Democratic Republic of Timor-Leste
Ministry of Public Works

Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste
Final Report
Annex 2: Products of the Project
(Checklists, Guidelines, Materials, etc.)

December 2019

Japan International Cooperation Agency (JICA）

Ingerosec Corporation
Earth System Science Co., Ltd.

EI
JR
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Annex 2: Products of the Project

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Note: Tetun versions are for reference only

Democratic Republic of Timor-Leste

Ministry of Public Works

Directorate General of Public Works

National Directorate of Roads, Bridges and Flood Control

CHECKLIST for Construction —March 2019

CHECKLISTS for Construction
March 2019

Contents

REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTÉRIO DAS OBRAS PÚBLICAS
GABINETE DO VICE MINISTRO
Av. Nicolau Lobato, Mandarin, Dili, Timor-Leste

Foreword

In the interest of constructing high quality and economically viable government infrastructure to serve the nation, these checklists for construction were prepared by the JICA Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste (CDRS) in collaboration with the *Direcção Nacional de Estradas, Pontes e Controlo de Cheias* (DNEPCC, 'National Directorate of Roads, Bridges and Flood Control') of the *Ministério das Obras Públicas* ('Ministry of Public Works'). We would like to thank JICA for their continuing support.

September, 2019

Eng. Nicolau Lino Freitas Belo
Vice Minister for Public Works
Ministry of Public Works

19-09-2019

Foreword by JICA

Japan International Cooperation Agency (JICA) has been conducting a technical cooperation project for development of capacity regarding road services, which is called CDRS, in order to facilitate the DNEPCC in properly managing and maintaining the road infrastructure that is the basis of social and economic activities. To this end, JICA has been dispatching a team of experts from March 2016 to December 2019. As a result of collaborative work with counterparts of the DNEPCC, these checklists for construction have been finalized. I hope that these checklists will contribute to infrastructure development and maintenance, and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials of the Government of the Democratic Republic of Timor-Leste for their close cooperation with the expert team.

September, 2019

Masafumi NAGAISHI
Chief Representative of JICA Timor-Leste Office
Japan International Cooperation Agency

1. Introduction

The field supervision of the DRBFC is to manage the quality of construction at each stage of the construction process in order to ensure that the construction is in accordance with the contract documents and national standards.

Quality control and safety management on site is being carried out by the experienced DRBFC senior engineers.

The CDRS Project compiled the CHECKLISTS for Construction as a tool for DRBFC staff in charge of construction management, local engineers and junior engineers with little experience in construction supervision in order to facilitate implementation of quality control and safety management on construction sites.

One of objective of the CDRS Project is the improvement of capacity of DRBFC construction management for maintenance and rehabilitation works. The CDRS Project carried out case studies and provided on-the-job training about how to apply the CHECKLISTS for Construction.

DRBFC staff will utilize the CHECKLISTS for Construction on site and it is expected the DRBFC will revise the checklists as necessary in the future.

2. Application of Checklist

The CHECKLISTS for Construction consists of three main sections corresponding to three aspects of construction supervision: I. Checklists for Quality Control, II. Checklists for Safety and III. Checklists for Construction Management. The application for each section is explained below.

I. Checklists for Quality Control should be applied during on-site inspections by inspectors of construction work. These checklists are very simple and focus on essential check points on site, so even junior staff can easily use them and can instruct contractors properly. In DRBFC, mainly the staff from the Department of Maintenance and Conservation (Dept. M&C) and junior staff from all departments should use these checklists.

II. Checklists for Safety Control should be applied by DRBFC supervisors and also by site staff from contractors. These checklists can be used by all personnel who are engaged and responsible for construction work.

III. Checklists for Construction Management, which includes a Checklist for Tender Documents and a Checklist for Inspection for the works done, should be used by staff in charge of procurement or evaluation of completed works on the site.

The DRBFC does not yet carry out tendering for the procurement, so the Checklist for Tender Documents is supplementary information for reference only.

3. Utilization of Checklist for Construction

The CHECKLISTS for Construction shall be utilized according to the aspect of activities;

1) Checklists for Quality Control

- Checklists for Quality Control (QC) are based on the “Standard Specifications for the Ministry of Public Works, Transport and Communications November 2014 Edition (SPC=MPWTC)”, which supersedes the “2005 Edition of MTCPW Standard Specifications for Highways, Bridges and Airport”.
- Checklists for QC are divided in four categories: Earthwork, Small Structures, Box Culverts and Road Pavement works.

  A designated checklist will be used for each construction item, such as Excavation, Embankment and Widening of Embankment. Each checklist shall be filled in according to the guidance on procedures and work items.
- The performance result of the works inspected on the site can be recorded on the checklists for QC. Such records can be used for clarification during checking / evaluations of accomplished work before payments.

2) Checklists for Safety

- Safety on construction sites is essential for supervising personnel of the Government, and also all workers, contactors and the general public.
- Safety activities can be carried out according to Checklists for Safety. The following are recommendable processes for each safety activity:

  i] Establish a “site safety committee including all contractors”

  ii] Discussion and selection of a safety activity or each site

  iii] The safety activities on the site and feedback to the site

3) Checklists for Construction Management

- During procurement stages, Checklists for Tender Documents (TD) can be used.

  First of all, the type of contract shall be selected and prepared while referring to Checklist for TD. Before announcement of invitations to tender, prepared document shall be checked again using the Checklist for TD.

- When the engineers in charge have to evaluate the works accomplished according to contract, the Checklist for Daily, Interim Payment and Final Inspection for the works done can be used. The filled in Checklist of Inspection for the works done can be used as evidence for clarifying / approval procedures.

4. Dissemination

On-the-job training (OJT) by DRBFC's Trainers should be carried out on possible construction sites under supervision by DRBFC In order to practice utilizing the "Checklists for Construction".

The DRBFC should later review the results of OJT, discuss about the contents of the checklists, and make improvements or amendment to the "Checklist for Construction".

As many times as possible, practice/ training/ OJT of using "Checklist for Construction" are carried out and its results will be feedback for brushing up "Checklist" and up-dating CHECKLIST.

Supplementary descriptions in the Tetun language shall be added in order to help staff better understand the contents of the checklists.

Using Checklist for construction are hoped by not only DRBFC staff but also other government officials and engineers of contractors in order that quality and safety of construction works in Timor Leste are to be improved

5. Checklists for Quality Control

5. Checklists for Quality Control

5-1 Earthwork
Terraplenagem

(1) Excavation (for Roadway)
Eskavasaun (ba estrada

1/2

CL_Excavation
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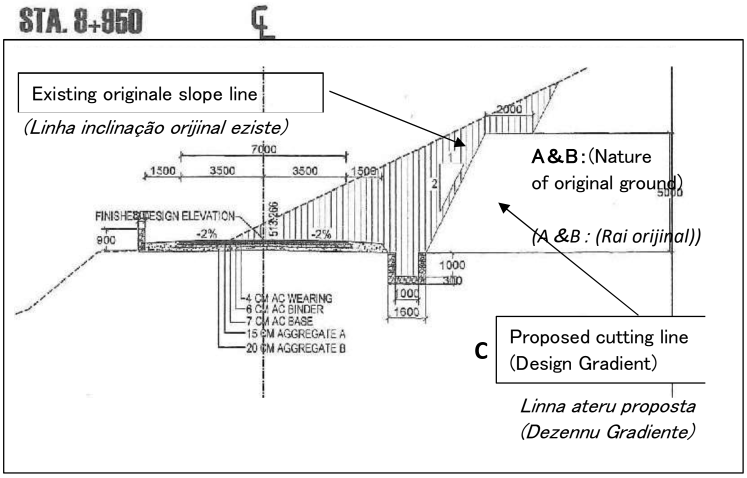
(this Checklist sheet apply for Roadway Excavation)
(Lista verifikasaun ida ne'e aplika ba eskavasaun ba estrada)



Example of **Cross Section**
Ezemplu SeksaunTransversal

Table of volume at this Cross Section
(Tabela Volume Seksaun Transversal ida ne'e)

	WORK ITEM		
1	Excavation	200.03	m^2
2	Embankment	-	m^2
3	AC Wearing	7.00	m^2
4	AC Binder	7.08	m^2
5	Base Course	7.18	m^2
6	Aggregate A	0.75	m^2
7	Aggregate B	1.50	m^2
8	Stone Masonry	1.35	m^2
9	Plaster	1.60	m^2

CHECKLIST for Excavation
Lista verifikasaun ba eskavasaun

Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY)
Name of Contractor: *Naran Kontraktor:*	Location: STA km - km *Fatin*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⓪	Preparatory activity *Aktividade preparatoriu*					
-1	Did you confirm the drawings? *Ita bo'ot komfirma ona dezennu ka?*	Yes *Sim*	No *Lae*			
-2	Did you confirm the construction work plan? *Ita bo'ot komfirma plano servisu konstrusaun nia ka?*	Yes *Sim*	No *Lae*			
①	Cross Section for Cutting Area of Road Excavation *Seksaun transversal ba aterru area escavasaun estrada*	Yes *Sim*	No *Lae*			
-1	Is the type of original ground stated in the Drawing or the Specification ? *Tipu rai orijinal indika iha dezennu ou espeksifikasaun?*	Yes *Sim*	No *Lae*			
-2	Are the drawings of cross section for Roadway provided? *Dezennu ba seksaun transversal ba estrada fornese ka lae?*	Yes *Sim*	No *Lae*			

CHECKLIST for Excavation 2/2

Lista verifikasaun ba eskavasaun

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
-3	Which interval length of cross section ? *Ida ne'ebe mak sai hanesan naruk interval ba seksaun transversal?)* 1) 25m 3) 100m 2) 50m 4) other length:__________m	Please mark the number				
-4	Are the proposed gradient of cutting line/slope shown on the "Cross Section"(C) ? *Proposta gradiente linna ateru/declive hanesan hatudu iha "seksaun Transversal"(C) ?*	Yes *Sim*	No *Lae*			
-5	Are original ground line also shown on the "Cross Section" ? *Rai orijinal mos hatudu hotu iha " Seksaun transversal"?*	Yes *Sim*	No *Lae*			
-6	Are the results of calculation of the area (m2), Excavated value, descrived on such Drawing ? *(Rezultadu husi kalkulasaun ba area (m2),valor eskavasaun, descreve iha dezennu ?)*	Yes *Sim*	No *Lae*			
②	Excavation Work *Servisu eskavasaun*					
-1	Which type of Excavation ? *Tipu eskavasaun mak ida ne'ebe?* 1)Unclassified Excavation *Eskavasaun ne'ebe la klasifika* 3) Common soil *Rail* 2)Rock Excavation *Fatuk* 4) Other Excavation	Please mark the number *(Favor fo marka iha numero)*			203.1.1	* 1) & 2) can be excavated by blasting and Rippering. ** 1) & 2) bele halo eskavasaun liu husi peledakkan no utiliza ripper.*
-2	Are the stakes of setting out and/or leading frames provided on the site? *Monta staka no papan petunjuk ne'e fornese iha sitiu ka lae?*	Yes *Sim*	No *Lae*		203.2.1	
-3	Are the line, grades and dimension of slope/ excavated area followed to the Drawing or the instructions by the Engineer ? *(Linna,klase no dimensaun declive/ area eskavasaun tuir dezennu ou instrusaun husi Enjinneru?)*	Yes *Sim*	No *Lae*		203.1	
-4	Which kinds of machine or method of excavation are carried out ? *Tipu Makina no matodu saida mak realiza ba eskavasaun?* 1) Excavator 3) Bulldozer with ripper 2) Buldozzer 4) Balsting method	Please mark the number *(Favor marka iha numeru)*			* In case of Blasting, works apply SPC section 203.2.5 "Presplitting" ** iha Kazu Peledakan, aplika iha Spesifikasaun seksaun 203.2.5"Pre-*	
-5	Have the Contractor instructed to the operator regading work procedure of Excavation ? *Kontraktor fo Intrusaun ba operador relasiona ho prosedimentu servisu eskavasaun ?*	Yes *Sim*	No *Lae*			
-6	Are conservation of Topsoil and Utilization of excavated material carried out satisfactory ? *Konservasaun husi rai superficial no utiliza material eskavasaun sira ne'e satisfatoriamente ka?*	Yes *Sim*	No *Lae*		203.2.2 203.2.3	
-7	Ground water and/or surface water from the cut surface is being processed appropriate? *Be rai okos no be superficial iha superficie corte ne'ebe atu prosesa apropriado ka lae?*	Yes *Sim*	No *Lae*			
-8	Is the floating stone on the slope appropriate removed? *Fatuk ne'ebe flutuamente iha declive ou taludes apropriado atu hasai ka lae?*	Yes *Sim*	No *Lae*			

(2) Embankment
Aterru

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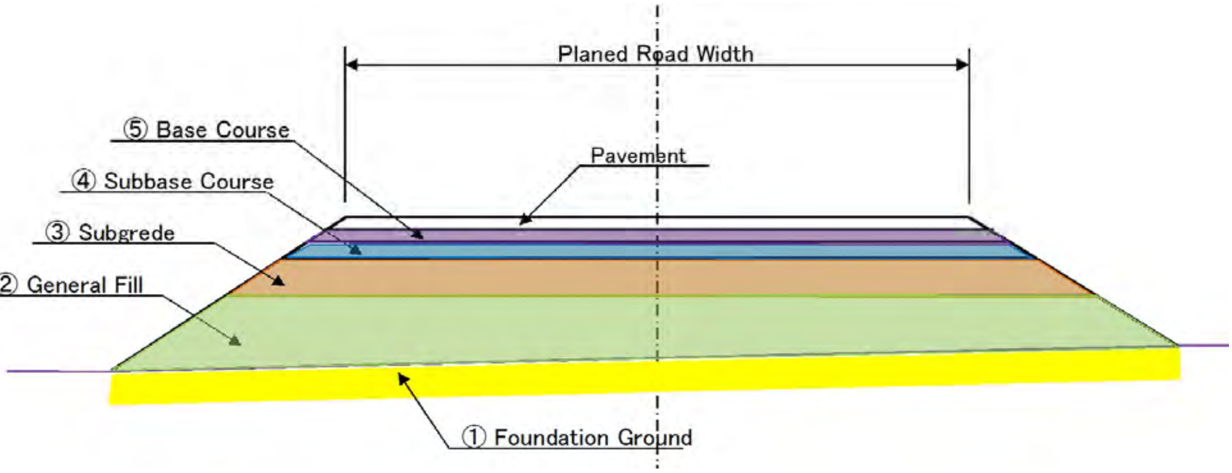

CHECKLIST for Road Embankment
Lista verifikasaun aterru estrada

Name of Project : *Naran Projetu :*		
Location : *Fatin:*		Date : / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*		Location: STA km – km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*	

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun*		Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan*
				Standards *Padraun*	SPC	
⓪	Preparatory activity					
	Aktividade preparatoriu					
	Did you confirm the drawings?	Yes	No			
	Ita bo'ot komfirma ona dezennu ka?	*Sim*	*Lae*			
	Did you confirm the construction work plan?	Yes	No			
	Ita bo'ot komfirma ona planu servisu konstrusaun nia ka ?	*Sim*	*Lae*			
①	Foundation Ground					
	Dasar Fondasi					
	Is strength of bearing ground sufficient?	Yes	No			
	Forsa bantalan rai nia nia suficiente ka lae?	*Sim*	*Lae*			
	If No, was replace damaged pipe with new pipe?	Yes	No			
	Se Lae, troka tiha ona pipa ne'ebe at ho pipa foun ka?	*Sim*	*Lae*			

CHECKLIST for Road Embankment
Lista verifikasaun aterru estrada

2/3

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan*
②	General Fill					150mm
	Preenchimento jeral					
	Did you check the general fill material?	Yes	No	ー		Material on site
	Ita bo'ot verifika ona material preechimento jeral?	*Sim*	*Lae*			(Material iha terenu)
	Did you check the type of compaction equipment?	Yes	No			Road roller、Macadam 10～12t
	Ita bo'ot verifika ona tipu ekipamentus ba Kompaktasaun?					
	Did you check the number of compaction?	Yes	No			10 numbers
	Ita bo'ot verifika ona numeru ba kompaktasaun?	*Sim*	*Lae*			
	Did you confirm the soil density test results?	Yes	No	95%		Inspected density: 96%
	Ita bo'ot komfirma ona rezultadu teste densidade rai nian?	*Sim*	*Lae*			Densidade ne'ebe halo inspeksaun: 96%
	Did you confirm the compacted thickness?	Yes	No	30cm		Inspected thickness: 30cm
	Ita bo'ot komfirma ona kompaktasaun ninia mahar?	*Sim*	*Lae*			Mahar ne'ebe halo inspeksaun tiha ona : 30 cm
③	Subgrade					
	Subleito					
	Did you check the subgrade material?	Yes	No	ー		Selected Material, From Borrow Pit No.1
	Ita bo'ot verifika ona material ba subgrade?	*Sim*	*Lae*			Material ne'ebe hili tiha ona husi posu impresta no.1
	Did you check the type of compaction equipment?	Yes	No			Road roller、Macadam 10～12t
	Ita bo'ot verifika ona tipu ekipamentu kompaktasaun?	*Sim*	*Lae*			
	Did you check the number of compaction?	Yes	No			10 numbers
	Ita bo'ot verifika ona numeru kompaktasaun?	*Sim*	*Lae*			
	Did you confirm the soil density test results?	Yes	No	95%		Inspected density: 96%
	Ita komfirma ona rezultadu teste densidade rai?	*Sim*	*Lae*			densidade ne'ebe inspeksionado : 96%
	Did you confirm the compacted thickness?	Yes	No	30cm		Inspected thickness: 30cm
	Ita bo'ot komfirma ona kompaktasaun nia mahar?	*Sim*	*Lae*			Mahar ne'ebe inspeksionado: 30 cm
④	Subbase Course					
	Subbase Course					
	Did you check the subbase material?	Yes	No	ー		Selected Material, From Borrow Pit No.1
	Ita bo'ot verifika ona sub base nia material?	*Sim*	*Lae*			Material ne'ebe selesionado husi borrow pit no.1
	Did you check the type of compaction equipment?	Yes	No			Road roller、Macadam 10～12t
	Ita bo'ot verifika ona ekipamentu kompaktasaun?	*Sim*	*Lae*			
	Did you check the number of compaction?	Yes	No			10 numbers
	Ita bo'ot verifika ona numeru kompaktasaun?	*Sim*	*Lae*			
	Did you confirm the soil density test results?	Yes	No	95%		Inspected density: 96%
	Ita bo'ot komfirma ona rezultadu teste densidade rai?	*Sim*	*Lae*			densidade ne'ebe inspeksionado : 96%
	Did you confirm the compacted thickness?	Yes	No	30cm		Inspected thickness: 30cm
	Ita bo'ot komfirma ona kopaktasaun nia mahar?	*Sim*	*Lae*			mahar ne'ebe inspeksionado: 30 cm

CHECK LIST for Road Embankment
Lista verifikasaun aterru estrada

3/3

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan*
⑤	Base Course					
	Kursu Baze					
	Did you check the base material?	Yes	No	—		Crushed stone for mechanical stabilization、CLASS A
	Ita bo'ot verifika ona material base?	*Sim*	*Lae*			fatuk fera ba stabilizasaun mekanika klasse A
	Did you check the type of compaction equipment?	Yes	No			Road roller、Macadam 10～12t
	Ita bo'ot verifika ona tipu ekipamentu kompaktasaun?	*Sim*	*Lae*			
	Did you check the number of compaction?	Yes	No			10 numbers
	Ita bo'ot verifika ona numeru kompaktasaun?	*Sim*	*Lae*			
	Did you confirm the soil density test results?	Yes	No	95%		Inspected density: 96%
	Ita bo'ot komfirma ona rezultado teste densidade rai?	*Sim*	*Lae*			densidade ne'ebe inspeksionado : 96%
	Did you confirm the compacted thickness?	Yes	No	30cm		Inspected thickness: 30cm
	Ita bo'ot komfirma ona kompaktasaun nia mahar?	*Sim*	*Lae*			Mahar ne'ebe inspeksionado: 30 cm

(3) Aggregate Surface (Wearing) Course

CL_Aggre. Surface Cource

Crushed Aggregate Course on Existing Pavement, with

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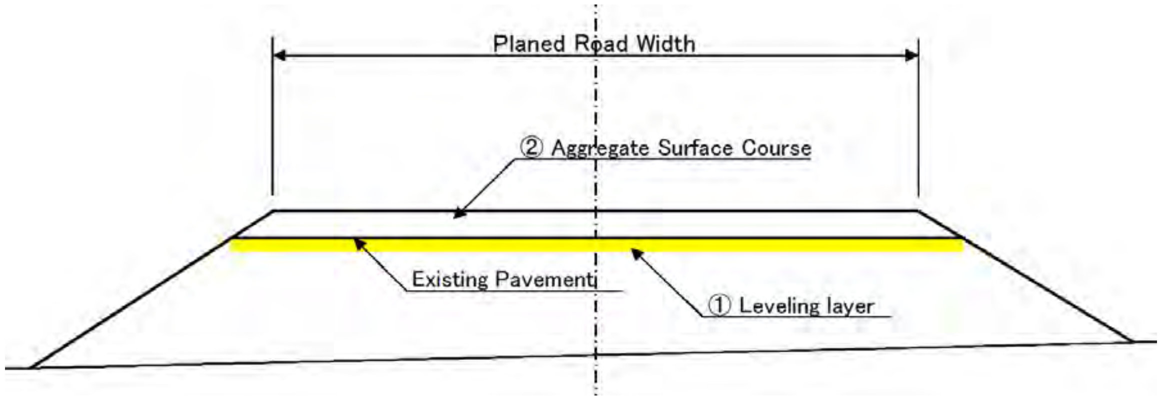

CHECKLIST for Aggregate Surface (Wearing) Course

Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km − km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC−Nov2014 Edition
Padraun spesifikasaun husi MOP−Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan*
⓪	Preparatory activity					
	Aktividade preparatoriu					
	Did you confirm the drawings?	Yes	No			
	Ita bo'ot komfirma ona dezenu ka?	*Sim*	*Lae*			
	Did you confirm the construction work plan?	Yes	No			
	Ita bo'ot komfirma ona planu servisu konstrusaun?	*Sim*	*Lae*			
①	Leveling Layer					
	Nivelamento dalas					
	Has the existing pavement been removed properly?	Yes	No			
	Pavimentu ne'ebe eziste removido ho lolos ona ka?	*Sim*	*Lae*			
	Was existing surface scarified, thoroughly loosened, reshaped, and recompacted appropriate?	Yes	No			
	Superficie ne'ebe eziste klarifikadu, completamente halo longgar,reforma no halo kompaktasaun fila fali ne'e apropriadu ka lae?	*Sim*	*Lae*			

CHECKLIST for Aggregate Surface (Wearing) Course 2/2

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
②	Aggregate Surface Course					
	Kursu Superficie agregada					
	Did you check the aggregate surface material?	Yes	No	―		Crushed stone for mechanical stabilization、CLASS A
	Ita bo'ot verifika ona material superficie agregat ka?					fatuk fera ba stabilizasaun mekaniko kalsse A
	Did you check the type of compaction equipment?	Yes	No			Road roller、Macadam 10～12t
	Ita bo'otverifika ona tipu ekipamentus ba kompaktasaun?					
	Did you check the number of compaction?	Yes	No			10 numbers
	Ita bo'ot verifika ona numeru kompaksaun ka?					
	Did you confirm the soil density test results?	Yes	No	95%		Inspected density: 96%
	Ita bo'ot komfirma ona reuzltadu teste densidade rai nia ka?					densidade ne'ebe inspeksionado : 96%
	Did you confirm the compacted thickness?	Yes	No	30cm		Inspected thickness: 30cm
	Ita bo'ot komfirma ona kompaksaun nia mahar ka?					mahar ne'ebe inspeksionado : 30 cm

(4) Widening of Embankment

1/2

CL_Widening of Embankment

Aterru alargamentu

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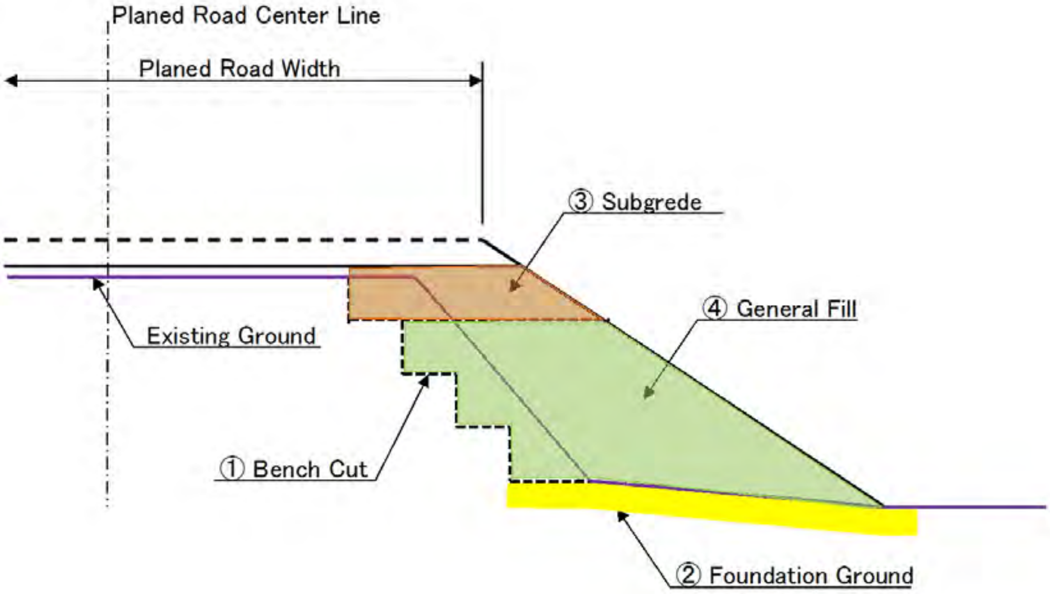


CHECKLIST for Road Widening of Embankment

Lista Verifikasaun ba aterru alargamentu estrada

Name of Project : *Naran Projetu :*		
Location : *Fatin:*		Date :　　/　　/　　(DD/MM/20YY)
Name of Contractor: *Naran Kontraktor:*		Location: STA　　km　–　　km *Fatin*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*	

SPC= Standard Specification of MPWTC–Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⓪	Preparatory activity					
	Actividade preparatorio					
	Did you confirm the drawings?	Yes	No			
	Ita bo'ot komfirma ona dezennu ka?	*Sim*	*Lae*			
	Did you confirm the construction work plan?	Yes	No			
	Ita bo'ot komfirma ona planu servisu konstrusaun ka?	*Sim*	*Lae*			
①	Bench Cut					
	Corte bankada					
	Was Bench Cut carried out appropriately?	Yes	No			
	Bench cut ne'e halao ho apropriado ona ka Lae?	*Sim*	*Lae*			

CHECKLIST for Road Widening of Embankment 2/2

Lista Verifikasaun ba aterru alargamentu estrada

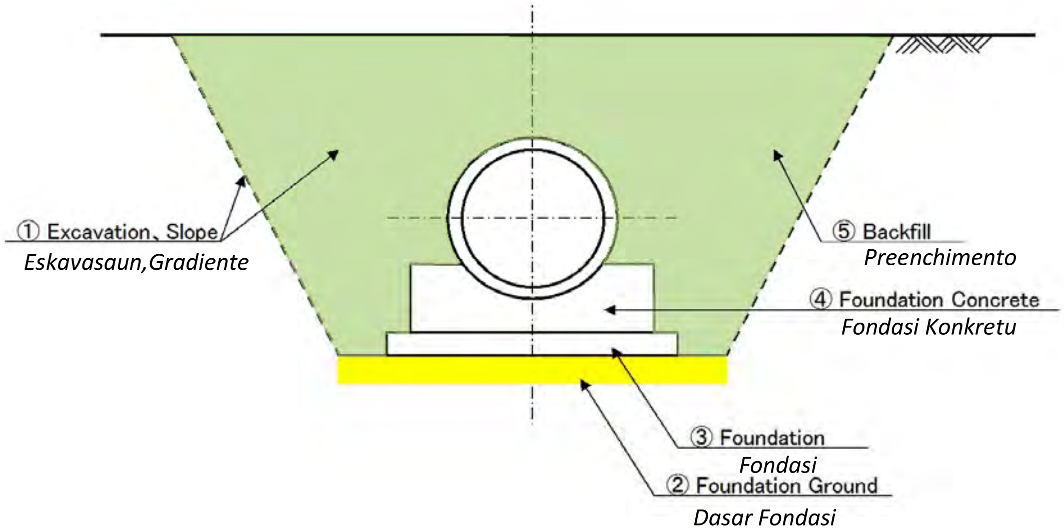
No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan*
②	Foundation Ground					
	Dasar Fondasi					
	Is strength of bearing ground sufficient?	Yes	No			
	Resistensia husi bantalan rai nian suficiente ka lae?	*Sim*	*Lae*			
	If No, was the replacement of soft ground appropriate?	Yes	No			Replacement, Thickness=60cm
	Se lae,subtitui rai ne'ebe mamar ne'e apropriadu ka lae?	*Sim*	*Lae*			subtituisaun, mahar = 60 cm
③	Subgrade					
	Subleito					
	Did you check the subgrade material?	Yes	No			Procedure from borrow pit No.1
	Ita bo'ot verifika ona material subgrade ka?	*Sim*	*Lae*			*Prosedimentu husi borrow pit no.1*
	Did you confirm the soil density test results?	Yes	No		95%	Inspected density: 96%
	Ita boot komfirma ona rezultadu teste densidade rai nian ka?	*Sim*	*Lae*			densidade ne'ebe inspeksionado: 96%
	Did you confirm the compacted thickness?	Yes	No		30cm	Inspected thickness: 30cm
	Ita bo'ot komfirma ona kompaksaun nia mahar ka?	*Sim*	*Lae*			Mahar ne'ebe inspeksionado: 30 cm
④	General Fill					
	Preenchimento jeral					
	Did you check the general filll?	Yes	No		—	Procedure from site
	Ita bo'ot verifika ona preenchimento jeral ka lae?	*Sim*	*Lae*			Prosedimentu iha terrenu
	Did you confirm the soil density test results?	Yes	No		90%	Inspected density: 96%
	Ita bo'ot komfirma ona rezultadu teste densidade rai nian ka?	*Sim*	*Lae*			densidade ne'ebe halo inspeksaun tiha ona : 96%
	Did you confirm the compacted thickness?	Yes	No		30cm	Inspected thickness: 30cm
	Ita bo'ot komfirma ona kompaksaun nia mahar ka?	*Sim*	*Lae*			Mahar ne'ebe inspeksionado : 30 cm

5-2 Small Structure
Estrutura kiik

(1) Pipe Curvert

1/2

CL_Pipe Culvert
Edited_20181002



CHECKLIST for Pipe Culvert
Lista Verifikasaun ba Pipe culvert

Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km – km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

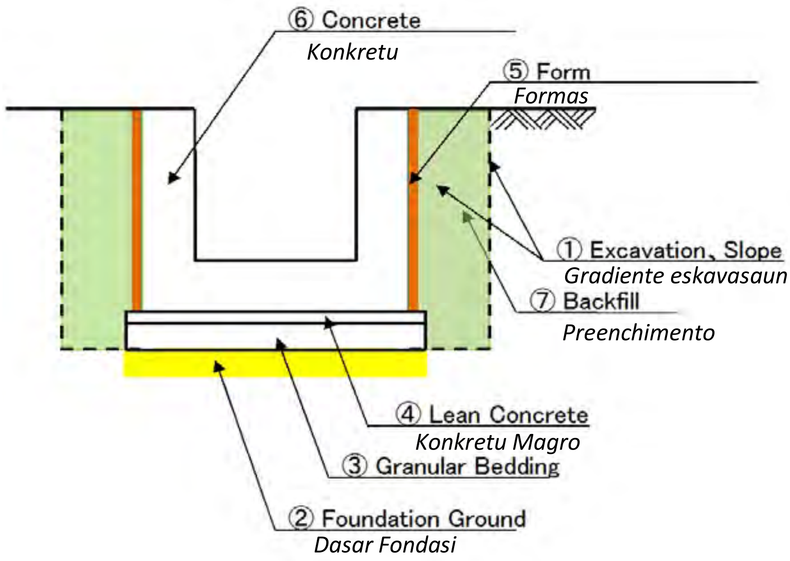
No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⓪	Preparatory activity					
	Aktividade preparatoriu					
	Did you confirm the drawings?	Yes	No			
	Ita bo'ot komfirma ona Dezennu ka?	*Sim*	*Lae*			
	Did you confirm the construction work plan?	Yes	No			
	Ita bo'ot komfirma ona konstrusaun nia planu servisu ka?	*Sim*	*Lae*			
①	Excavation、Slope					
	Ekavasaun, Gradiente					
	Was excavation width appropriate?	Yes	No			
	Eskavasaun nia largura apropriado ona ka?	*Sim*	*Lae*			
	Was excavation slope appropriate?	Yes	No			
	Eskavasaun nia gradiente apropriadu ona ka?	*Sim*	*Lae*			

CHECKLIST for Pipe Culvert 2/2

Lista verifikasaun ba pipe culvert

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
	Was removal of water appropriate?	Yes	No			
	Hasai be ne'e apropriado ona ka?	*Sim*	*Lae*			
②	Foundation Ground					
	Dasar Fondasi					
	Is strength of bearing ground sufficient?	Yes	No			
	Resistensia bantalan rai nia sufisiente ka lae?	*Sim*	*Lae*			
	If No, was replace damaged pipe with new pipe?	Yes	No			
	Se lae, subtitui pipe ne'ebe at ho pipe foun ka lae?	*Sim*	*Lae*			
③	Foundation					150mm
	Fondasi					
	Did you check the foundation material?	Yes	No			Crashed stone
	Ita bo'ot verifika material fondasi ka?	*Sim*	*Lae*			Fatuk fera
	Did you check the thickness of foundation ground?	Yes	No			
	Ita bo'ot verifika dasar fondasi nia mahar ka lae?	*Sim*	*Lae*			
④	Foundation concrete					
	Fondasi Konkretu					
	Did you check the class of concrete or concrete mixing contents before concrete casting?	Yes	No			
	Ita bo'ot verifika klasse konkretu ou konteudu mistura konkretu antes concretagem?	*Sim*	*Lae*			
	Did you check the thickness of foundation concrete?	Yes	No	95%		250mm
	Ita bo'ot verifika ona fondasi konkretu nia mahar ka?	*Sim*	*Lae*			
⑤	Precast Concrete Pipe					
	Concretagem pipe concrete					
	Did you check diameter of pipe?	Yes	No	—		Diameter 900
	Ita bo'ot verifika ona diametru pipe nian ka?	*Sim*	*Lae*			diametru 900
⑥	Backfill					
	Preenchimento					
	Did you check the backfill material?	Yes	No	—		Selected Material, From Borrow Pit No.1
	Ita bo'ot verifika ona material prenchimento ka?	*Sim*	*Lae*			Material ne'ebe selesionado husi borrow pit no. 1
	Has the compaction been carried out properly?	Yes	No			Vibrating Compacter 40～60kg
	Kompaktasaun halao ho apropriado ona ka?	*Sim*	*Lae*			kompaktador vibartorio 40～60kg
	Did you confirm the soil density test results?	Yes	No	95%		Inspected density: 96%
	Ita bo'ot komfirma rezultadu teste densidade rai ka?	*Sim*	*Lae*			densidade ne'ebe inspeksionado : 96 %
	Did you confirm the compacted thickness?	Yes	No	30cm		Inspected thickness: 30cm
	Ita bo'ot komfirma ona kopaktasaun nia mahar ka?	*Sim*	*Lae*			mahar ne'ebe inpeksionado : 30 cm

(2) Concrete Drainage
Drenajem konkretu



CHECKLIST for Concrete Drainage
Lista verifikasaun ba Drenajem konkretu

Name of Project： *Naran Projetu :*	
Location： *Fatin:*	Date：　　/　　/　　(DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA　　km　–　　km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⓪	Preparatory activity					
	Aktividade preparatoriu					
-1	Did you confirm the drawings?	Yes	No			
	Ita bo'ot komfirma ona dezennu ka?	*Sim*	*Lae*			
-2	Did you confirm the construction work plan?	Yes	No			
	Ita bo'ot komfima ona plano servisu konstrusaun ka?	*Sim*	*Lae*			
①	Excavation、Slope					
	Eskavasaun, Gradiente					
-1	Was excavation width appropriate?	Yes	No			
	Eskavasaun nia largura apropriadu ona ka?	*Sim*	*Lae*			
-2	Was excavation slope appropriate?	Yes	No			
	Eskavasaun nia gradiente apropriadu ona ka?	*Sim*	*Lae*			

CHECKLIST for Concrete Drainage 2/3

Lista verifikasaun ba Drenajem konkretu

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
-3	Was removal of water appropriate?	Yes	No			
	Remosaun be ne'e apropridu ona ka?	*Sim*	*Lae*			
②	Foundation Ground					
	Dasar Fondasi					
-1	Is strength of bearing ground sufficient?	Yes	No			
	Resitensia husi bantalan rai nia ne'e suficiente ona ka?	*Sim*	*Lae*			
-2	If No, was the replacement of soft ground appropriate?	Yes	No			Replacement, Thickness=60cm
	se lae, subtitui rai ne'ebe mamar ne'e apropriadu ka?	*Sim*	*Lae*			subtituisaun, mahar = 60 cm
③	Foundation					
	Fondasi					
-1	Did you check the foundation material?	Yes	No			Crashed stone
	Ita bo'ot verifika ona fondasi nia material ka?	*Sim*	*Lae*			Fatuk fera
-2	Did you check the thickness of foundation ground?	Yes	No			150mm
	Ita bo'ot verifika daasar fondasi nia mahar ka?	*Sim*	*Lae*			
④	Lean Concrete					
	Konkretu magro					
-1	Did you check the class of concrete or concrete mixing contents before concrete casting?	Yes	No			
	Ita bo'ot verifika ona konkretu ou konteudu mistura konkretu antes concretagem ka?	*Sim*	*Lae*			
-2	Did you check the thickness lean concrete?	Yes	No			
	Ita bo'ot verifika ona lean konkretu nia mahar ka?	*Sim*	*Lae*			
⑤	Form					
	Formas					
-1	Are the quality and thickness of the formwork material appropriate?	Yes	No			
	Kualidade no mahar material ba cofragem ne'e apropriado ka lae?	*Sim*	*Lae*			
-2	Is there a hole, rot or warp in the formwork?	Yes	No			
	iha ne'eba iha koak,dodok ka kleuk iha cofragem?	*Sim*	*Lae*			
-3	Is the form clamping metal fitting appropriately?	Yes	No			
	Forma logam ne'ebe habit apropriadu ka lae?	*Sim*	*Lae*			

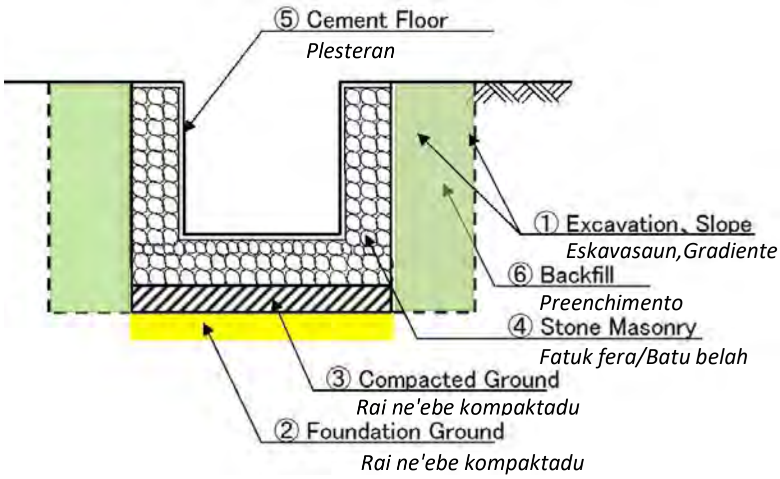
CHECKLIST for Concrete Drainage 3/3

Lista verifikasaun ba Drenajem konkretu

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun*		Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
				Standards *Padraun*	SPC	
⑥	Concrete					
	Konkretu					
−1	Did you check the class of concrete or concrete mixing contents before concrete casting?	Yes	No			
	Ita bo'ot verifika ona konkretu ou konteudu mistura konkretu antes concretagem ka?	*Sim*	*Lae*			
−2	Did you check the dimension before casting?	Yes	No			
	Ita bo'ot verifika ona dimensaun antes concretagem?	*Sim*	*Lae*			
−3	Has moist curing been carried out in a suitable method?	Yes	No			Covered sheet on the concrete surface
	cura úmida halao ka lae ho metodu ne'ebe adequadu?	*Sim*	*Lae*			folla koberta iha konkretu nia superficie
⑦	Backfill					
	Preenchimento					
−1	Did you check the backfill material?	Yes	No	—		Selected Material, From Borrow Pit No.1
	Ita bo'ot verifika ona material preenchimento ka?	*Sim*	*Lae*			material ne'ebe selesionado husi borrow pit no. 1
−2	Has the compaction been carried out properly?	Yes	No			Vibrating Compacter 40～60kg
	Kompaktasaun halao ho los ona ka?	*Sim*	*Lae*			kompaktador vibratorio 40～60kg
−3	Did you confirm the soil density test results?	Yes	No	95%		Inspected density: 96%
	Ita bo'ot komfirma ona rezultadu densidade rai nian ka?	*Sim*	*Lae*			densidade inspeksionado : 96%
−4	Did you confirm the compacted thickness?	Yes	No	30cm		Inspected thickness: 30cm
	Ita bo'ot komfirma ona kompaktasaun nia mahar ka?	*Sim*	*Lae*			mahar ne'ebe inspeksionado : 30 cm

(3) Stone Masonry Drainage
1/2
CL_SM Drainage

Drenajem ho Fatuk (Pas. Batu belah)
Edited_20181002



CHECKLIST for Stone Masonry Drainage
LISTA VERIFIKASAUN ba drenajem ho Fatuk

Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km – km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

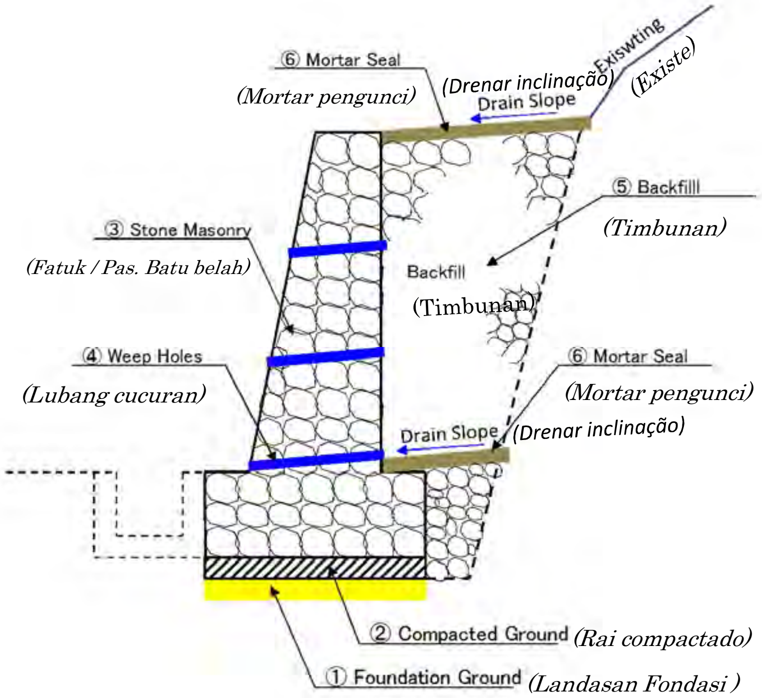
No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan*
⓪	Preparatory activity					
	Aktividade preparatoriu					
−1	Did you confirm the drawings?	Yes	No			
	Ita bo'ot komfirma ona dezennu ka?	*Sim*	*Lae*			
−2	Did you confirm the construction work plan?	Yes	No			
	Ita bo'ot komfirma ona planu servisu konstrusaun ka?	*Sim*	*Lae*			
①	Excavation、Slope					
	Eskavasaun, Gradiente					
−1	Was excavation width appropriate?	Yes	No			
	Eskavasaun nia largura apropriado ona ka?	*Sim*	*Lae*			
−2	Was excavation slope appropriate?	Yes	No			
	Eskavasaun nia gradiente apropriadu ona ka?	*Sim*	*Lae*			
−3	Was removal of water appropriate?	Yes	No			
	Remosaun be apropriadu ona ka?	*Sim*	*Lae*			

CHECKLIST for Stone Masonry Drainage 2/2
LISTA VERIFIKASAUN ba drenajem ho Fatuk

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
②	Foundation Ground					
	Dasar Fondasi					
−1	Is strength of bearing ground sufficient?	Yes	No			
	Resistensia bantalan rai suficiente ka lae?	*Sim*	*Lae*			
−2	If No, was the replacement of soft ground appropriate?	Yes	No			Replacement, Thickness=60cm
	se lae, subtitui rai ne'ebe mamar apropriado ka lae?	*Sim*	*Lae*			Subtituisaun,Mahar = 60 cm
③	Compacted Ground					
	Rai komspaktadu					
−1	Did you use the conpactor for compaction?	Yes	No			
	Ita bo'ot utilliza kompaktador ba halo kompaksaun ka?	*Sim*	*Lae*			
④	Stone Masonry					
	Fatuk (Pasangan batu belah)					
−1	Was Stone material appropriately?	Yes	No			150mm ≦ Stone thickness ＜ 225mm
	Material fatuk sira ne'e apropriadu ka lae?	*Sim*	*Lae*			150mm ≦ Fatuk nia mahar ＜ 225mm
−2	Was cement mortar composed appropriately?	Yes	No			Cement 1 : Sand 3
	Sementi mortar ninia kompostu apropriadu ka lae?	*Sim*	*Lae*			semente 1 : rai henek 3
⑤	Cement Floor					
	Plesteran					
−1	Was cement mortar composed appropriately?	Yes	No			Cement 1 : Sand 3
	Sementi mortar ninia kompostu apropriadu ka lae?	*Sim*	*Lae*			semente 1 : rai henek 3
⑥	Backfill					
	Preenchimento					
−1	Did you check the backfill material?	Yes	No	−		Selected Material, From Borrow Pit No.1
	Ita bo'ot verifika material preenchimento nia ka?	*Sim*	*Lae*			Material ne'ebe elesiona husi borrow pit nu. 1
−2	Has the compaction been carried out properly?	Yes	No			Vibrating Compacter 40～60kg
	Kompaktasaun halao ho lolos ka lae?	*Sim*	*Lae*			Kompaktador vibratorio 40～60kg
−3	Did you confirm the soil density test results?	Yes	No	95%		Inspected density: 96%
	Ita bo'ot komfirma rezultadu teste densidade rai nian ka lae?	*Sim*	*Lae*			densidade ne'ebe inspeksionado : 96%
−4	Did you confirm the compacted thickness?	Yes	No	30cm		Inspected thickness: 30cm
	Ita bo'ot komfirma kompaktasaun ninia mahar ka lae?	*Sim*	*Lae*			mahar ne'ebe inspeksionadu : 30 cm

(4) Stone Masonry Retaining Wall
Moru Retensaun ho Fatuk

Edited_20190213



<u>CHECKLIST for Stone Masonry Retaining Wall</u>
<u>*LISTA VERIFIKASAUN ba Moru Retensaun ho Fatuk*</u>

Name of Project : *Naran Projetu :*		
Location : *Fatin:*		Date : / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*		Location: STA km − km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*	

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⓪	Preparatory activity *Aktividade preparatoriu*					
-1	Did you confirm the drawings? *Ita bo'ot komfirna ona dezennu?*	Yes *Sim*	No *Lae*			
-2	Did you confirm the construction work plan? *Ita bo'ot komfirma ona planu servisu Konstrusaun nian ka?*	Yes *Sim*	No *Lae*			

CHECKLIST for Stone Masonry Retaining Wall 2/2

LISTA VERIFIKASAUN ba Moru Retensaun ho Fatuk

CL_SM Retaining Wall

Edited_20190213

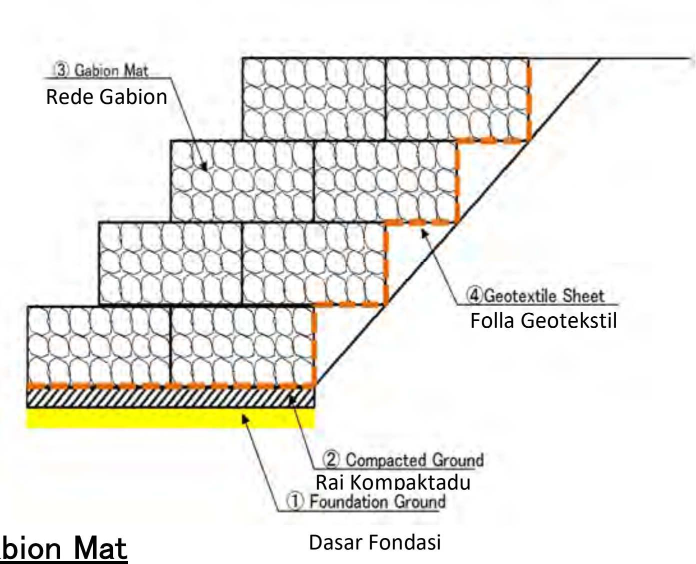
No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	Foundation Ground					
	Dasar Fondasi					
−1	Is strength of bearing ground sufficient?	Yes	No			
	Resistensia bantalan tanah suficiente?	*Sim*	*Lae*			
−2	If No, was the replacement of soft ground appropriate?	Yes	No			Replacement, Thickness=60cm
	se Lae, subtitui rai mamar ne'e apropriado ka?	*Sim*	*Lae*			*(Subtituisaun, mahar = 60cm)*
②	Compacted Ground					
	Rai Kompactado					
−1	Did you use the compactor for compaction?	Yes	No			
	Ita bo'ot utiliza Kompactador ba Kompaktasaun?	*Sim*	*Lae*			
③	Stone Masonry					
	Fatuk / Pasangan batu belah					
−1	Was Stone material appropriately?	Yes	No			150mm ≦ Stone thickness < 225mm
	Material hanesan fatuk sira ne'e apropriado ka?	*Sim*	*Lae*			150mm ≦ Fatuk nia mahar< 225mm
−2	Was cement mortar composed appropriately?	Yes	No			Cement 1 : Sand 3
	Komposto sementi mortar ne apropriado ona ka?	*Sim*	*Lae*			*Sementi 1 : Rai henek 3*
④	Weep Holes					
	Lubang cucuran					
−1	Was diameter of weep hole appropriate?	Yes	No			dia 100mm
	Lubang cucuran nia diametru apropriado ona ka?	*Sim*	*Lae*			*diametru 100 mm*
−2	Were Weep Holes laid out appropriately?	Yes	No			Interval 1m
	Lubang cucuran koloka ho lolos ona ka?	*Sim*	*Lae*			*Intervallu 1 m*
⑤	Backfill					
	Prenchimentu					
−1	Did you check the backfill material?	Yes	No			Crashed stone
	Ita bo'ot verifika ona material tba prenchimentu ka?	*Sim*	*Lae*			*Fatuk fera*
−2	Has the compaction been carried out properly?	Yes	No			Vibrating Compactor 40〜60kg
	compactação halo ho lolos ka?	*Sim*	*Lae*			*Compactador Vibratório 40 〜 60kg*
−3	Did you confirm the soil density test results?	Yes	No			N/A
	Ita bo'ot komfirma ona rezultadu teste densidade rai ka?	*Sim*	*Lae*			*La bele aplika*
−4	Did you confirm the compacted thickness?	Yes	No			N/A
	Ita bo'ot komfirma ona compactação nia mahar ka?	*Sim*	*Lae*			*La bele aplika*
⑥	Backfill					
	Preenchimento					
−1	Did you check the thickness of mortar seal?	Yes	No			100mm
	Ita bo'ot verifika mortar sheal nia mahar ka?	*Sim*	*Lae*			
−2	Was cement mortar composed appropriately?	Yes	No			Cement 1 : Sand 3
	Sementi mortar ninia komposto apropriado ona ka?	*Sim*	*Lae*			*sementi 1 : rai henek 3*

(5) Gabion Mat
rede Gabion

1/2

CL_Gabion

Edited_20181002



CHECKLIST for Gabion Mat
Lista verifikasaun ba rede Gabion

Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km – km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⓪	Preparatory activity *Aktividade preparatoriu*					
-1	Did you confirm the drawings? *Ita bo'ot komfirma ona dezennu ka?*	Yes *Sim*	No *Lae*			
-2	Did you confirm the construction work plan? *Ita bo'ot komfirma ona planu servisu konstrusaun ka?*	Yes *Sim*	No *Lae*			
①	Foundation Ground *Dasar Fondasi*					
-1	Is strength of bearing ground sufficient? *Resistensia bantalan rai suficiente ka?*	Yes *Sim*	No *Lae*			
-2	If No, was the replacement of soft ground appropriate? *se lae, subtitui rai ne'ebe mamar apropriado ka?*	Yes *Sim*	No *Lae*			Replacement, Thickness=60cm subtituisaun, mahar = 60 cm

CHECKLIST for Gabion Mat
Lista verifikasaun ba rede gabion

2/2

CL_SM Retaining Wall

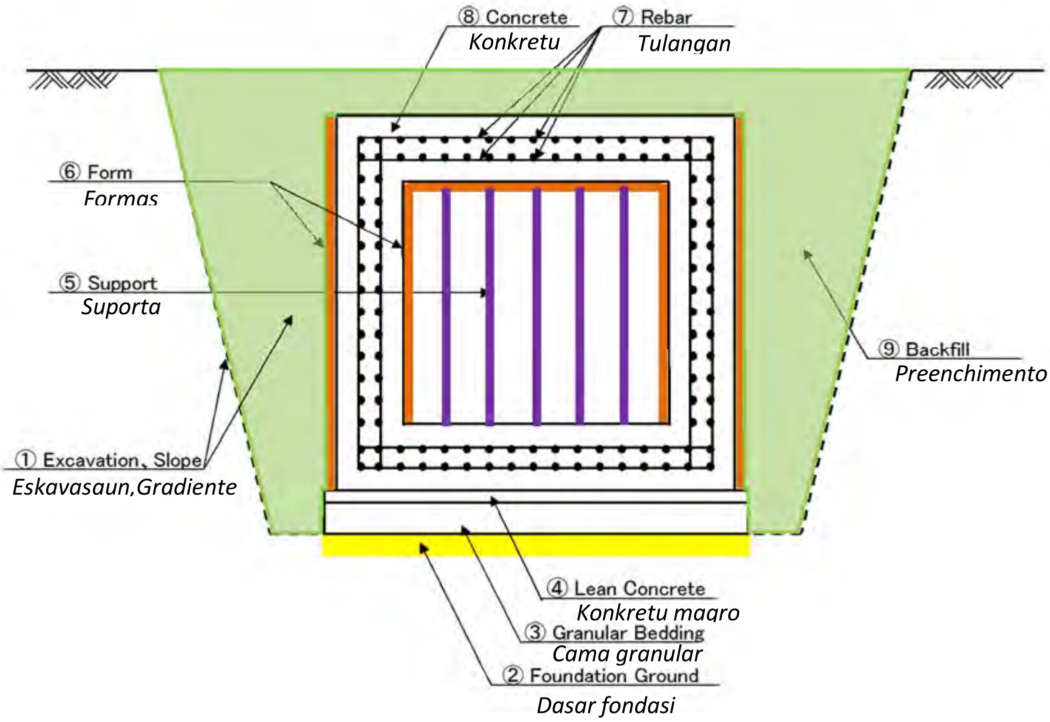
Edited_20190213

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
②	Compacted Ground					
	Rai kompaktadu					
−1	Did you use the conpactor for compaction?	Yes	No			
	Ita bo'ot utiliza komapktador ba komapkatasaun ka?	*Sim*	*Lae*			
③	Gabion Mat					
	Rede Gabion					
−1	Was Stone material appropriately?	Yes	No			150mm ≦ Stone thickness < 225mm
	Material fatuk apropriado ona ka?	*Sim*	*Lae*			150mm ≦ fatuk nia mahar < 225mm
−2	Was diameter of wire mesh appropriate?	Yes	No			
	Diametru wire mesh ne'e apropriado ka lae?	*Sim*	*Lae*			
−3	Was amount of galvanized coating for wire mesh appropriate?	Yes	No			350g/m2
	Kuantidade husi revelmento galvanizado ba wire mesh apropriado ona ka?	*Sim*	*Lae*			
⑤	Backfill					
	Preenchimento					
−1	Did you check the backfill material?	Yes	No			Crashed stone
	Ita bo'ot verifika ona material Preenchimento ka?	*Sim*	*Lae*			fatuk fera
−2	Has the compaction been carried out properly?	Yes	No			Vibrating Compacter 40～60kg
	Kompaksaun halao ho lolos ona ka?	*Sim*	*Lae*			*Compactador Vibratório 40 ～ 60kg*
−3	Did you confirm the soil density test results?	Yes	No			N/A
	Ita bo'ot komfirma rezultadu teste densidade rai nian ka?	*Sim*	*Lae*			labele aplika
−4	Did you confirm the compacted thickness?	Yes	No			N/A
	Ita bo'ot komfirma ona kompaktasaun ninia mahar ka?	*Sim*	*Lae*			labele aplika

5-3 Box Culvert

Box Culvert 1/5 CL_Box Culvert

Edited_20181002



CHECKLIST for Box Culvert
Lista verifikasaun ba Box Culvert

Name of Project: *Naran Projetu :*		
Location: *Fatin:*		Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*		Location: STA km - km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*	

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⓪	Preparatory activity *Aktividade preparatoriu*					
-1	Did you confirm the drawings? *Ita bo'ot komfirma ona dezennu ka?*	Yes *Sim*	No *Lae*			
-2	Did you confirm the construction work plan? *Ita bao'ot komfirma ona planu servisu konstrusaun nian ka?*	Yes *Sim*	No *Lae*			

CHECKLIST for Box Culvert
Lista verifikasaun ba Box Culvert

2/5

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	Excavation、Slope *Eskavasaun,Gradiente*					
	Was excavation width appropriate? *Eskavasaun nia largura apropriadu ona ka?*	Yes *Sim*	No *Lae*			
	Was excavation slope appropriate? *Eskavasaun nia gradiente apropriado ona ka?*	Yes *Sim*	No *Lae*			
	Was removal of water appropriate? *Hasai be ne'e apropriado ka lae?*	Yes *Sim*	No *Lae*			
②	Foundation Ground *Dasar Fondasi*					
−1	Is strength of bearing ground sufficient? *Resistensia bantalan rai nia sufisiente ka ale?*	Yes *Sim*	No *Lae*			
−2	If No, was the replacement of soft ground appropriate? *se lae,hasai rai mamar sira ne'e apropriadu ka lae?*	Yes *Sim*	No *Lae*			Replacement, Thickness=60cm subtitui, mahar=60 cm
③	Granular Bedding *Cama granular*					
−1	Did you check the cama granular material? *Ita bo'ot verifika ona material ba granular bedding?*	Yes *Sim*	No *Lae*			Crashed stone fatuk fera
−2	Did you check the thickness of granular bedding? *Ita bo'ot verifika ona cama granular ninia mahar ka?*	Yes *Sim*	No *Lae*			150mm
④	Lean Concrete *Konkretu Magro*					
−1	Did you check the class of concrete or concrete mixing contents before concrete casting? *Ita bo'ot verifika ona klasse konkretu ka konteudu konkretu nia mistura antes konkretagem?*	Yes *Sim*	No *Lae*			
−2	Did you check the thickness lean concrete? *Ita bo'ot verifika ona konkretu magro nia mahar ka?*	Yes *Sim*	No *Lae*			

CHECKLIST for Box Culvert
Lista verifikasaun ba Box Culvert

3/5

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⑤	Support *Suporta*					
−1	Are materials used not damaged, deformed, corroded etc.? *Material sira ne'ebe utiliza la a'at,la deformado,corroídos ka?*	Yes *Sim*	No *Lae*			
−2	Did you check removal timing, method and procedure of the support? *Ita bo'ot verifika ona tempu remosaun, metodu no prosedimentu husi suporta?*	Yes *Sim*	No *Lae*			
⑥	Form *Formas*					
−1	Are the quality and thickness of the form material appropriate? *Qualidade no material formas nian apropriado ka lae?*	Yes *Sim*	No *Lae*			
−2	Is there a hole, rot or warp in the form? *Iha formas ne'e iha koak, dodok ka lae?*	Yes *Sim*	No *Lae*			
−3	Is there an asperity or gap in the form? *Iha Formas laran ne'e ita hetan aspereza ou lakuna ka?*	Yes *Sim*	No *Lae*			
−4	Is the form clamping metal fitting appropriately? *Forma logam ne'ebe habit apropriadu ka lae?*	Yes *Sim*	No *Lae*			
−5	Whether the concrete formwork releasing oil is sufficiently applied to the inner surface of the form *Se Oleo kofrajem ba konkreto mak aplika ho suficiente ba iha superficie formas nia laran*	Yes *Sim*	No *Lae*			
−6	Did you check removal timing, method and procedure of the formwork? *Ita bo'ot verifika ona tempu ba remosaun, metodu no prosedimentu cofragem ka lae?*	Yes *Sim*	No *Lae*			

CHECKLIST for Box Culvert
Lista verifikasaun ba Box Culvert

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⑦	Rebar *Besi/Tulangan*					
-1	Did you confirm the quality of rebar? *Ita bo'ot komfirma ona qualidade tulangan ka lae?*	Yes *Sim*	No *Lae*			Confirmed by the certificate of quality Komfirma husi setifikadu kualidade
-2	Has the rebar been stored properly? *Besi/tulangan sira ne'e aruma ho didak ona ka lae?*	Yes *Sim*	No *Lae*			
-3	Has the rebar been thoroughly cleaned? *Besi/tulangan sira ne completamente mos tiha ona ka?*	Yes	No			
-4	Is the thickness of cover concrete been secured with an appropriate spacer? *kobre konkretu nia mahar seguru ho espaçador ne'ebe apropriadu ?*	Yes *Sim*	No *Lae*			Concrete clear cover 50mm
-5	Has the rebar been fixed sufficiently with binding wire? *besi/tulangan sira ne'e fixado ho suficiente uza arame ka lae?*	Yes *Sim*	No *Lae*			
-6	Are the number and diameter of rebars correct? *Numeru sira no diametru tulangan los ona ka lae?*	Yes *Sim*	No *Lae*			
-7	Are the position and interval of rebar appropriate? *Pozisaun no intervallu tulangan apropriado ona ka lae?*	Yes *Sim*	No *Lae*			
⑧	Concrete *Konkretu*					
-1	Did you check the class of concrete or concrete mixing contents before concrete casting? *Ita bo'ot verifika ona klasse konkretu ka konteudu konkretu nia mistura antes pengercoran ka ?*	Yes *Sim*	No *Lae*			
-2	Did you check the thickness befor concrete casting? *Ita bo'ot verifika ninia mahar antes pengecoran?*	Yes *Sim*	No *Lae*			slab: 510mm(500mm), wall: 505mm(500mm) bottom: 510mm(500mm)
-3	Did you check the inner size befor concrete casting? *Ita bo'ot verifika ona medida interno antes pengecoran ka?*	Yes *Sim*	No *Lae*			width: 4020mm(4000mm), height: 4050mm(4000mm)
-4	Did you check the slump and concrete tempture at concrete casting site? *Ita bo'ot verifika ona slump no konkretu nia temperatura iha fatin pengecoran ka?*	Yes *Sim*	No *Lae*			slump: :100mm concrete tempture: 30℃
-5	Is the capacity and number of vibration compaction machines appropriate? *Kapasidade no numeru husi makina kompaksaun husi vibrasaun apropriado ona ka?*	Yes *Sim*	No *Lae*			a piece of vibrator Vibrator pedasuk ida

CHECKLIST for Box Culvert
Lista verifikasaun ba Box Culvert

5/5

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⑧	Concrete（continue） *Konkretu (Kontinua)*					
-1	Has concrete work been done in the proper time from complete of mixing to complete of concrete casting? *obra konkretu ne'e hotu iha tempo ne'ebe lolos,desde kompleta mistura to'o kompleta fundição de konkretu?*	Yes *Sim*	No *Lae*			
-2	Did you check test piece for concrete strength test? *Ita bo'ot verifika ona parte balun husi teste konkretu nia resistensia?*	Yes *Sim*	No *Lae*			6 test pieces Teste pedasuk 6
-3	Has moist curing been carried out early after concrete casting? *Cura umida halao tiha ona antes fundição de konkretu ka lae?*	Yes *Sim*	No *Lae*			
-4	Has moist curing been carried out in a suitable method? *cura úmida halao ka lae ho metodu ne'ebe adequadu?*	Yes *Sim*	No *Lae*			Covered sheet on the concrete surface Folla koberta iha superficie konkretu
⑨	Backfill *Preenchimento*					
-1	Did you check the backfill material? *Ita bo'ot verifika ona materia prenchimento ka lae?*	Yes *Sim*	No *Lae*	―		Selected Material, From Borrow Pit No.1 material ne'ebe selesiona husi borrow pit no.1
-2	Has the compaction been carried out properly? *Kompaksaun halo ho lolos ona ka lae?*	Yes *Sim*	No *Lae*			Vibrating Compacter 40～60kg Kompaktador vibratorio 40～60kg
-3	Did you confirm the soil density test results? *Ita bo'ot komfirma rezultadu teste densidade rai ka?*	Yes *Sim*	No *Lae*	95%		Inspected density: 96% Densidade ne'ebe inspeksionado : 96%
-4	Did you confirm the compacted thickness? *Ita bo'ot komfirma ona kompaksaun ninia mahar?*	Yes *Sim*	No *Lae*	30cm		Inspected thickness: 30cm Mahar ne'ebe inspeksionado: 30 cm

5-4 Road Pavement WORKS

Obra pavimentasaun estrada

(1) Base Course / Sub-base Course

(for Road Pavement)

1/4

CL_Base Course

Edited_20181004

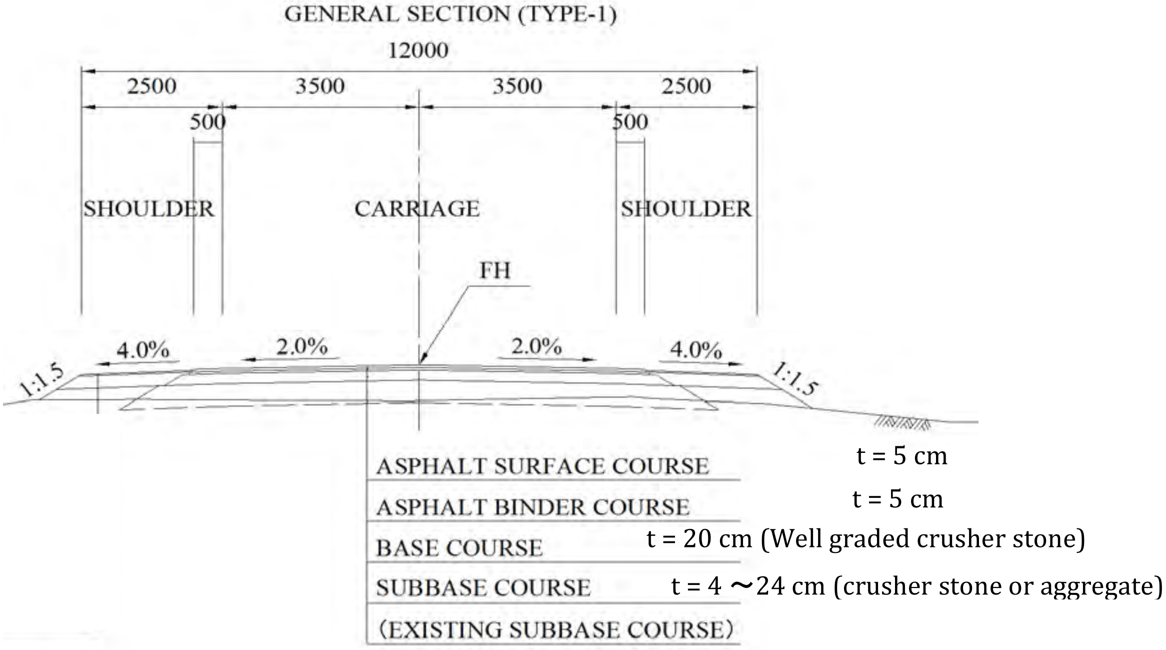


Figure 1. Example of Typical Section of Pavement (Rehabilitation Works)

Figura 1. Ezemplu kona ba Tipu seksaun pavimentasaun (obra Rehabilitasaun)

CHECKLIST for Base/Sub-base Course

Lista verifikasaun ba base/sub base

Type of Course: (upper/lower)

Tipu kona ba Kursu

Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km － km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition

Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan*
①	Construction Plan / Drawing					
	Planu konstrusaun / Dezennu					
-1	Is Consruction Plan prepared ?	Yes	No			
	Planu konstrusaun prepara ona ka?	*Sim*	*Lae*			
-2	Is Drawing prepared on the site?	Yes	No			
	Dezennu prepara ona iha terrenu ka?	*Sim*	*Lae*			

CHECKLIST for Base/Sub-base Course

2/4

Lista verifikasaun ba base/sub base

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan*
-3	Drawing is "Contract Drawing" or "Shop Drawing"	—	—			Contract Drawing / Shop Drawing
	Dezennu ne'e " Dezennu kontratu ka Dezennu servisu"					
-4	Thickness is indicated on the Drawing ?	Yes	No			
	Mahar ne'e indika iha dezennu ka lae?	*Sim*	*Lae*			
-5	Type/material of Base(sub-base) Course indicated on the drawing?	Yes	No			
	Tipu/Material husi base(sub base)course indika ona iha dezennu ka?	*Sim*	*Lae*			

CHECKLIST Base Course / Sub-base Course 3/4

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
<In case of Crushed Aggregate Base Course:303 / Aggregate Sub-Base Course:301 >						
<Iha Kazu kona ba curso baziku agregado esmogado:303/curso sub-baze agregadu:301>						
②	Checking "Material"					
	Verifika material					
-1	Are the material stored on the site properly?	Yes	No		308	
	Material sira armazenado iha sitiu ne'e apropriado ka lae?	Sim	Lae			
-2	Are the material free from organick matter and other detariolating matters?	Yes	No		301.2 303.2	
	Material sira ne'e livre husi materia organiku no sasan desariolantes?	Sim	Lae			
-3	Is the material satisfied with required "Grading" ?	Yes	No	JIS A 1102	301.2 303.2	Test frequency= each 1000m2
	Material hirak ne'e satifaz ho "klasifikasaun" ne'ebe nessesario ka lae?	Sim	Lae			Frekuensia ba teste = kada 1000m2
-4	Are the size of aggregate less than its maximum size?	Yes	No			subase and Class B<50mm, Class A<37.5mm
	Agregado nia nia medida ne'e menus husi nia medida maximu ka lae?	Sim	Lae			
-5	Is the material satisfied with required "Properties" ?	Yes	No	AASHTO T89,90, 193		PI, LI, Abration and Soaked CBR
	Material sira ne satisfaz ho nessesario " propriedades"?	Sim	Lae			
-6	Were the material tests resulted submitted for approval?	Yes	No			SPC Table301.1/2 and Table 303.1/2
	Rezultado husi teste ba material sira haruka ona atu halo aprovasaun ka lae?	Sim	Lae			
③	Checking "Compaction" workmanship					
	Verifikasaun obra "Kompaktasaun"					
-1	Are the spreading thickness proper ?	Yes	No		301.3.3 303.3.3	not exceed 150mm(in compacted)
	Espalhamento ninia mahar adequada ka lae?	Sim	Lae			la liu husi 150 mm (iha kompaktasaun)
-2	Are the compaction machine enough and properly ?	Yes	No		301.3 303.3	more than 8 ton roller is prefaerble
	Makina kompaktasaun sufisiente no adequada ka lae?	Sim	Lae			Roler liu toneladas 8 mak preferivel liu
-3	The numbers of pasiing by compaction machine, are enough?	Yes	No			Subbase;>2 passes, Base Course:>4 passes
	Numeru kompaktasaun ne'ebe passa ne'e suficiente ka lae?	Sim	Lae			
-4	Are Field Density carried out as specifed?	Yes	No			one test for every 200m of construction section
	Densidade iha kompu halao tuir espesifikasaun ka lae?	Sim	Lae			teste ida ba kada 200 m iha seksaun konstrusaun

CHECKLIST Base Course / Sub-base Course 4/4

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
-5	Have the Maximum Dry Density(MDD)already obtained ?	Yes	No	AASHTO T180	301.3 303.3	
	Densidade maran masimu hetan ona ka?	Sim	Lae			
-6	Field Density(FD) tested by sand-replacement method, are satisfied with the criteria of the Specification ?	Yes	No	AASHTO T199		refere to the Criterial of SPC: more than 100 %:
	Teste Densidade iha Kampo (DK) liu husi metodu subtitui rai henek, ne'e satifaz ho ninia kriteria husi espesifikasaun?	Sim	Lae			refere ba criteria husi spesifikasaun: liu husi 100%
-7	Other than sand-replacement method, wrote the what type of test are conducted ?	—	—			
	Alem de Metodu subtituisaun rai henek , hakerek tok tipu husi teste saida mak ita uza ?					
-8	Is the result of "⑩-4" satisfactory or not ?	Yes	No			
	Rezultado husi "⑩-4" ne'e satisfaz ka lae?	Sim	Lae			
④	Checking measurement for completed Course					
	Verifika medida ba kursu ne'ebe kompletu					
-1	Are the lines, grade and cross sections completed in accordance with the Drawing or as directed by the Engineer?	Yes	No		301.1 303.1	
	Linna, grau/klasse,seksaun transversal concluidos tuir dezennu ou instrusaun husi Enjinneru ka?	Sim	Lae			
-2	Is the thickness of layer ( ) within permitted variation?	Yes	No		301.3.5 303.3.5	Allowable tolerance: + 20mm(± 10mm) (Base Course)
	Dalas nia mahar tama ona ba variasaun ne'ebe permite ka?	Sim	Lae			toleransia ne'ebe permite: + 20mm(± 10mm) (Base Course)
-3	Is the Level of Surface within permitted variation?	Yes	No			ditto: +10mm, -20mm (+5mm, -10mm)
	Nivel superficie iha ona variasaun ne'ebe permite nia laran ona ka?	Sim	Lae			
-4	Is the Surface Irreguraity within permitted variation?	Yes	No	tes		ditto: 20mm
	Irregularidae superficie tama ona iha variasaun ne'ebe permitida ka?	Sim	Lae			

5-4 Road Pavement WORKS

Obra pavimentasaun estrada

(1) Base Course / Sub-base Course

(for Road Pavement)

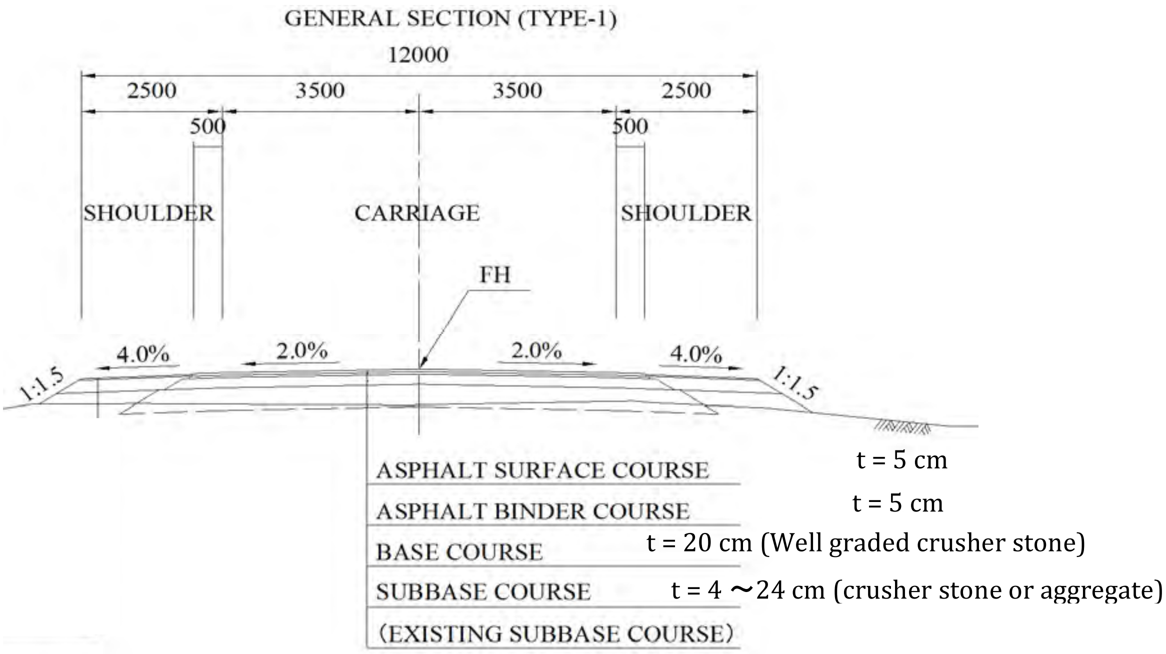


Figure 1. Example of Typical Section of Pavement (Rehabilitation Works)
Figura 1. Ezemplu kona ba Tipu seksaun pavimentasaun (obra Rehabilitasaun)

CHECKLIST for Base/Sub-base Course
Lista verifikasaun ba base/sub base

Type of Course: (upper/lower)
Tipu kona ba Kursu

Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km – km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

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Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	Construction Plan / Drawing					
	Planu konstrusaun / Dezennu					
-1	Is Consruction Plan prepared ?	Yes	No			
	Planu konstrusaun prepara ona ka?	*Sim*	*Lae*			
-2	Is Drawing prepared on the site?	Yes	No			
	Dezennu prepara ona iha terrenu ka?	*Sim*	*Lae*			

CHECKLIST for Base/Sub-base Course

Lista verifikasaun ba base/sub base

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
-3	Drawing is "Contract Drawing" or "Shop Drawing"	—	—			Contract Drawing / Shop Drawing
	Dezennu ne'e " Dezennu kontratu ka Dezennu servisu"					
-4	Thickness is indicated on the Drawing ?	Yes	No			
	Mahar ne'e indika iha dezennu ka lae?	*Sim*	*Lae*			
-5	Type/material of Base(sub-base) Course indicated on the drawing?	Yes	No			
	Tipu/Material husi base(sub base)course indika ona iha dezennu ka?	*Sim*	*Lae*			

