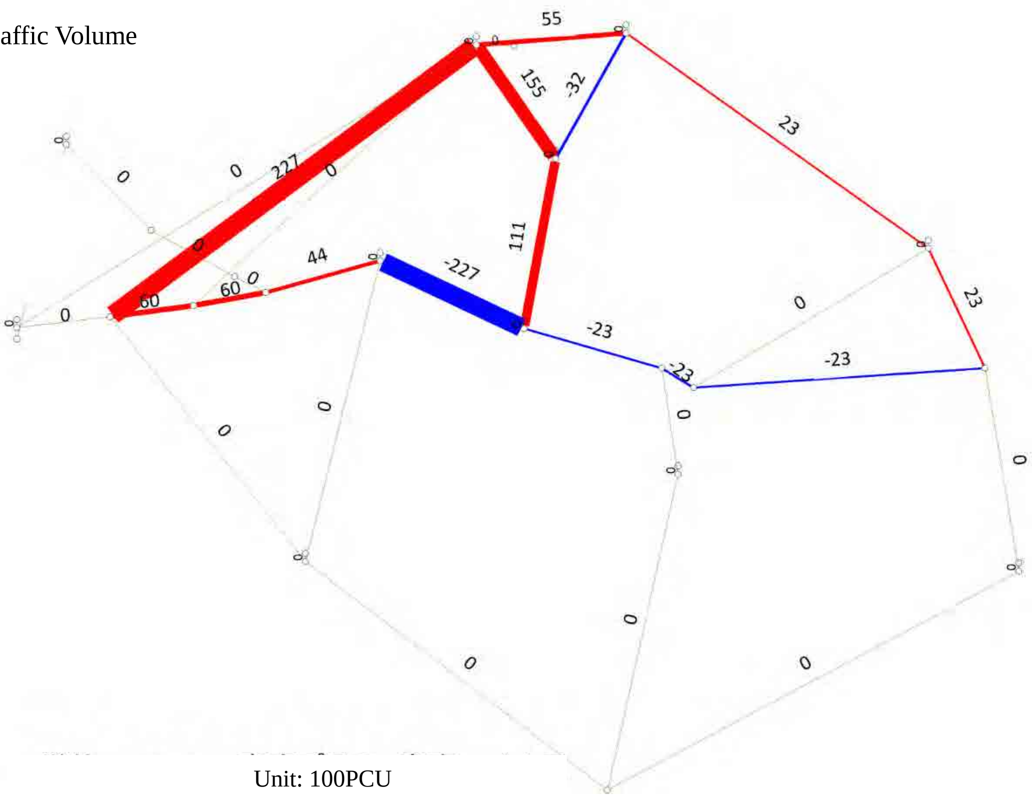
Route 2
Traffic Volume after Conversion



Unit: 100PCU
Scale: 1mm=30,000PCU

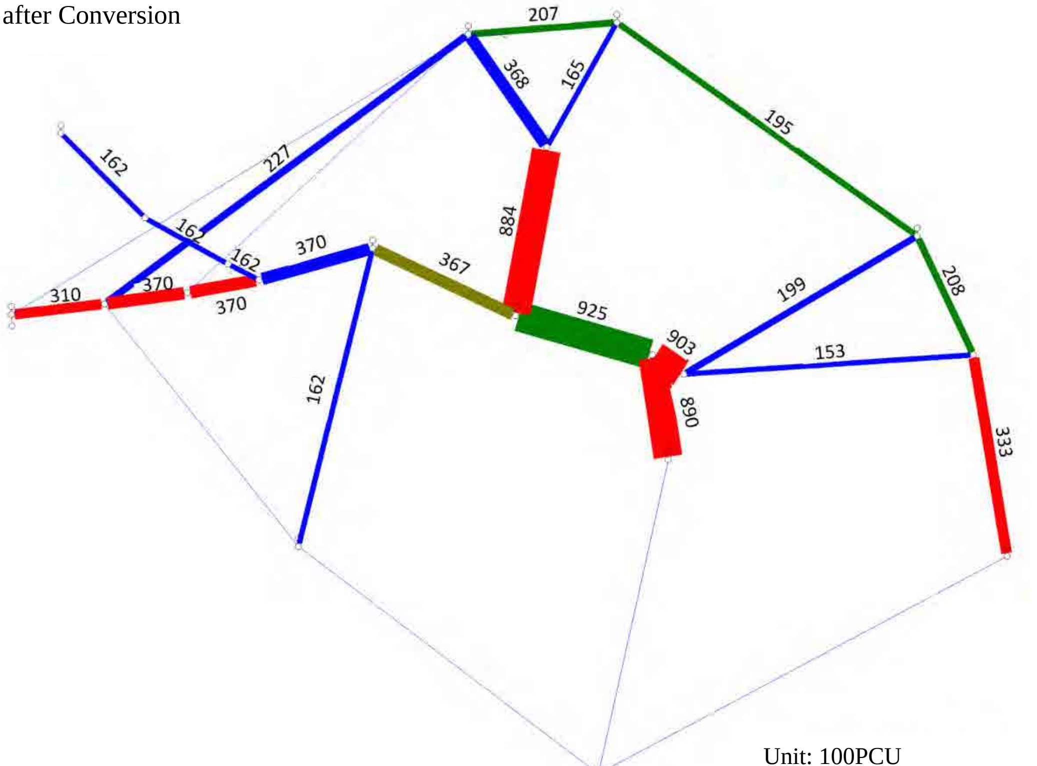
Figure 8-2-13. Traffic Volume Estimation (Route 2)

Route 3
Converted Traffic Volume



Unit: 100PCU
Red: Plus, Blue: Minus
Scale: 1mm=10,000PCU

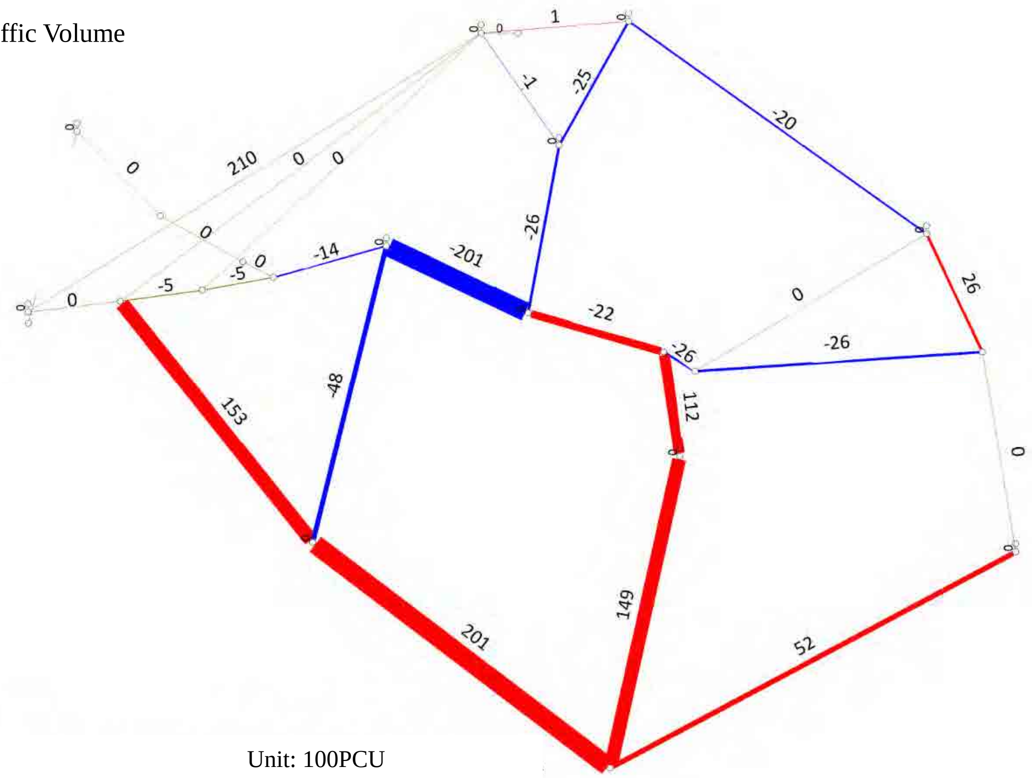
Route 3
Traffic Volume after Conversion



Unit: 100PCU
Scale: 1mm=30,000PCU

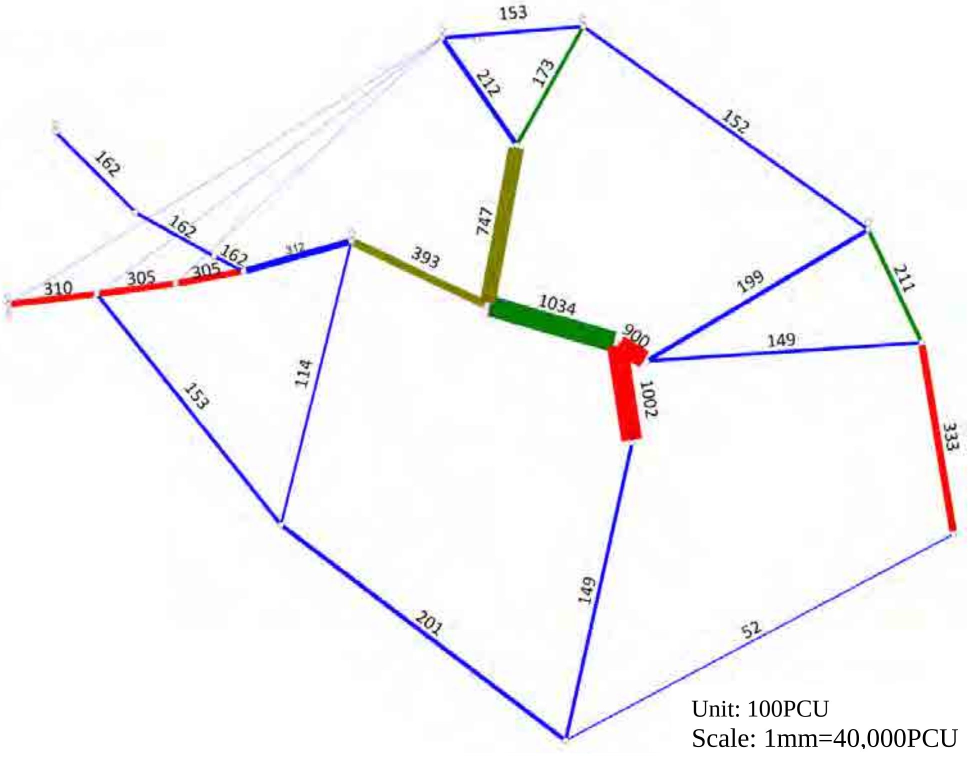
Figure 8-2-14. Traffic Volume Estimation (Route 3)

Route 4
Converted Traffic Volume



Unit: 100PCU
Red: Plus, Blue: Minus
Scale: 1mm=10,000PCU

Route 4
Traffic Volume after Conversion



Unit: 100PCU
Scale: 1mm=40,000PCU

Figure 8-2-15. Traffic Volume Estimation (Route 4)

8-2-5 Future Traffic Volume

1) Growth Ratio of Future Traffic Volume

It understands that little time has elapsed between 2017 Survey and this Study, and the latest situation around Mykolaiv City has remained largely unchanged. Accordingly, the growth ratio of future traffic used in 2017 Survey is also applied in this Study. As with 2011F/S, this growth ratio was estimated by a regression model using traffic count data and socioeconomic indicators. The GDP growth ratio, one of the socioeconomic indicators, was set between 2.5% and 3.5%. Based on this precondition, the growth ratios of future traffic volume are calculated and shown as follows:

Table 8-2-7. Growth Ratio of Future Traffic Volume

	Passenger cars	Buses	2-axle trucks	3+ axle trucks	Trailers
Annual average growth ratio	3.2%	2.0%	0.9%	3.0%	3.0%

2) Future Traffic Volume

The future traffic volume for each route are calculated from AADT and the growth ratio as follows:

Table 8-2-8. Future Traffic Volume (Vehicle Basis)

Route	Year	Bridge	Traffic volume (veh./day)					
			Pax	Bus	2-axle truck	3+ axle truck	Trailer	Total
Route1	2025	Vavarovsky	19,200	2,464	2,722	212	2,431	27,029
		Mykolaiv	12,555	1,840	1,446	124	1,367	17,332
	2040	Vavarovsky	30,647	3,333	3,100	330	3,782	41,192
		Mykolaiv	20,041	2,488	1,646	192	2,127	26,495
	2055	Vavarovsky	48,916	4,500	3,528	513	5,885	63,342
		Mykolaiv	31,987	3,359	1,873	299	3,310	40,830
Route2	2025	Vavarovsky	18,002	2,255	2,493	210	2,395	25,354
		Mykolaiv	13,754	2,049	1,675	126	1,403	19,006
	2040	Vavarovsky	28,734	3,049	2,839	326	3,727	38,676
		Mykolaiv	21,954	2,771	1,907	196	2,183	29,011
	2055	Vavarovsky	45,862	4,117	3,231	508	5,799	59,518
		Mykolaiv	35,041	3,741	2,170	305	3,396	44,654
Route3	2025	Vavarovsky	18,466	2,339	2,581	210	2,400	25,997
		Mykolaiv	13,289	1,964	1,587	126	1,398	18,364
	2040	Vavarovsky	29,475	3,164	2,939	326	3,735	39,640
		Mykolaiv	21,212	2,657	1,807	196	2,175	28,047
	2055	Vavarovsky	47,046	4,272	3,344	508	5,812	60,982
		Mykolaiv	33,857	3,587	2,057	305	3,384	43,190
Route4	2025	Vavarovsky	20,098	2,678	2,868	216	2,496	28,357
		Mykolaiv	11,657	1,625	1,300	120	1,301	16,004
	2040	Vavarovsky	32,081	3,622	3,266	336	3,885	43,189
		Mykolaiv	18,607	2,198	1,481	186	2,025	24,497
	2055	Vavarovsky	51,205	4,891	3,716	522	6,045	66,378
		Mykolaiv	29,699	2,968	1,685	290	3,151	37,793

Table 8-2-9. Future Traffic Volume (PCU basis)

