THE REPUBLIC OF PERU

FINAL REPORT
FOR
THE MASTER PLAN STUDY
ON
THE DISASTER PREVENTION PROJECT
IN
THE RIMAC RIVER BASIN

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MARCH 19[illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO, JAPAN

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SUPPORTING REPORT II

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X. STUDY ON STRUCTURAL PLAN FOR DEBRIS FLOW AND SLOPE FAILURE DISASTER

ABBREVIATION

1. Abbreviation of Peruvian Offices

CENTROMIN S.A.	Empresa Minera del Centro del Perú Center Perú Mining Company)
CAPECO +	Cámara Peruana de la Constructión (Peruvian Chamber of Construction
CONCITEC	Consejo Nacional de Ciencia y Tecnología (National Council of Science and Technology)
COOPOP	Cooperación Popular (Popular Cooperation)
CORDE CALLAO	Corporación de Desarrollo del Calao (Development Corporation of Callao)
CORDE LIMA	Corporación de Desarrollo de Lima (Development Corporation of Lima)
CORPAC	Corporación Peruana de Aviachión Comercial (Peruvian Corporation of Commercial Air Travel)
C.P.L.	Concejo Provincial de Lima (Provincial Council of Lima)
DGAF	Dirección General de Aerofotografia (Department of Aerophotographs)
DGASI	Directión General de Aguas, suelos e irrigaciones (General Direction of Water, Soil and Irrigations)
DHNM	Direccióndde Hidrología y Navegación de la marina (Navigations and Hydrographic Direction of the Peruvian Navy)
ELECTRO LIMA	Empresa de Electricidad de Lima (Electric Company of Lima)
ELECTRO PERU	Empresa de Electicidad del Perú S.A. (Electric Company of Perú)
ENACE	Empresa Nacional de Edificaciones (National Enterprise for Building)
ENAFER S.A.	Empresa Nacional de Ferrocarriles del Perú

	(Railroad National Company of Perú)
IGN	Instituto Geofísico Nacional (Geophysics Institute of Perú)
IMARPE	Instituto del Mar del Perú (Oceanic Institute of Perú)
INADE	Instituto Nacional de Desarrollo (Development National Institute)
INAF	Instituto Nacional de Ampliación de la Frontera Agrícola (National Institute for the Widening of Agriculture Lands Frontier)
INE	Instituto Nacional de Estadísticas (Statistics National Institute)
INP	Instituto Nacional de Planificación (Planning National Institute)
INFOR	Instituto Nacional Forestal y de Fauna (Forest, Fauna National Institute)
ING	Instituto Nacional Geográfico (National Geographic Institute)
INGEMMET	Instituto Geológico Minero y Metalúrgico (Metallurgy, Mining and Geologic Institute)
INVERMET	Inversiones Metropolitanas (Metropolitan Inversions)
MINIS. AERON.	Ministerio de Aeronáutica (Aeronautic Ministry)
MINIS. AGRIC.	Ministerio de Agricultura (Agriculture Ministry)
MINIS. ECON.	Ministerio de Economía y Finanzas (Economics and Finance Ministry)
MINIS. EDUCA.	Ministerio de Educación (Education Ministry)
MINIS. ENERG.	Ministerio de Energía y Minas (Energy and Mining Ministry)
MINIS. GUERRA	Ministerio de Guerra (War Ministry)
MINIS. INDUS.	Ministerio de Industria, Turismo e Integración

	(Industry, Tourism and Trade Ministry)
MINIS. INTER.	Ministerio del Interior (Interior Ministry)
MINIS. PESQ.	Ministerio de Pesquería (Fishing Ministry)
MINIS. PRESD.	Ministerio de la Presidencia (Presidency Ministry)
MINIS. PREE	Ministerio de Relaciones Exteriores (Foreign Relations Ministry)
MINIS. SALUD	Ministerio de Salud (Health Ministry)
MINIS. TRABJ.	Ministerio de Trabajo (Labour Ministry)
MINIS. TRANSP.	Ministerio de Transportes y Comunicaciones (Transports and Communications Ministry)
MINIS. VIVIE.	Ministerio de Vivienda y Construcción (Housing and Construction Ministry)
MUN. DIS. LIMA	Municipalidad Distrital de Lima (District Council of Lima)
MUN. DIS CALLAO	Municipalidad Distrital del Callao (District Council of Callao)
MUN. DIS. ATE	Municipalidad Distrital de Ate (District Council of Ate)
MUN. DIS. CHACL.	Municipalidad Distrital de Chaclacayo (District Council of Chaclacayo)
MUN. DIS. CHOS.	Municipalidad Distrital de Chosica (District Council of Chosica)
MUN. DIS. MATUc	Municipalidad Distrital de Matucana (District Council of Matucana)
MUN. DIS. SANMAT	Municipalidad Distrital de San Mateo (District Council of San Mateo)
NCTL +	Naturaleza, Ciencia y Tecnología Local (Nature, Science and Local Technology Organization)
ONERN	Oficina Nacional de Evaluación de Recursos Naturales

	(National Evaluation Office of Natural Resources)
PREDES +	Centro de Estudios y Prevencio de Desastres (Prevention Disasters and Studies Center)
PRES. CO. MI.	Presidencia del Consejo de Ministros (Presidency of the Ministries Cabinet)
SAN	Servicio AerofotogrMinisterio de Economía y Finanzas (Economics and Finance Ministry)
MINIS. EDUCA.	Ministerio de Educación (Education Ministry)
MINIS. ENERG.	Ministerio de Energía y Minas (Energy and Mining Ministry)
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PREDES +	Centro de Estudios y Prevencio de Desastres (Prevention Disasters and Studies Center)
PRES. CO. MI.	Presidencia del Consejo de Ministros (Presidency of the Ministries Cabinet)
SAN	Servicio Aerofotográfico Nacional (National Aerophotographics Service)
SE/CNDC	Secretaría Ejective/Comité Nacional de Defensa Civil (Executive Secretary/Civil Defense National Committee)
SEDAPAL	Servicio de Agua Potable y Alcantarillado de Lima (Drinkable Water and Sewering Service of Lima)
SENAPA	Servicio Nacional de Agua Potable y Alcantarillado (National Drinkable Water and Sewering Service)
SENAMHI	Servicio National de Meteorología e Hidrología

	(Meteorologic and Hydrologic National Service)
SNI	Sociedad Nacional de Industrias (National Industry Society)
UNFV	Universidad Nacional Federico Villarreal (Federico Villarreal National University)
UNMSM	Universidad Nacional Mayor de San Marcos (San Marcos University)
UNA	Universidad Nacional Agraria (Agriculture University)
UNI	Universidad Nacional de Ingeniería (Engineering National University)

\+ Private Offices

2. Abbreviation of Measurement

Length

mm	Millimeter
cm	centimeter
m	mete
Km	kilometer

Time

S or sec	second
min	minute
h or hr	hour
d	day
y or yr	year

Area

cm^2	square centimeter
m^2	square meter
ha	hectare
Km^2	square kilometer

Volume

cm^3	cubic centimeter
m^3	cubic meter
l	liter

Weight

g	gram
kg	kilogram
ton	metric ton

Other Measures

%	percent
°	degree
°C	degree centigrade
103	thousand
106	million
109	billion

Derived Measures

m^3/s	cubic meter per second
KWH	kilowatt hour
MWH	megawatt hour

Currency

US$	U S Dollar
I/.	Perú Inti
¥	Japanese Yen

3. Abbreviation of others

JICA	Japan International Cooperation Agency
GDP	Gross Domestic Product
GRODP	Gross Regional Domestic Product
GNP	Gross National Product
Ref.	Reference
O&M	Operation and Maintenance
El.	Elevation
WL	Water Level
HWL	High Water Level
FWL	Flood Water Level
LWL	Low Water Level
Fig.	Figure
Qda/Q	Quebrada (Small Tributary)
Spe	Slope

APPENDIX X

STUDY ON STRUCTURAL PLAN FOR DEBRIS FLOW AND SLOPE FAILURE DISASTER PREVENTION

Appendix X STUDY ON STRUCTURAL PLAN FOR DEBRIS FLOW AND SLOPE FAILURE DISASTER

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APPENDIX X

STUDY ON STRUCTURAL PLAN FOR DEBRIS AND SLOPE FAILURE DISASTER PREVENTION

1. GENERAL

In accordance with the basic concept and criteria established in Chapter III of the Main Report, the structural plans for debris flow and slope failure disasters are to be made in this Appendix X.

As there are so many quebradas (tributaries) and mountain slopes in the Rimac river basin, it is required to study in the following order for covering all the basin and making a plan with an appropriate level to each area.

(a) Division of study area

(b) Arrangement of features in each study area

(c) Evaluation of protective objects and danger in each study area

(d) Classification of Group (A, B or C)

(e) Estimation of disaster and damage in scale of long-term mid-term and short-term probability

(f) Study of structural plans for Groups "A" and "B".

(g) Evaluation and recommendation of structural plan for each Area of Groups "A" and "B".

(h) Study and recommendation of implementation program of structural plan

2. DIVISION OF STUDY AREA

The Rimac river basin with the catchment area of approximately 3,230 km^2 is to be divided into the following areas.

(A) Sub-basin area (Qda Area)

Qda Area is an area with an tributary which enters into the main river, Rimac river or Sta Eulalia river. As there are so many tributaries, Qda Area is to be selected as a tributary area with the catchment area of over 5-10 km2.

However, some Qda Areas with less than 5 km2 in catchment area such as Qda Carosio (0.4 km2) and Qda Corrales (1.4 km2) are also selected as units of Qda Area. These areas have important protective objects and high danger factor.

In addition, the areas located in the lower reach of the Rimac river are not divided into individual area of a tributary. The possibility of heavy rainfall is very low and no serious disaster has happened in the past in tributaries of the lower reach. It seems to be better to reduce the number of divided area for making the study as simply as possible.

(B) Mountain slope area (Spe Area)

Spe area is the area surrounded by the areas of Qda and the main river. The division of Spe Area is automatically decided as Qda areas are selected first. Some Spe Areas are to have not only mountain slope but also a tributary (or some tributaries) and qullies.

The results of division with the number are shown in Fig.X-2-1.

As seen in the figure, there are many areas as follows:

(A)	Qda Area	75 areas
	Rimac river	48 areas*
	Santa Eulalia river	27 areas
(B)	Spe Area	71 areas
	Rimac river	45 areas
	Santa Eulalia river	26 areas

Note: (1) Some mountain slope areas surrounded by Qda areas are omitted in case the area is very small and is expected to be classified as Group C. Therefore, number of Spe Area is fewer than that of Qda Area.

(2) *: Not including Qda Jicamarca (R-0)

3. MAIN FEATURES OF DIVIDED AREAS

3.1 Features of Each Quebrada Area

The features of all the Qda Areas are made by using the topographical map of 1/100,000 in scale. The following items are checked on the maps.

(A) No. of Qda Area

Numbering of Qda Area is made separately for Rimac river (R) and Santa Eulalia river (S).

In each river basin, the numbering is done from the downstream side to the upstream side. That is, Qda Area with smaller number is located in the downstream side.

(B) Name of Tributary

In case that there are some different names for a tributary, the following name is used.