CHECKLIST Base Course / Sub-base Course 3/4

No.	Check Items / *Verifika Itens*	Judgements / *Julgamentu* (Selection No.) / *Seleciona*		Specification / *Spesifikasaun* Standards / *Padraun*	SPC	Remaks / *Observasaun* (Printed figure is reference only) / *(Figura ne'ebe impressa hanesan referensia deit)*
<In case of Crushed Aggregate Base Course:303 / Aggregate Sub-Base Course:301 >						
<Iha Kazu kona ba curso baziku agregado esmogado:303/curso sub-baze agregadu:301>						
②	Checking "Material"					
	Verifika material					
-1	Are the material stored on the site properly?	Yes	No		308	
	Material sira armazenado iha sitiu ne'e apropriado ka lae?	Sim	Lae			
-2	Are the material free from organick matter and other detariolating matters?	Yes	No		301.2 303.2	
	Material sira ne'e livre husi materia organiku no sasan desariolantes?	Sim	Lae			
-3	Is the material satisfied with required "Grading" ?	Yes	No	JIS A 1102	301.2 303.2	Test frequency= each 1000m2
	Material hirak ne'e satifaz ho "klasifikasaun" ne'ebe nessesario ka lae?	Sim	Lae			Frekuensia ba teste = kada 1000m2
-4	Are the size of aggregate less than its maximum size?	Yes	No			subase and Class B<50mm, Class A<37.5mm
	Agregado nia nia medida ne'e menus husi nia medida maximu ka lae?	Sim	Lae			
-5	Is the material satisfied with required "Properties" ?	Yes	No	AASHTO T89,90, 193		PI, LI, Abration and Soaked CBR
	Material sira ne satisfaz ho nessesario " propriedades"?	Sim	Lae			
-6	Were the material tests resulted submitted for approval?	Yes	No			SPC Table301.1/2 and Table 303.1/2
	Rezultado husi teste ba material sira haruka ona atu halo aprovasaun ka lae?	Sim	Lae			
③	Checking "Compaction" workmanship					
	Verifikasaun obra "Kompaktasaun"					
-1	Are the spreading thickness proper ?	Yes	No		301.3.3 303.3.3	not exceed 150mm(in compacted)
	Espalhamento ninia mahar adequada ka lae?	Sim	Lae			la liu husi 150 mm (iha kompaktasaun)
-2	Are the compaction machine enough and properly ?	Yes	No		301.3 303.3	more than 8 ton roller is prefaerble
	Makina kompaktasaun sufisiente no adequada ka lae?	Sim	Lae			Roler liu toneladas 8 mak preferivel liu
-3	The numbers of pasiing by compaction machine, are enough?	Yes	No			Subbase;>2 passes, Base Course:>4 passes
	Numeru kompaktasaun ne'ebe passa ne'e suficiente ka lae?	Sim	Lae			
-4	Are Field Density carried out as specifed?	Yes	No			one test for every 200m of construction section
	Densidade iha kompu halao tuir espesifikasaun ka lae?	Sim	Lae			teste ida ba kada 200 m iha seksaun konstrusaun

CHECKLIST Base Course / Sub-base Course 4/4

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
-5	Have the Maximum Dry Density(MDD)already obtained ?	Yes	No	AASHTO T180	301.3 303.3	
	Densidade maran masimu hetan ona ka?	Sim	Lae			
-6	Field Density(FD) tested by sand-replacement method, are satisfied with the criteria of the Specification ?	Yes	No	AASHTO T199		refere to the Criterial of SPC: more than 100 %:
	Teste Densidade iha Kampo (DK) liu husi metodu subtitui rai henek, ne'e satifaz ho ninia kriteria husi espesifikasaun?	Sim	Lae			refere ba criteria husi spesifikasaun: liu husi 100%
-7	Other than sand-replacement method, wrote the what type of test are conducted ?	—	—			
	Alem de Metodu subtituisaun rai henek , hakerek tok tipu husi teste saida mak ita uza ?					
-8	Is the result of "⑩-4" satisfactory or not ?	Yes	No			
	Rezultado husi "⑩-4" ne'e satisfaz ka lae?	Sim	Lae			
④	Checking measurement for completed Course					
	Verifika medida ba kursu ne'ebe kompletu					
-1	Are the lines, grade and cross sections completed in accordance with the Drawing or as directed by the Engineer?	Yes	No		301.1 303.1	
	Linna, grau/klasse,seksaun transversal concluidos tuir dezennu ou instrusaun husi Enjinneru ka?	Sim	Lae			
-2	Is the thickness of layer ( ) within permitted variation?	Yes	No		301.3.5 303.3.5	Allowable tolerance: + 20mm(± 10mm) (Base Course)
	Dalas nia mahar tama ona ba variasaun ne'ebe permite ka?	Sim	Lae			toleransia ne'ebe permite: + 20mm(± 10mm) (Base Course)
-3	Is the Level of Surface within permitted variation?	Yes	No			ditto: +10mm, -20mm (+5mm, -10mm)
	Nivel superficie iha ona variasaun ne'ebe permite nia laran ona ka?	Sim	Lae			
-4	Is the Surface Irreguraity within permitted variation?	Yes	No	tes		ditto: 20mm
	Irregularidae superficie tama ona iha variasaun ne'ebe permitida ka?	Sim	Lae			

(2) Asphalt Pavement (AsP) 1/3

Pavimentasaun Aspal

CL_AsP-1_Design
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- Design & Specification Checking — *Verifika dezennu no Spesifikasaun*
  - ・Test for material — *Teste ba material*
    - Characteristic test for aggregat; Gradation, Specific density, Abrasion, Freakiness
      Teste kona ba karakteristika, agregadu, gradasaun, densidade ne'ebe spesifiku liu, abrasaun, esquisitice.
    - Characteristic test for asphalt; Penetration, Softening point, Ductility and so on
      Teste karakteristika ba aspal; penetrasaun, ponto de amolecimento, daktilitas nsst.
  - ・Mix Design — *Dezennu Mistura*
    - To decide mix proportion so that combined gradation satisfy specification requirements
      Atu decide proporsaun mistura nune'e bele kombina dradasaun ne'ebe bele satisfaztuir rekezitus spesifikasaun.
    - To decide proposed asphalt content
      Atu desidi konteudu aspal ne'ebe propoin
    - To check the stability and flow are satisfy specification requirement
      Atu verifika stabilidade no fluxo ne'ebe mak tuir rekezitus spesifikasaun.
  - (Plant)
    - To check weighing apparatus and thermometer
      Atu verifika aparelhos pesagem no termômetro
    - To check each cold bin flow
      Atu verifika fluxo kada compartementu ne'ebe malirin
  - ・Trial Mix & Pavement — *Mistura eksperimental no Pavimentasaun*
    - To check if asphalt mix is produced same characteristic as mix design
      Atu verifika se karik aspal nia mistura produs karakteristika ne'ebe hanesan ho dezennu mistura
    - To check the temperature is satisfy specification requirements
      Atu verifika temperatura ne'ebe mak tuir rekezitus spesifikasaun
    - To check compaction ratio satisfy specification requirements
      Atu verifika kompaksasaun ninia proporsaun tuir rekzitus spesifikasaun
    - To check compaction equipment are good condition to achieve density
      Atu verifika ekipamentus sira iha kondisaun diak nune'e bele hetan densidade.
- Daily Quality Control — *Kontrollu kualidade diaria*
- Core Sampling Test — *Teste Amostrajem prinsipal*

Figure: Overall checking points for Asphalt Pavement works
Figura: Pontus verifikasaun jeral ba obra pavimentasaun aspal

CHECKLIST for Design Mix & specification (AsP-1)
Lista verifikasaun ba dezennu mistura & Spesifikasaun (Aspal-1)

Type of Course: Surface(wearing) Course / Binder Course

Name of Project: *Naran Projetu :*			
Location: *Fatin:*		Date: / / (DD/MM/20YY) Data:	
Name of Contractor: *Naran Kontraktor :*		Location: STA km − km *(Fatin)*	
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*		

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun*: Standards *Padraun*	Specification: SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	Test for material *Teste ba material*					
−1	Have Sieve Tests for each type of aggregate ? *Iha kada tipo ba peneira agregat ka lae?*	Yes *Sim*	No *Lae*			
−2	Are caracteristic of aggregate satisfied ? *Karakteristika agregat sira ne'e satifaz ka lae?*	Yes *Sim*	No *Lae*			Secific Gravity, Abrasion, Free from derteriate matter etc. Gravidade spesifiku,abrasaun, livre husi deteriorar nsst

CHECKLIST for Design Mix & specification (AsP-1)
Lista verifikasaun ba dezennu mistura & Spesifikasaun (Aspal-1)

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
②	Tests for caracteristic of asphalt					<For Example figure only here>
	Teste ba karakteristika aspal					<Pur ezemplu figura deit iha ne'e>
-1	Prenetration value of asphlt is within specifiction?	Yes	No			Specified value (1/10mm): 60-80
	Valor penetrasaun apsal sira ne'e tama iha spesifikasaun ka lae?	*Sim*	*Lae*			valor ne'ebe spesifika (1/10mm): 60-80
-2	Specific Gravity of asphlt is within specifiction?	Yes	No			Specified value: more than 1.0
	Gravidade spesifika kona ba aspal nian iha espesifikasaun nia laran?	*Sim*	*Lae*			Valor ne'ebe spesifika: bo'ot liu 1.0
-3	Softening point of asphlt is within specifiction?	Yes	No			Specified value (℃): 44-52
	ponto de amolecimento aspal nian iha espesifikasaun nia laran?	*Sim*	*Lae*			Valor ne'ebe spesifika (℃): 44-52
-4	Ductility of asphlt is within specifiction?	Yes	No			Specified value [15℃](cm): more than 100
	Ductilidade aspal ne tama iha spesifikasaun ka lae?	*Sim*	*Lae*			Valor ne'ebe spesifika [15℃](cm): liu husi 100

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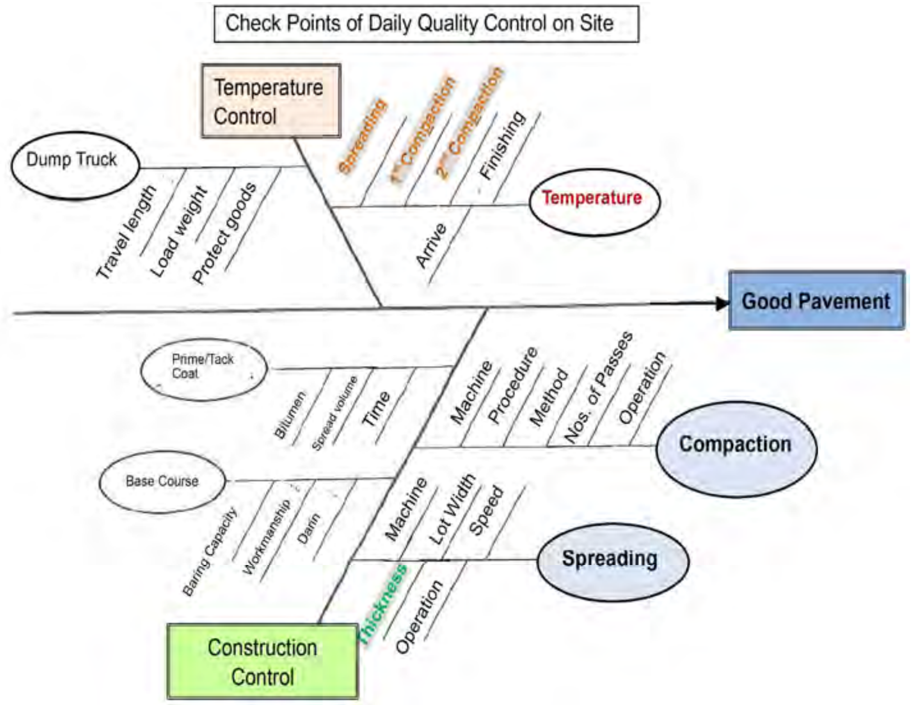
CHECKLIST for Design Mix & specification (AsP-1)

Lista verifikasaun ba dezennu mistura & Spesifikasaun (Aspal-1)

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
③	Mix Design					
	Dezennu mistura					
-1	Has Seive tests for proposed combined aggregate been carried out and is the Combination Gradation satifieced ?	Yes	No			
	Teste peneira ba kobinasaun agregat ne'ebe proposta halao ona no kombinasaun gradasaun ne'e satifaz ka lae?	*Sim*	*Lae*			
-2	Has Combination Ratio of each type of aggregate material already decided and is it Practicable?	Yes	No			
	Proposaun ba kada tipu material agregat desidi tiha ona no ida ne'e bele pratika ka lae?	*Sim*	*Lae*			
-3	Is proposed Asphalt content of asphalt concrete reasonalble and practicable?	Yes	No			
	Konteudu aspal konkretu ne'ebe propoin razoavel no praticavel ka lae?	*Sim*	*Lae*			
④	Check As Plant					
	Verifika fabrika aspal					
-1	Calibration of measuing equipment of asphalt plant is finised ?	Yes	No			
	Kalibrasaun ekipamntus sukat ba fabrika aspal nian hotu ona ka lae?	*Sim*	*Lae*			
⑤	Trial Mix & Pavement					
	Mistura tentativus no Pavimentus					
-1	Decide mixes at plant, cold & hot bin by Trail Mix or not?	Yes	No			
	Desidi mistura iha fabrika compartimento manas no malirin liu husi mistura esperimental ka lae?	*Sim*	*Lae*			
-2	Decide Optimum Compaction Temperature by Trial Pavement ?	Yes	No			
	Deside temperatura kompaktasaun ne'eebe ideal liu husi pavimento eksperimental?	*Sim*	*Lae*			
-3	Decide targeting spreading thickness by Trail Pavement ?	Yes	No			
	Deside segmenta ninia mahar liu husi pavimentu eskperimental ?	*Sim*	*Lae*			

CHECKLIST Listaverifikasaun | **Asphalt Pavement (AsP)** Pavimentasaun Aspal (AsP) | 1/2 | CL_AsP-2_Daily QC Edited_20181005



Laboratory test

< Hot bin gradation check >
Calculate combined gradation

< Marshal test >
Density check, Stability and flow

< Extraction test >
Asphalt content and gradation

< Core density >
Thickness and compaction ratio

CHECKLIST for Daily Quality Control on site (AsP-2)
Lista verifikasaun ba Kontrollu kualidade diaria iha terrenu (AsP-2)

Type of Course: Surface(wearing) Course / Binder Course

Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km – km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	Construction Control Plan *Planu kontrollu konstrusaun?*					
-1	Is Consruction Plan prepared ? *Planu konstrusaun preparado ona ka?*	Yes *Sim*	No *Lae*			
②	Spreading of asphalt concrete *Espalhamento aspal konkretu*					
-1	Thickness of finisher is apropriate? *Mahar/espessura husi acabamento nian apropriado ka lae?*	Yes *Sim*	No *Lae*			

CHECKLIST for Daily Quality Control on site (AsP-2)
Lista verifikasaun ba Kontrollu kualidade diaria iha terrenu (AsP-2)

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
-2	Speed of spreading is suite for compaction capacity?	Yes	No			
	Velosidade espalhamentu ne'e adequadu ba kapasidade kompaktasaun?	*Sim*	*Lae*			
③	Compaction of asphalt concrete					
	Kompaktasaun aspal konkretu					
-1	Combination of compaction machinery is adquate ?	Yes	No			Initial Comp=________________ , Secondary comp=
	Kombinasaun makina kompaktasaun ne'e adequada ona ka lae?	*Sim*	*Lae*			*Kompaktasaun inisiu=* *,Kompaktasaun segundu=*
-2	Order of compaction is properly carried out ?	Yes	No			
	Ordem ba kampaktasaun ne'e halao ho lolos ona k lae?	*Sim*	*Lae*			
-3	Numbers of passes of Machines are OK ?	Yes	No			
	Numero ne'ebe passa makinas sira ne OK ka lae?	*Sim*	*Lae*			
④	Temperature Control					< note of actual temprature on site >
	Kontrollu temperatura					*< nota temperatura real iha terrenu >*
-1	Arriving temperature of Asphalt(As) concrete is OK ?	Yes	No			
	Temperatura aspal ne'ebe to'o mai ne OK ka lae?	*Sim*	*Lae*			
-2	Spreading temperature of As concrete is OK ?	Yes	No			
	Temperatura espalhamento konkretu nia OK ka lae?	*Sim*	*Lae*			
-3	Initail Compaction temperature of As concrete is OK ?	Yes	No			
	Temperatura kampaksaun inisiu Aspal konkretu nian OK ka lae?	*Sim*	*Lae*			
-4	Secondary Compaction temperature of As concrete is OK ?	Yes	No			
	Temperatura kompaksaun aspal konkretu nian ne OK ka lae?	*Sim*	*Lae*			
-5	Temperrature of As concrete at Finishing works is OK ?	Yes	No			
	Temperatura aspal konkretu iha obra ne'e hotu ona ne'e OK ka lae?	*Sim*	*Lae*			

＊Table of Criteria of Temprature by Standard Specification, MoPWTC, (or as directed by the Engineer)

Tabela kona ba criteria temperatura husi padraun stpesifikasaun, (ka diretamente husi Enjinerru)

Table 411.5.4 - Requirements for Viscosity and Temperature of Bituminous Binder for Mixing and Compaction

No	Construction Process	Viscosity of Bituminous Binder	Type I 60-70 pen Bitumen (°C)
1	Mixing Marshall Mix Specimen	0.2	155 ± 1
2	Compacting Marshall Mix Specimen	0.4	145 ± 1
3	Mixing, Target Temperature Range	0.2 – 0.5	145 – 155
4	Loading Asphalt into the Truck	± 0.5	135 – 150
5	Delivery to finisher (paver	0.5 – 1.0	130 – 150
6	Breakdown Rolling (Steel Drum)	1 – 2	125 – 145
7	Secondary Rolling (Rubber Tire)	2 – 20	100 – 125
8	Finishing Rolling (Steel Drum)	< 20	≥95

CHECKLISTS Asphalt Pavement (AsP) 1/2

Lista Verifikasaun *Pavimentasaun aspal (Asp)*

Core Sampling Test — Core Sampling T

Teste Amostrjem Prinsipal — *Amostrajem prinsipal*

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Marshall Test for each product of Asphalt concrete should be carried out as per production day.

Compaction of Marshall Sample

Kompaktasaun amostrajem Marsall

Marshall Tests for every product

Teste Marsall ba kada produtu

As per specified interval, Core Sampling (10cm dia) shall be taken from the completed pavement, to measure the thickness and the Density and to check other caracterristic.

* Parameter for Evaluation of asphalt concrete;

$$(\%)\ \text{Degree of Compaction (Dc)} = \frac{\text{Density of Core Sample (Ds)}}{\text{Marshall maximum Density (Dm)}} \times 100$$

= > or < Specified %

CHECKLIST for Core Sampling Test (AsP-3)

Lista Verifikasaun ba Teste amostrajem prinsipal (Aspal-3)

Type of Course :	Surface(wearing) Course / Binder Course

Name of Project : *Naran Projetu :*	
Location : *Fatin:*	Date : / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km − km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	Marshall Test *Teste Marsall*					

CL_AsP-3_Core Sampling

CHECKLIST for Core Sampling Test (AsP-3) 2/2

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Lista Verifikasaun ba Teste amostrajem prinsipal (Aspal-3)

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
-1	Have Marshall Tests been carried out at evey production day of Asphlat concrete at Plant ?	Yes	No			Checking Test record on Lobatory?
	Teste marshall ne'e halao iha kada produsaun aspal konkretu loron-loron iha fabrica ka lae?	*Sim*	*Lae*			*verifika rejistu teste iha laboratorio*
②	Core Sampling					*(Figura ne'ebe impressa hanesan*
	Amostrajem prinsipal					
-1	Does Core on site sampled as per specified interval?	Yes	No			Specified Interval: one cre sampling as per 1,000m2
	Core ne'ebe amostra iha terrenu hanesan hatudu iha intervallu spesifikasaun ka lae?	Sim	Lae			*Intervallu spesifiku : core sampling ida per 1,000 m2*
-2	In each test, 3 specimen are sampled ?	Yes	No			
	iha kada teste, iha especime 3 mak sei amostra?	Sim	Lae			
③	Evaluation of Core Samples					
	Evaluasaun amostrajem prinsipal					
-1	Thickness Are same as with Design thickness ?	Yes	No			Design thickness of Binder Coure is 6 cm
	Mahar/espessura hanesan ho mahar/espessura dezennu?	Sim	Lae			*Mahar dezennu nian ba binder course mak 6 cm*
-2	Degree of Compaction (Dc); Are same as with Specification ?	Yes	No			Specifed Dc=95 %
	Grau kompaktasaun (GC); hanesan ho spesifikasaun ka ?	Sim	Lae			*spesifikasaun grau kompaktasaun = 95 %*
-3	Has extraction test of material from core ? Is it OK?	Yes	No			Asphalt content, Gradation of Aggregate
	Teste ba ekstrasaun material husi core iha ka? Id ne'e ok?	Sim	Lae			*konteudu aspal, gradasaun agregado*

6. Checklists for Safety Control

6. Checklists for Safety Control
Lista verifikasaun ba kontrolla seguransa

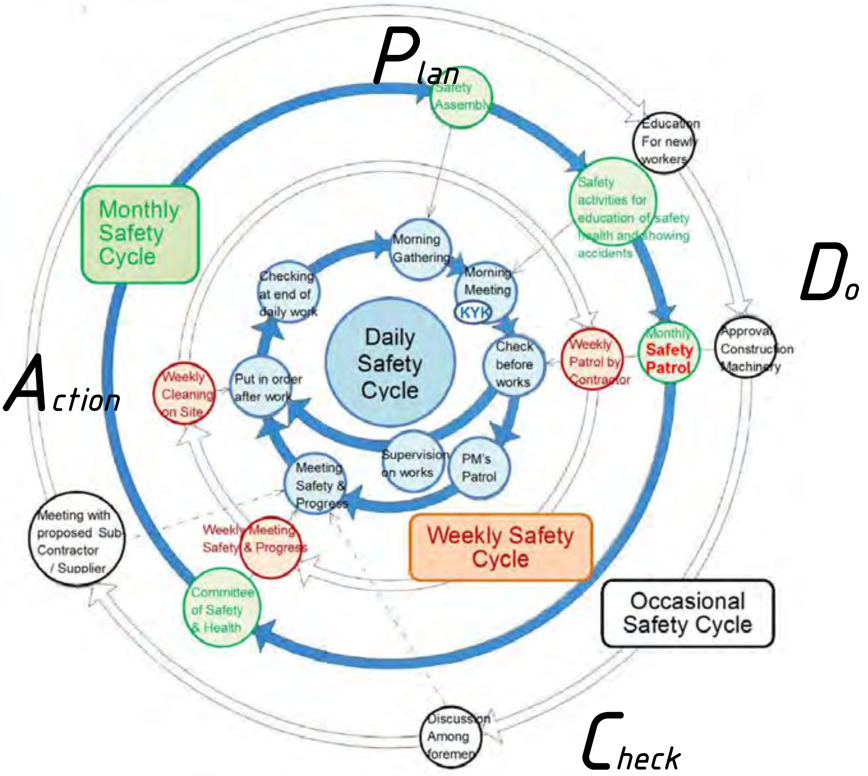
6-1 Daily Safety Checking
Verifikasaun diaria seguransa nian 1/3

CL_SC-10_Daily Checking

Edited_20190225

Activities for Safety construction *Circle*

Aktividade ba siklu seguransa ba konstrusaun



Example:Banner of Safety, presenting Slogan

Ezemplu :Spanduk seguransa nian,aprezenta slogan

<u>CHECKLIST for Daily Safety Checking</u> (SC-10)
<u>*Lista verifikasaun ba verifikasaun seguransa diaria*</u>

Name of Project: *Projetu nia naran:*	
Location: *Fatin :*	Date: / / (DD/MM/20YY) Date: / /
Name of Contractor: Mejori and management by Jonise *Kontraktor nia Naran*	Location: STA km – km *Fatin*
Name of Inspector: *Inspektor nia naran*	Name of Department: *Departementu nia naran*

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	Protection equipment for workers					
-1	Safety Helmets are weared by workers ? *Traballador sira utiliza kapasete seguransa ka lae ?*	Yes *Sim*	No *Lae*			
-2	Does workers keep proper shoes for his jobs ? *Traballador sira kontinua uza sapatu ne'ebe adequada ka ?*	Yes *Sim*	No *Lae*			

CHECKLIST for Daily Safety Checking (SC−10) 2/3

Lista verifikasaun ba verifikasaun seguransa diaria

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun*		Remaks *Observasaun*
				Standards *Padraun*	SPC	(Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
−3	In case of watchmen, works in the night and/or near heavy traffic;Do they wear a sfety(refecting) jacket ? *Iha kazu vigias, servisu iha tempu kalam no/ka besik trafiku ne'ebe intensu; sira uza jaket seguransa ka lae?*	Yes *Sim*	No *Lae*			

CHECKLIST for Daily Safety Checking (SC-10) 3/3

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *(Seleciona no.)*		Specification *Spesifikasaun* Standards *(Padraun)*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan*
②	Precaoution/instruction to workers *Prekausaun/instrusaun ba Traballador sira*					
-4	Does contrsctor's supervisior (SV) give precausion? *Kontraktor nia supervisor fo esplikasaunkona ba prosedimentu servisu ka lae?*	Yes *Sim*	No *Lae*			Regarding today's works, SV give Safety instruction / precaution to workers before start the works *Relasiona ho servisu ohin loron nian, supervisor hato instrusaun /prosedimentu seguransa nia ba traballador sira antes sira komesa*
-5	Morning, do Tool Box Meeting carry out ? *Tool Box meeting ne'e halao ka lae?*	Yes *Sim*	No *Lae*			Before start the works, contractor SV and a group of workers for each working group have a morning meeting regarding today's work procedure and dangerous point of today's work. *antes komesa servisu supervisor husi kontraktor no groupo traballador ba kadar groupu servisu halo entkontru dader relasiona ho prosedimentu servisu ohin loron nian no pontu perigozu husi servisu ohin loron.*

	・**Finding out Dangerous points** *Deskobre pontu perigozu*			
1)				
2)				
3)				

	・**Instructions and expecting counter-measures (if any)** *Instrusaun no espektasaun konba ba kontra medida (se iha)*			
1)				
2)				
3)				

Overall comments: *Komentariu en jeral*

CL_SC-20_Sfety Activity

6-2 Regulary Safety Activity
Aktividade seguransa regular

1/3

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Following regulary safety activies are desired on the site;
Aktividade seguransa tuir mai ne'e mak dezeja iha terrenu;

Tool box meeting

As a each working group, supervisors explain today's work procedures and safety remarks to workers

Hanesan kada gropu servisu nian, supervisores sira esplika kona ba prosedimentu servisu ohin loron nian no observasaun seguransa ba traballador sira

Safety Patrol

Jointly site inspection and find out dangerous points and if necessary instructions are to be made

Inspeksaun konjunta iha terrenu no deskobe pontus perigozus sira no halo instrusaun ne'ebe nessesariu

Safety Assembly

Safety Gatheings are to be made in order to promote all workers' awarness of Safety on the construction site.

Reuniaun seguransa sira tenki halo nune'e bele realiza atu nune'e bele promove ba traballador sira nia concientizasaun kona ba seguran iha fatin konstrusaun.

CHECKLIST for Regular Safety Activities (SC-20)
Lista verifikasaun ba aktividade seguransa regular(SC-20)

Name of Project: *Projetu nia naran:*	
Location: *Fatin :*	Date: / / (DD/MM/20YY) Date: / /
Name of Contractor: Mejori and management by Jonise *Kontraktor nia Naran*	Location: STA km – km *Fatin*
Name of Inspector: *Inspektor nia naran*	Name of Department: *Departementu nia naran*

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	*Safety Patrol by the Contractor*					
	Patrulla seguransa husi kontraktor					
-1	*Does PM or site engineer conduct Daily Safety Patrol ?*	Yes	No			
	PM ka Enjinerru iha terenu hala'o patrullamentu seguransa diaria ka?	*Sim*	*Lae*			
-2	*Does PM or site engineer conduct Weekly Safety Patrol ?*	Yes	No			*Joining sub-contractor is preferable.*
	PM ka Enjinerru iha terenu hala'o patrullamentu seguransa semanal ka?	*Sim*	*Lae*			*Hamutuk ho sub kontratantes ne'e preferivel liu*

CHECKLIST for Regulay Safety Activities 2/3
Lista verifikasaun ba aktividade seguransa regular(SC-20)

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
-3	*Does PM or site engineer conduct Monthly Safety Patrol ?*	Yes	No			*Joining Employer is preferable.*
	PM ou enjinerru iha terrrenu halao patrulla seguransa mensal ka lae?	*Sim*	*Lae*			*hamutuk ho empregador ne'e preferivel liu*
②	*Progress and Safety Meeting*					
	Progresu no enkontru seguransa					
-1	*Weekly Progress & Safety meeting is held?*	Yes	No			*Joining Employer and sub-contractor is preferable.*
	Enkontru ba Progressu semanal & seguransa nian halao ka lae?	*Sim*	*Lae*			*hamutuk ho empregador no subkontratantes sir preferivel liu*
-2	*Montly Progress & Safety meeting is held?*	Yes	No			*Joining Emplyor is essential*
	Enkontru ba Progressu mensal & seguransa nian halao ka lae?	*Sim*	*Lae*			*hamutuk ho empregador sira nemak essencial liu*
-3	*Site Safety Committee meeting is held ?*	Yes	No			
	Reuniaun komite seguransa iha terrenu realiza ka lae?	*Sim*	*Lae*			

CHECKLIST for Regulay Safety Activities 3/3
Lista verifikasaun ba aktividade seguransa regular(SC-20)

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
③	Regulay Safety Activities					
	Atividade seguransa regular					
-1	Have Safety Assembly been carried out ?	Yes	No			Safety Gatherings are to be made in order to promote all workers' awarness of Safety on the construction site
	Asembleia seguransa halao ona ka lae?	*Sim*	*Lae*			*Reuniaun ba seguransa nia tenki halo duni nune'e bele prompve traballador sira nia konsiensia kona ba seguransa iha fatin konstrusaun.*
-2	Educational training to operatotrs and workers, have been conducted?	Yes	No			Especiaaly, it is necessary when the workers come to the site first or the operators begins the new type of work procedure
	Formasaun ne'ebe edukativu ba operador no traballador sira halao ona ka ?	*Sim*	*Lae*			*especialmente, ida ne'e nessesario wainhira traballador sira halao sira nia servisu inisiu no operador sira comesa sira nia tipu prosedimentu ne'ebe foun.*
-3	Contractor's PM or site supervisors, do safety patrol/ checking to the site every day ?	Yes	No			Giving safety instruction and precaution is more important upon such patrol
	PM kontraktor nia ka supervisor iha terrenu, halo patrulla seguransa / verifika sitiu lor-loron ka lae?	*Sim*	*Lae*			*Fo instrusaun kona ba seguransa nian ne'e importante liu do que patrulla.*

	・Finding out Dangerous points *Deskobre pontus perigosus*			
1)				
2)				
3)				

	・Instructions and expecting counter-measures (if any) *Instrusaun no hein katak bele halo kontra medida (Karik iha)*			
1)				
2)				
3)				

Overall comments:
(Komentariu en-jeral)

1/2

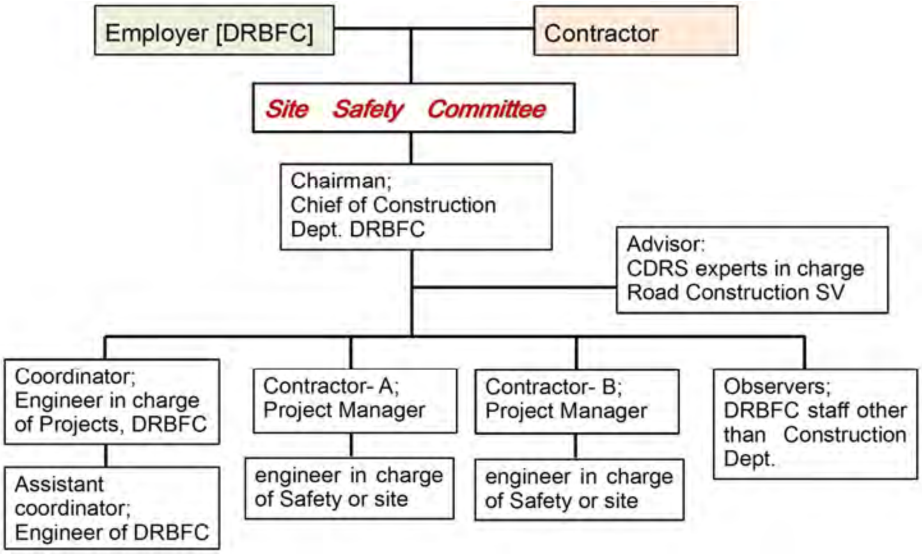
CL_SC-30_Sfety Committee

6-3 Safety organization and management
Organizasaun no jerenciamentu seguransa

Edited_20181005

Showing Example for Pilot Safety Activity site

Hatudu ezemplu ba pilotu aktividade seguransa iha terrenu



(SC-30)

CHECKLIST for Safety organization and management
Lista verifikasaun ba organizasaun no jerensiamentu seguransa

Name of Project: *Projetu nia naran:*		
Location: *Fatin :*		Date: / / (DD/MM/20YY) Date: / /
Name of Contractor: Mejori and management by Jonise *Kontraktor nia Naran*		Location: STA km − km *Fatin*
Name of Inspector: *Inspektor nia naran*	Name of Department: *Departementu nia naran*	

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	Site management by the Contractor					
	Jestaun seguransa iha terrenu husi kontraktor					
−1	Contractor's site supervisors, are stationaly on the site ?	Yes	No			
	kontraktor nia Supervisores lokal sira, iha terrenu ka lae?	*Sim*	*Lae*			
−2	Has Contractor a resident engineer on the site ?	Yes	No			
	Kontraktor nia enjinerru residente iha terrenu ka lae?	*Sim*	*Lae*			

CHECKLIST for Safety organization and management 2/2
Lista verifikasaun ba organizasaun no jerensiamentu seguransa

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
③	Site Organization and management					
	Organizasaun iha terrenu no ninia jestaun					
−1	Has the Contractor organization Scheme for management ?	Yes	No			
	Kontraktor sira iha eskema ba jerenciamentu ka lae?	*Sim*	*Lae*			
−2	Site Safety Commiitee, does Contractor established ?	Yes	No			Involvement of Employer is preferable
	Kontraktor estabele komisaun ba seguransa iha terrenu ka lae?	*Sim*	*Lae*			*involme an husi empregador sira ne'e preferivel liu.*

CHECKLIST for Safety organization and management 2/2
Lista verifikasaun ba organizasaun no jerensiamentu seguransa

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
③	Keeping Safety data and/or document					
	Asegura dadus seguransa ka dokumentus sira					
-1	Does keep record of numbers of workers and machinery?	Yes	No			
	Mantein rejistu numeru traballador no makina sira?	*Sim*	*Lae*			
-2	Does reserve the accident record, if any?	Yes	No			
	Reserva rejistu asidente , karik iha ?	*Sim*	*Lae*			

	・Finding out Dangerous points *Deskobre pontu perigozus*			
1)				
2)				
3)				

	・Instructions and expecting counter-measures (if any) *Instrusaun no hein katak bele halo konktra medida (Karik iha)*			
1)				
2)				
3)				

Overall comments: *Komentariu en-jeral*

6-4 Checklist for Safety Patrol

Lista verifikasaun ba patrulla seguransa 1/3

CL_SC-40_Safety Patrol

Edited_20181005

CHECKLIST: Safety Patrol
Lista verifikasaun: Patrulla seguransa

Name of Project: *Projetu nia naran:*		
Location: *Fatin :*		Date: / / (DD/MM/20YY) Date: / /
Name of Contractor: Mejori and management by Jonise *Kontraktor nia Naran*		Location: STA km - km *Fatin*
Name of Inspector: *Inspektor nia naran*	Name of Department: *Departementu nia naran*	

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
①	Participants and interval of "Safety Patrol"					
	Partisipante sira no intervallu "Patrulla seguransa"					
-1	Have you received "Announcement" of today" Patrol?	Yes	No			
	Ita bo'ot simu ona aviszu kona ba patrulla ohin loron ka?	*Sim*	*Lae*			
-2	DRBFC staff in charge, attend the Patrol?	Yes	No			
	Funsionario DNEPCC ne'ebe toma konta atende patrulla ne'e ka lae?	*Sim*	*Lae*			
-3	Contractor's staff in charge, attend the Patrol?	Yes	No			
	Kontraktor nia funsionariu sira atende patrulla ne'e ka lae?	*Sim*	*Lae*			
②	Inspection Points for Safety					
	Pontus inspeksaun ba seguransa					
-1	Workers wear safety helmets ?	Yes	No			
	Traballador sira uza kapasete seguransa ka lae?	*Sim*	*Lae*			
-2	Workers wear safety color vests ?	Yes	No			
	Traballador sira uza coletes colorido ba seguransa nia ka lae?	*Sim*	*Lae*			
-3	Were workers explained today's work procedure?	Yes	No			
	Traballador sira hetan esplikasaun kona ba prosedimentu servisu ohin loron nia ona ka seidauk?	*Sim*	*Lae*			
-4	Were workers explained today's dengourous points?	Yes	No			
	Traballador sira hetan esplikasaun kona ba pontus perigosus ba ohin loron nia ona ka seidauk?	*Sim*	*Lae*			

CHECKLIST: Safety Patrol
Lista verifikasaun: Patrulla seguransa 2/3

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
-5	Are there "watchman for Construction Machinery"? *Iha ne'eba iha vigia ba makina konstrusaun nia ka?*	Yes *Sim*	No *Lae*			

CHECKLIST: Safety Patrol
Lista verifikasaun: Patrulla seguransa 3/3

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
−6	Precaution Singnboard for Safety are provided on site? Quadro avizu Precução ba seguransa nia fornese ona iha terrenu ka?	Yes *Sim*	No *Lae*			
−7	Procedure of works is correct or not? *Prosedimentu servisu los ka lae?*	Yes *Sim*	No *Lae*			
−8	At same time, both works up/down are carried out or not? *Iha tempu ne'ebe hanesan , servisu rua iha leten / karaik halao hotu ka lae?*	Yes *Sim*	No *Lae*			
−9	Cutting gradient is OK, with no danger? *Gradiente corte nia los ona, no la iha perigozus?*	Yes *Sim*	No *Lae*			

	・Finding out Dangerous points *Deskobre pontus perigozus*			
1)				
2)				
3)				

	・Instructions and expecting counter-measures (if any) *Instrusaun no hein katak bele halo konktra medida (Karik iha)*			
1)				
2)				
3)				

Overall comments: *Komentariu en jeral*

7. Checklists for Construction Management

< Drafting: Reference Only>

7. Checklists for Construction Manegement
Lista verifikasaun ba jestaun konstrusaun

CL_TD-1

7-1 Tender Documents
Dokumentus konkursu

1. Type of Tender
Tipu Konkursu

Edited_20181005

Select & decide the Type of Tender (Contract)

Selesiona & deside tipu konkursu (Kontratu)

According to the Type of Tender (Contract), requirements and documments of Tender are to be diffent.
Firstly, Type of Tender or Contract are selected and decidied among below classification;
Bazeia ba tipu konkursu (kontratu), rekerementu no dokumentus konkursu mak sei diferente.
Primeiru, tipu konkursu ka kontratu mak selesionadu no deside tuir klasifikasaun tuir mai ne';

I. Categoriy of Competitiveness
I. Kategoria husi Kompetitividade

1 Open Tender (Bidding)
Konkursu aberta (licitação)
- 1-1: International Conpetetive Tender (Bid) ICB
- *1-1:Konkursu competitiva internasional (licitação)*
- 1-2: Domestic Tender : Only Timor Leste company can participate
- *1-2: Konkursu domestiku : Empreza lokal deit mak bele partisipa*
- 1-3: Conditional domestic Tender : Limitation of tender with some condition among domestic company
- *1-3: Konkursu domestiku kondisional : Limitasaun kona-ba konkursu sira ho kondisaun balun entre empreza doméstika*

2 Nomination, proposal and Negotiation Tender
Nomeasaun, proposta no konkursu negosiasaun
- 2-1: Single nomination company
- *2-1: Nomeasaun empreza unika*
- 2-2:Nomeasaun empreza plural : Procedure is almost the same as Type 1-2 and/or 1-3
- *: Prosedimentu sira mak kuaze hanesan ho tipu 1-2 no / ka 1-3*

II. Category of Terms of Contract (responsibility of Contractor)
II.Kategoria termus kontratu (responsabilidade kontratante)

A Contract consits of Design and Construction
Kontratu kompostu husi dezennu no konstrusaun

B Contract consits of only Construction
Kontratu kompostu husi kontrusaun deit

* This Check List applys only Domistic Type of Tender, because of 1-1Tender are large scale of Project and made by almost Loan Project
** Lista verifikasaun ida ne'e bele aplika deit iha tipu domestiku, tamba 1-1 konkursus ne'ebe ho skala bo'ot no maioria halo projetu imprestissimu.*

** 1-2 is as same as 1-3 only conditions, so show the List only 1-2
*** 1-2 hanesan mos ho 1-3 ninia kondisaun, nune'e hatudu deit lista 1-2*

*** Requirements of Tender Document is the same of both open (pulatal nomination) and single nomination. Only the evaluation for Tender is different.
****Rekezitus dokumentus konkursu sira ne'e mak hanesan kona ba nomeasaun plural aberta no unika nomeasaun aberta.Evaluasaun ba konkursu deit mak diferente.*

(CL_TD-1)

1. CHECKLIST for Selecting and decision of Type of Tender
Lista verifikasaun ba selesionado no desizaun kona ba tipu konkursu

Name of Project : *Naran Projetu :*	
Location : *Fatin:*	Date : / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km – km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
I	Categoriy of Competitiveness Protection equipment for workers					
	Kategoria kona ba kompetividade ekipamentus protesaun ba traballador sira					
①	Is Tender Open Bid or Nomination/Proposal Type?	Yes	No			If Yes: Forward ②Checking
	Tipu konkursu abertu ka nomeasaun / Tipu proposta?	*Sim*	*Lae*			*If No: it is Nomination/Proposal Type, Forward ③*
②	Are there any conditions of the candidate (Tenderer)?	Yes	No			if yes: Type 1-2
	Iha ne'ebe iha requisitos kona ba kandidatus sira(proponente)?	*Sim*	*Lae*			*If No: Type 1-3*
③	Is Nomination to only one company ?	Yes	No			if yes: Type 2-1
	Nomeasaun ne'e ba kompanna ida deit ka?	*Sim*	*Lae*			*If No: Type 2-2*
II	Category of Terms of Contract (responsibility of Contractor)					
	Kategoria kona ba termus kontratu (responsavel kontratante)					
①	Does Contract consits of Desing and Construction?	Yes	No			if yes: Type X-Y-A
	Kontratu sira kompostu husi dezennu no konstrusaun ka?	*sim*	*Lae*			If No: Type X-Y-B

< Drafting: Reference Only>

CL_TD-2

CHECKLIST for Tender Document
Lista verifikasaun ba dokumentus konskursu

2. Documents for Type 1-3-B
Dokumentus ba Tipu 1-3-B

Tender Documents for
Dokumentus konkursu ba

Kondisaun konkursu domestiku aberta
・Plural companys (Tenderers)
Empreza plural (proponente)
・Contract consits of only Construction
Kontratu kompostu husi konstrusaun deit

The Employer shall prepare following documents at each Procurement Stage
Empregador sira tenki prepara dokumentus tuir mai ne'e tuir kada etapa aprovizionamentu idak-idak

I. Announcement Stage
Etapa Anunsio

1 Notice of Tender to the Public — on Newspaper, Home Page of the Emplyor (DRBFC)
Notifikasaun kona ba konkursu publiku — iha Jornal, pagina Empregador (DNEPCC)

2 Qualification for proposed tenderer — : anual turn over, similar constrcution experience, number of engineers etc
Kualifikasaun ba proponente proposta — retornu annual, esperensia konstrusaun ne'ebe hanesan, numeru enginerru sira nsst.

3 Providing of Tender Document for propsed candidate
Fornese dokumentu konkursu ba candidatu proposto

II. Preparation of Tender Stage
Preparasaun kona ba etapa konkursu

CHECKLIST for Tender Document (CL_TD-2)
Lista Verifikasaun ba dokumentus konkursu

Example of necessary document for Type 1-3-B
Ezemplu kona-ba dokumentu ne 'ebé nesesáriu ba Tipu 1-3-B

	Volume I *Volume I*		✔	Contents and requirements for each document *Konteudu no rekezitus ba kada dokumentus*
10	Instruction to Tenderers *Instusaun ba proponente*	Section 1		
20	Tender Data Sheet *Folla dadus konkursu*	Section 2		
30	From of Contract Agreement *husi akordu kontratu*	Section 3		
40	Particular Conditions of Contract (PCC) *Kondisaun partikular kona ba kontratu*	Section 4		
50	General Conditions of Contract (GCC) *Kondisaun jeral kona ba kontratu*	Section 5		
60	Specifications *spesifikasaun*	Section 6		
61	Special Specification (if any) *spesifikasaun spesial (se iha)*			
70	Tendering Forms *Formulario konkursu*	Section 7		
	Power of Attorney *Procuração*	Appendix-B		
	Certificate of Signature of the issuer *sertifikadu asinatura emissor*	Appendix-C		

	Letter of Price/Technical Tender	Appendix-A,B		
	Koarta kona ba presu / konkursu teknikal			
	Proposed Construction Schedule	Appendix-D		
	Kalendariu konstusaun ne'ebe propoin			
	Proposed Contractor's key staff Schedule	Appendix-E		
	Proposta kontratante nia funsionario ninia kalendariu			
80	Form of Bill of Quantities			
	Formulario fatura/conta husi kuantidade			
	Volume II			
	Volume II			
	Drawing			
	Dezennu			
	Calculation Sheet of Quantities (Only Type A)			
	Kalkulasaun folla kuantidade (Tipu A deit)			

Notes: 1. In the Drawing, the length and width, dimensions of structure, dimentions of cross section and other values must be discribved in order calculate the quantities for each work item in the BoQ.

1. Iha dezennu, naruk no largura, dimensaun estrutura, dimensaun seksaun transversal no valor sira seluk tenki descreve atu nune'e bele kalkula kuantidade ba kada itens servisu iha BoQ.

2. Since existing site condition and other reasons, specil provions of sepecification are to be required, such special or particluar provisions would be added the Sepecification, as a" Special Technical Specification"

2. Desde kondisaun existante local no razaun sira seluk, spesifikasaun ninia provisaun mak atu bele sai nesesario , hanesan spesial ka partikular provisaun ne'ebehatama spesifikasaun, hanesan "Spesifikasaun teknika special".

III. Negotiation Stage (after open the Tender)
Etapa Negosiasaun (depois Konkursu aberta)

2. Documents for Type 1-3-B
Dokumentus ba Tipu 1-3-B

Name of Project: *Naran Projetu :*		
Location: *Fatin:*		Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*		Location: STA km - km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*	

< Drafting: Reference Only>

CL_TD-3

CHECKLIST for Tender Document
Lista verifikasaun ba dokumentus konkursu

3. Application of document for each Type of Tender
Aplikasaun kona ba dokumentus ba kada tipu konkursu

Edited_20181005

Number and kinds of required documents are different from the Type of Tender or Contract.

Numeru no dokumentus ne'ebe rekezitus mak la hanesan husi tipu konkursu ka kontratu

		Necessry documents: ● in right column *Dokumentus ne'ebe nesesariu : Iha koluna direta*	Type of Tender and/or Contrct Tipu kona ba konkursu no/ka kontratu							
			Open Tender (Bidding) *Konkursu aberta (licitação)*				Nomination, proposal and Negotiation Tender *Nomeasaun,proposta no konkursu negosiasaun.*			
			1-1-B	1-2-A	1-3-A		1-3-B	2-2-A	2-2-B	
I.		Announcement Stage *Etapa Anunsiu*								
	1	Notice of Tender to the Public *Informa konkursu ba Publiku*	●	●	●		●			
	2	Qualification for proposed tenderer *Kualifikasaun ba konkursu ne'ebe propoin*								
	1)	Finacial record of anula turn over of the company *Registu finanseiro annual ne'ebe fo fila ba kompania*	●		●		●			
	2)	Record / certificates of similar constrcution experience *Registu / certifikadu esperensia kontrusaun ne'ebe hanesan*	●		●		●			
	3)	Certificates of engineers in charge the Works *Certifika enginerru ne'ebe responsavel ba obra*	●		●		●			
	3	Providing of Tender Document for propsed candidate *Fornese dokumentus konkursu ba kandidatu propostu*								

II. Preparation of Tender Stage
Preparasaun kona ba etapa konkursu

Tender Document
Dokumentus Konkursu

	Volume I *Volume I*	Open Tender (Bidding) *Konkursu aberta (licitação)*				Nomination, proposal *Nomeasaun, proposta*			
		1-1-B	1-2-A	1-3-A		1-3-B	2-2-A	2-2-B	
10	Instruction to Tenderers *Intrusaun ba proponente*	●	●	●		●			
20	Tender Data Sheet *Folla dadus konkursu nia.*	●	●	●		●			
30	Form of Contract Agreement *Formulario kontratu*	●	●	●		●	●	●	
40	Particular Conditions of Contract (PCC) *Kondisaun kontratu partikular*	●							
50	General Conditions of Contract (GCC) *Kondisaun kontratu jeral*	●	●	●		●	●	●	
60	Specifications *Spesifikasaun*	●	●	●		●	●	●	
61	Special Specification (if any) *Spesifikasaun special (Karik iha)*								
70	Tendering Forms *Formulario konkursu*								
	Power of Attorney *Procução*	●	●	●		●	●	●	

	Certificate of Signature of the issuer	●							
	Certifikaduasinatura emissor								
	Letter of Price/Technical Tender	●	●	●		●	●	●	
	Karta kona ba presu/ konkursu tekniku								
	Proposed Construction Schedule	●							
	Proposta kalendariu konstrusaun								
	Proposed Contractor's key staff Schedule								
	proposta kalendariu funsionar husi kontratante								
80	Form of Bill of Quantities	●	●	●		●	●	●	
	Formulario lista husi kuantidade								
	Volume II								
	Volume II								
	Drawing	●	●	●		●	●	●	
	Dezennu								
	Calculation Sheet of Quantities (Only Type A)		●	●			●		
	Folla kalkulasaun kuantidade (Tipu A deit)								

Name of Project : *Naran Projetu :*	
Location : *Fatin:*	Date : / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km − km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

< Drafting: Reference Only>

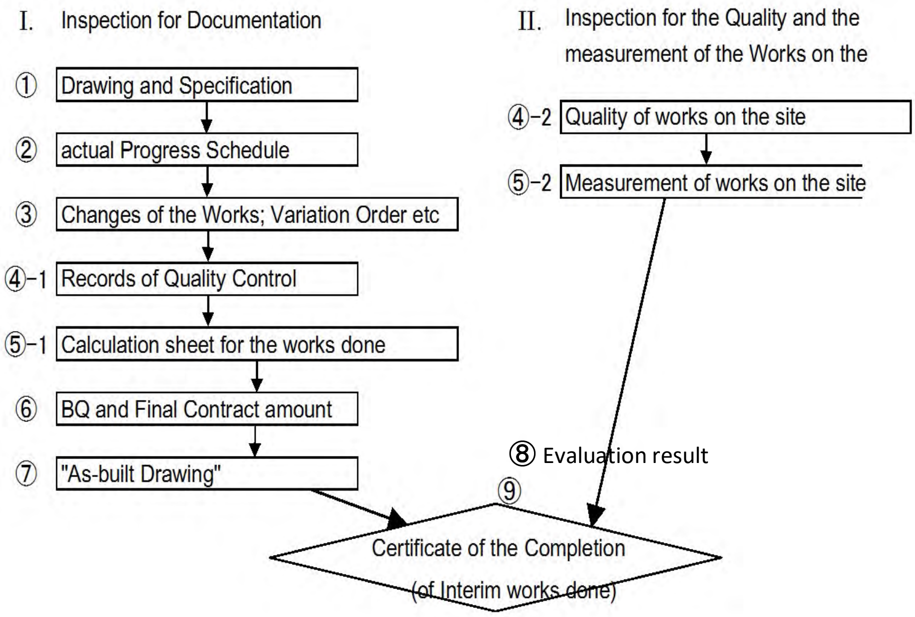
CL_03-20_Inspection for Paymet

7-2 Inspection for the works done 1/3 (Interim / Final) Inspection

7-2 Inspeksaun ba obra ne'ebe realiza tiha ona *Inspeksaun (Interino / Final)*

Flow of nomal procedure for Inspection

Fluxo prosedimentu normal ba inspeksaun



・Remarks
Observasaun
(Type of Inspection for Works and request checking points)
(Tipu inspeksaun ba obra no pedidu pontus verifikasaun)

1)Interim Inspection for the works done.
1) inspeksaun interinu ba obra ne'ebe finaliza ona

2)Final (Completion) Inspection
Inpeksaun final (acabamentu)

Type of Contract:
Tipu kontratu

2/3
(CM_03-20)

CHECKLIST for (Interim / Final) Inspection
Lista verifikasaun ba inspeksaun (interino/final)

Tender/Proposal, Design Built/only construction
Konkursu/proposta,Dezennu konstrusaun/konstrusaun deit

Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km − km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamento* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
I	Inspection for Documentation					
	Inpeksaun ba dokumentus					
①	Is Contract Drawing and Specification provided?	Yes	No			
	Dezennu no spesifikasaun husi kontrato fornese ka lae?	*Sim*	*Lae*			
②	Is the actual Progress Schedule provided?	Yes	No			
	Calendariu ba progressu servisu atual ne'e fornese ka lae?	*Sim*	*Lae*			
③	Is Variation Order(s), Claim(s) and other documents related the execution of the Works provided?	Yes	No			
	Pedidu variasaun,reklamasaun no dokumentus sira seluk ne'ebe relasiona ho ezekusaun obra nee forsese tiha ona ka seidauk?	*Sim*	*Lae*			
④	Is QC(Quality Control) records provided?	Yes	No			
	Rejistu ba kontrollu kualidade fornese ka lae?	*Sim*	*Lae*			

CHECKLIST for (Interim / Final) Inspection 3/3 (CM_03-20)
Lista verifikasaun inspeksaun (interino / Final)

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
⑤	Is the calculation sheet for the works done provided?	Yes	No			
	Folla kalkulasaun ba obra ne'ebe hotu ona ne'e fornese ka lae?					
⑥	Is the BQ and Final Contract amount provided?	Yes	No			
	BQ no montante kontratu final fornese ka lae?					
⑦	Is the "As-built Drawing" provided?	Yes	No			
	"As build Drawing " fornese ka lae?					
II	Inspection for the Quality and the measurement of the Works on the Site					
	Inpeksaun ba qualidade no medisaun ba obra iha terrenu					
①	Is the Quality of the works on site satisfactory? (is the site condition as same as QC records?)	Yes	No			
	Qualidade obra iha terrenu ne'e satisfatorio ka lae?(Kondisaun errenu nian hanesan ho registo kontrollu kualidade ka lae?)	*Sim*	*Lae*			
②	Is the site condition as same as the calculation sheet for the works done?	Yes	No			
	Kondisaun iha terrrenu hanesan ho folla kalkulasaun ba obra ne'ebe remata ona ka lae?	*Sim*	*Lae*			
III.	Evaluation of the Inspection	Yes	No			
	Evaluasaun ba inspeksaun	*Sim*	*Lae*			
	If "YES", PLS wrote next procedure Or If "No" PLS wrote outstanding issue.					
	se " Los" favor hakerek prosedimento tuir mai ka se "Lae" favor hakerek problema pendente ne'e.					
	1)					
	2)					
	3)					
IV.	Note, Remark and/or Comment					
	Notas,Obervasaun no/ ka komentariu					

< Drafting: Reference Only>

CL_DRW-1

7-3 Drawing
Dezennu

Contract/Shop/Reference Drawing

Edited_20181005

1/3
(CM_03-30)

CHECKLIST for Drawing
Lista verifikasaun ba dezennu

Type of Contract:
Tipu kontratu :

	Tender/Proposal, Design Built/only construction
Name of Project: *Naran Projetu :*	
Location: *Fatin:*	Date: / / (DD/MM/20YY) Data:
Name of Contractor: *Naran Kontraktor :*	Location: STA km - km *(Fatin)*
Name of Inspector: *Naran Inspektor:*	Name of Department *Naran Departementu*

SPC= Standard Specification of MPWTC-Nov2014 Edition
Padraun spesifikasaun husi MOP-Edisaun Nov2014

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
I	Type of Drawing					
	Tipu dezennu					
①	Which kind of Drawing among following type?	—	—			
	Tipu dezennu ida ne'ebe mak tuir tipu hirak ne'e?					
1)	Contract Drawing					1); approved by Engineer for propsed drawing
	Dezennu kontratu					*1); Aprova husi Enjinerru ba dezennu proposta*
2)	Shop Drawing					2); prepared by the Contractor
	Gambar kerja					*2); Prepara husi kontratante*
3)	Reference Drawing					3); for work done measurement at the Inspection
	Dezennu referensia					*3);ba obra ne'ebe hotu ona bele sukat durante halo inspeksaun*
4)	Other Drawing;					4)for;
	dezennu sira seluk					*4)ba;*
5)	As-Built Drawing:					5):
	Dezennu hanesan ho kontruido					
②	When drawing is checked ? (What pourpse ?)	—	—			< Checking points on the Drawing>
	wainhira mak verifika dezennu? (nia propozito saida?)					*< Pontus verifikasaun iha dezennu>*
1)	Tender stage or the time of making Contract					1);
	Etapa konkursu ka tempu halo kontratu					
2)	Daily (regularly) Quality Control					2);
	Kontrollu Kualidade Diaria (regularmente)					

2/3

No.	Check Items *Verifika Itens*	Judgements *Julgamentu* (Selection No.) *Seleciona no.*		Specification *Spesifikasaun* Standards *Padraun*	SPC	Remaks *Observasaun* (Printed figure is reference only) *(Figura ne'ebe impressa hanesan referensia deit)*
3)	Cerfining the works done for Payment (time of Inspection)					3);
	sertifika obra ne'ebe hotu ona ba pagamentu (Tempu inspeksaun)					
4)	Other occasion					4);
	Okaziaun sira seluk					
II	Requirement for the Drawing					
	Rekerementu ba dezennu					
③	Are the idintities of Drawing shown on the Drawing ?	—	—			
	Indentidade dezennu nia hatudu ona iha dezennu ka?					
1)	Name of Project and Drawing	Yes	No			
	Obra nia naran no dezennu	*Sim*	*Lae*			
2)	Name of Drawing and providing	Yes	No			
	Naran dezennu nia ne'ebe fornese	*Sim*	*Lae*			
3)	Name of approved and/or certified	Yes	No			
	Naran kona ba aprovasaun no/ka certifika tiha ona	*Sim*	*Lae*			
4)	Date of drawing and/or approval	Yes	No			
	Data dezennu niana no/ka aprovasaun	*Sim*	*Lae*			
④	Is the location of each work item descrived on the Drawing?	Yes	No			
	fatin ba kada obra sira ne'e deskreve ona iha dezennu ka?	*Sim*	*Lae*			
⑤	Is dimension of the structure drawn?	Yes	No			
	estrutura ninia dimensaun ne'e dezenna ka lae?	*Sim*	*Lae*			
⑥	Are number or detailed shape of structure shown?	Yes	No			
	Numeru no estrutura sira nia forma ne'ebe detalladu sira hatudu ka lae?	*Sim*	*Lae*			
⑦	Are Note or Specification of the works descrived ?	Yes	No			
	Nota ka obra sira nia spesifikasaun sira ne'e deskrebe ka lae?	*Sim*	*Lae*			
⑧	Does corresponde to the BQ(work item) on Quality?	Yes	No			
	Halo korespondensia ba BQ (item servisu) kona ba kualidade nian ka lae?	*Sim*	*Lae*			
⑨	Does corresponde to the BQ(work item) on Quantity?	Yes	No			
	Halo korespondensia ba BQ (item servisu) kona ba kuantidade nian ka lae?	*Sim*	*Lae*			

CHECKLIST for Drawing

3/3 (CM_03-30)

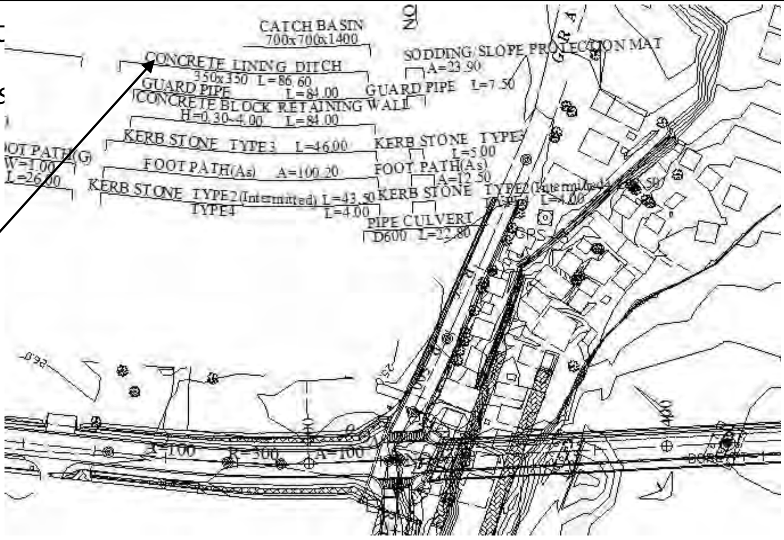
Lista verifikasaun ba dezennu

< Examples of the requirement —

< Ezemplu kona ba rekezitus s

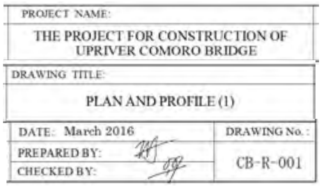
④ Is the location of each work item descrived on the Drawing?

fatin ba kada item servisu ne'e descreve ona iha dezennu ka?

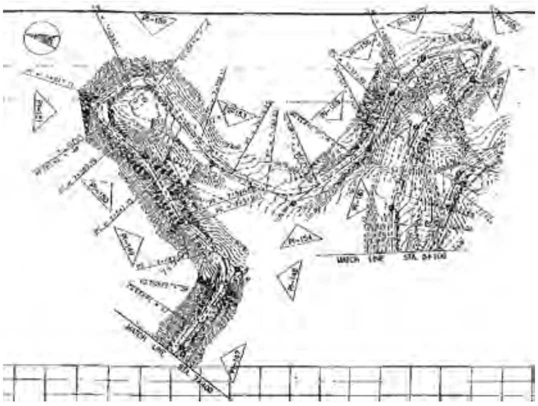


Indicating work items (such as "concrete Lining Dich" 350×350 L=86.60m) on the Plan Drawing

Indika item servisu (hanesan "concrete lining ditch" 350x350L=86.60m)iha planu dezennu nian.

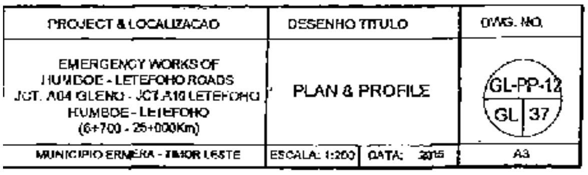


PROJECT NAME: THE PROJECT FOR CONSTRUCTION OF UPRIVER COMORO BRIDGE	
DRAWING TITLE: PLAN AND PROFILE (1)	
DATE: March 2016 PREPARED BY: CHECKED BY:	DRAWING No.: CB-R-001



This Plan Drawing does not describe any location of the structure (works) only for the proposed center line of rehabilitaing Road and showing Sation

Planu dezennu ida ne'e la descreve fatin strutura(obra) deit ba proposta linna sentral ba rehabilitasaun estrada no hatudu numeru stasaun .



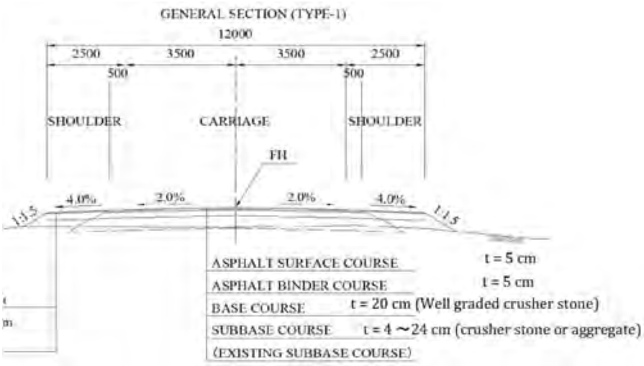
PROJECT & LOCALIZACAO	DESENHO TITULO	DWG. NO.
EMERGENCY WORKS OF HUMBOE - LETEFOHO ROADS JCT. A04 GLENO - JCT.A10 LETEFOHO HUMBOE - LETEFOHO (6+700 - 25+000Km)	PLAN & PROFILE	GL-PP-12 GL 37
MUNICIPIO ERMERA - TIMOR LESTE	ESCALA: 1:200 DATA: 2015	A3

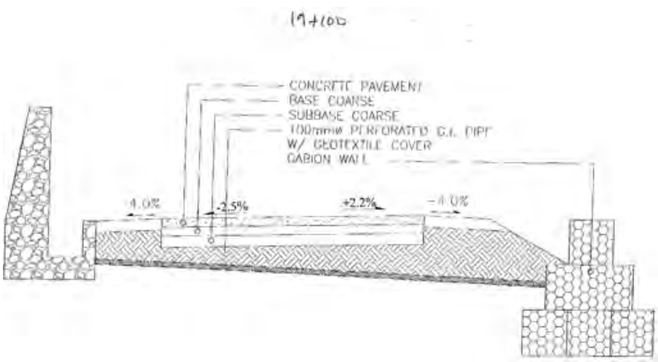
⑤ Is dimension of the structure drawn?

Dimensaun ba estrutura sira dezennada ka lae?

Dimensions of thickness of each layer of Road and wides should be indicated on the Cross Section Drawing of a proposed road as like right

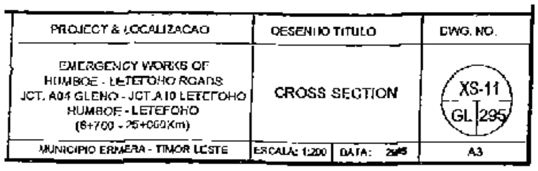
Dimensaun mahar ba kada dalas estrada nian no largura tenki indika iha dezennu seksaun transversal ne'ebe propoin iha estrada hanesan iha sorin ne'e.





Even on the detailed cross section of the road, there is no description of the thickness of Base Coures and Sub-base Course

Maske iha detallu seksaun transversal estrada nin, iha ne'eba laiha deskrisaun kona ba mahar base curse no sub base course



References:

Quality Control Plan

Quality Control Plan

NO	Material		Control Item	Control Method	Standard range: Criteria	Standard range: 採用元/Adoption	Frequency	Submit DOC	Inspection
1	Concrete	Cement	Portland Cement	AASHTO M 85 (ASTM C 150)		SPC 506.2.1 (SPC.901.1)	Each delivery time	Factory test result	Check of D.O.C.
		Fine Aggregate	Grading		Table 412.1	SPC 506.2.2 (SPC.412.2.2)		Test Result	By the Enginner
			Sieve analysis	AASHTO T 27		SPC506.3.1		Test result	By the Enginner
			Specific Gravity and absorption	AASHTO T 84		SPC506.3.1			
		Coarse Aggregate	Grading		Table 412.2, Table506.1	SPC 506.2.3 (SPC.412.2.3)		Test Result	By the Enginner
			Sieve analysis	AASHTO T 27		SPC506.3.1		Test result	By the Enginner
			Specific Gravity and absorption	AASHTO T 84		SPC506.3.1			
		Water			Table 915.1	SPC 506.2.4 (SPC.915.2)		Test result	By the Enginner
		Admixture		AASHTO M 154 AASHTO M 194		SPC 506.2.6 (SPC.412.2.7)		Factory test result	By the Enginner
2	Fresh Concrete		Slump	AASHTO T 119	Table 506.2	SPC 506.4.1 SPC 506.3.1		Test result	By the Enginner
			Air content	AASHTO T 121	N/A	SPC 506.3.1			
			Temperature for concrete		30℃、Delivery time less than 1 hour	SPC 506.4.4.5			
			Delivery time		less than 1 hour	SPC 506.4.4.5			
			Chlorine ion content		N/A				
	Compressive Strength test of Concrete		Minimum Compressive Strength		Table 506.2	SPC 506.4.1		Test Result	By the Enginner
			Sampling		3 concrete sylinder/1 sample (7 days and 28 days) 75m3/each class of concrete	SPC 506.3.1	each day		
			Evaluation		Statistical evaluation	SPC 506.3.3.a SPC 506.3.3.b.3)			
	Reinforcing Steel			AASHTO M 31 AASHTO M 42		SPC 506.2.5 (SPC.911.1)	Each delivery time	Factory test result	Check of D.O.C.
3	General Fill (Common Embankment)		Grading	AASHTO T 27	N/A			Test Result	By the Enginner
			Specific Gravity	AASHTO T 99	N/A				
			Water Content	AASHTO T 90	N/A				
			Liquid Limit	AASHTO T 88	N/A				
			Plasticity Index	AASHTO T 89	N/A				
			Four days soaked CBR	AASHTO T 193	≧ 6%	SPC 205.2.1.b	every 1000m3 (SPC 205.4.1.c)		
			Compaction (Maximum dry density)	AASHTO T 99	Max 95% (Layers 30cm of less below subgrade level) Max 100% (Layers more than 30cm below subgrade level)	SPC 205.4.2.a SPC 205.4.2.b	every 1000m3 (SPC 205.4.2.c)		
4	General Fill (Selected Embankment)		Grading	AASHTO T 27	N/A			Test Result	By the Enginner
			Specific Gravity	AASHTO T 99	N/A				
			Water Content	AASHTO T 90	N/A				
			Liquid Limit	AASHTO T 88	N/A				
			Plasticity Index	AASHTO T 89	N/A				
			Four days soaked CBR	AASHTO T 193	≧ 10%	SPC 205.2.2.b	every 1000m3 (SPC 205.4.1)		
			Compaction (Maximum dry density)	AASHTO T 99	Max 95% (Layers 30cm of less below subgrade level) Max 100% (Layers more than 30cm below subgrade level)	SPC 205.4.2.a SPC 205.4.2.b	every 1000m3 (SPC 205.4.2.c)		

Quality Control Plan

NO	Material	Control Item	Control Method	Standard range: Criteria	Standard range: 採用元/Adoption	Frequency	Submit DOC	Inspection
5	Subgrade (Selected Borriw for Topping)	Grading	AASHTO T 27	N/A			Test Result	By the Enginner
		Specific Gravity	AASHTO T 99	N/A				
		Water Content	AASHTO T 90	N/A				
		Liquid Limit	AASHTO T 88	N/A				
		Plasticity Index	AASHTO T 89	N/A				
		Four days soaked CBR	AASHTO T 193	≧ 10%	SPC 206.3.5 (SPC.205.2.2b)	every 1000m3 (SPC 205.4.1)		
		Compaction (Maximum dry density)	AASHTO T 99	Max 95%	SPC 206.3.5 (SPC.205.3.3)	every 1000m3 (SPC 205.4.2.c)		
		Proof Rolling	Visual check	N/A				
		In-situ CBR		N/A				
6	Sub Base course	Grading		Table 301.1	SPC 301.2	every 1000m3 (SPC 301.4.c)	Test Result	By the Enginner
		Liquid Limit	AASHTO T 89	Max.35%				
		Plasticity Index	AASHTO T 90	Min.12				
		Los Angeles Test	AASHTO T 96	Max.50%				
		Four days soaked CBR	AASHTO T 193	Min.25%		As directed by the Engineer (SPC 301.4.c)		
		Compaction (Maximum dry density)	AASHTO T 180, 191	≦ 100%	SPC 301.3.3	every 1000m3 (SPC 301.4.c)		
		Modified CBR value at 95% Compaction Density (%)	AASHTO T 193	N/A				
		Proof Rolling	Visual check	N/A				
		In-situ CBR		N/A				
7	Base course	Grading		Table 303.1	SPC 303.2.5	every 1000m3 (SPC 303.4.c)	Test Result	By the Enginner
		Liquid Limit	AASHTO T 89	CLASS A : 0-25% CLASS B : 0-35%				
		Plasticity Index	AASHTO T 90	CLASS A : Max.25% CLASS B : -				
		Soft Fragments	AASHTO T 112	CLASS A : 0-5% CLASS B : 0-5%				
		Four days soaked CBR	AASHTO T 193	CLASS A : Min. 90% CLASS B : Min. 60%		As directed by the Engineer (SPC 303.4.c)		
		Compaction (Maximum dry density)	AASHTO T 180, 191	≦ 100%	SPC 303.3.3	every 1000m3 (SPC 303.4.c)		
		Modified CBR value at 98% Compaction Density (%)	AASHTO T 193	N/A				
8	Stone Masonry Drainage	Srone material		150mm ≦ Stone thickness < 225mm	SPC 606.2.1			By the Enginner
		Cement mortar composed		Cement 1 : Sand 3	SPC 606.2.2			
9	Stone Masonry Retaining Wall	Srone material		150mm ≦ Stone thickness < 225mm	SPC 606.2.1			By the Enginner
		Cement mortar composed		Cement 1 : Sand 3	SPC 606.2.2			
10	Stone Masonry Railing	Srone material		150mm ≦ Stone thickness < 225mm	SPC 606.2.1			By the Enginner
		Cement mortar composed		Cement 1 : Sand 3	SPC 606.2.2			
11	Materials for Backifilling of Pipe Culvert	Four days soaked CBR	AASHTO T 193	≧ 10%	SPC 601.3.6 (SPC.205.2.2b)	every 1000m3 (SPC 205.4.1)		By the Enginner
		Compaction (Maximum dry density)	AASHTO T 99	Max 95%	SPC 601.3.6 (SPC.205.3.3)	every 1000m3 (SPC 205.4.2.c)		

Democratic Republic of Timor-Leste

Ministry of Public Works

Directorate General of Public Works

National Directorate of Roads, Bridges and Flood Control

Bridge Substructure Protection Guidelines

Guia de Proteção da Subestrutura de Ponte

Document type: Technical Specification
Document subtype:
Document language: E

Contents

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REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTÉRIO DAS OBRAS PÚBLICAS
GABINETE DO VICE MINISTRO
Av. Nicolau Lobato, Mandarin, Dili, Timor-Leste

Foreword

In the interest of constructing high quality and economically viable government infrastructure to serve the nation, these guidelines for optimal design of bridge substructure protection components were prepared by the JICA Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste (CDRS) in collaboration with the *Direcção Nacional de Estradas, Pontes e Controlo de Cheias* (DNEPCC, 'National Directorate of Roads, Bridges and Flood Control') of the *Ministério das Obras Públicas* ('Ministry of Public Works'). We would like to thank JICA for their continuing support.

September, 2019

Eng. Nicolau Lino Freitas Belo
Vice Minister for Public Works
Ministry of Public Works

19-09-2019

Foreword by JICA

Japan International Cooperation Agency (JICA) has been conducting a technical cooperation project for development of capacity regarding road services, which is called as CDRS, in order to facilitate the DNEPCC in properly managing and maintaining the road infrastructure that is the basis of social and economic activities. To this end, JICA has been dispatching a team of experts from March 2016 to December 2019. As a result of collaborative works with counterparts of the DNEPCC, these guidelines for design of bridge substructure protection have been finalized. I hope that these guidelines will contribute to infrastructure development and maintenance and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials of the Government of the Democratic Republic of Timor-Leste for their close cooperation with the expert team.

September, 2019

Masafumi NAGAISHI
Chief Representative of JICA Timor-Leste Office
Japan International Cooperation Agency

Acknowledgements

The Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste wishes to thank all parties involved in preparing and revising these Bridge Substructure Protection guidelines.

In support of the project, the officials of the (former) Ministry of Development and Institutional Reform: M. R. M. Cruz, J. L. C. C. P. Mestre and J. Santos; and the officials of the Ministry of Public Works: C. M. Henrique and especially R. H. F. Guterres; are hereby acknowledged.

In contributing to the preparation of this document, the officials of the DNEPCC: M. R. C. Monteiro, J. P. Amaral, J. M. G. Sousa, J. G. Carlvalho, I. M. L. Gutteres, N. Lobato, L. R. H. Corbafo, A. Araujo, J. L. Kehy and C. C. Monteiro; and the International Labour Organization's (ILO) technical assistance team of the Roads for Development Support Program (R4D-SP): A. O. Asare, K. H. Myaing and S. Done; are hereby acknowledged.

Feedback:

Any positive feedback for possible incorporation into future editions would be appreciated. Please send such comments or feedback to the below address.

Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
Address: Avenida da Restauração, Rai Kotu, Comoro, Dili, Timor-Leste
Telephone: +670 3311408

Introduction

The substructures of many river bridges in Timor-Leste do not have scour protection works installed. As a result, these bridges are easily damaged during floods and there is caving and settlement damage at the bottoms of abutments and piers.

If appropriate countermeasures are not applied to these bridges, there is risk of large scale damage such as overall bridge settlement or collapse.

From the aspect of operation and maintenance, repaired substructure is not sufficient.

As a result, substructures are repeatedly damaged by frequent flooding and become the level requiring total re-construction.

In response to this situation, these design guidelines describes the designs necessary for countermeasures to protect substructure from flood scour, based on engineering know-how.

These design guidelines primarily is prepared according to Japanese technical standards for countermeasures to protect bridge substructures from flood scour.

Sophisticated runoff simulations or require expensive materials for these countermeasures, like sheet piles or steel pipe piles, were exclude of these design guidelines with regard to the difficulty of implementing them by local contractures due to cost and technical level of manpower restraints.

It is expected that these design guidelines useful for flood countermeasures and help to reduce flood scour damage to bridge substructures in Timor-Leste.

Bridge Substructure Protection Guidelines

1 Scope

This document specifies minimum requirements and design methods for bridge substructure protection in Timor-Leste.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO maintains terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
Scour
Removal of underwater sand and stone material by river flow, especially at the base or toe of a structure

[SOURCE: ISO 21650:2007, 2.60]

3.2
Scour protection
Materials to place on the riverbed to prevent scour from developing around the foundation where the foundation penetrates into the riverbed

[SOURCE: ISO 29400:2015(en), 3.124]

3.3
Settlement
Permanent downward movement of a structure as a result of its own weight and other actions

[SOURCE: ISO 19901-8:2014(en), 3.34]

Figure 1 — River map of Timor-Leste

4 Characteristics of rivers in Timor-Leste

The sources of many of the rivers in Timor-Leste are in the mountains, at an altitude of 1000 m to 2000 m; they tend to flow sharply down from the steep mountains through low-altitude plains and then out into the ocean. The average annual rainfall in the northern region is approximately 1000 mm to 2000 mm and in the southern region it is 1500 mm to 2000 mm. Similar to rivers in Japan, these rivers have characteristics that cause flash floods to easily occur.

