LAND TRANSPORT AUTHORITY
INDEPENDENT STATE OF SAMOA

PREPARATORY SURVEY REPORT ON THE PROJECT FOR RECONSTRUCTION OF VAISIGANO BRIDGE IN INDEPENDENT STATE OF SAMOA

MARCH 2017

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

CENTRAL CONSULTANT INC.

CTI ENGINEERING INTERNATIONAL CO., LTD.

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PREFACE

The Japan International Cooperation Agency (JICA) decided to conduct a preparatory survey for cooperation involving the project for reconstruction of Vaisigano Bridge in the Independent State of Samoa, and outsourced the study to the joint venture that comprises Central Consultant Inc. and CTI Engineering International Co., Ltd.

From June 4 to July 31, 2016, the study group held discussions with Samoan government personnel and conducted field reconnaissance in the target region for the plans. The team then returned to Japan to continue to work on the study from there, and completed this report.

Hopefully, this report contributes to the progress of these plans and helps develop more friendship and goodwill between the two countries.

We would like to express our heartfelt appreciation to each of the people who offered their cooperation and assistance with this study.

March 2017

Akira Nakamura
Director General,
Infrastructure and Peacebuilding Department,
Japan International Cooperation Agency

SUMMARY

SUMMARY

(1) Overview of Samoa

The Independent State of Samoa ("Samoa") is an island nation that comprises the Samoan Islands, which are located on the west side of the South Pacific (Oceania) with longitude 171°W as the border. Samoan land area totals 2,830 km^2, and its population is 191,800 (World Bank, 2014); the population density is 68 people per km^2.

Samoa comprises two large islands, Upolu (1,700 km^2) and Savai'i (1,115 km^2), and seven smaller islands. Upolu and Savai'i are both volcanic islands, and the highest point on Savai'i is Mount Silisili at 1,858 m. Coral reefs have developed in some locations in the nation's coastal areas. The capital of Apia is located in the northern part of Upolu.

Samoa has a typical tropical marine climate, with high temperatures and high humidity. It has a rainy season, which generally lasts from November of one year to March of the next, and a dry season that lasts from April to October. Tropical cyclones affect the country from November to March. Annual rainfall differs significantly by topography; there is a roughly 1,500-mm difference in annual rainfall between the mountainous area (Afiamalu) and the plain (Nafanua). January sees the highest monthly rainfall at more than 1,000 mm. As for the mean air temperature at the Apia Observation Station over the past 10 years, there is not much difference between high and low temperatures; the difference between highs and lows is roughly 9°C. The high temperature over the past 10 years was 34.8°C (April 2011), and the low was 18.6°C (September 2015).

Samoa's GDP is 800 million USD (World Bank, 2014). The GDP per capita is 4,212 USD (World Bank, 2013). In addition, the GNI per capita is 4,060 USD (World Bank, 2014). The real economic growth rate is 1.2 % (World Bank, 2014), and inflation is 1.4% (World Bank, 2013). Total exports are 140.2 million USD, and total imports 452 million USD (Asian Development Bank, 2014). Main exports are fish and shellfish, noni products, beer and coconut cream, and main imports are food products, meat, machinery and transportation equipment. The main industries in Samoa are food processing, construction materials and automobile parts. Primary industries (agriculture, forestry and fishing) account for 10.2% of GDP, while secondary industries (including mining and electric power supply) account for 25.9% and tertiary industries (telecommunications, finance, retails and other service-related industries) account for 64.0%.

A major earthquake struck offshore of Samoa in September 2009 and generated tsunami waves. As a result, tourism revenue decreased while demand for financing disaster recovery increased. In December 2012, Cyclone Evan struck Samoa and caused tremendous damage. As a result of these and other disasters, the country finds itself in a difficult economic situation. Moreover, the economic structure is typical of an island nation, with a small domestic market that relies mostly on imports for its consumer goods and results in a perpetual trade deficit. However, the current deficit is not so large due to large surpluses from overseas remittances and services and transfer balances from tourism revenue.

(2) Project Background, History and Overview

The island of Upolu is home to the Samoan capital of Apia and over 140,000 people, which is roughly 80% of the entire population of Samoa. The country contains 1,202 km of roads and 52 bridges, 45 of which are on Upolu. The Vaisigano Bridge is located on a major arterial road that connects the city of Apia to Apia Port (Samoa's only commercial port) and Fagali'i Airport (for interisland flights). The bridge is an important part of the network of roads on Upolu, with an average of 14,300 cars per day passing over it in 2013 (an increase of 1,700 cars per day in the 10 years between 2003 and 2013).

The Vaisigano Bridge was first constructed at the beginning of the 20th century as a seven-span, steel bridge, and was replaced in 1953 with a concrete bridge atop a newly reinforced substructure that still stands. Despite work done in 1994 to repair corrosion of rebar and concrete peeling due to salt damage, the same damage reoccurred, and large vehicles have not been able to use the bridge since 2002. Large trucks transport goods from Apia Port to the industrial zone on the west side of Upolu, and they have been forced to take detours upstream to the Leone Bridge.

Samoa frequently suffers damage from cyclones, and the severe Cyclone Evan that struck in 2012 significantly damaged the country's road infrastructure. The superstructure of the Vaisigano Bridge was submerged, and the protective constructions on the foundations of the substructure were destroyed. In addition, the Leone Bridge, which served as a detour to the Vaisigano Bridge, was impassible due to damage suffered from fallen trees and the like flowing downstream from the mountainous area upstream, and subsidence of the piers due to scouring from floodwaters. Now, large vehicles are forced to detour further upstream to the Lelata Bridge, which adds more than one hour and even greater transportation expenses to the route across the Vaisigano Bridge.

In light of the above, replacing the Vaisigano Bridge is a pressing issue in Samoa, and the Samoan government recently requested grant aid from Japan for its replacement.

This study was conducted to verify the necessity and relevance of the requested aid, to create a preliminary design befitting a grant aid project, devise project plans and roughly calculate the cost of the project.

(3) Overview of Study Results and Project Description

JICA sent a team to Samoa to conduct a preparatory study for cooperation (preliminary design study) from June 4 to July 31, 2016. During the study, the team held discussions with relevant personnel from the Samoan government, and surveyed and investigated longitudinal plans for the bridge and access road, the location of the new bridge and alignment of the access road, the width of the bridge and roads, bridge structures, environmental and social considerations, natural conditions, traffic, circumstances for procuring construction equipment and machinery, operation and maintenance systems and other factors.

In Japan, the team considered the longitudinal dimensions of the bridge and access road, the location of the new bridge, the alignment of the access road, and construction plans based on the results of their study. They also calculated a rough cost of the project and performed other tasks to create a preliminary design. Then, another team was sent to Samoa from December 3-18, 2016 to present an overview of the preliminary design. That team discussed and confirmed the details of the preliminary design and responsibilities of the Samoan government with the Samoan side, and the Samoan side agreed to the design.

Regarding the vertical alignment of the bridge and access road, the road surface of the new bridge will be 1.5 m higher than that of the existing bridge to allow clearance of 1 m above 100-year high tides and 100-year flooding of the Vaisigano River caused by climate change, and to prevent driftwood from hitting girders.

As for the location of the new bridge, the proposal to shift the location 20 m downstream of the existing bridge was chosen because it removes the need to build a temporary bridge or detour roads, and its construction cost is the most economically efficient. It is worth noting that the raising of the bridge will make the hotel difficult to access, but this problem can be addressed by installing a side road.

As for the bridge structure, a three-span PC interconnected pretensioned hollow slab bridge was chosen in light of measures for salt damage and driftwood damage, impact on the surrounding environment, workability and economic efficiency. In addition, the team selected the construction method that offered the shortest duration until completion while striving for economic efficiency.

The plan outline below is the final proposal made based on these choices.

			Dimensions/Specifications
New bridge location			20 m downstream of the existing bridge
Width	Bridge		2 lanes of traffic x 3.5 m = 7.0 m; 2 shoulders x 0.5 m = 1.0 m; 2 sidewalks x 2.5 m = 5.0 m Total = 13.0 m (effective width)
	Access road		2 lanes of traffic x 3.5 m = 7.0 m; 2 shoulders x 0.5 m = 1.0 m; 2 sidewalks x 2.5 m = 5.0 m Total = 13.0 m (effective width)
Bridge structure			Three-span PC interconnected pretensioned hollow slab
Spans, bridge length			3 spans x 25.0 m = 75.0 m
Bridge surface pavement			Hot mix asphalt pavement (80 mm thick for lanes of
A1 abutment Downtown Apia side		Structure	Inverted T-type abutment
		Structural	H = 7 m
		Footing	Cast-in-place pile foundation (1.5-m diameter, L = 40.5
A2 abutment Fagali'i Airport side		Structure	Inverted T-type abutment
		Structural	H = 7 m
		Footing	Cast-in-place pile foundation (1.5-m diameter, L = 40.0
P1 Pier		Structure	Oval wall-type pier
		Structural	H = 10.0 m
		Footing	Cast-in-place pile foundation (1.5-m diameter, L = 37.0
Pier P2		Structure	Oval wall-type pier
		Structural	H = 10.0 m
		Footing	Cast-in-place pile foundation (1.5-m diameter, L = 36.0
Access road		Length	Downtown Apia side: Roughly 199 m; Fagali'i Airport side: Roughly 155.5 m; Apia Port side: Roughly 70 m;
		Pavement	Hot mix asphalt pavement (50-mm surface layer + 50-
Intersection (Fagali'i Airport side)			Roundabout style
Embankments	River	Structure	Inverted T-type retaining wall (right bank: 35 m);
	Sea wall	Structure	Riprap (Downtown Apia side: 120 m; Fagali'i Airport

(4) Project Work Schedule and Rough Project Cost

To implement this plan as a Japanese grant aid project, 10 months would be needed to design the implementation (including tasks related to bidding), and 27.5 months would be required for construction of facilities. In addition, the Samoan side would cover an estimated 34.7 million JPY of the rough project cost.

(5) Project Evaluation

1) Relevance

In light of the following points, it is deemed relevant to implement this project as a Japanese grant aid project.

a) The benefits of the project will reach a considerable number of Samoan citizens in the commercial district in western Apia, eastern Apia and the eastern region of Upolu. (The project will directly benefit 36,700 people in downtown Apia, 62,400 people in northwestern Upolu, and 44,300 people in Upolu and other regions for a total of 143,400 people, and will indirectly benefit 187,800 Samoan citizens.)

b) The project outcomes are urgently needed to facilitate physical distribution and improve the lives of residents. Project outcomes include enhancing the transportation network that comprises Beach Road, the nation's most important arterial highway, and arterial roads Matafagalte Street and Matautu Street; ensuring reliable passage of traffic, facilitating traffic, and reinvigorating the community economy.

c) The Samoan side is able to operate and maintain the bridge and road with its own funds, human resources and technology after the project is completed; excessively advanced technology is not required.

d) The Strategy for the Development of Samoa (SDS) 2012-2016 regards the Plan to Replace Vaisigano Bridge as a priority project, and names two critical challenges for the road sector: the improvement of roads connecting the port, airport and other important points to create a Samoa Economic Corridor, and roads that are resilient against cyclones and other disasters.

e) This project is a priority vehicle regarded as a specific strategy for "improving the reliability of the road network and strengthening it against natural disasters and inclement weather," which are named in the National Infrastructure Plan as critical challenges for the road sector.

f) This project has hardly any negative impact on the environment.

g) This project can be implemented without any particular trouble under the Japanese grant aid system.

h) The new bridge will be a three-span PC interconnected pretensioned hollow slab bridge, which is difficult to design and construct using Samoan technology; it is necessary and advantageous to use Japanese technology.

2) Effectiveness

i) Quantitative Effects

Implementing this project should deliver the following quantitative effects.

Indicator	Standard value (actual 2016 values)	Target value (2023, three years after project completion)
Annual average daily traffic, all vehicles (vehicles/day)	18,839 16,567[1]	17,300
Annual average daily traffic, freight vehicles (vehicles/day)	563	580
Freight vehicle travel time from Apia Port to Vaitele Industrial Zone (min)[2]	16.2	12.9
Transportation capacity: Travelers (people/year)	15,630,000	16,330,000
Transportation capacity: Freight (tons/year)	310,000	320,000

[1]Traffic volume does not include vehicles detoured from the upstream Leone Bridge because of closure due to typhoon damage.

[2]Daytime hours.

ii) Qualitative Effects

Implementing this project should deliver the following qualitative effects.

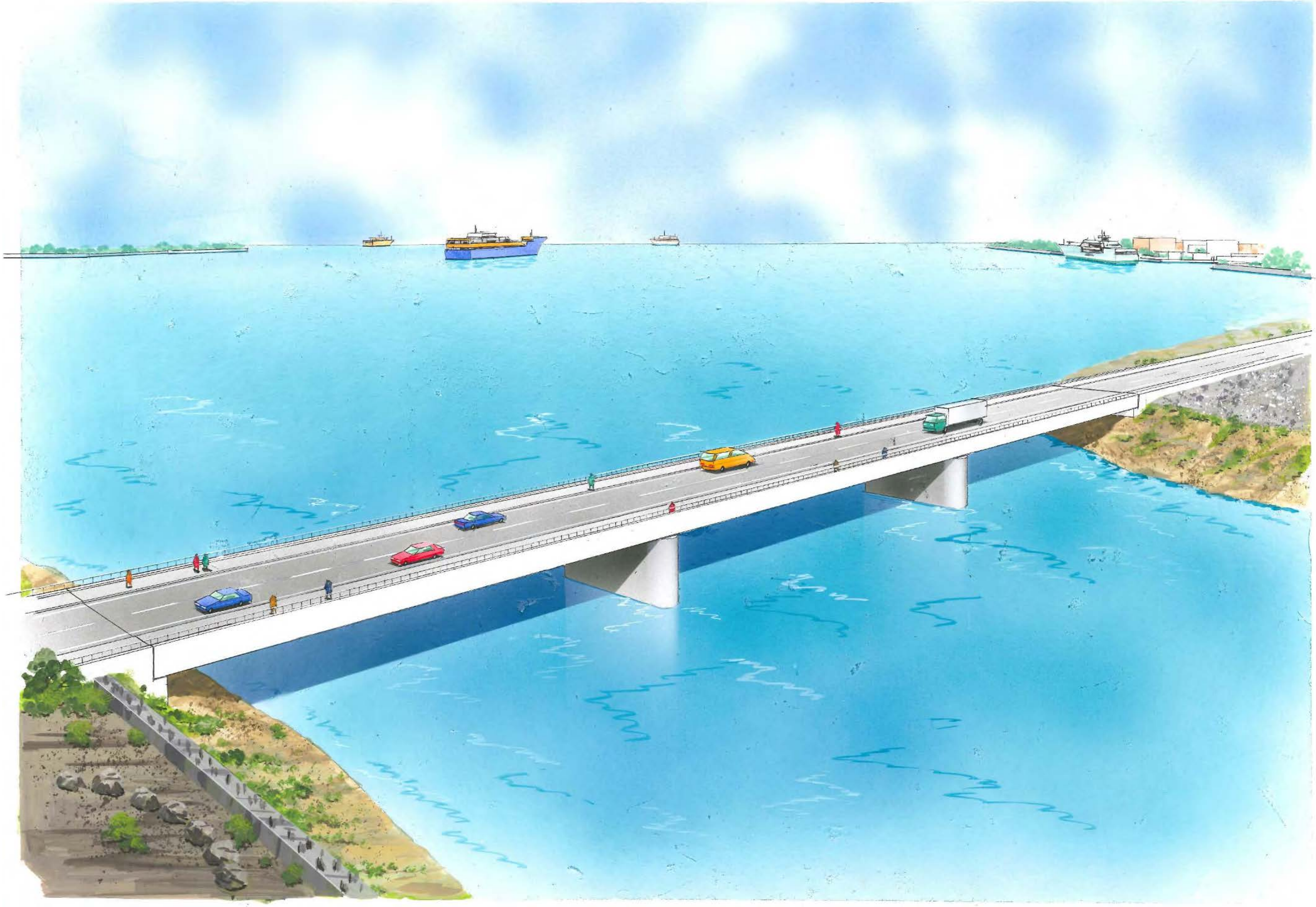
a) Shorten travel time to improve convenience and ensure reliable passage
b) Create disaster-resilient arterial roads
c) Increase load-bearing capacity

In light of the above, this project is deemed highly relevant and effective.

CONTENTS

[Appendices]

Project Location Map



Perspective of the Vaisigano Bridge

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Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
AusAID	Australian Agency for International Development
CBR	California Bearing Ratio
CIF	Climate Investment Fund
EIA	Environmental Impact Assessment
E/N	Exchange of Notes
ERAP	Enhanced Road Access Project
GDP	Gross Domestic Product
GNI	Gross National Income
HIV/AIDS	Human immunodeficiency virus infection / acquired immunodeficiency syndrome
HWL	High Water Level
IDA	International Development Association
IEE	Initial Environmental Evaluation
JICA	Japan International Cooperation Agency
LTA	Land Transport Authority
M/D	Minutes of Discussion
MONRE	Ministry of Natural Resources and Environment
MSL	Mean Sea Lebel
MWTI	Ministry of Works, Transport & Infrastructure
O/D	Outline Design Study
ODA	Official Development Assistance
PC	Prestressed Concrete
PCU	Passenger Car Unit
PPCR	Pilot Programme for Climate Resilience
PRIF	Pacific Region Infrastructure Facility
PUMA	Planning and Urban Management Agency
RC	Reinforced Concrete
SCF	Strategic Climate Fund
SDS	Strategy for the Development of Samoa
UNDP	United Nations Development Programme
WB	World Bank

Chapter 1　Background of the Project

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1-1 Background and Outline of the Request for Grant Aid

The island of Upolu is home to the Samoan capital of Apia and over 140,000 people, which is roughly 80% of the entire population of Samoa. The country contains 1,202 km of roads and 52 bridges, 45 of which are on Upolu. The Vaisigano Bridge is located on a major arterial road that connects the city of Apia to Apia Port (Samoa's only commercial port) and Fagali'i Airport (for interisland flights). The bridge is an important part of the network of roads on Upolu, with an average of 14,300 cars per day passing over it in 2013 (an increase of 1,700 cars per day in the 10 years between 2003 and 2013).

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1-2 Survey on Natural Conditions

1-2-1 Meteorological Surveys

The study team obtained and organized observation data from the area around the planned location of the new bridge (Apia) in an effort to fully understand the meteorological conditions for and in which the bridge and other facilities would be planned, designed, constructed and maintained. Meteorological data for Samoa can be obtained from the Australian government, the Meteorology Division (MET) of the Samoan Ministry of Natural Resources and Environment (MNRE), and private websites.

Table 1-2-1 Meteorological Survey Items and Documents Obtained

Survey Item	Details	Observation Location/Time	Source
Temperature	Mean monthly temperature	Apia/2006-2015 (past 10 years)	Australian government
Humidity	Mean monthly relative humidity	Apia/2011-2015 (past 5 years)	Private website
Rainfall	10-minute rainfall	Nafanua/2011-2015 (past 5 years)	MET
		Afiamalu/2011-2015 (past 5 years)	MET
Tide level	Annual maximum mean low tide	Apia Harbor/1993-2015 (past 23 years)	Australian government
Wind	Speed by hour	Apia/2011-2015 (past 5 years)	Australian government
	Direction by hour	Apia/2011-2015 (past 5 years)	

(1) Temperature

The study team organized mean temperatures from the Apia Observation Station over the past 10 years by month. There is not much difference between high and low temperatures throughout the years; the difference between highs and lows is roughly 9°C. The high temperature over the past 10 years was 34.8°C (April 2011), and the low was 18.6°C (September 2015).

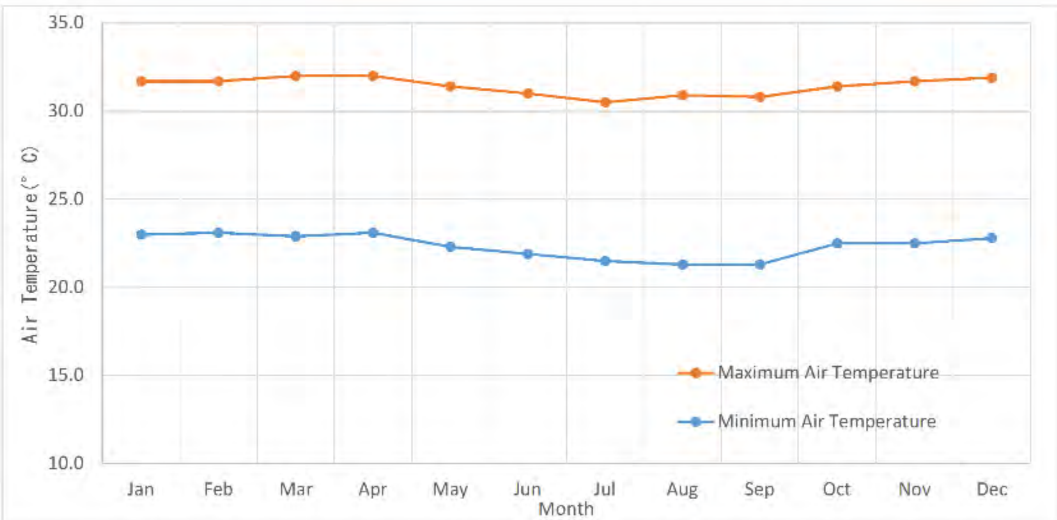


Figure 1-2-1 Mean Maximum Temperature by Month, Past 10 Years

Table 1-2-2 Maximum and Minimum Temperatures, Past 10 Years

Maximum Air Temperature

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
Jan		31.5	30	30.6	31.2	32.4	31.7	33	32.3	32.9	31.7
Feb		31.2	30	30.6	30.8	33.1	31.9	32.2	32.7	32.9	31.7
Mar		31	30.1	32.1	31.6	32.3	32.5	32.6	32.7	33.3	32.0
Apr	30.9	30.9	30.7	30.7	31.5	34.8	32.5	33	32.7	32.7	32.0
May	30.6	30.5	30	30	30.7	33.8	31.9	32	31.6	33	31.4
Jun	29.8	30.5	29.6	29.6	29.1	33.4	32.5	31.7	31.2	32.5	31.0
Jul	29.8	29.8	29.1	29.8	28.9	32.1	31.2	31.3	31.1	31.7	30.5
Aug	29.3	29.5	29.1	29.1	31.2	33.5	32	31.6	31.6	31.6	30.9
Sep	29.9	29.8	29.8	29	31.8	31.3	31.7	31.3	31.6	31.3	30.8
Oct	30.2	30.5	29.4	29.7	33.4	32.2	31.5	32.4	31.9	32.3	31.4
Nov	30.4	30.7	29.8	30.3	33.3	32.8	32.8	32.1	32.1	32.4	31.7
Dec	30.7	30.7	30.1	30.6	34.3	31.8	32.3	32.3	33.4	32.7	31.9

Minimum Air Temperature

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
Jan		22.7	22.5	23	23.7	20.7	22.7	23.5	24	24.1	23.0
Feb		23.5	22.7	22.4	23.8	21	23	24.1	23.6	24	23.1
Mar		21.8	21.8	23.6	23.8	22	22.6	23.2	23.5	23.7	22.9
Apr	22.9	23.4	22.2	23.2	23.1	22.1	23.4	24	23.3	23.8	23.1
May	21.5	22.8	22	23.2	23	21.5	21.7	23.5	22	22.1	22.3
Jun	21.9	22.3	22.4	21.1	22.2	21.6	21.5	22.3	21.6	21.6	21.9
Jul	22	22	20.2	21.1	22.8	21.3	21.7	22.4	20.7	21.1	21.5
Aug	20.3	20.2	20.8	22.2	23.8	20.5	21.5	22.3	21.6	19.7	21.3
Sep	22.4	21	21.9	20.2	20.4	21.9	23	21.7	22.1	18.6	21.3
Oct	22.4	22.6	22.5	21.7	22.2	22.2	23.1	23.3	22.9	21.6	22.5
Nov	22.1	23.1	22.9	22.8	20.7	22.4	24.1	22.8	20.8	23.6	22.5
Dec	23.5	22.8	22.8	21.9	20.9	21.7	24.2	23.8	24.1	22	22.8

(2) Humidity

The figures below show humidity at the Apia Observation Station over the past five years. There is not much difference between high and low humidity values throughout the years; the difference between highs around 95% and lows around 70% is roughly 25%.

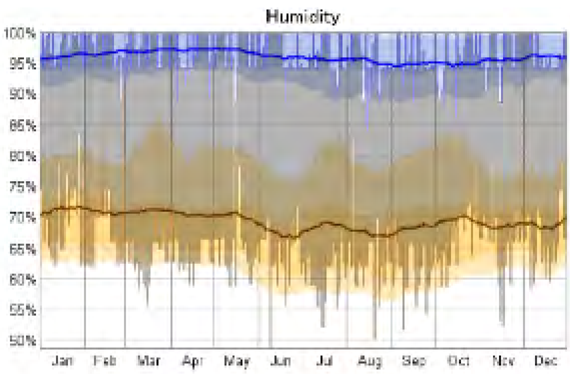


Figure 1-2-2 Humidity in 2011

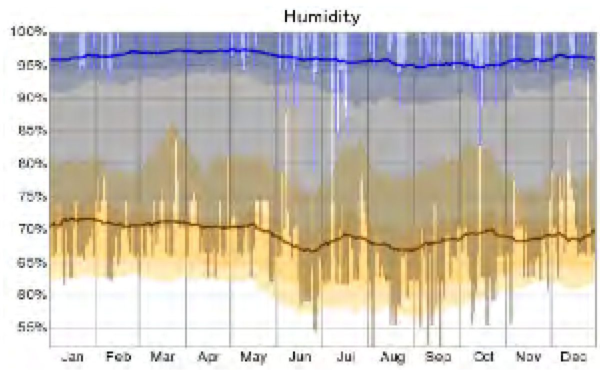


Figure 1-2-3 Humidity in 2012

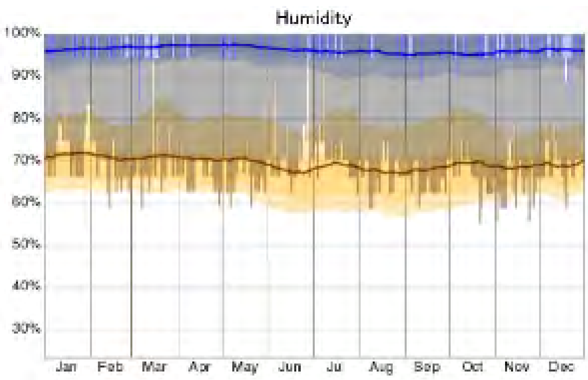


Figure 1-2-4 Humidity in 2013

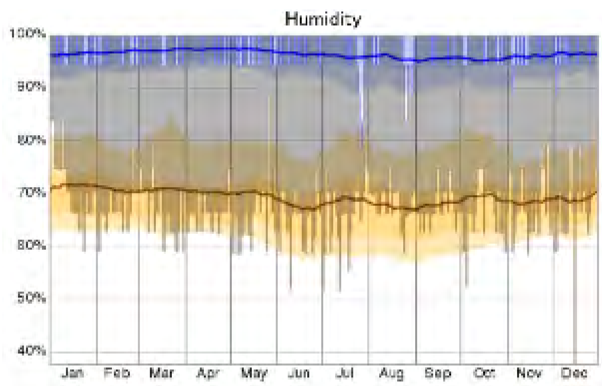


Figure 1-2-5 Humidity in 2014

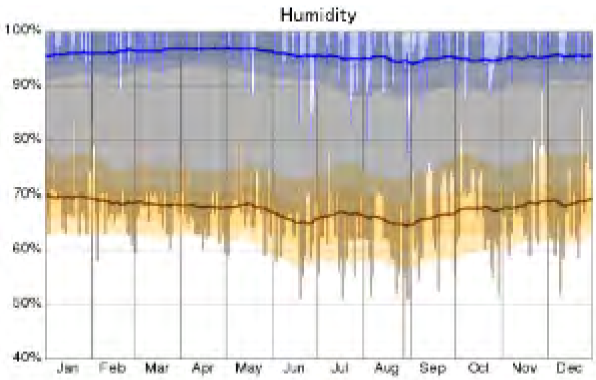


Figure 1-2-6 Humidity in 2015

(3) Rainfall

1) Monthly Rainfall

The study team organized daily rainfall data from two observation stations (Afiamulu and Nafanua) in the Vaisigano River catchment over the past five years by month. In general, the rainy season in Samoa lasts from November to April, and the dry season lasts from May to October. Tropical cyclones affect the country from November to April. Annual rainfall differs significantly by topography; there is a roughly 1,500-mm difference in annual rainfall between the mountainous area (Afiamalu) and the plain (Nafanua). January sees the highest monthly rainfall, while September sees the lowest.

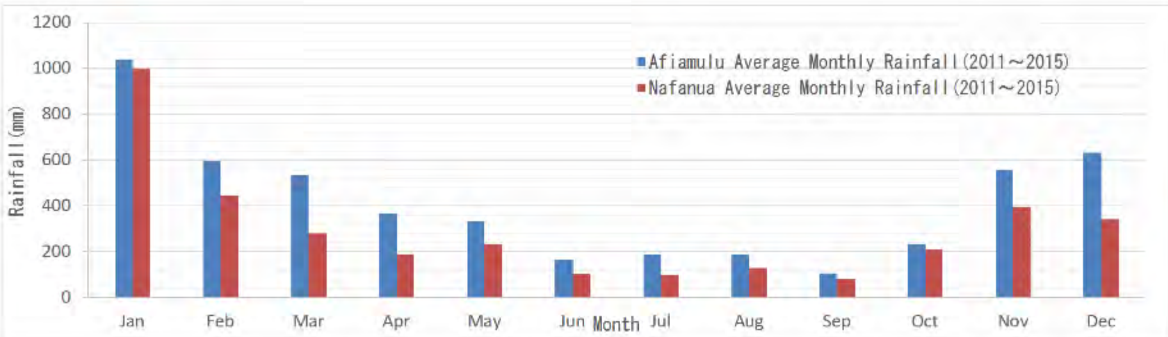


Figure 1-2-7 Monthly Rainfall

Table 1-2-3 Monthly Rainfall

Afiamalu Monthly Rainfall (mm)													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2011	993	541	494	347	No data	No data			No data	No data	No data	328	-
2012	934	659	829	365	458	134	190	57	148	258	224	1293	5551
2013	1172	700	406	483	252	254	177	362	157	199	No data	579	-
2014	1518	557	434	369	282	86	243	167	91	181	569	381	4879
2015	565	525	510	260	344	188	140	165	21	299	881	578	4477
Mean	1036	597	535	365	334	166	188	188	104	234	558	632	4936
Nafanua Monthly Rainfall (mm)													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2011	962	584	152	120	77	90	87	78	96	375	425	No data	-
2012	No data	469	379	No data	No data	31	89	50	69	178	177	595	-
2013	1033	410	281	261	247	186	176	371	171	134	238	No data	-
2014	No data	356	284	262	325	109	130	56	61	166	394	155	-
2015	No data	396	308	110	280	96	7	97	1	183	750	279	-
Mean	997	443	281	188	232	102	98	130	80	207	397	343	3499

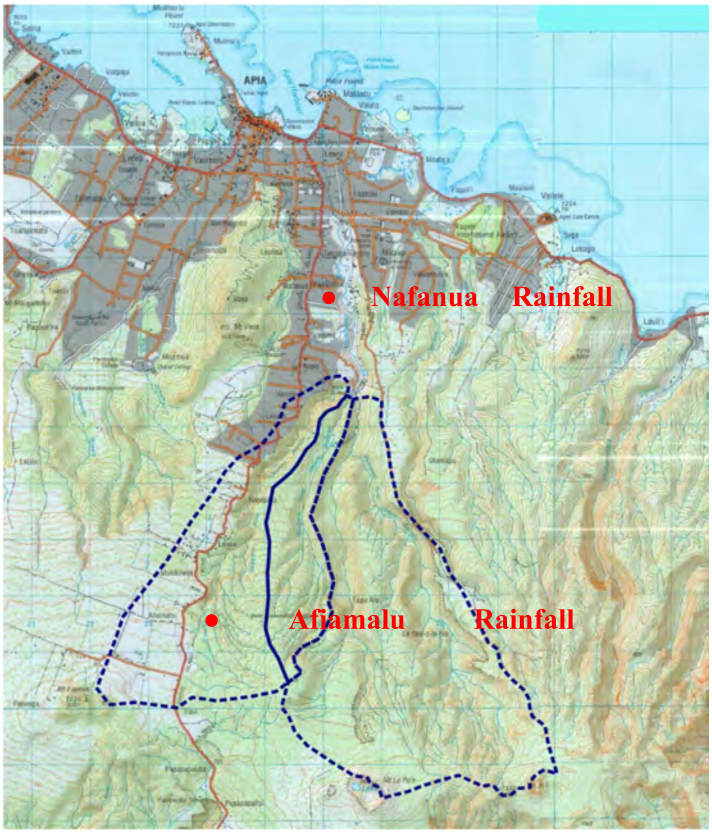


Figure 1-2-8 Observation Station Location Map

2) Mean Rainfall Intensity

The study team organized mean rainfall intensity data from two observation stations (Afiamulu and Nafanua) over the past five years, and compared it to estimated mean rainfall intensity in the Vaisigano River catchment. All the maximum mean rainfall intensity readings from the Afaimulu Observation Station came during Cyclone Evan in 2012, and comparing the mean rainfall intensity for a consecutive three-hour (180-minute) period, in which the outflow volume of the Vaisigano River is at its highest, reveals that Cyclone Evan has a return period shorter than 100 years.

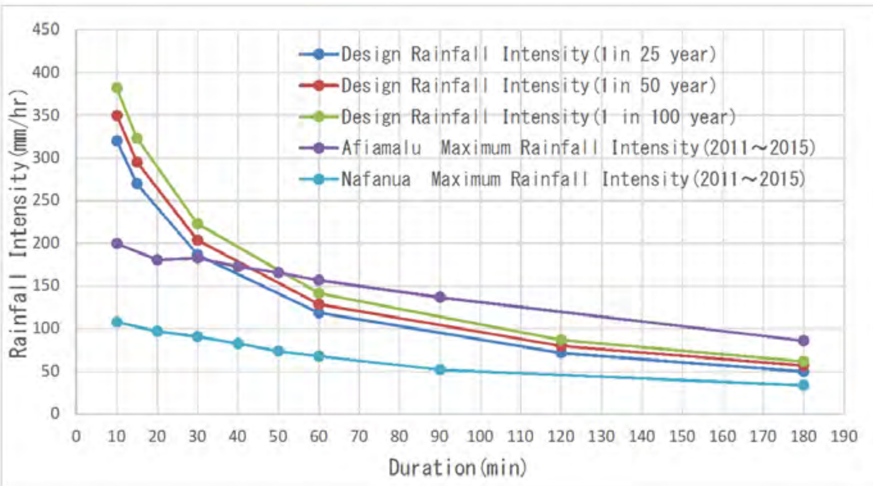


Figure 1-2-9 Mean Rainfall Intensity

Table 1-2-4 Mean Rainfall Intensity

Estimated Mean Rainfall Intensity of Vaisigano River (mm/hr)						
Return period	10min	15min	30min	60min	120min	180min
25	320	270	187	119	72	50
50	350	295	204	129	80	57
100	382	323	223	142	87	62

Estimated Mean Rainfall Intensity of Afiamalu (mm/hr)								
Year	10min	20min	30min	40min	50min	60min	90min	180min
2011	182	91	75	72	71	68	66	62
2012	200	181	183	173	166	157	137	86
2013	127	116	94	81	72	65	44	43
2014	127	91	93	86	78	73	53	39
2015	131	94	83	73	65	62	45	36
Max	200	181	183	173	166	157	137	86

Estimated Mean Rainfall Intensity of Nafanua (mm/hr)								
Year	10min	20min	30min	40min	50min	60min	90min	180min
2011	108	97	91	83	74	68	52	32
2012	108	72	66	58	50	47	47	34
2013	107	75	70	69	67	62	47	27
2014	95	79	68	68	65	59	47	26
2015	96	82	75	69	60	57	43	32
Max	108	97	91	83	74	68	52	34

(4) Tide level

The study team organized tide level data from Apia Harbor over the past 23 years. The mean tide level is CD+0.793 m. The highest tide level is CD+1.737 m recorded on December 13, 2012; this level was observed during Cyclone Evan.

Excluding data from February to October 1998, which appears to be abnormal, the trend of the mean tide level is 0.6 mm, which shows a mean tide level increase of 7 mm (0.0006 x 12) per year.

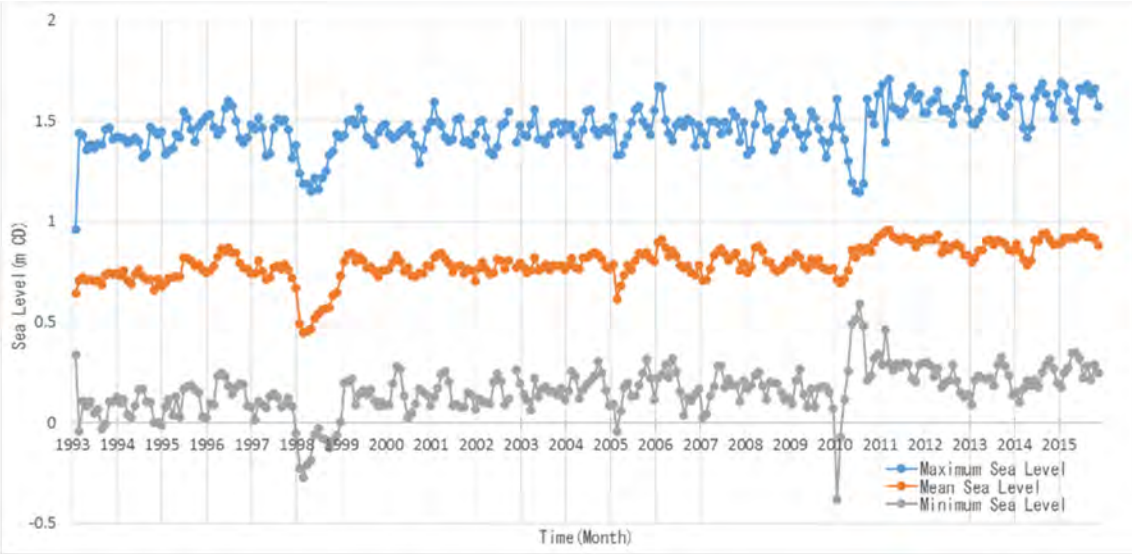


Figure 1-2-10　Monthly High, Mean and Low Tide Levels

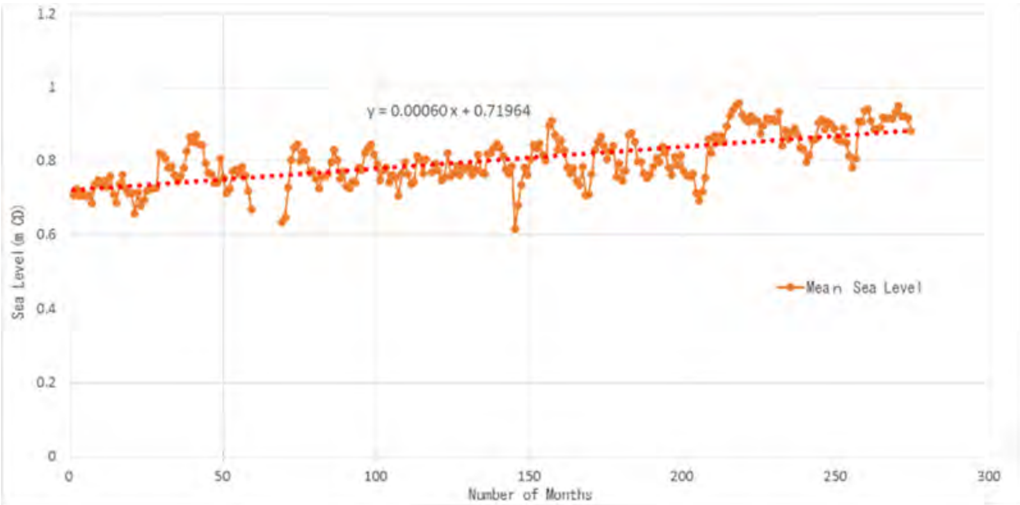


Figure 1-2-11　Trend of the Mean Tide Level

The table below is a list of standard tide levels established for the Apia Harbor Observation Station.

Table 1-2-5 Standard Tide Levels

Name	CD (Chart Datum)	Measured Standard MSL
Highest Astronomical Tide (HAT)	+1.53	+0.78
Mean High Water Springs (MHWS)	+1.28	+0.53
Mean High Water Neaps (MHWN)	+1.09	+0.34
Mean Sea Level (MSL)	+0.79	+0.04
Mean Low Water Neaps (MLWN)	+0.50	-0.25
Mean Low Water Springs (MLWS)	+0.31	-0.44
Lowest Astronomical Tide (LAT)	+0.09	-0.66

*The measured standard MSL is the standard height at the time of measurement: CD+0.75 m.
The MSL from the observation data is CD+0.793 m, a difference of 0.043 m.

Observed Values: 2/1993-5/2016

Observed High Tide Level: CD+1.737 (Measured standard MSL+0.987)

Mean High Tide Level: CD+1.468 (Measured standard MSL+0.718)

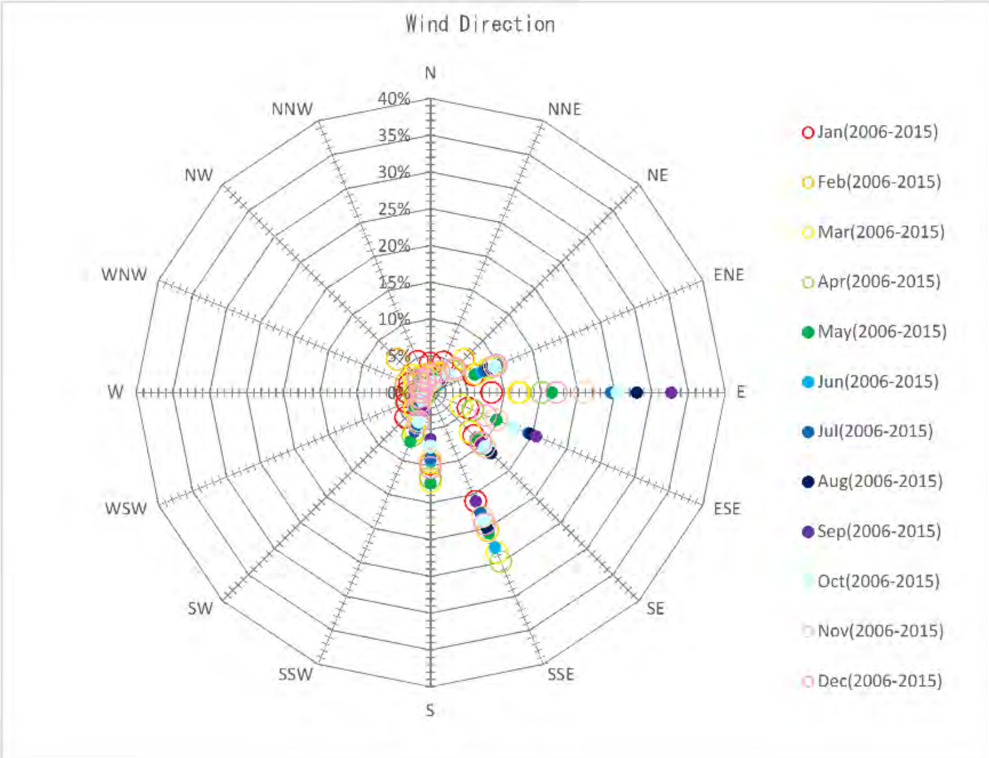
Mean Tide Level: CD+0.793 (Measured standard MSL+0.043)

Mean Low Tide Level: CD+0.157 (Measured standard MSL-0.593)

Observed Mean Low Tide Level: CD-0.381 (Measured standard MSL-1.131)

(5) Wind Direction and Speed

The study team organized mean wind direction and speed data from the Apia Observation Station over the past 10 years. The preeminent wind direction throughout the year is between east and south-southeast. As for wind speeds, the greatest values come from northern winds. The wind blows from the east most frequently, and speeds from that directly are also quite high.



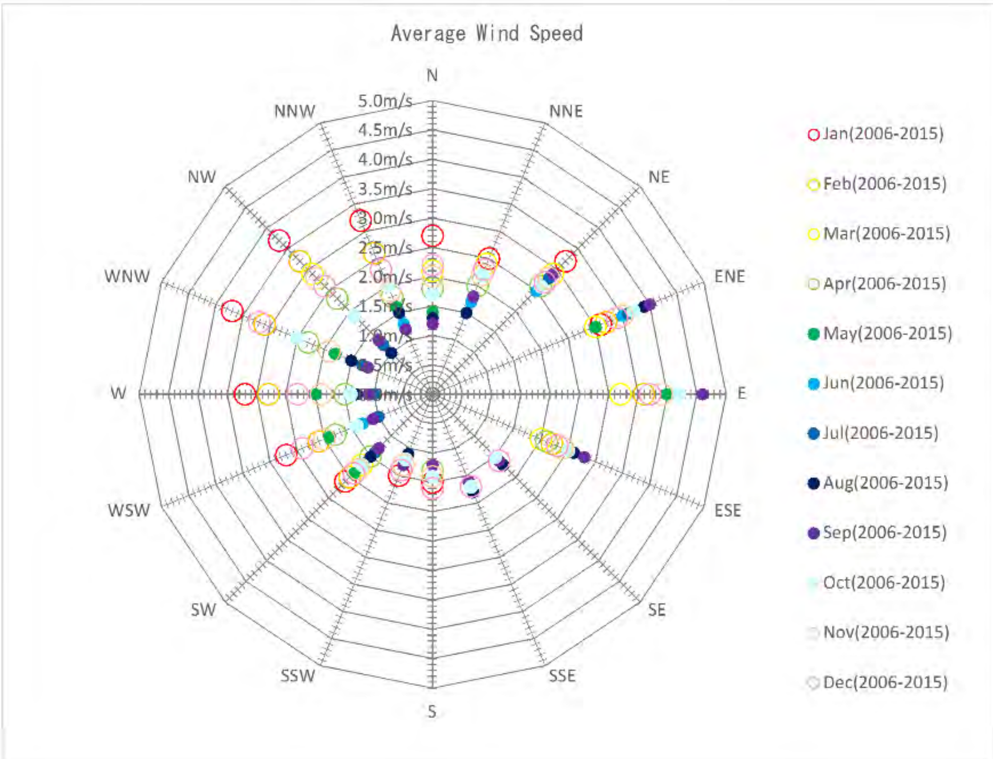


Figure 1-2-12 Wind Direction and Mean Wind Speed by Month, Past 10 Years

1-2-2 Hydrological Surveys

(1) River Channel Design Specifications

The Vaisigano River Channel Plan was implemented from 2014 to 2015 by an Australian consultant (WATER TECHNOLOGY) with funds from the United Nations Development Programme (UNDP). Design specifications are as follows.

- Catchment area: 34.3 km^2
- River length: 12.5 km
- Design scale: 20-year return period
- Rainfall intensity: 47-50 mm/h (three-hour intensity)
- Design discharge rate: 381 m^3/s (Roughly 270 m^3/s after flooding in the upper reach)
- Tide level at mouth: MSL+1.74 m
- Design high water level at new bridge location: MSL+2.2 m
- Design embankment height at new bridge location: MSL+2.7 m (clearance of 0.5 m)

Sources:

- EU EDF 8 – SOPAC Project Report 69c
- Vaisigano_Update_Flood_Study - Volume 1 Report
- Vaisigano_Update_Flood_Study - Volume 2 Report
- Vaisigano_Update_Flood_Study - Volume 3 Report
- Vaisigano river - Stage 1 Preliminary Revetment Investigation
- Vaisigano river - Stage 2 Preliminary Revetment Investigation
- Vaisigano river - Stage 3 Preliminary Revetment Investigation

The following are excerpts of specifications from these sources. As described previously, the design scale for determining bridge specifications is a return period of 100 years. The design discharge rate is 1,010 m^3/s (roughly 680 m^3/s after flooding in the upper reach), and the design high water level at the location of the new bridge is MSL+2.7 m.

1) Catchment Area and River Length

The figure below depicts the Vaisigano River catchment.

The catchment area is 34.3 km^2, and the river length is 12.5 km.

The upper reach is divided into three catchments: Eastern, Central and Western.

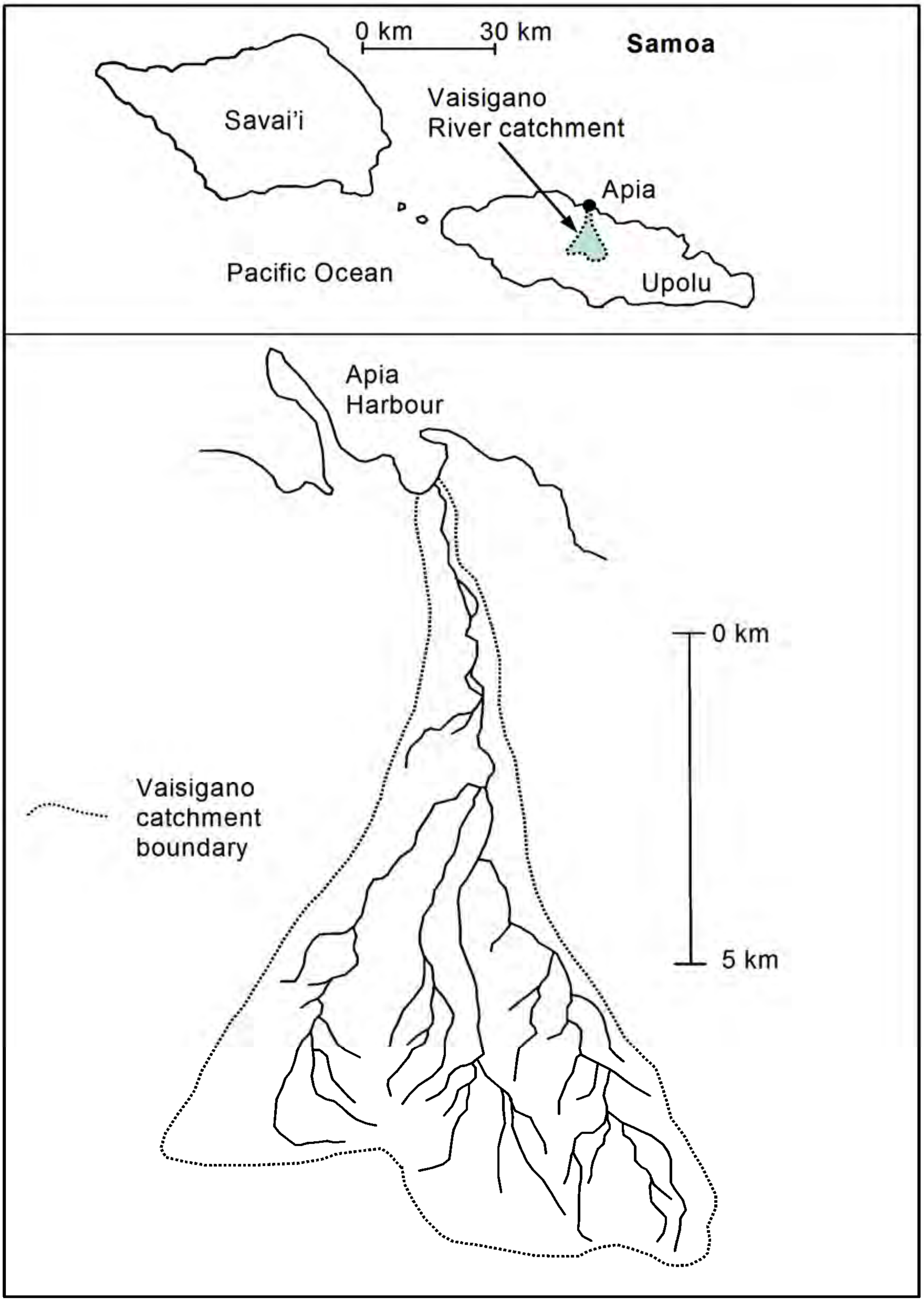


Figure 1-2-13 Catchment Area and River Length

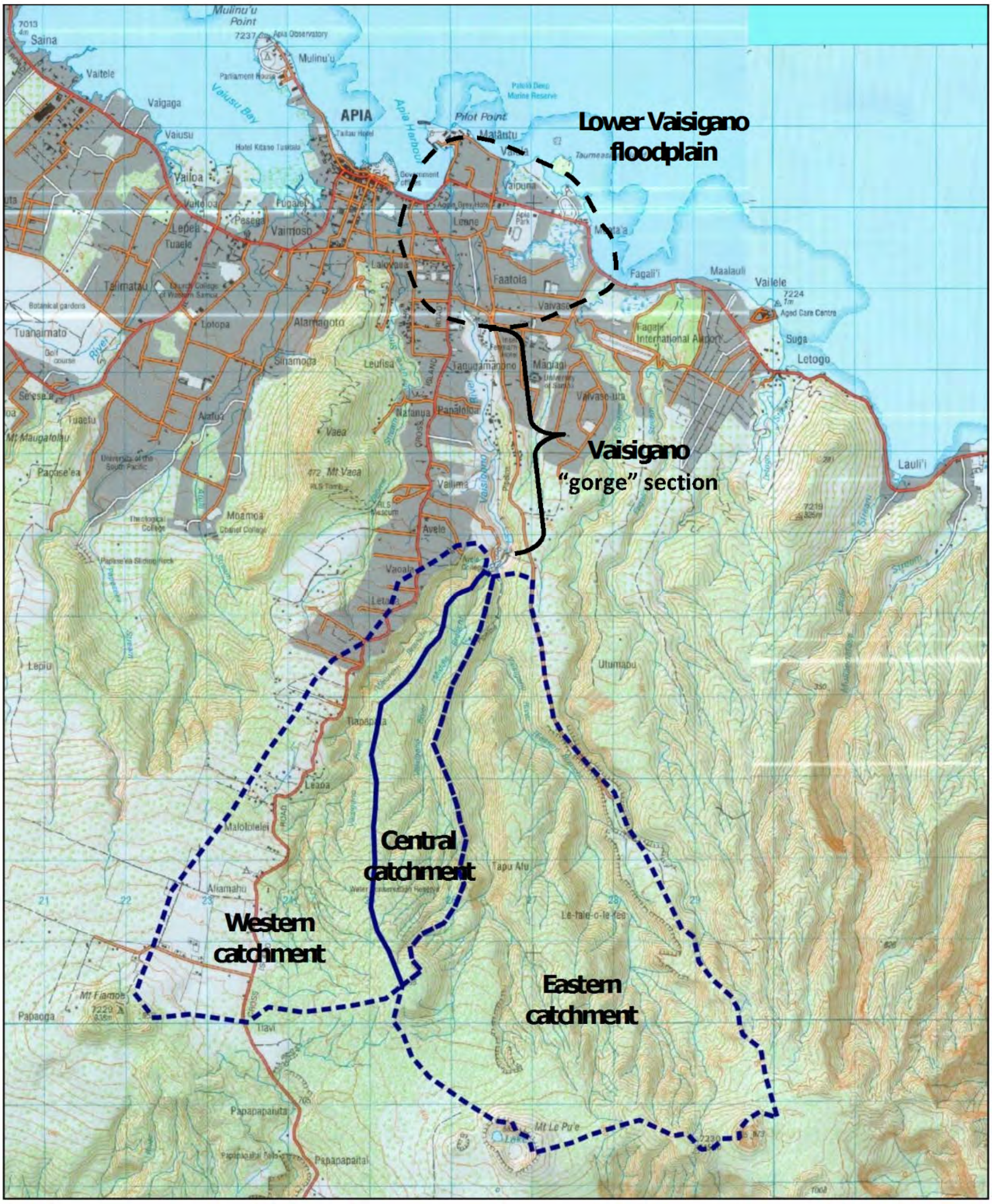


Figure 1-2-14 Upper Reach Catchment Divisions

2) Design Scale

No design scale was set for the river itself, but the use of a 20-year return period as the design scale is deemed relevant for the following reasons:

- Interviews with MNRE resulted in the use of a 20-year return period for the design scale of the embankments from the perspectives of land acquisition, aesthetic appeal and economic efficiency.
- MNRE is able to extend this construction work from the Vaisigano Bridge to the Leone Bridge (roughly 800 m), but will not be able to complete an embankment capable of functioning through 20-year events unless future construction work is done from the Leone Bridge to the Lelata Bridge (roughly 1,300 m).
- In light of this fact, it is highly unlikely that the embankment can be improved within the service lives of the bridges to function through events with return periods shorter than 20 years.
- Hazard maps, flood projections, alerts and other non-technical measures continue to improve, and should enable a proper response to floods that occur more often than once every 20 years.

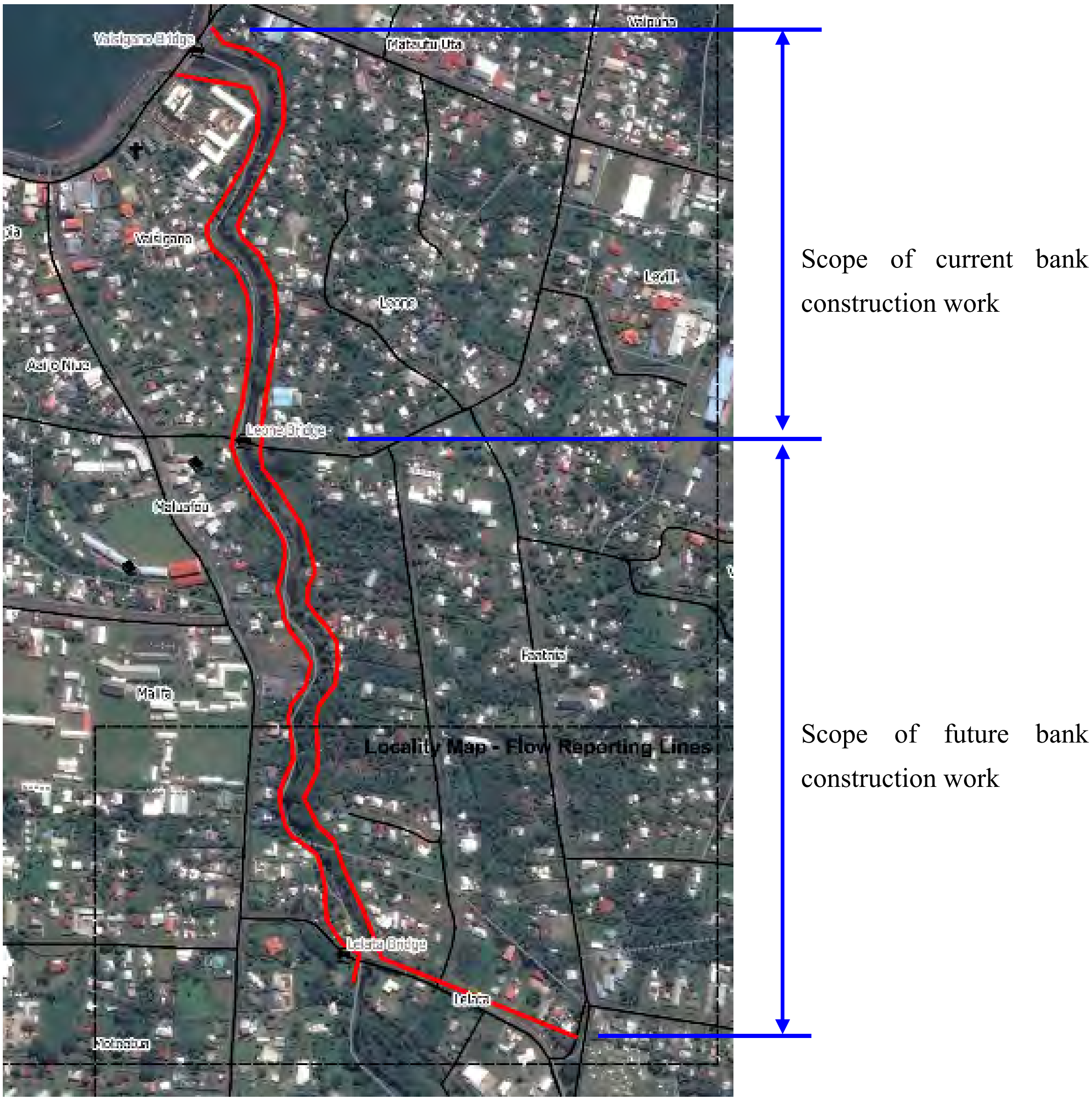


Figure 1-2-15 Scope of Bank Construction Work

3) Rainfall Intensity

The table below shows mean rainfall intensity for each return period and duration of rainfall.

According to the table, the longest duration of rainfall that produces the highest discharge rate for the Vaisigano River is three hours, and the three-hour rainfall intensity of a 20-year event is 47-50 mm/h.

The three-hour rainfall intensity for a 100-year event (the same design scale used during the bridge design) is 62 mm/h.

It is worth noting that this table was created in 2008, and does not account for Cyclone Evan, which struck in December 2012.

Table 1-2-6 Mean Rainfall Intensity by Duration of Rainfall and Return Period

1 hour	90	105	119	129	142
2 hours	57	66	72	80	87
3 hours	40	47	50	57	62

(source Punivalu 1983)

4) Design Discharge Rate

The design discharge rate is not calculated from rainfall intensity; rather, it is calculated from water levels observed at gauging stations over the 38 years from 1976 to 2013. Gauging stations are set up on the eastern side of the catchment. For the central and western parts of the catchment, which do not have gauging stations, discharge rates were calculated by multiplying the observed data from the eastern side by 1.7 to reflect the proportional area. In addition, a multiplier of 1.1 was used for the values below in consideration of increased rainfall in the year 2100.

Therefore, the design discharge rate for a 20-year event is 381 m^3/s (204 m^3/s x 1.7 x 1.1).

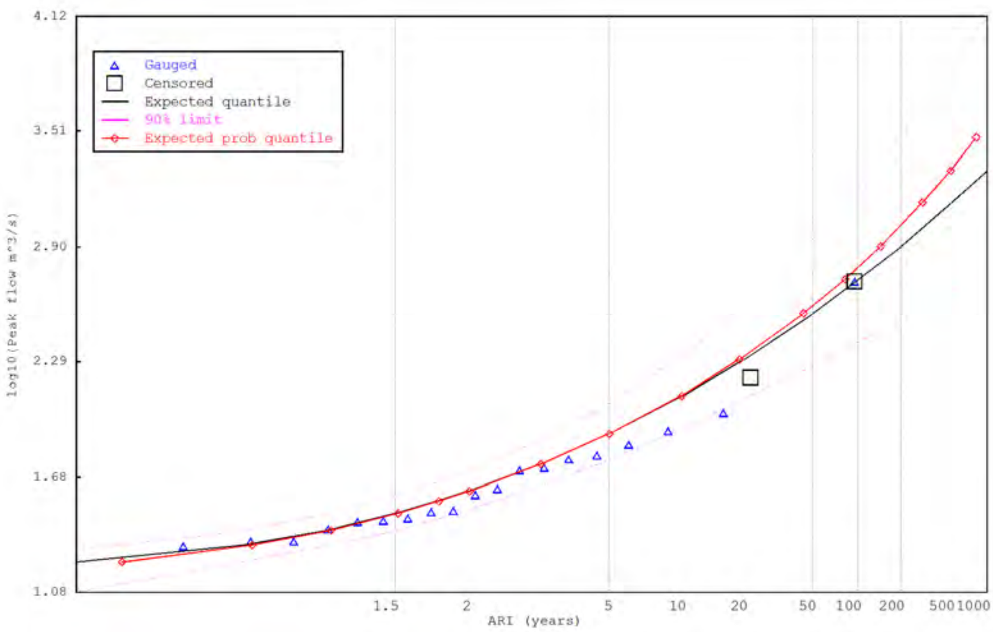


Figure 1-2-16 Design Discharge Rate by Return Period, Calculated from Gauging Station Water Levels

(Prior to applying 1.7 multiplier for proportional area, and 1.1 multiplier for increased rainfall in the year 2100)

Table 1-2-7 Design Discharge Rate by Return Period, Calculated from Gauging Station Water Levels
(Prior to applying 1.1 multiplier for increased rainfall in the year 2100)

Return Period (years)	Design event conditions at the Alaoa East Gauge (Vaisigano eastern catchment only)		Design Flows at EPC Weir (including eastern, central and western catchments) (m^3/s)
	Flow (m^3/s)	Level (m gauge datum based on extended rating curve)	
1	17	1.7	29
2	41	2.6	69
5	82	3.2	139
10	131	3.6	222
20	204	4.0	346
50	358	4.8	608
100	542	5.4	921
200	814	6.4	1,384
500	1,382	7.8	2,350
1,000	2,052	9.3	3,489

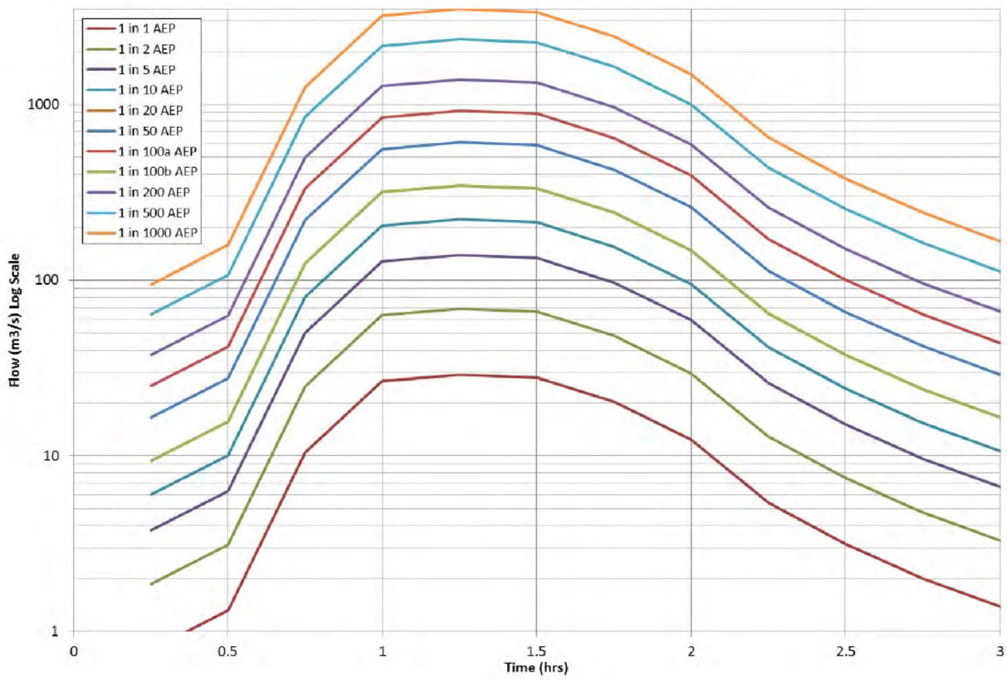


Figure 1-2-17 Hydrograph of Design Discharge Rate by Return Period, Calculated from Gauging Station Water Levels
(Prior to applying 1.1 multiplier for increased rainfall in the year 2100)

5) Tide Level at River Mouth

The tide level was set at MSL+1.74 m, which is the high tide level of MSL+1.00 m plus 0.74 m to account for sea level rise by the year 2100 due to climate change. Wave setup was not accounted for.

6) Design High Water Level and Design Embankment Height

The design high water level was calculated using flood inundation analysis based on a two-dimensional unstable flow model using TUFLOW. As shown in the figure below, the level at the Vaisigano Bridge is MSL+2.2 m.

The design embankment height is set at MSL+2.7 m to provide clearance of 0.5 m.

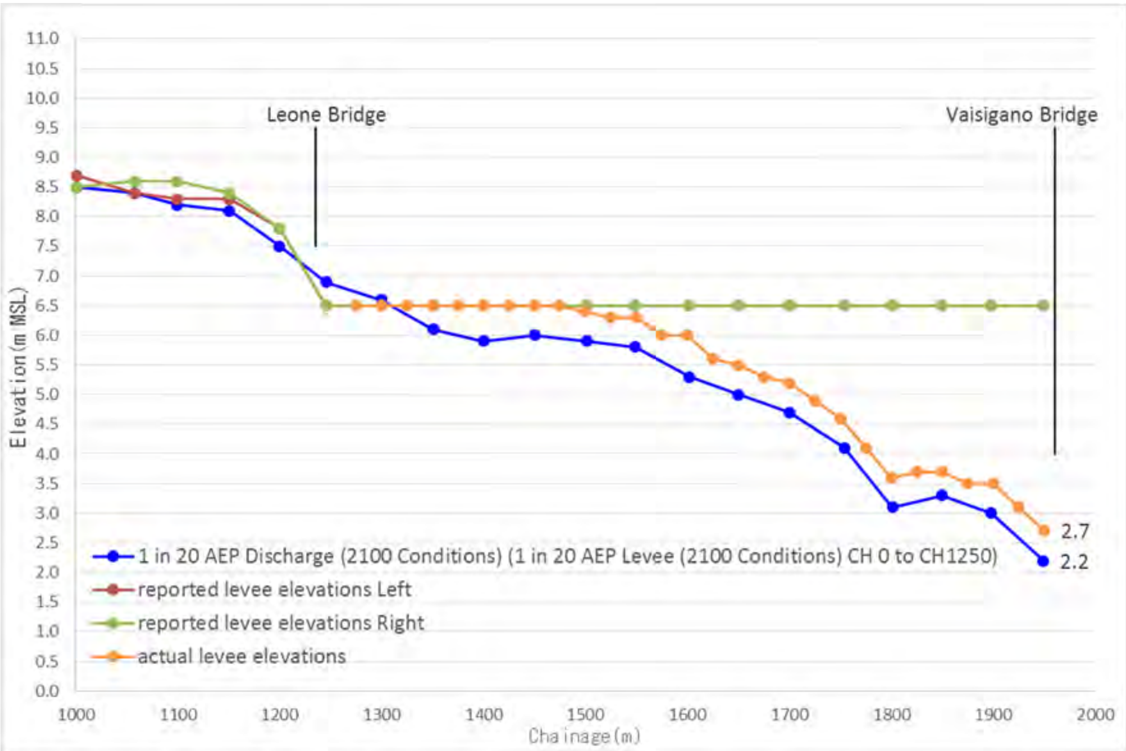


Figure 1-2-18 Water Level for 20-Year Event, and Longitudinal Diagram of Embankments

(2) Design Specifications for Embankment Improvement

See Section 3-2-2-5-5 (2) Vaisigano River Embankment Improvement Plan for design specifications for embankment improvement.

