CHAPTER 3

DETAILED INVENTORY SURVEY

3.1 General Information

The Detailed Inventory Survey (DIS) is used to inspect in detail the present condition of slopes selected under the Preliminary Inventory Survey (PIS), and to plan the appropriate countermeasures. The DIS is comprised of risk assessment, planning of countermeasures, and indicative feasibility assessment, using the Inventory Format Sheets 3, 4 and 5. The outputs of the DIS are the detailed record of the present condition of road slope disaster sites, the countermeasure plan for each disaster site and indicative feasibility assessment of the proposed countermeasure.

3.1.1 Objectives and Procedures for the DIS

The objectives and procedures for the DIS are shown in Table 3.1. The DIS is carried out by completing the inventory sheets designed specifically for this study as shown in Sheets 3 to 5.

Table 3.1 Objective and Procedure for the DIS

Inventory Format Sheet	Objective	Procedure
Sheet-3	1) Findings and classification of road slope failure 2) Measurement of disaster magnitude	1) Draw the front view of the road slope 2) Draw the cross section of the road slope
Sheet-4	3) Planning of countermeasures (3 alternatives)	3-1) Draw elevation view plan of the countermeasure 3-2) Draw the standard section of the countermeasure on the cross section sketches
	4) Cost estimation of the countermeasures	4) Estimate the cost of the countermeasure referring to the unit cost table
Sheet-5	5) Indicative feasibility assessment of the countermeasures	5) Calculate the feasibility indicators for the countermeasures based on the form
Sheet-6	6) Correction of road slope disaster records	6) Fill in the format sheet by DEO

3.1.2 Work Flow of the DIS

The flowchart for the DIS is shown in Figure 3.1 and is composed of four main steps. The inspectors have to follow the flowchart systematically for accuracy. Preparation work is required, especially in the review of the PIS results. The inspectors are required to make accurate measurements for Sheet 3. These measurements are used, together with the District Engineer's comments, for planning countermeasures as required in completing Sheet 4. At least two alternative countermeasures should be planned based on the judgment of the engineer. The judgment of the inspectors based on the present condition is required for Sheet 5. The last step of the DIS flowchart is checking and approval of the data and other input by the Section Chief of Maintenance/Planning, and the approval by the District Engineer or his assistant. The results of the DIS are then entered into the database.

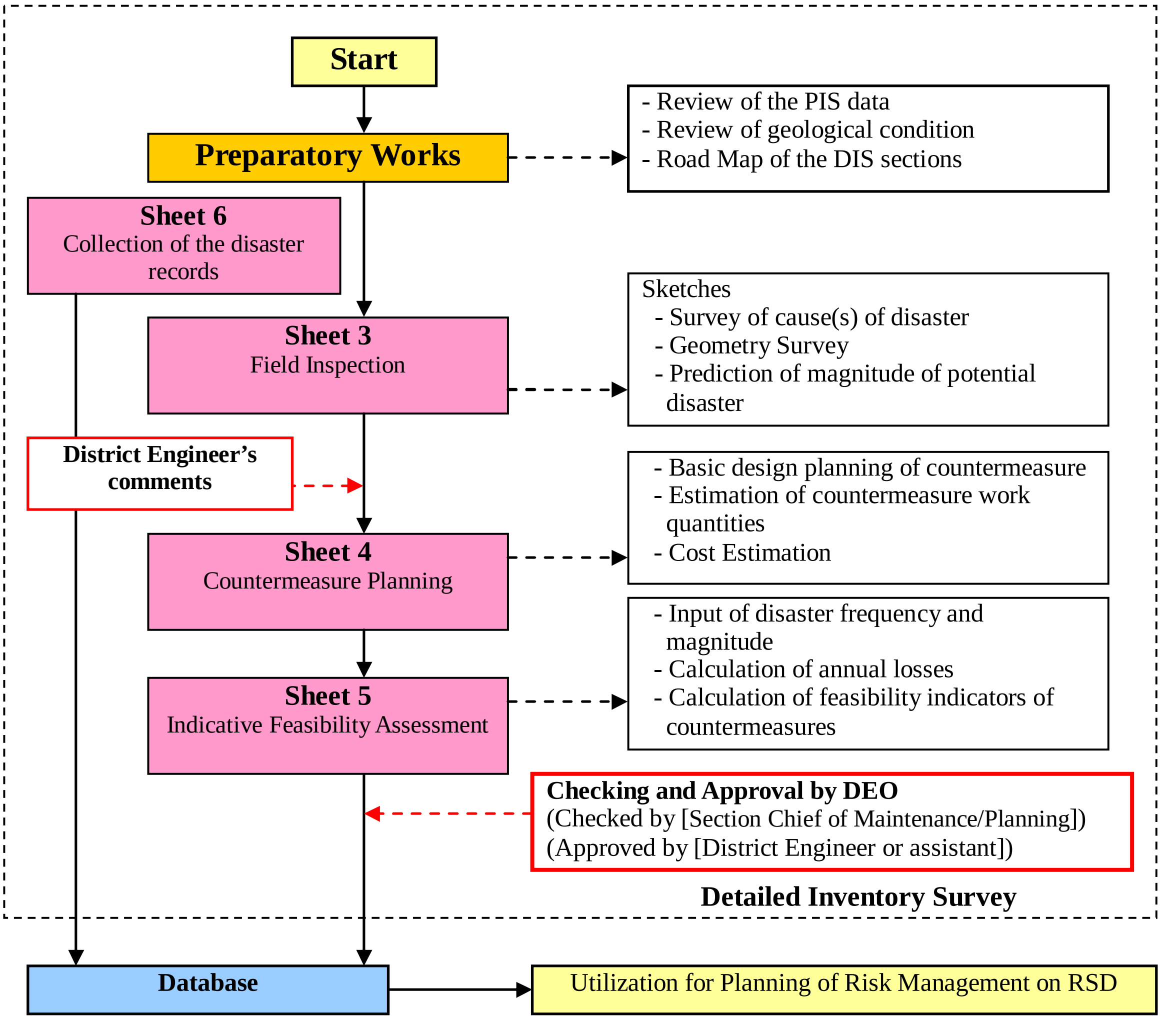


Figure 3.1 Flowchart of Detailed Inventory Survey

3.2 Method of Investigation (Sheet 3)

3.2.1 Tools for the Survey

In the DIS, tools are needed for field inspections, as well as for office works when planning the countermeasures and encoding the data into Sheets 3 to 5. The staffs require safe equipment for field inspections, and knowledge of how to accurately use the measuring tools. Computers and scanners are needed to input Sheets 3 to Sheet 5.

The required tools for each survey team are shown in Table 3.2.

Table 3.2 Tools for Field Inspection for DIS

Items	Specification	Usage
Vehicle		For travel to DIS section.
Camera	Digital camera or negative print camera	Record the road slope condition of DIS section. Arrange the photographs on Sheet 1.
Tape measure	More than 10 m One (1) roll	Measure distance or dimensions of objects.
Measuring Pole 	Minimum 2 m One (1) pole	Measure distance or dimensions of objects. To use to determine the height of road slopes.
Clinometer	Or a magnetic compass One (1) set	Measure angle of road slope.
Stationery	Pencil/Eraser/Ruler/ Protractor/Pen	Record conditions and dimensions of the road slope on Sheet 3.
Hammer	For geological survey	Inspect soil or rock on the road slope.
Safety Outfit 	Brush knife/Gloves/ Hardhat/Ropes/Raincoat/ Torch/Boots.	For protection when on road slope, in bush, etc.
Stationery	Pencil/Eraser/Ruler/ Protractor/Pen (Black ink)	Draw the countermeasure on Sheet 4. Record the dimensions clearly with pen before scanning.
Scanner	Compatible with Windows OS. Minimum A4 scan size	Scan Sheet 3 sketch and Sheet 4 countermeasure plan for conversion into digital files.
Computer	Windows OS, Microsoft Excel for filling out of the inventory sheet.	Used to make the digital files of Sheet 3 and Sheet 4. Encoding countermeasure cost on Sheet 4 and each parameter on Sheet 5.

3.2.2 Procedure of Drawing Sketches

To evaluate the magnitude and mechanism of the causes of the potential hazard for the DIS slope, Sheet 3 (sketch) is prepared. The inspector carries out the field inspection through a survey of the road slope and its vicinity using the suggested tools. The condition of the DIS slope is sketched in a front view and cross section on Sheet 3.

The sketches on Sheet 3 are used as the basis for the countermeasure plan on Sheet 4, where an outline of the present conditions of DIS slope. Sheet 3 sketches should be drawn clearly for scanning and inserted as a digital image in Sheet 3 in Excel format. The key points, items required and methods of sketches are as follows:

(1) Key Points of the Sketch

The inspector should complete the accurate observations before drawing the sketch of the DIS slope, to enable him to draw the sketch easily and plan sufficient countermeasure alternatives. The following items are key points of observation in the procedure for creating the sketch.

(a) The location of the disaster and the road, i.e. evaluate the influence of the disaster on the road;

(b) The original (before the current collapse/slide) surface line of the road slope and road structure;

(c) Water traces, geology of the road slopes, and any other factors that may trigger the disaster;

(d) Warnings of disaster such as cracks, springs, or a small collapse;

(e) The phenomena which may indicate the cause of the disaster;

(f) Major mechanisms of the disaster;

(g) It is necessary to sketch the range of countermeasures planned; and

(h) Existing structures to consider in the construction of countermeasure works (e.g. telephone lines, etc.).

(2) Basic Information/Items to be Included in Sheet 3

The following items are to be incorporated into the sketch to record the present condition of DIS slopes and countermeasure plans (see Table 3.3).

Table 3.3 Basic Information/Items to be Included in Sheet 3

Basic road slope structure	- Distance from road center to the toe of the road slope; - Geometry of the road slope (gradient, height, width); - Facilities on the road and road slope; and - Existing countermeasure works on the road slope.
Topography	- Road slope condition (flat area, roughness, knick line) and - Gullies (natural drainage).
Road slope hazard condition	- Collapsed road slope/scarp of landslides - Deformation in the road and road slope (depressions/upheaval) - Distribution of exposed rock and their stability mass - Distribution of pebbles and boulders and their stability
Existing Countermeasure	- Layout of countermeasure - Profile of countermeasure - Damage situation of countermeasure and current state of effectiveness
Geological data	- Soil/rock type - Condition of surface soil (moisture content) - Structure of bedding - Condition and structure of cracks and fracture zones - Weathering grade - Pattern of cracks
Photographs	- Location of photography
Location of cross section	- For front view sketches only

(3) Procedure for Drawing the Sheet 3 Sketch

The procedure for drawing the sketch in Sheet 3 is shown in Figures 3.2 and 3.3. At the survey section, put marks on the road with paint or other similar material every 20 m from the start-point of the DIS section before drawing the sketch in order to measure the objects accurately. Investigate the DIS section before drawing the sketch. Draw the sketch using your judgment as the inspector (refer to the stylized sketch in Figure 3.4 if needed).

A legend for the sketch for Sheet 3 has been prepared for the inventory survey. Some of the symbols were selected from the *Design Guidelines Criteria and Standards Volume-I (DPWH),* while some have been created in consideration of actual conditions of the national highway. The legend consists of structures, topography and geology. Geological symbols are limited to clay (or clayey soil), sand (or sandy soil), gravel (or gravelly soil), weathered rock, fractured rock and fresh rock to simplify the sketch.

The sketch is to be drawn clearly and highlighted by clearly visible black lines since it will be shown as a monochrome image in the RSMS. If the sketch is drawn using pencil, it should be retraced on a new sheet or the drawing highlighted using a black pen without any dirt on the sheet, so that it can be scanned clearly. Scan the original sketch of Sheet 3 and paste it on the digital file for Sheet 3. An example of a sketch is shown in Figures 3.5 and 3.6.