As Timor-Leste is an island country, the length of their rivers is short and share many natural characteristics with rivers in Japan, allowing the related river standards that have been established in Japan to be easily applied to Timor-Leste.

5 Condition of bridge substructures in Timor-Leste

The following figures show the scouring damage of Sahen Bridge's right bank abutment and pier. Due to scouring damage, the piles of the abutment are exposed and the caving of the footings can be seen on the bridge piers.

Figure 4 and Figure 5 show the scouring damage of Mora Bridge's pier. Due to scouring damage, the caving of the footings can be seen.

If appropriate countermeasures are not applied out and scouring is allowed to progress into the long term, overall bridge settlement damage (as can be seen in the figures 6, 7) is likely to occur.

Figure 2 — Sahen Bridge abutment 2017

Figure 3 — Sahen Bridge pier 2017

Figure 4 — Mora Bridge pier 2011

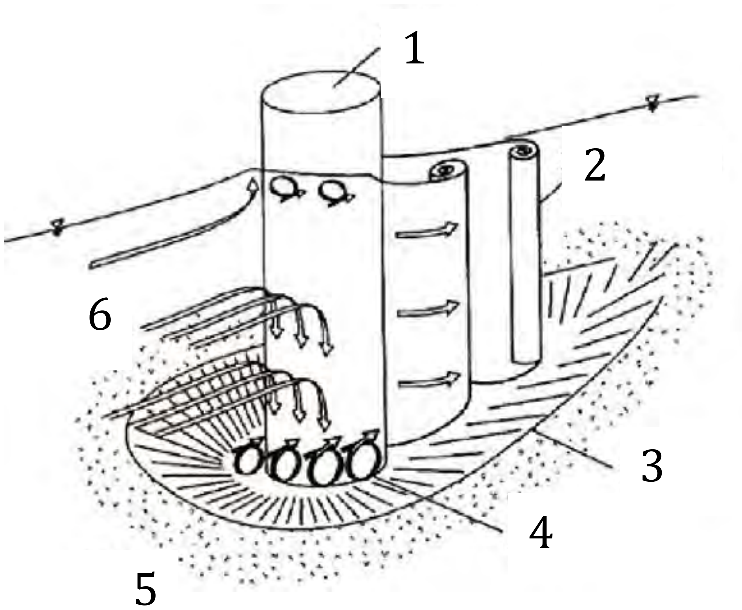
Figure 5 — Mora Bridge Pier 2011

Figure 6 — Bridge settlement damage due to bridge pier scouring (Japan example)

Figure 7 — Bridge settlement damage due to bridge pier scouring (Japan example)

6 Hydraulic phenomenon around bridge piers

Figure 8 shows the hydraulic phenomenon that occurs around bridge piers during flood. Bridge piers located in a river cause complex vortices and waves that disturb the flow and water surface during flood; as a result, an increase in water level and riverbed scouring occur.



Key
1 bridge pier
2 Karman's vortex
3 scour hole
4 horseshoe vortex
5 riverbed
6 flow

Figure 8 – Hydraulic phenomenon around bridge piers

Figure 9 shows the actual phenomenon around a bridge pier during floods. The occurrence of complex flow around the bridge pier is apparent.

Figure 9 — Hydraulic phenomenon around bridge piers (Japan example)

The following figures (Figures 10 and Figure 11) show the state of scour on a bridge pier after a flood in Japan. The flood caused a scour hole to form around the bridge pier.

Figure 10 — Actual phenomenon of pier (Japan example)

Figure 11 — Actual phenomenon of pier (Japan example)

7 Scour depth of bridge substructures

7.1 Scour depth around bridge piers

While it is ideal to use the results of runoff simulations and hydraulic model simulations to determine the local scouring depth around a bridge substructure, due to the need for advanced technology, experience, and experimental facilities, these methods are not always possible. These guidelines use an estimation formula, Formula (1), for scour depth, which does not require the aforementioned resources and is also utilized in Japan.

$$\frac{Z}{D}=f\cdot\left(\frac{h0}{D}\cdot\frac{h0}{dm}\cdot Fr\right) \qquad (1)$$

where

h_0 is the average water depth;

D is the diameter of bridge pier;

dm is the average grain diameter of riverbed material;

Fr is the Froude number; $\frac{Vm}{\sqrt{gh0}}$

Vm is the average velocity.

Z is the scour depth.

7.1.1 Procedure for estimating scour depth

The average water depth h_0 is calculated though a method of hydraulic analysis method utilizing either the uniform flow calculation or the non-uniform calculation.

Step 1

Calculate the dimensionless scour depth Z/D using the target location's average water depth h_0, the diameter of bridge pier D, average grain diameter of riverbed material dm, and Froude number Fr, in accordance with Figure 14.

Step 2

The resulting Z/D should be corrected for changes in flow direction due to flooding or nearby bridge piers. After these corrections, the depth of scour hole around a bridge pier can be calculated.

7.2 Scour depth around abutments

The depth of scouring around abutments doesn't have a clear calculation method that is used, even in Japan. Therefore, it is recommended to estimate and determine the scour depth around abutments based on the results of past field investigations of the abutment or nearby abutments.

Additionally, many of the bridges in Timor-Leste have short lengths for the footings depth of their abutments, so when new bridges are being planned, it is necessary to conduct the field investigations mentioned above and ensure sufficient lengths for footing depth.

7.3 Determination of scour hole width

The scour hole width is calculated in Japan formula by imputing the maximum scour depth Z and the average underwater angle of repose θ and the maximum scour depth from Figure 12 into Formula (2):

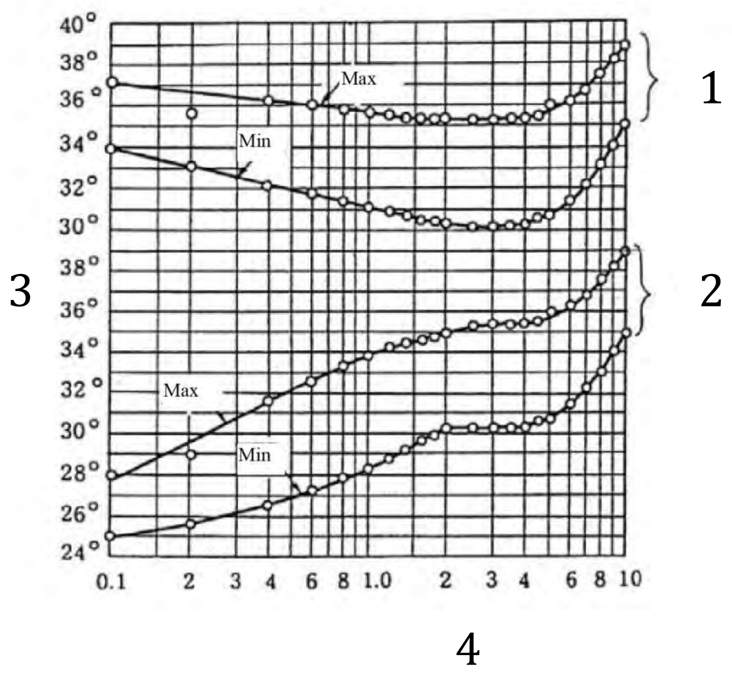
$$R=Z/\tan\theta \qquad (2)$$

where

R is the scour hole width;

Z is the maximum scour depth;

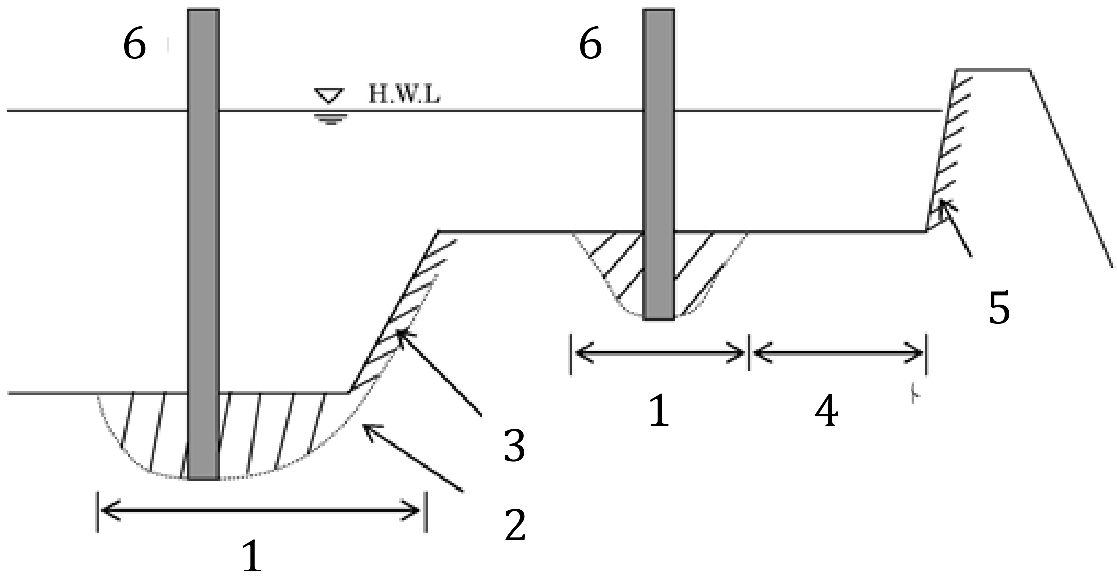
θ is the average underwater angle of repose;



Key

1 in air
2 underwater
3 angle of repose θ
4 dimater of river bed material

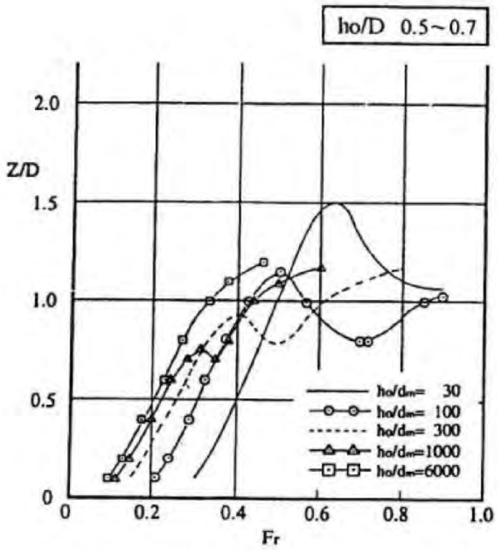
Figure 12 — Relationship between angle of repose θ and average grain angle



Key

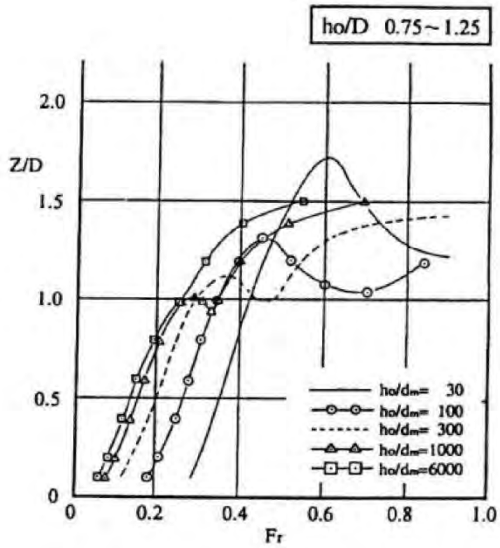
1 scour hole width
2 bank erosion from scouring
3 erosion from increased flow velocity
4 outside of scour area
5 bank erosion from scouring
6 pier

Figure 13 — Image of scouring around bridge piers



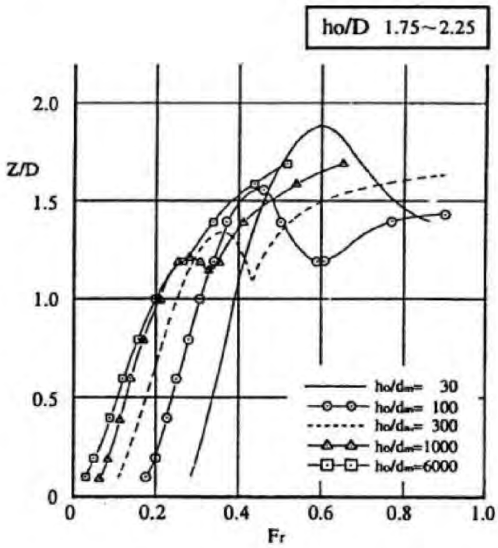
Relationship between Fr~Z/D and h_0/d_m

(h_0/D=0.5 to 0.7)



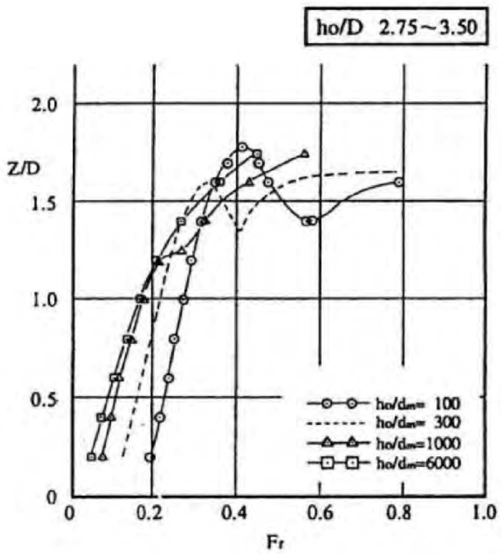
Relationship between Fr~Z/D and h_0/d_m

(h_0/D=0.75 to 1.25)



Relationship between Fr~Z/D and h_0/d_m

(h_0/D=1.75 to 2.25)



Relationship between Fr~Z/D and h_0/d_m

(h_0/D=2.75 to 3.50)

Figure 14 — Relationship between Fr~Z/D and h_0/dm

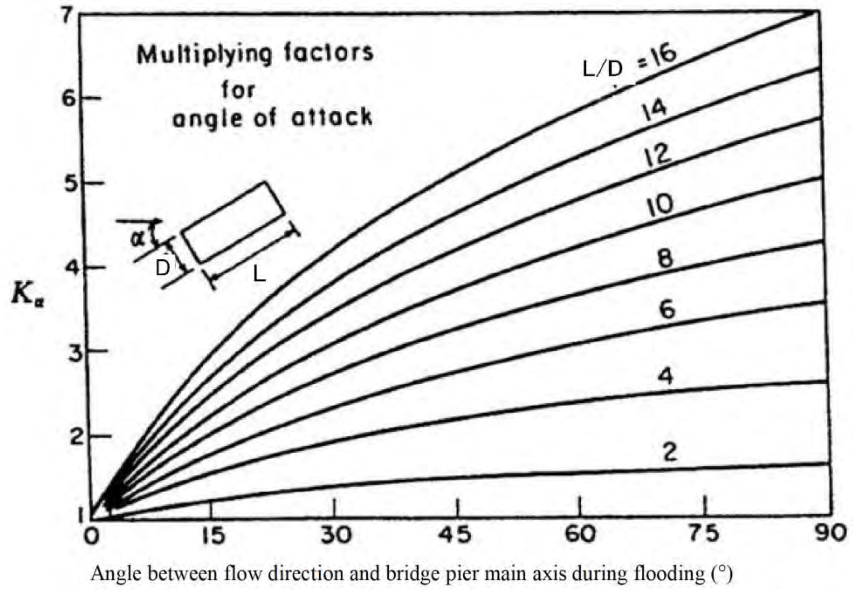


Figure 15 — Correction factor Kα for angle of attack

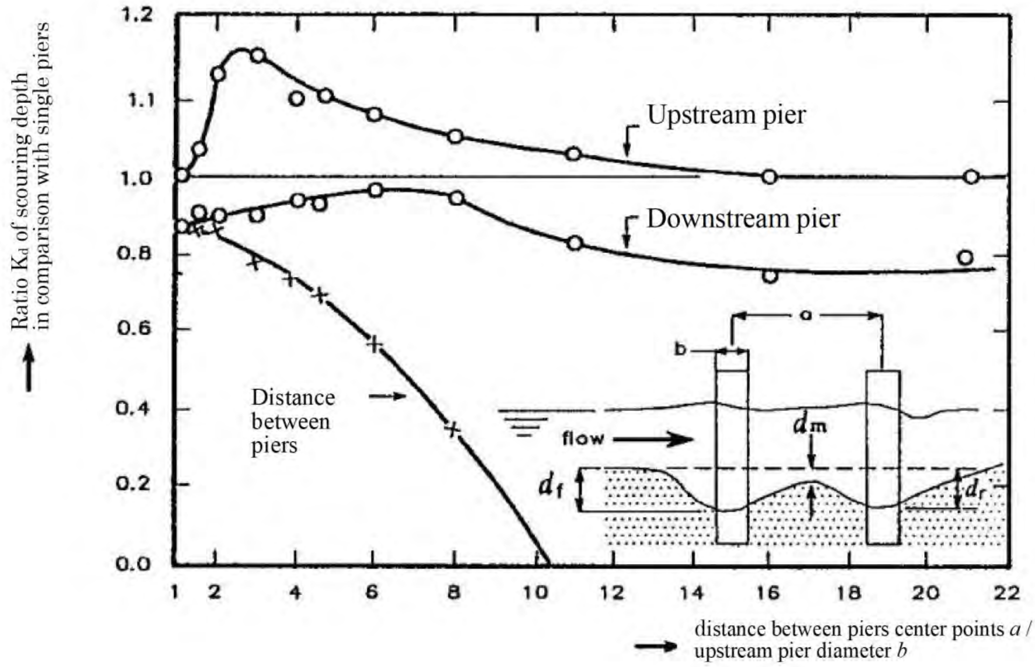


Figure 16 — Correction factor Kd for nearby piers

7.4 Calculation example-1

Examples are shown below

※ Calculation Condition:

Using Formula (1):

$$\frac{Z}{D}=f\cdot\left(\frac{h0}{D}\cdot\frac{h0}{dm}\cdot Fr\right)$$

Here

h_0	5.83m	is the average water depth;
D	2.0 m	is the diameter of bridge pier;
dm	24.9 mm	is the average grain diameter of riverbed material;
Fr	0.54	is the Froude number;
Z		is the scour depth.

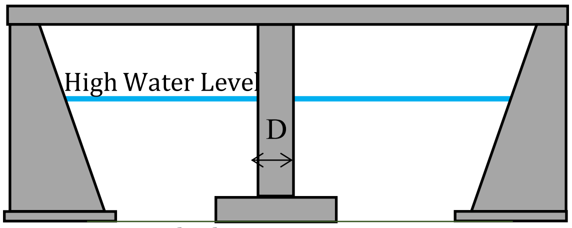


Figure 17 — Cross section

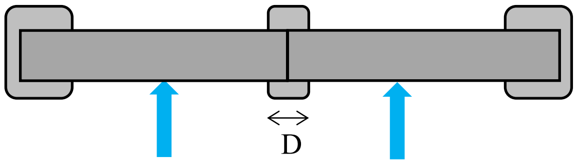


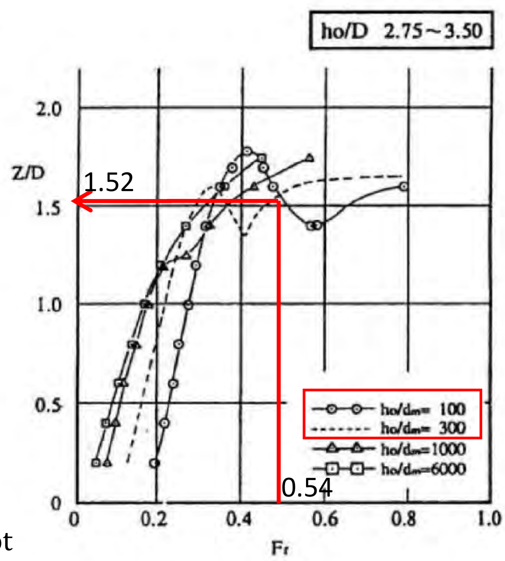
Figure 18 — Plan

To determine the average water depth, the high water level and the design riverbed are used:

High Water Level: 24.80m

Design riverbed; 18.97m

h_0: Average water depth; 24.80-18.97= **5.83 m**



Relationship between Fr~Z/D and h_0/d_m

(h_0/D=2.75 to 3.50)

Figure 19 — Relationship between Fr～Z/D

Now Z can be calculated as follows:

h_0/D=5.83/2.0=2.915

h_0/dm=5.83/0.0249=234.1

Z/D=1.5(refer to Figure 19)

Pier axis is parallel with river flow direction and there are not proximal bridges around the original bridge.

Therefore, correction factors Kα= 1.0 and Kd = 1.0 are adopted

Scour depth Z = (Z/D)・D・Kα・Kd

=1.52・2.0・1.0・1.0 = **3.0 m**

8 Protection of bridge substructures

In Timor-Leste, protection works as countermeasures for scouring are not installed on many bridge abutments and piers, many of which are confirmed to have scouring damage. Therefore, it is recommended to implement countermeasures for scouring on abutments and piers.

There are two types of protection work: gabion and foot protection block. However, due to issues with the durability (due to deterioration, etc.) of the metal wire used for gabion, it is recommended to that Timor-Leste take the same approach as Japan and use foot protection blocks.

Figure 20 — Gabion damaged situation Mora 2011

Figure 21 — Foot protection blocks in Japan

Figure 22 — Foot protection blocks in Japan

8.1 Types of foot protection blocks

Foot protection blocks are commonly used for bridges substructure protection in Japan. (As previously noted, rivers in Timor-Leste have many natural characteristics in common with those in Japan.) Therefore, there is an abundance of actual experience and data from hydraulic model experiment using foot protection blocks. The characteristic values of foot protection blocks differ according to their shape.

Table 1 — Types of foot protection blocks in Japan

8.2 Verification of dynamic stability of foot protection blocks

8.2.1 Basic policy

Foot protection work is required adequate weight to ensure stability against the hydrodynamic forces, width and height from estimated scouring.

1. Function

Foot protection work mitigates river scouring. It is directly exposed to the water flow. Therefore, it is necessary for the foot protection works to be stable against the water flow. This can be verified based on the fracture morphology from the same structural model as the slope protective works.

2. Damage Pattern

When the depth of embedment of the foundation is shallow and the foot protection works do not have enough width, the increased flow during floods will result in damage to the slope protective works. Additionally, if the foot protection work is not heavy enough for flow velocity, it will be washed away and cause damage to the entire revetment. Therefore to check for the necessary width of foot protection works, the same structural model as the slope protective works can be used to study the dynamic stability.

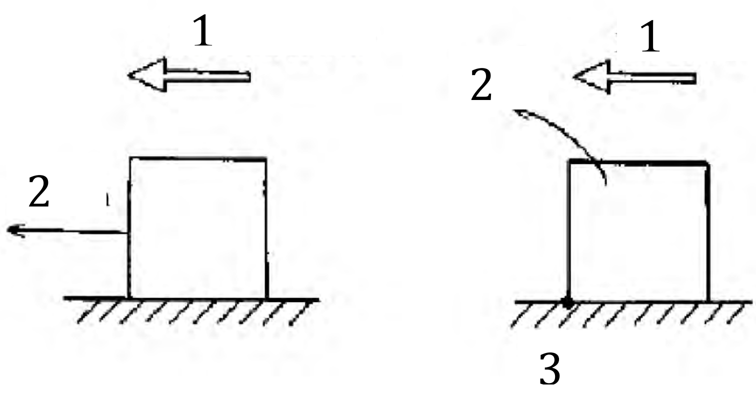
The same as the slope protective works, the damage pattern (rolling, sliding and traction) of the foot protection works is based on its shape and arrangement for this reason, the shape and arrangement are also reflected in the verification.

(1) Sliding

When the hydrodynamic force acting upon the component is greater than the friction on its bottom side, sliding occurs. This is taken into consideration for parts of foot protection work the furthest upstream, parts that stick out due to river fluctuations, or large irregular concrete blocks that receive flow force in their entirety. For example, this failure pattern can be seen in parts of the furthest upstream section of layered stacking type and random stacking type foot protection works.

(2) Rolling

This is when hydrodynamic force causes a component to turn over on a pivot point and roll. This damage pattern can be seen, for example, in parts of the furthest upstream section of layered stacking type and random stacking type foot protection works.



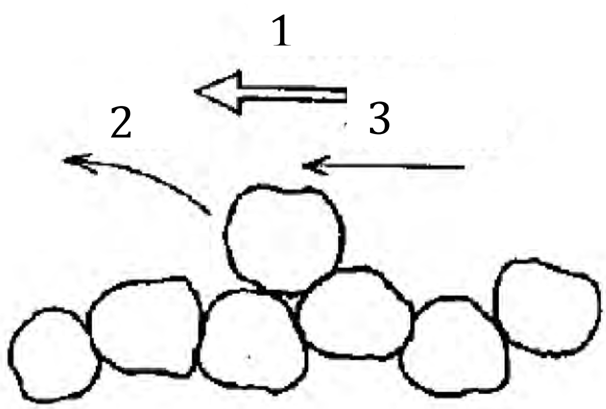
Key
1 direction of flow
2 motion
3 pivot point

Figure 23 — Sliding and Rolling

(3) Traction

The components receive drag and lift force from the directly of the flow and either repeatedly roll or experience some saltation in close proximity of the riverbed. This model is used for foot protection works with elements that are laid flat, such as natural stones or smooth, regular concrete blocks that are arranged in an orderly fashion.

For example, this can be seen in the damage of foot protection works using riprap or gabion.



Key
1 direction of flow
2 motion
3 tractive force

Figure 24 — Traction

3. Installation types

(1) Layered Stacking

The materials are stacked in a regular pattern. For example: evenly stacked blocks

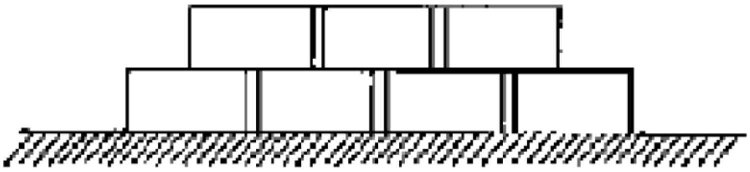


Figure 25 — Layered stacking

(2) Random Stacking

The materials are stacked in an irregular pattern. For example: stacked blocks, foot protective work using piled riprap

Figure 26 — Random stacking

(3) Gabion

A basket is filled with rocks or other materials. This refers to gabion foot protection work.

Figure 27 — Gabion

(4) Filled

The frame is filled with rocks or other materials. For example: fagot mattress or wooden mattress

Figure 28 — Filled

8.3 Calculation of weight of foot protection blocks

The following formula, Formula (3), is used in Japan to calculate the necessary weight of foot protection blocks:

$$W > a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \frac{\rho b}{g^2}\left(\frac{Vm}{\beta}\right)^6 \quad (3)$$

where

W is the weight of foot protection block

a is the factor of foot protection block shape

β is the factor of setting type

Vm is the average velocity

ρw: is the density of water (980 kg/m^3)

ρb is the density of blocks (2030 kg/m^3)

g is the acceleration of gravity (9.8 m/s^2)

Table 2 — Factor of α and β

Shape of block	specific gravity $\rho b/\rho w$	$a\times10^{-3}$	β
Type A: Projection	2.22	1.2	1.5
Type B: Plane	2.03	0.54	2.0
Type C: Triangular conic	2.35	0.83	1.4
Type D: Triangular bearing	2.25	0.45	2.3
Type E: Rectangle	2.09	0.79	2.8

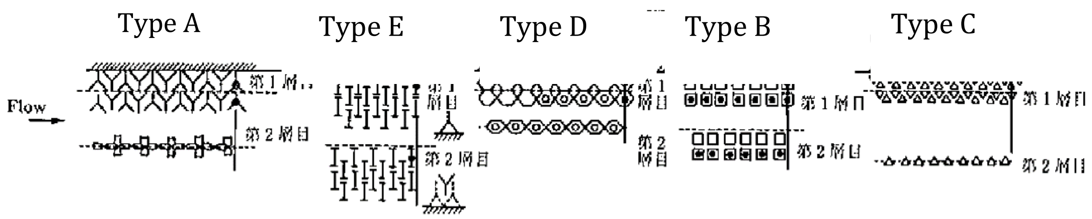


Figure 29 — Type of block arrangements

8.4 Calculation example-2

Examples are shown below

※ Calculation Condition:

Using Formula (1):

$$W>a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \frac{\rho b}{g^2}\left(\frac{Vm}{\beta}\right)^6$$

Here

W		is the weight of foot protection block
Vm	5.1m/s	is the river velocity;
Shape	Type B	is the block type;
α	0.54	is the block factor;
β	2.0	is the block factor;
ρw	980kg/m^3	is the density of water
ρb	2030kg/m^3	is the density of block
g	9.8m/s^2	is the acceleration of gravity

Now W can be calculated as follows:

$$W>0.54\times\left(\frac{1000}{2030-1000}\right)^3\times\frac{2030}{9.8^2}\times\left(\frac{5.1}{2.0}\right)^6$$

W>2872N

W>293kg

8.4.1 Average velocity

The flow velocity used in the calculation of foot protection block weight is calculated using the Manning formula for calculating the average velocity. The roughness coefficient is selected from the table below based on the conditions at the target river site.

$$Vm=\frac{1}{N}\cdot R^{2/3}\cdot I^{1/2}$$

where

N is the roughness coefficient

R is the hydraulic radius

I is the riverbed slope

Table 3 — Revised Ministry of Construction River and Erosion Control Standard (draft) Japan1997, Survey Section p132

River or channel conditions		Scope of Manning's n
Artificial channel, improved river	Concrete artificial channel	0.014～0.020
	Spiral half-pipe channel	0.021～0.030
	Channel with stone masonry on both banks (mud bed)	0.025 (mean value)
	Bedrock excavation	0.035～0.05
	Bedrock forming	0.025～0.04
	Clay riverbed with flow velocity not enough to cause scouring	0.016～0.022
	Sandy loam, clayey soil loam	0.020 (mean value)
	Drag line dredging, little weeds	0.025～0.033
Natural river	Small channel on plain, with no grass	0.025～0.033
	Small channel on plain, with grass and shrubs	0.030～0.040
	Small channel on plain, with lots of grass and gravel bed	0.040～0.055
	Mountain channel, with gravel and boulders	0.030～0.050
	Mountain channel, with boulders and large boulders	0.040 or higher
	Large channel, with sandy bed and little meandering	0.018～0.035
	Large channel, with gravel bed	0.025～0.040

Where, Hydraulic Radius (m) = Cross Section Area (m²) / Wetted perimeter (m)

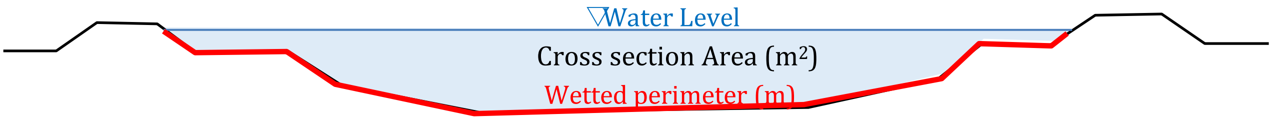


Figure 30 — Image of hydraulic radius

8.4.2 Determination of water level

Water level of using Manning formula for calculating the average velocity should be determined using the following method:

Solution 1. Calculation of non-uniform flow

Solution 2. Hearing survey with site residents, survey of past flood mark

In Timor-Leste, installation of rain fall station is insufficient for run off calculation and due to high cost topographic survey for calculation of non-uniform flow. As this reason, hearing survey with site resident or survey of past flood mark is realistic solution for set water level.

On the other hand, in the case of new bridge plan or new river plan for flood countermeasure, calculation of non-uniform flow should be encouraged for set water level in river. In this case, river discharge and return period are required for river study.it is encouraged to use same return period of original river plan.

These guidelines do not include an explanation about software operation for non-uniform flow. It is possible to get free software and operation manual below "US army Corps of Engineers" website.

http://www.hec.usace.army.mil/software/hec-ras/

Step 1
Implementation of river topographic survey
(Cross section, plane and profile)

Step 2
Calculations of each return period discharge using Rational formula and RRI model, etc.
Input data; Rainfall data, etc.

Step 3
Calculation of non-uniform flow using HEC-RAS software, etc.
Input data; Topographic data, etc.

Step 4
Determination of water level

Figure 31 — Study procedure of solculation1

Reference

1. Uniform flow

Flow is said to be uniform, when the velocity of flow does not change either in magnitude or in direction at any point in a flowing fluid, for a given time. For example, the flow of liquids under pressure through long pipelines with a constant diameter is called uniform flow.

2. Non-uniform flow

Flow is said to be non-uniform, when there is a change in velocity of the flow at different points in a flowing fluid, for a given time. For example, the flow of liquids under pressure through long pipelines of varying diameter is referred to as non-uniform flow. All these type of flows can exist independently of each other. So there can be any of the four combinations of flows possible:

1. Steady uniform flow

2. Steady non-uniform flow

3. Unsteady uniform flow

4. Unsteady non-uniform flow.

8.5 Installation width of foot protection blocks

Installation width of foot protection blocks should be more than 5m, but in the case server riverbed scoring, it should be set as described 7.3 Determination of scour hole width.

Annex A
(informative)

Case study of Sahen Bridge

A.1 Introduction

I. Reason of selection for case study
Reasons of selection for the case study for design check are as follows;

1) Generality of work item
The work items of the case study are protection work for bridge substructure.
Once the plan of these case study are successfully completed, the knowledge obtained by the case study will be developed to all the area of Timor-Leste.

2) Accessibility
The site is located near the major district town and it takes within 60 minutes' drive from the municipal office of DRBFC and the general security is also good.

3) Urgency and Importance
The road is considered the essential road and it is urgently required.

II. Protection works against scouring of bridges
1. Location of case study
The target site is located on the right side bank at Sahen River.

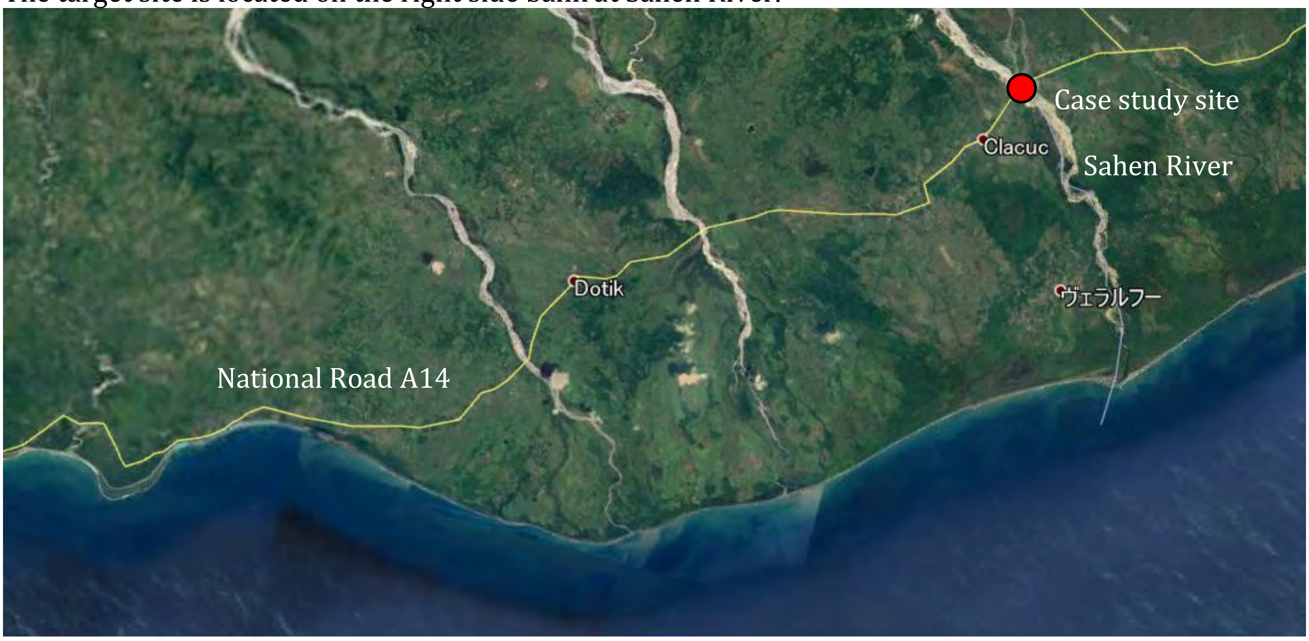


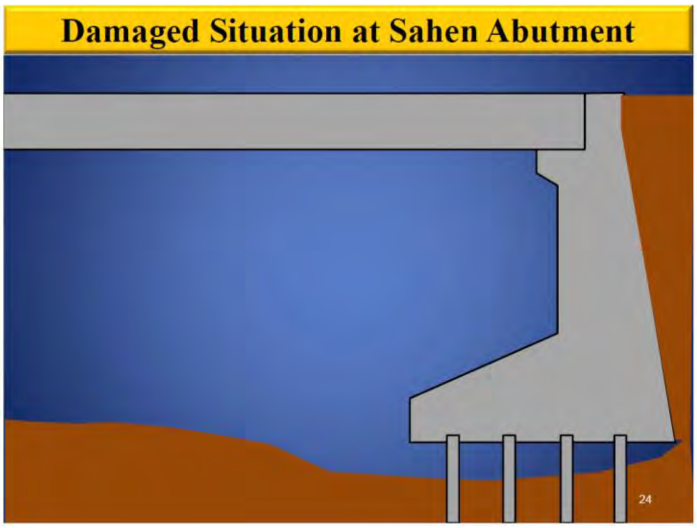
Figure Location of case study at Sahen

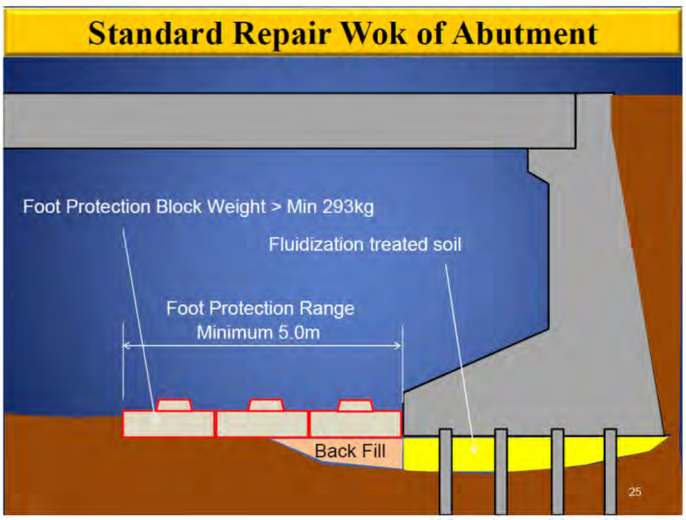
2. Current Situation

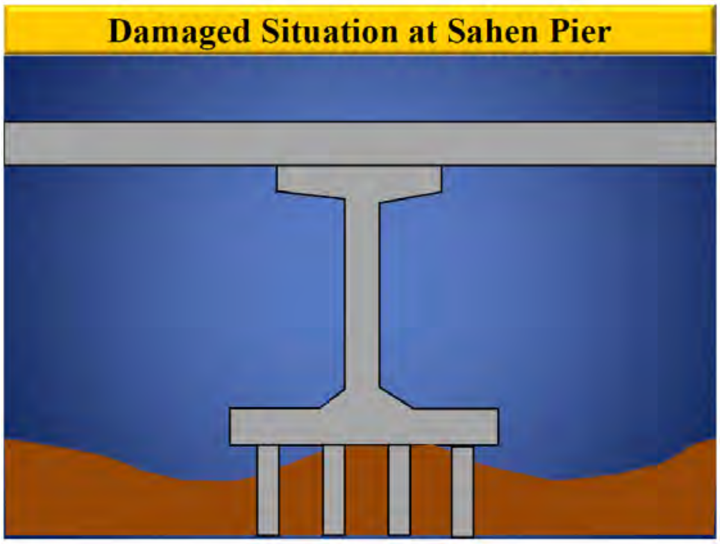
Following picture is shown scoring situation at right bank side abutment and right side pier.
There is no protection work in front of the abutment and pier, therefore it is necessary to rehabilitate based on technical analysis.

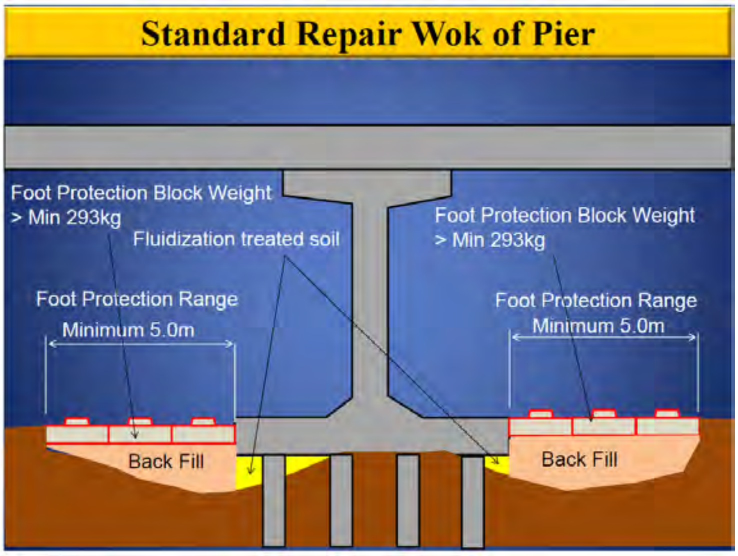
Photo Situation of damaged abutment and pier

A.2 Remedial measures



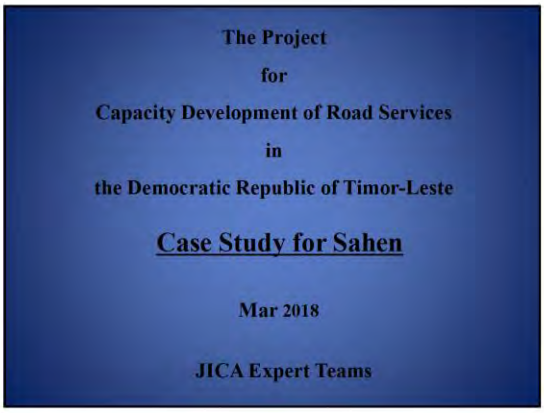


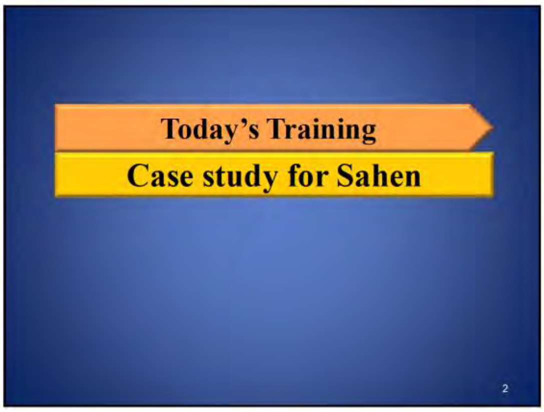

Damaged Situation at Sahen Pier

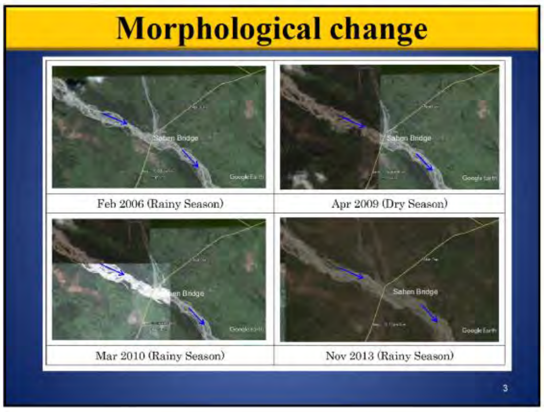

Standard Repair Wok of Pier
Foot Protection Block Weight
> Min 293kg
Fluidization treated soil
Foot Protection Block Weight
> Min 293kg
Foot Protection Range
Minimum 5.0m
Foot Protection Range
Minimum 5.0m
Back Fill
Back Fill

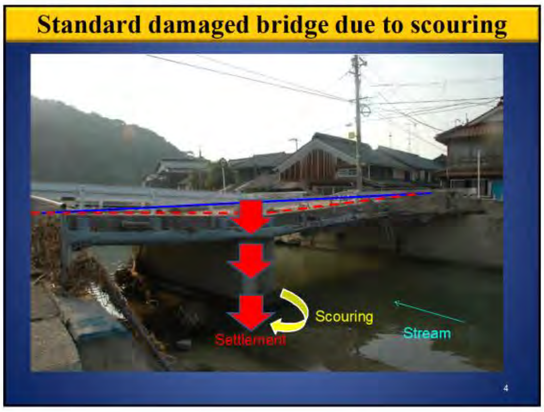

Countermeasure plan for Reference
Sahen River
Rightbank
Abutment
Leftbank
Abutment
Pier
Pier
Pier
20m
20m
20m
20m
20m
13m
13m
13m
Foot protection block
Foot protection block
Foot protection block
Foot protection block
Foot protection block
Google Earth
28

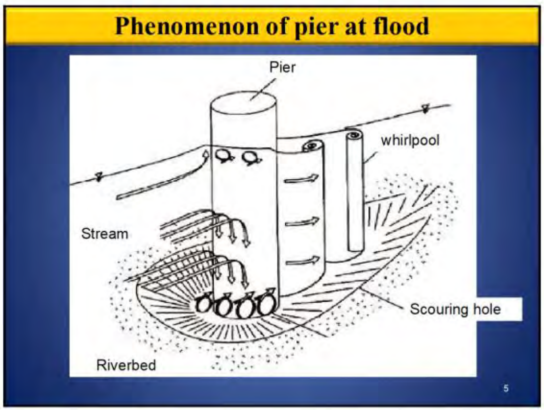
A.3 Training materials

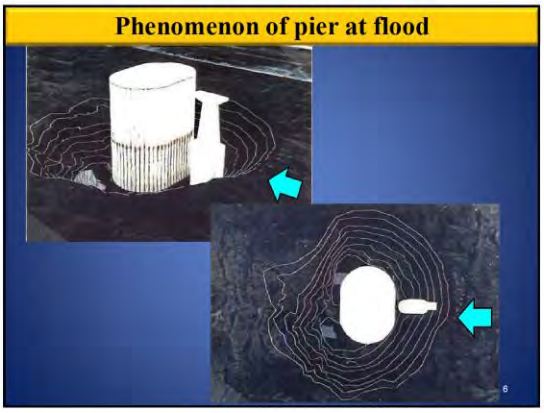


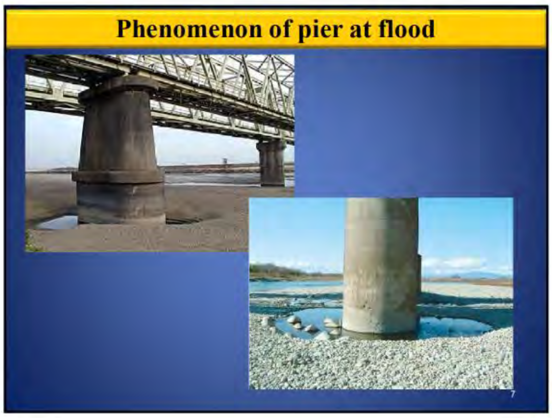


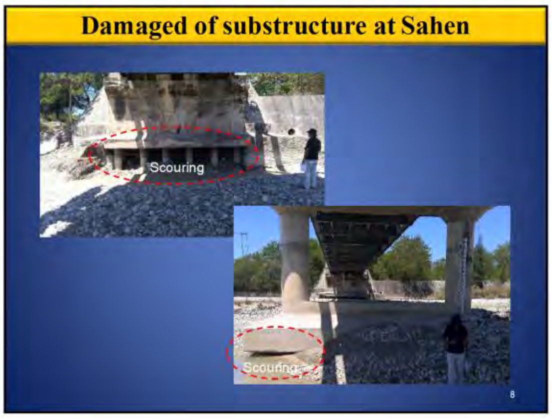


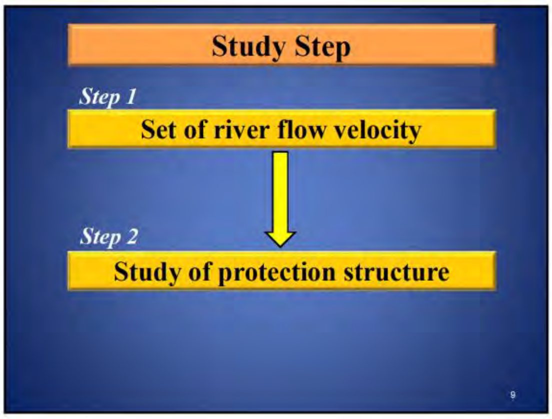


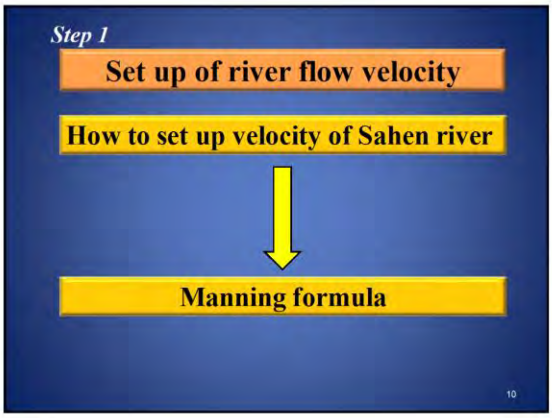


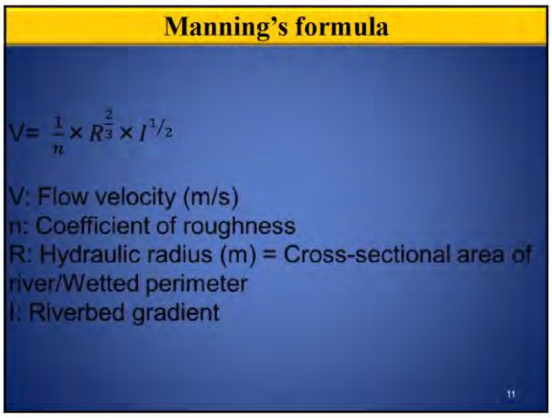


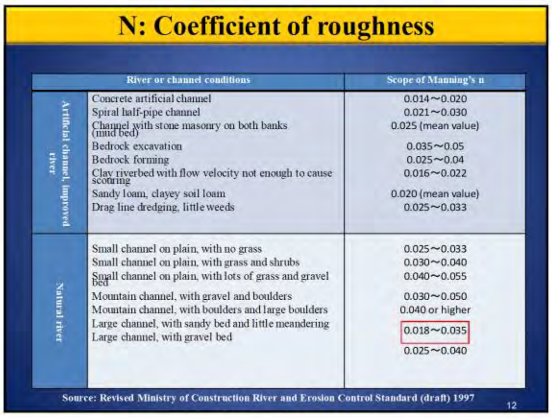






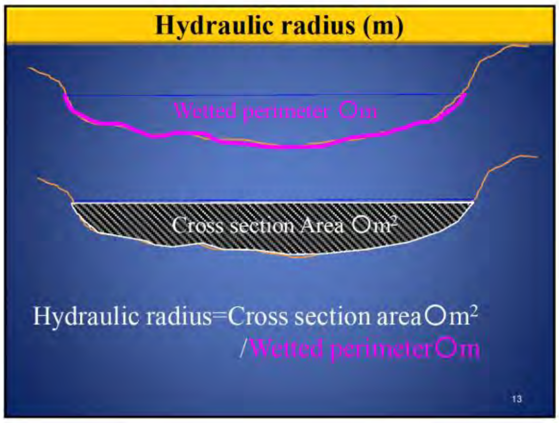


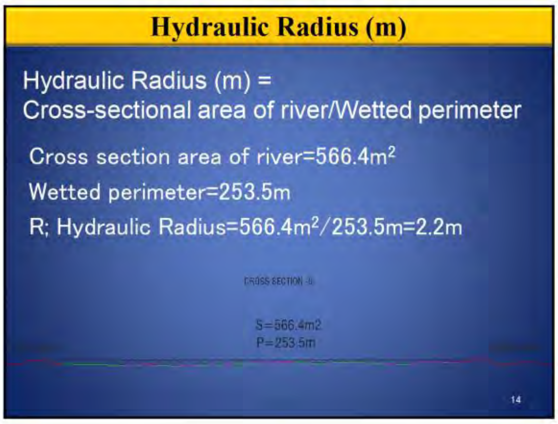


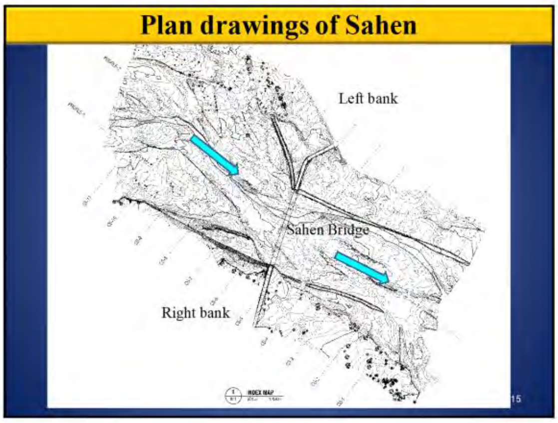

N: Coefficient of roughness

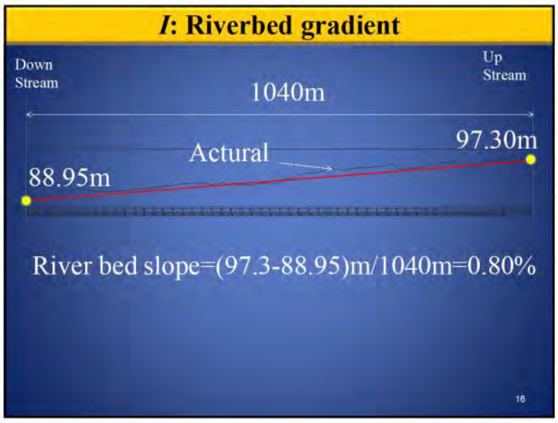
River or channel conditions		Scope of Manning's n
Artificial channel, improved river	Concrete artificial channel	0.014～0.020
	Spiral half-pipe channel	0.021～0.030
	Channel with stone masonry on both banks (mud bed)	0.025 (mean value)
	Bedrock excavation	0.035～0.05
	Bedrock forming	0.025～0.04
	Clay riverbed with flow velocity not enough to cause scouring	0.016～0.022
	Sandy loam, clayey soil loam	0.020 (mean value)
	Drag line dredging, little weeds	0.025～0.033
Natural river	Small channel on plain, with no grass	0.025～0.033
	Small channel on plain, with grass and shrubs	0.030～0.040
	Small channel on plain, with lots of grass and gravel bed	0.040～0.055
	Mountain channel, with gravel and boulders	0.030～0.050
	Mountain channel, with boulders and large boulders	0.040 or higher
	Large channel, with sandy bed and little meandering	0.018～0.035
	Large channel, with gravel bed	0.025～0.040

Source: Revised Ministry of Construction River and Erosion Control Standard (draft) 1997
12









Result of calculation

Cross section No.	No.6
n:Coefficient of roughness	0.03
S:Cross-sectional area of river (m2)	566.4
P:Wetted perimeter (m)	253.5
I:Riverbed gradient	0.008
R: Hydraulic radius	2.2
Vm: Mean flow velocity (m/s)	5.10
Q:Discharge(m3/s)	2886.1

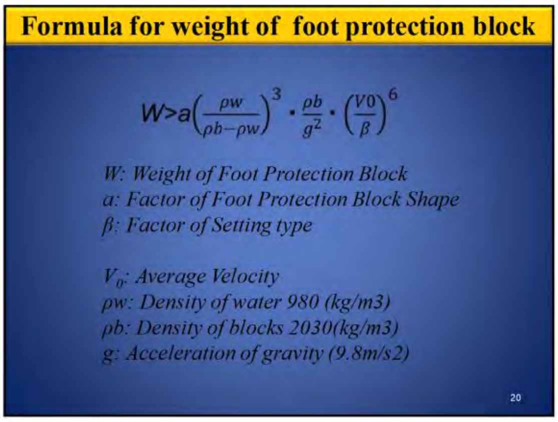
17

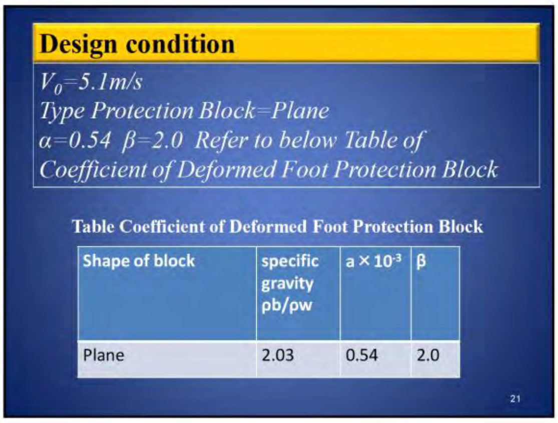
Step 2

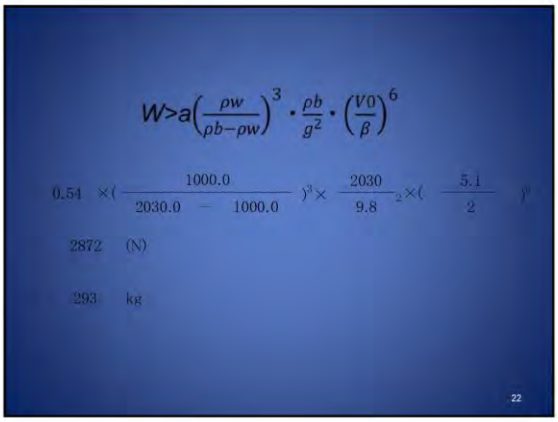
Study of protection structure

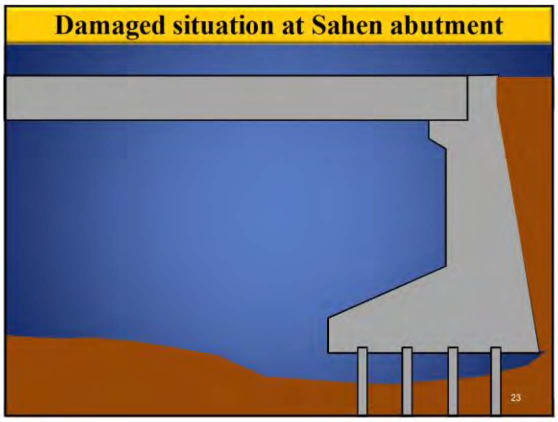
18

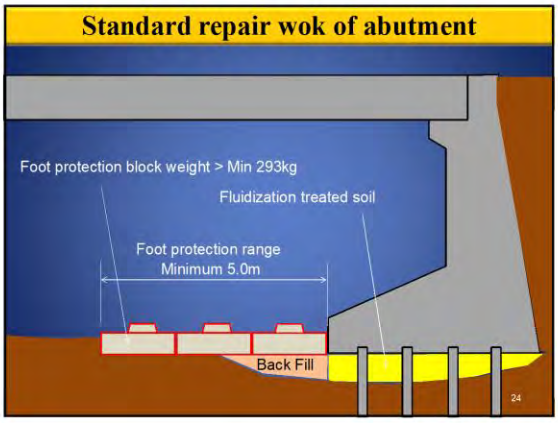

Standard foot protection work for scoring

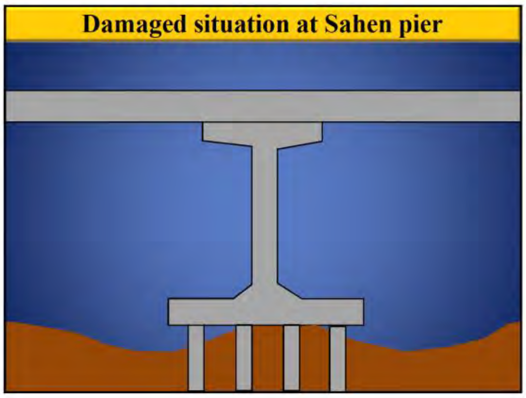

Formula for weight of foot protection block
$W>a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \cdot \frac{\rho b}{g^2} \cdot \left(\frac{V0}{\beta}\right)^6$
W: Weight of Foot Protection Block
α: Factor of Foot Protection Block Shape
β: Factor of Setting type
V_0: Average Velocity
ρw: Density of water 980 (kg/m3)
ρb: Density of blocks 2030(kg/m3)
g: Acceleration of gravity (9.8m/s2)
20

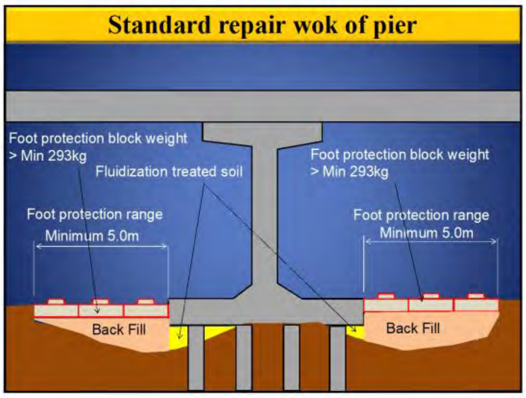

Design condition
V_0=5.1m/s
Type Protection Block=Plane
α=0.54 β=2.0 Refer to below Table of Coefficient of Deformed Foot Protection Block
Table Coefficient of Deformed Foot Protection Block
Shape of block | specific gravity ρb/ρw | a×10-3 | β
Plane | 2.03 | 0.54 | 2.0
21


$W>a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \cdot \frac{\rho b}{g^2} \cdot \left(\frac{V0}{\beta}\right)^6$
0.54 ×(1000.0 / 2030.0 − 1000.0)3× 2030 / 9.8 2×(5.1 / 2)
2872 (N)
293 kg
22


Damaged situation at Sahen abutment
23


Standard repair wok of abutment
Foot protection block weight > Min 293kg
Fluidization treated soil
Foot protection range
Minimum 5.0m
Back Fill
24


Damaged situation at Sahen pier

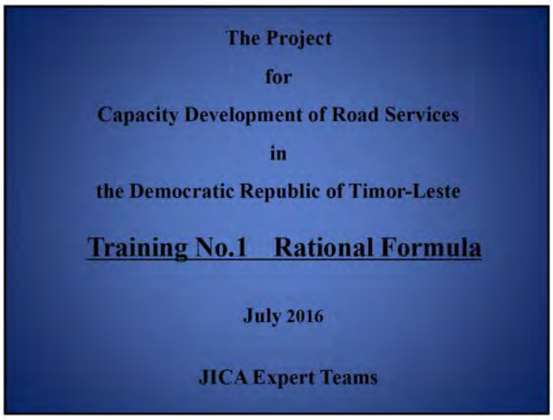

Standard repair wok of pier
Foot protection block weight
> Min 293kg
Fluidization treated soil
Foot protection block weight
> Min 293kg
Foot protection range
Minimum 5.0m
Foot protection range
Minimum 5.0m
Back Fill
Back Fill

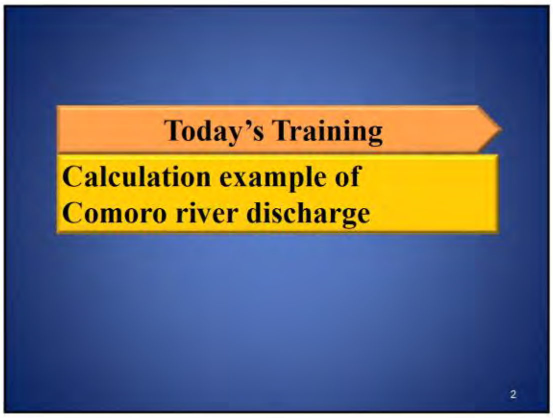

Countermeasure plan for reference
Sahen river
Rightbank
Abutment
Leftbank
Abutment
Pier
Pier
Pier
20m
20m
20m
20m
20m
13m
13m
13m
Foot protection block
Foot protection block
Foot protection block
Foot protection block
Foot protection block
Google Earth
27

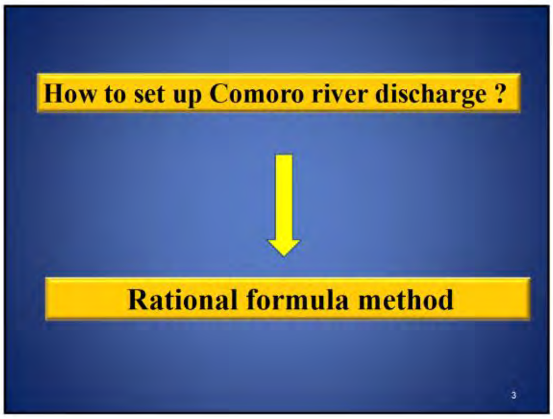
Annex B
(informative)

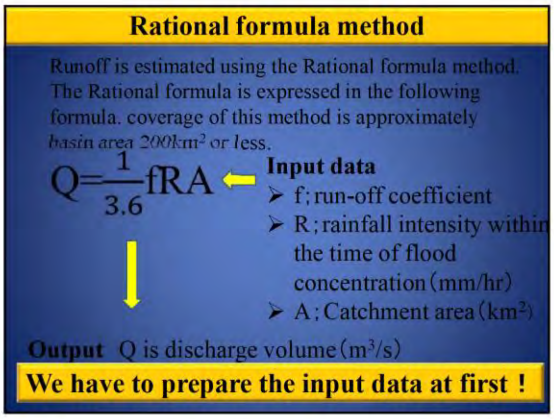
Training materials

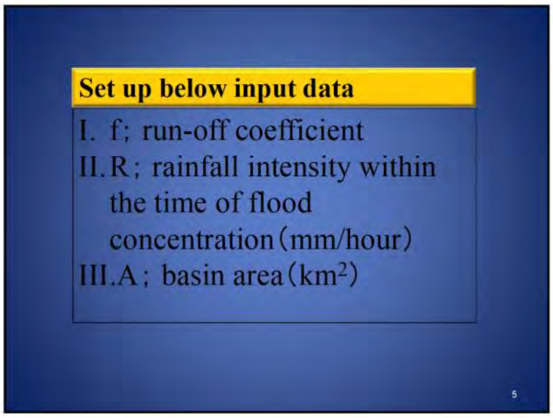
B.1 Rational method











What is runoff coefficient ?

Runoff coefficients depend on the land use, land condition of river basin. runoff coefficients are needed to calculate rain water runoff using the Rational method.

7

Runoff coefficient is 0.9

Runoff coefficient of Comoro river basin is determined to be 0.9 based on standard values in "Manual for River Works in Japan, Technical Criteria for River Works"

Steep mountainous region	0.75~0.90
Mountains of Tertiary strata	0.70~0.80
Rugged land and forests	0.50~0.75
Flat arable land	0.45~0.60
Irrigated paddy fields	0.70~0.80
Rivers in mountainous regions	0.75~0.85
Small rivers in level land	0.45~0.75
Large rivers in flat land	0.50~0.75

Source: Manual for River Works in Japan, Technical Criteria for River Works

8

II. Rainfall Intensity

9

What is Rainfall intensity ?

Rainfall intensity means momentary rainfall is converted one hour amount of rainfall.

Question

In the case rainfall is 2.5mm/one minute.
Which value is rainfall intensity ○ mm/hour ?

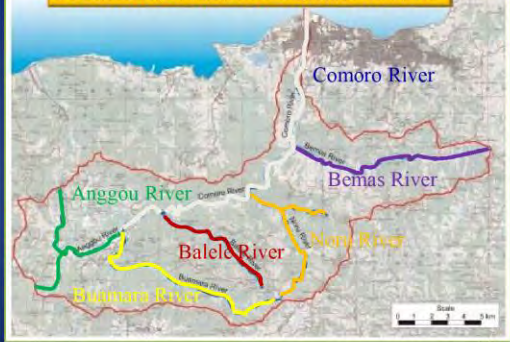
10

Answer

2.5mm/one minute × 60 minutes=150mm/hour

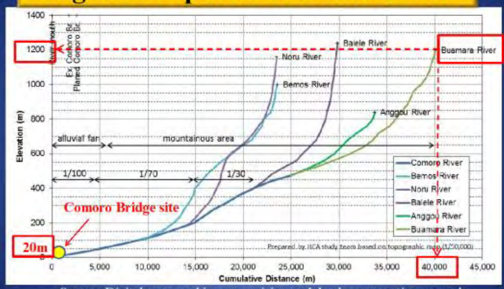
11

Catchment area of Comoro river



12

Longitudinal profile of Comoro river



Source: Digital topographic map revision and database operation manual for the study on urgent establishment of topographic mapping in East Timor (2000), JICA

13

R:Rainfall Intensity

Rainfall intensity is calculated by the following Mononobe's formula based on daily rainfall shown in below.

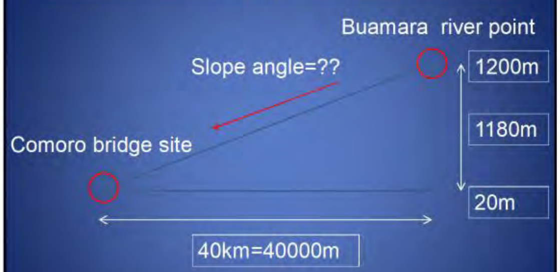
$$R = \frac{R_{24}}{24}\left(\frac{24}{T}\right)^{0.6}$$

Where, R is rainfall intensity within flood concentration time (mm/hr), R24 is 24-hour rainfall (mm), and T is flood concentration time. Rainfall intensity for each return period calculated using above formula is shown below table .

Return Period	R24=Daily Rainfall (mm)	R=Rainfall Intensity (mm/hr)
2-year	144.2	20.5
5-year	193.8	27.6
10-year	226.6	32.2
30-year	276.3	36.3
50-year	298.9	42.5
100-year	329.5	46.9

16

How to set up of slope angle?



Slope angle=1180/40000≒1/33

III. Basin Area

17

T: Flood concentration time

Flood concentration time is expressed using Kraven's formula as follows.

T = L/W

Where, T is flood concentration time (hour),

L is watercourse length⇒ 40,000(m),

W is flood flow velocity (m/s) shown in below.

I : Watercourse slope	over 1/100	1/100~1/200	below 1/200
W : Flood runoff velocity	3.5 m/s	3.0 m/s	2.1 m/s

Watercourse slope is 1/33, and so flood runoff velocity is 3.5m/s. flood concentration time is calculated using these values as follows.

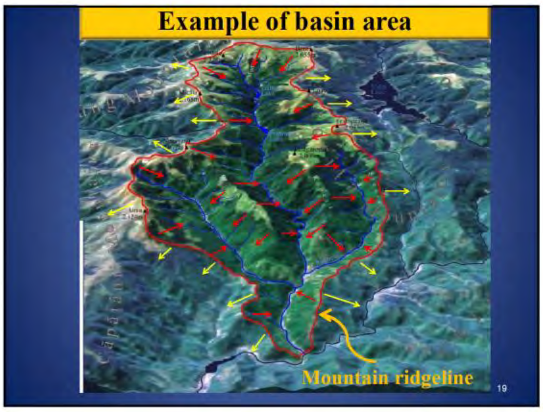
T = L/W = 40,000 (m) / 3.5 (m/s) = 3.1 (hour)

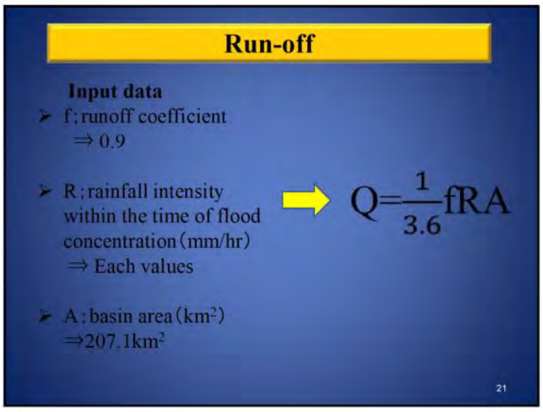
15

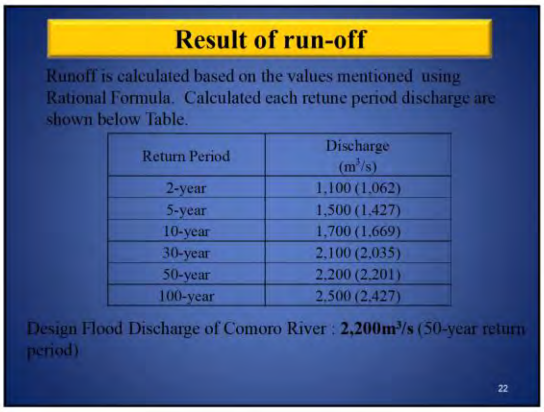
What is basin area ?

Basin area is an extent or an area of land where all surface water from rain, melting snow, or ice converges to a single point at a lower elevation, usually the exit of the basin, where the waters join another body of water, such as a river, lake, reservoir, estuary, sea, or ocean.

18

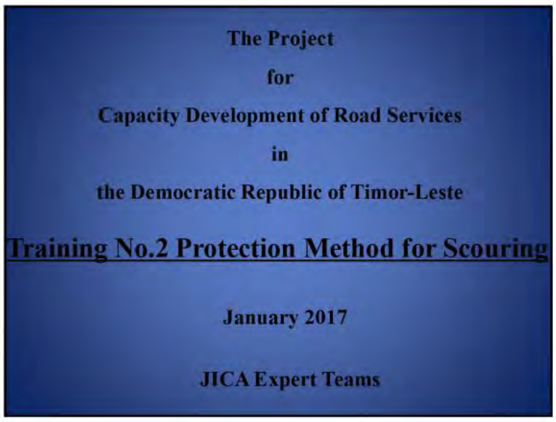


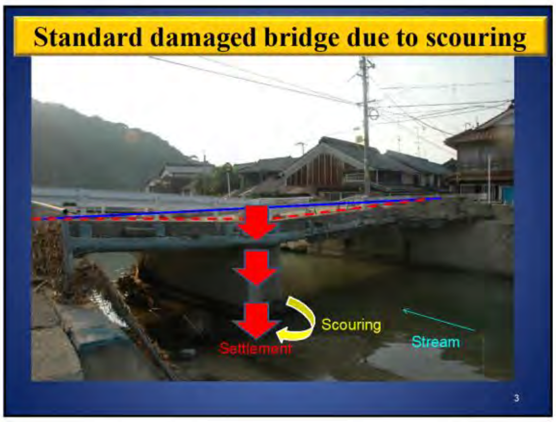


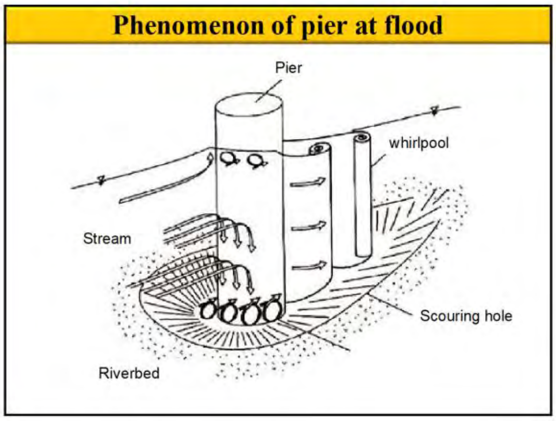


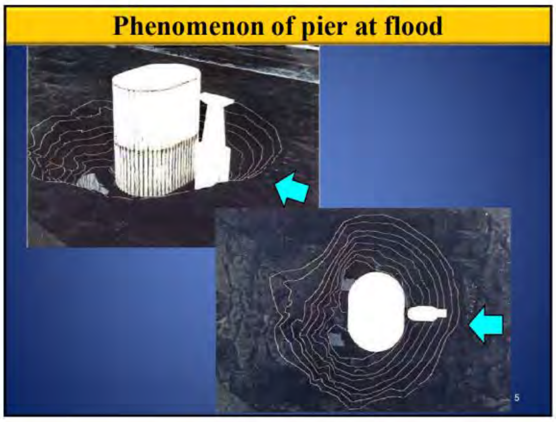
Return Period	Discharge (m^3/s)
2-year	1,100 (1,062)
5-year	1,500 (1,427)
10-year	1,700 (1,669)
30-year	2,100 (2,035)
50-year	2,200 (2,201)
100-year	2,500 (2,427)

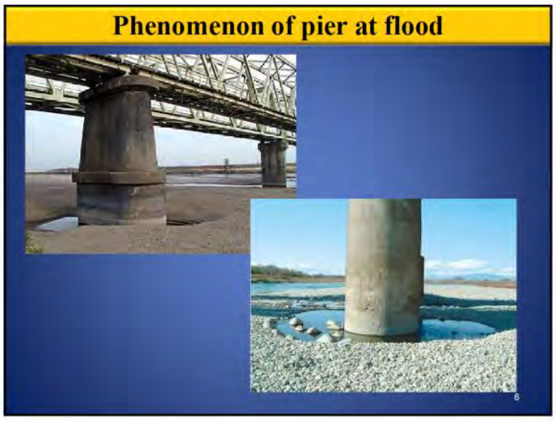
B.2 Protection method for scouring

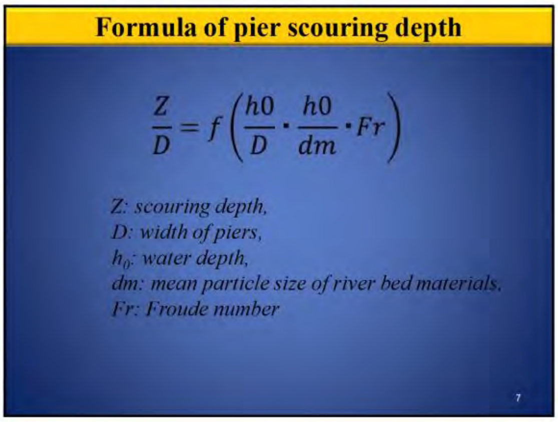


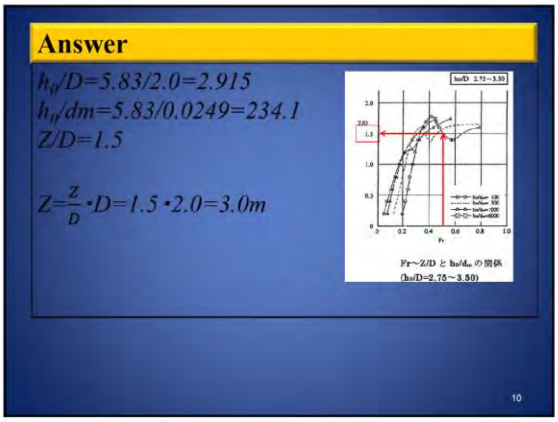


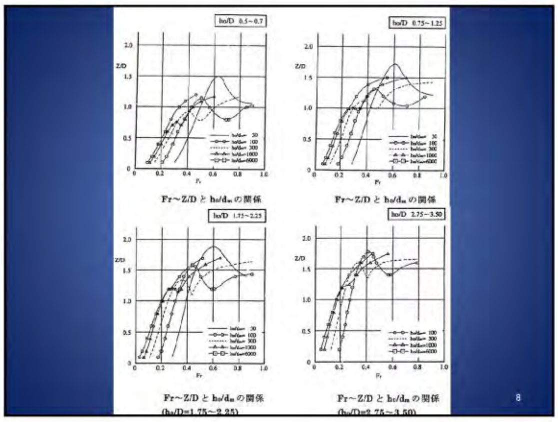




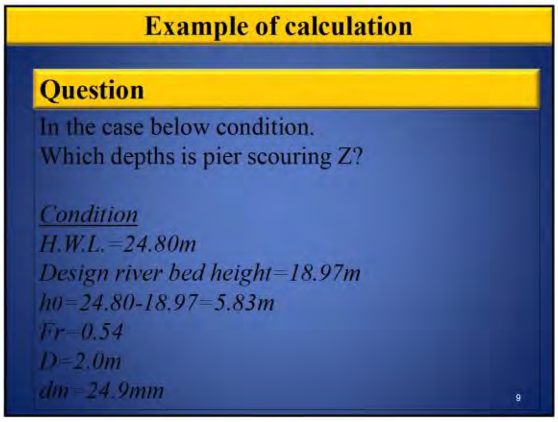


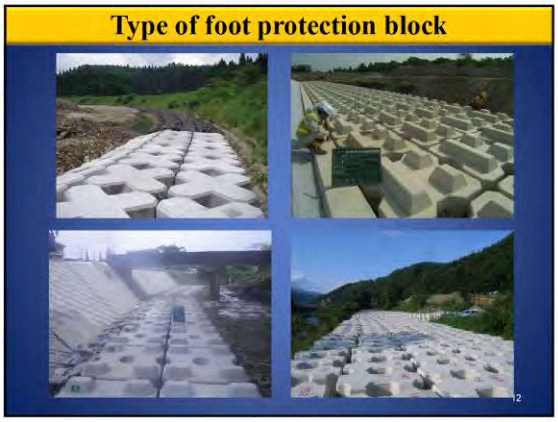

Formula of pier scouring depth
$\frac{Z}{D} = f\left(\frac{h0}{D} \cdot \frac{h0}{dm} \cdot Fr\right)$
Z: scouring depth,
D: width of piers,
h_0: water depth,
dm: mean particle size of river bed materials,
Fr: Froude number
7


Answer
$h_0/D=5.83/2.0=2.915$
$h_0/dm=5.83/0.0249=234.1$
Z/D=1.5
$Z=\frac{Z}{D} \cdot D=1.5 \cdot 2.0=3.0m$
Fr~Z/D と h0/dm の関係
(h0/D=2.75~3.50)
10


Fr~Z/D と h0/dm の関係
Fr~Z/D と h0/dm の関係
Fr~Z/D と h0/dm の関係
Fr~Z/D と h0/dm の関係
8


Standard foot protection work for scoring


Example of calculation
Question
In the case below condition.
Which depths is pier scouring Z?
Condition
H.W.L.=24.80m
Design river bed height=18.97m
h0=24.80-18.97=5.83m
Fr=0.54
D=2.0m
dm=24.9mm
9


Type of foot protection block

Formula for weight of foot protection block

$$W > a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \cdot \frac{\rho b}{g^2} \cdot \left(\frac{V0}{\beta}\right)^6$$

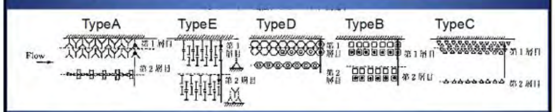
W: Weight of Foot Protection Block
a: Factor of Foot Protection Block Shape
β: Factor of Setting type

V_0: Average Velocity
ρw: Density of water 980 (kg/m3)
ρb: Density of blocks 2030(kg/m3)
g: Acceleration of gravity (9.8m/s2)

13

Table Coefficient of Deformed Foot Protection Block

Shape of block	specific gravity ρb/ρw	a × 10⁻³	β
TypeA: Projection	2.22	1.2	1.5
TypeB: Plane	2.03	0.54	2.0
TypeC: Triangular conic	2.35	0.83	1.4
TypeD: Triangular bearing	2.25	0.45	2.3
TypeE: Rectangle	2.09	0.79	2.8



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Example of Calculation

Question

In the case below condition.
Which size is foot protection block?

