Part-D

Geological Investigation of Proposed Schemes

Part-D: GEOLOGICAL INVESTIGATION OF PROPOSED SCHEMES

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D1 Introduction

D1.1 Project Sites

Studies so far have identified five (5) potential source development sites: i.e. (i) Laiban Dam/Laiban Low Dam and (ii) Kaliwa Low Dam on the Kaliwa River, (iii) either Kanan No. 1 or Kanan No. 2 Dam (mutually exclusive each other) and (iv) Kanan B1 Dam on the Kanan River, and (v) Agos Dam on the Agos mainstream. Further, the development plan includes several alternative water conveyance tunnels between the Kaliwa River Basin and Antiplo area, and also various structural works in Antipolo~Tanay area such as pipelines, power plants, water treatment plants and service reservoirs.

This Part-D describes the geological assessment for the proposed schemes stated above.

D1.2 Regional Geology

The Philippine Islands are situated on the circumpacific seismic belt, which is one of the areas in the world that is most conspicuously subject to earthquake. The Philippine archipelago is bounded on the east coast by active subduction faults known as the Philippine Trough and the Mindanao Trough. Another fault known as Philippine Master Fault crosses Central Luzon southeastwards from Lingayan Gulf to Dingalan Bay in Quezon Province, then trends southwards close to the east coast of Quezon Province and along the west coast of Bicol Peninsula to eastern Visayas, and then to Mindanao where it divides and forms the graben between the province of Surigao and Bukidnon (Ref. 3).

Geologically the project area is located in the Central Basin, which is characterized by Paleogene and older clastic and volcanic deposits. The Central Basin is bounded by the Philippine Rift fault system (Philippine Fault Zone: PFZ) on the east and northeast (a branch of which was identified near Infanta) and by the Valley Fault system on the west and southwest (Figure D2.1). Morphology indicates that the fault near Infanta has been active in comparatively recent geological times. Further, there are two faults, starting from the Marikina damsite (previously proposed by MWSP III) in the SSW direction, form the Marikina graben (Figure D2.2). Thus, the project area can be divided into four morphologically and geologically differing zones. (Ref. 3)

- The rugged mountains of Sierra Madre between the Philippine Fault and the Faults distributing in SSW direction from Marikina
- A triangular hilly zone between the SSW Faults and the Marikina graben
- The Marikina graben
- Gentle hills west of the Marikina graben, descending to the alluvial plain of Manila Bay

Land of the project area, from lithological viewpoint, consists mainly of eight (8) geological units, which include Quaternary Alluvium, Laguna, Tignoan, Madlum, Angat, Maybangain, Kinabuan, and Barenas-Baito Formations as follows:

a) Quaternary Alluvium (Qal)

Detrital deposits, mostly silt, sand, and gravel.

b) Laguna Formation ≈ Guadalupe Formation (Qg or GF)

Layers of thin to medium bedded, fine-grained tuffs, agglomerate, volcanic breccia and associated tuffaceous sediments.

c) Tignoan Formation (Nt or Ntf)

Agglomerate, volcanic breccia and tuff with interbedded fine sedimentary clastic rocks and volcanic flows.

d) Madlum Formation (MF)

Consist of upper, middle and lower members. Upper member is fairly fossiliferous, massive or obscurely bedded limestone. Middle member includes the basalt. Lower clastic member is calcareous sandstone and shale with conglomerate at the base.

e) Angat Formation (AF)

Well bedded massive limestone with siliceous layers and limy sandstone, calcareous shale, clayey sandstone, sandy limestone and conglomerate.

f) Maybangain Formation ≈ Bayagas Formation (Pm)

Equivalent to Bayagas, Masungi and Kanan formations; consisting of andesitic to basaltic flows, agglomerate, volcanic breccia, lapilli and lithic tuff with intercalated sedimentary rocks composed of siltstones, shaly sandstone conglomerate and limestone.

g) Kinabuan Formation (Kk or KF)

Thinly interbedded silty shale and calcereous sandstone with tuffaceous and siliceous layers capped by thin beds of limestone.

h) Barenas-Baito Formation (Kbb)

Pillow and massive basalt, red chert, red siliceous mudstone/shale and basaltic sedimentary rocks mostly sandstone and pyroclastics.

Table D1.1 summarizes the geological formations in the project area and Figure D1.1 presents the regional geological map.

D2 Active Faults

Previous studies pointed out that the project area is situated within a zone of active tectonics represented by the Philippine Fault and the Valley Fault as shown in Figure D2.1. Especially along the Philippine Fault, many large-scale earthquakes were recorded in past years as shown in Figure D2.3, and the relative movement of 6 cm was observed in 1991-1993 period (Ref. 28). Therefore, it can be said that the Philippine Fault has potential for a very high activity. According to the PHILVOLCS data, several “active faults” or “assumed active faults” are assumed in the project area, and some of them pass through nearby the proposed damsites as shown in Figure D2.2.

In the previous studies, many faults have been identified in the project area as shown in Figure D2.4. There may be a possibility that some of these faults be active faults, which has however not been clarified yet. In the case an active fault passes through nearby the proposed damsite, two problems should be solved as follows:

(i) Seismicity caused by earthquake along active fault
(ii) Deformation in dam-foundation caused by the movement of active fault

Analysis for (i) above can be made through seismic study as described in Section D3 hereinafter. With regard to (ii) above, no firm analysis method has been established to date. Therefore, detailed investigation is required to confirm the distribution, geological condition, and past activities of every active faults in the vicinity of the damsite. Generally, the method for the active fault investigation traces the following process:

a) Review of previous earthquake data in the area of 50 km in radius
b) Assessment of lineament and topographical features of Quaternary formations in the area of 10 km in radius around the damsite
c) Confirmation by field reconnaissance
d) In-situ investigation work as required (trenching, geological age assessment)

If highly active fault exists around the dam foundation area, a field study will be required for determining the alignment of the dam axis.

Similar investigation is also required for the alignment of tunnel and selection of location of various structures.

D3 Seismicity

The Study area is situated in the area of active tectonics represented by the Philippine Fault and the Valley Fault systems. According to the previous studies, most of the proposed five damsites would be subject to high peak acceleration and exposed to generally high degree of seismicity as shown in Table D3.1. Especially, the Agos damsite and Kanan damsite are located at only 7-8 km distant from the active Philippine Fault, and large earthquakes have been recorded around the areas as depicted in Figures D3.1 and D3.2. Therefore, in the future detailed design stage, a dynamic analysis is required for design of dam to confirm the stability of the dam body on occurrence of large earthquake.

Gutterridge Haskins & Davey, et. al. (2000) (Ref. 19) pointed out the possibility that water impoundment of Laiban Dam may induce an earthquake. On one hand, Electrowatt & Renardet (1984) (Ref. 12) is of negative opinion as to this possibility, but commented that “public concern would best be alleviated by installing a triangular array of three micro-seismograph stations north, south and west of reservoir to monitor local seismic activity for some years before and after impoundment of the reservoir.”

D4 Geotechnical Evaluation

D4.1 General

The Study at this stage reviewed the previous reports and conducted field reconnaissance, with paying attention particularly to the following items:

i) Possibility of water leakage from the limestone mass distributed in the reservoir area of Laiban Dam

ii) Possibility of water leakage from the Daraitan limestone mass distributed in the reservoir area of Agos Dam and Kaliwa Low Dam

iii) Grasping of the geological condition of Kaliwa Low Dam Site

Figure D4.1 shows a geological mapping prepared by this Study, and Figure D4.2 shows the distribution of limestones and young sediments around the Agos~Laiban reservoir areas.

D4.2 Laiban Dam

D4.2.1 Background

As for the Laiban Dam, Electrowatt & Renardet completed the detailed design in 1984, wherein Concrete Face Rockfill dam (CFRD) was proposed. In a review study in 1997, two types of dam, CFRD and Roller Compacted Concrete Dam (RCCD), were compared. The conclusion was the selection of CFRD with a statement that "no major change is proposed for dam, intake, water transfer tunnel, hydropower plant and water treatment works."

This Section D4.2 discusses the geology of Laiban Dam, mainly with evaluation of the limestone mass in the reservoir area.

The issue of solution-affected limestone mass distributed in the reservoir area has been examined by several studies since 1979. Electrowatt & Renardet concluded that "the water tightness of the reservoir would be assured for operational level up to EL. 270 m" (Ref. 3), but at the same time proposed that "it should be verified by subsurface exploration whether the hydro-geologic regime really would allow filtration losses at storage levels higher than EL. 270 m". However, no detailed investigation has been carried out since then.

D4.2.2 Dam Site

Lithology around the Laiban Dam site is older predominantly clastic sediments with limestone and intercalcations belonging to Barenas-Baito Formation, in the Cretaceous period, and it is composed by mudstone and claystone, occasionally cherty or marly siltstone, wacke, breccias and conglomerate, and calcarenites. According to the previous reports, the following problems have been identified:

a) Stability of the plinth foundation on the right bank side

b) Many small scale faults

c) Thick residual and colluvial soil on the right bank
d) Need of groundwater monitoring on the narrow ridge part of the right bank

It seems that these problems are of nature that can be dealt with suitable treatments in the construction works (Ref. 12). The previous study assessed that, geologically, the dam foundation would be suitable for both the CFRD and RCCD (Ref. 18). The previous study pointed out that seismic risk is high around the damsite.

Figure D4.3 shows geological profiles of the Laiban Dam axis.

D4.2.3 Reservoir Area

The distribution of the limestone mass was surveyed in detail by Electrowatt & Renardet in 1979 and 1984 studies (Ref. 1 & 13). In this JICA Study, it was observed that limestone mass is not distributed in so wide area as considered in the previous investigations, but widths of some limestone bodies are a little wider than indicated by Electrowatt & Renardet (1984) as shown in Figure D4.2.

In general term, there are many water springs, caves and water tunnels in the limestone area. With regard to the limestone in the Laiban reservoir area, however, it seems that each rock body of limestone is relatively small, distributed at shallow depths with limited continuity. Groundwater level appears to be relatively high. The elevation of the bottom layers of a largest limestone body situated at upper reach (a part of Masunguit limestone mass) is higher than EL. 270 m. These observations indicate that there is less possibility of water leakage from the reservoir of Laiban Dam, provided that each limestone body is distributed discontinuously.