(a) Name for the downstream stretch
(b) Name of main stream
(c) Name used by the inhabitants

In case there is no specific name, a name of near-by village or place is used.

(C) Distance

Distance from the river mouth of the Rimac river is shown. That is, the confluence of the Rimac river and a tributary is located on the point with the Distance from the river mouth along the main river.

(D) River Length

Length of tributary is measured in the following two cases.

(a) Length from the confluence to the end of river-like section which is roughly decided from the topographic map.

(b) Length from the confluence to the border line of the sub-basin. That is, the extension of river-like section is added.

The length is measured horizontally. The actual length is necessary to be modified by the slope gradient.

(E) Area

The area of each Qda basin is shown.

(F) Elevation

The highest and lowest elevations of the basin are shown. The highest portion is located on the border line of catchment area and the lowest portion is located generally at the confluence.

(G) Height Difference

The height of basin, the difference between the highest and the lowest, is shown.

(H) Average Slope

The average slope of each Qda Area is shown by the following methods.

(a) Ratio of horizontal distance to a unit of vertical height.
(b) Degree

The features of all Qda Areas are summarized in Table X-3-1.

Though the features are different by Qda Area, the particular features are to be described as follows:

(a) The highest portion of each Qda Area is remarkably high. Most Qda Areas have peak portion of higher than El.2,000 m.

(b) Height difference of each Qda Area is also remarkable. Most Qda Areas have a height of more than 1,000 m.

(c) Slope of tributary in Qda Area is generally very steep. Most tributaries have an average slope of steeper than 10° Tributaries with 30° or more in slope are also not exceptional.

3.2 Features of Each slope Area

The features of all the Spe Areas are made by checking the topographical maps of 1/100,000 in scale. The features are summarized in Table X-3-2. The items shown in the tables are to be explained as follows:

(A) No. of Spe Area

No serial number is used for Spe Areas. As Spe Area is located between two Qda Areas, number of adjacent Qda Areas are attached to find the location easily.

(B) Name of Spe Area

Names of Qda Areas adjacent to each Spe Area are shown.

(C) Distance

The distance from the river mouth to the middle of Spe Area stretch along the main river is shown.

(D) Section Length

The length of Spe Area along the main river is shown.

(E) Slope Length

The maximum horizontal length/width of mountain slope in each Spe Area is shown.

(F) Area

The area of Spe Area surrounded by Qda Area and the main river is shown.

(G) Slope Elevation

The highest and lowest elevations along the longest slope are shown.

(H) Height

Slope height at the longest slope, the difference of the highest and the lowest, is shown.

(I) Average Slope

The average slope of each Spe Area is shown by the ratio of horizontal length to vertical height as well as by the degree.

As shown in the tables, the three Spe Areas located in the lower reach have comparatively large area. As already explained in Section 2, the detailed division of Area is not made in the lower reach.

Some particular features of Spe Area are to be described as follows:

(a) The length of Spe Area is generally more than 1 km and less than 10 km.

(b) The horizontal length of slope is generally more than 1 km and less than 4 km.

(c) Slope height is higher than 500 m and most of them are lower than 2,000 m.

(d) Average slope gradient of Spe Area is steeper than 15° and about a quarter of them is steeper than 30°.

The scale of mountain slope is comparatively big as a unit to study the slope failure, land slide and debris flow which are expected to be happened on a mountain slope area. However, it seems that the detailed and specific study for all the slopes in the basin is difficult at the study level of master plan. It seems to be important to make clear the classification for the further study and show the general plan for the measures against disaster. The disaster in Qda Areas seems to be more serious and the priority of detailed study will be required for some Qda Area.

4. CLASSIFICATION OF DIVIDED AREAS

All the divided areas of Qda Area and Spe Area are to be classified into the following three groups for study level as the areas with priority of disaster prevention works need comparatively detailed study.

(a) Group A: The necessity of disaster prevention plan seems to be very high. The specific study of disaster and prevention measures is made in each individual area. The study is carried out for the long-term, mid-term, and short-term provisional plans.

(b) Group B: The necessity of disaster prevention plan seems to be comparatively high. The general plan is made in each area. However, the study level is not so specific in comparison with Group A.

(c) Group C: The necessity of disaster prevention plan seems to be low. The study for individual area is not to be carried out.

The classification is made judging from the level of protective object and level of danger of which criteria are described in Chapter III of the Main Report. As there are many factors to be considered and the conditions of each area are generally not simple enough to define them, the judgement is finally made by the synthetic viewpoints based on the discussion among engineers of the Study Team.

The major points and judgement of classification are summarized in Table X-4-1 and X-4-2.

The results of classification are obtained as shown in Fig. X-4-1 and listed as follows:

(A) Group A

(a) Qda Area : 7 areas

R-6	Q. Quirio
R-7	Q. Pedregal
R-8	Q. Carosio
R-9	Q. Corrales
R-19	Q. Rio Seco
R-32	Q. Paihua
S-1	Q. Cashahuacra

(b) Spe Area : None

(B) Group B

(a) Qda Area : 23 areas

R-1	Q. Chacracayo
R-2	Q. Chacrasana
R-3	Q. California
R-4	Q. Santa Maria
R-5	Q. La Cantuta
R-10	Q. La Ronda
R-11	Q. Santa Ana
R-13	Q. Cupiche
R-15	Q. Canchacalla
R-16	Q. Guayabo
R-17	Q. Agua Salada
R-18	Q. Esperanza
R-23	Q. Huacre
R-24	Q. Matata
R-15	Q. Cuchimachay
R-31	Q. Chucumayo
R-33	Q. Chacahuaro
R-34	Q. Pancha
R-35	Q. Viso
R-37	Q. Parac
S-2	Q. Redonda
S-3	Q. Infiernilla
S-5	Q. Lucuma

(b) Spe Area : 25 areas

R--/0	River mouth - Jicamarca
R--/1	River mouth - Chacracayo
R-0/2	Jicamarca - Chacrasana
R-1/3	Chacracayo - California
R-4/6	Santa Maria -Ronda
R-7/8	Pedregal - Carosio
R-8/9	Carosio - Corrales
R-9/-	Corrales - Confluence
R-10/-	La Ronda - Confluence
R--/11	Confluence - Santa Ana
R--/12	Confluence - San Juan
R-11/13	Santa Ana - Cupiche
R-13/16	Cupiche - Guayabo
R-16/17	Guayabo - Agua Salada
R-19/20	Rio Seco - Esperanza
R-20/21	Esperanza - Verrugas
R-21/23	Verrugas - Huacre
R-22/27	Linday - Yamajune
R-26/29	Chacamaza - Barranco
R-31/33	Chucumayo - Chacahuaro
R-37/40	Parac - R. Blanco
S--/1	Confluence - Cashahuacra
S--/4	Confluence - Alcula
S-1/2	Cashahuacra - Redonda
S-2/3	Redonda - Infiernilla

(c) Group C

(a) Qda Area : 45 areas

(b) Spe Area : 45 areas

5. DISASTER AND DAMAGE AT GROUP "A" AREAS

5.1 General

Before the study for making the disaster prevention plan, it is necessary to assume the possible disaster in each objective area.

There are so many factors and conditions for the occurrence of natural disaster, especially debris flow and slope failure. The assumption of disaster in each area is to be made on the basis of the past disasters, especially the disaster happened in March, 1987.

The disaster conditions on the following items are required to be assumed for the probable disasters of the long-term, mid-term and short-term.

(a) Decision of objective scale
(b) Estimation of deposit volume
(c) Estimation of deposit area
(d) Estimation of damage quantity
(e) Estimation of damage amount

5.2 OBJECTIVE SCALE AND DEPOSIT VOLUME

(1) Objective Scale

As already mentioned, the data for estimating the probable disaster in each Qda area are insufficient. There is no written record of past disaster in long term and the meteo-hydrological data are also not available to make reliable analysis of probable rainfall and flood. Only some verbal information from the inhabitants can be obtained.

The objective scale of disaster in each Group "A" areas is decided to be based on the scale of disaster happened in March 1987. In this case, the disaster in Qda. Pedregal is to be taken as the representative one as Qda. Pedregal suffered most serious damage among 5 Qda. areas; Qda. Quirio, Qda. Pedregal, Qda. Carosio, Qda. Corrales and Qda. Cashahuacra.

Though there are some factors to show the scale of disaster, it is decided to use the scale of deposit volume as the other factors such as the damage amount and disaster area are too much variable by the various characteristics of each area. The scale of deposit volume is assumed to be proportional to the drainage area of each Qda. Though the assumption will be rough, it seems that there is no more reliable way as far as the data obtainable at present.

Thus the objective scale of each Qda. area is decided to be as follows:

(A) Long-term scale
Scale of March 1987 disaster x 1.2* x F**

(B) Mid-term scale
Long-term scale x 0.5

(C) Short-term scale
Long-term scale x 0.1

* : 1.2 is the safety factor
**: Reduction factor to be explained in the following subsection (2).

(2) Reduction Factor (F)

It is necessary to consider the reduction of specific deposit volume per km^2 as the various conditions of sub-basin are different each other.

Though there are various conditions which effect on the runoff volume of sediments, it is considered that the conditions of vegetation are most important. It is generally known that the specific yield volume of debris and mud in bare land is 10 - 100 times larger than that in forest land.

The reduction factor is decided on the basis of vegetation conditions as follows:

F = 1 : Almost no vegetation

F = 0.8 : Vegetation covers more than 10% but less than 30% of the basin

F = 0.6 : Vegetation covers more than 30% but less than 60%

F = 0.4 : Vegetation covers more than 60% but less than 90%

F = 0.2 : Vegetation covers more than 90%

Note: (1) Though the difference of factor can be made larger from the general viewpoint, it is considered that the much part of runoff deposits from Qdas in the Rimac river basin are yielded from the unstable deposits in the channel located in the downstream stretch of each Qda. That is, the deposits volume is not always proportional to the uncovering ratio of vegetation.

(2) The area covered with hard rocks which seem to be hardly weathered is considered as vegetation area.

In case of Qda areas of Group "A", the reduction factor is decided as follows:

(a)	Qda Quirio	F = 1
(b)	Qda Pedregal	F = 1
(c)	Qda Carosio	F = 1
(d)	Qda Corrales	F = 1
(e)	Qda Rio Seco	F = 0.4
(f)	Qda Paihua	F = 0.4
(g)	Qda Cashahuacra	F = 1

(3) Deposit Volume

The deposit volume per 1 km2 of catchment area in Qda. Pedregal at the time of March 1987 disaster is calculated as follows:

$157,200\ m^3 \div 10.6\ km^2 = 14,800\ m^3/km^2$

Note: Deposit volume of March 1987 disaster is to be referred to Appendix VI "MARCH 1987 DISASTER"

The calculation for assuming the deposit volume in each Qda. area is made as summarized in Table X-5-1. The results in case of long-term scale are shown below.

(a)	Qda. Quirio	184,700 m^3
(b)	Qda. Pedregal	188,200 m^3
(c)	Qda. Carosio	7,100 m^3
(d)	Qda. Corrales	24,900 m^3
(e)	Qda. Rio Seco	292,700 m^3
(f)	Qda. Paihua	198,900 m^3
(g)	Qda. Cashahuacra	268,200 m^3

5.3 Deposit Area

It is necessary to assume the disaster (deposit) area for estimating the damage and also for making disaster prevention plan.