Route	Year	Bridge	PCU						Capacity	VCR
			Pax	Bus	2-axle truck	3+ axle truck	Trailer	Total		
Route1	2025	Vavarovsky	19,200	7,392	5,445	717	12,153	44,907	27,500	1.63
		Mykolaiv	12,555	5,519	2,892	418	6,836	28,220	70,000	0.40
	2040	Vavarovsky	30,647	9,998	6,200	1,115	18,911	66,871	27,500	2.43
		Mykolaiv	20,041	7,464	3,293	650	10,637	42,085	70,000	0.60
	2055	Vavarovsky	48,916	13,499	7,055	1,735	29,426	100,631	70,000	3.66
		Mykolaiv	31,987	10,077	3,747	1,012	16,552	63,376	70,000	0.91
Route2	2025	Vavarovsky	18,002	6,764	4,987	709	11,976	42,437	27,500	1.54
		Mykolaiv	13,754	6,147	3,350	425	7,013	30,689	70,000	0.44
	2040	Vavarovsky	28,734	9,148	5,678	1,103	18,635	63,298	27,500	2.30
		Mykolaiv	21,954	8,313	3,815	662	10,913	45,657	70,000	0.65
	2055	Vavarovsky	45,862	12,352	6,461	1,717	28,997	95,389	27,500	3.47
		Mykolaiv	35,041	11,224	4,341	1,030	16,981	68,617	70,000	0.98
Route3	2025	Vavarovsky	18,466	7,018	5,162	709	12,001	43,357	27,500	1.58
		Mykolaiv	13,289	5,893	3,174	425	6,988	29,770	70,000	0.43
	2040	Vavarovsky	29,475	9,492	5,878	1,103	18,674	64,623	27,500	2.35
		Mykolaiv	21,212	7,970	3,615	662	10,874	44,332	70,000	0.63
	2055	Vavarovsky	47,046	12,816	6,689	1,717	29,058	97,326	27,500	3.54
		Mykolaiv	33,857	10,760	4,113	1,030	16,920	66,681	70,000	0.95
Route4	2025	Vavarovsky	20,098	8,034	5,736	729	12,482	47,080	27,500	1.71
		Mykolaiv	11,657	4,876	2,600	405	6,507	26,046	70,000	0.37
	2040	Vavarovsky	32,081	10,866	6,532	1,135	19,423	70,037	27,500	2.55
		Mykolaiv	18,607	6,595	2,961	630	10,125	38,919	70,000	0.56
	2055	Vavarovsky	51,205	14,672	7,433	1,766	30,223	105,298	27,500	3.83
		Mykolaiv	29,699	8,905	3,369	981	15,755	58,709	70,000	0.84

Chapter 9 Study on the Slope Stability at the Bridge Construction Site

9-1 Overview

In this Chapter, the JICA Survey Team focuses on the slope stability at the bridge construction site on Routes 2 and 3, the more promising choices compared with the other Routes. The thoughts of the JICA Survey Team are based on additional information obtained from the geological survey conducted during the 2011 F/S and this Study in 2018, as well as a joint field survey conducted with the Public Works Research Institute of Japan in February 2019 (“the 2019 Survey”).

Specifically, the study entails: 1) Review of topographical and geological conditions in the survey area, 2) Study of the landslide occurrence process and development mechanism in the survey area, 3) Geological analysis, 4) Topographical analysis and 5) Consideration of the relationship with the road construction plan. Finally, tentative countermeasures will be proposed based on the above considerations.

Although the current conditions within a limited range at this moment were identified, long-term landslide characteristics and the location and extent of the landslide surface have yet to be identified precisely. Accordingly, further survey is necessary to improve the precision of countermeasures, and thus a landslide survey plan is proposed.

It is worth noting that both routes contain active and potential areas in which landslide activity does or may occur. Therefore, the 2019 Survey adopts a policy of excluding active areas highly susceptible to landslides from the locations in which to build bridge piers and abutments.

The survey confirmed that Route 3 has a smaller area susceptible to landslides than Route 2. Also, because the gullies developed there are heading toward the land, they will not feed water to the Southern Bug River. These conditions make it easy to consider countermeasures.

9-2 Review of Topographical and Geological Conditions in the Survey Area

As shown in Figure 9-2-1, the survey area is located in the riverbank area of the Southern Bug River, which meanders through the survey area. The outside bank of the river bend forms an undercut slope and the inside bank of the bend shows a slipoff slope. Generally, the current against the undercut slope is faster and eroding the slope, while the current against the slipoff slope is slower, which encourages deposition of material from the upper stream.

Such circumstances are clearly observed in the survey area; there is a possibility that the right bank, the outside bend, is scraped at all times (particularly when the river has risen following thawing), and the river deposits are widely distributed on the left bank, the inside bank of the bend (equivalent to legends ② to ④ of Figure 9-2-1: including terrace deposits at lower and medium levels).

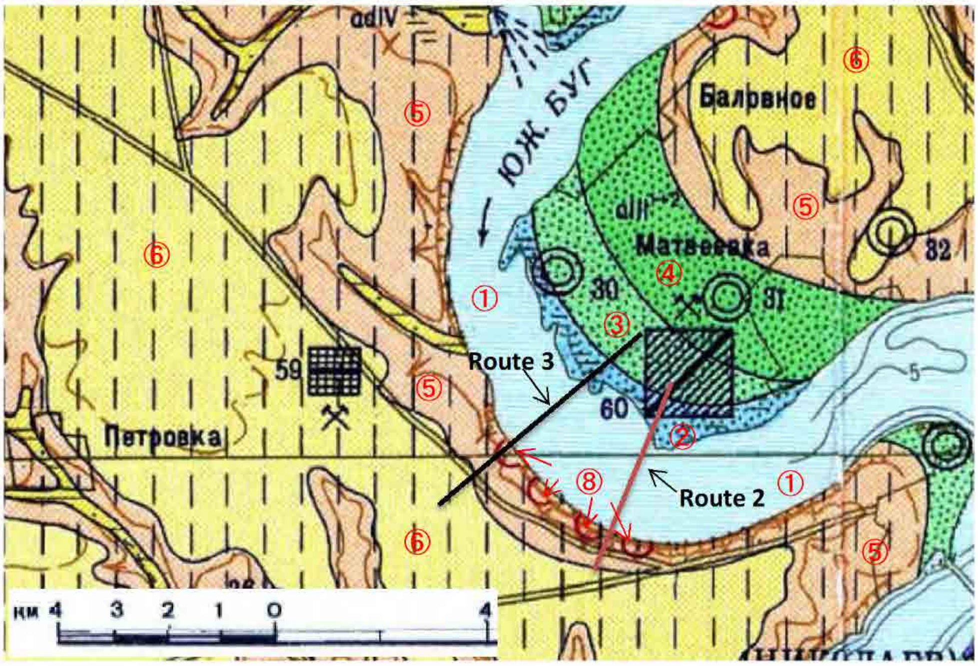
The plain plateau extends around the Southern Bug River, where the relative height from the river is between 40 and 100 m. On the plateau, 10 to 20 m of diluvial deposits with a loam layer (Legend ⑥: Pleistocene of the Quaternary Period (10k–1.64 million years ago): loam, compacted sand and consolidated clay and others) are accumulated. A basement stratum (Legend ⑦: before the Pliocene in the Neogene Period: (before ca. 5 million years ago): limestone and hard clay layers) widely distribute underneath the deposits but are not be observed directly in the survey area (except at a large-scale cliff).

On the gentle slope headed from the upper plain plateau toward the river, slope deposits accumulated from the plateau in the rear (Legend ⑤: loamy soil, sand, clay, limestone pebble and others) distribute widely alongside the river (particularly on the right bank slope) and possibly as far as the riverbank area.

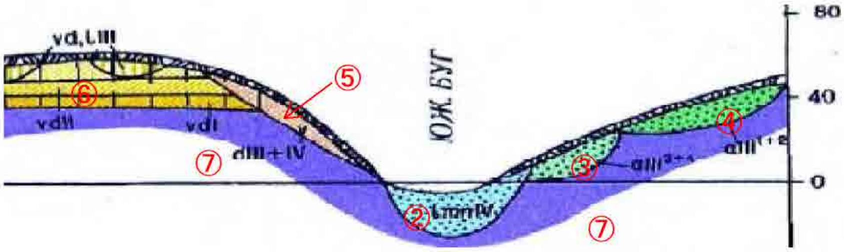
Slope deposits (Legend ⑤) in the deposition area of the river bank are easily denudated by the current. In particular, the progress of denudation is more apparent on the undercut slope of the right bank in the survey area.

Under such circumstances, these slope deposits become unstable due to repeated scraping at the toe of a slope of a river bank and slide downward as a relatively large block, and thus are likely to cause landslides (active unit of landslide, which refers to the area of soil and rock moving mass as a single unit, or which is likely to move as a landslide. Hereinafter referred to as a “block”).

Although it is marked as the landslide block (Legend ⑧) on the following map, the detailed distribution and development are likely to be unidentifiable on the map.



[Geological overview around the survey area (with the siet map on a scale)]



[Schematic profile around the survey area]

[Legend]

① : Current river

② : River and floodplain deposits

③ : Lower terrace deposits

④ : Middle terrace deposits

⑤ : Slope deposits

⑥ : Plateau deposits

⑦ : Basement stratum

⑧ : Landslide block

Source: Ministry of Geology of the USSR (Quatenary Deposits Map) L-36-VIII (1967)

Figure 9-2-1. Geological Conditions Surrounding the Survey Area
(Extracted from the Site Geological Map on a Scale with Some Revisions)

9-3 Estimation of the Landslide Occurrence Process and Development Mechanism in the Survey Area

The phenomena called “landslide” or “collapse” follows various processes. While a “landslide” and “collapse” are technically different, it can be difficult to clearly distinguish between them. They also affect each other, so assessments from a long-term perspective are needed to evaluate future impacts.

Considering above, the following sections present each stage of the landslide occurrence process and development mechanism in the survey area, taking into consideration the topographical and geological conditions.

Regarding topographical and geological conditions in the survey area, as mentioned in 9-2, unstable landslide blocks observed in the survey area are concentrated on the outside bend of the right bank, and their locations are limited to the area in which unconsolidated slope deposits are supplied from the plateau in the rear. These slope deposits widely distribute over a gentle slope on the right bank of the Southern Bug River, which is an undercut slope thus scraping by the current is thus remarkable.

9-3-1 Stage I: Before a Landslide Occurs

Before a landslide occurs, slope deposits (Sd) are stably and gently distributed over the slope. Even under such circumstances, the forefront slope in the Southern Bug River is continuously scraped off and the stability of the lower slope gradually declines. Eventually, small and irregular cracks are observable at the surface of the slope as the instability progresses.

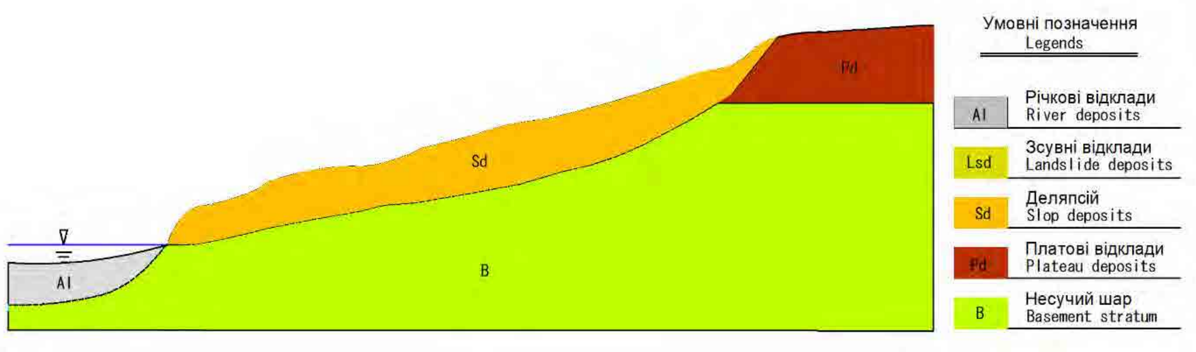


Figure 9-3-1. Slope before a Landslide Occurs (Stage I Schematic Profile)

9-3-2 Stage II: Occurrence of an Initial Landslide

When scraping of the toe of a slope progresses due to the current, the slope becomes increasingly unstable and ultimately starts slipping downward as a block; as a result, the initial landslide occurs. With the generation of a landslide block, the head of a cliff (↓: head scarp) and a valley-like topography on the side start to show.

The right bank slope on Route 3 is deemed to correspond to this stage. Figure 9-4-4 shows that the landslide mass is pushed into the river.

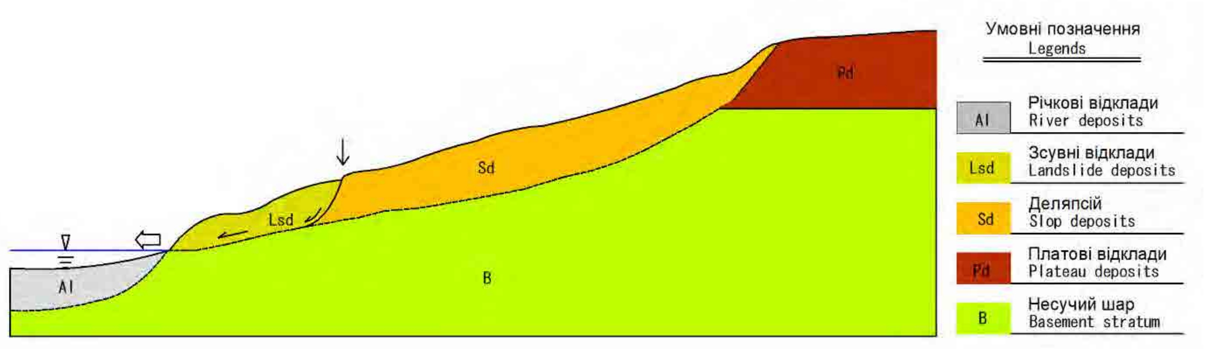


Figure 9-3-2. Slope after the Occurrence of an Initial Landslide (Stage II Schematic Profile)

9-3-3 Stage III: Landslide Development Mechanism

Although how fast the stages of landslide advance varies with each landslide block, when the slope toe (block toe) is repeatedly scraped off by the current after a landslide, the landslide part actively slips downward, which exacerbates the block instability.

Such increasing block instability affects the terrain and the scales of the head scarp and valley-like topography on the side increase; as a result, the block shape becomes clear.

Amid such phenomenon, the upper slope of the initial block becomes increasingly unstable and a subsequent (secondary) landslide is triggered.