Condition
V_0=3.0m/s
Type Protection Block=TypeB: Plane
α=0.54 β=1.0 Refer to Table of Coefficient of Deformed Foot Protection Block

15

Answer

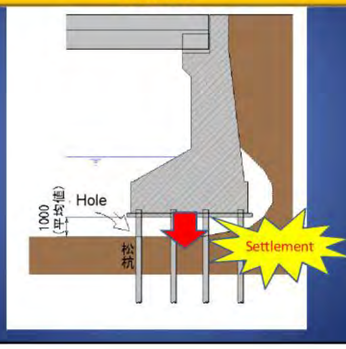
$$W > a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 * \frac{\rho b}{g^2} * \left(\frac{Vd}{\beta}\right)^6$$

$$=0.54\times\left(\frac{1000}{2030-1000}\right)^3 \times\frac{2030}{9.8^2}\times\left(\frac{3.0}{1.0}\right)^6$$

=7615N
=777.04kg

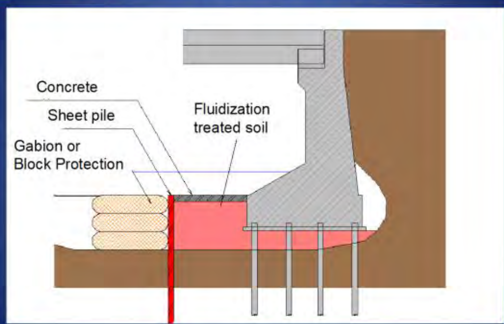
16

Standard damaged situation of abutment at flood



17

Standard repair wok of abutment

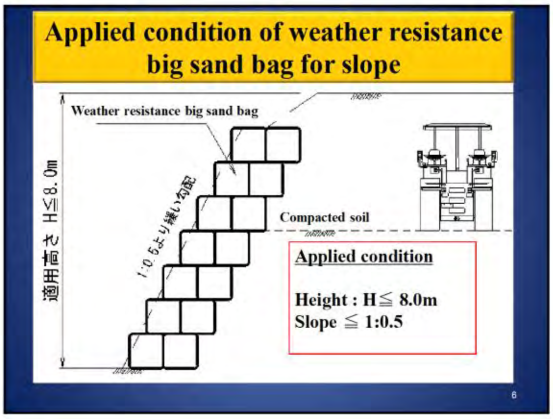


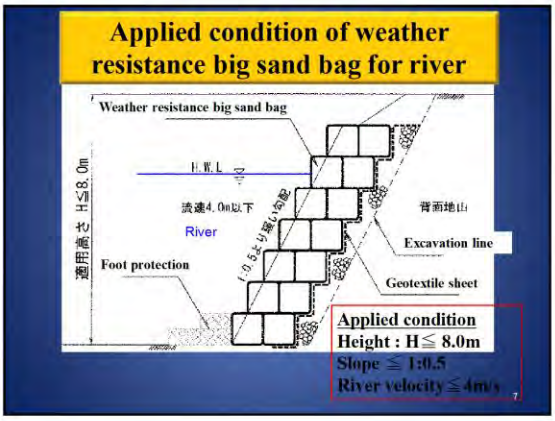
18


Fluidization treated soil
The feature of fluidization treated soil is able to construct in the small place.
Material; Soil ＋Cement＋Water
19


Vibratory hammer method
20

B.3 Big sandbags

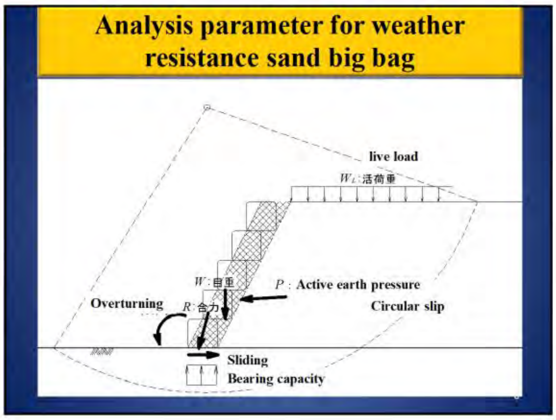


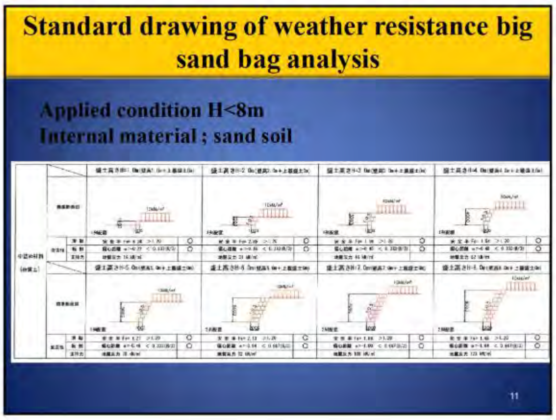


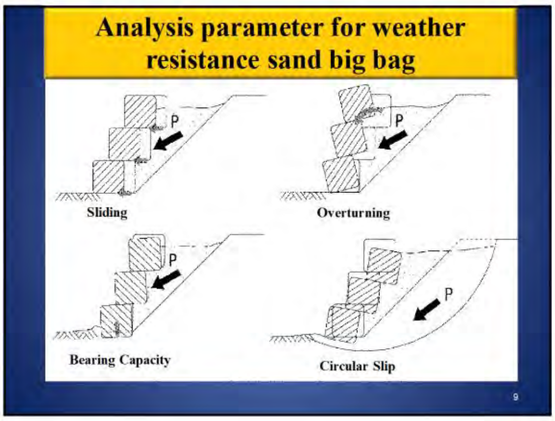
Safety factor for weather resistance big sand bag analysis

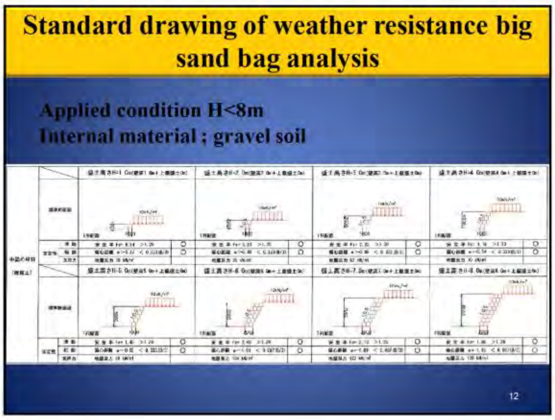
Item	Safety Factor
Compression Stress of Big Sand Bag	F≧1.5
Sliding	F≧1.2
Overturning	Eccentricity distance E≧B/3
Bearing Capacity	F≧2.0
Circular Slip	F≧1.05

10



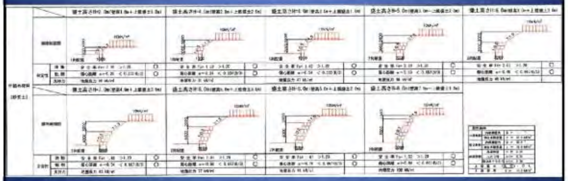






Standard drawing of weather resistance big sand bag analysis

Applied condition H<8m
Internal material ; sand soil



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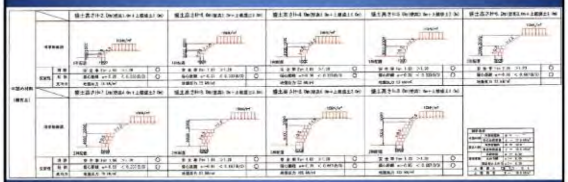
Standard drawing of weather resistance big sand bag analysis

Applied condition H<8m
Internal material ; gravel soil



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Comparison of normal and weather resistance type

	Normal type	Weather resistance type
Image		
Ultraviolet Rays	Weak	Strong
Cost	Cheap	Normal
Endurance	Weak	Strong
Strength	Weak	Strong

Normal big sand bag

The Normal type geo-bag is vulnerable to ultraviolet rays

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Recommended plan of weather resistance big sand bag

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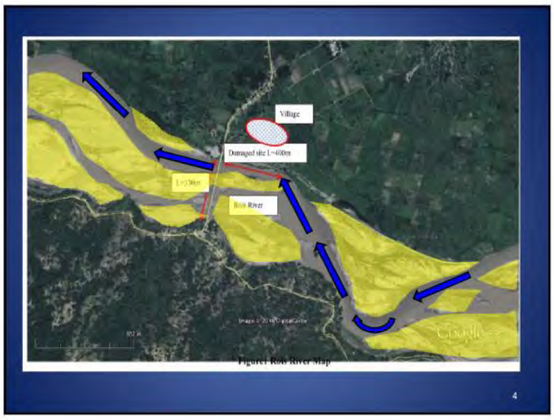
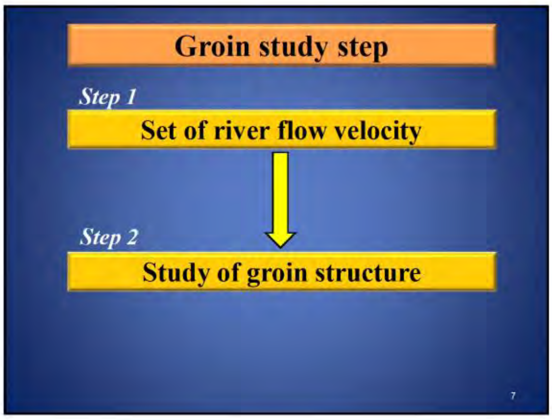
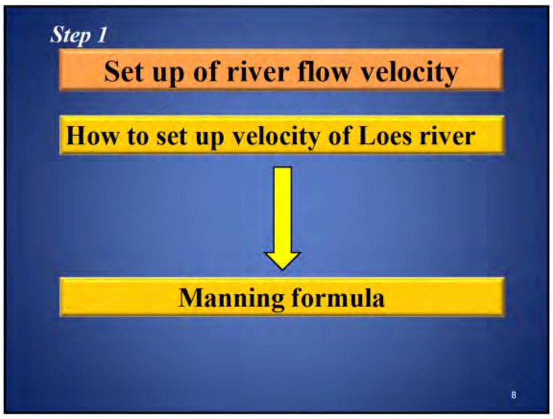
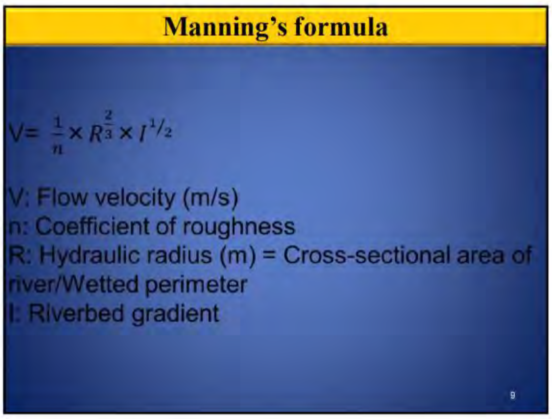
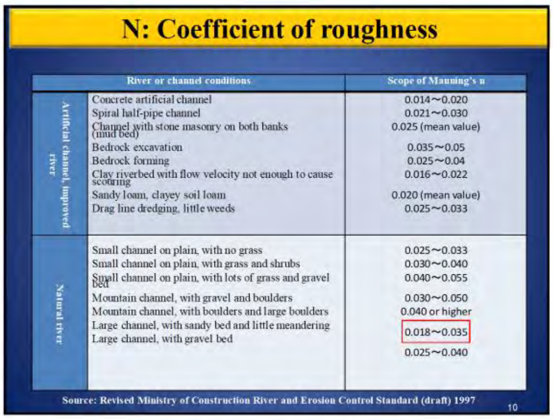
B.4 Groin method





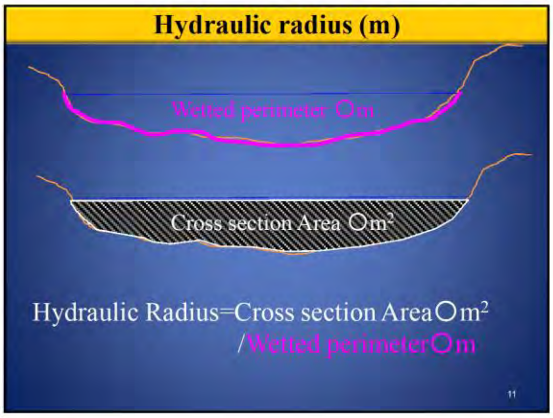


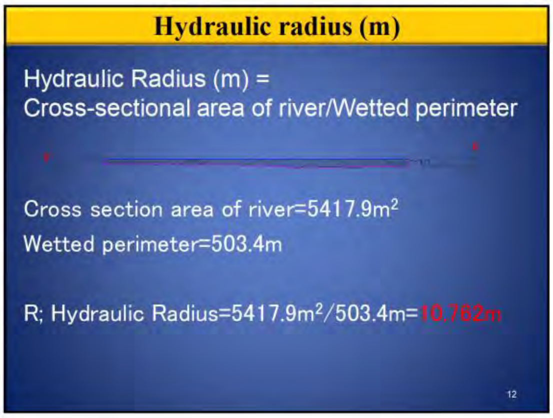




	River or channel conditions	Scope of Manning's n
Artificial channel, improved river	Concrete artificial channel	0.014～0.020
	Spiral half-pipe channel	0.021～0.030
	Channel with stone masonry on both banks (mud bed)	0.025 (mean value)
	Bedrock excavation	0.035～0.05
	Bedrock forming	0.025～0.04
	Clay riverbed with flow velocity not enough to cause scouring	0.016～0.022
	Sandy loam, clayey soil loam	0.020 (mean value)
	Drag line dredging, little weeds	0.025～0.033
Natural river	Small channel on plain, with no grass	0.025～0.033
	Small channel on plain, with grass and shrubs	0.030～0.040
	Small channel on plain, with lots of grass and gravel bed	0.040～0.055
	Mountain channel, with gravel and boulders	0.030～0.050
	Mountain channel, with boulders and large boulders	0.040 or higher
	Large channel, with sandy bed and little meandering	0.018～0.035
	Large channel, with gravel bed	0.025～0.040

Source: Revised Ministry of Construction River and Erosion Control Standard (draft) 1997





I: Riverbed gradient

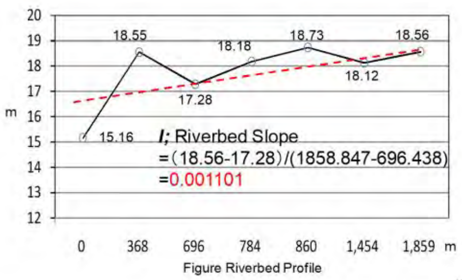


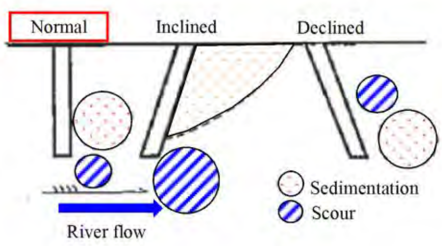
Figure Riverbed Profile

Comparison of Groin structure type

Result of calculation

Cross section No.	
n: Coefficient of roughness	0.035
S: Cross-sectional area of river (m2)	5417.9
P: Wetted perimeter (m)	503.4
I: Riverbed gradient	0.001101
R: Hydraulic radius	10.8
Vm: Mean flow velocity (m/s)	4.62

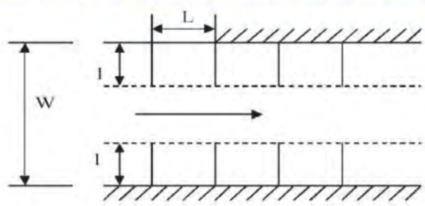
Set of direction type of Groin



Step 2

Study of Groin structure

Set of length and interval of Groin

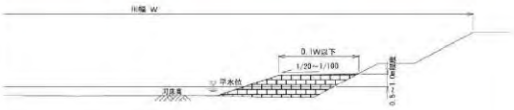


W: River Width=350m

I: Length of Groin (1<w/10)=350/10≦35m Selection 14m

L: Interval of Groin L=(1.5～2.0) ×I=20 ×2=40m

Set of Groin height



Groin height=
River depth 2.0m (field survey)+0.5m=2.5m

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Set of Groin weight

$$Dm = \frac{V0^2}{E1^2 \times 2g\left[\frac{\rho s}{\rho w}-1\right]}$$

Dm: diameter of stone
V_0: Average velocity=4.62m/s
G: Acceleration of gravity=9.8m/s
Pw: Density of water
ρs/ρw=2.65
E1=Factor of Strength turbulence=1.20

Source: Dynamically Design Method on Revetment, 2007, Japan

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Set of Groin diameter

$$Dm = \frac{V0^2}{E1^2 \times 2g\left[\frac{\rho s}{\rho w}-1\right]}$$

⇓

$$Dm = \frac{4.62^2}{1.2^2 \times 2 \times 9.8[2.65-1]}$$

$$Dm = 0.46m\ (Diameter)$$

$$Radius = 0.46/2 = 0.23m$$

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Set of Groin weight

$$W = \frac{4}{3} \times \pi \times r^3 \times \frac{\rho s}{\rho w}\ (Globe\ formula)$$
$$= 4/3 \times 3.14 \times 0.23^3 \times 2.65$$
$$= 134.9kg$$

i.e. Adoption Weight=200kg

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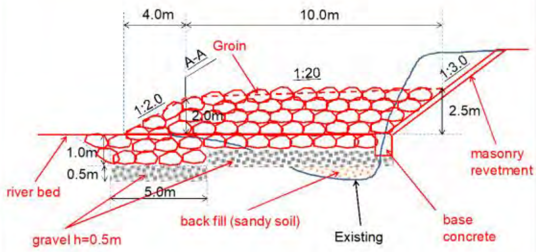
Standard cross section for reference



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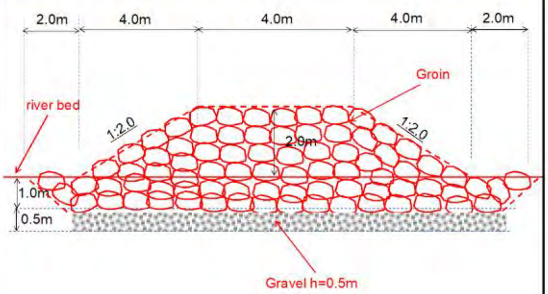
Front view for reference（A-A）



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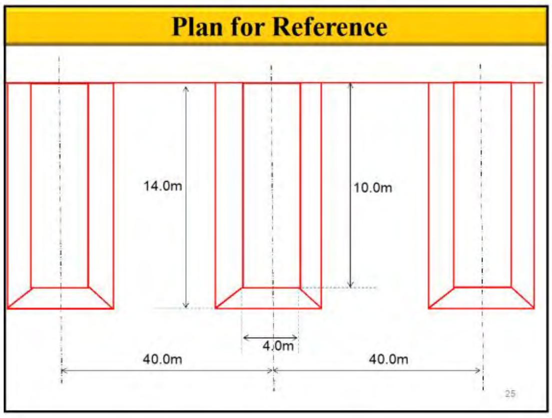
Plan for Reference
14.0m
10.0m
4.0m
40.0m
40.0m
25


水制 No.25


Plan for reference
14m
14m
40m
40m
40m
40m
40m
40m
40m
40m
Excavation
Excavation
Google Earth
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B.5 Bridge substructure protection

República Democrática de Timor-Leste

Ministério de Desenvolvimento e de Reforma Institucional

Ministério Geral das Obras Públicas

Direcção Nacional de Estradas, Pontes e Controlo de Cheias

DRAFT

Bridge Substructure Protection Guidelines

Diretrizes de Proteção da Subestrutura de Ponte

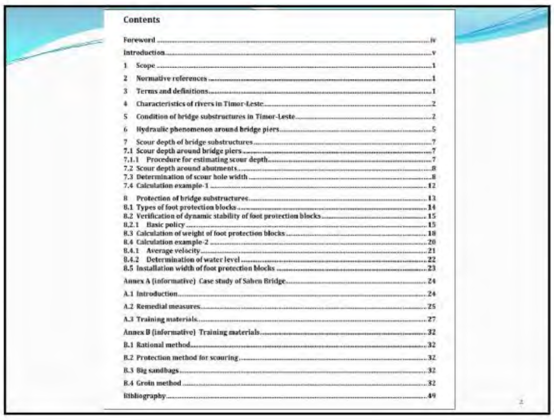
WD stage

Warning

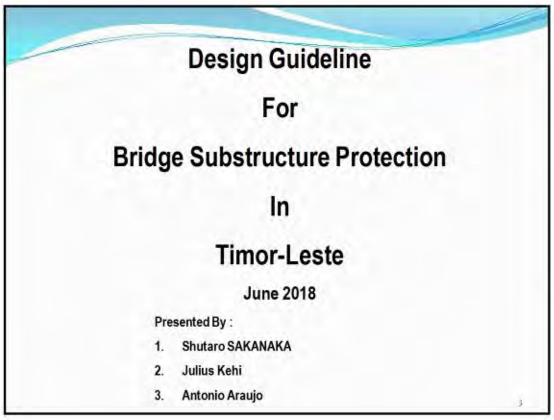
This document is not a Timor-Leste Standard. It is distributed for review and comment. It is subject to change without notice and may not be referred to as a National Standard.

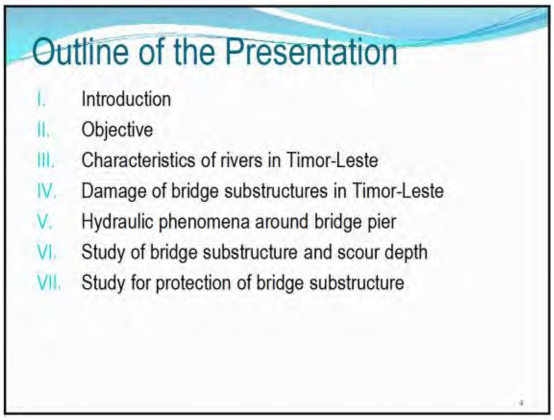
Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

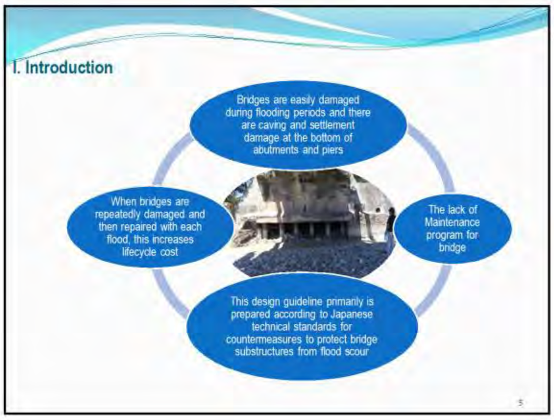
Document type: Technical Specification
Document subtype:
Document stage: (WD) Working Draft

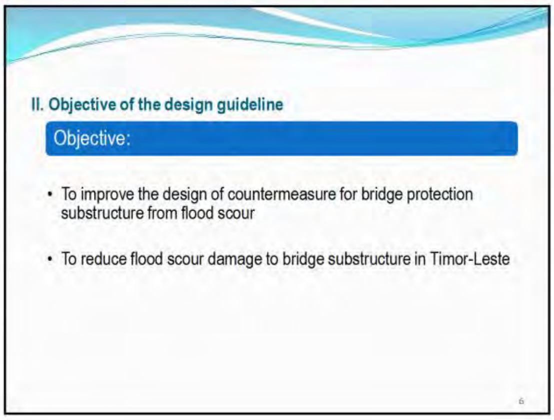


Contents









III. Characteristics of majority of Rivers in Timor-Leste

- Sources of many rivers in Timor-Leste are located in the mountainous area, at an altitude of 1000m to 2000m
- The average annual rainfall in the northern region of Timor-Leste is approximately 1000mm to 2000mm and in the southern region it is 1500 mm to 2000 mm
- The length of their rivers is short and share many natural characteristics with rivers in Japan

IV. Condition of Bridges Substructure in Timor Leste

- The following figures show the scouring damage of Sahen Bridges right bank abutment and pier.

Figure 1. Sahen bridge abutment 2017

Figure 2. Sahen bridge pier 2017

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- Figures 3 and 4 show the scouring damage of Mola Bridges Pier. Due to scouring damage, the caving of the footing can be seen

Figure 3. Mola bridge abutment 2011

Figure 4. Mola bridge abutment 2011

8

- If appropriate countermeasure are not applied out and scouring is allowed to progress into the long term, overall bridge settlement damage (as can see in figure 5,6) is likely to occur

Figure. 5 Bridge settlement damage due to bridge pier scouring (Japan Example)

Figure. 6 Bridge settlement damange due to bridge pier scouring (Japan Example)

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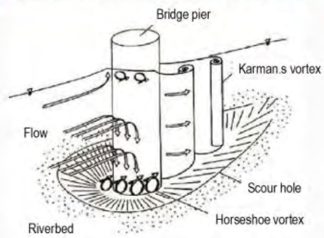
V. Hydraulic Phenomena Around Bridge Pier



- The figure shows the hydraulic phenomenon that occurs around bridge piers during flood.
- Bridge piers located in a river cause complex vortices and waves that disturb the flow and water surface during flood; as a result, an increase in water level and riverbed scouring occur

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Hydraulic Phenomenal around bridge pier (Japan Example)

The figure show the actual phenomenon around a bridge pier during floods.the occurrences of complex flow around the bridges pier apparent.

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The figure show the state of scour on bridge pier after a flood in Japan.The flood caused a scour hole to form around the bridge pier

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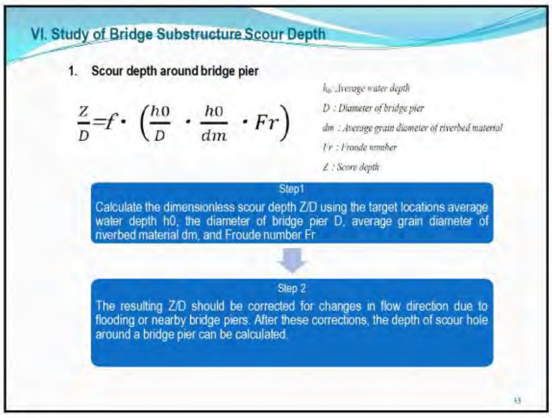
VI. Study of Bridge Substructure Scour Depth
1. Scour depth around bridge pier
$\frac{Z}{D} = f \cdot \left(\frac{h0}{D} \cdot \frac{h0}{dm} \cdot Fr\right)$
h_0 : Average water depth
D : Diameter of bridge pier
dm : Average grain diameter of riverbed material
Fr : Froude number
Z : Score depth
Step1
Calculate the dimensionless scour depth Z/D using the target locations average water depth h0, the diameter of bridge pier D, average grain diameter of riverbed material dm, and Froude number Fr
Step 2
The resulting Z/D should be corrected for changes in flow direction due to flooding or nearby bridge piers. After these corrections, the depth of scour hole around a bridge pier can be calculated.
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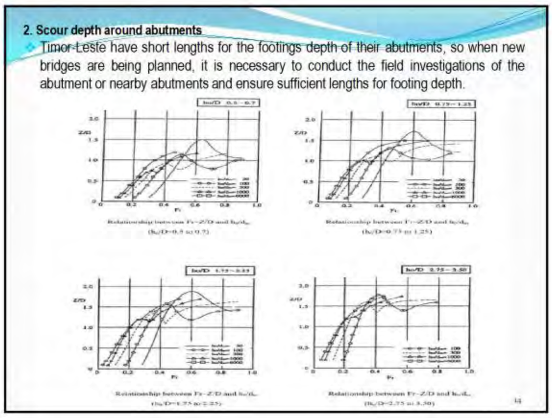
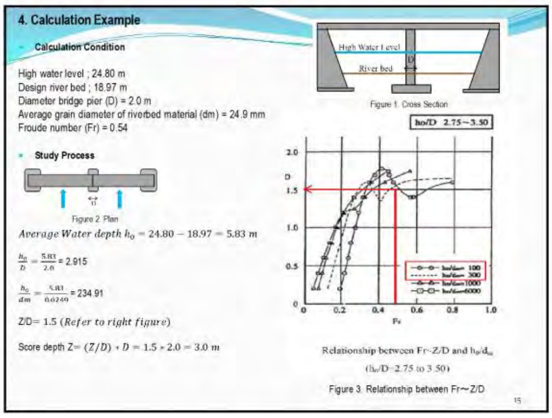
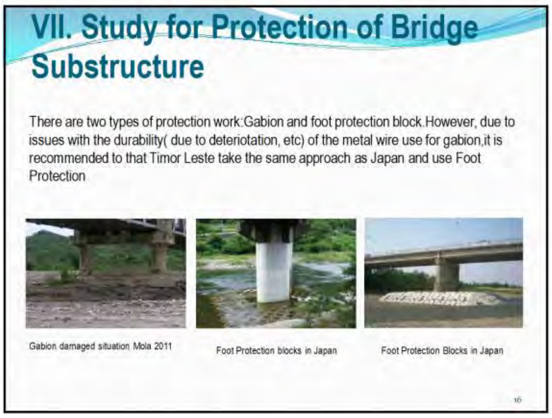

2. Scour depth around abutments
Timor-Leste have short lengths for the footings depth of their abutments, so when new bridges are being planned, it is necessary to conduct the field investigations of the abutment or nearby abutments and ensure sufficient lengths for footing depth.
14


4. Calculation Example
Calculation Condition
High water level ; 24.80 m
Design river bed ; 18.97 m
Diameter bridge pier (D) = 2.0 m
Average grain diameter of riverbed material (dm) = 24.9 mm
Froude number (Fr) = 0.54
Study Process
Figure 2 Plan
$Average\ Water\ depth\ h_o = 24.80 - 18.97 = 5.83\ m$
$\frac{h_o}{D} = \frac{5.83}{2.0} = 2.915$
$\frac{h_o}{dm} = \frac{5.83}{0.0249} = 234.91$
Z/D= 1.5 (Refer to right figure)
Score depth Z= $(Z/D) \cdot D = 1.5 \cdot 2.0 = 3.0\ m$
High Water Level
River bed
Figure 1. Cross Section
ho/D 2.75~3.50
Relationship between Fr-Z/D and h_o/d_m
(h_o/D 2.75 to 3.50)
Figure 3. Relationship between Fr~Z/D
15


VII. Study for Protection of Bridge Substructure
There are two types of protection work:Gabion and foot protection block.However, due to issues with the durability(due to deteriotation, etc) of the metal wire use for gabion,it is recommended to that Timor Leste take the same approach as Japan and use Foot Protection
Gabion damaged situation Mola 2011
Foot Protection blocks in Japan
Foot Protection Blocks in Japan
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Types of foot protection block
Types of foot protection blocks in Japan
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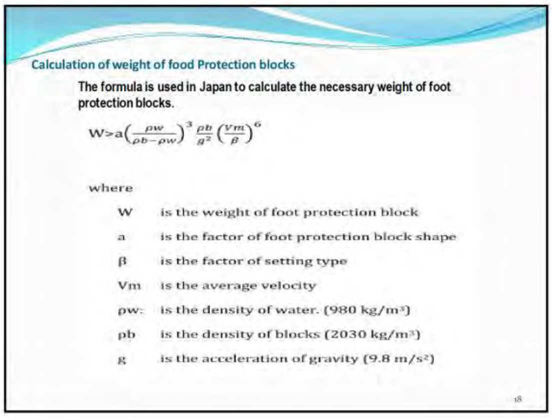
Calculation of weight of food Protection blocks
The formula is used in Japan to calculate the necessary weight of foot protection blocks.
$W > a\left(\frac{\rho w}{\rho b - \rho w}\right)^3 \frac{\rho b}{g^2} \left(\frac{Vm}{\beta}\right)^6$
where
W is the weight of foot protection block
a is the factor of foot protection block shape
β is the factor of setting type
Vm is the average velocity
ρw: is the density of water. (980 kg/m³)
ρb is the density of blocks (2030 kg/m³)
g is the acceleration of gravity (9.8 m/s²)
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Table Factor of α and β

Shape of block	specific gravity ρb/ρw	a×10⁻³	β
Type A: Projection	2.22	1.2	1.5
Type B: Plane	2.03	0.54	2.0
Type C: Triangular conic	2.35	0.83	1.4
Type D: Triangular bearing	2.25	0.45	2.3
Type E: Rectangle	2.09	0.79	2.8

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Calculation Example for weight of foot Protection Block

- Calculation Condition

$W > a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \frac{\rho b}{g^2}\left(\frac{Vm}{\beta}\right)^6$

Here

W		is the weight of foot protection block
Vm	5.1m/s	is the river velocity;
Shape	Type B	is the block type;
α	0.54	is the block factor;
β	2.0	is the block factor;
ρw	980kg/m³	is the density of water
ρb	2030kg/m³	is the density of block
g	9.8m/s²	is the acceleration of gravity

- Now W can be calculated as follows

$$W > a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \frac{\rho b}{g^2}\left(\frac{Vm}{\beta}\right)^6$$

$$W = 0.54 \times \left(\frac{1000}{2030-1000}\right)^3 \times \frac{2030}{9.8^2} \times \left(\frac{5.1}{2}\right)^6$$

$$W = 2872\ N$$

$$W = 293\ kg$$

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Average Velocity

The flow velocity used I the calculation of foot protection block weight is calculated using the manning formula for calculating the average velocity. The roughness coefficient is selected from the table below based on the conditions at the target river site.

River or channel conditions		Scope of Manning's n
Artificial channel, improved river	Concrete artificial channel	0.014～0.020
	Spiral half-pipe channel	0.021～0.030
	Channel with stone masonry on both banks (mud bed)	0.025 (mean value)
	Bedrock excavation	0.035～0.05
	Bedrock forming	0.025～0.04
	Clay riverbed with flow velocity not enough to cause scouring	0.016～0.022
	Sandy loam, clayey soil loam	0.020 (mean value)
	Drag line dredging, little weeds	0.025～0.033
Natural river	Small channel on plain, with no grass	0.025～0.033
	Small channel on plain, with grass and shrubs	0.030～0.040
	Small channel on plain, with lots of grass and gravel bed	0.040～0.055
	Mountain channel, with gravel and boulders	0.030～0.050
	Mountain channel, with boulders and large boulders	0.040 or higher
	Large channel, with sandy bed and little meandering	0.018～0.035
	Large channel, with gravel bed	0.025～0.040

Table. Revised Ministry of Construction River and Erosion Control standard (draft) Japan 1997,Survey Section P132

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Step 1

Set up of river flow velocity

How to set up velocity of Loes river

↓

Manning formula

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Manning's formula

$V = \frac{1}{n} \times R^{\frac{2}{3}} \times I^{1/2}$

V: Flow velocity (m/s)
n: Coefficient of roughness
R: Hydraulic radius (m) = Cross-sectional area of river/Wetted perimeter
I: Riverbed gradient

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N: Coefficient of roughness

River or channel conditions		Scope of Manning's n
Artificial channel, improved river	Concrete artificial channel	0.014～0.020
	Spiral half-pipe channel	0.021～0.030
	Channel with stone masonry on both banks (mud bed)	0.025 (mean value)
	Bedrock excavation	0.035～0.05
	Bedrock forming	0.025～0.04
	Clay riverbed with flow velocity not enough to cause scouring	0.016～0.022
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	Large channel, with sandy bed and little meandering	0.018～0.035
	Large channel, with gravel bed	0.025～0.040

Source: Revised Ministry of Construction River and Erosion Control Standard (draft) 1997

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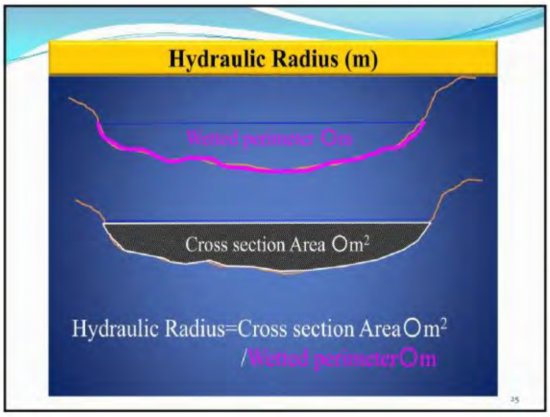
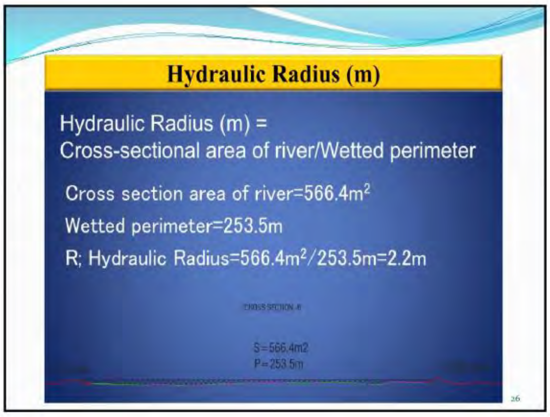
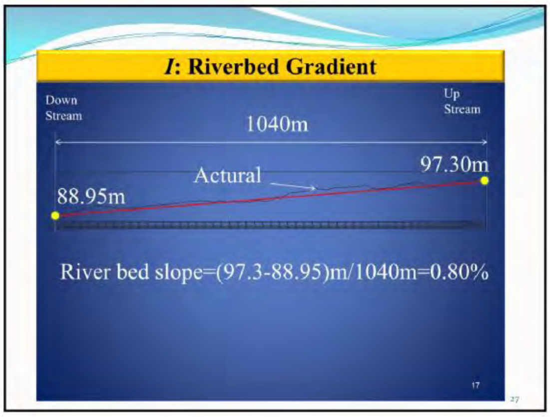
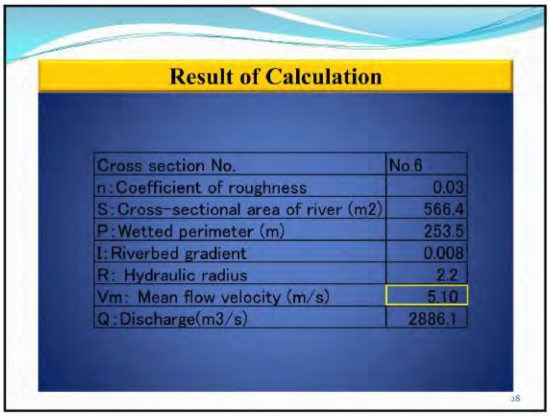

Hydraulic Radius (m)
Wetted perimeter Om
Cross section Area Om2
Hydraulic Radius=Cross section AreaOm2
/Wetted perimeterOm


Hydraulic Radius (m)
Hydraulic Radius (m) =
Cross-sectional area of river/Wetted perimeter
Cross section area of river=566.4m2
Wetted perimeter=253.5m
R; Hydraulic Radius=566.4m2/253.5m=2.2m
S=566.4m2
P=253.5m


I: Riverbed Gradient
Down Stream
Up Stream
1040m
Actural
97.30m
88.95m
River bed slope=(97.3-88.95)m/1040m=0.80%


Result of Calculation
Cross section No. No.6
n:Coefficient of roughness 0.03
S:Cross-sectional area of river (m2) 566.4
P:Wetted perimeter (m) 253.5
I:Riverbed gradient 0.008
R: Hydraulic radius 2.2
Vm: Mean flow velocity (m/s) 5.10
Q:Discharge(m3/s) 2886.1


OBRIGADO
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[1] Dynamically design method on revetment, 2007, Japan Institute of Country and Engineering

[2] Guidelines for river bridge plan (draft), 2009, Japan Institute of Construction Engineering.

República Democrática de Timor-Leste

Ministério das Obras Públicas

Direcção Geral das Obras Públicas

Direcção Nacional de Estradas, Pontes e Controlo de Cheias

Matadalan Substrutura Ponte

Bridge Substructure Protection Guidelines

Faze EFM

Atensaun

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Tipu Dokumentu: Spesifikasaun Teknikaocument
Subtipu Dokumentu:
Faze Dokumentu: (EFM) Esbosu Final Matadalan
Dokumentus ho lingua: TDT

Ministério das Obras Públicas
Direcção Geral das Obras Públicas
Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
Enderesu: Avenida da Restauração, Rai Kotu, Comoro, Dili, Timor-Leste
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Konteudu

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REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTÉRIO DAS OBRAS PÚBLICAS
GABINETE DO VICE-MINISTRO
Av. Nicolau Lobato, Mandarin, Dili, Timor Leste

Prefasiu

Iha interese ba harii ho qualidade as no ekonomikamente viabiliza infrastrutura hodi servi nasaun, matadalan ida ne'e atu optimija dezeñu garante substrutura ponte nebe prepara ona husi JICA Projeito Desenvolvimento Kapasidade ba Servisu Estrada iha República Democrática de Timor-Leste (CDRS) nebe iha kolaborasaun ho Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC), Ministério das Obras Públicas. Ami hakarak hato'o agradese ba JICA ba kontinua suporta.

Setembru, 2019

Eng. Nicolau Lino Freitas Belo
Vice-Ministro das Obras Públicas
Ministério das Obras Públicas

Prefasiu husi JICA

Japan International Cooperation Agency (JICA) halao ona projetu kooperasaun téknika ida ba desenvolvimento kapasidade kona ba servisu estrada, nebe'e hanaran CDRS, nune atu fasilita DNEPCC jere no halo manutensaun ba infra-estrutura estrada bazea ba actividade soscial no ekonomiku. Ba ida-ne'e nia rohan, JICA despasa ona ekipa espesialista sira husi fulan-Marsu tinan 2016 to'o fulan Dezembru tinan 2019. Hanesan resultadu husi kolaborasaun servisu husi parseira DNEPCC, matadalan ba substrutura ponte finalisa ona. Ha'u espera katak matadalan ida-ne'e sei kontribui ba dezenvolvimentu infra-estrutura no manutensaun, no valorizasaun relasaun belun di'ak entre nasaun rua.

Ikus liu, ha'u hakarak hato'o ha'u-nia apresiasaun sinceriamente ba funcionariu governu República Democrática de Timor-Leste nia ho equipa peritu.

Setembru, 2019

Masafumi NAGAISHI
Representante Chefe Gabinete JICA iha Timor-Leste
Japan International Cooperation Agency

Agradesimentu

Projetu ba Desenvolvimentu Kapasidade Servisu Estrada iha República Democrática de Timor-Leste (CDRS) hakarak atu fó-agradese ba parte hotu-hotu ne'ebé envolve an hodi prepara no revisaun matadalan substrutura ponte.

Apoia projetu ne'e, ofisial husi (eis) Ministério de Desenvolvimento e de Reforma Institucional: M. R. M. Cruz, J. L. C. C. P. Mestre and J. Santos; no ofisial husi Ministerio Obras Publiku: C. M. Henrique no especialmente ba R. H. F. Guterres; hodi rekonese.

Durante halo preparasaun ba dokumentus ida ne'e hetan kontribuisaun husi ofisial DNEPCC: M. R. C. Monteiro, J. P. Amaral, J. M. G. Sousa, J. G. Carlvalho, I. M. L. Gutteres, N. Lobato, L. R. H. Corbafo, A. Araujo, J. L. Kehy, C. C. Monteiro; no Organizasaun Internasional Trabalho ou International Labour Organization's (ILO) nudar ekipa asistente teknika ba apoiu programa Desenvolvimento Estrada (R4D-SP): A. O. Asare, K. H. Myaing, S. Done; hodi rekonese.

Komentariu:

Sei apresia tebes ba komentariu nebe positivu ba posibilidade inkorporasaun ba edisaun tuir mai. Favor fo komentario no sugestaun ba iha enderusu tuir mai ne'e.

Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
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Introdusaun

Substrutura ba ponte mota nian iha Timor-Leste barak mak la iha protesaun ba scour. Ne'ebe mak rezulta, ponte barak hetan estraga ho lalais durante mota bo'ot/inundasaun no halo koak bo'ot iha abutment no pilar nian okos.

Karik kontramedida ne'ebe apropriadu la aplika ba ponte sira ne'e, sei iha risku estraga ne'ebe ho skala bo'ot hanesan ponte sei hetan penurunan ka kolapsu.

Husi aspetu operasaun no manutensaun, hadia fila fali substrutura sei la suficiente.

Hanesan rezultadu, substrutura ne'ebe hetan estraga fila-fila husi inundasaun ne'ebe bebeik no sai nivel ne'ebe presiza re konstrusaun total.

Responde ba situasaun ida ne'e, dezenu matadalan ida ne'e deskreve dezenu ne'ebe mak presiza kontramedida ba protesaun substrutura husi inundasaun scour, bazea ba enjineirru nia konnesementu.

Dezenu matadalan ida ne'e prinsipalmente elabora tuir padraun teknika japaun nian ba kontramedida protesaun substrutura ponte nian husi inundasaun scour.

Simulasaun limpasan ne'ebe sofistikadu ka material ne'ebe karun ba kontramedida sira ne'e,hanesan sheet pile ka steel pipe piles,sire ne'ebe esklui iha matadalan relasiona ho difikuldade ba implementasaun husi kontraktor lokal sira hare ba iha nia kustu no nivel tekniku husi maundeobra restrisaun.

Espera katak matadalan ida ne'e bele ajuda ba kontramedida inundasaun no ajuda redus estragus husi inundasaun scour ba subtrutura ponte iha Timor-Leste.

Matadalan Substrutura Ponte

1 Ambitu

This document specifies minimum requirements and design methods for bridge substructure protection in Timor-Leste.

2 Referensia normativu

There are no normative references in this document.

3 Termu no definisaun

Ba objektivu dokumentu ida ne'e, aplika termu no definisaun tuir mai ne'e.

ISO mantein terminalojia baze dadus ba benifisiariu sira atu uja padraun iha enderesu tuir mai ne'e:

— Plataforma navigasaun online ISO: iha https://www.iso.org/obp

3.1
Scour
Foti sai rai henek iha be okos no material fatuk sira iha mota liu husi fluxo, especialmente iha baze no strutura nia ain okos

[FONTES: ISO 21650:2007, 2.60]

3.2
Protesaun ba Scour
Material ne'ebe atu tau iha riverbed atu prevene scour husi

[FONTES: ISO 29400:2015(en), 3.124]

3.3
Penurunan
Movimento descendente permanente strutura ida tamba nia todan no asaun sira seluk

[FONTES: ISO 19901-8:2014(en), 3.34]

Figura 1 — Mapa mota iha Timor-Leste

4 Karakteristika mota iha Timor-Leste

Mota iha Timor nia origem mak foho ho altitude 1000 m to'o 2000 m; sira sulin ho lalais husi foho lolon liu ba altitude neebe tetuk no sulin ba to'o tasi. Media udan ben anual iha regiaun norte mak aproksimamente entre 1000 mm to'o 2000 mm no iha regiaun sul nian wnre 1500 mm to'o 2000 mm. Atu hanesan ho mota iha Japaun, mota sira ne'e iha karakteristika ne'ebe bele kausa inundasaun ho lalais.

Timor-Leste hanesan pais insular, ho mota ne'ebe ladun naruk no ninia karakteristika natural atu hanesan ho Japaun, permite padraun Japaun ne'ebe estabele tiha ona iha Japaun atu aplika iha Timor-Leste.

5 Kondisaun substrutura ponte nian iha Timor-Leste

Figura tuir mai ne'e hatudu estragas husi scouring ponte sahen iha prte liman los ba abutmen no pilar. Relasiona ho estraga husi scouring,pilar abutmen nian no caving fondasi bele hare ho mos los iha pilar ponte.

Figura 4 no Figura 5 hatudu estragu husi scouring pilar Ponte Mola. Tanba estragu husi scouring, caving iha fondasi bele hare ho mos.

Se kontramedida ne'ebe apropriadu la aplika no scouring sei nafatin durante tempu naruk, mak ponte sei hetan penurunan tomak (bele hare iha Figura 6,7).

Figura 2 — Abutmen Ponte Sahen 2017

Figura 3 — Pilar Ponte Sahen 2017

Figura 4 — Pilar Ponte Mola 2011

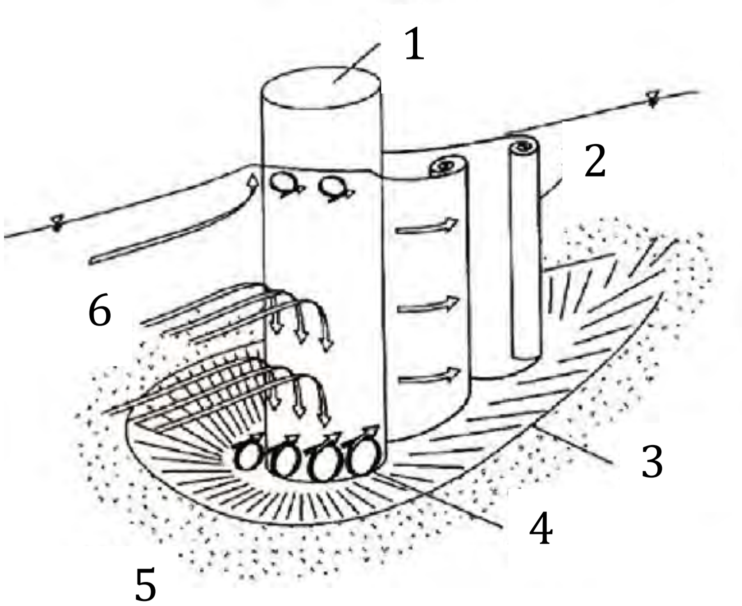
Figura 5 — Pilar Ponte Mola 2011

Figura 6 — Penurunan ponte tamba pilar ponte ne'ebe hetan scouring (Ezemplu iha Japaun)

Figura 7 — Penurunan ponte tamba pilar ponte ne'ebe hetan scouring (Ezemplu iha Japaun)

6 Fenomena hidrauliku iha pilar ponte

Figura 8 hatudu fenomena hidrauliku ne'ebe mosu iha pilar ponte durante inundasaun. Pilar ponte nian lokaliza iha mota ne'ebe kauza complex votices no laloran ne'ebe perturba fluxo no superficie be nian durante inundasaun; rezulta, nivel be nian nebe sae no scouring iha riverbed.



Chavi
1 pilar ponte
2 vórtice Karman
3 scour nia koak
4 vórtice horseshoe
5 mota laran
6 fluxo

Figura 8 – Fenomena hidrauliku iha pilar ponte

Figura 9 Hatudu fenomena atual iha pilar ponte nian durante inundasaun. Akontensimentu ba fluxo ne'ebe kompleksu iha pilar ponte nebe mak aparente.

Figura 9 — Fenomena hidrauliku iha pilar ponte (Ezemplu iha Japaun)

Figura sira tuir mai ne'e (Figura 10 no Figura 11) hatudu situasaun scour iha pilar pote depois de inundasaun iha Japaun. Kauza husi Inundasaun mak halo ona koak iha besik pilar ponte nian.

Figura 10 — Fenomena atual iha pilar (Ezemplu iha Japaun)

Figura 11 — Fenomena atual iha pilar (Ezemplu iha Japaun)

7 Profundidade scour nian iha substrutura ponte

7.1 Profundidade scour nian besik pilar ponte

Maske ida ne'e mak ideal liu atu uza rezultadu husi simulasaun limpasan no simulasaun modelu hidrauliku atu determina lokal profundidade besik substrutura ponte, relasiona ho nessesidade ba teknologia ne'ebe avansadu,esperensia, no fasilidade esperimental, metodu hirak ne'e sei la sempre posivel. Matadalan ida ne'e uza formulula estimativ, formula (1), ba profundidade scour, ne'ebe la ezije rekursu ne'ebe temi tiha ona no utiliza mos iha Japaun.

$$\frac{Z}{D} = f \cdot \left(\frac{h0}{D} \cdot \frac{h0}{dm} \cdot Fr \right) \qquad (1)$$

iha ne'ebe

h_0 mak mediu profundidade be;

D mak diametru pilar ponte nian;

dm mak mediu diametru grauns material mota laran nian;

Fr mak numeru Froude; $\frac{Vm}{\sqrt{gh0}}$

Vm mak mediu velosidade;

Z mak profundidade scour nian.

7.1.1 Prosedimentu ba estimasaun profundidade scour

Mediu be nia profundidade h_0 mak kalkulasaun liu husi metodu analiza hidrauliku ne'ebe utiliza kalkulasaun fluxo uniforme ka kalkulasaun naun-uniforme.

Etapa 1

Kalkulasaun dimensaun profundidade scour *Z/D* uza mediu profundidade be nian h_0 ne'ebe targetu tiha ona, pilar nian nia diamtru *D*, diameru mediu a aterial mot laran nian *dm*, no nmeru froude *Fr*, tuir figura 14.

Etapa 2

Rezuadu *Z/D* tenki korize atu bele muda diresaun fuxo nian relasiona ho inundasan ne'ebe besik iha pilr ponte. Depois de korize, profundidade kok ne'ebe besik pilar ponte bele kalkula.

7.2 Profundidade scour besik abutment

Profundidade scour iha besik abutmen laiha metodu kalkulasaun ne'ebe klaro, maske iha Japaun. Tan ne'e, rekomenda ba estimasaun no determina profundidade scour besik iha abutment bazea ba rezultadu investigasaun iha abutment no besik abutment.

Aleinde ne'e, ponte barak iha Timor-Leste mak iha fondasi pilar no abutment badak, tan ne'e wainhira planea atu halo ponte foun, nesesariu liu atu halo investigasaun hanesan mensiona tiha iha leten no asegura profundidade fondasi nian naruk ne'ebe sufisiente.

7.3 Deteminasaun largura Scour nia koak

Largura ba scour nia koak kalkula ho formula Japaun nian ho hatama profundidade masimu scour Z no mediu anglu iha be okos ne'ebe repousu θ no profundidade masimu husi Figura 12 ba iha formula (2):

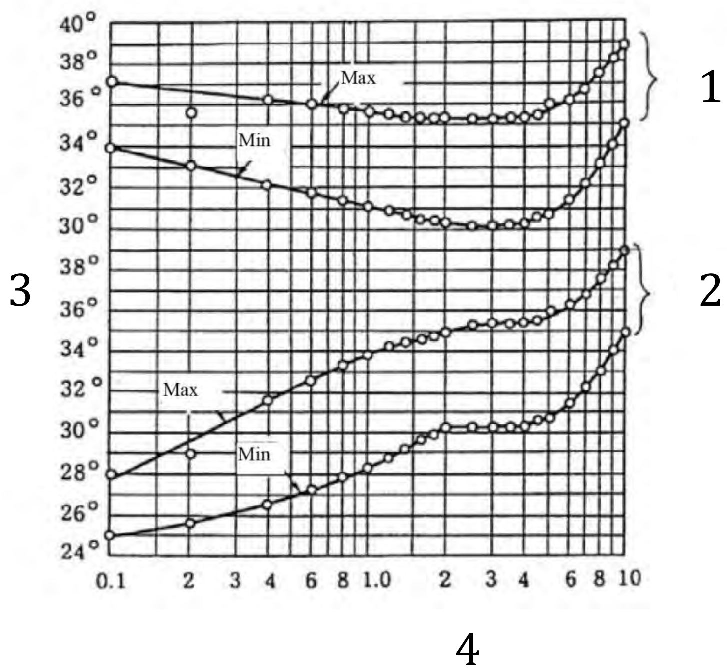
$$R = Z/\tan\theta \qquad (2)$$

iha ne'ebe

R mak largura koak scour nian;

Z mak pronfundidade masimu scour nian;

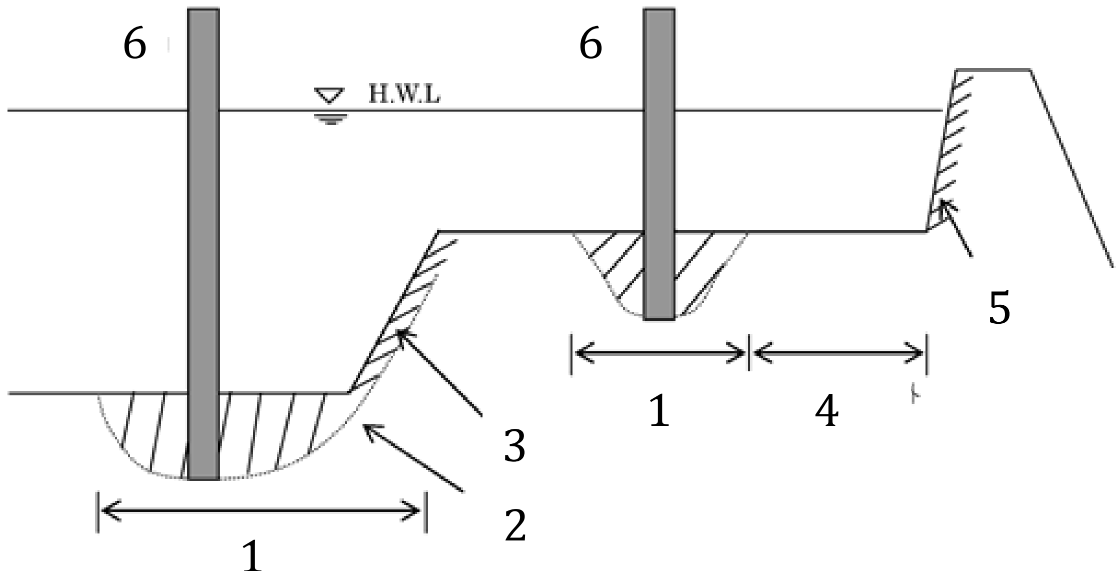
θ mak mediu angulo be okos ne'ebe repousa.



Chavi

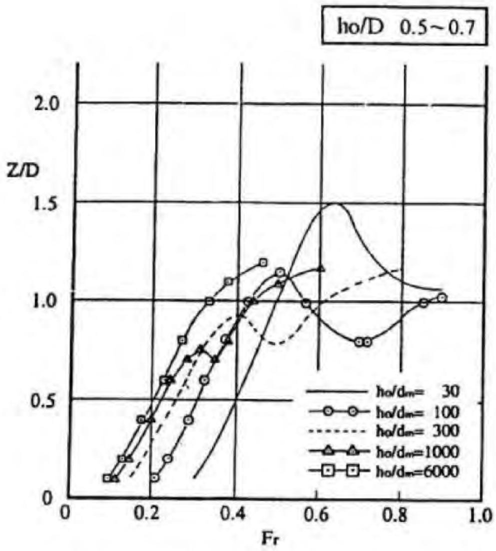
1 iha anin
2 iha be laran
3 ângulo de repouso θ
4 diametru material mota laran

Figura 12 — Relasaun entre Angulo repouza θ no media musan nia angulo



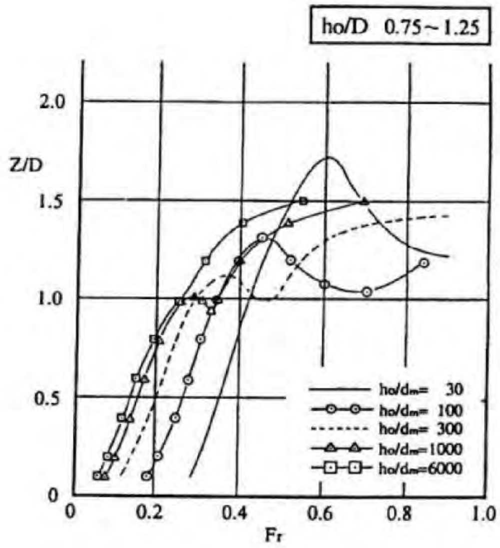
Chavi
1 largura koak scour
2 banco erosaun husi scouring
3 erosaun husi fluxo velosidade
4 sai husi area scour
5 banco erosaun husi scouring
6 pilar

Figura 13 — imagem husi scouring besik pilar



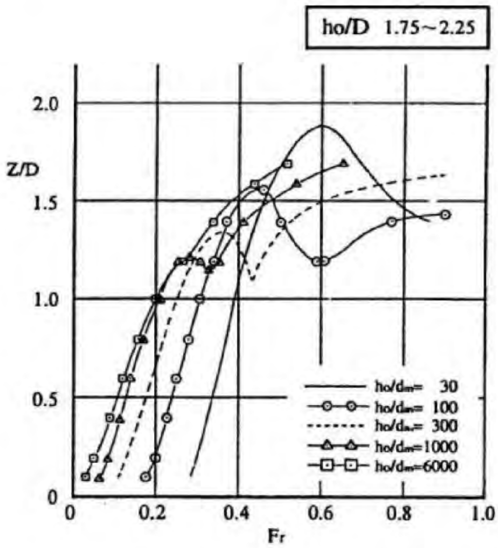
Relationship between Fr~Z/D and h_0/d_m

(h_0/D=0.5 to 0.7)



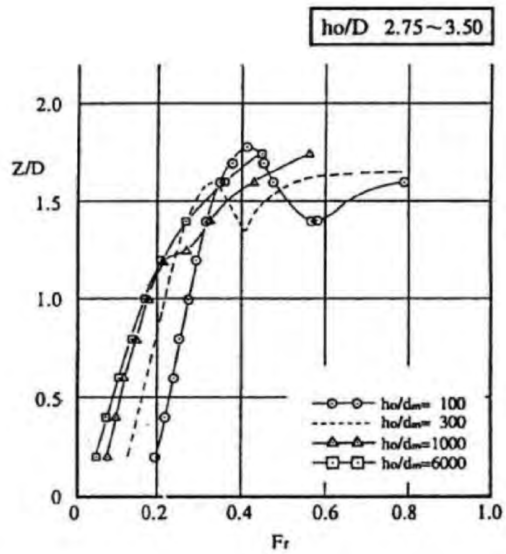
Relationship between Fr~Z/D and h_0/d_m

(h_0/D=0.75 to 1.25)



Relationship between Fr~Z/D and h_0/d_m

(h_0/D=1.75 to 2.25)



Relationship between Fr~Z/D and h_0/d_m

(h_0/D=2.75 to 3.50)

Figura 14 — Relasaun entre Fr~Z/D no h_0/dm

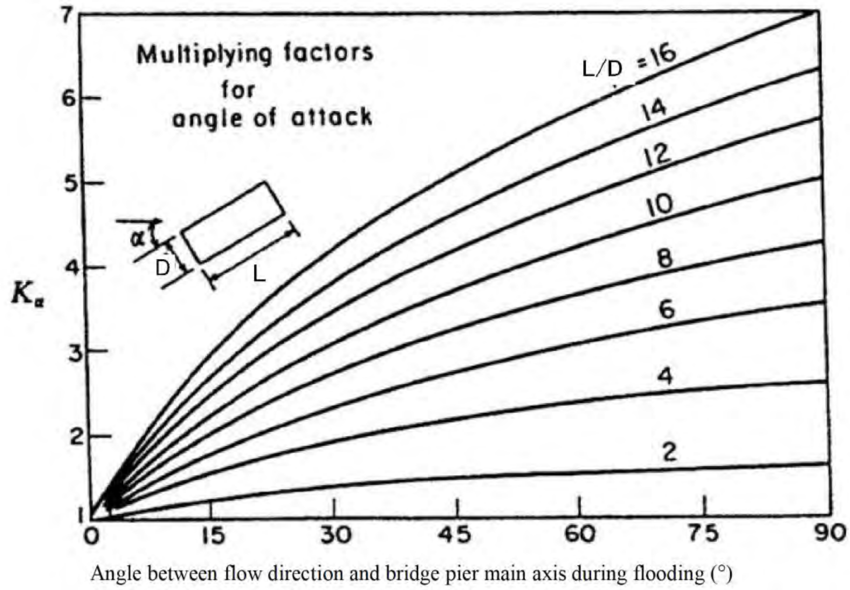


Figura 15 — Fatores koresaun Kα ba angulo ataka nian

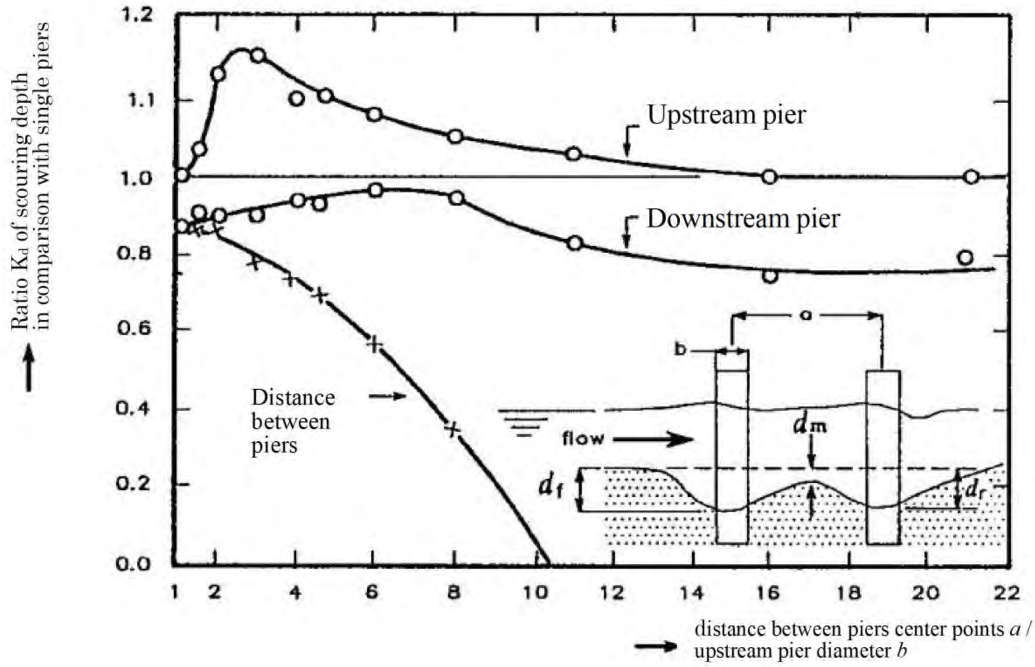


Figura 16 — Fatores koresaun Kd ba besik pilar

7.4 Ezemplu kalkulasaun 1

Ezemplu mak hatudu iha kraik ne'e.

※ Kondisaun kalkulasaun nian:

Uza Formula (1):

$$\frac{Z}{D}=f\cdot\left(\frac{h0}{D}\cdot\frac{h0}{dm}\cdot Fr\right)$$

iha ne'e

h_0	5.83m	mak mediu profundidade be;
D	2.0 m	mak diametru pilar ponte nian;
dm	24.9 mm	mak mediu idametru draun material mota laran;
Fr	0.54	mak numeru Froude;
Z		mak profundade scour.

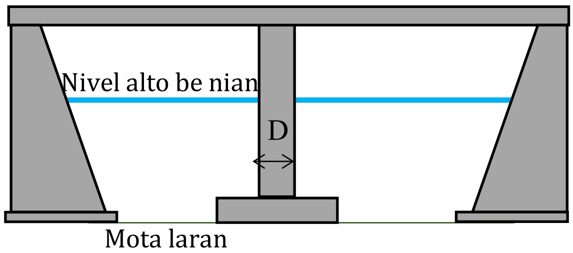


Figura 17 — Corte transversal

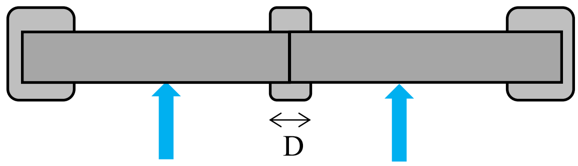


Figura 18 — Planu

Atu determina media profundidade be nian,tenki uza nivel altu husi be:

Be nian nivel altu: 24.80m

Dezenu mota laran: 18.97m

h_0, Media profundidade be: 24.80-18.97= **5.83 m**

Agora Z bele kalkula hanesan tuir mai ne'e:

h_0/D=5.83/2.0=2.915

h_0/dm=5.83/0.0249=234.1

Z/D=1.5 (hare iha Figura 19)

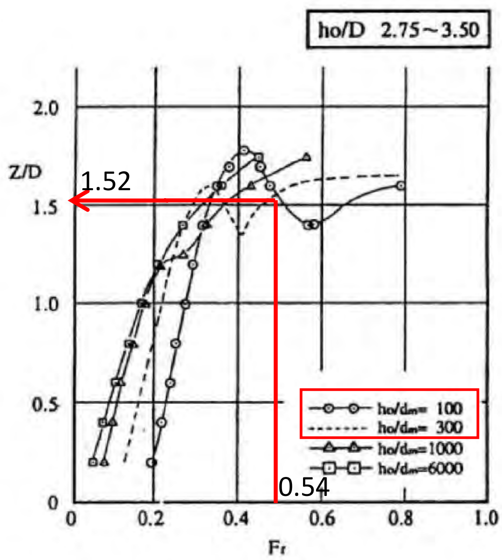
Pilar axis parrleru ho diresaun fluxo no iha neba laiha

ponte proximais ne'ebe besik ponte original.

Tanba ne'e, fator koresaun Kα= 1.0 no Kd = 1.0 adopta.

Profundidade scour, Z = (Z/D)・D・Kα・Kd

=1.52・2.0・1.0・1.0 = **3.0 m**



Relationship between Fr~Z/D and h_0/d_m

(h_0/D=2.75 to 3.50)

Figura 19 — Relasaun entre Fr∼Z/D

8 Protesaun ba ponte nian substrutura

Iha Timor-Leste, servisu protesaun hanesan kontramedida ba scouring la installa iha pilar no nia abutments, barak mak komfirma ona hetan estraga scouring. Tan ne'e mak rekomenda tebes atu implementa kontramedida ba scouring iha abutment no pilar.

Iha tipu 2 ba servisu protesaun nian: gabion no bloku protesaun. Maibe, tanba kestaun durabilidade (tanba detoriorasaun,etc.) husi arame besi sira ne'ebe uza ba gabion, tan nemak rekomenda ba Timor-Leste atu foti abordajen hanesan ho Japaun no uza bloku protesaun ba ponte nia pilar sira.

Figura 20 — Gabion ne'ebe hetan estraga iha Ponte Mola 2011

Figura 21 — Bloku protesaun ponte nia pilar iha Japaun

Figura 22 — Bloku protesaun ponte nia pilar iha Japaun

8.1 Typu bloku protesaun ba ponte nian pilar

Bloku protesaun ba ponte nia pilar babain uza ba protesaun substrutura ponte iha Japaun. (Hanesan hatete tiha ona, mota sira iha Timor-Leste iha karakteristika natural ne'ebe hanesan ho Japaun.) Tanba ne'e, esperencia atual barak no dadus husi eksperimentu modelu hidrauliku uza bloku protesaun. Valor karakteristiku husi bloku protesaun ponte nia pilar lahanesan ho sira nia modelu.

Tabela 1 — Tipu Protesaun ponte nia Pilar iha Japaun

8.2 Verifikasaun estabilidade dinamika bloku protesaun ponte nian pilar

8.2.1 Politika baziku

Servisu protesaun pilar presiza tebes todan ne'ebe adequada atu asegura stabilidade hasoru forsa hidrodinamika, largura no nia as husi estimasaun scouring.

1. Funsaun

Protesau iha pilar hamenus scouring iha mota. Diretamente expostu ba iha fluxo be nian. Tanba ne'e, nessesariu tebes ba servisu protesaun pilar atu bele stabil hasoru fluxo be nian. Ida ne'e bele verifika bazea ba fratura morfolozia husi modelu strutura ne'ebe hanesan hanesan mos ho protesaun ba rai halis.

2. Modelu estragu

Wainhira profundidade husi fondasi ne'ebe hakoi ba mak razu (dangkal) no servisu protesaun ba pilar la iha largura n'ebe mak sufisiente, fluxo ne'ebe aumenta durante inundasaun sei rezulta iha estragu ba servisu protesaun rai halis. Aleinde ne'e, se servisu protesaun ba pilar mak ladun todan demais ba fluxo velosidade, ida ne'e sei halo bele lori hotu no bele mos halo estraga iha ba revetimentu tomak. Tanba ne'emak importante tebes atu kontrollu largura husi servisu protesaun ba pilar, modelu strutura ne'ebe hanesanho servisu protesaun ba rai halis bele uza ba estuda ninia stailidade dinamika.

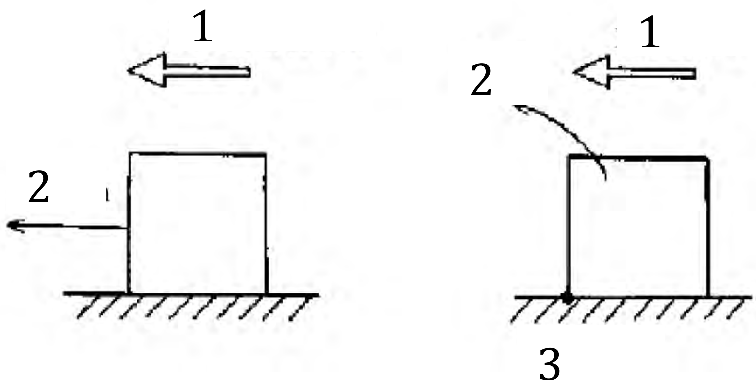
Hanesan mos ho servisu protesaun rai halis, modelu estragus (rolling, sliding and traction) ba servisu protesaun ne'ebe mak bazea ba modelu no ninia aranjamentu ba razaun ida ne'e, ninia modelu no aranjamentu mos bazea ba verifikasaun.

(1) Sliding

Wainhira forsa hidrodinamika halo komponente mak diak liu friksaun iha sikun kraik, bele halo sliding. Ida ne'e tenki tau ba konsiderasaun ba parte servisu protesaun pilar ponte nian iha mota ulun, prezemplu, modelu ne'ebe failla bele hare iha parte husi seksaun ne'ebe dok husi mota ulun ne'ebe ninia tipu hada kada layer no tipu hada ne'ebe acak ba servisu protesaun pilar.

(2) Rolling

Ida ne'e bainhira forsa hidrodinamika hamosu komponente ida hadulas iha pivot point no roll. Modelu estragu ne'e bele hare, por ezemplu, iha parte balun dok husi mota ulun nian.



