B-1 CONDITIONS OF WATER SOURCES

For the 2nd Phase of the Study, the Study Team conducted field surveys from mid-October to the end of November 2000. This field surveys and investigations were necessary due to the unavailability of historical data or reliable records on flows of the water sources. The survey focused on the following:

- Measurement of flow on rivers and springs.
- Observation of natural conditions in the catchment area of each water source.
- Interview with the local residents living near the intake sites.

The method used in Item 1 was the measurement of flow using bucket and stopwatch. For large flows, the digital current meter was used. The results were recorded together with EC (Electric Conductivity) and Temperature measured at site and shown in **Table B-1.1**

Item 2 was carried out in order to get more information on the characteristics of the catchment areas that may affect specific runoff. This investigation included vegetation and human activity. On-site observations were made and the results were recorded with geological information gathered. An evaluation of the catchments was made based on the data and the results shown in **Table B-1.3.**

Item 3 was conducted for the purpose of gathering complementary data on flow condition at each intake so that the minimum discharge in the dry season can be estimated. When the Study Team conducted flow measurement in places where rain had started to occur, interviews with local people were made to obtain information on the discharge during the dry season. In other places, the Study Team assumed that the measured discharges were the minimum one and the interviews were made as a confirmation.

The following are the study results from both field survey and from the analysis of existing data and they are shown by town/city.. The outline of the water sources covered by the Study is presented in **Table B-1.2** and their locations are shown in **Figure B-1.1 to B-1.19.** Groundwater sources are discussed separately in more detail in Chapter B-3

B-1.1 Dili

a.) Bemos

This river is the largest tributary of the Comoro River, which flows into the sea in the west of the city of Dili. The catchment has an area of 30.3 km^2 and collects first drops of water further from the east (over 8 km in distance).

Catchment Characteristics & Flow Conditions

The physiological feature of the catchment areas and the geological condition of the intake sites are interrelated. Black slate and phyllite are dominant and thin beds of fine sandstone can be observed from these rocks. These rocks belong to the Aileu formation. It shows tight folding in some outcrops and quartz vein along the cleavage. These features are common among the deformed rocks.

The type of surface vegetation varies principally depending on the altitude reflecting a change in climate and a change in intensity of human activity. Thick forests are limited to small areas on the left bank of the upper reach. Other parts are covered with a mosaic of grassland, bushland and thin forest.

There are two small communities on the northern edge of the catchment and many houses on the southern boundary. All these communities and houses are related to the main road to Aileu that traces the mountain ridge.

The flow measurement was carried out twice in the stream about 10 m above the intake. The first measurement gave a flow rate of 262 liter/s and the second 302 liter/s. An interview with WSS technicians who regularly make site inspections, revealed that the flow gradually begin to increase with a start of the rainy season, usually from beginning of November. In this sense, the measured flow rate may not represent the minimum flow of dry season. Thus the minimum flow rate in dry season was estimated to be 70% of the measured flow rate. They also mentioned that the last two years were a little drier than usual years and that no remarkable change was observed during the dry season (June to October) once the water level dropped. It was said that normal water level of the river is doubled in rainy season.

b.) Bemori

The intake has a smallest catchment area of 1.49 km^2. It forms part of the tributary (major tributary) to River Benamauk, where the two join together at the point one kilometer from the river mouth.

Catchment Characteristics and Flow Condition

The geological characteristic of Bemori is similar to that of Bemos. The type of surface vegetation varies principally depending on the altitude reflecting a change in climate and a change in intensity of human activity. The catchment is covered only with a mosaic of grassland, bushland and thin forest except for its uppermost part, which is covered with farms or short grass.

There are about a dozen communities on the southern edge of the catchment along the main road to Aileu.

Flow measurement was carried out twice in the stream about 5 m above the intake. The first measurement gave a flow rate of 31 liter/s and the second 27 liter/s. An interview with WSS technicians who regularly makes site inspections revealed that the flow gradually begin to increase with a start of raining, usually from beginning of November. In this sense, the measured flow rate may not represent the minimum flow of dry season. Thus the minimum flow rate in dry season was estimated to be 20 liter/s (70% of the measured flow rate). They also mentioned that the last two years were a little drier than usual years.

c.) Benamauk

The intake has a catchment area of 7.6 km^2. It is an only major tributary of the River Bemori and the two joins at the point one kilometer from the river mouth. The stream collects many small streams running down steep mountain slopes.

Catchment Characteristics and Flow Conditions

The geological characteristic of Benemauk River is similar to that of Bemos.The type of surface vegetation varies principally depending on the altitude reflecting a change in climate and a change in intensity of human activity. The catchment is covered only with a mosaic of grassland, bushland and thin forest except for its uppermost part, which is covered with farms or short grass.

There are a few communities in the catchment area and a paved road to Aileu passes on its southern edge.

The flow measurement was carried out twice in the stream about 5 m above the intake. The first measurement gave a flow rate of 40 liter/s and the second 50 liter/s. An interview with WSS technicians who regularly make site inspection revealed that the flow gradually begin to increase with a start of raining, usually from beginning of November. In this sense, the measured flow rate may not represent the minimum flow of dry season. Thus the minimum flow rate in dry season was estimated to be 32 liter/s (70% of the measured flow rate). They mentioned that the last two years were a little drier than usual years and that the stream water is least in October among the dry moths (June to Octover).

d.) Maloa River

The Maloa River is one of the major rivers which flows directly into the sea in Dili. The rive has a large sand-trap dam in its middle reach. There is a thick sediment on the riverbank and the stream cuts deep through the sediment below the dam. The intake collects water from two smaller streams that join 30 m upstream. The water is gathered from a small catchment area of 3.03 km^2.

Catchment Characteristics and Flow Conditions

The geological condition of the catchment should be quite similar to those of other catchments in Dili. This is because of uniform lithology of the Aileu formation. The outcrops observed on the right bank of the intake had clear planner cleavage and it strikes N50W and dips almost 90.

There are a few small communities at the top slope of the catchment and a car road passes through the communities. The catchment is partly covered with thick forest and the other parts are grass land with scattered trees of medium to small size. As generally observed in the mountainous outskirts of Dili, people damage the natural environment by felling trees and setting fire on bushes/grassland. As a result topsoil is exposed and washed off in heavy rains in some parts.

The flow measurement was carried out at the concrete chamber into which the water collected through the intake was flowing. The measurement gave a flow rate of 13 liter/s. An interview with the local farmers revealed that the flow was almost double compared with that of driest season. Thus the minimum flow rate in dry season was estimated to be 7 liter/s.

e.) Comoro Wells

There are five existing wells in the alluvial plain of the Comoro River: Comoro A to D. Two of the Comoro wells, A and D are working with enough yield for civic use. Comoro B and E are used for the military. The catchment area is 207.32 km^2. Neither rehabilitation nor drilling of new wells is considered necessary.

f.) Kuluhun and Bidau Wells

There are four existing wells in central Dili; Kuluhun A and B, Bidau 1 and 2. The total catchment area for the wells is 34.34 km^2. Among the four wells, Bidau 1 was selected for rehabilitation. According to the rehabilitation plan, a new well will be drilled if the rehabilitation works is not successful.

g.) Hera Wells

There are three existing wells in Hera area of eastern Dili; Hera A to C. All the wells were out of operation and selected for rehabilitation. The total catchment area is 50.83 km^2.

B-1.2 Atauro

a.) Mota Eklai

The water sources are located in a tiny branch stream of a small stream, which flows into the sea at the southern edge of the village of Vila. The water sources have a catchment area of 0.11 km^2.

Catchment Characteristics and Flow Conditions

The geology of the catchment area is volcaniclastic rocks of the Atauro formation. Downstream, rocks of volcanic conglomerate can be found. These rocks are boulder-size gray to black volcanic rock in pale yellow to gray tuff matrix. Upstream, the rocks are solid tuff without any volcanic boulders or pebbles. Both of the rocks found downstream and upstream are massive in appearance.

The catchment is covered with thin forest of various kinds of small to medium height trees.

There are no people living in the catchment.

The flow rate was measured at a reservoir located at an altitude of 280m. The water from the incoming pipe was measured to represent the flow rate from several small intakes upstream. It recorded a flow rater of 1 liter/s. Since it was before the first rain hit the dry ground surface of Villa, the value was taken to be the minimum in the dry season.

b.) Mota Tulai

The intake is located downstream the same stream in which Mota Eklai intake is located. It has a catchment area of 1.11 km^2 and includes that of Mota Rklai. However the water comes from springs that are not tapped by the Mota Eklai intake system.

The catchment condition is basically the same as that of Mota Eklai.

The flow measurement carried out at a reservoir tank recorded a flow rate of 2 liter/s and the value was taken for the minimum in the dry season for the same reason as Mota Eklai.

B-1.3 Manatuto

a.) Laclo River Infiltration Gallery

The Laclo River is one of the largest rivers in East Timor and has a catchment area of 1114 km^2 and its main course has a Length of 86 km. The Sumasse River is its main tributary with a catchment area of 167.2 km^2. It joins the Laclo River around 5 kilometers from the river mouth right at the place where the new infiltration gallery was installed.

Catchment Characteristics and Flow Conditions

The geology of the catchment of this large river covers principally five major geological formations of the Permian to the Tertiary. For the catchment of the Laclo, most of the area is covered by Aileu formation and Maubisse formation. For the sumase river catchment, Lolotoi formation is widely distributed in the upper reach while tertiary limestone of Aitutu formation is distributed in the lower reach. All these formations are made of well-consolidated hard rocks.

In the downstream where river is flowing on a flood plain, vegetation is scarce in both rivers. On the plateaus along the river are broad-leafed trees of small and medium height with only short growing underneath.

In the middle stream the mountain slopes are covered with a little more thicker forest consisting medium trees (mainly "Aibubu") and the small flatlands on both sides of the river are thin forest of tall trees with many small young trees underneath. The watershed mountain ridges are mostly grassland with only short grass. They are dotted with spots of forest. The forest coverage is roughly 60% for both rivers.

The catchment of the Laclo River extends deep into the mountainous inland of Timor Island. There are about five large settlements along the river downstream and clusters of smaller communities near the western watershed. Since the former settlements have larger population and sit closer to the intake, they may bring about more serious impacts on the water quality.

In the catchment of the Sumasse River, there are three small communities and one small town (Laclubar) upstream the catchment. Although these settlements are more than 10 kilometers away from the intake site and there is no eminent danger of water contamination, continuation of intensive farming will probably damage already poor vegetation.

Flow measurements were conducted at about 100 meters downstream the infiltration gallery. There were two major streams and a few tiny ones and the latter was omitted. The stream on the right bank side had a discharge of 3056 liter/s and the one close to the left bank recorded a discharge of 4840 liter/s. Both waters were muddy and yellowish.

Interview with the local people in the community of Krias (Sumasse upstream) revealed that rain had already started at the end of October. Another interview in Manatuto indicated that the river water is less and clear through August to October and the flow was about half the measured one. Apparently the water was turbid and perhaps doubled in discharge rate due to the rain upstream.
In rainy season when intensive rain continues, the flow is said to cover the whole river course with a maximum depth of about 2meters. Floods recede usually in a few hours once the rain stops in the catchment.

b.) Manatuto Spring

The spring (or undercurrent) comes from a tiny tributary of the Laclo River with a catchment area of only 2.43 km^2.

Catchment Characteristics and Flow Conditions

The geology of the site where the intake is located appears to be older river deposit composed of sand and silt with some pebbles and gravel. On the other hand, the rocks found in the catchment area are well-bedded calcareous mudstone and mudstone of the Aitutu formation. The bedding strikes N 15^o E and dips 40^o W at an outcrop.

The catchment is covered with only thin forest of medium height trees (mostly “aibubu”) with short grass underneath and some bamboo were observed along dry streams. However, around the intake, there is a thick forest of consisting of tall trees of various kinds including bamboo and coniferous trees.

There is no community or no permanent human activity except for the paved road crossing the upper reach of the catchment. There is not much traffic in the road.

Flow measurement was conducted at the stream flowing beside the intake tank. The measured discharge was 116 liter/s. The water was clear in spite of the turbid water in the main stream of the Sumasse. A local guide said the measured flow is as little as the one in the dry season. However, considering the fact that slight rain had already started in Manatuto the flow rate of the stream in the dry season should be a little less than the measured one.

The advantage of this small stream, as the guide said, is that it never becomes turbid. This is probably due to the fact that there is no human activity and that it runs through a flat plain with rich vegetation.

B-1.4 Baucau

a.) Wailia Spring

Since the topographycally determined catchment of Uailia spring is within the distribution area of Baucau limestone of the Quartnery, no river system is recognizable on the surface. The water is rather conveyed through underground channels formed in the limestone. Therefore, in this case, the above-mentioned catchment doesn't necessarily mean the actual catchment through which the spring collects water.

Catchment Characteristics and Flow Conditions

The reef limestone of Baucau formation is the dominant aquifer in the area. The limestone is white to pale yellow in fresh surface and contains a lot of fossils. It looks massive in outcrop but generally consists of accumulation of shells and corals with relatively weak cement. This characteristic of the formation exhibits high porosity. The surface water catchment area of Baucau is 40.6 km^2, however the aquifer from where the spring source originates may extends to the limestone area covering 256 km^2.

The surface of the plateau is covered mainly with grasses and bushes. Forests are seen only in some parts and its distribution is quite limited.

Large-scale settlements are located on the fringe of the limestone plateau especially along the main road to Viqueque. Although there are number of communities on the edge of the plateau, there is none in the catchment. The flatland on the plateau is mostly abandoned grassland presumably due to rocky surface. No large farmland is observed. Probably only possible contamination source is the airport located near the center of the plateau. However, this is in case of an accident, which involves a fuel leak.

Local contamination of water could occur because of the existence of many houses around the spring especially on the upper side of the slope.

Flow measurements were conducted at four points around the pump station in the town. One was done from the steel pipes coming into the intake pond and another in the overflow channel at the outlet of the pump station. Flow measurement was also conducted at the transmission channel close to the entrance of the pump station, while the other at the water park right next to the pump station. However, the last two measurements are not on the water source for the town's water supply. The results are shown in the table below.