The deposit area in each Qda Area is assumed by the following manners.

(A) For Qda areas which suffered the disaster in March 1987, the disaster areas are assumed on the basis of the actual disaster area at the time of March 1987 disaster.

(B) For the Qda areas which did not suffer the disaster in March 1987, the disaster area are assumed by the synthetical study based on the past disaster, land forms, channel conditions, etc.

(C) As the scale of March 1987 disaster and the objective scale is more or less different, the extension of disaster area is assumed in consideration of the deposit volume in each scale.

(D) The disaster area is to be shown with the following classification.

    (a) Serious destruction area (70-100% destroyed, say 90%)

    (b) Semi-destruction area (30-70% destroyed, say 50%)

    (c) Other affected area (0-30% destroyed, say 20%)

It is necessary to make the classification as the estimation of damage condition and amount will require more or less the level of destruction for each property.

The assumed disaster areas with classification in case of long-term, mid-term and short-term scales are shown in figures listed as follows:

(A)	Qda. Quirio	Fig. X-5-1, 2 and 3
(B)	Qda. Pedregal	Fig. X-5-4, 5 and 6
(C)	Qda. Carosio	Fig. X-5-7, 8 and 9
(D)	Qda. Corrales	Fig. X-5-7, 8 and 9
(E)	Qda. Rio Seco	Fig. X-5-10, 11 and 12
(F)	Qda. Paihua	Fig. X-5-13, 14 and 15
(G)	Qda. Cashahuacra	Fig. X-5-16, 17 and 18

5.4 Damage Quantity and Amount

The damage amount is to be estimated for the disaster assumed in each area. The procedure for damage estimate is described as follows:

(A) Checking the quantity of items to be damaged.

(a) House (No.)

- Upper class
- Middle class
- Lower class

(b) Public building (No. and m^2)

- Market
- School
- Others

(c) Farm land (ha.)

- Good harvest land
- Poor harvest land

(d) Public structures/facilities

- Road
- Bridge
- Well
- Park
- Other

(e) Traffic block

(f) Rehabilitation works

- Removal of debris* (m^3)
- Removal of mud (m^3)

* including destroyed structures/houses

(g) Human damage

- Death
- Wounded

(h) Other damage

(B) Decision of unit cost for each item of damage to be taken from the Inventory of Damageable Value shown in Appendix VI.

(C) Estimate of damage amount based on the quantities and the unit cost of damage.

The quantity of damage in each Qda. Area is estimated as summarized in Tables X-5-2 to X-5-8. The counting of quantity in each property item was carried out by using maps, aerial-photographs and site inspection.
Therefore, assumption was made for the classification and number of structures (especially houses). The quantities of indirect

damage are also assumed on the basis of the past disaster records and the examples of the other places.

The damage amount in each Qda Area is estimated on the basis of the quantities and the unit cost as shown in Tables X-5-9 to X-5-15. The summary of total damage is shown below.

(A) Qda. Quirio Area

(a)	Long-term scale	I./229.25 x 10^6
(b)	Mid-term scale	I./137.11 x 10^6
(c)	Short-term scale	I./29.09 x 10^6

(B) Qda. Pedregal Area

(a)	Long-term scale	I./466.61 x 10^6
(b)	Mid-term scale	I./267.36 x 10^6
(c)	Short-term scale	I./27.66 x 10^6

(C) Qda. Carosio Area

(a)	Long-term scale	I./101.78 x 10^6
(b)	Mid-term scale	I./57.45 x 10^6
(c)	Short-term scale	I./7.17 x 10^6

(D) Qda. Corrales Area

(a)	Long-term scale	I./127.84 x 10^6
(b)	Mid-term scale	I./77.30 x 10^6
(c)	Short-term scale	I./7.71 x 10^6

(E) Qda. Rio Seco Area

(a)	Long-term scale	I./215.97 x 10^6
(b)	Mid-term scale	I./96.22 x 10^6
(c)	Short-term scale	I./21.32 x 10^6

(F) Qda. Paihua Area

(a)	Long-term scale	I./222.28 x 10^6
(b)	Mid-term scale	I./113.62 x 10^6
(c)	Short-term scale	I./16.37 x 10^6

(G) Qda. Cashahuacra

(a)	Long-term scale	I./96.89 x 10^6
(b)	Mid-term scale	I./38.90 x 10^6
(c)	Short-term scale	I./6.88 x 10^6

6. DISASTER AND DAMAGE AT GROUP "B" AREA

6.1 General

The disaster and damage at Group "B" areas are to be estimated rather roughly in comparison with those at Group "A" areas due to the following reasons.

(a) The field investigation and data collection were carried out mainly for the expected Group "A" areas. Though the field investigation was carried out in all the areas of the basin, it is difficult to make definite survey for every area as there are so many areas.

(b) It seem to be not necessary to make specific plan for all the probable disaster areas. To decide the priority of study is important in the study level of master plan. The relatively definite plans are made for Group "A" areas, therefore, the plans made for Group "A" will become available references for Group "B" areas.

The study for Group "B" areas is made by assuming the various conditions as simply as possible. However, the estimation of disaster for Group "B" areas as well will be required for the evaluation of structural plans. That is, the evaluation from technical and economic aspects will be required for making a definite standard for deciding the feasibility of a structural plan.

The estimation of disaster in Qda areas and Spe areas is to be carried out separately in the following subsections 6.2 and 6.3.

6.2 Qda Areas

6.2.1 General Features of each Area

There are 23 Qda Areas in Group "B"

The Study Team had the field reconnaissance in all Qda areas of Group "B" though the detailed survey was not carried out. The particular features in regard to damage conditions in each Qda area of Group "B" are described as follows:

(A) Q. Chaclacayo (R-1)

There is a villa district in front of the outlet of valley and the end of erosion channel is not clear. As the comparatively deep erosion channel develops in the valley, the dangerous level at the end of erosion channel will be high.

(B) Q. Chacrasana (R-2)

The route of channel is not yet fixed though the valley is flat-base type. There is a village of low-income people in the downstream area of the Electro-Lima waterway. Additionally the embankment of materials excavated for the waterway tunnel is seen in the upstream side of the village.

(C) Q. California (R-3)

There is a flat-base valley of which channel is not yet fixed. There is a villa district in front of the valley outlet. The debris flow has to pass through the villa district.

(D) Q. Santa Maria (R-4)

There is a flat-base valley of which erosion channel is wide especially at the valley outlet. The village of low-income people is located on the terrace of quebrada channel which takes a route of narrow channel works located in the right bank side of downstream area. Some types of disaster are considerable if the debris flow occurs in the future. The district of Santa Maria de Chosica is located at the downstream end of the quebrada.

(E) Q. La Cantuta (R-5)

The channel in the flat-base valley is not yet fixed. There is a big recreation club on the fan extended in front of the valley outlet. Though some structures for debris flow are seen in the club area, the capacity against the debris flow seems to be not yet sufficient.

(F) Q. La Ronda (R-10)

The channel course in the flat-base valley is not yet fixed. The end portion of quebrada channel is not clear. There are some houses and the bypass road of Chosica town at the downstream side of fan.

(G) Q. Santa Ana (R-11)

The debris flow disaster happened in 1983 and 1985. The channel has no drainage structure at the crossing points of the national road as well as the railway.

(H) Q. Cupiche (R-13)

The disaster happened in 1983. At the crossing point with the national road, the channel structure is not seen. The debris flow has to run on the road.

(I) Q. Rio Canchacalla (R-15)

The big tributary with the catchment area of 118 km2 though no special property is seen on the fan. However, the volume of debris and mud will be big enough to dam up the main river. The main road is located on the opposite side of the confluence point.

(J) Q. Guayabo (R-16)

There is the facilities of mine at the outlet of the quebrada. The route of channel is not clear as the excavated materials from the mine are piled there. The main national road is located at the downstream end of fan.

(K) Q. Agua Salada (R-17) and Q. Del Pate (R-18)

The national road is now under construction for relocating the present way which is located in the lower end of fan. After the completion of the new road, the disaster for road will be small. However, there is a railway running on the fans of these quebradas. In 1983, the disaster happened in these two quebradas.

(L) Q. Huacre (R-23) and Q. Matata (R-24)

The debris flow happened in 1983. The national road was already relocated to the opposite side of the Rimac river. However, there are the road to Surco town , farm land, railway and some houses on the fans.

(M) Q. Cuchimachai (R-25)

On the fan of this Qda, the Surco town is located. Though the national road (N° 20) is already relocated, the old national road crossing the Qda is used for main road for the people of Surco town. There are more than 100 houses, railway station, railway, school, etc. in the probable disaster area.

(N) Q. Chucumayo (R-31)

The disaster occurred in 1983 caused by blockage of channel at the railway bridge. The farm land and some houses are located on the fan. The national road also runs along the main river (Rio Rimac).

(O) Q. Chacahuaro (R-33)

There are refinery facilities of a mine. The damage on the railway and the national road happened in 1983.

(P) Q. Pancha (R-34)

The damming-up of main river happened several times in the past. Though no remarkable properties are located on the fan, the run-off sediments will influence to the river bed rise in the downstream stretch.

(Q) Q. Viso (R-35)

The outlet of quebrada channel is located by cutting the river terrace of 30 m high. There are a small village, a railway station and a railway bridge. The quebrada channel is remarkably bent at the confluence point. The main road is located on the opposite side.

(R) Q. Parac (R-37)

The railway crosses the quebrada on the embankment which has the culvert channel for quebrada at the bottom. There are intake facilities for power in the main river at the downstream stretch of confluence point. The closing of main river will make serious damage on the facilities.

(S) Q. Redonda (S-2)

The big debris flow happened in 1983 and made serious damages on houses and road. The capacity of channel seems to be small and shallow especially at the crossing point with the road. There is a small village on the right bank of the quebrada.

(T) Q. Infiernillo (S-3)

The debris flow with disaster happened in 1983. The present channel is deep as it was eroded at the time of 1983 disaster. Some small villages and farm lands are located at the outlet area of valley and also on the deposit zone in the valley of main river, Sta Eulalia river.

(U) Q. Lucuma (S-5)

The disaster happened in 1983. There are a village at the outlet area of valley and some houses and farm lands in the area of confluence with the main river.

6.2.2 Deposit Volume

The deposit volume of Group "B" areas is estimated by the same method as taken for Group "A" areas.

The results of estimation are summarized in Table X-6-1.

6.2.3 Method of Damage Estimate

The disaster and damage amount in Qda area of Group "B" are estimated by the following manner.

(A) The quantity of disaster is not to be estimated in detail. It is estimated roughly only for some representative items which will share the most part of damage amount.

(B) The representative damages are decided to be the following three items.

(a) Houses
(b) Deposit removal works
(c) Traffic blockage

(C) The damage of houses is estimated by the following expression.

C1 = Nh x F x UCh

where,

Nh : Number of houses located in the probable disaster area (roughly estimated)

F : Reduction Factor *

UCh : Unit Cost of a typical house, including indoor movables in each area.