Chavi

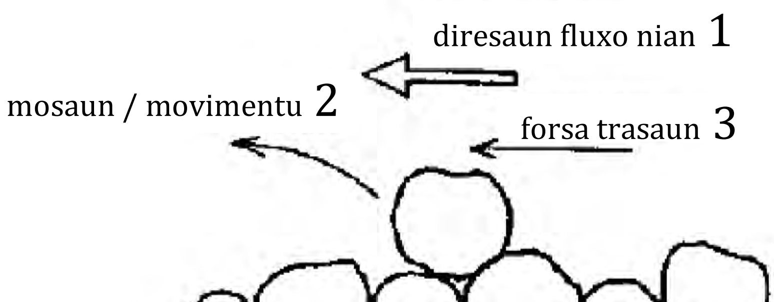
1 fluxo nian diresaun
2 mosaun
3 pontu pivot

Figura 23 — Deslizamentu no rolamentu

(3) Trasaun

Komponentes sira simu forsa hasae no dada diretamente husi fluxo no laos bebeik rollu ka esperensia saltasi besik iha mota laran. Modelu ida ne'e uza ba servisu protesaun pilar nia ain ho elementus ne'ebe hatoba deit, hanesan fatuk naural ka kaber, bloku konktretu babain ne'ebe forma ho rapidamente.

Por ezempluida ne'e bele hare husi estragu ne'ebe hetan husi servisu protesaun ne'ebe utiliza riprap no gabion.



Chavi

1 diresaun fluxo nian
2 mosaun / movimentu
3 forsa trasaun

Figura 24 — Trasaun

3. Tipu installasaun

(1) Nivel empillamentu

Material sira ne'e hada ho modelu ne'ebe baibain. Por ezemplu: bloku ne'ebe hada uniforme.

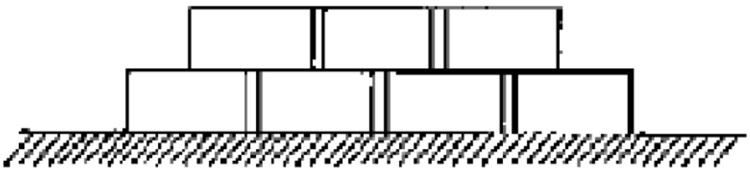


Figura 25 — Layered stacking

(2) Empillamentu acak

Material sira hada ho modelu naun-uniforme. Por ezemplu: hada bloku, servisu protesaun ho rip rap.

Figura 26 — Hada ho acak

(3) Gabion

Raga ne'e ense nakonu ho fatuk no material sira seluk. Ida ne'e refere ba iha servisu protesaun pilar ho gabion.

Figura 27 — Gabion

(4) Preense

Enkuadramentu ho preense ho fatuk ka material sira seluk. Ezemplu, matras fagot no matras ai.

Figura 28 — Preense

8.3 Kalkulasaun ba todan bloku protesaun pilar sira

Formula tuir mai ne'e, formula (3), ne'ebe uza iha Japaunho kalkulasaun ho todan bloku protesaun pilar ne'ebe nessesario liu:

$$W>a\left(\frac{\rho w}{\rho b-\rho w}\right)^{3}\frac{\rho b}{g^{2}}\left(\frac{Vm}{\beta}\right)^{6}\left(\frac{\rho w}{\rho b-\rho w}\right)^{3}\cdot\frac{\rho b}{g^{2}}\cdot\left(\frac{Vm}{\beta}\right)^{6} \qquad (3)$$

iha ne'ebe

- W mak todan bloku protesaun ba pilar
- a mak fator ba Modelu bloku protesaun pilar
- β mak fator ne'ebe define tipu
- Vm mak media velocidade
- ρw: mak densidade be nian (980 kg/m^3)
- ρb mak densidade bloku nian (2030 kg/m^3)
- g mak asselerasaun gravidade nian (9.8 m/s^2)

Tabela 2 — Fatores ba α no β

Bloku nian Modelu	Spesifiku gravidade ρb/ρw	$a \times 10^{-3}$	β
Tipu A: Projection	2.22	1.2	1.5
Tipu B: Plane	2.03	0.54	2.0
Tipu C: Triangular conic	2.35	0.83	1.4
Tipu D: Triangular bearing	2.25	0.45	2.3
Tipu E: Rectangle	2.09	0.79	2.8

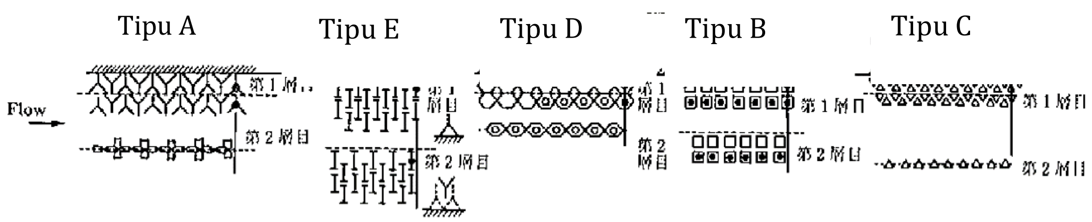


Figura 29 — Tipu arranju bloku

8.4 Ezemplu kalkulasaun 2

Ezemplu mak hatudu hanesan tuir mai ne'e.

※ Kondisaun kalkulasaun:

Uza Formula (1):

$$W>a\left(\frac{\rho w}{\rho b-\rho w}\right)^3\frac{\rho b}{g^2}\left(\frac{Vm}{\beta}\right)^6\left(\frac{\rho w}{\rho b-\rho w}\right)^3\cdot\frac{\rho b}{g^2}\cdot\left(\frac{Vm}{\beta}\right)^6$$

iha ne'ebe

W		mak todan husi bloku protesaun pilar;
Vm	5.1m/s	mak velosidade mota;
Modelu/Bentuk	Tipu B	mak tipu bloku;
α	0.54	mak fator bloku;
β	2.0	mak fator bloku;
ρw	$980kg/m^3$	mak densidade be;
ρb	$2030kg/m^3$	mak densidade bloku;
g	$9.8m/s^2$	mak akselarasaun gravidade.

Agora W bele kalkula hanesan tuir mai ne'e:

$$W>0.54\times\left(\frac{1000}{2030-1000}\right)^3\times\frac{2030}{9.8^2}\times\left(\frac{5.1}{2.0}\right)^6$$

W>2872N

W>293kg

8.4.1 Mediu velosidade

Velocidade fluxo nian ne'ebe uja ba kalkulasaun protesaun pilar nia todan ne'e kalkula uza formula Manning ba kalkulasaun media velocidade. Koefisiente roughness hili husi tabela iha kraik ne bazea ba kondisaun target mota iha terrenu.

$$Vm=\frac{1}{N} \cdot R^{2/3} \cdot I^{1/2}$$

iha ne'ebe

N mak koefisiente roughness

R mak radius hidrauliku

I mak mota laran nia klean

Tabela 3 — Revizaun Ministeriu konstrusaun iha Mota no Padraun kontrolu Erosaun (Esbosu) Japaun 1997, Seksaun Levantamentu p132

Kondisaun mota no Kanal		Eskopu husi Manning n
Kanal artifisial, mota ne'ebe hadia	Kanal artificial husi konkretu	0.014～0.020
	Kanal meiu spiral-pipa	0.021～0.030
	Kanal ho stone masonry iha ninia sorin-sorin (mud bed)	0.025 (mean value)
	Eskavasaun ba lapisan tanah keras	0.035～0.05
	Formalapisan tanah keras	0.025～0.04
	Mota laran ho rai tahu no nia velosidade fluxo la suficiente atu hamosu scouring	0.016～0.022
	Lempung pasir,tanah liat lempung	0.020 (mean value)
	Dragagem de dragagem, pequenas ervas daninhas	0.025～0.033
Mota natural	Kanal kiik ne'ebe iha rai tetuk,no laiha du'ut	0.025～0.033
	Kanak kiik iha rai tetuk, ho du'ut no arbustos	0.030～0.040
	Kanal kiik iha rai tetuk, ho du'ut no fatuk laran	0.040～0.055
	Kanal iha foho, ho gravel no fatuk bo'ot	0.030～0.050
	Kanal iha foho, ho fatuk bongkahan no bongkahan bo'ot	0.040 or higher
	Kanal bo'ot, ho material mota laran rai henek no kleurk kleur oituan	0.018～0.035
	Kanal bo'ot, no iha fatuk laran	0.025～0.040

iha ne'ebe, Radius Hidrauliku (m) = Cross Section Area (m^2) / Keliling basah (m)

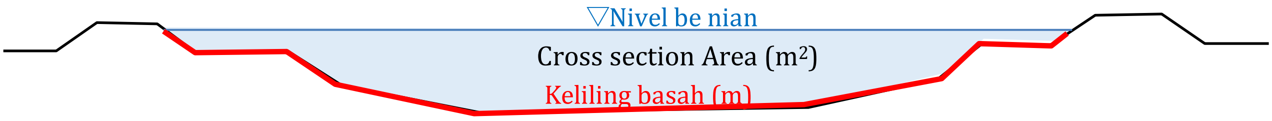


Figura 30 — Imagem radius hidrauliku

8.4.2 Determinasaun nivel be nian

Nivel be nian ne'ebe uza Manning formula ba kalkulasaun velosidade nian media tenki determina uza Metodu tuir mai ne'e:

Solusaun 1. Kalkulasaun fluxo naun-uniforme

Solusaun 2. Halo levantamentu dadus liu husi intervista ho komunidade sira ne'ebe besik, levantamentu dadus husi inundasaun iha passadu ninia marka.

Iha Timor-Leste, installasaun ba stasaun udan ben la sufisiente ba kalkulasaun limpasan no relasiona ho levantamentu topografiku nebe karun liu ba kalkulasaun fluxo naun-uniforme. Hanesan razaun ida ne'e, levantamentu ho intervista ho komunidade lokal ka levantamentu hoinundasaun passadu nian marka. Mak solusaun ne'ebe realistik ne'ebe bele uza ba define nivel be.

Iha parte seluk, iha kazu ba planu ponte foun ka planu ba mota ba kontramedida inundasaun, kalkulasaun naun-uniforme tenki enkoraja atu defini nivel be nian iha mota. Iha kazu ida ne'e, deskarga mota no periodu retornu mak presiza ba estudu mota nian. Ida ne'e enkoraja tebes atu uza periodu retornu ne'ebe hanesan ho plano original mota ninian.

Matadalan ida ne'e eksklui esplikasaun kona ba oprasaun software fluxo naun-uniforme, iha prosibilidade atu hetan software ne'e ho gratuita no operasaun manual iha website tuir mai ne'e "US Army Corps of Engineers". http://www.hec.usace.army.mil/software/hec-ras/

Etapa 1
Implementasaun levantamentu topografia mota nian
(Corte transversal, planu no perfil)

Etapa 2
Kalkulasaun ba kada deskarga ba periodu retornu ne'ebe utiliza formula Rasional no modelu RRI, nsst.
Hatama dadus; dadus udan ben, nsst.

Etapa 3
Kalkulasaun fluxo naun-unifrome utiliza software HEC-RAS, nsst.
Hatama dadus; dadus topografia, nsst.

Etapa 4
Determinasaun nivel be nian

Figura 31 — Estuda prosedimentu ba kalkulasaun 1

Referensia

1. Fluxo uniforme

Fluxo sei sai uniforme, wainhira fluxo nian velosidade la muda an iha magnetude ka iha diresaun ba qualaue pontus iha fluida ne'ebe sulin tuir tentu nebe'e determina tiha ona. Ezemplu, fluxo ne'ebe liquidu iha presaun nia okos liu husi pipa ne'ebe naruk ho kontanta diameter ne'ebe hanran fluxo uniforma.

2. Fluxo naun-uniforme

Fluxo sei sai uniforme,wainhira iha mudansa iha velosidade fluxo iha pontus diferensia fluida ne'ebe sulin, iha tempu ne'ebe termina ona. Ezemplu, fluxo husi liquida iha presaun nia okos ho varius diametru mak refere hanesan fluxo ne'ebe mak naun-uniforme. Tipu fluxo sira ne'e hotu bele eziste indenpendentimente ida no ba sira seluk. Nune'e posibel tebes atu halo combinasaun ba fluxo 4 ne'e:

1. Fluxo uniforme ne'ebe stavel

2. Fluxo naun-Uniforme ne'ebe stavel

3. Fluxo uniforme ne'ebe la stavel

4. Fluxo naun-uniforme ne'ebe la stavel

8.5 Instalasaun largura ba bloku protesaun pilar

Instalasaun largura ba bloku protesaun pilar nian tenki liu husi 5 m, maibe iha kazu ida ne'e scoring iha mota laran, tenki define hanesan deskreve 7.3 Determinasaun husi largura scour nia koak.

Annex A
(informativu)

Estudu kazu Ponte Sahen

A.1 Introdusaun

I. Razaun ba selesaun ba estudu kazu

Razaun ba selesaun ba estudu kazu ba kontrollu dezenu mak hanesan tuir mai ne'e:

1) Generalidade item servisu

Item servisu husi estudu kazu ne'e mak servisu protesaun ba substrutura ponte nian.
Hafoin planu kona ba estudu de kazu nemak kompleta, konessementu ne'ebe mak hetan husi estudu kazu ne'e sei dezenvolve ba area hotu-hotu iha Timor-Leste.

2) Acessibilidade

Fatin ne'e lokaliza besik ho sidade prinsipa distritu nian no han tempu minutu 60 husi edificio munisipal diresaun estrada e controlo de cheia no seguransa enjeral mos diak.

3) Urjenti no Importánsia

Estrada ne'e konsidera hanesan estrada ne'ebe importante tebes no presiza atensaun urgente.

II. Servisu protesaun hasoru scouring ba ponte

1. Area estudu kazu

Fatin ne'ebe targetu lokaliza iha mota sorin los Mota Sahen.

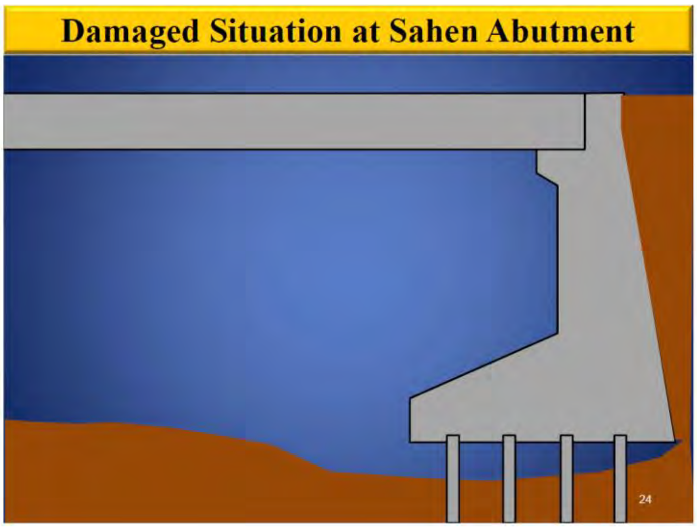
Figura area estudu kazu iha Sahen

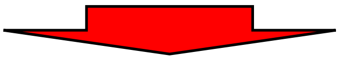
2. Situasaun atual

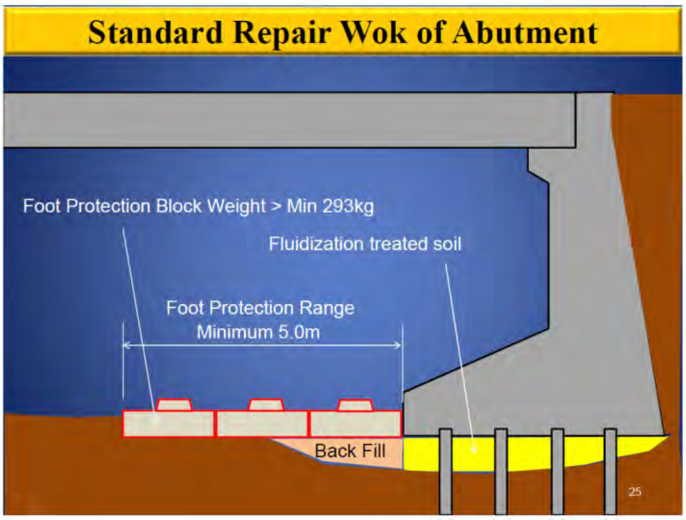
Figura tuir mai hatudu situasaun scoring iha mota ninin parte sorin los abutment no pilar iha parte sorin los. Iha ne'eba laiha servisu protesaun iha abutment ho pilar nian oin, tanba ne'e nessesariu tebes atu rehabilita bazeia ba analiza tekniku.

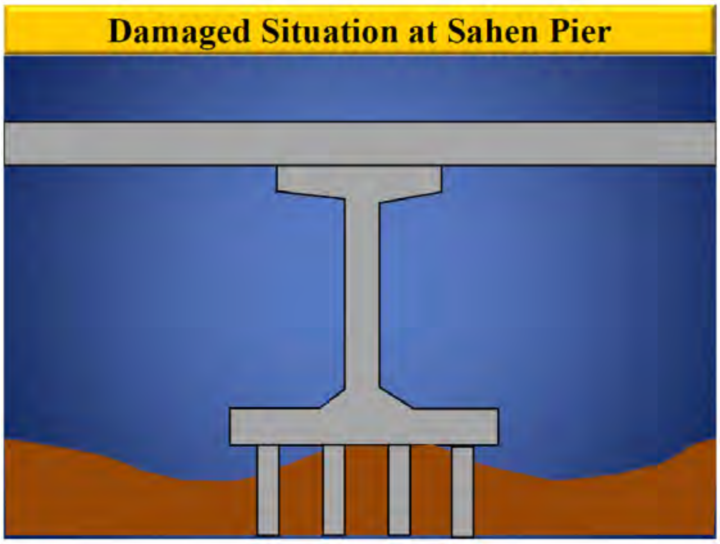
Imagem situasaun abut no pilar ne'ebe hetan estraga

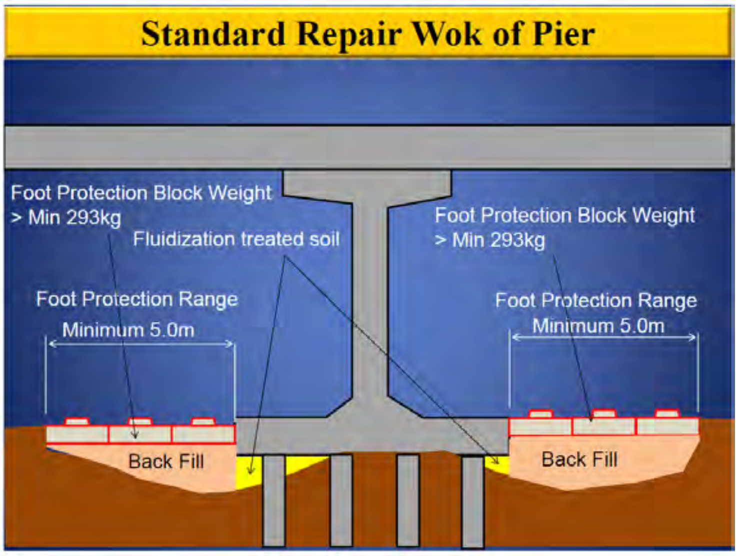
A.2 Medida koretivas








Damaged Situation at Sahen Pier


Standard Repair Wok of Pier
Foot Protection Block Weight
> Min 293kg
Fluidization treated soil
Foot Protection Range
Minimum 5.0m
Back Fill
Foot Protection Block Weight
> Min 293kg
Foot Protection Range
Minimum 5.0m
Back Fill


Countermeasure plan for Reference
Sahen River
Rightbank
Abutment
Leftbank
Abutment
Pier
Pier
Pier
20m
20m
20m
20m
20m
13m
13m
13m
Foot protection
block
Foot protection
block
Foot protection
block
Foot protection
block
Foot protection
block
Google Earth
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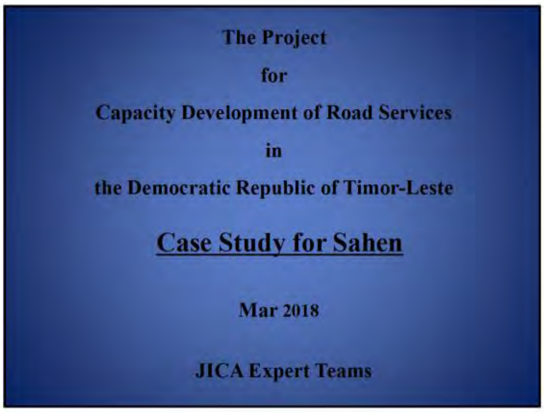
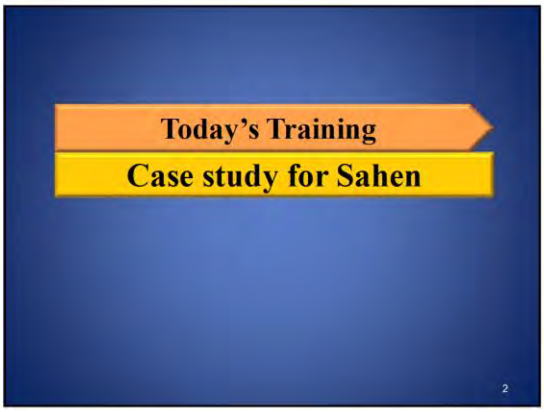
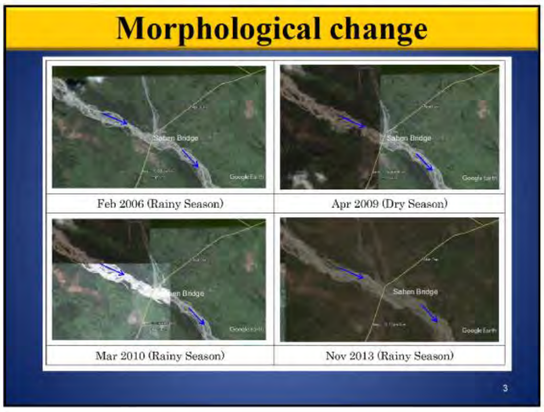
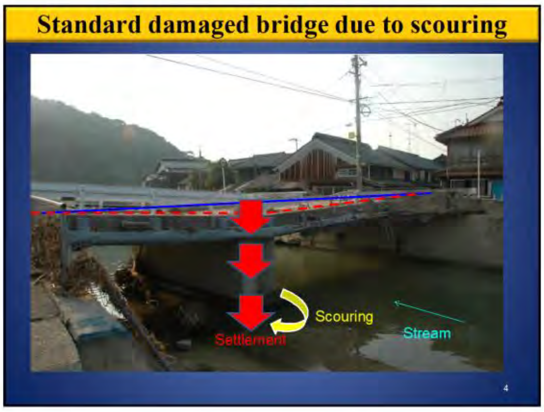
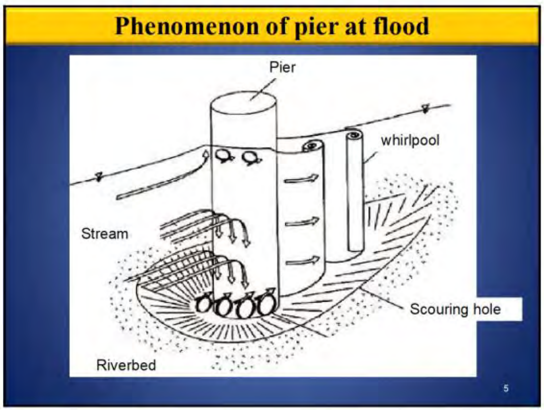
A.3 Material treinamentu

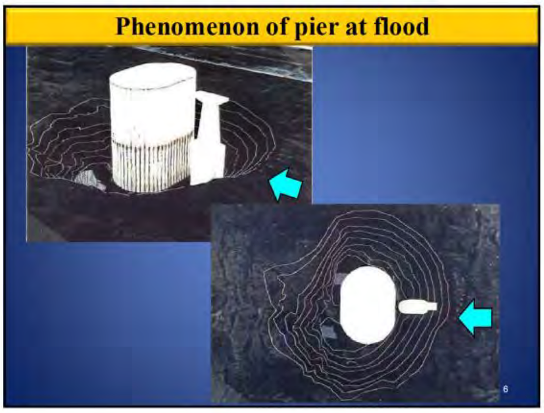












Phenomenon of pier at flood

7

Damaged of substructure at Sahen

8

Study Step

Step 1

Set of river flow velocity

↓

Step 2

Study of protection structure

9

Step 1

Set up of river flow velocity

How to set up velocity of Sahen river

↓

Manning formula

10

Manning's formula

$$V= \frac{1}{n} \times R^{\frac{2}{3}} \times I^{1/2}$$

V: Flow velocity (m/s)
n: Coefficient of roughness
R: Hydraulic radius (m) = Cross-sectional area of river/Wetted perimeter
I: Riverbed gradient

11

N: Coefficient of roughness

River or channel conditions		Scope of Manning's n
Artificial channel, improved river	Concrete artificial channel	0.014～0.020
	Spiral half-pipe channel	0.021～0.030
	Channel with stone masonry on both banks (mud bed)	0.025 (mean value)
	Bedrock excavation	0.035～0.05
	Bedrock forming	0.025～0.04
	Clay riverbed with flow velocity not enough to cause scouring	0.016～0.022
	Sandy loam, clayey soil loam	0.020 (mean value)
	Drag line dredging, little weeds	0.025～0.033
Natural river	Small channel on plain, with no grass	0.025～0.033
	Small channel on plain, with grass and shrubs	0.030～0.040
	Small channel on plain, with lots of grass and gravel bed	0.040～0.055
	Mountain channel, with gravel and boulders	0.030～0.050
	Mountain channel, with boulders and large boulders	0.040 or higher
	Large channel, with sandy bed and little meandering	0.018～0.035
	Large channel, with gravel bed	0.025～0.040

Source: Revised Ministry of Construction River and Erosion Control Standard (draft) 1997

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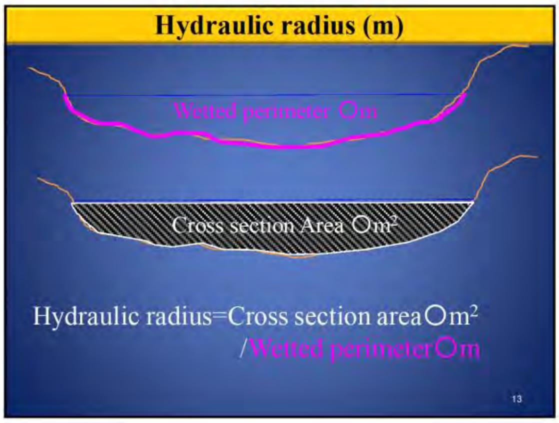
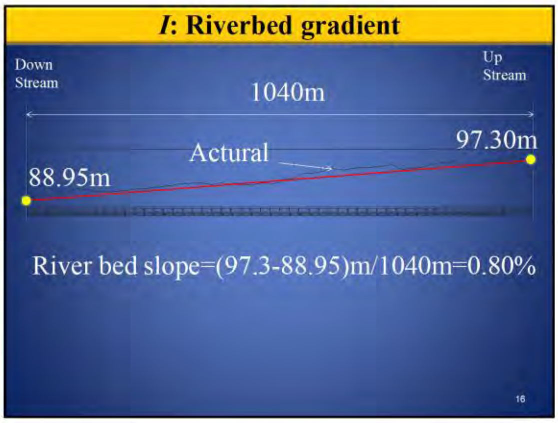
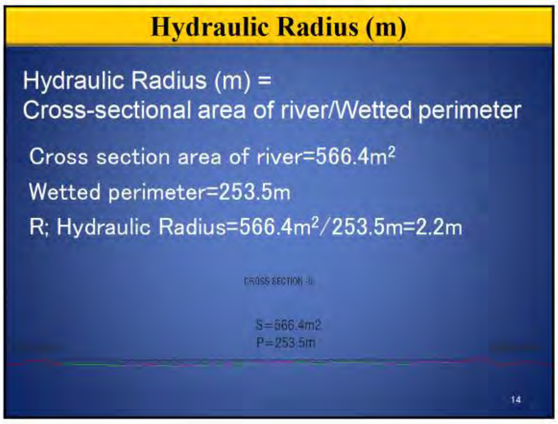
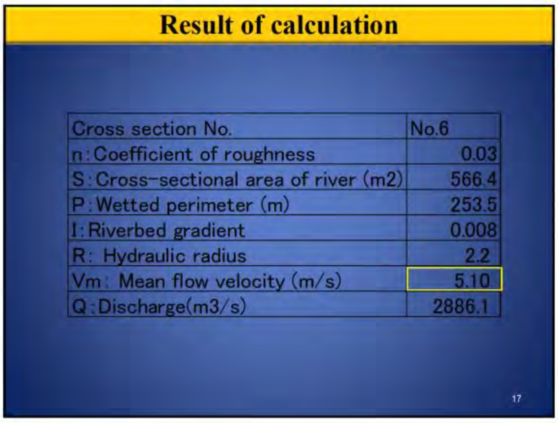
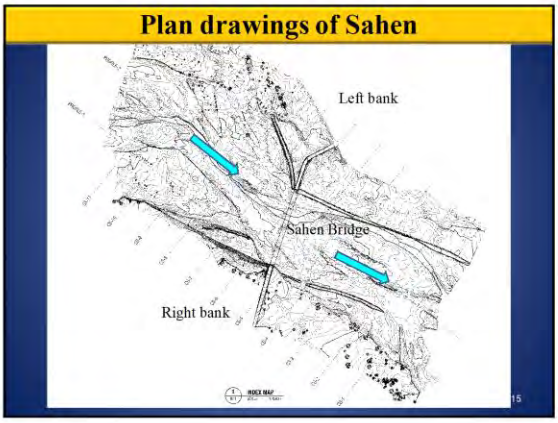


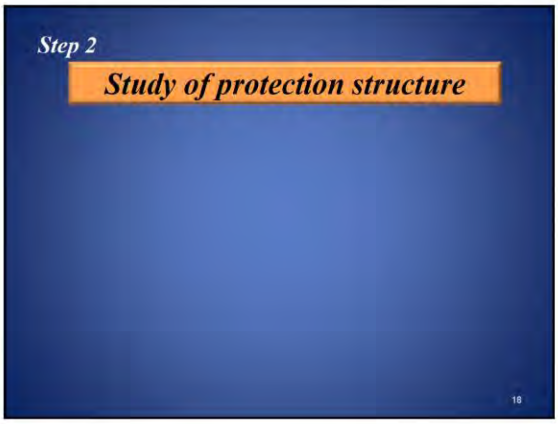


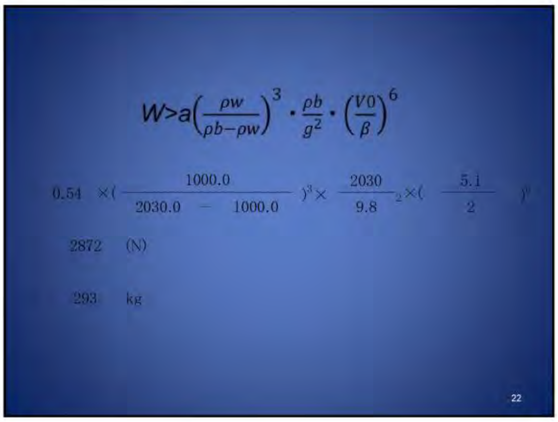


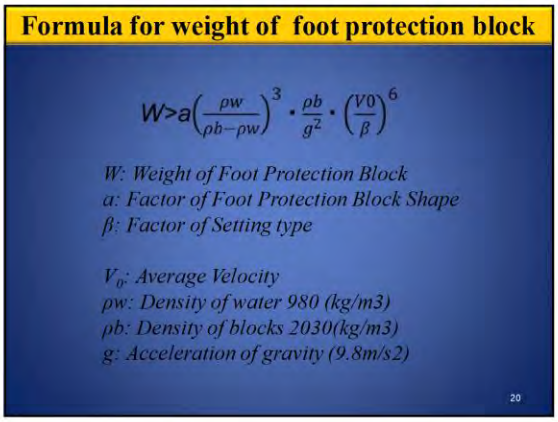


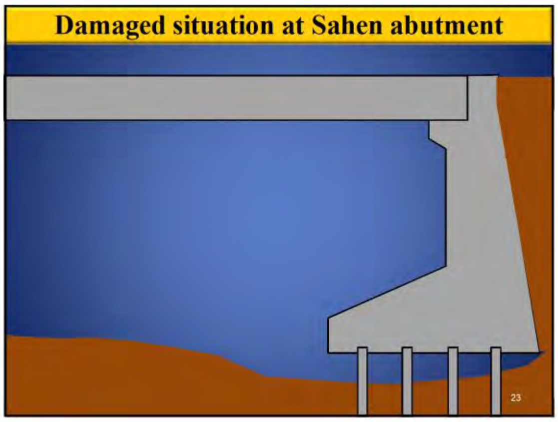
Cross section No.	No.6
n:Coefficient of roughness	0.03
S:Cross-sectional area of river (m2)	566.4
P:Wetted perimeter (m)	253.5
I:Riverbed gradient	0.008
R: Hydraulic radius	2.2
Vm: Mean flow velocity (m/s)	5.10
Q:Discharge(m3/s)	2886.1

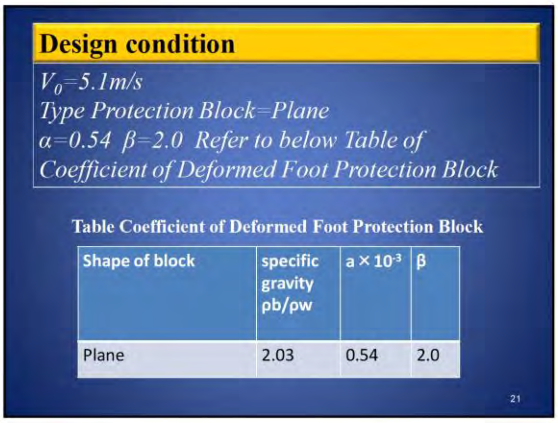




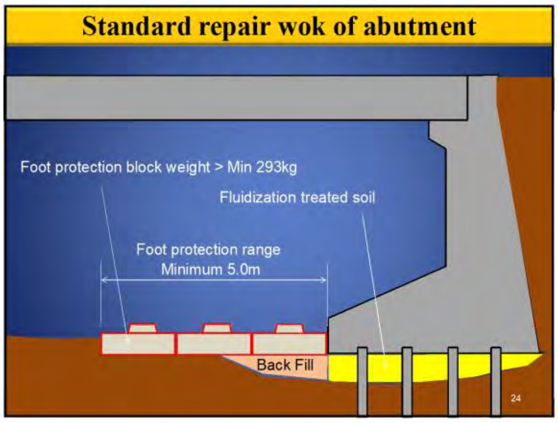


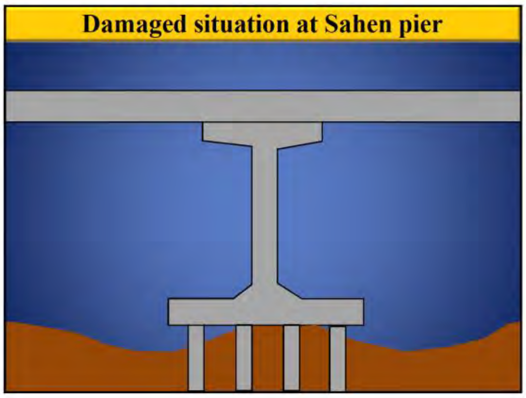


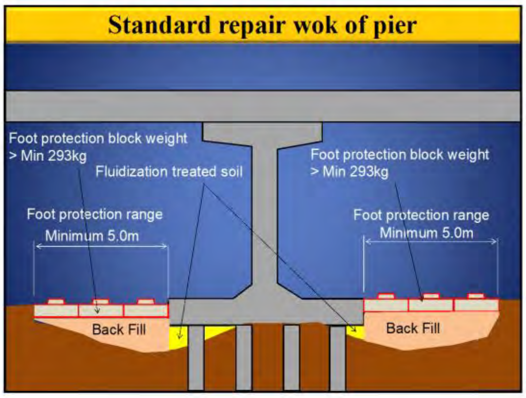




Shape of block	specific gravity ρb/ρw	a × 10⁻³	β
Plane	2.03	0.54	2.0




Damaged situation at Sahen pier

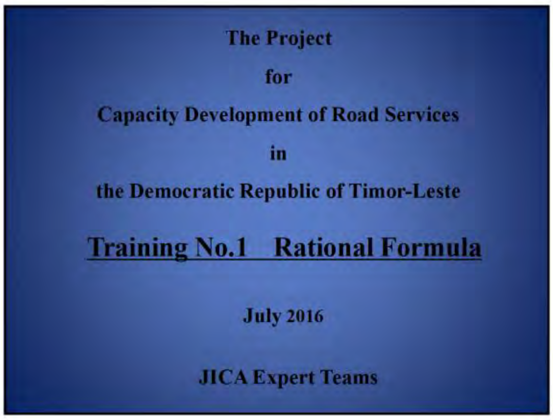

Standard repair wok of pier
Foot protection block weight > Min 293kg
Fluidization treated soil
Foot protection range Minimum 5.0m
Foot protection block weight > Min 293kg
Foot protection range Minimum 5.0m
Back Fill
Back Fill

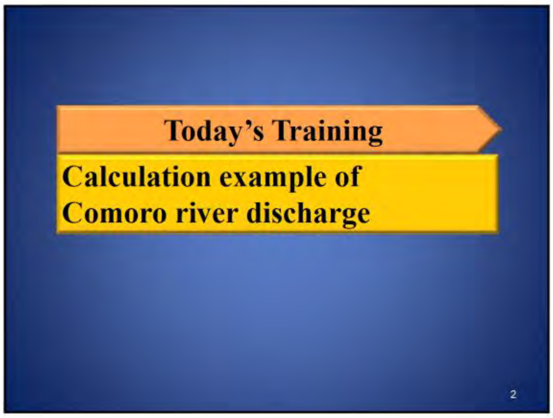

Countermeasure plan for reference
Sahen river
Rightbank Abutment
Leftbank Abutment
Pier
Pier
Pier
20m
20m
20m
20m
20m
13m
13m
13m
Foot protection block
Foot protection block
Foot protection block
Foot protection block
Foot protection block
Google Earth
27

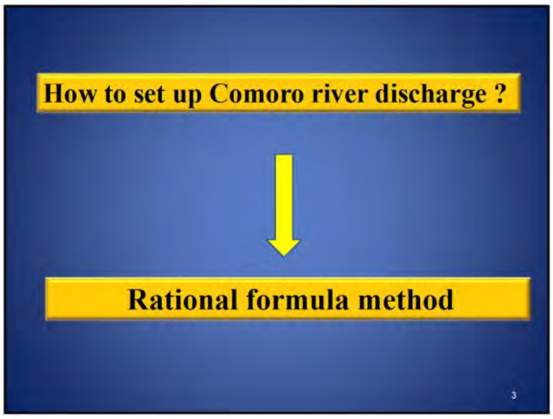
Annex B
(informativu)

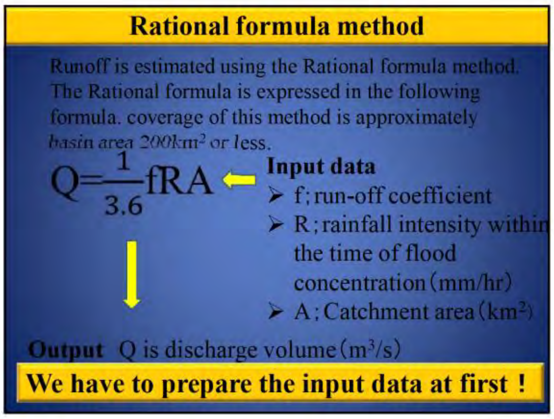
Material Treinamentu

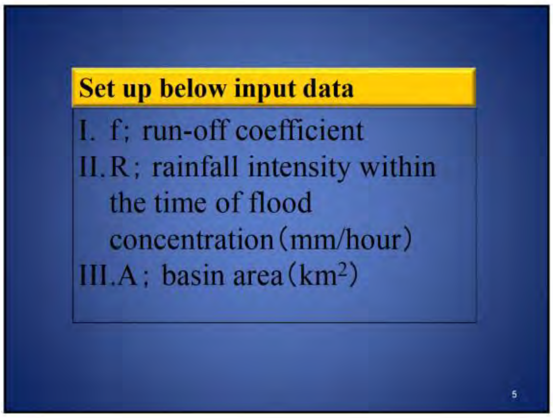
B.1 Metodu Rasional











What is runoff coefficient ?

Runoff coefficients depend on the land use, land condition of river basin. runoff coefficients are needed to calculate rain water runoff using the Rational method.

7

Runoff coefficient is 0.9

Runoff coefficient of Comoro river basin is determined to be 0.9 based on standard values in "Manual for River Works in Japan, Technical Criteria for River Works"

Steep mountainous region	0.75~0.90
Mountains of Tertiary strata	0.70~0.80
Rugged land and forests	0.50~0.75
Flat arable land	0.45~0.60
Irrigated paddy fields	0.70~0.80
Rivers in mountainous regions	0.75~0.85
Small rivers in level land	0.45~0.75
Large rivers in flat land	0.50~0.75

Source: Manual for River Works in Japan, Technical Criteria for River Works

8

II. Rainfall Intensity

9

What is Rainfall intensity ?

Rainfall intensity means momentary rainfall is converted one hour amount of rainfall.

Question

In the case rainfall is 2.5mm/one minute.
Which value is rainfall intensity ○ mm/hour ?

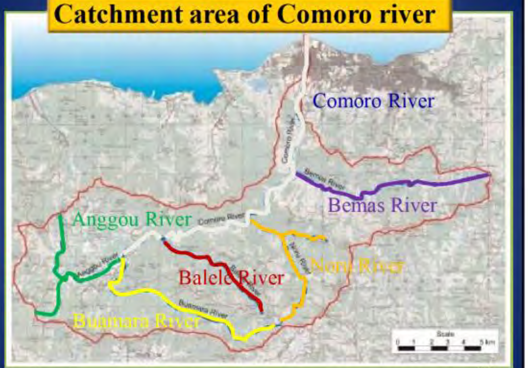
10

Answer

2.5mm/one minute × 60 minutes=150mm/hour

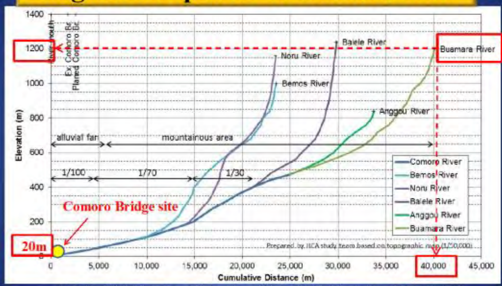
11

Catchment area of Comoro river



12

Longitudinal profile of Comoro river



Source: Digital topographic map revision and database operation manual for the study on urgent establishment of topographic mapping in East Timor (2000), JICA

13

R:Rainfall Intensity

Rainfall intensity is calculated by the following Mononobe's formula based on daily rainfall shown in below.

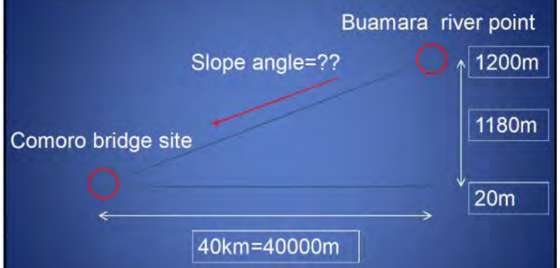
$$R = \frac{R_{24}}{24}\left(\frac{24}{T}\right)^{0.6}$$

Where, R is rainfall intensity within flood concentration time (mm/hr), R24 is 24-hour rainfall (mm), and T is flood concentration time. Rainfall intensity for each return period calculated using above formula is shown below table .

Return Period	R24=Daily Rainfall (mm)	R=Rainfall Intensity (mm/hr)
2-year	144.2	20.5
5-year	193.8	27.6
10-year	226.6	32.2
30-year	276.3	39.3
50-year	298.9	42.5
100-year	329.5	46.9

16

How to set up of slope angle?



Slope angle=1180/40000≒1/33

III. Basin Area

17

T: Flood concentration time

Flood concentration time is expressed using Kraven's formula as follows.

T = L/W

Where, T is flood concentration time (hour),

L is watercourse length⇒ 40,000(m),

W is flood flow velocity (m/s) shown in below.

I : Watercourse slope	over 1/100	1/100~1/200	below 1/200
W : Flood runoff velocity	3.5 m/s	3.0 m/s	2.1 m/s

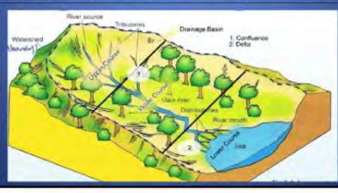
Watercourse slope is 1/33, and so flood runoff velocity is 3.5m/s. flood concentration time is calculated using these values as follows.

T = L/W = 40,000 (m) / 3.5 (m/s) = 3.1 (hour)

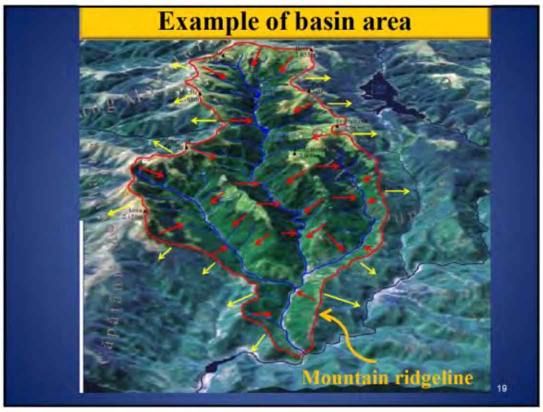
15

What is basin area ?

Basin area is an extent or an area of land where all surface water from rain, melting snow, or ice converges to a single point at a lower elevation, usually the exit of the basin, where the waters join another body of water, such as a river, lake, reservoir, estuary, sea, or ocean.



18



Run-off

Input data

- f : runoff coefficient
  ⇒ 0.9
- R : rainfall intensity within the time of flood concentration (mm/hr)
  ⇒ Each values
- A : basin area (km^2)
  ⇒207.1km^2

$$Q=\frac{1}{3.6}fRA$$

21

Result of run-off

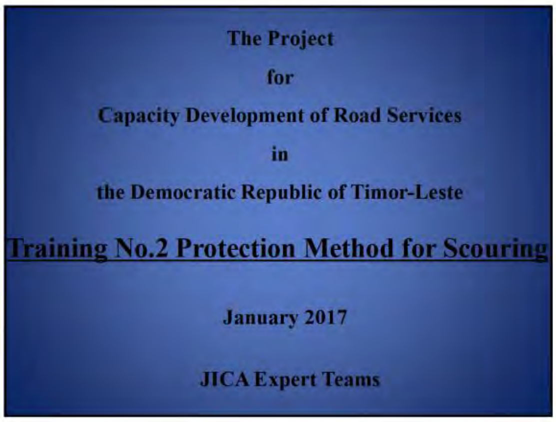
Runoff is calculated based on the values mentioned using Rational Formula. Calculated each retune period discharge are shown below Table.

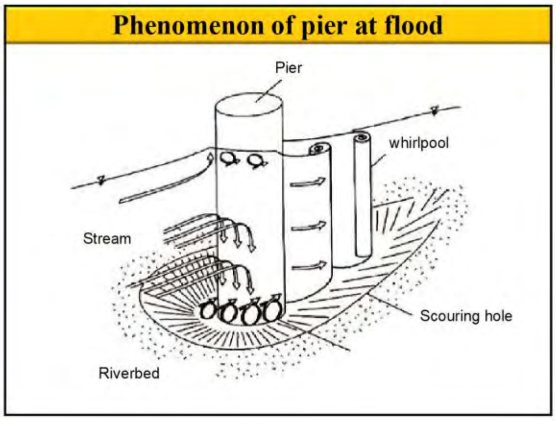
Return Period	Discharge (m^3/s)
2-year	1,100 (1,062)
5-year	1,500 (1,427)
10-year	1,700 (1,669)
30-year	2,100 (2,035)
50-year	2,200 (2,201)
100-year	2,500 (2,427)

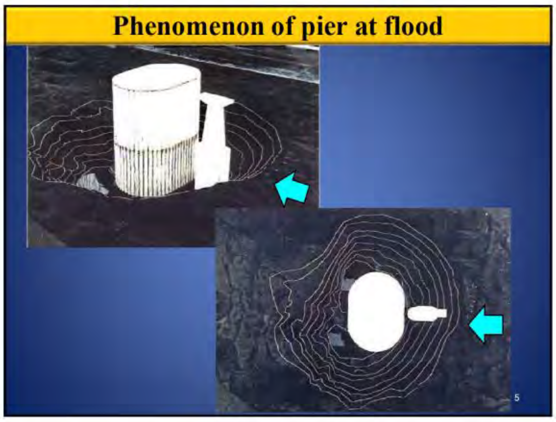
Design Flood Discharge of Comoro River : **2,200m^3/s** (50-year return period)

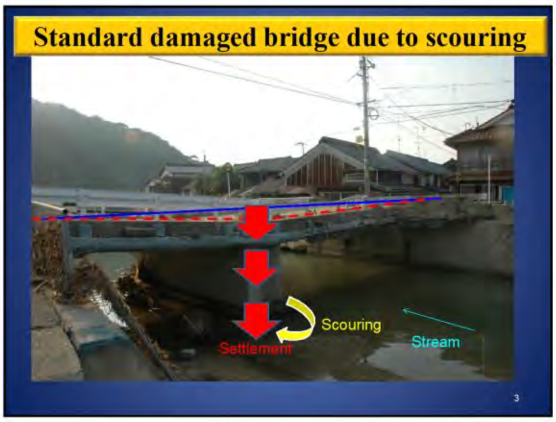
22

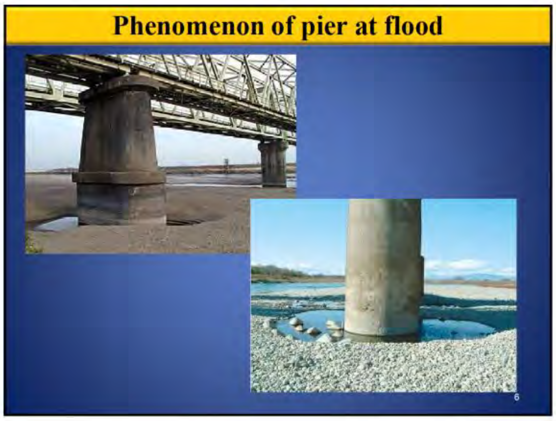
B.2 Metodu protesaun ba scouring

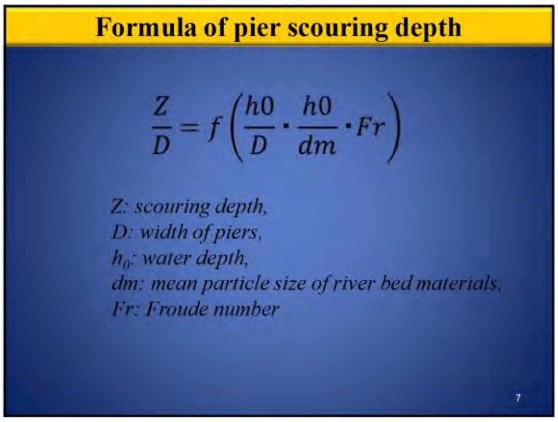


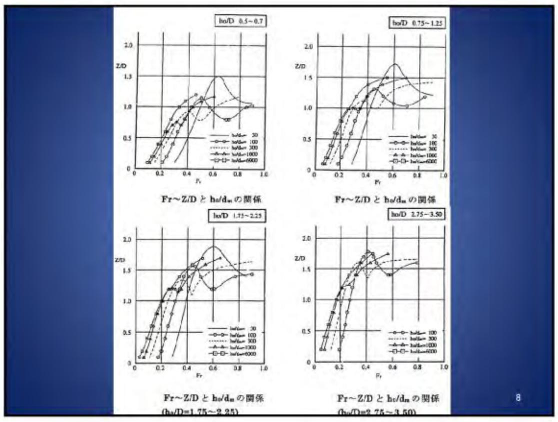


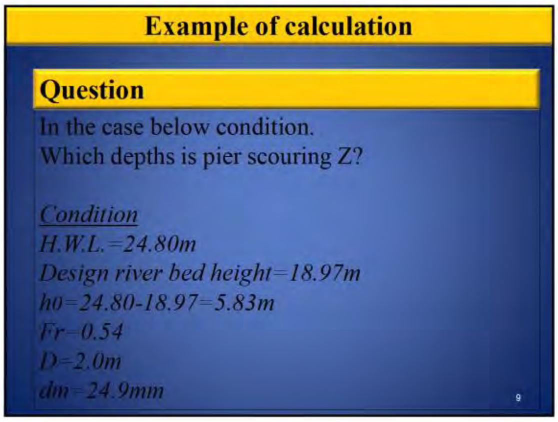


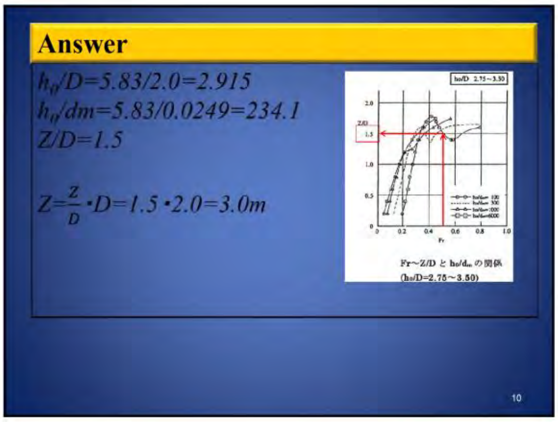




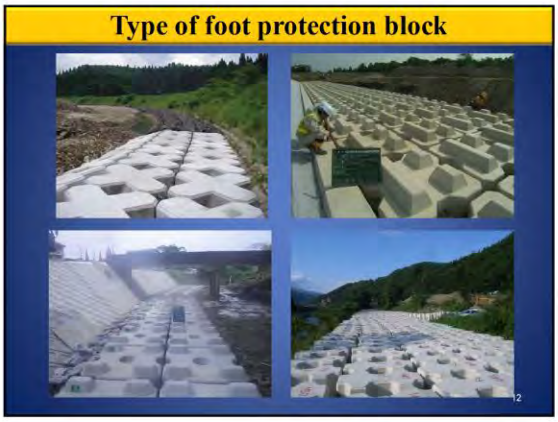

Formula of pier scouring depth
$\frac{Z}{D} = f\left(\frac{h0}{D} \cdot \frac{h0}{dm} \cdot Fr\right)$
Z: scouring depth,
D: width of piers,
h_0: water depth,
dm: mean particle size of river bed materials,
Fr: Froude number
7


8


Example of calculation
Question
In the case below condition.
Which depths is pier scouring Z?
Condition
H.W.L.=24.80m
Design river bed height=18.97m
h0=24.80-18.97=5.83m
Fr=0.54
D=2.0m
dm=24.9mm
9


Answer
$h_0/D=5.83/2.0=2.915$
$h_0/dm=5.83/0.0249=234.1$
$Z/D=1.5$
$Z=\frac{Z}{D}\cdot D=1.5\cdot 2.0=3.0m$
10


Standard foot protection work for scoring


Type of foot protection block
12

Formula for weight of foot protection block

$$W > a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \cdot \frac{\rho b}{g^2} \cdot \left(\frac{V0}{\beta}\right)^6$$

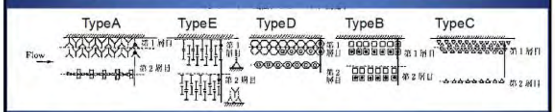
W: Weight of Foot Protection Block
a: Factor of Foot Protection Block Shape
β: Factor of Setting type

V_0: Average Velocity
ρw: Density of water 980 (kg/m3)
ρb: Density of blocks 2030(kg/m3)
g: Acceleration of gravity (9.8m/s2)

13

Table Coefficient of Deformed Foot Protection Block

Shape of block	specific gravity ρb/ρw	a×10⁻³	β
TypeA: Projection	2.22	1.2	1.5
TypeB: Plane	2.03	0.54	2.0
TypeC: Triangular conic	2.35	0.83	1.4
TypeD: Triangular bearing	2.25	0.45	2.3
TypeE: Rectangle	2.09	0.79	2.8



14

Example of Calculation

Question

In the case below condition.
Which size is foot protection block?

Condition
V_0=3.0m/s
Type Protection Block=TypeB: Plane
α=0.54 β=1.0 Refer to Table of Coefficient of Deformed Foot Protection Block

15

Answer

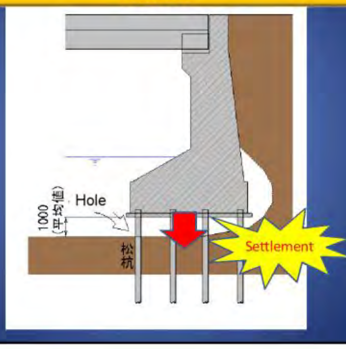
$$W > a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 * \frac{\rho b}{g^2} * \left(\frac{Vd}{\beta}\right)^6$$

$$=0.54 \times \left(\frac{1000}{2030-1000}\right)^3 \times \frac{2030}{9.8^2} \times \left(\frac{3.0}{1.0}\right)^6$$

=7615N
=777.04kg

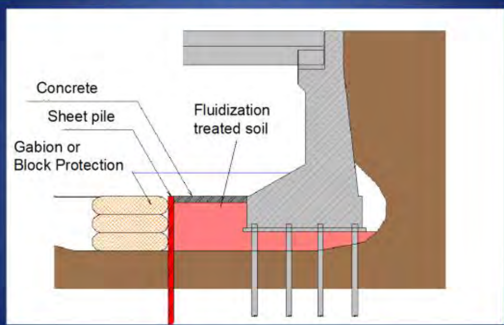
16

Standard damaged situation of abutment at flood



17

Standard repair wok of abutment



18


Fluidization treated soil
The feature of fluidization treated soil is able to construct in the small place.
Material; Soil +Cement +Water
19


Vibratory hammer method
FM2-55
20

B.3 Saku bo'ot rai henek

The Project
for
Capacity Development of Road Services
in
the Democratic Republic of Timor-Leste

Training No.3 Introduction of Weather Resistance Big Sandbag

April 2017
JICA Expert Teams

Today's Training

Weather resistance big sand bag method for damage site

2

Application works of weather resistance big sandbag

- ✓ Emergency works
- ✓ Temporary works

Notice:
Do not use weather resistance big sandbag for main civil works

3

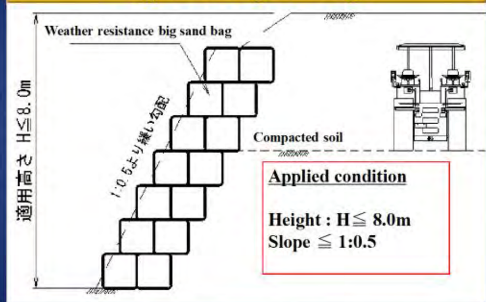
Example of weather resistance big sand bag

4

Example of weather resistance big sand bag

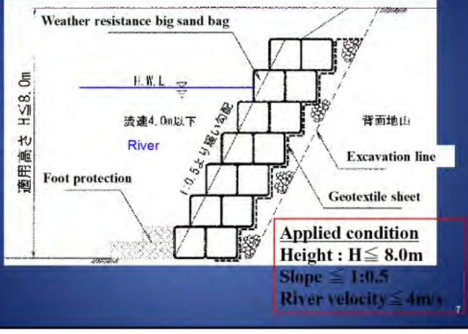
5

Applied condition of weather resistance big sand bag for slope



6

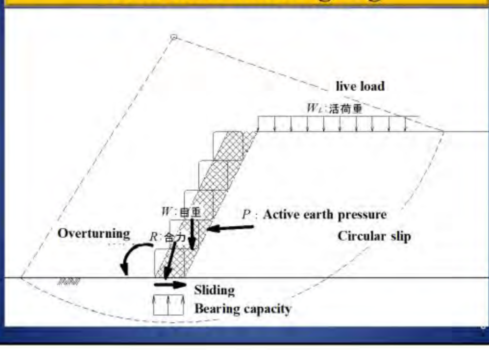
Applied condition of weather resistance big sand bag for river



Safety factor for weather resistance big sand bag analysis

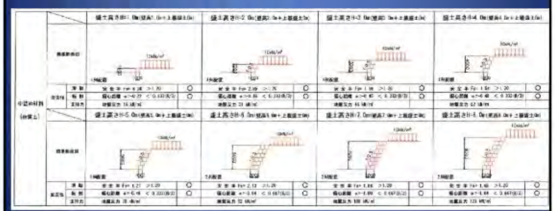
Item	Safety Factor
Compression Stress of Big Sand Bag	F≧1.5
Sliding	F≧1.2
Overturning	Eccentricity distance E≧B/3
Bearing Capacity	F≧2.0
Circular Slip	F≧1.05

Analysis parameter for weather resistance sand big bag

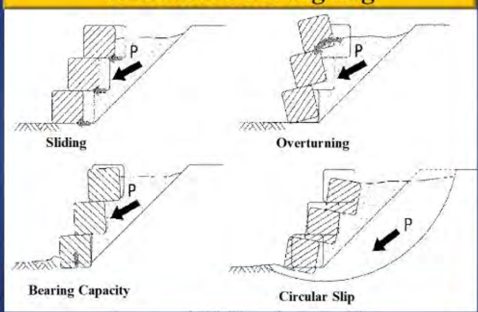


Standard drawing of weather resistance big sand bag analysis

Applied condition H<8m
Internal material ; sand soil

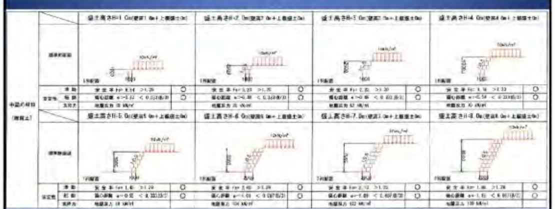


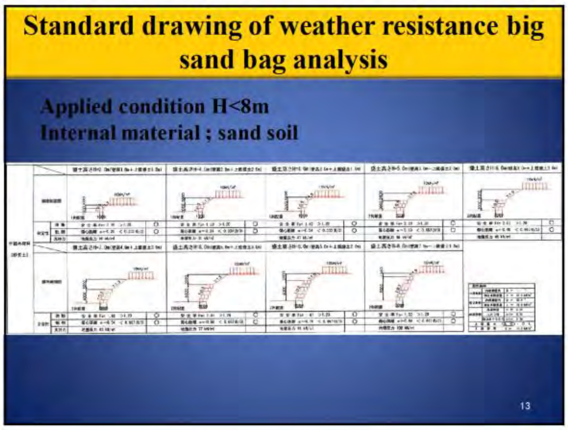
Analysis parameter for weather resistance sand big bag



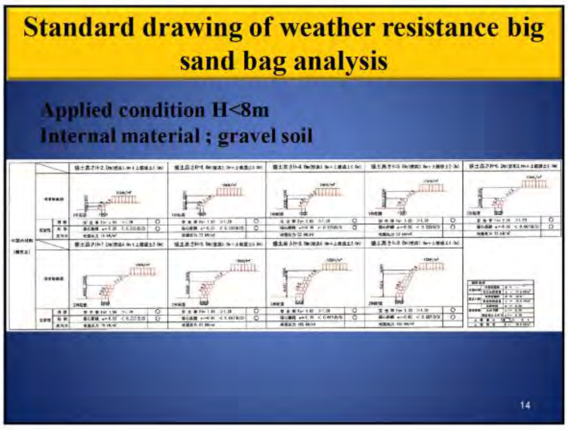
Standard drawing of weather resistance big sand bag analysis

Applied condition H<8m
Internal material ; gravel soil

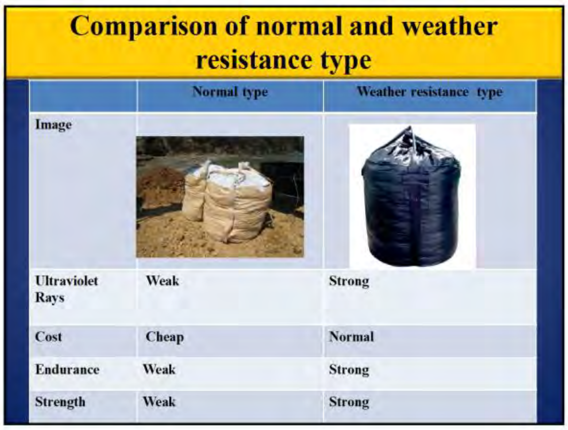



Standard drawing of weather resistance big sand bag analysis
Applied condition H<8m
Internal material ; sand soil
13

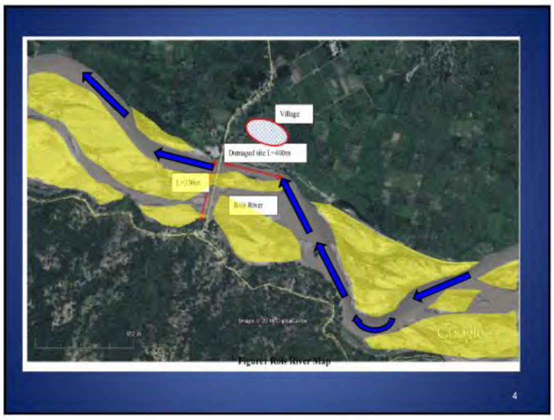

Normal big sand bag
The Normal type geo-bag is vulnerable to ultraviolet rays
16

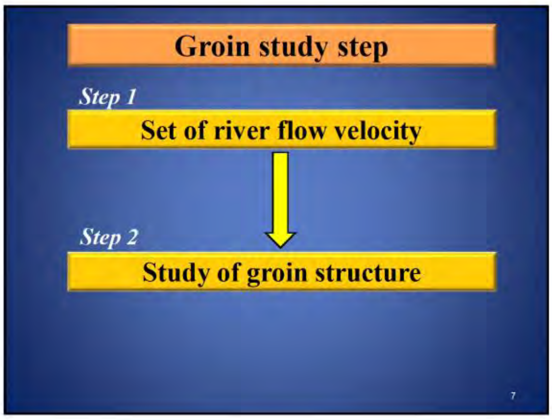

Standard drawing of weather resistance big sand bag analysis
Applied condition H<8m
Internal material ; gravel soil
14

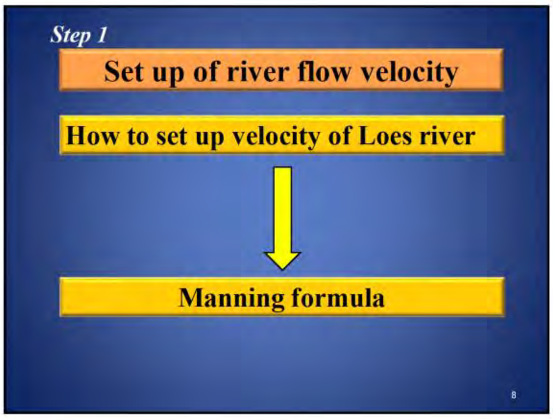

Recommended plan of weather resistance big sand bag
Normal big sand bag
Compacted soil
Resistance big sand bag
17

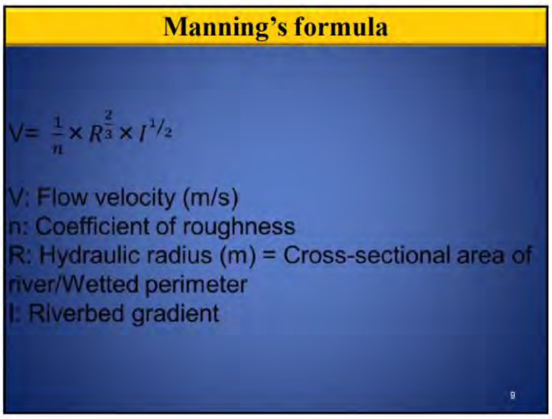

Comparison of normal and weather resistance type
Normal type
Weather resistance type
Image
Ultraviolet Rays
Weak
Strong
Cost
Cheap
Normal
Endurance
Weak
Strong
Strength
Weak
Strong

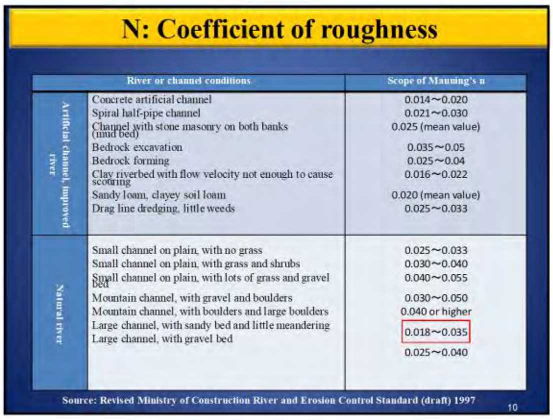
B.4 Metodu groin



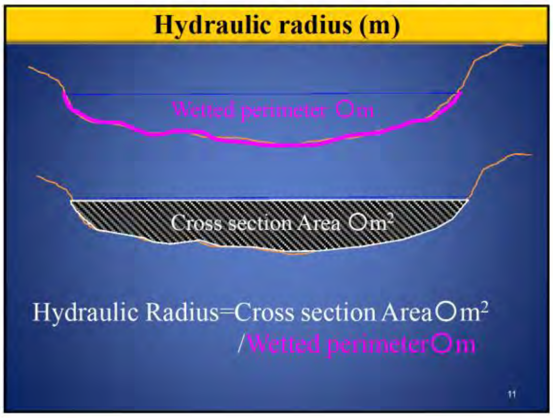


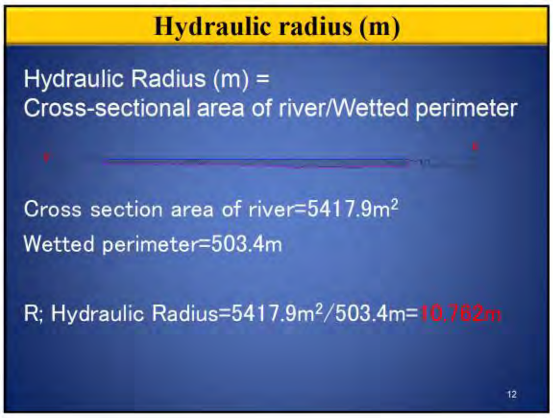






River or channel conditions		Scope of Manning's n
Artificial channel, improved river	Concrete artificial channel	0.014～0.020
	Spiral half-pipe channel	0.021～0.030
	Channel with stone masonry on both banks (mud bed)	0.025 (mean value)
	Bedrock excavation	0.035～0.05
	Bedrock forming	0.025～0.04
	Clay riverbed with flow velocity not enough to cause scouring	0.016～0.022
	Sandy loam, clayey soil loam	0.020 (mean value)
	Drag line dredging, little weeds	0.025～0.033
Natural river	Small channel on plain, with no grass	0.025～0.033
	Small channel on plain, with grass and shrubs	0.030～0.040
	Small channel on plain, with lots of grass and gravel bed	0.040～0.055
	Mountain channel, with gravel and boulders	0.030～0.050
	Mountain channel, with boulders and large boulders	0.040 or higher
	Large channel, with sandy bed and little meandering	0.018～0.035
	Large channel, with gravel bed	0.025～0.040





I: Riverbed gradient

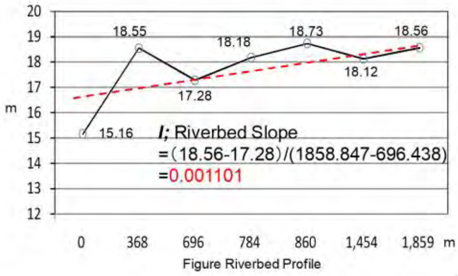


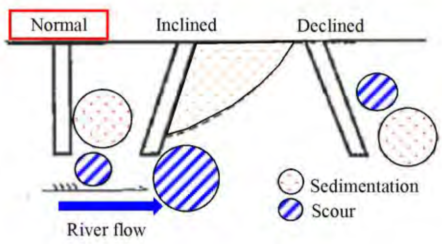
Figure Riverbed Profile

Comparison of Groin structure type

Result of calculation

Cross section No.	
n: Coefficient of roughness	0.035
S: Cross-sectional area of river (m2)	5417.9
P: Wetted perimeter (m)	503.4
I: Riverbed gradient	0.001101
R: Hydraulic radius	10.8
Vm: Mean flow velocity (m/s)	4.62

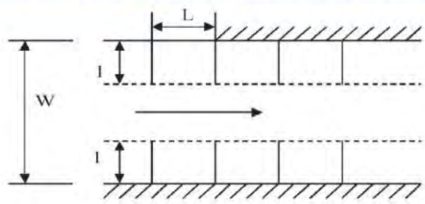
Set of direction type of Groin



Step 2

Study of Groin structure

Set of length and interval of Groin

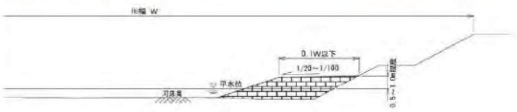


W: River Width=350m

l: Length of Groin (l<w/10)=350/10≦35m Selection 14m

L: Interval of Groin L=(1.5～2.0) ×l=20 ×2=40m

Set of Groin height



Groin height=
River depth 2.0m (field survey)+0.5m=2.5m

19

Set of Groin weight

$$Dm = \frac{V0^2}{E1^2 \times 2g\left[\frac{\rho s}{\rho w} - 1\right]}$$

Dm: diameter of stone
V_0: Average velocity=4.62m/s
G: Acceleration of gravity=9.8m/s
Pw: Density of water
ρs/ρw=2.65
E1=Factor of Strength turbulence=1.20

Source: Dynamically Design Method on Revetment, 2007, Japan

20

Set of Groin diameter

$$Dm = \frac{V0^2}{E1^2 \times 2g\left[\frac{\rho s}{\rho w} - 1\right]}$$

↓

$$Dm = \frac{4.62^2}{1.2^2 \times 2 \times 9.8[2.65-1]}$$

$$Dm = 0.46m\ (Diameter)$$

$$Radius = 0.46/2 = 0.23m$$

21

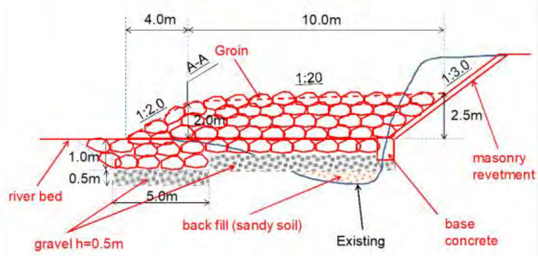
Set of Groin weight

$$W = \frac{4}{3} \times \pi \times r^3 \times \frac{\rho s}{\rho w} (Globe\ formula)$$
$$= 4/3 \times 3.14 \times 0.23^3 \times 2.65$$
$$= 134.9kg$$

i.e. Adoption Weight=200kg

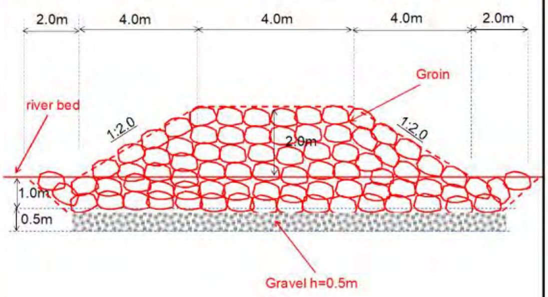
22

Standard cross section for reference

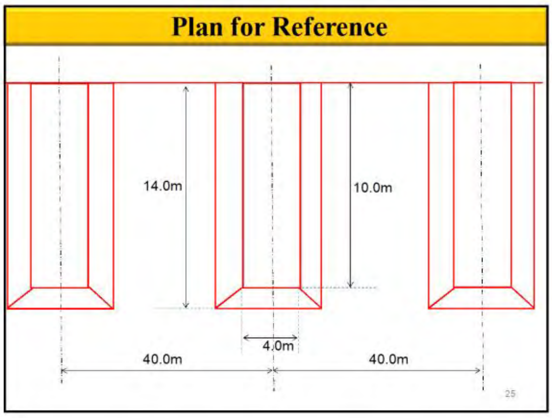


23

Front view for reference（A-A）



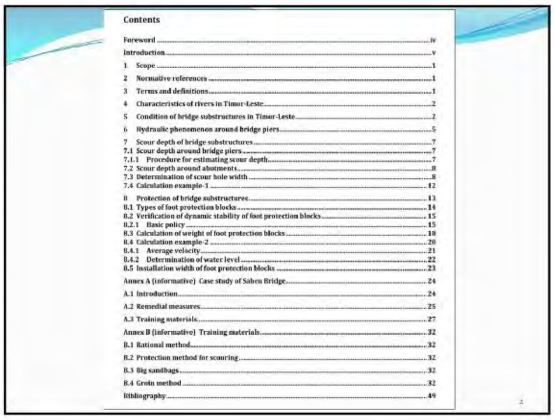
24

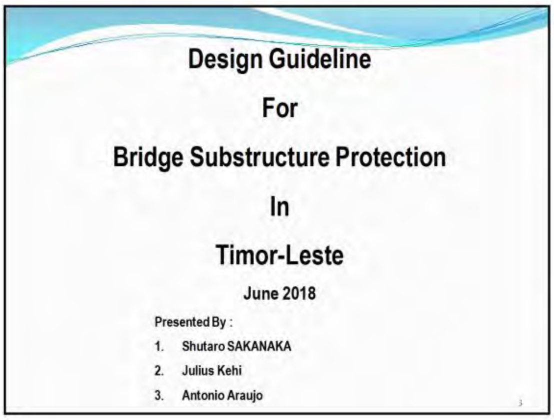

Plan for Reference
14.0m
10.0m
4.0m
40.0m
40.0m
25

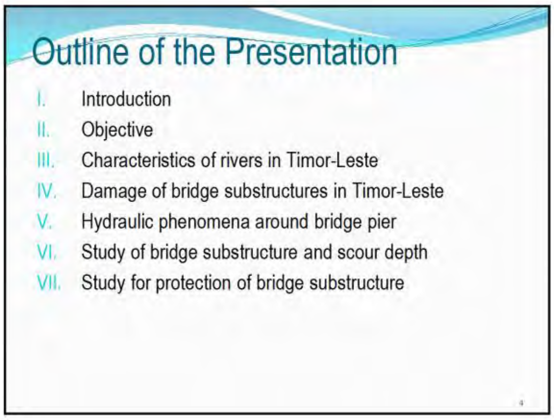

水制 No.25(最終点)

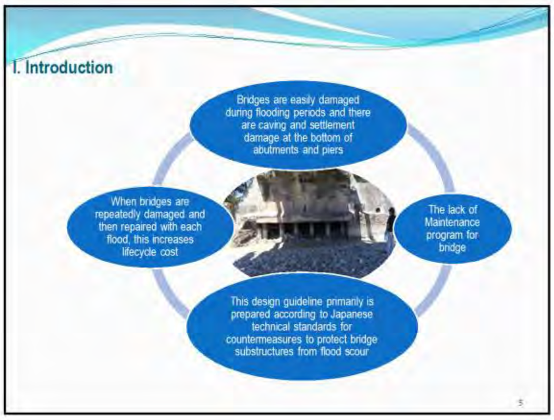

Plan for reference
14m
14m
40m
40m
40m
40m
40m
40m
40m
40m
Excavation
Excavation
Excavation
Google Earth
26

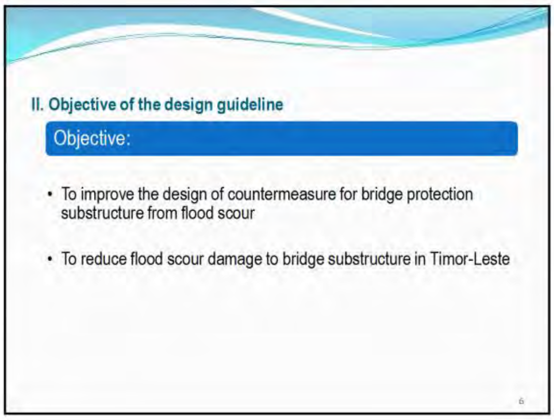
B.5 Protesaun ba substrutura ponte nian











III. Characteristics of majority of Rivers in Timor-Leste

- Sources of many rivers in Timor-Leste are located in the mountainous area, at an altitude of 1000m to 2000m
- The average annual rainfall in the northern region of Timor-Leste is approximately 1000mm to 2000mm and in the southern region it is 1500 mm to 2000 mm
- The length of their rivers is short and share many natural characteristics with rivers in Japan

IV. Condition of Bridges Substructure in Timor Leste

- The following figures show the scouring damage of Sahen Bridges right bank abutment and pier.