Location of Measurement	Discharge (L/s)	Remarks
Pipes in the intake pond	22	From two steel pipes
Overflow pipe of the pump station	40	In the overflow channel
Transmission channel	240	In a concrete channel

Water park	25	

The water in the transmission channel come from another spring about 50 m across the road while other waters seem to come from the springs close to each other and at a similar topographical level. It is quite difficult to specify each point spring and measure its discharge. For that reason, the production rate of the springs from which water is pumped up for distribution was estimated as a sum of over flow and pumping rate at the time of measurement. If we suppose the pumping rate is 15 L/s (maximum pump capacity is 25 L/s) the total production rate of the springs will be 55 L/s.

According to the interview with the UNTAET employee who works in the pump station, during the dry season (usually form the mid August to Mid October) they can sense a rapid water decrease in the collection chamber when pump is working. This statement indicates that the flow rate is a little less in the dry season although it never dries up. He also mentioned that the water is always clear.

The interview with the employee revealed that the spring located across the road from the pump station used to dry up in dry season from 1981 to 1990. This was because, as he says, some residents living near the airport diverted the underground flow by clogging a channel with palm tree fibers in order to get more water in the community.

B-1.5 Los Palos

a.) Papapa Spring

Papapa spring originates from the water collected throughout the limestone plateau to the west of the spring. Unlike other sources, there is no apparent stream in the catchment area. Potential strems seem to flow underground through subsurface channels formed in the limestone formation. However in some places, especially in the vicinity of the spring some small streams appear on the land surface and the pond at the intake site. These small streams are considered to bring about turbid water in rainy season because they wash out soil from the surrounding farmland into the pond in heavy rain.

Catchment Characteristics and Flow Conditions

Although no outcrop was observed in the vicinity of the intake site, it is assumed that the geological formation of the catchment area including the intake site belongs to the Baucau formation. Similar to the one observed in Baucau, the rock of this origin is more porous and has high porosity than any other limestone in the country. However some difference can be recognized between the topographic features of the two limestone plateaus. While the one in Baucau has rocky surface on rather flat topography, the one in Los Palos has a smooth surface with few rock protruding from the ground and the topographyically it has a wavy surface with a lot of hummocks. The catchment area for the surface water is estimated at 21.3 km^2 but the aquifer is interconnected and widely distributed in the area.

The catchment area is a flat land and mostly used as pasture by local farmers. In the east the land is covered with bushes with medium height trees scattered around. In the west almost all the land is covered with only short grass and trees are few and far between. Forest is observed only in a southern portion of the catchment.

There are two small communities in the catchment, namely: one in the middle stream and the other in the upstream. The people mostly engage in farming and animal breeding. They keep many buffaloes in the grassland and pigs in their back yard. The animal droppings can contaminate not only the water sources in the communities but also Papapa spring considering the geological conditions in the catchment.

Outgoing flows from the spring were measured at both weirs and also in channels downstream of one weir. The discharge recorded at the weir on the north is 17 liter/s and the discharges in the two channels are 54 and 28 liter/s. The total discharge from the spring is therefore 99 liter/s.

According to a local UNTAET water supply officer, the flow rate is almost as same as the minimum discharge throughout the dry season which usually starts at the beginning of August and ends at the end of October in Lospalos. The water level is said to significantly increase only when it starts heavily in January and the water overflows the weir top.. However, when the study team visited the site in March the water level was just as high as the one observed this time. Therefore increase in water level probably occurs only when rain continues for a few days or more.

Like many other intakes this water source has a problem of turbid water. Usually spring water from limestone caves and cracks is never cloudy. The reason that the water of Papapa spring becomes muddy is the water source is the mixture of actual spring water and the water from nearby surface streams.

B-1.6 Viqueque

a.) Builua (Loihunu) Spring

Builua spring in Viqueque springs out at the foot of a steep limestone cliff and geographically does not have a meaningful catchment area.

Catchment Characteristics and Flow Conditions

The type of rock observed at the site of the source is hard yellowish limestone while the rock exposed along the road cutting is reddish shale that crumbles easily and looks eroded from the outcrop. On the terrace around the springs many rock fragments of yellowish white calcarious siltstone containing abundant fossil of small pipe shape. These rocks are reported to belong to the Bobonaro formation, which seems to exhibit an enigmatic lithology. In the catchment area, there is a huge mass of limestone of Cablac formation. It is presumably bounded by a fault at the southern end. This geological condition seems to be closely related to the occurrence of the springs in the area. Although the catchment area traced on the topographic map is 65.7 km^2, the origin of the spring or the groundwater movement appears to be hydrogeologically complicated.

The surrounding areas of the spring are used as farmland and there are many coconuts and palm and coffee trees. The catchment is cover with thick forest of medium height trees.

There are only a few families living on the mountain ridge of the catchment and they are all engaged in small sclae farming. Therefore there is no serious pollution source in the catchment. On the other hand, local people do washings and bathing in the channels only a few meters away from the intake. Although this does not affect water supplied though pipes, it could pollute water, which runs down the slope and is used by communities down stream.

Flow measurement was conducted at three points; in two streams coming from the spring on the northern side and the other channel, which collects water from two springs. The discharges recorded are 23 and 17 liter/s for the former two points and 81 liter/s for the latter. The total discharge rate of the spring is therefore 121 liter/s.

According to the interview with farmers living near the spring, the water is least in November and December with its water level a few centimeters below that of October and it start increasing in January with the beginning of heavy rain. Therefore the measured flow rate is considered to be the annual minimum rate. He also mentioned that the water is always clear.

Since the dry season in Viqueque in terms of rainfall is through August to October, there is an apparent delay in the start of flow increase. The fact indicates that the spring water travels relatively slowly without being affected by the surface water or rainfall.

B-1.7 Same

a.) Carbulau Stream

The stream is one of the small tributaries of the River Coinaka that eventually joins at about 400m downstream. Like the other two sources, the stream originates from somewhere on steep mountain foot of the Cablaki mountains as a spring. The upper reach of the stream is so steep that the river course is covered with many limestone boulders.

Catchment Characteristics and Flow Conditions

An outcrop of pale yellow limestone was found on the right bank of the stream. The rocks in the river are pale gray, fine-grained dolomitic limestone and boulders of the same type of limestone as found in the outcrop. The observation seems to contradict to the geological map.

There are thin forests of various kinds of trees surrounding the intake. Rather thick forests are seen only in the middle reach and steep slope of the mountain where the upper reach is covered mostly with grass.

There are no settlements in the cachment but perhaps some traces of soil cultivation are seen around the area.

Since there was no surface flow observed and waters are coming in the intake from under the pile of boulders, flow measurement was conducted at a notched weir (one close to the fence) of the intake facility and also at a small over flowing stream from the concrete frame. It recorded a total of 20 liter/s. An UNTAET water supply officer said that the water in the facility was less and no over flow from the weir was observed in early October. Another interview with a bcal farmer suggested that the water is usually about half the observed one. Therefore the estimated minimum discharge was taken to be 10 liter/s.

In rainy season the flow rate is said to double and always clear. The study team observed abundant water overflowing the concrete frame of the facility and a large flow in the stream in March. It was about an hour after a strong rain started, the water was clear.

b.) Kotalala

The intake is located between two large streams of the River Uelala which probably branches off temporarily and joins right downstream. The intake collects two smaller streams with a circular concrete intake weir.
The river originates somewhere from the steep middle slope of the Cablaki Mountains (2483m at the highest summit) and runs down toward SE and joins its tributary, the River Ermelin to the north of the town of Same. The catchment is enclosed by rather high mountain ridges (over 1000m) forming a typical catchment basin with its outlet at the site of the intake. The river has rather gentle gradient up to a few kilometers upstream and around the intake. This is perhaps the surface of small-scale debris fans formed by the surrounding streams. Around the intake a small-scale braided-stream system is observed on top of the fan. The intake collects water from two of those small streams.

An outcrop was observed on the right bank of the large stream flowing close to the intake, at a foot of a steep slope. It was made of serpentizied page green rock and sheared black mudstone. The former is probably metamorphosed ultrabasic rock of Lolotoi formation. Many large limestone blocks are found on the ground beside the road.

Most of the catchmet is covered with thick forest consisting of medium height and tall trees except the mountain ridges that are usually cover with grass and rocks. On the right bank downstream of the catchment, the forests are less dense.

There is only a tiny settlement in the flat land of the left bank in the catchment and they are engaged in a small-scale farming.

Flow rate was measured at two inlets of the intake weir and they recorded 11.5 liter/s and 12 liter/s. One of the branched main streams beside the intake recorded a flow rate of 409 liter/s and the other one beside the road had a flow rate of 697 liter/s. Altogether the river had a flow rate of 1130 liter/s. An interview with a local farmer revealed that the rain had started more than three weeks before and the flows in the streams had significantly increased. He also said that the minimum flow in dry season (mid July to mid October) is a quarter of the one observed and that the water in large streams gets muddy only from time to time in rainy season.

Because of its peculiar topography the rain falling within the catchment quickly runs down the slope and get into the stream causing a rapid rise in its water level. The reason why the water doesn't get seriously muddy is that there is rich forest coverage and the existence of pure limestone.

c.) Merbute Spring

The spring is the source of a small tributary to the River Uelala. It is also situated on a small debris fan with a braided channel system on the surface. The spring is probably and originated from an under current of one of those streams.

Catchment Characteristics and Flow Conditions

The rocks found around the two above-mentioned water sources are calcareous mudstone. These are gray, fine-grained and very hard in structure. This type of rock including that found in the Carbulau catchment area has far less porosity than the ordinary limestones but still subject to chemical weathering. However, it is likely that these rocks are of debris deposits that have come from the mountains.

The catchment is covered with thick forests of tall and medium height trees at the lower part and thin forest of medium height trees at higher part.

There is no communities or farms in the area.

Since it was difficult to measure the discharge right at the spring, a stream seeping out from a side of the intake tank was measured. The stream is considered to be an overflow from the tank. It recorded about 3 liter/s of flow rate. The actual production rate of the spring may be a little more than this value, probably by one to two liters per second because some water was being transmitted through pipes.

There are two surface streams observed close to the intake; one just beside the intake tank and the other at 10 or 15meters away from the tank on the same side as the former stream. They had a flow rate of 4.5 liter/s and 11 liter/s respectively.

No information was obtained from the local people about this spring. However, in consideration of flow conditions of the other sources and hydrogeological conditions of the area. The flow rate in dry season is expected to drop to a half.

B-1.8 Ainaro

a.) Sarai River

The River Sarai collects water from steep slopes deep in the Lamerau mountain range. The low temperature of the water at 17.5^{o}C taken in April 2000 may indicate that the water flows out from the mountain originally as a spring.

There mountains form a round watershed on the northwest and many small streams meet in its center forming the Sarai River and it quickly flows down toward SE.

Catchment Characteristics and Flow Conditions

The geology of the catchment area including the intake point is dominantly limestone of Aitutu formation. The limestone is gray, hard and thickly bedded. It is mostly fine-grained and contains chert modules in some parts. The bedding observed at the right bank strikes N 35^o W and dips 50^o E. This limestone is also exposed on the flat plain where the reservoirs are located. However, it does not show a typical karstic topography.

Most of the catchment is covered with forest although thick forests are limited to the eastern part of the catchment. In some parts, higher up on the right bank of the River Sarai are grasslands.

There is no community and little human activity within the catchment.

Flow rate measurement was carried out at the transmission channel at the intake weir. It recorded a flow rate of 147 liter/s. Another measurement was done about 100m downstream in the main stream of the Sarai where the measured flow rate was 983 liter/s. The combined discharge is therefore 1130 liter/s.

Interviews with a water supply technician working at the site and with a local farmer revealed that the rain had already started 20 days earlier and the flow had significantly increased at the time of measurement. The water level at the intake weir turned out to be slightly higher than the one observed by the study team in March (rainy season). This is probably due to the rain, which had started a few hours earlier. The interviewees also told that at the end of the dry season, the stream in the Sarai River is remarkably small because most of the water is diverted to the transmission channel at the intake. The water is said to become turbid but usually clears away in a few hours.

B-1.9 Aileu

a.) Mantane River Infiltration Gallery

The River Mantane is one of the major tributaries of the River Monofonihun that flows meandering toward the east and finally joins the Laclo River. It has a catchment area of 62.8 km^2 and the main river course is about 15 km long.

Catchment Characteristics and Flow Conditions

Pale yellowish white silty alluvial terrace deposits were also observed at the bank of the river.

Most of the catchment is covered with thin forest or with grass/ bush land with medium height trees/spots of trees scattered. Thick forests are limited only to the southern most part and on the left bank midstream the catchment to the west of the village of Bandeirahun.

There is a small village of Bandeirahun about five kilometers up the river where it branches out. The upper reach is far less inhabited and there is no community.

Flow measurement was conducted twice: one in late October and the other in early November. The fist one was conducted at 60m upstream from the bridge and recorded a flow rate of 370 liter/s. The 2nd one was made about 50m downstream from the bridge and recorded a flow rate of 864 liter/s. The first one was conducted at the end of the dry season and the value was considered to be the minimum.

b.) Sloi Kraik

The intake is located upstream the Nunupung River that is a small the Kusiam River which its self eventually flows into the Mantane River to the south of the town of Aileu.

Catchment Characteristics and Flow Conditions

The rocks exposed around the intake are weak-metamorphosed fine sandstone to mudstone. The mudsone is rather philitic in appearance. These rocks are pale gray and no strong deformation was observed. The bed strikes at EW and dips 50 north.

The catchment is covered with mostly thin forest of tall trees of various kinds.

There is no houses or farm in the catchment.

Flow measurement was conducted at the intake weir by a small stream off the intake. The flow rate recorded was 4 liter/s. According to the interview, the two streams coming into the intake had roughly half the observed flow in the dry season.

c.) Naufaisaran Spring

The spring is located at the uppermost part of the Kusiam River, which joins the Mainfonihun River around the town of Aileu. Its catchment area is as small as 0.13 km^2 with the Tiumiri Mountain at its top.

Catchment Characteristics and Flow Conditions

The rocks exposed around the intake are weak-metamorphosed mudstone some with clear cleavage. The mudstone is rather philitic in appearance. The bed strikes EW to N50W and dips in both directions.

All the catchment is covered with thin forest of tall trees of “Aibubu” variety with only short grass growing underneath.

Though there are no houses or farm in the catchment, people seem to collect firewood and cut down trees.