(3) River Conditions

As described previously, the upper reach of the Vaisigano River is divided into Eastern, Central and Western catchments, and three rivers converge at the Alaoa Water Treatment Plant around 5 km from the mouth of the Vaisigano River. The flow capacity of the river is low downstream of the confluence, and floods with return periods shorter than five years result in outflow from the Vaisigano River into other catchments upstream of the Lelata Bridge (roughly 1.5 km from the mouth), which increases the inundation area of Apia.

Thus, embankment improvement is planned for the section from the Lelata Bridge to the river mouth.

The longitudinal slope of the riverbed differs significantly from section to section:

Section	Bed Slope	Remarks
Mouth (Vaisigano Bridge) to 0.5 km	1/530	Results of surveys for this study
0.5 km to 0.75 km (Leone Bridge)	1/170	Results of surveys for this study
0.75 km (Leone Bridge) to 1.02 km	1/210	Results of 2006 surveys
1.02 km to 1.65 km (Lelata Bridge)	1/50	Results of 2006 surveys

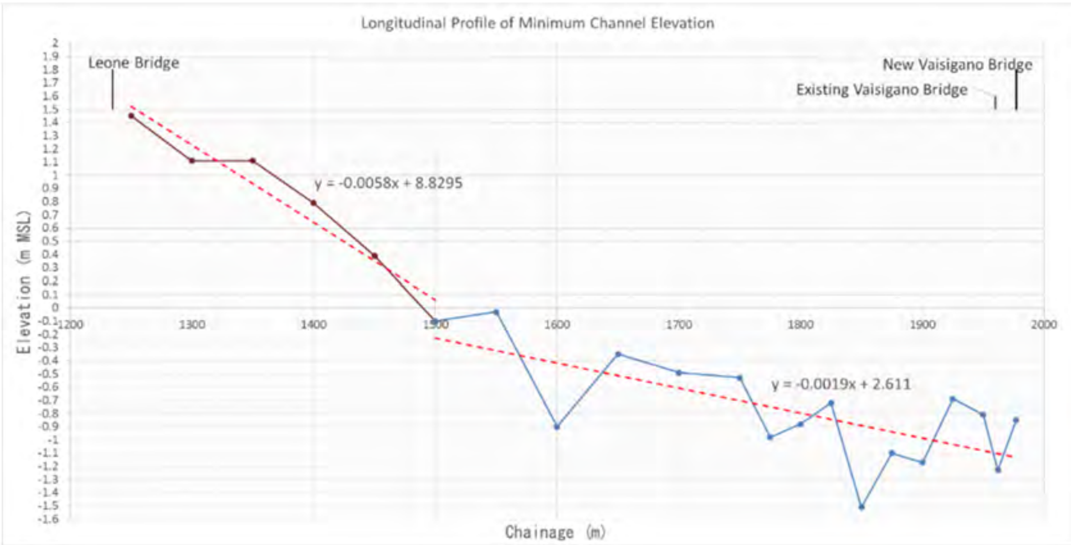


Figure 1-2-19 Results of Longitudinal Surveys for this Study

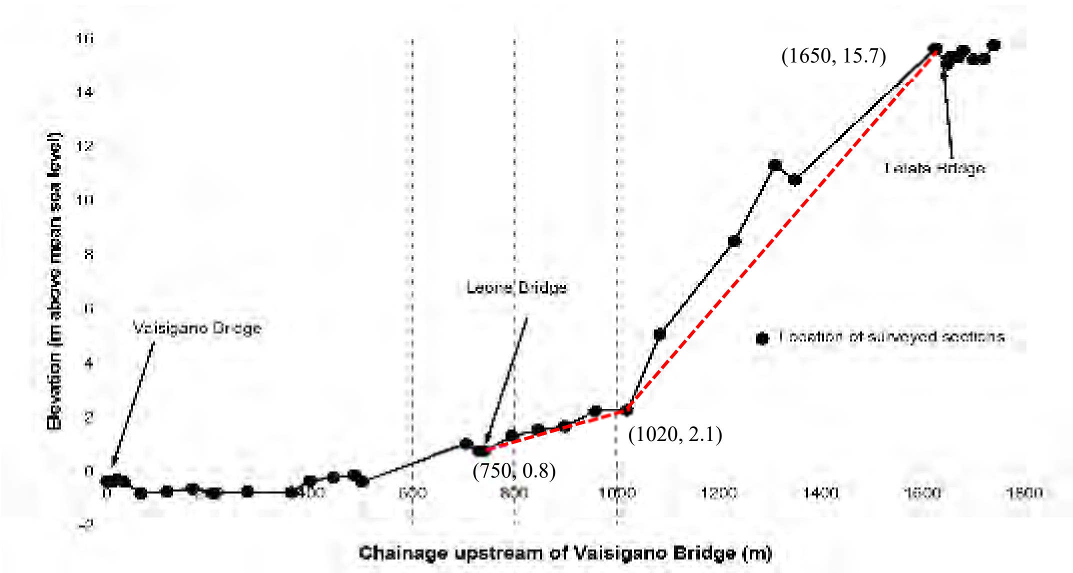


Figure 1-2-20 Results of 2006 Longitudinal Surveys

1) Upper Reach

The upper reach is a natural, pool-and-drop river that features levels composed of bedrock and boulders. Mountains on each side of the river are steeply sloped, and create an environment that produces large volumes of driftwood as seen during Cyclone Evan.

Downstream of the fixed weir roughly 250 m upstream of the treatment plant

Upstream of the fixed weir roughly 250 m upstream of the treatment plant

Picture 1-2-1 Existing Condition of Upstream Area

2) Lower Reach (Downstream of the Leone Bridge)

The riverbank is a riprap embankment. The riverbed near the Leone Bridge comprises rough gravel that changes to fine sand near the mouth as the longitudinal slope levels out. Sandbars do not form in the straight sections, but they do form on the inner parts of riverbends. Sandbars have formed on each bank below the Vaisigano Bridge, and they connect to the sandy beach along the shoreline.

Figure 1-2-21 Location Map of Picture of Downstream Area

No. 1 Lower Reach → Upper Reach

Leone Bridge Abutment :28m Interspace: 3

No. 1 Upper Reach → Lower Reach

No. 1

Riverbed material near Leone Bridge

No. 2 Upper Reach → Lower Reach

No. 3 Upper Reach → Lower Reach

No. 3 Lower Reach → Upper Reach

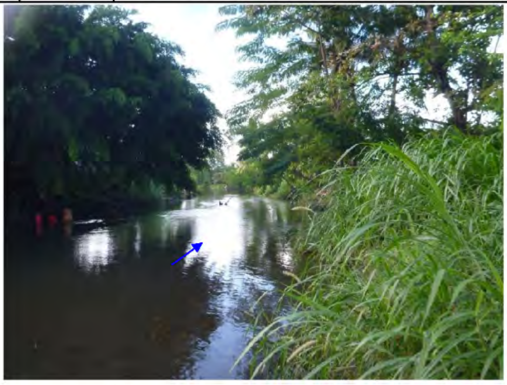
No. 4 Upper Reach → Lower Reach

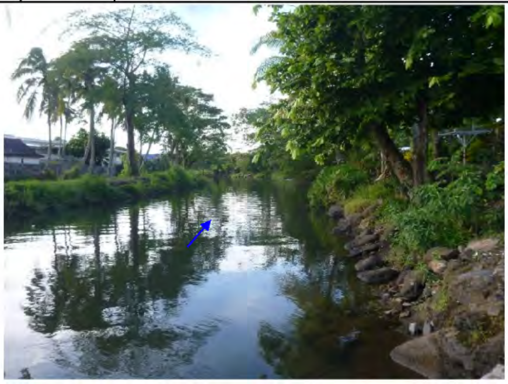
No. 4 Lower Reach → Upper Reach

Picture 1-2-2 Existing Condition of Downstream Area(1/3)

No.	5	Upper Reach → Lower Reach	No.	5	

No.	5	Upper Reach → Lower Reach	No.	6	Upper Reach → Lower Reach





No.	7	Upper Reach → Lower Reach	No.	7	Lower Reach → Upper Reach

No.	8	Upper Reach → Lower Reach	No.	8	Lower Reach → Upper Reach

Picture 1-2-3 Existing Condition of Downstream Area(2/3)

No.	9	Upper Reach → Lower Reach	No.	9	Lower Reach → Upper Reach

No.	10	Upper Reach → Lower Reach	No.	11	Left bank

Flap gate at Sheraton Hotel

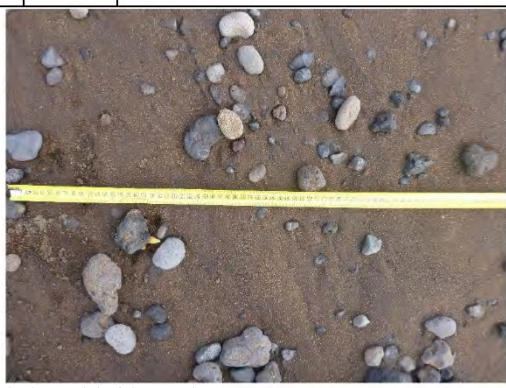
No.	12	Lower Reach → Upper Reach	No.	12	Lower Reach → Upper Reach

Vaisigano Bridge Bridge length: 75m Intervals: 7

Vaisigano Bridge Bridge length: 75m Intervals: 7

No.	12	Lower Reach → Upper Reach	No.	12	

Vaisigano Bridge Bridge length: 75m Intervals: 7



Riverbed material of the mouth

Picture 1-2-4 Existing Condition of Downstream Area(3/3)

3) Driftwood

Fallen trees that could become driftwood exist in the river throughout the upper and lower reaches.

Length: Aprox. 8m Diameter: Aprox. 1m

Diameter: Aprox. 1m


Length: Aprox. 4.3m


Length: Aprox. 8m


Length: Aprox. 8m Diameter: Aprox. 0.9m


Length: Aprox. 10m


Length: Aprox. 11m

Length: Aprox. 11m Diameter: Aprox. 1m

Picture 1-2-5 Drift Wood in River Channel

(4) Floods

A two-dimensional unstable flow model using TUFLOW was used to recreate the flooding that occurred during Cyclone Evan in December 2012, and a report organized evidence of water levels, rainfall and damage.

Below are the results of the recreated flooding and excerpts from the report.

1) Results of Recreated Flooding

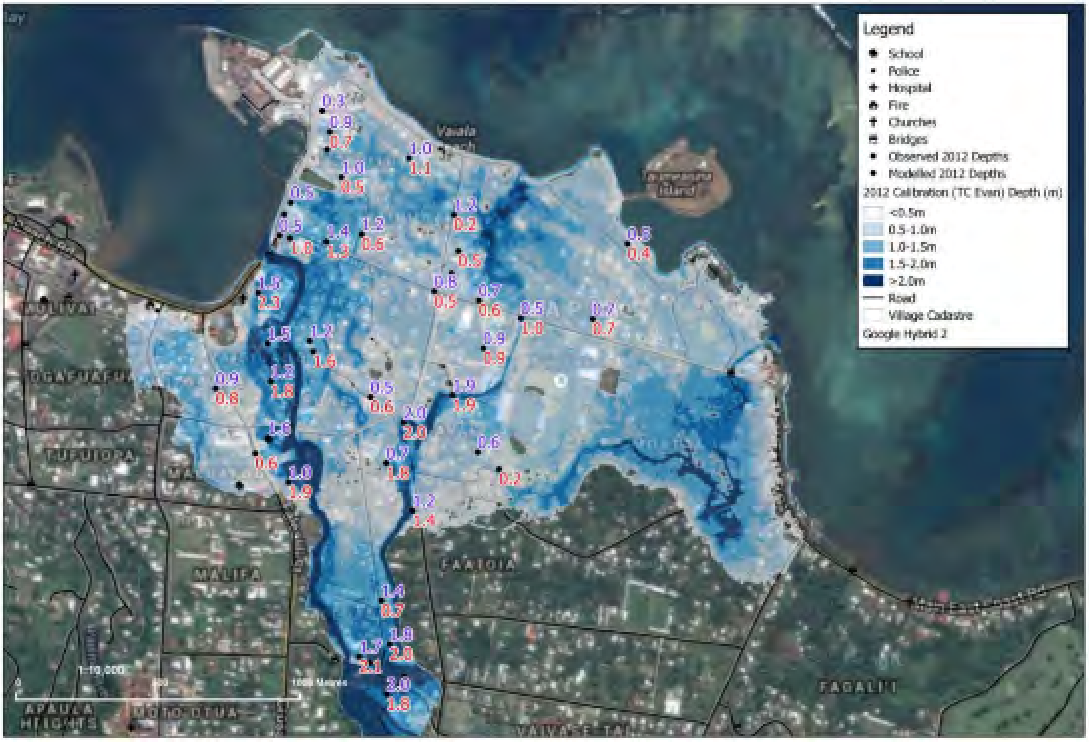


Figure 1-2-22 Recreation of Inundation Area during Cyclone Evan

2) Historical Inundation Depths

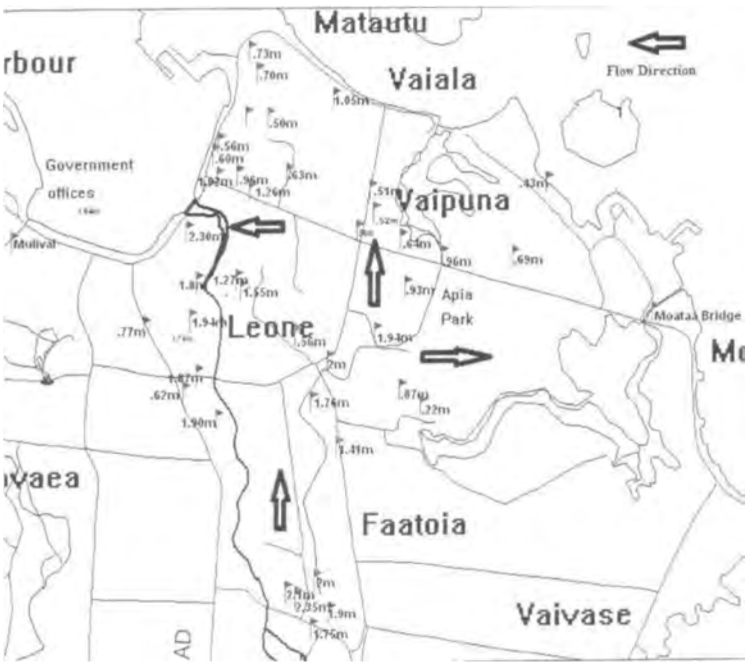


Figure 1-2-23 Historical Inundation Depths

During this study, the study team surveyed the ground levels of points where inundation depths were surveyed during Cyclone Evan in December 2012 and the floods of 2001, and assigned water levels to those points.

The figure below shows the results.

1～40 : Water Level of Flooding 2012(EVAN)

40～50 : Water Level of Flooding 2001

Figure 1-2-24 Historical Inundation Levels

3) Rainfall

Rainfall Station	1-day Fall (mm)	Hourly Rainfall for Afiamalu	(mm)
APIA	144.0	12-1	56
NAFANUA	207.0	1-2	65
AFIAMALU	413.8	2-3	85
ALAOA	467.0	3-4	30
FALEOLO	212.0		
TOGITOGIGA	205.4		

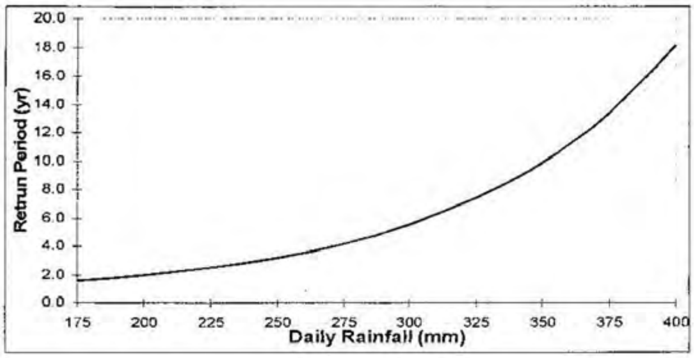


Figure 1-2-25 Precipitation at Cyclone Evan

4) Damage

Figure 5 Above SWA water treatment station at Alaoa

Figure 6 Magiagi area

Figure 7 Maagao area

Picture 1-2-6 Damege Caused by Cyclone Evan (1/2)

Figure 8 Damage to Houses and Cars at Lelata

Figure 9 Traditional Houses at Maagao

Figure 10 Damaged Bridge on Faatoia Road

Figure 12 Landslides in upper catchments

Figure 13 Logs and Debris accumulated at the SWA site

Picture 1-2-7 Damege Caused by Cyclone Evan (2/2)

(5) Consideration of Design High Water Level for Bridge Design

The design high water level of the Vaisigano River was determined in order to determine girder height for the Vaisigano Bridge.

1) Conditions for Consideration

a) Water Level Calculation Method

One-dimensional non-uniform flow calculation using HEC-RAS

b) Design Scale

The design scale during river improvement differs from that during bridge design; the design scale during bridge design is greater. Therefore, the river improvement design scale and required measures (building embankments, widening the channel, excavating the riverbed) will be determined first, and the design high water level for the bridge design will be the water level during floods in the improved river cross-section.

The design scale for river improvement was set to a 20-year return period during this study for the following reasons:

- MNRE's design scale for embankment improvement was set to a 20-year return period in light of feasibility, economic efficiency, environmental performance, land problems and other factors.
- Embankment improvement is planned through the upstream side of the Leone Bridge, and the renovation of the Lelata Bridge was also required, but the scope of the construction work this time only extends to the Leone Bridge.
- In light of these circumstances, it is extremely unlikely that the embankment can be improved within the service lives of the bridges to function through events with return periods shorter than 20 years.

In addition, the design scale during the bridge design was set to a 100-year return period in light of the type, importance level and other characteristics of the bridge with reference to the New Zealand Bridge Manual shown below.

Table 1-2-8 Annual Probability of Exceedance for Bridge Plan

Bridge categorisation	Importance level (as per AS/NZS 1170.0[2])	Bridge permanence*	Annual probability of exceedance for the ultimate limit state		Annual probability of exceedance for the serviceability limit state	
			ULS for wind, snow and floodwater actions	ULS for earthquake actions	SLS 1 for wind, snow and floodwater actions	SLS 2 for floodwater actions
Bridges of high importance to post-disaster recovery (eg bridges in major urban areas providing direct access to hospitals and emergency services or to a port or airport from within a 10km radius). Bridges with a construction cost exceeding $15 million (as at December 2012)†.	4	Permanent	1/5000	1/2500	1/25	1/100
		Temporary	1/1000	1/1000	1/25	1/100
Bridges on the primary lifeline routes (or similar new alignments) identified in figures 2.1(a), 2.1(b) and 2.1(c), categorised for the purposes of this manual on the basis of: • volume of traffic carried • route strategic importance (eg interconnection of centres of population) • redundancy of the regional roading network.	3	Permanent	1/2500	1/2500	1/25	1/100
		Temporary	1/500	1/500	1/25	-
Normal bridges, not falling into other levels. Footbridges.	2	Permanent	1/1000	1/1000	1/25	1/50
		Temporary	1/250	1/250	1/25	-
Bridges on no-exit or loop rural roads, not serving a through road function, and serving populations <50.	1	Permanent	1/500	1/500	1/25	1/25
		Temporary	1/50	1/50	-	-

Notes:
* Permanent bridge: design working life = 100 years. Temporary bridge: design working life ≤ 5 years.
† Values shall be adjusted to current value. For the relevant cost adjustment factor refer to the NZ Transport Agency's (NZTA) Procurement manual, Procurement manual tools, Latest cost index values for infrastructure, table 1 Cost adjustment factors, part 3 – Bridges[3].

The Vaisigano Bridge is the shortest route from central Apia to Apia Port and the domestic airport, and has an importance level of 4 as described on the table above.

c) Discharge Rate in the River Channel

The discharge rate for 100-year events was already considered during the embankment improvement design; the same will be used in this study.

Flood inundation analysis revealed that water pools, overflows, and otherwise does not flow out through the channel upstream of the Lelata Bridge, and clearly showed that the discharge rate in the Vaisigano River channel is lower than the total outflow. The study team used water level calculations from a 50-year flood (sectional area and flow speed) to estimate the difference between the total outflow and the discharge rate in the channel.

The resulting estimate is a channel discharge rate of two-thirds the total outflow as shown in the figure below.

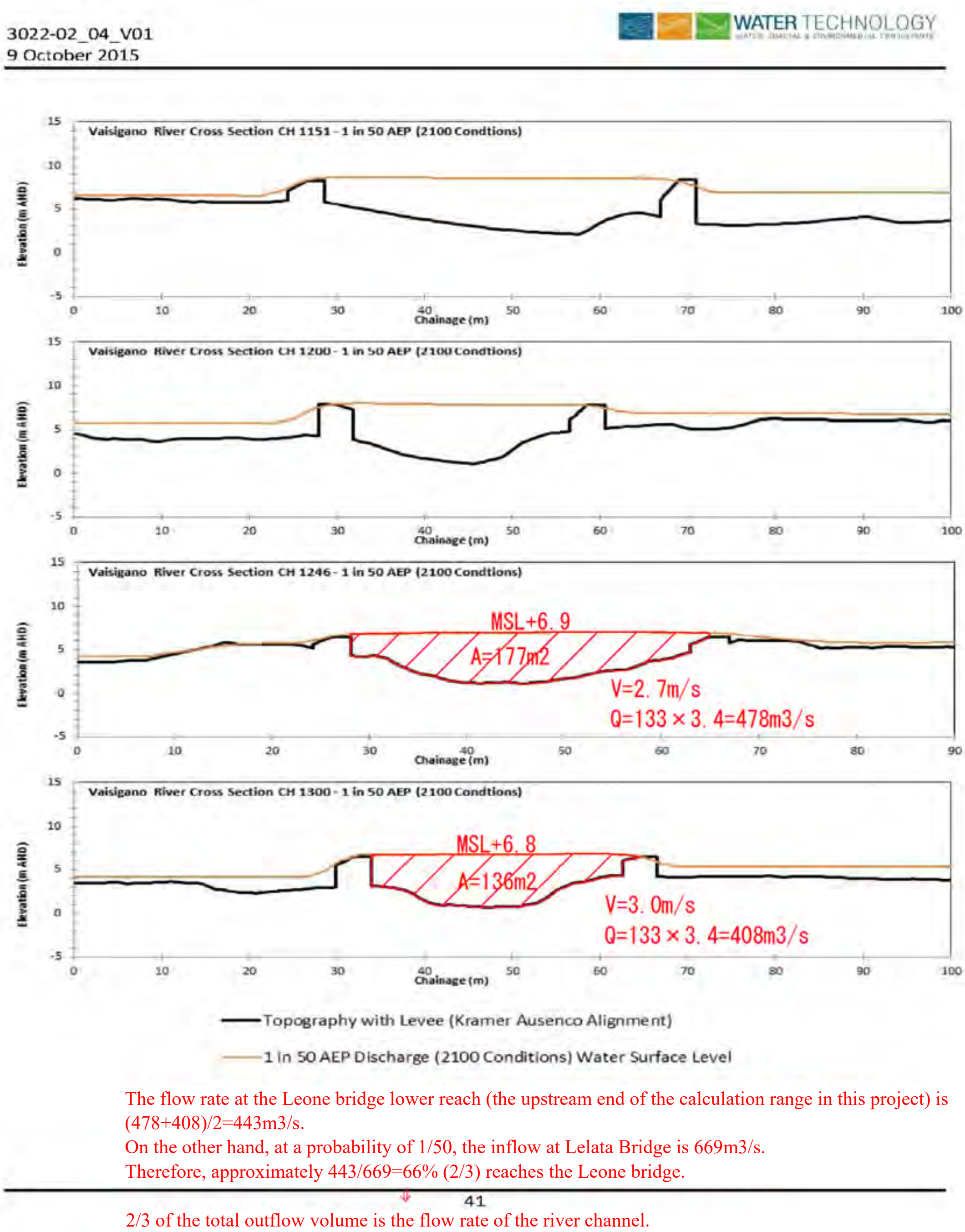


Figure 1-2-26 Ratio of Total Discharge to Discharge in River Channel at Downstream side of Leone Bridge

In addition, a multiplier of 1.1 was applied to match the multiplier used during embankment improvement to express the outflow expected due to increased rainfall intensity in the future.

Specifically, the peak discharge rate of Q = 680 m^3/s from the discharge rate hydrograph below was used.

Table 1-2-9 Discharge Table

Hour	Total Outflow	Increase	Inflow volume in river channel	Total Outflow - Inflow volume in river channel
		×1.1	×0.667	×0.333
0.00	0.0	0.0	0	0
0.25	25.0	27.5	20	10
0.50	45.0	49.5	40	10
0.75	350.0	385.0	260	130
1.00	850.0	935.0	630	310
1.25	921.0	1,013.1	680	340
1.50	900.0	990.0	670	320
1.75	650.0	715.0	480	240
2.00	400.0	440.0	300	140
2.25	200.0	220.0	150	70
2.50	100.0	110.0	80	30
2.75	65.0	71.5	50	30
3.00	45.0	49.5	40	10
3.25	0.0	0.0	0	0

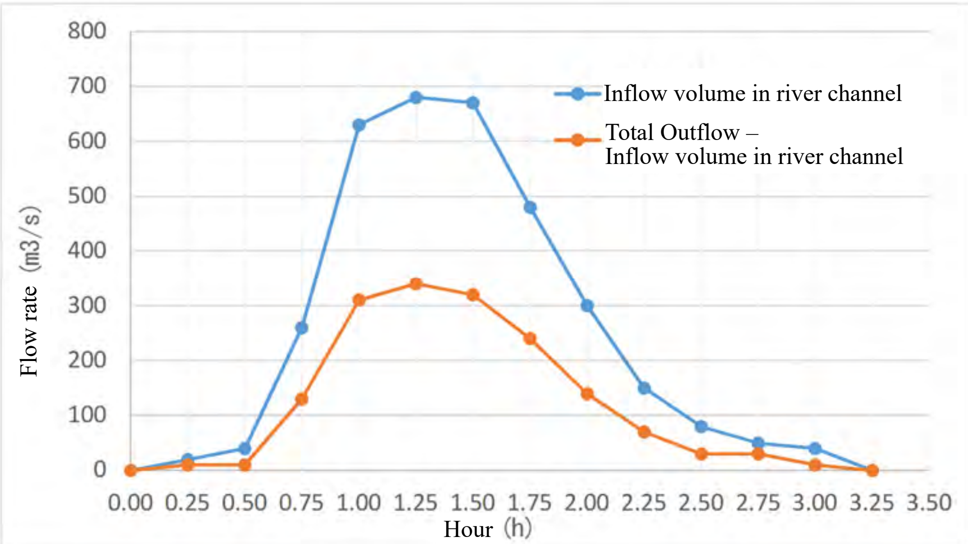


Figure 1-2-27 Discharge Hydrograph

d) Calculation Range and River End Water Level

Floodwaters continue to expand as they flow into the bay from the mouth of the river. Given the shape of Apia Port, the maximum expansion area is roughly 600 m as shown on the figure below, and the calculation start point was set at that maximum.

The floodplain created by the overflowing of the Vaisigano River likely stretches very wide downstream of the Leone Bridge; therefore, the calculation range extends to the Leone Bridge.

As explained previously, the water level at the river mouth is MSL+2.2 m, accounting for higher sea levels, storm surges and waves in the future.

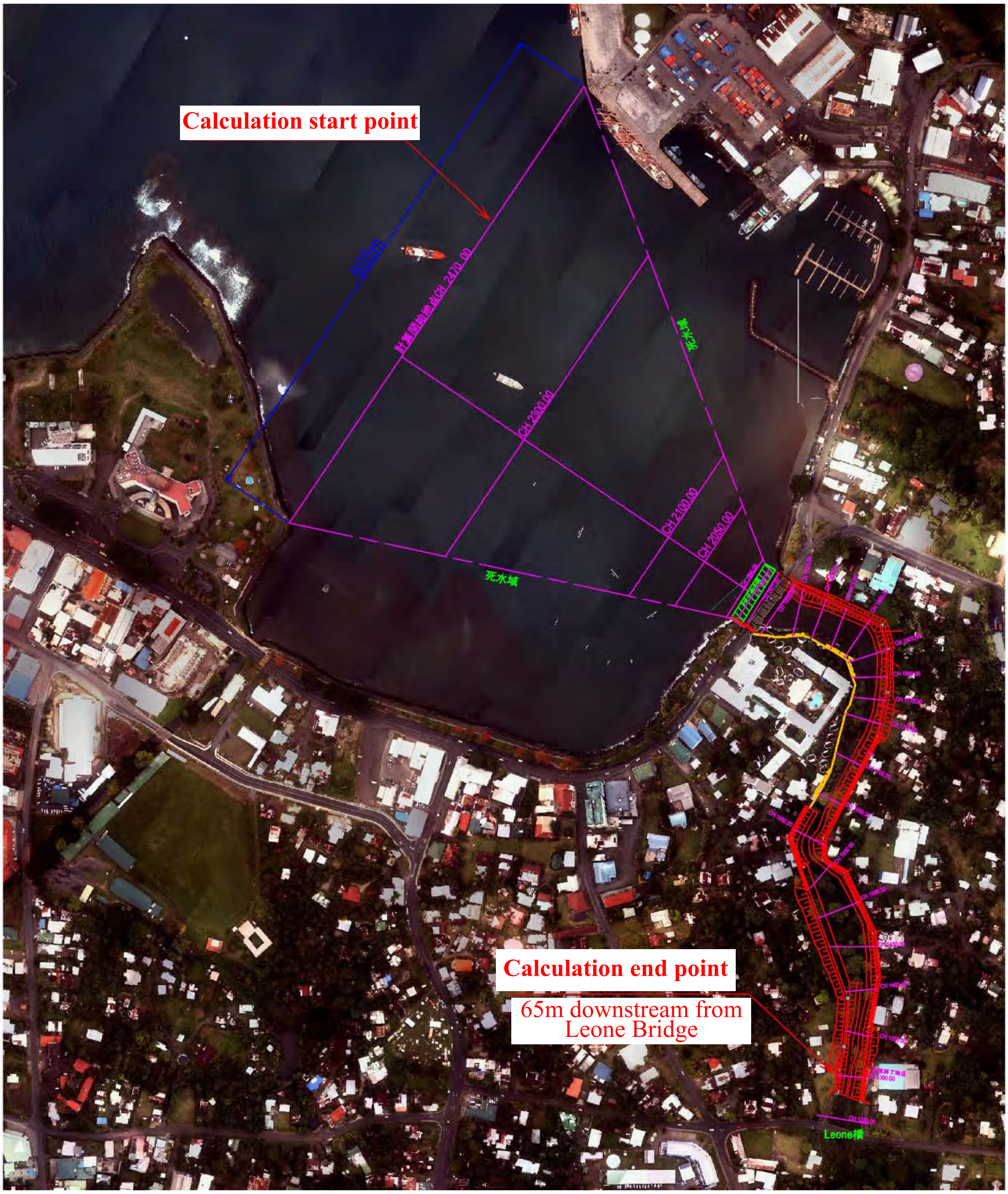


Figure 1-2-28 Caluculation Range of Water Level

e) Coefficient of Roughness

In light of the low discharge during normal times, the thick vegetation on the riverbanks and the economic difficulty of maintenance, the coefficient of roughness was set to n = 0.06, the same value used for the embankment improvement design.

f) Pier Dimensions

Number of piers: 2; Width: 2.0 m; Shape: Semicircular

Water height increase caused by piers: Use Yarnell's equation

g) Consideration of Overflow

The embankment will function through 20-year events; thus, 100-year floods will cause the water to flow over the crowns of the embankments. To account for these phenomena, the 625-m section on the right embankment downstream of the Leone Bridge is considered a side overflow zone. Hager's equation will be used as the overflow equation. In contrast, the topography on the inside of the left bank should prevent floodwaters from spreading over a wide area; thus, overflow will not be considered for the left side.

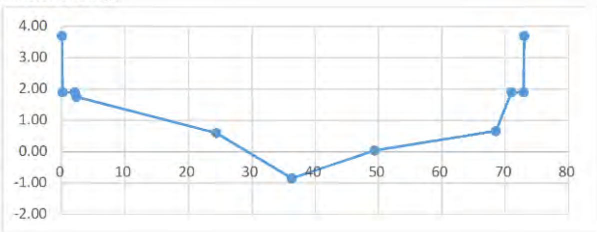
h) Channel Cross-Section

The embankment improvement design calls for no excavation or expansion of the river channel itself, only the use of retaining walls to raise embankment crowns. Therefore, the cross-section used for calculations is simply the lateral section of the channel in its current state with perpendicular walls built atop each side. A retaining wall built by the Sheraton Hotel exists near the hotel on the left bank, and its alignment and structure differ from MNRE's embankment improvement design. Interviews with MNRE revealed that the Sheraton's retaining wall would obviously be retained, and the channel cross-section reflects the presence of the wall. The channel cross-section at this point differs significantly from the embankment improvement design.

The figure below shows a typical bridge location cross-section.

Cross Section at Bridge and Downstream Side of Bridge

CH1995	475	0.00	3.70
CH1983	487	0.10	1.90
		2.00	1.90
		2.30	1.75
		24.37	0.60
		36.30	−0.85
		49.35	0.04
		68.52	0.66
		71.00	1.90
		72.90	1.90
		73.00	3.70



Cross Section at Upstream Side of Bridge

CH1971	499	0.00	3.70
		0.10	3.40
		0.45	1.90
		2.45	1.90
		2.98	1.64
		22.87	0.60
		34.80	−0.85
		47.85	0.04
		66.91	0.66
		69.40	1.90
		71.30	1.90
		71.40	3.70

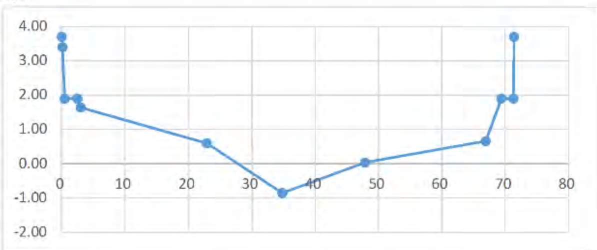


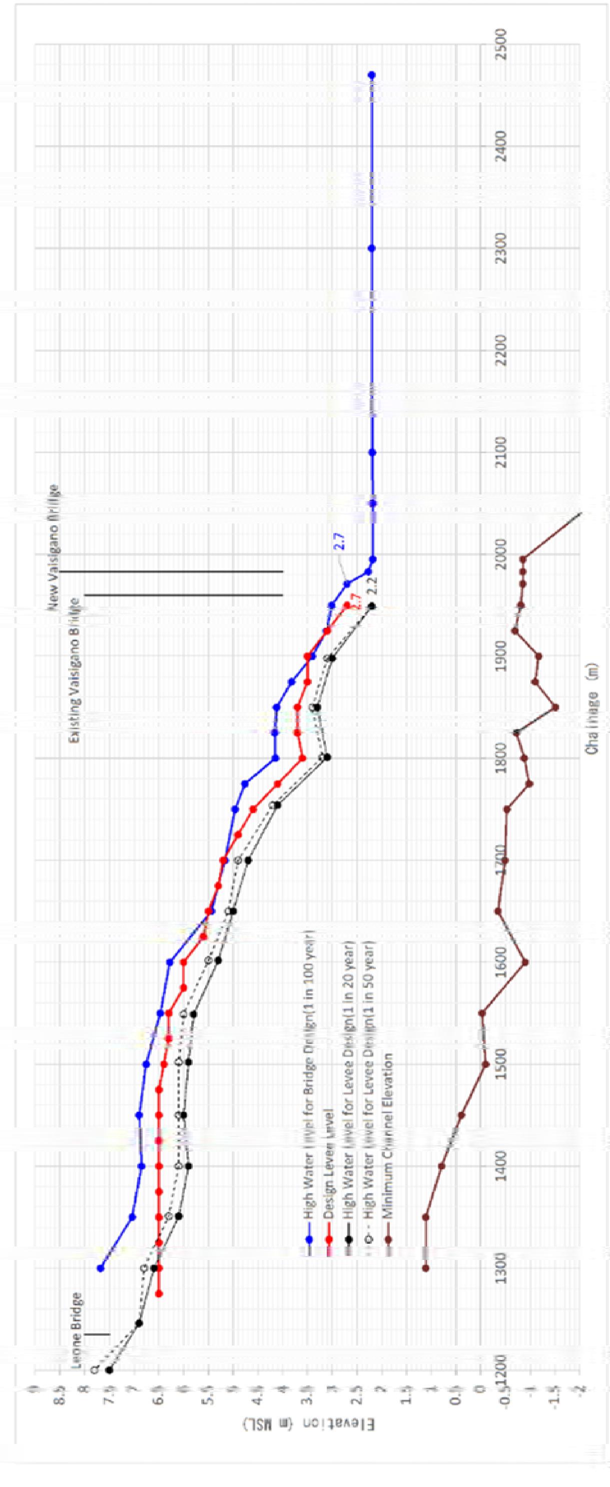
Figure 1-2-29 Typical Cross Section at Bridge Location

2) Results of Considerations

The results are shown on the next page.

The design high water level at the bridge location is MSL+2.7 m.

Since the discharge rate is Q = 680 m^3/s, the Cabinet Order concerning Structural Standards for River Management Facilities, etc. requires clearance of 1.0 m. Therefore, the height of the bridge's girders is MSL+3.7 m.



Chainage	River Sta	Length Chnl	Min Ch El	E.G. Elev	W.S. Elev	Crit W.S.	Frctn Loss	C & E Loss	Top Width	Q Channel	Vel Chnl	Flow Area	Froude # Chl
		(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m3/s)	(m/s)	(m2)	
1300	1170	50	1.11	8.56	7.68		0.52	0.01	30.35	680	4.15	163.8	0.57
1310	1160												
1350	1120	50	1.11	8.03	7.04		0.45	0.11	27.99	625.9	4.41	141.86	0.63
1400	1070	50	0.79	7.47	6.85		0.21	0.11	35.63	607.62	3.49	174.33	0.5
1450	1020	50	0.39	7.16	6.9		0.13		52.7	592.98	2.27	261.76	0.32
1500	970	50	-0.1	7.03	6.76		0.16	0.01	49.84	578.7	2.26	255.93	0.32
1550	920	50	-0.03	6.86	6.47		0.19		38.69	568.74	2.76	206.41	0.38
1600	870	50	-0.9	6.66	6.28		0.3	0.05	38.15	558.87	2.74	204.02	0.38
1650	820	50	-0.35	6.31	5.44		0.46	0.08	30.26	553.96	4.13	133.98	0.63
1700	770	50	-0.49	5.77	5.17		0.32	0.05	36.2	553.96	3.44	160.99	0.52
1750	720	25	-0.53	5.4	4.96		0.15		44.76	550.2	2.93	187.64	0.46
1775	695	25	-0.98	5.24	4.76		0.23	0.03	41.35	539.54	3.08	174.98	0.48
1800	670	25	-0.88	4.98	4.15		0.24	0.11	40.32	525.77	4.03	130.55	0.71
1825	645	25	-0.72	4.63	4.16		0.14	0.04	46.61	515.94	3.02	170.81	0.5
1850	620	25	-1.51	4.45	4.12		0.15	0.01	53.11	507.58	2.54	199.51	0.42
1875	595	25	-1.1	4.29	3.82		0.24	0.02	50.59	501.25	3.02	165.93	0.53
1900	570	25	-1.17	4.03	3.4		0.3	0.01	48.64	500.06	3.53	141.53	0.66
1925	545	25	-0.69	3.72	3.12		0.24	0.06	54.57	500.06	3.43	145.97	0.67
1950	520	21	-0.81	3.42	3.01		0.2	0.01	61.94	500.06	2.84	175.96	0.54
1971	499	5	-0.85	3.21	2.7	2.18			71.08	500.06	3.18	157.43	0.68
1983	487 BR U	14	-0.85	3.15	2.27	2.27			68.84	500.06	4.15	120.54	1
1983	487 BR D	5	-0.85	3.15	2.27	2.27			68.84	500.06	4.15	120.54	1
1995	475	55	-0.85	3.04	2.18	2.18	0.12	0.24	72.83	500.06	4.11	121.74	1.01
2050	420	50	-2.27	2.23	2.18		0.01	0.01	317.98	500.06	1.04	481.43	0.18
2100	370	200	-3.84	2.21	2.19	-1.46			279.99	500.06	0.56	887.45	0.08
2300	170	170	-9	2.2	2.2				465.4	500.06	0.13	3895.76	0.01
2470			-12	2.2	2.2	-10.68			604.38	500.06	0.08	6169.65	0.01

Figure 1-2-30 Result of Water Level Calculation

(6) Consideration of Sedimentation

There is a large difference between the steep slope of the upper reach and the gentle slope of the lower reach of the Vaisigano River. Thus, in qualitative terms, there is concern over landslides and other events in the mountainous area of the upper reach producing sand and fallen trees that are carried downstream and cause sedimentation at the river mouth. However, no additional sedimentation has occurred at the mouth, as shown in comparison with the riverbed depth in 2006 in the figure below. In addition, the roughly 1-m riverbed scour that occurs as the result of drawdown during flooding (which will be discussed later) makes it highly likely that any sedimentation would be flushed away during floods.

Therefore, sedimentation will not be considered during considerations of the design high water level for the bridge design.

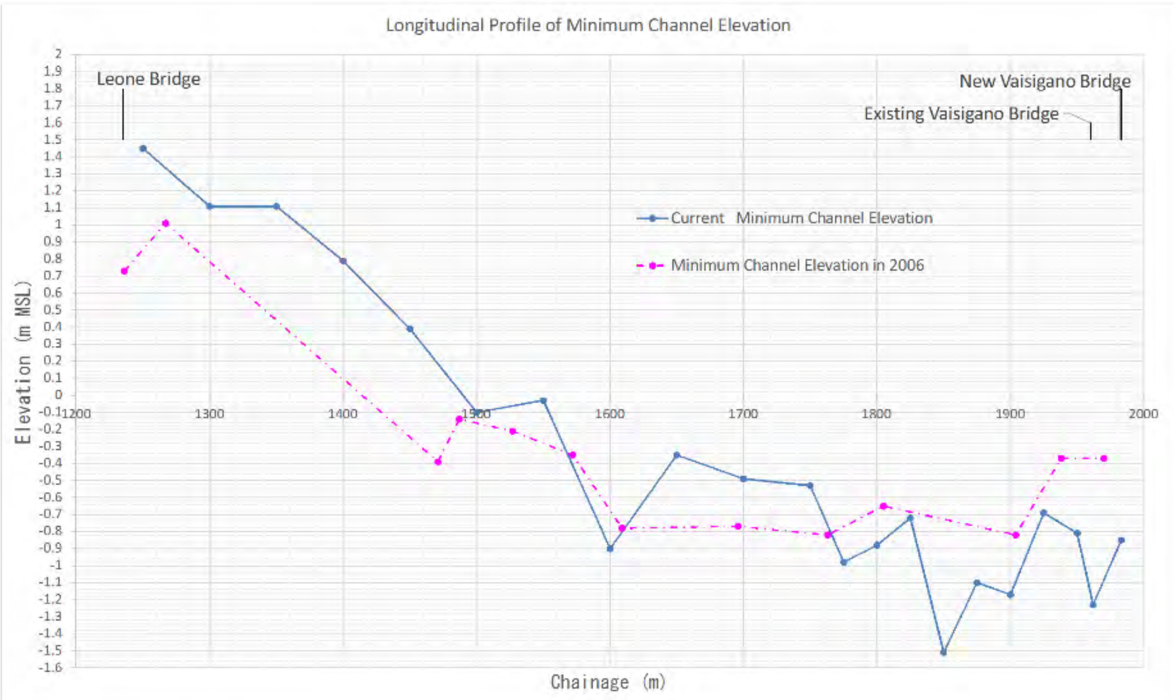


Figure 1-2-31 Longitudinal Profile of Minimum Channel Elevation

It is worth noting that waves have a significant effect on the riverbed depth at the river mouth, and that the depth there could rise along with the rising sea level caused by climate change. However, the shoreline would likely recede in this case, which makes it difficult to accurately project changes in riverbed depth at the bridge location. Additionally, even if the riverbed depth were to rise, it would occur gradually over a period of 100 years.

Therefore, the approach is to take no countermeasures at this stage, but to consider measures required to monitor the situation.

(7) Consideration of Scouring

The amount of scouring at the bridge location is determined in order to determine how deeply to embed bridge piers.

The results of the design high water level consideration described earlier show that the water level upstream of the bridge location is a drop-down curve. Therefore, the total amount of scouring is the amount of scouring caused by drawdown added to the amount of scouring at the bridge piers.

As a result of considerations done under the conditions below, the amount of scouring at the bridge location is 5.0 m, and the maximum riverbed depth is MSL-5.00 m (current bridge pier location riverbed depth of MSL+0.04 - 5.0).

Conditions for Consideration of Amount of Scouring Caused by Drawdown

Calculation method: Riverbed fluctuation calculation using simulated one-dimensional unstable flow using HEC-RAS

Riverbed material: Results of sieve analysis from the closest location to the surface level at the bridge location

Calculation period: 3 hours

Upstream edge sand feed condition: Balanced sand feed quantity

Sediment discharge equation: Laursen (Copeland)

Conditions for Consideration of Amount of Scouring at Bridge Piers

Calculation: CSU equation using HEC-RAS

(8) Shoreline Design Specifications

The Samoan government is currently receiving assistance from New Zealand to devise the Apia Waterfront Development Plan, a plan to develop the beachfront from the Mulinu'u area to Apia Port. The details are unclear at this point, but the waterfront plan is scheduled to be completed by the end of 2016.

(9) Shoreline Conditions

The existing shoreline seawalls were built under the Harbor and Seawall Disaster Recovery Improvement Plan 1992-1993, a Japanese grant aid project.

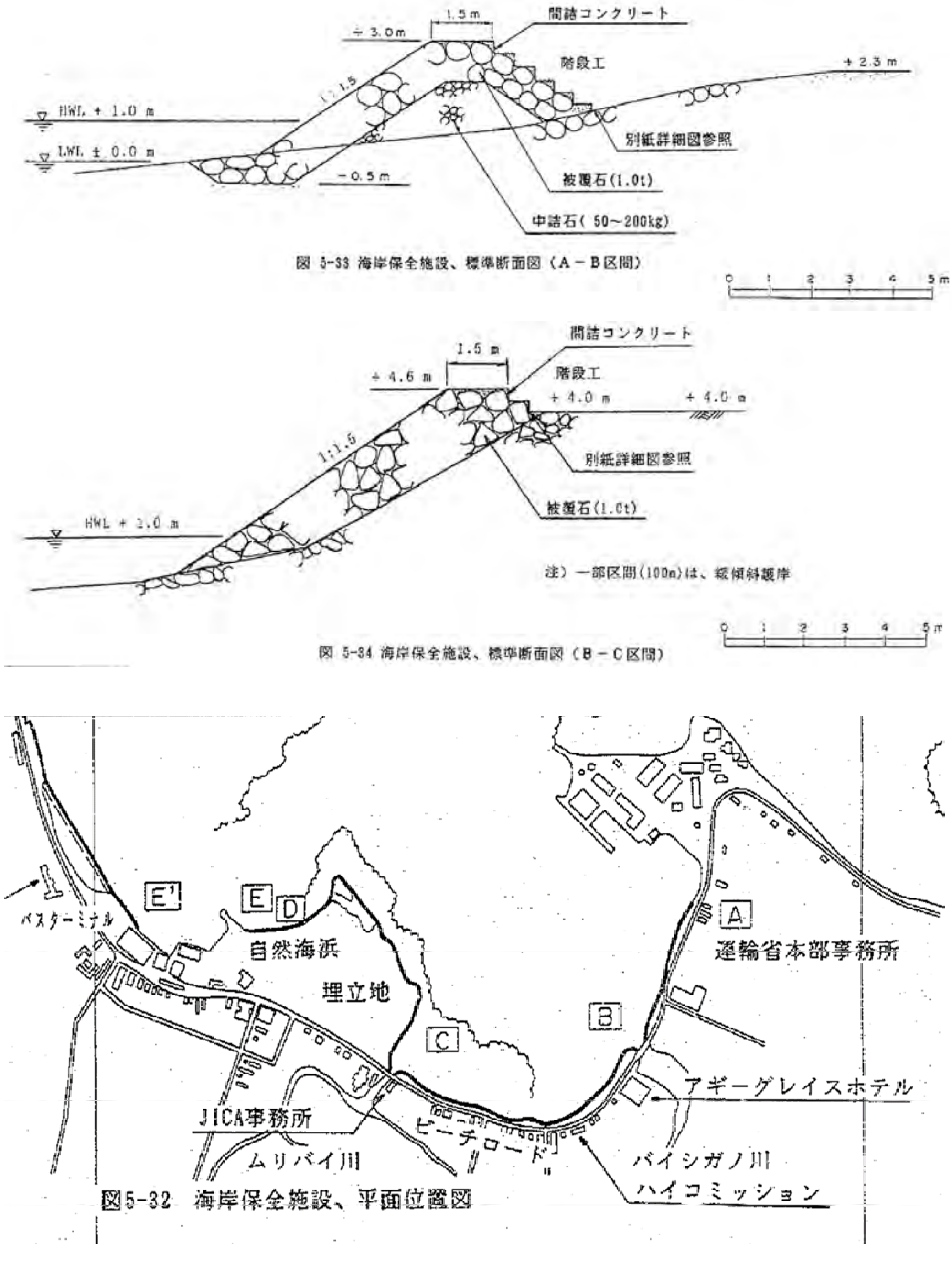


Figure 1-2-32 Structure of Existing Coastal Revetment

Measurements resulted in the following specifications：

- Shoreline seawall cross-section dimensions
- Shoreline seawall crown height and inner ground height
- Sea floor longitudinal dimensions

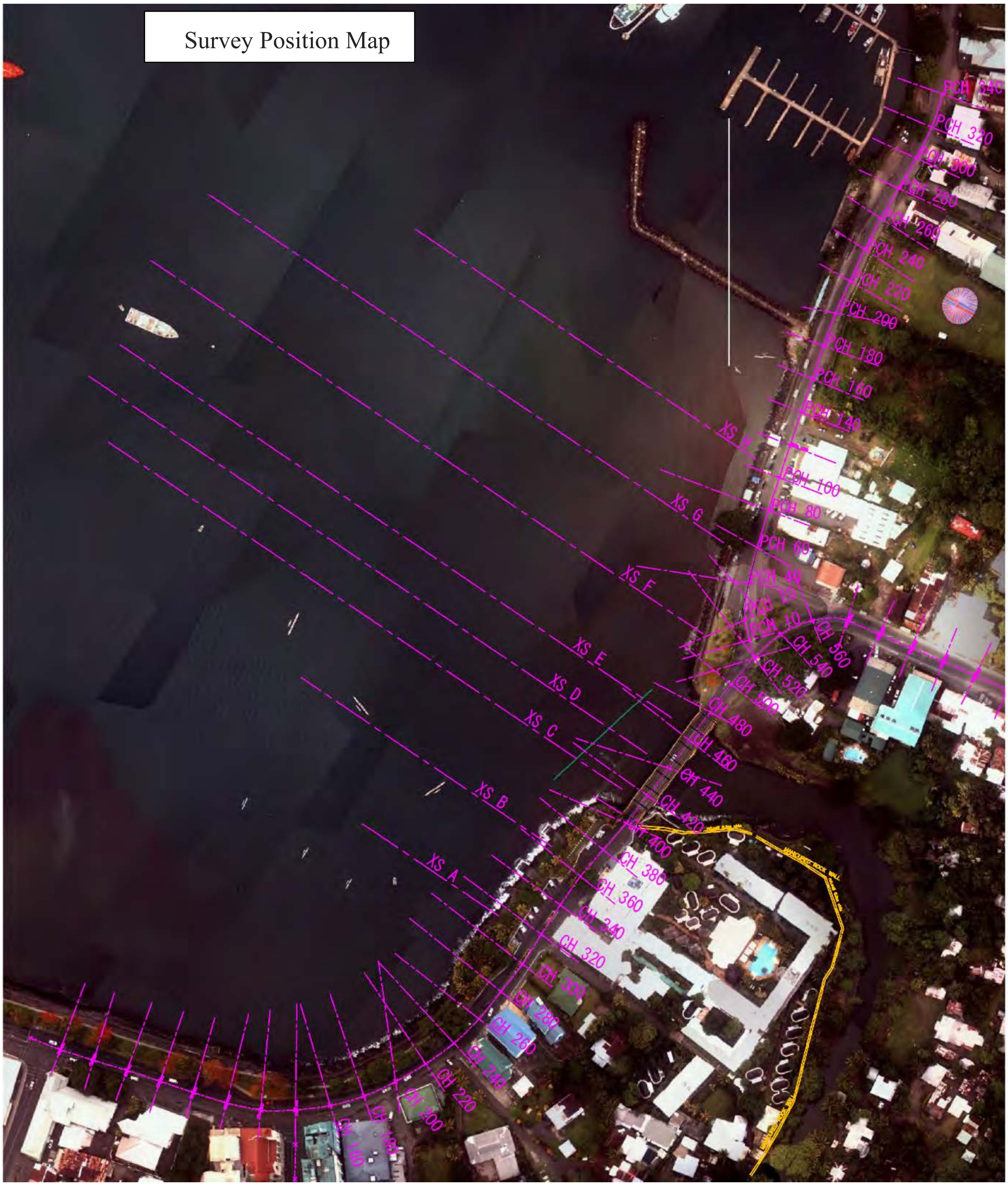
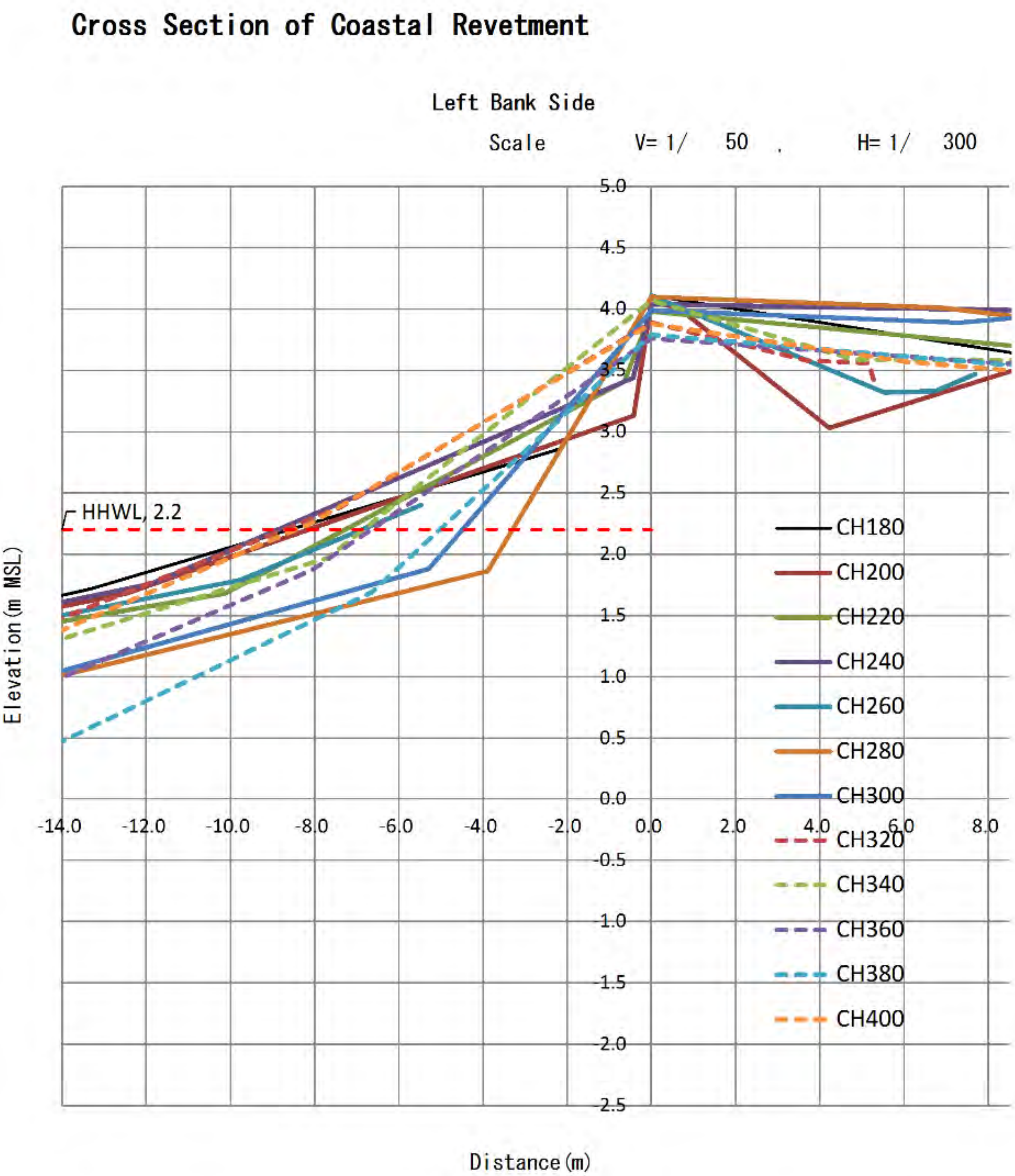
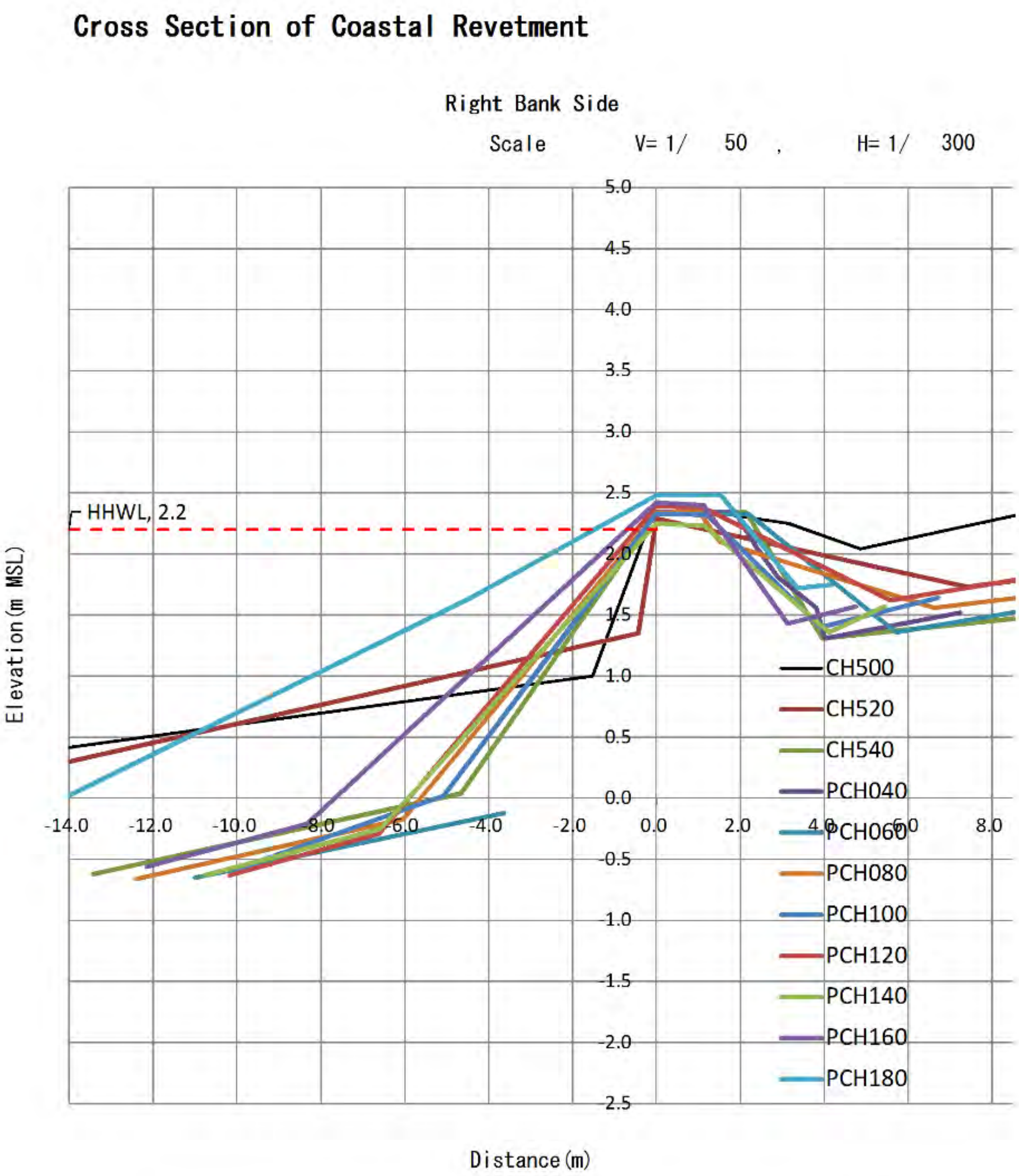


Figure 1-2-33　Location Map of Coastal Survey



Chainage	Gradient of Front Slope	Ground Level of Landside	Chainage	Gradient of Front Slope	Ground Level of Landside
CH180	1: 1.728	3.60	CH320	1: 4.907	3.36
CH200	1: 0.452	3.03	CH340	1: 3.662	3.59
CH220	1: 1.123	3.63	CH360	1: 4.27	3.33
CH240	1: 0.717	3.79	CH380	1: 3.162	3.30
CH260	1: 3.199	3.32	CH400	1: 4.969	3.46
CH280	1: 1.737	3.49			
CH300	1: 2.507	3.68			

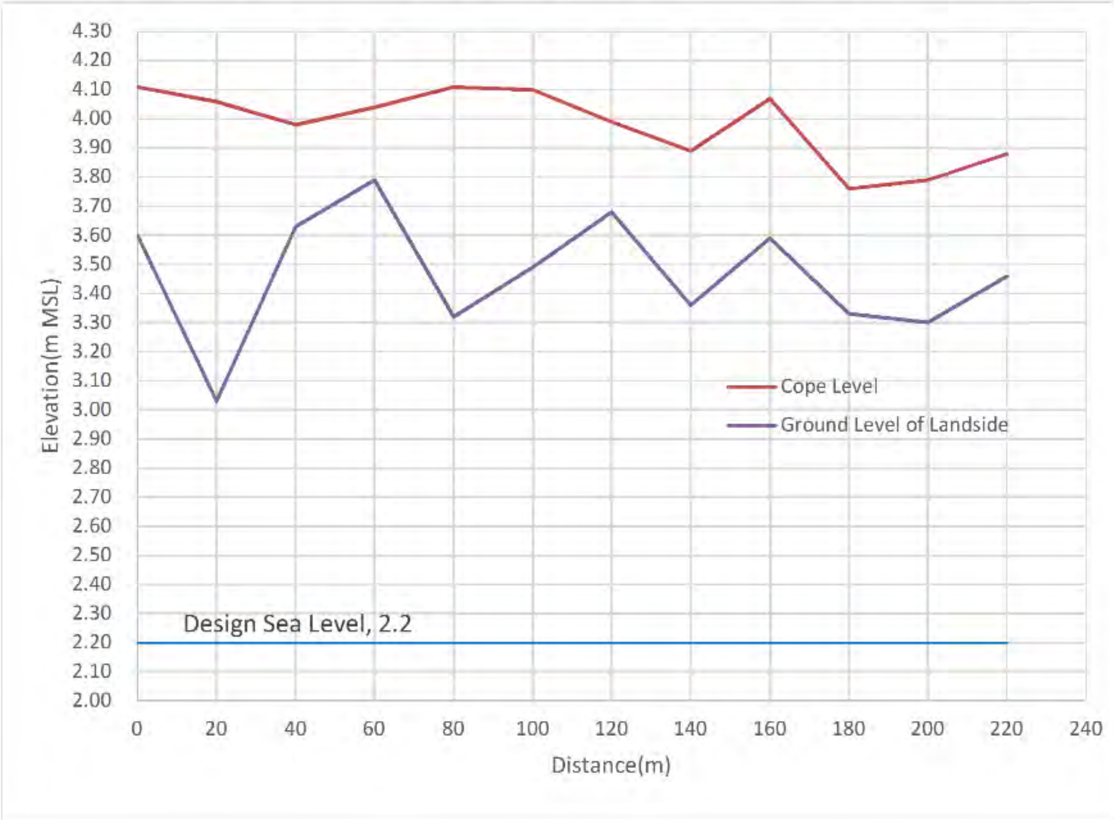
Figure 1-2-34 Cross Section of Coastal Revetment (Left Bank Side)



Chainage	Gradient of Front Slope	Ground Level of Landside	Chainage	Gradient of Front Slope	Ground Level of Landside
CH500	1: 1.078	2.04	PCH120	1: 2.47	1.62
CH520	1: 0.457	1.73	PCH140	1: 2.632	1.36
CH540	1: 2.026	1.31	PCH160	1: 3.171	1.43
PCH040	1: 2.187	1.31	PCH180	1: 5.282	1.72
PCH060	1: 1.486	1.36			
PCH080	1: 2.416	1.56			
PCH100	1: 2.199	1.40			

Figure 1-2-35 Cross Section of Coastal Revetment(Right Bank Side)

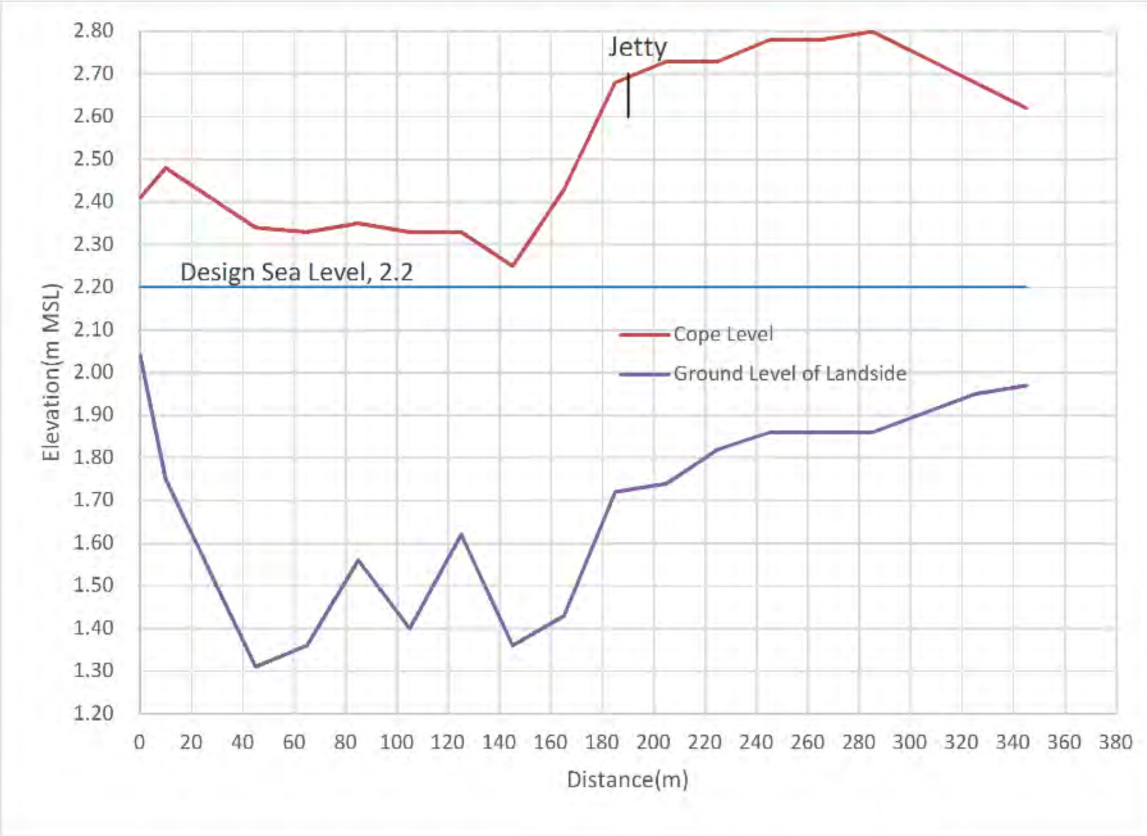
Cope Level of Coastal Revetment and Ground Level of Landside (Left Bank Side)



Chainage	Distance between Chainage (m)	Distance (m)	Cope Level (m MSL)	Ground Level of Landside (m MSL)
CH180	0	0	4. 11	3. 60
CH200	20	20	4. 06	3. 03
CH220	20	40	3. 98	3. 63
CH240	20	60	4. 04	3. 79
CH260	20	80	4. 11	3. 32
CH280	20	100	4. 10	3. 49
CH300	20	120	3. 99	3. 68
CH320	20	140	3. 89	3. 36
CH340	20	160	4. 07	3. 59
CH360	20	180	3. 76	3. 33
CH380	20	200	3. 79	3. 30
CH400	20	220	3. 88	3. 46

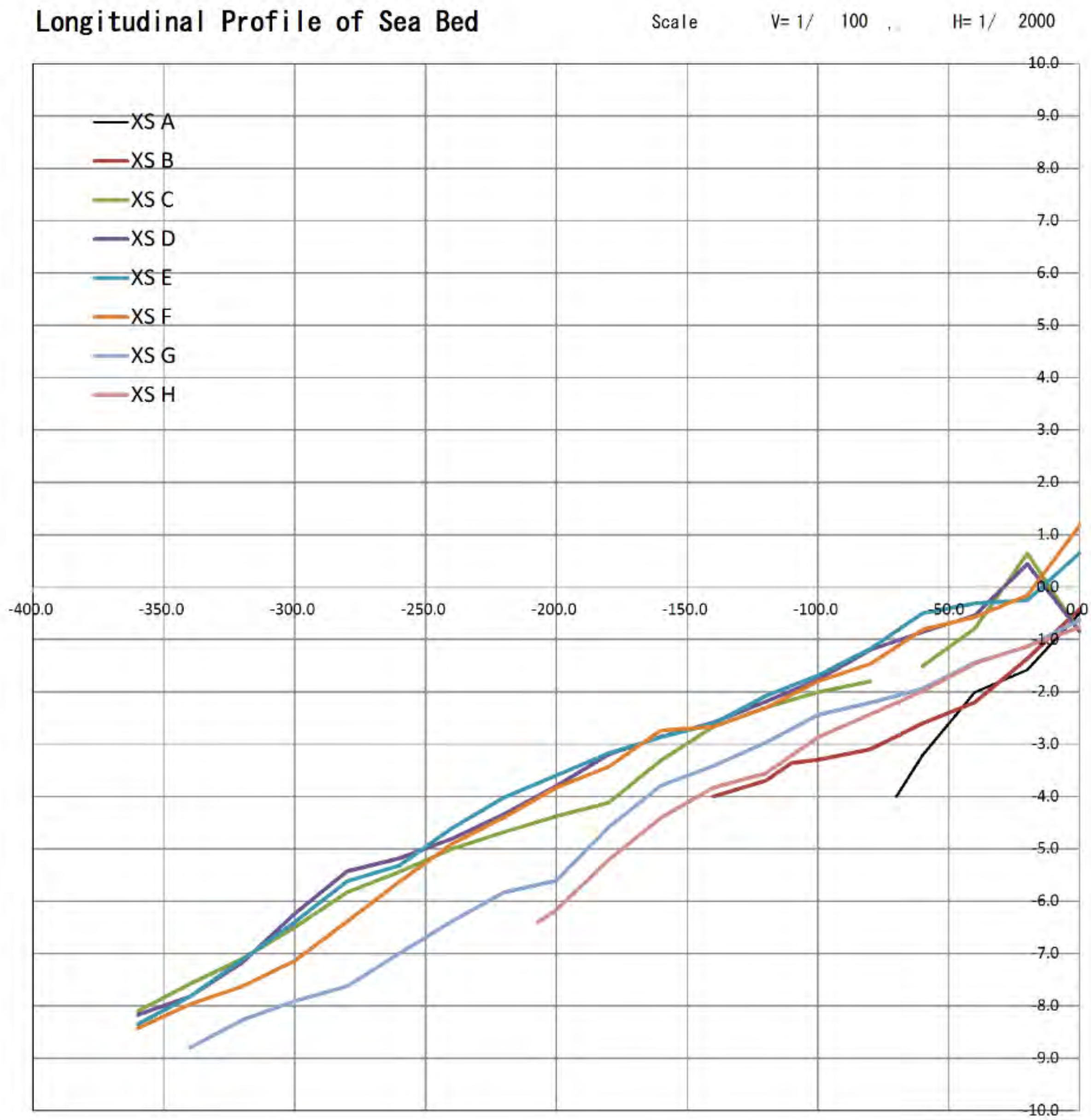
Figure 1-2-36 Cope Level of Coastal Revetment and Ground Level of Landside (Left Bank Side)

Cope Level of Coastal Revetment and Ground Level of Landside (Right Bank Side)



Chainage	Distance between Chainage (m)	Distance (m)	Cope Level (m MSL)	Ground Level of Landside (m MSL)
CH500	0	0	2. 41	2. 04
PCH20	10	10	2. 48	1. 75
PCH40	35	45	2. 34	1. 31
PCH60	20	65	2. 33	1. 36
PCH80	20	85	2. 35	1. 56
PCH100	20	105	2. 33	1. 4
PCH120	20	125	2. 33	1. 62
PCH140	20	145	2. 25	1. 36
PCH160	20	165	2. 43	1. 43
PCH180	20	185	2. 68	1. 72
PCH200	20	205	2. 73	1. 74
PCH220	20	225	2. 73	1. 82
PCH240	20	245	2. 78	1. 86
PCH260	20	265	2. 78	1. 86
PCH280	20	285	2. 8	1. 86
PCH320	40	325	2. 68	1. 95
PCH340	20	345	2. 62	1. 97

Figure 1-2-37 Cope Level of Coastal Revetment and Ground Level of Landside (Right Bank Side)



Slope Gradient of Sea Bed

XS A	1/ 20
XS B	1/ 39
XS C	1/ 44
XS D	1/ 42
XS E	1/ 40
XS F	1/ 41
XS G	1/ 42
XS H	1/ 37

Figure 1-2-38 Longitudinal Profile of Sea Bed

The pictures below show the conditions.