Figure 1. Sahen bridge abutment 2017

Figure 2. Sahen bridge pier 2017

- Figures 3 and 4 show the scouring damage of Mola Bridges Pier. Due to scouring damage, the caving of the footing can be seen

Figure 3. Mola bridge abutment 2011

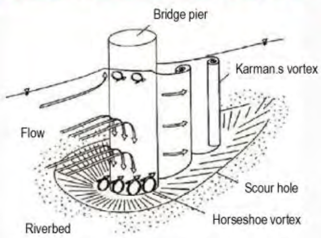
Figure 4. Mola bridge abutment 2011

- If appropriate countermeasure are not applied out and scouring is allowed to progress into the long term, overall bridge settlement damage (as can see in figure 5,6) is likely to occur

Figure. 5 Bridge settlement damage due to bridge pier scouring (Japan Example)

Figure. 6 Bridge settlement damange due to bridge pier scouring (Japan Example)

V. Hydraulic Phenomena Around Bridge Pier

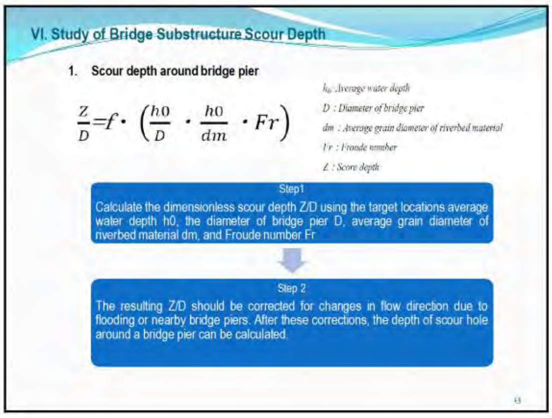


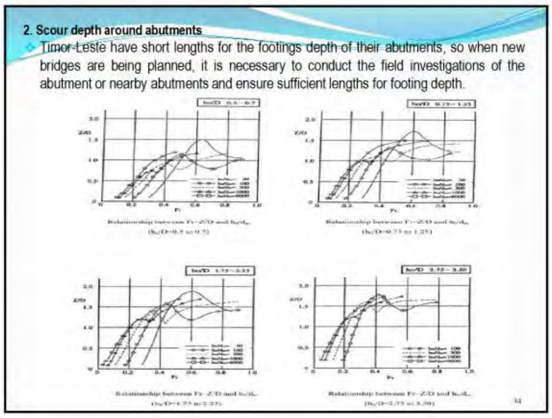
- ➢The figure shows the hydraulic phenomenon that occurs around bridge piers during flood.
- ➢ Bridge piers located in a river cause complex vortices and waves that disturb the flow and water surface during flood; as a result, an increase in water level and riverbed scouring occur

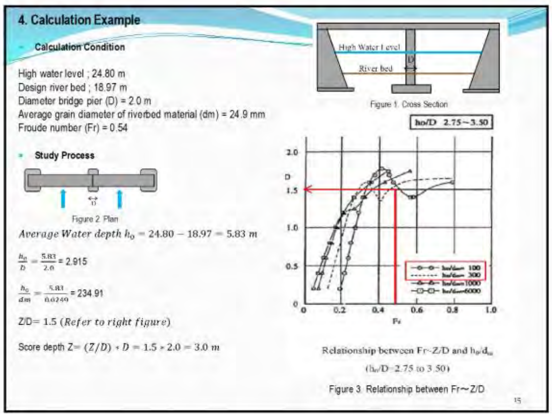
Hydraulic Phenomenal around bridge pier (Japan Example)

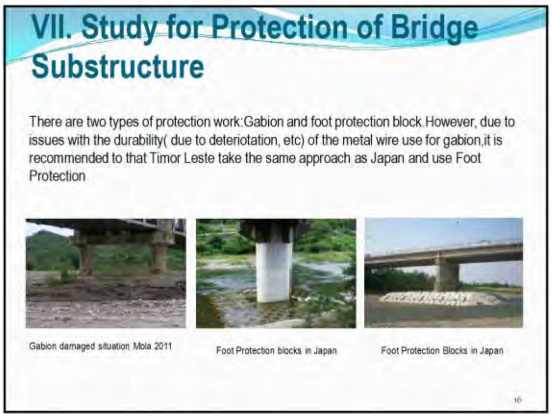
The figure show the actual phenomenon around a bridge pier during floods.the occurrences of complex flow around the bridges pier apparent.

The figure show the state of scour on bridge pier after a flood in Japan.The flood caused a scour hole to form around the bridge pier


VI. Study of Bridge Substructure Scour Depth
1. Scour depth around bridge pier
$\frac{Z}{D} = f \cdot \left(\frac{h0}{D} \cdot \frac{h0}{dm} \cdot Fr\right)$
h0 : Average water depth
D : Diameter of bridge pier
dm : Average grain diameter of riverbed material
Fr : Froude number
Z : Score depth
Step1
Calculate the dimensionless scour depth Z/D using the target locations average water depth h0, the diameter of bridge pier D, average grain diameter of riverbed material dm, and Froude number Fr
Step 2
The resulting Z/D should be corrected for changes in flow direction due to flooding or nearby bridge piers. After these corrections, the depth of scour hole around a bridge pier can be calculated.
13


2. Scour depth around abutments
Timor-Leste have short lengths for the footings depth of their abutments, so when new bridges are being planned, it is necessary to conduct the field investigations of the abutment or nearby abutments and ensure sufficient lengths for footing depth.
14


4. Calculation Example
Calculation Condition
High water level ; 24.80 m
Design river bed ; 18.97 m
Diameter bridge pier (D) = 2.0 m
Average grain diameter of riverbed material (dm) = 24.9 mm
Froude number (Fr) = 0.54
Study Process
Figure 2 Plan
Average Water depth h_0 = 24.80 − 18.97 = 5.83 m
$\frac{h_0}{D} = \frac{5.83}{2.0}$ = 2.915
$\frac{h_0}{dm} = \frac{5.83}{0.0249}$ = 234.91
Z/D= 1.5 (Refer to right figure)
Score depth Z= (Z/D) × D = 1.5 × 2.0 = 3.0 m
High Water Level
River bed
Figure 1 Cross Section
ho/D 2.75~3.50
Relationship between Fr~Z/D and h_0/d_m
(h_0/D=2.75 to 3.50)
Figure 3 Relationship between Fr~Z/D
15


VII. Study for Protection of Bridge Substructure
There are two types of protection work:Gabion and foot protection block.However, due to issues with the durability(due to deteriotation, etc) of the metal wire use for gabion,it is recommended to that Timor Leste take the same approach as Japan and use Foot Protection
Gabion damaged situation Mola 2011
Foot Protection blocks in Japan
Foot Protection Blocks in Japan
16


Types of foot protection block
Types of foot protection blocks in Japan
17

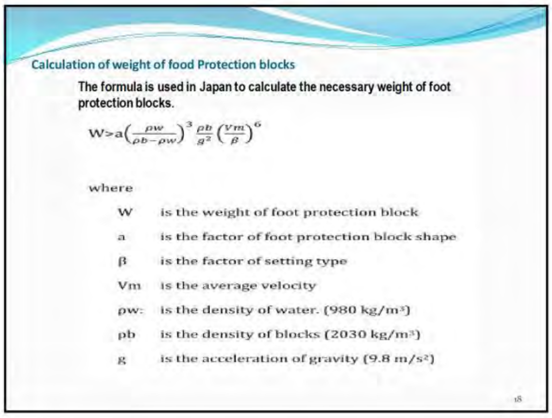

Calculation of weight of food Protection blocks
The formula is used in Japan to calculate the necessary weight of foot protection blocks.
$W > a\left(\frac{\rho w}{\rho b - \rho w}\right)^3 \frac{\rho b}{g^2}\left(\frac{Vm}{\beta}\right)^6$
where
W is the weight of foot protection block
a is the factor of foot protection block shape
β is the factor of setting type
Vm is the average velocity
ρw: is the density of water. (980 kg/m³)
ρb is the density of blocks (2030 kg/m³)
g is the acceleration of gravity (9.8 m/s²)
18

Table Factor of α and β

Shape of block	specific gravity ρb/ρw	α×10⁻³	β
Type A: Projection	2.22	1.2	1.5
Type B: Plane	2.03	0.54	2.0
Type C: Triangular conic	2.35	0.83	1.4
Type D: Triangular bearing	2.25	0.45	2.3
Type E: Rectangle	2.09	0.79	2.8

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Calculation Example for weight of foot Protection Block

- Calculation Condition

$W > a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \frac{\rho b}{g^2}\left(\frac{Vm}{\beta}\right)^6$

Here

W		is the weight of foot protection block
Vm	5.1m/s	is the river velocity;
Shape	Type B	is the block type;
α	0.54	is the block factor;
β	2.0	is the block factor;
ρw	980kg/m³	is the density of water
ρb	2030kg/m³	is the density of block
g	9.8m/s²	is the acceleration of gravity

- Now W can be calculated as follows

$$W > a\left(\frac{\rho w}{\rho b-\rho w}\right)^3 \frac{\rho b}{g^2}\left(\frac{Vm}{\beta}\right)^6$$

$$W = 0.54 \times \left(\frac{1000}{2030-1000}\right)^3 \times \frac{2030}{9.8^2} \times \left(\frac{5.1}{2}\right)^6$$

$$W = 2872\ N$$

$$W = 293\ kg$$

20

Average Velocity

The flow velocity used I the calculation of foot protection block weight is calculated using the manning formula for calculating the average velocity. The roughness coefficient is selected from the table below based on the conditions at the target river site.

River or channel conditions		Scope of Manning's n
Artificial channel, improved river	Concrete artificial channel	0.014~0.020
	Spiral half-pipe channel	0.021~0.030
	Channel with stone masonry on both banks (mud bed)	0.025 (mean value)
	Bedrock excavation	0.035~0.05
	Bedrock forming	0.025~0.04
	Clay riverbed with flow velocity not enough to cause scouring	0.016~0.022
	Sandy loam, clayey soil loam	0.020 (mean value)
	Drag line dredging, little weeds	0.025~0.033
Natural river	Small channel on plain, with no grass	0.025~0.033
	Small channel on plain, with grass and shrubs	0.030~0.040
	Small channel on plain, with lots of grass and gravel bed	0.040~0.055
	Mountain channel, with gravel and boulders	0.030~0.050
	Mountain channel, with boulders and large boulders	0.040 or higher
	Large channel, with sandy bed and little meandering	0.018~0.035
	Large channel, with gravel bed	0.025~0.040

Table. Revised Ministry of Construction River and Erosion Control standard (draft) Japan 1997,Survey Section P132

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Step 1

Set up of river flow velocity

How to set up velocity of Loes river

↓

Manning formula

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Manning's formula

$V = \frac{1}{n} \times R^{\frac{2}{3}} \times I^{1/2}$

V: Flow velocity (m/s)
n: Coefficient of roughness
R: Hydraulic radius (m) = Cross-sectional area of river/Wetted perimeter
I: Riverbed gradient

23

N: Coefficient of roughness

River or channel conditions		Scope of Manning's n
Artificial channel, improved river	Concrete artificial channel	0.014~0.020
	Spiral half-pipe channel	0.021~0.030
	Channel with stone masonry on both banks (mud bed)	0.025 (mean value)
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	Large channel, with sandy bed and little meandering	0.018~0.035
	Large channel, with gravel bed	0.025~0.040

Source: Revised Ministry of Construction River and Erosion Control Standard (draft) 1997

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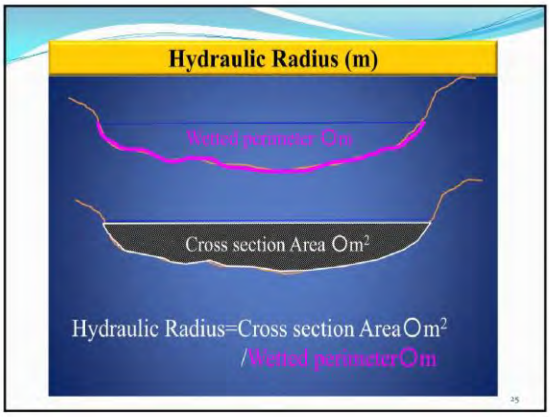
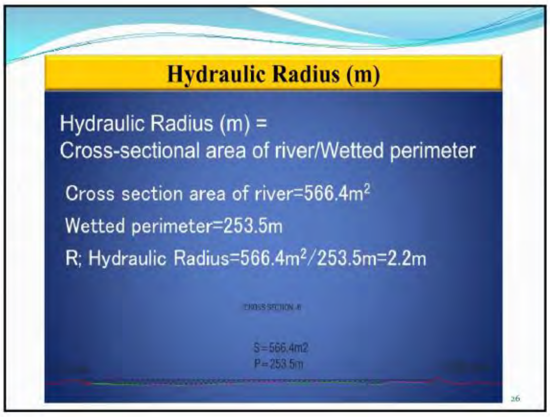
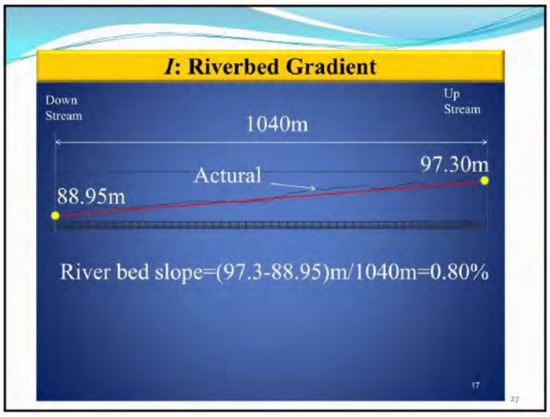
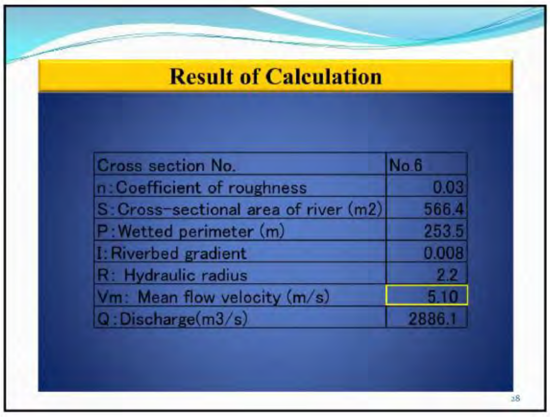

Hydraulic Radius (m)
Wetted perimeter Om
Cross section Area Om²
Hydraulic Radius=Cross section Area Om²
/Wetted perimeter Om
25


Hydraulic Radius (m)
Hydraulic Radius (m) =
Cross-sectional area of river/Wetted perimeter
Cross section area of river=566.4m²
Wetted perimeter=253.5m
R; Hydraulic Radius=566.4m²/253.5m=2.2m
S=566.4m2
P=253.5m
26


I: Riverbed Gradient
Down
Stream
Up
Stream
1040m
97.30m
Actural
88.95m
River bed slope=(97.3-88.95)m/1040m=0.80%
17
27


Result of Calculation
Cross section No. No.6
n: Coefficient of roughness 0.03
S: Cross-sectional area of river (m2) 566.4
P: Wetted perimeter (m) 253.5
I: Riverbed gradient 0.008
R: Hydraulic radius 2.2
Vm: Mean flow velocity (m/s) 5.10
Q: Discharge(m3/s) 2886.1
28


OBRIGADO
29

Bibliografia

[1] Dynamically design method on revetment, 2007, Japan Institute of Country and Engineering

[2] Guidelines for river bridge plan (draft), 2009, Japan Institute of Construction Engineering.

Democratic Republic of Timor-Leste

Ministry of Public Works

Directorate General of Public Works

National Directorate of Roads, Bridges and Flood Control

Road Guidelines — Drainage — Culvert Design

Guia de Estrada — Drenagem — Passagem Hidráulica

Document type: Technical Specification
Document subtype:
Document language: E

Contents

REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTÉRIO DAS OBRAS PÚBLICAS
GABINETE DO VICE MINISTRO
Av. Nicolau Lobato, Mandarin, Dili, Timor-Leste

Foreword

In the interest of constructing high quality and economically viable government infrastructure to serve the nation, these guidelines for optimal design of drainage components were prepared by the JICA Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste (CDRS) in collaboration with the *Direcção Nacional de Estradas, Pontes e Controlo de Cheias* (DNEPCC, 'National Directorate of Roads, Bridges and Flood Control') of the *Ministério das Obras Públicas* ('Ministry of Public Works'). We would like to thank JICA for their continuing support.

September, 2019

Eng. Nicolau Lino Freitas Belo
Vice Minister for Public Works
Ministry of Public Works

19-09-2019

Foreword by JICA

Japan International Cooperation Agency (JICA) has been conducting a technical cooperation project for development of capacity regarding road services, which is called CDRS, in order to facilitate the DNEPCC in properly managing and maintaining the road infrastructure that is the basis of social and economic activities. To this end, JICA has been dispatching a team of experts from March 2016 to December 2019. As a result of collaborative work with counterparts of the DNEPCC, these guidelines for design of culverts have been finalized. I hope that these guidelines will contribute to infrastructure development and maintenance, and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials of the Government of the Democratic Republic of Timor-Leste for their close cooperation with the expert team.

September, 2019

Masafumi NAGAISHI
Chief Representative of JICA Timor-Leste Office
Japan International Cooperation Agency

Acknowledgements

The Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste wishes to thank all parties involved in preparing these Culvert Design guidelines, and special thanks to M. Soares of DNEPCC for revising these guidelines.

In support of the project, the officials of the (former) Ministry of Development and Institutional Reform: M. R. M. Cruz, J. L. C. C. P. Mestre and J. Santos; and the officials of the Ministry of Public Works: C. M. Henrique and especially R. H. F. Guterres; are hereby acknowledged.

In contributing to the preparation of this document, the officials of the DNEPCC: M. R. C. Monteiro, J. P. Amaral, J. M. G. Sousa, J. G. Carlvalho, I. M. L. Gutteres, N. Lobato, A. Araujo, V. N. P. Araujo, L. R. H. Corbafo, J. Costa, M. F. Costa, R. Costa, S. Laranjinha, D. X. Deus, B. Ferreira, R. C. Freitas, P. C. R. Noronha and C. E. Ximenes; and the International Labour Organization's (ILO) technical assistance team of the Roads for Development Support Program (R4D-SP): A. O. Asare, K. H. Myaing, S. Done, S. F. Eqbali, V. Sam and D. H. Singh; are hereby acknowledged.

In addition, the Seeds of Life Program: S. Bacon is hereby acknowledged.

Feedback:

Any positive feedback for possible incorporation into future editions would be appreciated. Please send such comments or feedback to the below address.

Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
Address: Avenida da Restauração, Rai Kotu, Comoro, Dili, Timor-Leste
Telephone: +670 3311408

Introduction

These guidelines were developed by the JICA Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste in collaboration with the *Direcção Nacional de Estradas, Pontes e Controlo de Cheias* (DNEPCC, 'National Directorate of Roads, Bridges and Flood Control') for the purpose of developing capacity regarding drainage design of cross culverts.

The purpose of drainage design is to ensure reasonable capacity of drainage facilities, which means specifying culverts with sufficient drainage capacity to accommodate probable volumes of stormwater and at reasonable construction costs compared to their benefit to economic activities. Within the context of road crossings, the purpose of box culverts is to ensure the protection of road structures and road users.

The chronology of editions are as follows:

– First edition in English September 2019

The main changes compared to the previous edition are as follows:

– No changes

Road Guidelines — Drainage — Culvert Design

1 Scope

These guidelines aim to provide practical information for planning and design of box culverts for the purpose of culvert construction or reconstruction. These guidelines relate mainly to hydrological studies and hydraulic design. The design methodologies presented here have been recommended on the basis that they are easy in application and consistent in approach. Planning issues outlined in these guidelines are for reference and engineering judgement should be used concerning application based on site conditions, such as debris.

These guidelines do not cover cleaning, reconditioning, rehabilitation, repair, structural design or standard drawings of culverts. For information regarding construction management and maintenance on site, please see the relevant section in the *Standard Specifications* (Section 600 – Drainage and Slope Protection Structures) (1). For applications involving large rivers or long-span crossings, please adopt the *Bridge Design Standards & Manual* (2). For guidance on structural dimensions and reinforcement, please see the relevant structural design standard and standard drawings.

The language used in these guidelines is generally Latinate to facilitate comprehension by the engineers of the directorate.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standard Specifications (2014) (1)

Bridge Design Standards & Manual (2012) (2)

Road Geometric Design Standards (2010) (3)

3 Terms and definitions

For reference, a glossary of terms and their equivalent meaning in Tetun, Portuguese or Indonesian, and Japanese has been included at the back of these guidelines.

For the purpose of this document, the following terms and definitions apply.

ISO maintains terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
catchment
area of land where all of the water that is under it or drains off of it goes into the same place

[SOURCE: ISO 14055-1:2017(en), 3.2.19]

3.2
culvert
transverse drain or waterway structure under a road, railway, or canal, or through an embankment, in the form of a large pipe or enclosed channel

[SOURCE: ISO 6707-1:2017(en), 3.1.2.33]

3.3
return period
average number of years in which a stated action statistically is exceeded once

[SOURCE: ISO 12494:2017(en), 3.8]

3.4
river
natural body of water flowing continuously or intermittently along a well-defined course into an ocean, sea, lake, inland depression, marsh, or other watercourse

[SOURCE: ISO 5667-6:2014(en), 3.9]

3.5
subcritical flow
flow in an open channel at less than critical velocity, that has a Froude number of less than unity, and in which small surface disturbances can travel upstream

[SOURCE: ISO 772:2011(en), 1.7]

3.6
supercritical flow
flow in an open channel at more than critical velocity, that has a Froude number of greater than unity, and in which small surface disturbances cannot travel upstream

[SOURCE: ISO 772:2011(en), 1.8]

3.7
watercourse
channel on or below the earth's surface, through which water may flow

[SOURCE: ISO 6107-7:2006(en), 50]

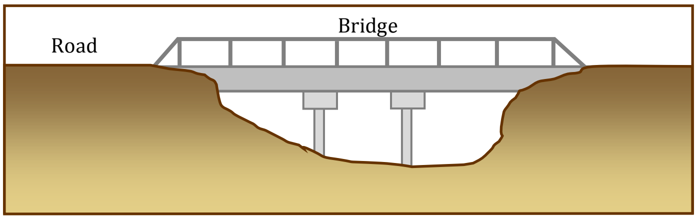
3.8
wetted perimeter
contact length between a stream of flowing water and its containing open channel, measured in a direction normal to the flow

[SOURCE: ISO 772:2011(en), 1.54]

4 Planning

4.1 Selection of structure

The first step in planning is selection of the most appropriate type of structure for crossing a watercourse. The two main types of structure for crossing are bridges and culverts. They both have advantages and disadvantages, as shown in Figure 4.1. There may also be other factors that an engineer needs to consider. If a bridge is a more appropriate, then please refer to the *Bridge Design Standards & Manual* (2).



Bridge

- o Cost of construction: higher
- o Watercourse flow: less affect
- o Debris: less problematic
- o Land-use / environment: less affect

Culvert

- o Cost of construction: lower
- o Watercourse flow: more affect
- o Debris: more problematic
- o Land-use / environment: more affect

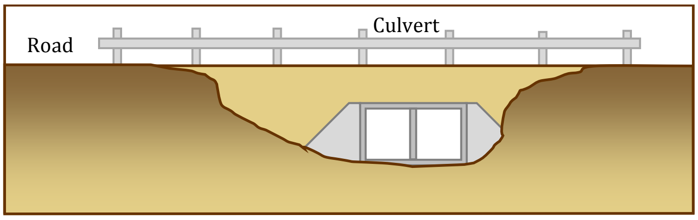


Figure 4.1 — Comparison of application of bridges and culverts

4.2 Overview of culverts

There are various shapes (rectangular box, circular pipe, elliptical pipe, arch pipe, etc.), materials (concrete, corrugated steel, etc.) and inlets (wing walls, flat headwall, square edge at crown, bevel at crown, etc.). These guidelines will primarily cover box culverts made of concrete. The parts of a culvert are shown in Figure 4.2 and Figure 4.3.

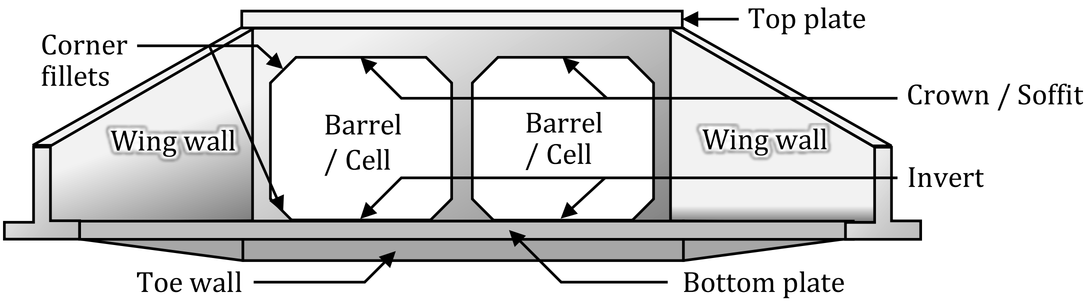


Figure 4.2 — Parts of a culvert on front elevation

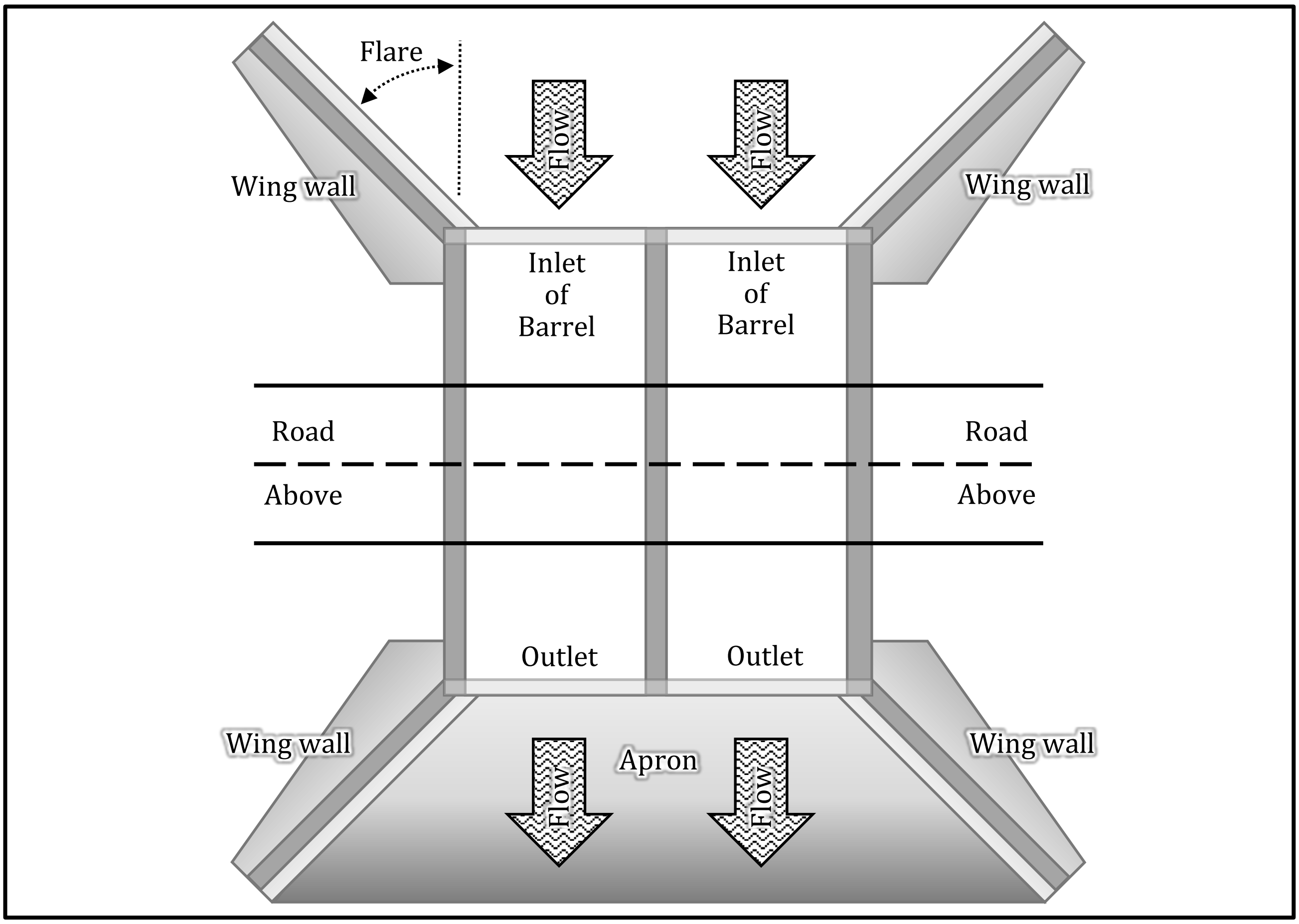


Figure 4.3 — Parts of a culvert on plan

4.3 Application of culverts

There are limitations to the application of culvert structures. The recommended range of application for each barrel of a concrete box culvert is shown in Table 4.1. It is possible to design beyond these limitations with sufficient consideration of structural design and traffic loads.

The proportion of a culvert (height : width) is normally in the range of 1 : 1 to 1 : 3. The most hydraulically efficient proportion is 1 : 2. However, the most normal proportion for road culverts is 1 : 1, because the culvert must structurally support the loads from traffic.

Table 4.1 — Recommended limits for a concrete box culvert (4) (5)

Property	Minimum	Maximum
Height, D	0.75 m (750 mm)	5.0 m (5000 mm)
Width, B	0.45 m (450 mm)	6.5 m (6500 mm)
Cover depth (of material) above top plate	0.5 m (500 mm)	—
Proportion (height : width)	1 : 1	1 : 3
Gradient of culvert	0.005 m/m (0.5%)	0.100 m/m (10%)

In principle, the geometry of a box culvert (width, gradient and bottom elevation) should be similar to the original watercourse in order to reduce sedimentation or erosion. The gradient should be more than (≥) 0.5% or 0.005 m/m to reduce sedimentation, and less than (≤) 10% or 0.100 m/m to ensure workability & prevent slippage.

4.4 Alignment of culverts

Culvert alignment is important for the function of the culvert and watercourse. If possible, the inlet and outlet of the culvert should be located in the natural channel at the intersection with the roadway fill slopes.

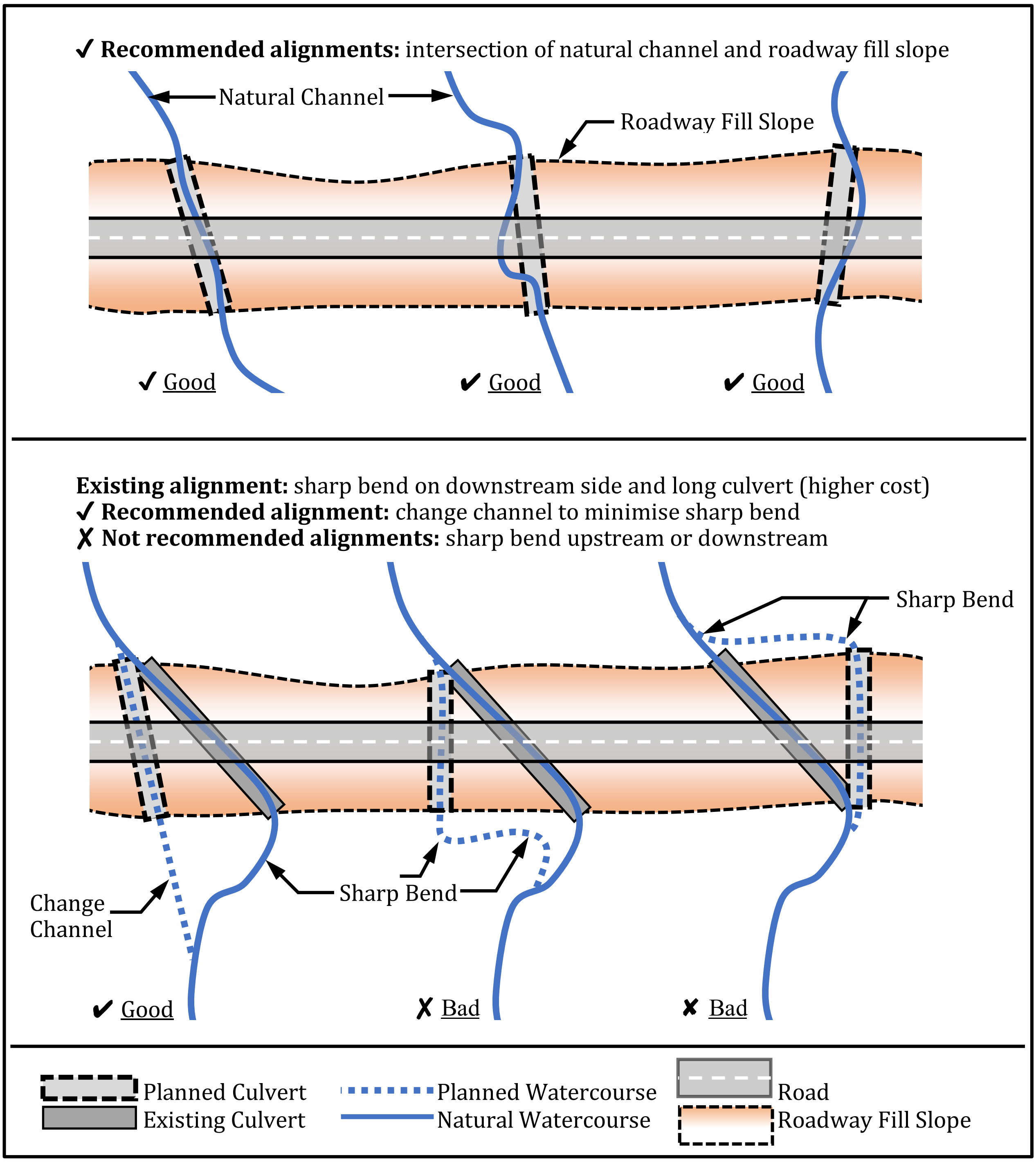


Figure 4.4 — Examples of culvert alignment

4.5 Design process

An outline of the stages for the process of design are shown in Figure 4.5.

Data collection	O Basic site information O Topographic data O Cartographic (map) / geospatial data O Rainfall data	Section 5
Rainfall analysis	O Frequency analysis O Calculation of daily rainfall for design	Section 6
Flood calculation	O Calculation of catchment area O Calculation of time of concentration O Calculation of rainfall intensity O Assessment of run-off coefficient O Calculation of flood discharge	Section 7
Open-channel hydraulics	O Selection of culvert size O Calculation of culvert capacity for discharge O Calculation of flow type and velocity	Section 8
Protection works	O Selection of protection measure and size	Section 9

Figure 4.5 — Outline of process for design

In some cases, a simplified process for design could be adopted, as shown in Figure 4.6. This process is based on adoption of a rainfall intensity of 200 mm/hour from the *Bridge Design Standards & Manual* (2). However, this process may result in excessive or insufficient designs and should be used with caution. This process should only be used for small applications on minor routes, such as rural local roads.

Data collection	O Basic site information O Cartographic (map) / geospatial data	Section 5
Flood calculation	O Calculation of catchment area O Rainfall intensity = 200 mm/hour O Assessment of run-off coefficient O Calculation of flood discharge	Section 7
Open-channel hydraulics	O Selection of culvert size O Calculation of culvert capacity for discharge O Calculation of flow type and velocity	Section 8
Protection works	O Selection of protection measure and size	Section 9

Figure 4.6 — Outline of simplified process for design

5 Data collection

The design of culverts requires an understanding of the site conditions. The following section outlines the various information that should be collected through site investigations and desk studies (off-site investigations).

5.1 Basic site investigation

A basic site investigation should be implemented on site for every culvert design. This information will be necessary for planning and also support the decisions made in the process of design regarding run-off. Examples of the information that is required are shown in Table 5.1 and Figure 5.1.

Table 5.1 — Example checklist of items for site investigation

☑	Information / Item of investigation	Possible source
☐	Coordinates of site location (latitude & longitude)	GNSS (GPS) receiver / smartphone
☐	Measurement of size of existing culvert (m), if any	Tape measure
☐	Measurement of level (m) of normal flow	Tape measure and marks on structures / land
☐	Photograph of normal flow	Camera / smartphone / local residents
☐	Measurement of level (m) of high flow / flood	Tape measure and marks on structures / land
☐	Photograph of high flow / flood	Camera / smartphone / local residents
☐	Date of high flow / flood	Local residents / officers / administration
☐	Photographs of whole site on elevation / along road	Camera / smartphone
☐	Photograph of surrounding mountains / terrain	Camera / smartphone
☐	Photograph of surrounding buildings / land features	Camera / smartphone
☐	Photographs of culvert inlet (proposed/existing)	Camera / smartphone
☐	Photographs of upstream / ascending direction	Camera / smartphone
☐	Photographs of culvert outlet (proposed/existing)	Camera / smartphone
☐	Photographs of downstream / descending direction	Camera / smartphone
☐	Aerial photograph of area	UAV (drone) / Satellite (Google Earth)

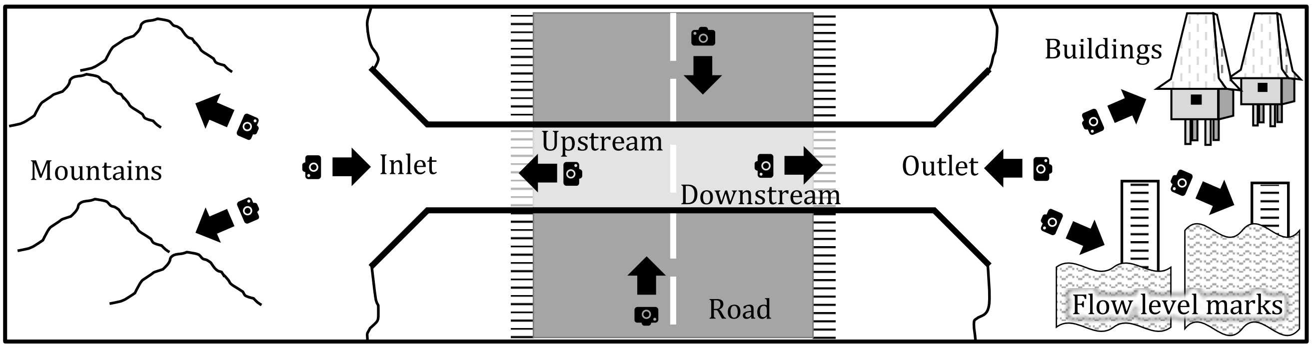


Figure 5.1 — Diagram of site photography

5.2 Topographic investigation

If possible, a topographic investigation should be implemented on site. This information will be necessary for planning and will form a fundamental part of the design calculations regarding the watercourse gradient. In addition, this information can improve the accuracy of a design and facilitate the verification of results. An example of the information that is required is shown in Table 5.2.

Table 5.2 — Example checklist of items for topographic investigation

☑	Information / Item of investigation	Possible source
☐	Level of invert (m AOD) at proposed/existing inlet	Total station / theodolite
☐	Level of invert (m AOD) at proposed/existing outlet	Total station / theodolite
☐	Level of road (m AOD)	Total station / theodolite
☐	Profile of watercourse	Total station / theodolite
☐	Cross sections of watercourse (2 / 3 sections in both directions)	Total station / theodolite

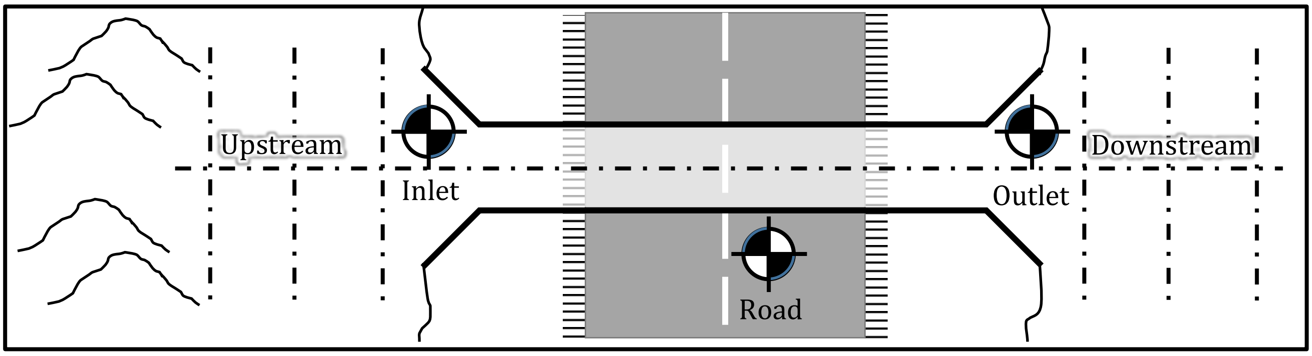


Figure 5.2 — Diagram of basic topographic survey

5.3 Cartographic investigation

A cartographic investigation should be implemented off-site for every culvert design. This map / geospatial information will form a fundamental part of the design calculations regarding the catchment. An example of the information that is required is shown in Table 5.3.

Table 5.3 — Example checklist of items for cartographic investigation

☑	Information / Item of investigation	Possible source
☐	Cartographic map (T755 series of 1:50,000 maps, etc.)	In-house resources (Mapping & GIS)
☐	Digital elevation model (GIS DEM raster)	In-house resources (Mapping & GIS)
☐	Watercourse line (GIS vector)	In-house resources (Mapping & GIS)
☐	Road line (GIS vector)	In-house resources (Mapping & GIS)

5.4 Rainfall data

A pluvial investigation should be implemented off-site for every culvert design. This rainfall data will form a fundamental part of the design calculations regarding the rainfall intensity. An example of the information that is required is shown in Table 5.4.

Table 5.4 — Example checklist of items for pluvial investigation

☑	Information / Item of investigation	Possible source
☐	Monthly rainfall data	In-house resources / relevant authority (see Annex C)
☐	Daily rainfall data	In-house resources / relevant authority (see Annex C)
☐	Short-interval / hourly rainfall data	(currently unavailable in Timor-Leste)

The availability of rainfall data will influence the design. The following are considered ideal characteristics for a set of rainfall data:

- 1+ stations in the catchment or near the catchment

- Records at 15-minute, 30-minute, 1-hour, 2-hour, 3-hour, 6-hour, 12-hour and 24-hour intervals
- Long records (30+ years)

In this case, the process of design can utilise intensity-duration-frequency (IDF) curves, as shown in Figure 5.3. The advantage of IDF curves is that storms can be accurately predicted. The disadvantage is that the development of IDF curves requires a significant amount of rainfall data.

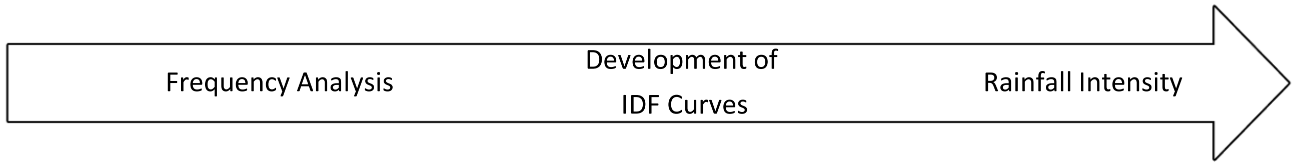


Figure 5.3 — IDF curves in the process of design

Currently, the method of IDF curves cannot be utilised in Timor–Leste, because of the limited length and limited detail of rainfall data. The following is a summary of characteristics for rainfall data in Timor-Leste:

- Currently 82 stations in operation across Timor-Leste (on average, 1 for every 180 km^2)
- Monthly rainfall records exist from 1950s (for 36 stations with gaps)
- Daily rainfall records exist for 40 weather stations (approximate availability)
- Long record of 34 years for daily rainfall in Dili (with gaps)
- Short records of 7 – 11 years for daily rainfall in other areas (approximately)

In the case of Timor-Leste, short-interval rainfall data is not available and only daily rainfall data is available, so the Mononobe formula should be utilised in the process of design, as shown in Figure 5.4. The Mononobe formula is used to derive an approximation of rainfall intensity for any storm duration from daily rainfall data. The advantage of the Mononobe formula is simplicity. However, the disadvantage is that the approximation of storms with short duration (6 hours or less) may not be accurate. The Mononobe formula is explained in more detail in Section 7.4.

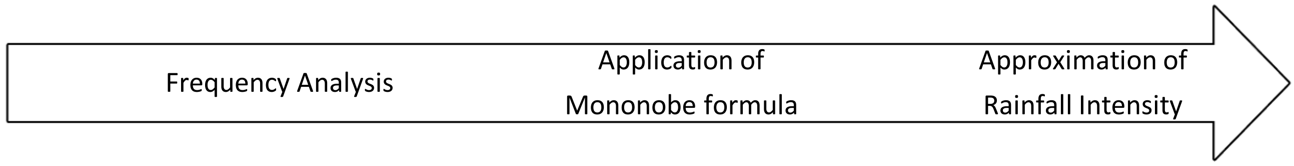


Figure 5.4 — Mononobe formula in the process of design

The rainfall varies depending on the region. The average of the monthly rainfall across the whole country is shown in Figure 5.5. In addition, the variance between the regions is indicated with the following summaries:

- Average of annual rainfall is approximately 1700 mm (whole country)
- Maximum of annual rainfall is approximately 3100 mm (Same)
- Minimum of annual rainfall is approximately 600 mm (Manatuto)

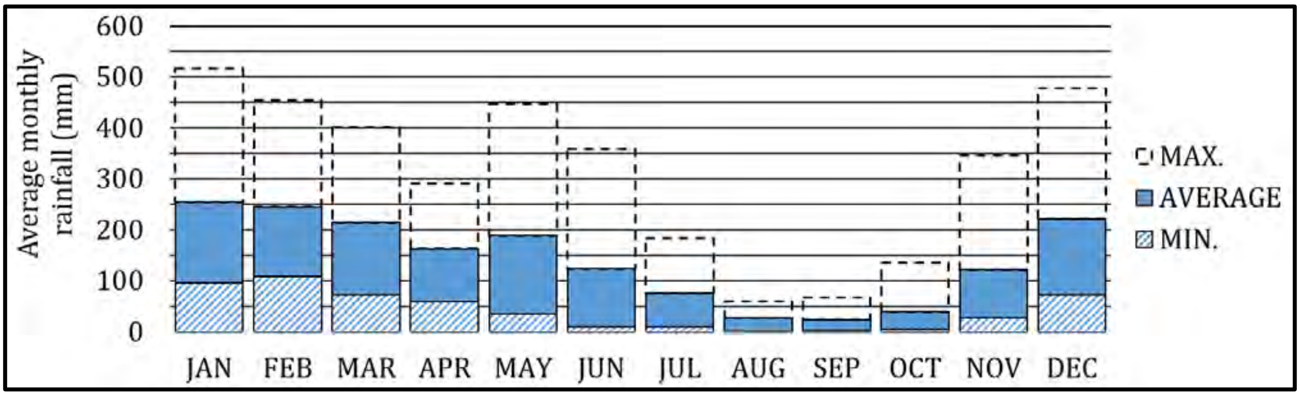


Figure 5.5 — Average of monthly rainfall in Timor-Leste

6 Rainfall analysis

Rainfall analysis reflects the hydrological risk for a road, and ensures protection against probable floods. The input of this process is a long record of daily rainfall, and the output is a maximum probable daily rainfall, also called the design daily rainfall.

The design daily rainfall is determined by analysis of historical rainfall records. The historical rainfall records show the relationship between the frequency of occurrence of storms and the magnitude of storms. The frequency of occurrence for a probable storm / design storm is called the 'return period'. The prediction of the magnitude of the storm for the return period determines the design rainfall.

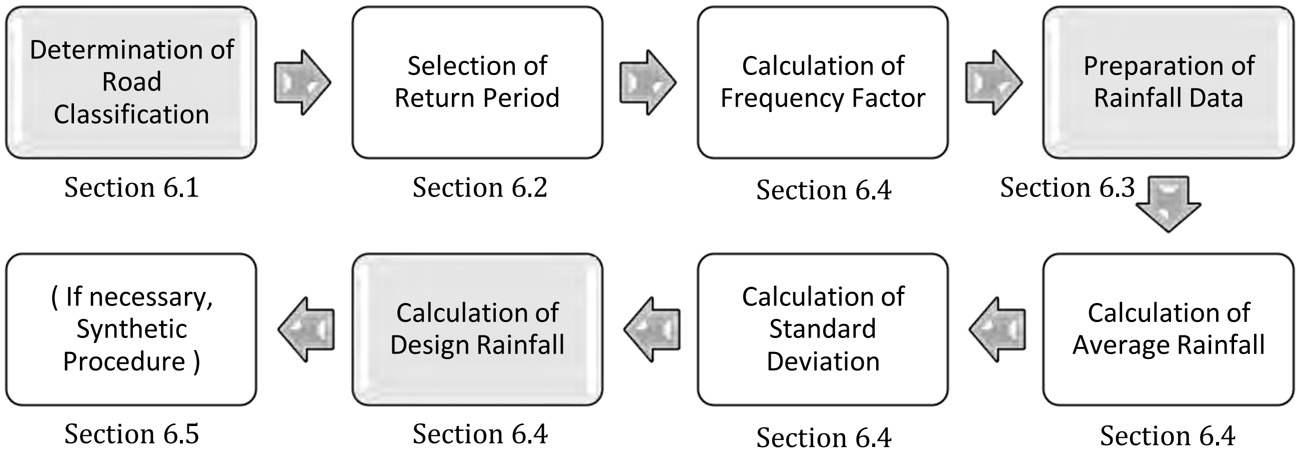


Figure 6.1 — Process of rainfall analysis

6.1 Classification of roads

According to the *Road Geometric Design Standards* (3), the roads in Timor-Leste are classified as shown in Table 6.1.

Table 6.1 — Classification of roads (3)

Rural Roads	Roads outside towns and cities.
National Roads	• Arterial roads are centres of national and international importance and roads terminating at international boundaries, connecting nation's capital and to region's capitals. • Provides high level of service for long distance movement of goods and people and thus to/from central corridors for especially heavy vehicles. • These roads link locations where change of transport mode is possible.
Regional Roads	• Roads that provides more local purposes, serve mainly traffic within regions and districts at lower speeds and shorter distances. • Roads that serve as collector of traffic to/from local network to the national road network.
Local Roads	• Local roads connecting sub-district capitals to villages and more remote areas with agricultural potential.
Urban Roads	Local roads inside towns and cities.
Urban Arterial Roads	• An Urban Arterial Road is a continuous road with partial access control for through traffic within urban areas. Basically it conveys traffic from residential areas to the vicinity of the central business district or from one part of a city to another

	which does not intend to penetrate the city centre. Arterial roads do not penetrate identifiable neighbourhoods. Smooth traffic flow is essential since it carries large traffic volume.
Urban Collector Roads	• A collector road is a road with partial access control designed to serve on a collector or distributor of traffic between the arterial and the local road systems. Collectors are the major roads that penetrate and serve identifiable neighbourhoods, commercial areas and industrial areas.
Urban Local Roads	• The local street system is the basic road network within a neighbourhood and provides direct access to abutting land. They are links to the collector road and thus serve short trip lengths. Through traffic should be discouraged.

6.2 Return period

The return period reflects the hydrological risk for a road. The selection of an appropriate mitigation of risk depends on the economic value / importance of a road asset. The balance between the cost of the road asset and the cost to protect the road asset is important: inadequate protection may allow damage of a road asset and a loss of economic value; excessive protection will cause unnecessary expenditure and an uneconomical solution.

The return period (years) represents probability of occurrence. The return period does not represent a guaranteed period without flooding and it is not related to the design life of a road. The probability of occurrence has an inverse relationship to the magnitude of rainfall events. Therefore, a long return period equals a low probability, which means a high magnitude of rainfall event.

Table 6.2 — Recommended return periods of rainfall for culverts (4) (6)

Road class	Level of drainage capacity	Return period of rainfall
National Roads / Urban Arterial Roads	High	10 years
Regional Roads / Urban Collector Roads	Medium	7 years
Local Roads / Urban Local Roads	Low	5 years

The classification of a road is related to its economic value. Therefore, selection of a return period is recommended based on the classification of a road, as shown in Table 6.2. The return period may be modified by the engineer in situations where a higher level of drainage capacity is desirable. For example, roads that are designed for service of major national assets and where the level of risk must be agreed in conjunction with other national authorities.

6.3 Preparation of rainfall data

The rainfall data for frequency analysis is the maximum of daily rainfall per annum. The preparation of rainfall data for analysis should be implemented in the following manner:

1. Acquisition of daily rainfall data
2. Examination of all data (365 days) in same annum (coeval data)
3. Selection of maximum rainfall value (1 day) per annum
4. Repetition of 2 and 3 (above) for every annum

Complete rainfall records are necessary for analysis. The confirmation of data integrity should be implemented in the following manner:

- If data contains null or erroneous values (for example, " ** " or " — " or " NA " or " -999.9 "), deletion of these values is necessary.
- If data for 1 annum is missing approximately 90 days (¼ annum) of data, then that annum is invalid and cannot be utilized for analysis.

6.4 Frequency analysis

Frequency analysis utilises a probability distribution for the prediction of design rainfall. A probability distribution is a general relationship between the frequency and the magnitude. The probability distribution conforms to the rainfall data, similar to a trend line (or line of tendency). An example of a probability distribution on a bell-shaped diagram is shown in Figure 6.2.

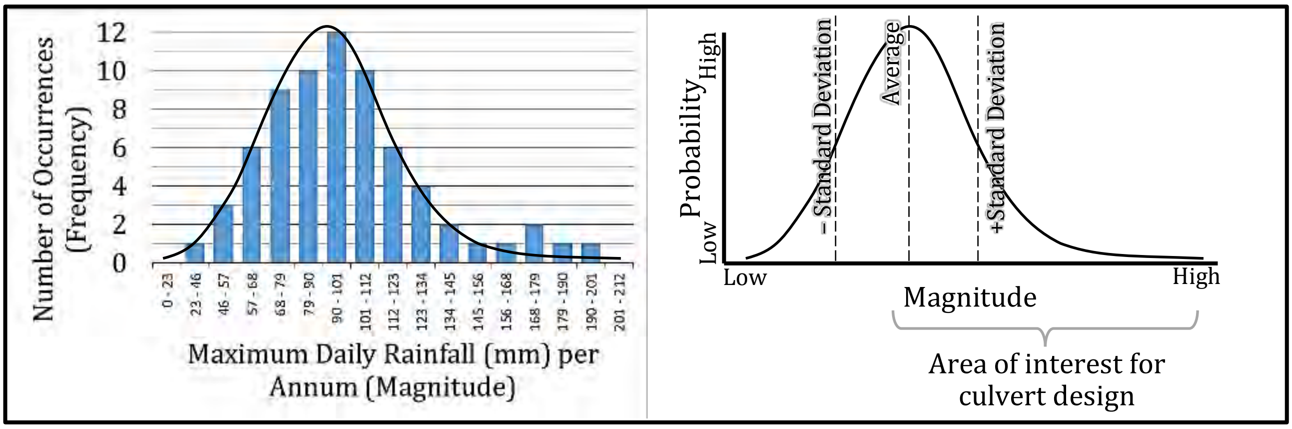


Figure 6.2 — Example of a probability distribution

For culvert design, it is necessary for prediction of higher-magnitude lower-probability for the design rainfall. The process of prediction utilises the 'Gumbel' distribution to represent the rainfall data.

The Gumbel distribution is adjusted to the rainfall data with two parameters: the average and the standard deviation. The return period is incorporated using a frequency factor. In essence, the Gumbel distribution predicts the magnitude of the design rainfall as a departure from the average rainfall. The departure depends on the number of standard deviations, where the number is the frequency factor (return period).

The following is the Gumbel distribution for calculation of the design rainfall:

$$R_{24} = \mu + \sigma \times K \quad [1]$$

where

- R_{24} design rainfall for a given return period (mm/day)
- μ average of rainfall records (mm/day), see equation 2
- σ standard deviation of rainfall records, see equation 3
- K frequency factor, see equation 4

The following is the equation for calculation of the average of rainfall data:

$$\mu = \frac{\sum X_i}{n} \quad [2]$$

where

- μ average of rainfall data (mm/day)
- X_i annual maximum of daily rainfall data values (mm/day)
- n number of rainfall data values

[NOTE: in spreadsheet software, this can be calculated using the AVERAGE function]

The following is the equation for calculation of the standard deviation of rainfall data:

$$\sigma = \sqrt{\frac{\sum(X_i - \mu)^2}{n-1}} \quad [3]$$

where

- σ standard deviation of rainfall data
- X_i annual maximum of daily rainfall data values (mm/day)
- μ average of rainfall records (mm/day)
- n number of rainfall data values

[NOTE: in spreadsheet software, this can be calculated using the STDEV or STDEV.S functions]

The following is the equation for calculation of the frequency factor (incorporation of return period):

$$K = -\frac{\sqrt{6}}{\pi} \times \left(\gamma + ln\left(ln\frac{T}{T-1}\right)\right) \quad [4]$$

where

- K frequency factor (normally between -1 and 5)
- π Pi mathematical constant = 3.14159
- γ Euler–Mascheroni constant = 0.5772
- T return period (years), see Table 6.2

[NOTE: in spreadsheet software, this can be calculated using the SQRT, PI and LN functions]

6.5 Synthetic procedure

In many cases in Timor-Leste, it is necessary to implement a synthetic (compensative) procedure. The reason is that most locations only have short records of rainfall data (see Section 5.4). Therefore, currently, Dili is the only location with rainfall data that is suitable for frequency analysis. Using the frequency analysis of design daily rainfall for Dili, it is possible to synthesise for other locations by scaling up / down (escalate / de-escalate) using the ratio of average annual rainfall as a multiplier. The procedure of deriving daily rainfall for any target location in Timor-Leste using Dili as a basis is shown in Table 6.3.

Table 6.3 — Synthetic procedure for deriving daily rainfall for a target location

Return period of rainfall	Design daily rainfall in Dili, R_{24} (mm/day)		Ratio of annual rainfall (multiplier)
10 years	131.4	×	(Target Location / Dili)
7 years	122.3		(... mm / 940 mm)
5 years	113.6		

For reference, a list of target locations and derived design daily rainfall are shown in Table 6.4.

Table 6.4 — List of target locations and derived design daily rainfall

Target location	Average annual rainfall (mm/day)	Multiplier		Design daily rainfall, R_{24} (mm/day) for return period		
				5 years	7 years	10 years
Dili	940	1.00		113.6	122.3	131.4
Ainaro	2653	2.82		320.5	345.3	370.8
Alas	1965	2.09		237.4	255.7	274.6
Algarve (Fazenda)	1870	1.99		225.9	243.4	261.3
Atauro (Mau-Meta)	871	0.93		105.2	113.4	121.7
Baguia	2399	2.55		289.8	312.2	335.3
Baucau	1208	1.29		145.9	157.2	168.8
Betano	1298	1.38		156.8	168.9	181.4
Bobonaro	2432	2.59		293.8	316.5	339.9
Dare	1533	1.63		185.2	199.5	214.2
Fatubessi	2929	3.12		353.8	381.2	409.3
Fohorem	1536	1.63		185.6	199.9	214.7
Gleno	1765	1.88		213.2	229.7	246.7
Hato-Builico	2418	2.57		292.1	314.7	337.9
Iliomar	2090	2.22		252.5	272.0	292.1
Laga	770	0.82		93.0	100.2	107.6
Laivai	696	0.74		84.1	90.6	97.3
Lautem	1511	1.61		182.5	196.6	211.2
Liquica	1383	1.47		167.1	180.0	193.3
Lore	1669	1.78		201.6	217.2	233.2
Lospalos	1918	2.04		231.7	249.6	268.0
Luro	1707	1.82		206.2	222.2	238.6
Maliana	2062	2.19		249.1	268.4	288.2
Manatuto	610	0.65		73.7	79.4	85.2
Oecusse	1070	1.14		129.3	139.3	149.5
Ossu	1948	2.07		235.3	253.5	272.2
Quelicai	1728	1.84		208.8	224.9	241.5
Same	3117	3.32		376.5	405.7	435.6
Soibada	2396	2.55		289.4	311.8	334.8
Suai	1355	1.44		163.7	176.3	189.4
Tutuala	1511	1.61		182.5	196.6	211.2
Uatolari	1879	2.00		227.0	244.5	262.6
Vemasse	706	0.75		85.3	91.9	98.7
Venilale	1764	1.88		213.1	229.6	246.5
Viqueque	1577	1.68		190.5	205.2	220.4
Zumalai	1328	1.41		160.4	172.8	185.6

NOTE Average annual rainfall values were taken from data records of the Ministry of Agriculture, Forestry and Fisheries (MAFF) for the period 1950s – 1990s. These should be supplemented by recent rainfall data if possible.

7 Design flood

The calculation of design flood determines the volume of water that will be discharged from the catchment during the design rainfall. The design flood determines the required capacity of the culvert. The procedure for calculation of a design flood is shown in Figure 7.1.

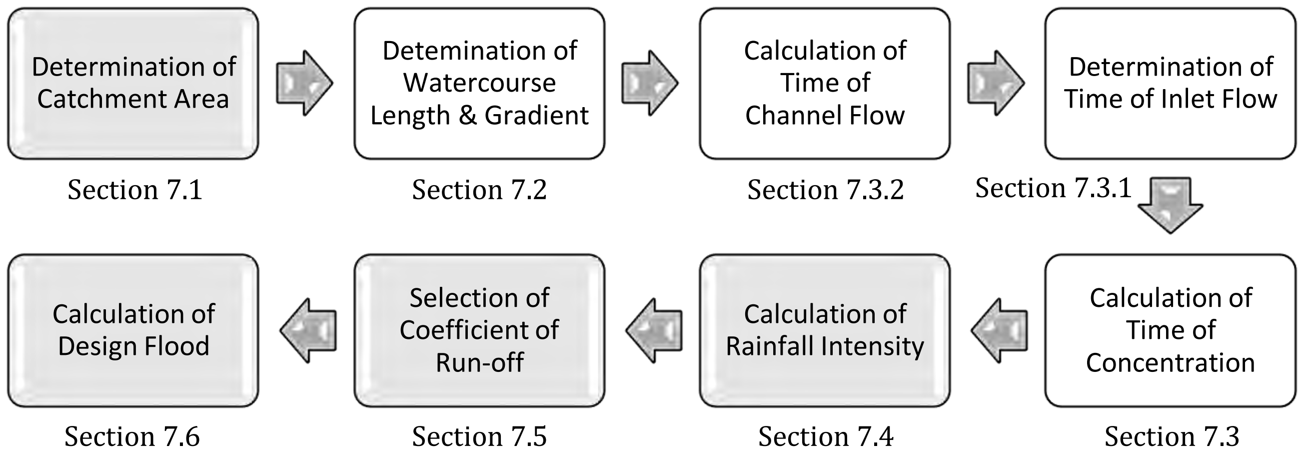


Figure 7.1 — Process of calculation of design flood

7.1 Catchment area

A catchment is an area of land that drains to a point of interest, such as a culvert, as shown in Figure 7.2. All water flow that originates inside the catchment area passes the point of interest before proceeding downstream. The watershed is the boundary between a catchment and its neighbour catchment. The extent of the watershed (boundary) can be identified by connecting the surrounding points with highest elevation, such a mountain summits, hilltops, ridges, saddles and spurs as shown in Figure 7.3.

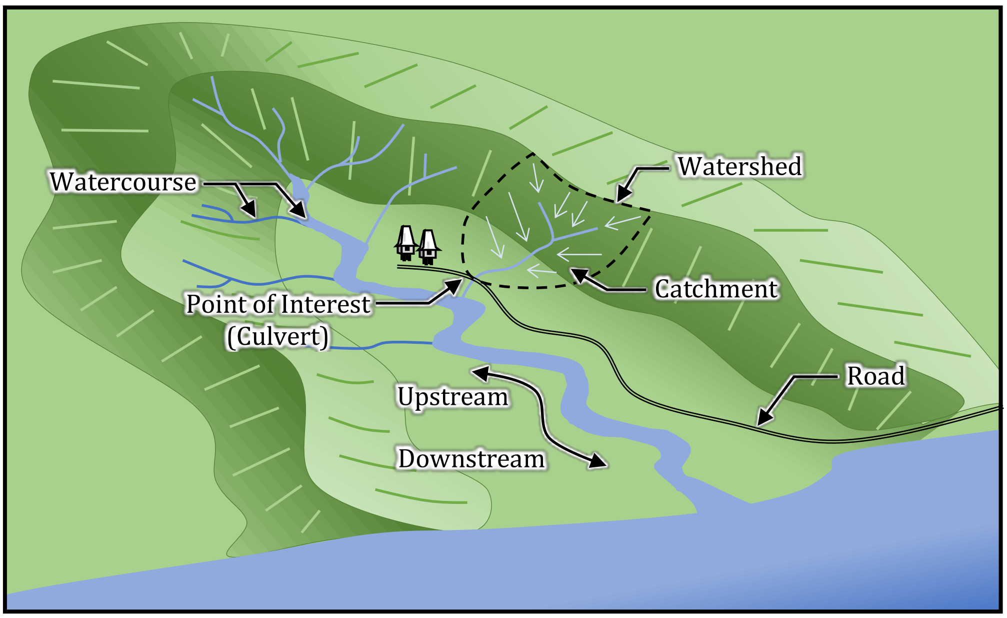


Figure 7.2 — Catchment area within a mountain basin

The size of a catchment has an important influence on the calculation of run-off. The size is expressed as area in terms of km^2 (1 km^2 = 1,000,000 m^2 = 100 ha). Topographical maps (1:50,000, such as T755 series) can be used for determination of catchment area. However, smaller scale maps (1:10,000) or geographic information system (GIS) data are recommended for small catchments. It is important for the designer to visit a site personally to obtain an impression of the characteristics of the catchment.

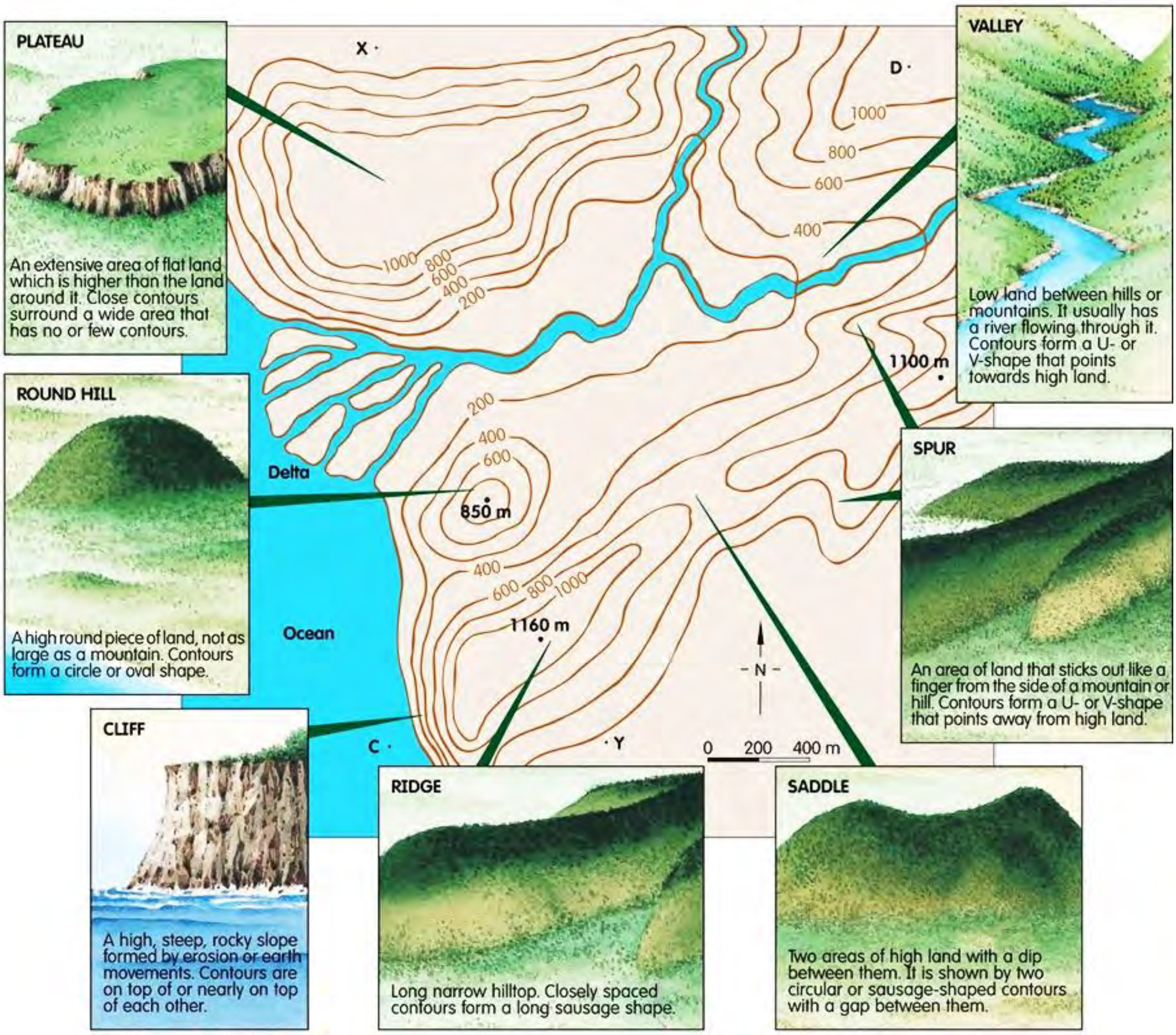


Figure 7.3 — Example of topographic features (7)

Measurement techniques for area include: transferring the catchment outline onto square-lined paper using tracing paper; importing and scaling maps into computer aided design (CAD) software; and using digital elevation models (DEMs, data) and spatial data in a geographic information systems (GISs, software). Usage of GISs is the recommended measurement technique for accurate results. If possible, a request for information should be made to the GIS & Mapping Section of DNEPCC.

The GIS & Mapping Section can analyse a catchment either by delineating a watershed based on contours (in other words, drawing a polygon shape file to represent a catchment) or by using algorithms to derive watersheds from digital elevation models (DEMs). Examples of algorithms for delineation include “r.watershed” and “r.water.outlet” in GRASS Tools of QGIS software, and “Watershed” in Spatial Analyst toolbox of ArcGIS software. An example sequence for delineating a watershed from a DEM is as follows:

- Step 1) Fill the depressions in the DEM
- Step 2) Calculate flow directions
- Step 3) Delineate the catchment and derive its area
    - Step 3.1) Choose the point of interest (“Outlet” in QGIS and “Pour Point” in ArcGIS)
    - Step 3.2) Delineate the watershed
    - Step 3.3) Calculate the area

In addition to the total catchment area, calculation of the sub-catchment areas is required if locations have distinctly different types of terrain. The boundary of terrain types can be analysed by site investigation, by satellite imagery or by land cover data.

7.2 Watercourse properties

Similar to Section 7.1, watercourse properties can be measured with topographical maps, CAD software or GIS. If possible, a request for information should be made to the GIS & Mapping Section of DNEPCC.

The watercourse properties required for calculation of time of concentration are the length and the gradient. The length of a watercourse (L) should be measured from the furthest discernible start of a watercourse to the point of interest, as shown in Figure 7.4.

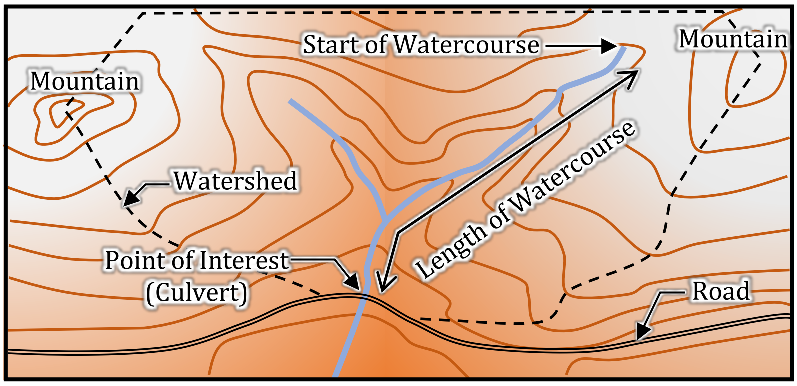


Figure 7.4 — Measurement of length of watercourse

The average gradient should be used for the gradient of a watercourse (G), as shown in Figure 7.5. The calculation of average gradient requires lengths (L values) and the heights (H values) at several points along the profile of the watercourse. In most spreadsheet software, the average gradient can be calculated utilising the LINEST function: *LINEST([H values] , [L values] , FALSE)* gives a result in m/m or *LINEST([H values] , [L values] , FALSE)*100* gives a result in percentage (%).

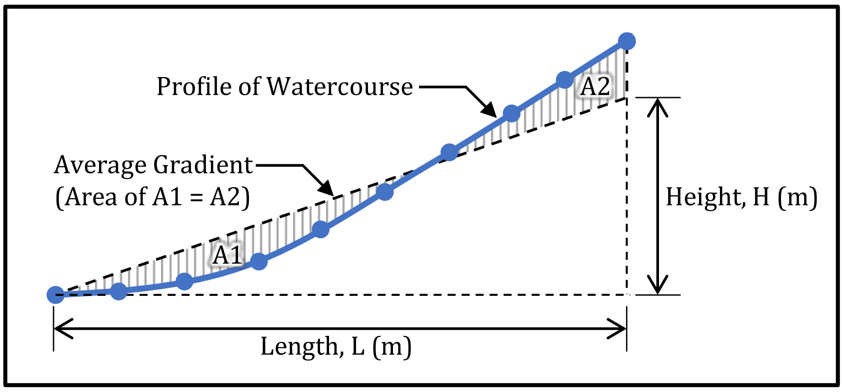


Figure 7.5 — Calculation of average gradient of watercourse

7.3 Time of concentration

The time of concentration is required for the calculation of rainfall intensity. The time of concentration is the time for water to flow from the furthest point in the watershed (i.e. the mountain) to the point of interest (i.e. the culvert). Different areas of a watershed contribute to run-off at different times after rainfall begins. Time at which all parts of the watershed begin contributing to the run-off from the basin, as shown in Figure 7.6. The time of concentration is calculated with equation 5.

The following is the equation for calculation of time of concentration:

$$t_c = t_e + t_f \quad [5]$$

where

t_c time of concentration (hours)

t_e time of flow from watershed to watercourse (hours), see Table 7.1

t_f time of flow from start of watercourse to point of discharge (hours), see equation 6

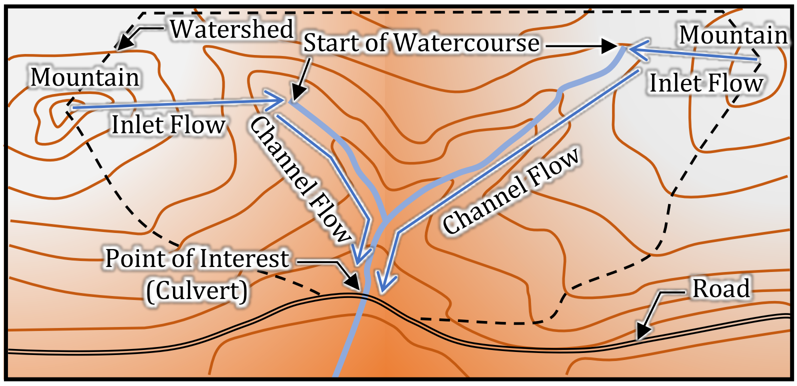


Figure 7.6 — Time of concentration

7.3.1 Time for inlet flow

The time for inlet flow is the time for surface flow to travel from the watershed to the start of the watercourse.

Table 7.1 — Inlet flow times (4)

Catchment type	Inlet time (minutes)	Inlet time (hours)
Mountainous land	15.0 – 30.0	0.25 – 0.50
Cut slopes	3.0 – 5.0	0.05 – 0.083
Urban areas	5.0	0.083

7.3.2 Time for channel flow

The time for channel flow is the time for surface flow to travel from the start of the watercourse to the point of interest (culvert). The Kraven Formula is an empirical equation based on basin data.

The following is the Kraven Formula for calculation of the time for channel flow:

$$t_f = \frac{L}{3600 \times W} \quad [6]$$

where

t_f time of flow from start of watercourse to point of discharge (hours)

L watercourse length (m)

W velocity of run-off (m/s), see Table 7.2

Table 7.2 — Velocity of run-off (4)

Gradient of watercourse, G			Velocity of run-off, W (m/s)
> 1 / 100	> 1.0%	> 0.010 m/m	3.5
1 / 200 – 1 / 100	0.5% – 1.0%	0.005 – 0.010 m/m	3.0
< 1 / 200	< 0.5%	< 0.005 m/m	2.1

7.4 Intensity of rainfall

Generally, storm intensity is inversely proportionate to storm duration for most climates. This inverse relationship means that shorter-duration storms have higher intensity of rainfall and longer-duration storms have lower intensity of rainfall, as shown in Figure 7.7.