* : Reduction factor is considered to estimate the same level of damage, that is, the scale with the same recurrence period. The recurrence period of long-term, mid-term and short-term scales will be assumed to be the same in each area. The factor is decided as explained in the next paragraph (D)

(D) The reduction factors for Qda areas of Group "B" are decided by the similar manner taken for Group "A" areas. That is, the ratio of vegetation area in each Qda area is used for the principle item to decide the factor. The ratio is decided as shown in Table X-6-1 which is prepared for estimation of deposit volume.

(E) The cost of deposit removal works is estimated by the following expression.

C2 = DV x UCd x KR

where,

DV : Estimated deposit volume

UCd : Unit Cost for removing the deposits

KR : Necessary ratio of removal

(F) The damage caused by traffic block is estimated by the following expression.

C3 = Day x UCt

where,

Day : Estimated days of traffic block (to be described later)

UCh : Damage amount caused by traffic block per day.

(G) The day(s) of traffic block is estimated on the basis of estimation for Group "A" areas by assuming that the day is in proportion to the estimated deposit volume. It is estimated as follows:

Deposit Volume ($\times 10^3$ m^3)	Day (S)
0-90	0-3
90-180	3-4
180-270	4-5
270-540	5-7
540-900	7-10
900 up	10-15

(H) The total damage amount is estimated by the following expression.

$$Ct = (C_1 + C_2) \times 1.2 + C_3 \times 1.1$$

There are some other items which would suffer the disaster. It is assumed that 20% of direct cost (house and deposit removal) and 10% of indirect cost (traffic block) are to be added for these other items.

(I) The amount in case of mid-term scale and short-term scale is obtained by deciding the ratios to that in case of long-term scale. The ratios are decided in reference to the results of Group "A" as follows:

Mid-term scale : 0.52
Short-term scale : 0.08

Note: The ratios are obtained as an mean ratio of the ratios in quebrada areas of Group "A" as shown in Table IV-6-2.

6.2.4 Damage Estimate

In accordance with the method described in the previous subsection 6.2.3, the damage amount of each Qda. area in case of long-term, mid-term and short-term scales is estimated.

The results of estimation are summarized in the following tables.

(a) Damage on houses (Table IV-6-3)
(b) Damage cost for deposit removal (Table IV-6-4)
(c) Damage due to traffic block (Table IV-6-5)
(d) Estimated damage of Qda. area in large scale (Table IV-6-6)
(e) Estimated damage of Qda. area in middle and small scales (Table IV-6-7)

6.3 Spe Areas

6.3.1 General

There are 27 Spe Areas in Group "B".

It seems that the study for Spe Area has more difficulty than Qda area. That is, it is hard to show the expected disaster and damage definitely due to the following reasons.

(a) Almost all the slopes have much potential of disaster if it rains heavily or a violent earthquake happens. That is, it is hard to assume where a disaster will happen in each Spe Area.

(b) There are too many Spe areas in Group "B". The detailed study for each area is difficult.

(c) The length of areas facing to slope is pretty long, generally several kilometers. In each Spe area, there are probable disaster areas of rock fall, landsliding, slope failure or debris flow. That is, Spe area has various land-form conditions including qullies and quebradas. It is difficult to study all the sections of each Spe area.

(d) The data and conditions for estimating the disaster are not sufficient for Spe areas.

In addition, the serious disaster usually happened in Qda areas in the past. It seems that the priority of study for Spe area is much lower than Qda area. It is expected that the further specific investigation and study can be carried out in the next study stage, possibly in the feasibility study stage, if required.

However it seems to be required to study for Spe areas as well for making a guideline for the next step of study. Therefore, it is decided to estimate the probable disaster and damage first by assuming the various conditions as simply as possible.

The Study Team had the field reconnaissance in almost all Spe areas of Group "B" but comparatively roughly. The particular features in regard to damage conditions in each Spe area of Group "B" are described as follows:

(A) River mouth - Jicamarca (R- -/0)

The area is located on the right bank of the Rimac river. The slopes in this stretch are generally located away from the river. The land in front of slopes is mainly used as the residential area. There is no information about the past disaster caused by rockfalls and slope failure if it rains heavily or the big earthquake happens though the probability is very low. It is difficult to select the particular dangerous areas.

(B) River mouth - Chaclacayo (R- -/1)

The area is located on the left bank of the Rimac river. The conditions of land use and probable disaster are the same as the Spe area of River mouth-Jicamarca (R- -/0). The difference is that there are some quebra-das in the upstream area where the debris flow will happen if it rains heavily.

(C) Jicamarca - Chacrasana (R- 0/2)

There are some small quebradas with village on the fan. The disaster caused by debris flow is probable though the probability is low and the scale is not big. In front of slopes, there are villages and farm land though the level of properties is not high.

(D) Chaclacayo - California (R- 1/3)

There are three small quebradas of which fan areas are used for farm land or villas. In front of these quebradas and slopes, the residential houses, villas, farm land, railway, and local road to Q. California are located. As there is a irrigation canal along the slope and the vegetation is developed below the canal, the slope seems to be comparatively stable at the lower part.

(E) Santa Maria - Quirio (R- 4/6)

A part of Chosica town is located in front of the slopes. There is one small quebrada with the residential area on the fan. The probability of disaster occurrence will be low as the probability of heavy rainfall is low.

(F) La Cantuta - La Ronda (R- 5/10)

There are three small quebradas with residential area or farm on the fan. Along the slope, there are many houses, town road railway, schools and farms. The area is developed as a part of Chosica town. It seems that residential houses located on the slope are very dangerous against rockfalls or slope failure.

(G) Quirio - Pedregal (R- 6/7)

The slope area is comparatively narrow and short. However, the residential area is densely developed on the slope as well as under the slope as a part of Chosica town.

(H) Pedregal - Carosio (R- 7/8)

There is one small quebrada with the residential area on the fan. Along the slope, the main part of Chosica town is developed and there are may houses, public buildings, power house (Electro Lima), park, roads and so on. The damage potential is very high if it rains heavily.

(I) Carosio - Corrales (R- 8/9)

The area is limited, however, the residential houses are densely located in front of the slope. The national road is also running there.

(J) Corrales - Cashahuacra (R- 9/- and S- -/1)

There are several gullies on the slope of which front areas has residential houses, farm land, and village roads.

(K) La Ronda - Confluence (R- 10/-)

The residential houses are not so densely located. But there is a railway and a by-pass road of national road No. 20 in front of the slope.

(L) Confluence - Santa Ana (R- -/11)

There are two quebradas which have residential district on the fan and some gullies which have farm land areas at the end. There are some village roads in this area. The national road and the railway are located comparatively far from the slope. The attention is given to the said two quebradas with priority of study.

(M) Confluence - San Juan (R- -/12)

There are several gullies on the slope which have residential houses, farm land, village roads and the national road (but only short distance) in front. The average property per unit distance along the slope seems to be low.

(N) Santa Ana - Cupiche (R- 11/13)

There is no quebrada but several gullies on the slope. The national road runs along the slope which has high potential of rock falls.

(O) Cupiche - Guayabo (R- 13/16)

There are two or three quebradas and some qullies. The national road (No. 20) and the national railway run along the slope. The Corcona town is located in the upstream side of this stretch. Attention is given to the protection of national road, railways and residential houses against the rockfall, slope failure and small scale of debris flow.

(P) Guayabo - Agua Salada (R- 16/17)

There are some qullies on the slope. Though the number of residential house is more or less 20 but the national road (No. 20) and the national railway run along the slope which will require the protection against rockfalls or slope failure as the slope surface looks unstable.

(Q) R. Seco - Esperanza (R- 19/20)

There are three qullies and one quebrada. The residential house is negligibly few, however, the national road (No. 20) and the national railway run on or along the slope.

(R) Esperanza - Verrugas (R- 20/21)

There are several gullies connecting with the national road (No. 20). There is one quebrada which has the bridge with sufficient flow capacity below the girder. The protection will be required for the national road and a part of railway against rockfall or slope failure.

(S) Verrugas - Huacre (R- 21/23)

On the slope located on the left bank of the Rimac river, there are three gullies and one quebrada which will cause the traffic block of national road (No. 20) and national railway if it rains heavily. The other parts of slope are also probable to make rockfalls or slope failure.

(T) Linday - Yamajune (R- 22/27)

On the right bank slope of the Rimac river, there are two gullies and one small quebrada which will cause serious disaster of traffic block of national road (No. 20). Though there is a power station of Electro Lima and a refinery of mine, the slope looks relatively stable. The rockfall will happen at any slopes along the national road which was newly constructed in 1987.

(U) Chacamaza - Barranco (R- 26/29)

There are several gullies and one quebrada which will cause the block of national railway which runs on the slope.

(V) Chucumayo - Chacahuaro (R- 31/33)

The Matucana town is located along the slope of this area. There is one probable landsliding portion and there are three qullies which will cause the damage on houses, national road and railway if it rains heavily.

(X) Confluence - Alcula (S- -/4)

There are many gullies and some small quebradas on the slope. There is no residential area along the slope except some farmer's houses. The farm land occupies that most parts of flat area along the slope as well as along the Sta. Eulalia river.

(Y) Cashahuacra - Redonda (S- 1/2)

There are a main road along the Santa Eulalia river, farm lands, and some small villages along the slope. The serious disaster of slope failure happened at Sta. Rosa de Palle Bajo village in March 1987.
There are some qullies and small quebradas.

(Z) Redonda - Infiernillo (S- 2/3)

The main road along the Sta. Eulalia river runs along the slope which has high potential of rockfalls and slope failure if it rains heavily. Some gullies are seen on the slope. Farms lands and some houses are also located facing to the slope.

6.3.2. Method of Damage Estimate

The disaster and damage amount in Spe area of Group "B" are estimated by the following manner.

(A) In each Spe area, the locations or areas of probable disaster are roughly selected at the time of field reconnaissance or by referring to the aero-photographs.

(B) The locations or areas of probable disaster are classified into the following types.

(a) Rock-fall/Slope failure
(b) Land sliding
(c) Debris flow

(C) It is difficult to select definitely the probable rock-fall or slope failure areas. The areas are to be shown by the section length (km) of dangerous slope usually along the main road in each Spe area.

(D) Probable land sliding area with considerable damage potential is to be shown by the location and scale of probable sliding area.

(E) Debris flow will happen in quebradas located in Spe area. The location of such quebradas with considerable damage potential are to be selected.

(F) The quantity of disaster is not to be estimated in detail. It is estimated roughly only for some representative items which will share the most part of damage amount.

(G) In each probable disaster locations or areas, the representative damages are decided to be the following two items.

(a) Houses
(b) Traffic block

(H) The damage of houses is estimated by the following expression.

$$C_1 = Nh \times F \times UCh$$

where,

Nh : Number of houses located in the probable disaster area (roughly estimated)

F : Reduction factor *

UCh : Unit Cost of a typical house, including indoor movables in each area.

* : To be explained in the following paragraph (I)

(I) The reduction factor for Spe areas are required to estimate the damage amount in case of the same scale in regard to the recurrence period of disaster as that for Qda areas.