In the next stage of investigation, it is required to confirm the detailed distribution of limestone blocks (in particular, limestone blocks occurring just upstream of the damsite and another at 2.5 km east from San Andres), relative positions with a fault, and the continuity of each block. The investigation will be by analysis of aerial photographs, detailed field reconnaissance and core drilling with water pressure test.

D4.2.4 Construction Materials

Rockfill material for dam embankment will be quarried from a volcanoclastic deposit situated approximately 1 km upstream from the dam. Concrete aggregates will be obtained from gravel in the Kaliwa River channel (Ref. 13). There seems to be no particular problem in this aspect.

D4.3 Kaliwa Low Dam

D4.3.1 Background

This scheme was originally proposed by MWSS's in-house consultants, and subsequently studied by a consulting firm, EDCOP. To date, EDCOP completed 'Project identification Assessment & Validation Study' (2001, Ref. 21) and 'Pre-

Feasibility Study for the Agos River Multi-Purpose Development' (2001, Ref. 22). Kaliwa Low Dam scheme is regarded as the first stage development of the subsequent development of the Agos Dam. The main purpose of this first stage project is to transfer the water for Metro Manila in an initial period, since the Agos Dam will require a time of about 10 years until it is commissioned.

Kaliwa Low Damsite No. 2 is identical to 'Kaliwa Downstream Site' surveyed under the Manila Water Supply III Study in 1979 (Ref. 3).

D4.3.2 No.1 Dam Site

Low Damsite No.1 is located some 300 m downstream of the confluence of Limananin Creek, where the river bed elevation is around EL. 110 m. It is accessible by an unpaved trail along the river, approximately 3 km downstream from Daraitan.

A topographic feature with steep slopes is developed around the site, caused by the distribution of stiff bedrock. The slope is relatively gentler on the right bank because of thicker weathering. Channel of the river flow is about 20 m in width in the dry season.

Rocks around the site consist of the alternation of sandstone, shale and conglomerate that belongs to the Maibangain Formation of early Palaeogene period. The foundation rock is very hard with closed bedding and joint planes, and no fractured zone was found. The base rock of the site seems to have enough shear strength for any type of the low dam construction. The condition of the riverbed under water flow, however, could not be confirmed by reconnaissance.

Figure D4.4 shows a profile sketch of the Kaliwa Low Dam No. 1 site.

D4.3.3 No.2 Dam Site

The site is located on the Kaliwa River, around EL.100 m at the river bed and approximately 5 km downstream of Barangay Daraitan, between Ligundinan creek and Queboroso creek, both right bank tributaries of the Kaliwa River. It is accessible by three trails, one from Barangay Daraitan, one from the confluence of Kanan and Kaliwa Rivers in the dry season, and the other from Marcos Highway in the rainy season.

The distribution of stiff rock forms comparatively narrow valley around the site. Of two alternative dam sites conceived at the No. 2 site, the upstream site seems more suitable for the dam axis, because of straight alignment of the river course downstream.

Rock of the chosen site mainly consists of pyroclastic rocks that belong to the Maibangain Formation of early Palaeogene period. Similar to the No. 1 site, the bedrock is weathered deeper on the right bank and the slope is gentler there, than on the left bank. The river water channel is about 20 m wide in the dry season. As for the pyroclastic rock, the matrix part has a less strength compared with the hard gravel part. The foundation rock is mostly massive, and there seems to be no fractured zone. The base rock of the site seems to have enough shear strength and low permeability, suitable for any type of the low dams. It was not able to confirm the condition of the riverbed under water flow by the site reconnaissance conducted during the 1st Field Investigation.

Figure D4.5 shows a profile sketch of the Kaliwa Low Dam No. 2 site.

D4.3.4 Construction Materials

The survey of borrow area and/or quarry site has not been carried out for the Kaliwa Low Dam site yet. Quarry and/or borrow areas of the Agos damsite is at 10 km distance, while that of the Laiban damsite is 5 km distant from the Kaliwa Low Dam No. 2 site. It is more effective to find out new material sites nearby the Kaliwa Low Dam site, considering the small volume of the dam body and the difficulty in access to the Agos and Laiban material sites. For example, river bed deposit along the Kaliwa River seems to be useful for concrete aggregates. The investigation for construction materials is required in the next stage.

D4.3.5 Access Road

Use of an old logging road on the right bank side is most effective for access to the Kaliwa Low Dam No. 2 site. This road is connected to the Marcos Highway with a distance of about 6km. It was in a good condition until around 1981. Though the road condition is rough at present, the access by vehicles will be possible if duly repaired with bulldozer. Approach to the Kaliwa Low Dam No. 1 is possible by constructing a branch from this old logging road. It is recommended to confirm the condition in detail and to repair it, because it is useful for future investigations at the Kaliwa Low Dam site. Figure D4.6 shows the condition of available access roads for the Kaliwa Low Dam sites

D4.4 Agos Dam

D4.4.1 Background

This scheme is just identical to the plan contemplated in the previous Agos Hydropower Feasibility Study in 1981 (Ref. 4 to Ref. 6). The previous study formulated a hydropower single-purpose scheme at this site, on the condition that the majority of upstream water would be diverted outside the basin for water supply to Metro Manila. The 1981 study proposed an Earth Core Rockfill Dam (ECRD).

On the other hand, a study in 1991 (Ref. 14) indicated the possibility of constructing a Roller Compacted Concrete Dam (RCCD), located about 140 m upstream of the original axis of the rockfill solution, where the river valley is narrower and the topography of the banks is more regular and stable, without lateral gullies cutting the slopes. The conclusion of the1991 study was that RCCD would be geologically acceptable and less costly than the ECRD by about 18% at direct implementation cost level.

D4.4.2 Dam Site

(1) General geography and geology.

The damsite is located just downstream of the junction of the Kanan River and Kaliwa River, about 20 km distant from the river mouth. Comparatively steep geographical features continue from the damsite for a 8 km downstream stretch. The valley becomes wider in further downstream reaches. The rocks around the damsite consist of the Maybangain Formation and the Tignoan Formation of early to middle stage in Palaeogene period (Ref. 38).

(2) Active Fault and Seismicity

The most important factor of damsite geology is the Philippine Fault (Infanta Fault), which develops in the N-S direction and passes about 8 km east of the damsite. Along the Philippine Fault, there are many records of large-scaled historical earthquakes. A relative movement of 6 cm in three years from 1991 to 1993 is reported. It is also known that there is a history of large-scale earthquake around Infanta as shown in Figures D2.3 and D3.1. The Philippine Fault can be highly active. Previous study for Laiban Dam in 1979 (Ref. 3) stated that "the seismic risk for a Kanan site will be higher than for the Marikina damsite or the Kaliwa site". According to the PHILVOLCS data, there is one (1) assumed active fault passing near the Kanan and Agos damsites by direction of NNW-SSE as shown in Figure D2.4.

Accordingly, the following analysis and investigation should be taken into account for the design of Agos Dam:

- Dynamic analysis for earthquake risk at time of detailed design
- Fault investigation around the damsite (see Section D2), and
- Installation of a seismograph for automatic recording of earthquake wave to take data for the dynamic analysis.

(3) Geological condition of the site

The base rock of the damsite consists of greywacke, conglomerate, fine-sandstone, and shale (Ref. 5). The most part of rock is massive and shows little bedding plane, except those observed in intercalation of thin layers of fine-sandstone and shale. Talus deposits composed of rock fragments and creeped residual soil are developed at the foot of the slopes along the river. Terrace of flood deposits are rather obscure in sharp bends around the damsite. River deposit of sand and gravel has a thickness of 30 to 40 m along the dam axis (Ref. 5). According to a previous study report by JICA (1981), the following three (3) problems were pointed out for the Agos damsite:

i) Thick residual soil or decomposed rock zone on the right abutment
ii) Thick river deposit
iii) Fault in the river bed and on the right bank

(a) Thick residual soil or decomposed rock zone on the right abutment:

As a common practice, the possibility of landslide should be considered in such a case that thick residual soil or decomposed rock zone is observed on the dam abutment. The pre-feasibility study by EDCOP (2001) stated that "slides were noted at higher elevations of both abutments apparently confined to the highly weathered sections of the agglomerate. These mass movements appear to be characteristic features of the agglomerate formation".

Field observation by JICA Study Team (2001) also noted that geophysical features be disturbed especially in the right abutment area. In the next stage, detailed investigations are required for confirming whether landslide exists or not on the both abutments. The investigation will include:

- Analysis of aerial photographs
- Detailed field reconnaissance survey
- Core drilling and geophysical exploration survey

(b) Thick river deposit in the river bed:

The depth of river deposit at the Agos damsite is 30 to 40 m with the bottom elevation lower than the sea level in some parts (Ref. 5). From a geographical point of view, the depth of deposit seems too thick compared with the river width of some 100 m. EDCOP (2001) proposed additional core drilling test for the confirmation (Ref. 22). A matter to be noted is that seismic prospecting conducted by JICA (1981) showed that the P-wave velocity of the deposit layers be around 2.5 km/sec, which seems a little high compared with ordinary velocity value of alluvial sand and gravel deposit. This matter will be confirmed in the next investigation.

The thick river deposit may be explained by the following factors:

- Marine transgression
- Possibility of regional subsidence of ground related with the movement of Philippine Fault or Philippine Trench

In the next stage, additional core-drilling and seismic prospecting investigations are required to reconfirm the thickness of riverbed deposit.

(c) Fault in the riverbed and on the right bank

Low velocity zones were observed in the riverbed and on the right abutment by seismic exploration survey along the dam axis in the previous JICA study (1981) (Ref. 5 and Ref. 6). Especially in the riverbed, a sheared zone was observed at 110-120 m section in the borehole No. DDH-18 drilled by the same study. There is no data, however, about detail condition and distribution of this sheared zone. Therefore, in the next stage, core-drilling investigation with water pressure test is required for confirmation of the condition of low velocity zones.