Although this cycle of instability varies by location due to different topographical and geological conditions, it progresses slowly. Generally, the block develops up to around the head of the slope deposit (near the shoulder of the plateau). The development of the block finally settles at the head of the slope. It is unlikely that the block continues to develop further inland.

The right bank slope on Route 2 is deemed to correspond to this stage; however, complementary geological survey shall be conducted to confirm the geological conditions, and the possibility of progression toward the inland shall be considered.

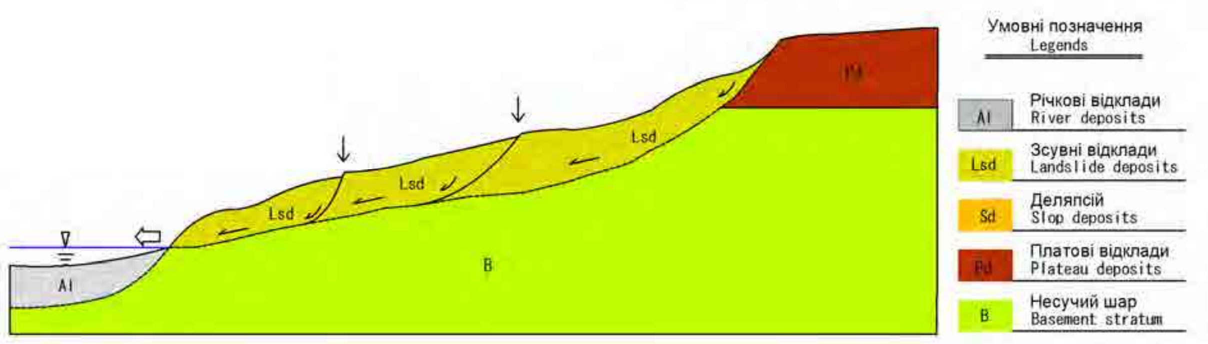


Figure 9-3-3. Slope where Compounded Slips are Developed (Stage III Schematic Profile)

9-4 Topographical Analysis

9-4-1 Route 2

A large landslide block covering the area of gully erosion seems to have developed along Route 2. Diagrams of the block (see Figure 9-4-2 and Figure 9-4-3) have been prepared on the following bases.

1) Scale of the Landslide Block and Topographical Features

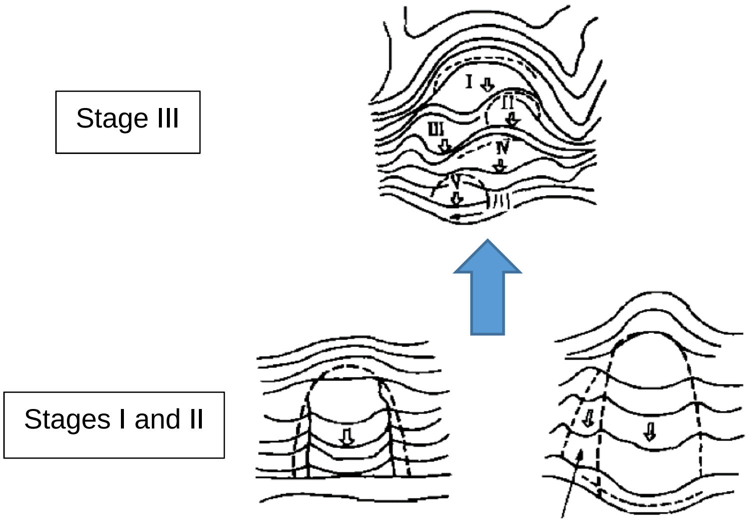
- The assumed maximum scale of the landslide block is 250 m in width and 280 m in length, an area large enough to cover the outer periphery of the gully erosion area.
- Around the BS+44m ground level at the most developed section of gully erosion, a step of 2 to 3 meters in height can be found surrounding the tip of the gully erosion area.
- Gully erosion has progressed to the constant slope gradient area in the upper part of the block. The contours around the gully erosion are uneven, and disturbances of the micro topography are observed,
- Gullies adjacent to each other can be found in the lower part of the block. Steps have formed in the slopes between the gullies, and the directions of the steps are all parallel to the river.
- Some of the small steps in the block are thought to indicate deformation of the head parts of the small collapses sliding directly into the gullies.

2) Considerations on the Geographical History of the Landslide Development

The landslide topography in this area is thought to have been formed in parallel with the development of the following topography. The following description is a hypothesis of the landslide development.

(1) Gullies develop solely and dendritically in the survey area and a horseshoe-like area emerges when tracing the head parts of these gullies. Since the bedrock is unstable and susceptible to erosion, there is a possibility that the potential blocks exist.

(2) The topographical characteristics of expected blocks is that it is in a slightly disordered state showing multiple step-like terrains. Though the gradient of the upper portion of the landslide slope is gentle, steps do exist within this portion of the slope. In a broader view, the topography of the bridge location on the right bank on Route 2 has multiple blocks with gentle upper slope and steep lower slope. Based on the description in 9-3, the process of development of this feature in a plan view is shown in Figure 9-4-1. A six-step landform showing traces of landslides is also observed (see Figure9-4-3).



Secondary landslide at the side

Figure 9-4-1. Landslide Topography

(3) Gullies may have developed due to the progression of erosion towards a valley, which itself is caused by disruption of the topography and groundwater concentration owing to the occurrence of the initial landslide. The development of gullies is conspicuous and widespread in this area when compared with adjacent areas. The gullies extend to gentle slope areas of the adjacent slope. From this perspective, it is possible that the gullies were developed beacuse past landslides loosened the blocks in a wide area creating unstable soil and because the condition favorable for concentration of groundwater was created.

(4) The slope collapse (due to river erosion and denundation) currently occurring in the riverside in the Route 3 area seems to have already occurred on Route 2. Following several erosions and denundations, the steep slopes at the toe of the current riverside area have already disappeared.

(5) Several spring water points were observed in a field survey. There is a possibility that a moderate level of drainage from inside of the slope is done.

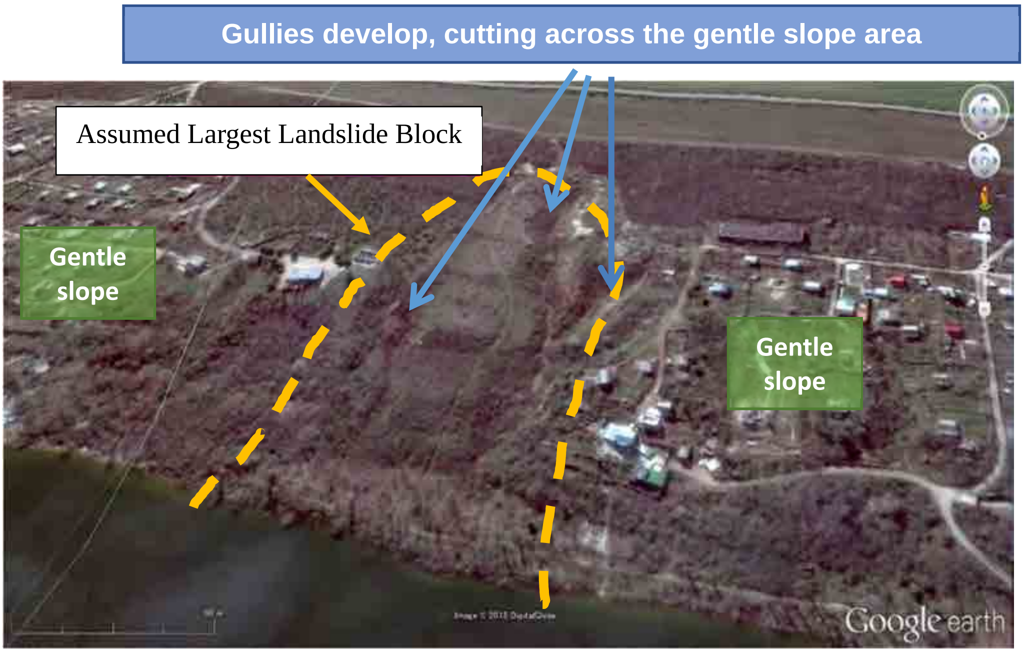


Figure 9-4-2. Landslide Block on the Right Bank on Route 2
(Google Earth Image modified by the JICA Survey Team)

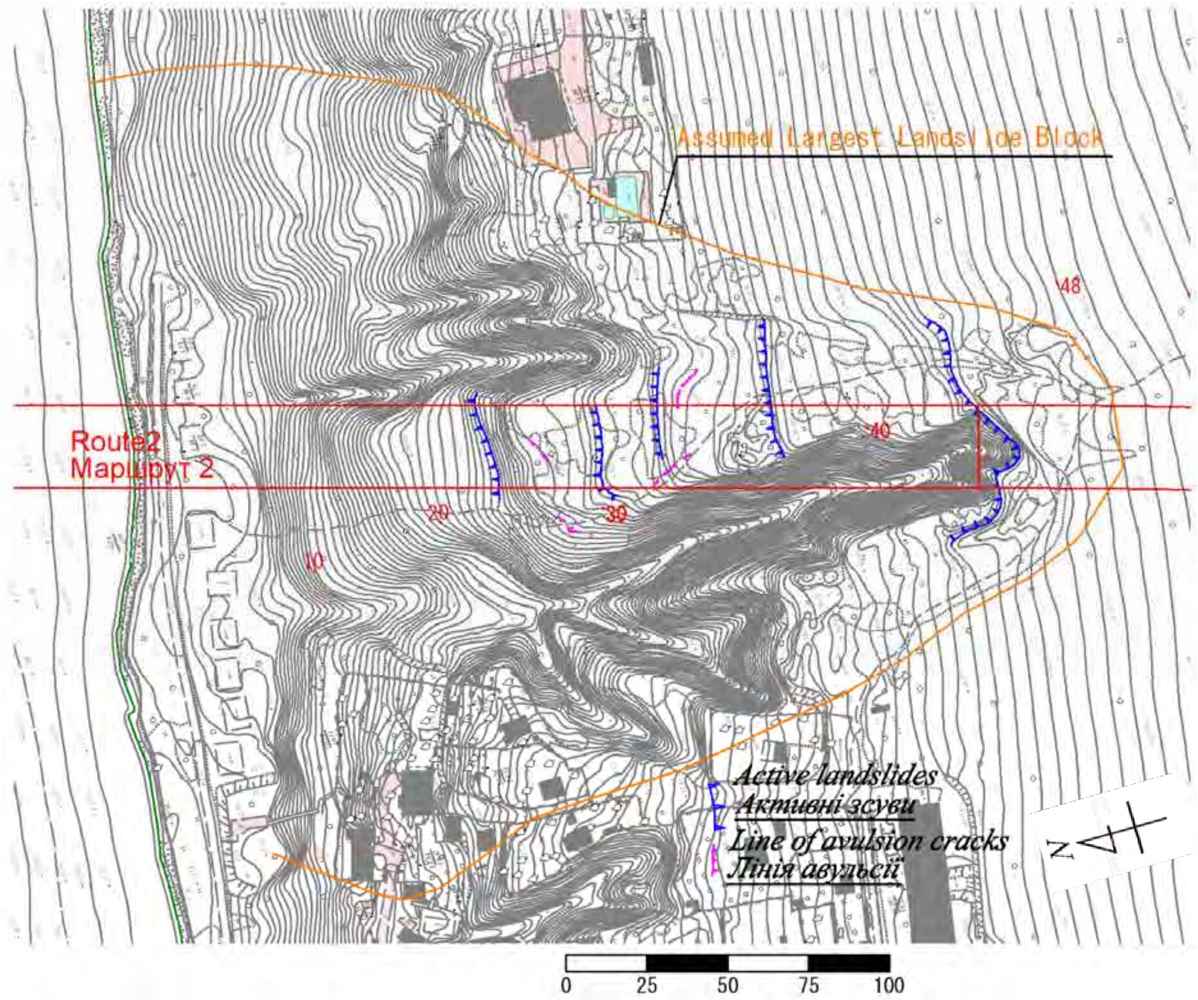


Figure 9-4-3. A Plan View of the Landslide Block on the Right Bank on Route 2

9-4-2 Route 3

Block ②, which shows a clear terraced landform, and Block ①, which is assumed to be the largest block in the survey area, are expected to exist on Route 3. Figures of the blocks (see Figure 9-4-5) are prepared based on the following grounds.

1) Block ① (broken line)

- A block 140 m wide and 120 m long. Lower part is a steep slope and the upper part a gentle slope.
- The largest expected landslide based on the inference that the blocks are likely to emerge repeatedly because the slope section along the river shows a clear landslide terrain.

2) Block ② (solid line)

- A block 105 m wide and 95 m long. Likewise Block ①, the lower part is steep and the upper part gentle.
- The head of the landslide block is based on deformation (step-like or cracks) observed in a field survey while the side of the block is based on the gully topography.
- Compared to Block ①, topographical characteristics are apparent in the periphery of the landslide area (head and side). So are multiple micro-geographical deformation (disordered surface terrains, open crack, small scale steps) at the steep slope in the lower part of landslide block. Accordingly, this area is highly likely to have moved recently. Along the river channel, blocks less than 100 m long and wide distribute in a line. The topography of Route 3 is different from that of Route 2. Since the terrain extends to the river channel in a hill form, it is susceptible to erosion and waves.

3) Chronological change of the slope collapse

Figure 9-4-4 shows that, in adjacent slopes since 2003, slope collapse is observable in the area in cyan (24th October 2010), but is not observed in data of 13th June 2003. While the timing is difficult to pinpoint, the collapse is deemed to have occurred in the past decade. In addition, areas in blue (11th October 2014) and in purple (5th April 2016) show that the collapse occurred progressively over the past six years and confirmed how it occurred drastically and at short intervals.