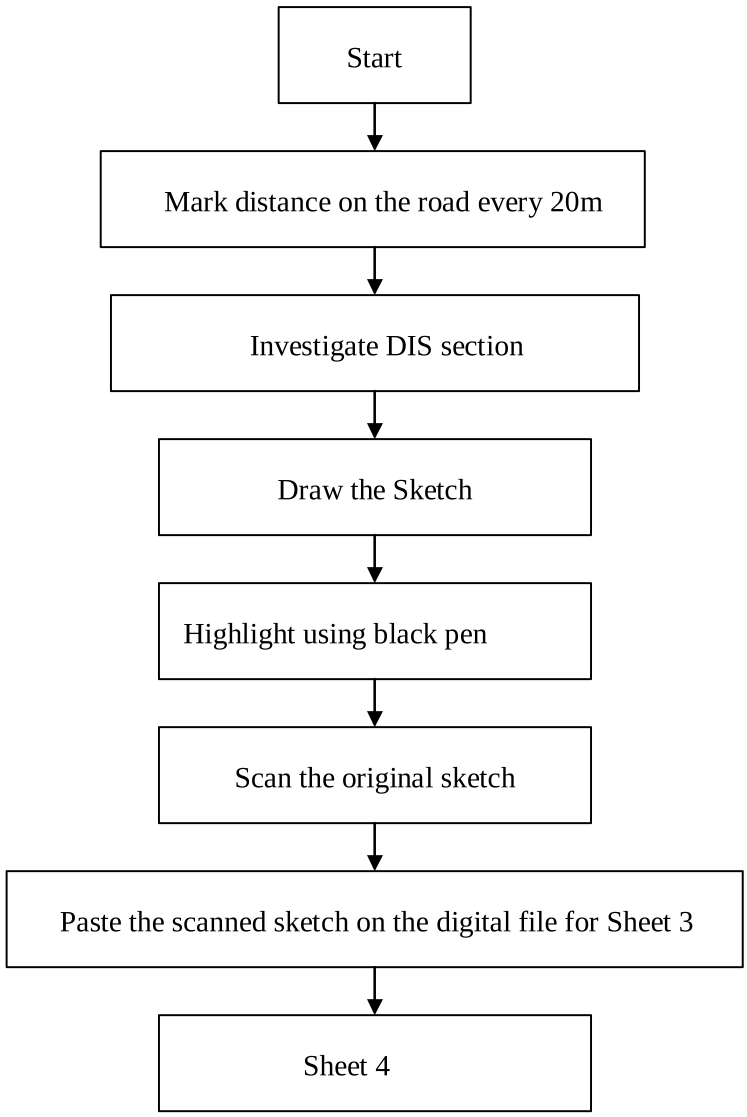


Figure 3.2 Flowchart of Procedure for Sheet 3 Sketch

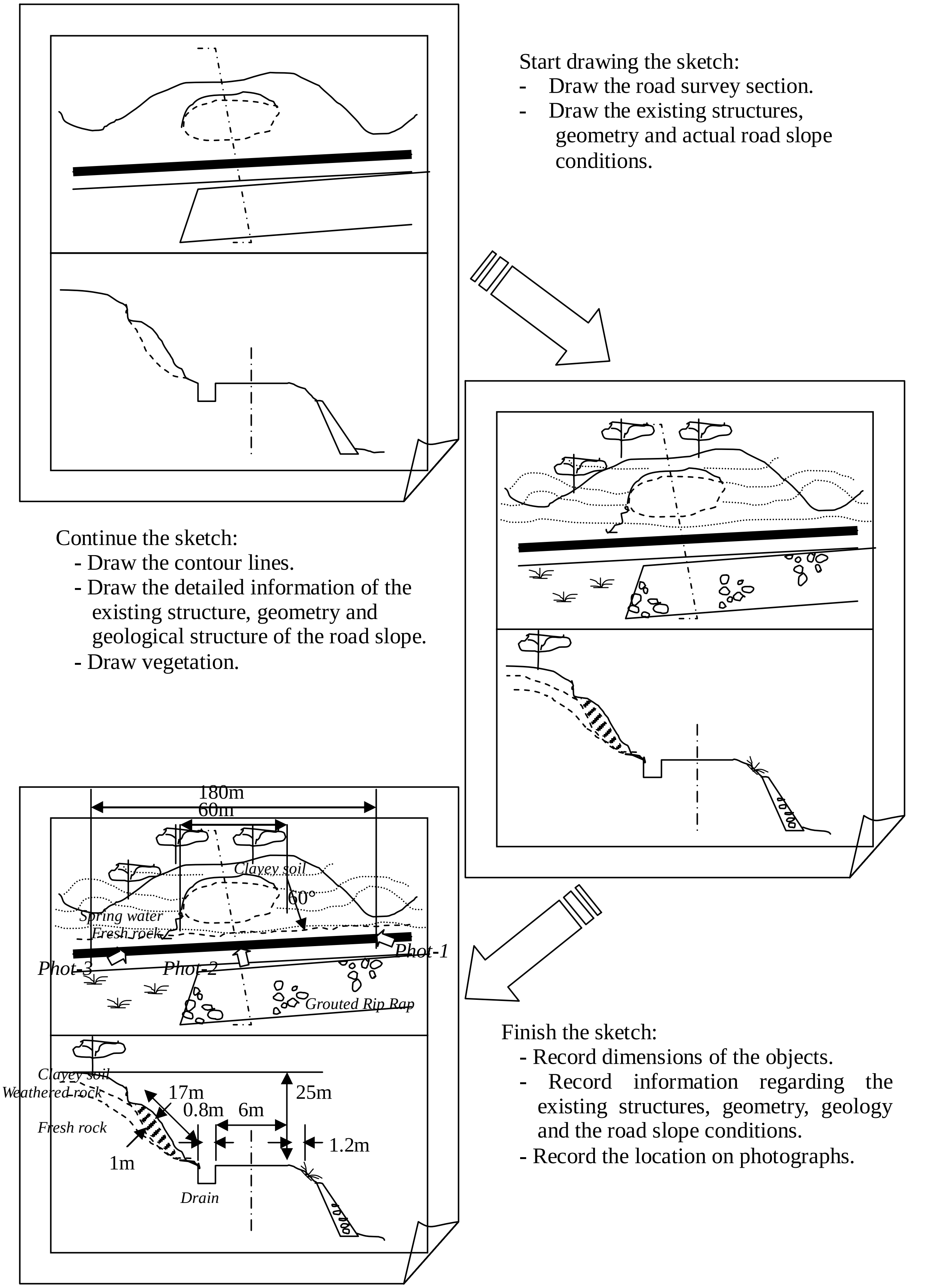


Figure 3.3 Procedure for Drawing the Sheet 3 Sketch

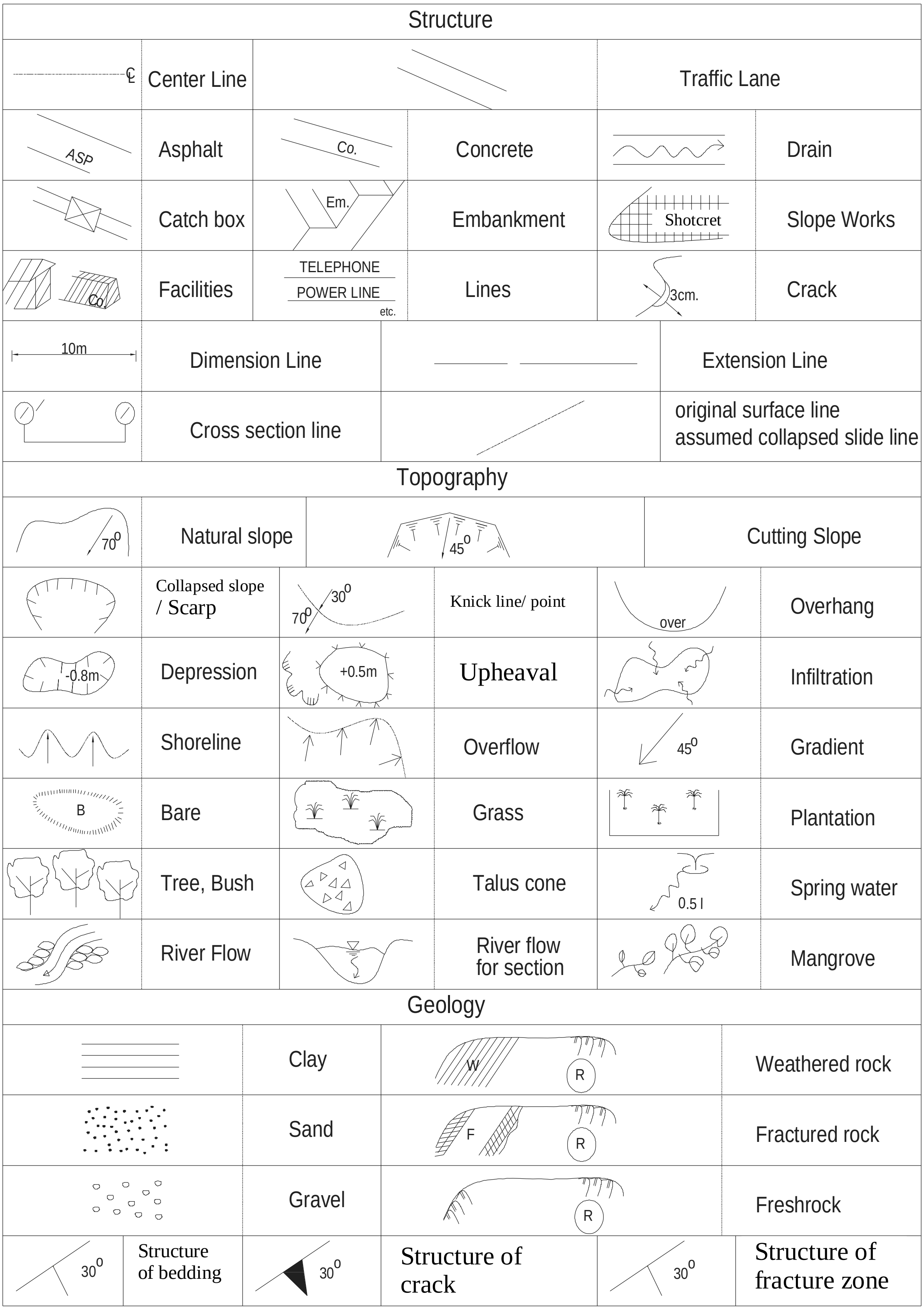


Figure 3.4 Symbols Used in Sheet 3

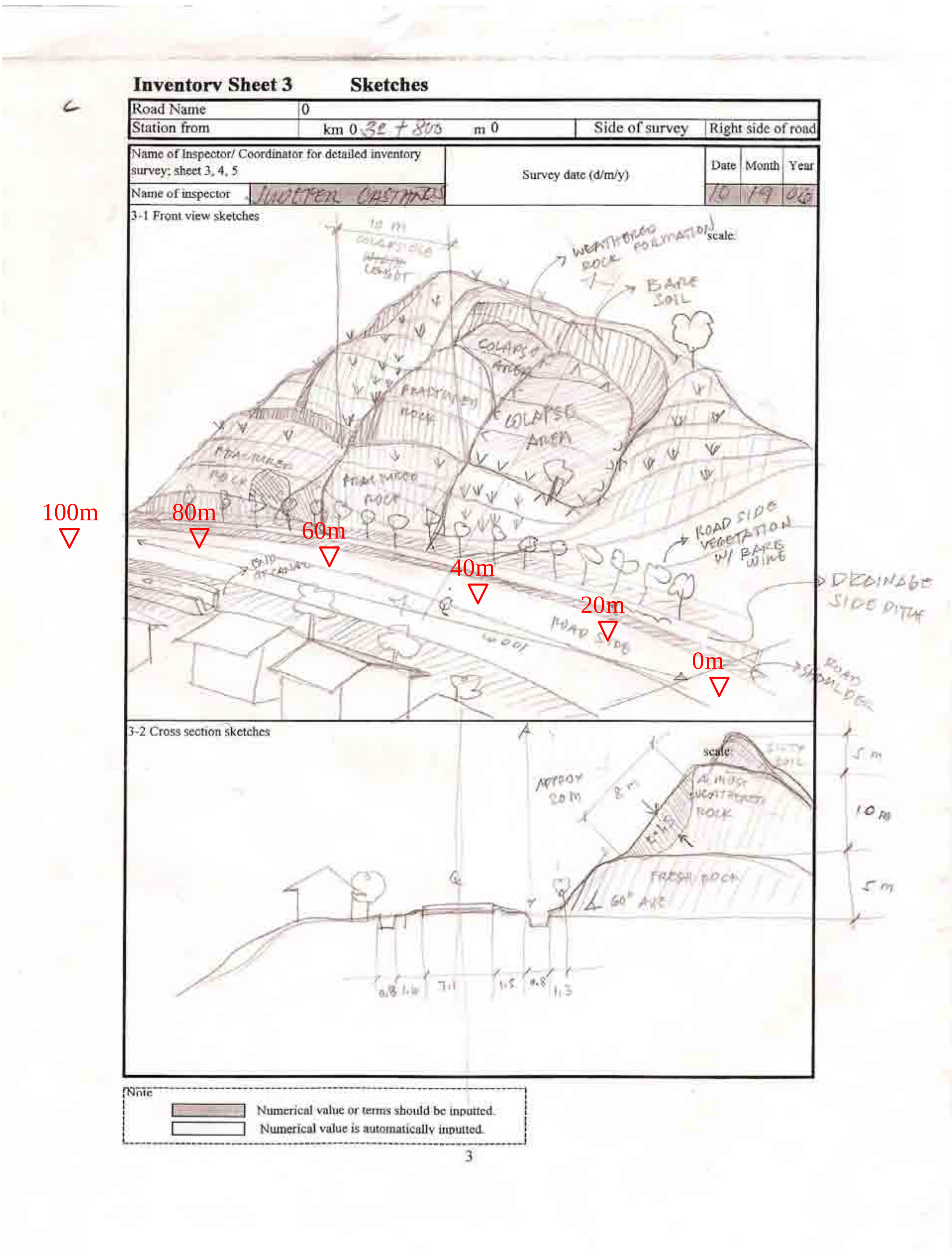
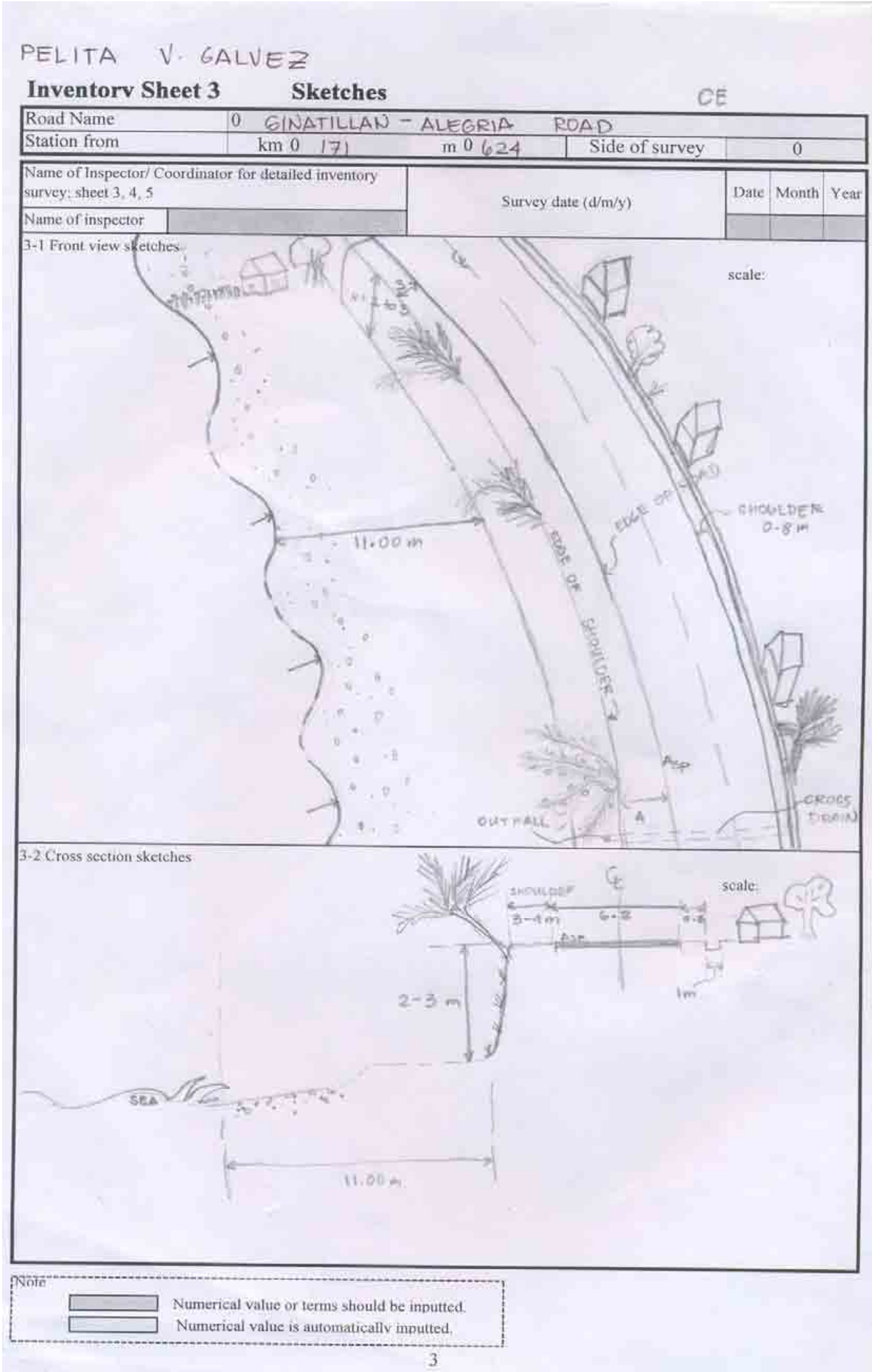


Figure 3.5 Example of Sheet 3 Sketch (1)


PELITA V. GALVEZ

Inventorv Sheet 3 **Sketches** CE

Road Name	0 GINATILLAN - ALEGRIA ROAD			
Station from	km 0 171	m 0 624	Side of survey	0

Name of Inspector/ Coordinator for detailed inventory survey: sheet 3, 4, 5	Survey date (d/m/y)	Date	Month	Year
Name of inspector				

3-1 Front view sketches

scale:

3-2 Cross section sketches

scale:

Note

Numerical value or terms should be inputted.