Incoming flow was measured inside the concrete housing. The flow rate recorded was 1.2 liter/s. According to the interview, the water coming into the intake was just as much as the one usually observed in dry season. In rainy season the intake tank is said to be full and the water overflows from it.

d.) Hularema Stream

The source is the uppermost part of the Ermetlaran River that is one of the minor tributaries of the Kusiam River.

Catchment Characteristics and Flow Conditions

The rocks exposed at the base of the intake structure are silicious mudstone and philitic mudstone. These rocks are dark gray and no strong deformation was observed. The bed strikes NS and dips 45W. This rock belongs to the Aileu formation.

Most of the catchment is covered with thin forest of tall trees. The soil is exposed in a part at the top and tees are less dense on the ridge.

Though there are no houses people do farming in the catchment,

Flow measurement was conducted at the intake and recorded a flow rate of 0.5 liter/s. An interview with a local farmer indicated that the flow was almost the same as the one usually observed in dry season.

B-1.10 Maubisse

a.) Raikuak Ulun

The spring is located beside one of the tiny branch streams of the Tereral River.

Catchment Characteristics and Flow Conditions

The outcrop in the stream around the intake is slightly metamorphosed greenish gray mudstone. Some large boulders of limestone and limestone conglomerate are found on the slope. The top soil has a peculiar color of reddish brown, which is probably caused by the existence of limestone and volcaniclastic rocks.

Generally the vegetation in the catchment areas of the town’s water sources is poor with only short grass covering the surface. Spots of tall trees are only seen along some streams or in depressions on the slopes. Soil is exposed in some parts.

Although there are no houses within the catchment, the flat land right above the intake is used as a farmland.

The water coming out of a short open-end pipe was measured and recorded a flow rate of 0.3 liter/s. Another member of the study team reported that water coming into a reservoir tank downstream had slightly less flow than the one from the pipe at the intake. Considering the loss during the transmission, the production rate of the spring can be estimated at 0.6 liter/s. The stream beside the intake had a flow rate of 0.9 liter/s. If the stream is combined, the total discharge from this water source is 1.5 liter/s.
The spring water is said to be never cloudy. When the study team visited the site in the rainy season, water was flowing out of the tank and the pipes. This indicates that the flow rate drastically increase in rainy season.

b.) Bucana Spring

The spring is located on a gentle slope Between the two branch streams of the Sara River which joins the River Colihuno to the south of the town. The catchment area was defined in consideration of nature of the spring. Topographical catchment would be far smaller.

Catchment Characteristics and Flow Conditions

The outcrop around the intake is gray shale with unclear planner cleavage. The observed outcrop strikes EW and dips steeply N or S.

The condition is quite similar to the one of Raikuak Ulun. There is a spot of forest of tall coniferous trees and coffee trees right above the intake.

There are few houses near the spring in the catchment where the surrounding flat lands are used as farmlands.

The flow rate was measured at the end of the pipe sticking out from the intake stone wall and also at the incoming pipe end inside the intake tank. The flow rates were 0.4 and 1.6 liter/s respectively. The total production rate of the spring is therefore 2 liter/s. An UNTAET water supply officer said the flow rate was little different than the one in dry season. The pictures taken earlier by another study team member bore it out.

This spring may be a product of peculiar geological setting of the area. The upper part of the catchments of Maubisse water sources is geologically made up of Limestone and volcaniclastic rocks with many limestone fragments. On the other hand the lower part of the catchments is mainly made up of black shale and siltstone. The spring is situated right between them. According to the geological map of the formation of limestone and volcaniclastic thrust over the latter formation. This means that the interface of the two formations is close to horizontal. It is suspected that the water collected through the limestone formation encounters far less permeable formation of mudstone and seeps out on ground surface.

c.) Filmou Spring

The water seeps out from a steep slope upstream of the Bederi River that joins the Colifuno River to the south of the town.

Catchment Characteristics and Flow Conditions

The outcrop in the stream around the intake is highly weathered gray mudstone and volcanic rocks. They are found under thick cover of reddish brown subsoil.

The condition is quite similar to the one of Raikuaku Uluun. Althoug on the left bank of the stream is a spot of forest of tall coniferous trees and coffee trees around and downstream from the intake.

There is a small community about a dozen meters above the intake on the right bank of the stream. The surrounding flat lands are used as farmlands.

Flow measurement was conducted at the pipe coming into a reservoir tank about 20m downstream. The recorded flow rate was 0.2 liter/s. Two other springs located nearby; one above and the other below the intake had a flow rate of 0.1 and 0.18 liter/s respectively. Acoording to an interview while the water from the latter two sources dry up or significantly diminish in the dry season, the one from the intake always has a constant flow close to the one observed. Therefore the minimum discharge in the dry season is estimated at 0.2 liters/s.

d.) Erulu Spring

The spring is located on a terrace like flatland inside the catchment of the Bederi River. Due to its peculiar position, the spring itself doesn't have a distinct catchment. However as it is located farely close to a water line of the River Bederi on the map, the catchment was set to cover the catchment of the steam itself.

Catchment Characteristics and Flow Conditions

There is no outcrop around the intake. The existence of rock fragments of greenish gray hard fine sandstone was observed. .

The vegetation is mainly of coffee trees above the intake up to the main road. The upper part is covered with thin forest of coniferous and broad leaf trees.

There is a dozen of houses on the mid slope of the catchment. There is also a small community on the flat area on the eastern edge and on the northern edge of the catchment.

Although direct measurement of the spring water could not be done, the flow rate was estimated by the measurement at two points around the intake; one at the base of the concrete tank where a small stream was flowing out from a crack of the tank, another at the end of a broken transmission pipe about 20m away from the tank. The flow rate recorded were 0.2 liter/s for the tank and 0.15 liter/s for the pipe. There was no information on how much water was being conveyed to the town through the pipe. Therefore it was estimated to be 0.15 liter/s for no specific reason. The total production rate of the spring is, then, 0.5 liter/s. The UNTAET water supply officer (Timorese) said that the flow was at the minimum level throughout an year.

e.) Other streams

There are some streams that can be used as water source in future. Flow rate was measured in some of those streams; the Sara River, Tereral River and Ersaka River. Those rivers recorded a flow rate of 18, 26, 48 liter/s in mid November.

B-1.11 Gleno

a.) Mota Boot

The intake is located mid reach of the Mauceum River, which joins the Bura River changing its name to Goumeca and finally flows into the Gleno River to the northwest of the town of Gleno. The intake has a catchment area of 6.44 km^2. Unlike the Bura River, which also branches off from the Goumeca River, it has rather steep valley. The main stream runs close to the northern border of the catchment collecting most of the rain water from the southern part of the catchment.

Catchment Characteristics and Flow Conditions

The rocks exposed around the intake are black shale or phylite of Aileu formation.

The catchment has a rather thick forest of tall trees around the intake. However it has a little complicated vegetation pattern. Half of the catchment is covered with less dense forest, grass and farms.

There are many small houses in the catchment especially in its upper reach. The distribution of there houses corresponds to the distribution of poor vegetation. A non-paved car road runs along the river on its left bank. This may result in erosion of subsoil and contribute to turbid water.

Flow measurement was made right above the intake weir and recorded a flow rate of 1300 liter/s. The water was apparently more than usual and cloudy after a few hours of rain. An interview with a local resident near the intake indicated that the flow in dry season was a quarter of the observed one.

b.) Mota Kiik

The stream is one of the branch streams of the Mauceum River. The intake has a catchment area of 0.81 km^2. The two-kilometer main stream has no branch streams.

Catchment Characteristics and Flow Conditions

The rocks exposed around the intake are green rock and black phylitic shale of Aileu formation. The same formation is distributed within the catchment of the Mota Kiik.

The catchment has a rather thick forest of tall trees in its uppermost reach and lower most each. Less dense forests, grasslands and farms are distributed in-between.

There are no houses in the catchment.

The flow rate of the stream was measured about 50m upstream from the intake. The flow rate was 80 liter/s. The measurement was made after raining started 10 days earlier in this area and the flow rate had increased significantly. A local resident said that the flow of the river is far smaller in dry season and showed an example pointing out a nearby small stream which turned out to have a 10 liter/s of flow rate.

c.) Ergrogo Spring

The spring is located on the catchment boundary of the Mota Boot and Mota kiik at higher at 100m higher up the slope from the two intakes. Thus geographically it would have only a tiny catchment area.

Catchment Characteristics and Flow Conditions

The geological condition is same as that of Mota Boot.

The catchment is covered with rather thick forest of tall trees with coffee trees growing underneath.

There are no houses in the catchment.

The flow was measured at the point of spring and recorded a flow rate of 7 liter/s. Another stream flowing beside the tank was measured and found to have a flow rate of 3 liter/s. According to a local resident, the spring always has the constant flow throughout an year but the stream diminishes in dry season.

B-1.12 Ermera

a.) Lubulala Spring

The spring is located at the uppermost reach of one of the branch streams of the Daurecca River which joins the River Gleno to the west of the town of Gleno.It has a small catchment area of 0.064 km^2.

Catchment Characteristics and Flow Conditions

The outcrops around the intake are black to greenish gray slate.

On the slope around the intake are tall trees with broad canopy scattered around among coffee trees. There are grasslands spotted with medium height trees on the right bank of the stream and on the ridge.

There are dozen of houses around the intake but not within the catchment.

The flow was measured at the point of spring and recorded a flow rate of 0.1 liter/s. An interview with a local farmer suggested that the flow is more than the one normally observed in dry season. On the other hand, a stream flowing nearby was said to have four times as much water as in dry season.

b.) Ersoi Spring

The spring is basically situated within the same catchment of the River Daurecca as Lubulala spring. The two springs are separated only by a gentle mountain ridge running in E-W direction. It also has the same catchment area of 0.64 km^2.

Catchment Characteristics and Flow Conditions

The geology in the catchment area is mainly black slate of the Aileu formation. In this area, the slate is often accompanied by some massive green rock, phyllitic red slate and some limestone. The cleavage of the slate strikes N 30^o W and dips 46^o E at the outcrop.

On the slope around the intake are tall trees scattered around among coffee trees. There are grasslands spotted with medium height trees on the right bank of the stream and on the ridge.

There are several houses within the catchment engaged in small-scale farming.

The flow rate measured at both intakes. One on the upper side had a flow rate of 0.45 liter/s at the point of spring. The other one downstream recorded a flow rate of 0.15 liter/s. The total flow rate is 0.6 liter/s. A local guide said that the flow had the same discharge as in dry season.

c.) Mota Bura Spring

The intake is located in the upper reach of the Bura River which runs down toward the east in an open valley and joins the River Mauceum to the south of the town of Gleno.

Catchment Characteristics and Flow Conditions

The geological feature of the catchment area for this source is generally similar to the above-mentioned Ersoi. An outcrop of slate with thin beds of sandstone was observed. The cleavage for this outcrop strikes east to west and dips 40^{o} N.

On the slope above the intake are tall trees scattered around among coffee trees. There are grasslands spotted with medium height trees on the mountain ridge. The area around the intake is used as farmland.

There are several houses within the catchment engaged in small-scale farming.

Flow measurement was made at the intake. The water coming out of the intake pipe was measured and recorded a flow rate of 1 liter/s. A local guide said that the flow had the same discharge as in dry season. In rainy season, according to the guide, the water overflow the tank but it never becomes cloudy.
Another flow measurement was made after a few hours of slight rain in the main stream of the Bura River. The flow rate was 94 liter/s. The river was said to be cloudy after a few hours of rain.

B-1.13 Liquica

a.) Liquica Wells

There are total of four wells drilled in the alluvial fan of the Gularloa River; Dato 1 &2 and Maumeta 1&2. The total catchment area is 14.8 km^2. Two of them, Maumeta 1 and 2, were selected for rehabilitation and a detailed information is presented in Chapter B-4.

b.) Laclo

The intake is located upstream the only major tributary of the Laclo river which is one of the main rivers in the town of liquica. The river has a wide source up to 6 km from the sea and runs down toward the north without any meandering. The intake has a catchment area of 1.1 km^2.

Catchment Characteristics and Flow Conditions

The geology of all the catchments in Liquica area is similar due to the rather uniform lithology of the Aileu formation that is widely distributed in northwestern East Timor. It is mainly composed of black schist and phyllite with some green rock and sandstone.

The catchment is mostly covered by thick forest of trees of various kinds and size.

There are many houses on the mountain ridge. In addition people do farming or tapping water in the area around the intake.

Flow measurement was conducted about 60m upstream from the intake. The flow rate was measured to be 2.3 liter/s. Considering the fact that it had rained a few times earlier, the minimum flow rate in dry season was decided to be 2 liter/s.

c.) Lilabu

The intake is located in midstream of the Malmeloa River, which is one of the small branches of the Laclo River. The river has a length of 5.5 km and a catchment area of 0.61 km^2.

Catchment Characteristics and Flow Conditions

The geological condition of the catchment area is similar to that of other catchments in Liquica.

The catchment is mostly covered with grass or bush with sporadic to rather dense growth of various kinds of trees.

There are only a few houses on the mountain ridge in the uppermost part. A non-paved road runs across the center of the catchment. This makes the water source area accessible and people seem to use the flatland along the river course for small scale farming.

Flow measurement was conducted in the introduction channel of the intake weir. The flow rate was measured to be 2 liter/s. A local guide who works for UNTAET water supply said the flow is almost same as in the dry season. However, for the same reason as Laclo water source, the minimum flow level may be around 1.5 liter/s. In rainy season, the water level in the channel was said to be up to the top. In the valley water was observed from the point only about 500m downstream the intake.

d.) Narlolo

The intake is located upstream the Tangkmom River which runs on the western side of the Gularloa River flowing directory down into the sea. The intake has a catchment that narrows upstream with an area of 0.63 km^2. It shares a part of its western border with Lulabu intake.

Catchment Characteristics and Flow Conditions

The geological condition of the catchment area is similar to that of other catchments in Liquica.

Similar to Lilabu, the catchment is mostly covered with grass /bushes and farms specled with thin forest of trees of various kinds and size.

There are only a few houses on the upstream mountain ridge. A non-paved road cuts across the southern tip of the catchment. People seem to frequent the area around the intake. Domestic animals were observed right above the intake.