For Qda areas, the reduction factors are decided on the basis of vegetation conditions. For Spe areas, the vegetation conditions in each area are considered as the basic factor, however, it is additionally considered that the slope gradient also has much effect on the probability of disaster occurrence.

Therefore, the reduction factors for Spe area are decided as follows:

$$F = F_1 \times F_2$$

where,

F_1 : Reduction factor based on the vegetation condition

F_2 : Reduction factor based on the slope gradient

F_1 is decided by the similar consideration taken for Qda areas and F_2 is decided on the basis of average slope gradient at representative slope in each Spe area as follows:

$35° \leq S < 40°$ $F_2 = 0.5$
$30° \leq S < 35°$ $F_2 = 0.4$
$25° \leq S < 30°$ $F_2 = 0.3$
$20° \leq S < 25°$ $F_2 = 0.2$
$15° \leq S < 20°$ $F_2 = 0.1$
$10° \leq S < 15°$ $F_2 = 0.05$

The reduction factors for Spe areas are assumed as summarized in Table X-6-8.

(J) The damage caused by traffic block on the national road is estimated by the following expression.

$$C_2 = Day \times UCt + Day' \times UCt'$$

where,

Day : Estimated days of traffic block on the national road

UCh : Damage amount caused by traffic block per day on the national road

Day' : Estimated days of traffic block on the railway or Sta. Eulalia main road

UCh' : Damage amount caused by traffic block per day on the railway or Sta. Eulalia main road

(K) The day(s) of traffic block in each Spe area is assumed as follows:

$$Day = \frac{D1}{2L} + \frac{Dn}{2N} \quad \text{(National road)}$$

$$Day' = \frac{D'l'}{2L'} + \frac{D'n'}{2N'} \quad \text{(Railway road or Sta. Eulalia main road)}$$

where,

L : Total length of national road (No. 20) facing to dangerous slope in Group "B"

l : Length of national road facing the dangerous slope in each Spe area

N : Total number of dangerous gulley (or quebrada) crossing the national road in Group "B" n : Number of dangerous gulley (including quebrada) crossing the national road in each Spe area.

L' : Total length of railway or Sta. Eulalia main road facing to dangerous slope in Group "B"

N' : Total number of dangerous gulley (including qulbrada) crossing the railway or Sta. Eulalia main road

l' : Length of railway or Sta. Eulalia main road facing to dangerous slope in each Spe area

n' : Number of dangerous gulley (including quebrada) crossing the railway or Sta. Eulalia main road

D : Total days of traffic block on the national road (No. 20) in Group "B" slopes in a year in the Rimac river basin (assumed)

D' : Total days of traffic block on the railway or Sta. Eulalia main road in Group "B" slopes in a year in the whole basin

Note: (1) One quebrada is counted as 5 gullies.

(2) Period of traffic block on the railway or Sta. Eulalia main road is assumed as 10% of that on the national road, on an average.

(3) Total day of traffic block in a year is assumed as 1 day for the main road and 0.5 day for the railway or Sta. Eulalia river.

(L) The total damage amount is estimated by the following expression

$$CT = C1 \times 1.5 + C2 \times 1.1$$

Besides the damage on houses and traffic, some other items have to be considered for estimating the total amount of damage. It is assumed that 50% of direct cost (house) and 10% of indirect cost (traffic block) are to be added for the other items.

(M) The amount in case of mid-term scale and short-term scales is obtained by using the same ratios as used for Qda areas.

6.3.3 Damage Estimate

In accordance with the method described in the previous subsection 6.3.2, the damage amount of each Spe area in case of long-term, mid-term and short-term scales is estimated.

The results of estimation are summarized in the following tables.

(a) Damage on houses (Table IV-6-9)
(b) Length of slope and number of gulley/quebrada in danger of Spe area (Table IV-6-10)
(c) Damage due to traffic block (Table IV-6-11)
(d) Summary of estimated damage of Spe area (Table IV-6-12)

7. CONCEIVABLE STRUCTURAL MEASURES

There are various structural measures to be conceivable for the disaster prevention/mitigation of debris/mud flow, land sliding and slope failure.

The structural measures classified in general are listed below.

(A) Against Landslides

- (a) Surface water drainage
- (b) Ground water drainage
- (c) Excavation
- (d) Counter embankment
- (e) River structures
- (f) Piling Work
- (g) Large diameter cylinder pile
- (h) Anchor Works
- (i) Retaining wall
- (j) Others

(B) Against Slope Failure

- (a) Surface water drainage
- (b) Ground water drainage
- (c) Vegetation
- (d) Surface protection works
- (e) Ground improvement works
- (f) Excavation
- (g) Retaining wall
- (h) Crib works
- (i) Anchor works
- (j) Counter embankment
- (k) Others

(C) Against Debris/Mud flow

- (a) Hill side works
- (b) Dam
- (c) Channel works
- (d) Revetment
- (e) Ground sill
- (f) Sand arresting works
- (g) Dike
- (h) Others

In each measures listed above, there are further detailed classification. Though the naming in English and classification are not definite for some measures, the further classification is to be made as described below. In this case, the same measures in the above list are not to be repeated.

(A) Surface Water Drainage

- (a) Water channel works
- (b) Permeation prevention works

(B) Ground-water Drainage

- (a) Open ditch
- (b) Under-drainage works
- (c) Horizontal boring works
- (d) Ground-water interception works
- (e) Vertical drain well
- (f) Drainage tunnel

(C) Excavation

- (a) Slope cut
- (b) Removing surface rocks

(D) Counter Embankment

(E) River Structures

- (a) Dam
- (b) Consolidation
- (c) Groyne
- (d) Revetment

(F) Pile Works

- (a) Driving pile
- (b) Inserting Pile

(G) Large Diameter Cylinder Works

(H) Anchor Works

(I) Retaining Wall

(J) Surface Protection by Vegetation

- (a) Sodding
- (b) Seed spraying
- (c) Vegetation mat
- (d) Vegetation block
- (e) Others

(K) Surface Protection by Structure

- (a) Pitching works
  - Stone pitching
  - Block pitching
  - Concrete pitching

(b) Crib works
- Block crib works
- Cast-in-place concrete crib works

(c) Spraying works
- Mortal spraying
- Concrete spraying

(d) Others
- Rock fall prevention works
- Avalanche control structures
- Slope anchor works
- Slope wire cylinder works

(L) Ground Improvement Works

(a) Grouting works
(b) Rock-bolt works

(M) Hill Side Works

(a) Simple dam
(b) Grading works
(c) Sheeting
(d) Water course works
(e) Conduit work
(f) Hurdle work
(g) Sapling Planting work
(h) Simple terracing work
(i) Covering work
(j) Seeding work
(k) Planting work

(N) Dam

. By function

(a) Spur consolidation dam
(b) Vertical erosion control dam
(c) River bed sediment discharge control dam
(d) Debris/Mud flow control dam
(e) Sediment run-off check and control dam

. By material

(a) Concrete
(b) Wet masonry (Rubble Concrete)
(c) Dry masonry
(d) Steel
(e) Earth
(f) Rock

. By type (shape)

(a) Gravity
(b) Buttress
(c) Arch
(d) Fill

(O) Channel Works

. By function

(a) Erosion control (Restraint of profile change)
(b) Meandering control (Reformation of alignment)
(c) Keeping flow capacity
(d) Prevention of slope failure

. By structure (Combination of the following structures)

(a) Revetment
(b) Ground sill
(c) Riverbed gindle
(d) Groyne
(e) Sand arresting pond
(f) Others

(P) Revetment

(a) Sodding
(b) Gabion
(c) Connected block pitching
(d) Stone pitching
(e) Concrete block pitching
(f) Concrete pitching
(g) Asphalt facing
(h) Steel sheet pile work

(Q) Ground sill

(a) Flat consolidation
(b) Drop consolidation

(R) Sand Arresting Works

(S) Dike

. By type and function

(a) Continuous dike
(b) Open dike
(c) Ring dike (Polder)
(d) Separation dike
(e) Training dike
(f) Overflow dike
(g) Others

. By material

(a) Earth dike
(b) Stone/Boulders dike
(c) Gabion dike

(T) Rock-Shed Works

(a) Tunnel
(b) Roof

8. STRUCTURAL PLAN FOR GROUP "A" AREA

8.1 Classification of Type for Structural Plan

From the various structural measures listed in the previous Section 7, the most appropriate measures have to be selected for each objective area.

The field reconnaissance reveals that the countermeasure for debris/mud flow disaster is basically divided into three/five types in accordance with the topographic, geological and land use conditions as follows;

(A) Type A : It is required to check the debris/mud flow as much as possible and control the excessive flow confining in the channel since the residential houses are already settled densely along the quebrada channel on the fan.

This Type A is considered to be divided into the following two types.

Type A1 : There is a suitable site(s) for check dam.

Type A2 : There is no suitable site for check dam.

(B) Type B : It is considered to be not reasonable from economic viewpoint to check the debris/mud flow by check dam as the residential houses are not located or thinly located along the channel of quebrada. However, it is required to control the course of flow for avoiding the disaster to farm lands and public structures such as road and railway.

This Type B is considered to be divided into the following two types.

Type B1 : There is no or a very few houses on the fan area.

Type B2 : There are some houses on the fan. It is required to control the direction of flow as much as possible at the top of fan.

(C) Type C : It is required to check the debris/mud flow as much as possible and control the excessive flow smoothly to the main river, the Rimac river or the Sta. Eulalia river, for avoiding the overflow from the main river since the densely populated residential areas and/or important public structures are located on the opposite side of the confluence or in the downstream stretch.

In case of Group "A" areas, it is classified as follows:

(A) Type A1 : Qda Quirio and Qda Pedregal

(B) Type A2 : Qda Carosio and Qda Corrales

(C) Type B1 : Qda Rio Seco

(D) Type B2 : Qda Cashahuacra

(E) Type C : Qda Paihua

8.2 Selection and Function of Structure

In consideration of the functions necessary for the above three types of countermeasure, the following structures are taken for selection.

(a) Dam

(b) Channel works (including excavation, revetment, concrete parapet wall and/or ground sill)

(c) Sand arresting works

(d) Dike

(e) Vegetation

The main functions of each structure are expected to be as follows:

(A) Dam

There are the following functions for dam to be constructed in debris/mud flow channel.

(a) Check of sediments run-off

(b) Prevention of occurrence/extension of hillside collapse

(c) Prevention of vertical erosion and sediments production

(d) Prevention of movement of unstable sediments accumulated on the river bed

(e) Control or regulation of flow

(B) Channel Works

The channel works has objectives to prevent disordered flows and longitudinal and trans-verse erosion. In other words, the channel works safely handles the flow, fixing the stream course and confining the flow in the channel. The channel works generally consists of revetment and ground sill. The revetment work is effective to confine and make smooth the water flow. The ground sills can stabilize the channel bed by preventing erosion, movement of sediments, and collapse of side slopes. It is also effective for protection of foundation of revetment.

(C) Sand Arresting Works

The sand arresting pocket, provided at the top of fan with a gentle slope and wide section, effectively dissipates the energy of debris/mud flow as well as control the outflow of debris/mud flow. The sediments content in the downstream flow is much reduced. It is necessary to remove the sediments in the pocket when filled with sediments.