Numerical value is automatically inputted.

3

Figure 3.6 Example of Sheet 3 Sketch (2)

3.3 Countermeasure Planning (Sheet 4)

Countermeasure planning for the DIS section has been discussed in Step 1 of Sheet 3, and is undertaken after the inspectors have drawn the sketch in the field. The inspectors ask the District Engineer's advice/comments on the countermeasures before drawing the countermeasure on Sheet 4. A minimum of three alternatives of possible countermeasures should be chosen and drawn on Sheet 4. The steps for planning, identification of the options, selection of the countermeasure and completion of inventory Sheet 4 are described below.

3.3.1 Countermeasure Plan

The methodology for countermeasure planning is shown in Table 3.4.

Step 1: Discuss and plan the countermeasures in the field in accordance with the concepts shown in Table 3.5.

Step 2: Plan the countermeasures with the participation of the District Engineer, draw its basic plan, and prepare a rough cost estimate in Sheet 4. The planning engineers determine the effect of the countermeasure and encode the reduction ratio of RCDp on Sheet 5.

Table 3.4 Method of Countermeasure Planning

Step	Method	Inventory Format Sheet
1	Field work - Discuss the concept of the countermeasure. - Plan a rough layout of the countermeasure.	Sheet-3
2	Field and office work - Basic design of the countermeasure (layout). - Estimation of quantity of works. - Estimation of unit price of works (construction and 20 years maintenance).	Sheet-4

Table 3.5 Countermeasure Alternative Policy

Alternative	Effectiveness	Risk Reduction Ratio
Alternative-I	High Effectiveness Permanent countermeasures to prevent disasters	0.7-1.0 (70%- 100%)
Alternative-II	Moderate Effectiveness Mitigating the disasters to some extent	0.3 – 0.7 (30% - 70%)
Alternative-III	Low Effectiveness Some treatment	0.0-0.3 (0-30%)

The Risk Reduction Ratio (Annual Loss) should be determined by the planning engineer and input into Sheet 5 (refer 3.4.2 (3) 3-2).

3.3.2 Countermeasure Options

The engineer-in-charge of the DIS can select any type of countermeasure that he chooses. When planning for countermeasures, traditional/common methods used in the Philippines are to be applied as far as practicable. However, if road slope conditions are determined to be too difficult to prevent disasters by using traditional methods, new methods should be considered and selected from the countermeasure options shown in the following sections (Refer to the detailed information on countermeasures in Guide III Design of Countermeasures). Proposed countermeasures for each disaster type are shown in Appendix 2 with the typical/standard structures.

Main considerations for selection of countermeasure options are given below:

(1) Water Treatment

(a) Surface Drainage and Sub-Surface Blind Drainage

The cross-section of the drainage facilities should be large enough to cope with the rainwater or sub-surface water to be collected. Sub-surface drainage works shall be adopted if spring water exists under normal conditions and/or during rainfall.

(b) Horizontal Drain Holes

Attention should be paid to the target location of the drainage, configuration, diameter, angle, length, outlet protection, and connection to surface drainage (channel).

(c) Flow Structure

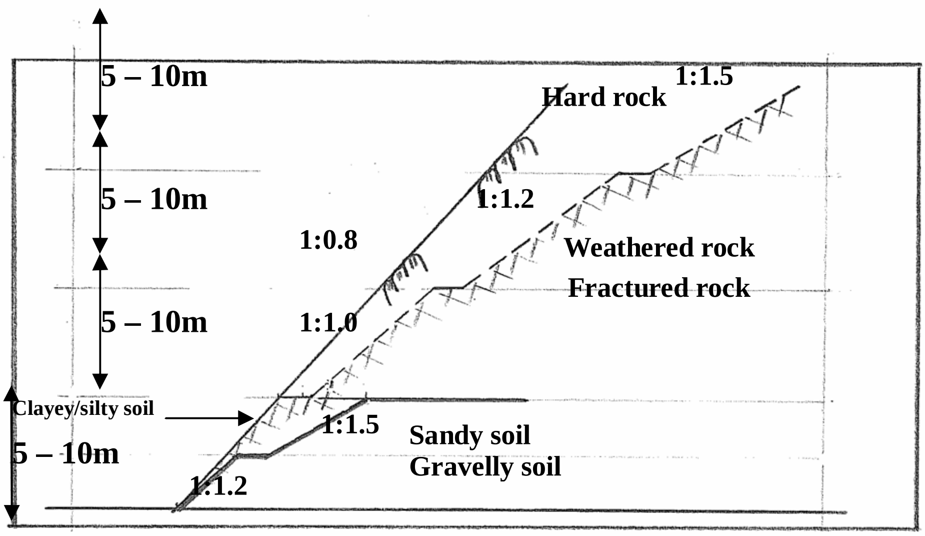
The location of the causeway, where debris flow or surface water will be allowed to pass, is important. If water is to be allowed to pass over the road surface, the surface should have thick pavement that is resistant to scouring from the flow. In case of a culvert (under drain), attention should be paid to length, gradient, structure and cross-section size. Large under-drains (2 to 3 m deep) with collecting walls are suitable for ground with low permeability.

(2) Earth Works

(a) Cuts

Cuts should be applied at the source of the collapse and head of a landslide following the standards for cutting described in the "Manual on Planning and Designing of Countermeasures." In cases where a large road slope is present above the target area, it is necessary to ascertain that no potential disaster areas exist in the area. Proper measures should be taken to prevent potential disasters. The cutting of the road slope must be planned with proper protection works.

The appropriate gradients for cuts are shown in Figure 3.7.



Character of Soil or Bedrock	Height(m)	Gradient (Vertical : Horizontal)
Hard rock		1:0.3 - 1:0.8
Weathered rock Fractured rock	0 – 10m	1:0.6 - 1:0.8
	20 – 30m	1:1.0 - 1:1.2
	More than 30m	1:1.2 – 1:1.5
	Less than 10m	1:0.8 - 1:1.0
Clayey/Silty soil	Less than 5m	1:1.0 - 1:1.2
Sandy soil	5 – 10m	1:1.2 - 1:1.5
	Less than 5m	1:1.0 - 1:1.2
Gravelly soil	5 - 10m	1:1.2 - 1:1.5

Note: Without slope stability works such as ground anchoring, the gradient is the same as shown in the guideline on road earth works (Japan Road Association, supervised by the Ministry of Land Infrastructure Transportation of Japan)

Figure 3.7 Appropriate Gradients for Cuts

(3) Fills

Counterweight filling should be planned at the toe of the target disaster area. It is important to use permeable materials for filling. In general, under drains and drainage mats should be provided so that no free groundwater (unconfined ground water) level forms in the fill.

Reinforced filling is a new technology for the mitigation of road slope disasters, particularly on a steep and deep valley side with limited space for construction. This has the same function as a retaining wall.

Sandbag walls are newly developed geo-textile reinforced earth walls in Japan. Sandbag walls are generally designed as a retaining wall to retain soil mass on steep slopes or in a restricted right-of-way situation. Its typical application includes the restoration and stabilization of road slips, highway retaining walls on steep slopes, embankment walls for temporary or permanent road widening, and so on.

(4) Vegetation Works

Vegetation is a method of road slope protection with plant cover to (a) reduce surface erosion caused by running water and rainfall; (b) prevent infiltration from rainfall; and (c) fasten subsurface soil to a root system. Mangrove planting is a method of preventing coastal erosion to reduce the force of waves crashing onto the coastline. These works should be used as widely as possible because of their lower cost and low impact on the environment and landscape.

(5) Structures

(a) Slope Works

Slope works mainly include pitching work, shotcrete and crib works. These works are primarily used to protect against surface weathering and erosion, and in some cases, to control small-scale rock falls.

Pitching works are commonly used on slopes gentler than 1V:1.0H. When the slope gradient is greater than 1V:1.0H, the methods used are concrete retaining walls, stone masonry retaining walls and block masonry retaining walls. Pitching works are applied to prevent surface weathering, scouring, stripping and erosion and, in some cases, to prevent small-scale soil slope collapse.

Crib works are commonly used on steep slopes of highly weathered or heavily jointed rocks accompanied with abundant springs, especially where falls cannot be fixed with shotcrete works. Crib works are chiefly applied (a) to prevent surface weathering, scouring and erosion and, in some cases, (b) to control both rock fall and small-scale slope failure.

(b) Walls and Resisting Structures

This work is composed mainly of retaining walls and catch works. Generally, retaining walls are classified by the design criteria, applications, function, etc. into several types, namely; gabion retaining walls, stone masonry retaining walls, and concrete retaining walls. Retaining walls are used for (a) prevention of small-scale shallow soil slope collapse and toe collapse of large-scale soil slope collapse or landslides, and (b) foundations for other slope protection works such as crib work.

In principle, retaining wall design includes the analysis of (a) sliding, (b) overturning, typically at the toe of walls, (c) bearing capacity of the foundation ground, and (d) overall stability (Stability analysis must not consider only the stability of the wall itself, but also of the overall slope of which the wall may be a part of).

Catch fences are designed to protect road traffic from rock fall damage, but differ from rock nets in that they are installed near the road to be protected. Rock nets are used to cover slopes that have a potential for rock fall in order to protect road traffic from rock fall damage.

(c) Anchoring and Piling

Where the other works cannot meet the degree of safety required, rock bolts with concrete cribs can be used. The method is generally planned to cope with small, shallow surface collapse of about 3 to 5 m in thickness. Rock bolts in association with concrete cribs is applied to stabilize the shallow surface collapse by exerting a force the increased resisting power against shear force by the tension force of the rock bolts. Rock bolts with concrete cribs keep the overall slope together, consequently preventing local collapse.

Compared with other countermeasures, ground anchors are costly but reliable. Recently, this method has been applied increasingly to cut slopes at toe of landslides. Compared with rock bolts and soil nailing, ground anchors have a relatively large resistance to sliding force and are therefore used to stabilize relatively large-scale slope failures. Ground anchors are intended to prevent landslides through the tensile strength of the high tensile strength steel wire or bars installed across the slip surface.

Similar to ground anchors; steel pipe piles are costly but reliable. The work is recommended especially when the ground is firm and has sufficient resistance against landslide mass. Moreover, steel pipe piles are generally used when the slope of a landslide area or sliding surface is relatively gentle or a potential landslide has a large scale. Steel pipe piles are intended to prevent landslides through the doweling action between the landslide mass and stable ground by applying the shear strength of the steep piles to the sliding surface or by using the wedge effect of steel piles.

(d) Protection Works

These works includes Rock sheds, Check dams and Wave-absorbing (or wave-dissipating) works.

Rock sheds are reinforced concrete or steel structures covering a road. They are very costly and should only be planned and designed in areas of extreme rock fall hazard. It is applied to reduce road disasters due to rock fall or rock mass failure by absorbing the impact force of a falling rock mass or shifting the movement direction of the rock mass failure and rock fall.

Check dams are implemented (a) to prevent erosion and toe failure of potentially unstable slopes; (b) to prevent and eliminate damage from the debris flow itself; and (c) to improve the stability of a slope through sedimentation behind the dam.

Wave-absorbing works are a common countermeasure for coastal erosion in Japan. These works are very costly and should only be planned and designed in areas where other works cannot meet the degree of safety required.

(6) Other Works

Other works include re-alignment, bridges and so on, that require different judgment criteria for re-opening a practical/feasible route.

3.3.3 Countermeasure Selection

The general flow of countermeasure selection is shown in Figure 3.8. The flow describes the procedure for deciding on the selection of countermeasures. The inspectors can select the countermeasures based on their own judgment and experience. The inspectors should select three alternatives for one DIS section. More than one countermeasure may be selected for one alternative plan under the present condition of the DIS section.

The concept of selection is based on the following four criteria:

(1) Effectiveness of overcoming problems with water;

(2) Effectiveness of vegetation works or earth works;

(3) Effectiveness of structures; and

(4) Re-alignment only.

Primary consideration in the procedure for the selection is the treatment of problems with water for the DIS section. The major causative factors for a disaster are surface water and sub-surface water from heavy rains. The next consideration is vegetation or earth works, which are generally simpler methods than structures. The third consideration is choosing an appropriate structure that is compatible with the permanent countermeasures for Alternative I. The final consideration is re-alignment, only this requires different judgment criteria for re-opening or identifying of a detour/ practical route.

A flow chart for the selection of the different disaster types is shown in Appendix 3.

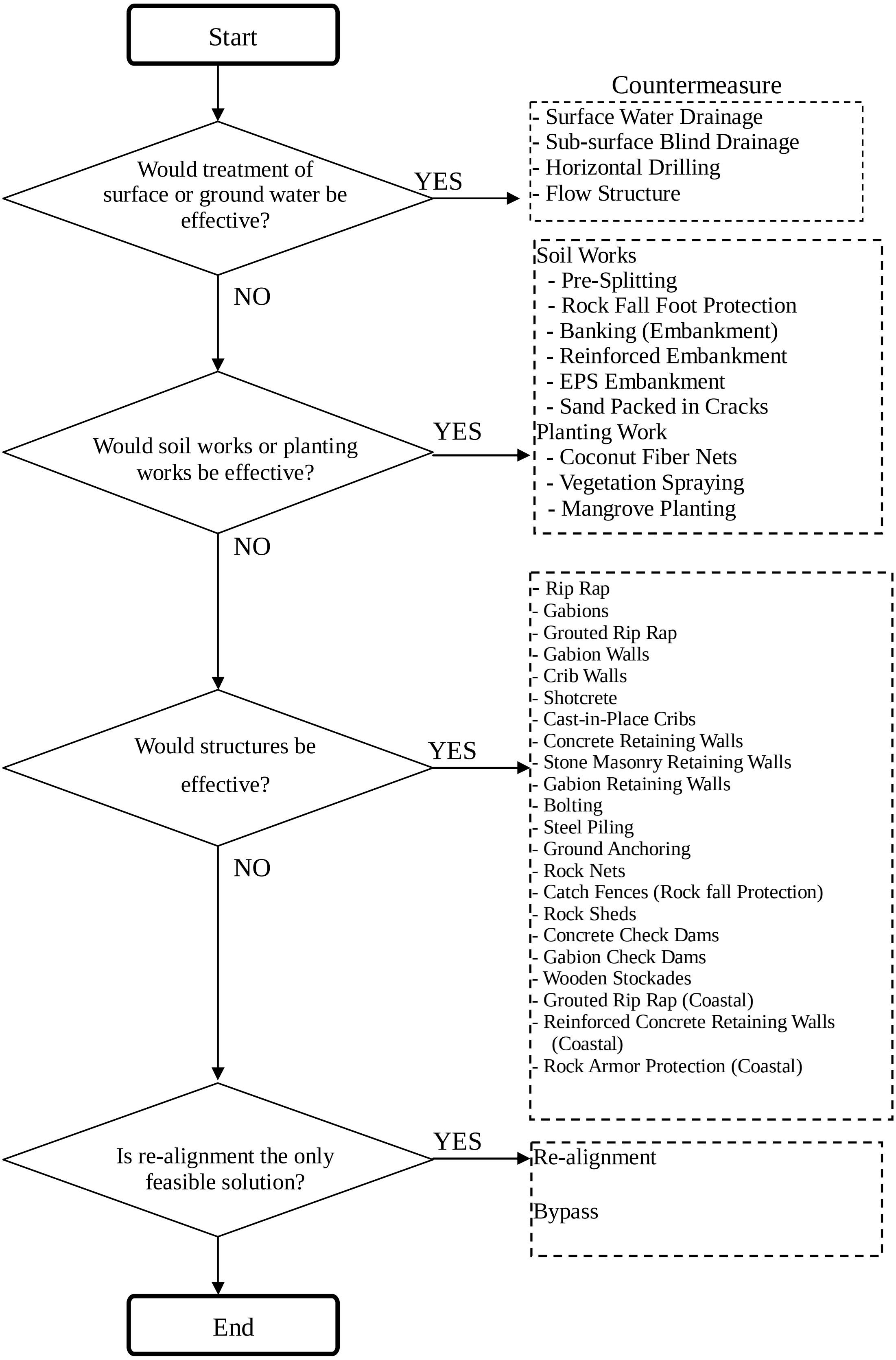


Figure 3.8 General Flow of Countermeasure Selection

3.3.4 Completion of Sheet 4

(1) Procedure for completion of Sheet 4

The procedure for completion of Sheet 4 is shown in Figure 3.9 and illustrated further in Figure 3.10. Remarks for filling out Sheet 4 are shown Figure 3.11. This consists of five steps as given below:

Step 1

Trace the outline of the DIS section from Sheet 3 to Sheet 4. The outline will consist of the road structure, dimensions of the disaster such as information related to the countermeasure plan.