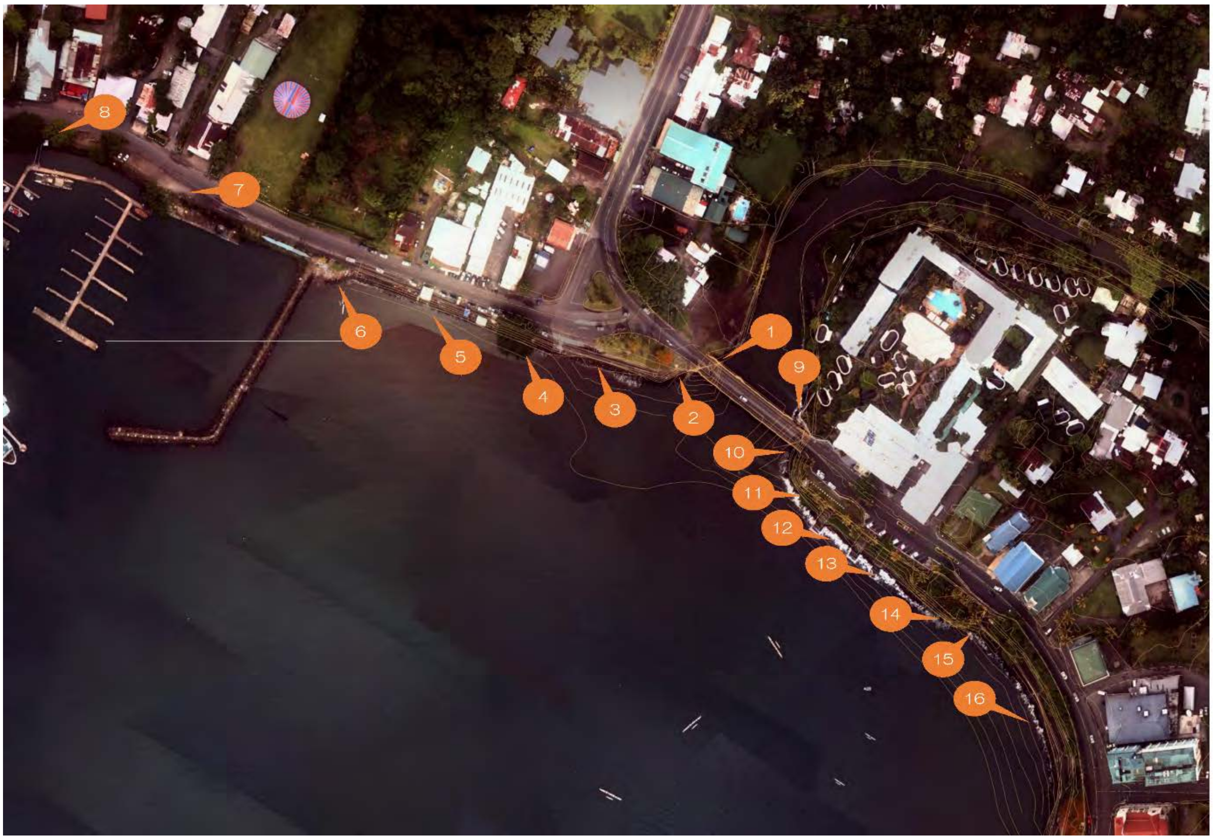


Figure 1-2-39 Location Map of Picture of Coastal Area

No.	1		No.	2	
					
No.	3		No.	4	
					
No.	5		No.	6	
					
No.	7		No.	8	
					

Picture 1-2-8 Existing Condition of Coastal Area (1/2)

No.	9		No.	10	
					
No.	11		No.	12	
					
No.	13		No.	14	
					
No.	15		No.	16	
					

Picture 1-2-9 Existing Condition of Coastal Area (2/2)

(10) Consideration of Wave Height for Bridge Design

As a measure against salt damage, girder heights must be HWL plus at least half of wave height.

Considerations under the following conditions resulted in girder heights of MSL+3.28 m for a design wave height of 2.16 m (MSL+2.2 m + 2.16/2)

However, the maximum wave destination point is 3.88 m (MSL+2.2 m + 2.8 m × 0.6).

Conditions for Consideration

- ・Design significant wave height: 4 m
- ・Frequency: 11.0 s
- ・Riverbed depth at bridge location: MSL-0.6 m
- ・Design depth: 2.8 m

1-2-3 Topographic Surveys

The study team conducted topographic surveys near the Vaisigano Bridge in order to ensure the accuracy required to conduct this preparatory study. The team used the results to fully and accurately understand the topographic conditions at the project site, and to determine the structure and scale of the target structures. The results were helpful in the process of designing, creating the construction schedule and making calculations.

Table 1-2-10 shows the details and Figure 1-2-40 shows the results of the topographic surveys conducted near the Vaisigano Bridge.

Table 1-2-10 Measurement Survey Details

	Survey Item	Scale/Specifications	Unit	Quantity
Topographic Survey	BM	Installation of measurement base points	--	1
	Planar topographic	160,000 m^2 (road) + 95,000 m^2 (river) - 25,000 m^2 (overlap)	m^2	141,700
	Longitudinal road measurements	Road sector: 800 m (main road), 370 m (access road)	m	1,170
	Lateral road measurements	Existing road lateral pitch of 20 m: Measured width 100 m x 41 cross-sections (main road); Measured width 50	m	5,050
	Longitudinal	740 m upstream of planned location of new bridge	m	740
	Lateral river measurements	Upstream side: Width 100 m x 13 cross-sections (including change points); Width 50 m x 7 cross-	m	1,650
	Existing bridge	Measurement of main dimensions of existing bridge	--	1
	Depth contour	260 m x 8 cross-sections; 300 m x 1 cross-section; 60	m	2,980

Figure 1-2-40 Vaisigano Bridge Topographic Survey Chart

1-2-4 Geological Surveys

(1) Survey Overview

Boring surveys were conducted at the Vaisigano Bridge to explore the ground supporting the substructure, and to determine the type of foundation and height of the substructure. The boring was done in four locations: two at the abutments and two at the piers (in the river). Table 1-2-11 shows details about the geological survey.

Table 1-2-11 Geological Survey Details

	Survey Item	Survey Location	Quantity		Remarks
Geological/Soil Surveys	Mechanical boring	On land (abutments) In the river (piers)	Excavation length: 93.7 m (2 locations) Excavation length: 93.3 m (2 locations)	Total: 187 m (4 locations)	Earth/sand: 167 m; Rock: 20 m Temporary fill falsework used in the river
	Standard penetration tests	On land (abutments) In the river (piers)	71 tests (2 locations) 71 tests (2 locations)	Total: 142 tests (4 locations)	Earth/sand N-value/1-m depth
	Soil tests	On land (abutments) In the river (piers)	1 test (15 samples) (2 locations) 1 test (15 samples) (2 locations)	Total: 30 samples (4 locations)	Soil classification, sieve analysis, water content analysis, consistency tests, etc.
	Rock tests	On land (abutments) In the river (piers)	1 test (2 samples) (2 locations) 1 test (2 samples) (2 locations)	Total: 4 samples (4 locations)	Water content analysis, density tests, unconfined compression tests, etc.
	CBR tests (conducted in a lab)	Existing road bed Borrow pit	1 test (2 samples) (2 locations) 1 test (1 sample) (1 location)	Total: 3 samples (3 locations)	Existing road bed Embankment material (borrow material)
	Aggregate tests (coarse aggregate)	Quarry or aggregate plant	1 test (1 sample) (1 location)		Sieve-analysis tests, density tests, alkali silica reactivity tests, etc.
	Aggregate tests (fine aggregate)	Extraction location or aggregate plant	1 test (1 sample) (1 location)		Sieve-analysis tests, density tests, alkali silica reactivity tests, etc.

Picture 1-2-10 Boring Survey on Land (A2)

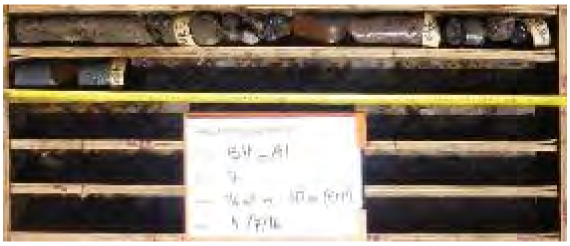
Picture 1-2-11 N-Value Observation on Land (A2)

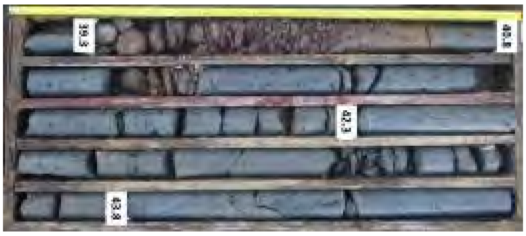
Picture 1-2-12 Fill Dirt at the Boring Location in the River (P2)

Picture 1-2-13 Boring Survey in the River (P2)

(2) Boring Survey Results

The survey location at the mouth of the Vaisigano River is an alluvium deposit. The upper layer consists of layers of sand and sand mixed with pebbles, followed by a continuous layer of fine sand. Between roughly 30 m to 41 m are fine sandy layers and layers of weathered basalt. The surveys confirmed a layer of compacted, unweathered basalt that starts between roughly 41 m and 42 m and continues for at least 5 m, and this layer can be the ground that supports the structure.

BH-A1 Cores	**BH-P1 Cores**
0 m-39.5 m	0 m-44 m
	
	
31.2 m-47 m	42.55 m-47 m
	
	
• Sand mixed with pebbles from 0 m-3 m • Mixed layer of silt and sand with N-value 4-16 from 3 m-16 m • Sandy silt with N-value 6-25 from 16 m-25 m • Gravelly sand with N-value 17-26 from 25 m-35 m • Weathered basalt with N-value at least 50 from 35 m-42 m • Compacted, unweathered basalt from 42 m, can serve as bearing layer	• Gravelly sand with N-value 6-10 from 0 m-3 m • Mixed layer of silt and sand with N-value 5-7 from 3 m-14 m • Sandy silt with N-value 6-25 from 14 m-25 m • Mixed layer of silt and sand with N-value 17-26 from 25 m-28 m • Weathered basalt with N-value at least 50 from 38 m-42 m • Compacted, unweathered basalt from 42 m, can serve as bearing layer

BH-P2 Cores	**BH-A2 Cores**
0 m-40 m	0 m-46.7 m
	
	
	
0 m-46.3 m	26 m-38 m
	
	
• Sand mixed with pebbles from 0 m-3 m • Mixed layer of silt and sand with N-value 2-7 from 6 m-13 m • Sandy silt with N-value 6-25 from 13 m-29 m • Gravelly sand with N-value 32-41 from 29 m-31 m • Sandy silt mixed with gravel with N-value 7-50 from 31 m-41 m • Compacted, unweathered basalt from 41 m, can serve as bearing layer	• Sand mixed with pebbles with N-value 5-16 from 0 m-10 m • Mixed layer of silt and sand with N-value 4-7 from 10 m-14 m • Sandy silt with N-value 3-10 from 14 m-20 m • Mixed layer of silt and sand with N-value 17-26 from 20 m-27 m • Sandy silt with N-value 10-20 from 34 m-37 m • Weathered basalt with N-value at least 50 from 37 m-41 m • Compacted, unweathered basalt from 41 m, can serve as bearing layer

(3) Soil Layer Structures

The figure below is a soil structure diagram for the location of the Vaisigano Bridge, created from the results of the geological surveys.

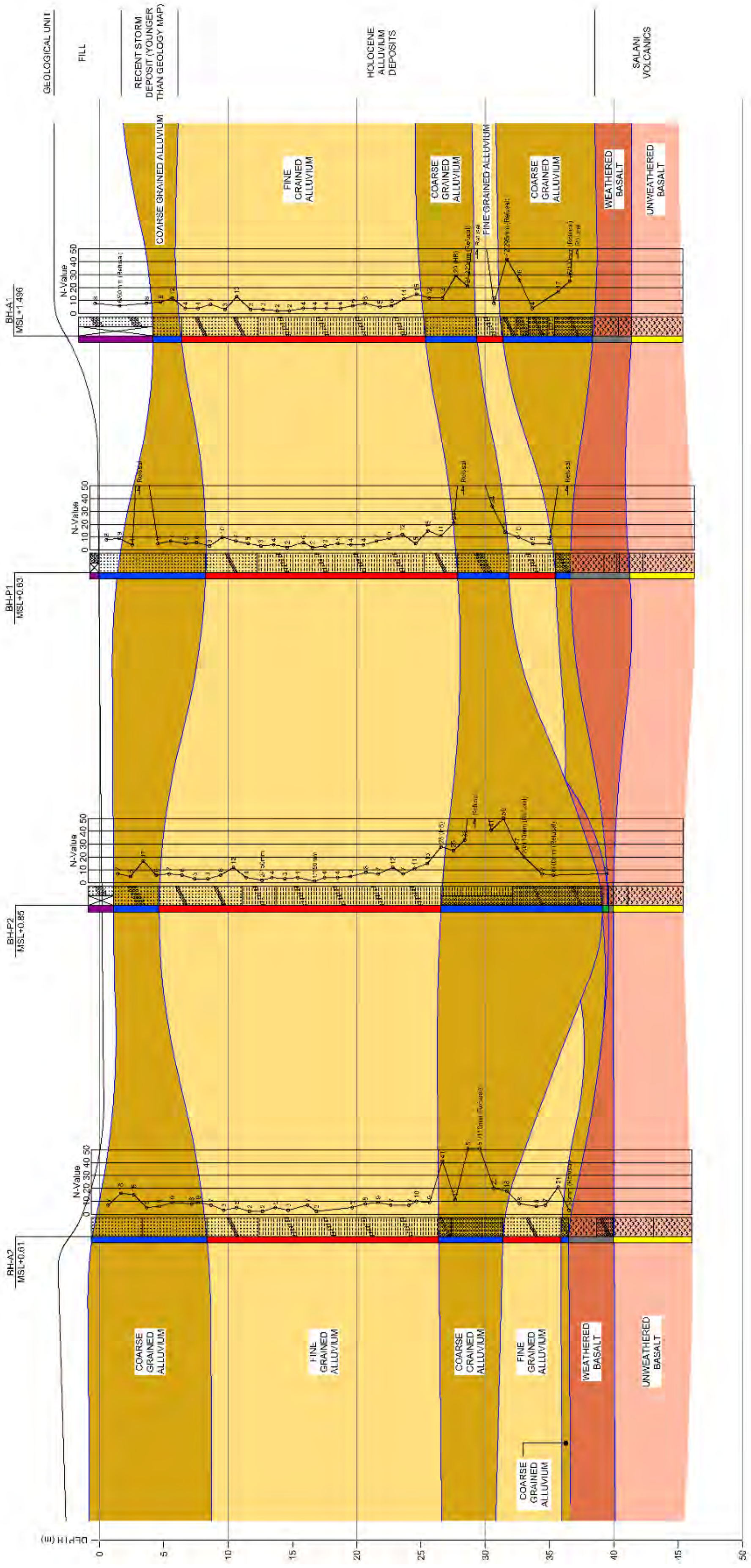


Figure 1-2-41 Soil Structure Diagram

1-2-5 Environmental Social Consideration

1-2-5-1 Overview of Project Components

(1) Project Content and JICA Environmental Categories

This is a bridge reconstruction project, based on a request from the Samoan Government. It does not qualify as a large-scale road, railway, and bridge sector project as given in the JICA Guidelines for Environmental and Social Consideration (April 2010; hereinafter JICA Environmental Guidelines). It is also not judged to have a major adverse impact on the environment, has no environmentally sensitive features, and is not in an environmentally sensitive region. Given this, the project is classified as Environmental Category B based on the JICA Environmental Guidelines.

In consultations with LTA and MNRE, we have confirmed that an Environmental Impact Assessment (EIA) will be required for this Project according to Samoan law. As such, the Study Team will assist in preparing an EIA.

1-2-5-2 Basic Environmental and Social Circumstances

Samoa (officially, the Independent State of Samoa) is an island nation located east of Australia in the South Pacific Ocean at a longitude of 13°35’ S and latitude of 172°20’ W. As volcanic islands with nearby coral reef, Samoa is warm year round, preserving its rich, tropical natural environment. The Samoan people are of Polynesian descent. The country sees much damage from cyclones, earthquakes and tsunamis, and other natural disasters. More will be said about the weather and hydrology of Samoa in 1-2Survey on Natural Conditions.

Figure 1-2-42 Location of Samoa

(1) Conservation Areas

The conservation areas and Key Biodiversity Areas (KBAs) on Upolu, where the Project will take place, are given in Table 1-2-12. Lake Lonotoo National Park is the only land in Samoa registered under the Ramsar Convention. There are six Important Bird Areas (IBAs) in Samoa, five of which are located on Upolu. Five of the eight KBAs are also IBAs. All IBAs are categorized as A1 (globally threatened species habitats) and A2 (restricted-range species habitats). The locations of these areas and their relative position to the Project Site are illustrated in Figure 1-2-43.

Table 1-2-12 Biodiversity Areas of Upolu

No.	Name	Category	IBA	Area (ha)	Region Name
1	O le Pupu Pue National Park	National park	A1. A2	4,228	Siumu and Falealili
2	Lake Lonotoo National Park	National park	-	Incl. in 8	
3	Aleipata Marine Protected Area	Conservation area	A1. A2	4,842 (marine) 156 (land)	Aleipata
4	Safata Marine Protected Area	Conservation area	-	5,870 (marine) 101 (land)	Safata
5	Palolo Deep Marine Protected Area	Conservation area	-	33	Vaimauga west
6	Eastern Upolu Craters	KBA	A1. A2	4,759	Aleipata and Lepa
7	Uafato-Tiavea Coastal Forest	KBA	A1. A2	2,316	Vaa o Fonoti
8	Apia Catchments	KBA	A1. A2	8,336	Vaimauga West, Faleata, Siumu

Source: Priority Sites for Conservation in Samoa, annotated by Study Team

Legend:
Conservation area
Key Biodiversity Area
FR: Forest reserve
NP: National park
MPA: Marine protected area
CA: Community conservation area
Project Site

Source: Priority Sites for Conservation in Samoa

Figure 1-2-43 Nature conservation areas

As appearing in Figure 1-2-43, Mt. Vaea Reserve was designated as a memorial park for Robert Louis Stevenson, author of *Treasure Island*, and a conservation area in the Stevenson Memorial Reserve and Mount Vaea Scenic Reserve Ordinance of 1958. The reserve is a local place of recreation due to its proximity to the city center and is not classified as either a natural conservation area or KBA in any strict sense.

Vaisigano Bridge and the Project will be located a short 1 km distance from Palolo Deep Marine Reserve. Designated in 1974 based on the National Park and Reserves Act, the Palolo Deep Marine Reserve is a coral reef surrounding the edge of an atoll and is rich with coral, algae, fish, sea urchins, and other biota.

The important biota in Palolo Deep Marine Reserve are as given below.

Table 1-2-13 Important biota living in Palolo Deep MR

	Common Name	Scientific Name	IUCN Category
Fish	Giant Grouper	*Epinephelus lanceolatus*	Vulnerable
Coral	No particular name	*Acropora aculeus*	Vulnerable
Coral	No particular name	*Acropora aspera*	Vulnerable
Coral	No particular name	*Acropora paniculata*	Vulnerable
Coral	No particular name	*Pavona dexussata*	Vulnerable
Coral	No particular name	*Porites Nigrescens*	Vulnerable

Source: Priority Sites for Conservation in Samoa

The relative positions of these locations to the Project Site are illustrated in Figure 1-2-44. Located outside the bay, the Palolo Deep Marine Reserve should barely be impacted by the Project Site in Apia Bay. The yellow line shown in the figure is a boundary of the Reserve (Source：Lowell & Toloa, Palolo Deep National Marine Reserve (1994)).

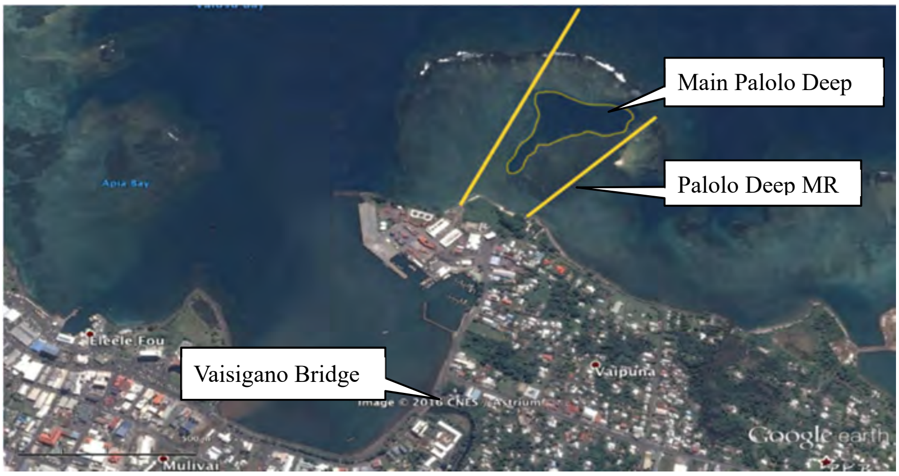


Figure 1-2-44 Vaisigano Bridge and Palolo Deep Marine Reserve

(2) Cultural Heritage, etc.

While Samoa has no ruins currently registered as UNESCO World Heritage, the Fagaloa Bay-Uafato/Tiavea conservation zone and the Manono, Apolima and Nuulopa Cultural Landscape are both applying for UNESCO World Heritage status. Neither should be impacted by the Project; the Fagaloa Bay-Uafato/Tiavea conservation zone is approximately 30 km removed from the Project Site, and the Manono, Apolima, and Nuulopa Cultural Landscape is on a minor island.

(3) State of Natural Environment

Samoa is an island nation with volcanic activity, surrounded by coral reef and rich in both marine and land biodiversity. Introduction of invasive species is a problem in recent years. Table 1-2-14 lists the number of species confirmed to reside in Samoa.

Table 1-2-14 Important species to Samoan biodiversity

Species	Endemic	Native	Introduced	Threatened	Total*
Flowering plants	156	c. 500	c. 500	c. 136	c. 1000
Ferns	-	-	-	-	220
Ground birds	15	33	3	14	55
Seabirds	-	-	3	N/A	21
Reptiles	1	4	-	4	14
Ants	12	-	11	N/A	59
Snails	-	64	N/A	-	64
Butterflies	3	20	4	1	28
Moths		170	-	-	170
Freshwater animals (fish)	-	89	-	-	89
Freshwater crustaceans	-	22	-	-	22
Coral	-	-	4	-	N/A
Marine vertebrates	-	-	-	4	8
Marine invertebrates	-	-	-	14	95
Fish	N/A	890	2	-	991
Whales	-	-	-	-	5
Dolphins	-	-	-	-	6

Source: Convention on Biological Diversity, 2009

Endangered and threatened species in Samoa are as follows:

Table 1-2-15 Endangered and threatened species in Samoa

Species	Common Name	Scientific Name	Status
Animals	Sheath-tailed bat	*Emballonura semicaudata*	Endangered
	Samoan flying fox	*Pteropus samoensis*	Threatened
	White-necked flying fox	*Pteropus tonganus*	Threatened
Birds	Samoan moorhen Puna'e	*Gallinula pacifica*	Endangered
	Toothbilled pigeon	*Didunculus trigirostris*	Threatened
	Ma'o	*Gymnomyza samoensis*	Threatened
Butterflies	Samoan swallowtail butterfly	*Papilio godeffroyi*	Endangered
Sea turtles	Hawksbill turtle	*Eretmochelys mbricata*	Threatened
	Green turtle	*Chelonia mydas*	Threatened

Source: Convention on Biological Diversity

The project area is located in the urban area, so that there is no natural vegetation and only limited numbers of trees exist as street trees and artificial visitation. Such environment limits the space of habitat for fauna and biodiversity is very low in the area. There were no threatened or endangered fauna species. The fauna recorded at the site survey was shown in Table 1-2-16.

Table 1-2-16 Terrestrial Fauna recorded at the project area

	English Name	**Scientific Name**	**Samoan Name**
Birds	Common myna	*Acridotheres tristis*	Maina
	Cardinal honeyeater	*Cardinal myzomela*	Segasegamau'u
	Jungle Myna	*Acridotheres fuscus*	Maina
	Polynesian Triller	*Lalage maculosa*	Miti
	Red-vented Bulbul	*Pycnonotus cafer*	Tolai
	Black-naped tern	*Sterna sumatrana*	Gogosina
	Buff-banded rail	*Gallirallus philippensis*	Ve'a
Butterfly	Pacific eggfly	*Hypolimnas antilope lutescens*	Pepe
	Common crow	*Euploea lewinii bourkei*	Pepe

Marine biology survey was undertaken in three sites around the periphery of the Vaisigano Bridge in attempting to observe the baseline status of key marine resources. Table 1-2-17 lists the fish, invertebrate and marine plants species that were recorded and comprise the marine biodiversity of the site. The fauna and flora species recorded are mainly benthic organisms that can tolerate salinity fluctuations and turbid condition. The coral, rare and important species were not observed in the area.

Table 1-2-17 Marine fauna and flora of the Vaisigano Bridge area

	Name	Sites		
		A (about 300m north of the river mouth)	B (about 300m west of the river mouth)	C (about 300m southwest of the river mouth)
FAUNA	Mullet	X	X	X
	Parrotfish (*fuga*)	X		
	Hydroid *(Pennaria disticha)*	X	X	X
	Oyster *(Crassostrea mordax)*	X	X	
	Oyster *(Sacostrea cucullata)*	X	X	
	Rock oyster	X		
	Sponges	X	X	X
	Ascidians		X	X
	Crabs		X	
	Clams		X	
	Barnacles		X	
	Anemones		X	
	Tube-worms		X	
FLORA	Green algae *(Caulerpa serrulata)*	X		
	Brown algae *(Sargassum cristaefolium)*	X		
	Green algae *(Chlorodesmis fastigiata)*			X
	Green algae *(Bryopsis pennata)*		X	X
	Green algae *(Dictyosphaeria versluysii)*			X

(4) Air Quality

In Samoa, there has not been monitored ambient air quality due to the absence of the equipment for collection and analysis of the air sample, and lack of human resource. Therefore, there is no quantitative information of current air quality as baseline. One official of MNRE answered at the interview that MNRE thinks the air quality is acceptable in Samoa but they hope to start monitoring with the institutional setup in future.

Since Samoa is located in South Pacific and far from adjacent courtiers, the pollutant is hard to spread transnationally and the impact is limited inside the country. The low industrial activities do not generate much amount of pollutant. Accordingly, the main source of air pollution is exhaust gas of vehicles. The number of registered vehicles in Samoa was 17,449 in 2013 and 93% of that were passenger cars. The number of registered vehicles in Okinawa prefecture in Japan which has similar size of the area (2,281 km2) was 1,113,630, that is to say the vehicle number is much less than Okinawa and the amount of exhaust gas shall be also much less. For this reason, the air quality in Samoa is considered good, and the opinion of MNRE is also supportive.

The quantitative evaluation of air quality may be difficult for some more years in Samoa because of the current condition of Samoan capability. Therefore, the baseline of air quality is assessed qualitatively.

(5) Water and Sediment Quality

The water quality at the mouth of Vaisigano River and Apia bay was tested both dry season and rainy season. Sampling points are shown in Figure 1-2-45.

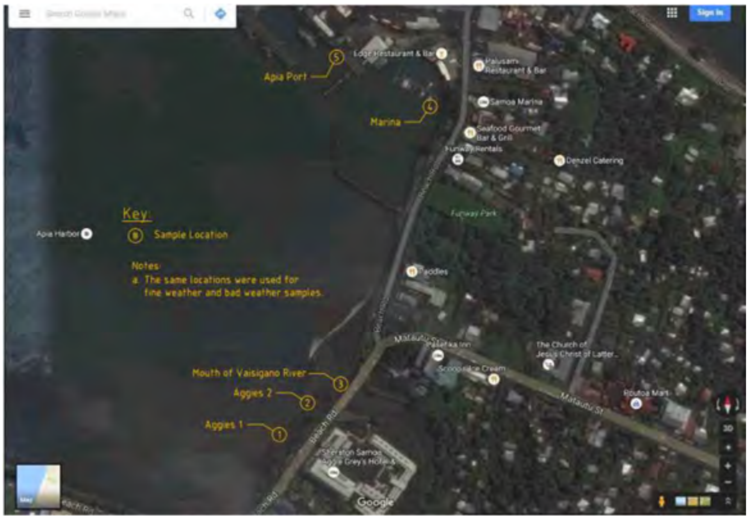


Figure 1-2-45 Sampling Point of Water Quality Test

The result of water quality testing is summarized in Table 1-2-18.

Table 1-2-18 Water Quality near Project Area

	Unit	1	2	3	4	5	Reference*
Dry season (2016/8/1)							
pH		8.11	8.14	7.83	8.09	8.14	7～8.3
Lead	mg/l	0.36	0.65	0.34	0.29	0.48	0.01
Cadmium	mg/l	0.03	0.03	0.03	0.03	0.03	0.003
Coliform	cfu/100ml	30	10	29	34	27	-
Fecal coliform	cfu/100ml	20	<1	19	22	15	-
Turbidity	NTU	2.66	1.58	0.60	1.30	3.34	-
Salinity	PSU	18.14	17.74	18.11	4.31	17.86	-
Total suspended solid	mg/l	6	8	6	7	8	-
Rainy season（2016/11/10）							
pH		8.12	8.08	7.06	8.12	8.17	7～8.3
Lead	mg/l	0.26	0.30	0.13	0.30	0.28	0.01
Cadmium	mg/l	0.006	0.006	0.008	0.008	0.007	0.003
Coliform	cfu/100ml	66	54	63	78	52	-
Fecal coliform	cfu/100ml	52	34	51	60	42	-
Turbidity	NTU	2.97	1.86	1.54	1.70	3.57	-
Salinity	PSU	16.12	14.60	0.05	17.02	17.12	-
Total suspended solid	mg/l	42	38	53	59	54	-

* Reference is environmental standards of Japan

The salinity of seawater is generally in a range around 35 PSU (Practical Salinity Unit). The most of water samples have the salinity value from 14 to 18 PSU, which are categorized in brackish water, because the sampling location is inside of the bay and diluted by the river water. The reference value shown in the table is quoted from Japanese ambient water quality standards. All samples have relative high value of cadmium and lead concentration. The existence of fecal coliform may indicate the effect of domestic effluent contamination from upper stream. The concentration of heavy metals observed in the rainy season tends to be lower than the dry season. On the other hand, the total suspended solid in water sample of the rainy season is high, which might be caused by the heavy rain.

The quality of the sediment was tested because the disturbance of sediment might affect the water quality. The samples of sediment were collected at the expected location of the bridge foundation construction. The result is shown in Table 1-2-19. The sample did not indicate accumulation of the heavy metals into the sediment.

Table 1-2-19 Sediment Quality Test Result

	Unit	1	2
Lead	mg/kg	2.31	0.37
Cadmium	mg/kg	0.90	0.07

(6) Noise and Vibration

MNRE carried out the noise survey at the project site on 16th December 2016. MNRE conducted the noise survey from 8:40am to 5:10pm at the northwest side and southwestern side of the bridge. The equipment was placed at two to three meters from the road on the reserves. The observed equivalent sound level was in the range from 64dBA to 67dBA. And the background noise recorded during no vehicular movement was 52.3dBA. Samoa has the noise policy and defines permissible level of noise for the combination of noise source and noise receiving property. The categories of the noise sources are five, such as Residential use, Commercial use, Religious use, Industrial use and construction. There is no particular category for the road noise. To compare with the Japanese standards of noise for the area bordering on road, the observed data meets the standard for a space near the main road.

Table 1-2-20 Noise Survey Result with Comparison to Japanese Standard

Environmental standards（Area bordering on road）Maximum allowable limit				Survey result
	Area	Day	Night	
1	Area entirely used for the residential purpose bordering on two-lane road	60dB	55dB	64dBA ～ 67dBA
2	Area mainly used for the residential purpose bordering on two-lane road or Area used for residential purpose, commercial and industrial purpose bordering on road	65dB	60dB	
3	Area bordering on main road	70dB	65dB	

MNRE noise measurement procedure is not same as of Japanese standard, so that the measured result may not be comparable directly. Because MNRE set the equipment near to the road, the result is considered to show higher value to compare with the measurement result by Japanese method. Moreover, the location of noise receiving property is farther and the noise at the property shall be lower than the reported value.

Samoa has no standard for vibration so that there is no equipment and person who is capable to measure. The project area is the commercial area with offices and commercial properties mainly. There is no particular business to generate noise and vibration. Therefore, the main source of the noise and vibration in this area is the road traffic. The current condition of the noise and vibration in the area is considered in an acceptable level.

(7) Administrative Districts and Population

Samoa comprises two main islands—Upolu and Savai'i—and several minor islands. Administratively, the nation comprises 11 political districts, further sub-divided into 41 smaller *faipule* districts. While the faipule districts serve no administrative function, they are used as election districts; census data is also organized by faipule district. The Project Site is located in the Vaimauga West faipule district of Tuamasaga district.

The Samoan capital Apia has no city administration. Apia is an area comprising 44 settlements in Vaimauga West and Faleala East, including the area where the Project Site lies.

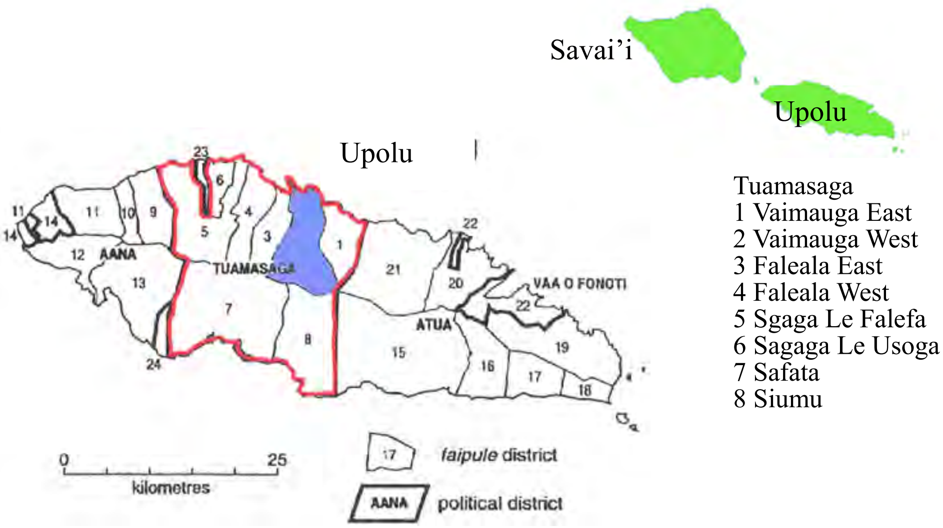


Figure 1-2-46 Upolu administrative districts

A summary of Samoan demographics is given in Table 1-2-21.

Table 1-2-21 Population, area, and population density of Samoa

Region	Population				Area	Pop. Density
	1981	1991	2001	2011	km^2	2011
Samoa total	156,349	161,298	176,710	187,820	2,785	67
Apia	33,170	34,126	38,836	36,735	60	612
NE Upolu	40,360	40,409	52,576	62,390	251	249
Upolu, other districts	39,669	41,713	42,474	44,293	780	57
Savai'i	43,150	45,050	42,824	44,402	1,694	26

Nationally, Samoan population has grown by 6.2 percent between 2001 and 2011. This growth differs greatly between regions; whereas Savai'i population has hardly increased at all, northeast Upolu population has increased greatly. Population density has been high in the capital of Apia, but is on the decline between 2001 and 2011.

Households average between seven and eight persons, with no difference in household composition between urban and rural areas.

(8) Economic Indicators

The Samoan economy is largely dependent upon development aid, remittances from family living abroad, tourism, agriculture, and fishing. The Samoan per capita GDP is 5,200 USD (2015 estimates). According to the 2015 figures, 10.9 percent of this total is from agriculture, 28.3 percent from industry, and 60.8 percent from the service industry (from the CIA World Factbook). Meanwhile, roughly two thirds of the work force work in agriculture and fishing, and 90 percent of exports by value are agricultural and fishery products. Industry is predominantly food processing and manufacturing of construction materials and automotive parts. The project area is commercial area and there are hotels, shops, offices, and fewer residences. The persons who live in this area are mainly salaried workers. No registered fishery has been recorded in the Apia bay and personal fishing by the resident is not observed. Some residents at upper stream of the Vaisigano River wash the clothes in the river but the people in the project area do not do washing in river.

(9) Land Usage

Land usage for Upolu in 2014 is given in Table 1-2-22.

Table 1-2-22 Upolu land usage

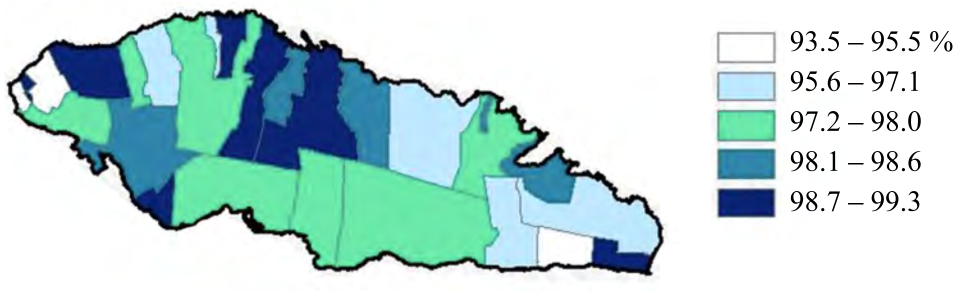
	Area (ha)	Percentage (%)	Definition
Barren Land	100	0.09	Barren land with no plant life
Built up areas	5,754	5.12	Urban areas with residences, parks, commercial and industrial buildings, etc.
Medium Forest	498	0.44	Forest of moderate density
Open Forest	30,743	27.34	Forest with discontinuous tree coverage
Plantation Forest	494	0.44	Forest with planted trees
Secondary Forest	18,782	16.71	Forest that has regrown after harvest
Grassland	8,794	7.82	Land dominated by herbs and grasses
Infrastructure	233	0.21	Roads, airports, and other infrastructural development
Lakes	225	0.20	Lakes
Mangroves	324	0.29	Mangrove forest
Mixed Crops	12,240	10.89	Mixed farmland of root crops and tree crops
Plantation	26,624	23.68	Farmland for palms and other tree crops
Rivers	56	0.05	Rivers and streams
Scrub	7,267	6.46	Perennial shrubs of less than 5 m
Wetland	294	0.26	Swamps and marshes

Source: Forest statistics, SBS

If including secondary forests, forest coverage is high at roughly 45 percent. By area, farmland is the next largest at 35 percent. The Project Site is in an urban area.

(10) Education and Literacy Rates

Literacy rates are high in Samoa at an excess of 90 percent in all regions. Literacy in Apia for those aged 15 to 24 is over 98 percent. The rate of those who have received primary education in the Project Area of Vaimauga West is 79 percent.



Source: Samoa Socio-economic Atlas 2011

Figure 1-2-47 Literacy rates (15-24 year olds)

(11) State of Health and Hygiene

Samoa has an infant mortality rate of 20 per 1,000 births (per 2014 DHS reports) and a maternal mortality rate of 46 per 100,000 births (per the 2011 National Census), both of which are favorable globally. Ninety-nine percent of drinking water is improved, with a 92 percent usage rate for improved sanitation facilities (both per the UNSD MDG Indicator Database). Both figures are high.

1-2-5-3 Environmental and Social Consideration Systems and Organizations in Samoa

(1) Environmental and Social Consideration Systems and Organizations

The Samoan agency in charge of environment issues is the Ministry of Natural Resources and Environment (MNRE). The MNRE is structured with several divisions under the Minister, each in charge of a different sector.

Minister of Natural Resources and Environment

- Planning and Urban Management Agency
- Forestry Division
- Meteorology Division
- Water Resources Division
- Global Environment Division
- Legal Unit
- Technical Division
- Environment and Conservation Division
- Land Management Division
- Corporate Service Division
- Renewable Energy Division
- Disaster Management Davison

Samoan laws pertinent to environmental issues are listed below.

Table 1-2-23 Samoan environmental laws

Name of Legislation	Responsible Authority	Purpose
National Park and Reserves Act 1974	MNRE	To establish and manage national parks and conservation areas
Planning and Urban Management Act 1974	MNRE	Framework for establishing a specialized agency (PUMA) and planning for development, management and conservation
Lands Surveys and Environment Act 1989	MNRE	Land management, environmental conservation, and conservation of wildlife and fish stocks
Waste Management Act 2010	MNRE	Solid waste collection, disposal, and management
Water Resources Management Act 2008	MNRE	Conservation and management of Samoan water resources
Forestry Management Act 2011	MNRE	Effective, continuing forest conservation
Marine Wildlife Protection Regulations 2009	MNRE	Protection and management of sea animals
Protection of Wildlife Regulations 2004	MNRE	Protection and management of land wildlife
PUMA Environmental Impacts Assessment Regulations 2007	MNRE	Regulation regarding development consent and EIA

Fisheries Act 1988	Ministry of Agriculture and Fishery	Management, development and conservation for fishing
Animals Ordinance 1960	MAF	Management and conservation of livestock and wildlife; import/export management
Marine Pollution Prevention Act 2008	Ministry of Works, Transport and Infrastructure	Prevention of marine pollution due to ship passage

Samoa has ratified the following multilateral environmental agreements:

- United Nations Framework Convention on Climate Change 1992
- Kyoto Protocol to the Framework Convention on Climate Change 2005
- Convention on Biological Diversity 1992
- Nagoya Protocol
- Vienna Convention for the Protection of the Ozone Layer 1985
- Montreal Protocol on Substances that Deplete the Ozone Layer 1987
- United Nations Convention to Combat Desertification 1994
- Convention on the Protection of World Heritage and Natural Heritage 1972
- Convention on the Prior Informed Consent Procedure for Hazardous Chemicals and Pesticides in International Trade
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
- Convention on Persistent Organic Pollutants
- Convention of Wetlands of International Importance
- Convention on Migratory Species of Wild Animals
- Conventional on International Trade in Endangered Species of Wild Fauna
- United Nations Convention on the Law of the Sea
- Cartagena Protocol on Biosafety to the Convention of Biological Diversity
- International Treaty on Plant and Genetic Resources for Food and Agriculture
- Minamata Convention (recently)
- Plant Protection Agreement for the South East Asia & Pacific Region
- Strategic Approach to International Chemicals Management

(2) Environmental Standards, Etc

In terms of its own environmental standards, Samoa only has standards for noise. The country is working towards creating its own reference values, which will account for the unique qualities of the nation (hearing from MNRE CEO). Headquartered in Samoa and advising the government on environmental issues, the Secretariat of the Pacific Regional Environment Programme (SPREP) was interviewed, but indicated no guidelines with regard to environmental standards.

Environmental quality is not monitored on the small island due to its population of roughly 190,000, its lack of the human resources needed for environmental monitoring, and its lack of budget capacity.

The only variable measured with any regularity is water quality, which is inspected by the Samoa Water Authority (SWA). Other than water quality, there are no local private contractors capable of taking environmental measurements.

PUMA of MNRE did form a noise policy in 2011, and noise restrictions are in place. Restrictions are determined for each noise source and affected party combination, as shown in Table 1-2-24.

Table 1-2-24 Samoa noise standards

Noise Source	Receiving Property (LAeq, 10 minutes)											
	Residential Use			Commercial Use			Religious Use			Industrial Use		
	Daytime	Evening	Night	Daytime	Evening	Night	Daytime	Evening	Night	Daytime	Evening	Night
Residential Use	55	50	45	60	55	50	60	55	50	60	55	50
Commercial Use	60	55	50	60	55	50	60	55	50	65	60	55
Religious Use	65	55	50	70	60	50	70	60	50	70	65	60
Industrial Use	65	60	55	70	65	60	70	65	60	75	70	65
Construction	75	70	-	75	70	-	75	70	-	75	70	-

Note: Daytime is defined as 7:00 to 18:00, evening as 18:00 to 22:00, and night as 22:00 to 7:00.

The noise source of concern to the Project is represented under construction. For construction, the regulated equivalent sound levels (LAeq) at site boundaries are 75 dB during the daytime and 70 dB in the evening across all facilities affected by the noise. Compared to the regulated noise standards of between 75-85 dB in Japan for specific construction work by type, these standards are stricter given the narrow selection of work types. PUMA will allow additional operation hours and noise levels for construction work in certain cases, depending on the work location and surrounding environment. PUMA is the only local body with the equipment capable of measuring noise levels, which it uses to measure noise on site when there is a claim.

Air quality has not been measured to date; there is no air quality sampling or analyzing equipment locally, or any technicians trained to use such equipment. The same is true for environmental vibration level measurements. For drinking water standards, many variables cannot be measured locally, resulting in water quality being de facto unmonitored. For drainage, while there are no regulations, contractors are required to submit any risks of environmental impact in their Environmental Management Plan (EMP) to MNRE to gain approval for development applications. Contractors must also manage and treat their drainage properly. If anything looks to be out of order in local waters, MNRE takes action on any claims.

For items that MNRE is unable to measure, they are unable to verify monitoring results given by contractors. Thus, it will be critical in implementing projects in Samoa to evaluate the environmental impacts in terms of what the impacts will be, how they will be mitigated, and how they will be controlled.

(3) Environmental Impact Assessment Procedure

The EIA procedure is stipulated in the Planning and Urban Management (Environmental Impact Assessment) Regulations of 2007. All projects in Samoa are required to attain development consent from the Planning and Urban Management Agency (PUMA), a division of MNRE. Contractors are to submit a Development Consent Application (DCA), which is comprised in part by the EIA report. As EIA approval can take some time, however, contractors can submit the EIA report to PUMA in advance of DCA submission.

General progression for the EIA process is as follows:

a) Application for development: Project proponent submits application for development to PUMA

b) PUMA judgment: PUMA judges whether a Preliminary Environmental Assessment Report (PEAR) or Comprehensive Environmental Assessment Report (CEAR) will be appropriate based on details provided in the application, determining the content to be written in the report. PEAR is the equivalent of an Initial Environmental Examination (IEE), and CEAR is the equivalent of an EIA. Reports are to be formatted according to PUMA forms.

c) Environmental and social assessments

The project proponent conducts environmental and social assessments to fulfill the above requirements and reports the findings.

d) Report submission and review

PUMA circulates the EIA to the relevant agencies to solicit comments.

e) Third party opinions and public hearings

As necessary, PUMA may request a third party agency to review the EIA. They will also conduct public hearings for residents when necessary. PUMA determines when public hearings are necessary and will notify the project proponent whether a hearing will be held within two weeks following EIA submission.

f) Approval

According to PUMA, approval normally takes approximately two to three months.

Samoa has prepared guidelines, dubbed the Samoa Codes of Environmental Practice, which contractors are required to follow for environmental management when performing projects. These guidelines have been referenced for the Project as well. The 14 chapters of the guidelines are as follows.

1. COEP 1 Administrative Procedures
2. COEP 2 Road Planning, Design and Construction
3. COEP 3 Consultation
4. COEP 4 Land Acquisition and Compensation
5. COEP 5 Construction Camps
6. COEP 6 Road Construction Erosion Control Construction
7. COEP 7 Slope Stability
8. COEP 8 Quarry Development and Operations
9. COEP 9 Gravel Extraction
10. COEP 10 Coastal Protection
11. COEP 11 Drainage

12. COEP 12 Traffic Control During Construction
13. COEP 13 Earthworks (Draft)
14. COEP 14 Cellular Telecommunications Facilities

1-2-5-4 Comparison of Alternatives (Including the Zero Option)

Alternatives in terms of bridge location and height, approach road alignment, intersection format, construction methods, and other factors are currently being compared and discussed in terms of the technical aspects, environmental and social concerns, and cost.

A comparison of the alternatives for bridge location is given in Table 1-2-25.

The Zero Option is not acceptable because the fear of flooding will continue and the possibility of collapse of the bridge will remain. The alternative 3 is also not acceptable because of highest cost and worse alignment of the road. The alternative 2 is a plan to reconstruct the new bridge at the same location of the existing one. It requires the temporary bridge construction with higher cost, and the effect of constriction is bigger. The alternative 2 is a plan to use the existing bridge during construction of the new one and it results in the reduction of cost. The new bridge will be shifted 20 m toward seaside and the impact of the construction work, e.g. noise, vibration and exhaust gas will be reduced. Additionally, the noise and vibration during operation is also expected to reduce. Therefore, alternative 2 is assessed as the best option.

Table 1-2-25 Comparison of Alternatives

Alternative Plans		Proposal 1	Proposal 2	Proposal 3	Zero Option
Plan description		Existing bridge location is used	Bridge location is shifted approximately 20 m downstream from the existing bridge	Bridge location is shifted approximately 50 m downstream from the existing bridge	Existing bridge is used as-is.
New bridge alignment		As the existing bridge is straight, reconstructing the bridge in the existing location would have an excellent alignment	As alignment would be nearly the same as the existing bridge, the bridge section would be straight with an excellent horizontal alignment	Bridge would be S-shaped. Horizontal alignment would be poorer than the existing bridge, making bridge length much longer.	—
Temporary bridge and detour route		With reconstruction at the same location, the existing bridge and road could not be used, requiring a temporary bridge and detour route to be constructed.	No temporary bridge or detour route required. The new bridge would be shifted approx. 20 m downstream, leaving the existing bridge and road open for use.	No temporary bridge or detour route required. The new bridge would be greatly shifted downstream, leaving the existing bridge and road open for use.	—
Environmental/social considerations	Impact to adjacent hotel	Bridge profile will be increased by 1.5 m, obstructing hotel access. Being adjacent to the bridge, impact to the hotel during construction would be great.	Obstruction to hotel access from the profile increase of 1.5 m can be alleviated with a side road. The added distance from the hotel to the new bridge will reduce impact from construction. Once in service, this may reduce road noise.	Obstruction to hotel access from the profile increase of 1.5 m can be alleviated with a side road. The added distance from the hotel to the new bridge will reduce impact from construction. Once in service, this may reduce road noise.	Potential risk of flooding continues.
	Impact to residents near the project site	Residents may have impacts from construction work, such as noise, viblation and air pollution. However, construction site is far and imlact is less. Fear for flooding will be less.	Residents may have some impacts from construction work, such as noise, viblation and air pollution. However, construction site is far and imlact is less. Fear for flooding will be less.	Residents may have some impacts from construction work, such as noise, viblation and air pollution. Construction site is farest among these options and imlact is very less. Fear for flooding will be less.	Potential risk of flooding continues.

Resettlement and right of way	Reconstruction in the existing location will in general not require any resettlement or right-of-way acquisition.	As there are no residences in the new alignment, no resettlement will be required. However, a right-of-way will be required to build the new approach road.	As there are no residences in the new alignment, no resettlement will be required. However, a right-of-way will be required to build the new approach road.	Not necessary
Cost	Not as cost-efficient as Proposal 2. Bridge construction costs are the same, but a temporary bridge and detour route must also be built.	The most cost-efficient option. Does not require construction of a temporary bridge or detour route, and bridge construction costs are much less than Proposal 3.	The least cost-efficient option. Does not require construction of a temporary bridge or detour route, but bridge construction costs are very high.	The economic losses from deterioration of the existing bridge in terms of restricting passage of trucks and larger vehicles cannot be ignored.
Resistance to natural disaster	100-year tide levels and floods will not inundate the main girders, and the risk of secondary disaster from driftwood will be eliminated.	100-year tide levels and floods will not inundate the main girders, and the risk of secondary disaster from driftwood will be eliminated.	100-year tide levels and floods will not inundate the main girders, and the risk of secondary disaster from driftwood will be eliminated.	Another cyclone on the scale of Cyclone Evan is highly likely to result in flood damage.
Bridge integrity and safety	New bridge construction will restore bridge integrity and safety.	New bridge construction will restore bridge integrity and safety.	New bridge construction will restore bridge integrity and safety.	A risk of bridge collapse has been indicated due to aging and extreme damage from Cyclone Evan in 2012.
Evaluation and reason	Second best	Best	Third best	Worst
	It requires a temporary bridge, and raises the cost. The noise/ vibration effect of construction is relatively high.	From the viewpoint of cost and the lowest negative impact on environmental issues, it seems the best.	Due to the highest cost and alignment difficulty, it is not adequate.	The fear of flood and damage of bridge will continue and it is hard to select this option.

1-2-5-5 TOR for Scoping and Environmental and Social Assessments

The scoping result is shown in Table 1-2-26 and TOR based on the scoping listed in Table 1-2-27.

Table 1-2-26 Scoping Result

Category	Impacts		Evaluation		Reasons for Assessment
			Design/Construction	Operation	
Pollution Measures	1	Air Pollution	B-	C	Construction: While temporary, operation of construction equipment and related vehicles is expected to worsen air quality. Operation: Air pollution may increase due to increased traffic volume, but a positive effect can also be expected as the bridge will alleviate traffic jams.
	2	Water pollution	B-	D	Construction: Wastewater from the work site may result in water pollution. During foundation work, such as piers and abutments, stirring up bottom sediment may cause water pollution. Operation: No elements to cause water pollution.
	3	Solid waste	B-	D	Construction: Demolishing the existing bridge will produce waste. Domestic waste will also increase due to workers. Operation: No waste expected that would impact the surrounding environment.
	4	Soil pollution	D	D	Construction/Operation: No work expected to cause soil pollution.
	5	Noise and vibration	B-	C	Construction: Noise and vibration is expected from operation of construction equipment and vehicles, removal of existing bridge, and other work. Operation: Noise and vibration may increase due to increase in traffic volume.
	6	Ground Subsidence	D	D	Construction/Operation: No work or other factors expected to cause ground subsidence.
	7	Offensive odors	D	D	Construction/Operation: No work or other factors expected to cause offensive odors.
	8	Sediment	B-	D	Construction: Work in the river and on the shoreline may stir up bottom sediment. Operation: No possibility of impact on sediment.
Natural Environment	9	Conservation areas	B-	D	Construction: While there is a marine reserve area nearby, the reserve lies outside the bay and thus will not be greatly impacted by work in the bay. Operation: No possibility of impact.

	10	Ecosystems	B-	D	Construction: As this will be a reconstruction of the existing bridge, impacts on the land ecosystem are not expected to be great. However, there are concerns of impact to the existing marine life from moving seaward on the shoreline. Also, increased turbidity during the work from turbid water and agitation of bottom sediment could have impacts. Operation: No possibility of impact
	11	Hydrology	B-	B+	Construction: With the bridge located at the lower reach of the river, impact to river flow will likely be minimal. Construction methods which will not obstruct flow during flood season must be discussed, however. Operation: In light of rising tide levels due to flooding and climate change, the bridge will be higher than before, and the piers will be spaced wider apart for improved river flow. These measures will reduce the chances of damage from flooding and other factors.
	12	Topography and geology	D	D	Construction/Operation: Impacts to topography and geology will be avoided by enhancing levees and improving river flow.
Social Conditions	13	Resettlement	D	D	Construction/Operation: Bridge design will shift the bridge downstream (seaward) from the existing bridge. No one is living in the Project implementation zone or will be resettled.
	14	Poverty	C	B+	Construction: Poverty levels at the Project Site are being investigated. Operation: Raising the bridge level will reduce the risk of flooding, possibly having positive impacts on the poor.
	15	Ethnic minorities and indigenous peoples	C	C	Construction/Operation: We are currently investigating whether there are any ethnic minorities or indigenous peoples living in or near the Project Site.
	16	Local economies, such as employment, livelihood, etc.	B+	B+	Construction: Construction employment will be a plus for the local economy. Operation: The improved traffic conditions are likely to have a great positive effect on the local economy.
	17	Land and local resource usage	B-	B+	Construction: The land surrounding the work site will need to be borrowed temporarily. Operation: With the bridge being shifted seaward, the road will also be moved, leaving an empty lot in the area occupied by the current road. This lot could be put to effective use.
	18	Water usage	D	D	Construction/Operation: As the Project Site is at the mouth of the river and no water is being used, the Project will have no impact.

	19	Existing social infrastructure and services	B-	B+	Construction: Traffic jams are expected during construction. Also, water pipes, fuel pipes, and communication lines are attached to the current bridge and will need to be properly moved. Operation: Improvements to traffic are expected to have a greatly positive effect.
	20	Social capital, local decision-making bodies and other social organizations	D	D	Construction/Operation: The Project is not expected to impact social capital or social organizations.
	21	Misdistribution of benefits and damages	D	D	Construction/Operation: No elements of the Project will impact distribution of damage and benefits in the local area.
	22	Local conflicts of interest	D	D	Construction/Operation: The Project should not create any local conflicts of interest.
	23	Cultural heritage	D	D	Construction/Operation: There are no cultural heritage sites located in or near the project area.
	24	Landscape	B-	B-	Construction/Operation: Views from the hotel facing the existing bridge could be obstructed.
	25	Gender	D	D	Construction/Operation: The Project is not expected to have any particularly negative
	26	Children's rights	D	D	Construction/Operation: The Project is not expected to have any particularly negative
	27	HIV/AIDS and other infectious diseases	B-	D	Construction: While the bridge is relatively small at 75 m long, the possibility of increased infectious disease due to an influx of construction workers will be reviewed. Operation: No possibility of impact
	28	Working conditions (incl. occupational safety)	B-	D	Construction: Working environment for construction workers must be considered. Operation: No possibility of impact
Other	29	Accidents	B-	B-	Construction: Considerations for accidents during the work must be made. Operation: With the changes in alignment, safe passage of traffic will need to be ensured.
	30	Transnational impacts and climate change	D	B+	Construction: This Project should not have much transnational impact or negative impact on climate change. Operation: Reducing traffic jams should also reduce exhaust emissions for a positive environmental impact.

<u>Scores</u>

A: Great impact expected. B: Some impact expected. C: Impact unknown; confirmation study required. D: Slight impact; no study needed.

+: Positive impact; -: Negative impact

Table 1-2-27 TOR Plan

Impacts		Study Items	Study Method
1	Alternative plan analysis	1) Bridge location, height, design 2) Construction methods	1) Authority hearings, study precedents, etc. 2) Authority hearings, study precedents, etc.
2	Air Pollution	1) Applicable standards 2) Current air quality 3) Impacts during construction 4) Impacts during service	1) Literature research, precedents, hearings 2) Literature research, hearings 3) Estimate emissions for construction vehicles/ machinery, generators, etc. 4) Estimate vehicle traffic emissions
3	Water pollution	1) Turbid water 2) Sediment	1) Check construction methods and work which could cause turbid water, estimate scale, study water quality 2) Check construction methods and work which could agitate bottom sediment and estimate scale
4	Solid waste	1) Construction waste 2) General waste	1) Estimate type/volume of construction waste generated by removal of existing bridge, hearings on how to dispose 2) Hearings on how to dispose of general waste
5	Noise and vibration	1) Applicable standards 2) Current noise and vibration 3) Impacts during construction 4) Impacts during service	1) Literature research, precedents, hearings 2) Literature research, hearings, measurement 3) Estimate levels for construction vehicles/ machinery, generators, etc. 4) Estimate levels from vehicle traffic
6	Sediment	1) Sediment quality	1) Literature research, survey of sediment quality near the work site
7	Conservation areas	1) Impact of work on conservation areas	1) Estimate impact to marine reserves
8	Ecosystems	1) Ecosystems	1) Confirm rare species in the area, investigate bay marine life. Literature research and field study.
9	Hydrology	1) Construction impacts	1) Estimate river flow before and after bridge reconstruction
17	Land and local resource usage	1) Current land use	1) Hearings and cadastral survey
19	Existing social infrastructures and services	1) Traffic volume survey results 2) Utilities survey results	1) Analyze traffic volume survey and estimate congestion 2) Confirm where/how to move utilities affixed to existing bridge, hearings with owners
24	Landscape	1) Landscape	1) Confirm current views and estimate view after the Project
27	HIV/AIDS and other infectious diseases	1) Current state of infectious diseases 2) Impact from the Project	1) Interviews on current state of infectious diseases 2) Estimate scale and duration of the work
28	Working conditions (incl. occupational safety)	1) Current status of work-related injury 2) Current status of implemented work safety measures	1) Literature research, hearings 2) Interviews
29	Accidents	1) Current traffic accident statistics 2) Current status of measures	1) Literature research, hearings 2) Interviews

1-2-5-6 Progress for Environmental and Social Assessments

Results from the field study and the outsourced study of environmental and social considerations are summarized in the table below.

Table 1-2-28 Results of environmental and social study

<table>
<tr><th>Field</th><th>Impacts</th><th>Evaluation Results</th></tr>
<tr><td>Pollution Measures</td><td>Air Pollution</td><td>
Samoa has no institutional structure for monitoring air quality. MNRE has no experience measuring air quality, and there is no surveying or measuring equipment available locally. There is no base quantitative data for air quality in Samoa as to date, air quality has never been surveyed, even on a project basis. As monitoring for air quality requires a certain duration of time, as well as trained engineers and measuring equipment, it is currently not realistic in Samoa to monitor air quality at the project level by taking measurements. Thus, for this Project, estimates were taken based on the emission sources to arrive at mitigation measures.
During the construction period, impacts are expected in terms of emissions from construction vehicles and machinery, as well as dust during the earthwork and bridge removal. The level of pollution was estimated by simple Puff Model with the assumption of no wind diffusion in case of heavy vehicles operation at same time. The result is shown the table below with the comparison of Japanese standards and the air pollution level is very low.
<table>
<tr><th>Parameter</th><th>Unit</th><th>Estimation</th><th>Permissible level of Japanese standards</th></tr>
<tr><td>CO</td><td>ppm</td><td>0.063</td><td>10ppm (daily average per 1hour)
20ppm (8-hour average per 1 hour)</td></tr>
<tr><td>NO2</td><td>ppm</td><td>0.008</td><td>0.04ppm~0.06ppm or less (daily average per 1hour)</td></tr>
<tr><td>PM</td><td>mg/m^3</td><td>0.004</td><td>0.10mg/m3(daily average per 1hour)
0.20mg/m3 (1hour value)</td></tr>
</table>
Samoa is not industrialized and the main source of air pollution is exhaust gas of vehicles. The number of vehicles is very less than the countries like Japan and the baseline air quality is considered well. It is supported by the opinion of MNRE. Therefore, the effect of the construction is in acceptable level. However, the effort to control the exhaust gas by the management of the construction vehicle and appropriate operation should be paid.
During operation, impact is expected from the emissions of passing vehicles. A figure of 0.8 percent is estimated for annual growth of vehicle traffic in Samoa. Traffic in Samoa will grow by 8.3 percent in ten years' time, but as some of this will be diverted with the repair of Leone Bridge upstream and other factors, traffic near the Vaisigano Bridge is expected to grow by 6.0 percent after ten years in service. Meanwhile, improvements to the approach road intersection are expected to improve traffic flow, reducing intersection delays to a third of their current levels. Thus, reductions in traffic congestion can be expected to reduce cumulative emissions. Additionally, the shift of the bridge location toward the seaside will reduce the direct impact of vehicles to the premises near the road.
</td></tr>
</table>

<table>
<tr><td></td><td>Water pollution</td><td>With the Project Site being at the end of the river, work impacts on river water quality should be safe to ignore. Turbid water generated by the work could affect water quality in the bay, however.

Sediment quality was also surveyed due to the possibility of bottom sediment getting stirred up during bridge foundation work. Soil samples were taken near the area where bridge foundation work is expected to take place. The results are given below:

<table>
<tr><th></th><th>Units</th><th>1</th><th>2</th></tr>
<tr><td>Lead</td><td>mg/kg</td><td>2.31</td><td>0.37</td></tr>
<tr><td>Cadmium</td><td>mg/kg</td><td>0.90</td><td>0.07</td></tr>
</table>

At these concentration levels, even if suspension by weight reaches 1 percent turbidity, levels for these contaminants will be well below what is currently included in water. Thus, turbidity is what presents the issue in terms of water pollution due to bottom sediment agitation.</td></tr>
<tr><td></td><td>Solid waste</td><td>Samoa has the Waste Management Act of 2010 in terms of solid waste legislation. This legislation lists 1) arrangements for provision of collection services for commercial, industrial and domestic waste, 2) landfill management, 3) authorization of waste disposal, and 4) proper management of waste storage among the responsibilities of the competent environmental authority (currently MNRE). Ocean dumping and incineration of waste are generally not permitted. Samoa currently has no incineration plants. Upolu has one landfill disposal site: Tafaigata landfill. With JICA assistance, Tafaigata landfill has instated a semi-aerobic, hygienic method of disposal known as the Fukuoka Method, and is widely known as a model case for Pacific island nations. The landfill accepts general waste and all non-recyclable waste. Construction waste is accepted at a fee.
The bulk of the construction waste generated by the Project will comprise steel material and concrete rubble from demolition of the old bridge. Steel material can be recycled. When consulted, MNRE said that they sell waste from demolition of public structures through public bidding and, in the interest of promoting recycling and reducing waste, recommended the same process in this case. In order to minimize construction waste, we will consider how best to recycle those resources which can be utilized. The waste volumes currently anticipated are as follows:

<table>
<tr><th>Materials</th><th>Amount (m^3)</th><th>Source(s)</th></tr>
<tr><td>Steel</td><td>15</td><td>Existing bridge</td></tr>
<tr><td>Concrete</td><td>1.010</td><td>Existing bridge, sidewalk pavement, curbstone, stairs, revetments</td></tr>
<tr><td>Asphalt</td><td>320</td><td>Road pavement</td></tr>
</table>
Workers will also produce domestic waste during construction. It is dumped to the authorized damping site with payment as general waste.</td></tr>
</table>

	Noise and vibration	The nearby hotel will be impacted the most by noise and vibrations during construction. Shifting the new bridge position seaward will reduce the impact from construction work, but given the close proximity, removal of the existing bridge and approach road is expected to have a large impact. With sufficient distance from all nearby residences, the impact on residences by work noise and vibration should be small. Distance from the hotel to the existing bridge is approximately 20 m, as is the straightline distance to the new road to be built. Bridge removal will reportedly produce noise levels of 120 dB; simple attenuation at a distance of 20 m will reduce this to 64 dB, satisfying Samoan work noise standards of 75 dB (and Japanese standards of 75-85 dB). Together with dust measures, installing a temporary enclosure and/or sound insulation sheet is expected to further reduce noise by another 15 dB. Pile driving and extraction during bridge foundation work is expected to be a large noise source, but with the bridge being shifted 20 m seaward, impacts to the hotel and nearby residences will be reduced. For roadwork, while the work will not produce much noise, a temporary enclosure will be discussed for in front of the main hotel entrance and other areas to help in terms of negative aesthetic impacts. Once the bridge and approach road are in service, the seaward shift will move all noise and vibrations away and is anticipated to improve noise and vibration by means of distance attenuation.
	Sediment	While neither Japan nor Samoa have any real standards for sediment, given the tendency for heavy metals to concentrate in bottom sediment, there is the risk of suspension affecting water quality. Results of the water quality analysis are as given in Water Pollution above. As is shown, concentration levels are not high, and the impact of the work stirring up bottom sediment will mainly be in terms of increased turbidity.
	Conservation areas	There are no conservation areas within the Project area.
	Ecosystems	The Project site is in an urban area with no natural vegetation, only roadside trees and planted plants. Thus, there is little place here for animals to live; in the study, diversity was poor, with six species of ground birds and one species of marine bird observed. Accordingly, impact to the land ecosystem is limited. Diversity in terms of marine biota is low due to the stagnant waters in the bay and accumulated mud from floodwaters from the river. In the biological survey, all flora and fauna living in the site are strong in muddy areas, with no rare or endangered species.
	Hydrology	Abutment work will be scheduled to avoid the rainy season, and the Project is being planned to avoid any situation where the work will obstruct river flow. The design for the new bridge provides for a 1-meter clearance height over 100-year storm surge and flood levels and measures to keep driftwood from striking the bridge girders, greatly reducing the chances of flood damage. Installing the revetments will also further reduce these flood damage risks.
	Land Usage	Impacts in terms of land usage will be limited. As the new bridge and approach road are planned to be shifted seaward, the main work site consists of the current bridge and road ROW, and the coastline.