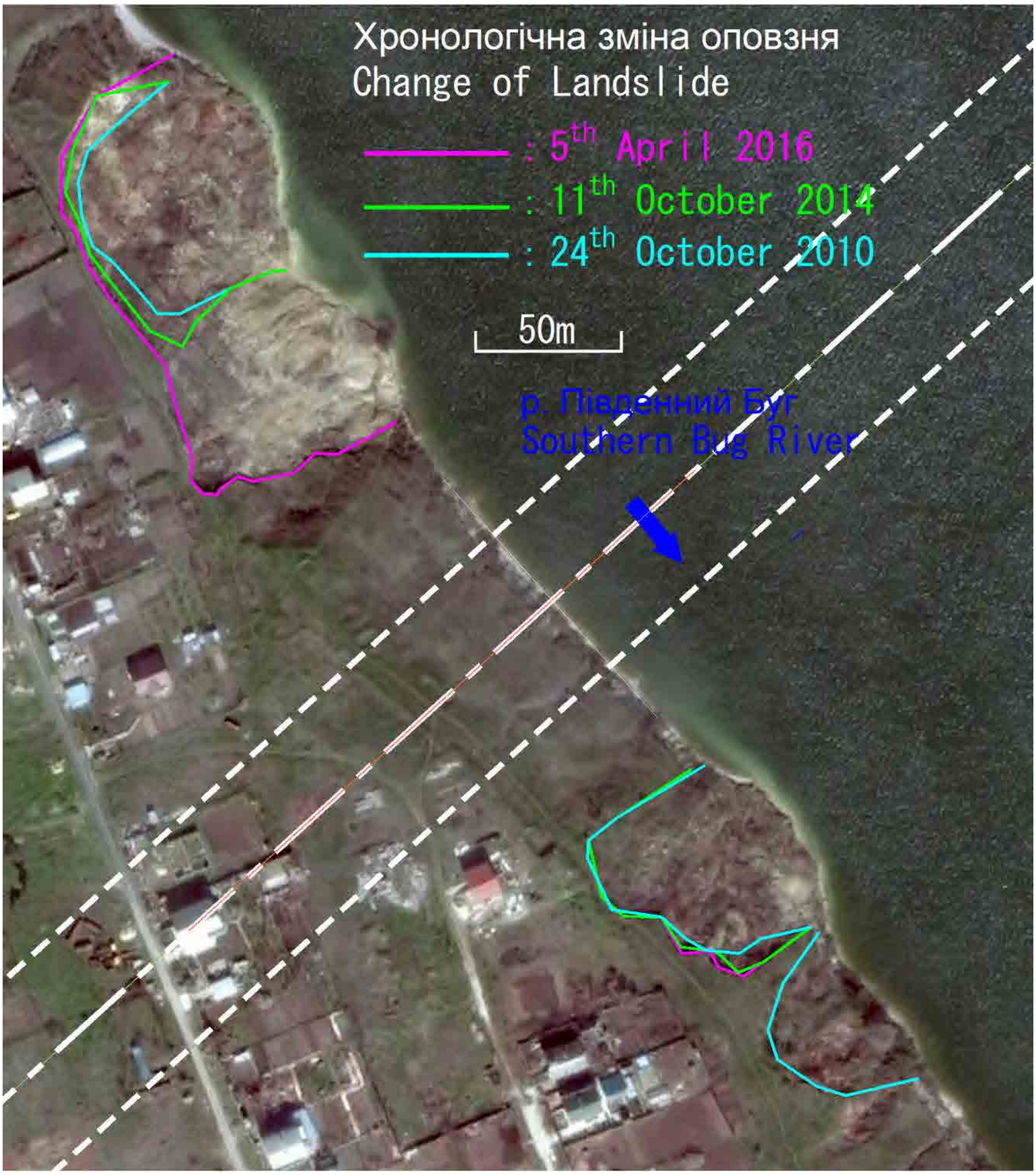


Figure 9-4-4. Landslide Area in the Right Bank on Route 3 (Google Earth)

There is a possibility that limestone exposed at the slope toe of these blocks are formed into the steep cliff by the collapse due to the wind waves. While micro-geography of the inland is considered to be attributable to the rise in the groundwater level during rainy and snow-melting seasons, which caused frequent landslides in the surrounding area.

Since the head of the landslide at this moment is located approximately 120 m from the edge of the river (see Figure 9-4-5), construction of any abutment, pier or other structures in this area should be avoided. Moreover, a landslide is highly likely to extend to the backward slopes with the surrounding conditions in mind.

It is necessary to conduct additional surveys where the abutments can be installed based on the risk of expansion to the back slope related with the expecting scale of the active landslide area.

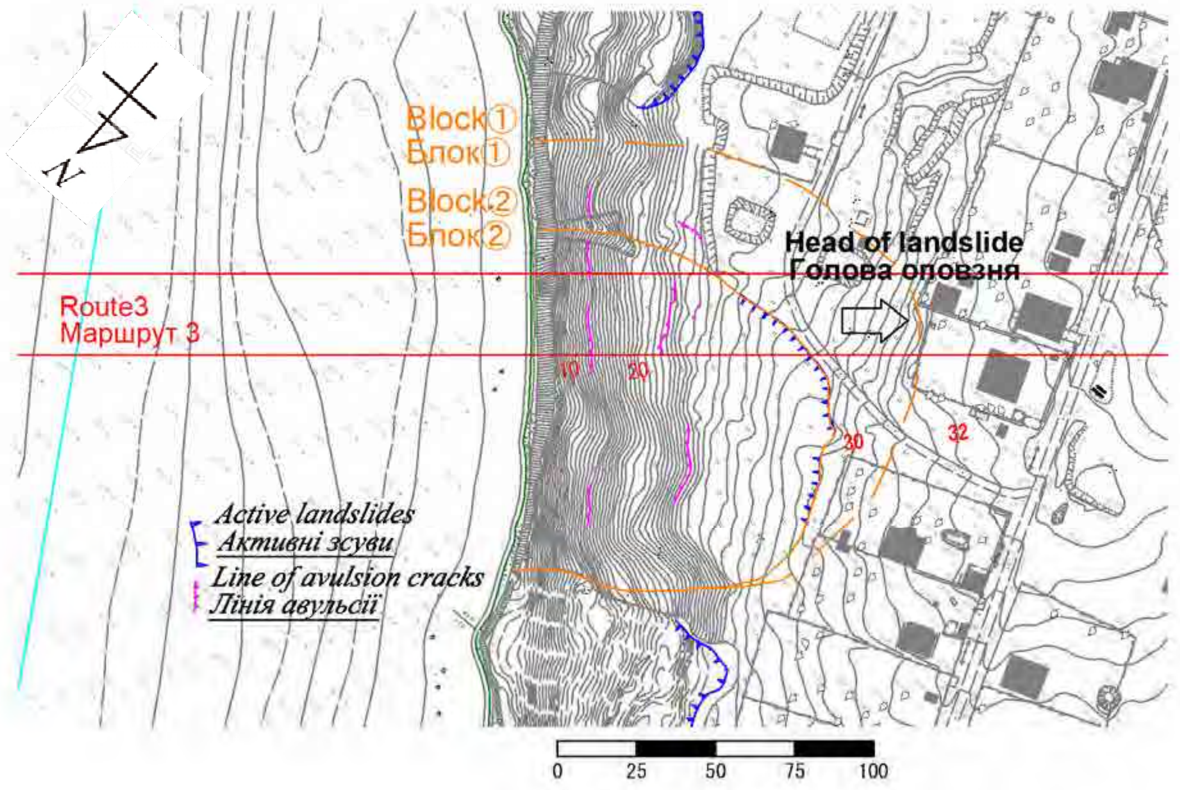


Figure 9-4-5. A Plan View of the Landslide Block in the Right Bank on Route 3

9-5 Geological analysis

9-5-1 Route 2

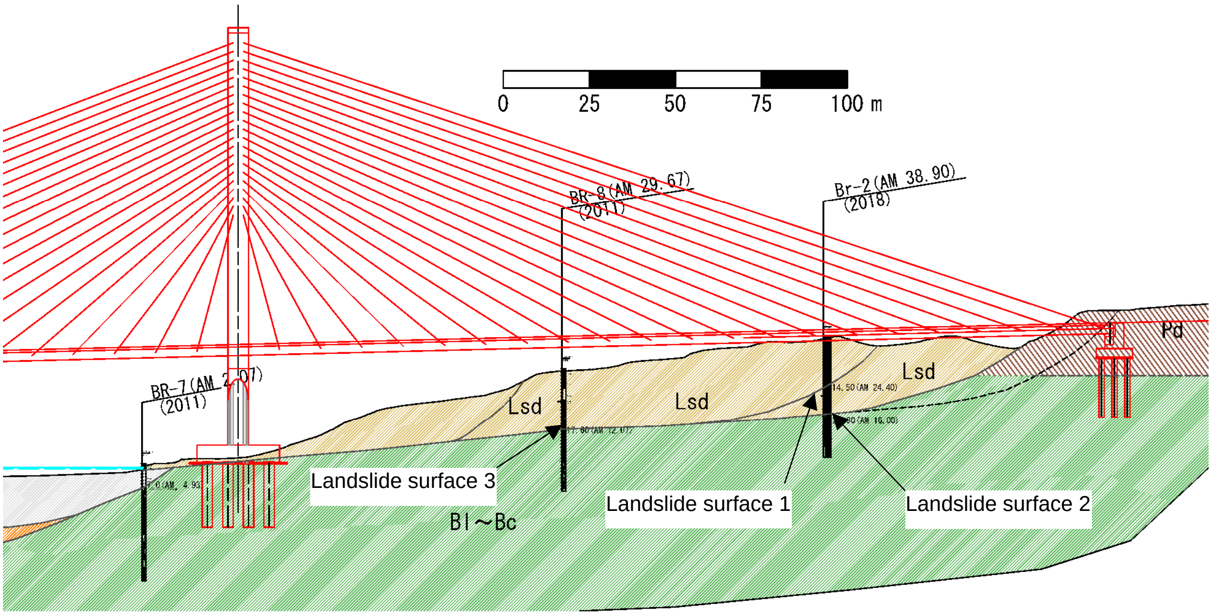


Figure 9-5-1. Image of each Boring Site on the Right Bank Slope (Route 2)

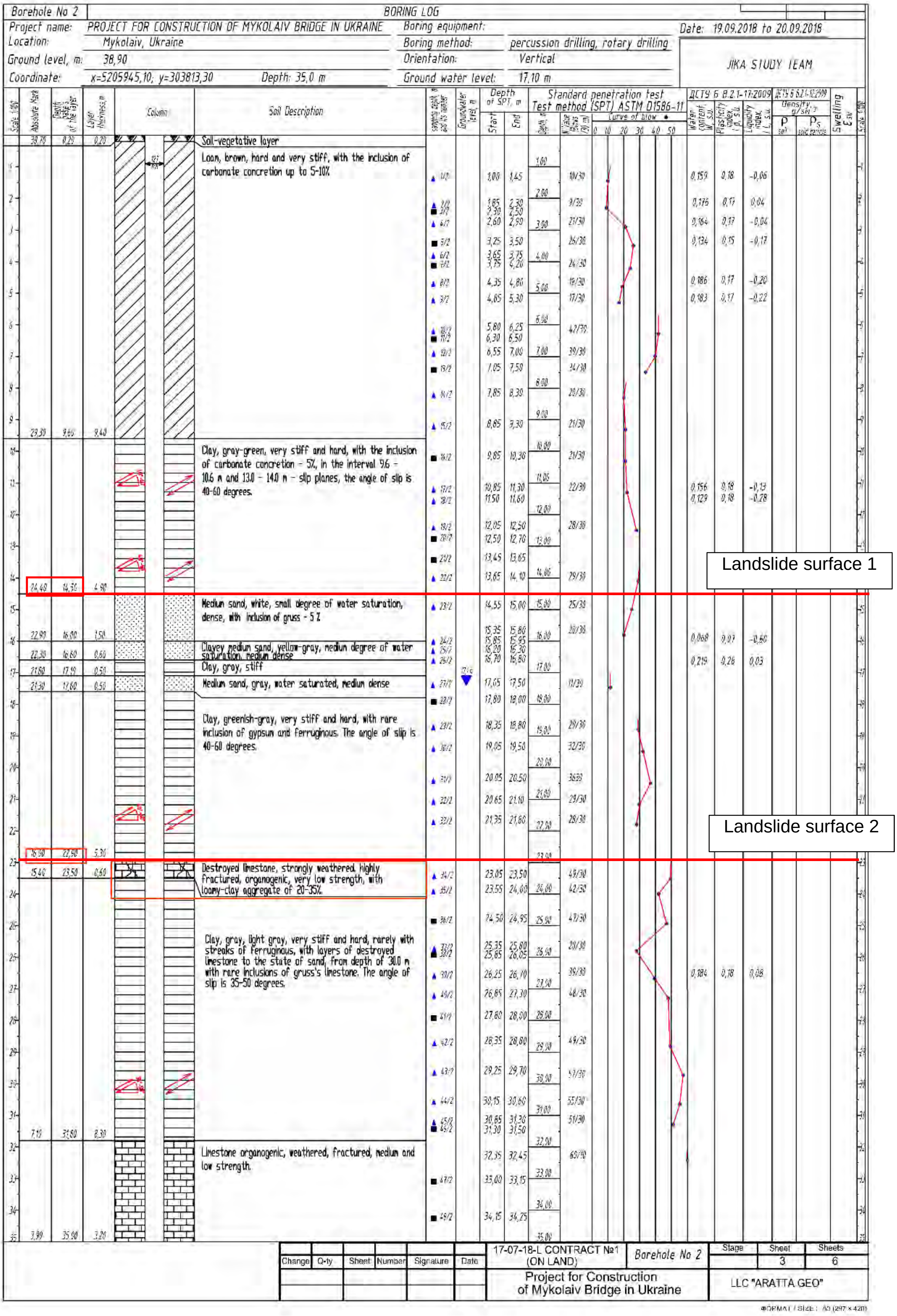
Figure 9-5-1 shows a cross-section of stratum of the land part and Figure 9-5-2 shows boring logs. Both figures are based on the geological survey carried out in this Study. A correlation between the cross-section and plan view is shown in Figure 9-7-1.

During this Survey, a boring survey was conducted at one location (Br. 2) in the block and two locations (Br. 6 and 7) near the right bank inside the river. Along with their results, results of two boreholes (Br. 7: Figure 9-5-3, and BR. 8: Figure 9-5-4) drilled during the 2011 F/S were considered.

The survey result is shown in Figure 9-5-5. For Br. 2, slickenside (landslide trace) is observed from boring samples obtained from the area near G.L-14.50m (Figure9-5-2, landslide surface 1) and G.L-22.90 m (Figure 9-5-2, landslide surface 2). Since the sample above G.L-23m are generally loose (N value is below 30), there is a possibility that this layer is landslide mass.

Another slickenside is also observed at a depth of around 30 m in this borehole but the sample indicated compacted layer (N value exceeding 40) which may point to stable ground.

The 2019 Survey confirmed that spring water was coming out of a grayish-white layer of loose sand in several places in the gullies (See Figure 9-5-6). Although the locations and elevations of the spring water are not connected on a single plane, it is estimated that there is a strong causal relationship between the sand layer and landslides; thus, it is an important key layer for complementary survey and landslide analysis of this block in the future. There is also a need to consider the distribution of this sand layer in future drainage work plans, which serve as landslide countermeasures.