(d) Comparison of dam type:

An Earth Core Rockfill Dam (ECRD) was proposed in the 1981 JICA study (Ref. 5). The previous study mentioned the possibility of concrete gravity dam construction, stating that "for concrete gravity dam, the foundation excavation should be made to the fresh rock zone. Sufficient shear strength of foundation against slide of concrete gravity dam can be obtained only in this zone. However, confirmation of shear strength by in-situ rock test will be required in the future stage of investigation". On the other hand, Roller Compacted Concrete Dam (RCCD) was studied by ELC (1991) at the 140 m upstream of the site proposed for ECRD in 1981. The following adverse factors, however, are considered for RCCD construction.

i) Large amount of excavation in thick river deposit
ii) Fault in the foundation area (riverbed and right bank)
iii) Possibility of land slide on the abutment
iv) High risk of seismicity around damsite
v) Impact on river environments due to the recuperation of a large amount of river bed deposit (for concrete aggregates material) in the downstream reaches of the Agos river

Therefore, it can be said that fill type dam, which mainly consists of rock materials, seems more suitable for the Agos dam.

Figure D4.7 shows the geological profile along the Agos Dam axis.

D4.4.3 Construction Materials

The previous studies by JICA (1981) and ELC (1991) conducted some investigations for construction materials of Agos dam through core-drilling, seismic exploration and laboratory test. The results are described below:

(1) Rock and Riprap Materials

Material of 3.5 millions m^3 can be collected from both banks of Kaliwa river at 500 m upstream from the Kanan-Kaliwa confluence. Additional 6.0 millions m^3 can be produced from the excavation in spillway area. These materials consist of sound greywacke, basalt and pyroclastic rock, having unconfined compressive strength of 1160 to 1430 kgf/cm^2, which is hard and stable enough for rockfill embankment (Ref. 5).

(2) Concrete Aggregates

Coarse aggregate can be collected from river bed deposits of the Agos River, and fine aggregate from the coastal beach sand and the river sand (Ref. 5). On the other hand, the ELC study (1991) envisaged to take concrete aggregates from river deposits: 2 millions m^3 from dam foundation area and 3 millions m^3 from the Agos River downstream from the damsite (Ref.14).

(3) Core Material.

For impervious core material, highly to completely weathered rock distributed in the areas of high elevation around the Agos damsite, downstream river banks and afterbay weir site are proposed (Ref. 5). The ELC study (1991) suggested the blending of gravel collected from river deposits with residual soil, the product of intensive weathering (Ref. 14).

D4.5 Reservoir Area of Kaliwa Low Dam and Agos Dam

D4.5.1 Background

As for the reservoir area of Agos and Kaliwa Low Dams, the possibility of water leakage from Daraitan limestone mass is the focus in the previous studies (Ref. 3, Ref. 5, Ref. 14, Ref. 22). Field reconnaissance by the JICA Study Team during the 1st Field Investigation in 2001 noted the following three potential problems:

- i) Watertightness of Daraitan limestone mass
- ii) Accumulation of riverbed sediments around the confluence of Kaliwa river and Limananin creek
- iii) Hot spring at the upstream of Kaliwa Low Dam No.2 site.

D4.5.2 Watertightness of Limestone Mass

Daraitan limestone mass is situated at the upstream part of reservoir area with a width of 1.5 km, distributing in N-S direction. The previous study indicated that “loss of water through the fault zone or limestone in a northerly direction is physically impossible. Towards the south, the limestone seems to wedge out or to be cut off by faults, which also would exclude water losses in this direction. Nevertheless, geologic evidence in this respect is not conclusive. Subsurface exploration, consisting mainly of borehole drilling with permeability tests and core sampling, would be necessary to definitely resolve the possibility” (Ref. 3).

Moreover, the previous JICA study (1981) noted that “only a few developments of cavities have been found, but the problem of leakage seems negligible because of the shallow high water level at the limestone area and the presence of other impervious beds between this area and Laguna de Bay. Existence of not a few lines of surface water streams originating higher than El. 300 m in this area can be taken as a proof of high groundwater table and imperviousness of the bed rocks” (Ref. 5).

On the other hand, EDCOP (2001) noted that “The presence of permeable limestone at Kaliwa Low Dam No. 1 site has led to selection of No. 2 site” and “the Daraitan limestone is folded and is disposed in a N-S direction. If the fold plunged to the south or towards the lower elevation as inferred from the available structural data, its extension underneath has to be investigated to determine extent of possible water loss through the overlying pyroclastics of the Laguna Formation”. The same report also stated that “the limestone plunges southward at a moderate angle and occurrence will preclude the significant loss of impounded water from the reservoir through the observed cavities" (Ref. 22).

According to the site reconnaissance conducted by the JICA Study Team (2001), many cavities, holes, and water-spring points are observed in Daraitan limestone area, which indicate the possibility of existence of many natural water routes inside the deeper part of limestone mass. For example, along the Kaliwa River, it is found that natural tunnel of 1.5 m diameter gushes out water of 500 liters/minute. The dip and strike of bedding plane in Daraitan limestone is almost disturbed by some faults and foldings. However, on the right side of the river, that seems plunged toward southwest. Along the Matilatiday creek, a right tributary of the Kaliwa river, no surface water flow is observed in the dry season, so that there is a possibility of water leakage from this creek.

However, the volume of water flow in the Kaliwa River seems unchanged throughout the sections of limestone area. According to the study by EDCOP (2001), "flow measurements at selected sections upstream and downstream of the limestone body in Mt. Daraitan did not indicate any loss of water as the Kaliwa river flows through the said formation" (Ref. 22).

A matter to be confirmed is the possibility of water leakage from Daraitan limestone mass in the case of raising the water level about 20 m after water storage in the reservoir area. In the next stage of investigation, the following are subjects of further confirmation:

i) Continuity of Daraitan limestone mass toward the San Antonio (8 km south of the Kaliwa River) area
ii) Distribution and condition of the faults connecting with Daraitan limestone (Ref. 38), especially in the San Antonio area

Daraitan limestone mass is overlain by thick Quaternary deposits (Laguna Formation), and some sub-surface investigations are necessary. The following investigations are required in the next stage:

- Analysis of aerial photographs
- Field reconnaissance in detail, with ad-hoc flow measurement in each creek
- Seismic and/or electric explorations
- Core drilling with water pressure test

Figure D4.8 shows an assumed geological profile of Mt. Daraitan~San Antonio~Pagus area.

D4.5.3 Riverbed Sediments at Confluence of Limanamin Creek

In the reservoir area, river deposits of varied scales are observed at river bends and confluence. It was observed that riverbed sediments of about 3,000 m^3 is accumulated at the confluence of Limananin creek, about 300m upstream of the Kaliwa Low Dam No. 1 site (See Figure D4.1). From the geological point of view, the deposit mainly consists of limestone boulders and gravel produced from Mt. Daraitan area. According to local people, there was only a half volume (1,500 m^3)

of sediments before a heavy flood in 1999. Source materials for the sedimentation, such as boulder stones and talus deposits, are still distributed abundant around Daraitan limestone gorge, and hence large volume of sand and gravel will be transported downstream continuously.

Therefore, Kaliwa Low Dam No. 1 site seems disadvantageous in view of a possibility of quick accumulation of sediments yielded from the deposits at Limanamin creek.

D4.5.4 Hot Spring

A confined hot spring was observed at a point of about 600 m upstream from the Kaliwa Low Dam No.2 site. Spring water is about 40-50 degrees without taste and smell. Analysis of water quality indicates rich sulfates and chlorides as shown in Table D4.1, but these values are under the standard values of the Philippine National Standard for Drinking water (1993). According to the analysis of aerial photographs, a 8 km long NE-SW lineament develops through the vicinity of the hot spring point. From regional geologic point of view, there is no sign of active volcanic belt or new plutonic rock. Hence, the source mechanism of this hot spring is not clear. In any case, the hot spring seems to have connection with the said lineament.

As shown in Section D2 above, there is a possibility that some lineaments around the project area may be classified as active fault. As a result, there will be a need of paying attention to the following matters:

i) Kaliwa Low Dam No. 2 site

- Fault with confined hot water
- Faults
- Water leakage through the faults

ii) Agos reservoir area

- Water leakage through the limestone mass

iii) Tunnel nearby the hot spring point

- Fault with confined hot water

In the next stage of the study, the following investigations will be required:

- Analysis of aerial photographs
- Investigation by hearing with questionnaire to the local people
- Field reconnaissance in detail
- Measurement of electric conductivity, pH, etc. around the hot spring area
- Water sampling and analysis
- Core drilling with water pressure test and temperature logging
- Seismic prospecting.

D4.6 Agos Afterbay Weir

D4.6.1 Background

The previous studies (Ref .4 to Ref. 6) examined the construction of a floating type weir at a point of about 8 km downstream of the Agos Dam site, where the river width is some 260 m. Core drilling and seismic prospecting were carried out around the site in the 1981 JICA study.

D4.6.2 Weir Site

Base rock of the site is composed of greywacke and conglomerate with thin layers of sandstone and shale, and these rocks are same as those distributed at the Agos damsite. The thickness of riverbed deposit, which consists of sand and gravel, reaches 50 m at maximum along weir axis. Therefore, a floating weir was proposed in the 1981 JICA study.

The same study noted that "the possible leakage through the river deposit under the weir body, which is highly pervious but might not be effectively grouted, will be controlled by long flow lines created by means of apron and/or blanket. This will reduce the possibility of piping. The foundation excavation on both abutments should be made at least into the weathered rock zone, with appropriate design of the weir sections to secure stability against sliding, overturning and/or piping by seepage water. Accordingly, excavation of 5 to 10 m will be required at least"

In the next stage of investigation, additional core drilling is required for reconfirmation of the results of survey by JICA (1981), especially thickness and conditions of the deposit, permeability of the weathered rock zone.

Figure D4.9 shows the profile of Agos Afterbay Weir axis.

D4.6.3 Construction Materials

A quarry site for the afterbay weir construction was proposed in the area located on the left bank of the weir site (Ref. 5). The lithology of quarry site consists of massive conglomerates intercalated by fine sandstone layers. In the next stage of investigation, the selection of quarry sites should be made through detailed field reconnaissance, seismic exploration, core drilling and laboratory test.