	Poverty	Samoa defines two kinds of poverty lines, such as Food Poverty Line (FPL) and Basic Needs Poverty Line (BNPL). Based on the social survey carried out by this study, the almost all households are over the FPL but BNPL in the project area. The beggar is not observed in downtown. So the poverty is not serious in the area.
	Utilities	Discussions are already underway with the water and communication authorities. We have discussed the timing and methods for movement of the lines and received consent for relocation.
	Landscape	The plans currently being discussed have the bridge being raised 1.5 m and moved further seaward from the current bridge location, and thus should not result in a big change in terms of landscape and views. Also, the promenade is planned for restoration to its current state. The palm trees currently lining the promenade will be either transplanted or replanted in order to recreate the current landscape. Views from the hotel could be obstructed during the construction. Either sound insulation sheets or temporary enclosures are planned to reduce noise and vibration. We will have to consider what to do about the views from the hotel.
	Infectious diseases	While Samoa does have occasional outbreaks of typhoid fever, rubella and other viral infections, other infectious disease is reportedly infrequent. According to UNAID reports, HIV rates are extremely low in Samoa; from the first reported case in 1990 to 2014, there have been 24 cases, of which most are sexually transmitted. Education on preventing infections is fundamental, however, as other than HIV, sexually transmitted diseases are on the rise.
	Working conditions	Samoa is currently working to reduce work-related accidents based on the Occupational Safety & Health Act of 2002 and the Occupational Safety and Health Regulations of 2014. According to 2014 data from the International Labour Organization (ILO), 38 males fell casualty to non-fatal accidents in Samoa in 2014. With a reported workforce population of 37,800 for 2014, this represents roughly a 0.1 percent accident rate. Workers at construction site are generally use protection tools such as helmet, so that working condition seems acceptable in Samoa.
	Accidents	The death of road accident is generally in the range from 10 to 20 a year without special occasion of traffic direction change in 2009 to 2010. 76% of the death of traffic are pedestrians. According to WHO report the traffic accident ratio of Samoa is 15.8 per 100,000 populations. It is not high but the preventive measures during construction e.g., the signboard, guiding person are important. The change of the alignment of the approach road requires the change of approaching direction and change of crossroad. Therefore, the safety measures should be taken. These are incorporated in the road design.

1-2-5-7 Stakeholder Meeting

An overview of the content in the stakeholder meeting is given in Table 1-2-29. Minutes of the meeting are attached in the appendix. Stakeholder opinions on moving the utility lines, safe design for the access road to the hotel, and other issues have been reflected in the project plans. Also, following the Q&A session on environmental and social assessments in the public hearings for residents, the residents supported Alternative 2 and agreed with Project implementation. The residents' biggest concern was what measures would be taken to prevent flood damage; they were happy to hear that rebuilding an improved bridge would have a synergistic effect with the separate river levee improvement project to further reduce future risks of flooding. Other than the examples listed in the table below, there were also individual resident interviews with owners of land which would be directly affected by the work. Through the all discussions and meetings, the negative opinion was not stated by the attendant.

Table 1-2-29 Stakeholder meeting implemented content

Topic	Date/Place		Participants	Format	Details Discussed
Operators of utilities connected to existing bridge	2016/6/22 LTA		Water, electricity, communication, and fuel operators LTA Study Team Total: 14	Meeting	Explanation of Project plans and need to relocate utility lines. Q&A on procedures and issues with moving the utility lines.
Hotel beside Project Site	2016/7/15 Sheraton Hotel		Hotel managers LTA Study Team Total: 5	Meeting	Explanation of Project plans. The hotel manager expressed concerns regarding safe hotel access from the new road alignment and road drainage; responded that these would be dealt with in designs.
Neighboring residents	2016/10/3 Maluafou College Hall		Residents and resident representatives from the neighboring area Total: 13	Public hearing	Explanation of Project plans and scoping results. Free discussion. Questions centered on the merits of new bridge construction in terms of flood damage and how robust the bridge would be. Also explained that the government or LTA would be responsible for how to utilize the land emptied after relocating the approach road.
Neighboring residents and business entities	2016/10/26 Maluafou College Hall		Residents, representative of business entities, and resident reps from the neighboring area Total: 25	Public hearing	Summary of the Project and explanation of the environmental and social assessment and plan alternatives. Free discussion. Questions covered details on mitigating impacts during construction and other details. Participants supported Alternative 2 in the alternative comparison.
Hotel beside Project Site	2016/11/7 Sheraton Hotel		Hotel managers LTA Study Team Total: 4	Meeting	Explanation of the result of survey and mitigation measures. The hotel manager told that the impact by the construction will be manageable but the construction during high season is better to be reduced.

1-2-5-8 Impact Assessment

Based on the results of the field study and environmental and social assessments, as well as the opinions shared in the Stakeholder meetings, impact assessments of the scoping results have been revised as outlined in the following table.

Table 1-2-30 Impact assessment

Field	Impacts	Impact Assessment at Scoping		Impact Assessment Based on Study Results		Reasons for Assessment
		Design/ Construction	Operation	Design/ Construction	Operation	
	Air Pollution	B-	C	B-	D	Construction: While temporary, emissions from movement and operation of construction equipment and related vehicles, as well as dust generated in existing bridge removal and other work, is expected to worsen air quality. Operation: Traffic is not expected to increase greatly, and improvements to the approach road intersection should reduce traffic congestion. Thus, air quality should not be any worse than current levels, and study evaluation is changed in D.
	Water pollution	B-	D	B-	D	Construction: Wastewater from the work site may result in water pollution. During foundation work for the piers and abutments, stirring up bottom sediment may cause water pollution. Operation: No possibility of impact
	Solid waste	B-	D	B-	D	Construction: Demolishing the existing bridge and part of the road pavement will produce waste. Waste will also increase due to workers. Operation: No waste expected that would impact the area environment.
	Noise and vibration	B-	C	B-	D	Construction: Noise and vibration is expected from operation of construction equipment and vehicles, pile driving and extraction, existing bridge removal, and other work. Operation: Traffic is not expected to increase greatly. Also, the bridge and approach road are to be shifted seaward, which should actually reduce noise and vibrations from the road. Thus, the after work evaluation is D.
	Sediment	B-	D	B-	D	Construction: Work in the river and on the shoreline may increase turbidity by stirring up bottom sediment. Operation: No work to generate disturbance on sediment.
	Conservation areas	B-	D	D	D	Construction: While there is a nearby marine reserve, the reserve lies outside the bay and will only see limited impact from work in the bay. Also, the current ocean currents are not expected to be directly impacted by the Project. Thus, the after work evaluation is D. Operation: No impact by the project.
	Ecosystems	B-	D	B-	D	Construction: As this will be reconstruction of an existing bridge, impacts on the land ecosystem are not expected to be great. However, increased turbidity due to turbid water and bottom sediment agitation during the work could have an impact. Operation: No impact by the project.

	Hydrology	B-	B+	B-	B+	Construction: With the bridge located at the lower reaches of the river, impact to river flow will likely be minimal. Work must be scheduled not to obstruct flow during flood season, however. Operation: In light of rising tide levels due to flooding and climate change, the bridge will be higher than before, and the piers will be spaced wider apart for improved river flow. These measures will reduce the chances of damage from flooding and other factors.
	Poverty	C	B+	D	B+	Construction: There are no poor in the immediate vicinity of the project site. Operation: Raising the bridge level will reduce the risk of flooding, possibly having positive impacts on lower income classes.
	Employment, livelihood and local economy	B+	B+	B+	B+	Construction: Construction employment will be a plus for the local economy. Operation: The improved traffic conditions are likely to have a great positive effect on the local economy.
	Land and local resource usage	B-	B+	B-	B+	Construction: The land surrounding the work site will need to be borrowed temporarily. Operation: With the bridge being shifted seaward, the road will also be moved, leaving an empty lot in the area occupied by the current road. This lot could be put to effective use.
	Existing social infrastructure and services	B-	B+	B-	B+	Construction: Traffic jams are expected during construction. Also, water pipes, fuel pipes, and communication lines are attached to the current bridge and will need to be properly moved. Operation: Improvements to traffic are expected to have a greatly positive effect.
	Landscape	B-	B-	B-	D	Construction: Views from the hotel could be obstructed during the removal of the road facing the hotel and current bridge next to the hotel. Operation: The promenade for the approach road will be reconstructed almost exactly to its current state, and there is little chance that views will suffer. Evaluation is a D.
	HIV/AIDS and other infectious diseases	B-	D	B-	D	Construction: While the bridge is relatively small at 75 m long, there is possibility of increased infectious disease due to an influx of construction workers. Operation: No impact by the project.
	Working conditions (incl. occupational safety)	B-	D	B-	D	Construction: Working environment for construction workers must be considered. Operation: No impact by the project.
	Accidents	B-	B-	B-	D	Construction: Considerations for accidents during the work must be made. Operation: Improvements to the intersection will improve traffic, possibly reducing the rate of accidents. Thus, the after work evaluation is D.
	Transnational impacts and climate change	D	B+	D	B+	Construction: Samoa is located at South Pacific and far from neighbor countries, thus there is little possibility of transnational pollutant transport. Operation: Reducing traffic jams should also reduce exhaust emissions for a positive environmental impact.

<u>Scores</u>

A: Great impact expected. B: Some impact expected. C: Impact unknown; confirmation study required. D: Slight impact; no study needed.
+: Positive impact; -: Negative impact

1-2-5-9 Mitigation Measures and Their Implementation Costs

The mitigation measures to be taken based on the results of the environmental and social assessments and impact assessments given above are as outlined in the table below.

Table 1-2-31 Impacts and mitigation measures

Impacts	Mitigation Measures (During Construction)	Implementing Body	Supervisory Authority	Costs
Air Pollution	Temporary enclosures and covers will be used to contain dust, and the amounts generated will be minimized by spreading water during work that generates dust. Emissions from work vehicles and machinery will be reduced by enforcing registration of vehicles and machinery, and keeping them well maintained and managed.	Contractors	LTA MNRE	Construction costs
Water pollution	Work that could generate turbid water, such as the foundation work for abutments and piers, will take place inside cofferdams to avoid direct discharge into the river. As necessary, water will be neutralized or treated for sedimentation. Water turbidity will be monitored and controlled with visual inspections. If anything is found to be abnormal, work will stop immediately so that appropriate measures can be taken. Samples will also be taken to analyze water quality.	Contractor	LTA MNRE	Construction costs
Solid waste	Construction waste will be recycled as much as possible. For disposal, the set fees will be paid to dispose at certified disposal sites. For domestic waste from the workers, disposal will be outsourced at a fee according to local rules for general waste disposal.	Contractor	LTA MNRE	Construction costs
Noise and vibration	Noise and vibrations from the work will be reduced by installing temporary enclosures or sound insulation sheets between the site and potentially impacted facilities. In addition, work hours will be limited to daytime only, with no work on weekends or holidays. Noise and vibrations will be monitored during the work to confirm that they are kept at acceptable levels. Operators will be trained in work procedures in order to limit noise and vibrations. In addition, at the time of removal of the existing A1 abutment, the hotel side will move guests to the back rooms away from the road.	Contractor	LTA MNRE	Construction costs
Sediment	Given the risk of bottom sediment being stirred up, measures will be taken to mitigate water pollution.	Contractor	LTA MNRE	Construction costs
Ecosystems	Impacts will be mitigated with water pollution prevention measures.	Contractor	LTA MNRE	Construction costs

Hydrology	Work implementation will be scheduled to avoid working in the river during flood season. The relevant authorities will be consulted to take separate measures in times of emergency, such as cyclones.	Contractor	LTA	Construction costs
Land and local resource usage	LTA will be responsible for temporarily leasing the land surrounding the work site.	LTA	MNRE	Samoan governmental budget
Existing social infrastructure and services	Impacts from traffic congestion and detours rising from the work will be minimized by posting signboards, deploying traffic guides, and making public announcements to local residents. For the utility lines, a relocation plan is already made, and relocation will move forward fully consulting with the relevant parties during implementation.	Contractor	LTA	Construction costs
Landscape	In efforts to minimize impact to views from the hotel closest to the work site, the location and periods for installing the temporary enclosures and sheets will be given due consideration. The work schedule will also be shared with the hotel.	Contractor	LTA	Construction costs
HIV/AIDS and other infectious diseases	The working parties will be educated on a periodic basis in efforts to prevent infectious diseases.	Contractor	LTA	Construction costs
Working conditions (incl. occupational safety)	The working parties will be educated on a periodic basis in efforts to prevent work accidents. Safe tools will be supplied as necessary.	Contractor	LTA	Construction costs
Accidents	For construction vehicle operation, a safe driving plan will be prepared, and drivers will attend safety classes to prevent accidents.	Contractor	LTA	Construction costs

1-2-5-10 Land Acquisition and Resettlement

(1) Need for Land Acquisition and Resettlement

There are no residents or buildings of any type on the Project Site, and thus no one will be resettled. In terms of right of way, the bridge will be shifted downstream (seaward), requiring a new right of way for the approach road. Road plans will be adjusted to remain fully contained within the current road right-of-way and government-owned lands. Accordingly, no private lands will need to be acquired.

If a government agency is using the government land for public works, authorization will need to be obtained. First, the organization to use the land (LTA in the case of this Project) will submit a request form listing a summary of the project, location of the desired government land, use objective, and other details to the MNRE Minister. As chair of the Land Board, the MNRE Minister will then approve land usage. For projects of national importance, a copy of the request is passed onto the Prime Minister to push the process forward. For public works, this process generally takes about 1-2 months.

(2) Legal Framework to Land Acquisition and Resettlement

The following legislation provides the relevant legal framework for land acquisition and resettlement in Samoa:

- The Constitution
- Property Law Act 1952
- Taking of Land Act 1964
- Land Titles Registration Act 2008 and regulations
- Survey Act 2010 and regulations
- Alienation of Customary Land Act 1965
- Land Transport Authority Act 2007
- Land Valuation Act 2010; and
- Samoa Code of Environmental Practice.

Land for public use (transfer of freehold land or customary land) is to be expropriated according to the Taking of Land Act of 1964. If it becomes apparent that land expropriation will be required, the freehold landowner, or *matai* (chief) with *pule* (authority) over the customary land, is to be notified (takes approximately one month). The owner or *matai* is given 28 days to submit an objection. If no written objection is submitted, the Minister of MNRE announces the land expropriated and proceeds.

Land is titled and purchased in accordance with the Land Titles Registration Act of 2008. This legislation is only applicable for private transfer of freehold land, however, and does not apply to customary land.

1) Land Classifications

Land in Samoa is classified as follows.

a) Customary land

The majority of Samoan land is owned under customary ownership, a right protected by the constitution. Land rights for customary land are owned by the *matai* or family chief. Land distribution within a family is determined by the family chief. There are two methods of transferring customary lands: lease, and public purpose, as defined in the Taking of Land Act of 1964.

b) Freehold land

Freehold land is managed by the deeds registration system. Management records are public and can be accessed if a search fee is paid. Fair market value for freehold land is determined by the buyer's offered purchase price, comparison with other purchased land, and the accessible services and amenities.

c) Government land

Government land is managed by the Land Board, established based on the Lands, Surveys and Environment Act of 1989. Government land comprises approximately 12 percent, or 85,630 acres (346 km^2) of the total 725,000 acres (2,934 km^2) of land in Samoa. The transfer process for government land is also stipulated in the Lands, Surveys and Environment Act of 1989. Leases of government land require Land Board permissions, and lease duration cannot exceed 20 years. All land within 3 m of natural waterways in Samoa is government land.

2) Land Valuation

Land valuations and evaluator licensing is regulated by the Land Valuation Act of 2010.

a) Freehold land

The Samoan government does not conduct any annual valuations for freehold lands. Values for freehold land are determined on the open market based on there being a willing buyer and seller.

b) Customary land

Customary land can be leased, but not sold or mortgaged. In the past, there have been customary lands assigned market values with reference to freehold lands.

A summary follows below:

Table 1-2-32 Summary of land ownership system in Samoa

	Landowner	Land Acquisition Procedure
Customary land	*matai*	As sale of these lands is not recognized, they are leased in accordance with the Alienation of Customary Land Act of 1965. Expropriation and compensation in cases of public use, however, are stipulated in the Taking of Land Act of 1964.
Freehold land	Landowner	Land rights are managed by the deeds registration system, and purchases are allowed according to the Land Titles Registration Act of 2008. Expropriation and compensation in cases of public use, however, are stipulated in the Taking of Land Act of 1964.
Government land	Government	Can be acquired by lease following the Lands, Surveys and Environment Act of 1989.

(3) Scale and Scope of Land Acquisition and Resettlement

No one resides in the Project Site, and thus there will be no resettlement. As the bridge will be relocated, road alignment will be shifted seaward, and a new right of way will be required for the approach road. Rights of way for national roads are set in the Land Transport Authority Act of 2007 as being up to 11 m in either direction of the centerline. In the case that privately-owned land lies adjacent to the road within a distance of 11 m, however, the right of way will be until the land boundary. The survey is under responsibility of the LTA. The all land for the project will be designed in the area of existing road reserves and government owned land. Therefore, the land acquisition will not be necessary.

1-2-5-11 Others

(1) Monitoring Plan (Tentative)

The tentative monitoring plan as of this moment is given in the following table. As field study on the environmental and social impacts is currently underway, monitoring will be performed based on the results of the actual environmental impact evaluations.

Table 1-2-33 Monitoring plan (Construction)

Impacts	Item	Monitoring Method	Location	Frequency	Responsibility
Air pollution	Dust	Visual	Around work site	Daily	Contractor
	Exhaust gas	Resister and managing log book	Construction Office	Monthly	Contractor
Noise	Noise	Equipment measurement	Border with neighboring facilities	Daily throughout the construction period	Contractor
	Noise and vibration	Record of operation time	Construction Office	Daily throughout the construction period	Contractor
Water pollution	Turbidity	Visual	Point of wastewater influx	Daily during earthwork Weekly outside of earthwork	Contractor
	Water quality	pH, EC, COD, turbidity, oil content	Point of wastewater influx	In cases of abnormalities	Contractor
Solid waste (domestic)	Waste management	Visual	Domestic waste	Weekly	Contractor
Solid waste (construction)	Proper discharge of waste	Visual	Staging area	At waste disposal	Contractor
Sediment	Bottom sediment agitation	Visual	Around work site	Daily during pier work	Contractor
Ecosystem	The effect of ecosystem is mainly created by the water pollution, thus the water quality monitoring will cover the ecosystem impact.				
Hydrology	Construction schedule in rainy season	Work monthly report	Work office	Monthly during rainy season	Contractor
Land use	Lease of land	Contract document	Work office	Time of making contract	LTA
Infrastructure and social services	Mitigation measures for disturbance of traffic	Work monthly report	Work office	Monthly	Contractor
Landscape	Protection of landscape	Work monthly report	Work office	Monthly	Contractor
infectious disease	Safety and health management	Work monthly report	Work office	Monthly	Contractor
Working conditions	Safety and health management	Work monthly report	Work office	Monthly	Contractor
Accidents	Safety and health management	Work monthly report	Work office	Monthly	Contractor

(2) Monitoring Form (Tentative)

Based off the above, the following is the monitoring form currently being discussed.

Table 1-2-34 Monitoring form (tentative)

Monitoring items		Procedure	Result	Measures to be taken	Reference standard	Frequency
Dust		Visual inspection			Acceptable or not	Daily
Noise (A-weighted equivalent sound level in dB)		Sound level meter			Samoan standard	Daily
Noise and vibration		Operation time check			Stated operation time in EMP	Daily
Water quality (turbidity, oil)		Visual inspection			Acceptable or not	Daily
Water quality	pH	Laboratory test			Japanese discharge standard	At the time of abnormal observation of turbidity or oil
	EC					
	COD					
	Turbidity					
	Oil					
Domestic waste		Patrol			Acceptable or not	Weekly
Constriction waste		Patrol			Acceptable or not	Monthly
Sediment		Visual inspection			Acceptable or not	Daily during foundation work for the substructures
Hydrology		Construction plan preventing flood			Acceptable or not	Once at rainy season
Land Use		Lease condition			Acceptable or not	At the time of contract of lease
Traffic management		Patrol			Stated procedure in EMP	Monthly
Landscape		Patrol			Stated procedure in EMP	Monthly
Accident		Patrol			Acceptable or not	Monthly
Claim and comment		Report check			Acceptable or not	Monthly

(3) Environmental Checklist

The current environmental checklist is as shown in Table 1-2-35.

Table 1-2-35 Environmental checklist

Category	Environmental Item	Main Checkpoints	Yes: Y No : N	Specific Environmental and Social Considerations (Reason for Yes or No, rationale, mitigation measures, etc.)
1 Approvals, explanations	(1) EIA and environmental approvals	(a) Have environmental assessment reports (EIA Report, etc.) been created? (b) Has the EIA Report, etc. been approved by the government of the relevant country? (c) Does approval for the EIA Report, etc. have attached conditions? If there are attached conditions, have those conditions been met? (d) Apart from the above, have environmental approvals been obtained from local governing agencies if required?	(a) Y (b) N (c) N (d) N	(a) EIA Report was prepared and submitted on 25th January 2017 by LTA to PUMA. (b) It has not been approved at the end of January 2017. (c) Before EIA approval, PUMA may make comments on the material if deemed necessary. (d) No permissions or approval other than the above are required.
	(2) Explanation for local stakeholders	(a) Has an appropriate explanation of the Project content and impacts been given to local stakeholders with full disclosure, and has their agreement been obtained? (b) Have resident and stakeholder comments been reflected in the Project details?	(a) Y (b) Y	(a) Meetings with stakeholders and public hearing have been held several times. All stakeholders understood necessity of the project and agreed on its implementation. (b) Upon consulting with the hotel near the Project Site, the management had opinions on ensuring safety for the approach road to the hotel and on road drainage. Measures for these items have been integrated into the design.
	(3) Alternative plan analysis	(a) Have multiple alternative plans for the Project been analyzed? (Including analysis of items related to the environment/society.)	(a) Y	(a) Road alignments, bridge height, construction methods, and other items were analyzed and the best plan was selected from the viewpoint of cost effectiveness and least adverse impacts on environmental and social issues. The selected plan was accepted by stakeholders.

Category	Environmental Item	Main Checkpoints	Yes: Y No : N	Specific Environmental and Social Considerations (Reason for Yes or No, rationale, mitigation measures, etc.)
2 Pollution Measures	(1) Air pollution	(a) Is there an impact from air pollutants emitted by travelling vehicles, etc.? Is there compliance with the environmental standards of the relevant country? (b) If air pollution in the area near the route already exceeds environmental standards, will the Project further exacerbate air pollution? Will anti-pollution measures be taken?	(a) Y (b) N	(a) Increase of vehicle numbers after starting operation is not expected so much. Improvement of approach road will ease the traffic congestion. Road alignment will shift towards sea side and the distance from residences and building will increase. From these reasons, the condition of air quality will be acceptable. (b) Samoa does not have environmental standards or guidelines of air quality. Therefore, the measured data of air quality is not available. But it seems very well currently. Based on above discussion, air quality will not become worse after project.
	(2) Water quality	(a) Will the water quality in the areas downstream decline due to soil runoff from exposed surface soil in landfilled areas and areas where earth was cut? (b) Will the Project impact water sources such as wells in the surrounding area?	(a) N (b) N	(a) While there is no work that would result in soil runoff, riverwork and shorework may generate turbid water. The use of temporary cofferdam will be constructed to prevent such fear of turbid water pollution. (b) There is no work that will affect groundwater or water sources.
	(3) Noise and vibration	(a) Is the level of noise and vibration from railways and traveling vehicles in compliance with the standards of the relevant country? (b) Is the level of low-frequency sound from railways and traveling vehicles in compliance with the standards of the relevant country?	(a)N/A (b) N/A	(a)(b) Samoa has its own noise policy, but there are no standards for vibration, low-frequency sound, and regulation for road noise. Since change of road alignment, the noise source will move away from residents and commercial activity such as hotels. It will result in reduction of noise and vibration.
	(1) Protected areas	(a) Is the site located within a protected area as stipulated by the laws of the relevant country and international treaties? Does the Project impact protected areas?	(a) N	(a) There are no protected areas within the Project Site.

Category	Environmental Item	Main Checkpoints	Yes: Y No : N	Specific Environmental and Social Considerations (Reason for Yes or No, rationale, mitigation measures, etc.)
3 natural environment	(2) Ecosystems	(a) Does the site include virgin forests, tropical old-growth forests, or important ecological habitats (coral reef, mangrove swamps, mudflats, etc.)? (b) Does the site include habitats for rare species that must be protected according to the laws of the relevant country or international treaties? (c) If a significant impact on the ecosystem is a concern, have measures been taken to mitigate the impact? (d) Have measures been taken in regard to blockage of movement paths for wild animals and livestock, and to division of habitats? (e) Will the construction of the bridge/road cause deforestation and poaching that accompanies development, desertification, and/or dried swamps, etc? Is there a risk of disturbing the ecosystem due to an introduction of pests or non-native species (those not naturally inhabiting the region)? Have countermeasures for this been prepared?	(a) N (b) N (c) N (d) N (e) N	(a) The site does not contain any virgin forests, tropical old-growth forests, or important ecological habitats (coral reef, mangrove swamps, mudflats, etc.). (b) No habitats for any rare species are present in the site. (c) No major concerns. (d) There will be no blockage of movement paths for wild animals and livestock or division of habitats. (e) Given that the Project is for reconstruction of a pre-existing bridge, the Project will not have any new additional impact.
	(3) Hydrology	(a) Will the flow of surface water or ground water be adversely impacted by changes in the river system caused by the placement of structures?	(a) N	(a) The bridge is being designed to improve river flow compared with the existing bridge.
	(4) Topography and geology	(a) Are there places with poor soil quality on the route where slope failure or landslides may occur? If so, has proper action been taken through construction methods, etc.? (b) Will slope failure or landslides occur due to civil engineering work such as landfilling or earth cutting? Have appropriate measures been taken to prevent slope failure and landslides? (c) Will soil runoff occur in areas of landfilling, earth cutting, soil disposal, and/or soil extraction? Have appropriate measures been taken to prevent soil runoff?	(a)N (b)N (c)N	(a) There are no areas with poor soil quality. (b) None of the included work would cause soil failure or landslides. (c) As soil will be extracted from a PUMA-approved, managed borrow pit, there are no concerns of soil runoff in the borrow pit. Soil disposal should be minimal, and impact is expected to be limited.

Category	Environmental Item	Main Checkpoints	Yes: Y No : N	Specific Environmental and Social Considerations (Reason for Yes or No, rationale, mitigation measures, etc.)
	(1) Land acquisition and Resettlement	(a) Will there be any involuntary resettlement that accompanies project implementation? If so, have efforts been made to minimize the impact of resettlement? (b) Have proper explanations regarding compensation and livelihood reconstruction measures been given to residents prior to resettlement? (c) Has a study been conducted for resettlement with a plan including compensation for replacement costs and recovery of local infrastructure? (d) Will payment of compensation be made prior to resettlement? (e) Has a document for compensation policies been drafted? (f) Does the plan for resettlement include proper consideration for social vulnerable persons such as women, children, the elderly, the poor, and ethnic minorities/indigenous peoples? (g) Will an agreement regarding resettlement be reached prior to resettlement? (h) Is there a system in place for the appropriate implementation of resettlement? Are implementation capacity and budgetary provisions sufficient? (i) Is there a plan for monitoring the effects of resettlement? (j) Has a system been created for processing complaints?	(a)N (b) N/A (c) N/A (d) N/A (e) N/A (f) N/A (g) N/A (h) N/A (i) N/A (j) N/A	(a) There will be no involuntary settlement, meaning that questions (b)-(j) are not applicable.

Category	Environmental Item	Main Checkpoints	Yes: Y No : N	Specific Environmental and Social Considerations (Reason for Yes or No, rationale, mitigation measures, etc.)
4.Social Environment	(2) Lives and livelihoods	(a) If a bridge/access road is built for new development, will there be an impact on existing means of transportation and the residents using those means? Will there be large changes in land usage/ livelihood means, and/or loss of employment? Does the plan give consideration to mitigating these impacts? (b) Will the lives of other residents be adversely impacted by the Project? Will consideration be given to mitigating these impacts if necessary? (c) Is there a risk of disease outbreaks (including infectious diseases such as HIV) from the population influx from other regions? Will considerations for appropriate public health measures be made according to need? (d) Will road traffic in the surrounding areas be negatively impacted by the Project? (congestion, increase in accidents, etc) (e) Will this hinder the movement of residents? (f) Will overpasses, etc. block sunlight or cause electromagnetic wave interference?	(a) N (b) N (c) N (d) N (e) N (f) N	(a) The Project is a bridge reconstruction and cannot be considered new development. The bridge should improve existing means of transportation and resident life and should not have any negative impact. (b) There are no concerns of adverse impact. (c) Impacts from population influx will be limited to the construction period. (d) The Project should help to improve road traffic. (e) No. (f) There should be no such impediments. The new bridge will be only 1.5 m higher than the existing bridge and shifted to a location further seaward than the existing bridge.
	(3) Cultural heritage	(a) Does the Project present a risk of damaging anthropological, historical, cultural, religiously important heritages or historical remains? Have measures stipulated by the domestic laws of the relevant country been considered?	(a) N	(a) No anthropological, historical, cultural, religiously important heritages or historical remains have been identified in the Project Site.
	(4) Landscape	(a) If there are any landscapes that should be especially considered, will they be adversely impacted? If so, will necessary measures be taken?	(a) Y	(a) There is a promenade on the road before and after the bridge. This promenade will be shifted, with its current form kept nearly intact.
	(5) Ethnic minorities and indigenous peoples	(a) Have considerations been made to lessen the impact on the culture and lifestyles of ethnic minority groups and indigenous people of the relevant country? (b) Will the rights regarding land and resources of ethnic minorities and indigenous peoples be respected?	(a) N/A (b) N/A	(a)(b) There are no ethnic minorities or indigenous peoples living near the Project Site.

Category	Environmental Item	Main Checkpoints	Yes: Y No : N	Specific Environmental and Social Considerations (Reason for Yes or No, rationale, mitigation measures, etc.)
	(6) Working conditions	(a) Are laws pertaining to working conditions in the relevant country being observed for the Project? (b) Are the physical aspects of safety for people working on the Project being considered? (These may include installing safety equipment to prevent work-related accidents and management of toxic substances.) (c) Are the non-physical aspects of safety for people working on the project being planned and implemented? (These may include formulating a plan for safety/health and conducting safety education including traffic safety and public health.) (d) Will appropriate measures be taken to ensure that Project security personnel do not compromise the safety of people working on the Project or residents of the area?	(a) Y (b) Y (c) Y (d) Y	(a) Adherence to laws concerning working conditions will be made explicit in contracts with contractors and managed. (b) To be managed with an Environmental Management Plan (EMP). (c) To be managed with an EMP. (d) To be managed with an EMP.
5 Other	(1) Confirm impacts during construction	(a) Will mitigation measures be prepared for pollution during construction? (noise, vibration, turbid water, dust, gas emissions, waste, etc.) (b) Will the natural environment (ecosystem) be adversely impacted by construction work? Will mitigation measures be prepared for these impacts? Will mitigation measures be prepared for these impacts? (c) Will the social environment be adversely impacted by construction work? Will mitigation measures be prepared for these impacts?	(a) Y (b) Y (c) Y	(a) Mitigation measures will be taken under EPM for managing all noise, vibration, turbid water, dust, gas emissions, and waste discharged from the work site. Implementation details will be listed in the EMP. (b) Only common species were observed and impact on marine ecosystem is not significant. However, the measures for reduction of turbid water will be taken. (c) The more vehicles may access the work site and temporary traffic regulation will occur. Such condition will result in the traffic congestion and necessity of detours. It will be mitigated by the use of sign board, assignment of traffic controller, information disclosure to residents, etc. These materials should be included in EMP.

Category	Environmental Item	Main Checkpoints	Yes: Y No : N	Specific Environmental and Social Considerations (Reason for Yes or No, rationale, mitigation measures, etc.)
	(2) Monitoring	(a) Will monitoring for the employer be planned and conducted for environmental items that may have an impact from among those listed above? (b) In what way, will the items of the relevant plan, along with methods and frequencies, etc. be stipulated? (c) Will a monitoring system for the employer be established? (including organization, personnel, equipment, budget, etc., and the continuity of these items) (d) Has the method and frequency, etc. for reporting from the employer to the governing agencies been defined?	(a) Y (b) Y (c) Y (d) Y	(a) EMP is attached in EIA, and contractors will adhere to the EMP under LTA supervision. (b) Environmental and social impacts are expected to occur only at the construction stage. Detailed monitoring plan will be created by the modification of EMoP in EMP with the consideration of construction procedures. (c) Monitoring will be conducted by the contractor under supervision of LTA. The budget for monitoring equipment is secured. (d) It is stipulated in the EMP.
6 Focal points	Referencing other environmental checklists	(a) If necessary, relevant items from other checklists pertaining to roads, railways, and forestry may be added to this list and assessed. (For large-scale deforestation, etc.) (b) If necessary, relevant items from other checklists pertaining to the transmission, transformation, and distribution of electricity may be added to this list and assessed. (For constructing facilities for the transmission, transformation, and distribution of electricity, etc.)	(a) N/A (b) N/A	(a) None (b) None
	Precautions when using the environmental checklist	(a) If necessary, trans-boundary problems or impacts on global climate change may be checked. (For example, trans-boundary waste disposal, acid rain, depletion of the ozone layer, factors contributing to global warming, etc.)	(a) N/A	(a) None

Chapter 2   Contents of the Project

Chapter 2 Contents of the Project

2-1 Basic Concept of the Project

2-1-1 Overall Objectives and Project Purpose

2-1-1-1 Developlement Strategic Plan

The Samoan Government has the following development projects in the road sector:

- Strategy for the Development of Samoa (SDS) 2012-2016
- National Infrastructure Strategic Plan (NISP)

(1) Strategy for the Development of Samoa 2012-2016

The key issues for the road sector in the SDS 2012-2016 are the following:

- Maintaining road network connections to airports, seaports, and harbors
- Developing construction standards for roads and drainage
- Strengthening climate change measures for road network planning and design

A specific example of these projects is as follows:

- Expanding the Samoa Economic Corridor to four lanes between Faleolo and Apia and strengthening climate change measures

(2) National Infrastructure Strategic Plan

The key issues for the road sector in the NISP are the following:

- Maintaining and upgrading the Samoa Economic Corridor
- Improving safety for the road network and strengthening measures for natural disaster an inclement weather

Thus, maintenance of the Samoa Economic Corridor is the most important issue in terms of road maintenance for Samoa. The Vaisigano Bridge targeted by the Project also lies on the Samoa Economic Corridor.

2-1-1-2 Overall Project Objectives and Project Purpose

The overall project objectives and project purpose are as follows:

- **Overall Objectives**

To contribute to the social and economic growth of Samoa by rebuilding the Vaisigano Bridge on Beach Road, a major arterial road for the nation, to facilitate smooth transport.

- **Project Objective**

Located on the access road to Apia Port, a major arterial road, the Vaisigano Bridge that Samoa has requested for reconstruction connects the commercial district in western Apia to the eastern part of the city and eastern Upolu. With traffic volume reaching 18,839 vehicles per day and vehicle

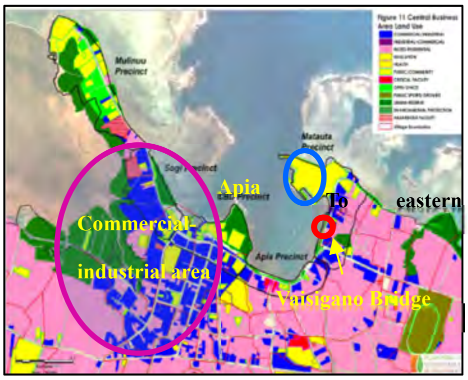


Figure 2-1-1 Waterfront Development Project

ownership anticipated to grow in Apia, the importance of the bridge will likely expand in the future. Also, reconstruction of the Vaisigano Bridge is positioned as a key component in terms of Apia's Waterfront Development Project. The Waterfront Development Project is a project currently underway to beautify the city by updating the coastal area extending to the west of Apia Port (see Figure 2-1-1), which includes the Vaisigano Bridge.

The Vaisigano Bridge was first constructed at the beginning of the 20th century as a seven-span steel bridge, and was replaced in 1953 with a concrete bridge atop a newly reinforced substructure that still stands. Despite work done in 1994 to repair corrosion of rebar and concrete peeling due to salt damage, the same damage reoccurred, and large vehicles have not been able to use the bridge since 2002. Large trucks transport goods from Apia Port to the industrial zone on the west side of Upolu, and they have been forced to take detours upstream to the Leone Bridge.

Samoa frequently suffers damage from cyclones, and the severe Cyclone Evan that struck in 2012 significantly damaged the country's road infrastructure. The superstructure of the Vaisigano Bridge was submerged, and the protective work on the foundations of the substructure were destroyed. In addition, the Leone Bridge, which served as a detour to the Vaisigano Bridge, was impassible due to damage suffered from fallen trees and the like flowing downriver from mountainous areas upstream. Now large vehicles are forced to detour further upstream to the Lelata Bridge, which adds more than one hour and even greater transportation expenses to the route across the Vaisigano Bridge.

The project objectives are to rebuild the Vaisigano Bridge for passage of larger vehicles with increased load tolerances and traffic speeds, and to install sidewalks on both sides with sufficient width to ensure all pedestrians, including wheelchair users, etc. can pass safely, and to make life more convenient for residents along the road.

2-1-2 Basic Concept of the Project

To achieve the above objectives, the Project will reconstruct the Vaisigano Bridge with grant aid assistance. The Project will help by improving bridge performance and safety. It will connect the commercial district in western Apia to eastern Apia and eastern Upolu and can be expected to spur social and economic growth in Samoa.

2-2 Outline Design of the Requested Japanese Assistance

2-2-1 Design Strategy

The Project is to perform the outline design for repairs to the Vaisigano Bridge located on Beach Road, which is at risk of collapse due to deterioration, salt damage, and severe damage sustained in Severe Tropical Cyclone Evan in 2012.

The Vaisigano Bridge will be rebuilt to allow for passage of larger vehicles with increased load tolerances and traffic speeds, and sidewalks will be installed on both sides with sufficient width to ensure safe, universal passage for all pedestrians and to make life more convenient for residents along the road. Based on the requests from the Samoan Government and results from field reconnaissance and consultations, the Project will be planned based on the following strategy.

2-2-1-1 Basic Strategy

Design strategy in performing the outline design will be as follows.

(1) Scope of the Cooperation Project

Samoa submitted a formal request for Grant Aid Assistance for the Project to the Japanese Embassy in August 2015. In the request, Samoa indicated that the Vaisigano Bridge, located where Beach Road crosses the Vaisigano River, was deteriorating and had sustained damage in the form of inundation and scouring in Cyclone Evan in 2012 and was at risk of collapse. Thus, the Project was for reconstruction of the bridge.

A Preparatory Study was conducted to reconfirm the requested details, while also confirming longitudinal plans for the bridge and approach road, bridge and approach road location, width, construction plan and budgetary estimates, environmental and social considerations, natural conditions, and other details. Upon consulting with Samoa, the main contents of the Project for Japanese Grant Aid Assistance as finally confirmed are as follows:

- Construction of a PC bridge (2-lane bridge with walkways on both sides)
- Construction of the approach road (including intersections)
- River revetment work (including scouring measures)
- Shore revetment work
- Removal of the existing bridge

(2) Longitudinal Plan for Bridge and Road

There were three proposals for profile height of the bridge and road: raising 0.5 m, raising 1.0 m, or raising 1.5 m. A summary of these proposals was laid out clearly with the pros and cons for each, and after consultation, LTA agreed that Proposal 3 (raising the bridge and road 1.5 m) was the best for the following reasons.

a) Has an allowance height of 1 m over 100-year tide and flood levels, and no driftwood would impact the piers.

b) The impacts on the surrounding area (hotel, churches, etc.) of raising the bridge by 1.5 m can be mitigated by installing a frontage road.

(3) Bridge Location and Approach Road

There were three proposals for where to position the Vaisigano Bridge: the existing bridge location, shifted 20 m downstream, or shifted 50 m downstream. A summary of these proposals was explained to LTA with the pros and cons for each, and after consultation, LTA agreed that Proposal 2 (shifting the bridge 20 m downstream) was the best for the following reasons.

a) Obstruction to hotel access from the profile increase can be alleviated with a frontage road.

b) This is the most cost-efficient option as it does not require construction of a temporary bridge or detour route, and bridge construction costs are much less than Proposal 3.

(4) Scale

1) Reference Span Length

Reference span length was calculated using the following equation:

Span Length $L = 20 + 0.005Q$ Where Q is the design flood discharge (m^3/sec)

Design flood discharge for the Vaisigano River at the location of the Vaisigano Bridge is 680 m^3/s. Thus, reference span length was calculated as:

Span Length $L = 20 + 0.005Q = 20 + 0.005 \times 680 = 23.4$ m

2) Project Scope for Approach Road

From the longitudinal plan for the bridge and road, the bridge needed to be raised 1.5 m from the existing bridge, and an approach road bridging the span between the new bridge and the existing road surface height on Beach Road would be required. Work on the approach road will be performed with Japanese Grant Aid Assistance. The Project scope includes a total of 424.5 m for this work: approximately 199 m on the Apia side, 155.5 m on the side of Fagali'i Airport, and 70 m on the Apia Port side.

(5) Request Details and Discussed Checklist Items

Outline design will proceed under the conditions mutually agreed upon between both countries and the Study Team. The following Table describes the requested details and the checklist items discussed as of the preparatory study.

Table 2-2-1 Request details and discussed checklist items

Item	Description of Request	Check and Agenda Items
No. of Lanes	2-lanes	2-lanes
Bridge Location	Current bridge location	20 m downstream from current bridge
Length	75 m	75 m
Type	7-span RC hollow slab bridge	3-span PC hollow slab bridge
Width	7.535 m (width of lanes) + 1.980 m (sidewalk width) x 2 = 11.495 m	8.0 m (width of lanes) + 2.5 m (sidewalk width) x 2 = 13.0 m
Design Speed	-	50 km/h
Design Live Load	HS20-S16-41	B Live Load
Approach Road	-	Approx. 199 m on Apia side, 155.5 m on side of Fagali'i Airport, and 70 m on Apia Port side (total 424.5 m)
River revetment work	-	35 m on left bank, 30 m on right bank
Coastal revetment work	-	120 m on Apia side, 130 m on Fagali'i Airport side

2-2-1-2 Plan for Natural Conditions

(1) Topography and Geology

The bridge is located at the mouth of the Vaisigano River, a river with a basin area of 34 km^2 and flow channel of 12 km flowing through the capital of Apia. Near the mouth, the river bends at a width of approximately 70 m and gradient of around 1:40, discharging the sediment and cobblestone that forms the ocean shore. While there is shoal movement at the river mouth due to flooding and waves, terrain in this location is stable, and bridge construction in roughly the same location as the existing bridge should be acceptable.

(2) Weather and Hydrology

1) Temperature, Humidity, and Wind Speed

Average temperatures for the past 10 years at the Apia observation station show only a small year-to-year variance of approximately 9°C for both high and low temperatures. The 10-year high was 34.8°C (April 2011), and the 10-year low was 18.6°C (September 2015).

In terms of humidity as well, there has been little year-to-year variance in the past five years in both highs and lows, with only 25 percent difference between the highs of 95 percent humidity and lows of 70 percent. As the bridge location gets rather hot and humid during the rainy season, great care will need to be taken in terms of bridge member temperature changes for the design and in casting and curing the concrete during the construction.

Winds in the region are not particularly strong, staying between 1.0-4.5 m/s throughout the year. However, given the salt content expected from cyclones, measures will be taken to prevent salt damage.

2) Rainfall and Rain Patterns

Rainfall amounts for the past five years from the Afiamula and Nafanua observation stations in the Vaisigano River basin were sorted by month. Annually, Samoa experiences a rainy season from November to March and dry season from April to October. From November to March is also the period the nation is subject to tropical cyclones. Annual rainfall differs greatly by terrain, with a difference of approximately 1,500 mm in rainfall between the hills (Afiamalu) and plains (Nafanua). The highest monthly rainfall is in January, exceeding 1,000 mm per month. Such weather conditions are to be sufficiently accounted for in planning as flooding can have a great impact on the construction plan and project schedule. In particular, aims will be to complete all foundation and substructure work on the piers and abutments, river revetment work, and any other work in the river outside of the flood season.

3) Climate Change

In the future, sea levels and rainfall are both expected to increase due to global warming. Accounting for these increases in the Vaisigano River flood measures, the plan assumes that sea level will increase 1.0 m and flood levels 10 percent by 2100.

4) Design Wave and Tide Levels

Upon analysis of cyclone-generated wave and tide levels with future sea level increases, the 100-year design significant wave height for Apia Port was 4.0 m at a frequency of 12 seconds and tide level of 2.2 m. These results are used in analysis of river mouth flood levels, as well as of the river and coastal revetments. Also note that breaker waves due to a shallowed seabed are accounted for with waves hitting the river mouth and shore.

5) Design Flood Discharge

Design discharge was studied during levee development planning. It is calculated from the 38 years (1976-2013) of gauging station water level data, not from rainfall intensity.

As the gauging station is located in the east end of the basin, the flow rates do not account for discharge in the central and western areas and are thus multiplied by an area ratio of 1.7 to account. Further, a factor of 1.1 is used to account for increases in rainfall amounts by the year 2100.

From the inundation analysis during levee development planning, approximately a third of the discharge at the design scale (100-year flooding) at time of bridge design should discharge outside the river channels due to accumulation upstream of the Lelata Bridge, overflow, and other factors. Thus, flow rates within the channels are as shown below:

100-year discharge as calculated from water levels: 542 m3/s x 1.7 x 1.1 x 2/3 = 680 m3/s

Given the approximate discharge of 530 m^3/s during Cyclone Evan in December 2012, this shows that Cyclone Evan was close to a 100-year flood.

6) Design High Water Level

From discussions to follow in Section 2-2-2-3 Consideration of Longitudinal Bridge Plan, the design high water level of the Vaisigano River at the Vaisigano Bridge location is MSL+2.7 m.

(3) Seismic Design

1) Seismic Overview

The boundary between the Pacific Plate and the Indo-Australian Plate is one of the most seismically active regions in the world. Samoa experienced earthquakes of M8.0 on April 7, 1995, M8.0 on May 3, 2006, M7.7 on March 19, 2009, and of M8.1 on September 29, 2009. The September 29, 2009 quake was particularly damaging, with at least 189 dead between Samoa, American Samoa, Tonga and neighboring islands, as well as hundreds injured. As Samoa has had multiple large earthquakes in the past, design for the bridge in the study requires adequate consideration for seismic design.

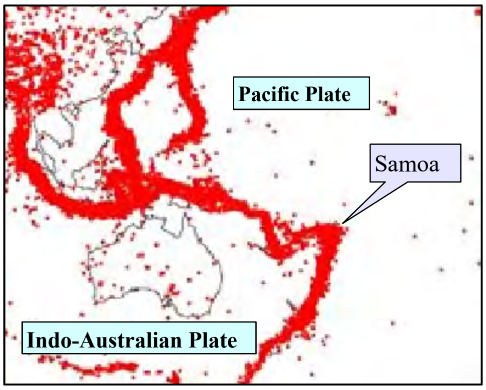


Figure 2-2-1 Map of major plates and seismic distribution

2) Seismic Design Strategy

The Vaisigano Bridge is located on Beach Road, a major arterial road that connects the Samoan capital of Apia to Fagali'i Airport (for interisland flights) and Apia Port (Samoa's only commercial port). If an earthquake were to collapse Vaisigano Bridge, it would cripple regional distribution and have many adverse effects on capacities in rescue, medical, firefighting, and other related activity. Given the exceedingly important role of the bridge, seismic reinforcement is essential. Thus, the basic strategy for the bridge design is to improve earthquake resistance of the bridge as a whole.

2-2-1-3 Traffic Plan

In order to determine the status of bridge area traffic in its current configuration, traffic surveys were conducted at two non-intersection locations on Vaisigano Bridge and Lelata Bridge, two intersection locations near Vaisigano Bridge, and one intersection location near Lelata Bridge to accompany future traffic estimates and pavement design for Vaisigano Bridge.

(1) Overview of Traffic by Vehicle Type

1) Survey Details

Details on the traffic surveys are as shown in the table below.

Table 2-2-2 Traffic survey details

Item	Details
Survey method	Crossing traffic measured by an examiner (by vehicle type, by direction, by time)
Survey points	Non-intersection: Vaisigano Bridge (St. 1) and Lelata Bridge (St. 2) Intersections: Near Vaisigano Bridge (St. 3&4) and near Lelata Bridge (St. 5)
Date of surveys	Vaisigano Bridge and Lelata Bridge: July 13 (Wed.) and 15 (Fri.), 2016 Vaisigano Bridge eastern intersection: July 7 (Thu.), 2016 Vaisigano Bridge western intersection, and Lelata Bridge intersection: July 14 (Thu.), 2016
Times	12 hours (7:00 – 19:00)

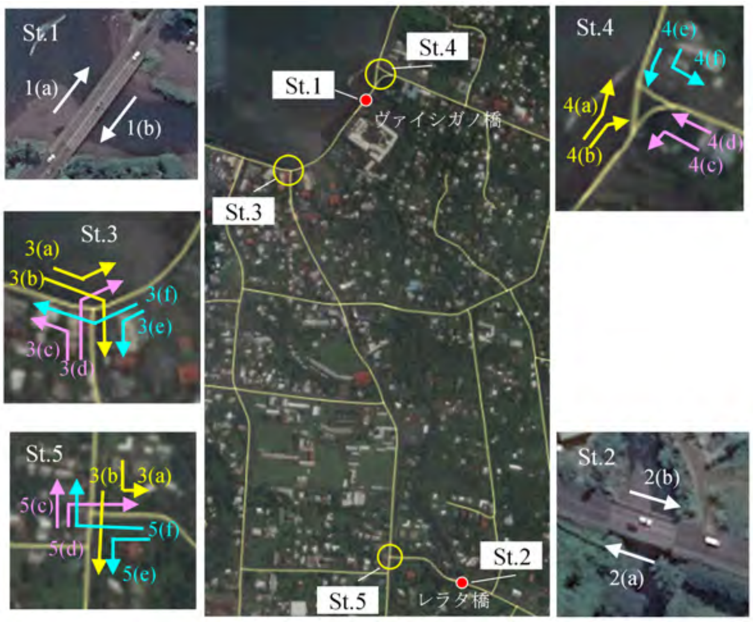


Figure 2-2-2 Traffic survey points

2) Current Traffic Volumes

Current traffic volume was calculated based on the traffic survey data using a day/night ratio and a day variation coefficient. The day/night ratio and day variation coefficient were taken from a weeklong 24-hour continuous traffic survey that LTA conducted in 2013 for Vaisigano Bridge and Lelata Bridge. In terms of the times surveyed, it should be noted that Leone Bridge, which is located between Vaisigano Bridge and Lelata Bridge, is closed to traffic, and thus Vaisigano Bridge and Lelata Bridge traffic includes that diverted from Leone Bridge.

Table 2-2-3 Current traffic volumes (2016)

Survey point	Survey date	Cars	Buses	Smaller trucks	Large trucks	Total (12 hrs.)	Peak hour traffic	Peak rate	Day/night ratio	Day variation coefficient	Daily traffic volume
Vaisigano Bridge	July 7	14,879	469	523	2	15,873	1,582	10%	1.29	0.89	18,179
	July 13	14,336	474	527	1	15,338	1,581	10%	1.29	0.87	17,171
	July 15	15,341	534	574	0	16,449	1,665	10%	1.29	1.00	21,166
	Avg.	14,852	492	541	1	15,887	1,609	10%			**18,839**
	Distrib. %	93.5%	3.1%	3.4%	0.0%	100.00%					
Lelata Bridge	July 13	11,690	357	378	161	12,586	1,785	14%	1.25	0.89	13,971
	July 14	10,483	350	322	117	11,272	1,564	14%	1.25	0.89	12,513
	July 15	11,705	388	384	130	12,607	1,749	14%	1.25	0.80	12,579
	Avg.	11,293	365	361	136	12,155	1,699	14%			**13,021**
	Distrib. %	92.9%	3.0%	3.0%	1.1%	100.00%					

Current traffic volume on Vaisigano Bridge and Lelata Bridge can be characterized as follows.

<u>Current traffic on Vaisigano Bridge:</u>

- Daily traffic volume (2016): 18,839
- Peak rate: 10%
- Vehicle distributions: Cars (93.5%), buses (3.1%), freight vehicles (3.4%)

<u>Current traffic on Lelata Bridge:</u>

- Daily traffic volume (2016): 13,021
- Peak rate: 14%
- Vehicle distributions: Cars (92.9%), buses (3.0%), freight vehicles (4.1%)

(2) Accounting for traffic diverted from Leone Bridge in design traffic volume calculations

Future traffic volume was estimated to calculate the design traffic volume, a base criterion for determining road geometry.

1) Basic strategy

The basic strategy for future traffic volume estimations in the study is as follows.

- Work on Leone Bridge, currently still under reconstruction, will be complete when Vaisigano Bridge goes into service in 2020.
- Traffic distribution between the three bridges was treated as being 52 percent for Vaisigano Bridge, 24 percent for Leone Bridge, and 24 percent for Lelata Bridge. This distribution was set based on analysis of past traffic data (2003-2013) for the three bridges crossing Vaisigano River before Cyclone Evan hit.
- Future traffic volume was estimated for the first 20 years of service, from 2020 to 2040, based on the current traffic volumes (2016) as calculated from the traffic survey data.
- Annual traffic growth rates for each of the three bridges across Vaisigano River starting with 2020 was treated as being 0.58 percent for Vaisigano Bridge, 1.36 percent for Leone Bridge, and 0.80 percent for Lelata Bridge. These annual growth rates were estimated referencing traffic data from before Cyclone Evan.

Table 2-2-4 Data analysis of the three bridges across Vaisigano River

Period	Year	Traffic volume (vehicles/day)		
		Vaisigano Bridge	Leone Bridge	Lelata Bridge
Before Evan	2003	12,610	5,382	5,555
	2004	12,683	5,455	5,601
	2005	12,757	5,529	5,648
	2006	12,831	5,605	5,695
	2007	12,905	5,681	5,743
	2008	12,980	5,758	5,790
	2009	13,055	5,836	5,838
	2010	13,131	5,916	5,885
	2011	13,207	5,996	5,933
	2012	13,281	6,078	5,981
	Distrib. %	*52%*	*24%*	*24%*
	Growth %	*0.58%*	*1.36%*	*0.80%*
After Evan	2013	14,296	0	11,254
	Distrib. %	*56%*	*0%*	*44%*

2) Future traffic volume for the three bridges across Vaisigano River

From current traffic volumes (2016), future traffic volume through 2020, when all three bridges will be in service concurrently, was estimated with a total growth rate of 0.8 percent for all three bridges. From 2020 onward, future traffic volume was estimated from the growth rates for each bridge, based on the traffic volumes for each bridge as distributed using the above distribution ratios. Estimates are shown in the table below.

Table 2-2-5 Future daily traffic volume for the three bridges across Vaisigano River

Unit：Number/day

year	Vaisigano	Leone	Lelata	Total	
2016	18, 839	Impossible to pass	13, 021	31, 860	
2017				32, 115	Elongation 0.8%
2018				32, 372	
2019				32, 631	
2020	17, 104	7, 894	7, 894	32, 892	Allocation
2021	17, 203	8, 001	7, 957	33, 162	
2022	17, 303	8, 110	8, 021	33, 434	
2023	17, 403	8, 221	8, 085	33, 709	
2024	17, 504	8, 332	8, 150	33, 986	
2025	17, 606	8, 446	8, 215	34, 266	
2026	17, 708	8, 560	8, 281	34, 549	
2027	17, 810	8, 677	8, 347	34, 834	
2028	17, 914	8, 795	8, 414	35, 122	
2029	18, 018	8, 915	8, 481	35, 413	
2030	18, 122	9, 036	8, 549	35, 707	Elongation per bridge
2031	18, 227	9, 159	8, 617	36, 003	
2032	18, 333	9, 283	8, 686	36, 302	
2033	18, 439	9, 409	8, 756	36, 604	
2034	18, 546	9, 537	8, 826	36, 909	
2035	18, 654	9, 667	8, 896	37, 217	
2036	18, 762	9, 799	8, 967	37, 528	
2037	18, 871	9, 932	9, 039	37, 842	
2038	18, 980	10, 067	9, 111	38, 159	
2039	19, 090	10, 204	9, 184	38, 479	
2040	19, 201	10, 343	9, 258	38, 801	

(3) Indicators for Traffic Volume

Of the indicators for traffic volume described in “3-4-2-1Quantitative Effects”, the following calculations were performed regarding freight vehicle travel times and transportation capacity.

1) Freight Vehicle Travel Time from Apia Port to Vaitele Industrial Zone

Travel times for freight vehicles were set for each of three zones on the route from Apia Port to Vaitele Industrial Zone. Note that the calculation of 2016 transportation times in Zone 1 and Zone 2 are based on actual values observed during field surveys.

Table 2-2-6 Freight Vehicle Travel Time

Year	Zone 1			Zone 2			Zone 3[1]			Total Travel Time
	Distance	Speed	Travel Time	Distance	Speed	Travel Time	Distance	Speed	Travel Time	
2016	0.80 km	12 km/h	4.0 min	0.75 km	26.4 km/h	1.7 min	5 km	40 km/h	7.5 min (travel time) + 3 min (idle time[2])	16.2 min
2023		40 km/h	1.2 min		40 km/h	1.2 min				12.9 min

[1]The project will not affect Zone 3; thus, the values stay the same.

[2]Time loss was set to 30 seconds per traffic light. There are six signal-controlled intersections in Zone 3.

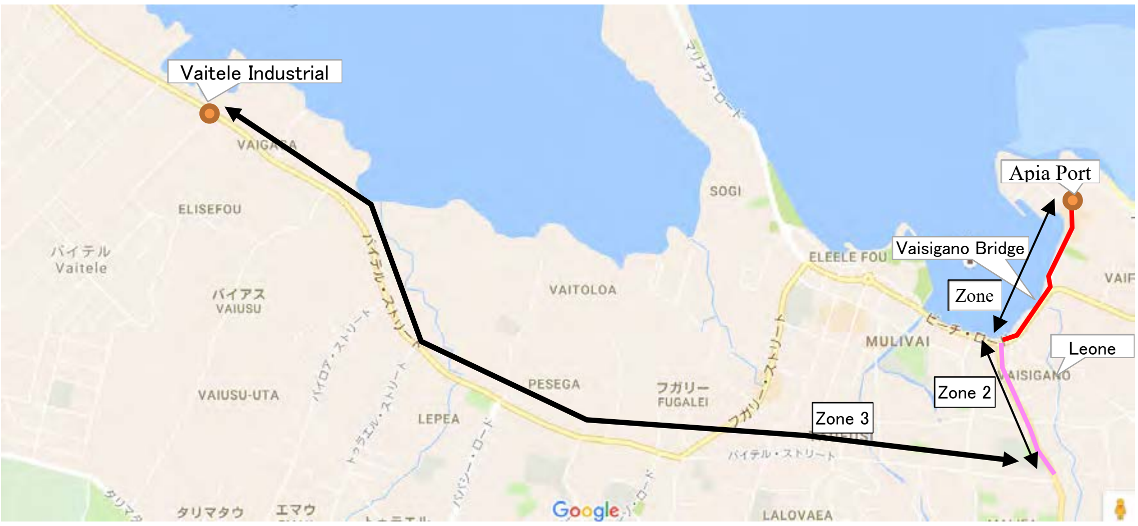


Figure 2-2-3　Zones from Apia Port to Vaitele Industrial Zone

2) Transportation Capacity: Travelers Per Year

-The volume of passenger cars, buses and freight vehicles was calculated based on the mix rates of buses (3.1%) and freight vehicles (3.4%) observed during traffic surveys.

-The number of passengers was set to 2.5 people for passenger vehicles, and eight people for buses.

-2016 passenger capacity: 15.63 million passengers/year ((15,490 vehicles/day x 2.5 people + 514 vehicles/day x 8 people) x 365 days)

-2023 passenger capacity: 16.33 million passengers/year ((16,179 vehicles/day x 2.5 people + 536 vehicles/day x 8 people) x 365 days)

3) Transportation Capacity: Freight Volume Per Year

-Freight volume was set to three tons per vehicle, and trips were assumed to be one-way.

-2016 freight volume: 310,000 tons/year (563 freight vehicles/day [16,567 vehicles/day x 3.4%] x 3 t x 0.5 x 365 days)

-2023 freight volume: 320,000 tons/year (580 freight vehicles/day [17,300 vehicles/day x 3.4%] x 3 t x 0.5 x 365 days)

(4) Overview of Pedestrian Foot Traffic

- In terms of foot traffic (surveyed over 12 hours on a weekday), Vaisigano Bridge had three times the pedestrians of Lelata Bridge: 755 to 231.
- Looking by time of day, foot traffic for both bridges peaked during commute hours, from 7-8 am and 4-6 pm.
- Whereas Lelata Bridge had less than 10 pedestrians per hour crossing at certain times, Vaisigano Bridge had comparatively more foot traffic outside of peak hours. Also, foot traffic is expected to increase in the future due to bridge development in this Project, as well as the Waterfront Development Project.

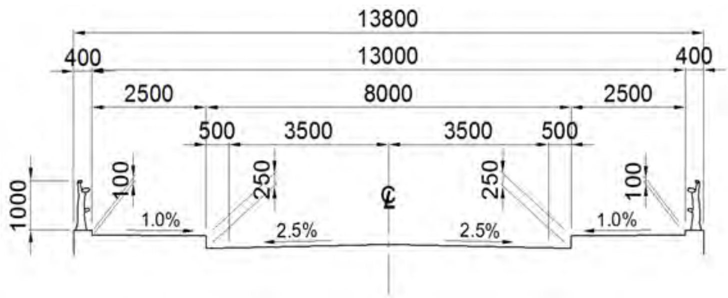
2-2-1-4 Planned Widths

Widths for the bridge and approach road will be compliant with Australian standards (Austroads). While basing on site circumstances and reflecting the items discussed with the Samoan side, widths were decided as follows:

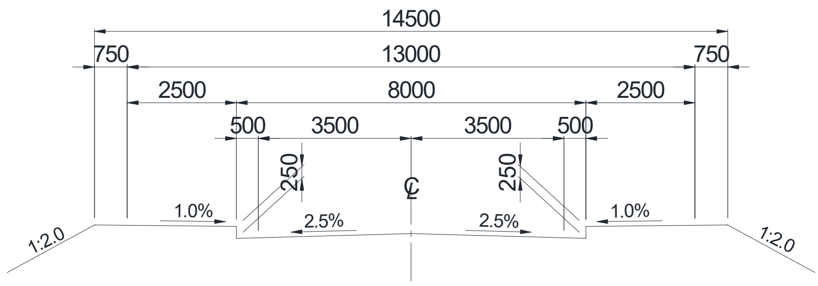
- Based on the standard width for lanes in urban arterial roads of 3.3-3.5 m, lane width will be 3.5 m as daily vehicle traffic is currently high, between 18,000 and 19,000 cumulative in both directions.
- Looking to ensure that shoulders will be at least as wide as the current shoulders (0.25-0.5 m), the minimum paved area will be 0.5 m.
- A width of 2.5 m was allotted for the sidewalks, allowing 1.5 m space for pedestrians and wheelchairs to pass each other and another 1.0 m of dedicated space for bicycles. While this plan is wider than the existing sidewalk (1.7-2.0 m), given the high foot traffic on Vaisigano Bridge—currently at 755 pedestrians in both directions over a 12-hour period on a weekday—this seems appropriate in light of Japanese thoughts on sidewalk width.

The width configurations for the bridge and approach road sections are as given in the figures below.

Bridge section



Approach road



*Sidewalk width: Will be 2.5 m, but may be reduced to 2.0 m if necessary due to ROW status, etc.

Figure 2-2-4 Width configurations for bridge and approach road

2-2-1-5 Strategy on Design Live Load

For the following reasons, design for the Vaisigano Bridge uses a B live load as stipulated by the Japanese Specification for Highway Bridges (SHBJ).

a) A SHBJ-rated B live load has a higher bending moment than the design live load in New Zealand standards.
b) As this Project is for Japanese Grant Aid Assistance and Samoa does not have its own specification for highway bridges, LTA has agreed to applying Japanese standards (the SHBJ).

2-2-1-6 Plans for River Revetment Design

River revetment design will proceed with the following strategy to ensure safe abutments.

- In order to ensure smooth flow in floods, the normals and structural format for revetments will be matched to the already planned levee revetments upstream.
- Given that scouring depth due to changes in flow velocity is expected to be roughly 5 m, foot protection will be installed in the bridge section to control scouring.
- Flow velocity at the bridge location will be accounted for in terms of revetment safety.

2-2-1-7 Plans for Coastal Revetment Design

Design for coastal revetment along the approach road will proceed with the following strategy.

- Revetments will be riprap to match surrounding coastal revetments. Stairs will also be installed to grant beach access.
- Revetments will be high enough near the abutments to prevent overtopping waves, and riprap will be heavy enough to maintain stability against incoming waves. Note, however, that height for the existing adjoining coastal road revetments do not account for rising sea levels and thus may be overtopped by waves in the future. Conversely, if the coastal revetments are too high, draining floodwaters from the lowlands will be more difficult, possibly increasing damage from inundation. Accordingly, it would be appropriate to monitor sea level increases and incoming waves and floods, formulate a flood management plan, and raise coastal road revetments according to said plan.
- Riprap foot protection will be used to help prevent scour on the face of the revetment.
- In the interest of stability for approach road banks, the side slopes will be at a 1:2 slope.

2-2-1-8 Plan for Socioeconomic Conditions

The items and measures to be considered in planning, design and construction of the bridge are as follows:

a) Dust during construction: Take measures to prevent spread of dust, including spreading water.
b) Noise and vibration during construction: Select construction methods which minimize noise and vibration.
c) Discharge of pollutants (oil, etc.): Implement measures to prevent spilling of pollutants.

d) Soil runoff and river contamination: Implement measures to prevent soil contamination and river pollution.
e) Traffic obstructions: Conduct safety training for construction vehicles.
f) Borrow pit/stone pit measures: A location with lower environmental load is to be selected for the borrow pit. For the stone pit, the existing stone pit is to be used to the extent possible to avoid excavating in a new location.
g) Accidents: All construction workers are to undergo safety and health training to prevent accidents.

2-2-1-9 Plan for Construction Conditions

(1) Labor Situation

This will be the first bridge in Samoa constructed with Japanese Grant Aid Assistance, and few bridges have been constructed by other donors. As such, there are few experienced construction companies, engineers, or workers available locally. Further, hardly any have the skill to or experience in working on PC bridge construction. Given this, basic strategy will be to send Japanese engineers for the work requiring advanced skills and which local workers are inexperienced in, and using local engineering and labor as much as posible in other areas.

For pavement, there are two companies with asphalt plants and paving machinery, so paving technicians can be hired locally.

Note here that when workers are employed, employers are to adhere to the Samoan Labour and Employment Act of 1972.

(2) Materials Procurement

1) Cement

There is no domestic production of cement in Samoa; product from New Zealand (Golden Bay Cement) or Fiji is used. As New Zealand cement is of a stable quality and exhibited no issues in testing, this cement will be used in the Project.

Note that we have confirmed that New Zealand cement is distributed within Samoa, and that Apia Concrete Products (APC) in Apia is a local distributor.

2) Rebar, Steel Material, PC Steel Material

There is no rebar produced locally in Samoa, and construction contractors generally procure their own from China, New Zealand, and other countries. While there is a local supplier, they are not capable of procuring large quantities.

Steel is also not produced locally and is barely even in circulation in Samoa. When needed, it is procured from Southeast Asia, China, New Zealand, and other steel-producing regions.

PC steel and other materials required for bridge construction are also not produced locally in Samoa. No distributor could be found for PC steel, and so procurement from Japan or a third country is being considered.