Step 2 Draw the countermeasure plans on Sheet 4, that is a plan and a section for each alternative countermeasure. The plans are to be drawn clearly and highlighted with highly visible black lines since it will be shown as a monochrome image in the RSMS. If the sketch is drawn using pencil, it should be highlighted using a black pen without any dirt on the sheet for scanning.

Step 3 Estimate the construction quantities of structure or potential collapse volume for the unit cost estimation. Record the quantities on Sheet 4 with a pencil or a pen.

Step 4 Scan the original plans of the countermeasures (Sheet 4).

Step 5 Paste the scanned plans of the countermeasures on the digital file of Sheet 4 and encode the countermeasure works, units, quantities and unit prices into the appropriate cells. The costs of the countermeasures are calculated automatically.

(2) Rough Cost Estimates

The inspectors can assume unit costs for the countermeasures according to each DEO's standards. However, if unit costs are not set, refer to Tables 3.6 and 3.7. Pay attention to the unit price differentials per region for their application. Re-opening cost is included in the cost estimation and cost of cutting. Maintenance cost for 20 years for the planned countermeasures is estimated by the inspector and included in the total cost of the countermeasures.

If a countermeasure selected is not among the standard types, rough cost estimates should be done for the plan by the inspectors.

Example of Sheet 4 is shown in Figures 3.12 and 3.13.

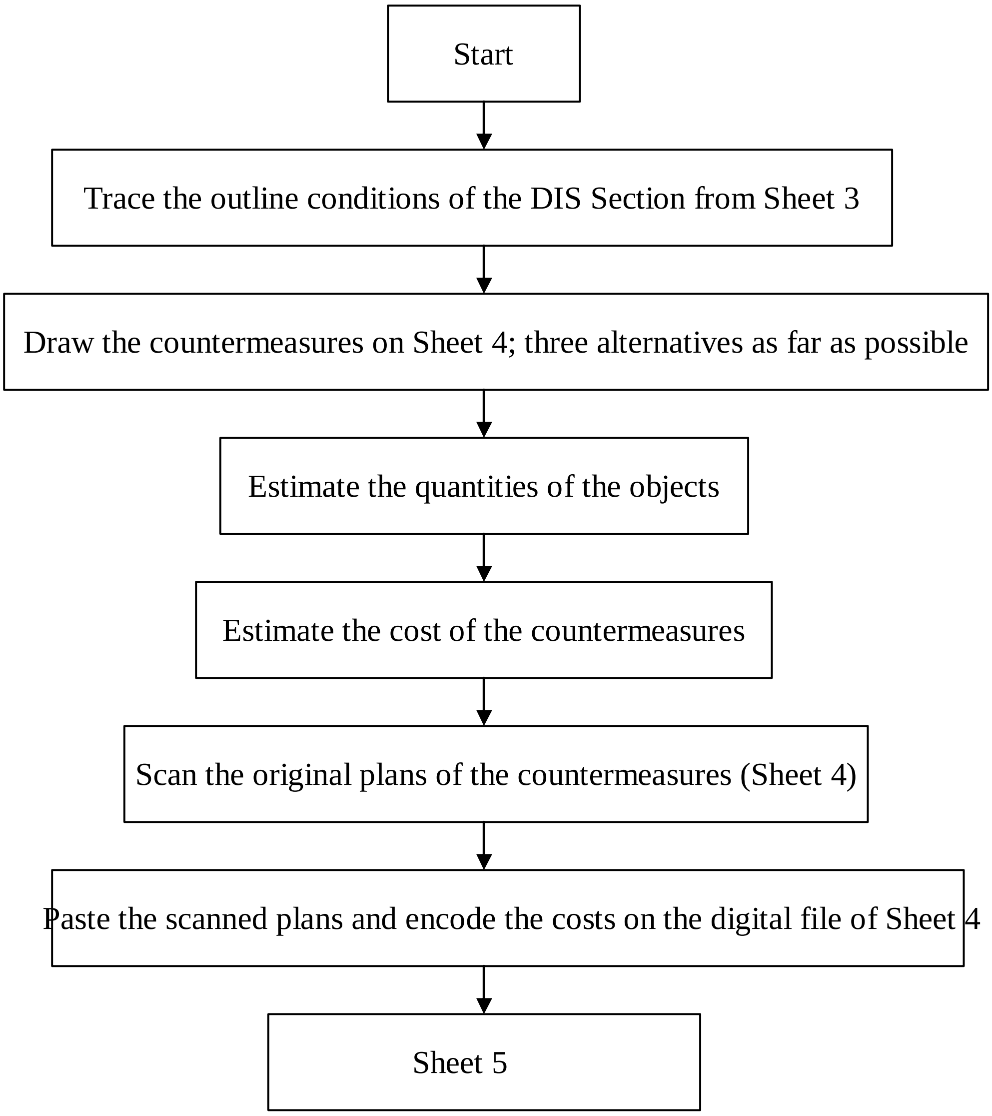
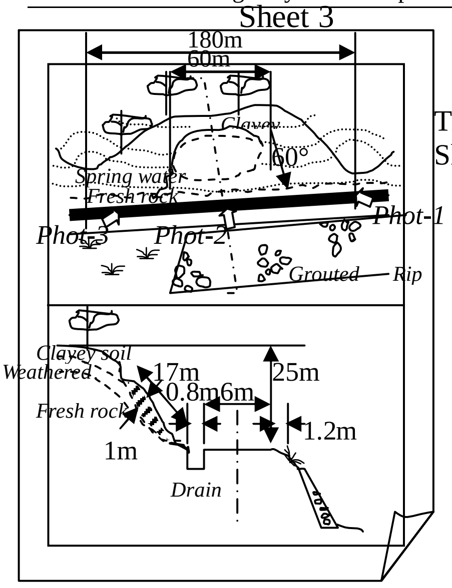
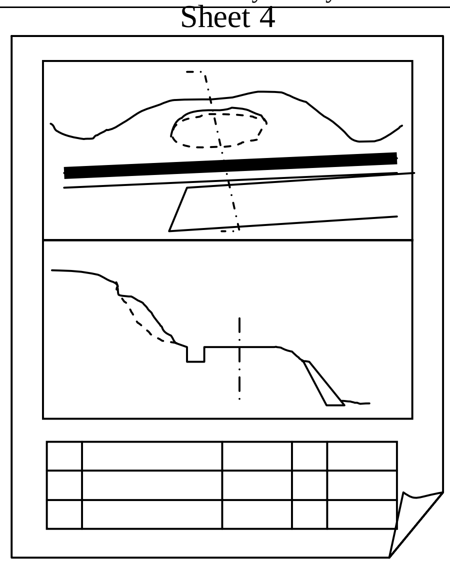
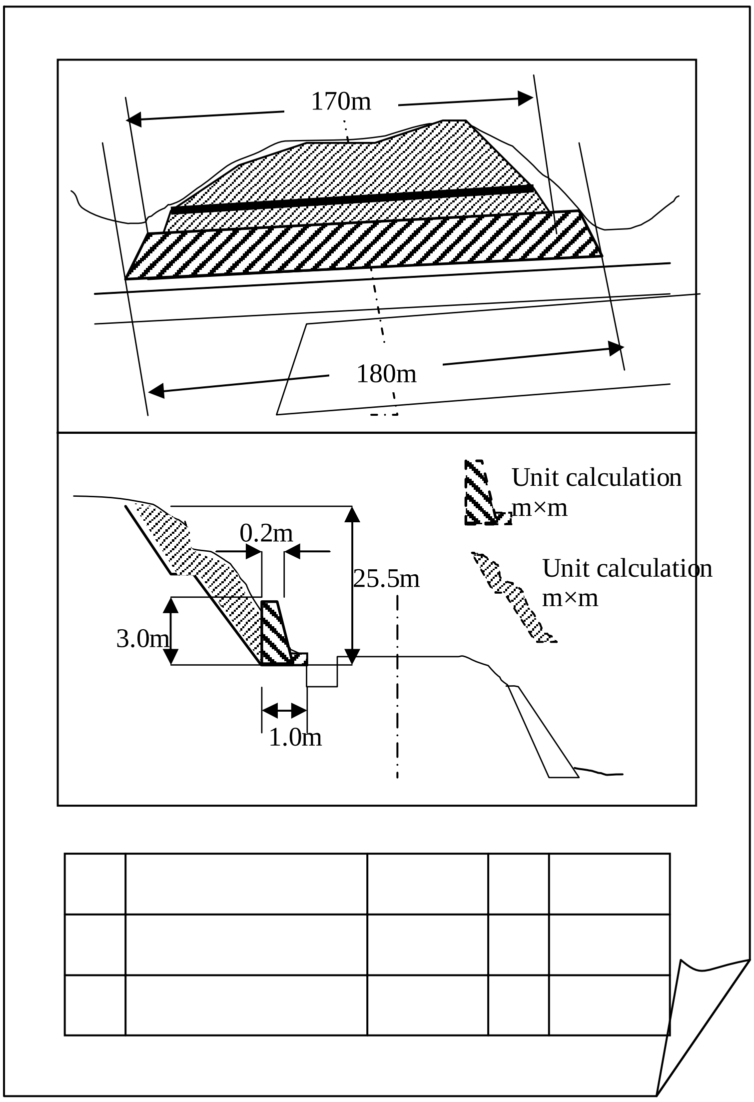


Figure 3.9 Procedure for Completion of Sheet 4



Trace outline of Sheet 3 to Sheet 4





Draw countermeasure plans on Sheet 4.

Estimate the total quantities of the structure or potential collapse volume using units of measurement for the cost estimations.

Record the quantities on Sheet 4.

Record the countermeasure works, units, quantities and unit prices for encoding to Sheet 4 digital file

Figure 3.10 Procedure for Drawing Sheet 4 Countermeasure Plan

Inventory Sheet 4-1 Planning of Countermeasures Alternative I

Road Name	0						
Station from	km	0	m	0	Side of survey	Left side of road	

4-1 Plan of countermeasures (plane layout and descriptions)

They will be easy to visualize from sectional views

(1) Illustrate the construction plans.

(It is not necessary to illustrate the form of the countermeasures exactly)

(2) Pay attention at the origin and destination point side of the slope.

4-2 Section of countermeasures

(1) Assess the future potential slope disasters.

(2) Select countermeasures for an assumed disaster.

(3) Plan three types of countermeasures.
(High, medium and low effectiveness for disaster reduction)

(4) Pay attention to both the valley and mountain side slopes.
(The possibility of construction should be evaluated.)

4- 3 Cost estimation with 20 years maintenance

No.	Work	Unit	Quantity	Unit price (pesos)	Amount (pesos)
1					0
2					0
3					0
4					0
5					0
6					0
7					0
	Total Cost				0

Note
- (pink) Numerical value or terms should be inputted.
- (light blue) Numerical value is automatically inputted.

4-1

Calculate automatically

Figure 3.11 Remarks for Filling out of Sheet 4

Table 3.6 Unit Cost of Countermeasures (1) (2006 Price)

Type	Item No.	Work Item		Unit	Unit Price (PHP)	Data source	Remarks
Soil Slope Collapse	SC1	Cutting		m^3	430	1	Soil/Soft Rock
	SC2	Coconut Fiber Net		m^2	260	1	with sodding
	SC3.1	Surface Water Drainage	Drainage	m	2,910	1	Reinforced concrete gutter
	SC3.2		Catch Basin	ea	6,210	1	80 x 80 x 80 cm
	SC4.1	Cast-in-Place Crib	Crib	m^2	2,270	1	Excluding riprap
	SC4.2		Vegetation Spraying	m^2	330	1	
	SC5	Concrete Retaining Wall		m	17,440	1	
	SC6	Stone Masonry Retaining Wall		m	13,000	1	
	SC7	Gabion Retaining Wall		m	1,366	2	3 meter high wall
Rock Slope Collapse	RC1	Pre-Splitting		m^3	1,570	1	Scaling & trimming of rock
	RC2	Rock Fall Foot Protection		ea	5,720	1	
	RC3	Shotcrete		m^2	1,970	1	100 mm thick
	RC4.1	Cash-in Place Crib	Crib	m^2	2,270	1	Similar to Item SC 4.1
	RC4.2		Shotcrete	m^2	1,970	1	100 mm thick
	RC4.3		Vegetation Spraying	m^2	330	1	Similar to Item SC 4.2
	RC5	Concrete Retaining Wall		m	17,440	1	Similar to Item SC 5
	RC6	Stone Masonry Catch Wall		m	13,000	1	Similar to Item SC. 6
	RC7	Bolting		ea	4,150	1	20 mm dia. long steel bars
	RC8	Rock Net		m^2	320	1	Japanese description
	RC9	Catch Fence (Rock fall Protection)		m	5,720	1	
Landslide	LS1	Cutting		m^3	430	1	Similar to Item SC 1
	LS2	Banking	Ordinary Soil	m^3	490	2	
			Selected Borrow	m^3	742	2	
	LS3.1	Water Drainage	Drainage	m	2,910	1	Similar to Item SC 3.1
	LS3.2		Catch Basin	ea	6,210	1	Similar to Item SC 3.2
	LS4.1	Sub-surface Blind Drainage	Crushed Stone Placing	m	5,070	1	
	LS4.2		Catch Basin	ea	6,210	1	Similar to Item SC 3.2
	LS5	Gabion Wall		m^3	1,366	2	Similar to Item SC 7
	LS6	Steel Piling		m	21,380	1	500 mm dia. steel pipe