D4.7 Kanan Dams

D4.7.1 Background

The 1981 JICA study examined a dam at Kanan No.1 site as a hydropower single-purpose scheme. The dam is proposed to be of a concrete gravity type to create a reservoir of FSL 300 m (Ref. 5).

The previous study on Manila Water Supply III Project (MWSP III) by Electrowatt et al (1979) proposed that Kanan No.2 Dam (or Kanan-2 Dam) should come up on development stream next to the Laiban Dam scheme. The Kanan No. 2 Dam is virtually for water supply single-purpose development, diverting the Kanan River water to the Laiban reservoir. The previous study proposed a 160m high dam of earth-core rockfill construction at a preliminary design level (Ref. 3).

Kanan B1 Dam as hydropower single-purpose scheme was studied in the feasibility study for Small Hydropower Projects by NPC/Nippon Koei-Lahmeyer in 1992 (Ref. 15). The previous study envisaged constructing a 74.5 m high CFRD associated with a reservoir of FSL 180 m. Kanan B1 Dam axis lies 300 m upstream of Kanan-4 Site studied by MWSP III (1979).

Common to all sites selected on the Kanan River, it is noted that the Philippine Fault (Infanta Fault) with high activity exists at about 8 km east. In this context, this fault issue should be taken into account in the design of all the dams proposed on the Kanan river. The detail in this aspect is described in Subsection D4.4 for Agos Dam.

D4.7.2 Kanan No.1 Dam Site

The JICA study report (1981) describes that, "this damsite is selected at a V section gorge about 21 km upstream from the confluence of the Kanan and Kaliwa. This gorge has parallel high cliffs on both banks for 800m in straight line, being composed of very hard and massive greywacke intercalated with thin fine sandstone layers with pebbles and boulders of 2 to 30 cm in diameter. It is judged that any type of any high dam can be supported with sufficient safety. However, a very narrow river section and very high and rapid flood at this damsite suggest that it is preferable to construct a concrete gravity dam instead of fill type dams" (Ref. 5).

On one hand, MWSP III study (1979) (Ref. 3) carried out test pit digging and seismic prospecting to assess the geological condition of the site. MWSP III study pointed out that the thickness of weathering on the ridge at the top of the left abutment is 30 m or more, and concluded that "Site No. 1 is only marginally suited for an embankment dam of the proposed height and slope."

According to the Preliminary Geo-hazard Maps prepared by the Mines and Geosciences Bureau (MGB) (Ref 38), the geology of the No. 1 site is classified as a part of the Mayabangain Formation of Lower Palaeogene and lithologically almost similar to that of the Agos site and Kaliwa Low Dam site. The fresh bedrock of Kanan No.1 site is judged to have enough shear strength for a concrete gravity dam of several tens meters of height. However, the following adverse factors are noted for this site:

i) An extensive grouting work for seepage cut-off is required along thin ridge on the right-bank, which extends over a length of some 700 m (a hydraulic gradient at FSL 300 m is 1/3~1/4)
ii) Since the weathered rock at the top of the left bank is thick, there would be a limit for the dam height
iii) Seismic risk is high

Figure D4.10 shows a geological profile of the Kanan No. 1 Dam axis.

D4.7.3 Kanan No.2 Dam Site

MWSP III study (1979) carried out test pit digging and seismic prospecting to study the geological condition of the site. The No. 2 site shows relatively gentle topographic feature compared with No. 1 site. The base rock is composed of massive rocks such as conglomerates, agglomerates, occasionally lava flows, sandstone, mudstone with fossils, chert and graywacke. The seismic prospecting revealed 3.0 km/sec of P-wave velocity in fresh rock, which was evaluated as "indicating a comparatively good geotechnical quality" (Ref. 3).

The geology is equivalent to Mayabangain Formation of Palaeogene period, and almost similar to that occurring at the No. 1 site, Agos site and Kaliwa Low Dam site (Ref. 38). The weathering layer of abutments is comparatively thick, 10-20 m at the bottom of slope and 20-30 m at the upper part (Ref. 3). In such a case, there is a possibility of existence of unstable mass causing landslide or thick talus deposit. For example, the feasibility study for the Kanan B1 scheme identified the area of landslide at the originally contemplated site (Kanan-4 site in MWSP III), and had to shift the dam axis to a location of 400 m upstream (Ref. 15).

Main subject of the next stage investigation will be to evaluate the following matters:

- i) Distribution of overburden, weathered rock zones and faults
- ii) Survey of unstable slopes that may develop to landslide
- iii) Investigation of shear strength and permeability of the bedrock
- iv) Selection of a borrow pit and a quarry site and confirmation of quality of materials

Figure D4.11 shows a geological profile of the Kanan No. 2 Dam axis.

D4.7.4 Kanan B1 Dam Site

In the feasibility study for the Kanan B1 Dam (1992), field reconnaissance, core drilling with water pressure test, test pitting and some laboratory tests were carried out. According to this report, "the outcropping rock mass in the site area consists mainly of older clastics and volcanoclastic deposits of Cretaceous to Miocene age. They are mainly greywacke, conglomerate and calcareous breccia" (Ref. 15).

According to Ref. 38, the geology of the B1 site belongs to the Mayabangain Formation in early stages of Palaeogene period and is almost similar to that of Agos site, Kaliwa Low Damsite, Kanan No. 1 and No. 2 sites. The feasibility study identified that " The faulted or broken zone with a thickness of 35-40 m covers also one third of the valley floor to the west. Distinctly jointed but undisturbed rock layers superimpose the fault zone to the east towards the right abutment", and estimated the uni-axial compressive strength of the fault part on the left abutment to be about 100-200 kgf/cm^2 (Ref. 15).

As stated before, the Kana B1 Dam was originally proposed at Kanan-4 site of MWSP III, which was shifted to the location of 400 m upstream due to the existence of landslide at the original location. Although there is some minor landslides in the shifted Kanan B1 site, it is of an extent not affecting the proposed excavation works.

The overall geology indicates that the Kanan B1 site involves the following problems:

i) Existence of fault, which occupies about 1/3 of the river bed foundation.
ii) Small scale landslides in abutment.
iii) High seismic risk.

Judging from the factors stated above, the Kanan B1 Dam is proposed to be of a fill type construction. An extensive foundation treatment will be required.

Figure D4.12 shows the cross sectional geological features of the Kanan B1 Dam axis.

D4.7.5 Construction Materials

With regard to construction materials for Kanan dams, a series of test pittings and laboratory tests were carried out by MWSP III study (1979), JICA feasibility study (1981) and Kanan B1 feasibility study (1992). The following are the findings from those studies:

(1) Rock and Riprap Materials

Four (4) rock quarry sites were selected on both banks of the Kanan River, located upstream and downstream from the Kanan No.2 site within a distance of 1 to 2 km. The rocks are composed of hard pyroclastic rock and greywacke (Ref. 3 and Ref. 5). The quarry is of almost same geology as the quarry site for the Agos dam. The rock materials seem to have enough strength and stability. On the other hand, the Kanan B1 feasibility study selected two (2) quarry sites at the location of some 3 km downstream from the Kanan No.2 site and further three (3) quarry sites around the Kanan B1 site. Rock of these quarries mainly consists of conglomerate and greywacke.

(2) Concrete Aggregates

Coarse aggregate will be collected from quarry sites and from excavation of structure foundations. The materials are pyroclastic rock and sandstone (Ref. 3 and Ref. 15). Though river sand is suitable for fine aggregate, the river sand deposit available from the Kanan River in the vicinity is supposed to be limited, only enough to suffice the production of 1.0 million m^3 of concrete. It is, therefore, necessary to take additional quantities from the river deposits downstream of the Kaliwa-Kanan confluence (Ref. 3). Kanan B1 study contemplates to get coarse aggregates from the river deposits in the Kanan River and Agos River.

(3) Filter and Transition Materials

Silty sand and sandy gravel deposits accumulated along the Kanan River at 9-13 km downstream from the Kanan No.2 site are possible sources of materials for the filter and transition zones of rockfill dam (Ref. 3 and Ref. 5). Since the available volume is limited, it is planned to acquire additional quantities from river deposit around the Kaliwa-Kanan confluence (Ref. 3). Kanan B1 study plans to mix the riverbed deposit and the quarried materials for production of coarse transition material.

(4) Core Material

Several places are selected along the Kanan River. Proposed Lagmic area and Pitigan areas are 7 to 15 km upstream from the proposed damsites.

D4.8 Water Transfer Tunnels

Geological study at this Study stage covers five water transfer tunnels: (i) Kaliwa~Pililla tunnel, (ii) Kaliwa~Abuyod tunnel, (iii) Laiban~Tanay tunnel and (iv) Laiban~Pantay tunnel, and (v) Kanan~Laiban tunnel. The tunnels (i) to (iv) are parts of four alternative conveyance waterways for water supply for Metro Manila and the tunnel (v) is a transbasin tunnel for water transfer from Kanan No.2 reservoir to Laiban reservoir.

D4.8.1 Kaliwa~Pililla Transfer Tunnel

This study examined the geology of three (3) alternative tunnel routes, of which two (2) are as proposed in the EDCOP pre-feasibility study (2001) and one (1) is the route proposed in this Study. They are called herein TR-1, TR-2 and TR-3, respectively (see Figure D4.2 for the layout of a part of the tunnel routes).

The geological assessment hereunder is based on information available from existing literatures, since no field investigation has been conducted at the present stage.

(1) TR-1 (15.5 km in length) for Kaliwa Low Dam No.1

Tunnel TR-1 is proposed to pass from Kaliwa River at Limunanin creek up to Pililla. It passes through three (3) rock groups as follows:

i) Daraitan Limestone Mass
ii) Kinabuan Formation and Barenas-Baito Formation, consisting of basalt and sedimentary rocks
iii) Laguna Formation, consisting of pyroclastic sediments and tuff

Intake is located on depositional side of the Kaliwa River, where limestone with minor solution cavities exists. In several creek-crossing points and fault zones, there will be water inflow during the construction work, particularly in tunneling in the Daraitan limestone mass. There may also be a possibility of landslides at the portals of tunnel (Ref. 22).