3) Bridge Accessories

Bridge accessories can be procured from neighboring countries, but many have issues and compromise quality. Procuring from Japan is preferred.

4) Concrete and Aggregate Plants

There are construction contractors in Apia with their own concrete and aggregate plants. Other than the contractors, APC (a concrete manufacturer) supplies 50 MPa concrete. Like the contractors, APC has its own aggregate pit and aggregate plant, and for sand, they use sand from the river (nearly oceanside). Therefore, for the Project, concrete and aggregate produced in these plants will be purchased.

5) Asphalt Plant

There are two construction contractors with their own asphalt plants. Therefore, for the Project, asphalt produced in these plants will be purchased.

6) Aggregate

In the study, four of the five construction contractors asked had their own aggregate pits and were producing crushed stone for paving and aggregate for concrete. A concrete company also had its own aggregate pit, from which aggregate could be procured. Sand is collected from crushed stone plants, the river, and the ocean. Therefore, for the Project, aggregate produced in these quarries and pits will be purchased.

7) Fill Material

As with the aggregate pits, construction contractors have their own borrow pits for fill material, and it is confirmed that this is available for procurement. Local materials were sampled from the borrow pit of one company and tested, and quality is satisfactory.

(3) Construction Machinery Procurement

The heavy machinery used in construction in Samoa is owned by the construction contractors; no leasing companies were found. The bigger construction companies have their own dump trucks, backhoes, and other machinery they use regularly, but do not have any larger cranes, bulldozers, truck-mounted concrete pumps, or other machinery for which use is more infrequent. With the vendors in Samoa having essentially no experience with PC bridge work, none of the gantry cranes, larger cranes, or other larger construction machinery which would be used during superstructure work could be found. Thus, this larger machinery will be procured from Japan.

In terms of Samoan experience with pile foundations, there were those with experience with steel H-piles, but none with cast-in-place piles (casing rotary drilling, etc.). Also, no earth drill excavators or hydraulic excavator rigs could be found. Thus, machinery for cast-in-place piles will be procured from

Japan.

(4) Bridge and Road Design and Construction Standards

As Samoa has no design standards in place for bridges, roads, and riverwork and because this Project is Japanese Grant Aid Assistance, in general Japanese standards will be applied in the design. Work will also be compliant with New Zealand, Australia, and AASHTO standards.

a) Bridge design
- Specification for Highway Bridges (Japan, 2014)
- Bridge manual (New Zealand, 2014)

b) Road and pavement design
- Road Construction Ordinance (Japan, 2015)
- AustRoads (Australia, 2015)
- AASHTO (American Association of State Highway and Transportation Officials)

c) River design
- Ordinance for Structural Standards for River Administration Facilities (Japan, 2015)

2-2-1-10 Plan for Using Local Contractors

Samoan contractors have little experience working on bridges, and in particular have almost no experience with PC bridges. However, China Railway did rebuild the Leone Bridge (PC hollow slab bridge similar in format to Vaisigano Bridge) upstream of Vaisigano Bridge, and we should be able to utilize the experience from the Leone Bridge work.

Local contractors do have experience with structural work, roadwork, and paving work, and their technical ability appears to be relatively high.

In terms of local consultants, there are a few in Apia, but few engineers. In the boring work this time, the supervisor was sent out from Australia. We found that a grant aid assistance water supply works project currently in progress was having trouble in hiring engineer consultants. Work for local consultants appears to be limited to surveying, geological surveys, traffic surveys, environmental studies, and similar work.

2-2-1-11 Plan for O&M Capacity of Implementing Agency

The leading authority for the Project is the Land Transport Authority (LTA), which operates under the Ministry of Works, Transport and Infrastructure (MWTI).

The LTA was established in December 2008 and is in charge of road asset management and road administration. They manage all road classes in Samoa, from Class 1 to 3. The LTA has nine divisions employing 115.

Within LTA, new project procurement and management are handled by the Procurement and Programming Division (PPD) and Project Management Division (PMD), respectively. The PMD split off from the PPD in February 2015, mainly to work on World Bank projects. PPD and PMD are the contacts for this Project.

The PPD has nine members including the Division Manager, and PMD has five members including the Division Manager.

PPD's role is to both handle procurement work for new projects and to outsource procurement for daily O&M work for drainage, roads, and landscaping to contractors. Road network asset management also falls under PPD jurisdiction.

In charge of World Bank projects, PMD is currently working on the 1) Enhanced Climate Resilience of West Coast Road Project and 2) Enhanced Road Access Project.

2-2-1-12 Strategy for Setting Facility Grades

Being the major arterial road connecting the Samoan capital of Apia to Fagali'i Airport (for interisland flights) and Apia Port (Samoa's only commercial port), Beach Road's role is expected to expand in the future as local distribution increases and the region develops.

Given its importance due to its location, the crossing of Vaisigano River on Beach Road, Vaisigano Bridge is given the following grades.

a) Design standards

- Specification for Highway Bridges (Japan, 2014)
- Bridge manual (New Zealand, 2014)
- Road Construction Ordinance (Japan, 2015)
- AustRoads (Australia, 2015)
- AASHTO (American Association of State Highway and Transportation Officials)
- Ordinance for Structural Standards for River Administration Facilities (Japan, 2015)

b) Design live load

A B live load as stipulated in the 2012 SHBJ is used. A live load of B is sufficient to withstand current traffic levels in Samoa.

c) Width

- Bridge section – lane width: 3.5 m × 2 = 7.0 m, shoulder: 0.5 m × 2 = 1.0 m, walkway: 2.5 m × 2 = 5.0 m; Total: 13.0 m
- Approach road section – lane width: 3.5 m × 2 = 7.0 m, shoulder: 0.5 m × 2 = 1.0 m, walkway: 2.5 m × 2 = 5.0 m; Total: 13.0 m

d) Road classification

- Urban arterial road (Australian standards)

e) Design speed

- 50 km/h (40 km/h restriction for trucks)

2-2-1-13 Plan for Construction Methods and Schedule

(1) Plan for Construction Methods

Annually, Samoa experiences a rainy season from November to April and dry season from May to October. From November to April is also the period the nation is subject to tropical cyclones. The highest monthly rainfall is in January, exceeding 1,000 mm per month. Thus, foundation and substructure work in the river has to be avoided between November and April if at all possible. If riverwork proves to be unavoidable in this period, great care must be taken with the foundation and substructure work, especially with work such as coffering and excavation.

(2) Plan for Construction Schedule

As mentioned above, the rainy season in the bridge reconstruction area is from November to April, and the highest monthly rainfall is in January, exceeding 1,000 mm per month. Thus, work plans must be scheduled efficiently to account for these periods of high rainfall.

2-2-2 Basic Plan

2-2-2-1 Basic Plan Work Flow

The Basic Plan consists of studying what is necessary for implementing the Project—conducting a survey of existing conditions, considering the longitudinal bridge plan, choosing the bridge location and size, discussing the bridge type, considering environmental and social concerns—and selecting a bridge type. A work flowchart of the Basic Plan follows below.

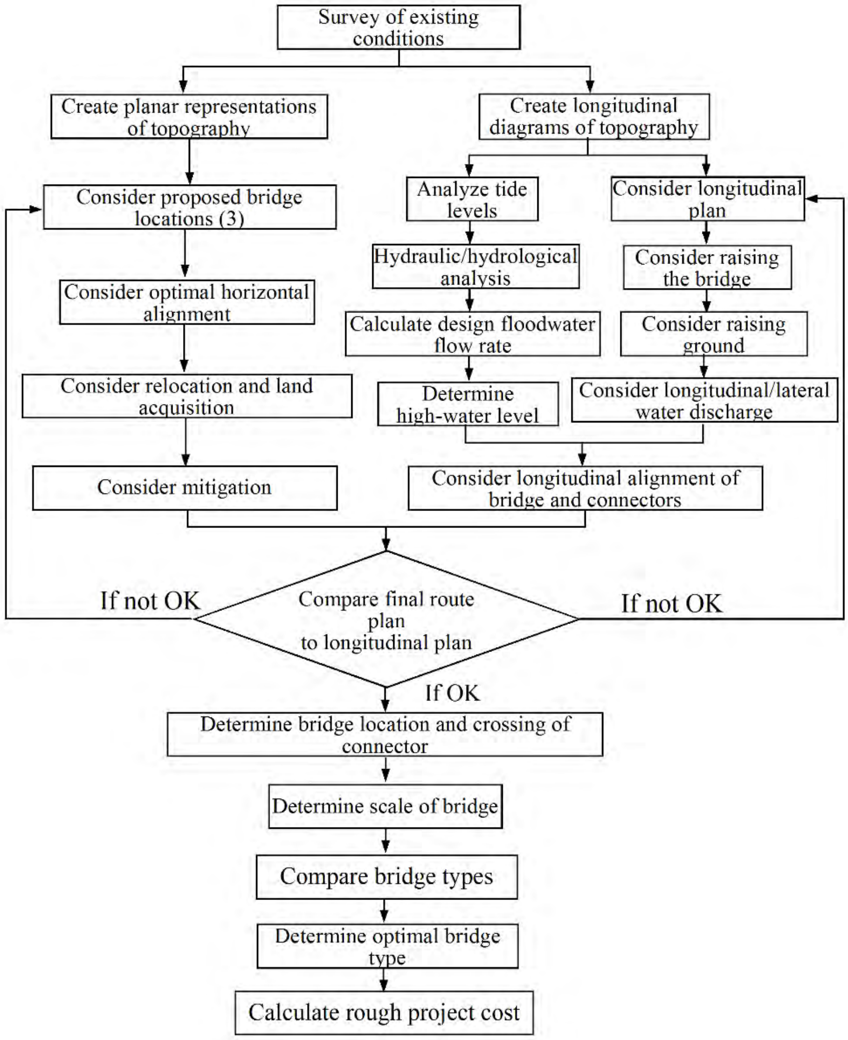


Figure 2-2-5　Study Work Flowchart

2-2-2-2 Deterioration and Damage on the Existing Bridge

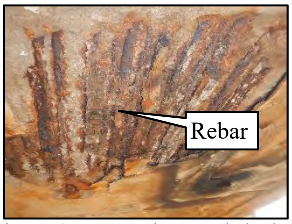
Constructed in 1953, the Vaisigano Bridge is a 74.76 m long (seven 10.68-meter spans) and 11.495 m wide concrete bridge. It is indicated as being at risk of collapse due to deterioration and severe damage in Cyclone Evan in 2012. Given this, the bridge was evaluated for soundness to determine the degree of damage and verify the prospects of reconstruction. The findings were also to be reflected in the facility and construction plans as needed. Results from the survey of existing bridge condition will also serve as reference when discussing the bridge removal plan (process, schedule, costs, etc. for removal work).

The results of the survey of existing bridge condition are given in Table 2-2-7.

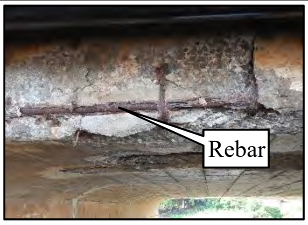
Table 2-2-7 Survey Results of Existing Bridge Situation

Name		Vaisigano Bridge			
Specifications	Year built	1953	Location	13°49'52.50"N, 171°45'36.04"E	
	Average daily traffic (2013)	14,300 cars/day	Elevation: 3.29 m	Distance: Roughly 1 km from Apia	
	Vehicle classification	100% passenger cars (large vehicles prohibited)			
	Width	7.535 m (width of lanes) + 1.980 m (sidewalk width) x 2 = 11.495 m			
	Design live load	H20-S16-41			
	Super-structure: Type	Seven-span concrete slab bridge			
	Super-structure: Length	7 @ 10.680 m = 74.76 m			
	Substructure	Abutments: RC		Piers: Wall-type RC	
	Foundation	Abutments: Pile foundation (estimated)		Piers: Pile foundation (estimated)	
Survey results	Transportation functionality (role)	・The Vaisigano Bridge is located on Beach Road, a major arterial road that connects the Samoan capital of Apia to Fagali'i Airport (for interisland flights) and Apia Port (Samoa's only commercial port); its transportation functionality (role) is extremely high. ・The average daily traffic in 2013 was 14,300 cars per day; its transportation functionality (role) is extremely high.			
	Soundness (degree of damage)	・Corrosion of rebar due to salt damage is pronounced (Pictures 1-6). ・Concrete spalling, and peeling and falling off is pronounced (Pictures 1-8). ・Sedimentation around the bridge piers is pronounced (Pictures 11 and 12).			
	Structural properties (stability)	・Corrosion has eaten away at too much of the rebar area (Pictures 1-3, 5 and 6). ・Concrete spalling, and peeling and falling off (Pictures 1-8) is pronounced, and that has caused pronounced corrosion of rebar (Pictures 1-6).			
Observations		・Concrete is peeling and falling off across wide areas due to salt damage and poor workmanship, and that has caused pronounced corrosion of rebar (Pictures 1-6), which greatly increases the likelihood of the bridge collapsing. ・The bridge is close to load bearing capacity and is in danger of collapsing; thus, it would be best to replace it as soon as possible.			

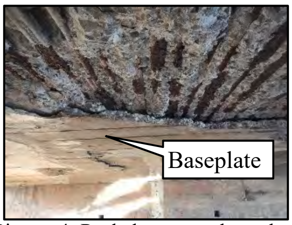
Picture 1: Extremely corroded rebar



Picture 2: Extremely corroded rebar

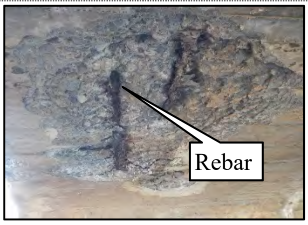


Picture 3: Unprotected rebar

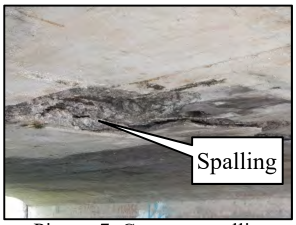


Picture 4: Peeled concrete baseplate

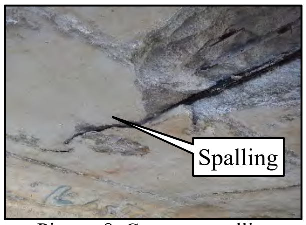
Picture 5: Concrete peeling and falling



Picture 6: Concrete peeling and falling off



Picture 7: Concrete spalling

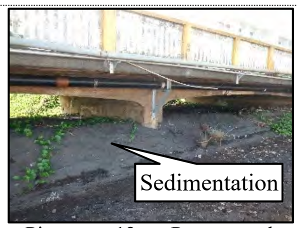


Picture 8: Concrete spalling


Picture 9: Damaged railing

Picture 10: Exposed rebar at railing

Picture 11: Pronounced sedimentation at bridge piers



Picture 12: Pronounced sedimentation at bridge piers

2-2-2-3 Consideration of Longitudinal Bridge Plan

(1) Effects of Climate Change

Storm surges and high waves caused by cyclones and future sea level rises due to climate change must be considered before determining the longitudinal height of the bridge. The Samoan government has already investigated future sea level rises, storm surges and high waves through an agreement with the Australian government, which set the 100-year sea rise in Apia Port (where the Vaisigano Bridge is located) at 2.2 m by 2090.

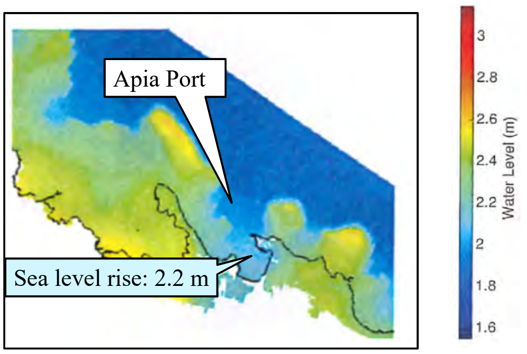


Figure 2-2-6 Climate Change-Induced Sea Level Rise in Samoa

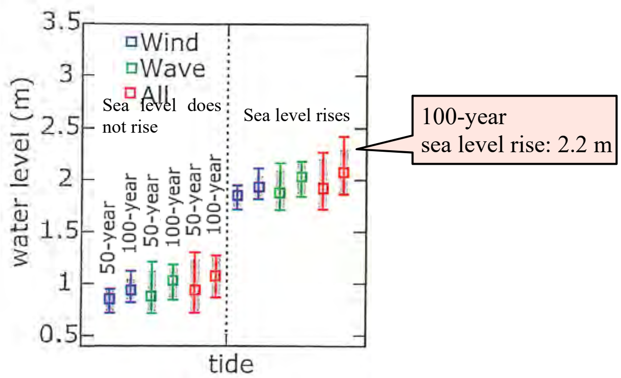


Figure 2-2-7 Climate Change-Induced Sea Level Rise in Apia Port

(2) Effects of Flooding

1) Flooding Level Considerations

The Vaisigano River rises due to flooding from rain from cyclones and the like. Thus, the effects of increased water levels due to flooding must be considered when developing longitudinal bridge plans. The Vaisigano Bridge crosses the Vaisigano River at its mouth, and is very susceptible to the effects of any sea level rise at Apia Port. If a 100-year cyclone or similar disaster strikes Apia Port with its sea level increased 2.2 m due to climate change as described in (1) above, the Vaisigano River would flood and rise 2.3 m over its current level (20-year flood) and 2.7 m (100-year flood).

Picture 2-2-1 Driftwood Accumulation during Cyclone Evan

Note that during the severe Cyclone Evan in 2012, driftwood accumulated at the bridge, and the bridge was submerged due to the increased water level upstream. Thus, a sufficient longitudinal bridge height is required to allow driftwood to pass underneath.

From the water level analysis based on the results of field exploration, the design high water level at the bridge location was MSL+2.7 m.

As river flow is 680 m^3/s, the Ordinance for Structural Standards for River Administration Facilities dictates that a clearance height of 1.0 m is required, giving us a flow rate of MSL+3.7 m below the bridge girders.

2) Vaisigano River Revetment Development Plans

As further explained below (2-2 Results other than the measure plans), given the 20-year flood levee work planned for this year in the section between Vaisigano Bridge and Leone Bridge, structures from the downstream end of the levee and the upstream end of the new Vaisigano Bridge will need to be coordinated.

A structural diagram of the Vaisigano River levee at the bridge location is given in the figure below.

The levee crown height of MSL+2.7 m is safely below the girder under clearance of MSL+3.7 m.

Crest level: MSL+2.7 m (Directly upstream of Vaisigano Bridge)

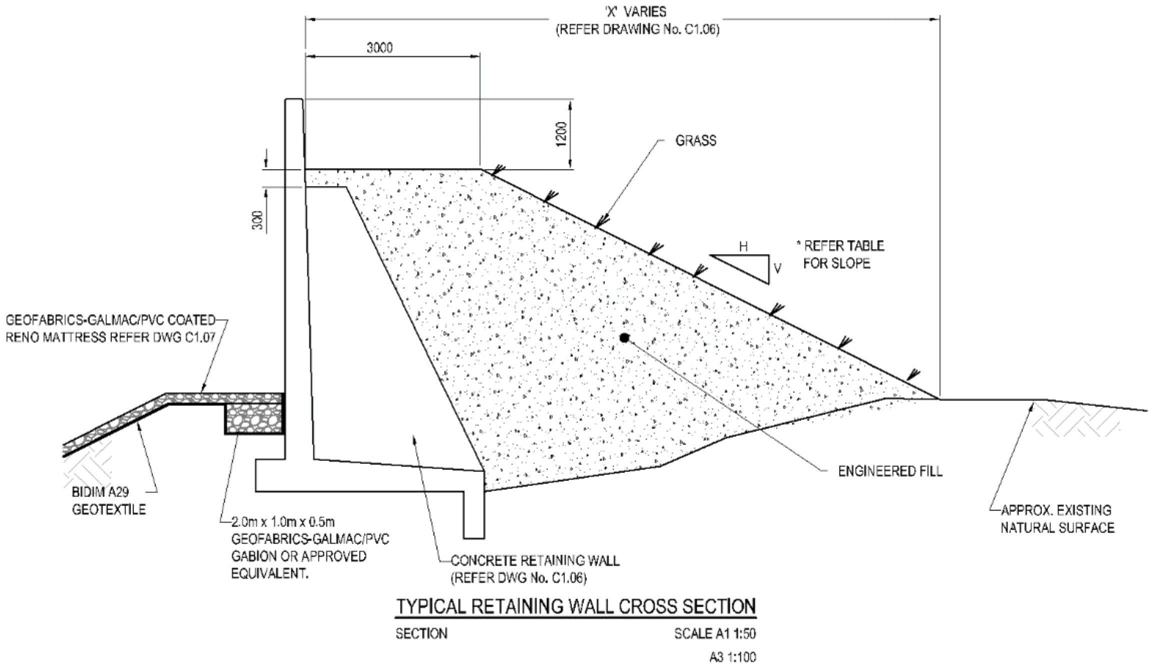


Figure 2-2-8 Structural diagram of Vaisigano River levee

(3) Longitudinal Plans for Bridge and Road

1) Raised Height

From sections (1) and (2) above, the bridge will be raised as depicted in the following table.

Table 2-2-8 Longitudinal height of the bridge

	Profile Consideration Items	Height	Notes
1	Sea level increase due to climate change	MSL+2.2 m	
2	High water level (HWL) due to cyclones and natural disaster	MSL+2.7 m	Sea level increase and flood levels
3	Clearance height from HWL to under clearance of main girder	1.0 m	500-2,000 m^3/s
4	Bridge structure height	1.2 m	1.0 m high main girder, 0.2 m thick pavement
5	Total height (2 + 3 + 4)	MSL+4.9 m	
6	Current road surface height (abutment position)	MSL+3.4 m	
7	Bridge raised height (5-6)	1.5 m	

2) Longitudinal Road Plan

With the bridge being raised 1.5 m, the basic approach and controls for the longitudinal road plan are as follows:

- In the interest of safe passage, the profile gradient for the road near the intersections will be kept to a gentle grade of 2.5 percent or lower.
- Profile alignment will be kept consistent with the existing road at the origin and endpoint sides.

3) Longitudinal Bridge Plan

The longitudinal bridge plan will be developed accounting for sea level rises due to climate change, high water levels due to cyclones and similar factors. The following three longitudinal bridge plan proposals were compared based on impact during floods, road profile alignment, impact from banking, environmental and social concerns, cost efficiency, and other factors to determine the optimal plan (see Table 2-2-9):

- Proposal 1 (Raise bridge 0.5 m): A proposal to raise the bridge 0.5 m over the current site ground height in light of the height needed to withstand 100-year storm surges caused by climate change and the 20-year flood levels of the levee development plan.

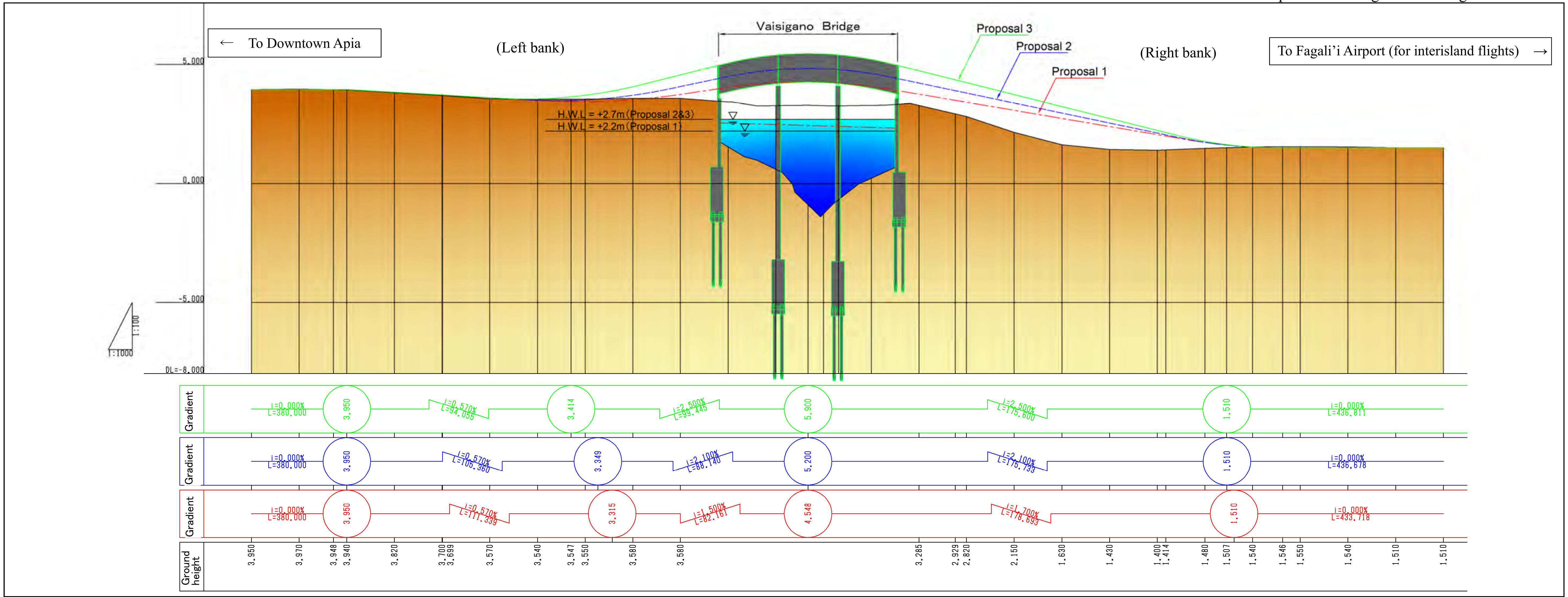
- Proposal 2 (Raise bridge 1.0 m): A proposal to raise the bridge 1.0 m over the current site ground height based on the height needed to withstand 100-year storm surges caused by climate change and 100-year flood levels, as well as an under clearance of 0.5 m for the main girders.
- Proposal 3 (Raise bridge 1.5 m): A proposal to raise the bridge 1.5 m over the current site ground height based on an under clearance of 1.0 m for the girders for design flood discharge for Proposal 2.

Overviews of the above three proposals, along with the pros and cons of each, were explained to and discussed with LTA, at which point LTA agreed that Proposal 3 (raising the bridge 1.5 m) was best for the following reasons:

a) No driftwood would strike the main girders in 100-year storm surges or flood levels.
b) The impacts on the surrounding area (hotel, churches, etc.) of raising the bridge by 1.5 m can be mitigated by installing frontage roads.

Table 2-2-9 gives a comparison of the proposed longitudinal bridge plans.

Table 2-2-9 Comparison of Longitudinal Bridge Plans



	Alternate proposals	Proposal 1 (Raise bridge 0.5 m)		Proposal 2 (Raise bridge 1.0 m)		Proposal 3 (Raise bridge 1.5 m)	
	Overview	· Proposal to set new bridge longitudinal height to 3.9 m, adding the structure height (1.2 m) to the 20-year flood levels of the levee development plan (2.2 m) and the under clearance for the main girders (0.5 m). (raise the bridge 0.5 m over its present height of 3.4 m)		· Proposal to set new bridge longitudinal height to 4.4 m, adding the structure height (1.2 m) to the 100-year flood levels, accounting for 100-year climate changes (2.7 m), and the under clearance for the main girders from the 20-year levee development plan (0.5 m). (raise the bridge 1.0 m over its present height of 3.4 m).		· Proposal to set new bridge longitudinal height to 4.9 m, adding the structure height (1.2 m) to the 100-year flood levels, accounting for 100-year climate changes (2.7 m), and the under clearance of 1.0 m for the main girders. (raise the bridge 1.5 m over its present height of 3.4 m).	
Evaluation	Effects of flooding	· Main girders at risk of inundation in a 100-year flood (2.7 m). · Driftwood may crash into the main girders during floods.		· Main girders not at risk of inundation in a 100-year flood (2.7 m), but risk of driftwood striking main girders.		· No risk of main girders being inundated in a 100-year flood (2.7 m) or being struck by driftwood.	
Evaluation	Longitudinal alignment of road	· No alignment issues. Profile gradient is 1.5 percent on the left bank side and 1.7 percent on the right bank side. This is the most gradual longitudinal alignment of the three proposals.		· No big alignment issues. Profile gradient is 2.1 percent on both the left and right bank sides.		· No big alignment issues. Profile gradient is 2.5 percent on both the left and right bank sides. Grading is kept gentle at 2.5 percent at the intersection.	
Evaluation	Effects of embankment	· The embankment will be 0.5 m than that of the existing road; problems are unlikely.		· The embankment will be 1.0m, affecting the hotel, church, intersection and the rest of the surrounding area.		· The embankment will be 1.5 m, affecting the hotel, church, intersection and the rest of the surrounding area.	
Evaluation	Environmental and social considerations	· The bridge will be raised only 0.5 m; it will cause no problems related to environmental and social considerations.		· The embankment will be 1.0m, causing problems related to environmental and social considerations for the hotel, church, intersection and the like, but installing a service road can solve the problems.		· The embankment will be 1.5 m, causing problems related to environmental and social considerations for the hotel, church, intersection and the like, but installing a service road can solve the problems.	
Evaluation	Economic efficiency	· This is the most economically efficient proposal of the three because the longitudinal height is the lowest.		· The economic efficiency of this proposal ranks between the other two because the longitudinal height also ranks between the other two.		· This is the least economically efficient proposal of the three because the longitudinal height is the highest.	
Evaluation	Overall evaluation	· 100-year storm surges and flood levels will not reach the main girders. · Driftwood may crash into the main girders during floods. · The embankment will be 0.5m; it will hardly impact the surrounding area. · This is the most economically efficient proposal of the three.	△	· Driftwood will not crash into the main girders during 100-year storm surges or floods, but it may if there is sedimentation. · The 1.0m embankment will impact the surrounding area (hotel, church, etc.), but constructing a service road can solve the problems. · The economic efficiency of this proposal ranks between the other two.	○	· Driftwood will not crash into the main girders during 100-year storm surges or floods even when sedimentation has raised the riverbed 1.0 m or more. · The 1.5-m embankment will impact the surrounding area (hotel, church, etc.), but constructing a service road can solve the problems. · This is the least economically efficient proposal of the three because the longitudinal height is the highest.	◎

2-2-2-4 Consideration of Bridge Location

The reconstruction of the Vaisigano Bridge has been proposed due to its deterioration, lack of load bearing ability and other negative attributes. Location of the new bridge was considered based on Proposal 3 to raise the bridge profile height by 1.5 m from 2-2-2-2 Deterioration and Damage on the Existing Bridge. Here, the following three bridge location proposals were compared based on alignment and structural format of the new bridge, need for a temporary bridge and detour routes, environmental and social concerns, cost efficiency, and other factors to determine the optimal plan.

(1) Proposed Bridge Locations

1) Proposal 1: Current bridge location

The following points form the basis (reasons) for rebuilding in the current location:

a) Rebuilding the bridge in the current location minimizes environmental and social issues, such as resettlement and land acquisition.
b) The current favorable plane alignment would be maintained by rebuilding in the current location as the current bridge and the approach road before and after the bridge are in straight alignment.
c) Rebuilding in the current location eliminates the need to construction any new approach road, preserving and utilizing the current approach road to its utmost.
d) However, a retaining wall up to 1.5 m in height in front of the hotel would pose an environmental and social issue as it would limit access for hotel patrons.

2) Proposal 2: Shifting the bridge downstream 20 m

The following points form the basis (reasons) for rebuilding the bridge 20 m downstream of the current location:

a) Despite the right bank upstream of the current bridge being an empty lot, shifting upstream presents problems given that the hotel, church, and other buildings are on the left bank side. Thus, any shift will have to be downstream of the current location.
b) No temporary bridge or detour route will be required by shifting the new bridge 20 m downstream of the current bridge location as it would leave the existing bridge and road open for use during construction.
c) Shifting the location 20 m downstream and installing a frontage road between the hotel and approach road would retain hotel access for hotel patrons.
d) While it would present the issue of acquiring the land, as the area downstream of the current bridge is coastline with no residences or other buildings, there would be no environmental or social issues due to resettlement or building removal.

3) Proposal 3: Shifting the bridge downstream 50 m

The following points form the basis (reasons) for rebuilding the bridge 50 m downstream of the current location:

a) Shifting bridge location 50 m downstream of the current bridge would avoid any impact to the hotel.
b) No temporary bridge or detour route will be required by shifting the new bridge 50 m downstream of the current bridge location as it would leave the existing bridge and road open for use during construction.
c) While it would present the issue of acquiring the land, as the area downstream of the current bridge is coastline with no residences or other buildings, there would be no environmental or social issues due to resettlement or building removal.

(2) Comparison and Analysis of Bridge Locations

Overviews of the proposals being compared, along with the pros and cons of each, were explained to and discussed with LTA, at which point LTA agreed that Proposal 2 (shifting the bridge 20 m downstream) was best for the following reasons:

a) Obstruction to hotel access from the profile increase can be alleviated with a frontage road.
b) This is the most cost-efficient option as it does not require construction of a temporary bridge or detour route, and bridge construction costs are much less than Proposal 3.

Table 2-2-10 shows a comparison and analysis table of bridge locations, and Figure 2-2-9 shows the longitudinal plan and plane plan views of the bridge and road.


5. Hotel parking lot


4. Church next to the hotel


3. Hotel next to the bridge


2. Total view of the Vaisigano Bridge


1. Total side view of the Vaisigano Bridge

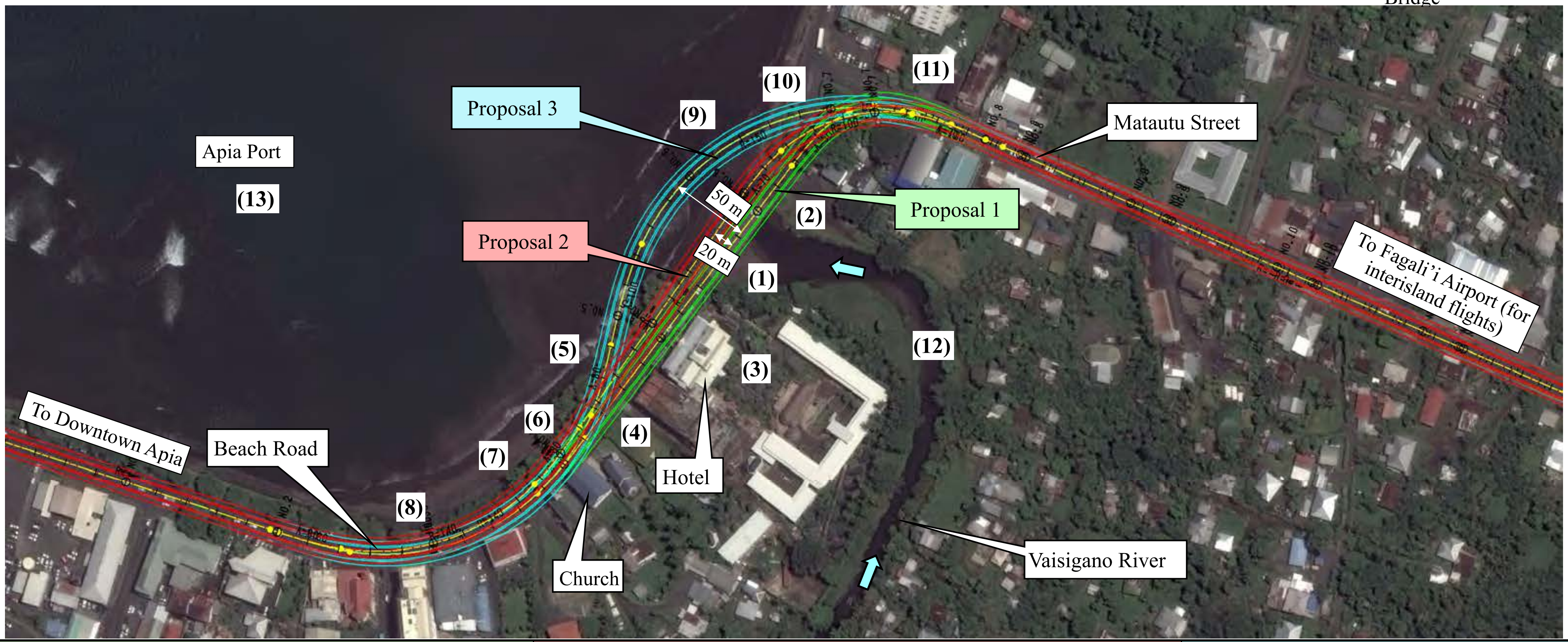

9. Sedimentation at the Vaisigano Bridge


10. Heavy traffic on Beach Road


6. To two lanes from three


7. Promenade along the seashore


8. Promenade in front of the hotel




11. Steeply sloped intersection


12. Vaisigano River


13. Apia Port

Alternate proposals		Proposal 1 (Current location)	Proposal 2 (Shift 20 m downstream)	Proposal 3 (Shift 50 m downstream)
Overview		・A proposal to build the new bridge at the same location as the existing bridge.	・A proposal to shift the new bridge roughly 20 m downstream of the location of the existing bridge.	・A proposal to shift the new bridge roughly 50 m downstream of the location of the existing bridge.
Evaluation	New bridge alignment and structure type	・The existing bridge is straight, and the horizontal alignment is extremely good because the replacement would be built in the same location. ・A concrete bridge would be best because the new bridge would be straight and located on the seashore. ・PC three-span interconnected hollow slab bridge (Length = 3 @ 25.0 m = 75.0 m)	・The new bridge would have nearly the same alignment as the existing bridge and be straight, so the horizontal alignment is extremely good. ・A concrete bridge would be best because the new bridge would be straight and located on the seashore. ・PC three-span interconnected hollow slab bridge (Length = 3 @ 25.0 m = 75.0 m)	・The alignment is S-shaped; the horizontal alignment is extremely poor compared to the existing alignment and the new bridge would be extremely long (150 m compared to the 75-m existing bridge). ・A concrete bridge would be difficult due to the S-shaped curve; it would have to be a steel bridge, which would cause concern over corrosion due to salt. ・Five-span continuous steel-plate girder bridge (Length = 5 @ 30 m = 150.0 m)
	Need for temporary bridge or detours	・The replacement would be built in the same location, so the existing bridge and roads will not be usable; a temporary bridge and detour must be constructed.	・Since the new bridge would be shifted roughly 20 m downstream, the existing bridge and roads will be usable; there is no need for a temporary bridge and detour.	・Since the new bridge would be shifted well downstream, the existing bridge and roads will be usable; there is no need for a temporary bridge and detour.
	Environmental and Social Considerations	・The longitudinal height will be raised 1.5 m, making the hotel difficult to access. In addition, construction will impact the hotel significantly because it is adjacent to the bridge. ・Generally, there will be no relocation or land acquisition because the new bridge will be built in the same location as the existing bridge.	・The longitudinal height will be raised 1.5 m, making the hotel difficult to access, but this can be addressed by constructing a service road. ・Nobody lives along the new horizontal alignment, so there will be no relocation, but land acquisition will be necessary to build the new access roads.	・The longitudinal height will be raised 1.5 m, making the hotel difficult to access, but this can be addressed by using existing roads. ・Nobody lives along the new horizontal alignment, so there will be no relocation, but land acquisition will be necessary to build the new access roads.
	Construction work involved (construction expenditure ratio)	・New bridge construction, new access road construction (400 m transition due to raising of longitudinal height), temporary bridge and detour road construction, existing bridge removal (construction expenditure ratio: 1.21)	・New bridge construction, new access road construction (425 m), temporary bridge and detour road construction, existing bridge removal (construction expenditure ratio: 1.00)	・New bridge construction, new access road construction (450 m), existing bridge removal (construction expenditure ratio: 2.45)
	Overall evaluation	・The longitudinal height will be raised 1.5 m, making the hotel difficult to access. In addition, construction will impact the hotel significantly. ・Although the bridge construction cost is the same as that of Proposal 2, the economic efficiency is considerably less than that of Proposal 2 since it requires the construction of a temporary bridge and detour. ・There will be no relocation, removal of buildings or land acquisition. △	・The longitudinal height will be raised, making the hotel difficult to access, but this can be addressed by constructing a service road. ・There will be no relocation, but land acquisition is necessary. ・Since the construction of the temporary bridge and detour is not necessary and the bridge construction cost is very cheap compared to Proposal 3, the economic efficiency will be the most dominant. ◎	・The longitudinal height will be raised, making the hotel difficult to access, but this can be addressed by using existing roads. ・There will be no relocation, but land acquisition is necessary. ・There is no need to construct a temporary bridge and detour, but the bridge construction cost would be extremely high; this is the least economically efficient proposal. △

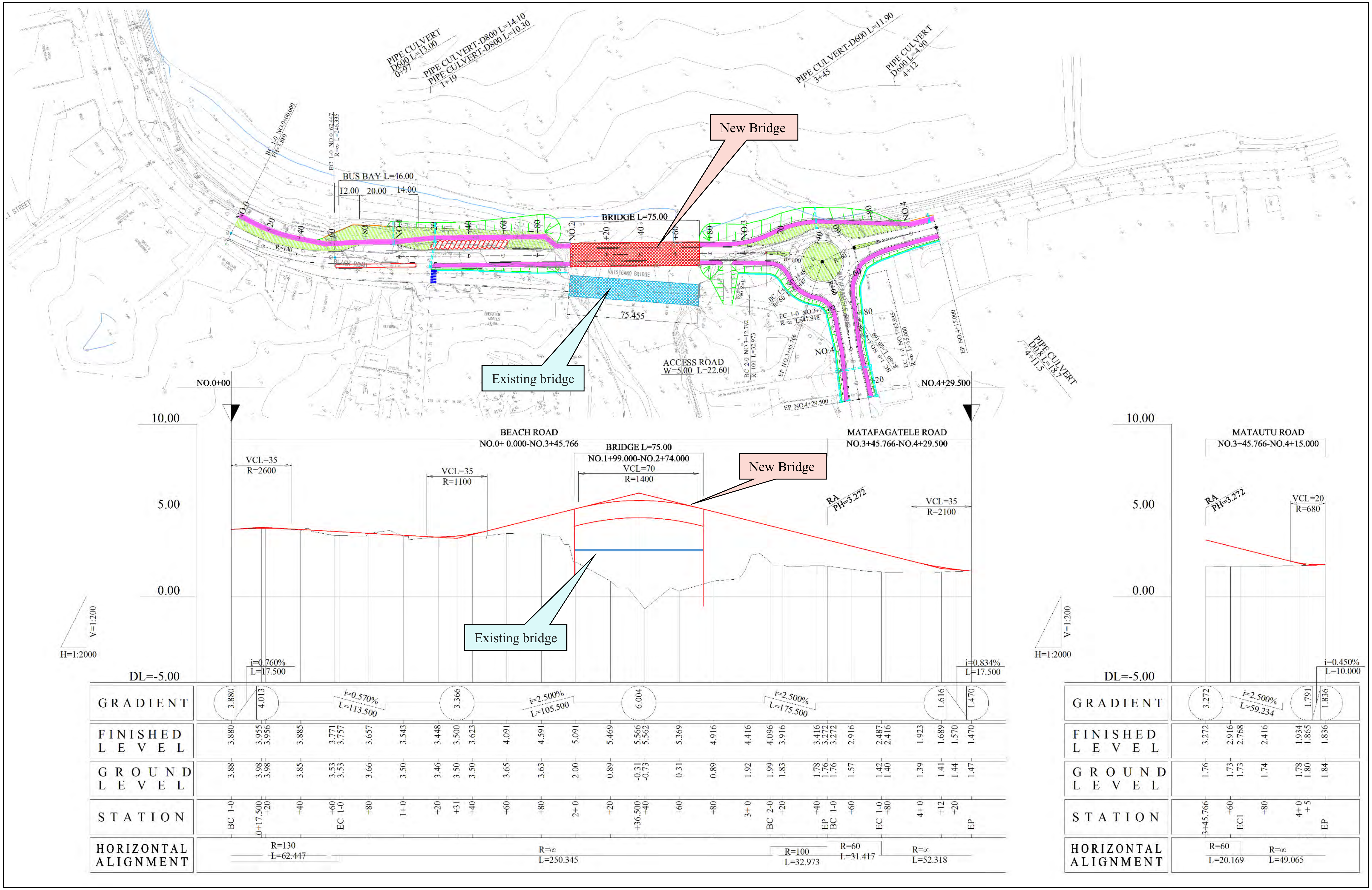


Figure 2-2-9 Longitudinal plan and plane plan view of the bridge and road

2-2-2-5 Master Plan

2-2-2-5-1 Applicable Design Standard Conditions

(1) Bridge Design Conditions

1) Hydrological Conditions

a) Design Scale

Flood design scale is set to a 20-year scale for river development in Samoa, but separate determinations are required for design scale for bridge planning to comprehensively account for actual damage from previous flooding, bridge importance, JICA experience, and other factors.

In this Project, a design scale of 100 years was used for the bridge location for the following reasons:

i) Cyclone Evan in 2012, the largest tropical cyclone to strike Samoa, was approximately a 100-year storm.

ii) At the time of design for the Vaisigano Bridge, New Zealand standards (Bridge Manual, 2014) gave a return period of 100 years given the bridge type and importance level.

iii) In JICA Grant Aid Assistance, a design scale of 100 years is used for important bridges in regions subject to large-scale disaster.

b) Design Flood Discharge

From 2-2-1-2(2)5) Design Flood Discharge, the 100-year design flood discharge in the bridge plan is 680 m^3/s.

c) Design High Water Level

From 2-2-1-2(2)6) Design High Water Level, the design high water level at the Vaisigano Bridge location is MSL+2.7 m.

d) Clearance Height

The under clearance for the main girders corresponding to a design flood discharge of 680 m^3/s at the Vaisigano Bridge location is 1.0 m.

e) Embedded depth

The conditions decided for embedded depth for bridge piers are: 1) Ensure at least 2.0 m of overburden from the deepest river bed height to the top of the footing, and 2) Foot protection is installed at the pillar bases to prevent local scour. For the abutments, the condition decided for embedded depth is that the bottom of the footing must reach the deepest river bed height.

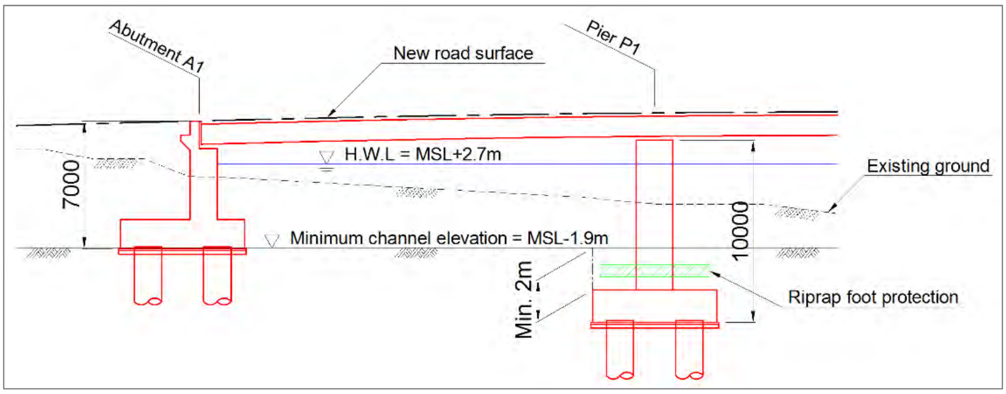


Figure 2-2-10 Embedded depth

2) Design Live Load

A live load of B as stipulated in the 2012 SHBJ is used. A live load of B is sufficient to withstand current traffic levels in Samoa.

3) Seismic Load

The design horizontal seismic coefficient used to calculate horizontal force in an earthquake was calculated based on the following New Zealand and Samoan standards.

- Bridge manual – Third edition, NZ Transport Agency
- NZ 4203:1992 Code of practice for general structural design and design loadings for buildings
- National Building Code – 1992, Samoa

The equation for calculating design horizontal seismic intensity is:

C = Ch (T1, 1) x Sp x R x Z x Ls

Where:

C: Lateral force coefficients for the equivalent static method

Ch (T1, 1): Basic seismic hazard acceleration coefficient = <u>1.0</u>

Sp: Structural performance factor = <u>0.67</u>

R: Risk factor = <u>1.3</u>

Z: Zone factor = <u>1.05</u>

Ls: Limit state factor for the serviceability limit state = <u>1/6</u>

Thus, the design horizontal seismic coefficient used in the seismic design for the bridge is <u>0.2</u>.

4) Material Strength

Strengths for the various materials used in the Project are as follows:

a) Prestressed concrete

Design strength for the concrete used in the main girders (pre-tensioned slab girders) is σck = 50 N/mm^2.

Design strength for the concrete used in the crossbeams (filling and consolidated crossbeams) is σck = 30 N/mm^2.

b) Reinforced concrete

Design strength for the concrete used in the substructure (abutments and piers) and bridge surface work (wheel guard and sidewalks) is σck = 24 N/mm^2.

Design strength for the underwater concreting used in the pile foundation (cast-in-place piles) is σck = 24 N/mm^2 (nominal strength of 30 N/mm^2).

c) Plain concrete

Design strength for the concrete used in the adjustment concrete (bridge surface work) and level concrete (substructure) is σck = 18 N/mm^2.

d) Rebar

The rebar used in superstructure and substructure work (all structural members) will be SD345 (JIS G 3112) equivalent.

e) PC steel

PC steel used in the main cables will be 1S15.2 SWPR7BN (JIS G 3536) equivalent.

PC steel used in the transverse prestressed cables will be 1S21.8 SWPR19N (JIS G 3536) equivalent.

5) Procedure for setting the span length

Figure 2-2-11 shows the procedure for setting the span length.

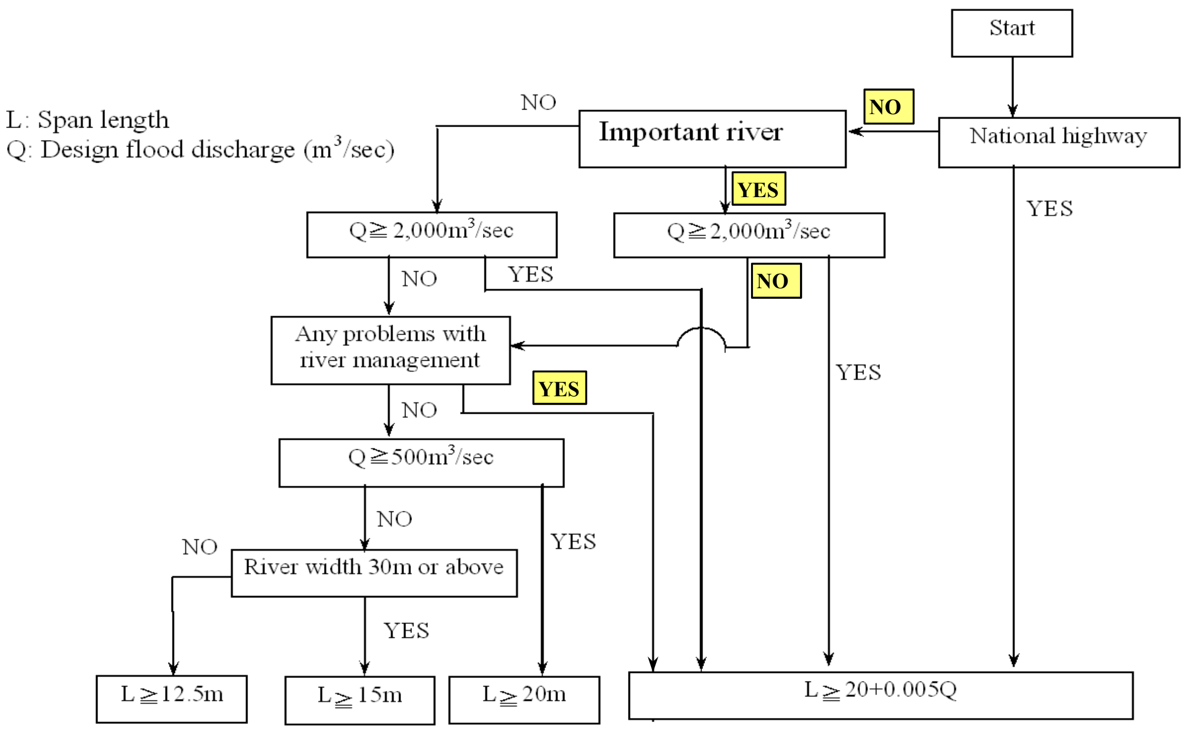


Figure 2-2-11 Procedure for setting span length

Calculating based on this procedure for setting span length, span length for the Project bridge is 23.4 m or greater for a design flood discharge of $680m^3/s$.

(2) Road Design Conditions

Road design is in conformance with the 2004 Road Construction Ordinance of Japan and Australian standards. Note also that pavement design is in conformance with the 2006 Pavement Design Manual of Japan, whereas the pavement structure will be checked against AASHTO standards.

The road geometric standards are given in Table 2-2-11.

Table 2-2-11 Road geometric standards ＊applicable design speed of 50 km/h

Road classification				Urban arterial roads			Remarks
Design speed				40 km/h	50 km/h	60 km/h	
Plane Alignment	Minimum radii of horizontal curves based on superelevation	Desirable	m	36	56	98	Urban roads
		Absolute	m	31	49	75	
	Minimum horizontal curve lengths	Minimum	m	45	70	100	
	Transition curves	Maximum radius requiring spiral		60 or under is not required			
Profile alignment	General maximum grades	Flat	%	na	na	6 - 8	na:not applicable
		Rolling	%	na	na	7- 9	
		Mountainous	%	na	na	9 - 10	
	Minimum grades	Desirable	%	1.0			Road with kerb and channel
		Absolute	%	0.3			
	Minimum length of crest vertical curve	Minimum	m	20 -30	30 - 40	40 - 50	
		Min. grade change requiring a crest curve	%	1.0	0.9	0.8	
	Minimum size crest vertical curve	Desirable	K value	3.5	6.8	11.8	General (Rt=2.0s)
		Absolute		2.9	5.4	9.2	
	Minimum size sag vertical curve	Desirable	K value	4.0	7.0	10.0	Urban roads and rural roads with street lighting
		Desirable		7.0	11.0	16.0	Urban roads and rural roads without street lighting
	Typical minimum vertical clearance	Main and arterial roads	m	5.4			Include future provision of 0.1m
		Other roads	m	4.6			

2-2-2-5-2 Planned Widths

As mentioned before in 2-2-1-4 Planned Widths, the planned widths are as follows.

The cross section of the bridge will be two 3.5 m-wide traffic lanes (7.0 m), two 0.5 m-wide shoulders (1.0 m), and two 2.5 m-wide walkways (5.0 m) for a total effective width of 13.0 m.

The standard cross section of the approach road will be two 3.5 m-wide traffic lanes (7.0 m), two 0.5 m-wide shoulders (1.0 m), two 2.5 m-wide walkways (5.0 m), and two 0.75 m-wide protective shoulders (1.5 m) for a total effective width of 14.5 m.

2-2-2-5-3 Consideration of Bridge Length

With the existing bridge being 75 m and MNRE's river revetment development being planned to align with the abutment locations of the existing bridge, the bridge will also be 75 m in length. The following positions were determined for the abutments so that the abutments align with the levee on the upstream side and are on the line of sight for the existing abutments.

- A1 abutment：No. 1 + 99.0 m（199.0m from starting point No.0）
- A2 abutment：No. 2 + 74.0 m（274.0m from starting point No.0）

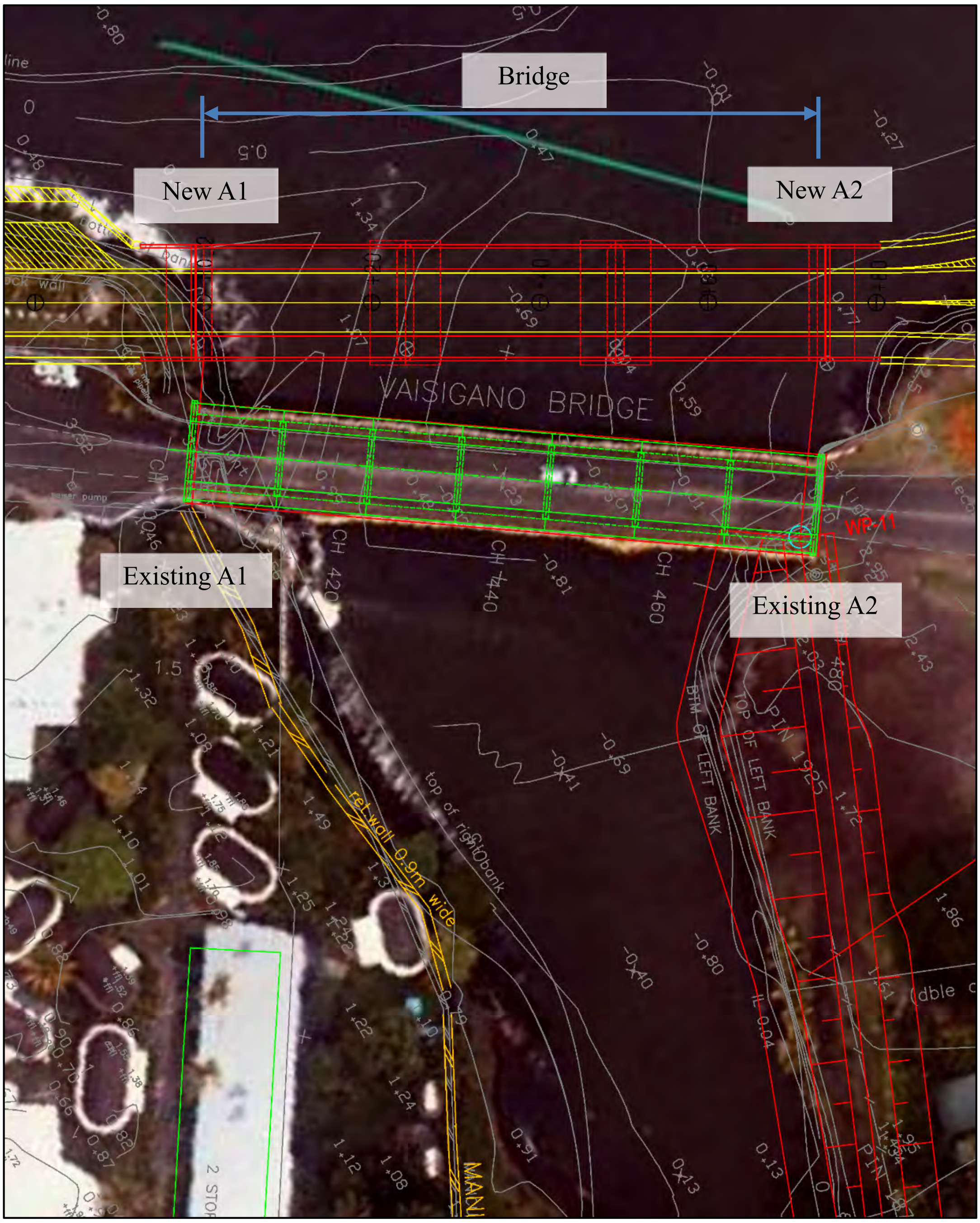


Figure 2-2-12　Abutment positioning

2-2-2-5-4 Consideration of Bridge Type

(1) Measures for Driftwood

The superstructure of the Vaisigano Bridge was submerged and the foundations of its substructure were damaged during Cyclone Evan because driftwood accumulated on the upstream side of the bridge, and the bridge blocked the outflow of floodwaters, which caused the water level upstream to rise. Thus, the accumulation of driftwood must be prevented.

Picture 2-2-2 Driftwood Accumulated During Cyclone Evan Flooding

The length of the driftwood that arrived at the bridge was determined by the width of the river channel and shape of the flow path, and it accumulated between the bridge's spans and underneath its girders. These points will be confirmed, and every effort will be made to prevent the accumulation of driftwood.

In concrete terms, span length will be set to 20 m or longer to prevent driftwood from accumulating as 20 m is the longest driftwood generally expected.

(2) Consideration of Measures Against Salt Damage

1) Conditions for Salt Damage

Generally, steel material will be prone to advanced corrosion in temperatures of 20°C or higher and humidity of 70 percent or above. Figure 2-2-13 shows the relation between average monthly temperatures and relative humidity in Okinawa, Tokyo, and Sapporo. In it, we see that Naha (Okinawa) conditions are prone to advanced steel corrosion for seven months out of the year. Looking at the past 10 years of temperature and humidity data from the Apia observation station in Samoa, low temperatures are 20° or higher and low humidity is 70 percent or higher throughout the entire year. Thus, steel will be prone to advanced corrosion throughout the year.

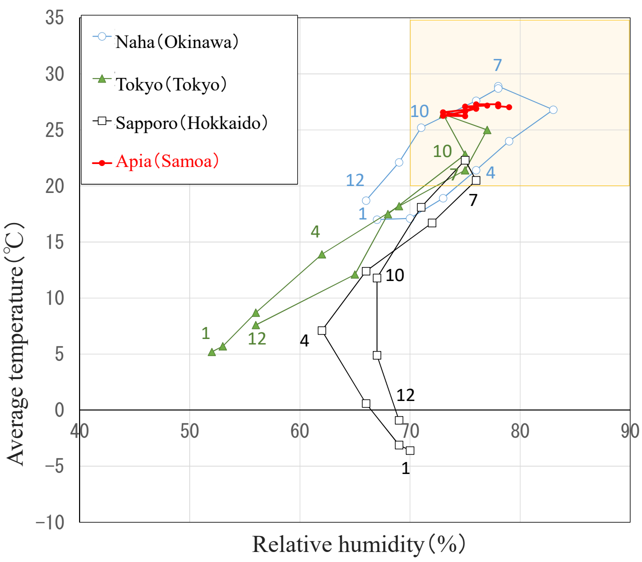
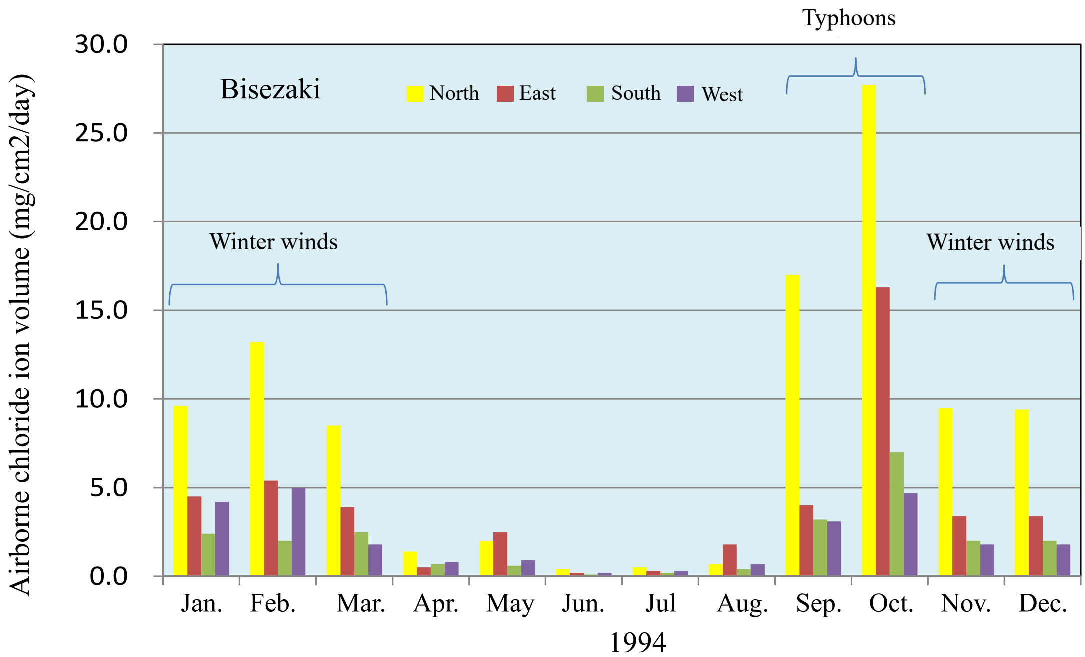


Figure 2-2-13 Monthly climograph averages

Conditions for salt damage are also greatly impacted by wind direction and speed, as well as coastline type. Figure 2-2-14 shows the observation data for airborne salt content by month in Okinawa Prefecture. The figure shows that seasonal winter winds blowing down from the continent (strong northerly winds) and the accompanying waves, as well as typhoons from summer though autumn, are largely responsible for carrying the airborne salt content in Okinawa. Next, Figure 2-2-15 shows the relation between the coastline type and airborne salt content in Okinawa. There is great variation in airborne salt content depending on the coastal form, even for coastlines said to be prone to salt damage.

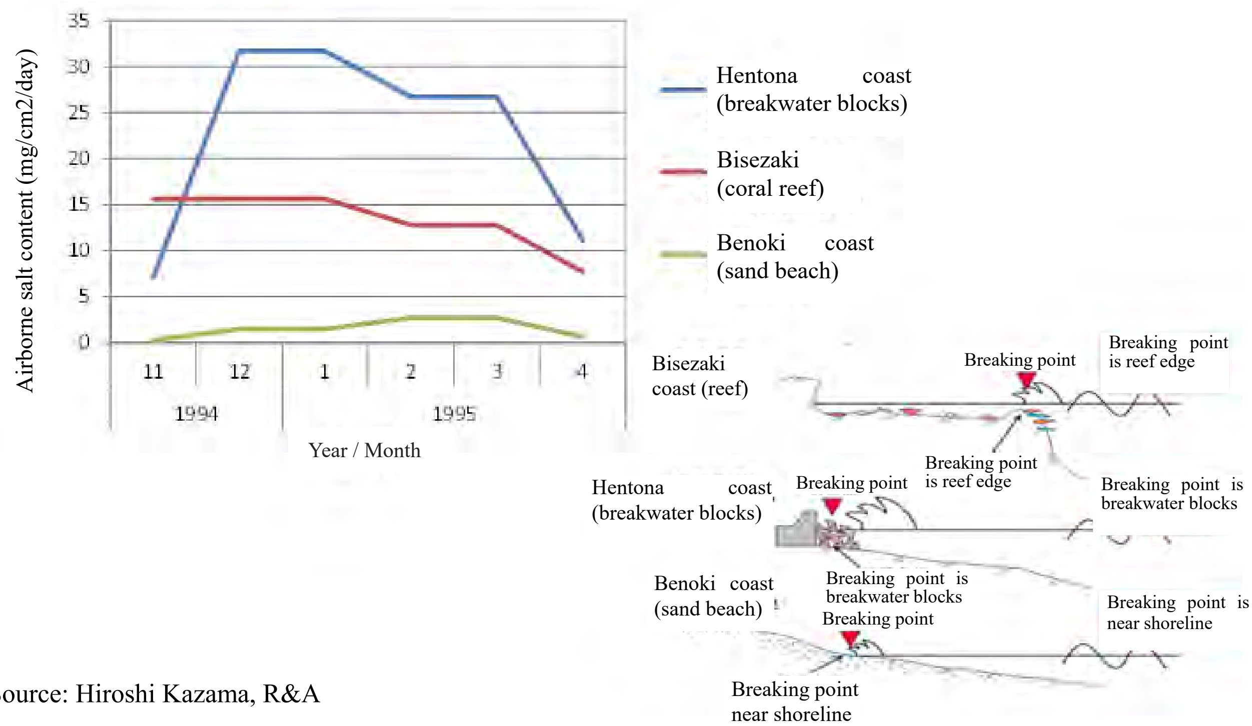
In Samoa, most of the wind throughout the year is easterly. Given this and the Vaisigano Bridge being located in a bay on the north side of Upolu, salt damage is expected to be relatively mild. However, with the reef edges offshore and nearby revetment to be built, airborne salt content on the Vaisigano Bridge should be high due to sea breezes. Also, as in Okinawa, cyclones will carry large amounts of salt content when they strike.

Looking at measurements of the airborne salt content taken with thin mortar over a period of approximately six months (July 2015 to January 2016), a high 7.2 kg/m^3 of salt content was deposited on the center handrails of the bridge.



Tanigawa, et. al. Research on durability of reinforced concrete structures when exposed to severe salt damage (Effects of acrylic rubber waterproofing film): Japan Journal of Structural Systems, Vol. 487, pp. 11-19, Sept. 1996

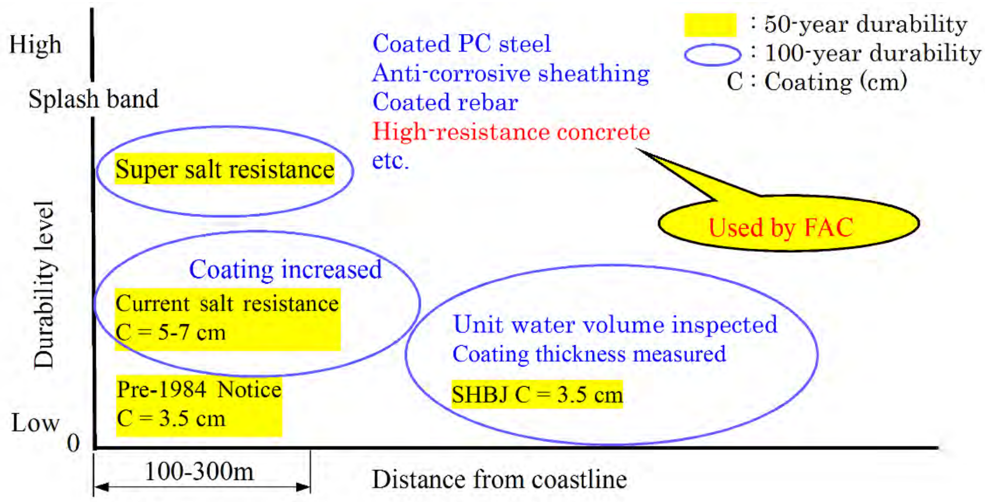
Figure 2-2-14 Monthly climograph averages



Source: Hiroshi Kazama, R&A

Figure 2-2-15 Relation between coastline type and airborne salt content

Given this, on the Okinawa coastline, where salt damage is the most severe in Japan, structures are treated to increase resistance to salt damage by performing the measures given in Figure 2-2-16, and by using materials such as coated PC steel, corrosion-resistant sheathing, coated rebar, and high-durability concrete (e.g. fly ash concrete).