Note: Data Source 1: Refer Appendix-5, 2: Nation wide average of IPRSD of DPWH in 2006

Table 3.7 Unit Cost of Countermeasures (2) (2006 Price)

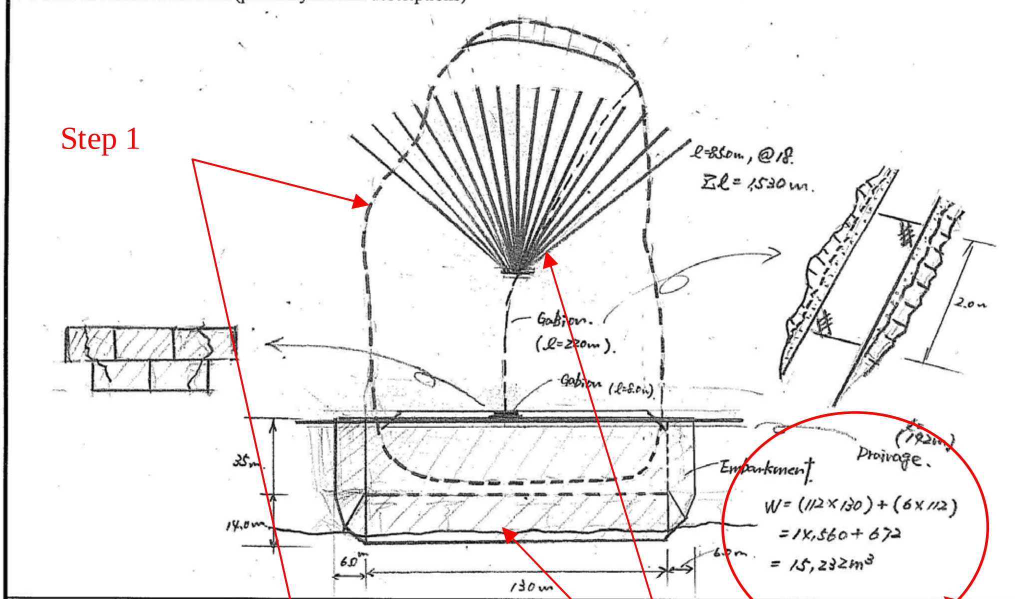
Type	Item No.	Work Item		Unit	Unit Price (PHP)	Data source	Remarks
Road Slip	RS1	Cutting		m^3	430	1	Similar to Item SC 1
	RS2	Coconut Fiber Net		m^2	260	1	Similar to Item SC 2
	RS3	Reinforced Soil Embankment		m^3	1,520	1	
	RS4.1	Water Drainage	Drainage	m	2,910	1	Similar to Item SC 3.1
	RS4.2		Catch Basin	ea	6,210	1	Similar to Item SC 3.2
	RS6	Banking		m^3	490	2	Similar to Item LS 2
Debris Flow	DF1.1	Concrete Check Dam	Check Dam	ea	467,360	1	Reinforced concrete 2 m base x 5 m height structure
	DF1.2		Cutting	m^3	430	1	Similar to Item SC 1
	DF1.3		Gabion	m	9,490	1	2 layers about 4 m long
	DF2.1	Gabion Check Dam	Check Dam	ea	179,030	1	4 layers gabion box 1 x 1 x 2m
	DF2.2		Cutting	m3	430	1	Similar to Item SC 1
River Eros	RE1	Rip Rap		m	2,590	1	
	RE2	Gabion		m^3	1,366	2	
	RE3	Grouted Rip Rap		m^3	1,919	2	
	RE4	Wooden Stockades		m	3,000	1	
Costal Ero	CE1	Grouted Rip Rap		m^3	1,919	2	
	CE3	Concert Retaining Wall		m	17,440	1	Similar to Item RC 5
	CE4	Mangrove Planting		m^2	7	2	5 trees per 4 sq. m on cross-stitch

Note: Data Source 1: Refer Appendix-5, 2: Nation wide average of IPRSD of DPWH in 2006

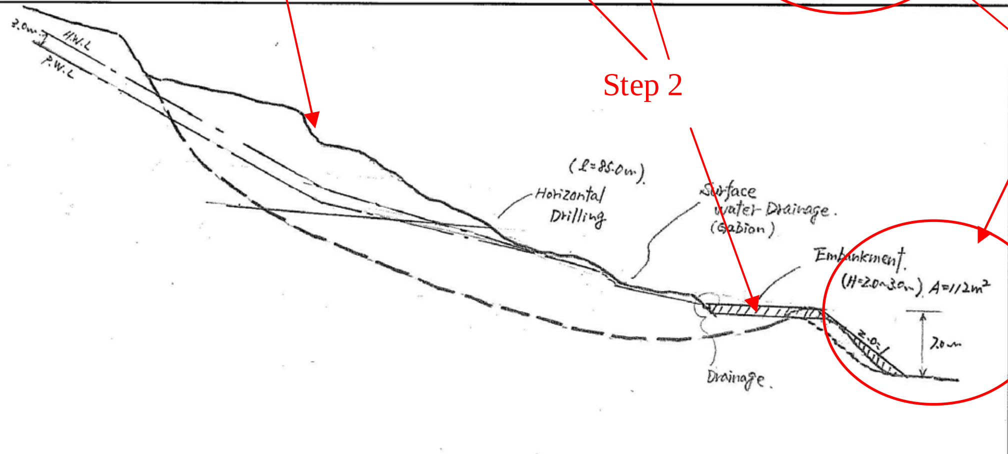
Inventory Sheet-4 **Planning of Countermeasures** Alternative

Road Name	0				
Station from	km 0	m	0	Side of survey	Right side of road

4-1 Plan of Countermeasures (plane layout and descriptions)



4-2 Section of countermeasures



4- 3 Cost estimation

No.	Work	Unit	Quantity	Unit price (pesos)	Amount (pesos)
1	Embankment	m3	15,232	1,500	22,848,000
2	Gabion.	m	228	11,250	2,565,000
3	Drainage	m	142	11,250	1,597,500
4	Horizontal	m	1,530	10,500	16,065,000
					0
					0
					0
Total Cost					43,075,500

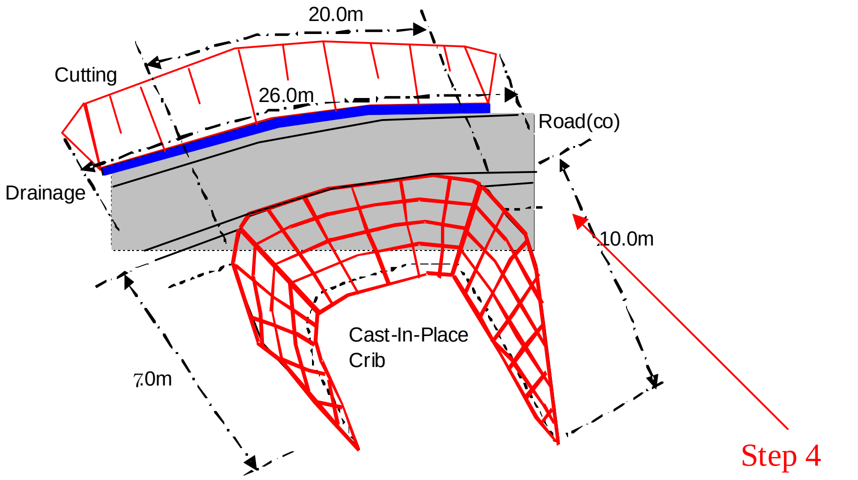
Note
- (shaded) Numerical value or terms should be inputted.
- (blank) Numerical value is automatically inputted.

Figure 3.12 Example of Sheet 4 Countermeasure Plan
(Lagawe-Banaue Road: 301km + 200: Alternative-I)

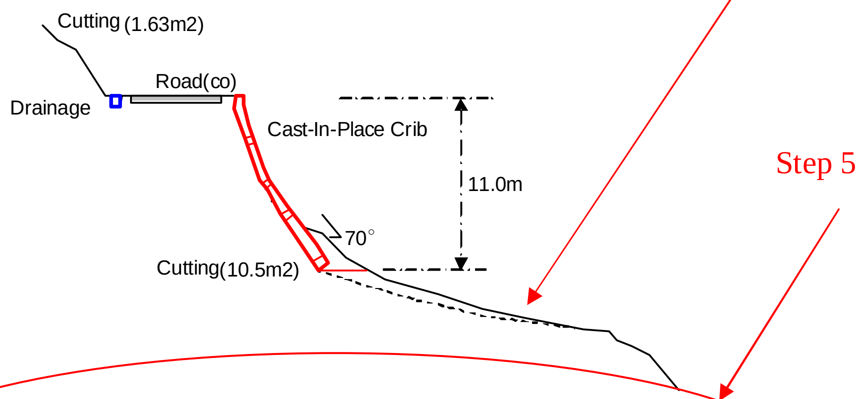
Inventory Sheet-4 Planning of Countermeasures Alternative

Road Name	0					
Station from	km	0	m	0	Side of	Left side of

4-1 Plan of Countermeasures (plan layout and descriptions)



4-2 Section of countermeasures



4- 3 Cost estimates

No.	Work	Unit	Quantity	Unit price (pesos)	Amount (pesos)
1	Cast-In-Place Crib	m2	330.6	17,250	5,702,850
2	cutting	m3	252.4	1,500	378,600
					0
					0
					0
					0
					0
	Total Cost				6,081,450

Note
- (pink) Numerical value or terms should be inputted.
- (light blue) Numerical value is automatically inputted.

Figure 3.13 Example of Sheet 4 Countermeasure Plan
(Wright-Taft Road: 858 + 250: Alternative-II)

3.4 Indicative Feasibility Assessment (Sheet 5)

The indicative feasibility assessment, which is the preliminary estimate of the economic viability of specific countermeasures identified to mitigate RCDs, is carried out in Inventory Sheet 5 (Sheet 5).

3.4.1 General

In Sheet 5, the estimates of disaster frequency and magnitude, annual losses, risk reduction ratio due to implementation of a specific countermeasure and cost/benefit analysis of the countermeasures are undertaken.

The equations used for the indicative feasibility assessment differ per disaster type, which requires a different sheet for each type and results in the preparation of seven different sheets (Sheet 5-1 to Sheet 5-7).

3.4.2 Setting the Method for Inputting Required Values

(1) Disaster Frequency and Magnitude

1-1) Disaster Frequency or FRCDp

FRCDp has been previously calculated in Sheet 2. The calculated value of FRCDp is used and has been linked to the appropriate cell in Sheet 5.

1-2) Accumulation Volume on the Road per RCD/Length of Road Closure Site

(Accumulation Volume on the Road per RCD for Sheet 5-1: Disaster type - Soil Slope Collapse and Sheet 5-2: Disaster type - Rock Slope Collapse)

The “accumulation volume on the road per RCD” is computed by multiplying the “ratio of accumulation” to collapsible materials and the estimated volume of collapsible materials per RCD”, as shown in the following equation:

$g = e*f$ (equation 3.1)

where:

g = accumulation volume on the road per RCD (m^3 per RCD)

e = volume of collapsible materials per RCD (m^3 per RCD)

f = ratio of accumulation to collapsible materials (ratio)

(Length of Road Closure Site for Sheet 5-3: Disaster type - Landslide and Sheet 5-4: Disaster type - Road Slip; Sheet 5-5: Disaster type - Debris Flow; Sheet 5-6: Disaster type - River Erosion; and Sheet 5-7: Disaster type - Coastal Erosion)

The 'length of the road closure site' is estimated based on the current range of slope deformation, referencing to past closure examples in nearby areas and similar slope conditions.

1-2-1) Coefficients for Volume Estimation

The method for estimating the dimensions of the collapsible material/area is selected from the following and as shown in Figure 3.14

Max : The maximum dimensions of the collapsible material area are predicted.

Average: The average dimensions of the collapsible material area are predicted.

No input: In case the dimensions cannot be predicted such as for rock fall phenomena.

If 'Max' is selected: "a", the coefficient for the volume estimation is empirically set at a = 0.7

If 'Average' is selected: "a", the coefficient for volume estimation is set at a = 1.0

If 'No input' is selected: no coefficient for volume estimation is set.

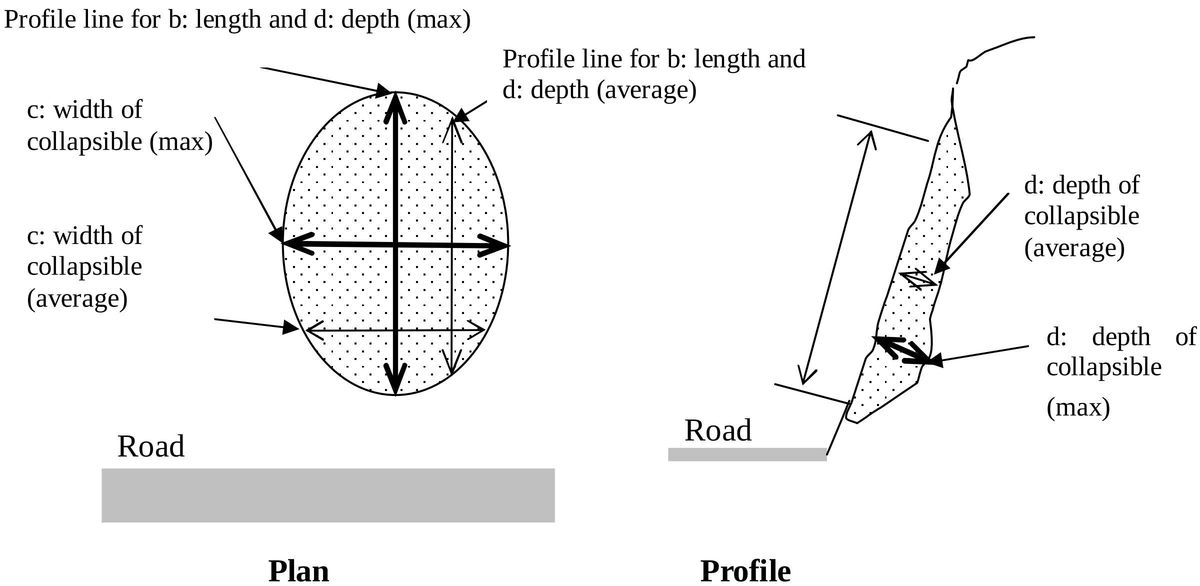


Figure 3.14 Instructions for Estimating the Dimensions of Collapsible Volume

1-2-2) – 1-2-6) Length, Width, Depth, and Volume of Collapsible Materials

The volume of collapsible materials is automatically calculated by inputting the required dimensions, namely: length, width and depth of the collapsible materials using the equation given below (refer to Figure 3.14):

e = a*b*c*d (equation 3.2)

where

e = volume of collapsible materials (m^3 per RCD)

b = length of collapsible materials (m)

c = width of collapsible materials (m)

d = depth of collapsible materials (m)