(2) TR-2 (19.4 km in length) for Kaliwa Low Dam No.2

Tunnel TR-2 is laid out from the Kaliwa Low Dam No.2 site near Queboroso creek up to Pililla. The same geology appears as TR-1 except sandstone and conglomerate occurring in 0-3 km section. Some parts of 0-3 km section have comparatively thin overburden, which is about 10-13 m thick. Distribution of faults is almost same as TR-1. Tunneling work will encounter water inflow, especially in creek-crossing points, fault zones and limestone mass (Ref. 22).

(3) TR-3 (20.2 km. Length) for Kaliwa Low Dam No.2

Alignment starts at the Kaliwa Low Dam No.2 site and ends in Pililla. The route is identical to that of Alternative Route B-1a examined in Supporting Report Part-F. Geological conditions through the tunnel are as follows:

i) 0-5.7 km Section: Composed of pyroclastic rocks, sandstone, conglomerate, shale, etc., which belong to the Maybangain Formation. Generally, the rocks are hard and impervious. Faults are distributed and cut a Quarternary layer at 5.2 km and 5.7 km points (Ref. 5 and Ref. 38).

ii) 5.7-7.4 km Section: Karstified limestone exists, with many cavities and high permeability.

iii) 7.4-11.5 km Section: Consists of shale, limestone, chert, basalt and pyroclastic rocks, classified into the Kinabuan Formation and Barenas-Baito Formation. In general, rocks are hard and impervious.

iv) 11.5-12.3 km Section: Including small masses of limestone, which has many cavities and high permeability. At 12.3 km point, there is an assumed fault cutting a Quarternary deposit. This is the section with the thinnest overburden (40 m in thickness).

v) 12.3-20.2 km Section: Composed of Quarternary deposits such as tuff, pyroclastic rock, tuffaceous sandstone, etc. and some parts are welded. These belong to the Laguna Formation, which seems to have varying geological members, such as soft tuffs and hard pyroclastic rocks.

Geotechnical characteristics of the routes TR 1 to TR-3 are summarized as follows:

- In the creek-crossing points, fault zone and limestone masses, it is necessary to pay due attention to groundwater inflow and ground stability during construction work, and also to the ground permeability after the construction. Concrete lining is indispensable especially for the section through limestone.
- The first 60% section consists of hard rocks of Cretaceous to Paleogene, but the remaining 40% section seems to have complicated geological setting with soft zones, composed of disintegrated clay to sand, soft rock and comparatively hard rock that will appear alternately.
- As for the tunnel outlet, especially in Pililla side, the slope stability should be examined.
- Active fault (PHILVOLCS) may extend from Pinugay in the northwest and cross the tunnel near Sampaloc. It is required to confirm whether tunnel alignment crosses the extended line of the fault or not.

- Confined hot spring is recognized around the intake site in the Kaliwa River. There may be a possibility for the tunneling work to encounter sudden hot water inflow. It is necessary to carry out geological investigations for confirmation of groundwater condition, especially in the uppermost section of the tunnel alignment.
- The tunnel routes TR-1 and TR-3 are favorable in the aspect of the thickness of overburden. Geologically, unstable elements are concentrated at 12.3 km point of TR-3. The route TR-3 is located farthest from the active fault line indicated by Ref. 38.
- Laguna Formation with varying components ranging from soft soil to comparatively hard rock has a possibility to deposit more thickly in southern area. Therefore, the section through the Laguna Formation may be longer in the route TR-3 than in TR-1 and TR-2.
- Details should be clarified by field reconnaissance, core drilling, seismic prospecting, groundwater investigation, laboratory test, etc. in the next stage.

Figure D4.13 shows the assumed geological profile along the TR-3 tunnel alignment. However, this tunnel route was finally ruled out from further study as the result of cost comparison with the other route plans (see Supporting Report Part-F).

D4.8.2 Kaliwa~Abuyod Transfer Tunnel

This tunnel route was proposed after the first assignment of the Geologist to this Study is over. Hence, the following geological assessment is based on information available from existing literatures.

The tunnel is laid out between Kaliwa Low Dam and a powerhouse proposed at Abuyod. The total length is about 28 km. A part of the proposed route is shown in Figure D4.2. General geology of the tunnel is as follows:

i) 0-5.4 km Section: Composed of pyroclastic rocks, sandstone, conglomerate, shale, etc., which belong to the Maybangain Formation. Generally, the rocks are hard and impervious. Faults are distributed at 1.1km, 3.9 km and 5.1 km points. The fault at 5.1 km cuts a Quarternary layer. The fault at 1.1 km is an assumed active fault according to PHILVOLCS map.

ii) 5.7-6.4 km Section: Karstified limestone exists, with many cavities and high permeability. Both ends of this section are bordered by faults cutting the Quarternary layer.

iii) 6.4-17.8 km Section: Composed of shale, limestone, chert, basalt and pyroclastic rocks, classified into the Kinabuan Formation and Barenas-Baito Formation. In general, rocks are hard and impervious. Ground cover is thinnest at 10.2 km point (some 70 m).

iv) 17.8-19.6 km Section: This section passes through just underneath the limestone mass of Masunguit Rocks where many cavities and high permeability are foreseen. It is not certain at present whether the tunneling will encounter this limestone mass. There is an assumed fault at 17.8 km point.

v) 19.6 km point: The tunnel will encounter a fault designated by PHILVOLCS (2000) as active.

vi) 19.6-28.0 km Section: Consists mainly of shale and sandstone of Kinabuan Formation. In general, the rocks are hard and impervious.

The proposed tunnel route is geologically assessed as follows:

- Owing to alignment along the mountain ridges, there will be no particular problem in the aspect of ground cover and unbalanced ground pressure. Instead, the tunnel is aligned to have five bends.
- Tunnel will pass relatively homogeneous and hard geological layers (Cretaceous-Old Tertiary period), not encountering Quarternary layers. It is presumed that tunneling by TBM may possibly be effective.
- In the fault-fracture zones and limestone sections, there may be difficulties of excessive water seepage and unstable ground. Concrete lining will be required in the limestone sections.
- Care for landslide will be required at tunnel portal on the Abuyod side.
- The fault at 19.6 km point, which is assumed to be active according to PHILVOLCS, should be investigated in detail in the subsequent phase.
- Confined hot spring is recognized around the intake site on the Kaliwa river. There may be a possibility for the tunneling work to encounter sudden hot water seepage. Subsequent investigation should confirm the groundwater condition especially of the uppermost section of the tunnel alignment.

Figure D4.14 shows the assumed geological profile along the Kaliwa-Abuyod tunnel.

D4.8.3 Laiban~Tanay Transfer Tunnel

This tunnel is to convey water from Laiban Low Dam to a powerhouse located on the bank of Tanay River, about 5 km north of Tanay town. Further, the water is conveyed to a water treatment plant at Karan Batu via pipeline and tunnel. The total length of waterway is about 18.5 km. A part of the proposed route is shown in Figure D4.2. General geology of the waterway route is as follows:

i) 0-11.4 km Section: Composed of shale, sandstone, chert, basalt, pyroclastic rocks, which belong to the Kinabuan Formation and Barenas-Baito Formation. Generally, the rocks are hard and impervious. Faults are distributed at 1.0km, 2.2 km, 3.0 km and 4.0 km points. The fault at

2.2 km point cuts a Quarternary layer. Ground cover is thinnest at 1.0 km point (55 m thick). There is a possibility to encounter a limestone zone at 1.5 km point.

ii) 11.4 –14.4 km Section: The tunnel passes through just underneath the limestone mass of Masunguit Rocks having many cavities and high permeability. It is not certain at present whether the tunneling will encounter this limestone mass. There is an assumed fault at 11.4 km point.

iii) 12.4 km Point: The fault at this point is an active fault according to the PHILVOLCS map.

iv) 14.4-15.0 km Section: Composed of shale, sandstone, pyroclastic rocks, conglomerate, etc., which belong to the Kinabuan Formation and Maybangain Formation. Generally, the rocks are hard and impervious.

v) 15.0-16.0 km Section: Pipeline is proposed for this section.

vi) 16.0-18.5 km Section: Composed of Quarternary deposits such as tuff, pyroclastic rock, tuffaceous sandstone, etc., which belong to the Laguna Formation. The Laguna Formation consists of varying components ranging from soft soil to comparatively hard rock. There is a possibility that some parts are heavily weathered to clayey or sandy condition.

The proposed waterway route is geologically assessed as follows:

- Owing to alignment along the mountain ridges, there will be no particular problem in the aspect of ground cover and unbalanced ground pressure. Instead, the tunnel is aligned to have five bends
- In the first 15 km section, the tunnel passes relatively homogeneous and hard geological layers (Cretaceous-Old Tertiary period). It is presumed that tunneling by TBM may possibly be effective in this section. The last 2.5 km section passes the Quarternary deposits consisting of varying layers of sand, soft rock and hard rock. Use of TBM in this section will presumably be not effective.
- In the fault-fracture zones and limestone sections, the tunneling may encounter difficulties of excessive water seepage and unstable ground. Concrete lining will be required in the limestone sections.
- Care for landslide will be required at tunnel portals.
- The fault at 12.4 km point, deemed to be active, should be investigated in detail in the subsequent phase.

Figure D4.15 shows the assumed geological profile along Laiban-Tanay tunnel.

D4.8.4 Laiban~Pantay Transfer Tunnel

As for Laiban~Pantay Transfer Tunnel, detailed design was completed by Electrowatt (1984). Geology along the tunnel is composed of hard agglomerate, sandstone, and clastic rock, of which unconfined compressive strength is estimated to be more than 610 kgf/cm^2. Though the sheared zone is not recognized by field reconnaissance and core drilling, preparation for the unexpected encounter with low quality rock is necessary (Ref.10).

Electrowatt and Renardet (1984) classified the rock quality into four (4) classes as Class 1 to 4. It is proposed that individual rock anchors for Rock Class 1 (sound and unweathered rock), anchors, shotcrete and steel ribs for Rock Classes 3 and 4 (altered or closely fractured rock). The thickness of concrete lining is proposed to be 0.25 m in zones of Rock Classes 1 and 2 and 0.45 m for Rock Classes 3 and 4. For the most downstream 400 m alignment, a steel-lined tunnel is selected as the overburden load is insufficient to withstand the internal pressure of tunnel.