Flow measurement was conducted in the stream about 30m upstream from the intake weir. The flow rate was measured to be 0.7 liter/s. A local guide who works for UNTAET water supply said the flow is almost same as in the dry season. However, for the same reason as Laclo water source, the minimum flow level may be around 0.5 liter/s. Water was observed from the point about 100m downstream from the intake. The existence of another intake for wet season use on the dry river course indicated that the flow will increase drastically in rainy season probably by 5 to 10 times.

e.) Daulo

The broken intake is located in the midstream of the Gularloa River about 200m upstream from the confluence with the Fanaloa River. The intake has a largest catchment area of 8.23 liter/s among the water sources of Liquica. The main river course runs meandering on the northern margin of the catchment collecting most of the water from its southern side.

Catchment Characteristics and Flow Conditions

The geological condition of the catchment area is similar to that of other catchments in Liquica.

The catchment is mostly covered with thin forest of trees of various trees. Its lower part is less densely covered with tress.

There are many houses on the upstream mountain ridge.

Flow measurement was conducted at two sites in the stream around the broken intake and right below the confluence. The flow rate was found to be 10 liter/s for the former site and 15 liter/s for the latter. The difference is probably due to the existence of undercurrent at the intake site. The flow rate was therefore taken to be 15 liter/s. A local guide who works for UNTAET water supply said the flow is almost same as in the dry season. However, for the same reason as other water sources, the minimum flow level in dry season should be a little less.

f.) Eanlua

The intake is located in the stream of the Eanaloa, 100m upstream the confluence with the Gularloa River. The catchment has an area of 2.11 km^2 with its main stream running nearly straight in NW-SE direction.

Catchment Characteristics and Flow Conditions

The geological condition of the catchment area is similar to that of other catchments in Liquica.

The vegetation on the left bank of the stream and in the area around the intake is poor with mostly small trees or bushes covering the surface. Thick forests of various trees are only observed on the right bank.

There are many houses on the mountain ridge, which surrounds the catchment basin.

Flow measurement was conducted at the reservoir tank near the intake. Water from three pipes is seen coming into the tank and they recorded a total flow rate of 3.8 liter/s. A local guide who works for UNTAET water supply said the flow is almost same as in the dry season. However, for the same reason as other water sources, the minimum flow level in dry season should be a little less.

g.) Raisape

The intake was located midstream the Gularloa River. Since the facility had been all washed away by flood and there was barely a trace, detailed survey was not carried out at the site. There was a flow in the river course at the site and it seemed to have a flow rate of 5 to 6 liter/s.

h.) Metagou

The stream water of Metagou comes from uppermost reach of the Mamarai River. The river meets its main tributary at the point km from the river mouth and runs down the distance nearly straight into the sea. The intake has a catchment area of only 0.16 km^2, which is included in the catchment of the Emelaloa water source.

Catchment Characteristics and Flow Conditions

The geological condition of the catchment area is similar to that of other catchments in Liquica.

The catchment is mostly covered by thick forest of small and medium height trees of various kinds.

There are only a few houses on the mountain ridge in the upper part of the catchment.

There are two intakes in separate streams. Flow measurement was conducted at the two intakes. The upstream one had a flow rate of 0.3 liter/s and the downstream one had a flow rate of 0.2 liter/s. A local guide who works for UNTAET water supply said the flow becomes almost half the observed one in the dry season.

i.) Emilaloa

The Intake is located on the Haiunapa River (upper part of the Carbulaeloa River). The catchment area of the intake is 4.33 km^2 and the catchment includes that of Metagou.

Catchment Characteristics and Flow Conditions

The geological condition of the catchment area is similar to that of other catchments in Liquica.

The upper part of the catchment is mostly covered by rather thick forest of small and medium height trees of various kind. The lower part is mainly bush and grassland spotted with bunch of small trees.

There is a small community of Bazartete on its eastern border and a non-paved road from the community cuts across the eastern tip of the catchment.

Flow measurement was conducted at the intake and recorded a flow rate of 20 liter/s. A local guide who works for UNTAET water supply said the flow becomes almost half the observed one in the dry season.

Peculiar alteration of rocks is easily observable around the Emilalua intake and downstream. The black schist outcrop around the intake showed some degree of alteration in appearance; faded color, rounded edges. When hit, the rock crumbled easily into the mixture of rock fragment and clay. A small portion of the mountain slope on the other side of the intake seemed to have had a landslide judging from the debris piled at the site. In addition to the above, orange precipitation of iron hydroxide, probably such as limonite was clearly observed on some parts of wet river course. The river water had a strange taste. The cause of this alteration is not clear. With reagard to the rocks exposed in this area, there is nothing out of the ordinary.

B-1.14 Suai

No site survey was conducted in the following areas for safety reasons. The descriptions were based on the reports of other survey teams and existing data. It is said that there are following 6 main water sources in the town of Suai.

a.) Olivio	Stream
b.) Ameriko & Maugusu	Stream
c.) Maugusu	Spring
d.) Kuluai	Spring
e.) Sukabilaran 1	Borehole
f.) Sukabilaran 2	Borehole

The 2 wells were drilled in the southestern area of the town. The pumping rate of these wells is reported to be 6 L/s. The catchment area is estimated at 39.0 km^2. The wells are located in the early Quatanery sediments that are weekly consolidated and even gently deformed. The permeability may not be as high as that of Holocene alluvial sediment. In consideration of the small catchment area and its geology, much yield of a single well probably cannot be attained.

The surface and spring water sources make use of the water of the Karaulun river system. The 2 springs are located somewhere in midstream of two branch streams flowing southward to join the Karaulun. Inflow into each intake structure of the springs is reported to be a few liters per second.

The two intake sites for the surface water sources (Olivo, Americo) are said to be located in the tributaries of the Karaulun River flowing in the northwestern part of the catchment. This river drains the town originating from several tributaries mostly in the north and northwestern mountains of Suai towards the Timor Sea. Olivo the intake is not used at present. It has a catchment area of 2.19 km^2. The other surface water intake is said to be located in Ameriko River and has a catchment area of 3.5 km^2. Based on the information of the topographical map, there are no houses in the water resource areas. However the vegetation may not be very thick.

B-1.15 Maliana

Only a brief site survey and interviews was conducted in Maliana for safety reasons. The descriptions of the water sources included in this section were based on reports of other survey teams and existing data. As confirmed by the reports, there are six water sources for the town's water supply as follows:

a.) Beamos	Stream
b.) Beapelu	Springs
c.) Aikumu	Stream
d.) Beamos	Stream
e.) Dabucci	Springs
f.) Irrigation canal	

All the intakes are located in the upper reach of the Bulobo River, which flows northward to join the Marobo River. The Bulobo River gather many streams only from its eastern bank to the north of Maliana and forks out into several streams of similar size to the south of the town.

Dabucci and Beapelu intakes collect water from several springs. Judging from the pictures and digital video clips taken by another team, the flow rate of there intakes is no more than 0.5 liter/s. The total production rate will be perhaps around 1 liter/s. These sources have catchment area of no more than 2 km^2. None of other intakes of surface stream have larger catchments indicating limited potential of water from mountain streams.

On the other hand a digital video clip showing a river flow from which the irrigation canal extract water suggested a large flow rate of the river Sosso. It probably had a flow rate of several hundreds of liters per second although the water was quite muddy.

Geologically the area corresponds to the distribution area of the Tertiary calcareous sedimentary rocks except for the uppermost reach of the area where some igneous rocks are exposed in addition to limestone.

Traces of habitation is not shown, although it reveals poor vegetation indicating cultivation of small-scale farmland could be found around the catchment area especially at Aikumu and Beremau water sources.

Table B-1.1 Flow Rate and On-site Water Quality Measurement Data (1/2)

No.	Town		Water Source Name	Topo Label	Type		Observed Discharge (late Oct. to late Nov.)	Catchment Area	EC 1st	EC 2nd	Temp 1st	Temp 2nd	pH 1st	pH 2nd	Date 1st	Date 2nd
							(liter/sec)	(km2)	(micro S/m)		(degree C)					
1.	Dili	1	Bemos		Stream	1	282	30.3	13.6	26.4	23.3	24.1	-	-	11-Apr	17-Oct
		2	Bemori		Stream	1	29	1.49	24.4	-	24.3	-	-	-	5-Apr	-
		3	Benemauk		Stream	1	45	7.6	10.3	-	24.6	-	-	-	5-Apr	-
		4	Maloa	DIL-WS001	Stream	1	13	3.02	-	30.9	-	28.3	-	8.5	-	11-Dec
		5	Comoro A	DIL-WS005	Borehole	5	40	207.32	37.1	-	27	-	-	-	-	-
		6	Comoro B	DIL-WS002	Borehole	5	(35)		-	-	-	-	-	-	-	-
		7	Comoro C		Borehole	5	---		-	-	-	-	-	-	-	-
		8	Comoro D	DIL-WS003	Borehole	5	31		37.3	-	27	-	-	-	-	-
		9	Comoro E	DIL-WS004	Borehole	5	(20)		37.4	-	30	-	-	-	-	-
		10	Kuluhun A		Borehole	5	16	34.34	37.7	36.6	27.6	27.9	-	-	-	17-Oct
		11	Kuluhun B		Borehole	5	36		42.4	38.8	27.7	27.9	-	-	-	17-Oct
		12	Bidau 1		Borehole	5	---		-	35.5	-	28.8	-	-	-	26-Oct
		13	Bidau 2		Borehole	5	---		46.8	-	29	-	-	-	-	-
		14	Hera A		Borehole	5	---	6.87	-	-	-	-	-	-	-	-
		15	Hera B		Borehole	5	---	16.04	-	56.5	-	28.8	-	-	-	-
		16	Hera C		Borehole	5	---	27.92	-	-	-	-	-	-	-	-
2.	Atauro	1	Mota Eklai		Streams	1	1	0.103	34.1	-	17.5	-	-	-	24-Mar	-
		2	Mota Tulai		Spring	3	2	1.11	-	-	-	-	-	-	-	-
		3	Mota Lampia		Spring	1	(2)	0.704	-	-	-	-	-	-	-	-
3.	Manatuto	1	Manatuto	MAN-WS01	Spring	3	116	2.43	56.4	53	27.1	28.2	-	7.9	7-Apr	17-Nov
		2	Laclo River		River	2	7900	1281.2	-	47	-	34.9	-	8.3	-	17-Nov
4.	Baucau		Wailia		Spring	4	55	40.6	42.8	42	26.6	26.9	-	-	20-Mar	20-Nov
5.	Lospalos		Papapa	LOS-WS03	Spring	4	99	21.3	54.1	54.4	26	26.6	-	7	22-Mar	23-Nov
6.	Viqueque		Loihunu	VIQ-WS01	Spring	4	121	18	57.9	55.7	27.1	26.9	-	-	22-Mar	21-Nov
7.	Same	1	Carbulau		Stream	1	20	1.03	26.2	29	19.7	19.7	-	8	27-Mar	16-Nov
		2	Kotalala		Stream	1	1120	10.94	33.7	36.7	20.4	21.7	-	7.7	27-Mar	16-Nov
		3	Mirbute Bituruli		Spring	3	3	0.515	27.1	30.7	21.7	23.5	-	7.7	27-Mar	16-Nov
8.	Ainaro		Sarai		Stream	1	1130	8.93	34.1	29.98	17.5	18.2	-	-	28-Mar	15-Nov
9.	Aileu	1	Mantane		River	2	370, 864	62.77	9.5	22.5	22.6	28.5	-	-	4-Apr	6-Nov
		2	Sloi Kraik		Stream	1	4.0	0.99	10.3	15.9	22.1	22.3	-	7	4-Apr	6-Nov
		3	Naufaisaran		Spring	3	1.2	0.125	-	5.19	-	21.7	-	5.9	4-Apr	6-Nov
		4	Hularema		Spring	3	0.5	0.365	9.3	12.48	21.6	22.8	-	-	4-Apr	6-Nov

Table B-1.1 Flow Rate and On-site Water Quality Measurement Data (2/2)

No.	Town		Water Source: Name	Topo Label	Type		Observed Discharge (late Oct. to late Nov.)	Catchment Area	EC 1st	EC 2nd	Temp 1st	Temp 2nd	pH 1st	pH 2nd	Date 1st	Date 2nd
							(liter/sec)	(km2)	(micro S/m)		(degree C)					
10.	Maubisse	1	Raikuak Ulun		Spring	3	1.5	1.26	-	37.9	-	20.9	-	-	4-Apr	7-Nov
		2	Bucana		Spring	3	2.0	0.47	30.8	31	19.6	20.9	-	6.9	4-Apr	7-Nov
		3	Filmou		Spring	3	0.2	0.17	-	20.7	-	18.2	-	7.9	4-Apr	18-Nov
		4	Erulu		Spring	3	0.5	0.23	29.1	28	19.6	22.1	-	6.9	4-Apr	7-Nov
11.	Gleno	1	Mota Boot	GLE-WS01	Stream	1	1300.0	6.44	19.5	18.85	21.9	21.8	-	8.5	21-Mar	10-Nov
		2	Mota Kiik	GLE-WS02	Stream	1	80.0	0.81	17.9	19.17	20.7	20.2	-	8.4	21-Mar	11-Nov
		3	Ergrogo		Spring	3	10.0	0.5	-	38.9	-	20.9	-	7.6	21-Mar	11-Nov
12.	Ermera	1	Lubulala	ERM-WS03	Spring	3	0.1	0.064	-	15.55	-	19.4	-	6.9	-	10-Nov
		2	Ersoi	ERM-WS02	Spring	3	0.6	0.064	25.8	23.8	20.7	20.6	-	7.2	-	10-Nov
		3	Mota Bura	ERM-WS01	Spring	3	1.0	0.905	38.7	37.4	19.8	20.9	-	7.6	-	10-Nov
13.	Liquica	1	Dato 1		Borehole	5	---	14.8	-	-	-	-	-	-	-	-
		2	Dato 2		Borehole	5	---		-	-	-	-	-	-	-	-
		3	Maumeta 1		Borehole	5	---		-	-	-	-	-	-	-	-
		4	Maumeta 2		Borehole	5	---		-	-	-	-	-	-	-	-
		5	Laclo	LIQ-WS13	Stream	1	2.3	1.14	-	51.90	-	27.50	-	7.70	-	3-Nov
		6	Lilabu	LIQ-WS06	Stream	1	2.0	0.61	-	63.60	-	25.00	-	7.80	-	3-Nov
		7	Narlolo	LIQ-WS05	Stream	1	0.7	0.63	61.3	69.3	28.6	27.4	-	7.7	31-Mar	3-Nov
		8	Daulo		Stream	1	15.0	8.23	-	58.2	-	29.5	-	7.9	-	1-Nov
		9	Eanlua	LIQ-WS09,10	Stream	1	3.8	2.11	-	63.6	-	26.5	-	7.5	-	1-Nov
		10	Raisape		Stream	1	5.0	-	-	-	-	-	-	-	-	-
		11	Metagou	LIQ-WS11,12	Stream	1	2.0	0.16	-	32.7	-	21.2	-	-	-	27-Oct
		12	Emilaloa	LIQ-WS07	Stream	1	20.0	4.33	48.3	69.8	26.3	27.9	-	-	31-Mar	27-Oct
14.	Suai	1	Olivio		Stream	1	(1)	2.19	-	-	-	-	-	-	-	-
		2	Ameriko & Maugusu		Stream	1	(1)	3.5	-	-	-	-	-	-	-	-
		3	Maugusu		Stream	1	-	-	-	-	-	-	-	-	-	-
		4	Kuluai		Spring	3	(1)	1.4	-	-	-	-	-	-	-	-
		5	Sukabilaran 1		Borehole	5	-	39.04	-	-	-	-	-	-	-	-
		6	Sukabilaran 2		Borehole	5	-		-	-	-	-	-	-	-	-
15.	Maliana	1	Beamos		Spring	3	(1)	0.03	-	-	-	-	-	-	-	-
		2	Aikumu		Spring	3	(150)	2.02	-	-	-	-	-	-	-	-
		3	Irrigation canal		Stream	1	(200)	8.56	-	-	-	-	-	-	-	-