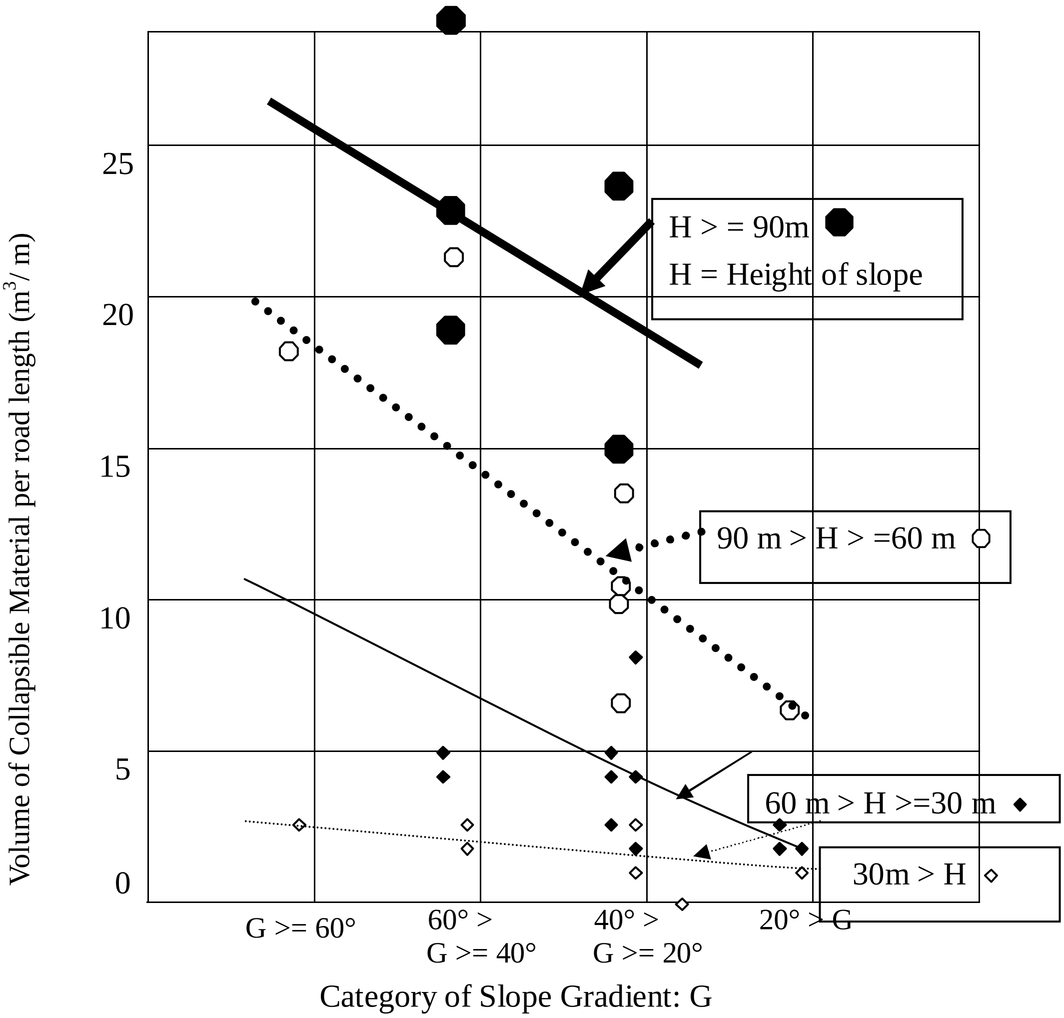
a = coefficient for volume estimation

In case max values (for length, width, and depth) are used, a = 0.7

In case average values (for length, width, and depth) are used, a = 1.0

The length, width and depth dimensions are estimated based on the current range of slope deformation and referring to past collapse examples in nearby areas and similar slope conditions.

When these dimensions cannot be predicted, for example in the case of rock fall, the ‘volume of collapsible materials’ is estimated using Figure 3.15, which shows the relationship between the collapsible volume and the slope gradient per slope height category.



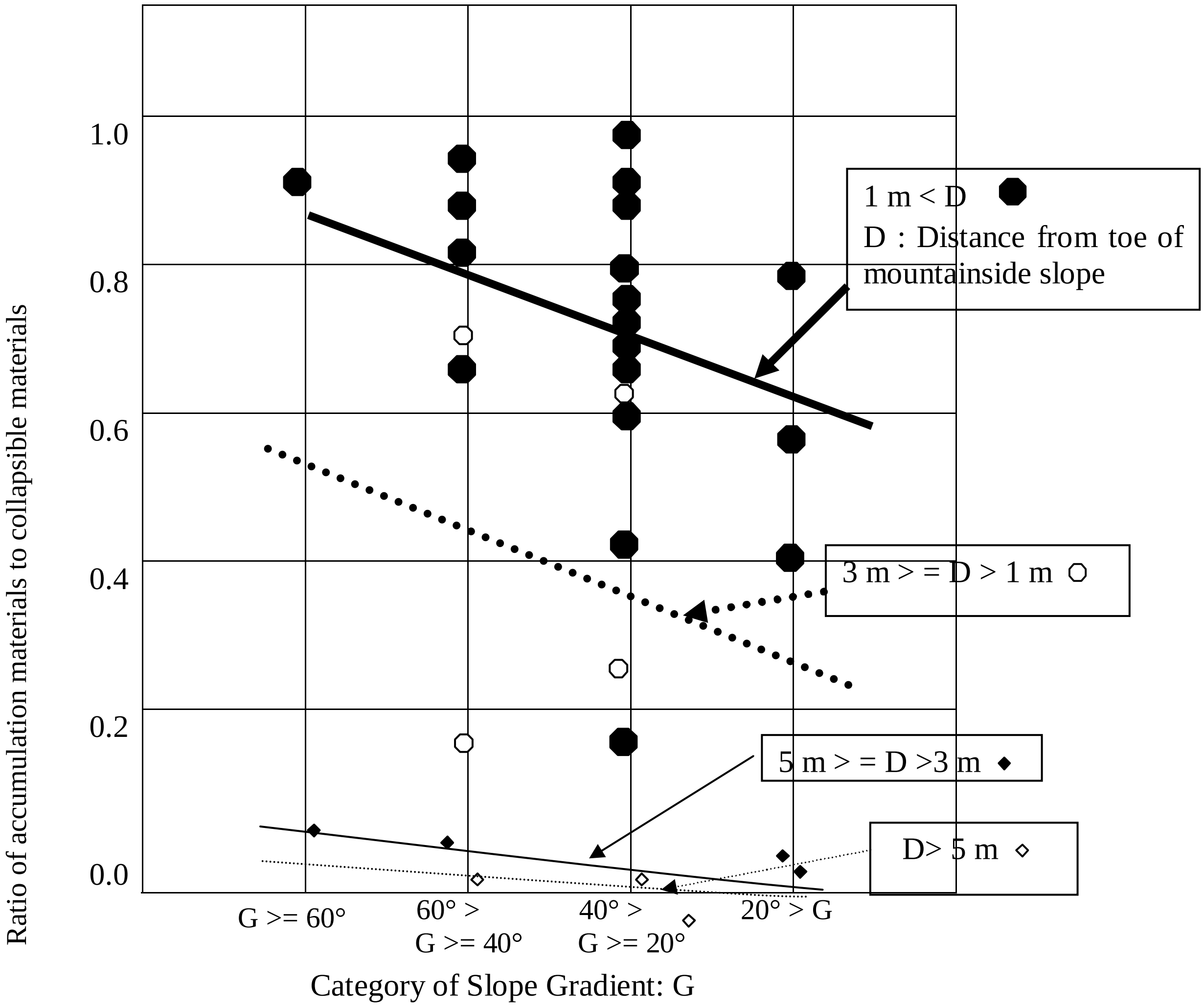
This chart was formulated using the data from the PIS questionnaire results as of 2006 and disaster observations in Benguet and Ifugao provinces in September 2006.

Figure 3.15 Chart for Estimating Collapsible Volume

1-2-6) Ratio of Accumulated Materials to Collapsible Materials

The ratio of the accumulated volume of soil/rock on the road and the collapsible volume of soil/rock is estimated by referring to past collapse experiences in nearby areas or similar slope conditions.

When the ratio of the accumulated volume of materials to the collapsible materials cannot be calculated, it is estimated by using Figure 3.16. This was formulated based on experience and is the relationship between the ratio of accumulated materials and collapsible materials and the slope gradient category for each 'distance from the road to the toe of the mountainside slope.



This chart was formulated based on the PIS questionnaire results in 2006 and disaster observations in Benguet and Ifugao provinces in September 2006.

Figure 3.16 Chart for Estimating the 'Ratio of Accumulated Volume to Collapsible Volume'

(2) Annual Losses

The total annual loss due to the occurrence of RCD in the target site is estimated as follows:

$u = j + m + t$ (equation 3.3)

where:

u = total annual loss (pesos per year)

j = annual reopening cost (pesos per year)

m = annual value of human lives lost (pesos per year)

t = annual detour cost (pesos per year)

The calculation for “u” is automatic by inputting the following:

2-1) Annual Reopening Cost

The annual reopening cost is estimated by referencing local conditions.

The following equations have been formulated using data of reopening costs of a specific Philippine national road and should be used for reference only.

(for Sheet 5-1: Disaster type - Soil Slope Collapse and Sheet 5-2: Disaster type - Rock Slope Collapse)

The annual reopening cost is calculated using the equation below:

$j = FRCDp * RC$ (equation 3.4)

$RC = h * g + i$ (equation 3.5)

where:

j = annual reopening cost (pesos per year)

FRCDp = potential frequency of road closure disaster (no. per year)

RC = reopening cost per RCD (pesos)

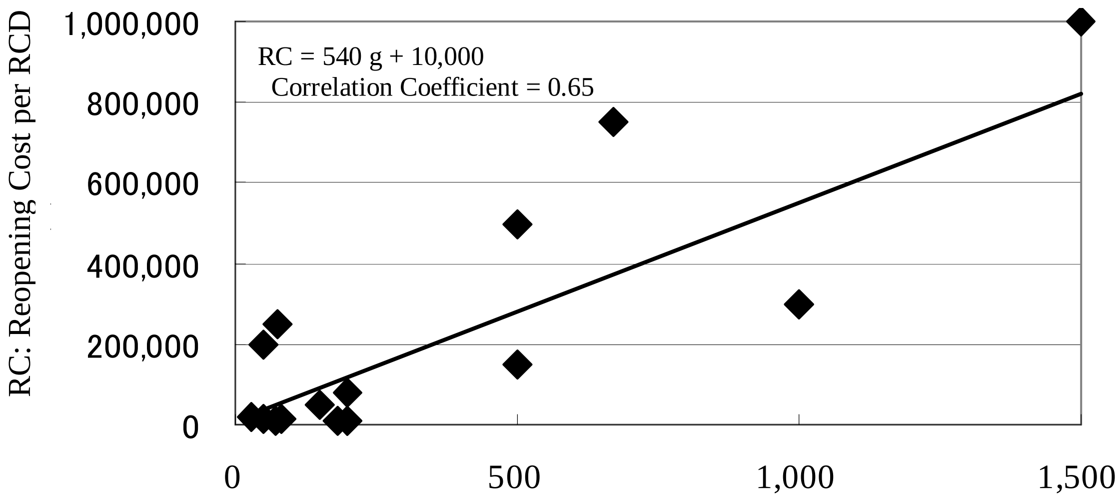
h = reopening cost per accumulation volume at closure site (excludes fixed cost) (pesos per m^3)

g = accumulation volume on the road per RCD (m3 per RCD)

i = fixed cost for reopening per RCD (pesos per RCD)

The value of 'h' and 'i' in equation 3.5 should be set by referring to local experience and actual results obtained, though this assumes that the engineer of the DEO would be responsible for preparing the estimate.

Just as a reference, a chart showing the relationship between accumulation volume and reopening cost (data from questionnaire survey for RCDs on national highway in the Philippines from 1996 to 2005) is shown in Figure 3.17. From the correlation analysis of this data, "h" of equation 3.5=540 pesos and "i" =10,000 pesos.



h = reopening cost per accumulation volume at closure site (excludes fixed cost) (pesos per m^3) = 540

i = fixed cost for reopening per RCD (pesos per RCD) = 10,000

Figure 3.17 Chart showing the Relationship between Accumulation Volume and Reopening Cost (Data from questionnaire survey for RCDs on national highway in the Philippines from 1996 to 2005)

(for Sheet 5-3: Disaster type –Landslide; Sheet 5-4: Disaster type - Road Slip; Sheet 5-5: Disaster type - Debris Flow; Sheet 5-6: Disaster type - River Erosion and Sheet 5-7: Disaster type - Coastal Erosion)

The annual reopening cost is calculated using the equation below:

j = FRCDp * RC (equation 3.6)

RC = h * LRC+ i (equation 3.7)

where:

j = annual reopening cost (pesos)

FRCDp = potential frequency of road closure disaster (nos. per year)

RC = reopening cost per RCD (pesos)

h = reopening cost per length of road closure site (excluding fixed cost) (pesos per m)

LRC = length of road closure site (m)

i = fixed cost for reopening per RCD (pesos per RCD)

The value of ‘h’ and ‘i’ in equation 3.7 should be set by referring to local experience and actual results obtained, though this assumes that the engineer of the DEO would be responsible for preparing the estimate.

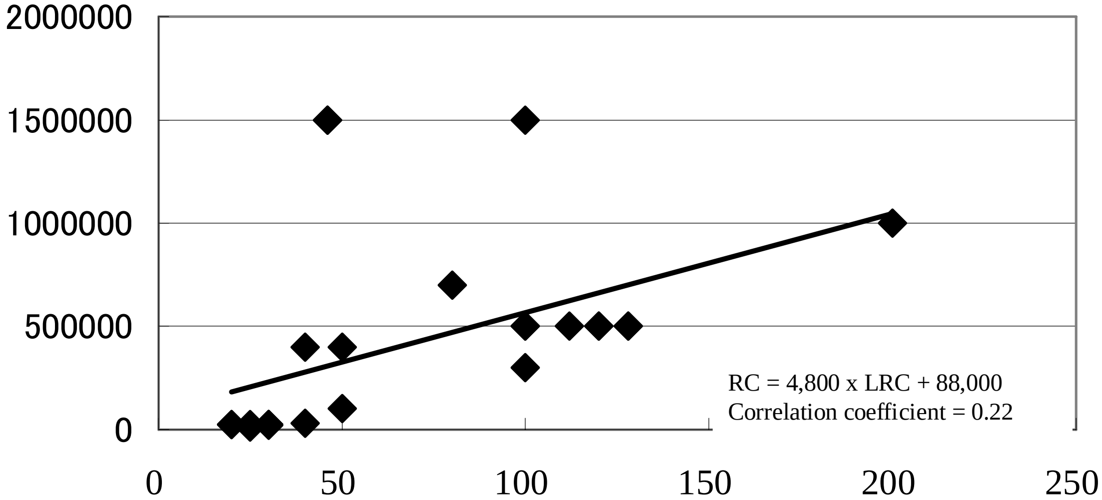
Just for reference, a chart showing the relationship between the Length of the Road Closure Site (LRC) and the Reopening cost per RCD (RC) on national highways in the Philippines (data of questionnaire survey for RCDs from 1996 to 2005) is shown in Figure 3.18. From the correlation analysis of this data, ”h” and ”i” of equation 3.7 are obtained and shown in Table 3.8.