On the other hand, excavation by drilling and blasting method was recommended in the tender design. Re-evaluation of TBM (Tunnel Boring Machine) option in 1997 brought with the proposal that "an unlined tunnel may be more economical in case of an excavation in Rock Class 1 by TBM as the rock surface is left smooth enough to avoid an excessive increase of the required tunnel diameter" (Ref.18).

D4.8.5 Kanan~Laiban Transbasin Tunnel

Kanan~Laiban Transfer Tunnel has a length of about 16 km, starting from Makalia River of the Kanan basin and ending at Limutan River of the Kaliwa basin. The tunnel passes the Maibangain Formation~Younger clastic series of the Miocene Kinabuan Formation and Barenas – Baito Formation. The first section is composed of clastic sediments. In some parts of this section, tunnel support work with systematic rock bolting and steel ribs are necessary. The remaining few kilometer section consists of younger clastic sediments with limestone lenses.

The previous MWSP III study (1979) describes that "Consequently, it is highly probable that the tunnel would encounter the faults as well as the Miocene sediments." The fault zones, because of their limited width, should not be considered a decisive disadvantage. It is rather the Miocene shale that might cause difficulties because of its tendency for air slaking. It is known from experience that tunnels of small diameter in shale will normally not cause trouble if shotcrete is applied soon after each blasting to avoid deterioration of the rock surfaces.

The final stretch of the tunnel alignment is in the zone of the clastic and pyroclastic rocks with limestone intercalation, which is a typical geological pattern in the area of the Laiban reservoir.

There is possibility of water inflow in the limestone area, while clastic sediments and pyroclastic rocks have low permeability (Ref. 3)

D4.8.6 Adaptability of TBM (Tunnel Boring Machine)

In the Umiray-Angat Transbasin Project, a water transfer tunnel, 13.1 km long and 4.3 m in diameter, was driven in 2 years (1998-2000). The geology along the Umiray-Angat tunnel belongs to the Mayabas Formation, which is equivalent to

Maybangain Formation extensively distributed around Agos~Kanan~Kaliwa project area. The rock of the Mayabas Formation (Maybangan Formation) mainly consists of andesite, basaltic agglomerate and basalt with small limestone lenses. Unconfined compressive strength was estimated at 410-610 kgf/cm^2 by the previous studies.

The main tunnel of Umiray-Angat alignment was excavated by use of a double shield Tunnel Boring Machine (TBM), the latest type of the TBM. In normal conditions, the progress was 1,000 m per month. This equipment allows the excavation of the tunnel through a very wide range of rock conditions and simultaneous installation of the concrete pre-cast segmental lining. Some geological conditions causing the slow-down of the progress of TBM excavation were as follows:

i) Water inflow in the unlined excavation section at a rate of 100 liter/sec for more than 24 hours,

ii) Sheared zone with incoherent material requiring additional ground treatment to stabilize the excavation face, and

iii) High in-situ stress creating such exceptional pressure squeezing the shields as to necessitate hand excavation around the shield.

TBM could be used for the tunnels proposed in the Agos River Basin development. The following are the comments from geological viewpoints:

(1) Kaliwa~Pililla Transfer Tunnel

The tunnel passes through the following geological zones:

i) Maybangain Formation, composed of pyroclastic rock, sandstone, conglomerate and shale

ii) Daraitan limestone mass which is soluted

iii) Kinabuan Formation and Barenas-Baito Formation, composed of shale, sandstone, chert, basalt, pyroclastic rock, etc.

iv) Laguna Formation of tuff, pyroclastic rock, taffaceous sandstone, etc. in Quarternary time

Rock of i) and ii) above is estimated to have 500-1,000 kgf/cm^2 in unconfined compressive strength, and seems to be suitable for excavation by TBM. Rock of iv) Laguna Formation is a complex mixture of varied materials including soil, soft rock and hard rock. Even if 60% part of the tunnel alignment consists of hard rocks, the remaining 40% is composed of varying conditions of rock, rendering the general geotechnical condition to be far from homogeneity, which suggests the unsuitability of the use of TBM.

(2) Kaliwa~Abuyod Transfer Tunnel

The tunnel is driven in the Maybangain, Kinabuan and Baremas-Baito Formations. As noted in Subsection 4.8.2 above, the use of TBM would be suitable in these geological formations.

(3) Laiban~Tanay Transfer Tunnels

The waterway consists of two tunnels: upper tunnel of 15 km long and lower tunnel of 2.5 km long. The upper tunnel is driven in the Kinabuan and Baremas-Baito Formations, while the lower tunnel in the Laguna Formation. As noted in Subsection 4.8.3 above, the use of TBM would be suitable for the upper tunnel and not suitable for the lower tunnel.

(4) Laiban~Pantay Tunnel

Geology of Laiban~Pantay area belongs to Barenas-Baito Formation and mainly consist of hard agglomerate, sandstone and clastic rock of which unconfined compressive strength is estimated to be more than 610 kgf/cm^2 (Ref.10). TBM could be used in this tunnel.

(5) Kanan~Laiban Transbasin Tunnel

Geological formation along the tunnel alignment are shown as follows:

i) Maybangain Formation of clastic rock, etc.

ii) Miocene Clastic Series of shale, etc.

iii) Kinabuan Formation and Barenas-Baito Formation composed of clastic rock, pyroclastic rock, etc. with limestone lens

This tunnel may be more suitable for the use of TBM than the other tunnels. It should be noted, however, that the geological structure and setting in this highly tectonic zone is more or less distorted with frequent faults of various sizes, and the bedrock can never be homogeneous.

D4.9 Construction around Antipolo-Tanay Area

D4.9.1 Background

Many structures, such as pipeline, tunnel, power station, water treatment plant and service reservoir, are planned in Antipolo-Tanay Area. The MWSP III Review Study (1997) carried out the design review of Laiban~Pantay~Taytay waterway facilities, consisting of tunnel No. 2, tunnel No. 3, pipeline, Pantay water treatment plant, Tanay reservoir, Antipolo reservoir and Taytay pressure control station (Ref.18). Especially for the tunnel No. 2, core drilling, seismic exploration and test adit excavation were carried out, and steel-lined tunnel was proposed. MWSP III study (1979 and 1984) pointed out the possibility of liquefaction in the area, especially in the Marikina valley.

D4.9.2 Engineering Geology

Antipolo~Tanay area can be divided into three (3) geo-morphological areas, such as a little steep-hilly area, gentle-hilly area and low flat area. According to the geological maps by MGB (Mines and Geosciences Bureau), the geology of each area can be presented as follows:

(1) A little steep-hilly area:

- Madlum Formation (MF)
  Limestone, basalt, calcareous sandstone, shale, conglomerate
- Angat Formation (AF)
  Limestone, sandstone, calcareous shale, clayey sandstone, sandy limestone and conglomerate
- Kinabuan Formation (KK or KF)
  Silty shale, calcareous sandstone, tuffaceous and siliceous layers, limestone

(2) Gentle-hilly area:

- Laguna Formation ≈ Guadalupe Formation (Qg or GF)
  Layers of thin to medium bedded, fine-grained tuffs, agglomerate, volcanic breccia and associated tuffaceous sediments. Vitric tuffs and welded volcanic breccias with subordinate amount of tuffaceous, fine-to-medium grained sandstone.

(3) Low flat area:

- Quaternary Alluvium (Qal)
  Detrital deposits, mostly silt, sand, and gravel

Engineering geology of each morphological area is described as follows.

(1) A little steep-hilly area:

Limestone, sandstone, shale, conglomerate, basalt, etc. of Cretaceous to Neogene ages distribute in the relatively steep hills. Fresh part of them is assumed to be hard and to have enough bearing capacity for proposed construction. In the next stage of investigation, core drilling with standard penetration test is required for confirmation of thickness of extremely weathered layer and bearing capacity.

As for tunnel construction, though this area seems to have a good rock condition, attention should be paid to thickness of weathered layer and high permeable limestone. According to hazard map prepared by MGB, this area falls in landslide prone areas as shown in Figure D4.16. For example, a large-scale landslide occurred around the Cherry Hill north from Antipolo in 1998.

In selecting the location and preparing the design of structures, possibility of landslide should be considered and investigated.

(2) Gentle-hilly area:

The area consists mostly of Quaternary deposits of the Laguna Formation, consisting of tuff, pyroclastic rock, tuffaceous sandstone, etc. and some parts are welded. For the foundation of structures, fresh parts of these rocks seems to have comparatively good bearing capacity, but some part is possibly soft, especially in weathered zone or tuffaceous zone. Core drilling with standard penetration test is required to know the in-situ conditions.

For tunnel planning, detailed investigations with drilling and seismic prospecting are important because rock condition is not homogeneous. Potential landslide needs to be examined for some parts of this area with appearances of collapse and disturbance. Many landslide prone areas exist also in this area, according to the MGB's hazard map in Figure D4.16.

(3) Low flat area:

Unconsolidated sand, silt, clay and gravel form the low flat alluvial area. Some parts of this area may possibly be not suitable for spread foundation. Possibility of liquefaction by earthquake is a serious problem in the area. According to MGB's hazard map, the area is included in liquefaction-prone area as shown in Figure D4.17. Core drilling with standard penetration test, hand-auger boring and some sounding tests are required in the next stage.

Antipolo~Tanay area includes a high seismic risk, which is located between the Philippine Fault and the Valley Fault (see Figure D2.2). Therefore, in the preparation of plans or designs, high seismic risk should be taken into account. The MWSP III Review Study (1997) established the following peak ground acceleration for the design of structures other than dam and intake works (Ref.17).