Source: Hiroshi Kazama, R&A

Figure 2-2-16 Durability levels

For reconstruction of the Vaisigano Bridge, in addition to the state of the existing bridge and nearby bridges on the coast, properties of the available materials, construction costs and other factors, the existing bridge was also surveyed for salt damage (from airborne salt content) as shown in Figure 2-2-17. As seen in the figure, the survey consisted of attaching thin mortar plates (4 x 4 x 0.5 cm) on both ends and the center of the seaward wheel guard of the bridge. Each mortar plate was placed and recovered roughly monthly. The recovered plates were then smashed to analyze the chloride ion content in the mortar with potentiometric titration.

Analysis results from June 22 to July 22 are given in Table 2-2-12. These results show that more than 0.2 kg/m^3 of chloride ion is being deposited from the sea per day on average. These values are comparable to the airborne salt content in Ogimi village in Okinawa, which experiences severe salt damage in winter. Given the results, salt measures equivalent to those taken in Okinawa are likely necessary in reconstruction of Vaisigano Bridge. These results are only from a month of analysis, however; continued measurements and comprehensive salt damage measures which account for the results, as well as the surrounding environment and applicable materials, will be required.

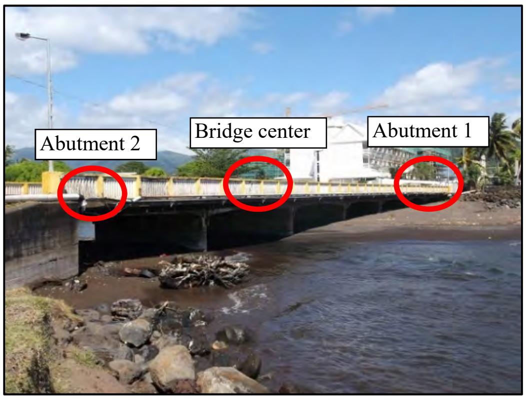


Figure 2-2-17　Summary of study on airborne salt content

Table 2-2-12　Airborne salt content analysis results

*taken June 22-July 22, 2016

Location	Total chlorine ion content (kg/m^3)	Avg. daily chlorine ion content (kg/m3/da.)
Abutment 1	6.14	0.204
Abutment 2	7.07	0.236
Bridge center	6.94	0.231

2) Salt Damage on the Existing Bridge

On the superstructure, given the low clearance and the damage on members prone to airborne salt accumulation, salt damage is likely the main cause of the damage to the concrete. On the substructure, no salt damage was found, presumably due to rebar being covered or there not being much rebar. Cracks in the bridge axis direction on the superstructure and substructure are likely due to drying shrinkage and hydration heat, likely occurring in the initial phase of construction. Note that there were no signs of cracking from alkali-aggregate reactions or structural cracking from fatigue or other causes.

Given how mended areas on the superstructure are also deteriorating and that there are areas of concrete spalling, internal salt content appears to be extremely high.

Table 2-2-13 shows the state of salt damage on the existing bridge.

Table 2-2-13　Salt Damage on the Existing Bridge

Inspected Component			Damage	Cause of Damage
Bridge surface	Road section		Paved with concrete. No issues due to damage found. Relatively sound.	
	Walkway section		Paved with concrete. No issues due to damage found. Relatively sound.	
	Handrails		Externally, appear to have been repainted regularly. Although damaged in areas, look to be sound overall.	Aging
Super-structure	Main girders		Wide areas of RC delamination and spalling spotted on main girders between A1-P1 and P5-P6 spans, which have low clearance. On sides, spalling and delamination of concrete found on downstream (seaward) side, but upstream side was relatively sound.	Salt damage Drying shrinkage Hydration heat
			Axis direction cracking found on the P5-P4 span. Thought to be due to drying shrinkage and hydration heat.	
	Deck Overhang		As with the main girders, concrete delamination and spalling in spots on the downstream (seaward) side.	Salt damage
			Upstream side was sound overall.	
Sub-structure	Pillars		No damage found, other than cracking likely attributed to drying shrinkage and hydration heat. Sound overall.	Drying shrinkage Hydration heat

3) Measures Against Salt Damage

a) Bridge plan to reduce bonding of airborne salt

Upon observing the other bridges built near the Vaisigano Bridge along the coast, many are rigid-framed structures to which salt content is relatively less likely to adhere. Also, given how structure near the supports is normally susceptible to damage from salt and other sources, the structure of these bridges is simple with no supports or bridge seats, slowing the progress of salt damage. A structure less prone to adhering salt has proven effective in increasing bridge durability. Bridge structures to which salt readily bonds (such as T-girder bridges, which suffer pronounced salt damage) will be avoided, and a hollow slab bridge or structure that otherwise minimizes the area to which salt can bond and otherwise accounts for salt damage is effective against salt damage.

The field reconnaissance showed that even those bridges of the same type and similar age located on the coast were in better shape if they had higher clearance. Thus, the clearance from ocean surface to the bottom of the girders will be made as high as possible (generally, HHWL + half wave height).

b) Selection of materials to ensure durability

Water-cement ratio, aggregate, slump and the like significantly affect the durability of concrete. Thus, the properties of local materials must be fully understood, and mix proportions and the like will be considered in the selection of the type of concrete to use. In addition, care must be taken regarding the intrinsic chloride and alkali-aggregate reactivity of the aggregates and materials selected. As fly ash concrete, which can improve resistance to salt, was confirmed in the field study to be available locally in Samoa, it will be considered for use once specimens have been tested for strength and salt resistance.

PC steel, coated rebar, polyethylene sheaths, and other corrosive-resistant materials will also be selected.

In the detailed design, the proper mix proportions must be determined accounting for study results on airborne salt content and other environmental factors, as well as the properties of the rebar, aggregate, cement, and other materials to be used. In light of the Samoan environmental features, a detailed study will be performed if fly ash cement is to be used, excluding the cold-weather regulations and utilizing the combined results from Okinawa.

The main issue with using New Zealand-made fly ash cement will be the need to check fly ash content when cement used. As this cement is high in fly ash content, fly ash levels will need to be adjusted, likely resulting in inconsistent content levels. Further, fly ash cement strength will have to be sufficiently tested when used in the superstructure.

In addition, New Zealand results are with highly durable concrete admixtures with microsilica, also known as silica fume. Thus, microsilica use will also need to be considered along with fly ash cement use.

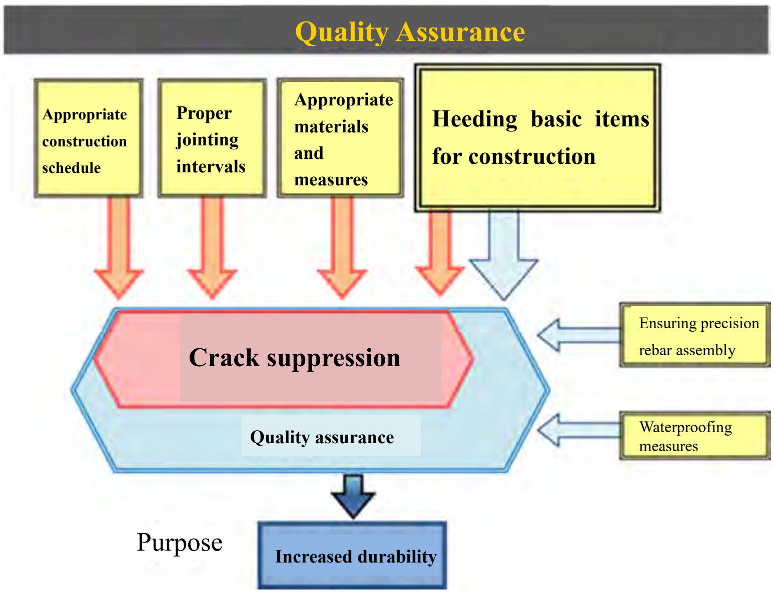
c) Detailed design to ensure durability

As previously mentioned, salt conditions in Samoa are expected to be at least as bad as in Okinawa given the high temperatures and humidity. Therefore, the extraordinary salt measures listed in Figure 2-2-16 are likely necessary for materials used in reconstruction of Vaisigano Bridge.

Further, as also mentioned above, effective means of salt damage prevention include raising bridge clearance, avoiding bridge structures susceptible to salt bonding, and using a hollow slab bridge or structure that otherwise minimizes the area to which salt can bond and otherwise accounts for salt damage.

d) Construction management to ensure durability

In addition to material selection and structural considerations, maintaining concrete quality in the early stages is essential to building a durable concrete structure. This means ensuring that construction and concrete curing is done properly. The six initiatives given in Figure 2-2-18 (in yellow boxes) are needed to ensure the quality of concrete structures.



Source: Yamaguchi Pref. Construction Dept.

Figure 2-2-18 Conceptual diagram on ensuring concrete structure quality

① Appropriate construction schedule

An appropriate construction schedule will be selected to avoid to the extent possible concrete placing during the hotter months.

While impossible to avoid completely in areas such as Samoa that are hot year round, the dry season is relatively cooler and is thought to be the most suitable timing for construction.

② Proper jointing intervals

Jointing intervals will be made as short as possible as shorter jointing intervals tend to reduce the maximum cracking width. Here, jointing interval refers to the number of days between successive pours. For example, for the abutments, this would be the days between casting the footings and casting the next vertical wall.

③ Appropriate materials and measures

Appropriate materials and measures will be discussed and implemented to restrict cracking. These measures will include material selection (rebar reinforcement, glass fiber, expanding material to restrict hydration heat, etc.), using control joints, and curing.

④ Heeding basic items for construction

The consultant will determine construction status using a checklist and assist the contractors in building a quality concrete structure.

⑤ Ensuring precision rebar assembly

To prevent insufficient covering, the covering detail drawings and other drawings will be made easy to understand so as not to be misunderstood by contractors. Also, contractors will assemble rebar accurately and firmly in the set positions indicated in the design.

⑥ Waterproofing measures

Moisture affects the aging of concrete structures. Thus, various standards and manuals will be used to study how to prevent moisture from entering the concrete structure, structurally reducing entering moisture, and/or building quick drainage into the structure.

In addition to the above quality assurance measures, the construction schedule must be flexible in cases, such as delaying the demolding timing for fly ash concrete if the cement needs more time to develop sufficient strength. Further, after removing the molds, concrete must be properly cured using curing sheets and other tools.

In areas experiencing salt damage as severely as Samoa, it is ideal for construction management to consider the quality assurance measures above for concrete structures.

e) Establishment of maintenance system

i) Studying the aging process as needed for maintenance

The use of impregnated material visible from the exterior will be considered for easy maintenance. In addition, the effect of airborne salt content, temperature, humidity, wind bearing and speed, and other environmental factors, as well as how concrete responds in terms of salt penetration speed, internal corrosion speed of rebar, and other factors, must be determined in order to maintain the concrete structure properly. Therefore, exposure testing is being considered with a specimen with the same concrete mix proportions as the new bridge to measure these concrete response factors and accumulate data for use in future maintenance.

ii) Human resource development

Given the importance of developing local human resources to building a proper maintenance system, OJT may be implemented.

(3) Consideration of Bridge Type

1) Comparison of Proposed Bridge Types

The seven spans of the existing RC bridge are extremely short at 10.68 m. A large quantity of driftwood accumulated behind the bridge during Cyclone Evan due to its low height and narrow spans. Therefore, multiple alternate proposals of bridge types that emphasize the effects of flood levels and driftwood, workability, economic efficiency and maintainability will be compared to determine the optimal proposal.

Picture 2-2-3 The narrow, low-clearance Vaisigano Bridge

In addition, given that the Vaisigano Bridge abuts the seashore and will corrode from salt damage, a PC bridge is preferable to a steel bridge. There is also a need to consider a bridge with low main girder height to keep the longitudinal height of the bridge as low as possible. Thus, the basic strategy is to analyze which bridge types will meet such criteria. Table 2-2-14　Superstructure format and recommended applicable spans) compares the following selected bridge types with regards to structural properties (salt resistance), workability, environmental impact, river properties, driftwood measures, and cost.

- Proposal 1: Two-span PC interconnected post-tensioned T-girder bridge (37.5 m spans, 75.0 m length; A in Table 2-2-14)
- Proposal 2: Three-span PC interconnected pre-tensioned hollow slab bridge (25.0 m spans, 75.0 m length; B in Table 2-2-14)
- Proposal 3: Four-span PC interconnected pre-tensioned hollow slab bridge (18.75 m spans, 75.0 m length; C in Table 2-2-14)

Table 2-2-14 Superstructure format and recommended applicable spans

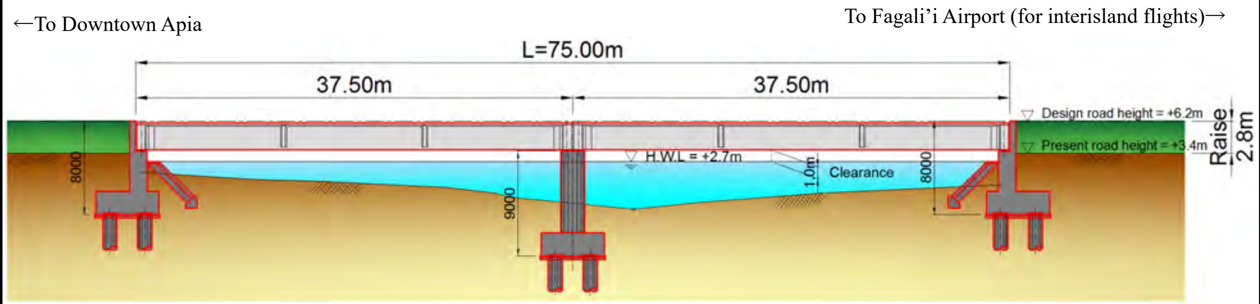
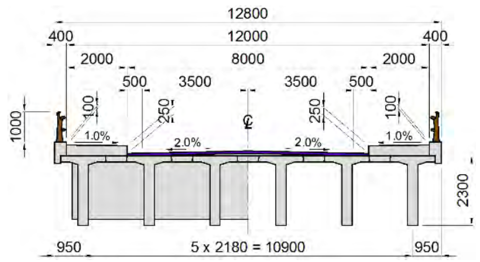
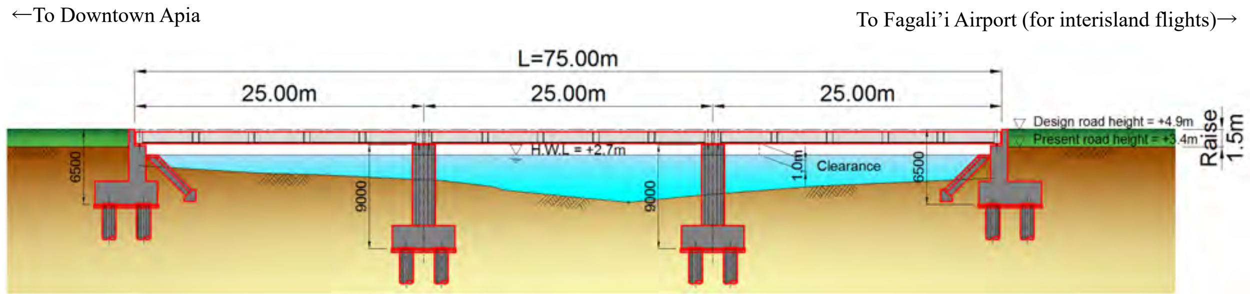
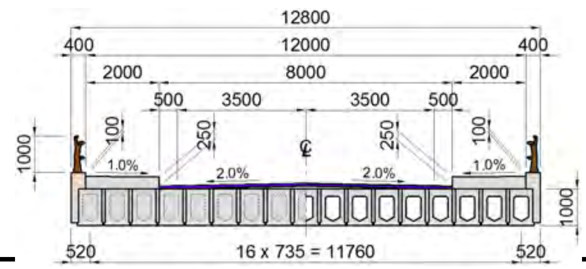
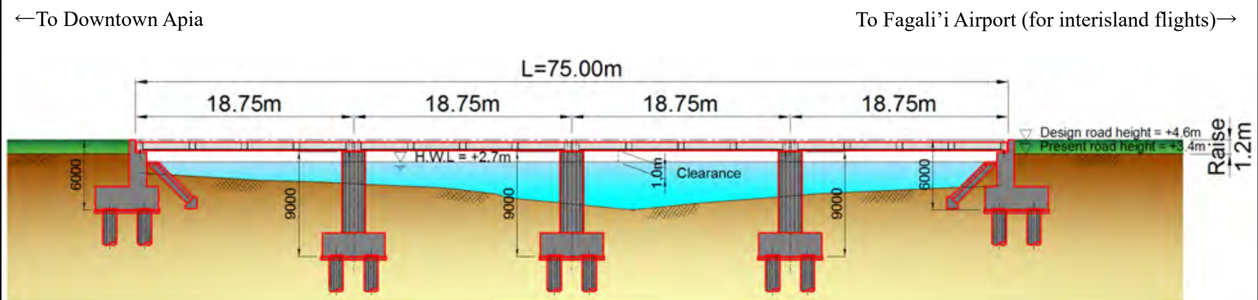
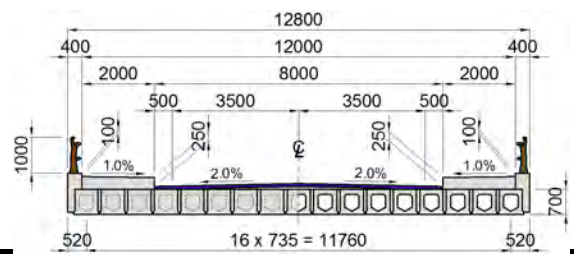
Superstructure type		Recommended span (50 m / 100 m / 150 m)	Curve applicable: Main structure	Curve applicable: Bridge deck	Girder height Span ratio
Steel bridge	Simple composite plate girder		○	○	1/18
	Simple plate girder		○	○	1/17
	Continuous plate girder		○	○	1/18
	Simple box girder		○	○	1/22
	Continuous box girder		○	○	1/23
	Simple truss		×	○	1/ 9
	Continuous truss		×	○	1/10
	Reverse Langer girder		×	○	1/6,5
	Reverse Lohse girder		×	○	1/6,5
	Arch		×	○	1/6,5
PC bridge	Pretentioned girder		×	○	1/15
	Hollow slab		○	○	1/22
	Simple T girder		×	○	1/17,5
	Simple composite girder		×	○	1/15
	Continuous T girder, composite girder		×	○	1/15
	Continuous composite girder		×	○	1/16
	Simple box girder		○	○	1/20
	Continuous box girder (cantilever method)		○	○	1/18
	Continuous box girder (Push-out or support method)		○	○	1/18
	π shaped rigid frame ridge		×	○	1/32
RC Bridge	Hollow slab		○	○	1/20
	Continuous spandrel-filled arch		○	○	1/ 2

A B C

2) Comparison and Analysis

Comparison and analysis of the above three proposals is given in Table 2-2-15. Overviews of the three proposals, along with the pros and cons of each, were explained to and discussed with LTA, at which point LTA agreed that Proposal 2 (a two-span PC interconnected pre-tensioned hollow slab bridge) was best for the following reasons:

a) Girders can be lowered by 1.0 m, keeping the raised height of the bridge surface to 1.5 m.
b) Span length of 25 m fulfills the required width of 20 m for preventing driftwood from accumulating.
c) The shape has good resistance to salt damage and will restrict salt from adhering to the bridge.
d) This is the most cost-effective option.

<table>
<tr><th>Bridge type</th><th colspan="3">Characteristics</th></tr>
<tr><td rowspan="6">Proposal 1: Two-span PC interconnected post-tensioned T-girder bridge

</td>
<td>Structural properties (resistance to salt damage)</td><td colspan="2">・A typical PC girder post-tensioned bridge with many previous examples built with grant aid.
・Salt can easily infiltrate the members during construction, much of which takes place on the river; protective covering of rebar and PC steel can easily become uneven; salt can quickly permeate concrete because it is not strong; and salt can easily attach itself to this type of bridge. In light of the above, resistance to salt damage is weaker than that of other proposals.</td></tr>
<tr><td>Workability</td><td colspan="2">・Girder erection, assembly of precast block main girders and other operations must be performed on the rear surfaces of abutments, necessitating a rather large work yard in front of the hotel; sufficient consideration must be given to the impact to the surrounding area.
・Estimated work schedule: Roughly 22 months</td></tr>
<tr><td>Negative impact to surrounding environment</td><td colspan="2">・The structure will be taller than those of other proposals, and the impact of the raised road surface will significantly affect the roadsides.
・Views of the sea from the hotel will be greatly obstructed.</td></tr>
<tr><td>River characteristics and measures for driftwood</td><td colspan="2">・This proposal features the fewest piers, but it has few advantages over Proposal 2 in terms of safety because the presence of piers in the middle of the river will lead to blockage of river flow due to driftwood.
・Driftwood catching in between girders can block river flow.
・Driftwood can collide with outside girders on the upstream side and damage main girders.
・River area blockage at high-water level is the lowest of the three proposals, at roughly 2.8% (target: 6% or lower).</td></tr>
<tr><td>Economic efficiency</td><td colspan="2">・This is the least economically efficient. (Estimated construction expenditure ratio: 1.11)</td></tr>
<tr><td>Overall evaluation</td><td>In terms of structural properties, workability, negative impacts to the surrounding environment, river characteristics and measures for driftwood, and economic efficiency, this proposal is not as strong as the others.</td><td>△</td></tr>
<tr><td rowspan="6">Proposal 2: Three-span PC interconnected pretensioned hollow slab bridge

</td>
<td>Structural properties (resistance to salt damage)</td><td colspan="2">・A PC girder pretensioned hollow-section bridge with many previous examples built with grant aid. Simple pretensioning facilities will be constructed on site to manufacture girders.
・Salt cannot easily infiltrate the members during construction, little of which takes place on the river; protective covering of rebar and PC steel can easily stay even; salt cannot quickly permeate concrete because it is strong; and salt cannot easily attach itself to this type of bridge. In light of the above, resistance to salt damage is higher than that Proposal 1.
・This type of bridge is well suited for technology transfer because little capital investment is required for facilities for manufacturing and erection</td></tr>
<tr><td>Workability</td><td colspan="2">・Girders can be erected extremely quickly, and few tasks will be performed on the rear surfaces of abutments. Thus, construction can be implemented smoothly with little impact to the surrounding area.
・Estimated work schedule: Roughly 20 months</td></tr>
<tr><td>Negative impact to surrounding environment</td><td colspan="2">・The structure height ranks between the heights of the other proposals, and the raised road surface will have a relatively low impact on the roadsides.
・Views of the sea from the hotel will not be as greatly obstructed as in Proposal 1.</td></tr>
<tr><td>River characteristics and measures for driftwood</td><td colspan="2">・This proposal features more piers than Proposal 1, but it has few advantages over Proposal 1 because the lack of piers in the middle of the river will lead to blockage of river flow due to driftwood.
・River area blockage at high-water level is roughly 5.6%, which is within the allowable level (target: 6% or lower).</td></tr>
<tr><td>Economic efficiency</td><td colspan="2">・This proposal is the most economically efficient. (Estimated construction expenditure ratio: 1.00)</td></tr>
<tr><td>Overall evaluation</td><td>In terms of structural properties and workability, this proposal ranks evenly with Proposal 3. However, it is better in terms of economic efficiency, work schedule and river characteristics and measures for driftwood. This proposal is likely the best overall.</td><td>◎</td></tr>
<tr><td rowspan="6">Proposal 3: Four-span PC interconnected pretensioned hollow slab bridge

</td>
<td>Structural properties (resistance to salt damage)</td><td colspan="2">・A PC girder pretensioned hollow-section bridge with many previous examples built with grant aid. Simple pretensioning facilities will be constructed on site to manufacture girders.
・Salt cannot easily infiltrate the members during construction, little of which takes place on the river; protective covering of rebar and PC steel can easily stay even; salt cannot quickly permeate concrete because it is strong; and salt cannot easily attach itself to this type of bridge. In light of the above, resistance to salt damage is higher than that Proposal 1.
・This type of bridge is well suited for technology transfer because little capital investment is required for facilities for manufacturing and erection</td></tr>
<tr><td>Workability</td><td colspan="2">・Girders can be erected extremely quickly, and few tasks will be performed on the rear surfaces of abutments. Thus, construction can be implemented smoothly with little impact to the surrounding area.
・Estimated work schedule: Roughly 21 months</td></tr>
<tr><td>Negative impact to surrounding environment</td><td colspan="2">・The structure height is the lowest of all proposals, and the raised road surface will have little impact on the roadsides.
・Views of the sea from the hotel will be obstructed least among the proposals.</td></tr>
<tr><td>River characteristics and measures for driftwood</td><td colspan="2">・This proposal features the most piers, but the presence of piers in the middle of the river give it the highest likelihood of leading to blockage of river flow due to driftwood. In addition, the span length does not satisfy standards.
・River area blockage at high-water level is roughly 8.5%, which exceeds the target level of 6%.</td></tr>
<tr><td>Economic efficiency</td><td colspan="2">・This proposal is slightly less economically efficient than Proposal 2. (Estimated construction expenditure ratio: 1.05)</td></tr>
<tr><td>Overall evaluation</td><td>In terms of structural properties and workability, this proposal ranks evenly with Proposal 2. However, it is worse in terms of economic efficiency, work schedule and river characteristics and measures for driftwood.</td><td>△</td></tr>
</table>

(4) Consideration of Substructure and Foundation Formats

1) Bearing Layer Selection

According to the boring survey, an alluvial layer from the Holocene epoch (second of the Quaternary period) has settled down close to 40 m from the surface, with a bedrock layer of volcanic rock (basalt) beneath it. The alluvial layer contains interbedded sediment, silt, and gravel, with an overall low N-value that varies greatly. Starting with the surface layer, the N-values are 4-17 for the first stratum (sediment), 2-15 for the second stratum (sandy silt), 7-50 for the third stratum (gravel), 5-21 for the fourth stratum (sandy silt to silty sand), and 4-42 for the thin layer of gravel deposit on top of the bedrock. There are no sandy soil strata with N-values of 30 or greater or cohesive soil strata with N-values of 20 or greater which could act as a bearing layer. The top layer of basalt distributed near 40 m from the surface is weathered for the first 0.3 m to 4.6 m, but harder, unweathered rock appears under this. RQD near the top layer is approximately 0-20 percent, and RQD for the unweathered portion is approximately 60-80 percent. The weathered rock near the top layer is thin overall with a greatly varying depth. Therefore, the unweathered basalt wil be used as the bearing layer for the bridge foundation.

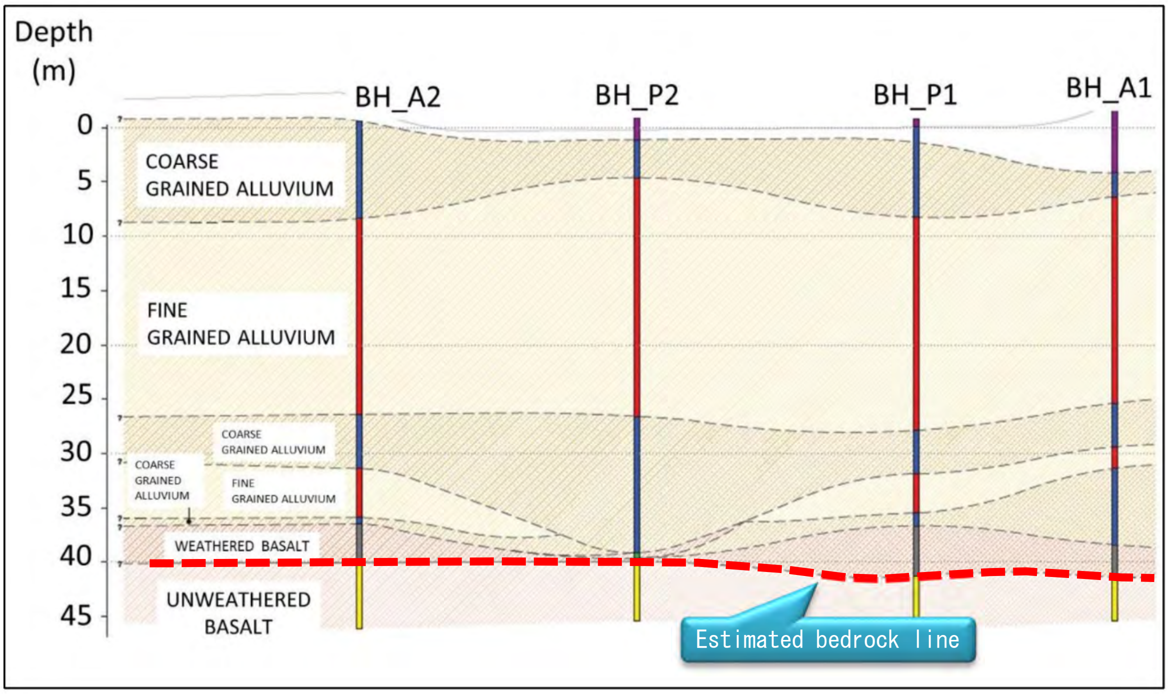


Figure 2-2-19 Soil profile view

2) Substructure Format Selection

Given that the bearing layer will be at a depth of approximately 40 m from the surface, the foundation format for the abutments and piers will be a pile foundation. Therefore, height for the abutments and piers (from crest to footing bottom) is determined from the road design height and footing embedded depth as shown in Figure 2-2-10. Abutments A1 and A2 will be 7.0 m tall, and piers P1 and P2 will be 10.0 m tall. The formats for abutments and piers were selected according to these heights, referencing the substructure format selection table shown in Table 2-2-16. An inverted T format was selected for both abutments A1 and A2 (A in the table), and an oval wall-type format was selected for both piers P1 and P2 (B in the table).

Table 2-2-16　Substructure format selection

Bridge part	Structure type	Applicable height (m) 10 20 30	Characteristics
Abutment	1.Gravity type		With shallow support ground, the gravity type is suitable for direct foundation.
	2.Reverse T-style	A	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.
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	B	Tall bridge piers. Suitable for bridges with high external force.

3) Foundation Format Selection

The foundation formats for abutments and piers were selected according to bearing layer depth, workability, cost, and other factors, referencing the foundation format selection table as shown in Table 2-2-17. Given that the bearing layer is 40 m from the surface, as well as the superior workability and cost compared to other constructions, cast-in-place piles (using full rotary all casing) were selected in light of our wealth of experience with the format in similar projects. The other foundation format options were taken to be unsuitable for the following reasons:

i) Spread footing is suited to shallow bearing layers close to 5 m in depth and not to deeper bearing layers.

ii) Driven pile foundations, bored pile foundations, and other prefabricated pile foundations are not as workable with hard rock bearing layers due to the difficulty in embedding the pile ends.

iii) Caisson foundations, steel pipe sheet pile foundations, and cast-in-site diaphragm wall foundations can offer advantages depending upon the structural load scale and working conditions, but are clearly not cost-effective options for this bridge.

Table 2-2-17 Foundation format selection

Selection requirements				Direct foundation	Cast pile foundation			Inner excavation pile foundation						Cast in-situ pile foundation				Caisson foundation		Steel pipe sheet pile foundation	underground continuous wall foundation
								PHC pile			Steel pipe pile										
					RC pile	PHC pile P	Steel pipe pile	Final impact driving method	Blast agitation	Concrete impact	Final impact driving method	Blast agitation	Concrete impact	All casing	Reverse	Earth drill	Chicago board	Pneumatic	Open		
Ground requirements	Below support layer	Soft ground in the interlayer		△	○	○	○	○	○	○	○	○	○	○	○	○	×	○	○	○	○
		An extremely hard layer inside the inter layer		○	×	△	△	○	○	○	○	○	○	△	○	△	○	○	△	△	○
		Gravel in the interlayer	Gravel size 5 cm or below	○	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
			Gravel size 5 cm～10 cm	○	×	△	△	△	△	△	△	△	△	○	○	△	○	○	○	△	○
			Gravel size 10 cm～50 cm	○	×	×	×	×	×	×	×	×	×	△	×	×	○	○	△	×	△
		The layer has liquefiable ground		△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Conditions of the support layer	Support layer depth	Below 5 m	○	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
			5～15 m	△	○	○	○	○	○	○	○	○	○	○	△	○	○	○	○	△	△
			15～25 m	×	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
			25～40 m	×	×	○	○	○	○	○	○	○	○	○	○	△	△	○	○	○	○
			40～60 m	×	×	△	○	△	△	△	○	○	○	△	○	×	×	△	○	○	○
			60 m or above	×	×	×	△	×	×	×	×	×	×	×	△	×	×	×	△	△	△
		Soil properties of the support layer	Cohesivvve soil (20 ≦ N)	○	○	○	○	○	×	△	○	×	△	○	○	○	○	○	○	○	○
			Sand/ gravel (30 ≦ N)	○	○	○	○	○	○	×	○	○	×	○	○	○	○	○	○	○	○
		High gradient (30º or above)		○	×	△	○	△	△	△	○	○	○	○	△	△	○	○	△	△	△
		The surface of the support layer is severely uneven		○	△	△	○	△	△	△	○	△	△	○	○	○	○	○	△	△	○
	Groundwater	Groundwater level is close to the ground surface		△	○	○	○	○	○	○	○	○	○	○	○	△	△	○	○	○	○
		Significant amount of spring water		△	○	○	○	○	○	○	○	○	○	○	○	△	×	○	○	○	△
		Artesian groundwater 2 m above the ground surface		×	○	○	○	×	×	×	×	×	×	×	×	×	×	△	△	○	×
		Groundwater velocity is 3m/ min or above		×	○	○	○	○	×	×	○	×	×	×	×	×	×	○	△	○	×
Structural properties	Load size	Low vertical load (span length 20m or below)		○	○	○	○	○	○	○	○	○	○	○	○	○	○	×	△	×	×
		Moderate vertical load (span length 20m to 50m)		○	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		High vertical load (span length 50m)		○	×	△	○	△	△	△	○	○	○	○	○	△	○	○	○	○	○
		Horizontal load is lower than vertical load		○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△
		Horizontal load is higher than vertical load		○	×	△	○	△	△	△	○	○	○	○	○	○	○	○	○	○	○
	Support type		Support pile	/	○	○	○	○	○	○	○	○	○	○	○	○	○	/	/	/	/
			Friction pile	/	○	○	/	/	/	/	/	/	/	○	○	○	/	/	/	/	/
Construction requirements	Construction on water		Water depth below 5m	○	○	○	○	△	△	△	△	△	△	×	○	△	×	△	△	○	×
			Water depth 5m or above	×	△	△	○	△	△	△	△	△	△	×	△	×	×	△	△	○	×
	Limited work space			○	△	△	△	△	△	△	△	△	△	△	△	△	○	△	△	×	△
	Batter pile construction			/	△	○	○	×	×	×	△	△	△	△	×	×	×	/	/	/	/
	Effects of toxic gas			△	○	○	○	○	○	○	○	○	○	○	○	○	×	×	○	○	○
	Surrounding environment		Oscillation noise measures	○	×	×	×	△	○	○	△	○	○	△	○	○	○	○	○	△	○
			Effects on adjacent structures	○	×	×	△	△	○	○	△	○	○	○	○	○	△	△	△	△	○

2-2-2-5-5 Considerations for River Revetments

(1) Revetment development plan of Vaisigano River

Flood analysis of the Vaisigano river and water level calculation were carried out from 2014 to 2015 by the UNDP (United Nations Development Programme) funding. Based on this result, the design of the embankment corresponding to the probability of 1/20 years from the Lelata bridge to the Vaisigano bridge has been completed. The construction of the section of the Vaisigano Bridge from Leone Bridge will be started during this year.

Flooding analysis and water level calculation will be described in detail in the hydrological survey and the plan and the vertical profile of the embankment of the section of the Vaisigano Bridge from the Leone Bridge where construction will be started this year will be attached below.

Figure 2-2-20　Plan of revetment development plan of Vaisigano River (1/3)

Figure 2-2-21　Plan of revetment development plan of Vaisigano River (2/3)

Figure 2-2-22 Plan of revetment development plan of Vaisigano River (3/3)

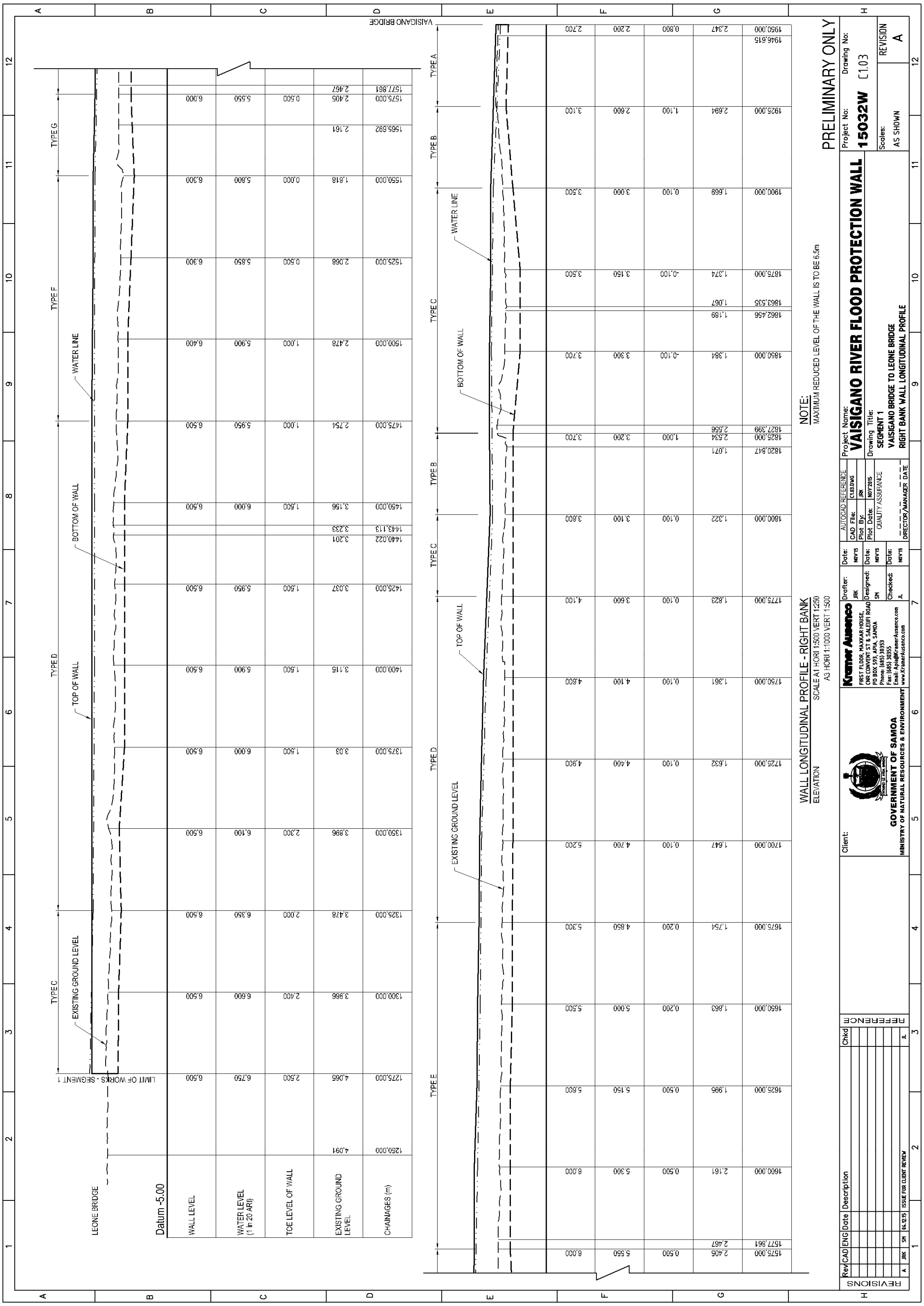


Figure 2-2-23 Longitudinal profile of revetment development plan of Vaisigano River (1/2)

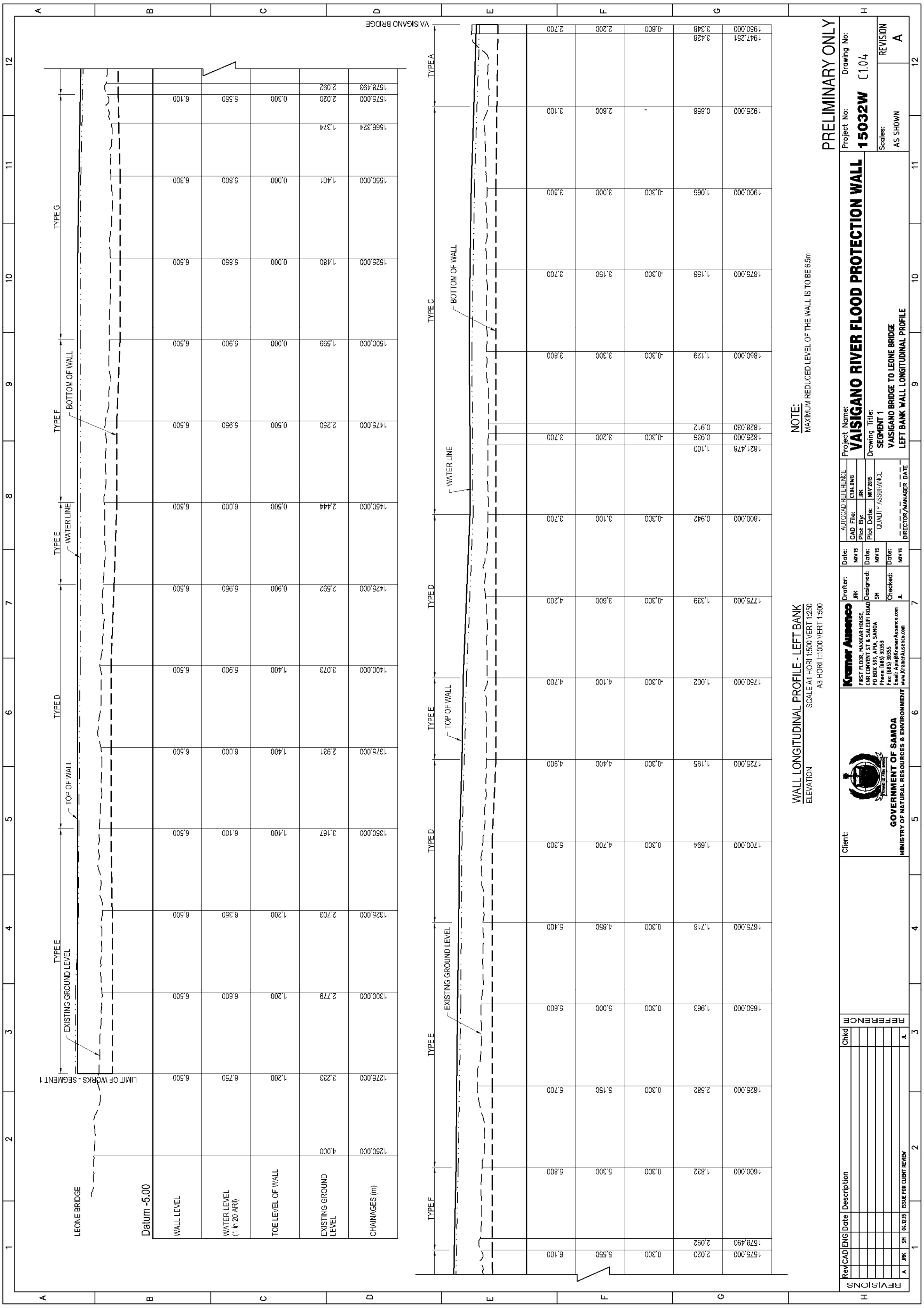


Figure 2-2-24 Longitudinal profile of revetment development plan of Vaisigano River (2/2)

(2) Revetment Construction

In efforts to coordinate with the upstream levee development plans, the revetments will be a concrete retaining wall construction with riprap foot protection installed on the front surface.

To avoid inhibiting the river cross section, the right bank revetment must have the exact same sectional shape as the levee upstream and thus will use the same inverted-T retaining wall structure.

On the left bank side, the river has a slight allowance in terms of cross section due to an ineffective flow area, and the levee (masonry wall) already being complete due to the Sheraton Hotel. As the left bank revetment will interfere with removal of the existing bridge, the existing bridge abutment will be left in place and a gravity retaining wall built on its façade. For similar reasons, another gravity retaining wall will be put between the existing bridge and the new bridge. Due to the ineffective flow area, part of the retaining wall will lie in the river channel, but water gauge calculations have confirmed that this will not be an issue.

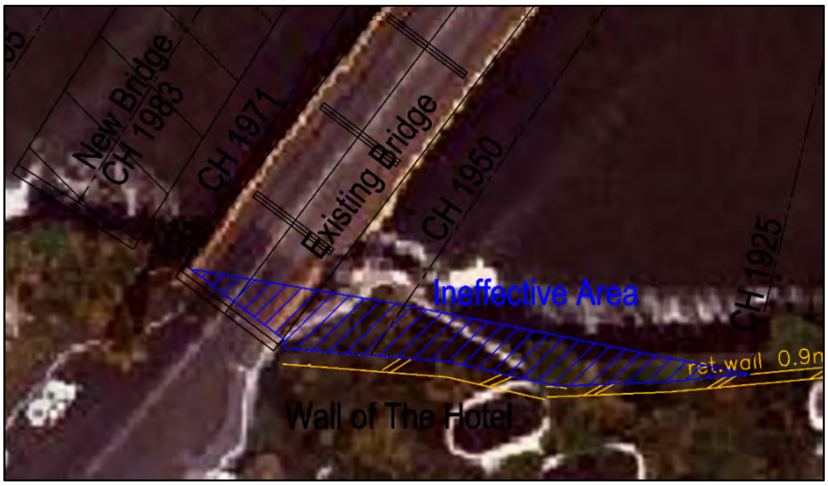


Figure 2-2-25 Location of ineffective flow area

Figure 2-2-26 Levee alongside existing bridge abutment

In terms of foot protection, while mattress cages are used upstream due to the seawater, riprap will be used at the river mouth due to the wave action and other factors.

(3) Deciding Major Structural Specifications

For drawings of each structure, refer to 2-2-3 Outline Design Drawings.

Table 2-2-18 Structural Specifications of River Revetments

Item	Value	Notes
Gravity retaining wall 1 (left bank)		
Crown width	0.7 m	
Base width	3.1 m	
Height	4.0 m	
Facade slope gradient	1:0.3	
Rear facade slope gradient	1:0.3	
Gravity retaining wall 2 (left bank)		
Crown width	0.7 m	
Base width	1.9 m	
Height	4.0 m	
Facade slope gradient	1:0.3	
Rear facade slope gradient	straight	
Inverse-T retaining wall (right bank)		
Vertical wall thickness	0.4 m	
Vertical wall height and total height	2.9 m, 3.3 m	
Bottom slab thickness	0.4 m	
Bottom slab width	2.5 m (0.6 m toe, 1.5 m heel)	
Footing		
Crown width	2.0 m	
Crown height	MSL+1.9 m	
Slope gradient	1:2.0	
Upper inclined plane riprap diameter and weight	0.9 m, 1.6 t	
Upper inclined plane thickness	1.8 m	
Lower inclined plane riprap diameter and weight	0.4 m, 0.15 t	
Lower inclined plane thickness	0.8 m	
Toe length	7.5 m	
Toe crown height	MSL-1.1 m	
Upper toe riprap diameter and weight	0.4 m, 0.15 t	
Upper toe thickness	0.8 m	
Lower toe riprap diameter and weight	0.2 m, 0.01 t	
Lower toe thickness	0.4 m	

(4) Structural Specifications for Bridge Pier Footing

Other than riverbed scouring from the pier, riverbed scour from drawdown is also possible.
Thus, footing specifications are decided using hydraulic quantities from both before and after the riverbed scour from drawdown. Going by the minimum and maximum installation ranges required and footing thicknesses as listed in Bridge Scour 2000, the bridge pier footing crown shows no issues with regard to the minimum values as it is embedded 2 m below the maximum riverbed depth.

Table 2-2-19 Structural Specifications of Footing

Item	Value	Notes
Boulder diameter	0.35 m	
Layer thickness	0.7 m	
Crown height	MSL-2.8 m	0.9 m of overburden from maximum riverbed depth
Installation range	2.0-m perimeter around the piers	

2-2-2-5-6 Considerations for Coastal Revetments

(1) Revetment Construction

Revetment construction is to be decided between riprap, concrete retaining wall, and concrete block pitching. As shown in the table of the comparison given in Table 2-2-20, riprap will be used for the revetment.

Table 2-2-20 Comparison of coastal revetment structures

Structure Type	Overview	Evaluation	Selected
Riprap	The road embankment is covered with riprap and classed as a pitching revetment. The slope gradient is 1:2.0. Two layers are needed on the structure, with each layer twice as thick as the riprap diameter. Also doubling as a breakwater, this structure reduces the height of striking waves.	・This is the most cost-effective option. ・The simple construction makes for easy maintenance and repair.	○
Concrete retaining wall	The road embankment is a gravity-type earth retaining wall and classed as an earth-retaining structure. The seaward side would be a smooth concrete surface, amplifying striking waves and necessitating riprap on the wall façade to act as a breakwater.	・This is the least cost-effective option. ・Cofferdam required during wall construction. ・Retaining wall maintenance and repair are somewhat difficult.	
Concrete block pitching	The road embankment is covered with concrete pitching and classed as a pitching revetment. The revetment can have somewhat of a breakwater effect with the right gap between blocks, but wave height will still be higher than the other proposal even at a slope gradient of 1:3.0.	・Less cost-efficient. ・Wave height is higher than the other proposal. ・Difficult to procure the same blocks in the future.	

(2) Deciding Major Structural Specifications

For drawings of each structure, refer to 2-2-3 Outline Design Drawings.

Table 2-2-21 Structural Specifications of Coastal Revetments

Item	Value	Notes
Gravity retaining wall 1		
Crown width	0.4 m	
Base width	1.24 m	
Height	2.1 m	
Facade slope gradient	1:0.2	
Rear facade slope gradient	1:0.2	
Gravity retaining wall 2		
Crown width	0.4 m	
Base width	1.57 m	
Height	3.9 m	
Facade slope gradient	1:0.2	
Rear facade slope gradient	1:0.1	
Riprap revetment		
Crown width	3.5 m	
Crown height	MSL+5.09-MSL+2.56 m	
Slope gradient	1:2.0	
Upper inclined plane riprap	1.1 m, 3.3 t	
Upper inclined plane	2.2 m	
Lower inclined plane riprap	0.5 m, 0.3 t	
Lower inclined plane	1.0 m	
Inclined plane groundsill	-	
Toe length	7.5 m	
Toe crown height	MSL-1.1 m for arc-shaped rubbing section	Other areas: MSL–0.2 m
Upper toe riprap diameter and	0.5 m, 0.3 t	
Upper toe thickness	1.0 m	
Lower toe riprap diameter	0.2 m, 0.02 t	
Lower toe thickness	0.4 m	

2-2-2-5-7 Considerations on Proximity Construction

The bridge will be constructed in a location adjacent to the existing bridge which is currently in service. If the existing bridge is to be removed before construction, a temporary detour bridge will be needed, and the existing utility lines will need to be temporarily relocated. Thus, we explored the possibility of keeping the existing bridge in service throughout the construction period by ensuring the minimum separation needed. The following three points were considered:

a) Impact of structure excavation on the existing bridge
b) Impact of retracting the cofferdam (temporary steel sheet piles) on the existing bridge
c) Securing enough space for heavy machinery entry

Upon reviewing construction of Abutment A1 and Pier P1, with the new bridge positioned approximately 20 m downstream of the existing bridge and assuming about 5 m of separation from the Abutment A1 location, it was decided that construction with the existing bridge in use will be possible. However, as retracting the temporary steel sheet piles could adversely impact the existing bridge, this work is planned to take place after new bridge construction is complete and traffic is completely switched over.

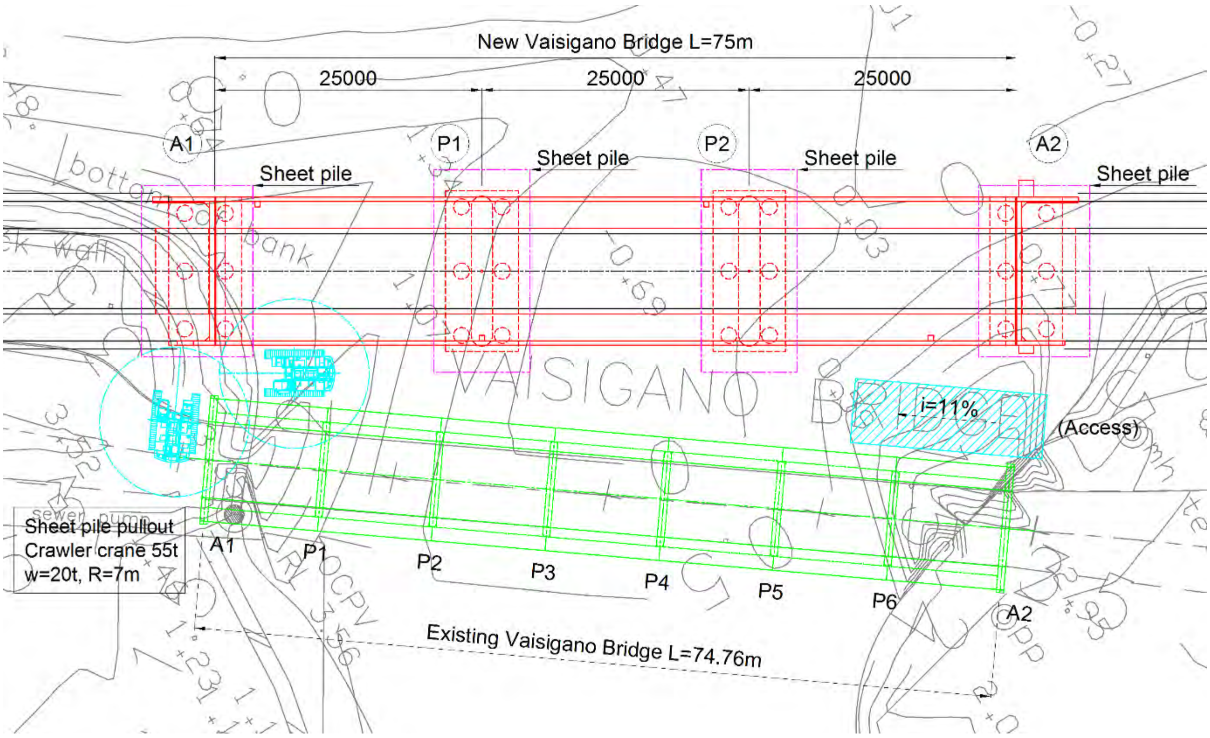


Figure 2-2-27 Proximity construction: plane figure of construction

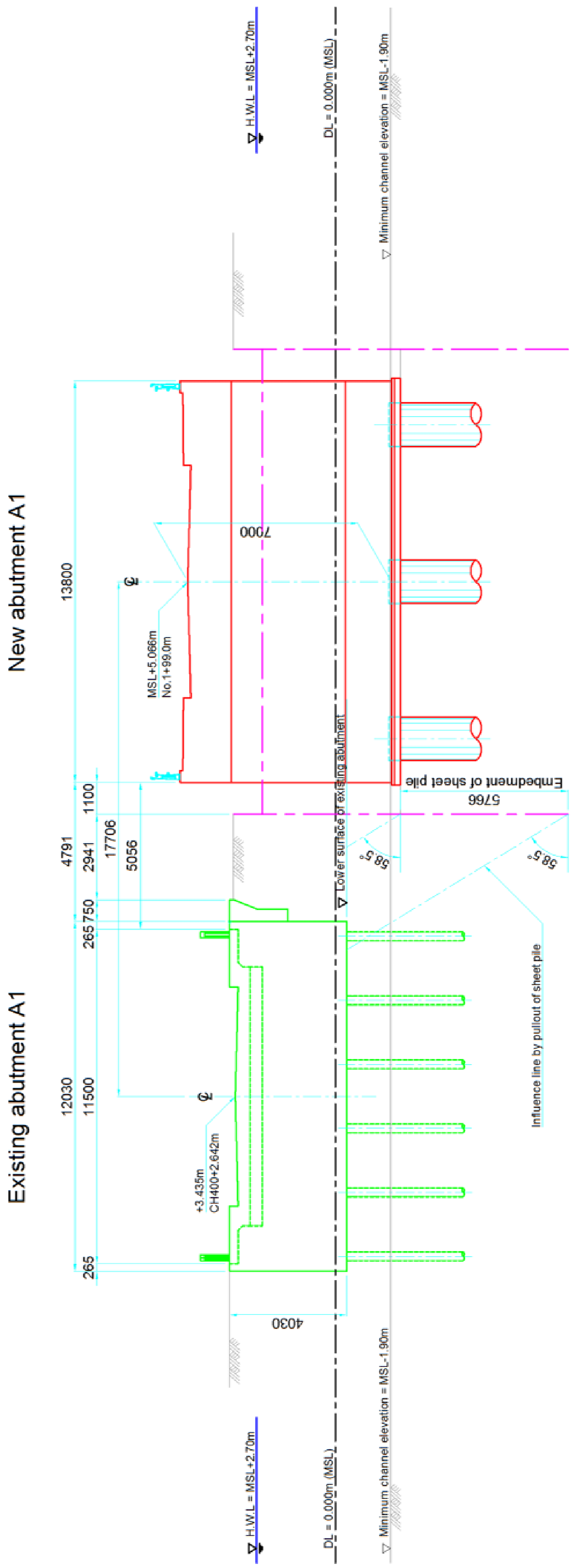


Figure 2-2-28　Section view of construction (Abutment A1)

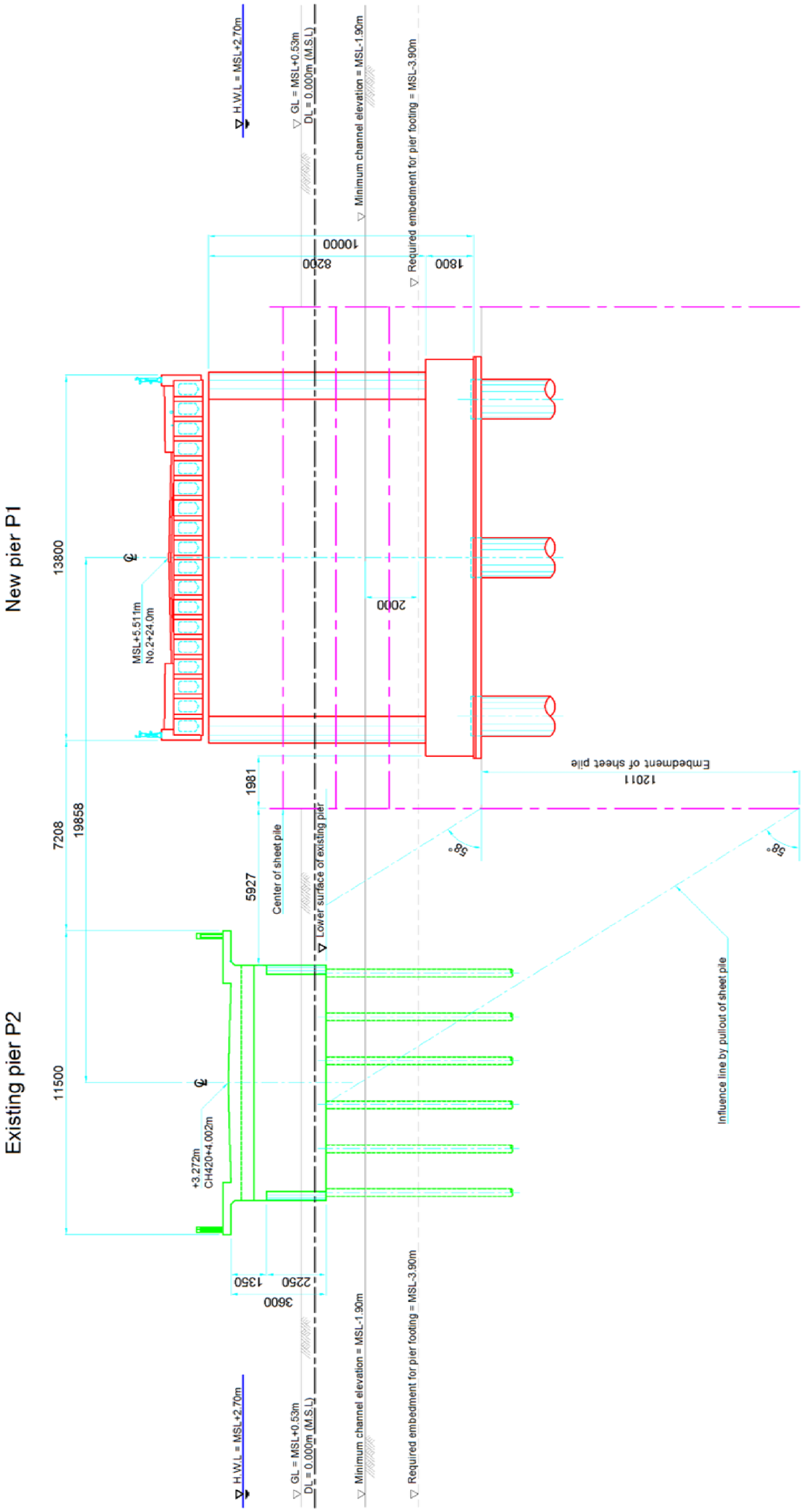


Figure 2-2-29　Section view of construction (Pier P1)

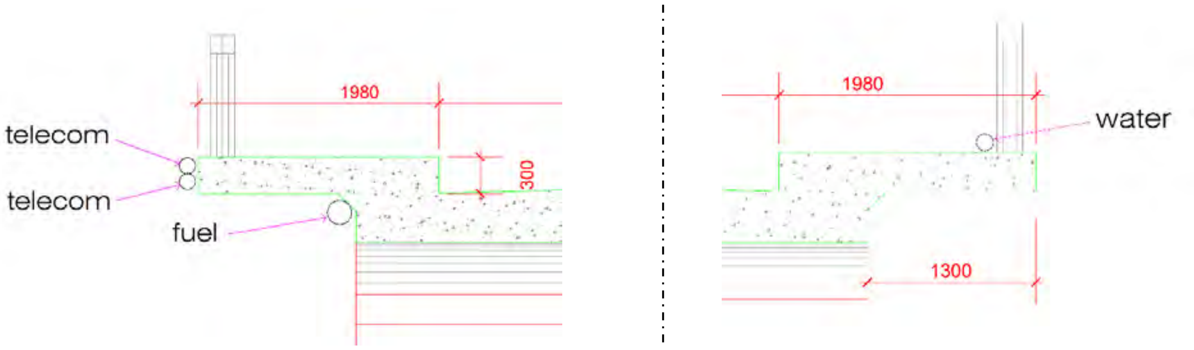
2-2-2-5-8 Considerations of Recipient Country Obligations

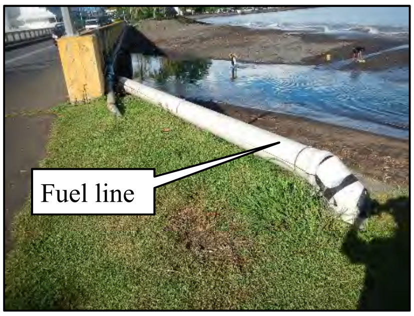
(1) Types and Locations of Utilities

There are four types of utility lines attached to the Vaisigano Bridge: fuel lines, water lines, communication cables, and power lines. These utility lines and their respective locations are as given below.

Bridge center

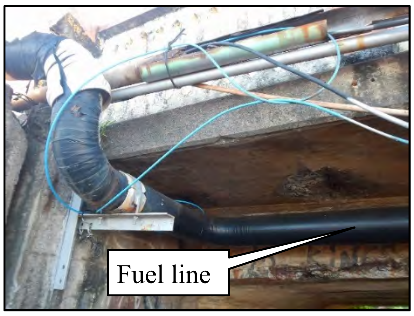
Downstream side (seaward) | Upstream (mountain) side utilities



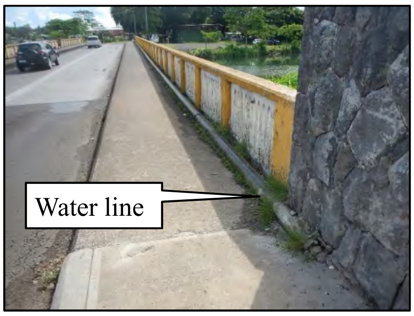


Fuel line

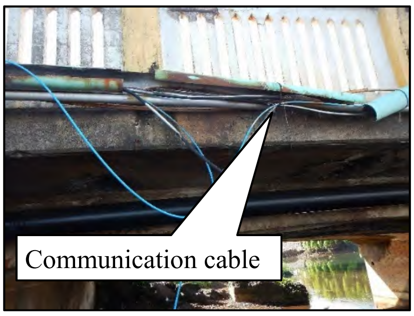
Fuel line



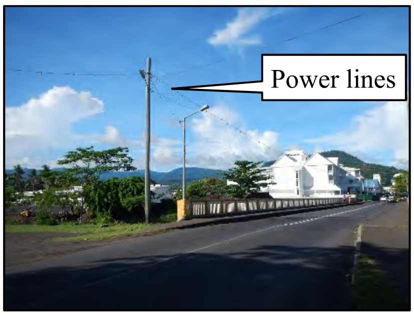
Fuel line



Water line



Communication cable



Power lines

Figure 2-2-30 Obstructions on the Vaisigano Bridge

(2) Consideration of Relocation for Utilities

Relocation for the existing fuel lines (PPS), water lines (SWA), communication cables (BlueSky and CSL), and overhead streetlight power lines (EPC) was discussed.

1) Relocation Plans

a) Fuel lines: PPS

- Initial relocation: Buried lines obstructing Abutment A1 construction will be temporarily relocated to the existing roadside. (Length of relocated lines: 16 m)
- Second relocation: The lines attached to the current bridge will be relocated to the downstream side of the new bridge (attached by brackets), and buried lines for the existing road will be relocated roadside on the new road. (Length of relocated lines: 335.6 m)

b) Water lines: SWA

The lines attached to the current bridge will be relocated to the downstream side of the new bridge (attached by brackets; length of relocated lines: 167.5 m)

c) Communication lines: Bluesky, CSL

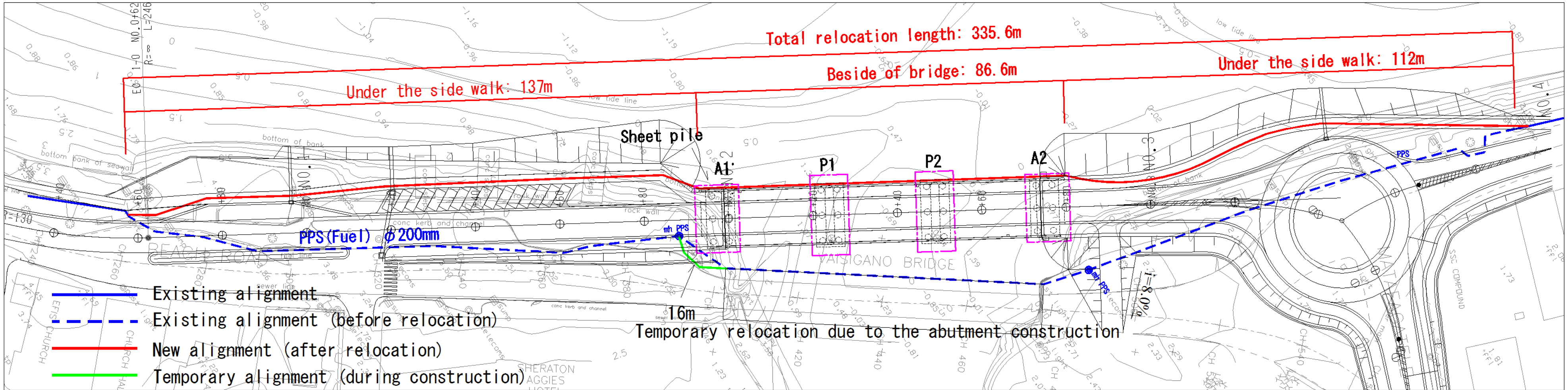
- Initial relocation: Buried lines obstructing Abutment A1 construction will be temporarily relocated to the existing roadside. (Length of relocated lines: 16 m for BlueSky lines, 16 m for CSL lines)
- Second relocation: The lines attached to the current bridge will be relocated to the upstream side of the new bridge (buried under sidewalk section), and buried lines for the existing road will be relocated roadside on the new road. (Length of relocated lines: 276.5 m for BlueSky lines, 347.5 m for CSL lines)

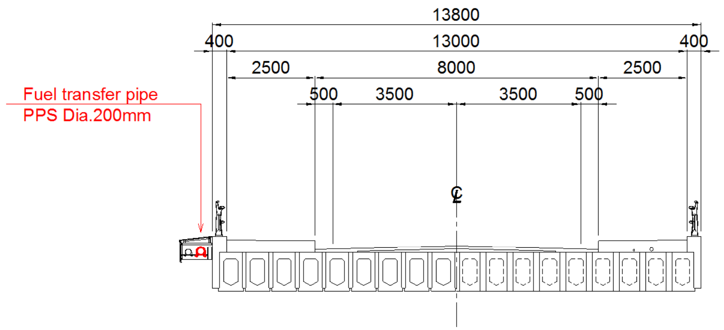
d) Overhead streetlight power lines (EPC)

Utility poles and overhead lines in the work zone will be either removed or temporarily relocated to where they will not impede construction.