Table 3.8 Reference Value for Estimating Reopening Cost

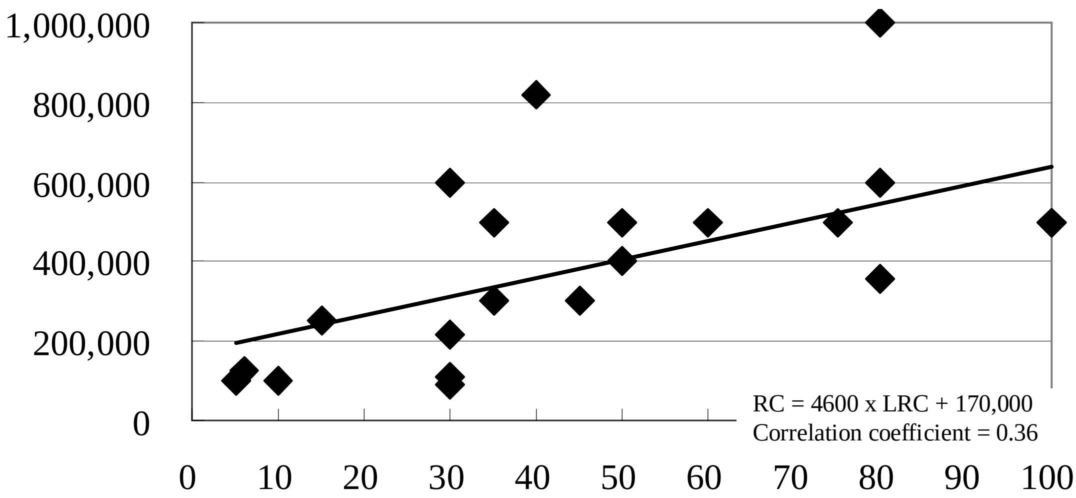
Disaster Type	h= reopening cost per length of road closure site (excluding fixed cost) [pesos per m]	i = fixed cost for reopening per RCD [pesos per RCD]	Correlation coefficient
LS: Landslide	4,800	8,800	0.22
RS: Road Slip	4,600	170,000	0.36
DF: Debris Flow	1,200	12,000	0.39
RE: River Erosion and CE: Costal Erosion	1,600	890,000	0.25

(Data from questionnaire survey for RCDs on national highway in the Philippines from 1996 to 2005. The correlations are low in each disaster type)

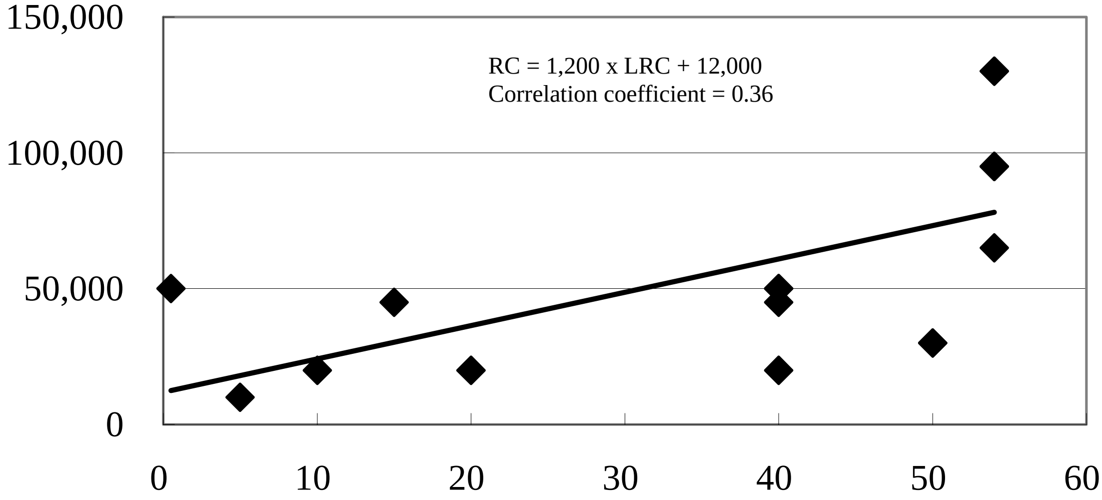
Landslide



Road Slip



Debris Flow



River Erosion and Costal Erosion

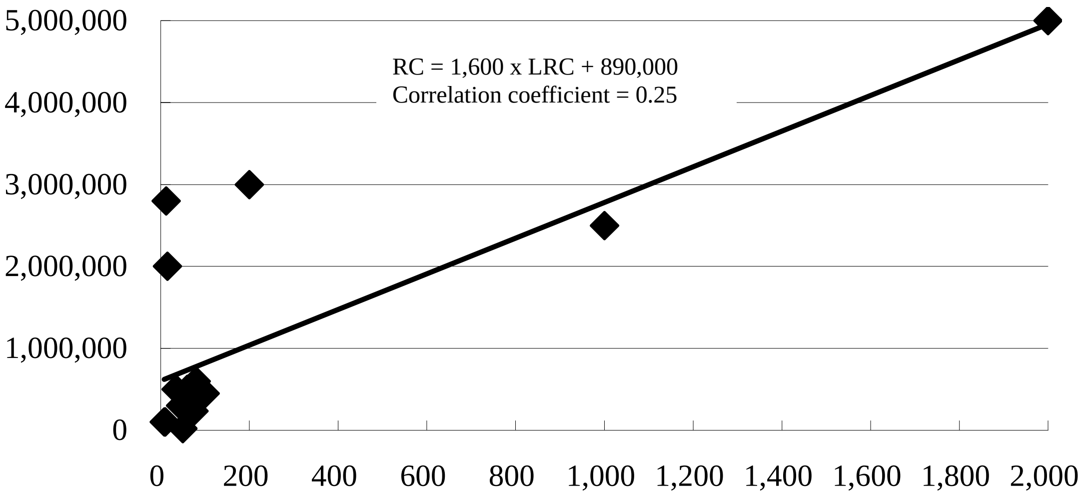


Figure 3.18 Charts for Estimating Reopening Cost per Length of Road Closure

(Data from questionnaire survey for RCDs on national highway in the Philippines from 1996 to 2005)

2-2) Annual Value of Human Lives Lost

The value of human lives lost is estimated using the following equation:

m= FRCDp * k * l (equation 3.12)

where:

m = Annual value of human lives lost (pesos per year)

FRCDp = Potential frequency of road closure disaster (no. per year)

k = Average number of human deaths per RCD

l = Value per human life lost (deaths)

2-2-1) Average Number of Deaths per RCD

The average number of deaths per RCD is the total number of deaths due to RCDs divided by the total number of RCDs for the period under consideration.

The estimate of the average number of deaths per RCD is given below:

0.003 (persons per RCD) (equation 3.13)

This was estimated using the data shown in Table 3.9.

Table 3.9 Average Number of Deaths per RCD

Data Period = 2 years (2004 & 2005)		
Total number of death for all RCDs	Total number of RCDs (A more accurate figure is being estimated)	Average number of deaths per RCD
14	5,415	0.003

2-2-2) Unit Value of Human Lives Lost

One estimate of the unit value of human life lost due to road accidents is PHP 2,300,000[1] based on a study conducted jointly by the Asian Development Bank (ADB) and the Association of Southeast Asian Nations (ASEAN) in 2004 and is recommended for adoption in this survey. The evaluation is shown in Appendix 6.

[1] ADB-ASEAN Regional Road Safety Program Accident Costing Report: The Cost of Road Traffic Accidents in the Philippines, Manila, 2004.

2-3) Annual Detour Cost

The annual detour cost is estimated in terms of the additional vehicle operating cost incurred in using a detour road when the survey site is closed due to RCD.

When an alternative route to the closed survey road exists, the equation to estimate the annual detour cost is as follows:

t = FRCDp* p*q((o*s)-(n*r)) (equation 3.14)

where:

t = Annual detour cost

FRCDp = Potential FRCD (no./ year)

p = AADT: Annual Average Daily Traffic on the survey site

q = Nos. of estimated closure days for the survey road

n = Length of survey road (from entry to exit point of detour road to avoid the road closure site on the survey road [see Figure 3.19]) (km)

o = Length of detour road (from entry to exit point of detour road to avoid road closure site on survey road [see Figure 3.19])) (km)

r = Average Vehicle Operating Cost/unit of AADT/km on the survey road

s = Average Vehicle Operating Cost/unit of AADT/km on the detour road

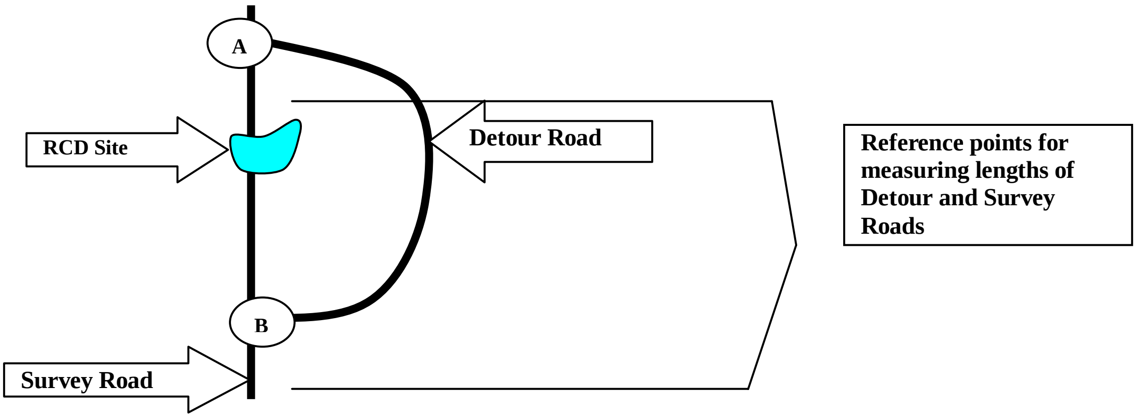


Figure 3.19 Reference Points for Measuring Lengths of Survey and Detour Roads

2-3-1) Lengths of survey and detour roads are measured by the DEO

The reference points are the vehicle entry/exit points on the detour road to avoid the RCD site.

2-3-2) AADT: Average Annual Daily Traffic on the Survey Site

Latest AADT of the surveyed section is filled out. The data is processed as shown in the Baguio-Bontoc Road (Halsema Highway) example to subsequently estimate the average vehicle operating cost on the survey and detour roads per AADT unit. .

Table 3.10 Example of AADT and Percent Share of Each Vehicle Type (Baguio-Bontoc Rd)

Vehicle Types	Volume	% of Total AADT
Motor driven Tricycle	19	0.64
Car	1027	34.44
Passenger Utility	242	8.12
Goods Utility	1546	51.84
Small Bus	19	0.64
Large Bus	1	0.03
2 Axle Truck	64	2.15
3 Axle Truck	57	1.91
4 Axle Truck/trailer	1	0.03
5 Axle Truck/trailer	6	0.20
4 Axle Trailer	0	0.00
5 Axle Trailer	0	0.00
AADT	2,982	100.00

2-3-3) Number of Predicted Closure Days of the Whole Width of the Road on the Survey Site per RCD

The number of closure days of the whole width of the survey road due to a disaster is predicted and the corresponding cell filled out. When traffic on one lane is open in the prospective disaster site, the closure day is equal to 0.

Figures 3.20 to Figure 3.21 can be used as reference for the prediction of road closure days due to disaster.

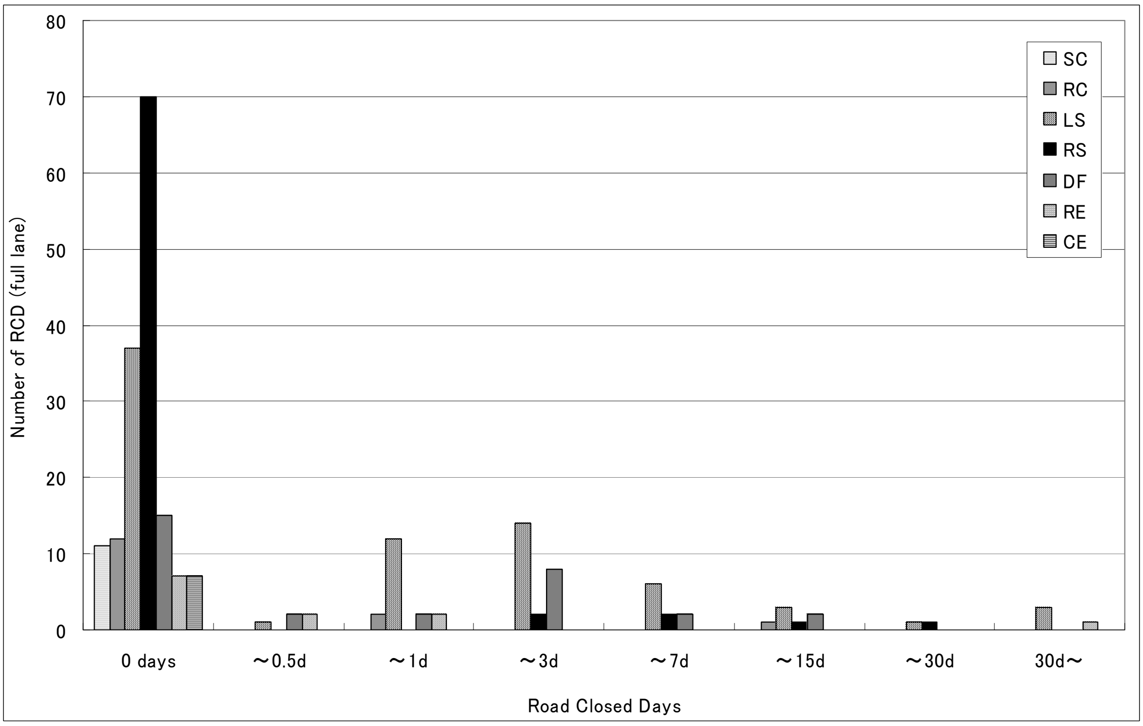
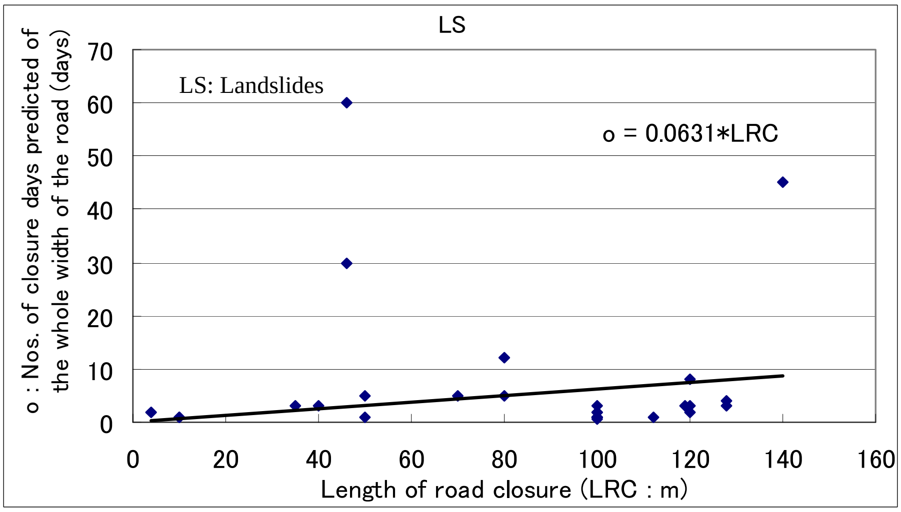
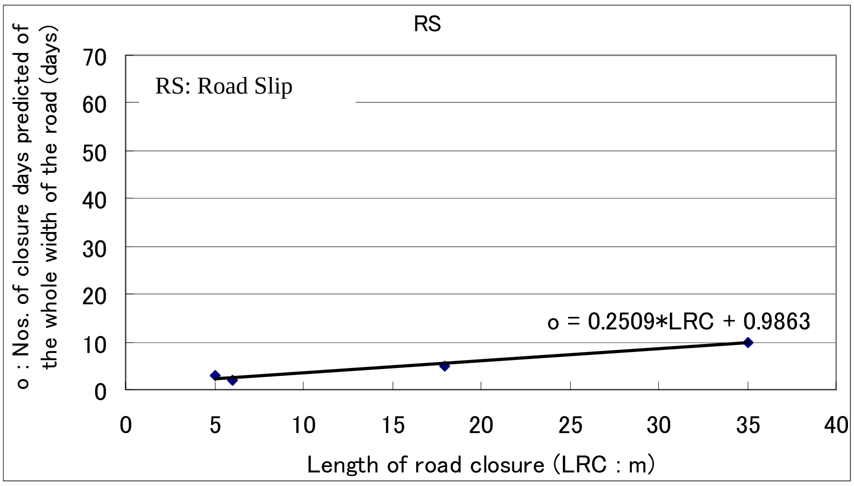
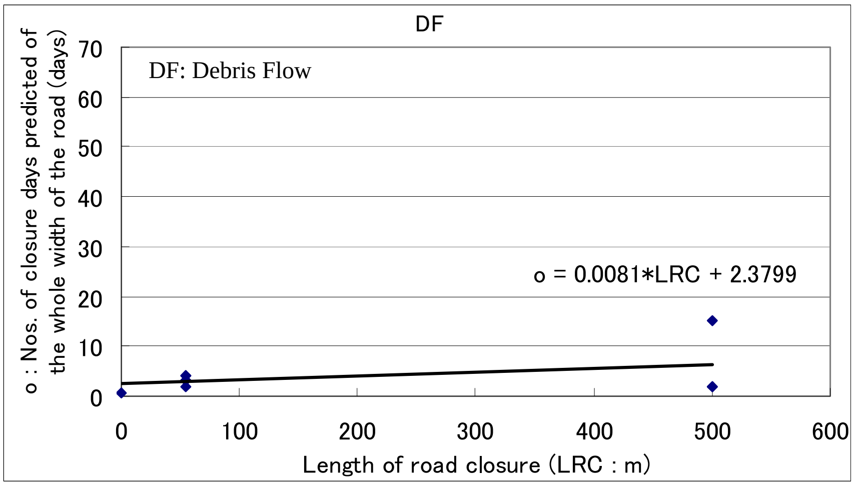