- Rock and Hard Soil = 0.25g
- Medium Soil = 0.40g,
- Soft Soil = 0.70g

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Maps and Data

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Tables

Table D1.1 Table of Geological Formation

Time		Formation	Symbol	Explanation
Quaternary	Holocene	Quaternary Alluvium	Qal	Detrital deposits, mostly silt, sand, and gravel.
	Pleistocene	Laguna Formation ≅ Guadalupe Formation	Qg or GF	Layers of thin to medium bedded, fine-grained tuffs, agglomerate, volcamic breccia and associated tuffaceous sediments.
Tertiary	Middle Miocene	Tignoan Formation	Nt or Ntf	Agglomerate, volcanic breccia and tuff with interbedded fine sedimentary clastic rocks and volcanic flows.
		Madlum Formation	MF	Consist of upper, middle and lower members. Upper member is fairly fossiliferous, massive or obscurely bedded limestone. Middle includes the basalt. Lower clastic member is calcareous sandstone and shale with conglomerate at the base.
	Early Miocene	Angat Formation	AF	Well bedded massive limestone with siliceous layers and limy sandstone, calcareous shale, clayey sandstone, sandy limestone and conglomerate.
	Paleocene~Eocene	Maybangain Formation ≅Bayagas Formation	Pm	Equivalent to Bayabas, Masungi and Kanan formation; consists of andesitic to basaltic flows, agglomerate, volcanic breccia, lapili and lithic tuff with intercalated sedimentary rocks composed of siltstones, shaly sandstone conglomerate and limestone.
Cretaceous		Kinabuan Formation	Kk or KF	Thinly interbedded silty shale and calcereous sandstone with tuffaceous and siliceous layers capped by thin beds of limestone.
		Barenas-Baito Formation	Kbb	Pillow and massive basalt, red chert, red siliceous mudstone/shale and basaltic sedimentary rocks mostly sandstone and pyroclastics.

Table D3.1 Acceleration Value of Each Proposed Dam Site

Reports	Type	Acceleration of Each Dam Site				
		Laiban	Agos	Kanan		
				-1	-2	B-1
Manila Water Supply III Project, Appendix B, Geology and Geotechnics, Dec.1979, Electrowatt	Peak Acceleration	0.15g (50years) 0.20g (100years) 0.40g (1000years)	-	-	-	-
	Design Accelerration	-	-	-	-	-
Feasibility Report on Agos River Hydropower Project, Data Book III , Geological Exploration, March 1981, JICA	Peak Acceleration	-	0.58g			-
	Design Accelerration	-	0.15~0.20g			-
Manila Water Supply III Project, Summary, Engineering Report, July.1984, Electrowatt & Renardet	Peak Acceleration	0.50g (MDE) 0.40g (OBE)	-	-	-	-
	Design Accelerration	-	-	-	-	-
Feasibility Study - Agos Project, Main Report – Draft, Oct. 1991, ELC Electroconsult	Peak Acceleration	-	0.58g	-	-	-
	Design Accelerration	-	0.15~0.20g	-	-	-
Small Hydropower Projects, Feasibility Study, Draft, Volume IV : Kanan B1 Scheme, Nov. 1992, Nippon Koei-Lahmeyer	Peak Acceleration	-	-	-	-	0.46g
	Design Accelerration	-	-	-	-	0.26g
	Design Accelerration	-	-	-	-	0.23g
Manila Water Supply III, Project Review, Volume 1 : Feasibility Review, Feb. 1997, Electrowatt & Renardet	Peak Acceleration	0.50g (MDE) 0.30g (OBE)	-	-	-	-
	Design Accelerration	-	-	-	-	-

NOTE:
According to the guidelines of the ICOLD (International Committee on Large Dams);
For the MDE (Maximum Design Earthquake) a total failure of the structure has to be avoided, however major damage is accepted. For the OBE (Operating Basis Earthquake) minor damage may occur, but all major equipment has to remain operational.

Table D4.1 Quality of Water Sampled from Kaliwa Hot Spring

Item	Units	Phil. National Std for Drinking Water (1993)	MWSP III Study (1982) sampled from Kaliwa River		JICA Study (2001) sampled from Kaliwa Hot Spring
			1978 - 79	1981	2001
pH		6.5-8.5	8	8	8.5
Taste		Unobjectionable			bland
Color	TCU	5	10	48	5
Odor		Unobjectionable			nil
Turbidity	NTU	5	10	34	4.20
Alkalinity $CaCo_3$	mg/L		143	149	100.00
Bicarbonates (HCO_3)	mg/L				80
Acidity (CaCo3)	mg/L				nil
Free Carbon Dioxide (CO_2)	mg/L				nil
Hardness ($CaCo_3$)	mg/L	300 (CaCo3)	107	175	116.5(T), 104.00(Ca),
Chlorides	mg/L	250	4.4	3	87.4
Calcium	mg/L		42	-	41.7
Sulfates	mg/L	250	6	-	214.2
Iron	mg/L	1	0.25	1.3	0.05
Ammonia NH_3	mg/L		0.15	-	
Oxygen consumed	mg/L		0.9	-	
Magnesium	mg/L				3
Fluoride	mg/L	1			0.381
P - Alkalanity	mg/L				10
Residual Chlorine	mg/L				-
Conductivity	ms/cm				0.793