Borehole No 2

BORING LOG

Project name: PROJECT FOR CONSTRUCTION OF MYKOLAIV BRIDGE IN UKRAINE

Location: Mykolaiv, Ukraine

Ground level, m: 38,90

Coordinate: x=5205945,10; y=303813,30

Depth: 35,0 m

Boring equipment:

Boring method: percussion drilling, rotary drilling

Orientation: Vertical

Ground water level: 17,10 m

Date: 19.09.2018 to 20.09.2018

JIKA STUDY TEAM

Soil-vegetative layer

Loam, brown, hard and very stiff, with the inclusion of carbonate concretion up to 5-10%

Clay, gray-green, very stiff and hard, with the inclusion of carbonate concretion - 5%, in the interval 9.6 - 10.6 m and 13.0 - 14.0 m - slip planes, the angle of slip is 40-60 degrees.

Medium sand, white, small degree of water saturation, dense, with inclusion of gruss - 5 %

Clayey medium sand, yellow-gray, medium degree of water saturation, medium dense

Clay, gray, stiff

Medium sand, gray, water saturated, medium dense

Clay, greenish-gray, very stiff and hard, with rare inclusion of gypsum and ferruginous. The angle of slip is 40-60 degrees.

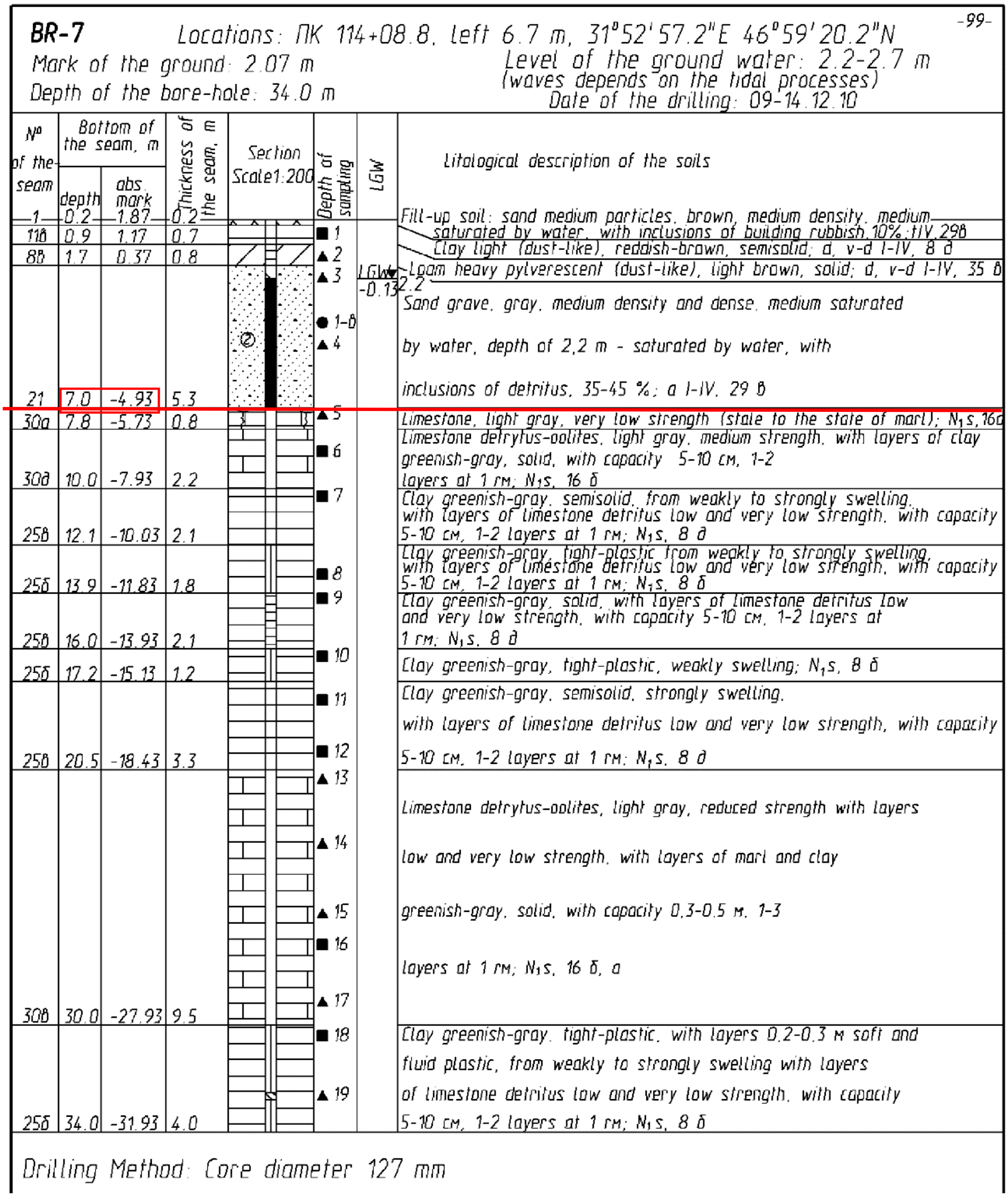
Destroyed limestone, strongly weathered highly fractured, organogenic, very low strength, with loamy-clay aggregate of 20-35%.

Clay, gray, light gray, very stiff and hard, rarely with streaks of ferruginous, with layers of destroyed limestone to the state of sand, from depth of 30.0 m with rare inclusions of gruss's limestone. The angle of slip is 35-50 degrees.

Limestone organogenic, weathered, fractured, medium and low strength.

Change	Q-ty	Sheet	Number	Signature	Date	17-07-18-L CONTRACT №1 (ON LAND)	Borehole No 2	Stage	Sheet	Sheets
									3	6
						Project for Construction of Mykolaiv Bridge in Ukraine		LLC "ARATTA GEO"		

Figure 9-5-2. 2018 Boring Log (Br. 2)



BR-7 Locations: ПК 114+08.8, left 6.7 m, 31°52'57.2"E 46°59'20.2"N

Mark of the ground: 2.07 m

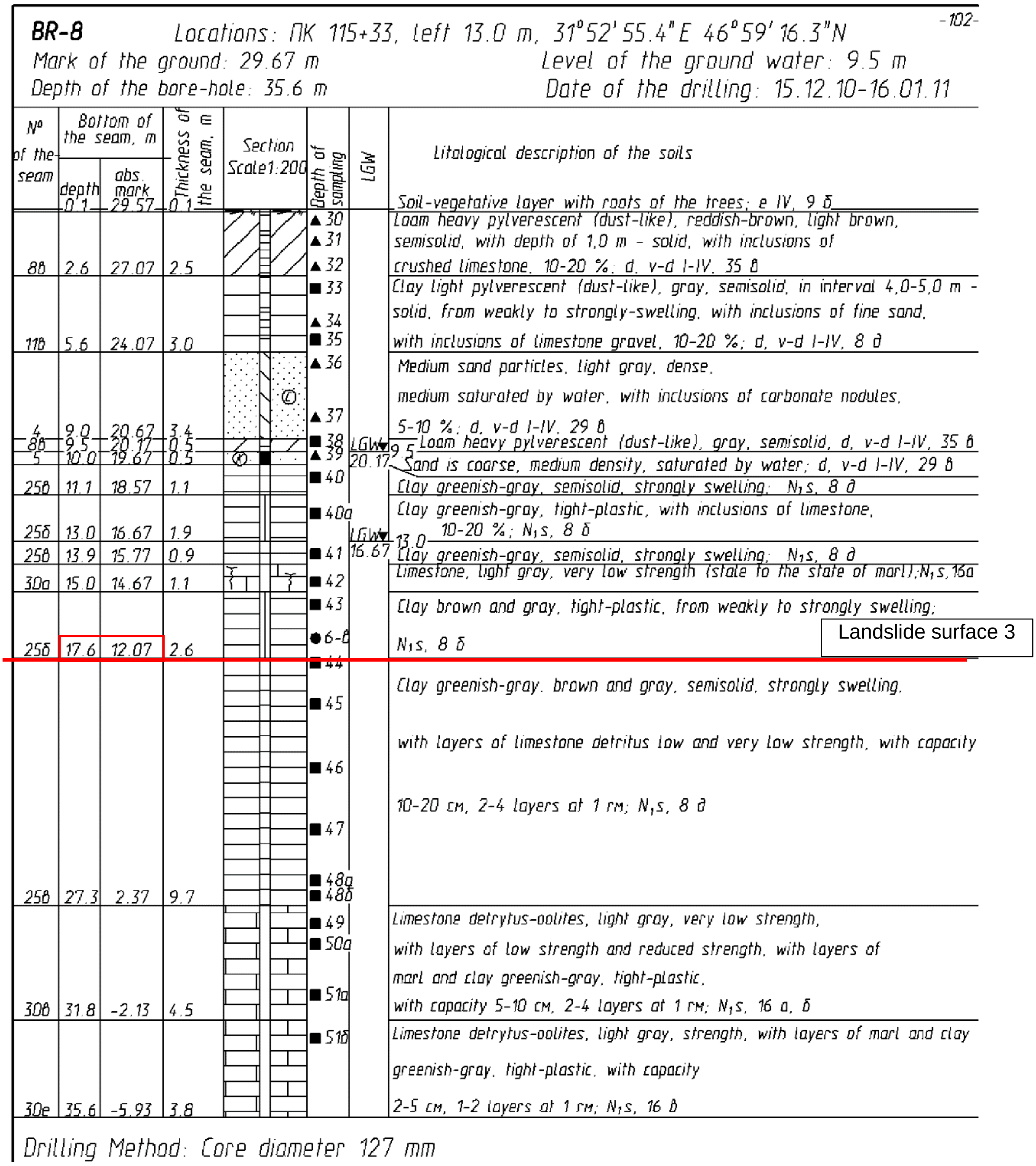
Depth of the bore-hole: 34.0 m

Level of the ground water: 2.2-2.7 m
(waves depends on the tidal processes)
Date of the drilling: 09-14.12.10

№ of the seam	Bottom of the seam, m		Thickness of the seam, m	Section Scale1:200	Depth of sampling	LGW	Litalogical description of the soils
	depth	abs. mark					
1	0.2	1.87	0.2				Fill-up soil: sand medium particles, brown, medium density, medium saturated by water, with inclusions of building rubbish 10%; tIV, 29в
11б	0.9	1.17	0.7		■ 1		Clay light (dust-like), reddish-brown, semisolid; d, v-d I-IV, 8 д
8б	1.7	0.37	0.8		▲ 2		Loam heavy pylverescent (dust-like), light brown, solid; d, v-d I-IV, 35 б
21	7.0	-4.93	5.3	②	▲ 3 ● 1-б ▲ 4	LGW ▼ -0.13	2.2 Sand grave, gray, medium density and dense, medium saturated by water, depth of 2,2 m - saturated by water, with inclusions of detritus, 35-45 %; a I-IV, 29 б
30а	7.8	-5.73	0.8		▲ 5		Limestone, light gray, very low strength (stale to the state of marl); N_1s, 16д
30д	10.0	-7.93	2.2		■ 6		Limestone detrytus-oolites, light gray, medium strength, with layers of clay greenish-gray, solid, with capacity 5-10 см, 1-2 layers at 1 гм; N_1s, 16 б
25в	12.1	-10.03	2.1		■ 7		Clay greenish-gray, semisolid, from weakly to strongly swelling, with layers of limestone detritus low and very low strength, with capacity 5-10 см, 1-2 layers at 1 гм; N_1s, 8 д
25б	13.9	-11.83	1.8		■ 8		Clay greenish-gray, tight-plastic from weakly to strongly swelling, with layers of limestone detritus low and very low strength, with capacity 5-10 см, 1-2 layers at 1 гм; N_1s, 8 б
25в	16.0	-13.93	2.1		■ 9		Clay greenish-gray, solid, with layers of limestone detritus low and very low strength, with capacity 5-10 см, 1-2 layers at 1 гм; N_1s, 8 д
25б	17.2	-15.13	1.2		■ 10		Clay greenish-gray, tight-plastic, weakly swelling; N_1s, 8 б
25в	20.5	-18.43	3.3		■ 11 ■ 12		Clay greenish-gray, semisolid, strongly swelling, with layers of limestone detritus low and very low strength, with capacity 5-10 см, 1-2 layers at 1 гм; N_1s, 8 д
30в	30.0	-27.93	9.5		▲ 13 ▲ 14 ▲ 15 ■ 16 ▲ 17		Limestone detrytus-oolites, light gray, reduced strength with layers low and very low strength, with layers of marl and clay greenish-gray, solid, with capacity 0,3-0,5 м, 1-3 layers at 1 гм; N_1s, 16 б, a
25б	34.0	-31.93	4.0		■ 18 ▲ 19		Clay greenish-gray, tight-plastic, with layers 0,2-0,3 м soft and fluid plastic, from weakly to strongly swelling with layers of limestone detritus low and very low strength, with capacity 5-10 см, 1-2 layers at 1 гм; N_1s, 8 б

Drilling Method: Core diameter 127 mm

Figure 9-5-3. 2011F/S Boring Log (BR. 7)