(D) Dike

The dike is provided to confine the flow in the channel and/or control the direction of flow . In case of debris flow control, the width between the dike and the channel is wider in the upstream side and narrower in the downstream side for training the flow to the channel.

(E) Vegetation

Plantation of trees in the area located on the top of fan is considerable for not only restraining the yield of sediments but also controlling the debris flow. The latter function is important as the plantation will be carried out on the top of fan where the water supply will be possible.

8.3 Structural Plan in Each Qda Area of Group "A"

8.3.1 Basic Considerations for Structural Plan

For planning the structures, the following conditions are to be considered.

(A) General

(a) The structural plan is made for the debris flow of long-term scale.

(b) It is assumed that 30% of the total volume (to be deposited in the downstream area) is produced in the outbreak area located in the upstream side of erosion channel and 90% in the erosion channel located in the transportation (flowing) zone.

Note: It is necessary to refer to Section 5 "Mechanism of Debris Flow" in Appendix VI.

(c) The structural plan is made by the combination of dam, channel works, sand arresting works, dikes, vegetation and the appurtenant structures.

(B) Dam

(a) The height of dam will be lower than 15 m in principle. As the foundation is composed of the deposit materials, the dam higher than 15 m will not be stable.

Note: The height of back-fill portion in erosion channel is not considered as a part of dam height.

(b) The range of damsite is to be decided from the synthetical consideration of channel/valley conditions.

(c) The necessity of check dam is considered not only by the appropriate dam site with sufficient sand arresting capacity but also the land use conditions in the downstream area. That is, a quebrada with high potential of damage will require check dam(s).

(d) The height and number of check dam are to be decided in consideration of the sand arresting capacity and the land form conditions at the proposed dam site. One or two main dams, which are comparatively high for bigger sand arresting capacity, are to be planned for quebradas with catchment area over 5 km^2 in principle and with the necessity of check dam.

(e) The erosion channel in the stretch of dam site is to be back-filled.

(f) In case of stepped dams (a series of dam), an upstream dam is planned at a location where the estimated accumulation line of the downstream dam intersects the existing channel bed.

(g) Design gradient of sediment accumulation line of a dam is assumed at 1/2 - 2/3 of the gradient of existing channel bed.

(h) Water flowing over the opening of a dam falls perpendicularly to the axis of the dam. Therefore, the direction of a dam axis is arranged to be perpendicular to the thalweg of the downstream side at the center of the opening.

(i) The direction of each dam in a series of dams is arranged to be perpendicular to its downstream thalweg, in principle. The center of the opening of each dam is, thus, on the thalweg at the opening center of an immediately upstream dam.

(j) The opening of a dam has sufficiently large section for leading through the design discharge. Its position is determined in consideration of the topographical and geological conditions, channel conditions, etc.

(k) Opening width is determined on the basis of existing channel width and opening height is given by adding a freeboard above the design water level.

(l) The type of dam classified by materials is decided in consideration of the easiness of construction, cost of construction, safety of structure, availability of materials, etc.

(m) The gradient of the downstream slope at an overflow part is generally 1:0.2.

(n) The dam foundation is required to have sufficient bearing force against destruction by shearing friction and seepage water, etc.

(o) The wing of dam is designed to be not overflowed, in principle.

(p) Drain holes, which have three functions of (i) to reduce the water pressure acting to the dam, (ii) to discharge fine size of sediments and (iii) to use as the diversion facility during construction, are provided in the dam.

(q) Sub-dam is generally constructed at the downstream side of dam. The height is decided for making sufficient functions for preventing scouring of foundation and lowering of river bed.

(r) The dam is designed to be safe enough against external forces such as static hydraulic pressure, sediment pressure, uplift pressure, seismic force, impact force of debris flow, etc.

(C) Channel works

(a) The channel works are to be located in the downstream stretch of dam section.

(b) Type and dimension of channel works are to be decided mainly in consideration of the various conditions of present channel and planned channel.

(c) The channel works are generally planned with groundsill work and revetment.

(d) The discharge considered for planning of channel work contains small sediment content since erosion control work in the upstream stretch is already in progress.

(e) The channel work has no bottom slab, in principle. However, the channel with bottom slab may be planned when the critical velocity for bed grain diameters is smaller than the velocity produced by design gradient and design water depth.

(f) The groundsill works are planned at the point of gradient change and also at locations with a interval for making gentle channel gradient. The riverbed gindle, groundsill without head-height, is also used between the groundsills if required for fixing the bed on the way.

(g) The freeboard of groundsill work is determined on the basis of the design discharge and the channel bed gradient.

(h) The alignment of channel works is as smooth as possible.

(i) When the channel bed gradient is changed, it becomes gradually gentle toward the downstream stretch.

(j) For channel works, the excavation method is adopted as far as possible. That is, the embankment or wall structure is not desirable though it will be accepted when the land use level is low, the excavation is difficult from economical viewpoint, or the excavation is not reasonable for making a smooth gradient.

(k) The design cross-section of channel works is planned by utilizing the existing channel width fully. Its width is not smaller than the previous channel width.

(l) The planning of location, length and kind of revetment require the considerations for cross section and profile of channel, slope gradient, earth conditions, etc.

(m) The sufficient depth for the foundation of revetment is considered against scouring by debris flow.

(n) The height of revetment is the height of design water level in principle.

(o) The materials and type of revetment are decided on the basis of the slope gradient, availability of materials and stability against debris flow.

(D) Sand arresting works

(a) Sand arresting works with training dike and overflow section is generally provided at the top of fan for the quebrada which does not have an appropriate site of check dam.

(b) The wing portion, training dike, has sufficient height and stability against the attach of debris flow.

(c) The shape of sand arresting works is decided in consideration of land form at the site.

(d) The capacity of arresting works is decided in consideration of the removal of sediments once a year or several years.

(e) The overflow section is located for the control of flow direction smoothly to the downstream channel.

(E) Dike

(a) Dike for training the flow is generally provided in a quebrada which does not require check dam and the land use level is not so high.

(b) The dike alignment is arranged so as to make the channel width narrow in the downstream side. If required, a series of open dike is arranged along the channel.

(c) The location of dike is decided along higher portions on both banks of channel.

(d) The height of dike is decided for preventing the overflow in case of the attack of debris flow.

(e) The dike section is designed to be stable enough against the impact of debris flow.

(f) Polder dike is considered for protecting a property locally located on a fan.

(F) Plantation

(a) The plantation of trees will be considered at the top of fan and in devastated land in the lower area of fan as it seems to be difficult to plant on the mountain slope due to the shortage of water.

(b) The selection of kind of tree, method of plantation and arrangement of location are important for expecting the sufficient function. It will be required to test the plantation methods in various cases before actual plantation for disaster prevention works.

(G) Other structures

(a) For protection of road or railway at the crossing points, the bridge or tunnel is considered. If there is already such structure, the improvement by extension and/or repair of structure is considered.

8.3.2 General Layout and Profile of Structural Plan in Each Qda Area

As already explained in subsection 8.1, the quebradas of Group "A" is classified into three/five types by the various conditions of quebrada. The structural plans for each type are generally made as follows:

(A) Type A

(a) Channel works for erosion control of fan and fixing of channel route

(b) A series of dam at the upstream stretch of channel works for debris/mud checking and erosion control (Type A1)

(c) Sand arresting works at the upstream side of channel works as there is no appropriate dam site for checking sufficient volume of debris/mud (Type A2)

(B) Type B

(a) Training dikes and excavation of channel for regulating the course of flow

(b) Protection of public structures such as road and railway and/or improvement of existing protection structures

(c) Low dam for sand arresting and erosion control at the top of fan (Type B2)

(d) Plantation for sand arresting at the top of fan or energy dissipation on banks (Type B2)

(C) Type C

(a) Dam for checking the debris/mud erosion control and fixing of hillside base

(b) Low dam(s) for energy dissipation, flow direction control and erosion control at the downstream stretch of check dam

(c) Excavation at the outlet of quebrada channel for smooth inflow to the main river

(d) Dike on the bank of main river located on the opposite side of quebrada outlet for protecting overflow from the main river and attack of debris flow to opposite side properties

The schematical features of each type are shown in Fig. X-8-1 for brief understanding of the difference.

The structural plans of quebrada area of Type A in Group "A" are made in the following procedure.

(a) The alignment of channel is decided in consideration of present land forms, location of properties, course of present channel, course of old channel and location of main river. The channel is to be arranged as straight as possible.

(b) The profile of channel route is prepared by using the topographic maps as well as the survey results in each quebrada.

(c) The study for providing check dam is made.

(d) The ranges of dam section, if the dam is appropriate,and channel works section are decided on the map and profile of channel.

(e) The design discharge of structures in each Qda channel is estimated.

(f) The location and scale of dam(s), if required, are decided on the map as well as on the profile of channel.

(g) The type of channel works, if required, and the location/interval of ground sill are decided.

(h) For quebradas without check dam, the location and type of low dam with training dike are studied and decided.

The alternative study is actually made on the way of above procedure especially for the alignment of channel, the range of each kind and type of structure, and location and interval of structures.

The structural plans for the other types are made by the similar manners.

The proposed structural plans in each quebrada are to be shown in the figures listed below.

(A) Alignment of Channel and General Layout of Structures

(a) Q. Quirio
Fig. X-8-2
Fig. X-8-3 (only downstream stretch)

(b) Q. Pedregal
Fig. X-8-4
Fig. X-8-5 (only downstream stretch)

(c) Q. Carosio
Fig. X-8-6

(d) Q. Corrales
Fig. X-8-7

(e) Q. Rio Seco
Fig. X-8-8
Fig. X-8-9 (only downstream stretch)

(f) Q. Paihua
Fig. X-8-10

(g) Q. Cashahuacra
Fig. X-8-11
Fig. X-8-12 (only downstream stretch)

Note: Maps of 1/25,000 or 1/5,000 are used to show the alignment.

(B) Channel Profile and Location of Structures

(a) Q. Quirio — Fig. X-8-13

(b) Q. Pedregal — Fig. X-8-14

(c) Q. Carosio — Fig. X-8-15

(d) Q. Corrales — Fig. X-8-16

(e) Q. Rio Seco — Fig. X-8-17

(f) Q. Paihua — Fig. X-8-18

(g) Q. Cashahuacra — Fig. X-8-19

(C) Design Discharge in Quebradas of Group "A"

The results of calculation for design discharge in each quebrada area are summarized in Table X-8-1.

The considerations taken for making the structural plan in each quebrada are explained as follows:

(A) Qda Quirio

(a) At upstream side of present residential area, at around EL. 980 m, the main dam with the height of about 15 m is constructed for sediment storage, flow velocity regulation and mitigation of channel bed gradient.

(b) At upstream stretch of the main dam, three check dams with the height of about 10 m are constructed in series for lessening the river bed gradient (from the present 1/7 - 1/10 to 1/12 - 1/15) and also for preventing the channel bed scouring. The flowing energy of debris flow will be much reduced.

(c) In the stretch from the main dam to the Rimac river, the channel works will be provided for confining the flow in the channel.

(d) The channel width will be about 20 - 30 m and arranged to be as straight as possible.