Note
* : Estimation based on the measured flow rate and interview with local people
** : Theoretically calculated based on the existing data in the course of water balance calculation
Numbers in parenthesis indicate the figure is based on a second hand data

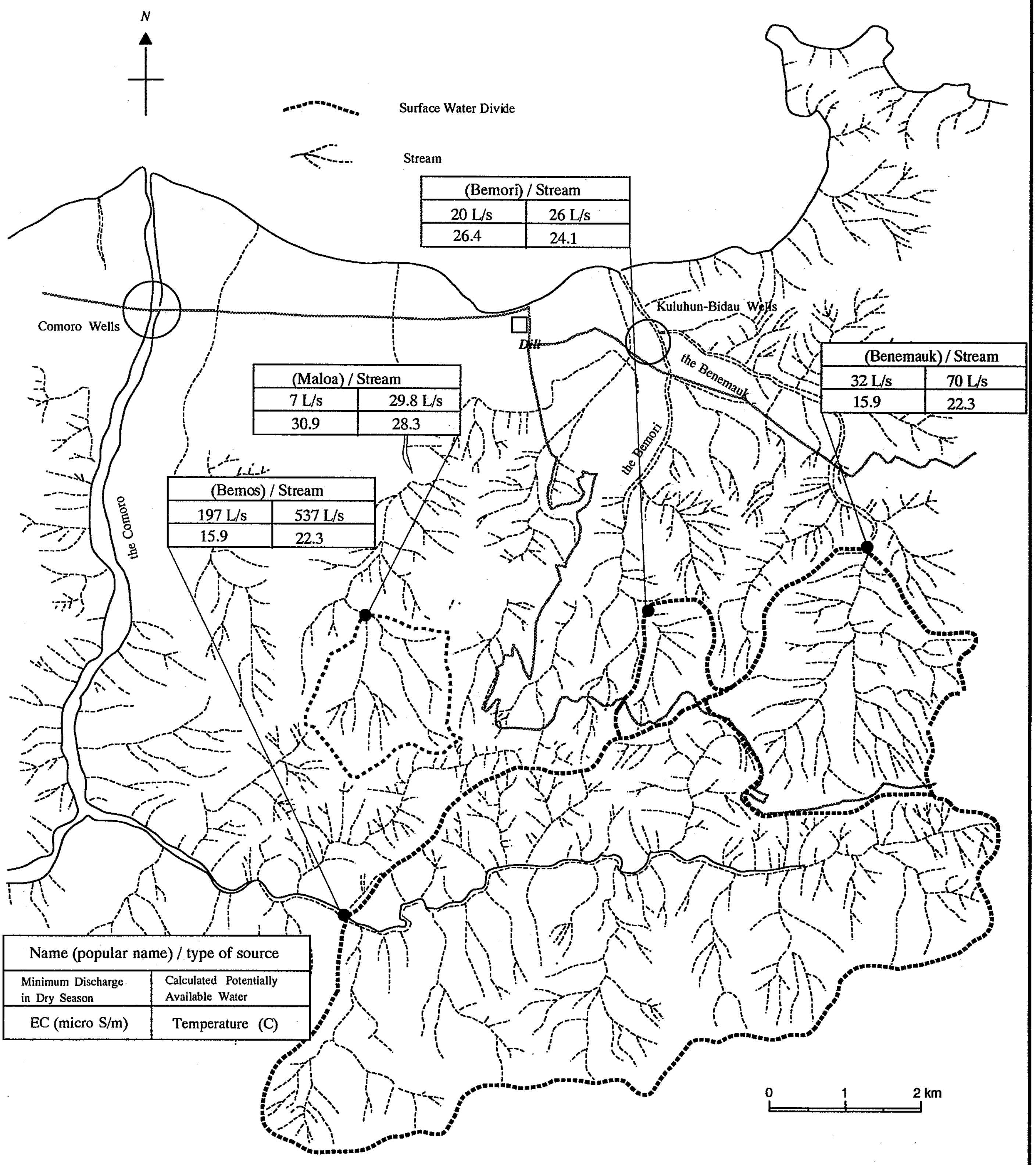
Table B-1.2 Sources of Water Supply in 15 Towns (1/2)

No.	Town	Water Source				Location			Catchment	Surface geology at the intake site	Existing Condition (Nov. 2000)	
			Name	Type		Coordinates		Altitude	Area			
						UTM-E	UTM-N	(mASL)	(km2)			Remarks
1.	Dili	1	Bemos	Stream	1	81680	45715	215	30.27	Philite, Aileu formation	in use	
		2	Bemori	Stream	1	85485	49650	195	1.49	Philite, Aileu formation	in use	
		3	Benemauk	Stream	1	88350	50620	155	7.6	Philite, Aileu formation	in use	
		4	Maloa	Stream	1	82055	50392	170	3.02	Schist, Aileu formation	in use	
		5	Comoro A	Borehole	5	79124	52348	25		Alluvial sediment	in use	
		6	Comoro B	Borehole	5	79515	53374	25		Alluvial sediment	UNTAET	
		7	Comoro C	Borehole	5	78734	53171	25	207.32	Alluvial sediment	abandoned	no pump
		8	Comoro D	Borehole	5	78846	53133	25		Alluvial sediment	in use	
		9	Comoro E	Borehole	5	78841	52898	25		Alluvial sediment	(in use)	for UNTAET
		10	Kuluhun A	Borehole	5	85596	52734	20		Alluvial sediment	in use	
		11	Kuluhun B	Borehole	5	85381	53010	20	34.34	Alluvial sediment	in use	
		12	Bidau 1	Borehole	5	85678	53646	15		Alluvial sediment	abandoned	
		13	Bidau 2	Borehole	5	85517	53174	15		Alluvial sediment	in use	used in General Hospital
		14	Hera A	Borehole	5	91855	53229	50	6.87	Alluvial sediment	abandoned	
		15	Hera B	Borehole	5	93058	54909	30	9.17 + 6.87	Alluvial sediment	abandoned	no pump
		16	Hera C	Borehole	5	93361	54259	40	27.92	Alluvial sediment	out of use	no electric power
2.	Atauro	1	Mota Eklai	Stream	1	85000	85260	310	0.103	Volcaniclastic rock, (Atauro formation)	in use	Group of small streams
		2	Mota Tulai	Spring	3	-	-	-	1.11	Volcaniclastic rock, (Atauro formation)	in use	Group of small springs
		3	Mota Lampia	Stream	1	(84875)	(84700)	-	0.704	Volcaniclastic rock, (Atauro formation)	in use	
3.	Manatuto	1	Manatuto	Spring	3	26984	47457	160	2.43	Calcarious mudstone, Aitutu formation	out of use	Pipe line broken
		2	Laclo	River	2	28832	56151	40	1281.2	Quartanery	soon in use	Newly constructed by JICA
4.	Baucau	1	Wailia	Spring	4	19575	63441	340	40.6(256*)	Reef limestone, Baucau formation	in use	
5.	Los Paros	1	Lospalos	Spring	4	78439	57950	410	21.3	Reef limestone, Baucau formation	in use	
6.	Viqueque	1	Loihuno	Spring	4	11510	28060	360	65.7	Limestone, Bobonaro formation	in use	
7.	Same	1	Carbulau	Stream	1	91137	9675	760	1.03	(Dolomitic limestone), Lolotoi formation	in use	
		2	Kotalala	Stream	1	88518	5979	730	10.94	Dolomitic limestone, Lolotoi formation	in use	
		3	Mirbute Bituruli	Spring	3	89159	6142	680	0.515	Dolomitic limestone, Lolotoi formation	in use	
8.	Ainaro		Ainaro	Stream	1	73093	7616	1070	8.88	Limestone, Aitutu formation	in use	
9.	Aileu	1	Mantane	River	2	82260	31330	870	62.77	Alluvial sediment	out of use	
		2	Sloi Kraik	Stream	1	(81250)	(35500)	960	0.99	(Slate), Aileu formation	in use	
		3	Naufaisaran	Spring	3	(81780)	(37910)	1150	0.125	(Slate), Aileu formation	in use	
		4	Hularema	Spring	3	(80750)	(37730)	1150	0.365	(Slate), Aileu formation	in use	
10.	Maubisse	1	Raikuak Ulun	Spring	3	(84350)	(22686)	1650	1.26	(Volcaniclastic), Maubissei formation	in use	
		2	Bucana	Spring	3	84840	22450	1530	0.47	(Volocaniclastic), Maubisse formation	in use	(442 uS/cm, 21C; tank)
		3	Filmou	Spring	3	(85500)	(23450)	1620	0.17	(Shale), Wailuli formation	in use	repaired
		4	Erulu	Spring	3	85625	22730	1440	0.23	Shale, Wailuli formation	in use	

Table B-1.2 Sources of Water Supply in 15 Towns (2/2)

No.	Town		Water Source Name	Type		Location Coordinates UTM-E	UTM-N	Altitude (mASL)	Catchment Area (km2)	Surface geology at the intake site	Existing Condition (Nov. 2000)	Remarks
11.	Gleno	1	Mota Boot	Stream	1	66325	30500	1015	6.44	Slate, Aileu formation	in use	repaired
		2	Mota Kiik	Stream	1	66550	30600	1030	0.81	Green rock, Aileu formation	in use	repaired
		3	Ergrogo	Spring	3	(67000)	(29700)	1080	0.5	Slate, Aileu formation	in use	
12.	Ermera	1	Lubulala	Spring	3	-	-	1450	0.064	Slate, Aileu formation	in use	
		2	Ersoi	Spring	3	62690	31520	1380	0.064	Slate, Aileu formation	in use	
		2	Mota Bura	Spring	3	63294	31170	1235	0.905	Slate, Aileu formation	in use	
13.	Liquica	1	Dato 1	Borehole	5	56980	49570	48	14.8	Alluvial fan deposit	abandoned	no pump, plugged with stones
		2	Dato 2	Borehole	5	57238	49377	55		Alluvial fan deposit	abandoned	no pump, plugged with stones
		3	Maumeta 1	Borehole	5	57651	49481	47		Alluvial fan deposit	out of use	Rehabilitation failed
		4	Maumeta 2	Borehole	5	57412	49579	50		Alluvial fan deposit	out of use	Rehabilitation failed
		5	Laclo	Stream	1	(55040)	(47580)	395	1.17	(Slate), Aileu formation	in use	Rametau Res.
		6	Lilabu	Stream	1	(55440)	(47600)	224	0.43	(Slate), Aileu formation	in use	Rametau Res.
		7	Narlolo	Stream	1	56451	47350	235	0.63	Slate, Aileu formation	in use	Intake repaired
		8	Daulo	Stream	1	(57700)	(45850)	300	8.23	(Slate), Aileu formation	in use	Intake brocken
		9	Eanlua	Stream	1	(58300)	(45900)	320	2.11	(Slate), Aileu formation	in use	Sar-lema Res.
		10	Raisape	Stream	1	(57600)	(47180)	-	0.18	(Slate), Aileu formation	out of use	only a trace of intake tank
		11	Metagou	Stream	1	(59450)	(46800)	900	0.455	(Slate), Aileu formation	in use	pipe line repaired
		12	Emilaloa	Stream	1	(59460)	(48330)	310	0.145	(Slate), Aileu formation	in use	Lauhata Res.
14.	Suai	1	Olivio	Stream	1	(45000)	(74500)	-	(2.19)		out of use	
		2	Ameriko & Maugusu	Stream	1	(44000)	(75000)	-	(3.5)		in use	
		3	Maugusu	Spring	3	(48500)	(69000)	-			in use	
		4	Kuluai	Spring	3	(48500)	(69000)	-	1.4		in use	
		5	Sukabilaran 1	Borehole	5	---	---	-	(39.04)		in use	
		6	Sukabilaran 2	Borehole	5	---	---	-			in use	
15.	Maliana	1	Beamos	Stream	1	---	---	-	---		in use	
		2	Aikumu	Stream	3						in use	
		3	Dabucci	Spring	3						in use	
		4	Beapelu	Spring	1						in use	
		5	Beremau	Spring	1	---	---	-	---		in use	
		6	Colegio	Spring	1						in use	
		7	Irrigation canal	Stream	1	---	---	-	---		in use	

Type 1: Mountain Stream
Type 2: Large River in flatland
Type 3: Small-scale spring (seeping out of undercurrent)
Type 4: Large-scale spring related to limestone
Type 5: Groundwater



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SOURCE(S) OF WATER SUPPLY IN DILI