2) Relocation Plan Figures

a) PPS fuel lines





Relocation length

Temporary: 16m
New alinment: 335.6m (=137m+86.6m+112m)

Figure 2-2-31 Fuel line relocation plan

b) SWA Water lines

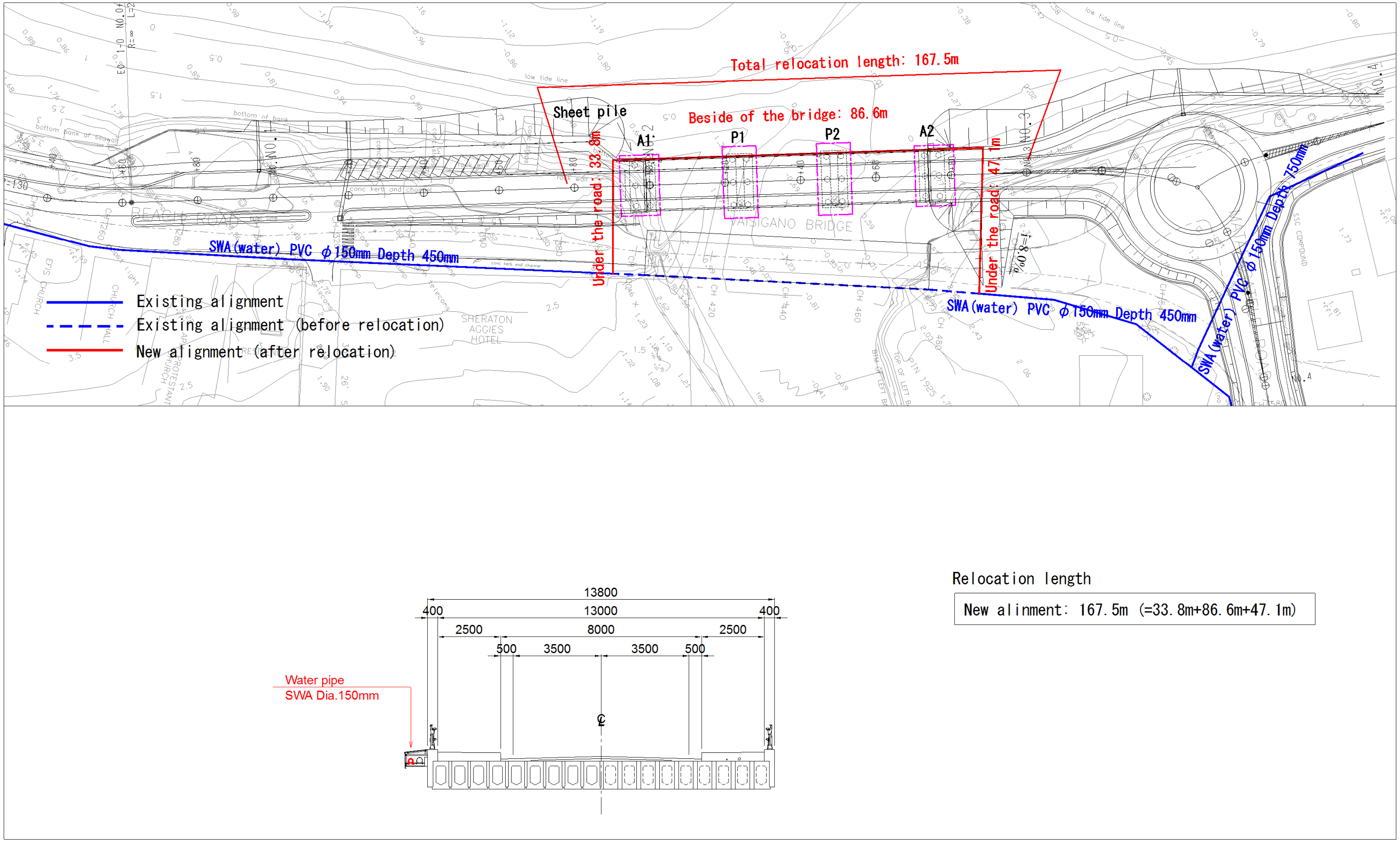


Figure 2-2-32 Water line relocation plan

c) Bluesky communication cables

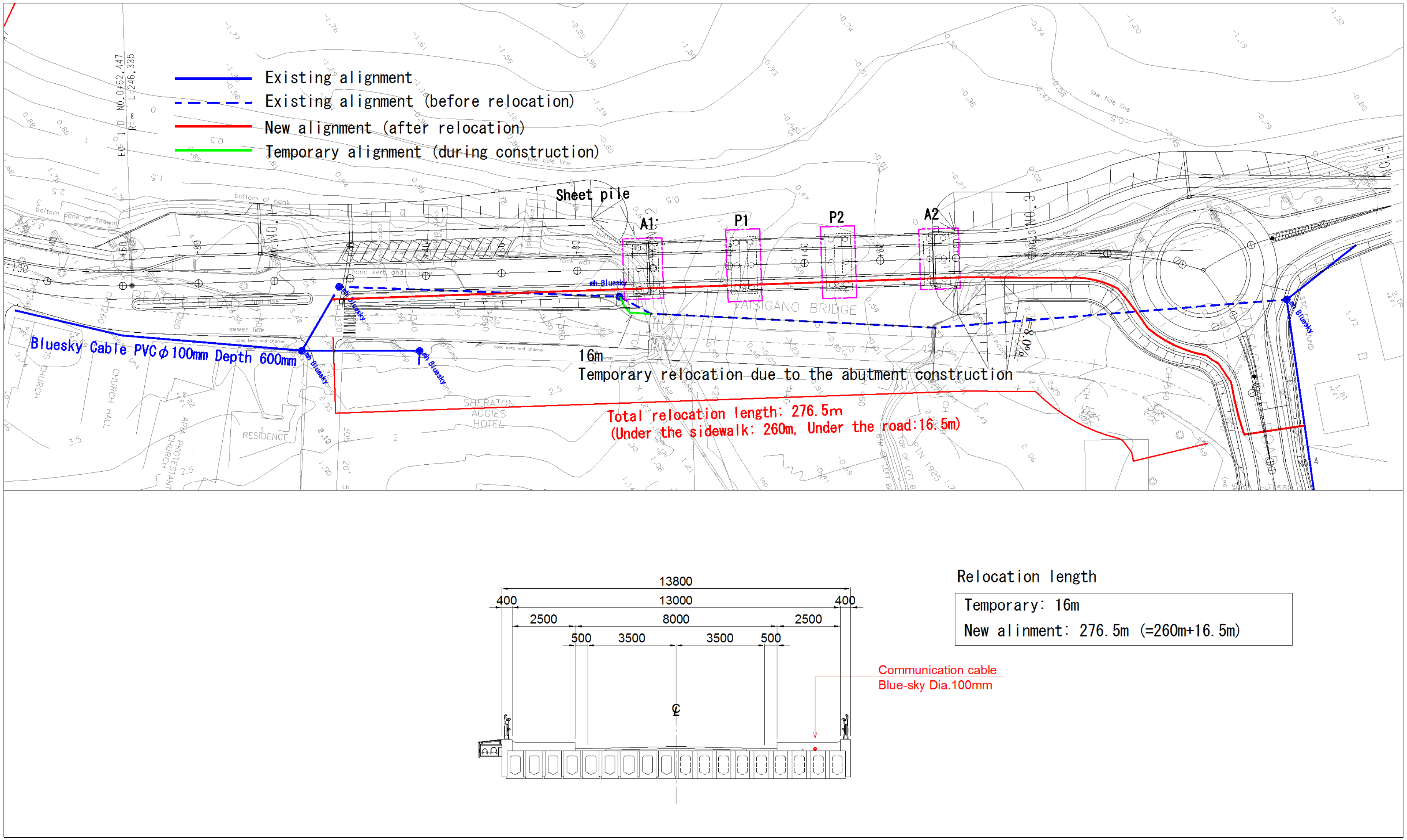


Figure 2-2-33 Communication cable relocation plan (1)

d) CSL communication cables

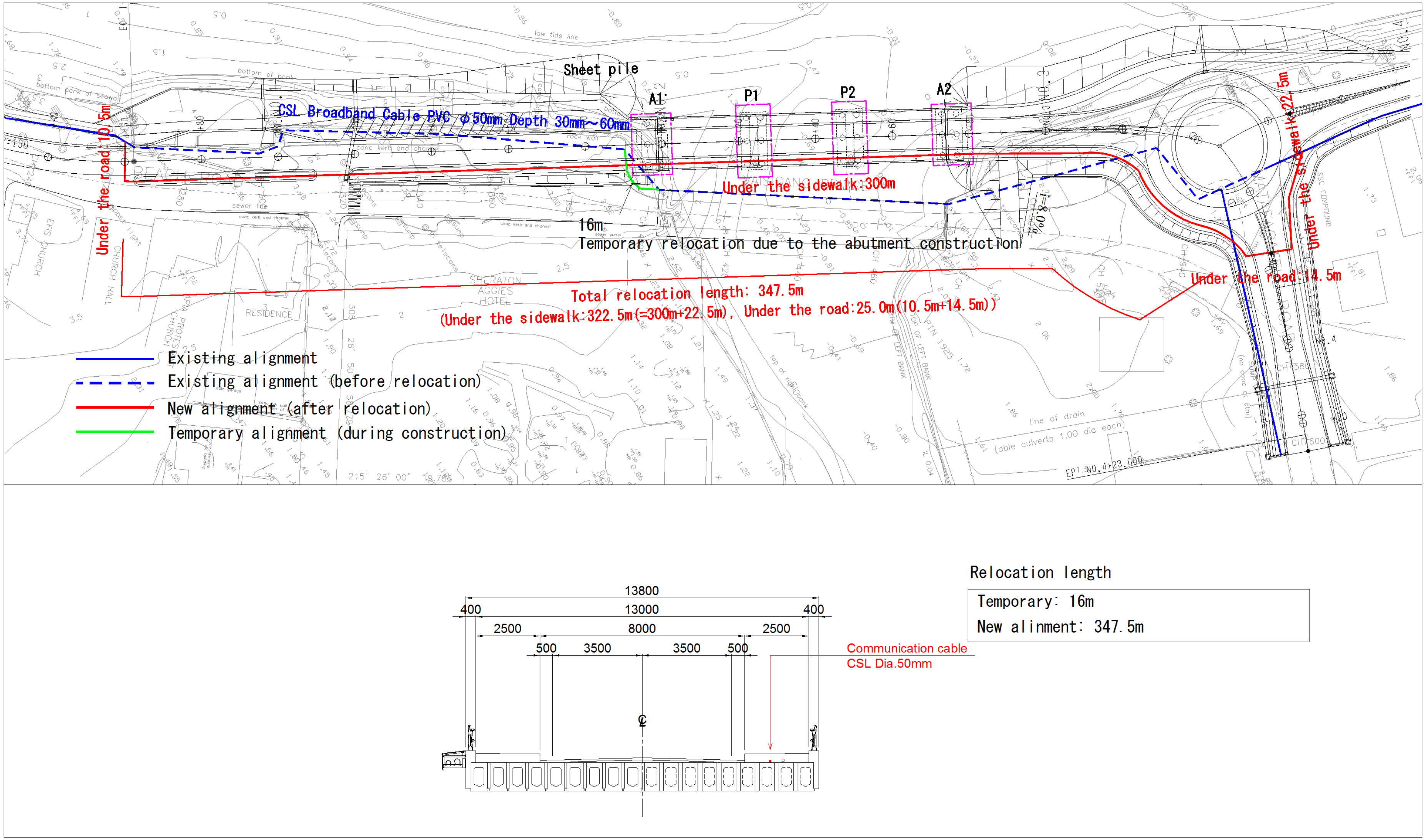


Figure 2-2-34 Communication cable relocation plan (2)

e) Overhead streetlight power lines (EPC)

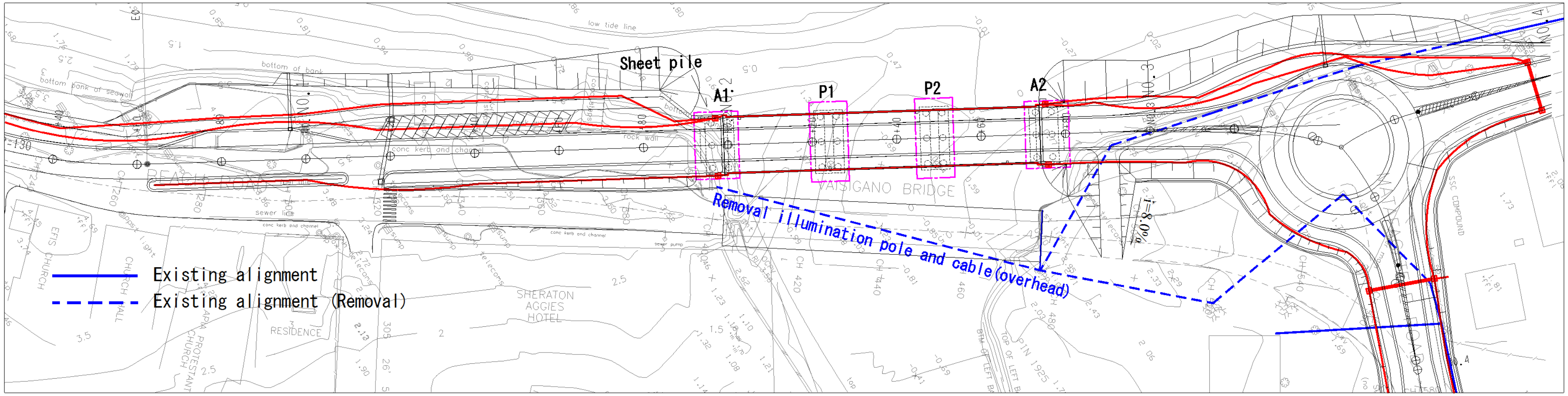


Figure 2-2-35 Overhead power line relocation plan

(3) Considerations for Temporary Yard

The candidate sites for the temporary yard are shown below. A simple shop will be needed to fabricate the girders, necessitating a site of approximately 10,000 m^2 (100 m x 100 m). Thus, we are currently consulting with LTA to select a temporary yard location to be two of the sites below or another site to be recommended by LTA.

Site Number	Picture	Estimated area	Site Condition
①		30m×100m	Grass Private land
②		40m×120m	Many trees Private land
③		30m×100m	Grass Private land
④		50m×90m	Grass, Pavement Parking, land sale area

Figure 2-2-36 Temporary yard candidate sites

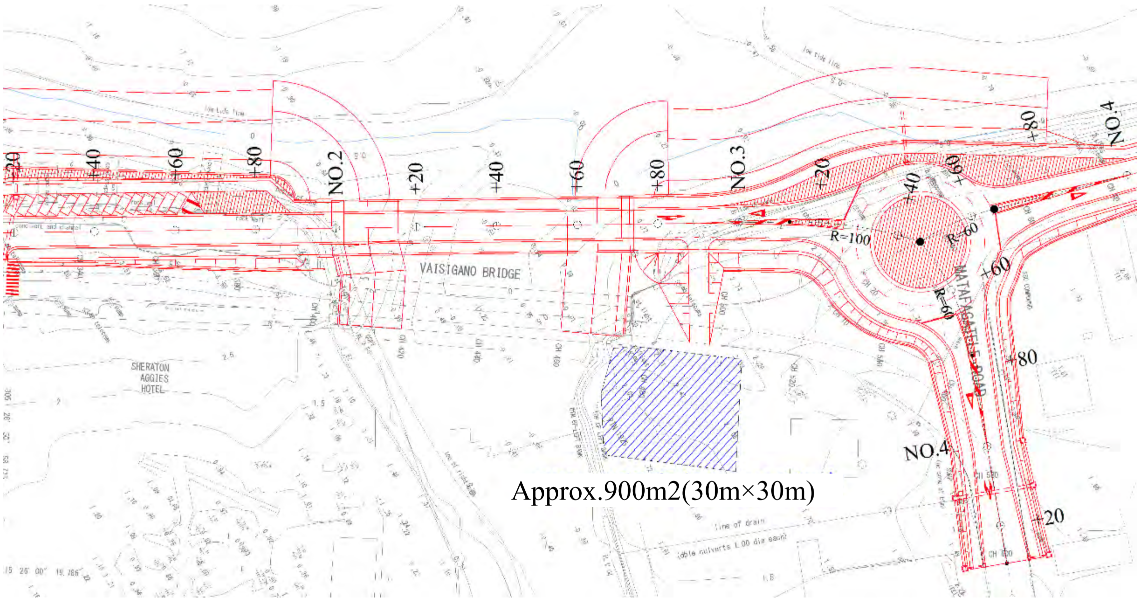


Figure 2-2-37　Construction yard at the time of demolishing the existing bridge

(4) Borrow Pit and Quarry

The candidate sites for the borrow pit and quarry are shown below.

No	①	②	③	④	⑤
Picture					

Figure 2-2-38　Borrow pit and quarry candidate sites

(5) List of Recipient Country Obligations

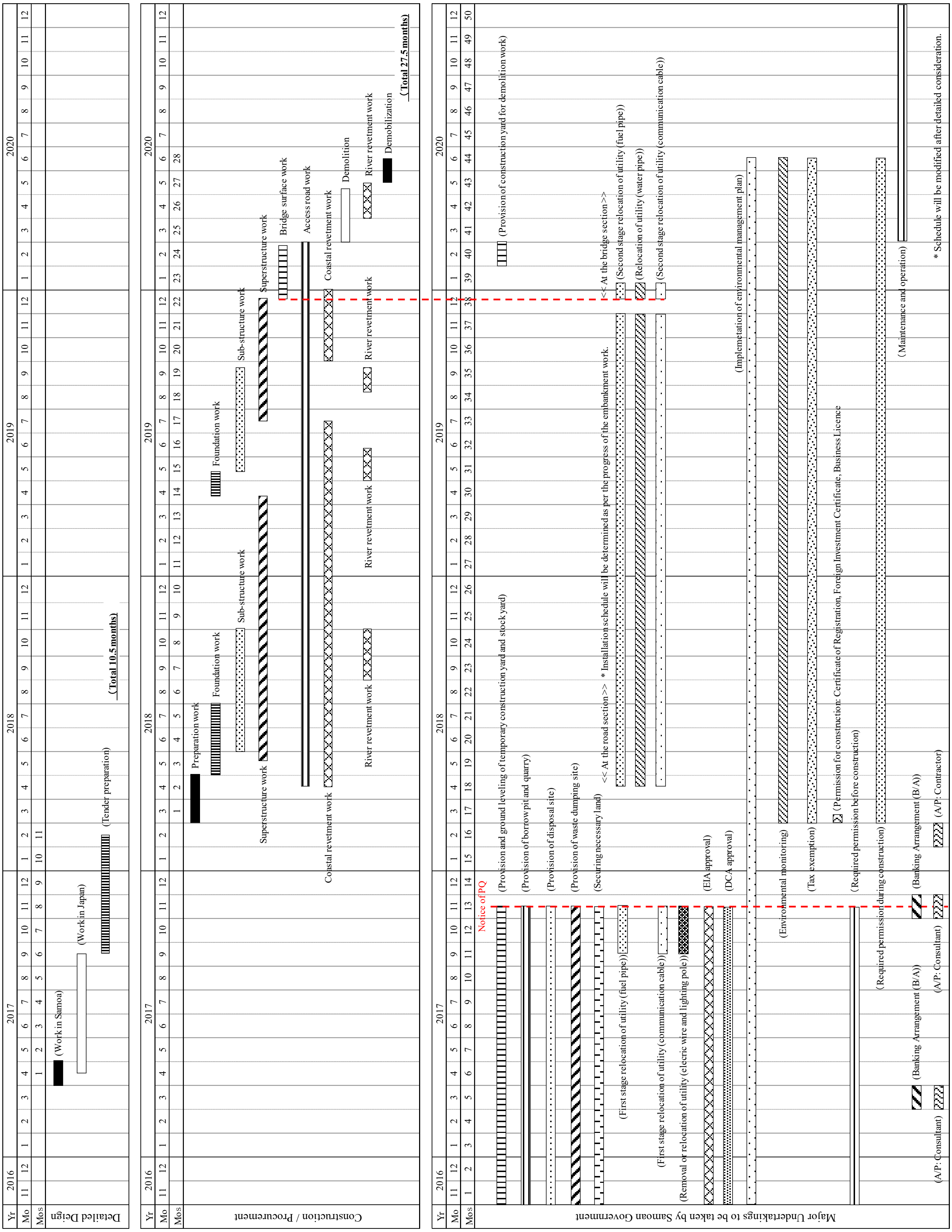
Table 2-2-22 List of Recipient Country Obligations

Resposibility	Content	Deadline
1. Construction yard provision and grading	(1) Identify an appropriate site for the construction yard by the DFR briefing (early December 2016). Yard to be selected from the candidates in Figure 2-2-27 and those proposed by LTA. (2) Required area for the construction yard is 10,000 m^2. If this cannot be covered with one location, it will be broken into two locations.	By prequalifying notices
2. Borrow pit and quarry provision	(1) Select appropriate sites for the borrow pit and quarry before prequalifying notices are made. Sites are to be selected from the candidates in Figure 2-2-28 and those proposed by LTA. (2) If prospects are limited to contractor-owned freehold lands, LTA will provide support to make the land available when construction commences.	By prequalifying notices, or when work starts
3. Spoil bank provision	(1) The work will produce very little surplus soil and thus soil will be disposed of the same as waste materials.	By prequalifying notices
4. Waste disposal site provision	(1) According to MNRE, waste materials may possibly be sold by auction and reused. LTA will work to reduce waste to a minimum and properly dispose of any remaining waste at designated landfills.	By prequalifying notices
5. Land acquisition	(1) Acquire as appropriate any lands required for approach road and coastal revetment construction in conjunction with the shift in bridge location.	By prequalifying notices
6. Fuel line relocation	(1) Initial relocation: Temporarily relocate buried lines obstructing Abutment A1 construction to the existing roadside. (See Figure 2-2-22)	By prequalifying notices
	(2) Second relocation: Relocate the lines attached to the current bridge to the downstream side of the new bridge (attached by brackets), and buried lines for the existing road to the roadside on the new road. (See Figure 2-2-22)	Bridge section: During bridge surface work (after brackets installed) Earthwork section: During earthwork (before paving)
7. Water line relocation	(1) Relocate the lines attached to the current bridge to the downstream side of the new bridge (attached by brackets; see Figure 2-2-23)	Bridge section: During bridge surface work (after brackets installed) Earthwork section: During earthwork (before gutters installed)
8. Communication line relocation (BlueSky and CSL)	(1) Initial relocation: Temporarily relocate buried lines obstructing Abutment A1 construction to the roadside of the current road. (See Figures 2-2-24 and 2-2-25)	By prequalifying notices
	(1) Second relocation: Relocate the lines attached to	Bridge section: During

Resposibility	Content	Deadline
	the current bridge to the upstream side of the new bridge (buried under sidewalks), and buried lines for the existing road to the roadside on the new road. (See Figures 2-2-24 and 2-2-25)	bridge surface work (before sidewalk casting) Earthwork section: During earthwork (before paving)
9. Utility pole and overhead power line relocation	(1) Remove or temporarily relocate utility poles and overhead lines in the work zone to a location that does not impede construction. (See Figure 2-2-26)	When work starts
10. Environment	(1) Submit the EIA report to PUMA and follow through with the process until approval by the DFR briefing (early December 2016).	By DFR briefing (early Dec. 2016)
	(2) Submit Development Consent Application (DCA) to PUMA together with the design plan and drawings, and follow through with the process until approval.	During detailed design implementation period
	(3) Obtain PUMA approval for the EIA and DCA.	By prequalifying notices
	(4) Supervise contractor in preparing and implementing the EMP.	Planning: Before work starts Implementation: During work period
	(5) Accept contractor environmental monitoring reports and monitor to make sure that the EMP is being implemented properly.	During construction period
11. Tax exemption procedures	(1) Customs: Submit the master list for imported equipment and materials as prepared by the contractors to the Ministry for Revenue (MoR) and obtain approval for exemption.	When work starts
	(2) Value-Added Goods and Services Tax (VAGST): Support the MoR in properly exempting taxes (through reimbursement).	During construction period (Bimonthly)
12. Construction permit/certificate acquisition	(1) Support Japanese companies in obtaining the following required documents: ・ Certificate of Registration, from Ministry of Commerce, Industry and Labour ・ Foreign Investment Certificate, from Ministry of Commerce, Industry and Labour ・ Business Licence Certificate, from Ministry for Revenue	When work starts
	(2) Obtain the construction permits and certificates required before the work commences.	By prequalifying notices
	(3) Obtain the construction permits and certificates required during the work period.	During construction period
13. Maintenance work	(1) Based on the JICA Study Team maintenance plan, perform maintenance work for Vaisigano Bridge and the approach road. (2) Maintain the budget and personnel required for operation and maintenance of the facilities built in the Project.	After completion (after delivery)

(6) Schedule for Recipient Country Obligations

Table 2-2-23 Schedule for Recipient Country Obligations



2-2-2-5-9 Considerations for Approach Road

(1) Consideration Policy

If the design height of the new bridge is higher than the existing road, it will create height differences between commercial facilities, residences and other buildings near the Project site. Thus, a service road will be built and measures taken that do not obstruct access to roadsides. Further, based on usage, alternate facilities to compensate functionality of road structures (drainage, safety devices, etc.) and ancilliary road facilities (parking lot, bus bay, etc.) affected by the Project will be considered as needed.

Table 2-2-24 Considerations for facility scale

Road structures and ancilliary facilities	Facility scale
Service road	• A width of 5.5 will be secured for the service road fronting the hotel to allow two-way traffic (and standing vehicles), per Australian standards.
Drainage	• Standards for annual rainfall: 5-year rain for gutters and street sewers, 10-year rain for pipe culverts crossing the road • Design rainfall intensity: 135 mm/h (continuous rainfall for 10 mins.) • As the route is an arterial road, pipe culverts crossing the road will be a minimum diameter of 0.8 m in the interests of maintenance.
Traffic safety devices	• Streetlights will be installed on the bridge, approach road, and intersection for improved safety for nighttime traffic. LEDs will be used for the lamps, which will be sized according to Japanese streetlight installation standards. Also, sidewalk lights will be installed for sections where the sidewalk and road are separated. • Road markings and road signs will be installed according to Samoan and Australian standards.
Parking lot	The parking lot will retain the same number of spaces (14) if at all possible.
Bus bay	The bus bay will general retain the same format in terms of a bus stop lane, deceleration lane, and acceleration lane.

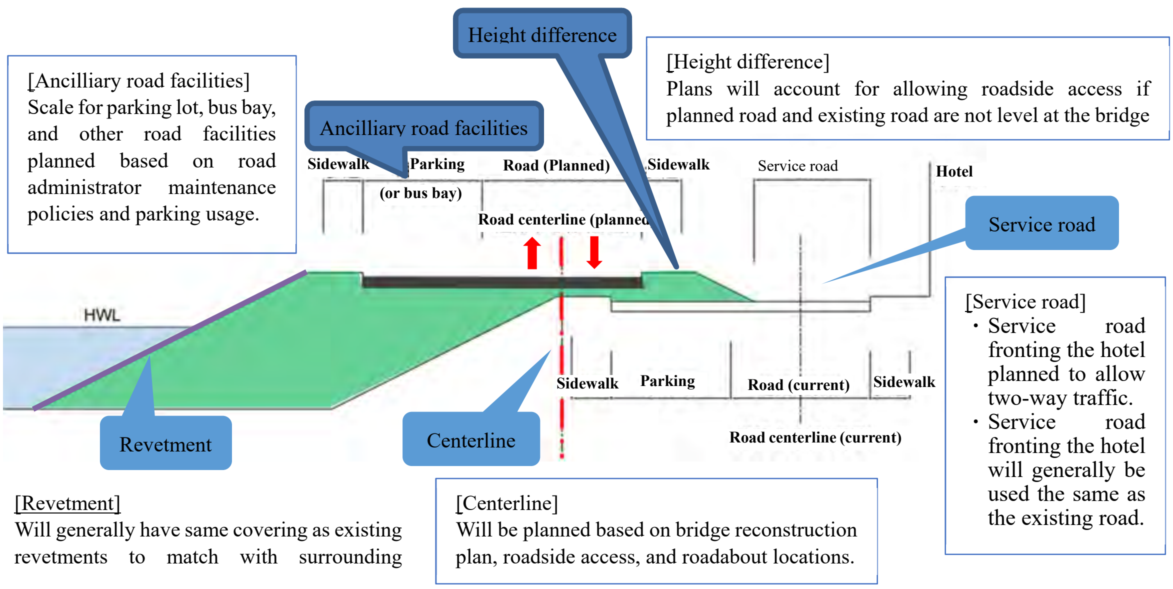


Figure 2-2-39 Conceptual diagram of approach road (west of bridge)

(2) Pavement Design

1) Basic Policy of Pavement Design

The following is a summary of the basic policy on pavement design.

Table 2-2-25 Basic policy on pavement design

Item	Applicable	Remarks
Design criteria	Austroads	Pavement Structural Design 2012
Pavement type	Flexible pavement	Standard type of arterial road in Samoa
Design period	20 years	Asphalt concrete pavement structure
Reliability	90%	Heavily trafficked urban arterial road
Subgrade design CBR	15	The results of CBR testing for the three samples collected from the project site were 35, 130 and 80 for Pit 01, Pit 02, and the borrow pit, respectively. The calculated CBR is 25, assuming a standard deviation of 31.8 after dismissing the maximum value of 130. The study team, however, adopted a subgrade design CBR of 15 referring to similar projects in Samoa supported by the WB.
Type of design vehicle	Heavy vehicles, including medium-sized trucks	The vehicle type for the pavement design was assumed to be large/medium-sized trucks running through the roundabout.

Source: JICA Study team

2) Pavement Structure

The table below summarizes the proposed pavement structure.

Table 2-2-26 Proposed pavement structure

Pavement layer	Thickness	Material
Wearing course	5 cm	Hot mix asphalt concrete
Binder course	5 cm	Hot mix asphalt concrete
Base course	10 cm	Mechanically stabilized crushed stone
Sub-base course	15 cm	Crushed rock

Source: JICA Study team

3) Cumulative Number of Heavy Vehicle Axle Groups

The cumulative number of heavy vehicle axle groups (N_{DT}) anticipated in the design lane over the design period is estimated by the following equation.

$$N_{DT} = 365 \times AADT \times DF \times \%HV/100 \times LDF \times CGF \times N_{HVAG}$$

$$N_{DT} = 2.51 \times 10^6 \times N_{HVAG}$$

$$N_{DT} = 11.8 \times 10^6$$

AADT	Annual average daily traffic for the first year of use (vehicles per day)	17,100
DF	Direction factor	0.5
%HV	Average percentage of heavy vehicles (%)	3.7
LDF	Lane distribution factor	1.0
CGF	Cumulative growth factor $\text{CGF} = \frac{(1+0.01R)^P - 1}{0.01R}$ R: annual growth ratio (0.8%) P: design period (20 years)	21.6
N_{HVAG}	Average number of axle groups per heavy vehicle	4.7

Note: The average percentage of heavy vehicles given in the table, 3.7%, is based on the results of the traffic survey at the intersection on the eastern side of the Vaisigano Bridge.

The average number of axle groups per heavy vehicle (N_{HVAG}) is estimated based on the sum of the proportions of the single-axle-with-single-tyres (SAST) types and tandem-axle-with-single-tyres (TAST) types (both of which may be steer axles), after classifying all heavy vehicles investigated into five axle group types. Based on the results of the axle load survey carried out by the study team, the sum of the proportions of the SAST and TAST types is 0.2138. Thus, N_{HVAG} is 1/0.2138 = 4.7.

4) Project Traffic Load Distribution of Heavy Vehicles

The table below summarizes the project traffic load distribution by the proportion of each type of axle group and each load. The figures are based on the results of the axle load survey carried out by the study team. The study team investigated 148 axles in 30 vehicles. The axle groups are classified into the following five group types.

- SAST：Single Axle with Single Tyres
- SADT：Single Axle with Dual Tyres
- TAST：Tandem Axle with Single Tyres
- TADT：Tandem Axle with Dual Tyres
- TRDT：Triaxle With Dual Tyres

Table 2-2-27 Project traffic load distribution by the proportion of each type of axle group and each load

Axle group / Load (KN)	SAST	SADT	TAST	TADT	TRDT
10					
20					
30					0.027586
40	0.013793			0.041379	0.013793
50	0.096552	0.006897		0.034483	0.006897
60	0.082759	0.013793		0.062069	0.000000
70	0.020690			0.075862	0.013793
80				0.082759	0.041379
90				0.089655	0.034483
100				0.068966	0.041379
110				0.041379	0.013793
120				0.027586	0.013793
130				0.020690	0.006897
140					
150					
160					
170					0.006897
Proportion	0.2138	0.0207	0.0000	0.5448	0.2207

Source: JICA Study team

5) Pavement Damage in terms of Standard Axle Repetitions

The following equation evaluates the number of standard axle repetitions (SARs) or passages of the standard axle:

$$SARm_{ij} = \left(\frac{L_{ij}}{SL_i}\right)^m$$

where

$SARm_{ij}$: number of standard axle repetitions (or passages of the standard axle) that causes the same amount of damage as a single passage of axle group type i with load L_{ij}, where the load damage exponent is m

SL_i : standard load for axle group type i

L_{ij} : j^{th} load magnitude on the axle group type i

m : load damage exponent for the damage type

Table 2-2-28 Loads on standard axle groups

Axle group type	Nominal tyre section width		Load（kN）
SADT	Not provided		80
TADT	Not provided		135
TRDT	Not provided		181
SAST	Less than 375mm At least 375mm but less than 450mm 450mm or more		53 58 71
TAST	Less than 375mm At least 375mm but less than 450mm 450mm or more		90 98 120

Source: Austroads

The average of SAR per heavy vehicle axle group (HVAG) for each damage type is calculated by multiplying the SAR value for each axle group load of each axle group type, or $SARm_{ij}$ (value shown in the Austroads guide), by the frequency of damage occurrence (value shown in Table 2-2-26.The average SAR/HVAG for each damage type is the sum of the weighted damage values. These values are summarized in the table below.

Table 2-2-29 Average SAR/HVAG for each damage type

Damage type	Damage exponent (m)	Damage index	Value of damage index
Overall damage (granular pavement)	4	ESA/HVAG	0.43
Asphalt fatigue	5	SAR5/HVAG	0.41
Rutting and shape loss (permanent deformation)	7	SAR7/HVAG	0.47
Fatigue of cemented materials	12	SAR12/HVAG	1.03

Note: Equivalent Standard Axle (ESA), Standard Axle Repetitions (SARs), Heavy Vehicle Axle Group (HVAG)
Source: JICA Study Team

From the table above, the average number of standard axle repetitions (SARs) per equivalent standard axle (ESA) for each damage type is as follows.

- Fatigue of asphalt： SAR5/ESA=0.41/0.43=0.95
- Permanent deformation： SAR7/ESA=0.47/0.43=1.09

6) Design Standard Axle Repetitions

The design number of ESA of loading (DESA) and the design number of SARs (DSAR5 and DSAR7) are calculated as follows.

- DESA
  = ESA/HVAG×N_{DT}= $0.43\times11.6\times10^6$= 5.1×10^6
- DSAR5 (fatigue of asphalt) = SAR5/ESA×DESA= $0.95\times5.0\times10^6$= 4.8×10^6
- DSAR7 (permanent deformation) = SAR7/ESA×DESA= $1.09\times5.0\times10^6$= 5.5×10^6

7) Comparison of Pavement Structure

The study team compared the pavement structures of four alternatives.

Table 2-2-30 Comparison of pavement structures

	Conditions	Unit	Alt-1	Alt-2	Alt-3	Alt-4
Asphalt concrete layer	E = 1080 Mpa Poisson = 0.4	cm	10	10	5	5
Base course	E = 350 Mpa Poisson = 0.35	cm	15	10	15	10
Sub-base course	E = 250 Mpa Poisson = 0.35	cm	15	15	15	15
Subgrade	E = 150 Mpa Poisson = 0.45	-	-	-	-	-
Max. tensile strain	At the base of AC layer	με	251	260	204	210
Max. compressive strain	At the top of the subgrade	με	334	390	409	479
Allowable number of repetitions	Asphalt fatigue	N	10.5×10^6	8.8×10^6	29.7×10^6	25.7×10^6
	Permanent deformation	N	13.0×10^9	4.4×10^9	3.1×10^9	1.0×10^9

Note: The elastic modulus of the asphalt concrete layer was set by calculating the monthly elastic modulus based on the monthly air temperature and pavement temperature over a 12-month period in Samoa. Consequently, the average elastic modulus was set at 1080 (standard deviation of 97)

- The maximum tensile strain at the base of the asphalt concrete layer and the maximum compressive strain at the top of the subgrade of each alternative above were set by analyzing the stress-strain produced in the pavement using multi-layered elastic systems.
- The following equation was then used to calculate the allowable number of repetitions for asphalt fatigue and for permanent deformation for each alternative:

Asphalt fatigue
$$\mathrm{N} = \mathrm{RF}\left[\frac{6918\ (0.856\ V_b+1.08)}{E^{0.36}\mu\varepsilon}\right]^5$$

where

N : allowable number of repetitions of the load

με : load-induced tensile strain at the base of the asphalt (microstrain)

V_b : percentage of bitumen in the asphalt by volume (11%)
E : asphalt modulus (MPa)
RF : reliability factor for asphalt fatigue (1.5 for reliability of 90%)

Permanent deformation $$N = \left[\frac{9300}{\mu\varepsilon}\right]^7$$

where
N : allowable number of repetitions of the load
με : vertical compressive strain at the top of the subgrade (microstrain)

8) Result of Pavement Structure Comparison

The allowable number of repetitions of all alternatives exceeded the design standard axle repetitions. This confirmed that all of the alternative pavement structures were mechanistically stable. The following is a summary of the pavement structure evaluation.

Table 2-2-31 Screening of pavement structure

Damage type	**Design standard axle repetitions**	**Allowable number of repetitions**			
		Alt-1 AC 10cm Base 15cm Sub-b 15cm	Alt-2 AC 10cm Base 10cm Sub-b 15cm	Alt-3 AC 5cm Base 15cm Sub-b 15cm	Alt-4 AC 5cm Base 10cm Sub-b 15cm
Asphalt fatigue	4.8×10^6	10.5×10^6	8.8×10^6	29.7×10^6	25.7×10^6
Permanant deformation	5.5×10^6	13.0×10^9	4.4×10^9	3.1×10^9	1.0×10^9
Screening		OK	OK	OK	OK
Recommendation		Alt-2			

The study team recommends that the Alt-2 pavement structure be adopted for the approach roads, in consideration of the following reasons.

- Comparing Alt-1 and Alt-2, which have asphalt concrete layer thicknesses of 10cm, the base course of Alt-2 is 5cm thinner than that of Alt-1. Alt-2 is therefore recommendable in light of its economical advantage.
- Alt-3 and Alt-4, with asphalt concrete layer thicknesses of 5cm, were both found to be free of problems in mechanical stability, in the analysis by the Austroads method. When examining them by the Japanese pavement structural design method or TA method, however, the asphalt concrete layer thickness of 5cm was found to be insufficient. The calculation indicates a 10cm thickness for both Alt-3 and Alt-4, instead of 5cm. The Japanese pavement manual also stipulates 10cm as the minimum thickness of an asphalt concrete layer for more than 250 heavy vehicles per day. The projected number of heavy vehicles per day in 2040 is estimated to be approximately 370. Thus, Alt-3 and Alt-4 are not recommendable for the Japanese Grant Project.

2-2-2-5-10 Consideration of Intersection

(1) Reasons Intersection Improvement is Needed

With the reconstruction of the Vaisigano Bridge, the intersection will be shifted seaward and the ground in the area of the intersection needs to be raised approximately 1.5 m.

(2) Basic Strategy for Interspection Improvement

- While accounting for the land usage and roadside access in the area of the intersection, land acquisition will be kept to a minimum.
- The intersection format used will be the best one that allows safe and smooth transport for future intersection traffic (in 2040).
- Safety measures will also take into account nighttime driving and maintaining traffic order.
- Given that the area is susceptible to flooding, plans will account for making the intersection able to run autonomously in times of disaster.

(3) Flow of Study on Optimal Intersection Format

Table 2-2-32 Flow of study on optimal intersection format

Study Flow	Overview of Study Results
1. Conduct traffic survey of current intersection	• Traffic flow surveyed for 12 hours from 7:00-19:00 on July 7, 2016 (Thu.).
2. Determine traffic patterns of current intersection	• A total of 16,992 vehicles entered the intersection during the 12-hour period. • A total of 1,667 vehicles entered the intersection in the peak hour (17:00-18:00). • The main flow of traffic travels on Beach Road in the Vaisigano Bridge and Matafagateli Road directions, with peak hour traffic comprising 75 percent of all traffic. • Aprpoximately 93 percent of vehicles are cars. • Port-related large freight vehicles comprise approximately 0.4 perecnt of all traffic.
3. Set traffic conditions for the future intersection (2040)	• Annual growth rate for intersection traffic: 0.8% • Day variation coefficient: 0.89 (Thursday; LTA 2013 data) • Passenger vehicle conversion factor: 2 (large trucks; see HCM)
4. Comparison of formats for intersection improvement	• Various forms of T-intersections and roundabouts were analyzed and compared. • If a T-intersection with no traffic signal, traffic in the 4(e) direction (from Apia Port to Vaisigano Bridge) will turn right to merge with the main flow of traffic, requiring in a 3-minute wait per vehicle for right turns. This intersection format has Level of Service (LOS) issues. • Inserting a traffic signal in the T-intersection removes the LOS issue for 4(e) traffic presented above. • With a roundabout, there will be no LOS issues for incoming traffic. This also eliminates the need to install a traffic signal. • Result: A roundabout format will be used.
5. LOS for optimal intersection format	• Analyzing whether to go with a one-lane or two-lane roundabout, the two-lane proposal was found to shorten delays on all inbound roads, particularly for traffic entering from Matafagateli Road. *LOS: C for one-lane roundabout, B for two-lane roundabout • Result: A two-lane roundabout will be used.

(4) Intersection Traffic Patterns (Current)

(Observation date: Jul. 7, 2016 (Thu.)

Figure 2-2-40 Overview of survey point

In its current state, a total of 16,992 vehicles entered the intersection in 12 hours. Peak traffic for a one-hour period was from 17:00 to 18:00 at 1,667 vehicles, followed by 8:00 to 9:00 with 1,606 vehicles. Looking at peak hour traffic by direction, 694 vehicles traveled on Beach Road from Vaisigano Bridge to Matafagateli Road (the 4(b) direction), and 564 vehicles traveled on Beach Road from Matafagateli Road to Vaisigano Bridge (the 4(c) direction). These two traffic patterns account for approximately 75 percent of traffic overall with 1,258 vehicles total.

Table 2-2-33 Overview of hourly traffic by direction (12 hours of traffic)

Time \ Direction		4a	4b	4c	4d	4e	4f	Total (vehicles)
07:00	08:00	90	299	457	22	74	16	958
08:00	09:00	181	483	712	59	132	39	1,606
09:00	10:00	229	481	564	43	177	44	1,538
10:00	11:00	193	391	447	46	189	50	1,316
11:00	12:00	183	419	428	46	161	44	1,281
12:00	13:00	192	522	469	78	233	40	1,534
13:00	14:00	247	477	440	47	208	56	1,475
14:00	15:00	208	491	486	58	208	55	1,506
15:00	16:00	190	471	455	50	195	57	1,418
16:00	17:00	157	545	475	45	155	50	1,427
17:00	18:00	135	694	564	29	190	55	1,667
18:00	19:00	133	487	445	39	121	41	1,266
12 hours		2,138	5,760	5,942	562	2,043	547	16,992

Source: The Study Team

Looking at traffic by vehicle type for each direction over the 12 hours, cars comprised an overwhelming 93 percent of all vehicles. Meanwhile, large freight vehicles in directions 4d and 4f between Apia Port comprise approximately 0.4 perecnt of all traffic.

Table 2-2-34 Overview of directional traffic by vehicle type (12 hours of traffic)

Direction	Car	Mid. Bus	Long Bus	Mid. Truck	Heavy Truck			Total
					Long Truck	Mid. Comb.	Long. Comb.	
4a	2,014	43	0	81	0	0	0	2,138
4b	5,405	183	0	172	0	0	0	5,760
4c	5,521	236	0	184	1	0	0	5,942
4d	485	0	0	41	36	0	0	562
4e	1,943	7	0	92	1	0	0	2,043
4f	478	3	0	37	29	0	0	547
12 hrs.	15,846	472	0	607	67	0	0	16,992

(5) Intersection traffic volume by direction during peak hours (future)

Future intersection traffic volume during peak hours was 1,797 vehicles total for all directions. Traffic volume for each direction is organized in the table below. Note that the following points were assumed for these future values:

- Average daily traffic (ADT) base taken as the observation values multiplied by a day variation coefficient of 0.89
- Future values set as being approximately 20 years after completion of the Vaisigano Bridge
- Future traffic volume estimated based on annual traffic growth of 0.8 percent
- Passenger car unit (PCU) set as a factor of 2.0, with a 1.87 percent rate of large vehicles

Table 2-2-35 Traffic by direction during peak hours (future)

By Direction		Current (2016)		Future (2040)	
Entering from	Entering to	Observed value	ADT Base	ADT Base	ADT Base
		Veh./hr.	Veh./hr.	Veh./hr.	PCU/hr.
Vaisigano Bridge	4a (Apia Port)	135	120	146	148
	4b (Matafagateli Road)	694	618	748	762
Matafagateli Road	4c (Vaisigano Bridge)	564	502	608	619
	4d (Apia Port)	29	26	31	32
Apia Port	4e (Vaisigano Bridge)	190	169	205	209
	4f (Matafagateli Road)	55	49	59	60
Total		1,667	1,484	1,797	1,831

Note: Current observation values taken from the peak hour (17:00-18:00) of a traffic survey in July 2016 (Thurs.)

(6) Comparison of intersection improvements

The T-intersection and roundabout formats were analyzed and compared. A T-intersection would require a signal to control traffic from Apia Port to Vaisigano Bridge, making it a disadvantage in terms of operating cost and mainenance. Further, with the area susceptible to flooding, a roundabout has the advantage of allowing the intersection to run autonomously in times of disaster. Thus, a roundabout will be the format used.

Table 2-2-36 Comparison of intersection improvements

	Alt. A	Alt. B
Conceptual Diagram		
Intersection format	T-intersection	Roundabout
Intersection overview	Main traffic flow between A-B, secondary traffic between C. This format prioritizes A-B traffic.	Format prioritizing circling traffic
Issues	This intersection format presents LOS issues. Vehicles turning right from C to A have to turn right and merge with the main flow of traffic, requiring in a 3-minute wait per vehicle for right turns. (Green line in figure)	Due to the intersection angle, difference in the inner race for tractor-trailers turning left from C to B is great. (Green line in figure)
Countermeasure s	Installing a traffic signal would ensure an appropriate LOS.	The road will be widened to ensure enough room for tractor-trailers to turn left. Also, appropriate measures will be taken to keep cars and other vehicles from driving on the extension.
Evaluation	・ The T-intersection format would require the operating costs and maintenance of a traffic signal, making it a disadvantage. ・ With the area susceptible to flooding, a roundabout has the advantage of allowing for autonomous operation in times of disaster. ・ Given the above, the roundabout format offers a comparative advantage.	

(7) Roundabout Level of Service

1) Traffic Volume

Traffic volume for a two-lane roundabout with a single entry lane is calculated using the following equation, referencing the Highway Capacity Manual (HCM):

$$c_{e,pce} = 1{,}130e^{(-0.7\times10^{-3})v_{c,pce}}$$

Where
$c_{e,pce}$: Traffic volume (PCU/hr.)
$v_{c,pce}$: Traffic conflicts (circling traffic at merge point; PCU/hr.)

2) Average Delay Times

Average delay time for a two-lane roundabout with a single entry lane is calculated using the following equation, referencing the HCM:

$$d = \frac{3{,}600}{c} + 900T\left[x - 1 + \sqrt{(x-1)^2 + \frac{x\left(\frac{3{,}600}{c}\right)}{450T}}\right] + 5 \times \min[x, 1]$$

Where
d: Average delay time (secs./vehicle)
x: Lane capacity ratio
c: Lane capacity (vehicles/hr.)
T: 0.25 hr. (15-min analysis)

3) Criteria for Determining Level of Service

LOS for roundabouts is based on the following criteria, referencing Austroads:

Table 2-2-37 LOS criteria

Level of Service	Average Delay Time *d* (secs./veh.)
A	d ≤ 10
B	10 < d ≤ 20
C	20 < d ≤ 35
D	35 < d ≤ 50
E	50 < d ≤ 70
F	70 < d

4) Level of Service

Capacity ratio (traffic volume/traffic capacity) for each of the roundabout entry points is under 0.9, resulting in a LOS of C or above for each. Thus, no particular issues were found in terms of roundabout traffic volume or LOS.

Table 2-2-38 Roundabout LOS

Entry point		Traffic Conflicts	Traffic Vol.	Traffic Entering Intersection	Capacity Ratio	Average Delay	LOS
		(PCU/hr.)	(PCU/hr.)	(PCU/hr.)		(secs./veh.)	
A	4a+4b	32	1105	910	0.82	29.4	C
B	4c+4d	209	976	651	0.67	16.1	B
C	4e+4f	762	663	269	0.41	12.1	B

2-2-2-5-11 Consideration of Number of Lanes

The number of lanes needed for Vaisigano Bridge was considered based on potential traffic and design hourly volume (DHV). The results were as follows:

- As the basic Austroads approach to traffic capacity references the 2010 Highway Capacity Manual (HCM2010), the HCM2010 was referenced to set the basic capacity.
- Potential traffic for Vaisigano Bridge was calculated as 3,040 PCUs per hour per two lanes. This was derived by taking the basic capacity of 3,200 PCUs per hour per two lanes and compensating for a lateral margin.
- DHV was calculated as 2,045 PCUs per hour per two lanes by accounting for the mix rate of freight vehicles and buses on Vaisigano Bridge during peak hours in 2040.
- DHV divided by potential traffic is 0.67, which is less than the reduced volume/capacity ratio of 0.9 (considering urbanization state of the Project site).

Table 2-2-39 Vaisigano Bridge capacity (two-lane traffic)

Capacity, Volume	Item	Value	Unit	Notes
Capacity	Basic capacity	3,200	PCU/hr./2 lanes	From HCM2010
	(lateral margin correction)	0.95		
	Potential traffic	3,040	PCU/hr./2 lanes	Total bi-directional PCU/hr.
Volume	Design daily volume (2040)	19,200	Veh./da.	Total bi-directional vehicles/hr.
	(Peak rate)	10	%	From traffic survey results
	(Large vehicle correction factor)	1.07		6.5% larger vehicles @ 2.0 passenger car conversion factor
	Design hourly volume	2,045	PCU/hr./2 lanes	Total bi-directional PCU/hr.
DHV/potential traffic		0.67		

*Note on Japanese basic capacity

Even using the Japanese basic capacity, DHV/potential traffic is 0.86, which is under 0.9.

Table 2-2-40 (Reference: Japan) Vaisigano Bridge capacity (two-lane traffic)

Capacity, Volume	Item	Value	Unit	Notes
Capacity	Basic capacity	2,500	PCU/hr./2 lanes	From road traffic capacity (Japan Road Association)
	(lateral margin correction)	0.95		
	Potential traffic	2,375	PCU/hr./2 lanes	Total bi-directional PCU/hr.
Volume	Design daily volume (2040)	19,200	Veh./da.	Total bi-directional vehicles/hr.
	(Peak rate)	10	%	From traffic survey results
	(Large vehicle correction factor)	1.07		6.5% larger vehicles @ 2.0 passenger car conversion factor
	Design hourly volume	2,045	PCU/hr./2 lanes	Total bi-directional PCU/hr.
DHV/potential traffic		0.86		

In addition to the capacity-based considerations for number of lanes, two lanes were deemed appropriate for Vaisigano Bridge in light of the following points:

a) The Samoan government has no plans to convert the Apia urban arterial road network to four lanes.
b) Design capacity for the approach road roundabout meets the LOS, and traffic congestion will have little impact on traffic flow.
c) Given the alternate routes in Leone Bridge and Lelata Bridge, two lanes will have little impact on efficient transport of goods.

2-2-2-5-12 Social Survey

The following items were investigated to determine the beneficial effects of bridge improvement. A total of 150 households were interviewed in the four villages around Vaisigano Bridge (1 interviewee per household). The sample rate for each village is given below.

Table 2-2-41 Households interviewed and sample rates for each village

Village	Households interviewed	Sample rate
Vaisigano	30	20%
Leone	45	30%
Matautu-tai	15	10%
Matautu-uta	60	40%
Total	150	100%

Social attributes of the interviewees are as given below.

Table2-2-42 Social attributes of interviewees

Gender		Education	
Male	45%	Elementary school	12%
Female	55%	Middle school	62%
Age		High school	23%
15-19	3%	Vocational school	3%
20-24	11%	Other	0%
25-29	2%	Years of residence	
30-34	14%	0-5	9%
35-39	8%	6-10	10%
40-44	9%	11-20	11%
45-49	11%	21+	70%
50+	43%	Employment status	
Nationality		Employed	37%
Samoan	98%	Unemployed	51%
Other	2%	Retired/pensioners	12%

(1) Overview of Resident Living Environments

1) Population

Populations from 2011 and 2016 for the four villages surveyed are given below. The population has risen in Leone village, albeit only slightly, and fallen in the other three villages. According to census data from the Samoa Bureau of Statistics, the urban population in Samoa fell from 2006 to 2011, and a decline of 0.5 percent is projected for the years of 2011 to 2016.

Table2-2-43 Village and national population

Village	2011	2016
Vaisigano	267	265
Leone	609	632
Matautu-tai	192	170
Matautu-uta	811	791
Samoa (all)	187,820	194,899 (est.)
Samoa (urban)	36,735	35,762 (est.)

Source: Samoa Bureau of Statistics

The trends for number of households in the surveyed villages and their neighboring villages are given below. Comparing 2011 and 2016, many of the villages have slightly more households now, whereas others are in decline. The total number of households in the villages neighboring Vaisigano Bridge expanded from 653 in 2011 to 679 in 2016.

Table2-2-44 Households in villages neighboring Vaisigano Bridge

Village	2011	2016
Vaisigano	42	44
Leone	72	81
Matautu-tai	30	34
Matautu-uta	98	113
Aai o Niue	23	26
Apia	29	30
Faatoialemanu	155	164
Lelata	38	35
Malifa	33	35
Maluafou	13	18
Motootua	120	99
Total	653	679

Source: Samoa Bureau of Statistics

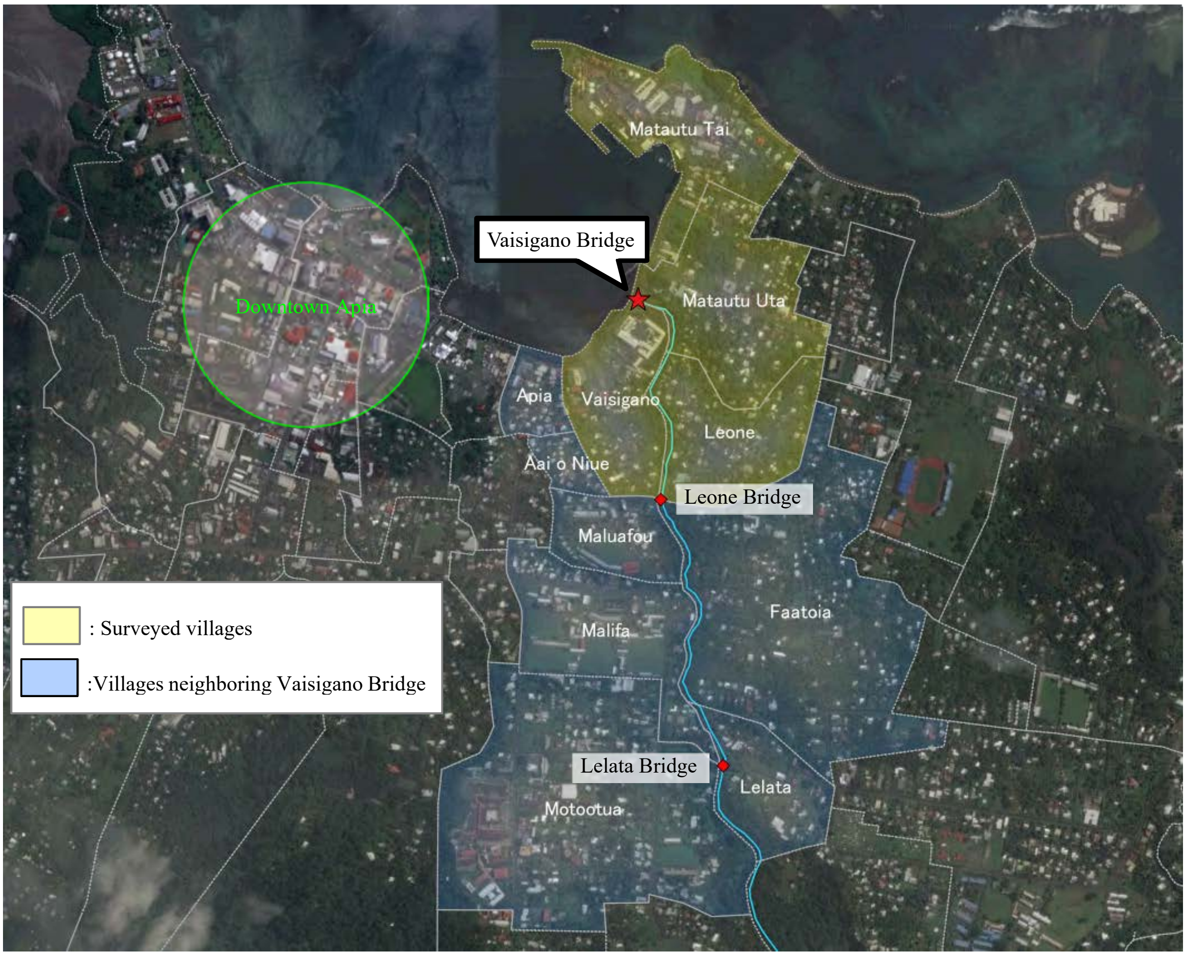


Figure 2-2-41 Villages neighboring Vaisigano Bridge

2) Economic Activity

Comparing employment figures for those aged 15 and older from the interview results, the unemployed outnumbered the employed at 56 percent of those interviewed. Employment figures for Samoa as a whole show the same trends, with 41 percent employment and 59 percent unemployment. The most common economic activity was housewive/husband at 39.4 percent, followed by employee at 31.6 percent.

Table 2-2-45 Major economic activities

Economic activity	Vaisigano	Leone		Matautu-tai	Matautu-uta	%
Total	191	369		122	531	100%
Employed						
Subtotal	93	164		39	238	44%
Employer	1	6		1	0	0.7%
Employee	69	103		26	186	31.6%
Self-employed	9	31		7	22	5.7%
Manufacturing	0	1		0	5	0.5%
Street vendor	0	10		0	0	0.8%
Subsistence farmer	0	4		2	2	0.7%
Seeking employment	14	9		3	23	4.0%
Unemployed						
Subtotal	98	205		83	293	56%
Housewife/husband	64	144		59	211	39.4%
Student	31	46		23	66	13.7%
Unable to work	3	15		1	16	2.9%

Source: Samoa Bureau of Statistics, Population and Housing Census 2011

3) Religion

The majority of Samoans are some form of Christian, with churches playing an integral role in the villages as a place of communion and information exchange. Near the four villages surveyed, most people attended the Congregational Christian Church of Samoa (CCCS) at 624, followed by the Catholic Church at 225, Assemblies of God church at 209, Baptist church at 129, and Latter Day Saints church at 110.

Table 2-2-46 Religion in Samoa

Village	CCCS (EFKS)	Catholic	Assembly of God	Baptist Church	Latter Day Saints	Jehovah's Witness	Worship Centre	CCCJ (Ekalesa Pouesi)	Methodist
Vaisigano	51	35	6	0	25	9	0	44	3
Leone	123	60	142	105	16	52	0	0	7
Matautu-tai	124	8	0	0	11	0	21	0	4
Matautu-uta	326	122	61	24	58	18	27	0	18
Total	624	225	209	129	110	79	48	44	32

Village	Pentecostal	Bahia	Peace Chapel	Protestant	Seventh Day Adventist	Voice of Christ	Other Churches	No Religion	Not reported
Vaisigano	0	0	10	4	0	0	54	0	0
Leone	16	0	0	1	1	0	5	0	0
Matautu-tai	0	0	0	2	0	0	0	0	1
Matautu-uta	11	15	5	6	5	1	0	2	4
Total	27	15	15	13	6	1	59	2	5

4) Land Usage

a) Project Site

Land usage on the Project site includes a beach area, roads, coastal revetments, a hotel, restaurants, shops, and open space. Other than these, there is a bus shelter and taxi station. The seafront side of Beach Road is scheduled to be developed in the Waterfront Development Project.

b) Land Ownership

Of the residents living near Vaisigano Bridge, 112 households are on customary land, and 107 households live on freeheld land.

Table 2-2-47 Land ownership for area residences

Village	Customary land	Freehold land	Leased land	Not reported	Total
Vaisigano	36	4	2	0	42
Leone	47	24	1	0	72
Matautu-tai	14	12	4	0	30
Matautu-uta	15	67	13	3	98
Total	112	107	20	3	242

Source: Samoa Bureau of Statistics

c) Coastal Areas

Of the villages near Vaisigano Bridge, Vaisigano, Matautu-tai, and Matautu-uta lie along the coastline and are thus extremely prone to damage from coastal disasters. Furthermore, these nearby villages are also directly impacted by flooding as they are located in the lower catchment area of the Vaisigano River. Land development started in the flat coastal lands in downtown Apia, and from there, the vast majority has subsequently spread inland, leaving coastal lands susceptible to natural disaster.

On the west side of Vaisigano Bridge, the seawall area, there are paddleboats, fautasi (boat) races, and other watersports. The east side of the bridge is beach, which local residents and tourists use as a recreation area for rugby, walking, and jogging.

(2) Social Infrastructure

1) Schools

In Samoa, primary and secondary schools include state-run, mission-run, and private educational institutions. Primary school is compulsory, starting from age five and including grades one through eight. Secondary school is five years, from grades nine through thirteen. After secondary school graduation, there is a post-school education and training (PSET) system, consisting of university (including high school-level education), vocational schools, and other after-work education and training programs. The Vaimauga region, where the Vaisigano Bridge lies, has 24 primary and secondary schools, as well as the National University of Samoa, the highest national educational institution.

Table 2-2-48 Number of primary and secondary schools

Region/District	Government				Mission				Private				Grand Total
	Primary	Pri-Sec	Secondary	Total	Primary	Pri-Sec	Secondary	Total	Primary	Pri-Sec	Secondary	Total	
Apia Urban													
Faleata	10		1	11	1	1	4	6	4	2	1	7	24
Malifa			1	1									1
Vaimauga	11		3	14	5	1	2	8	2			2	24
Apia Urban Total	21		5	26	6	2	6	14	6	2	1	9	49
Rest of Upolu													
Aana No. 1	8		1	9	1	1	1	3					12
Aana No. 2	10		1	11									11
Aleipata	8		1	9									9
Anoamaa No. 1	4		1	5									5
Anoamaa No. 2	6			6	2			2					8
Fagaloa	4			4									4
Falealili	9		2	11									11
Lefaga	4		1	5									5
Lepa/Lotofaga	5		1	6									6
Safata	8		1	9									9
Sagaga	8		1	9	3		2	5					14
Rest of Upolu Total	74		10	84	6	1	3	10					94
Savaii													
Faasaleleaga No. 1	6		1	7	2		2	4					11
Faasaleleaga No. 2	6		1	7	2	1		3					10
Itu Asau No. 1	5		1	6									6
Itu Asau No. 2	4			4					1			1	5
Itu-o-Tane No. 1	5		1	6									6
Itu-o-Tane] No. 2	7		1	8	1			1					9
Palauli	7		1	8			1	1					9
Savaii Sisifo	8		2	10									10
Savaii Total	48		8	56	5	1	3	9	1			1	66
Grand Total	143		23	166	17	4	12	33	7	2	1	10	209

Source: Education Statistical Digest 2015, Ministry of Education, Sports and Culture

2) Medicine

The Vaimauga region also contains Tupua Tamasese Meaole Hospital, the national general hospital. A new building was constructed in 2015, and the facility offers 24-hour emergency outpatient consultations. Still, there is a lack of specialists. Foreign doctors dispatched from overseas and doctors from private hospitals in Apia travel around to make consultations.

3) Police

On the west side of Vaisigano Bridge, there is a police station about 500 m up Beach Road before reaching downtown Apia. There is also a fire station next to the police station.

4) Cemeteries

The closest cemetery to Vaisigano Bridge is the Maagiagi Cemetery near the National University of Samoa. Operating since around 1900, the MNRE-managed cemetery is for war casualties and their bereaved family. There is a looming shortage of burial plots given the increases in population in recent years, but no new construction is currently planned.

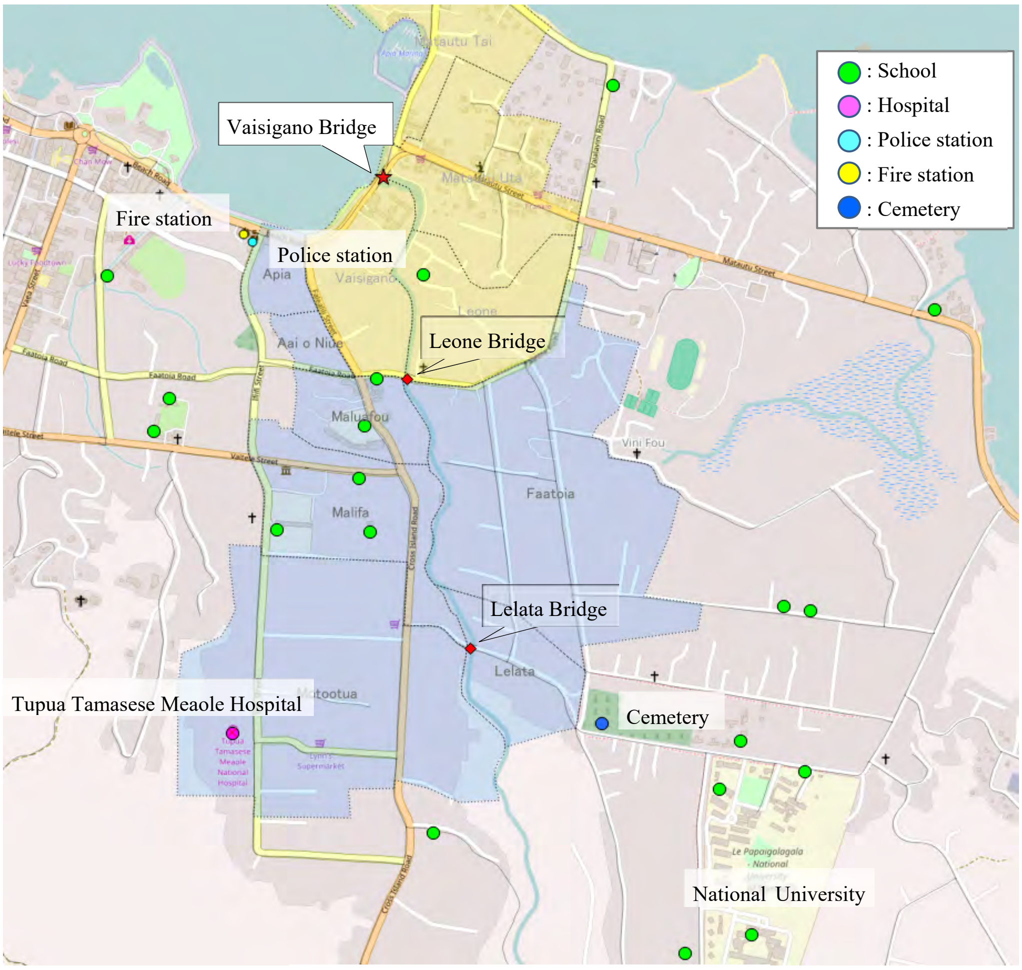


Figure 2-2-42　Social infrastructure

5) Utilities

a) Electricity

Vaisigano Bridge area residents get their electricity from the Samoa Electrical Power Corporation (EPC), relayed from the Tanugamanono substation. Interview respondents reported that they provide stable electrical supply service. The main usage for electricity is house lighting. Currently, there is a push to increase electrical capacity using renewable energy resources.

b) Communications

BlueSky Samoa is the service provider for the landline communication network in the Vaisigano Bridge area. The cellular providers are again BlueSky Samoa and Digicel, both of which are said to have provided reliable communications service in the 2007 disaster. Mobile phone penetration in Samoa has soared in the past few years.

c) Water

Water is provided by the Samoa Water Authority (SWA), the main service provider in Samoa. SWA does have several outstanding issues, including dealing with high non-absorption rates, turbid water treatment during the rainy season, and slumping water fee collections. JICA is currently implementing the Capacity Enhancement Project for Samoa Water Authority in Cooperation with Okinawa to help improve these issues.

(3) Details on River Crossing

In the Apia metropolitan area, the Vaisigano River divides east from west, with river crossing points at Vaisigano Bridge, Leone Bridge (currently closed), and Lelata Bridge. With Vaisigano Bridge traffic restricted for larger vehicles, Vaisigano Bridge is used as the crossing for cars, smaller buses, smaller trucks, and pedestrians. Larger vehicles cross the Vaisigano River at Lelata Bridge.

Car crossing is generally for the purposes of medium to long distance movement between east and west, commuting, picking up children from school, and going downtown. Also, in the traffic survey, roughly 25 percent of the cars using Vaisigano Bridge were taxis. Taxis are used both by tourists and local residents going downtown for shopping and other purposes. During field reconnaissance, shoppers were seen queuing for taxis at a local supermarket. Bridge pedestrians are likely crossing the bridge primarily for their commutes, and for entertainment and their hobbies. In the morning and evening, walkers, joggers, and fishers were seen using the bridge in addition to commuters. On the weekend, people were also seen heading to the beach for marine sports.

(4) Network Benefits

The following are possible benefits from a networking perspective:

- Vaisigano Bridge is on the Samoa Economic Corridor connecting east to west. Rebuilding the bridge as part of the wider road network will help to functionally enhance the economic corridor.
- The current bridge is in danger of collapse due to its age and significant flood damage. Rebuilding it will deflect the risks of collapse and ensure a stable transport route.
- The new bridge will have 2.5-meter sidewalks installed on both sides to allow those in wheelchairs and on bicycles to use the bridge. This will improve pedestrian safety and reduce the risk of traffic accidents.
- Securing a stable transport route for vehicle traffic and improving pedestrian safety can be expected to expand inter-regional networks.

(5) Benefits as Critical Infrastructure in Disaster

The following are possible benefits of the bridge as critical infrastructure in a disaster:

- Large vehicle are restricted from using the current bridge due to insufficient load-bearing capacity. Rebuilding would allow passage of larger vehicles, including emergency vehicles, reducing the time needed for rescues in affected areas and making for smoother delivery of emergency supplies.
- The new bridge has enough clearance to avoid inundation for Vaisigano River flood levels, even accounting for climate change and 100-year flooding. Reducing the risk of damage to water lines, fuel lines, and communication lines on the bridge will help to ensure service for essential utilities.
- Given that the Vaisigano River divides east from west, in a disaster, east and west communities could be separated and unable to move between east and west if all three bridges are closed. Bridge reconstruction can be expected to serve an important role in avoiding road closure in a disaster and maintaining redundancy.