(e) The channel runs along the right side hill along the existing channel. However, the new excavation will be required for making the channel without remarkable bending in the downstream stretch.

(f) The ground sill located in the channel will be constructed with the interval of 30-50 m for preventing the erosion of channel bed as well as a sufficient energy dissipation of debris flow by mitigating the present channel bed to about 1/20 in gradient.

(g) The channel has to enters to the main river (Rimac river) smoothly for preventing the disturbance as well as blockade of main river flow.

(B) Qda Pedregal

(a) At upstream stretch of dam section (approximately EL. 1,080 m), the upstream main dam with height of about 15 m is constructed for sediments storage, flow velocity regulation and mitigation of channel bed gradient.

(b) At downstream stretch of dam section (approximately EL. 1,010 m) in the upstream side of channel works section, the downstream main dam with height of 10-15 m is constructed for the same functions as the primary main dam.

(c) In the stretch between the both main dams, supplementary check dams with height of about 10 m are constructed mainly for mitigating the channel bed gradient (from the present 1/8 to 1/13) and also for preventing the channel bed scouring. The flowing energy of debris flow will be much reduced in these dams.

(d) In the channel works stretch located downstream of the downstream main dam, the present channel gradient of about 1/10 will be lessened to 20-30. The channel width will be about 30-40 m in consideration of the allowance for the possible excessive debris overflowed from the dam.

(e) The channel alignment is arranged as straight as possible. Three routes of channel alignment are considered by the difference how much the channel runs along the existing/old channel. The most smooth alignment is selected though much excavation is required.

(f) The groundsill located in the channel works will be constructed with the interval of 30-50 m for the sufficient energy dissipation of debris flow and prevention of channel bed erosion.

(g) The channel has to enters to the main river smoothly for preventing the disturbance as well as blockade of main river flow.

(C) Qda Carosio

(a) As there is no appropriate location of check dam mainly due to steep profile, the dam with training section is constructed for sand arresting and also for training the flow to the downstream channel.

(b) The training dam is constructed at the top of fan, at about EL. 930 m.

(c) The present road running almost straightly from the top of fan down to the national road is used as the channel.

(d) The channel width will be limited to be 6-8 m as the houses are densely located along the road and the footpath is required on both sides of the channel.

(e) The channel is extended to the main river. The careful consideration has to be made at the crossing point with the national road.

(D) Qda Corrales

(a) As there is no appropriate location of check dam mainly due to steep profile, two sets of dam with training section are constructed for sand arresting and also for training the flow to the downstream stretch.

(b) The training dams are constructed at the top of fan where the garbage dumps are located at present. The garbages have to be removed before the dam construction.

(c) The dam height will be more or less than 10 m. The upper dam will be founded at about EL. 950 m and the lower dam will be at EL. 930 m.

(d) The channel works will be provided at the downstream stretch from the dam to the main river. The channel width will be about 10 m and has a series of ground sills for lessening the channel gradient.

(e) The careful consideration has to be made at the crossing point with the national road.

(E) Qda Rio Seco

(a) In consideration of land use condition, mainly used as farm land, on the fan, it is decided not to construct the check dam.

(b) At the top of fan, the training dikes are constructed to train the flow on the channel.

(c) Though the existing channel has considerably wide cross section, the improvement of alignment and cross section will be required at some portions.

(d) The dikes for training the debris flow overtopping from the channel section are provided at some places in consideration of the topography and the course of channel.

(e) There are three crossing points with the railway and one crossing point with the national road. Though such points are already protected by bridge or tunnel at present, the improvement works of protecting structure especially by extending the protection length will be required.

(F) Qda Paihua

(a) The main dam with the height of about 30 m is constructed at about EL. 2,480 m as the large scale land sliding zone is located at the upstream side on the left bank slope of which bottom is at around EL. 2,520 m.

(b) The supplementary dam with the height of about 5-10 m is constructed just at upstream stretch of the confluence, at about EL. 2,410 m for regulating the flow direction, erosion control of channel and energy dissipation of flow.

(c) The right bank at the outlet of the quebrada is cut slant for regulating the direction of debris flow smoothly to the main river.

(d) The existing dike located on the left bank of main river and in front of the outlet of Qda Paihua is improved for preventing the overflow to Matucana town area.

(G) Qda Cashahuacra

(a) In consideration of land use condition on the fan and the topography, it is decided not to provide the check dam.

(b) At the top of fan, the training dike is constructed for preventing the flow into the old channel.

(c) At the top of fan, possibly connecting with the downstream end of the first training dike, the dam with the height of 5-10 m is constructed for making sand arresting area and erosion control of channel.

(d) At the downstream stretch of the first training dike, the next training dike is constructed for preventing the flow into the farm land area located on the left bank of existing channel.

(e) As the protective objects, mainly houses, are located on the right bank of existing channel at the downstream stretch, the existing channel section is excavated widely and deeply at the downstream stretch.

(f) The third training dike is constructed along the said excavation channel for preventing the flow to the right bank area.

(g) The local polder dikes are constructed for the areas with high damage potential on the fan.

(h) The plantation of trees is considered at the top portion of fan and also on the both banks in the downstream stretch for restraining the debris flow.

8.3.3 Design of Structures

The design of structures of structural plan for each Group "A" area is prepared.

First, the basic design of standard type of structure is prepared as listed as follows:

(A) Dam (See Fig. X-8-20)

(B) Channel Works

(a) Type A (See Fig. X-8-21)
Excavation

(b) Type B (See Fig. X-8-22)
Excavation + Revetment

(c) Type C (See Fig. X-8-23)
Excavation + Parapet Wall

(d) Type D (See Fig. X-8-24)
Excavation + Revetment + Ground Sill

(e) Type E (See Fig. X-8-25)
Excavation + Parapet Wall + Ground Sill

(C) Dike (See Fig. X-8-26)

Then the design of main structures, dams, of structural plan is made.

As the existing maps do not cover the areas for proposed dam site and/or the scale is not sufficient for making the design drawing with specific dimensions, the new maps of some areas are prepared by using the aerial photographs taken in March 1987, after the serious disaster.

The design of dams in all the Group "A" Areas is prepared as shown in Figures X-8-27 to X-8-44 which consist of the following three kinds of figure for each Qda Area.

(a) General layout of dams
(b) Profile of dam section
(c) Plan, elevation and sections of dams

In regard to the design of dam, some comments are described for the reference as follows:

(a) The kind, type and basic dimensions are decided in reference to the standard design usually used in Japan. The stability analysis for the design was not carried out as it is still the master plan stage.

(b) The type in regard to material of each structure is decided in consideration of construction cost, availability of materials, stability of structure, etc. as concrete gravity type with boulders inside of its body.

8.3.4 Quantity And Cost

The Quantities for constructing structures in each Qda Area are calculated on the basis of design drawings/ figures/tables prepared in Subsection 8.3.3.

The items for quantity are decided as simple as possible in consideration of the convenience of cost estimate.

The results of quantity estimate for each structure are summarized in Table X-8-2.

The cost estimate of construction works is carried out by using the quantities estimated in this Subsection and the unit cost estimated in Appendix VIII. The results are shown in Tables X-8-3.

The project cost of each Qda Area is calculated on the following construction and conditions.

(A) Preparatory works (1)

(B) Construction works (2)

(C) Compensations (3)

(D) Engineering service & Government administration (4)

(E) Physical contingency (5)

Note: (1) 5% of (B)
(2) Miscellaneous cost (5%) is to be included
(3) To be estimated individually for each area
(4) 7.5% of (A + B + C)
(5) 15% of (A + B + C + D)

The compensation cost is required for the land acquisition and relocation of houses. The compensation cost of each Qda area is estimated as shown in Table X-8-4.

The results of cost estimate for each structure of each Qda Area are summarized in Table X-8-5. The total project cost of structural plan in Qda Areas of Group "A" is shown below.

(a)	Qda Quirio	US$ 8,623.4 x 10^3
(b)	Qda Pedregal	US$ 11,649.4 x 10^3
(c)	Qda Carosio	US$ 1,432.7 x 10^3
(d)	Qda Corrales	US$ 3,054.5 x 10^3
(e)	Qda Rio Seco	US$ 3,145.9 x 10^3
(f)	Qda Paihua	US$ 6,442.1 x 10^3
(g)	Qda Cashahuacra	US$ 3,057.4 x 10^3

8.4 Calculation for Economic Evaluation of Structural Plan in Group "A" Areas

8.4.1 Conditions for Economic Evaluation

The economic evaluation by EIRR is made individually for the structural plans of each Group "A" area in this section.

The conditions for evaluation are adopted as follows:

(a) The evaluation horizon is 50 years after the commencement of construction.

(b) Project cost for constructing structures in each area is disbursed in four years for A1 and C types by the ratios of 0.2 for the first year, 0.4 for the second year, 0.2 for the third year and 0.2 for the last year and three years for A2, B1 and B2 types by the ratios of 0.3 for the first year, 0.4 for the second year and 0.3 for the third year.

(c) The operation and maintenance cost is required annually. The annual maintenance cost is assumed at 0.5% of the Main construction cost annually from the next year of the completion of construction and at 0.25% for the third and forth years of A1 and C types and for the third year of A2, B1 and B2 types.

(d) The damage cost caused by disaster is considered as the benefit produced by the disaster prevention structures.

(e) The period of each scale is assumed to be 100 years for long-term scale, 50 years for mid-term scale and 10 years for short-term scale.

(f) The annual benefit is calculated by assuming the damage of the other probable years to be varied proportionally between the amount of long-term scale and mid-term scale or between the amount of mid-term scale and short-term scale.

(g) The annual benefit is born from the next year of completion and a half of annual benefit is born in third and forth year for A1 and C types and third year for A2, B1 and B2 types.

(h) The construction will start from 1990.

(i) The properties of each area will increase by 3% annually.

Note: It is anticipated that the number of inhabitants in the most divided areas will be considerably increased in the future judging from the past change and the traffic volume of main road will be increased gradually in accordance with the increase of Peruvian economy.

(j) The price level of June 1987 is used.

8.4.2 Calculation for Evaluation

The calculation for economic evaluation is carried out individually for the construction project in long-term plan of each Qda area.

First, the annual benefit is calculated as shown in Table X-8-6 to X-8-12. Then the calculation of Economic internal rate of return (EIRR) is carried out by using the data already estimated.

The calculation tables for economic evaluation of each area are shown in Table X-8-13 to X-8-19. The results are obtained as follows:

Results of Calculation for Economic Evaluation for Group "A" Oda Areas

Name of Quebrada	Project Cost (US$ 10^3)	EIRR (%)
Quirio	8,623.4	5.25
Pedregal	11,649.4	5.65
Carosio	1,432.7	9.85
Corrales	3,054.5	6.02
Rio Seco	3,145.9	5.09
Paihua	6,442.1	5.09
Cashahuacra	3,057.4	4.15

The evaluation for the results of calculation will be made in Section 11 of this Appendix X.

9. STRUCTURAL PLAN FOR GROUP 'B' AREAS

9.1 General

The study of structural plan for Group "B" is to be carried out roughly due to the following reasons.

(a) There are many Qda areas and Spe areas, 50 areas in total, in Group "B". It is difficult to make detailed study for each area.