-102-

BR-8 Locations: ПК 115+33, left 13.0 m, 31°52'55.4"E 46°59'16.3"N

Mark of the ground: 29.67 m Level of the ground water: 9.5 m

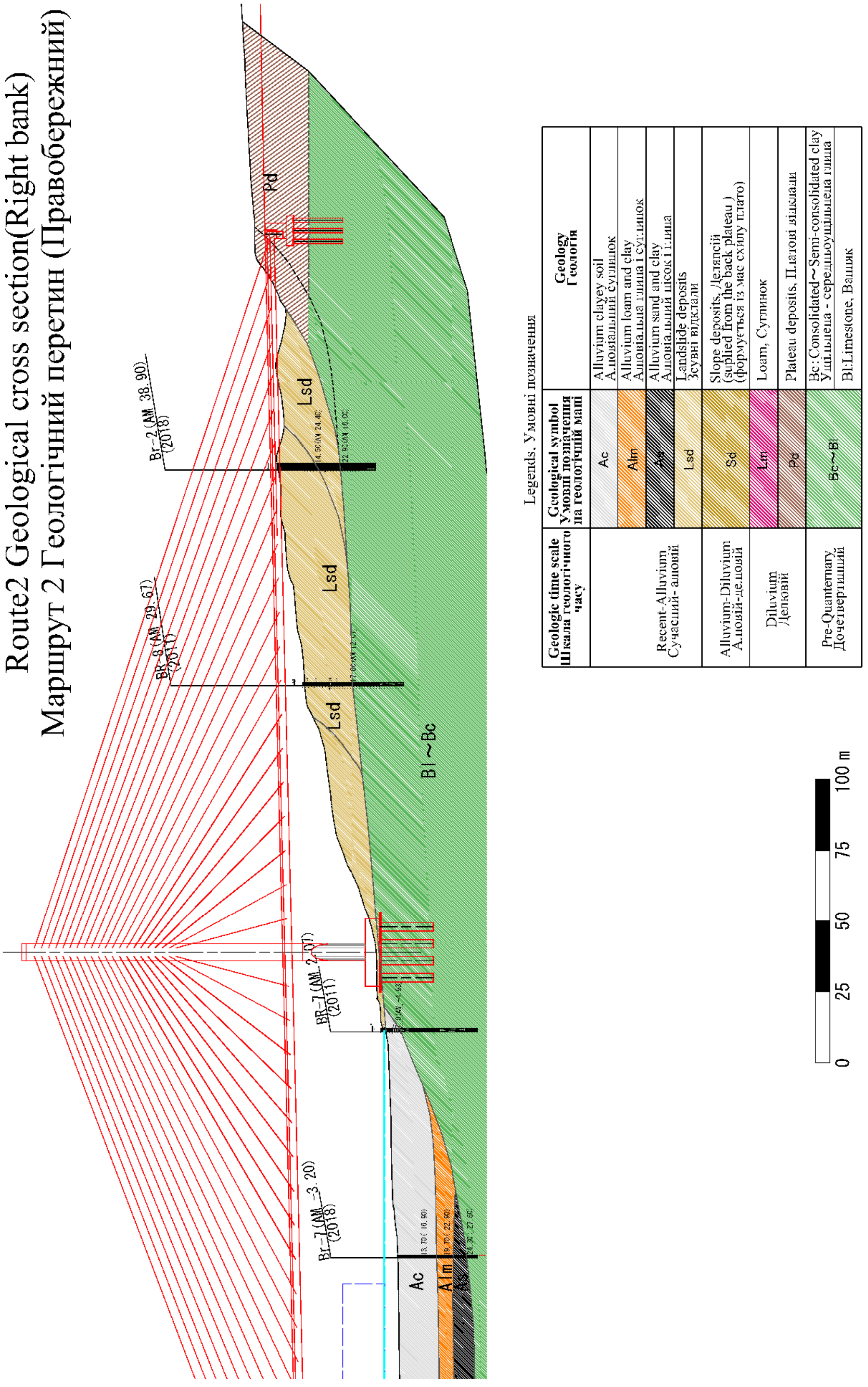
Depth of the bore-hole: 35.6 m Date of the drilling: 15.12.10-16.01.11

№ of the seam	Bottom of the seam, m depth	Bottom of the seam, m abs. mark	Thickness of the seam, m	Depth of sampling	LGW	Litological description of the soils
	0.1	29.57	0.1			Soil-vegetative layer with roots of the trees; e IV, 9 б
8б	2.6	27.07	2.5	▲30 ▲31 ▲32		Loam heavy pylverescent (dust-like), reddish-brown, light brown, semisolid, with depth of 1,0 m - solid, with inclusions of crushed limestone, 10-20 %; d, v-d I-IV, 35 б
11б	5.6	24.07	3.0	■33 ▲34 ■35		Clay light pylverescent (dust-like), gray, semisolid, in interval 4,0-5,0 m - solid, from weakly to strongly-swelling, with inclusions of fine sand, with inclusions of limestone gravel, 10-20 %; d, v-d I-IV, 8 д
4	9.0	20.67	3.4	▲36 ▲37		Medium sand particles, light gray, dense, medium saturated by water, with inclusions of carbonate nodules, 5-10 %; d, v-d I-IV, 29 б
8б	9.5	20.17	0.5	■38	LGW 9.5 20.17	Loam heavy pylverescent (dust-like), gray, semisolid, d, v-d I-IV, 35 б
5	10.0	19.67	0.5	▲39		Sand is coarse, medium density, saturated by water; d, v-d I-IV, 29 б
25б	11.1	18.57	1.1	■40		Clay greenish-gray, semisolid, strongly swelling; N_1s, 8 д
25б	13.0	16.67	1.9	■40а	LGW 13.0 16.67	Clay greenish-gray, tight-plastic, with inclusions of limestone, 10-20 %; N_1s, 8 б
25в	13.9	15.77	0.9	■41		Clay greenish-gray, semisolid, strongly swelling; N_1s, 8 д
30а	15.0	14.67	1.1	■42		Limestone, light gray, very low strength (state to the state of marl);N_1s,16а
25б	17.6	12.07	2.6	■43 ●6-б		Clay brown and gray, tight-plastic, from weakly to strongly swelling; N_1s, 8 б
25в	27.3	2.37	9.7	■44 ■45 ■46 ■47 ■48а ■48б		Clay greenish-gray, brown and gray, semisolid, strongly swelling, with layers of limestone detritus low and very low strength, with capacity 10-20 см, 2-4 layers at 1 гм; N_1s, 8 д
30в	31.8	-2.13	4.5	■49 ■50а ■51а		Limestone detrytus-oolites, light gray, very low strength, with layers of low strength and reduced strength, with layers of marl and clay greenish-gray, tight-plastic, with capacity 5-10 см, 2-4 layers at 1 гм; N_1s, 16 а, б
30е	35.6	-5.93	3.8	■51б		Limestone detrytus-oolites, light gray, strength, with layers of marl and clay greenish-gray, tight-plastic, with capacity 2-5 см, 1-2 layers at 1 гм; N_1s, 16 б

Landslide surface 3

Drilling Method: Core diameter 127 mm

Figure 9-5-4. 2011F/S Boring Log (BR. 8)


Route2 Geological cross section(Right bank)

Маршрут 2 Геологічний перетин (Правобережний)

Figure 9-5-5. Image of a Geological Cross-Section of Route 2 (Right Bank)

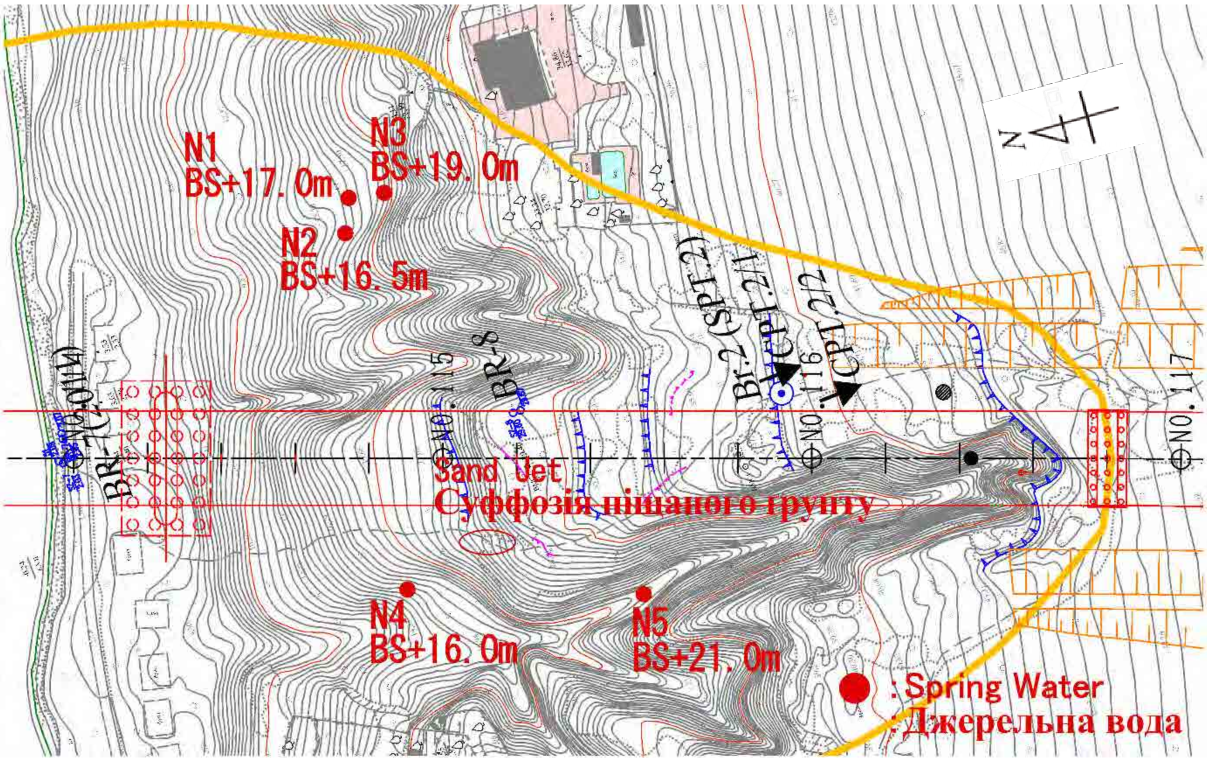


Figure 9-5-6. Locations of Spring Water (Route 2)

9-5-2 Route 3

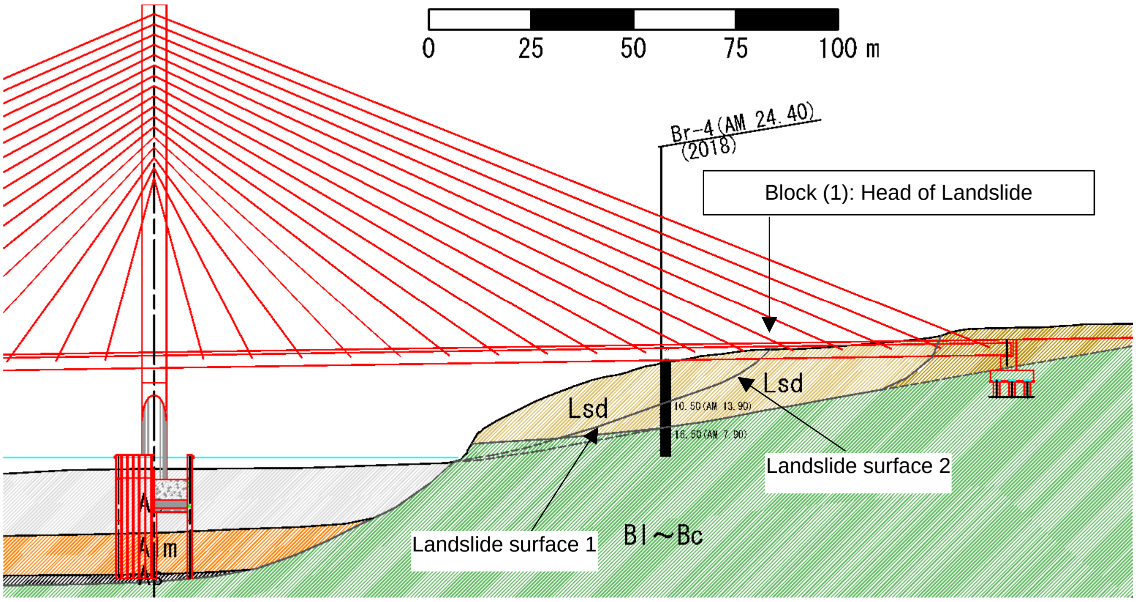


Figure 9-5-7. Image of Boring Site on the Right Bank Slope (Route 3)

Figure 9-5-7 shows a cross-section of stratum on the land part and Figure 9-5-8 shows boring logs. Both figures are based on the geological survey carried out in this Study. A correlation between the cross-section and plan view is shown in Figure 9-7-2.

The survey result is shown in Figure 9-5-9. For Br. 4, slickenside (landslide trace) is observed from boring samples obtained from the area near G.L-10.50 m (Figure 9-5-8, landslide surface 1) and G.L.-16.50 m (Figure 9-5-8, landslide surface 2). In addition, boring samples collected in the area shallower than G.L.-16.50 m, are entirely loose. Therefore, those area can be seen as the result of landslide movements.

The expected landslide surface located at a depth of 16.5 m in Br. 4 is the bottom base in the case of Block ① (landslide surface 2) as shown in Figure 9-4-5. Geological basis for this inference is that its N value varies between 20 and 40 within the range of G.L.-10.5 to 16.5 m and its consolidation level is unstable. Slickensides (landslide traces) are also observed in this layer of the boring sample.