Figure B - 1.1

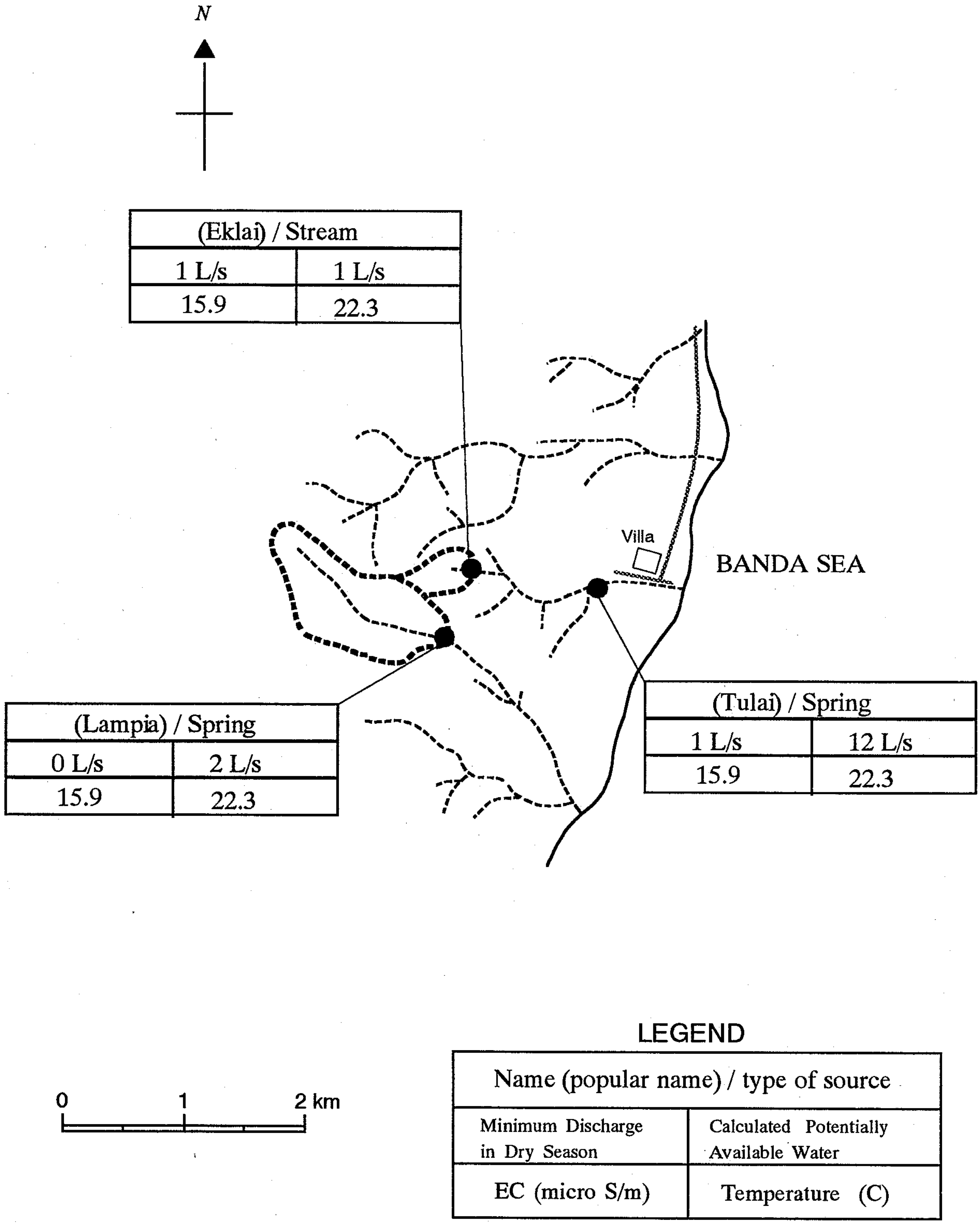

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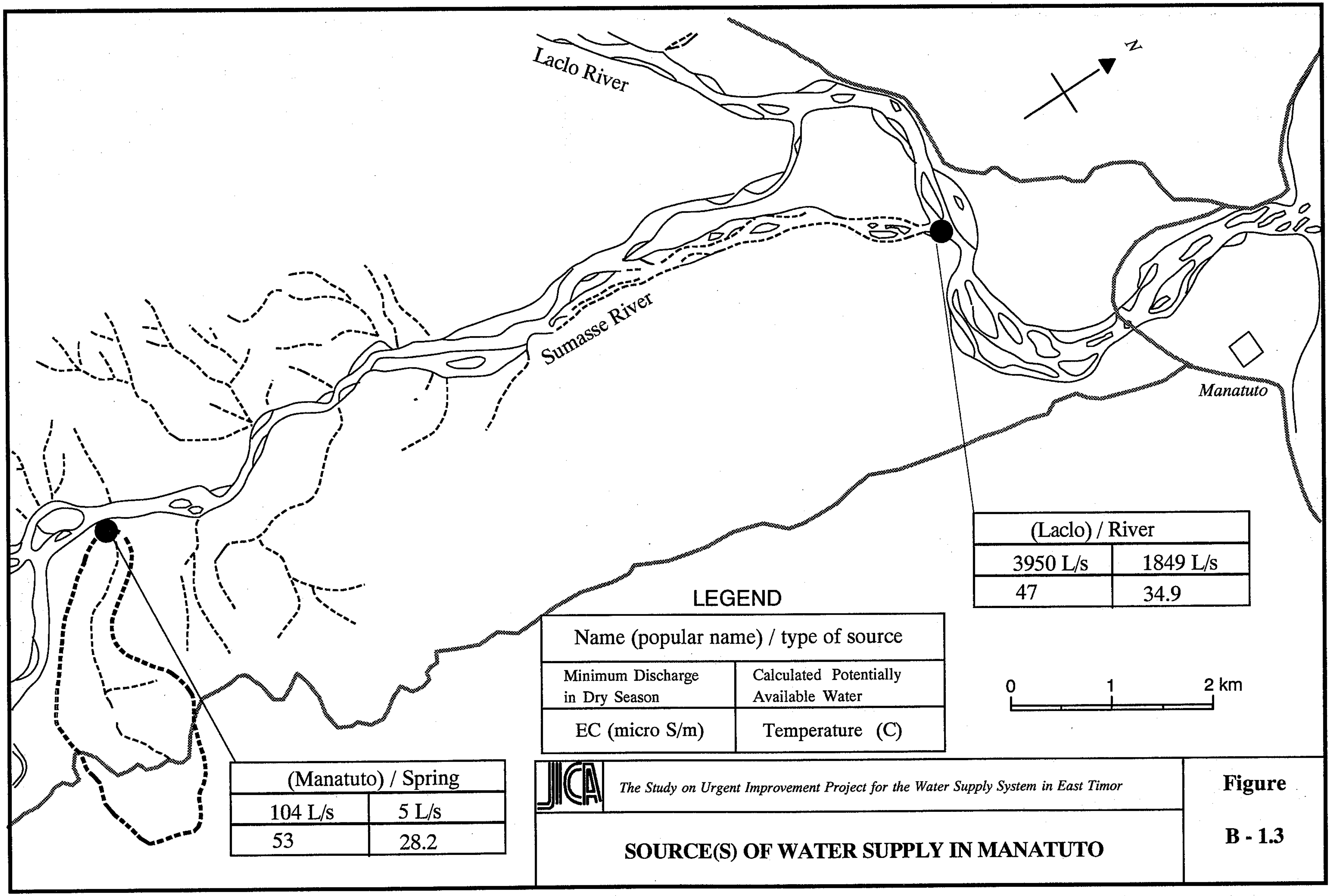
Figure B - 1.2

SOURCE(S) OF WATER SUPPLY IN ATAURO



(Laclo) / River	
3950 L/s	1849 L/s
47	34.9

LEGEND

Name (popular name) / type of source	
Minimum Discharge in Dry Season	Calculated Potentially Available Water
EC (micro S/m)	Temperature (C)

(Manatuto) / Spring	
104 L/s	5 L/s
53	28.2

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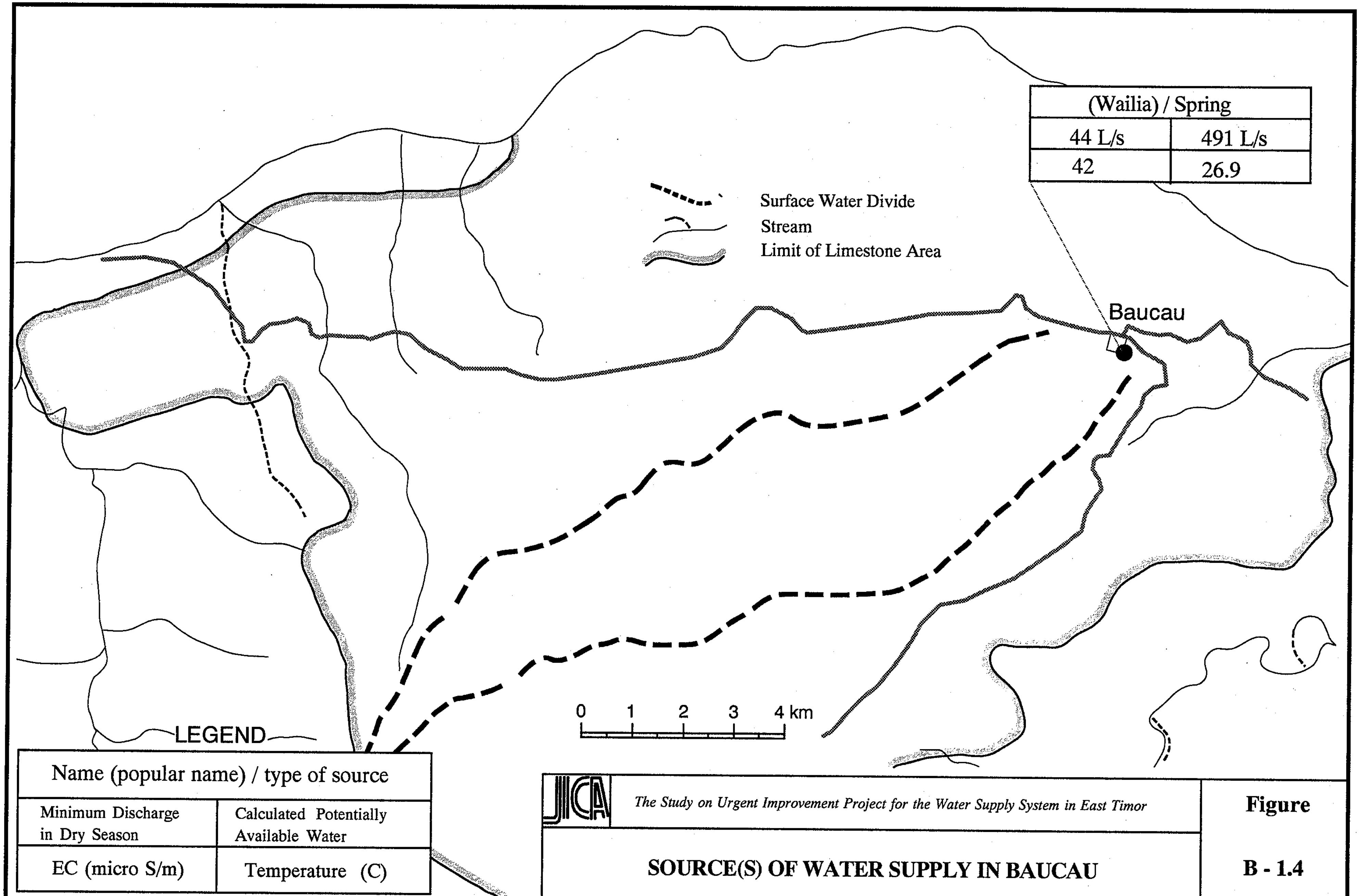
SOURCE(S) OF WATER SUPPLY IN MANATUTO

Figure B - 1.3



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SOURCE(S) OF WATER SUPPLY IN BAUCAU