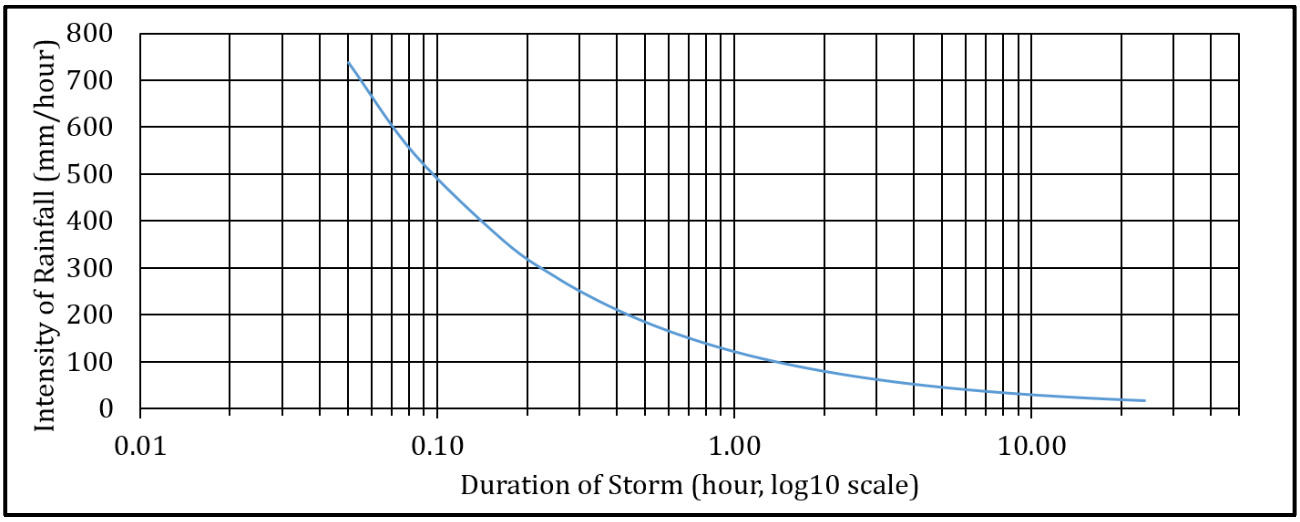


Figure 7.7 — Example of the inverse relationship of an intensity-duration curve

The design intensity of rainfall is when the duration of a storm is equal to the time of concentration, as shown by (b) in Figure 7.8. As shown in (a), when the duration of a storm is less than the time of concentration, then all of the catchment area is not discharging to the culvert, so it is not the maximum discharge. As shown in (c), when the duration of a storm is more than the time of concentration, then the intensity of rainfall will be lower, so it is also not the maximum discharge. Time of concentration is when all parts of the watershed start to contribute to the run-off from the basin and this is when the design intensity of rainfall occurs.

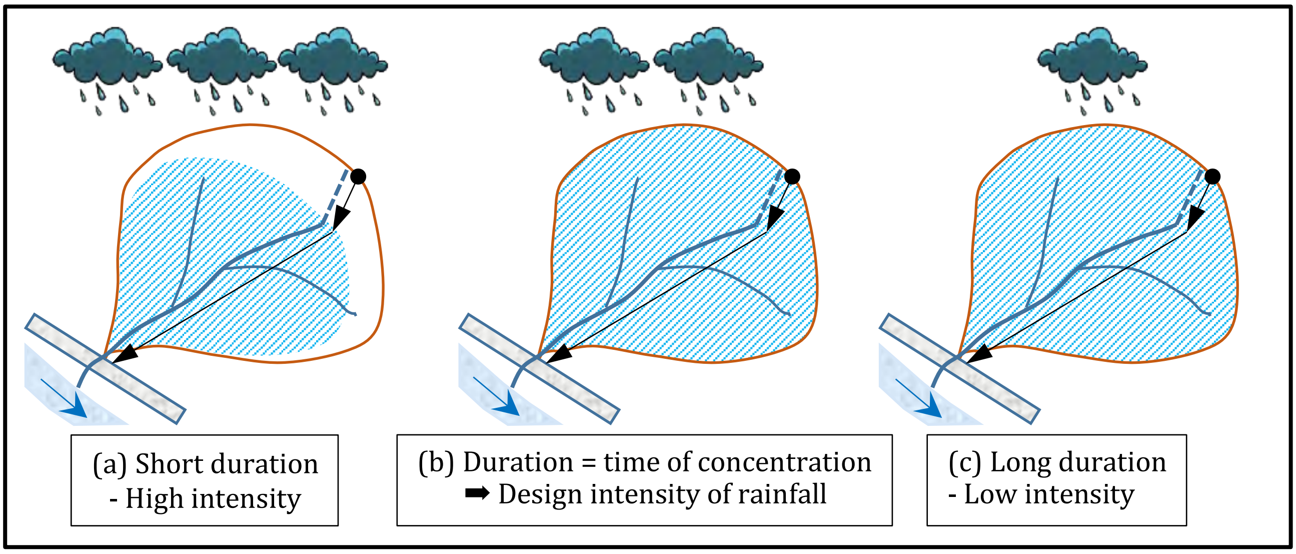


Figure 7.8 — Design intensity of rainfall for maximum probable discharge

As mentioned in Section 5.4, there is insufficient rainfall data in Timor-Leste for creation of intensity-duration curves, such as Figure 7.7. The Mononobe Formula is an empirical equation for estimation of intensity of rainfall. It is a practical solution for applications with few rainfall data.

The following is the Mononobe Formula for calculation of the rainfall intensity:

$$i = \frac{R_{24}}{24} \times \left(\frac{24}{t_c}\right)^{0.6} \quad [7]$$

where

- i rainfall intensity (mm/hour)
- R_{24} design daily rainfall (mm/day), see Section 6
- t_c time of concentration (hours), see equation 5

The disadvantage of the Mononobe Formula is that it may not accurately predict intensity of rainfall for storms with a short duration (<6 hours). It is recommended that Timor-Leste collects rainfall data at 15-minute, 30-minute, 1-hour, 2-hour, 3-hour, 6-hour, 12-hour and 24-hour intervals in all weather stations. Provided this data can be collected, intensity-duration-frequency (IDF) charts could be developed by 2050 and hydrological design techniques could be refined.

7.5 Coefficient of run-off

Run-off is water from rainfall that flows on the surface (in other words, surface flow). The amount of rainfall that becomes run-off flow depends on the amount of water lost by infiltration and evaporation. This loss of water due to infiltration and evaporation is represented by a coefficient of run-off. Therefore, the coefficient of run-off is the proportion of rainfall that becomes run-off.

Recommended coefficients of run-off, C, are shown in Table 7.3. A higher coefficient of run-off indicates that more rainfall becomes run-off, and likewise a lower coefficient of run-off indicates the less rainfall becomes run-off.

If you a catchment area contains different types of terrain, then application of a weighted coefficient is recommended. The weighted coefficient should be calculated as shown in equation 8.

Table 7.3 — Coefficients of run-off (4)

Terrain type	Coefficient of run-off	Average value
Road surfaces and sloped surfaces	0.70 – 1.00	0.85
Steep mountainous land	0.75 – 0.90	0.83
Gentle mountainous land	0.70 – 0.80	0.75
Undulating land and woods	0.50 – 0.75	0.63
Flat farmlands	0.45 – 0.60	0.53
Rice paddy (fields)	0.70 – 0.80	0.75
Urban areas	0.60 – 0.90	0.75
Forest zones	0.20 – 0.40	0.30
Catchment areas of mountain streams	0.75 – 0.85	0.80
Catchment areas of small rivers on flat land	0.45 – 0.75	0.60
Catchment areas of major rivers of which more than half run on flat land	0.50 – 0.75	0.63

The following is the equation for calculation of a weighted coefficient of run-off:

$$C = \frac{(C_1 \times A_1 + C_2 \times A_2 + \cdots + C_n \times A_n)}{(A_1 + A_2 + \cdots + A_n)} \quad [8]$$

where

- C weighted coefficient of run-off (dimensionless)
- $C_{1,2,n}$ coefficients of run-off for different types of terrain (dimensionless), see Table 7.3
- $A_{1,2,n}$ areas of catchments with different types of terrain (m^2), see Section 7.1

7.6 Rational method

The Rational Method shall be applied for calculation of a design flood. It was first proposed in 1851 by an Irish engineer called Mulvaney. It is based on a simplistic relationship between rainfall and run-off for empirical prediction of discharge from a catchment. This method is appropriate for the following design conditions:

- Calculation of peak discharge
- Ungauged sites (without streamflow / river data)
- Deterministic analysis based on rainfall
- Catchments without significant water storage (no lakes, no ponds, no wetlands, etc.)
- Applicable < 15.0 km^2 (5)
- Best suited ≤ 0.8 km^2 (7)

The limitation of application to catchments < 15.0 km^2 is because the coefficient of run-off cannot accurately represent water storage (or hydrologically complex catchments). The method assumes that intensity of rainfall is uniform over the catchment; hence, the peak run-off is assumed to occur when duration of a storm equals the time of concentration.

The following is the Rational Method equation for calculation of peak discharge:

$$Q_P = \frac{1}{3.6} \times C \times i \times A \qquad [9]$$

where

Q_P peak discharge or design flood of a watercourse (m^3/s)
C coefficient of run-off, see Table 7.3
i rainfall intensity (mm/hour), see equation 7
A catchment area of watercourse (km^2)

As mentioned in Section 4.5, a simplified process for design based on adoption of a rainfall intensity of 200 mm/hour from the *Bridge Design Standards & Manual* (2) could be used for small applications on minor routes, such as rural local roads. For reference, design floods of the simplified process are shown in Table 7.4.

Table 7.4 — Examples of design floods for small applications using the simplified process

Coefficient of run-off, C	Design flood, Q_P, (m^3/s) for a catchment area of									
	0.1 km^2	0.2 km^2	0.3 km^2	0.4 km^2	0.5 km^2	0.6 km^2	0.7 km^2	0.8 km^2	0.9 km^2	1.0 km^2
0.20	1.2	2.3	3.4	4.5	5.6	6.7	7.8	8.9	10.0	11.2
0.30	1.7	3.4	5.0	6.7	8.4	10.0	11.7	13.4	15.0	16.7
0.40	2.3	4.5	6.7	8.9	11.2	13.4	15.6	17.8	20.0	22.3
0.45	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
0.50	2.8	5.6	8.4	11.2	13.9	16.7	19.5	22.3	25.0	27.8
0.55	3.1	6.2	9.2	12.3	15.3	18.4	21.4	24.5	27.5	30.6
0.60	3.4	6.7	10.0	13.4	16.7	20.0	23.4	26.7	30.0	33.4
0.65	3.7	7.3	10.9	14.5	18.1	21.7	25.3	28.9	32.5	36.2
0.70	3.9	7.8	11.7	15.6	19.5	23.4	27.3	31.2	35.0	38.9
0.75	4.2	8.4	12.5	16.7	20.9	25.0	29.2	33.4	37.5	41.7
0.80	4.5	8.9	13.4	17.8	22.3	26.7	31.2	35.6	40.0	44.5
0.85	4.8	9.5	14.2	18.9	23.7	28.4	33.1	37.8	42.5	47.3
0.90	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0

NOTE: The above values are for the simplified process that adopts a rainfall intensity of 200 mm/hour. These values should be used with caution. Where possible, the full process should be used and rainfall intensity should be calculated.

8 Open-channel hydraulics

Open-channel hydraulics is characterised by water flowing under gravity and at atmospheric pressure due to the water surface being in contact with the air (a free surface). The process of design is outlined in Figure 8.1

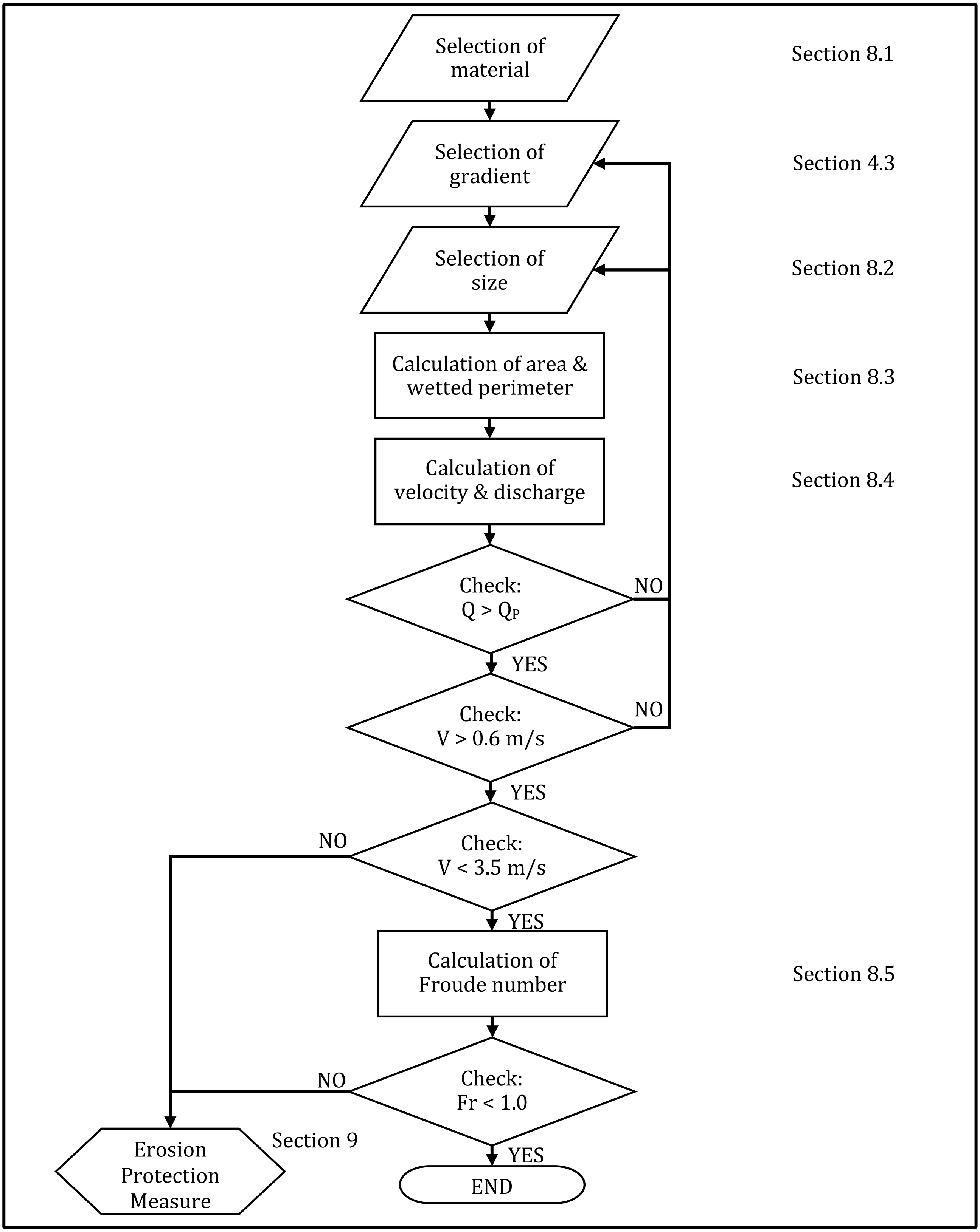


Figure 8.1 — Process of calculation of open-channel flow

8.1 Material of culverts

The material (and condition) of a channel determines the roughness. The roughness is the representation of the frictional resistance of the boundary shear force. For uniform flow calculations, the gravity forces must balance the frictional resistance forces which constitute the boundary shear force (τ). This concept is outlined in Figure 8.2.

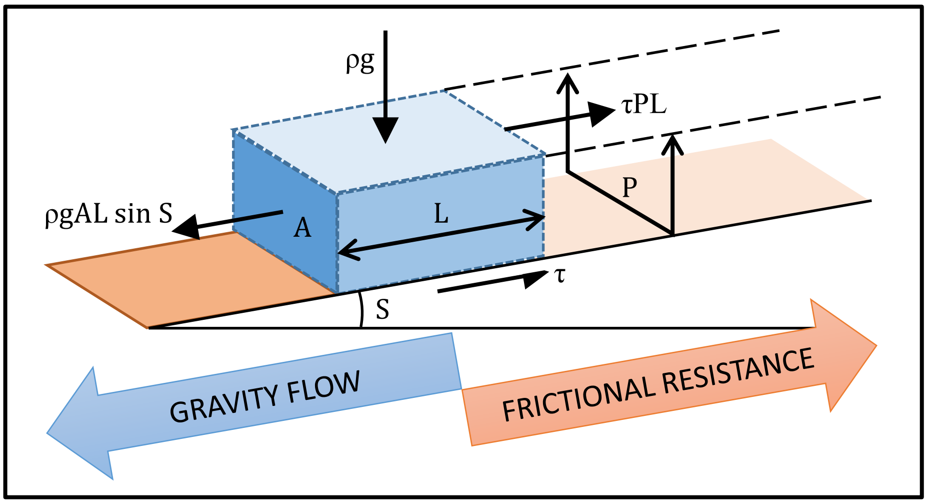


Figure 8.2 — Concept of uniform flow

The roughness is represented in the calculation of flow by the Manning number, *n*. The normal material for construction of box culverts is concrete. The recommended values of Manning number for concrete are shown in Table 8.1.

Table 8.1 — Recommended values of Manning number (4)

Material of culvert	Manning number, *n*
Concrete:	
Cast in-situ concrete	0.015
Factory-made concrete products	0.013

8.2 Size of culvert

It is recommended that selection of the size of a culvert is in accordance with the relevant structural design standard. For reference, the size of culverts are shown in Table 8.2, Table 8.3 and Table 8.4.

Table 8.2 — Standard dimensions for single culverts (8)

Width, b (mm)	Height, D (mm)	Thickness of wall & fillets, w (mm)
1000	1000	160
1000	1500	170
1000	2000	180
2000	1000	220
2000	1500	230
2000	2000	250
2000	2500	260
2000	3000	280
3000	1500	280
3000	2000	300
3000	2500	300
3000	3000	300

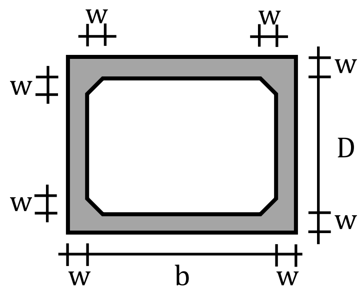


Table 8.3 — Standard dimensions for double culverts (9)

Width, b (mm)	Height, D (mm)	Thickness of wall & fillets, w (mm)
1500	1000	200
2000	1000	240
2000	1500	240
2000	2000	240
2000	2500	250
2000	3000	260
2500	1500	260
2500	2000	260
2500	2500	260
2500	3000	280
3000	1500	300
3000	2000	300
3000	2500	300
3000	3000	300

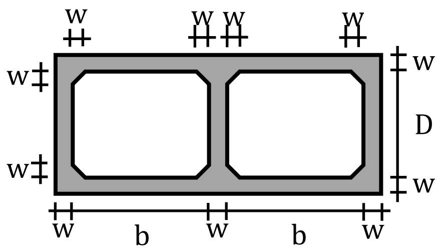
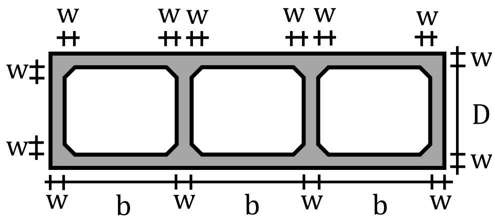


Table 8.4 — Standard dimensions for triple culverts (10)

Width, b (mm)	Height, D (mm)	Thickness of wall & fillets, w (mm)
1500	1000	160
1500	1500	170
1500	2000	180
1500	2500	220
1500	3000	260
2000	1000	200
2000	1500	220
2000	2000	250
2000	2500	260
2000	3000	300
2500	1500	280
2500	2000	280
2500	2500	280
2500	3000	300
3000	1500	300
3000	2000	300
3000	2500	300
3000	3000	300



8.3 Geometry of culverts

The geometry of a culvert affects the frictional resistance. In addition to the boundary roughness, frictional resistance will increase as the size of the boundary increases. The size of the boundary is calculated as follows.

The area is the cross-sectional area of flow in the direction normal (perpendicular) to the direction of flow. The wetted perimeter is the length of the perimeter that is in contact with the flow measured in the direction normal (perpendicular) to the direction of flow. The hydraulic radius is the ratio of the area to the wetted perimeter, as shown in equation 10. The surface width is the width of the channel at the free surface.

The following is the general equation for calculation of hydraulic radius:

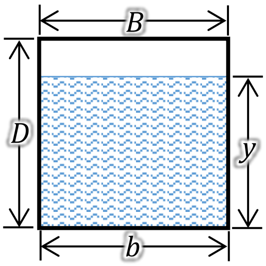
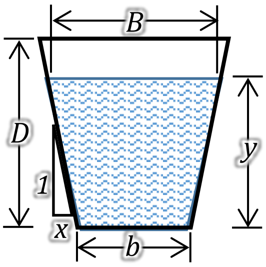
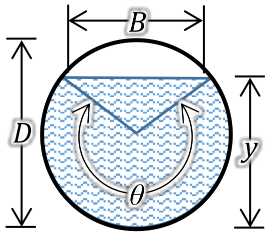
$$R = \frac{A}{P} \qquad [10]$$

where

- R hydraulic radius (m)
- A cross-sectional area of flow (m^2)
- P wetted perimeter (m)

The equations for calculating the properties for geometries of some channels are shown in Table 8.5. These guidelines are concerning box culverts, so equations for rectangular geometries shall be applied. The equations for trapezoidal and circular geometries have been provided for reference only.

Table 8.5 — Geometric properties for channels

Geometry	 **Rectangle (box)**	 **Trapezoid**	 **Circle (pipe)**
Area of flow, A (m^2)	$b \times y$	$(b + x \times y) \times y$	$\frac{1}{8} \times (\theta - sin\,\theta) \times D^2$
Wetted perimeter, P (m)	$b + 2 \times y$	$b + 2 \times y \times \sqrt{1 + x^2}$	$\frac{1}{2} \times \theta \times D$
Hydraulic radius, R (m)	$\frac{b \times y}{b + 2 \times y}$	$\frac{(b + x \times y) \times y}{b + 2 \times y \times \sqrt{1 + x^2}}$	$\frac{1}{4} \times \left(1 - \frac{sin\,\theta}{\theta}\right) \times D$
Surface width, B (m)	b	$b + 2 \times x \times y$	$\left(sin\frac{\theta}{2}\right) \times D$
Angle of flow, θ (radians)			$2 \times \cos^{-1}\left(1 - 2 \times \frac{y}{D}\right)$

where
- b base width (m)
- y depth of flow (m)
- D internal height or diameter (m)
- x width per 1-m height of side slope (m)
- θ angle of flow (radians)

8.4 Design capacity of culverts

The design capacity of discharge for culverts is calculated with equation 11. The design capacity should be more than the design flood, ($Q > Q_P$).

The following is the equation for calculation of design capacity for culverts:

$$Q = \frac{A^{5/3} \times S_0^{\;1/2}}{P^{2/3} \times n} \qquad [11]$$

where
- Q design capacity of culvert (m^3/s)
- A area of flow (m^2)
- P wetted perimeter (m)
- S_0 gradient of culvert (m/m)

For reference, it should be noted that equation 11 is a combination of the equation for discharge and the Manning equation, as shown below in equations 12 and 13, respectively.

The following is the general equation for calculation of discharge:

$$Q = A \times V \qquad [12]$$

where
- Q design capacity of culvert (m^3/s)
- A area of flow (m^2)
- V velocity of flow (m/s), see equation 13

Sedimentation and debris affects the hydraulic performance of culverts. A margin of 20% of cross-sectional area (A) is recommended for anticipation of sedimentation. In other words, depth of flow should be designed as less than or equal to 80% of the internal height of a box culvert ($y \leq 0.8 \times D$).

The following is the Manning equation for calculation of velocity for culverts:

$$V = \frac{1}{n} \times R^{2/3} \times S_0^{1/2} \qquad [13]$$

where

- V velocity of flow (m/s)
- n Manning coefficient of roughness, see Table 8.1
- R hydraulic radius (m), see Section 8.3
- S_0 culvert gradient (m/m)

The velocity of flow affects the erosion and sedimentation of a culvert. The normal range of velocity of flows are 0.6 m/s ≤ V < 3.5 m/s. In order to reduce the amount of sedimentation, it is recommended that flow velocities are more than 0.6 m/s; if not, regular maintenance should be considered. In order to reduce the amount of erosion, it is recommended that flow velocities are less than 3.5 m/s; if not, erosion protection measures should be considered.

Examples of the design capacity of culverts at various gradients is shown in Table 8.6.

Table 8.6 — Design capacities for example culverts

Size of culvert			Design capacity, Q, (m^3/s) for gradient of							
b (m)	**D (m)**	**y (m)**	**0.5%**	**1.0%**	**1.5%**	**2.0%**	**2.5%**	**3.0%**	**5.0%**	**7.0%**
1.0	1.0	0.8	1.72	2.43	2.98	3.44	3.84	4.21	5.44	6.43
1.0	1.5	1.2	2.83	4.00	4.89	5.65	6.32	6.92	8.93	10.57
1.0	2.0	1.6	3.96	5.61	6.87	7.93	8.86	9.71	12.53	14.83
1.5	1.0	0.8	3.00	4.25	5.20	6.01	6.72	7.36	9.50	11.24
1.5	1.5	1.2	5.07	7.17	8.78	10.14	11.33	12.41	16.03	18.96
1.5	2.0	1.6	7.23	10.22	12.52	14.46	16.16	17.70	22.86	27.04
1.5	2.5	2.0	9.44	13.35	16.35	18.88	21.11	23.13	29.86	35.33
1.5	3.0	2.4	11.69	16.53	20.24	23.37	26.13	28.63	36.95	43.73
2.0	1.0	0.8	4.39	6.21	7.61	8.79	9.82	10.76	13.89	16.44
2.0	1.5	1.2	7.55	10.68	13.08	15.11	16.89	18.50	23.88	28.26
2.0	2.0	1.6	10.91	15.43	18.90	21.83	24.40	26.73	34.51	40.84
2.0	2.5	2.0	14.39	20.35	24.92	28.78	32.18	35.25	45.51	53.84
2.0	3.0	2.4	17.94	25.37	31.07	35.88	40.11	43.94	56.73	67.12
2.5	1.5	1.2	10.20	14.42	17.66	20.39	22.80	24.98	32.25	38.15
2.5	2.0	1.6	14.89	21.06	25.79	29.78	33.30	36.47	47.09	55.72
2.5	2.5	2.0	19.79	27.98	34.27	39.58	44.25	48.47	62.58	74.04
2.5	3.0	2.4	24.82	35.10	42.99	49.64	55.49	60.79	78.48	92.86
3.0	1.5	1.2	12.95	18.32	22.43	25.90	28.96	31.72	40.95	48.46
3.0	2.0	1.6	19.08	26.98	33.04	38.16	42.66	46.73	60.33	71.38
3.0	2.5	2.0	25.52	36.09	44.21	51.04	57.07	62.52	80.71	95.49
3.0	3.0	2.4	32.18	45.51	55.73	64.35	71.95	78.82	101.75	120.40

8.5 Type of flow

In addition to velocity of flow, the type of flow should be considered when assessing if erosion protection measures are necessary. The type of flow can be considered with the Froude number, as shown in Figure 8.3. The Froude number indicates the flow type as follows:

- $Fr > 1$: supercritical flow (fast)
- $Fr = 1$: critical flow (change point)
- $Fr < 1$: subcritical flow (slow)

The following is the equation for calculation of Froude number and simplification for box culverts:

$$Fr = \frac{V}{(g \times y)^{0.5}} = \left(\frac{{Q_P}^2 \times b}{g \times (y_n \times b)^3}\right)^{0.5} \qquad [14]$$

where

- Fr Froude number (dimensionless)
- V velocity of flow (m/s)
- g gravitational acceleration (m/s^2) = 9.81 m/s^2
- y depth of flow (m)
- Q_P peak discharge or design flood of a watercourse (m^3/s)
- y_n normal depth of flow (m)
- b base width of culvert (m)
- g gravitational acceleration (m/s^2) = 9.81 m/s^2

Normal depth of flow, y_n, can be calculated by changing the depth of flow, y, and subsequently recalculating the area, A, and wetted perimeter, P, for equation 11 until the design capacity is equal to the design flood ($Q = Q_P$). Alternatively, the Newton-Raphson Method may also be used for efficient convergence of $Q = Q_P$.

In addition to high velocity of flow, erosion protection measures at outlets should be considered for supercritical flows where Fr > 1. Recommendations for selection and dimensions of erosion protection measures are outlined in Section 9.

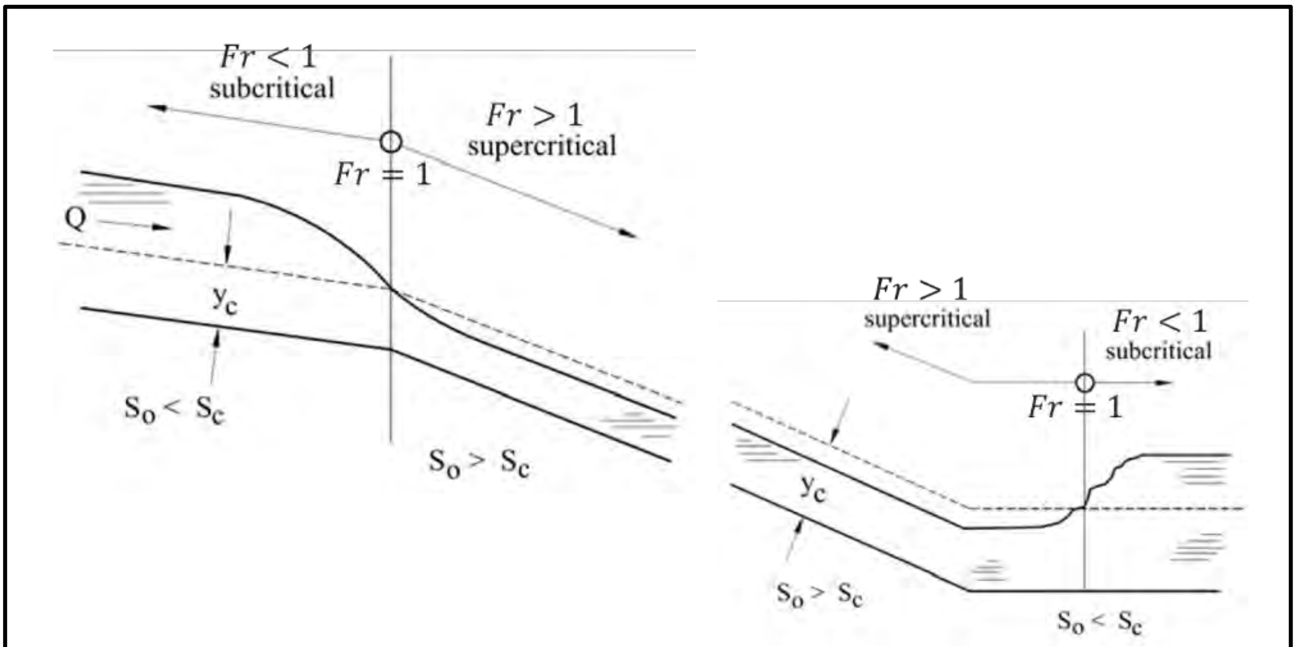


Figure 8.3 — Concept of Froude number indicating type of flow (5)

9 Protection works

Protection measures are necessary where erosion can occur. Outlets of culverts are more problematic and examples of erosion are shown in Figure 9.1. Generally, erosion occurs where:

- velocity of flow is high / flow is supercritical, see Sections 8.4 and 8.5
- direction of flow changes rapidly (i.e. sharp bends), see Section 4.4

Figure 9.1 — Examples of erosion at culvert outlets (7)

9.1 Inlet protection

Erosion upstream of culverts is rarely a problem if inlets have standard wing walls. In case of erosion, provision of stone pitching or gabion mat, or construction of a concrete apron between the wing walls is usually sufficient. Stone pitching of size 200 mm and for a distance of twice the culvert height is normal, as shown in Figure 9.2. A concrete apron at the inlet is shown in Figure 9.3.

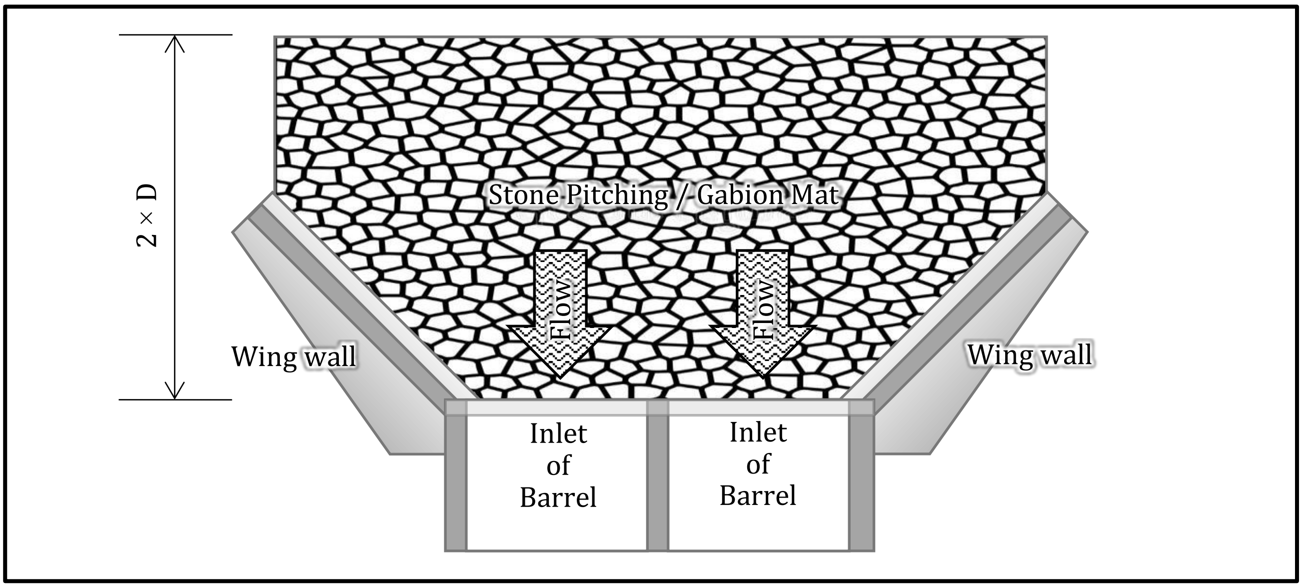


Figure 9.2 — Inlet protection using stone pitching / gabion mat

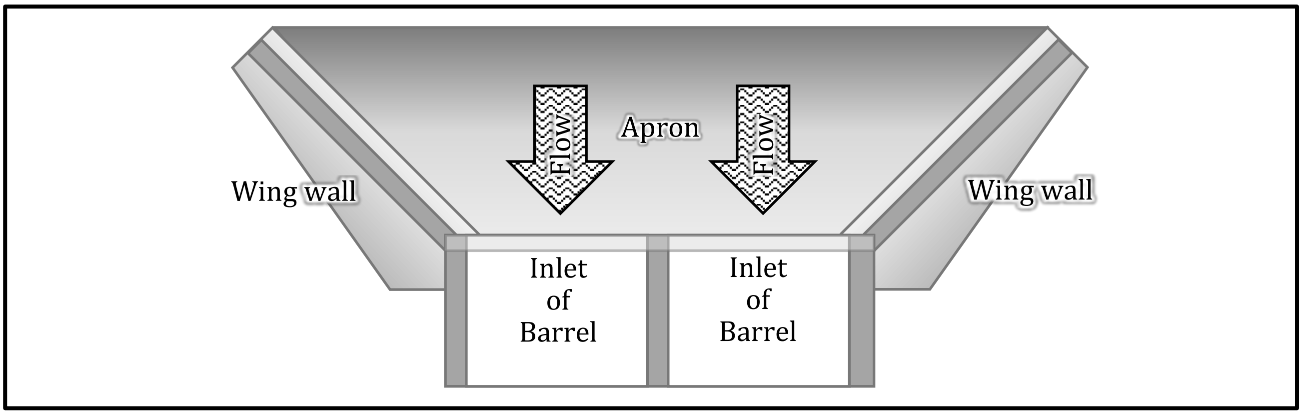


Figure 9.3 — Inlet protection using concrete apron

9.2 Outlet protection

Erosion downstream of culverts is more frequent because of the change in velocity of flow. The change in velocity of flow is because of the difference in cross-section and roughness of channel. The purpose of protection measures is to reduce the velocity until it is similar to the flow in the natural channel.

Erosion protection measures are a standard part of construction for outlets. For normal applications, measures for outlets are similar to inlets, as shown in Figure 9.2 and Figure 9.3. In cases where erosion is a serious concern, a structure for energy dissipation is recommended. The following structures are possible solutions for erosion protection at outlets:

- Type 1 stone stilling basin, see Figure 9.5
- Type 2 stone stilling basin, see Figure 9.6
- Type 3(a) and 3(b) stone stilling basins, see Figure 9.7 and Figure 9.8
- Type 5 concrete stilling basin, see Figure 9.9

9.2.1 Selection of protection measure

The method for selection of an appropriate erosion protection measure is shown in Figure 9.4. Two lines should be drawn perpendicular to axes. The intersection of two lines shows the recommended measure.

Normal flow depth at the outlet and Froude number are required for this selection method. Normal flow depth and subsequently the Froude number for box culverts can be calculated according to Section 8.5. The y-axis is ratio of the normal depth of flow to the height of culvert, y_n / D, and the x-axis is the Froude number, Fr.

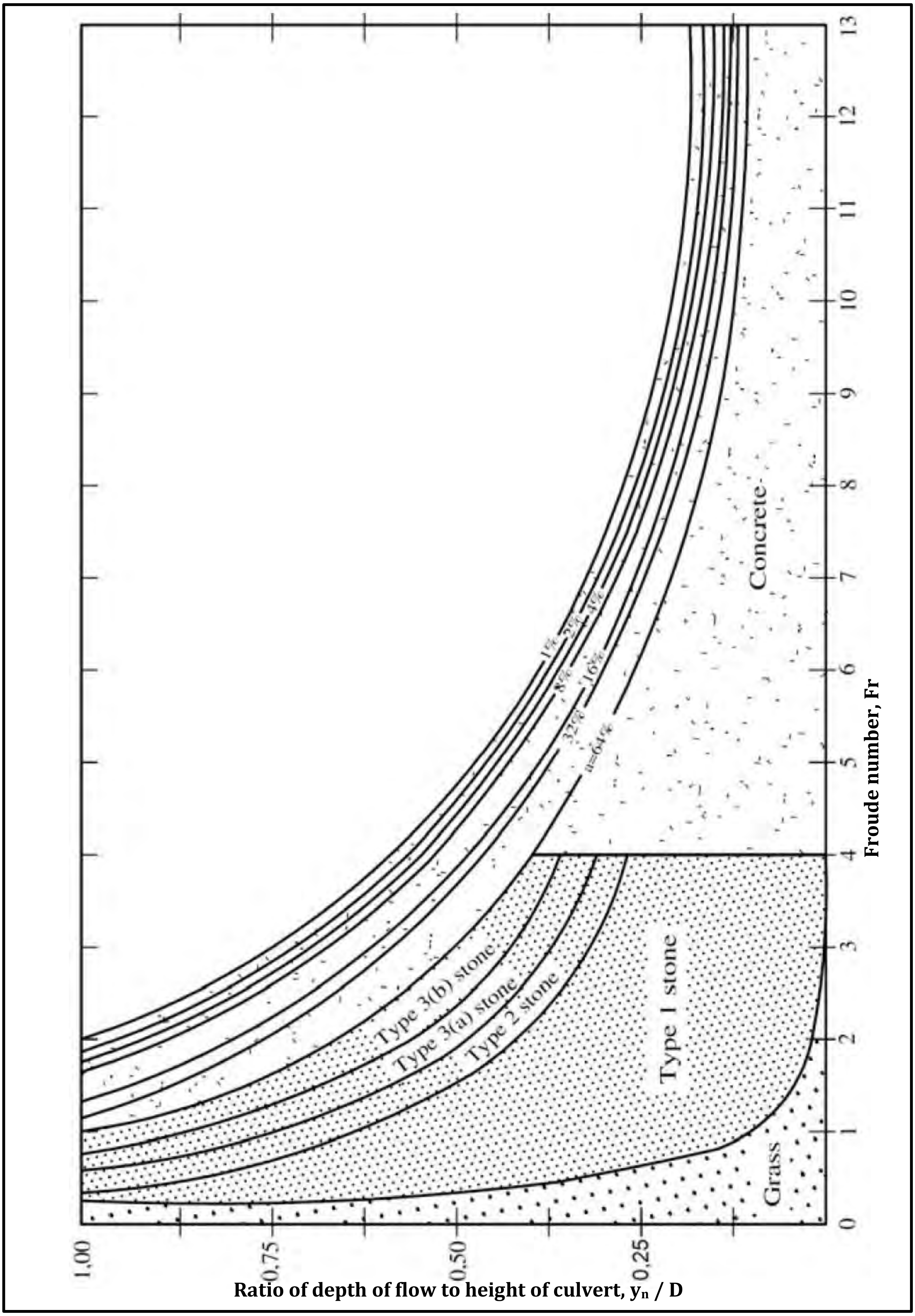
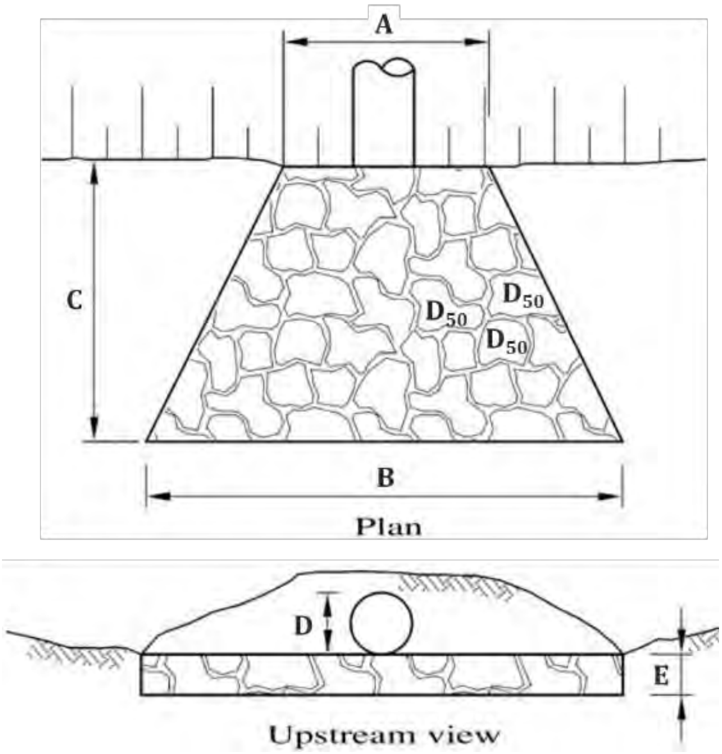


Figure 9.4 — Method of selection of erosion protection measure (5)

9.2.2 Detailing of protection measures

The recommended dimensions and construction of erosion protection measures are shown in Figure 9.5, Figure 9.6, Figure 9.7, Figure 9.8 and Figure 9.9.



D = height of culvert (m)

$A = 3 \times D$
= width of stone basin at outlet (m)

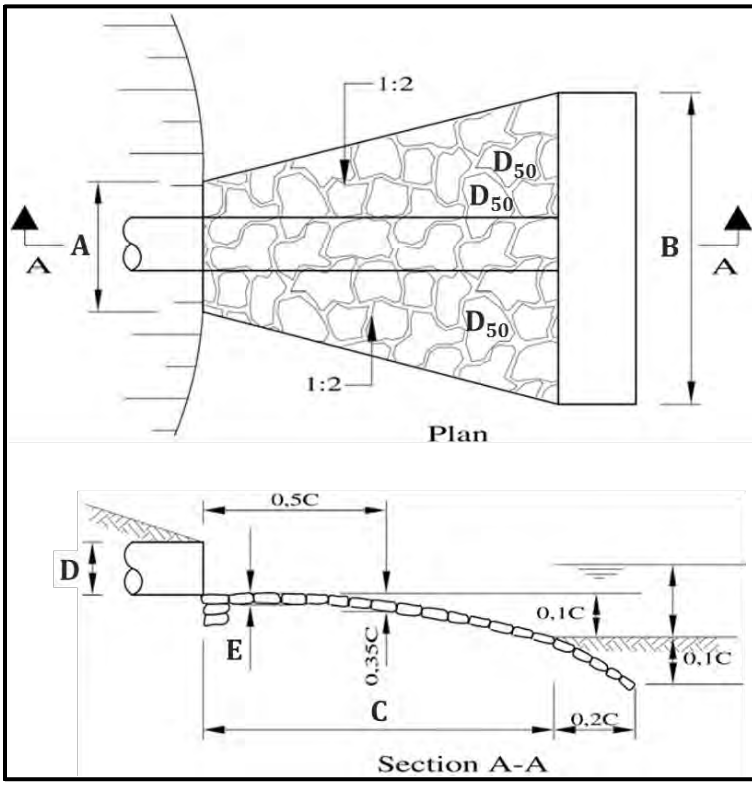
$B = A + C$
= width downstream (m)

$C = 3.0792 \times \frac{Q}{D^{1.6}} + 2.4384$
= length of stone basin (m)

$E = 0.5 \times D \times Fr$
= thickness of stone basin (m)

$D_{50} = 0.0883 \times \frac{Q^{1.333}}{D^{2.333}}$ = minimum size of stones in 50% of basin material (m)

Figure 9.5 — Diagram of type 1 stone stilling basin (5)



D = height of culvert (m)

$A = 3 \times D$
= width of stone basin at outlet (m)

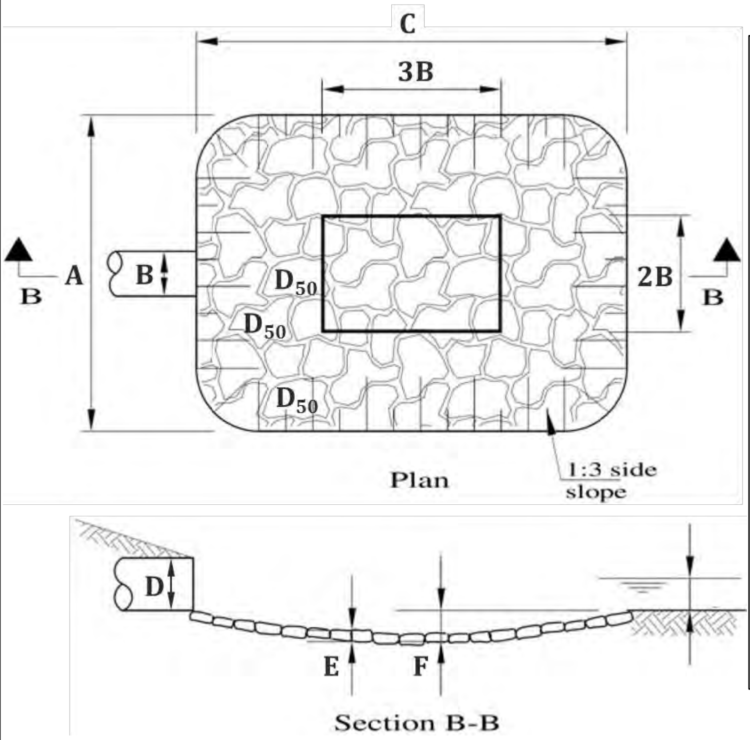
$B = 5 \times D$
= width downstream (m)

$C = 5 \times D$
= length of stone basin (m)

$E = 2 \times D_{50}$
= thickness of stone basin (m)

$D_{50} = 0.0707 \times \frac{Q^{1.333}}{D^{2.333}}$ = minimum size of stones in 50% of basin material (m)

Figure 9.6 — Diagram of type 2 stone stilling basin (5)



D = height of culvert (m)

B = width of culvert (m)

$A = 2 \times D + 6 \times F$
= width of stone basin (m)

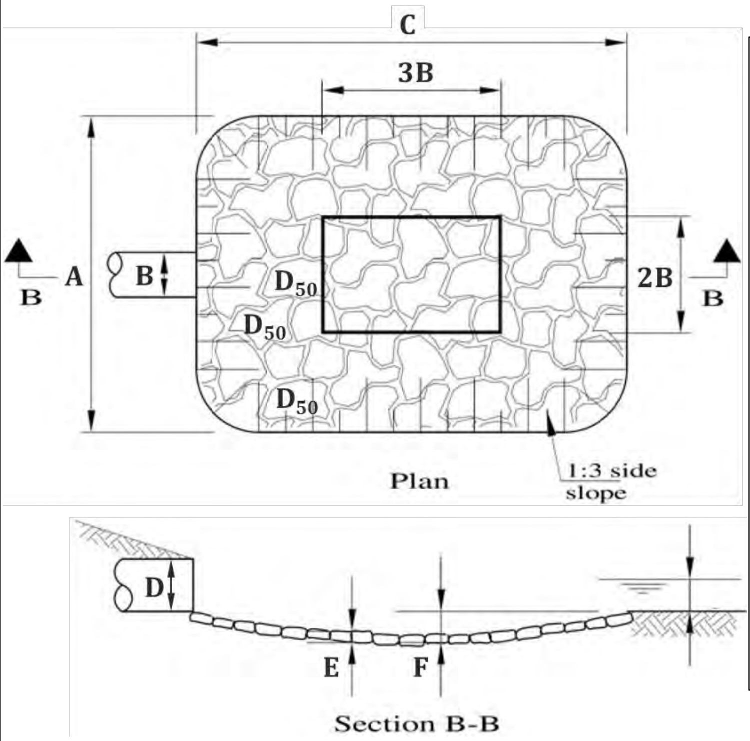
$C = 3 \times D + 6 \times F$
= length of stone basin (m)

$F = 0.5 \times D$
= depth of stone basin (m)

$E = 2 \times D_{50}$
= thickness of stone basin (m)

$D_{50} = 0.0552 \times \frac{Q^{1.333}}{D^{2.333}}$ = minimum size of stones in 50% of basin material (m)

Figure 9.7 — Diagram of type 3a stone stilling basin (5)



D = height of culvert (m)

B = width of culvert (m)

$A = 2 \times D + 6 \times F$
= width of stone basin (m)

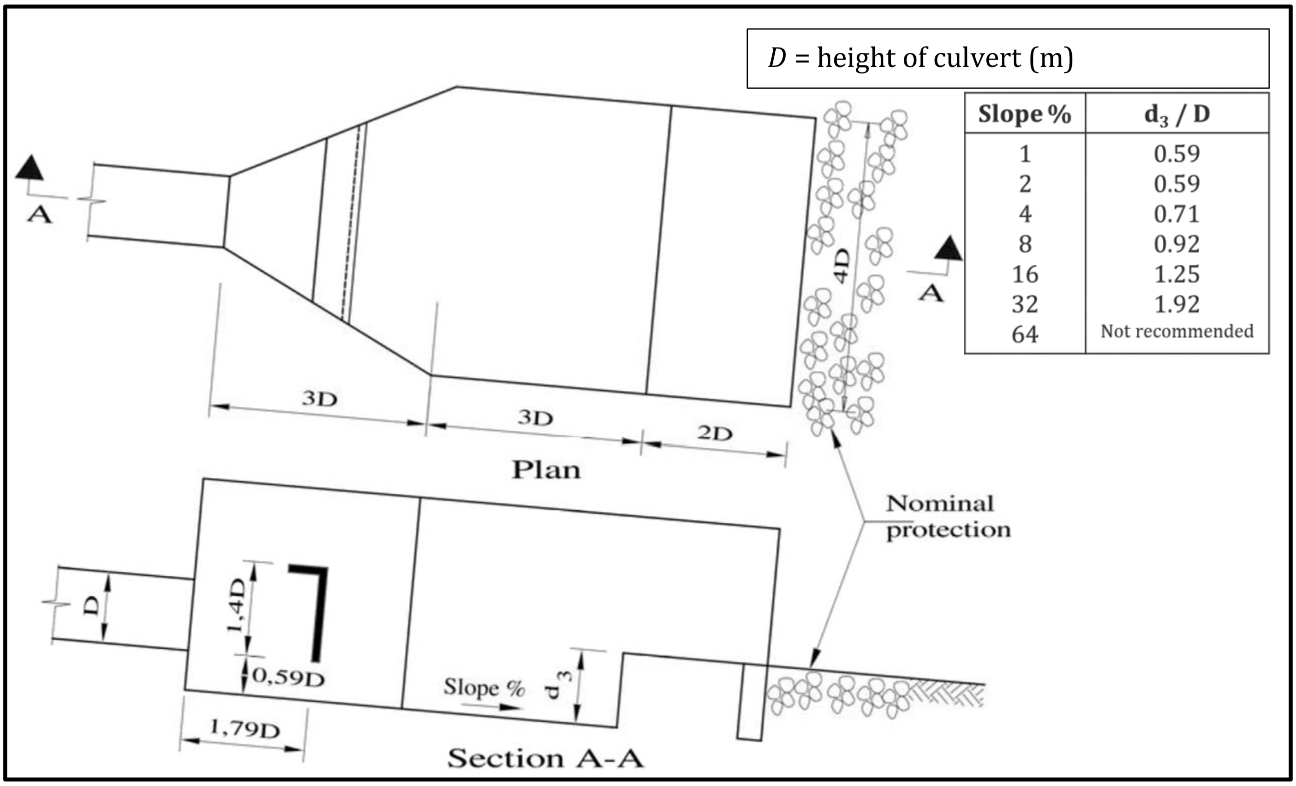
$C = 3 \times D + 6 \times F$
= length of stone basin (m)

$F = D$
= depth of stone basin (m)

$E = 2 \times D_{50}$
= thickness of stone basin (m)

$D_{50} = 0.0362 \times \frac{Q^{1.333}}{D^{2.333}}$ = minimum size of stones in 50% of basin material (m)

Figure 9.8 — Diagram of type 3b stone stilling basin (5)



D = height of culvert (m)

Slope %	d_3 / D
1	0.59
2	0.59
4	0.71
8	0.92
16	1.25
32	1.92
64	Not recommended

Figure 9.9 — Diagram of type 5 concrete stilling basin (5)

Glossary

English	Tetun / Portuguese / Indonesian	Japanese
Alignment	Alinhamento / Penjajaran	線型
Allowance height	Altura / Tunjangan tinggi	余裕高
Annual maximum daily rainfall	Chuva diária máxima anual	年最大日降雨量
Annual rainfall	Chuvas anuais	年間降雨量
Area (cross-section of flow)	Área (seção transversal do fluxo)	通水断面積
Artificial channel	Canal artificial / Saluran buatan	人工水路
Basin	Bacia / Baskom	流域
Catastrophe	Catastrophe / Malapetaka	災害
Catchment area	Área de captação / Area tangkapan	集水地域
Channel profile	Perfil do canal	溝形断面
Coefficient	Coeficiente	係数
Critical depth	Profundidade crítica / Kedalaman kritis	臨界深度
Critical flow	Fluxo crítico / Aliran kritis	限界の流れ
Departure	Partida	偏差計算
Depth (of flow)	Profundidade (do fluxo) / Kedalaman (arus)	水深
Discharge	Descarga	排水
Discharge capacity	Capacidade de descarga / Merancang kapasitas debit	通水量
Duration	Duração	期間
Elongated	Alongada / Memanjang	伸びた
Empirical	Empírico	経験的
Erosion protection measure	Medida oinsa atu prvene erosaun	浸食防止工法
Evaporation	Evaporação	蒸発
Extrapolation	Extrapolação	外挿
Factor	Fator	因子
Flood hazard	Perigo de inundação / Bahaya banjir	洪水の危険
Flow	Aliran / Fluxo / Mengalir	流れ
Frequency	Freqüência	周波数
Friction	Atrito / Gesekan	摩擦
Frictional resistance	Resistência à fricção / Resistensi gesekan	きしみ反応
Froude number	Numeru Froude / Nural Froude	フルード数
Gradient	Gradiente/Kemiringan	流路勾配
Gradient / bed slope	Gradiente / Encosta do rio / lereng sungai	勾配
Gravitational acceleration	Aceleração gravitacional / Percepatan gravitasi	重力加速度
Headwater	Kedalaman air di Upstream	上流
Height of culvert (internal)	Altura do cais (interno) / Tinggi gorong-gorong (internal)	高さ
Hydraulic jump	Salto hidráulico / Lompatan hidrolik	跳水
Hydraulic mean depth	Profundidade média hidráulica	流体平均深さ
Hydraulic radius	Raio hidráulico / Radius hidrolik	径深
Infiltration	Infiltração	浸潤
Influence	Influência	影響
Interpolation	Interpolação	内挿
Lag	Atraso / Ketinggalan	時差（遅れ）
Limitation	Limitasaun / Limitação	制限
Longitudinal section	Seção longitudinal	縦断面
Magnitude	Magnitude	マグニチュード

English	Tetun / Portuguese / Indonesian	Japanese
Manning's roughness coefficient	Coeficiente de rugosidade de Manning / Koefisien kekasaran Manning	粗度係数
Maximum 24-hour rainfall / Probable daily rainfall	Chuva máxima de 24 horas / Chuva diária provável	確率日降雨量
Mean	Média	平均
Natural channel	Canal natural / Saluran alami	自然水路
Newton-Raphson method	Metodo Newthon-Rapshon	ニュートン・ラプソン法
Normal depth	Kedalaman normal	等流水深
Normal flow	Aliran normal	等流の流れ
Occurrence	Ocorrência / Kejadian	発生
Peak	Pico / Puncak	ピーク（最大）
Ponding	Ponding / Kolam	たん水
Prediction	Predição	予測
Probability	Probabilidade	確率
Probability distribution	Distribuição de probabilidade	確率分布
Rainfall	Udan / Chuva / Precipitação	降雨
Rainfall intensity	Intensidade da chuva	降雨強度
Rational Method	Método Racional (hidrología)	合理式
Return period	Período de retorno	確率年
Riprap	Riprap (Fatuk kasar nebe usa ba protesaun ba erosaun)	護床工
Runoff	Escoamento / Limpasan	流出
Sedimentation	Sedimentação / Pengendapan	堆積
Sharp bend	Curva acentuada / Tikungan tajam	急カーブ
Standard deviation	Desvio padrão	標準偏差（SD）
Stilling basin	Posisi cekungan	減勢池
Storage	Armazenamento	貯水池
Subcritical flow	Fluxo subcrítico / Aliran subkritis	常流
Supercritical flow	Fluxo supercrítico / Aliran supercritical	射流
Tailwater	Kedalaman air di Downstream	下流
Time of concentration	Tempo de concentração	洪水到達時間
Trial-and-error method	Metodo trial no error	試行錯誤手法
Uniform	Uniforme	均一
Urbanised	Urbanizado	都市化された
Velocity	Velocidade / Kecepatan	洪水速度
Watercourse	Curso de água / Anak sungai	水路
Watershed	Bacias hidrográficas / Batas air	分水地点
Weighted average	Média ponderada	加重平均
Wetted perimeter	Perímetro molhado / Perimeter terbasah / Keliling basah	潤辺
Width (internal)	Largura (interna) / Lebar (internal)	幅

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11. —. *Standar Gorong-gorong Persegi Beton Bertulang Tipe Triple [Standard for Double Concrete Box Culverts].* Jakarta : Indonesian Directorate General of Highways, 2009. BTI/T.

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Annex A
(informative)

Case study of Sesurai Culvert

A.1 Introduction

The case study of a culvert in Sesurai, Manufahi Municipality, was selected to demonstrate the process of design for culverts and provide technology transfer through on-the-job training. The rationale for selection of this culvert as a case study was as follows:

- Generality of work item: the case study concerned a new construction of a culvert for cross drainage under a road. Once completed, the knowledge obtained by the case study could be applicable to other areas of Timor-Leste.
- Accessibility: the site was located near a major district town, it was within 60 minutes' drive from a municipal office of the DNEPCC and the general security in the region was good.
- Importance: the road was considered an essential road and it urgently required appropriate drainage.

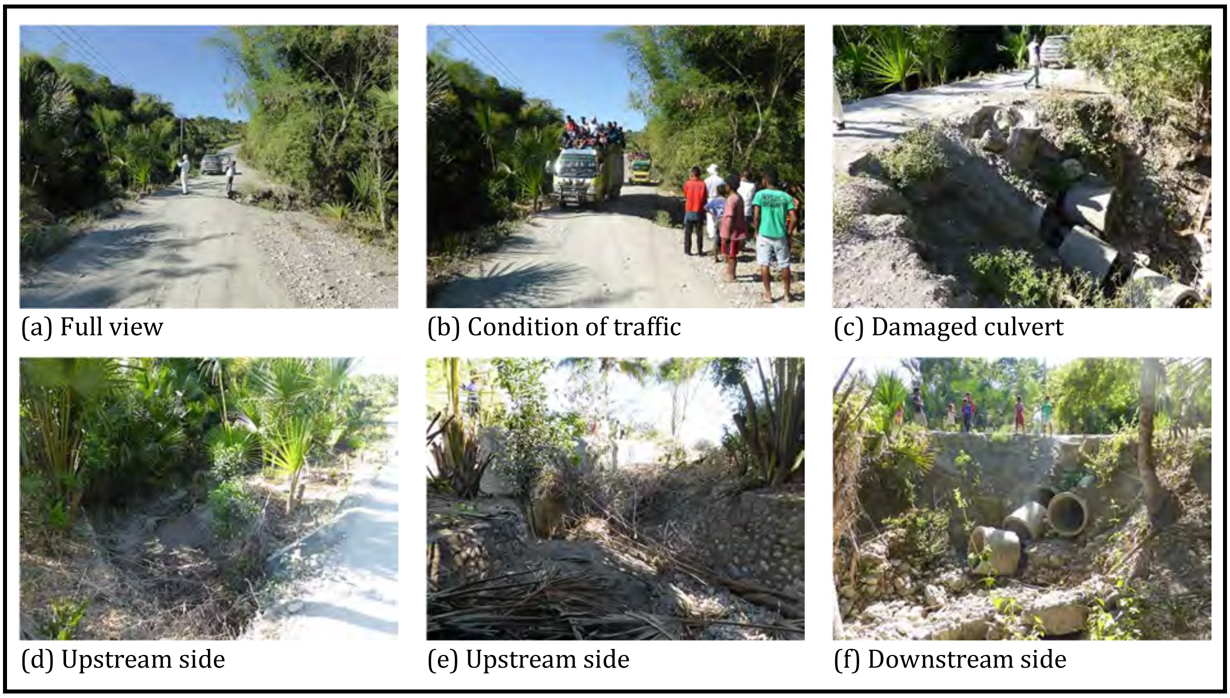
A concrete box culvert was planned for the site with capacity greater than the existing pipe culvert. The DNEPCC began planning for the reconstruction work in late 2016 and training for the case study started in early 2017. The purpose of the case study was to determine if the size of the culvert was appropriate.

A.2 Site Conditions

The location of the case study was in the south of Sesurai village on the A05 National Road between Same and Betano in Manufahi Municipality, as shown in Figure A. The region is mountainous and the elevation of the site was approximately 140 m above sea level.

Figure A — Location of the case study of Sesurai Culvert

On the site, there was an existing pipe culvert that had been damaged and half of the road width had collapsed, as shown in Figure B and Figure C. The cause of the damage was a small watercourse that had overtopped the road, because the capacity of the existing pipe culvert was insufficient.



(a) Full view
(b) Condition of traffic
(c) Damaged culvert
(d) Upstream side
(e) Upstream side
(f) Downstream side

Figure B — Site conditions on 16/09/2016

(g) Full view
(h) Inlet of culvert
(i) Outlet of culvert

Figure C — Site conditions on 23/02/2017

A.3 Data collection

Basic site investigations were conducted and the photographs of the site were collected, as shown in Figure B and Figure C. The coordinates of the site were measured as latitude S009° 07' 01.38" and longitude E125° 41' 49.88" (-9.11705, 125.69719) using WGS84 datum. There was no flow in the watercourse at the time of the site visits. An aerial view of the site and an approximate line of the watercourse are shown in Figure D.

A topographic survey was conducted by a contractor in November 2017 after the construction had been completed. Normally a topographic survey is conducted before construction. The survey confirmed the flow conditions of the culvert and allowed a check of the as-built design.

Map data was provided by the DNEPCC. The *Hatoudo* map was used for the design (edition 1 – DIGO, series T755, sheet 2406 63, produced in 2005). The scale of the map was 1:50,000. GIS data was provided by the Mapping & GIS Section of DNEPCC. The GIS elevation data used was the Advanced Spaceborne

Thermal Emission and Reflection Radiometer (ASTER) global digital elevation model (GDEM) version 2 (ASTER GDEM is a product of METI and NASA) sourced via the EarthExplorer tool of the US Geological Survey.

- EarthExplorer tool: http://earthexplorer.usgs.gov/

Daily rainfall data was provided by the National Directorate for Water Resource Management, the Agriculture and Land Use Geographic Information System (ALGIS), and the Comoro Bridge Project. Historical monthly and annual rainfall data was provided by Ministry of Agriculture, Forestry and Fisheries (MAFF). National rainfall and climate maps were provided by the Seeds of Life (SoL) program.

- ALGIS data source: http://timoragriresearch.weebly.com/
- MAFF data source: http://gov.east-timor.org/MAFF/English/climate_and_hydrology.htm
- SoL data source: http://seedsoflifetimor.org/

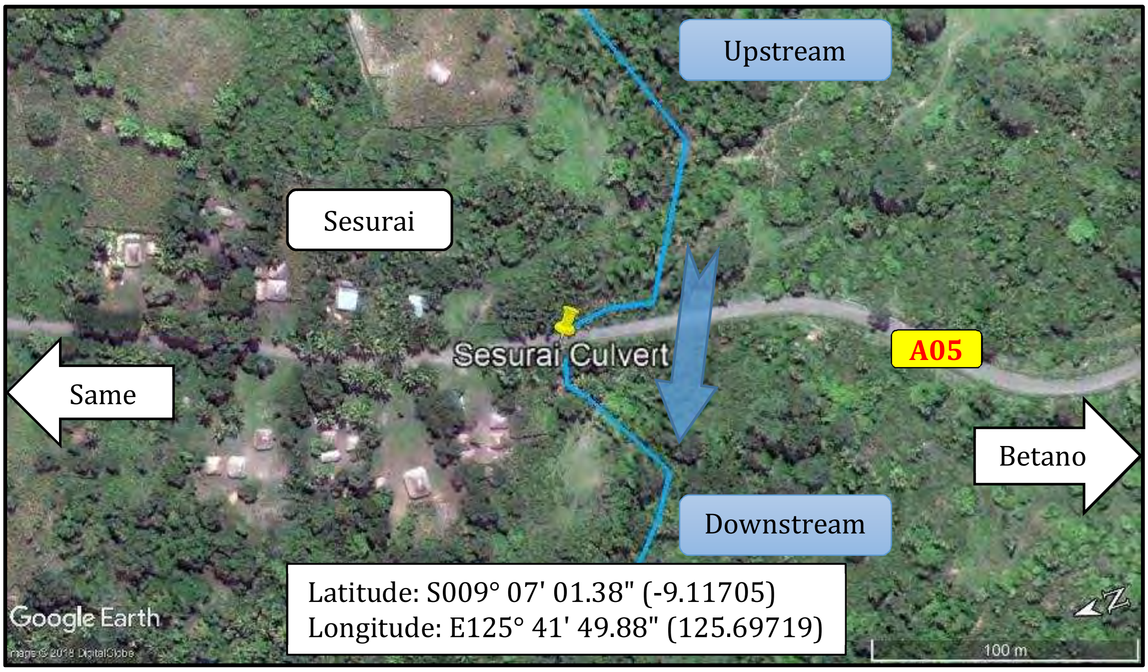


Figure D — Aerial view of the case study site (Google Earth, 2010)

A.4 Rainfall analysis

This section will discuss the selection of rainfall data and frequency analysis. The calculations for frequency analysis are shown in the following sections of Section A.10:

1) Annual maximum daily rainfall data
2) Maximum probable daily rainfall
3) Synthetic procedure

The location of the case study has medium to high rainfall, as shown in Figure E. The weather station in Same was most appropriate for the design of the culvert. Although the weather station in Betano was nearest to the site, it was a coastal location and so rainfall was less.

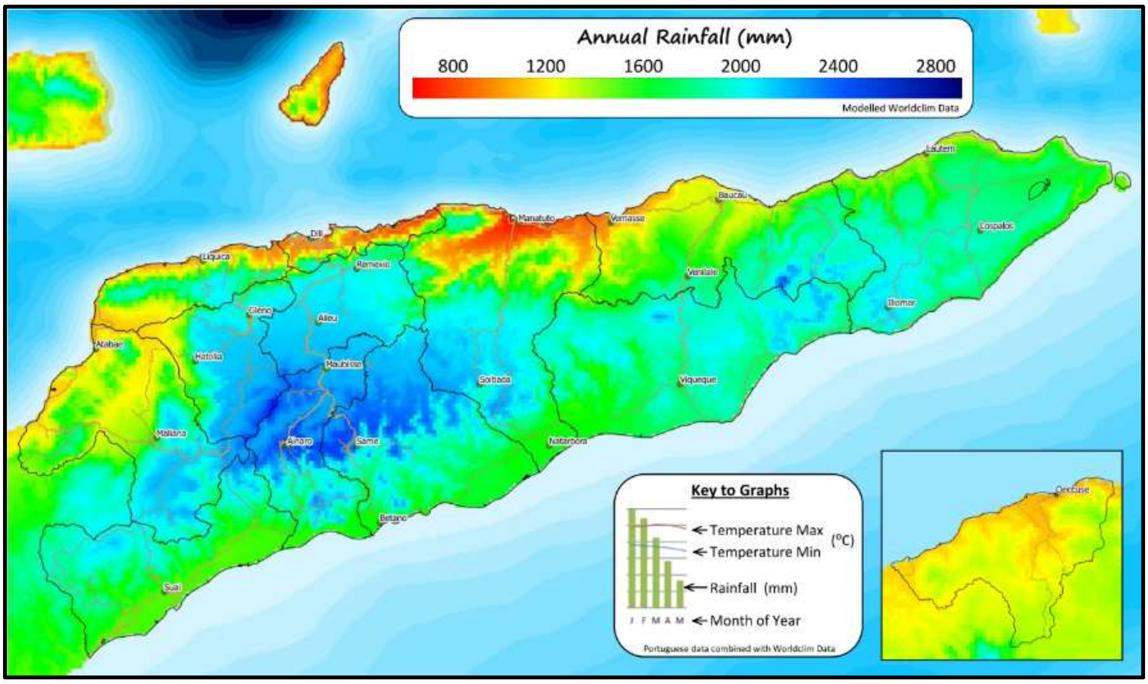


Figure E — Annual rainfall map of Timor-Leste (Seeds of Life, 2014)

The daily rainfall data for Same was from 2010 to 2016. This record was only 6 years long, so it was insufficient for frequency analysis. The daily rainfall data for Dili was from 1978 to 2016 and was 34 years long. Therefore, a synthetic procedure was adopted using the daily rainfall for Dili to predict the design rainfall (maximum probable daily rainfall) and then this value was scaled up to Same using a comparison of the average annual rainfall.

In one year, the 1 day with the most rainfall out of 365 day is called the annual maximum daily rainfall. The 34 years of annual maximum daily rainfalls were summarised. The average (mean) and standard deviation of these 34 years was calculated.

Average (mean), μ = 91.7 mm/day

Standard deviation, σ = 30.4364 mm/day

The classification of the A05 road is a "National Road". Therefore, a high level of drainage capacity was required and a return period of 10 years was adopted for the design from Table A.

Return period, T = 10 years

Table A — Recommended return period of rainfall for culverts

Road class	Level of drainage capacity	Return period of rainfall
National Roads / Urban Arterial Roads	High	10 years
Regional Roads / Urban Collector Roads	Medium	7 years
Local Roads / Urban Local Roads	Low	5 years

For a 10-year return period, the maximum probable daily rainfall of 131.4 mm/day in Dili was calculated using the Gumbel distribution.

Gumbel distribution, $R_{24} = \mu + \sigma \times K$

$= \mu + \sigma \times -\sqrt{6} / \pi \times (\gamma + \ln(\ln(T / (T - 1)))$

$= 91.7 + 30.4364 \times -\sqrt{6} / 3.1416 \times (0.5772 + \ln(\ln(10 / (10 - 1)))$

$R_{24} = 131.4$ mm/day (in Dili)

The average annual rainfall was 940 mm/year in Dili and 3117 mm/year in Same, as shown in Figure F. The ratio of the average annual rainfalls was used as a conversion factor. The conversion factor of 3.32 was used to multiply the daily rainfall. Therefore, the design rainfall was 435.6 mm/day in Same.

Conversion factor = 3117 / 940 = 3.32

R_{24} = 131.4 × 3.32 = 435.6 mm/day (in Same)

MONTHLY RAINFALL DATA (mm)
STATION : TT001 - DILI
PERIOD : 1953 - 1974

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1953	124	81	181	264	16	11	2	3	24	0	70	137	912
1954	122	81	93	208	150	37	2	27	21	81	99	327	1248
1955	244	122	281	240	226	184	212	293	290	288	183	288	2851
1956	143	20	14	141	41	340	38	75	51	26	101	226	1216
1957	55	170	116	50	21	97	179	0	0	0	16	188	892
1958	96	300	151	48	39	52	56	54	16	3	61	132	1008
1959	229	167	61	46	34	81	5	0	0	25	33	91	770
1960	274	159	223	122	37	0	22	5	1	28	79	147	1097
1961	278	198	95	66	18	0	33	1	2	19	2	75	787
1962	164	94	97	66	82	84	1	66	6	20	75	172	927
1963	156	63	267	102	142	2	0	0	0	0	0	130	862
1964	111	46	135	88	181	8	3	2	15	61	139	50	837
1965	60	198	117	13	16	10	4	1	1	17	13	25	474
1966	120	244	288	16	58	20	0	24	0	38	108	148	1063
1967	114	72	133	32	46	0	1	0	4	9	36	33	480
1968	92	128	103	90	198	236	87	2	0	1	10	190	1137
1969	116	107	58	26	55	14	4	4	8	26	0	157	576
1970	109	132	123	114	104	24	6	0	8	85	55	99	859
1971	99	40	116	59	133	16	41	3	23	28	110	230	896
1972	60	80	179	43	25	0	0	16	0	0	14	164	580
1973	263	327	267	159	177	14	7	10	7	1	87	176	1496
1974	133	94	97	58	71	57	13	44	37	47	97	110	858
1975													
1976													
1977	257	71	107	80	34	0	0	4	2	0	0	120	675
1978	149	109	264	68	63	70	28	25	13	68	72	56	985
1979	37	72	101	15	190	47	4	0	0	14	66	104	650
1980	232	70	98	177	64	40	11	0	1	6	44	247	990
1981	186	74	127	104	113	34	24	5	17	13	193	59	949
1982	185	106	57	71	3	5	1	10	0	0	4	81	523
1983	123	181	112	139	41	39	0	2	0	21	77	81	816
1984	133	115	86	248	261	34	0	10	89	9	51	118	1154
1985	59	110	141	56	188	21	42	0	25	7	64	293	1006
1986	188	126	77	127	56	27	22	33	0	3	58	52	769
1987	233	61	193	20	23	13	23	0	0	0	59	137	762
1988	239	271	216	44	79	0	1	6	8	92	190	116	1262
1989	52	192	265	269	41	71	14	38	0	0	19		961
1990	243	51	39	178	28	3	38	8	0	0	20	95	703
1991	14	131	49	209	4	0	0	0	0	0	53	50	510
1992	131	80	97	59	0	11	0	3	0	0	64	307	752
1993	427	30	108	232	6	15	2	0	0	18	49	127	1014
1994	211	152	137	86	25	6	0	0	1	0	7	159	784
1995	146	119	326	269	96	65	0	0	0	14	139	31	1205
1996	123	200	112	71	52	0	1	10	0	48	78	281	976
1997	185	187	69	61	26	28	0	1	0	0	16	55	628
1998	17	87	454	294	76	23	72	1	8	11	354	65	1462
1999	304	92	204	244	8	79	0	0	0				
Mean	156	125	147	115	74	43	22	17	15	26	70	138	940
MIN	14	20	14	13	0	0	0	0	0	0	0	25	474
MAX	427	327	454	294	261	340	212	293	290	288	354	327	2851

MONTHLY RAINFALL DATA (mm)
STATION : TT024 - SAME
PERIOD : 1956 - 1974

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956				378	371	426	260	313	28	170	221	262	
1957	275	373	509	52	232	127	345	0	3	31	118	789	2854
1958	316	427	450	146	295	395	85	100	1	288	242	298	3041
1959	242	337	177	348	819	488	111	5	37	57	41	200	2862
1960	292	434	218	253	795	140	169	33	113	27	158	372	3004
1961	112	445	135	218	110	68	75	4	3	32	93	150	1447
1962	575	441	192	236	145	238	184	64	0	69	237	260	2640
1963	599	523	299	364	339	109	18	35	0	0	0	264	2550
1964	431	268	277	234	945	145	38	61	261	337	676	118	3789
1965	663	284	440	245	213	195	85	3	0	42	0	426	2595
1966	425	485	376	153	126	332	46	45	106	2	281	635	3012
1967	165	425	473	87	176	137	68	0	7	48	13	397	1995
1968	292	169	417	314	627	522	679	83	0	0	0	613	3716
1969	488	363	155	45	287	386	342	86	40	50	112	513	2864
1970	182	287	187	360	986	588	310	22	72	145	669	420	4227
1971	425	154	1106	499	353	253	164	0	9	229	421	374	3985
1972	183	682	619	517	716	509	49	2	10	0	20	498	3803
1973	526	380	597	375	663	291	229	272	252	10	286	412	4291
1974	291	633	137	686	289	365	113	17	127	54	343	374	3426
MEAN	360	395	376	290	447	301	177	60	56	84	207	388	3117
MIN	112	154	135	45	110	68	18	0	0	0	0	118	1447
MAX	663	682	1106	686	986	588	679	313	261	337	676	789	4291

Figure F — Monthly rainfall data for Dili and Same (MAFF)

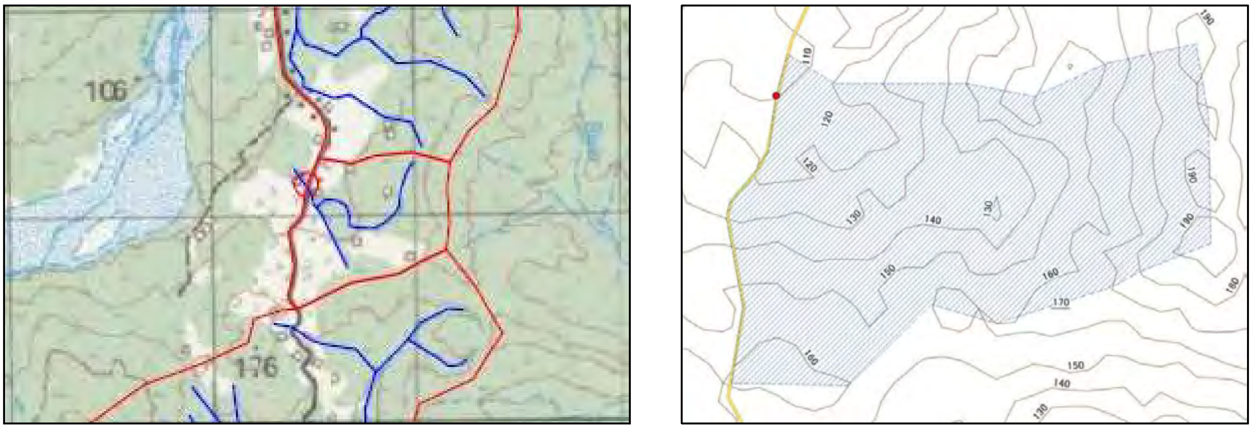
A.5 Design flood

This section will discuss the calculation of the design flood. The calculations for design flood are shown in the following sections of Section A.10:

4) Catchment data
5) Time of concentration
6) Intensity of rainfall
7) Coefficient of run-off
8) Discharge of catchment

The catchment area was initially estimated as 0.44 km² using the *Hatoudo* topographic map of scale 1:50,000. Afterwards, digital elevation model (DEM) data was used to produce contours in geographic information system (GIS) software, called QGIS. The catchment area was refined and calculated as 0.32 km² using the GIS data. A comparison of the two techniques for determining catchment area are shown in Figure G. The GIS data is considered more accurate, so the 0.32 km² was adopted for the catchment area.