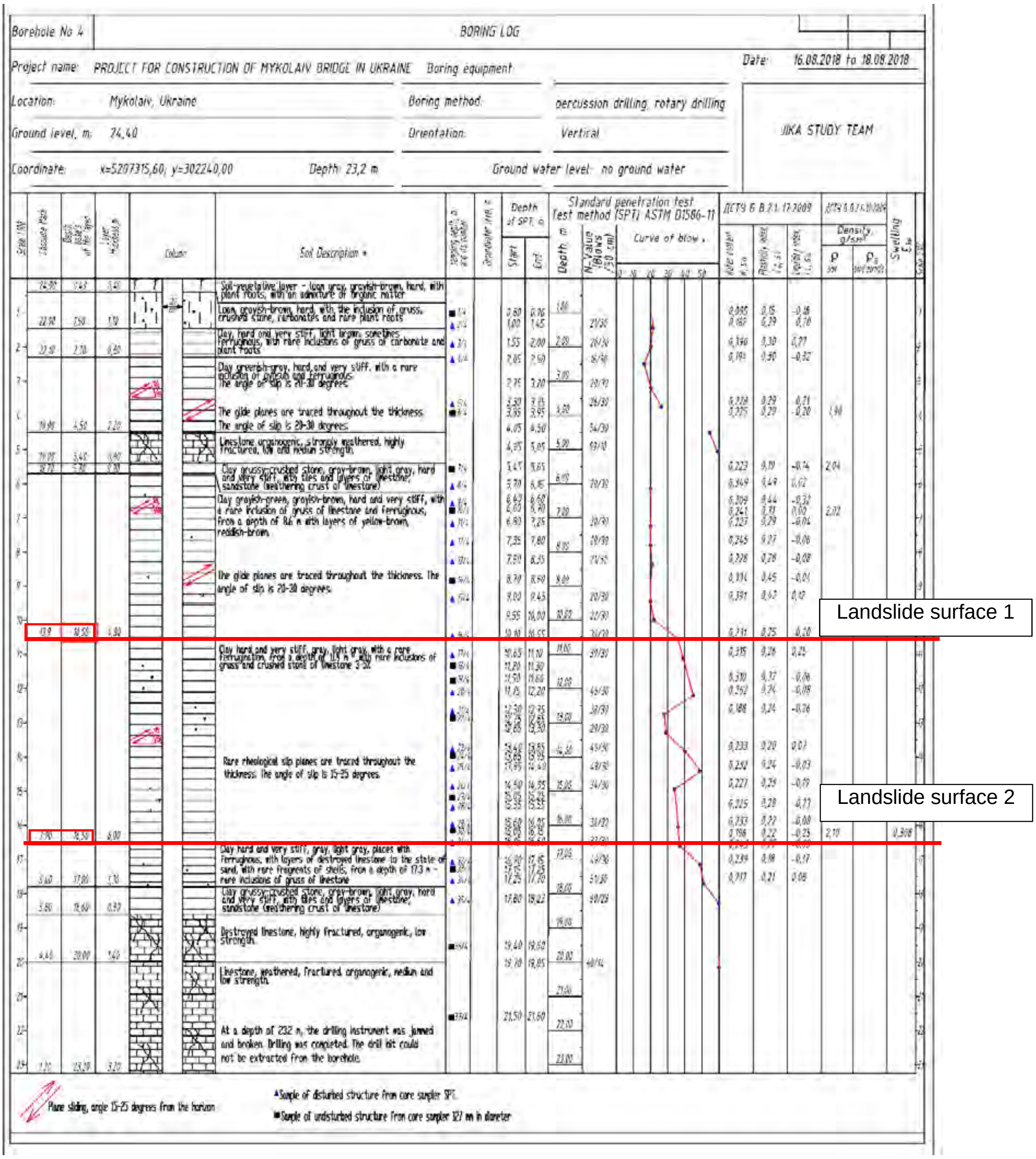
Expert experience tells that the deepest landslide surface is around 20 m based on the landslide width (approximately 120 m). However, stable ground (clay and limestone) showing an N value exceeding 50 exists under G.L-16.5 m in this borehole, which confirms the existence of Block ① at this depth.

From the boring survey conducted in the river, a weak alluvium formed by the existing river deposits has accumulated down to G.L.-27 m and none of the aforementioned landslide soil mass is observed in the river area.

It is worth noting that the 2019 Survey revealed that the limestone exposed at the slope toe of the blocks comprises two-layer structures, with a fragile layer on top and a hard layer on the bottom (Figure 9-5-10); it is estimated that the bottom layers are embedded in the ground. In addition, the Senior Researcher from the Public Works Research Institute of Japan stated following matters during the 2019 Survey.

- Outcrops at the foot of the landslide show that no disruption has occurred.
- Hence, landslides and the big disruptions they bring, have not occurred around this area.
- Small-scale collapses (initial landslide-type collapses) have the potential to occur in this area in the future, as has been observed in nearby areas.

In light of these expectations and to be on a safe side, both the fragile upper layers and hard bottom layers of the limestone exposed at the slope toe of the blocks are envisioned to disappear by collapse, and the state will be identical to that of Route 2. The broken lines in Figure 9-5-7 denote the envisioned lansdslide surfaces.



Borehole No 4

BORING LOG

Project name: PROJECT FOR CONSTRUCTION OF MYKOLAIV BRIDGE IN UKRAINE

Boring equipment:

Date: 16.08.2018 to 18.08.2018

Location: Mykolaiv, Ukraine

Boring method: percussion drilling, rotary drilling

Ground level, m: 24,40

Orientation: Vertical

JIKA STUDY TEAM

Coordinate: x=5207315,60; y=302240,00

Depth: 23,2 m

Ground water level: no ground water

Soil-vegetative layer – loam gray, grayish-brown, hard, with plant roots, with an admixture of organic matter

Loam, grayish-brown, hard, with the inclusion of gruss, crushed stone, carbonates and rare plant roots

Clay, hard and very stiff, light brown, sometimes ferruginous, with rare inclusions of gruss of carbonate and plant roots

Clay greenish-gray, hard and very stiff, with a rare inclusion of gypsum and ferruginous. The angle of slip is 20-30 degrees.

The glide planes are traced throughout the thickness. The angle of slip is 20-30 degrees.

Limestone organogenic, strongly weathered, highly fractured, low and medium strength.

Clay grussy-crushed stone, gray-brown, light gray, hard and very stiff, with tiles and layers of limestone, sandstone (weathering crust of limestone)

Clay grayish-green, grayish-brown, hard and very stiff, with a rare inclusion of gruss of limestone and ferruginous, from a depth of 8.6 m with layers of yellow-brown, reddish-brown.

The glide planes are traced throughout the thickness. The angle of slip is 20-30 degrees.

Clay hard and very stiff, gray, light gray, with a rare ferrugination, from a depth of 11.9 m with rare inclusions of gruss and crushed stone of limestone 3-5%.

Rare rheological slip planes are traced throughout the thickness. The angle of slip is 15-25 degrees.

Clay hard and very stiff, gray, light gray, places with ferruginous, with layers of destroyed limestone to the state of sand, with rare fragments of shells, from a depth of 17.3 m – rare inclusions of gruss of limestone

Clay grussy-crushed stone, gray-brown, light gray, hard and very stiff, with tiles and layers of limestone, sandstone (weathering crust of limestone)

Destroyed limestone, highly fractured, organogenic, low strength.

Limestone, weathered, fractured, organogenic, medium and low strength.

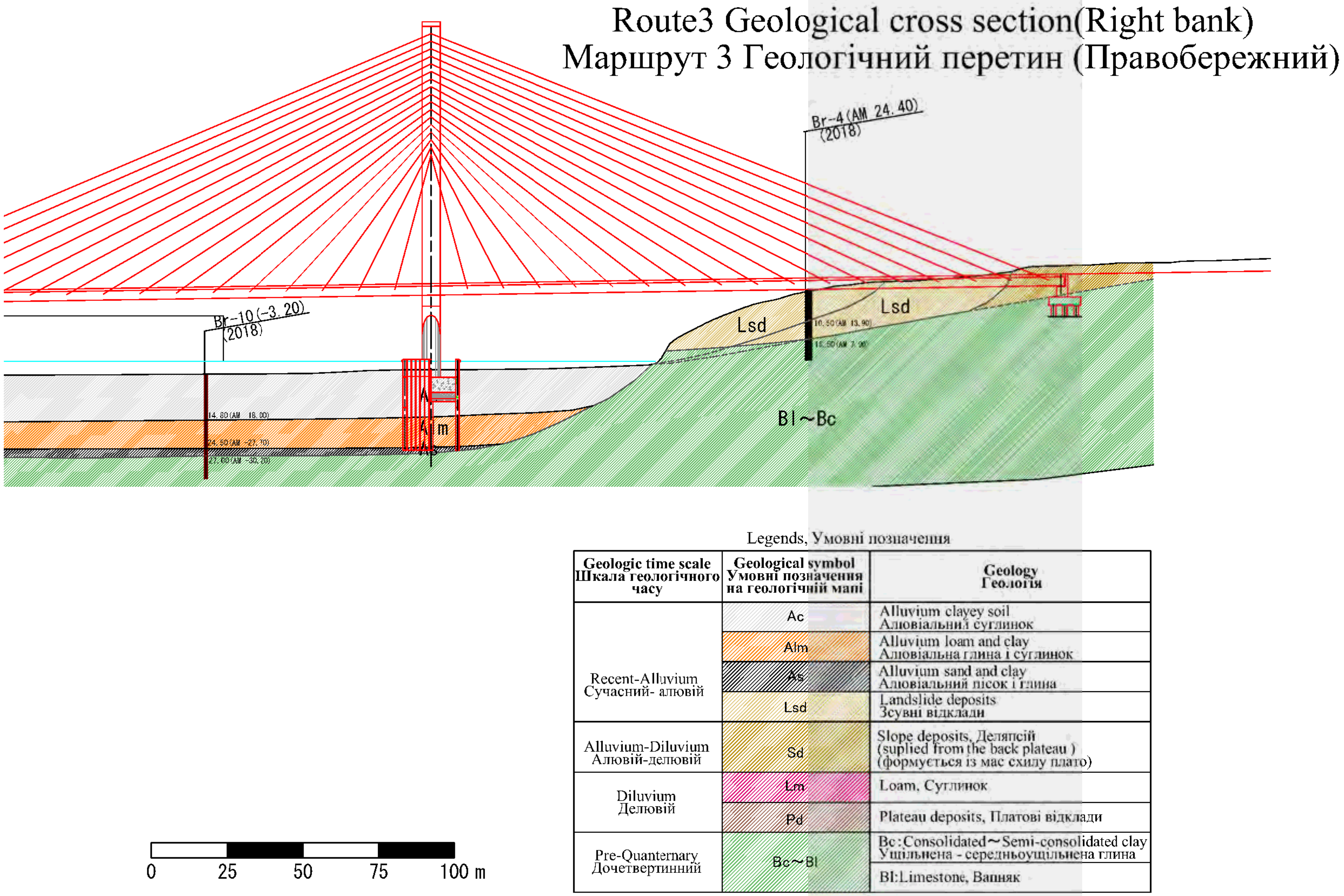
At a depth of 23.2 m, the drilling instrument was jammed and broken. Drilling was completed. The drill bit could not be extracted from the borehole.

Plane sliding, angle 15-25 degrees from the horizon

▲Sample of disturbed structure from core sampler SPT.

■Sample of undisturbed structure from core sampler 127 mm in diameter

Figure 9-5-8. 2018 Boring Log (Br. 4)



Legends, Умовні позначення

Geologic time scale Шкала геологічного часу	Geological symbol Умовні позначення на геологічній мапі	Geology Геологія
Recent-Alluvium Сучасний- алювій	Ac	Alluvium clayey soil Алювіальний суглинок
	Alm	Alluvium loam and clay Алювіальна глина і суглинок
	As	Alluvium sand and clay Алювіальний пісок і глина
	Lsd	Landslide deposits Зсувні відклади
Alluvium-Diluvium Алювій-делювій	Sd	Slope deposits, Делявсій (suplied from the back plateau) (формується із мас схилу плато)
Diluvium Делювій	Lm	Loam, Суглинок
	Pd	Plateau deposits, Платові відклади
Pre-Quanternary Дочетвертинний	Bc～Bl	Bc:Consolidated～Semi-consolidated clay Ущільнена - середньоущільнена глина
		Bl:Limestone, Вапняк

Figure 9-5-9. Image of Geological Cross-Section of Route 3 (Right Bank)

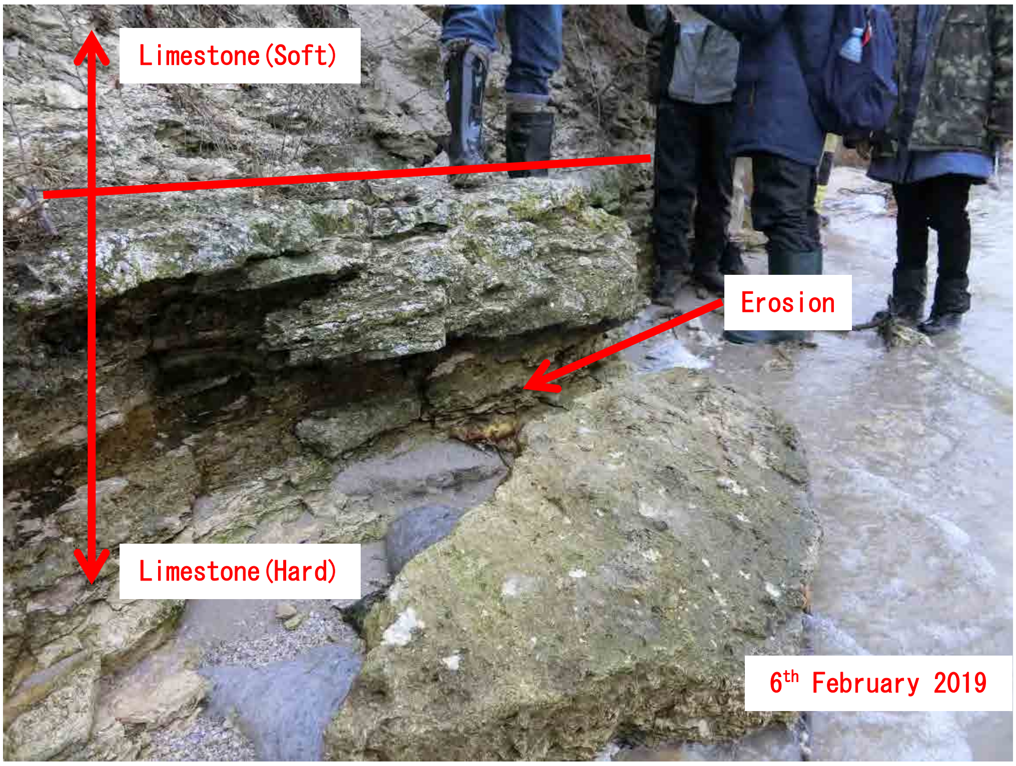


Figure 9-5-10. Exposed Limestone at the Toe of the Block Slope

9-6 Consideration on the Relevance with the Road Construction Plan

9-6-1 Route 2

The planned locations of abutments are outside the landslide zone, however, landslide blocks are expected to exist below the abutments. Therefore, it is necessary to investigate the landslide activity and the effects on the abutments continuously. Even if further surveying confirms no landslide activities per se, there is still a concern over slope stability. Gullies have developed in the envisioned landslide blocks, and multiple spring water have been observed. Progression of these erosions would exercabate slope instability.

These places where spring water comes out match the distribution of the grayish-white loose sand layer (aquifer); this likely has a strong correlation with the development of the gullies, and the sand layer may be one of the factors that induces landslides.

As part of the complementary survey ongoing as of June 2019, a landslide mechanism analysis shall be conducted in addition to the tests to determine the landslide surfaces and stability analyses and the like. Together these shall contribute to plans for the prevention works that are to also function during construction.

9-6-2 Route 3

This Route in the road construction plan is located between several collapse sites with activity history. Erosion of the slope toe is now observed in “Stage I” described in 9-3. However, the risk of topographical and geological deformation similar to adjacent landslide terrain is high depending on topographical deformation caused by rainfall, snow melting and other natural conditions in the future.