Figure 3.20 Frequency Distribution of Road Closure Days per RCD

(Based on available data of 229 RCDs on the national highway from 1996-2006)







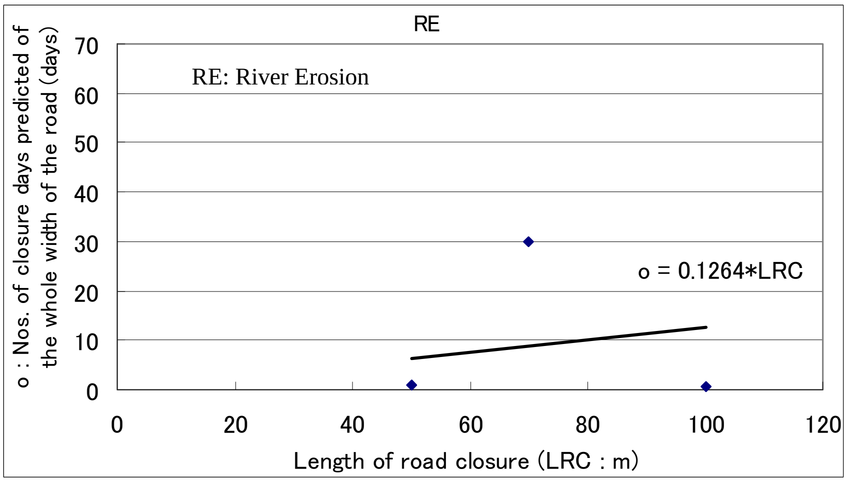


Figure 3.21 Charts for Estimating the Number of Road Closure Days by Length of Road Closure Alignment for various RCDs

(Based on available data on RCDs on national highways from 1996-2006)

2-3-4) Average Vehicle Operating Cost per AADT unit/km on the Survey and Detour Roads

The Average Vehicle Operating Cost (AVOC) per AADT unit/km on the Survey and Detour Roads should be input based on the typical condition of the survey and detour roads, i.e., the closed road is paved and in fair condition, while the detour road is unpaved and in poor condition. The methodology for calculating the AVOC uses the data given in Tables 3.4.6 and 3.4.7.

The DPWH regularly updates its estimate of vehicle operating costs used in the evaluation of road projects. This is applicable in the analysis of detour cost and the most recent estimate (as of October 2006) given in Table 3.11

Table 3.11 Estimated Vehicle Operating Cost (VOC) per Road Surface Type and Condition per km (VOC/km) (pesos)

SURFACE		Vehicle Type	Running Cost	Fixed Cost	Running + Fixed	Time Cost	VOC Running + Fixed + Time
Type	Condition						
PAVED	V.BAD	CAR/VAN	10.99	0.53	11.52	1.73	**13.25**
		JEEPNEY	7.58	2.60	10.18	2.56	**12.74**
		BUS	14.21	4.76	18.97	14.76	**33.73**
		TRUCK	18.28	5.59	23.87	0.00	**23.87**
		MCYCLE	1.38	0.32	1.70	2.28	**3.98**
		OTHERS	1.68	5.64	7.32	1.29	**8.60**
	BAD	CAR/VAN	9.62	0.40	10.02	1.30	**11.31**
		JEEPNEY	6.64	1.95	8.58	1.92	**10.51**
		BUS	11.97	3.57	15.54	11.07	**26.61**
		TRUCK	15.39	4.19	19.58	0.00	**19.58**
		MCYCLE	1.20	0.24	1.44	1.71	**3.15**
		OTHERS	1.47	2.82	4.29	0.64	**4.93**
	FAIR	CAR/VAN	8.24	0.27	8.51	0.87	**9.37**
		JEEPNEY	5.69	1.30	6.99	1.28	**8.27**
		BUS	9.72	2.34	12.07	7.27	**19.33**
		TRUCK	12.51	2.75	15.26	0.00	**15.26**
		MCYCLE	1.03	0.10	1.13	0.65	**1.81**
		OTHERS	1.26	1.61	2.87	0.37	**3.24**

SURFACE		Vehicle Type	Running Cost	Fixed Cost	Running + Fixed	Time Cost	VOC Running + Fixed + Time
Type	Condition						
PAVED	GOOD	CAR/VAN	6.87	0.23	7.10	0.74	**7.84**
		JEEPNEY	4.74	1.11	5.85	1.10	**6.95**
		BUS	7.48	2.01	9.49	6.24	**15.74**
		TRUCK	9.62	2.36	11.98	0.00	**11.98**
		MCYCLE	0.86	0.08	0.94	0.57	**1.51**
		OTHERS	1.05	1.41	2.46	0.32	**2.78**
UNPAVED	V.BAD	CAR/VAN	13.05	0.93	13.99	3.04	**17.03**
		JEEPNEY	9.01	4.57	13.58	4.51	**18.09**
		BUS	17.20	8.26	25.47	25.62	**51.09**
		TRUCK	22.13	9.70	31.83	0.00	**31.83**
		MCYCLE	1.63	0.32	1.95	2.28	**4.23**
		OTHERS	2.00	5.64	7.63	1.29	**8.92**
	BAD	CAR/VAN	10.99	0.55	11.55	1.81	**13.35**
		JEEPNEY	7.58	2.71	10.30	2.68	**12.98**
		BUS	14.21	4.91	19.12	15.22	**34.34**
		TRUCK	18.28	5.76	24.04	0.00	**24.04**
		MCYCLE	1.38	0.24	1.62	1.71	**3.33**
		OTHERS	1.68	2.82	4.50	0.64	**5.14**
	FAIR	CAR/VAN	8.93	0.39	9.33	1.29	**10.61**
		JEEPNEY	6.16	1.93	8.09	1.90	**10.00**
		BUS	11.22	3.72	14.94	11.54	**26.48**
		TRUCK	14.43	4.37	18.80	0.00	**18.80**
		MCYCLE	1.12	0.12	1.24	0.86	**2.09**
		OTHERS	1.37	1.88	3.24	0.43	**3.67**
	GOOD	CAR/VAN	7.90	0.30	8.20	0.96	**9.16**
		JEEPNEY	5.45	1.45	6.90	1.43	**8.33**
		BUS	9.35	2.62	11.97	8.12	**20.08**
		TRUCK	12.03	3.07	15.10	0.00	**15.10**
		MCYCLE	0.99	0.10	1.09	0.68	**1.77**
		OTHERS	1.21	1.41	2.62	0.32	**2.94**

Source: DPWH Planning Service

(3) Indicative Feasibility Indicators for the Countermeasures

The objective of the DIS is to determine the indicative economic viability of each countermeasure and to compare the viability indicators of all possible countermeasures to select the most economically viable countermeasure. Potential frequency of road closure disaster with countermeasure and three benefit/cost analysis measures are used to estimate the economic worth of the specific countermeasure: Benefit/Cost Ratio (BCR), Economic Net Present Value (ENPV) and the Economic Internal Rate of Return (EIRR) of the countermeasure's benefit and cost streams. These are estimated assuming a 20-year project life:

$$BCR = [\sum_{y=0}^{y=20} x/(1+0.15)^y] / [v/(1+0.15)^y] \qquad \text{(equation 3.15)}$$

where:

BCR= Benefit/Cost Ratio at 15% discount rate

x= decrease in annual loss due to countermeasure

v= cost of countermeasure including 20 year maintenance cost

y= year from countermeasure installation (year of countermeasure installation is y = 0)

$$ENPV= [\sum_{y=0}^{y=20} x/(1+0.15)^y] - [v/(1+0.15)^y] \qquad \text{(equation 3.16)}$$

where:

ENPV= Economic Net Present Value

x= decrease in annual loss due to countermeasure

v= costs of countermeasure including 20 year maintenance cost

y= year from countermeasure installation (year of countermeasure installation is y = 0)

0.15= assumed discount rate (opportunity cost of capital or OCC)

EIRR= Economic Internal Rate of Return

It is the "discount rate r" where the present value of the benefit stream is equal to the present value of the cost stream over the project life.

$$\sum_{y=0}^{y=20}[(x_y-v_y)/(1+r)^y] = 0 \qquad \text{(equation 3.17)}$$

where:

$y=$ year from countermeasure installation (year of countermeasure installation is $y = 0$)

$x_y=$ benefit in year 'y' (pesos/year)

$x_{0=}$ 0, $x_{1,}\ x_2 \ldots\ldots\ldots\ x_{20\,=}$ x (x: decrease in annual loss due to countermeasure)

$v_y=$ cost in year 'y' (pesos/year)

$v_{y=}$ cost of countermeasure inclusive of 20 years maintenance, $v_{1,}\ v_2 \ldots\ldots v_{20} = 0$

$r=$ discount rate = Economic Internal Rate of Return

The proposed countermeasure is viable from the economic viewpoint if the estimated BCR > 1, ENPV > 0 at the 15% discount rate; and the computed EIRR > 15%.

Table 3.12 illustrates the estimation of the BCR, ENPV and EIRR.

Table 3.12 Estimates of BCR, ENPV and EIRR using Microsoft Excel

Assumptions:

Discount rate: Opportunity cost of capital =15%

V_0 =Cost of countermeasure with 20 yeas maintenance = PHP 10 million

x =Annual benefits (reduction in losses due to RCD) = PHP 1,250,000

Economic life of countermeasure = 20 years

y: year	v_0: cost of countermeasure inclusive of 20 year maintenance (pesos)	x_y: annual benefit (pesos/year)	Net Benefits
0	10,000,000		-10,000,000
1		1,250,000	1,250,000
2		1,250,000	1,250,000
3		1,250,000	1,250,000
4		1,250,000	1,250,000
5		1,250,000	1,250,000
6		1,250,000	1,250,000
7		1,250,000	1,250,000
8		1,250,000	1,250,000
9		1,250,000	1,250,000
10		1,250,000	1,250,000
11		1,250,000	1,250,000
12		1,250,000	1,250,000
13		1,250,000	1,250,000
14		1,250,000	1,250,000
15		1,250,000	1,250,000
16		1,250,000	1,250,000
17		1,250,000	1,250,000
18		1,250,000	1,250,000
19		1,250,000	1,250,000
20		1,250,000	1,250,000
Present Value at 15% discount rate	8,695,652	7,824,164	
	BCR at 15% discount	**0.90**	
	ENPV at 15% discount		**−1,892,031**
	EIRR	**10.93%**	

3-1) Cost of Countermeasures with 20 Year Maintenance

The estimates of the costs of the countermeasures are given in Sheet 4 and are linked to the appropriate cells in Sheet 5.

3-2) Risk Reduction Ratio in RCD Due to Specific Countermeasure

The specific countermeasure reduces the RCD/FRCDp. The risk reduction ratio corresponding to the different countermeasures' effectiveness should be input in the appropriate cells. Example of the risk reduction ratios are shown in Table 3.13

Table 3.13 Examples of Risk Reduction Ratios

Countermeasure's Effectiveness	Example of Disaster Reduction Ratio	Type of Countermeasure
High Effectiveness: RCD reduction is between 70%-100%	0.7 – 1.0	❑ Retaining walls for RS ❑ Embankment of landslide toe ❑ Cutting of LS head ❑ Sabo dams for DF
Moderate Effectiveness: RCD reduction is between 30%-70%	0.3 – 0.7	❑ Catch walls ❑ Guard fences ❑ Retaining walls for SC ❑ Road drainage for RS
Low effectiveness: RCD reduction is between 0%-30%	0.0 – 0.3	❑ Vegetation for SC

3-3) Annual Benefits Due to a Specific Countermeasure

The benefits that are generated by a countermeasure are the decreases in annual losses due to avoidance of reopening costs and detour cost and decrease in the occurrence of deaths. These are estimated as follows:

$$x_I = u*w \qquad \text{(equation 3.19)}$$

where:

x = Decrease in total annual losses due to the specific countermeasure

u = Total annual loss

w = Risk reduction in RCD due to the countermeasure