Catchment area, A = 0.32 km²



Catchment of 0.44 km² on *Hatoudo* map | Catchment of 0.32 km² on GIS software

Figure G — Catchment area in estimation and calculation

The watercourses were identified on the *Hatoudo* map, because there was no GIS data for this feature. The lengths and elevations are shown in Figure H and summarised in Table B. A visualisation of the profile of the watercourse is shown in Figure I. The main watercourse was from A-B-C-D. The total length of the watercourse was approximately 911 m. The average gradient of the watercourse was calculated as approximately 5.3% using the Linest function in spreadsheet software.

Length of watercourse, L = 119.3 + 311.6 + 480.5 = 911.4 m

Gradient of watercourse, G = LINEST({change in elevations} , {cumulative lengths} , FALSE)
= LINEST({0;5;20;50},{0;119.3;430.9;911.4},FALSE)
= 0.053 m/m = 5.3% = 1/19

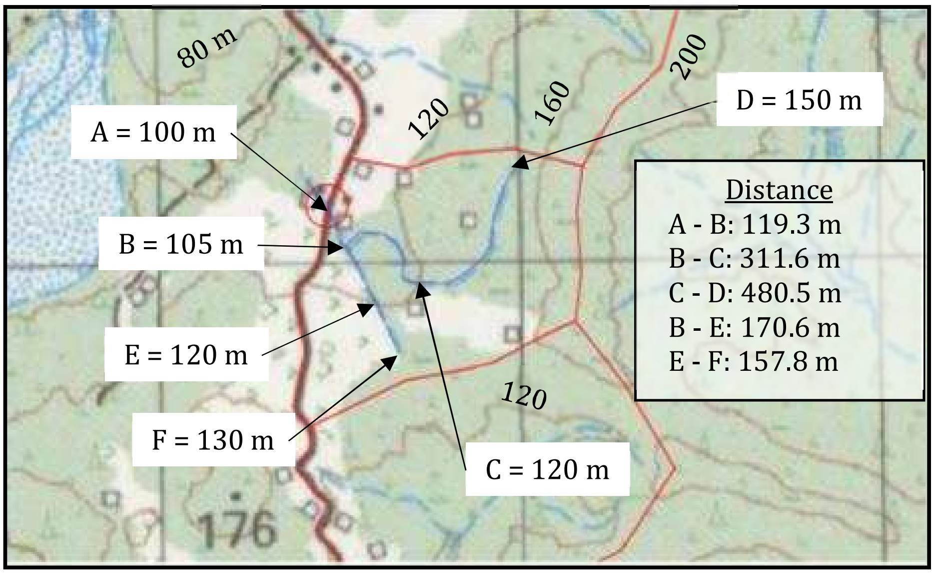


Figure H — Profile of watercourse showing elevation and distance

Table B — Summary of watercourse lengths and elevation

Point	Length (m)	Cumulative length (m)	Absolute elevation (m AOD)	Change in elevation (m)
Main channel				
D (mountain)	480.5	911.4	150	50
C	311.6	430.9	120	20
B	119.3	119.3	105	5
A (culvert)	0	0	100	0
Branch channel				
F (mountain)	157.8	447.7	130	30
E	170.6	289.9	120	20
B	119.3	119.3	105	5
A (culvert)	0	0	100	0

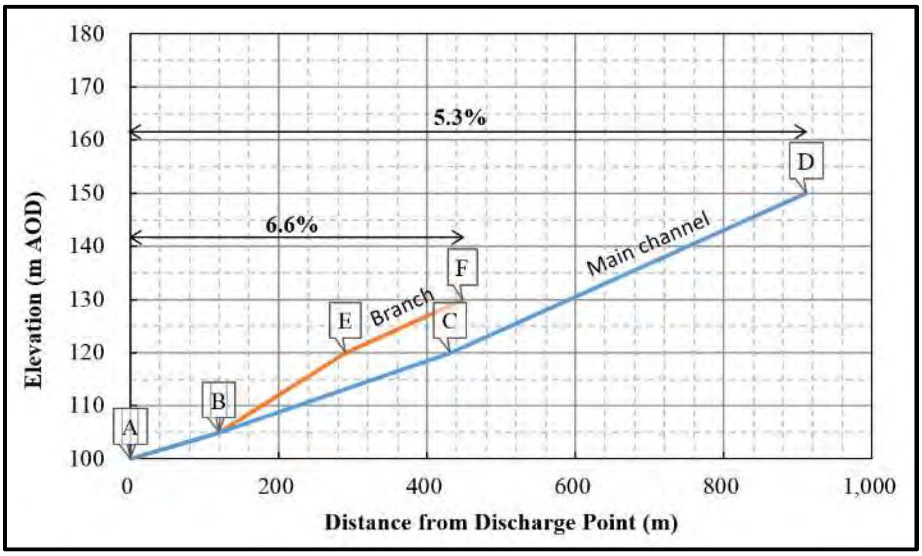


Figure I — Visualisation of profile of watercourse

The velocity of run-off for a gradient of 5.3% was 3.5 m/s according to Table C.

Velocity of run-off, W = 3.5 m/s

Table C — Velocity of run-off

Gradient of watercourse, G			Velocity of run-off, W (m/s)
> 1 / 100	> 1.0%	> 0.010 m/m	3.5
1 / 200 – 1 / 100	0.5% – 1.0%	0.005 – 0.010 m/m	3.0
< 1 / 200	< 0.5%	< 0.005 m/m	2.1

The time of channel flow was calculated as 0.07 hours using the Kraven formula.

Time of channel flow, t_f = L / (3600 × W)
= 911.4 / (3600 × 3.5) = 0.07 hours

Table D — Inlet flow times

Catchment type	Inlet time (minutes)	Inlet time (hours)
Mountainous land	15.0 – 30.0	0.25 – 0.50
Cut slopes	3.0 – 5.0	0.05 – 0.083
Urban areas	5.0	0.083

The approximate time of inlet flow was adopted as 0.33 hours from Table D, considering that it is a small catchment in mountainous land. The time of concentration was calculated as 0.41 hours by combining the time of inlet flow and the time of channel flow.

Time of inlet flow, t_e = 20 minutes = 0.33 hours

Time of concentration, t_c = $t_e + t_f$ = 0.33 + 0.07 = 0.41 hours

The design rainfall intensity was calculated as 209.9 mm/hour using the Mononobe formula. It was desirable to calculate using intensity-duration-frequency curves; however, there was insufficient rainfall data for this method, so the Mononobe formula was adopted.

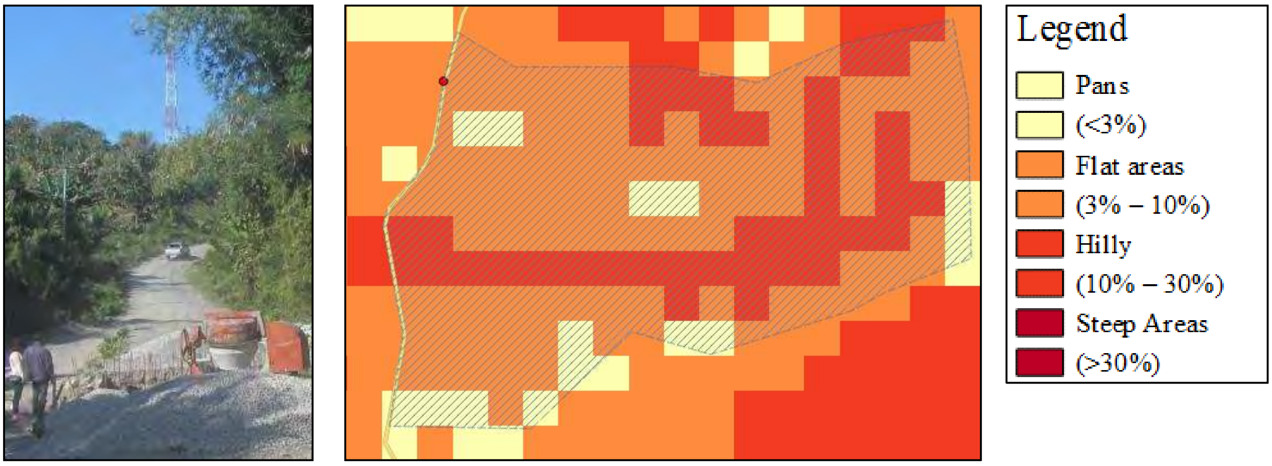
Design intensity of rainfall, i = $(R_{24} / 24) \times (24 / t_c)$ ^0.6
= (435.6 / 24) × (24 / 0.41) ^0.6
= 209.9 mm/hour

The terrain of the catchment was considered "steep mountainous land" based on cartographic map information that showed a mountainous region, so the coefficient of run-off was initially selected as 0.83 from Table E. The coefficient was re-assessed after a site visit and analysis of gradients in the catchment. The site visit observed that the terrain of the catchment was "gentle mountainous land". This observation was confirmed with a GIS analysis of the DEM data that found an average gradient of 8% in the catchment, as shown in Figure J. The coefficient of run-off was changed to 0.75.

Coefficient of run-off, C = 0.75 (average value of "gentle mountainous land")

Table E — Recommended coefficients of runoff

Terrain Type	Coefficient of Run-off	Average Value
Road surfaces and sloped surfaces	0.70 – 1.00	0.85
Steep mountainous land	0.75 – 0.90	0.83
Gentle mountainous land	0.70 – 0.80	0.75
Undulating land and woods	0.50 – 0.75	0.63
Flat farmlands	0.45 – 0.60	0.53
Rice paddy (fields)	0.70 – 0.80	0.75
Urban areas	0.60 – 0.90	0.75
Forest zones	0.20 – 0.40	0.30
Catchment areas of mountain streams	0.75 – 0.85	0.80
Catchment areas of small rivers on flat land	0.45 – 0.75	0.60
Catchment areas of major rivers of which more than half run on flat land	0.50 – 0.75	0.63



Site visit | Heat map of gradients in the catchment | Mostly flat areas

Figure J — Observation from site visit and heat map of gradients in catchment

The design flood was calculated as 13.99 m^3/s using the Rational method.

Design flood, Q_P

$$= (1/3.6) \times C \times i \times A$$
$$= (1/3.6) \times 0.75 \times 209.9 \times 0.32$$
$$= 13.99\ m^3/s$$

A.6 Design capacity

This section will discuss the calculation of the design capacity of the culvert. The calculations for design capacity are shown in the following sections of Section A.10:

9) Geometry of culvert
10) Profile of culvert
11) Material of culvert
12) Discharge capacity of culvert

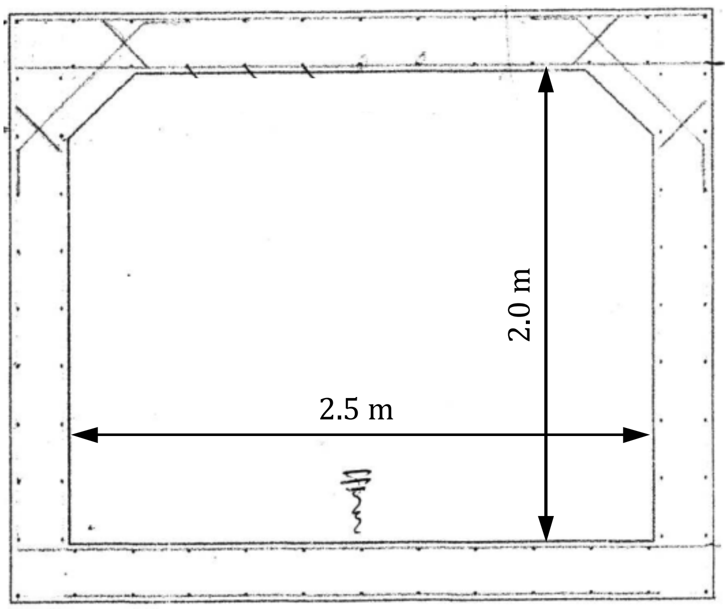


Figure K — Culvert geometry in the contract drawings

The culvert geometry was decided by the municipal office of the DNEPCC, as shown in Figure K. The purpose of the design check was to determine if the size was appropriate. The height of the culvert was 2.0 m and the width of the culvert was 2.5 m. The total cross-sectional area was 5.0 m². However, a margin of 20% was recommended in order to accommodate sedimentation. Therefore, the area of flow was reduced to 80% to 4.0 m², which is equivalent to a depth of flow of 1.6 m. The wetted perimeter was calculated as 5.7 m and the hydraulic radius was 0.7 m.

Total area,	A_T	$= b \times D = 2.5 \times 2.0 = 5.0\ m^2$
Depth of flow,	y	$= 0.8 \times D = 0.8 \times 2.0 = 1.6\ m$
Area of flow,	A	$= b \times y = 2.5 \times 1.6 = 4.0\ m^2$
(Alternative)	A	$= 0.8 \times A_T = 0.8 \times 5.0 = 4.0\ m^2$
Wetted perimeter,	P	$= b + 2 \times y = 2.5 + 2 \times 1.6 = 5.7\ m$
Hydraulic radius,	R	$= A / P = 4.0 / 5.7 = 0.7\ m$

According to the results of the topographic survey, the elevation of the culvert is 138.410 m AOD and the profile of the culvert is as shown in Figure L.

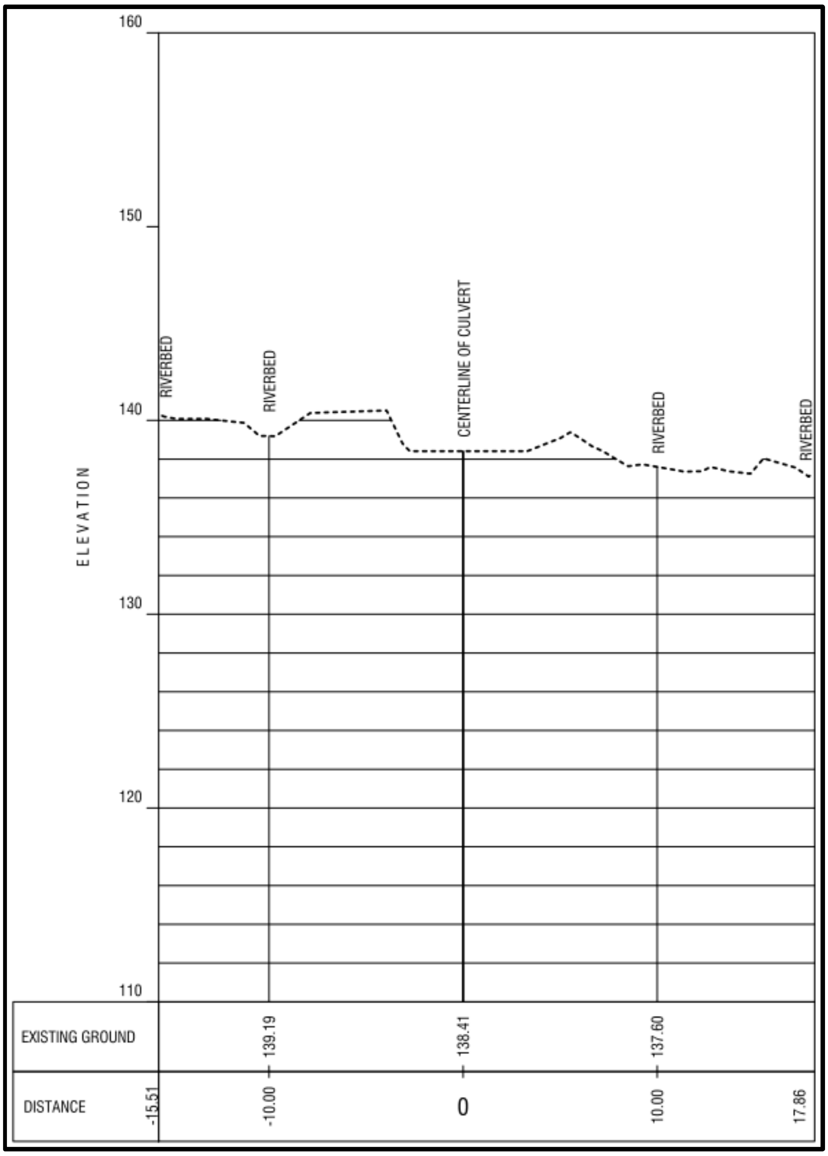


Figure L — Profile of watercourse from topographic survey

The gradient of the as-built culvert is 0%. It is not possible to calculate gravity flow with the Manning equation for this gradient. Therefore, the minimum recommended gradient of 0.5% was adopted for the calculations. It is recommended that construction of culverts have a gradient between the minimum of 0.5% to the maximum of 10.0% in the future.

Gradient of culvert, S_0 = 0.5% = 0.005 m/m

The material of the culvert is cast in-situ concrete, so the Manning number of 0.015 was adopted for the coefficient of roughness from Table F.

Coefficient of roughness, n = 0.015

Table F — Recommended values of Manning number

Material of culvert	Manning number, *n*
Concrete:	
Cast in-situ concrete	0.015
Factory-made concrete products	0.013

The design capacity of the culvert was calculated as 14.89 m³/s using the Manning equation for discharge.

Design capacity, Q = $(A \wedge (5/3) \times S_o \wedge (1/2)) / (n \times P \wedge (2/3))$
= $(4.0 \wedge (5/3) \times 0.005 \wedge (1/2)) / (0.015 \times 5.7 \wedge (2/3))$
= 14.89 m^3/s

(Alternative) Q = $A \times V = A \times ((R \wedge (2/3) \times S_o \wedge (1/2)) / n)$
= $4.0 \times ((0.7 \wedge (2/3) \times 0.005 \wedge (1/2)) / 0.015)$
= 14.89 m^3/s

The comparison of the design capacity and design flood from Section A.5 shows that the culvert is sufficient.

Q = 14.89 m^3/s > 13.99 m^3/s

$Q > Q_P$ ∴ culvert is sufficient

A.7 Conditions of flow

This section will discuss the calculation of the design capacity of the culvert. The calculations for conditions of flow are shown in the following sections of Section A.10:

13) Flow conditions in culvert
14) Design remarks

In order to consider the necessity of erosion protection at the outlet, calculation of the normal depth of flow, velocity of flow and Froude number were required. It was recommended to use spreadsheet software for calculation of the normal depth of flow, because it required complex and repetitive calculations.

The simplest method for calculation of normal depth of flow was the trial-and-error method. The process was as follows:

1. Select a depth of flow, y
2. Calculate area of flow, A, and wetted perimeter, P

3. Calculate discharge capacity, Q(y), using the Manning equation for discharge
4. Check $Q(y) = Q_P$
   If $Q(y) \neq Q_P$, then repeat steps 1 to 4
   If $Q(y) = Q_P$, then normal depth of flow, $y_n = y$

The complex method for calculation of normal depth of flow was the Newton-Raphson Method. The process was as follows for box culverts:

1. Select a depth of flow, y_0
2. Calculate area of flow, A, and wetted perimeter, P
3. Calculate discharge capacity, $Q(y_0)$, using the Manning equation for discharge
4. Calculate $\Delta Q(y) = Q(y_0) - Q_P$
5. Calculate $Q'(y) = (y_0 \wedge (2/3) \times b \wedge (5/3) \times S_o \wedge (1/2) \times (6 \times y_0 + 5 \times b)) / (n \times 3 \times (2 \times y_0 + b) \wedge (5/3))$
6. Calculate next depth of flow, $y_1 = y_0 - \Delta Q(y) / Q'(y)$
7. Repeat steps 1 to 6 several times
   If $\Delta Q(y) = 0$, then normal depth of flow, $y_n = y_0$

The normal depth of flow was calculated as 1.53 m for a discharge of 13.99 m^3/s through the culvert.

Normal depth of flow, y_n = 1.53 m

The velocity of flow for normal depth of flow was calculated as 3.67 m/s using the Manning equation. The velocity of flow was higher than the recommended velocity of culverts (3.67 m/s > 3.5 m/s). Therefore, this was the indicator that erosion protection measures at the outlet were recommended.

Normal area of flow, A_n $= b \times y_n = 2.5 \times 1.53 = 3.81\ m^2$

Wetted perimeter, P_n $= b + 2 \times y_n = 2.5 + 2 \times 1.53 = 5.55$ m

Hydraulic radius, R_n $= A_n / P_n = 3.81 / 5.55 = 0.6870$

Velocity of flow, V_n $= (R \wedge (2/3) \times S_o \wedge (1/2)) / n$
$= (0.6870 \wedge (2/3) \times 0.005 \wedge (1/2)) / 0.015$
$= 3.67$ m/s

The Froude number was another potential indicator that erosion protection measures at the outlet were recommended. The Froude number was lower than 1. Therefore, the type of flow in the culvert was subcritical. If the Froude number had been higher than 1 and type of flow had been supercritical, then this would have been an indicator that erosion protection measures at the outlet were recommended.

Gravitational acceleration, g = 9.81 m/s^2

Froude number, Fr $= V / (g \times y) \wedge 0.5$
$= 3.67 / (9.81 \times 1.52) \wedge 0.5$
$= 0.95$

Type of flow $Fr < 1$ = subcritical flow
$Fr = 1$ = critical flow
$Fr > 1$ = supercritical flow

If either the velocity of flow is high or the type of flow is supercritical, then erosion protection measures at the outlet should be recommended. For Sesurai culvert, the velocity of flow was the main indicator that erosion protection measures at the outlet were recommended.

A.8 Protection works

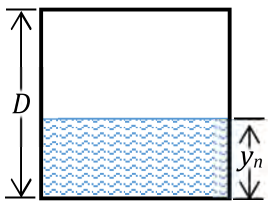
This section will discuss the recommendation of protection works. The calculations for erosion protection measures at the outlet are shown in the following sections of Section A.10:

15) Selection of protection measure
16) Detail of protection measure

Considering the Froude number and the ratio of normal depth of flow to height of culvert, the Type 2 stone stilling basin was selected as shown in Figure M.

Froude number, Fr = 0.95

Ratio of flow depth, y_n / D = 1.53 / 2.0 = 0.76



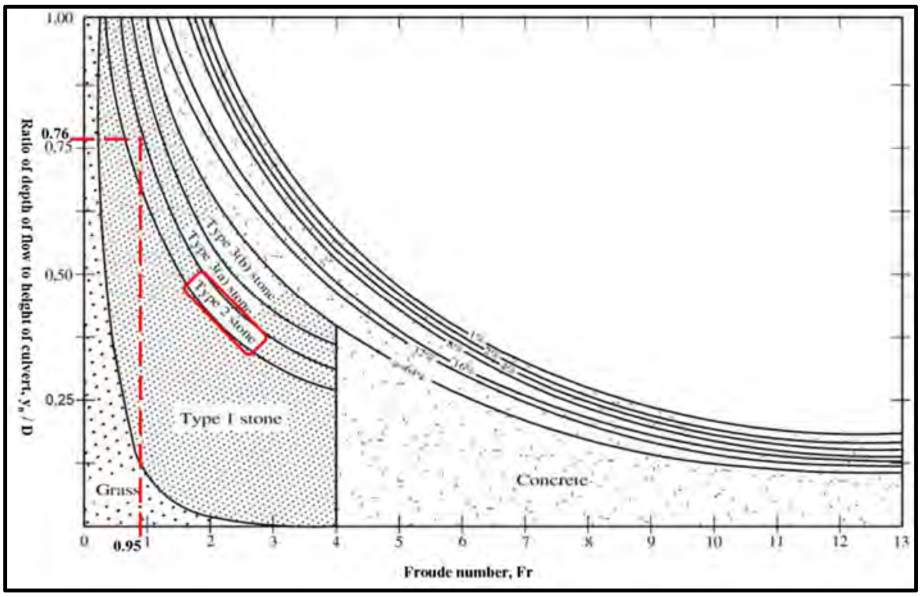


Figure M — Selection method for erosion protection measure at outlet (Drainage Manual, 2013)

The recommended erosion protection measure at the outlet was type 2 stone stilling basing design as shown in Figure N. The recommended dimensions of the design were as follows:

A = 3 × D = 3 × 2.0 = 6.0 m
B = 5 × D = 5 × 2.0 = 10.0 m
C = 5 × D = 5 × 2.0 = 10.0 m
D_{50} = 0.0707 × (Q_P ^ 1.333 / D ^ 2.333)
= 0.0707 × (13.99 ^ 1.333 / 2.0 ^ 2.333) = 0.47 m
E = = 2 × D_{50} = 2 × 0.47 = 0.95 m

The material for the stone pitching or gabion mat should be a well-graded mixture with 50% of stones equal to or larger than the D_{50} size. Furthermore, the diameter of stones should not be more than 1.5 times the D_{50} size.

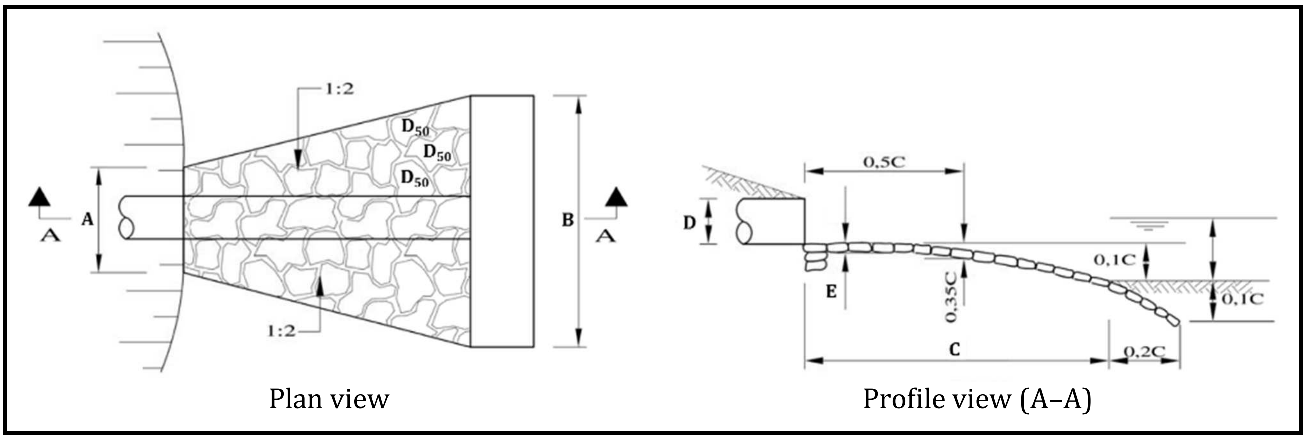


Figure N — Type 2 stone stilling basin (US Army Waterways)

The alignment of the culvert to the natural watercourse was such that there were sharp bends in the direction of flow upstream of the culvert, as shown in Figure O. These areas of concern had potential for erosion, so monitoring of the upstream watercourse and consideration of erosion protection measures, such as gabions, was recommended.

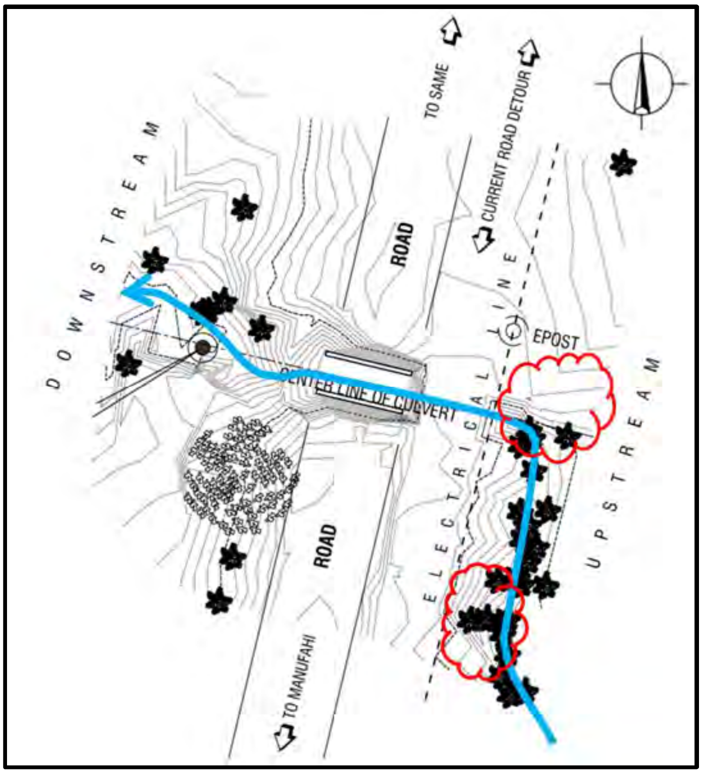


Figure O — Plan view of site from topographic survey showing areas of concern

A.9 Design remarks

This section will summarise the results of the culvert design. The main conclusion from this case study was that the capacity of the Sesurai culvert was sufficient. However, there may be high velocity of flow, so erosion protection measures were recommended for the outlet. Furthermore, monitoring of the upstream watercourse and consideration of erosion protection measures was recommended.

In future projects, it was recommended that culverts have a minimum gradient of 0.5% and that adjustment of the culvert alignment be considered.

ANNEX

A.10 Calculation notes

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	Section:	RAINFALL ANALYSIS		Engineer: Date: 30-Oct-17

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1) Annual maximum daily rainfall data

Table 1.1 – Annual maximum daily rainfall in Dili

Date	Annual maximum daily rainfall (mm/day)
28/03/1978	110.0
16/04/1979	60.0
29/01/1980	85.0
25/11/1981	80.0
12/01/1982	58.0
13/02/1983	77.0
01/01/1984	109.0
01/01/1985	136.6
01/01/1986	95.2
06/03/1989	57.0
05/03/1990	91.0
08/04/1991	74.0
01/01/1992	67.6
21/01/1993	158.0
09/01/1994	73.0
28/03/1995	99.0
06/02/1996	92.8
02/01/1997	84.6
13/11/1998	116.8
11/01/1999	121.0
09/02/2003	54.2
06/02/2004	126.7
29/03/2005	113.4
21/12/2006	69.4
22/11/2007	69.4
20/02/2008	81.6
23/01/2009	34.6
07/07/2010	178.6
02/02/2011	96.9
11/05/2012	110.1
26/02/2013	82.7
15/04/2014	98.7
12/02/2015	99.7
18/12/2016	54.8

Source: National Directorate for Water Resource Management

Source: Comoro Bridge Project

2) Maximum probable daily rainfall

Gumbel distribution for maximum probable daily rainfall,

$R_{24} = \mu + \sigma \times K$

$= 91.6588 + 30.4364 \times 1.3046$

$R_{24} =$ 131.4 mm/day in Dili

Gumbel distribution

Average (mean), $\mu = (110 + 60 + \ldots + 54.8) / 34$

$\mu =$ 91.6588 mm/day

Standard deviation, $\sigma = \sqrt{((110 - 91.7 + 60 - 91.7 + \ldots + 54.8 - 91.7)^2 / 33)}$

$\sigma =$ 30.4364 mm/day

Frequency factor, $K = -\sqrt{6} / \pi \times (\gamma + \ln(\ln(T / (T - 1)))$

$= -\sqrt{6} / 3.1416 \times (0.5772 + \ln(\ln(10 / (10 - 1)))$

$K =$ 1.3046

Pi constant, $\pi =$ 3.1416

Euler–Mascheroni constant, $\gamma =$ 0.5772

Return period, $T =$ 10 years

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Table 2.1 – Recommended return periods of rainfall for culverts

Road class	Level of drainage capacity	Return period of rainfall, T
National Roads / Urban Arterial Roads	High	10 years
Regional Roads / Urban Collector Roads	Medium	7 years
Local Roads / Urban Local Roads	Low	5 years

Manual for Highway Earthworks, 2009

Code for the Design of Drainage of Highway Surfaces, 1994

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Table 2.2 – Calculation of maximum probable daily rainfall for Dili

Return period, T	Frequency factor, K	Maximum probable daily rainfall, R_{24} (mm/day)
10 years	1.3046	131.4
7 years	1.0079	122.3
5 years	0.7195	113.6

3) Synthetic procedure

Conversion from: Dili
Average annual rainfall = 940 mm/year

Conversion to: Same
Average annual rainfall = 3117 mm/year

Ministry of Agriculture, Forestry and Fisheries (MAFF)

Conversion factor = 3117 / 940 = 3.32

Table 3.1 – Synthetical calculation of design daily rainfall for Same

Return period, T	Maximum probable daily rainfall in Dili, R_{24} (mm/day)			Design daily rainfall, R_{24} (mm/day)
10 years	131.4	× 3.32	=	435.6
7 years	122.3	× 3.32	=	405.6
5 years	113.6	× 3.32	=	376.5

Design daily rainfall, R_{24} = 435.6 mm/day

R24 = 435.56 mm/day

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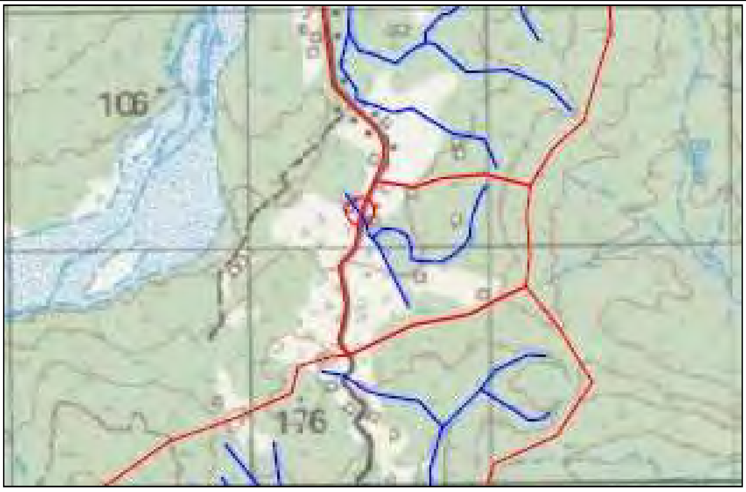
4) Catchment data

Location of discharge point

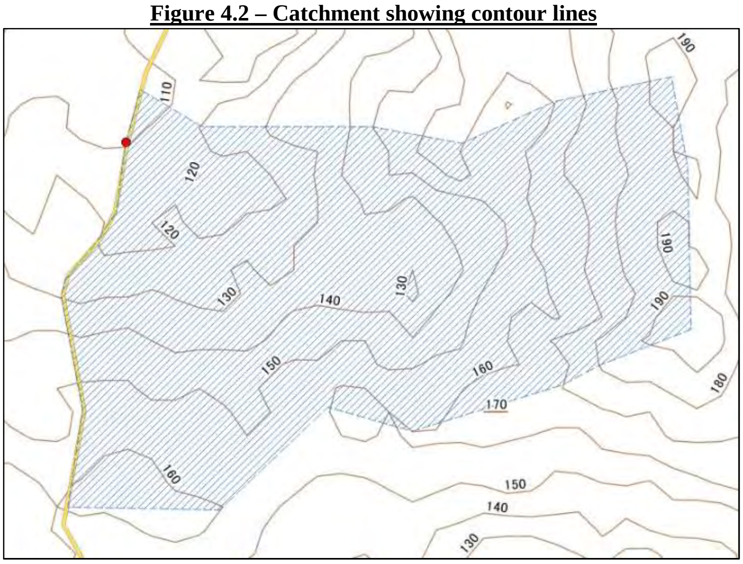
Latitude =	-9.11705 °	
	(S009° 07' 01.38")	
Longitude =	125.69719 °	
	(E125° 41' 49.88")	
Catchment area, A =	0.32 km²	A = 0.32 km²

Figure 4.1 – Catchment showing location of culvert, watershed and watercourses



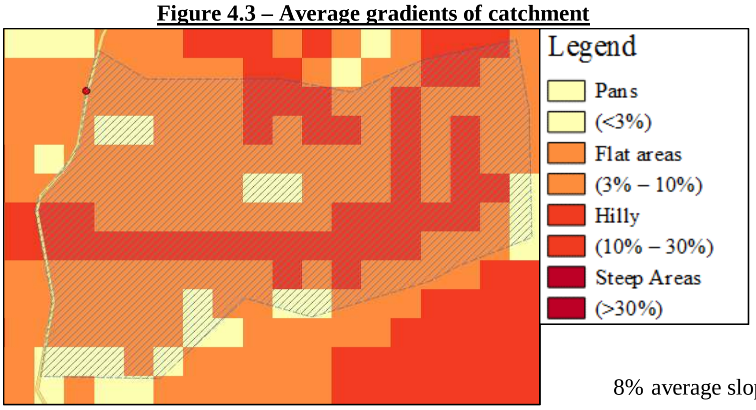
Mapping & GIS Section
Hatoudo map

Figure 4.2 – Catchment showing contour lines



Mapping & GIS Section
GIS software

Figure 4.3 – Average gradients of catchment



8% average slope

Mapping & GIS Section
GIS software

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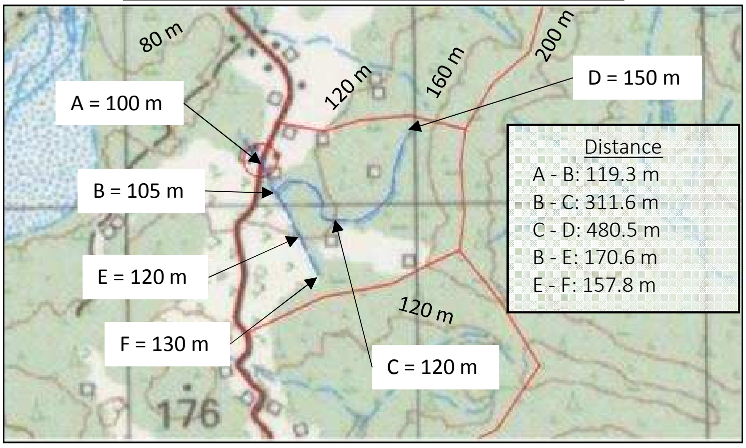
4) Catchment data
(continued)

Figure 4.4 – Elevations and lengths of watercourses



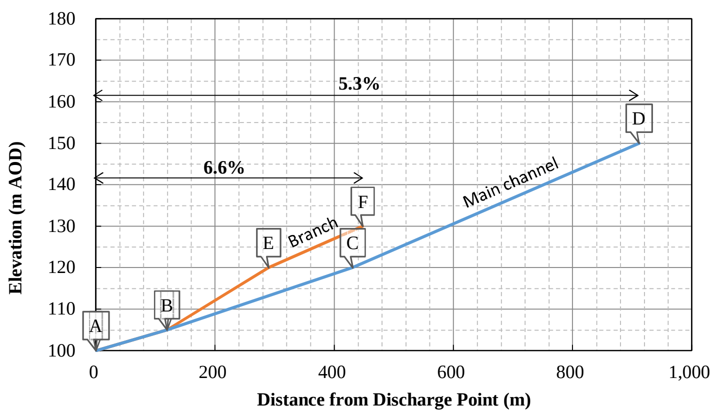
Mapping & GIS Section
Hatoudo map

Table 4.1 – Calculation of gradient of watercourse

	Point	Distance (m)	Cumulative dist. (m)	Elevation (m AOD)	Elevation change (m)	Gradient of channel	
Main channel							
mountain	D	480.5	911.4	150	50	5.3%	Mapping & GIS Section
	C	311.6	430.9	120	20		
	B	119.3	119.3	105	5		
culvert	A	0	0	100	0		
Branch channel							
mountain	F	157.8	447.7	130	30	6.6%	Mapping & GIS Section
	E	170.6	289.9	120	20		
	B	119.3	119.3	105	5		
culvert	A	0	0	100	0		

Total length of channel, L = 911.4 m
Gradient of watercourse, G = 5.3%

Figure 4.5 – River Profile



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5) Time of concentration

Time of concentration, $t_c = t_e + t_f$ — Manual for Highway Earthworks, 2009

t_e = Time of inlet flow

t_f = Time of channel flow

Table 5.1 – Recommended times for inlet flow

Catchment type	Time of inlet flow (min)	Time of inlet flow (hours
Mountainous land	15.0 – 30.0	0.25 – 0.5
Cut slopes	3.0 – 5.0	0.05 – 0.083
Urban areas	5.0	0.083

Manual for Highway Earthworks, 2009

Time of inlet flow, t_e = 20.0 minutes

t_e = 0.33 hours

Table 5.2 – Recommended velocities for channel flow

Gradient of watercourse, G	Velocity of run-off, W (m/s)
> 1.0%	3.5
1.0% – 0.5%	3.0
< 0.5%	2.1

Manual for Highway Earthworks, 2009

Gradient of watercourse, G = 5.3%

∴ Velocity of run-off, W = 3.5 m/s

Time of channel flow, $t_f = L / (3600 \times W)$ — Kraven Formula

t_f = 911.4 / (3600 × 3.5) = 0.07 hours

Time of concentration, $t_c = t_e + t_f$

t_c = 0.33 + 0.07 = 0.41 hours — tc = 0.41 hours

6) Intensity of rainfall

Design intensity of rainfall, $i = \frac{R_{24}}{24} \times \left(\frac{24}{t_c}\right)^{0.6}$ — Mononobe Formula

$= \frac{436}{24} \times \left(\frac{24}{0.41}\right)^{0.6}$

Design intensity of rainfall, i = 209.9 mm/hour — i = 209.9 mm/hour

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7) Coefficient of run-off

Table 7.1 – Recommended coefficients of runoff

Catchment Type	Coefficient of runoff	Average value
Road surfaces and sloped surfaces	0.70 – 1.00	0.85
Steep mountainous land	0.75 – 0.90	0.83
Gentle mountainous land	0.70 – 0.80	0.75
Undulating land and woods	0.50 – 0.75	0.63
Flat farmlands	0.45 – 0.60	0.53
Rice paddy (fields)	0.70 – 0.80	0.75
Urban areas	0.60 – 0.90	0.75
Forest zones	0.20 – 0.40	0.30
Catchment areas of mountain streams	0.75 – 0.85	0.80
Catchment areas of small rivers on flat land	0.45 – 0.75	0.60
Catchment areas of major rivers of which more than half run on flat land	0.50 – 0.75	0.63

Manual for Highway Earthworks, 2009

Table 7.2 – Calculation of weighted coefficient of runoff

Catchment type (land uses)	Catchment area (km²)	Coefficient of runoff
Gentle mountainous land	0.32	0.75

Coefficient of runoff, C = 0.75

8) Discharge of catchment

Design flood of catchment, $Q_P = \frac{1}{3.6} \times C \times i \times A$

Rational Method

$= \frac{1}{3.6} \times 0.75 \times 209.9 \times 0.32$

Design flood of catchment, Q_P = 13.99 m³/s

QP = 13.99 m³/s

Table 8.1 – Summary of discharge results for different return periods

Return period, T	Intensity of rainfall, i (mm/hour)	Channel discharge, Q_P (m³/s)
10 years	209.92	13.99
7 years	195.49	13.03
5 years	181.47	12.10

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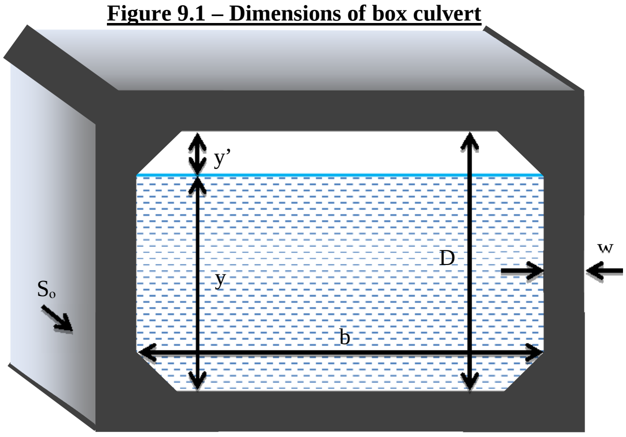
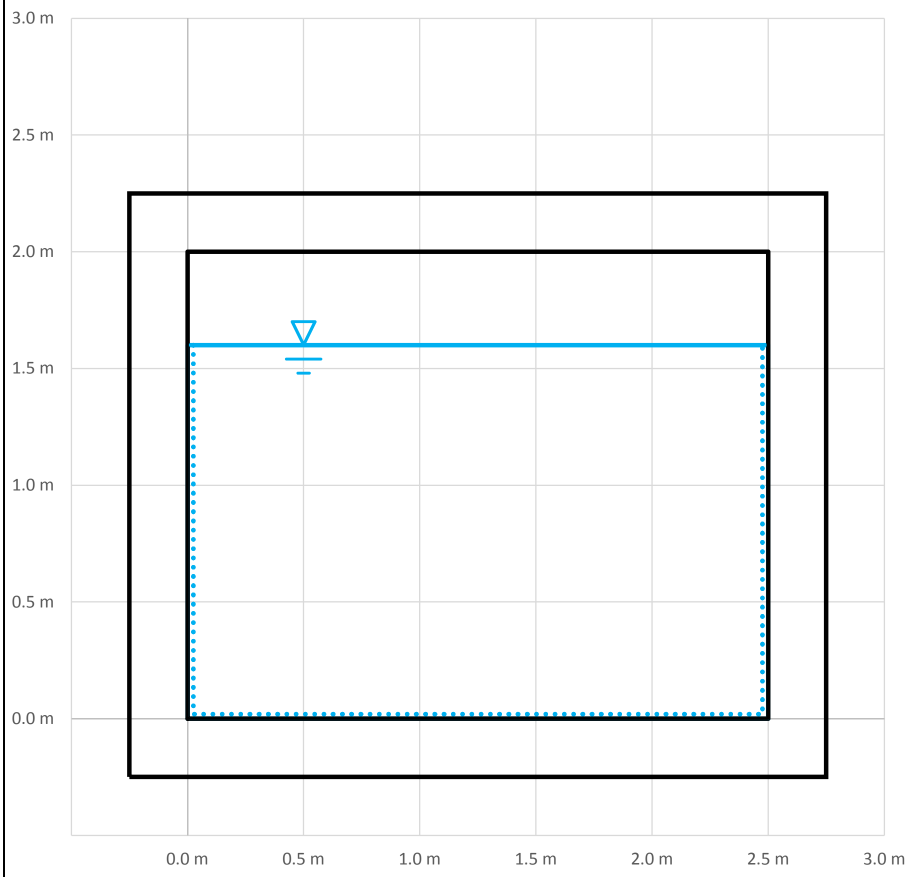
9) Geometry of culvert

Figure 9.1 – Dimensions of box culvert



Culvert width (internal), b =		2.50 m		
Culvert height (internal), D =		2.00 m		
Thickness of wall & fillets, w =		0.25 m		
Type of culvert =		single		
Total area of culvert, A_T =	2.50 × 2.00 =	5.00 m²	(b × D)	
Margin in case of sedimentation, y' =	0.2 × 2.00 =	0.40 m	(0.2 × D)	Manual for Highway
Depth of flow, y =	0.8 × 2.00 =	1.60 m	(0.8 × D)	Earthworks, 2009
Area of flow, A =	2.50 × 1.60 =	4.00 m²	(b × y)	
Wetted perimeter, P =	(2.50 + 2 × 1.60) =	5.70 m	(b + 2 × y)	
Hydraulic radius, R =	4.00 / 5.70 =	0.70 m	(A / P)	
Gravitational acceleration, g =		9.81 m/s²		Newton's law

Figure 9.2 – Cross section of culvert



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10) Profile of culvert

From topographic survey:

Elevation at inlet, EL_{in} = 138.440 m AOD — Source: Topographic survey

Elevation at outlet, EL_{out} = 138.410 m AOD

Change in elevation, $EL = EL_{in} – EL_{out}$

EL = 138.44 – 138.41 = 0.030 m

Culvert length, L = 6.0 m

Gradient of culvert, S_o = EL / L

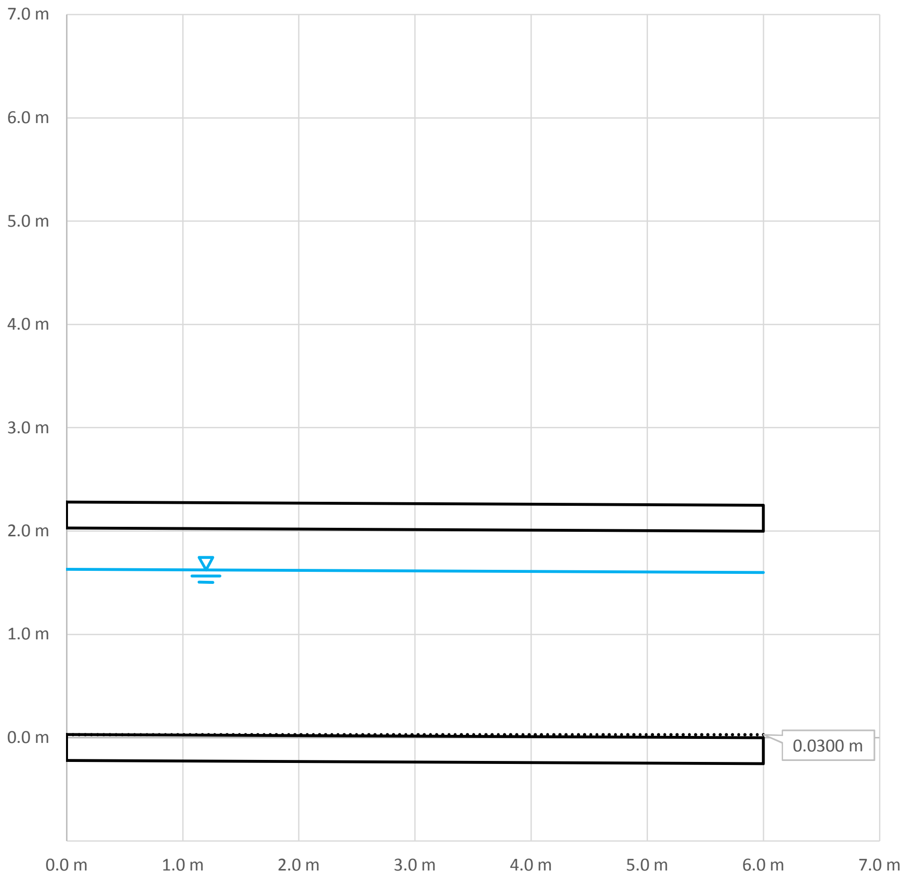
= 0.030 / 6.0 = 0.005 (m / m)

S_o = = 0.5%

Check of gradient: $0.005 \le S_o < 0.100$

$0.005 \le 0.005 < 0.100$ ∴ OK — Slope OK

Figure 10.1 – Longitudinal profile of culvert



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11) Material of culvert

Table 11.1 – Manning's *n* for closed conduits flowing partly full

Material and type of conduit	***n value***
Concrete:	
Factory-made concrete products	***0.013***
Cast in-situ concrete	***0.015***

Manual for Highway Earthworks, 2009

Coefficient of roughness, n = 0.015

n = 0.015

12) Discharge capacity of culvert

Design capacity of culvert, $Q = (A^{\wedge 5/3} \times S_o^{\wedge 1/2}) / (n \times P^{\wedge 2/3})$

$= \dfrac{(4.00 \wedge (5/3) \times 0.005 \wedge (1/2))}{(0.015 \times 5.70 \wedge (2/3))}$

Q = 14.89 m³/s

Manning equation for discharge

(Alternative), Q = A × V

$= A \times (R^{\wedge 2/3} \times S_o^{\wedge 1/2}) / n$

= 4.00 × (0.70 ^ (2/3) × 0.005 ^ (1/2)) / 0.015

Q = 14.89 m³/s

Discharge equation

Discharge & Manning equation

Design flood of watercourse, Q_P = 13.99 m³/s

Check of capacity: $Q > Q_P$

14.89 m³/s > 13.99 m³/s ∴ OK

Capacity OK

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13) Flow conditions in culvert

Normal depth using Newton-Raphson Method

$y_1 = y_0 - (Q(y_0) - Q_P) / Q'(y_0)$

Where: $Q(y) = (A^{5/3} \times S_o^{1/2}) / (n \times P^{2/3})$ — Manning equation for discharge

$= (b^{5/3} \times y^{5/3} \times S_o^{1/2}) / (n \times (b + 2 \times y)^{2/3})$

$Q'(y) = \dfrac{(b^{5/3} \times y^{2/3} \times S_o^{1/2} \times (5 \times b + 6 \times y))}{(n \times 3 \times (b + 2 \times y)^{5/3})}$ — Differential equation of Manning equation

Table 13.1 – Iterative calculation of normal depth of flow

	y_0	$Q(y_0)$	$Q(y_0) - Q_P$	$Q'(y_0)$	y_1	
Start	5	58.93	44.93	13.36	1.6360	→ next y_0
Iteration 1	1.6360	15.32	1.33	12.07	1.5259	→ next y_0
Iteration 2	1.5259	14.00	0.01	11.93	1.5252	→ next y_0
Iteration 3	1.5252	13.99	0.00	11.93	1.5252	→ $y_1 = y_0$

∴ convergence

Normal depth of flow, y_n = 1.53 m (final y_0)

Normal area of flow, A_n = 2.50 × 1.53 = 3.81 m² ($b \times y_n$)

Normal wetted perimeter, P_n = 2.50 + 2 × 1.53 = 5.55 m ($b + 2 \times y_n$)

Normal hydraulic radius, R_n = 3.81 / 5.55 = 0.69 m (A_n / P_n)

Normal velocity of flow, $V_n = (R^{2/3} \times S_o^{1/2}) / n$ — Manning equation

= (0.69 ^ (2/3) × 0.005 ^ (1/2)) / 0.015

V_n = 3.67 m/s

Froude number

Froude number, $Fr = \{ (Q_P^{2} \times b) / (g \times A_n^{3}) \}^{1/2}$ — Froude equation

= { (13.99^2 × 2.5) / (9.81 × (1.53 × 2.5)^3) }^(1/2)

Fr = 0.95

Significance of Froude number:
- Fr > 1 ⇒ supercritical flow
- Fr = 1 ⇒ critical flow
- Fr < 1 ⇒ subcritical flow

Fr = 0.95 < 1

∴ Flow conditions: subcritical

Critical depth

Critical depth, $y_c = \{ (Q_P / b)^{2} / g) \}^{1/3}$ — Box culverts only

= { (13.99 / 2.5) ^ 2 / 9.81) } ^ (1/3)

= 1.47 m

Area of flow, A_c = 1.47 × 2.50 = 3.68 m² ($y_c \times b$)

Wetted perimeter, P_c = 2 × 1.47 + 2.50 = 5.45 m ($y_c + y_c + b$)

Critical gradient of culvert, $S_c = (Q_P^{2} \times n^{2} \times P_c^{4/3}) / A_c^{10/3}$

= (13.99 ^ 2 × 0.015 ^ 2 × 5.45 ^ (4/3)) / (3.68 ^ (10/3))

= 0.005 (m / m)

= 0.5%

14) Design remarks

Slope check: 0.005 ≤ 0.005 < 0.100 ∴ OK

Capacity check: 14.89 m³/s > 13.99 m³/s ∴ OK

Flow velocity check: subcritical and 0.6 m/s ≤ 3.67 m/s > 3.5 m/s

∴ Consider erosion protection measures

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15) Selection of protection measure

Froude number, Fr = 0.95

Ratio of y_n / D = 1.53 / 2.00 = 0.76

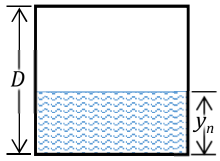
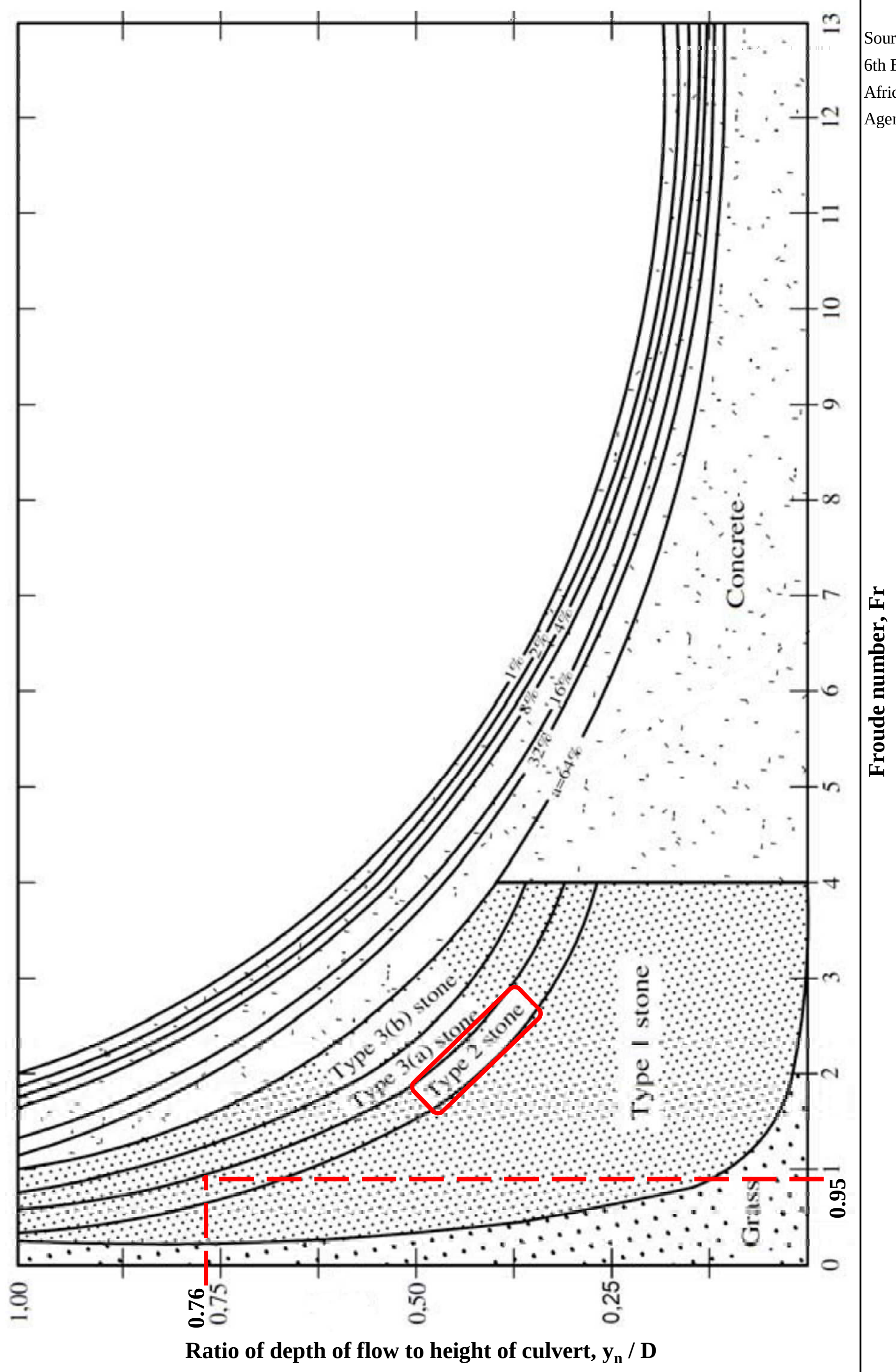


Figure 15.1 – Selection method for erosion protection measure at outlet



Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

∴ Adopt type 2 stone stilling basin

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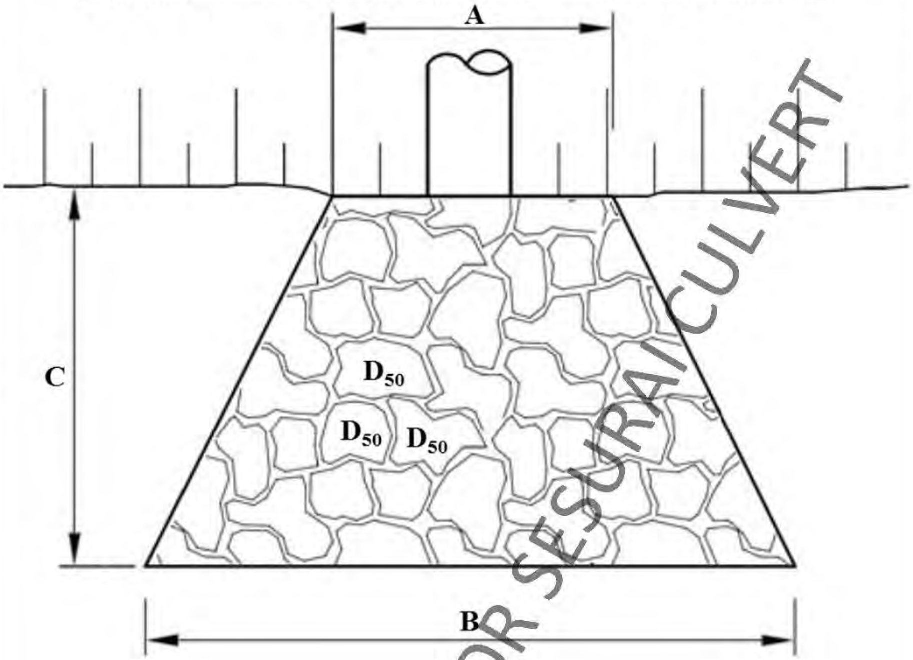
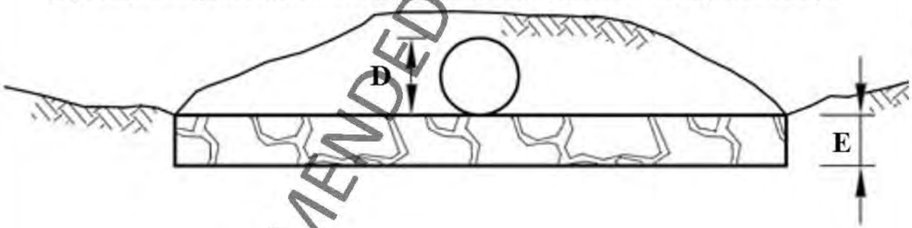
16) Detail of protection measure

Figure 16.1 – Plan view of Type 1 stone stilling basin (US Army Waterways)



Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

Figure 16.2 – Upstream view of Type 1 stone stilling basin (US Army Waterways)



Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

Dimensions of type 1 stone stilling basin

Height of culvert, D = 2.0 m

Width of basin at outlet, A = $3 \times D =$ 6.0 m

Width of basin downstream, B = $A + C =$ 6.0 m

Length of basin, C = $3.0792 \times (Q_P / D^{1.6}) + 2.4384$

= 3.0792 × (13.99 / 2.00 ^ 1.6) + 2.4384

C = 16.7 m

Thickness of basin, E = $0.5 \times D \times Fr =$ 0.95 m

Minimum size of 50% of stones, $D_{50} = 0.0883 \times (Q_P^{1.333} / D^{2.333})$

= 0.0883 × (13.99 ^ 1.333 / 2.00 ^ 2.333)

$D_{50} =$ 0.59 m

Bed material should be a well-graded mixture with 50% equal to or larger than the design size, D_{50}. The diameter of stones should not be more than 1.5 times the D_{50} size.

Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

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16) Detail of protection measure (continued)

Figure 16.3 – Plan view of Type 2 stone stilling basin (US Army Waterways)

Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

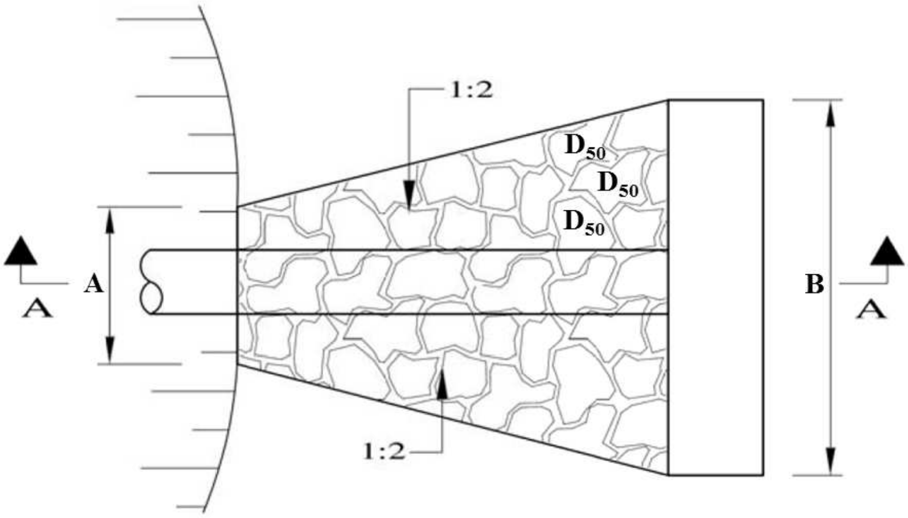
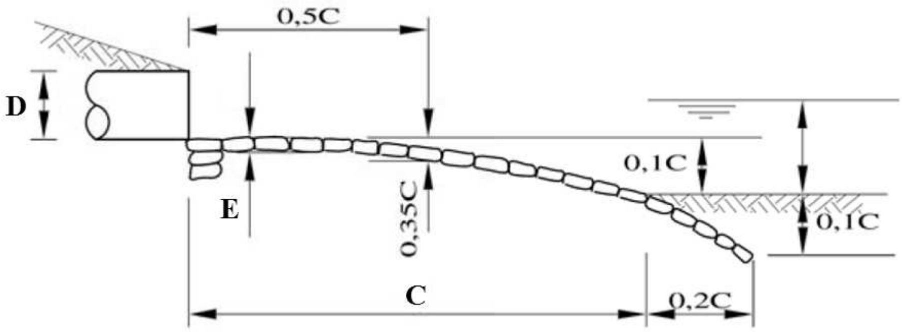


Figure 16.4 – Cross section (A-A) of Type 2 stone stilling basin (US Army Waterways)

Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.



Dimensions of type 2 stone stilling basin

Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

Height of culvert, D =		2.0	m
Width of basin at outlet, A =	3 × D =	6.0	m
Width of basin downstream, B =	5 × D =	10.0	m
Length of basin, C =	5 × D =	10.0	m
0.1 C =	0.1 × C =	1.0	m
0.2 C =	0.2 × C =	2.0	m
0.35 C =	0.35 × C =	3.5	m
0.5 C =	0.5 × C =	5.0	m
Thickness of basin, E =	$2 \times D_{50}$ =	0.00	m

Minimum size of 50% of stones, $D_{50} = 0.0707 \times (Q_P^{1.333} / D^{2.333})$

= 0.0707 × (13.99 ^ 1.333 / 2.00 ^ 2.333)

D_{50} = 0.47 m

Bed material should be a well-graded mixture with 50% equal to or larger than the design size, D_{50}. The diameter of stones should not be more than 1.5 times the D_{50} size.

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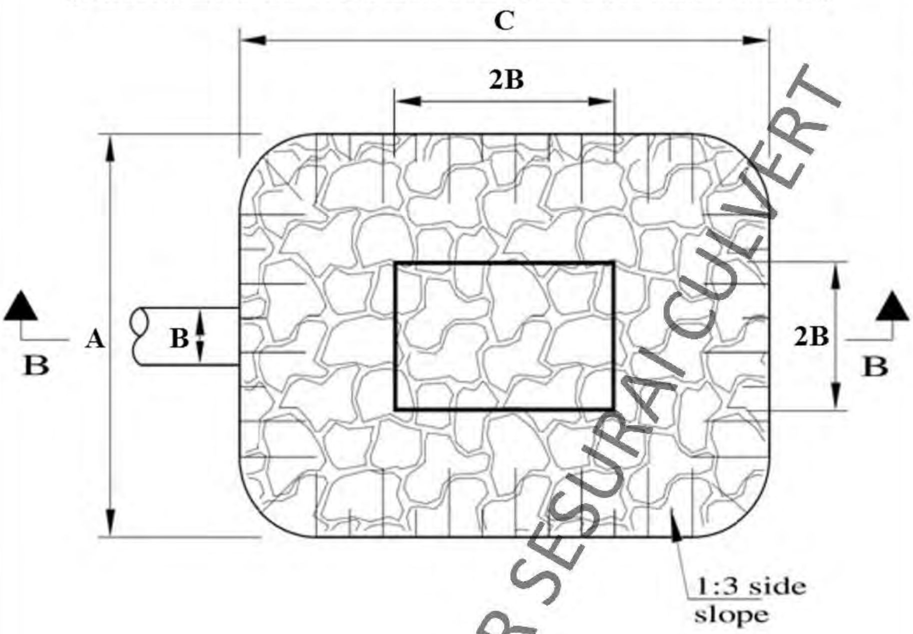
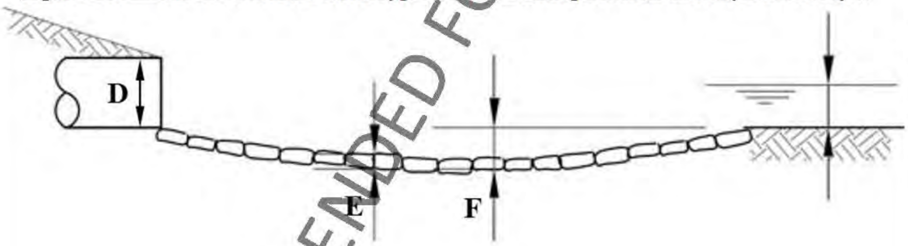
16) Detail of protection measure (continued)

Figure 16.5 – Plan view of Type 3a stone stilling basin (US Army Waterways)



Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

Figure 16.6 – Cross section (B-B) of Type 3a stone stilling basin (US Army Waterways)



Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

Dimensions of type 3a shallow stone stilling basin

Height of culvert, D =		2.0	m
Width of culvert, B =		2.5	m
Width of basin, A =	2 × D + 6 × F =	10.0	m
Length of basin, C =	3 × D + 6 × F =	12.0	m
Depth of basin, F =	0.5 × D =	1.0	m
Thickness of basin, E =	2 × D_{50} =	0.74	m

Minimum size of 50% of stones, $D_{50} = 0.0552 \times (Q_P^{1.333} / D^{2.333})$

$= 0.0552 \times (13.99 \wedge 1.333 / 2.00 \wedge 2.333)$

D_{50} = 0.37 m

Bed material should be a well-graded mixture with 50% equal to or larger than the design size, D_{50}. The diameter of stones should not be more than 1.5 times the D_{50} size.

Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

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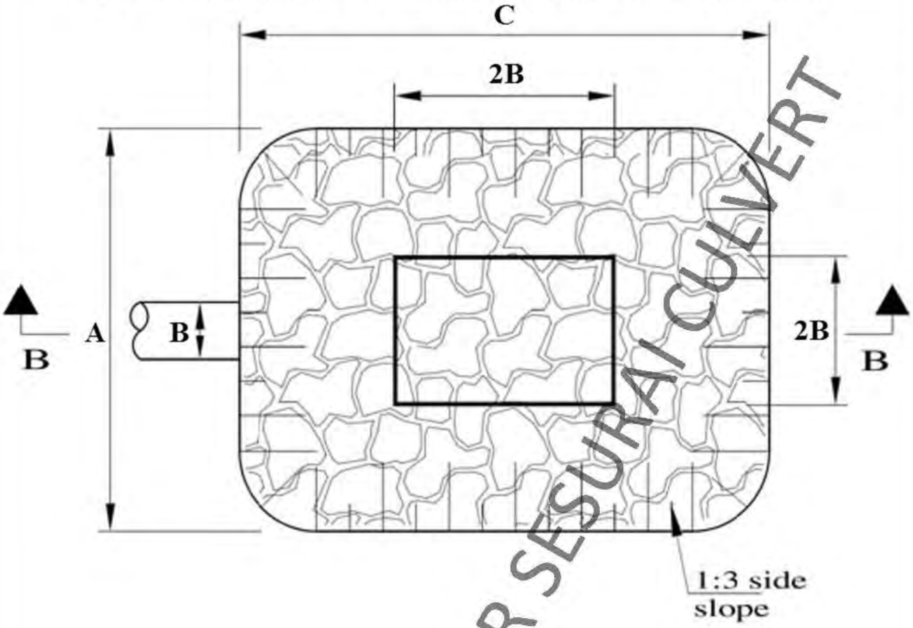
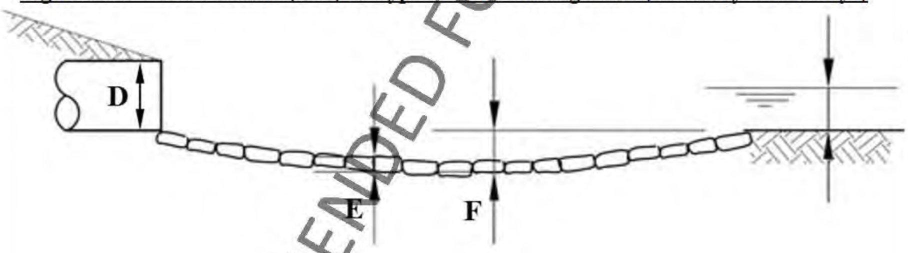
16) Detail of protection measure (continued)

Figure 16.7 – Plan view of Type 3b stone stilling basin (US Army Waterways)



Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

Figure 16.8 – Cross section (B-B) of Type 3b stone stilling basin (US Army Waterways)



Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

Dimensions of type 3b deep stone stilling basin

Height of culvert, D =		2.0 m
Width of culvert, B =		2.5 m
Width of basin, A =	$2 \times D + 6 \times F$ =	16.0 m
Length of basin, C =	$3 \times D + 6 \times F$ =	18.0 m
Depth of basin, F =	$0.5 \times D$ =	2.0 m
Thickness of basin, E =	$2 \times D_{50}$ =	0.48 m

Minimum size of 50% of stones, $D_{50} = 0.0362 \times (Q_P^{1.333} / D^{2.333})$

$= 0.0362 \times (13.99 \wedge 1.333 / 2.00 \wedge 2.333)$

$D_{50} =$ 0.24 m

Bed material should be a well-graded mixture with 50% equal to or larger than the design size, D_{50}. The diameter of stones should not be more than 1.5 times the D_{50} size.

Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

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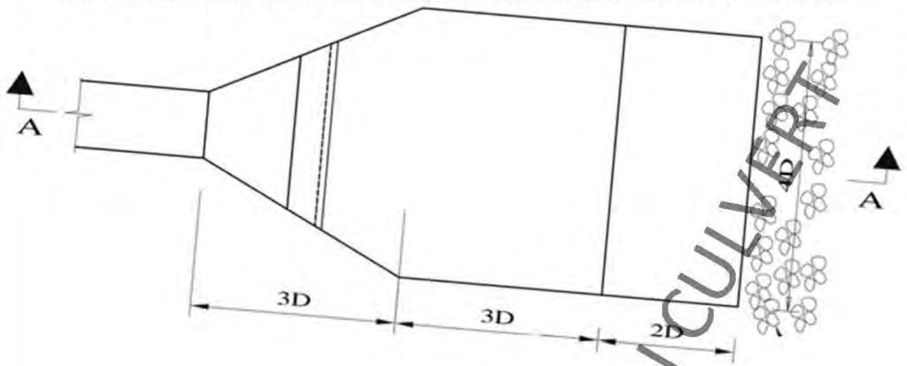
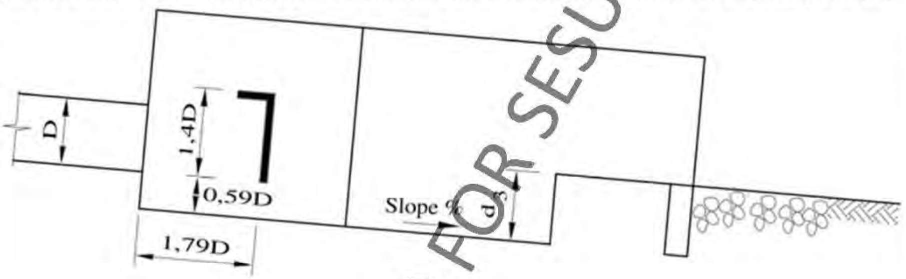
16) Detail of protection measure (continued)

Figure 16.9 – Plan view of Type 5 concrete stilling basin (US Army Waterways)



Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

Figure 16.10 – Cross section (A-A) of Type 5 concrete stilling basin (US Army Waterways)



Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

Dimensions of type 3b deep stone stilling basin

Height of culvert, D =		2.0 m
2 D =	2 × D =	4.0 m
3 D =	3 × D =	6.0 m
4 D =	4 × D =	8.0 m
0.59 D =	0.59 × D =	1.2 m
1.4 D =	1.4 × D =	2.8 m
1.79 D =	1.79 × D =	3.6 m
S_0 =		0.5%

Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

a %	d_3 / D
1	0.59
2	0.59
4	0.71
8	0.92
16	1.25
32	1.92
64	Not recommended

Source: Drainage Manual, 6th Edition, The South African National Roads Agency SOC Ltd.

d_3 = 0.59 × D = 1.18 m

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