Figures

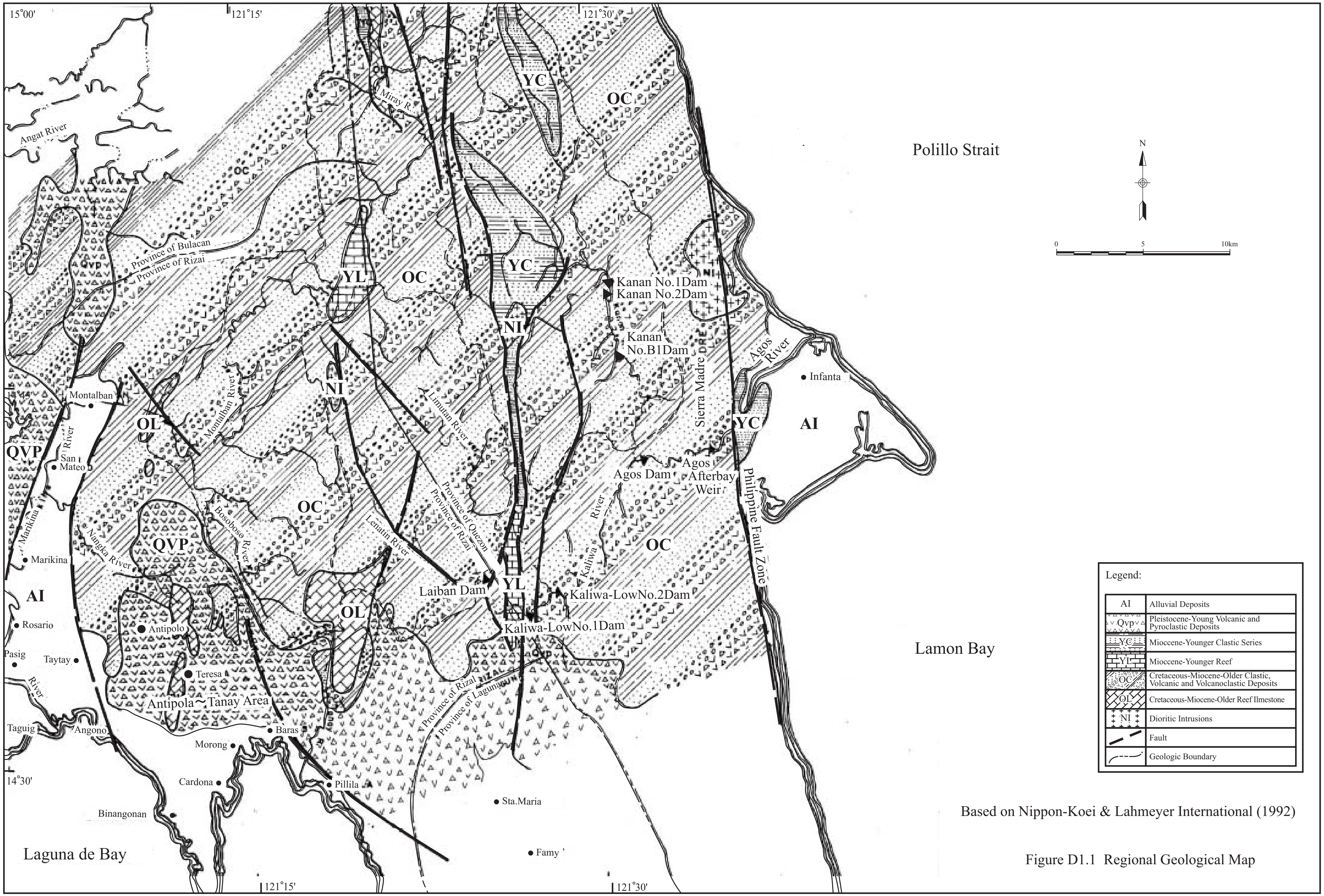
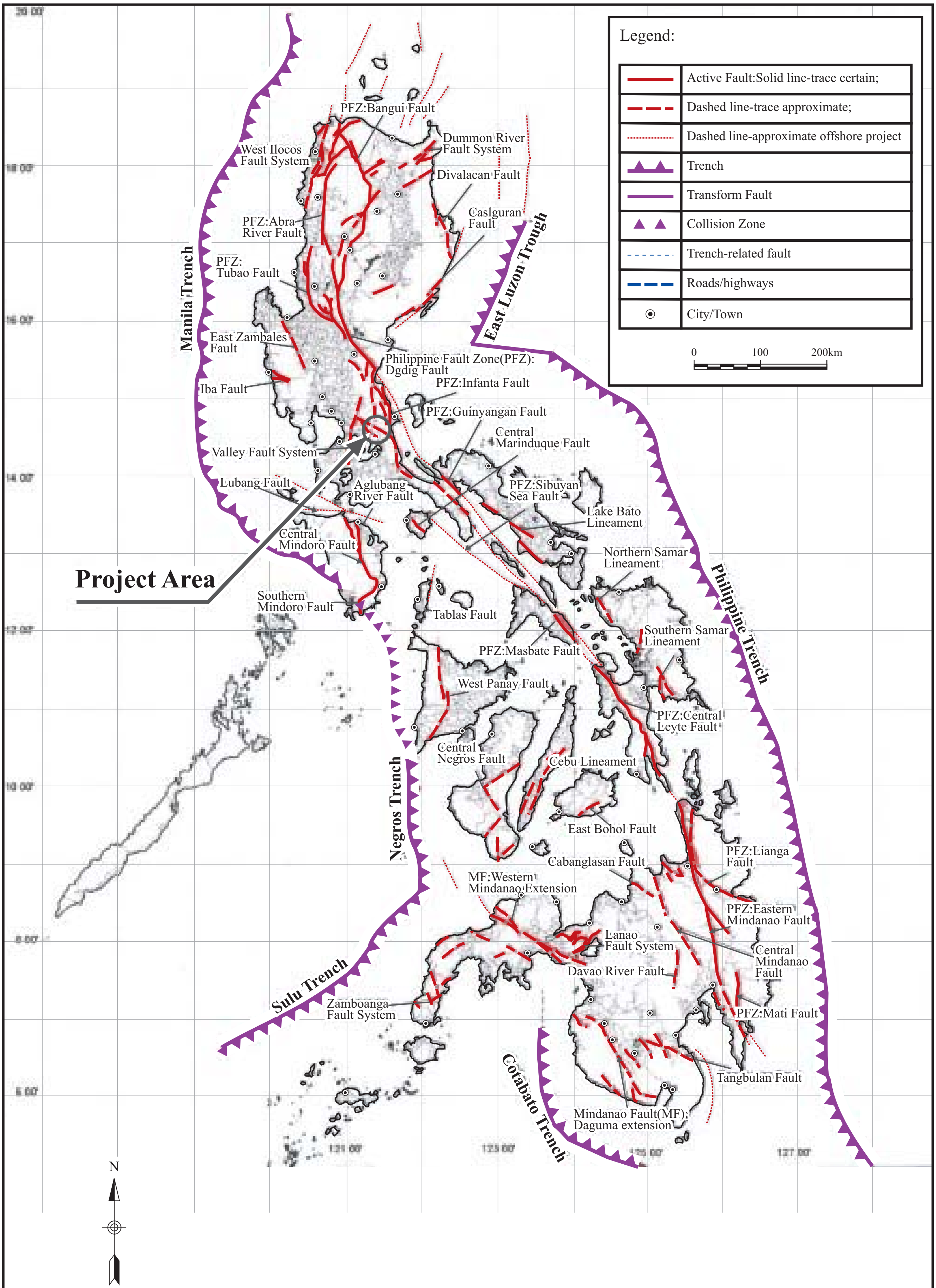
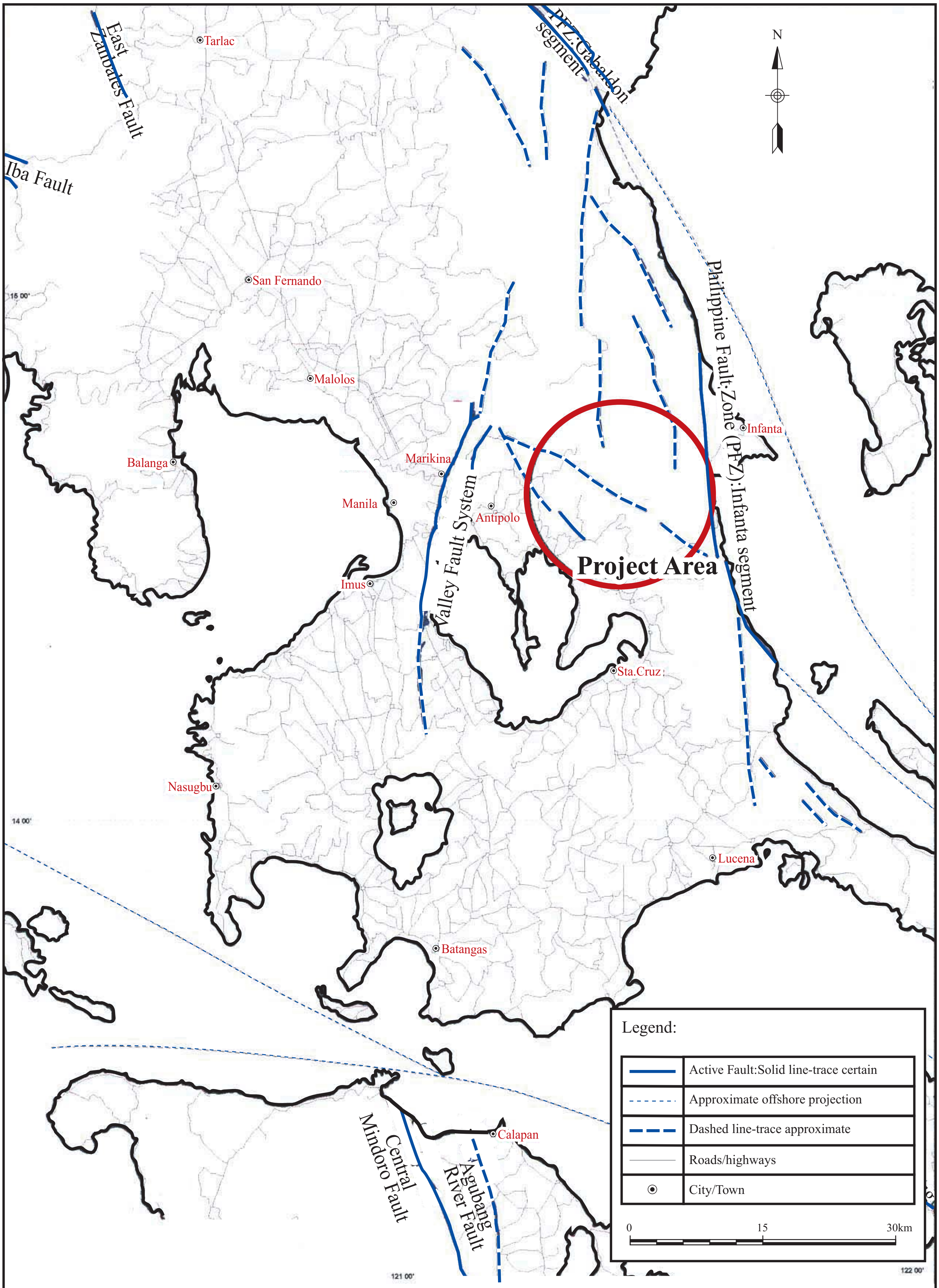


Figure D1.1 Regional Geological Map



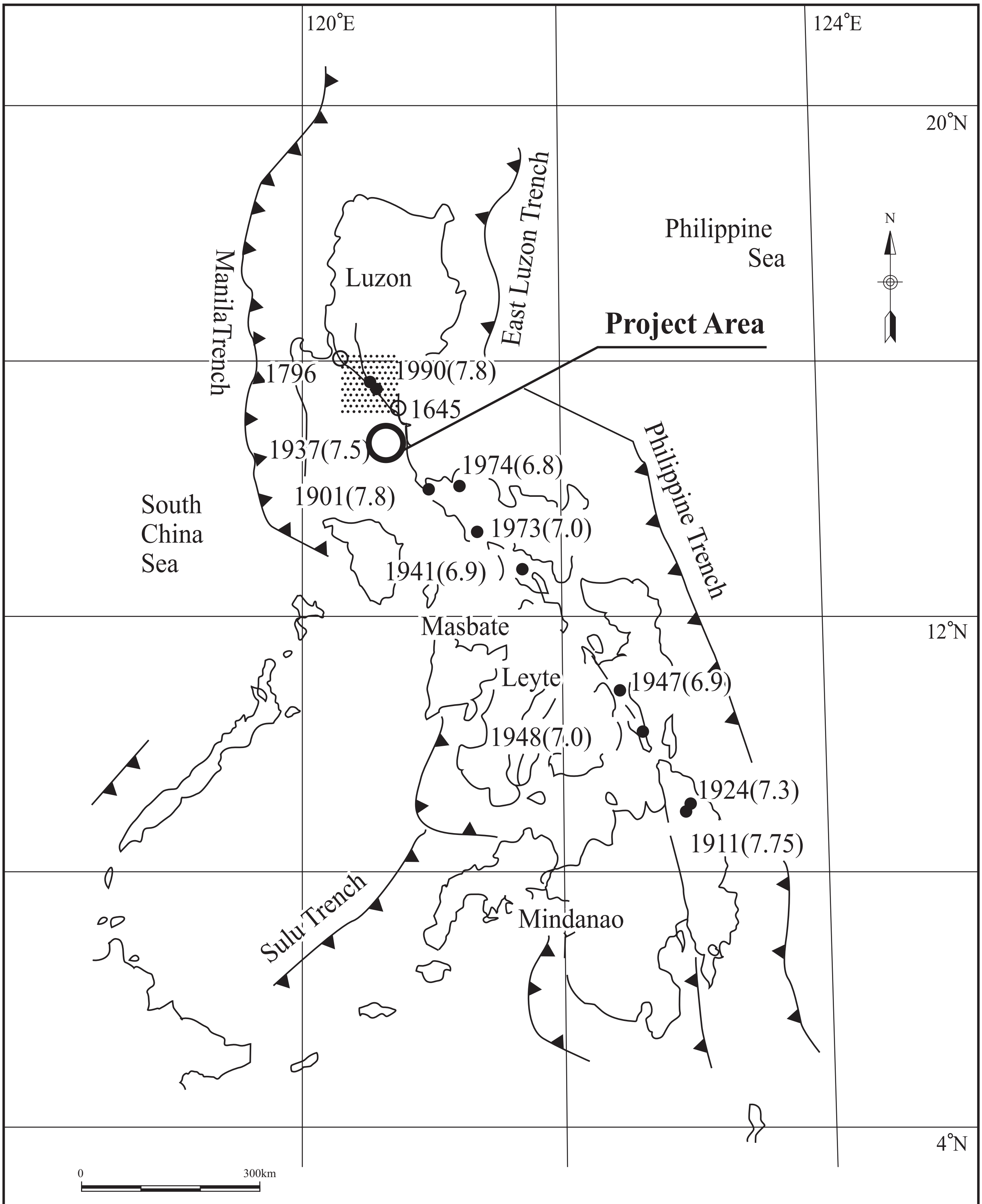
Source: PHILVOLCS (2000)

Figure D2.1
Distribution of Active Faults and Trenches in Philippines



By PHILVOLCS (2000)

Figure D2.2
Distribution of Active Faults in Southern Luzon



Epicenters of the 1990 Luzon Earthquake and locations of the large earthquakes along the Philippine Fault in this

Source: Nakata et.al (1996)

Figure D2.3
Large Earthquakes Along the Philippine Fault (1901-1990)