It is preferable to avoid conducting cutting and embankment works and constructing structures in the block, due to the possibility of the retrograding landslide will affect behind plateau area. Accordingly, sufficient consideration will be needed for landslide potential areas.

As part of complementary survey ongoing as of June 2019, a landslide mechanism analysis shall be conducted, and the scale of the landslide block shall be determined and its sliding activity shall be considered. Together these shall contribute to plans for the prevention works that are to also function during construction.

9-6-3 Common Matters in Routes 2 and 3

1) Earth cut work in the plateau around T1506

The survey area is located on a flat plateau as described in 9-2. A boring survey at a depth of G.L-10.5m (Br. 3/1) was conducted during this Study, revealing distributed loam up to G.L-1.8 m and consolidated clay layers distributed throughout the lower part. These are both plateau deposits (Pd) formed in the Pleistocene and, in terms of forming periods and layers, different from slope deposits (Sd) which will assist the landslide moving.

Therefore, an important focus in the earth cutting work around the survey area should be the slope gradient of the cutting work and slope plotection measures (prevention work for slaking such as vegetation work, frame work, etc.) after the cutting work, rather than the impact of cutting work on the blocks near the river.

9-7 Future Direction (Proposal of Complementary Survey Items)

9-7-1 Common Survey Items in Routes 2 and 3

1) Field survey (including on-site interviews)
2) Boring survey (the excavation depth should be sufficient to catch the slip surface. The survey should include topographical analysis using the measuring result of all core boring.)
3) Installation of groundwater level monitoring holes (including six months after the snow-melting season)
4) Installation of a pipe strain gauge (including six months after the snow-melting season)
5) Installation of moving and crack measurement piles (using an extensometer or two-point measurement piles, or continuous piles for sections where deformation is uncertain)
6) Monitoring of 3), 4), and 5) (including six months after the snow-melting season)
7) Comprehensive landslide analysis (conduct a geological cross-section analysis with the boring survey result)

9-7-2 Bill of Quantity

Table 9-7-1. Bill of Quantity

Survey item	Route 2	Route 3	Remarks
1. Field survey	1 set	1 set	✓ Including on-site interview ✓ Including a topographical analysis using measurement results
2. Boring survey	3 holes (25m × 3 holes) Hole No.1 ℓ=25 m Hole No.2 ℓ=25 m Hole No.3 ℓ=25 m (See Figure 9-7-1)	3 holes (25m × 3 holes) Hole No.4 ℓ=25 m Hole No.5 ℓ=25 m Hole No.6 ℓ=25 m (See Figure 9-7-2)	✓ All core boring ✓ The boring depth should be the level achieving the expected supporting layers ✓ Inserting groundwater level monitoring hole and pipe strain gauge after drilling
3. Groundwater level measurement	3 holes × 12 months	3 holes × 12 months	✓ Including six months after the snow-melting season
4. Pipe strain gauge measurement	3 holes × 12 months	3 holes × 12 months	✓ Including six months after the snow-melting season
5. Measurement of the movement between two points	4 points × 12 months	4 points × 12 months	✓ Including six months after the snow-melting season ✓ Measuring by a ground extensometer or two-point measurement pile ✓ Using a continuous pile for the section with uncertain deformation
6. Moving pile measurement	2 traverse lines × 12 months	1 traverse line × 12 months	✓ Including six months after the snow-melting season
7. Comprehensive landslide analysis	1 set	1 set	

Note: The final quantity of each set of monitoring equipment is determined based on the field survey result.

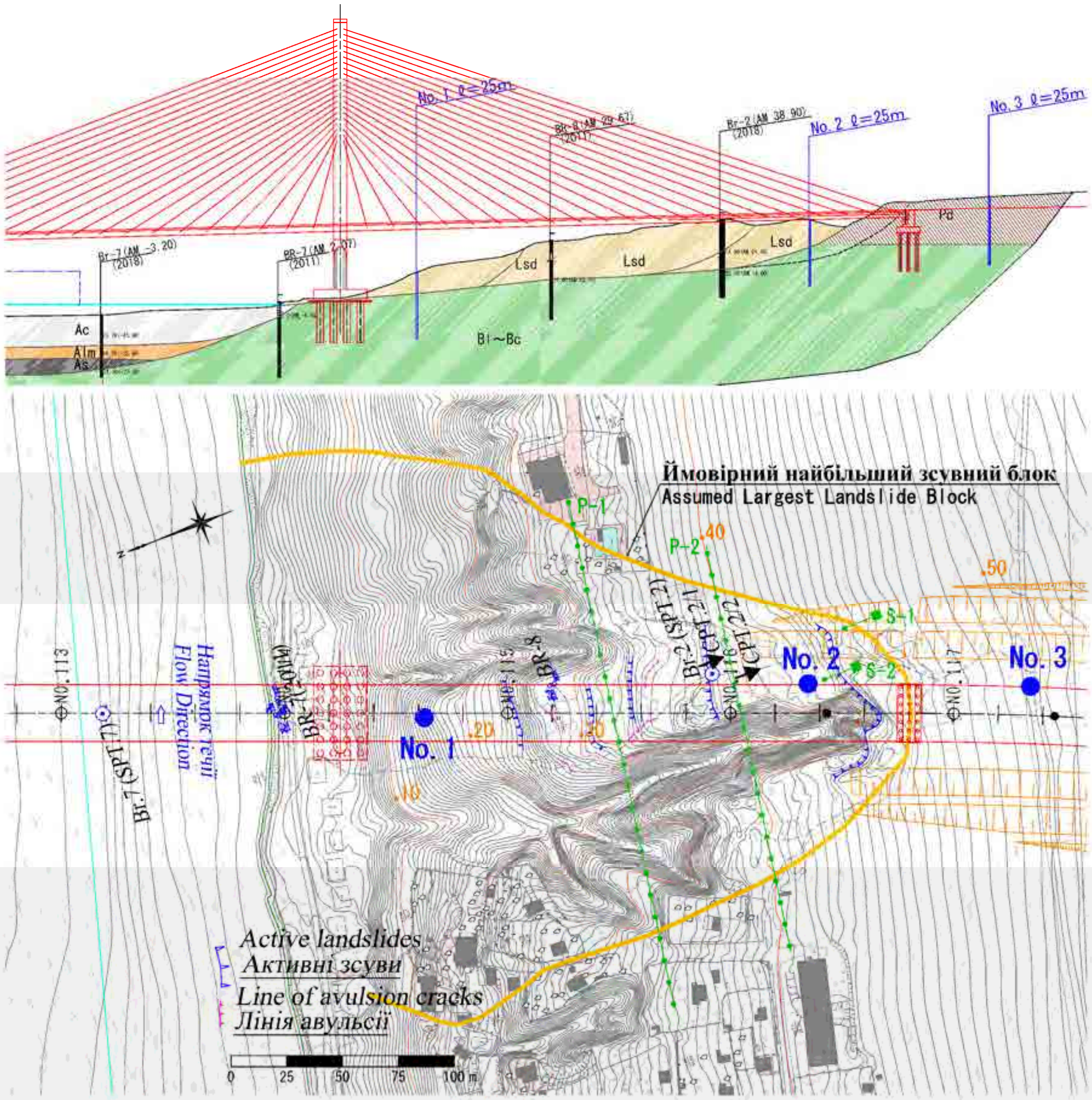
The complementary survey plan for Route 2 is shown in Figure 9-7-1 and for Route 3 in Figure 9-7-2.

Legends, Умовні позначення

Geologic time scale Шкала геологічного часу	Geological symbol Умовні позначення на геологічній мапі	Geology Геологія
Recent-Alluvium Сучасний- алювій	Ac	Alluvium clayey soil Алювіальний суглинок
	Alm	Alluvium loam and clay Алювіальна глина і суглинок
	As	Alluvium sand and clay Алювіальний пісок і глина
	Lsd	Landslide deposits Зсувні відклади
Alluvium-Diluvium Алювій-деловій	Sd	Slope deposits, Делювій (suplied from the back plateau) (формується із мас схилу плато)
Diluvium Деловій	Lm	Loam, Суглинок
	Pd	Plateau deposits, Платові відклади
Pre-Quaternary Дочетвертинний	Bc～Bl	Bc:Consolidated～Semi-consolidated clay Ущільнена - середньоущільнена глина
		Bl:Limestone, Вапняк

0 25 50 75 100 m

Legends, Умовні позначення	
No.1 ℓ=25m	Planned boring location Заплановані позиції буріння



Legends, Умовні позначення

● **:Planned boring locations (Nos. 1 to 3)**
Заплановані позиції буріння (№1-3)

:Observation of Displacement Stake（P-1,2）
Спостереження зміщення палі（P-1,2）

:Observation of Extensometer（S-1,2）
Спостереження екстензометра（S-1,2）

Figure 9-7-1. Map of Complementary Survey Plan (Route 2)

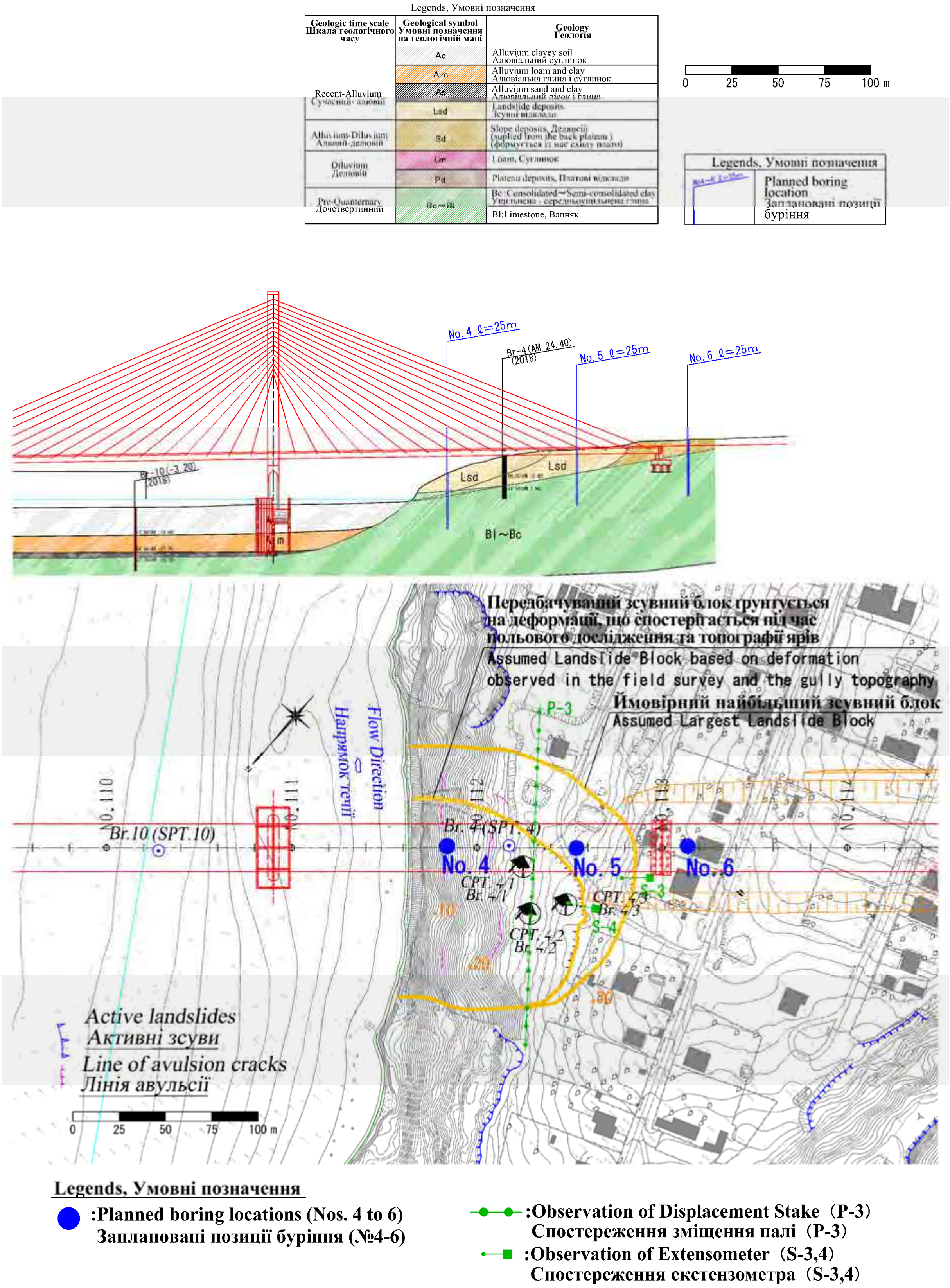


Figure 9-7-2. Map of Complementary Survey Plan (Route 3)

9-8 Results of Complementary Geological Survey Conducted in April-October 2019

9-8-1 Route2

1) Boring Survey

The boring survey shown in the table below was conducted for Route 2.

Table 9-8-1. Quantity of Boring Survey for Route 2

Borehole No.	Elevation (m)	Survey depth (m)	Location	Groundwater level (m)
Br-11 (No. 1 Initial plan)	18.6	25.0	Bottom part of envisioned landslide	-19.1
Br-12 (No. 2 Initial plan)	41.3	26.0	Top part of envisioned landslide	-24.0
Br-13 (No. 3 Initial plan)	49.8	25.0	Plateau (apart from envisioned landslide)	None

Boring survey and field survey made the following information clear:

- The sand layer confirmed at Br-8 (2011) and Br-2 (2018) was also confirmed at two boreholes (Br-12 and Br-13) from this survey.
- The sand layer confirmed at these four boreholes is nearly 3 m thick and distributed around the cross section of the main road at an elevation of 21–25 m; it is deemed to be a uniform layer of sediment unaffected by displacement such as landslides.
- Spring water was confirmed in the sand layer at the gully portion of the site at an elevation of 21 m. The location is on the same plane when projected onto the main section.
- Spring water was confirmed in the sand layer of the main gully in both February and May 2019; therefore, a steady aquifer may be present.
- Based on the boring survey, it is deemed that there is only one sand layer; however, it does not match the sand layer confirmed near the gully at an elevation of 16 m in February. The sand layer near the elevation of 16 m may have been moved downward by a landslide.
- The constituent layers of the upper sand layer are clearly different: the main component at Br-13 on the plateau is brown loamy soil, but the main component at Br-12, which is inside the initially envisioned landslide, is green-gray to gray-brown clay.

The following are map of the survey, pictures of the core samples and boring logs.