Figure B - 1.4

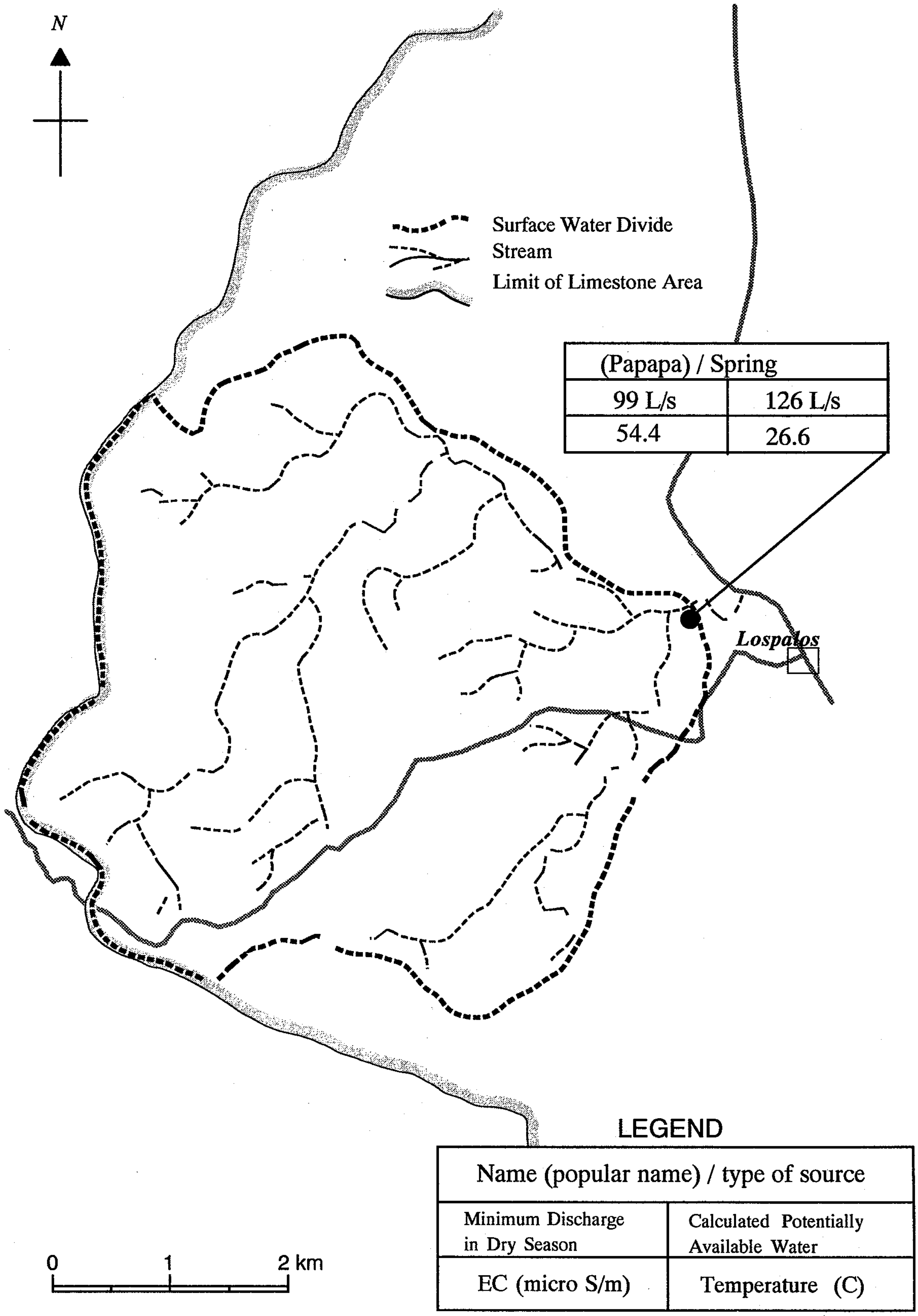

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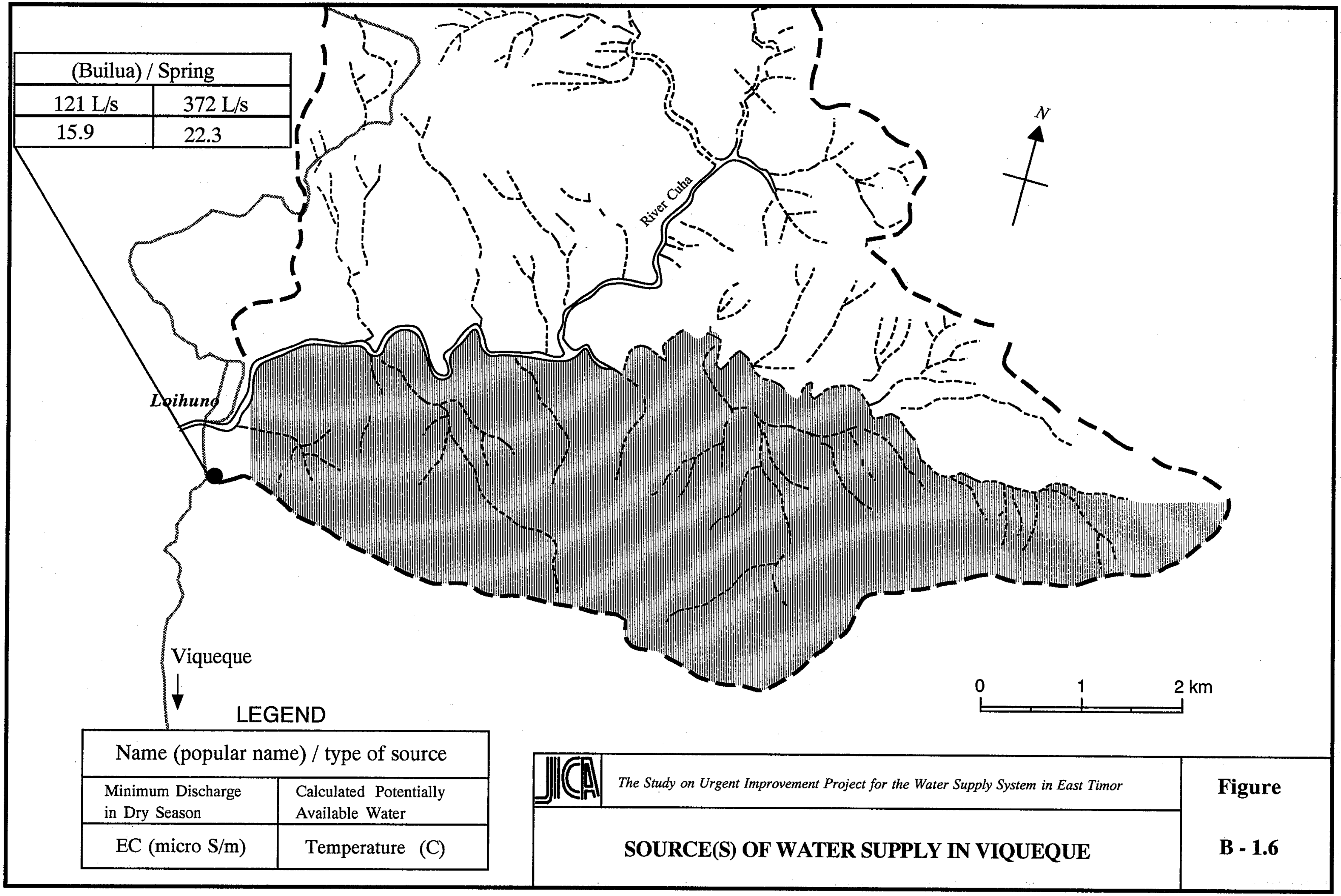
Figure B - 1.5

SOURCE(S) OF WATER SUPPLY IN LOSPALOS



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SOURCE(S) OF WATER SUPPLY IN VIQUEQUE

Figure B - 1.6

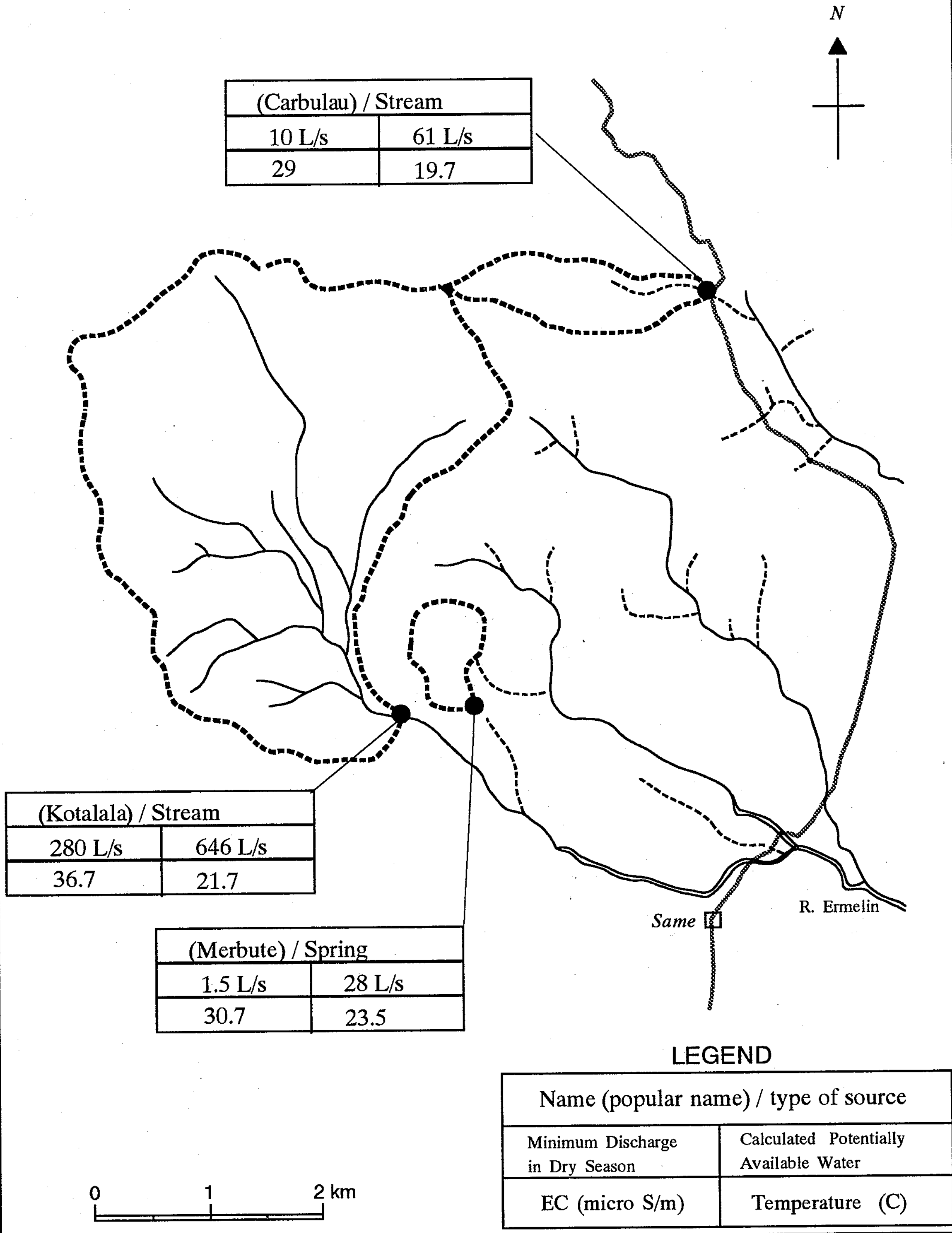

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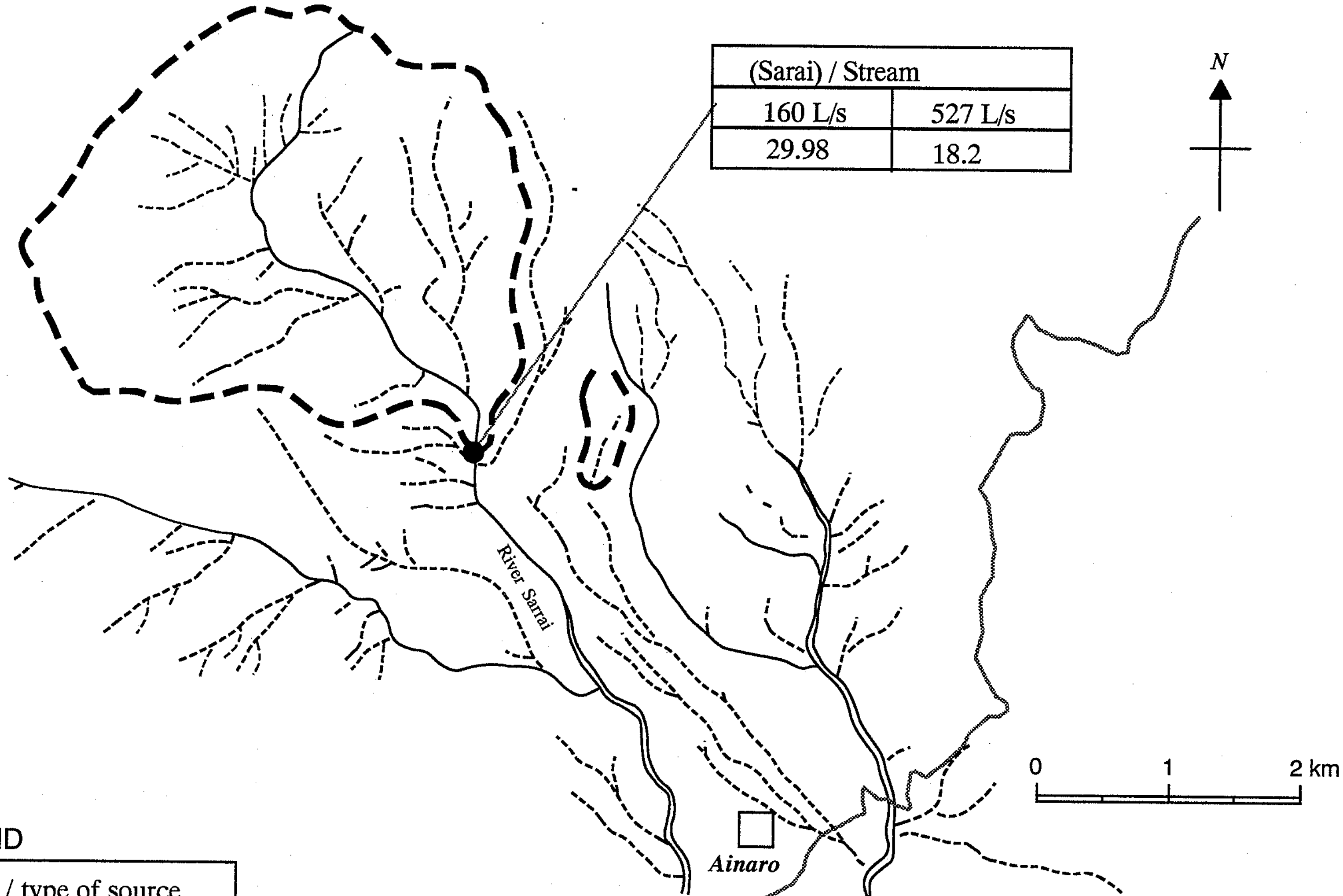
Figure B - 1.7

SOURCE(S) OF WATER SUPPLY IN SAME



LEGEND

Name (popular name) / type of source	
Minimum Discharge in Dry Season	Calculated Potentially Available Water
EC (micro S/m)	Temperature (C)