(b) The study for Qda areas of Group "A" is carried out comparatively in detail for each Qda area. As the features of Qda areas are more or less similar each other, the study results of Qda area for Group "A" will be available for Group "B" areas.

(c) The investigation and data collection for Group "B" areas are not carried out specifically.

The study for structural plan of Qda areas and Spe areas is to be carried out separately in the following subsections 9.2 and 9.3. The evaluation of the structural plan in each Qda area and Spe area is to be carried out in Subsection 9.4.

9.2 Structural Plan of Qda Areas in Group "B"

The structural plan for Qda areas in Group "B" is approximately made referring to the results of structural study for Group "A". The plan is made as follows:

(A) Plan of Structure

All the Qda areas are to be classified into the following five types by the various conditions such as land form, stream profile, land use, drainage area, location of protective properties and etc.

Type A1 : Quirio/Pedregal type
Type A2 : Carosio/Corrales type
Type B1 : Rio Seco type
Type B2 : Cashahuacra type
Type C : Paihua type

The explanation of particulars and features of each type for Qdas of Group "A" is described in Section 8 of this Chapter.

The classification of Qda areas in Group "B" is studied and the results are shown in Table X-9-1.

The specific locations and dimensions of each structure are difficult to be determined at this stage since there are too many areas in Group "B" and the conditions for definite plan and design of structures are not obtained sufficiently.

However, the approximate plans for Qda areas of Group "B" are made on the basis of topographical maps, aerial photographs, rough profiles of quebradas, photographs taken at the site and field inspection at the site.

The structural plans for all the quebrada areas in Group "B" are shown the following figures.

(a) Structural plan Fig. X-9-1 to 23
(b) Structures on profile Fig. X-9-24 to 46

(B) Quantity Estimate

The quantity of structural plan in each area is estimated by using the plans prepared in the above paragraph (A). The results are shown in Table X-9-2.

(C) Project Cost Estimate

The Construction cost is estimated by multiplying the quantity of main work item by the ratio of the project cost and the quantity obtained by the estimate for the same type of Group "A" area.

The results of project and cost estimate are shown in Table X-9-3.

9.3 Structural Plan of Spe Areas in Group "B"

The structural plan for Spe Areas in Group "B" is made as follows:

(A) Plan of Structures

There are the following types of disaster in Spe area of the Rimac river basin.

(a) Debris flow in quebrada
(b) Rockfall/Slope failure in gulley or on Slope

It is considered that the scale of debris flow in Spe Areas is generally small since the scale of quebrada is small.

For the debris flow/rockfall/slope failure, the following structures are considered.

(a) Bridge (in gulley/quebrada)
(b) Rockshed tunnel (in gulley/quebrada)
(c) Retaining wall (on slope)

Though there are some other structural measures to be conceivable, only the representative structures are selected for the study on this stage.

The typical design of bridge, rockshed tunnel and retaining wall is prepared in this section as seen in Figures IV-9-47 to IV-9-50.

Though the structural plan for each Spe area is not shown as a figure, the following items are to be shown in Table X-9-4 for estimating the quantities as well.

(a) Kind
(b) Number
(c) Type
(d) Scale or Basic dimension (Length)

(B) Estimate of Construction Cost

The quantity and cost of each structure provided in each Spe area are estimated by the following expression for each structure.

(Length of each structure) x
(Unit Cost per unit length)

The unit construction cost of each structure is decided as shown in Table X-9-5 which is decided on the basis of unit cost estimate shown in appendix VIII and the standard design of structures.

The results of cost estimate are summarized in Table X-9-6.

9.4 Calculation for Economic Evaluation of Structural Plan in Group "B" Areas

The calculation for economic evaluation for structural plan for Group "B" areas is carried out by the similar way as taken for Group "A" areas though the cost and benefit estimated for Group "B" areas are relatively rough in comparison with those for Group "A" areas.

The results of calculation for economic evaluation for every area in Group "B" are summarized in Table X-9-7 for Qda areas and in Table X-9-8 for Spe areas.

The economic evaluation will be made in Section 11 of this Appendix X.

10. COMMENTS ON STRUCTURAL PLAN FOR GROUP "C" AREAS

Though any definite study is not carried out for areas classified as Group "C", it is recommended to carry out the further investigation and study at the next opportunity. Though they are selected as Group "C", it does not mean that it is not necessary to make any disaster prevention plan. The Group "C" areas are considered to have low priority of disaster prevention in comparison with the areas of Group "A" and "B" at present conditions. However, it can be said that the Group "C" areas also have possibility to suffer disaster in the future.

Some comments on disaster prevention plan for Qda areas Group "C" are described for the reference as follows:

(A) Qda Esperanza (R-20), Qda Verrugas (R-21), Qda Linday (R-22), Qda Yamajune (R-27), Qda Palcacancha (R-28) and Qda Barranco (R-29)

The debris flow happened several times in these quebradas in the past. However there is no remarkable protective objects except the traffic structures which are scheduled to be replaced by construction of new road with bridge with sufficient flow capacity under the girder. It will be required to observe the sediments yield from the viewpoint of sediment control for the main river and to take counter-measures if necessary.

(B) Qda Chacamaza (R-26), Qda Lucume (R-30) and Qda Ocatara (R-36)

On the fan located at the outlet of valley, the national road No.20 and national railway run through. It is required to check the flow capacity at the crossing points and stability of crossing structure especially against scouring.

(C) Qda Challumay (R-38)

The national road No.20 run through the fan area. It will be required to check the protection of the road.

(D) Qda Turumanya (R-39)

The mine facilities are located at the outlet of valley and in front of national road No.20. The culvert waterway runs under the facility area. It is informed that the clogging of the culvert inlet occurred several times in the past. It will be required to check the capacity of culvert waterway. It is better to take the principle that beneficiaries should pay for a project like the case in this quebrada.

(E) Rio Blanco (R-40)

Though the yield of sediment per unit area will be comparatively small as most part of this area is covered with vegetation and stable rocks. However, the area is so big that total volume of sediments yield is big. The attention should be given to the control of sediments for the main river.

(F) Qda Tranquilla (R-41)

The U-shape valley made by glacial action is developed. The outlet area of valley is pretty steep and the course of waterway is not yet fixed. As there are a part of Chicla town, national road and national railway at the lower portion of outlet area, the study for protection of these structures and properties will be required.

(G) Qda Santa Rosa (R-42) and Qda Tacpin (R-43)

In the outlet of valley, the large scale spoil banks of mine are made. It seems that the outflow from these Qda areas is not so much, however, the flow is drained through tunnel culvert to the main river at present. It will be required to check the capacity of drainage facilities and stability of spoil banks.

(H) Qda Veintiuno (R-44) and Qda Antranra (R-48)

The rational railway crosses the valleys by embankment with culvert channel. It will be required to check the capacity of culvert and stability of embankment.

(I) Qda Alcula (S-4) and Qda Santo Domingo (S-6)

The comparatively large scale fan is formed and the run-off of sediments seem to be active. Though there is no remarkable protective object, it will be required to consider the sediments from these quebradas from the viewpoints of basin-wide control.

(J) Qda Huanchunya (S-7)

The river terrace is developed at the outlet of valley. Though present river runs along the right side of fan, there is a village on the left bank side. It will be required to consider the protection of village area possibly by revetment of channel.

(K) Qda San Antonio (S-8) and Qda Negro (S-9)

The main road along Sta. Eulalia river crosses the outlet of valley. The protection of road will be required.

(L) Qda Vuda (S-10), Qda Mito Mito (S-11), Qda Rio Carhuayuma (S-12), Qda Del Zorrillo (S-13), Qda Marropuquio (S-14), Qda Carhuachazo (S-15), Qda Maquerhua (S-16), Qda Challamayllo (S-17), Qda Pozo (S-18), Qda Huancacocha (S-19) and Qda Chilcacocha (S-20)

Most of these quebradas have steep hanging valley. Though there is no remarkable protective object at the outlet of valley, the local roads connecting villages located on the slope of mountains cross these valleys. It will be required to consider the protection of these roads and counter-measure at the time of disaster.

(M) Qda Pillihua (S-21), Qda Acobamba (S-22), Qda Collque (S-23), Rio Shuncha (S-24), Qda Yanac (S-25), Qda Huasca (S-26) and Rio Pallca (S-27)

The U-shape glacier made valley is developed and there are lagoons at the upper area. Though it seems that the ground surface is stable, it will be necessary to consider the case of overflow or rupture at these lagoons.

11. PROPOSED STRUCTURAL PLAN FOR Qda AREAS AND Spe AREAS

11.1 General

The study for structural plans was made separately for the following groups.

(a) Group "A" Areas
(b) Qda Areas of Group "B"
(c) Spe Areas of Group "B"
(d) Group "C" Area

As already explained in Section 4 of this Appendix X, the classification on divided areas is made, based on the level of protective object and level of danger, prevention works, as follows:

(a) Group "A" areas have the first priority for the execution of project.

(b) Group "B" areas have the second priority for the execution of project.

(c) Group "C" areas have low priority for the execution of project.

It is judged that the viability of structural plans for Group "C" areas is so low that the definite study for Group "C" areas will be not required at least at present site conditions.

Therefore, the structural plans are made for Group "B" areas as well as Group "A" areas.

11.2 Technical Evaluation

The structural plan in each area is made in consideration of the best combination of various technical aspects which include the following matters.

(A) In case of Qda Area

(a) Location of dam(s) is selected at the best place to have the impounding capacity as much as possible and to prevent erosion in the channel.

(b) The scale of dam is decided to be lower than 15 m in consideration of stability of dam on the foundation composed of fan deposits.

Note: The dam on upstream narrow stretch of fan can be higher than 15 m as the foundation is expected to be stable.

(c) The wing portions of dam are extended as much as possible to the both side slope surfaces for preventing overflow from a side of dam.

(d) The direction of dam is arranged to control the flow into the center of valley where the channel works will be provided in the downstream stretch of dam.

(e) The section of dam is designed to be stable against the probable external forces.

(f) The channel works is provided to control the excessive flow from dam safely to the main river.

(g) The alignment of channel works are decided as straight as possible in consideration of characteristics of debris flow which usually does not turn without strong impact.

(h) The section of channel works is designed to have sufficient capacity of design discharge.

(i) The profile of channel works is arranged to dissipate the energy of flow by making gentle gradient of channel.

(j) The sides and base of channel works are designed to be protected by wet-masonry or concrete slab for preventing longitudinal and trans-verse erosion.

(k) The location and direction of dikes are decided to confine the flow inside; channel side.

(l) Plantation of trees is recommended for Qda Cashahuacra for restraining the yield of sediments and the energy of debris flow. Plantation in Qda Cashahuacra will be a model case. That is, plantation will be available to be provide in the other areas as well if the model case can get good results.

(m) Bridge or rockshed tunnel is planned at crossing points of channel and main road/railway for protecting the transportation routes.

(B) In Case of Spe Areas

For the Spe Areas, the definite plan is not prepared for individual areas. However, the structures are selected as follows:

(a) Bridge is provided at the crossing point of main road/railway and quebradas/big gullies for handling the debris flow safely to the downstream stretch.