(6) Poverty Rate Data

There are two standards for poverty rates in Samoa: the food poverty line (FPL) and the basic needs poverty line (BNPL). A person is defined as being extremely poor if their expenditures are below the FPL and poor if below the BNPL. These standards differ from the generally used international poverty line denoting those living on less than $1.9 per day (purchasing power parity). According to the Household Income and Expenditure Survey (HIES) in 2013 and 2014, surveying a total of 16,443 people in 2,348 households (approximately 8.5 percent of the population), figures for those below the BNPL and FPL were 18.8 and 4.3 percent respectively for the nation, and 24.0 and 4.5 percent respectively in downtown Apia.

Table2-2-49 Poverty lines (2013-14)

SAT in parentheses

Area	FPL (person/wk.)	Non-food expenditures (person/wk.)	BNPL (person/wk.)	BNPL (household/wk.)
	A	B	C = A+B	D
Samoa	US$13.69 (34.49)	US$9.84 (24.78)	US$23.53 (59.27)	US$208.50 (525.19)
Downtown Apia	US$13.69 (34.49)	US$13.81 (34.78)	US$27.50 (69.27)	US$257.68 (649.07)

*1 SAT = 0.397 USD

Source: Samoa Hardship and Poverty Report

Interview results for Vaisigano Bridge area residents regarding weekly household income are given in the table below. Comparing the downtown Apia BNPL of US$257.68 (for 2013-14) and the survey results, 42.6 percent of households are below the BNPL. Of those who responded, 1.6 percent of households (two households) could be below the FPL.

Table2-2-50 Weekly household income (from interviews)

Units: households

	<US$50	US$50-US$250	US$251-US$500	> US$500	No response
Vaisigano	0	6	8	12	1
Leone	2	16	8	3	11
Matautu-tai	0	7	1	5	1
Matautu-uta	0	21	18	15	15
Total	2	50	35	35	28
Percentage	1.6%	41.0%	28.7%	28.7%	Excl.

2-2-2-5-13 Project Scope

The currently anticipated scope of the Project was determined to confirm its consistency and reach over MNRE's Waterfront Development Project.

An overall plane view of Vaisigano Bridge is given in Figure 2-2-43.

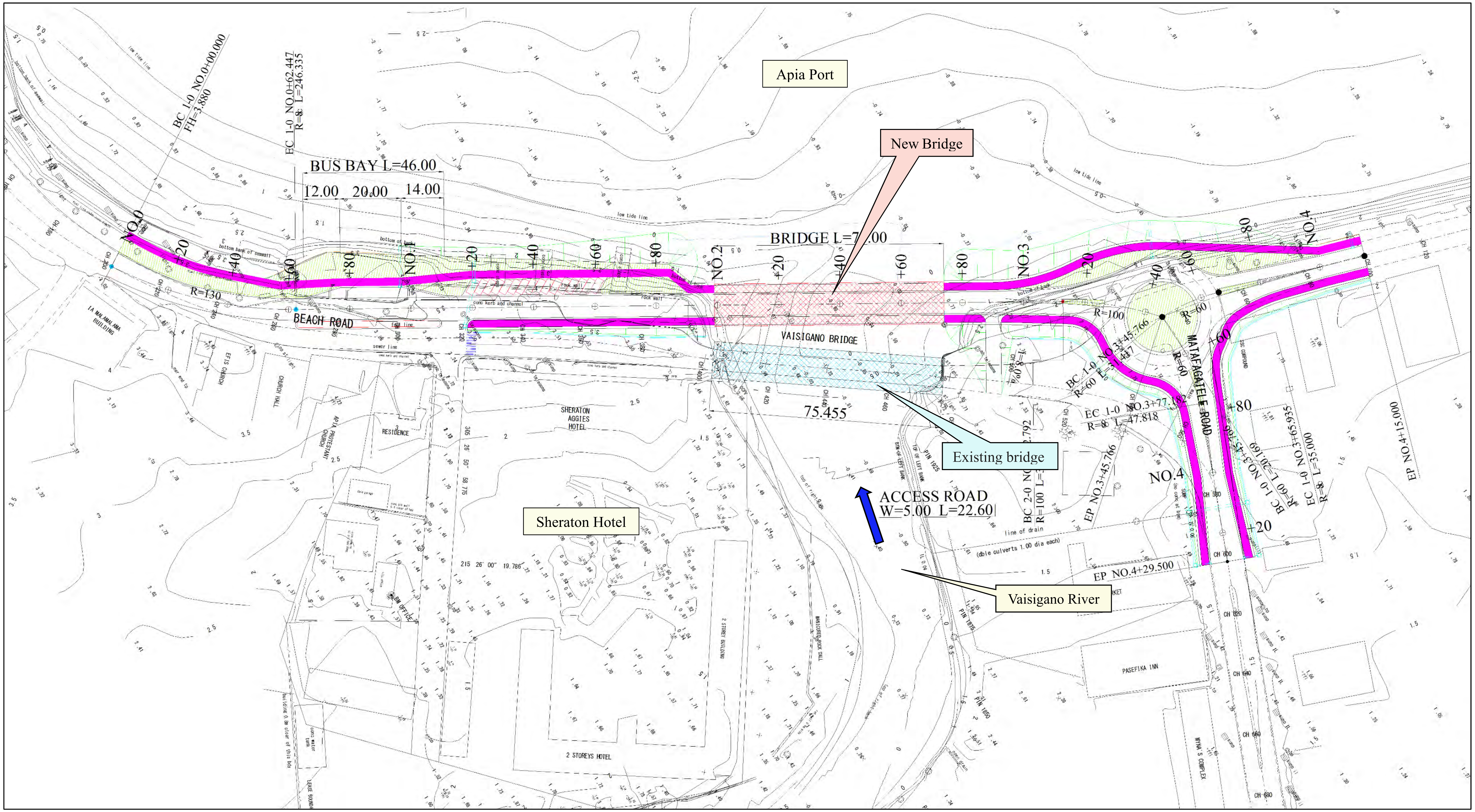


Figure 2-2-43 Overall plane view of Vaisigano Bridge

2-2-2-5-14 Facility Overview

Table 2-2-50　Facility overview

is an overview of facilities for this Project determined in light of the considerations above.

Table 2-2-51　Facility overview

<table>
<tr><th colspan="3">Item</th><th>Format/Specifications</th></tr>
<tr><td colspan="3">Bridge Location</td><td>Shifted 20 m downstream from current bridge location</td></tr>
<tr><td rowspan="2">Width</td><td colspan="2">Bridge Section</td><td>Lane width: 3.5 m × 2 = 7.0 m, shoulder: 0.5 m × 2 = 1.0 m, walkway: 2.5 m × 2 = 5.0 m; Total: 13.0 m (effective width)
Wheel guards: 0.4 m x 2 = 0.8 m = Total 13.8 m (total width)</td></tr>
<tr><td colspan="2">Approach Road Section</td><td>Lane width: 3.5 m × 2 = 7.0 m, shoulder: 0.5 m × 2 = 1.0 m, walkway: 2.5 m × 2 = 5.0 m; Total: 13.0 m (effective width)
Protective shoulder: 0.75 m x 2 = 1.5 m = Total 14.5 m (total width)</td></tr>
<tr><td colspan="3">Bridge Type</td><td>Three-span PC interconnected pretensioned hollow slab bridge</td></tr>
<tr><td colspan="3">Effective Span, Bridge Length</td><td>3 x 25.0 = 75.0 m</td></tr>
<tr><td colspan="3">Bridge Surface Pavement</td><td>Hot asphalt pavement (80 mm on road section)</td></tr>
<tr><td colspan="2" rowspan="3">A1 Abutment
(Apia side)</td><td>Type</td><td>Inverted T</td></tr>
<tr><td>Structure Height</td><td>H=7 m</td></tr>
<tr><td>Foundation Work</td><td>Cast-in-place pile foundation (φ 1.5 m, L = 40.5 m, n=6 piles)</td></tr>
<tr><td colspan="2" rowspan="3">A2 Abutment
(Fagali'i Airport side)</td><td>Type</td><td>Inverted T</td></tr>
<tr><td>Structure Height</td><td>H=7 m</td></tr>
<tr><td>Foundation Work</td><td>Cast-in-place pile foundation (φ 1.5 m, L = 40.0 m, n=6 piles)</td></tr>
<tr><td colspan="2" rowspan="3">P1 Pier</td><td>Type</td><td>Oval</td></tr>
<tr><td>Structure Height</td><td>H=10.0 m</td></tr>
<tr><td>Foundation Work</td><td>Cast-in-place pile foundation (φ 1.5 m, L = 37.0 m, n=6 piles)</td></tr>
<tr><td colspan="2" rowspan="3">P2 pier</td><td>Type</td><td>Oval</td></tr>
<tr><td>Structure Height</td><td>H=10.0 m</td></tr>
<tr><td>Foundation Work</td><td>Cast-in-place pile foundation (φ1.5 m, L = 36.0 m, n=6 piles)</td></tr>
<tr><td colspan="2" rowspan="2">Approach Road</td><td>Length</td><td>Approx. 199 m on Apia side, approx. 155.5 m on Fagali'i Airport side, approx. 70 m on Apia Port side; Total: 424.5 m</td></tr>
<tr><td>Pavement</td><td>Hot asphalt pavement (50 mm surface layer, 50 mm binder course; 100 mm total)</td></tr>
<tr><td colspan="3">Intersection (Fagali'i Airport side)</td><td>Roundabout type</td></tr>
<tr><td rowspan="2">Revetment</td><td>River revetment</td><td>Type (Length)</td><td>Inverted T (22 m on right bank, 17 m on left bank)</td></tr>
<tr><td>Shore revetment</td><td>Type (Length)</td><td>Riprap (160 m on Apia side, 130 m on Fagali'i Airport side)</td></tr>
</table>

2-2-3 Outline Design Drawings

The next page contains outline design drawings based on the master plan above.

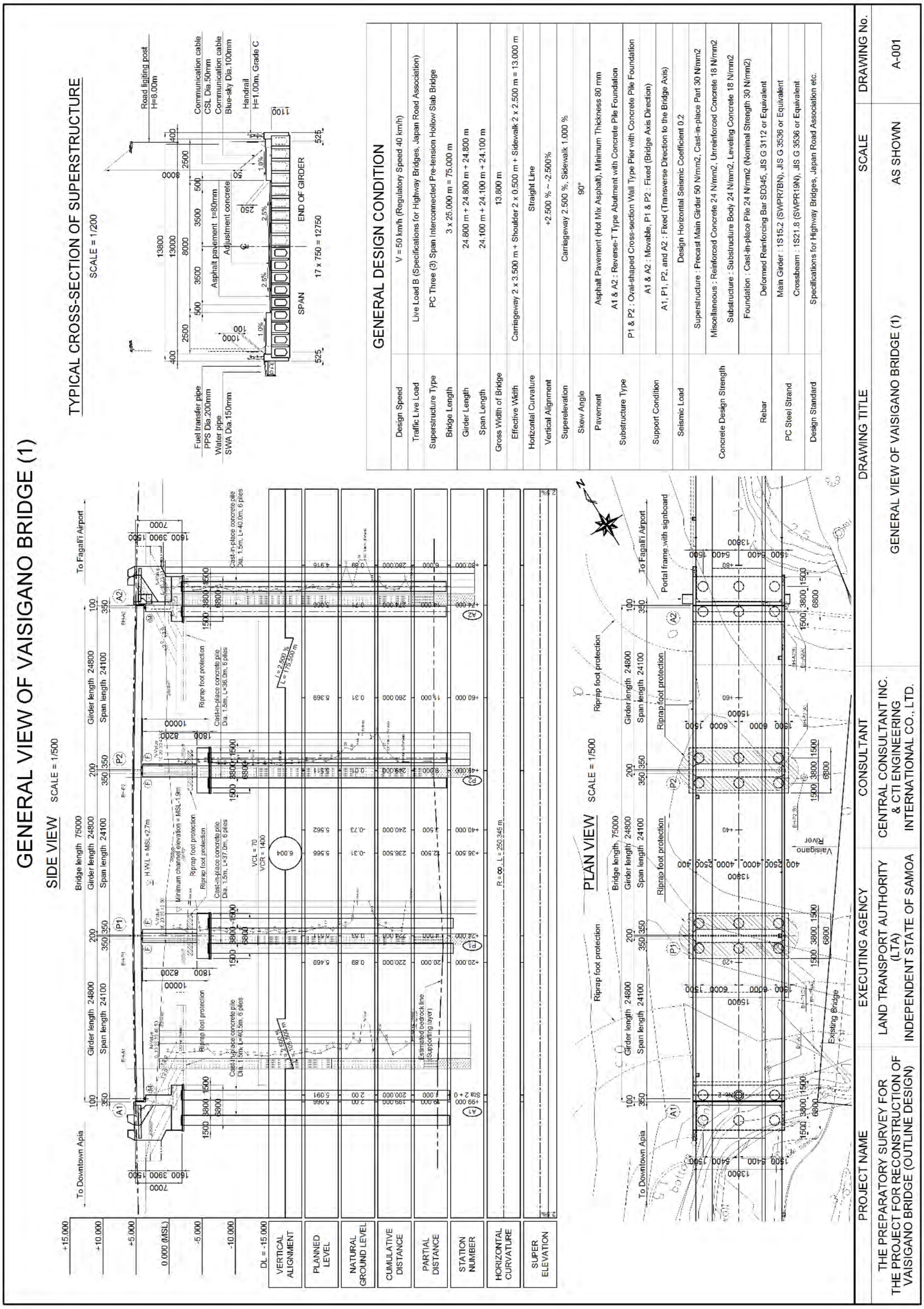


Figure 2-2-44 General view of Vaisigano Bridge

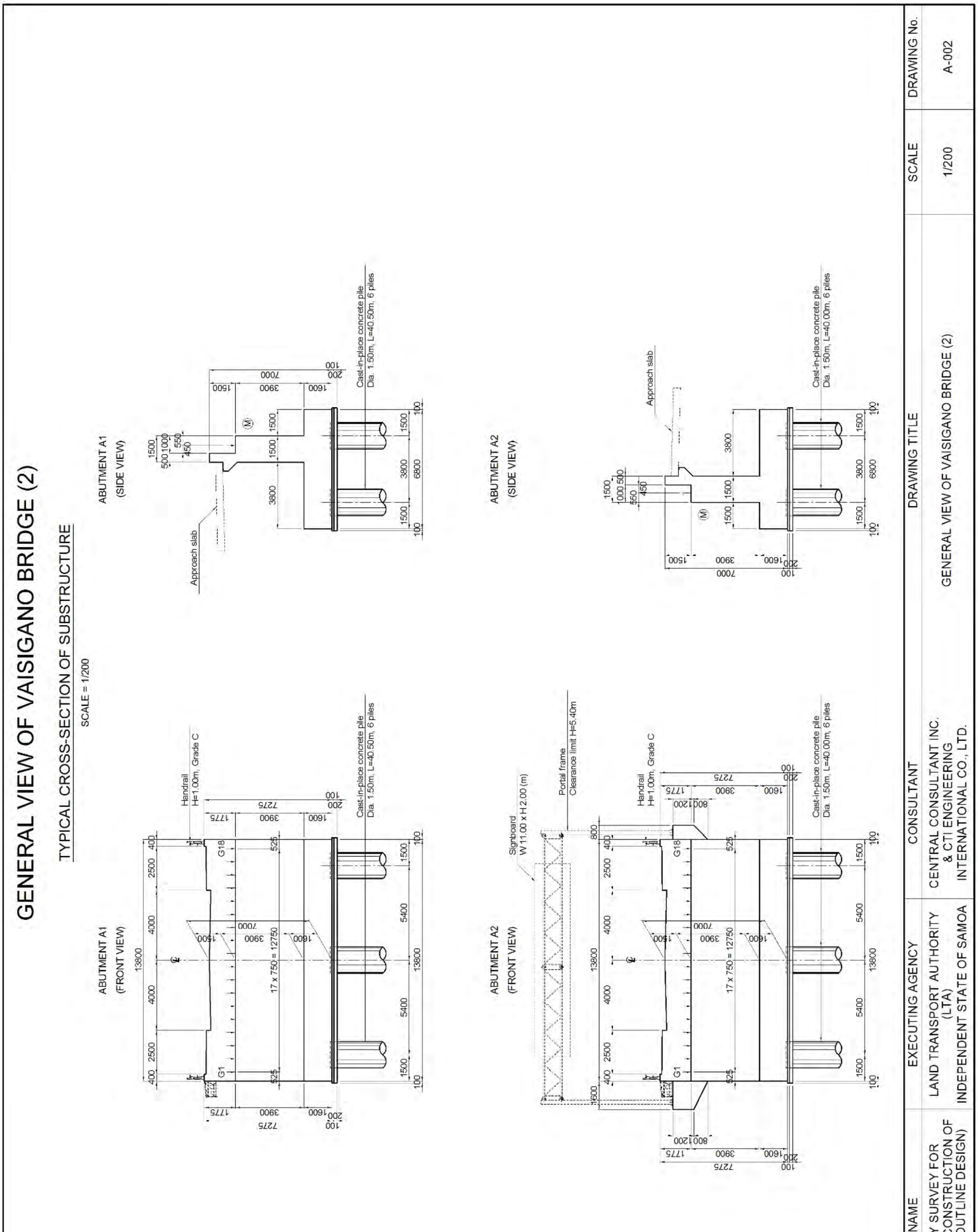


Figure 2-2-45 General view of A1 and A2 abutment

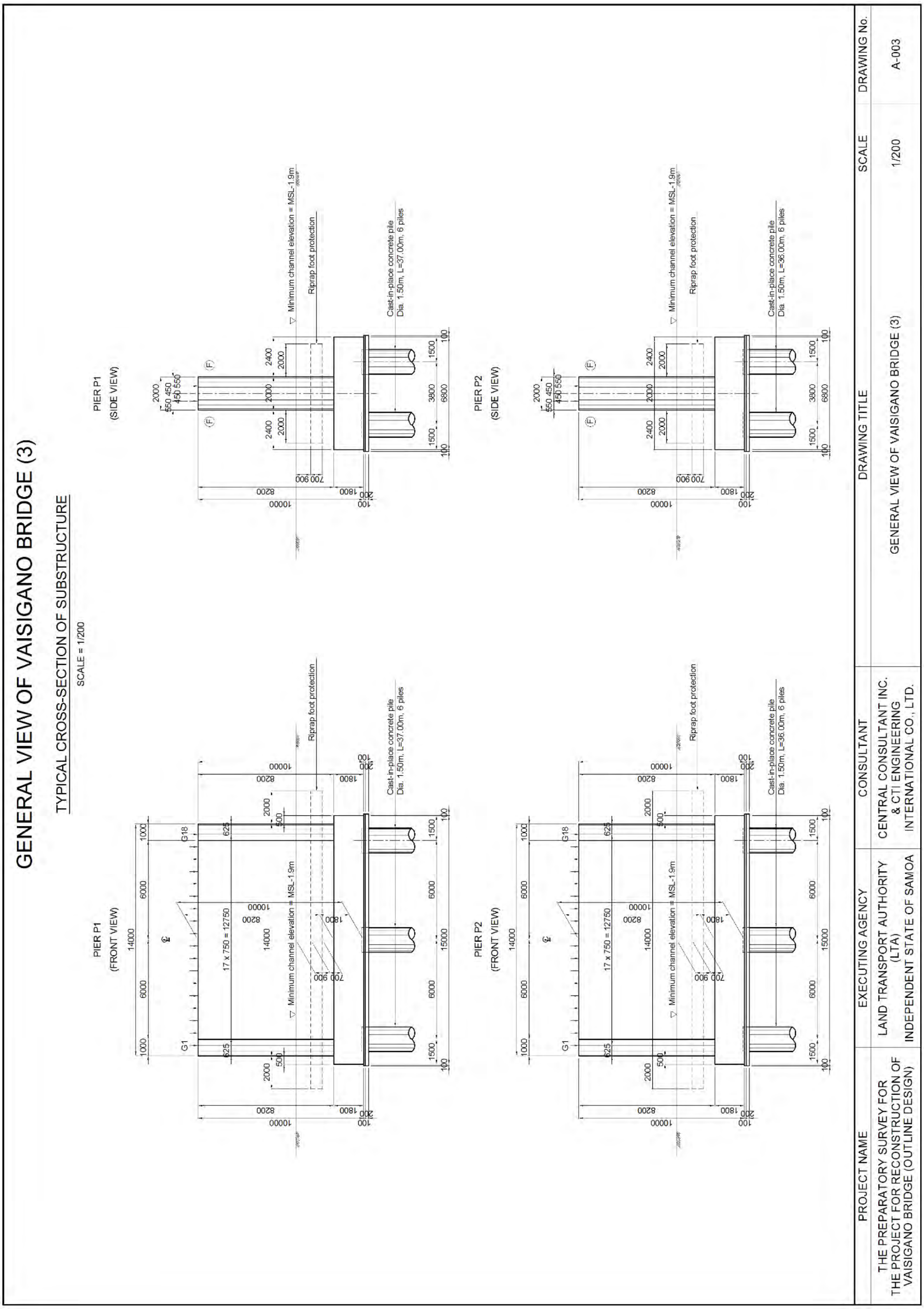


Figure 2-2-46 General view of P1 and P2 pier

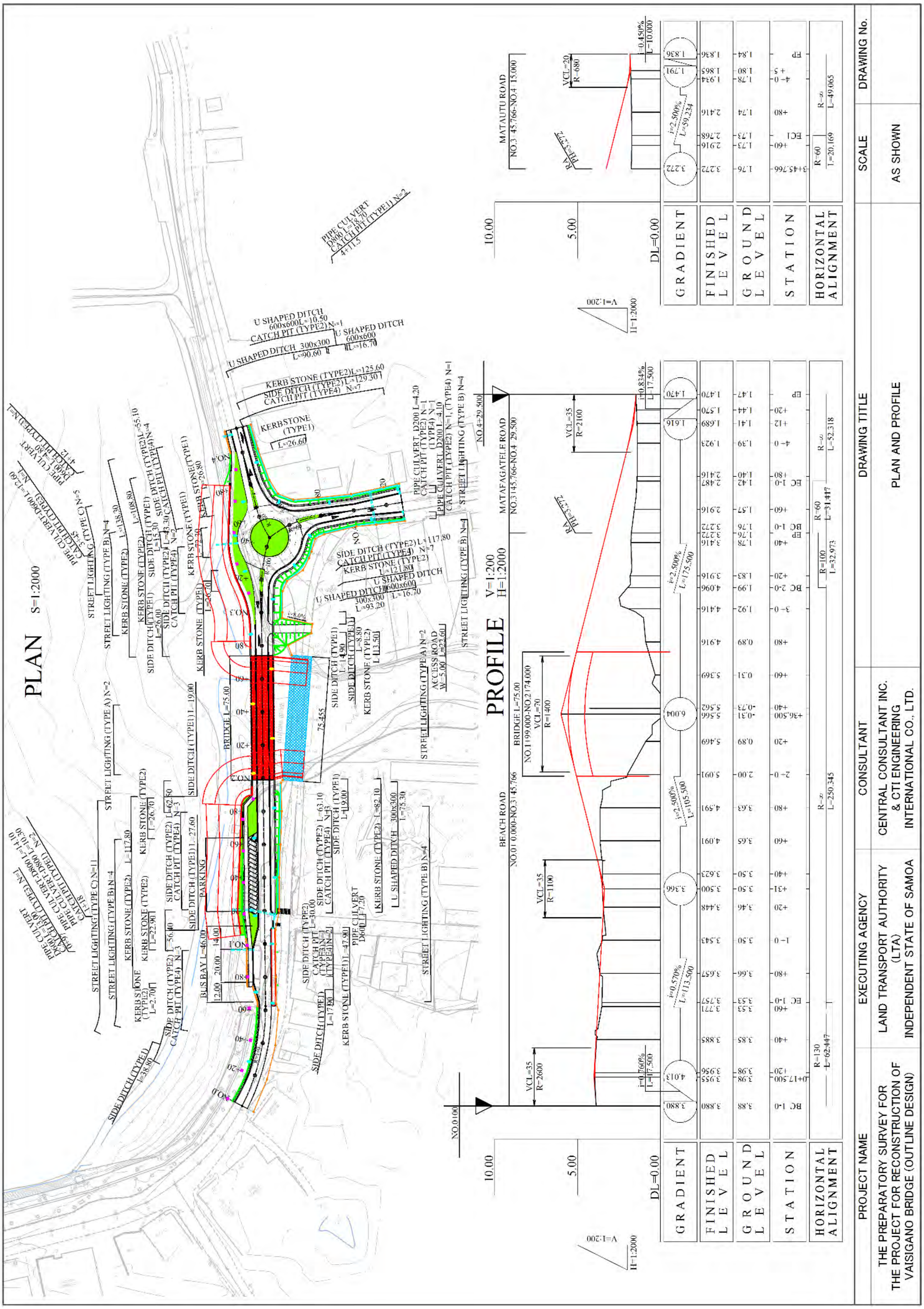


Figure 2-2-47 Plan and profile view of approach road

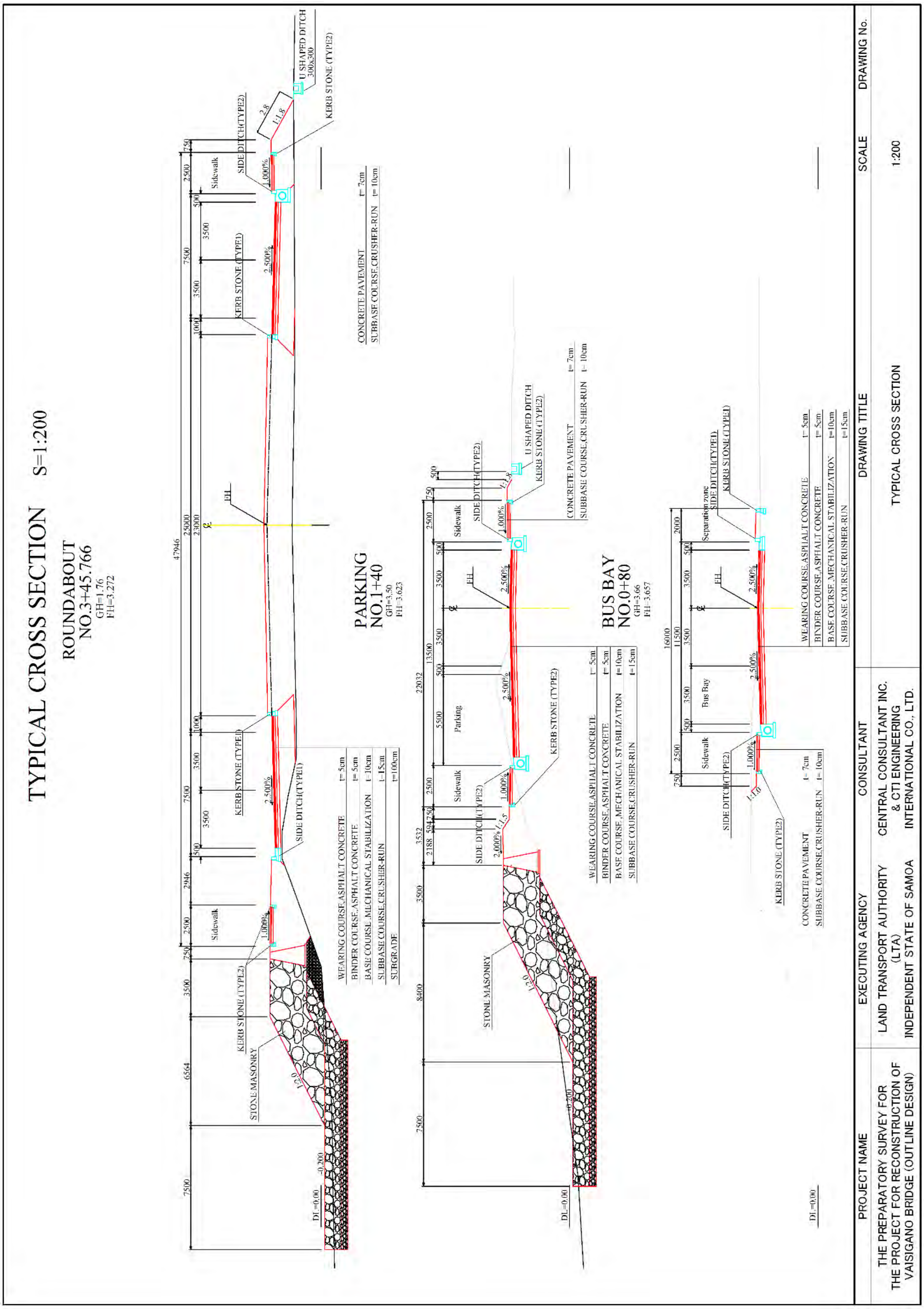


Figure 2-2-48 Typical cross section view of approach road

Figure 2-2-49 Plan of river revetment / coastal revetment

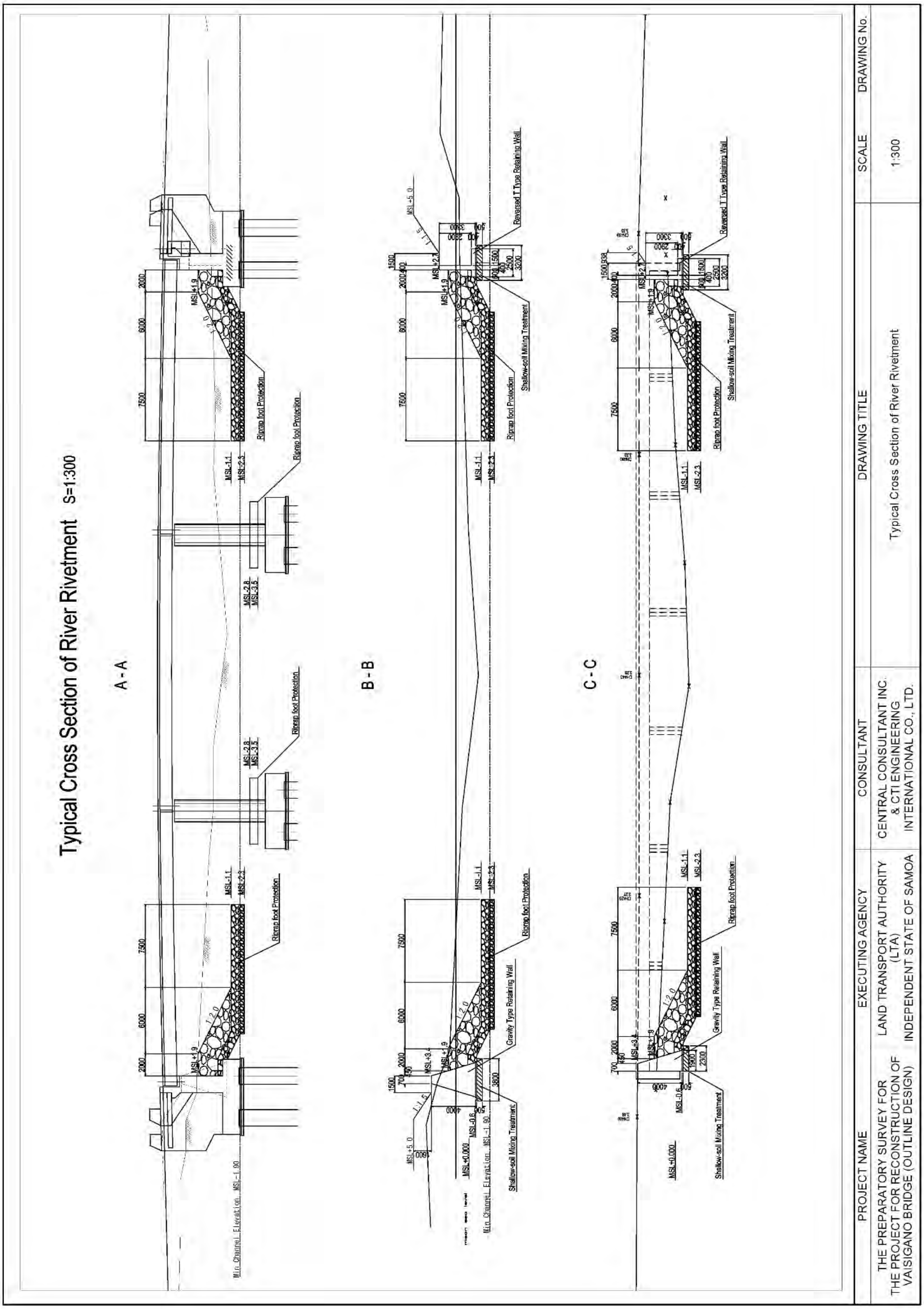


Figure 2-2-50 Typical cross section view of river revetment

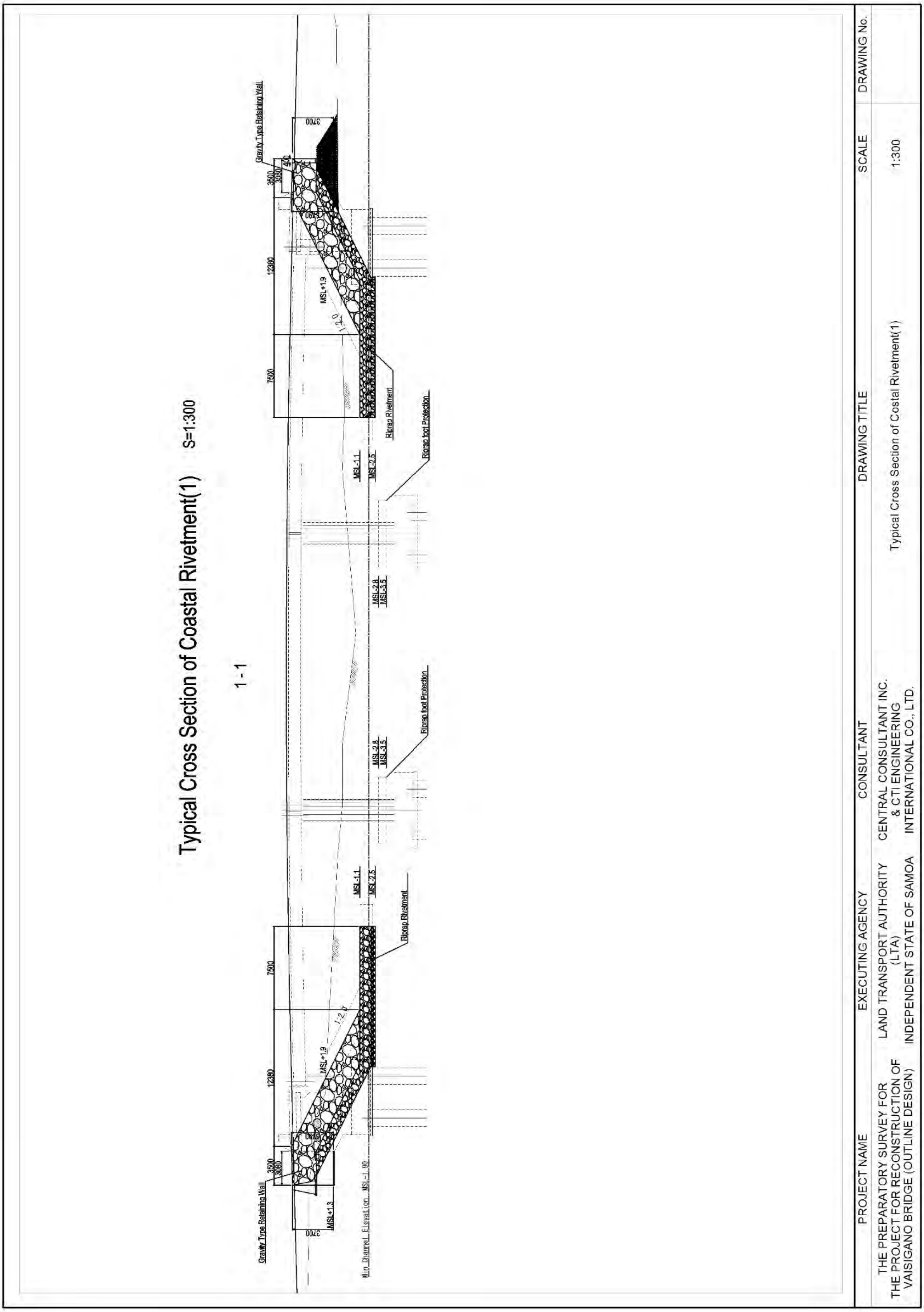


Figure 2-2-51 Typical cross section view of coastal revetment (1)

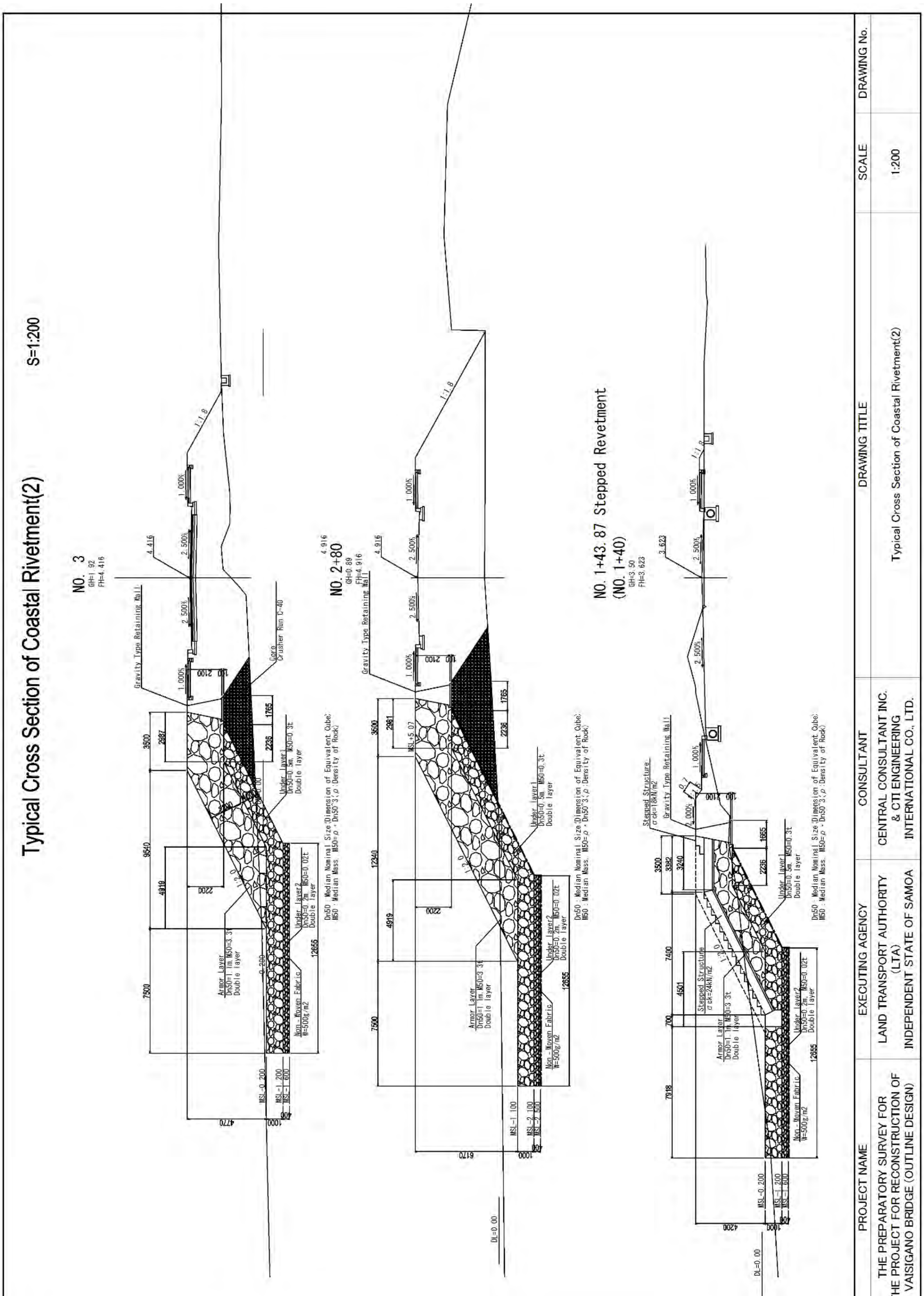


Figure 2-2-52 Typical cross section view of coastal revetment (2)

2-2-4 Construction Plan

2-2-4-1 Construction Policy

This Project will be implemented within the framework of Japanese Grant Aid Assistance, and the following construction policies will be considered.

a) Local engineers, laborers, equipment, and materials will be used to the extent possible to help stimulate the local economy, create employment opportunities and encourage technology transfer in the course of implementing this plan.

b) As the partner country scope, Samoa will be tasked with securing land required to implement this Project (for the approach road, construction yard, etc.) before prequalification notices are made.

c) Samoa will be requested to exempt all taxes and tariffs imposed by the country, including customs, internal taxes, and VAT with regards to the Project, including procurement and import of work-related equipment and materials.

d) Samoa will be tasked with allowing personnel executing the Project to freely enter and leave Samoa.

e) During the foundation work, geological conditions will be confirmed and the work precisely supervised, including confirmation of the bearing ground surface for the pile foundation, to ensure reliable construction.

f) A realistic, sound construction plan will be devised, accounting for rainfall morphology and water level fluctuations and adopting appropriate, reasonable construction methods.

g) Post-completion maintenance and repair schedules and methods, as well as operation policies will be proposed. As part of this, OJT for the Samoan engineers to head up future maintenance will be included as part of the Project.

2-2-4-2 Important Considerations for Construction

(1) Ensuring Safety during the Construction Period

The following are the main considerations to be made to ensure safety during the construction period.

- As construction vehicle traffic will be great on Beach Road, where the site access point is located, security guards will be posted at the access point in help prevent accidents.
- As some work will take place in the river, sufficient systems for monitoring river swelling and a communication network will be established in the interest of safely preventing accidents due to swelling.

(2) Environmental Conservation during the Construction Period

The following are the main considerations to be made for environmental conservation during the construction period.

- Water sprinkling and speed restrictions will be put in place to control the amount of dust created by the movement of construction vehicles.

- Early morning and late night hours will be avoided for the work due to the noise and vibrations that construction machinery create.
- Measures such as securing a spare tank and pump will be taken to prevent river water pollution from mud discharged in riverwork for the substructure and foundation.
- Sodding and other measures will be taken on embankment slopes.

(3) Observing Labor Standards Legislation

Construction contractors will observe current Samoan legislation related to construction and will prevent conflict with workers and ensure safety by observing appropriate working conditions and customs when employing workers.

(4) Fully Utilizing Non-Flood Seasons

Samoa has hot temperatures and much rainfall. The rainy season is November to April, with more than 1,000 mm of rainfall in the heavy months. For the pier and foundation work to take place in the river, costs for river diversion work will fluctuate greatly depending upon the implementation period. Thus, the plan is to perform pier and foundation work for the Project during the non-flood seasons (May to October), with a focus on reducing costs for river diversion work. Accordingly, these conditions will be clearly stated in the tender documents so that all bidders are informed without exception during bidding, and construction contractors will be directed to fully utilize the non-flood periods during the implementation.

(5) Focus on Quality Control for Concrete

The bulk of the work in the Project is concrete work; major work will be the A1 abutment, A2 abutment, P1 pier, and P2 pier for the substructure and concrete pillars and PC cables for the superstructure. Accordingly, quality control for concrete must be treated as a top priority item in work implementation. Quality control will focus on managing aggregate, sand, water, cement, and other materials; regulating concrete mixing plant specifications; regulating concrete transport; managing concrete casting and curing; and other tasks.

2-2-4-3 Construction Work Scopes

The table below is an overview of the respective scopes of the Japanese and Samoan governments in implementing this Grant Aid Assistance project.

Table 2-2-52 Respective responsibilities of Japanese and Samoan governments

Japanese Side Responsibilities	Samoan Side Responsibilities
・Reconstruction of Vaisigano Bridge (75 m long) and construction of the 424.5-m approach road, revetments, and other facilities. ・Removal of the existing bridge. ・Safety measures for work and general traffic through the work zone during the work period. ・Measures to prevent pollution due to work during the work period. ・Procurement, importing and transportation of construction equipment indicated in the Equipment Procurement Plan. Re-exporting imported equipment to the countries from which it was procured. ・Execution design as shown in the Construction Supervision Plan, preparing tender and contract documents, tender assistance, and construction supervision for the work. Includes supervision for the Environmental Management Plan (EMP).	・Land acquisition and removal of impacted facilities required for this plan. ・Arranging land for temporary facilities required for the Project for free. ・Removal and relocation work for the fuel lines, water lines, power lines, and communication lines impacted by implementation of the Project. ・Providing power, phone service, water service and other utilities for the site office and residences. ・Issuing IDs to construction personnel and stickers for construction vehicles. ・Arranging waste disposal areas required for this cooperation Project. ・Monitoring the overall work zone during the construction period. ・Exemption from customs duties and internal taxes levied by the Samoan government as well as other surcharges based on tax policy. ・Monitoring by Samoan government personnel during the construction period. ・Granting Japanese and other third country personnel involved in this Project the right to enter and stay in Samoa. ・Cover bank fees (opening of bank accounts and payment authorization procedures). ・Monitoring of environmental and social considerations during the work period and during service.

2-2-4-4 Construction Supervision Plan

(1) Basic Policy for Construction Supervision Work

This Project is expected to be implemented within the framework of Japanese Grant Aid Assistance, and the following construction policies will be the basic policy for construction supervision work.

- The quality of construction has a huge impact on the lifespan and durability of completed facilities; thus, construction will be supervised with the utmost focus on quality supervision. Particular care will be given to concrete work, foundation work, and river work on the revetments.

- Following quality supervision in importance are progress management, safety management and payment supervision.
- To fulfill these supervision objectives, joint site inspections and regular meetings with construction contractors and the consultant will be held once per week to confirm problems and discuss ways to deal with them.
- In addition, regular meetings between representatives of LTA (the client), construction contractors and the consultant will be held once per month to confirm problems and discuss ways to deal with them.
- Local engineers will be hired as inspectors, and efforts to transfer technology in terms of methods for the construction supervision objectives of quality, progress and safety management.
- Instructions to construction contractors, records of all meetings and reports to the client will be documented and reported in physical document form.

(2) Consultant's Construction Supervision Work

The following is the main work included in the consultant's contract.

1) Tender document preparation phase

Make the implementation design for each facility based on the results of the outline design study report. Then prepare construction contract documents and get Samoan government representative LTA to approve the resulting documents below.

- Design report
- Design drawings
- Tender documents

2) Construction tender phase

With the help of the consultant, LTA will hold a public tender to select construction contractors with Japanese nationality. In addition, representatives selected by the Samoan government to participate in these public tenders and construction contracts after the tenders will have all approval authorities concerning construction contracts. The consultant will assist LTA by performing the following services.

- Tender announcement
- Preliminary qualification examination
- Tender and tender assessment

3) Construction supervision phase

Construction contractors selected as a result of tenders and Samoan government representative LTA will sign construction contracts, and the consultant will order the construction contractors to begin construction and will begin supervising construction. As part of this supervision work, the consultant will report the progress of construction directly to LTA, the Embassy of Japan in Samoa, and JICA in addition to sending monthly reports to other relevant personnel as necessary. The consultant will supervise construction contractors by offering them improvement strategies and suggestions for business conduct related to work progress, quality, safety and payment as well as for technical work. The consultant will also inspect the work for flaws one year after they have completed construction supervision work. These inspections will conclude their consulting services.

(3) Personnel Plans

The following personnel and roles are required for each of the detailed design, construction tender and construction supervision phases.

1) Detailed design phase

- Project manager: Responsible for technical aspects of the detailed design, managing overall project coordination and responding to the client.
- Bridge engineer (superstructure): Conducts field surveys, structure calculation, and quantity estimation and create design drawings related to superstructure design.
- Bridge engineer (substructure): Conduct field surveys, structure calculation, safety calculation, and quantity estimation and create design drawings related to substructure design.
- Road engineer: Calculate the final alignment for road design, determine the typical cross-sections, consider banking work, design the final road drainage, create design drawings and conduct quantity estimation.
- River engineer: Conduct field surveys, structure calculation, safety calculation, and quantity estimation and create design drawings related to river structure design.
- Construction plan/estimation: Create the construction plan and prepare estimations using design quantities and individual construction costs derived from detailed design outcomes.
- Tender documents: Create tender documents.

2) Construction tender phase

Assist LTA with finalizing prequalification examination documents and tender documents, conducting prequalification examinations and assessing the tendered construction bids.

- Project manager: Manage the aforementioned consultant services throughout the entire tender.
- Bridge engineer: Approve tender documents and assist in the tender assessment.

3) Construction supervision phase

- Project manager: Manages all consultant construction supervision services.
- Resident engineer: Oversees construction management on site, and reports construction progress to and coordinates with relevant Samoan organizations.
- Structural engineer: Reviews construction plans for bridge and revement work, and performs stress controls for concrete work and superstructure PC work. During foundation work, checks the floor surface identified after excavation and makes any needed on-site adjustments for the foundation work.

2-2-4-5 Quality Control Plan

The quality control plan for the Project is given in the following table.

Table 2-2-53 List of quality control items (proposal)

Item			Test Method	Frequency of Test
Subgrade (macadam)	Blended material		Liquid limit, plasticity index (<sieve No. 4)	For each blend
			Particle-size distribution (blending)	〃
			Aggregate abrasion loss test	〃
			Aggregate density test	〃
			Maximum dry density (compaction test)	〃
	Laying		Density test (compaction rate)	Once/day
Prime coat / tack coat	Material	Bituminous material	Quality certificate	For each material
			Application amount	Per 500 m^2
Asphalt	Material	Bituminous material	Quality certificate, ingredient analysis table	For each material
		Aggregates	Particle-size distribution (blending)	For each blend, once/month
			Water absorption	For each material
			Aggregate abrasion loss test	〃
	Blending test		Stability	For each blend
			Flow value	〃
			Porosity	〃
			Aggregate porosity	〃
			Tensile strength (indirect)	〃
			Residual stability	〃
			Design asphalt amount	〃
	Laying		Mixing temperature	As needed
			Rolling temperature	For each transport
			Marshall test	About once/day
Concrete	Material	Cement	Quality certificate, chemical & physical test results	For each material
		Water	Ingredient test result	For each material
		Admixture	Quality certificate, ingredient analysis table	For each material
		Fine aggregates	Oven dry density	For each material
			Grain size distribution, fineness modulus	〃
			Percentages of clay lumps and soft particles	〃
		Coarse aggregates	Oven dry density	For each material
			Flake content	〃
			Particle-size distribution (mix)	〃
			Sodium sulfide diagnosis (missing mass)	〃
	At the time of blend test		Compressive strength test	For each blend
	At the time of laying		Slump	Once/batch
			Temperature	Once/day
	Strength		Compressive strength test (7 days, 28 days)	Once/day or = 50 m^3
Steel bars	Material		Quality certificate, tensile test result	For each lot
Structural steel	Material		Mill sheet	For each lot
Coating	Material		Quality certificate, ingredient table	For each lot
Bearing	Material		Quality certificate, strength test result	For each lot
Lighting equipment	Material		Quality certificate, strength test result	For each lot

Note) The test is basically conducted once before use. Whenever material is changed, the test shall be conducted each time.

2-2-4-6 Equipment and Material Procurement Plans

(1) Construction Material Procurement

Sand, aggregate, road base materials and lumber can be produced locally. Others need to be imported. Material procurement policy is as follows.

- Procure imported products that are always available for purchase and are of sufficient quality.
- Procure products that cannot be procured locally from Japan or a third country. Compare factors such as price, quality and time required for customs to determine where to procure these products.

Possible suppliers for the main construction materials are as shown in the table below.

Table 2-2-54　Possible suppliers for the main construction materials

Item	Supplier			Reason for supplying from Japan
	Samoa	Japan	3rd country	
PC steel		○		Not in distribution in Samoa. Can be sourced in other nearby countries, but may not meet specifications.
Handrails		○		Not in distribution in Samoa. Handrails are highly visible to bridge users, and there may be defects with product from other nearby countries due to their unstable quality.
Temporary facility steel		○		Not in distribution in Samoa. Can be sourced in other nearby countries, but may not meet specifications.
Rubber bearings		○		Not in distribution in Samoa. Can be sourced in other nearby countries, but may not meet specifications due to unstable material quality (of rubber).
Bitumen	○			
Aggregate	○			
Asphalt bitumen	○			
Portland cement	○			
Expansion joints		○		Not in distribution in Samoa. Can be sourced in other nearby countries, but may not meet specifications due to greatly unstable quality.
Rebar		○		Not produced in Samoa. Confirmed that contractors will source their own from China, New Zealand or other countries. Will be sourced from Japan as while there is a local supplier, they are not capable of procuring large quantities.
Formwork wood	○			
Main girder steel formwork		○		Will be sourced from Japan given the required precision.
Diesel	○			
Gasoline	○			
Bridge deck waterproofing material		○		Not in distribution in Samoa. Can be sourced in other nearby countries, but may not meet specifications.

(2) Construction Machinery

Construction machinery for road construction can be procured within Samoa. However, machinery for bridge production and erection cannot be procured within Samoa, thus it will be procured from Japan or a third country.

There is a ready-mixed concrete plant and asphalt plant near the work areas, and thus product from these plants will be purchased.

The possible suppliers for the main construction machinery and reasons for supplying from Japan are as shown in the table below.

Table 2-2-55 Possible suppliers for main construction machinery

Equipment model	Supplier			Reason for supplying from Japan
	Samoa	Japan	3rd country	
Dump trucks (2t, 4t, 10t)	○			
Bulldozers (15t, 20t, 32t)	○			
Backhoes (0.45 m^3 (accumulator), 0.80 m^3 (accumulator)	○			
Tractor excavator (Wheel loader) 1.2 m^3	○			
Large breaker, 1300 kg	○			
Trailer (35t)	○			
Pole trailer		○		Not available locally, and sourcing from another country would make it harder to source parts for needed maintenance of malfunctions due to no guarantees on equipment procurement and deadlines.
Road grader	○			
Water truck	○			
Tire roller	○			
Vibration roller	○			
Asphalt finisher	○			
Agitator truck	○			
Concrete pump vehicle		○		Not available locally, and sourcing from another country would make it harder to source parts for needed maintenance of malfunctions due to no guarantees on equipment procurement and deadlines.
Cooling plant		○		
Truck crane (max 25t)	○			
Truck crane (160t)		○		Not available locally, and sourcing from another country would make it harder to source parts for needed maintenance of malfunctions due to no guarantees on equipment procurement and deadlines.
Crawler crane (60-65t)		○		
Vibro-pile driver		○		
Full hydraulic rotary pile driver		○		

2-2-4-6-2 Implementation Schedule

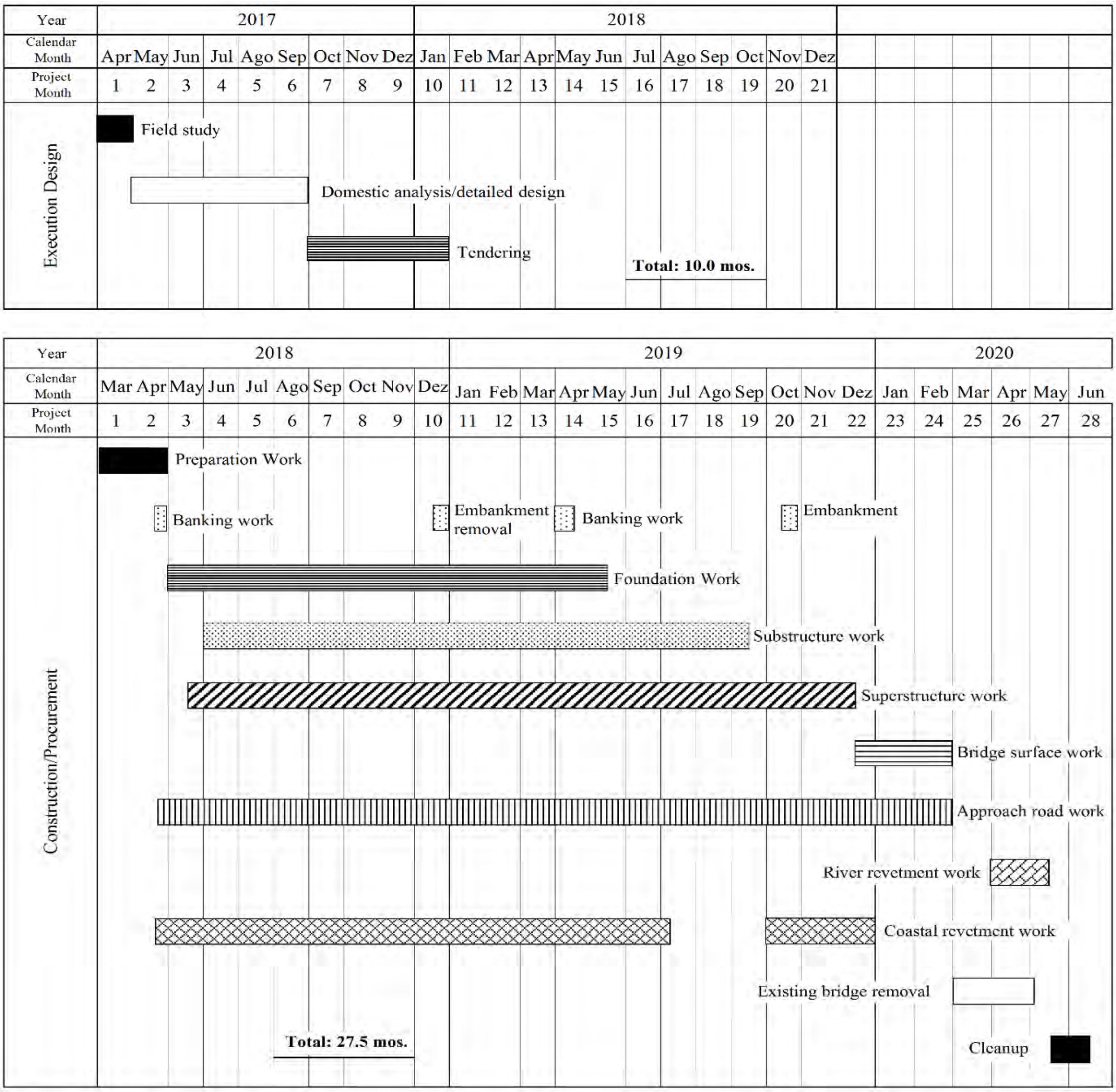
After the exchange of notes (EON) for execution design of the Project is concluded, the consultant will sign a consultant work contract with the Samoan government and start on Project execution design work as Grant Aid Assistance. After starting the work, the consultant will conduct a two-week field study for execution design, then return to Japan and draft the detailed design and tender documents.

Subsequently, after concluding the EON for tender assistance work, construction supervision work, and bridge construction, the consultant will assist the Samoan government in preparing the tender documents; qualifying, tendering, and selecting contractors; signing the work agreements; and other tasks related to the tender process as their tender assistance work.

After bidding, construction contractors will exchange work agreements with the Samoan government for Japanese government certification. Once certified, the consultant will issue the construction contractors a work order to start the construction.

The implementation schedule for the above work is given in the following table.

Table 2-2-56 Work implementation schedule



2-3 Obligations of Recipient Country

In the implementation of this Project, the Samoan government should assign these tasks accordingly.

2-3-1 General Information for Japanese Grant Aid Assistance

- Provide data and information required to implement this project plan.
- Acquire land required to implement this project plan (rights of way, work areas, camp yards, land for material storage).
- Grade each construction site before starting construction.
- Open a Japanese bank account in the name of the Samoan government and issue authority to pay.
- Swiftly unload cargo at the unloading point in Samoa and ensure that tax and customs duty exemptions are enforced.
- Exempt Japanese corporations and citizens contributing to the Project from customs duties, internal taxes and other taxes levied by Samoa as they provide products and services according to approved contracts.
- Based on approved contracts and in order to receive services, allow project personnel to enter Samoa and stay in both countries to do project work.
- Grant permission and other authority related to project implementation as necessary.
- Properly and effectively maintain and manage facilities built under this Project.
- Assume responsibility for all expenses generated in the scope of project work but not covered by Japanese Grant Aid Assistance.

2-3-2 Matters Specific to This Project

- Remove facilities negatively affected by construction
- Attain MNRE approval of EIA
- Secure land outside existing rights of way as required for this plan
- Relocate the fuel lines, water lines, power lines, communication lines, utility poles, and distribution lines obstructing the work
- Arrange and grade temporary yards
- Arrange spoil banks and waste disposal areas

(To be completed before prequalification notice is made)

- Issuing IDs to construction personnel and stickers for construction vehicles
- Monitor the overall construction area during the construction period
- Monitoring by Samoan government personnel during the construction period

2-4 Project Management and Maintenance Plan

Samoa will supervise the implementation and maintenance for this Project. LTA of the MWTI will head up the maintenance for the bridge, approach road, and revetments newly constructed in the Project.

A resident supervisor will propose post-completion maintenance and repair schedules and methods, as well as operation plans. As part of this, OJT for the Samoan engineers to head up future maintenance will be included as part of the Project.

Post-completion maintenance work can be divided into maintenance performed regularly on an annual basis, and that performed every few years. The types of maintenenace required for this project are as shown below.

2-4-1 Maintenance Methods

(1) Required Yearly Inspections and Maintenance

The inspections and maintenance required yearly are as follows:

- Cleaning and removal of sediment and waste clogging bridge surface drainpipes and drainage
- Waste removal and cleaning of expansion joint and around supports
- Repainting pavement markings and other traffic safety work maintenance
- Post-flood inspection and repair for revetment work
- Post-flood removal of fallen rocks, driftwood, and other detritus
- Weeding road shoulders and slopes
- Patching pavement

(2) Maintenance Performed at Predetermined Intervals

- Maintenance to be performed approximately once every five years is as follows:
  - Overlay of pavement for the bridge surface and approach road
  - Revetment inspection and repair
  - Inspect, repaint, and repair handrails

2-4-2 Maintenance System

The following will be performed to ensure the maintenance methods in 2-4-1 Maintenance Methods above are conducted properly.

a) A maintenance team comprising the following members will be established within LTA:
   - Engineer: 1
   - Inspectors: 2
   - Recorder: 1

b) A system will be put into place that can swiftly treat any small-scale repairs deemed necessary in regular inspections.

c) Training will be planned for the inspectors and recorder by means of developing maintenance manuals and dispatching specialists. Regular inspection records will be compiled into a database, facilitating accurate estimates for necessary maintenance costs.

d) Project drawings (as-built drawings, bridge inventories, etc.) will be stored, and a system built to facilitate future repairs.

2-5 Estimated Costs for the Project

2-5-1 Estimated Grant Aid Project Costs

2-5-1-1 Cost Born by the Government of Japan

The project will be implemented in accordance with the Japan's Grant Aid scheme and the cost will be determined before concluding the Exchange of Note for the project.

2-5-1-2 Expenses Borne by the Samoan Side

Table 2-5-1 Expenses Borne by the Samoan Side

Resposibility	Item Cost (x10,000 SAT)	JPY Equivalent (x10,000 JPY)
(1) Land lease fees	29.1	1,259
(2) Fuel line material cost	10.2	443
(3) Water line material cost	9.9	428
(4) Communication cable material costs	10.3	444
(5) Lighting overhead power line removal costs	0.1	4
(6) Bank fees	20.6	892
Total	80.2	3,470

2-5-1-3 Estimate Conditions

- Time of estimate: Jul. 2016
- USD exchange rate: $1.00 = 109.04 JPY (3-month average from Jun. 30 to Sept. 30, 2016)
- SAT exchange rate: SAT1.00 = 43.28 JPY (3-month average from Jun. 30 to Sept. 30, 2016)
- Construction period: 27.5 months
- Other: This Project is implemented according to the Japanese government Guidelines for Grant Aid. The above project cost estimations will be revised by the Japanese government before the EON.

2-5-2 Operation and Maintenance Cost

The O&M for the new bridge, approach road, and revetments developed in the Project will be managed by LTA. Annual average O&M costs are estimated at SAT 48,100. As shown in the table below, the main O&M tasks following Vaisigano Bridge construction are daily inspections, cleaning, and repairs. These O&M costs total 0.6% of the LTA roads maintenance budget for 2016 of 8.2 million SAT. LTA is thus thought to be sufficiently capable of handling the O&M.

Table 2-5-2 Main O&M items and expenses

Category	Frequency	Area Inspected	Work Details	Est. Cost (1,000s SAT)		Notes
				Per Inspection	Per Annum (Annual Avg.)	
Drainage O&M	4 times/yr.	Bridge surface drains and gutters	Sediment removal	2.5	9.8	
Expansion joint and bearing O&M	Annually	Around expansion joints and bearings	Remove trash and clean	0.4	0.4	
Traffic safety work O&M	Annually	Road markings	Repaint	0.4	0.4	10% of direct cost anticipated
Road maintenance	Twice annually	Road shoulders and slopes	Weeding	1.0	2.0	
Inspection and repair for revetments and bed protection	When flooded (expected every 5 years)	Revetments and bed protection	Repair damaged areas	54.5	10.9	2% of direct cost anticipated
Pavement maintenance and repair	Once/5 yrs.	Paved surfaces	Overlay and repair cracks, potholes, etc.	54.0	10.8	10% of direct cost anticipated
Direct construction cost					34.3	
Overhead (40%)					13.7	
Annual O&M costs (yearly average)					48.1	

Chapter 3　Project Evaluation

Chapter 3 Project Evaluation

3-1 Preconditions

Preconditions for implementing this project:

a) 10,000 m^2 of land for a temporary construction yard and other uses are required for the construction of the Vaisigano Bridge. LTA has provided four candidate locations. In the future, candidate locations will be specified during the detailed design, and if someone else is using the land, land vacation and other preparations must be complete by the time the PQ announcement is made.

b) Approval and authorization of an environmental impact assessment (EIA) is required for bridge construction.

c) Appropriate candidate locations for borrow areas and quarries must be selected by the time the PQ announcement is made.

d) Permits for quarrying and tree removal are required for the borrow areas and quarries.

3-2 Necessary Inputs by Recipient Country

Necessary efforts the partner country must make to produce and sustain the project outcomes:

a) Securing funds set out in this report (Section 2-5-1-2: Expenses Borne by the Samoan Side) in advance to facilitate project implementation.

b) Of the above requirements, borrowed land for the construction yard and the like must be secured completely and finally by the time construction starts.

c) To ensure the long-lasting functions of the bridge, road and embankments to be built under this project, secure the personnel and funding required for the according operation and maintenance described in this report (Section 2-4: Project Operation Plan).

3-3 Important Assumptions

Important assumptions for producing and sustaining the project outcomes:

a) Although the new bridge and access road are designed for speeds of 50 km/h, it is located in an urban area. Signage that limits the speed to 40 km/h as a measure to prevent accidents, and other safety measures should be rigorously undertaken.

b) Although the new bridge and access road are designed to handle the 43-ton loads of trailer trucks, enforcement of prohibitions of overloading and other measures to extend the structures' depreciation period should be rigorously undertaken.

c) In principle, plans call for prohibiting large vehicles from entering Apia city limits. Thus, measures to prohibit the passage of large vehicles (except emergency vehicles) across the new bridge should be rigorously undertaken.

3-4 Project Evaluation

3-4-1 Relevance

In light of the following points, it is deemed relevant to implement this project as a Japanese grant aid project.

a) The benefits of the project will reach a considerable number of Samoan citizens in the commercial district in western Apia, eastern Apia and the eastern region of Upolu. (The project will directly benefit 36,700 people in downtown Apia, 62,400 people in northwestern Upolu, and 44,300 people in Upolu and other regions for a total of 143,400 people, and will indirectly benefit 187,800 Samoan citizens.)

b) The project outcomes are urgently needed to facilitate physical distribution and improve the lives of residents. Project outcomes include enhancing the transportation network that comprises Beach Road, the nation's most important arterial highway, and arterial roads Matafagalte Street and Matautu Street; ensuring reliable passage of traffic, facilitating traffic, and reinvigorating the community economy.

c) The Samoan side is able to operate and maintain the bridge and road with its own funds, human resources and technology after the project is completed; excessively advanced technology is not required.

d) The Strategy for the Development of Samoa (SDS) 2012-2016 regards the Plan to Replace Vaisigano Bridge as a priority project, and names two critical challenges for the road sector: the improvement of roads connecting the port, airport and other important points to create a Samoa Economic Corridor, and roads that are resilient against cyclones and other disasters.

e) This project is a priority vehicle regarded as a specific strategy for "improving the reliability of the road network and strengthening it against natural disasters and inclement weather," which are named in the National Infrastructure Plan as critical challenges for the road sector.

f) This project has hardly any negative impact on the environment.

g) This project can be implemented without any particular trouble under the Japanese grant aid system.

h) The new bridge will be a three-span PC interconnected pretensioned hollow slab bridge, which is difficult to design and construct using Samoan technology; it is necessary and advantageous to use Japanese technology.

3-4-2 Effectiveness

3-4-2-1 Quantitative Effects

Implementing this project should deliver the following quantitative effects.

Indicator	Standard value (actual 2016 values)	Target value (2023) (three years after project completion)
Annual average daily traffic, all vehicles (vehicles/day)	18,839 16,567[1]	17,300
Annual average daily traffic, freight vehicles (vehicles/day)	563	580
Freight vehicle travel time from Apia Port to Vaitele Industrial Zone (min)[2]	16.2	12.9
Transportation capacity: Travelers (people/year)	15,630,000	16,330,000
Transportation capacity: Freight (tons/year)	310,000	320,000

[1]Traffic volume does not include vehicles detoured from the upstream Leone Bridge because of closure due to typhoon damage.
[2]Daytime hours.

3-4-2-2 Qualitative Effects

Implementing this project should deliver the following qualitative effects.

a) Shorten travel time to improve convenience and ensure reliable passage
b) Create disaster-resilient arterial roads
c) Increase load-bearing capacity

In light of the above, this project is deemed highly relevant and effective.