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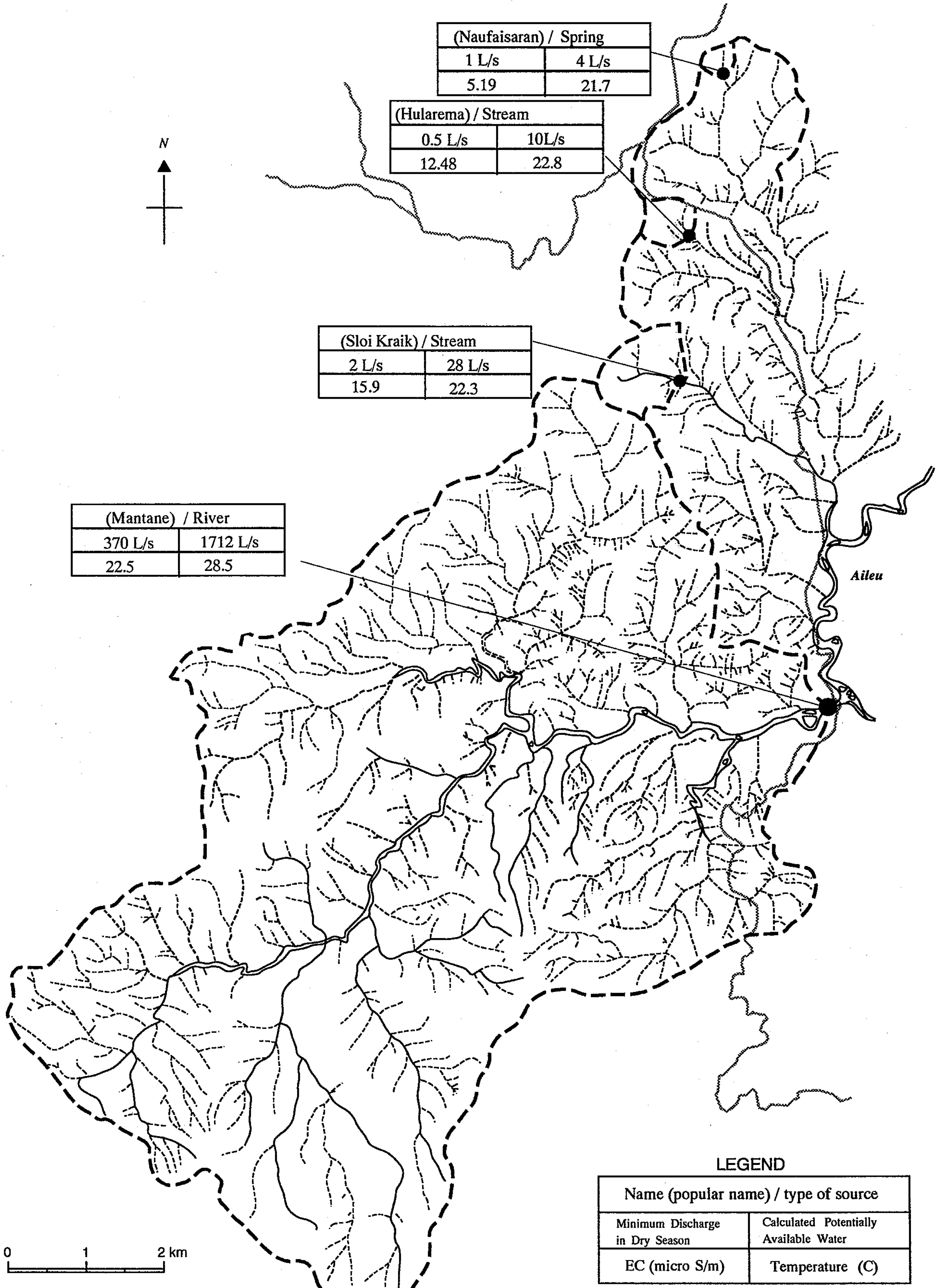
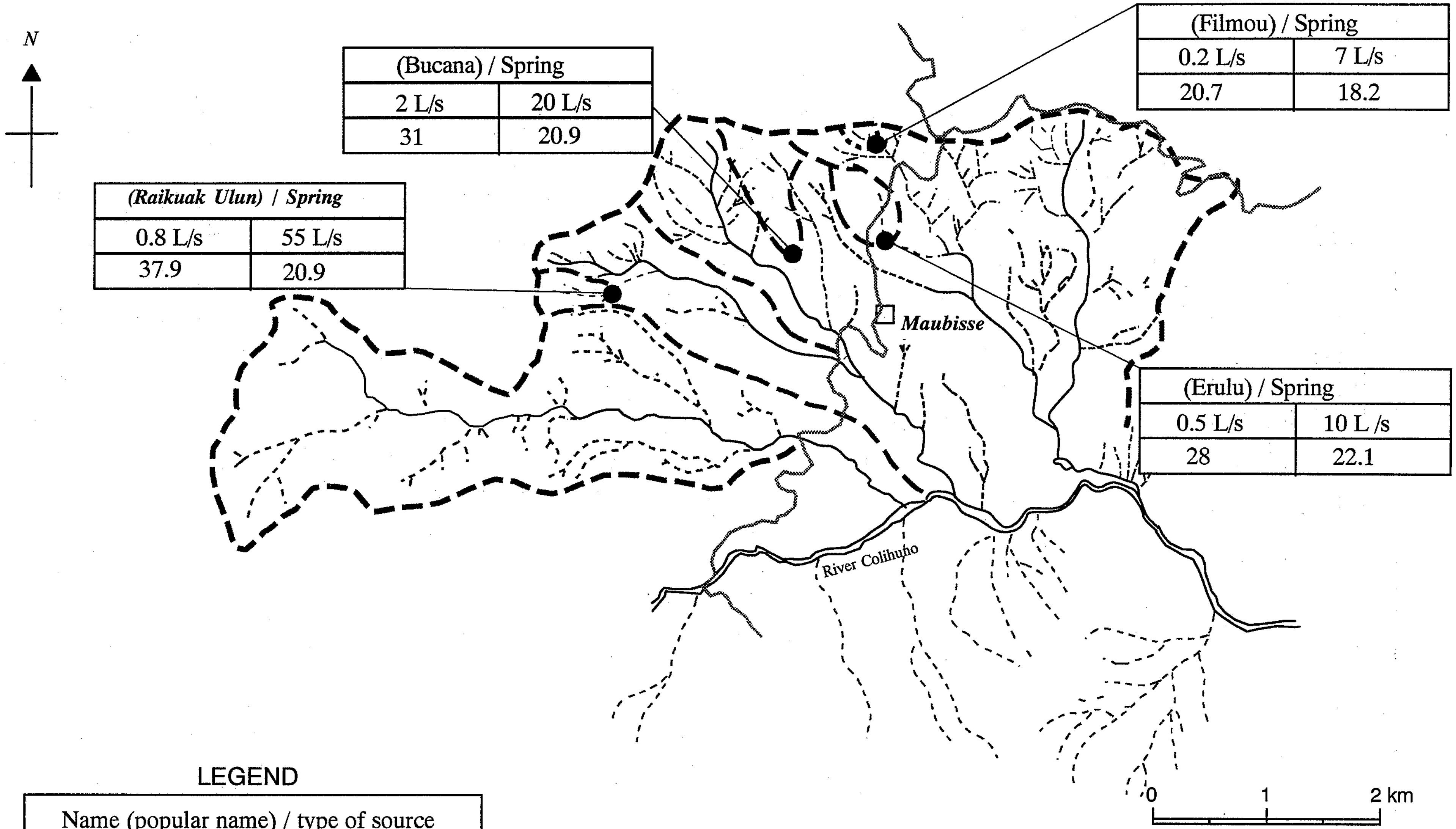
SOURCE(S) OF WATER SUPPLY IN AINARO

Figure B - 1.8



JICA	The Study on Urgent Improvement Project for the Water Supply System in East Timor	Figure
	SOURCE(S) OF WATER SUPPLY AND THIER POTENTIAL IN AILEU	**B - 1.9**



LEGEND

Name (popular name) / type of source	
Minimum Discharge in Dry Season	Calculated Potentially Available Water
EC (micro S/m)	Temperature (C)

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SOURCE(S) OF WATER SUPPLY IN MAUBISSE

Figure B - 1.10

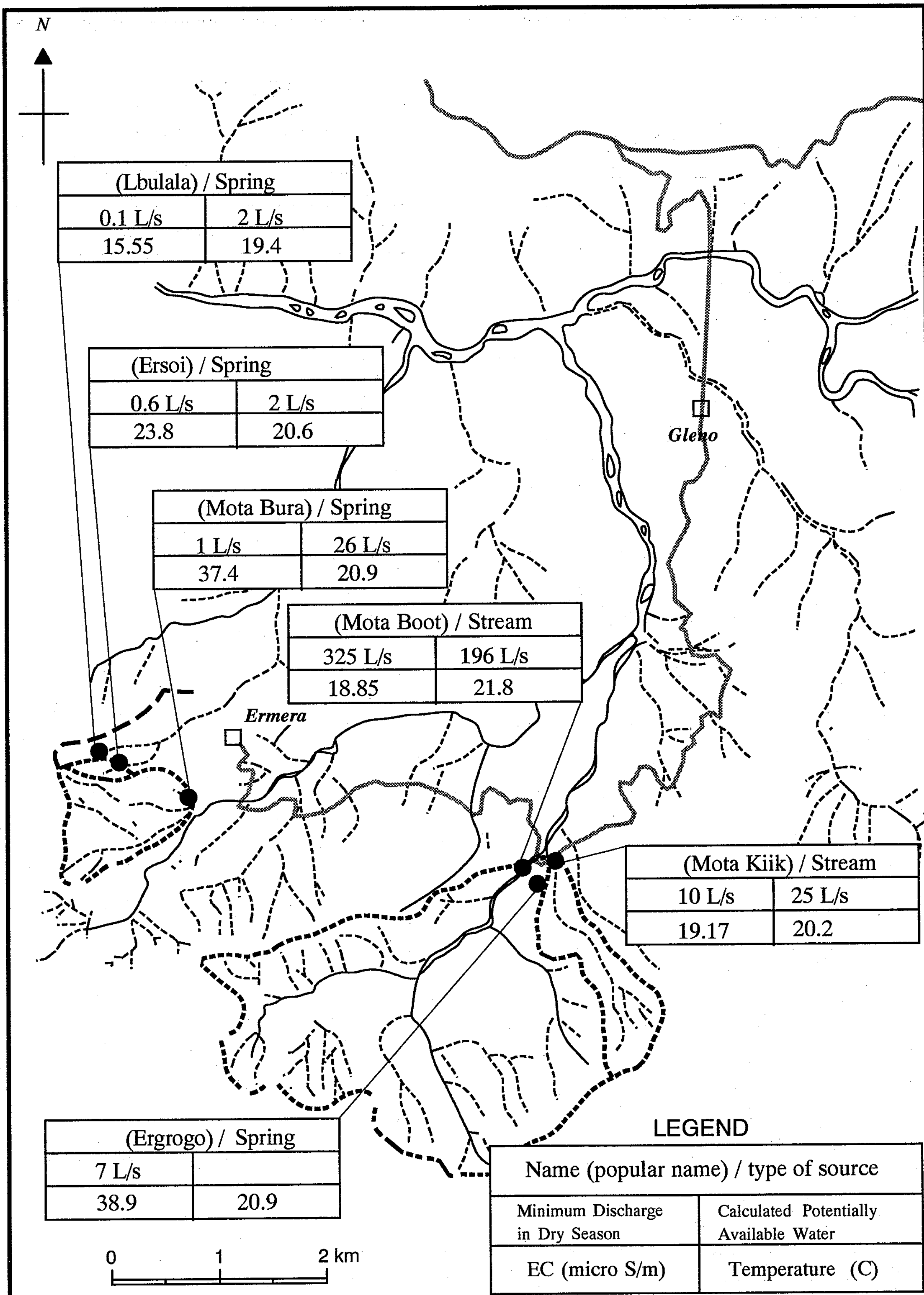

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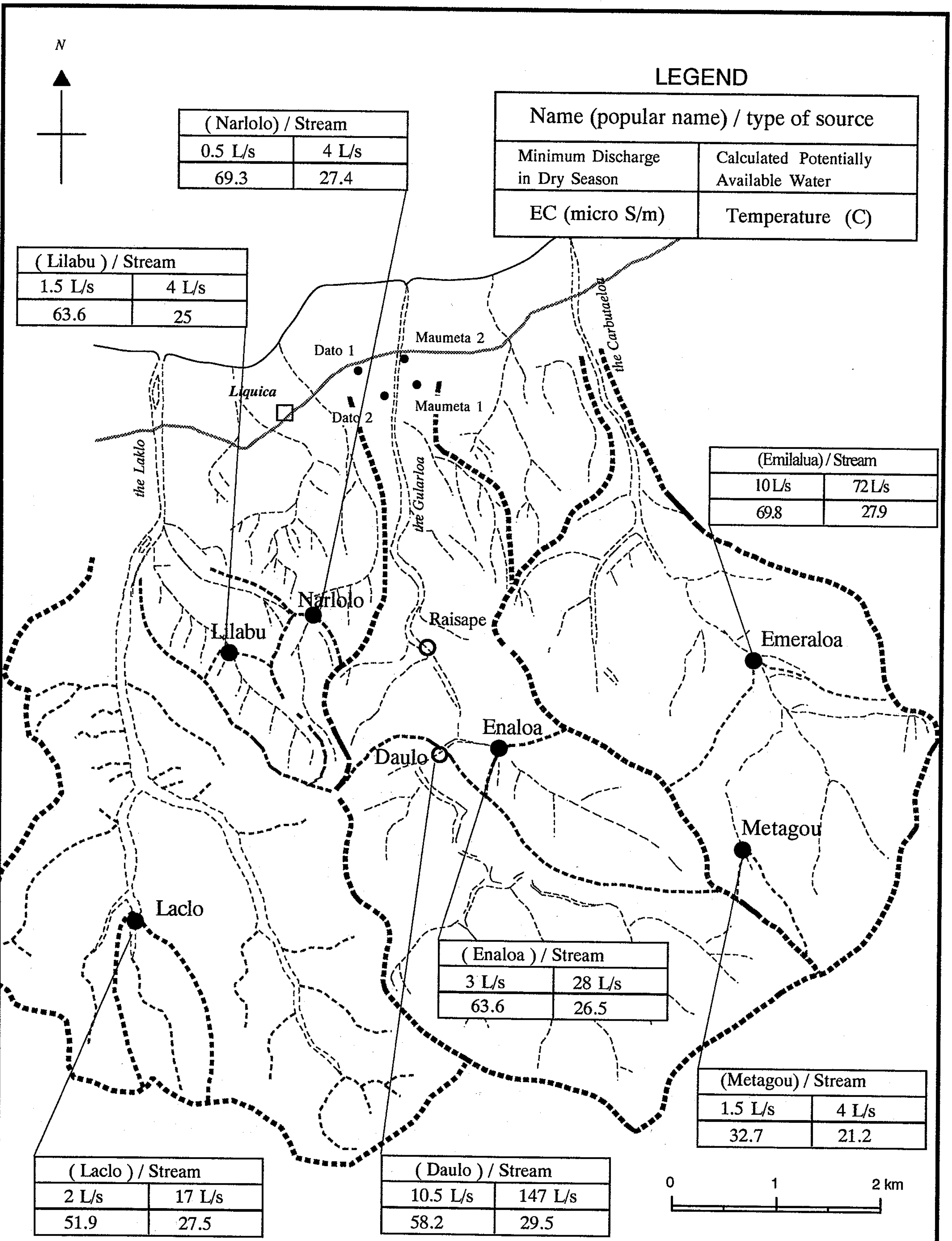
Figure B - 1.11

SOURCE(S) OF WATER SUPPLY IN GLENO, ERMERA



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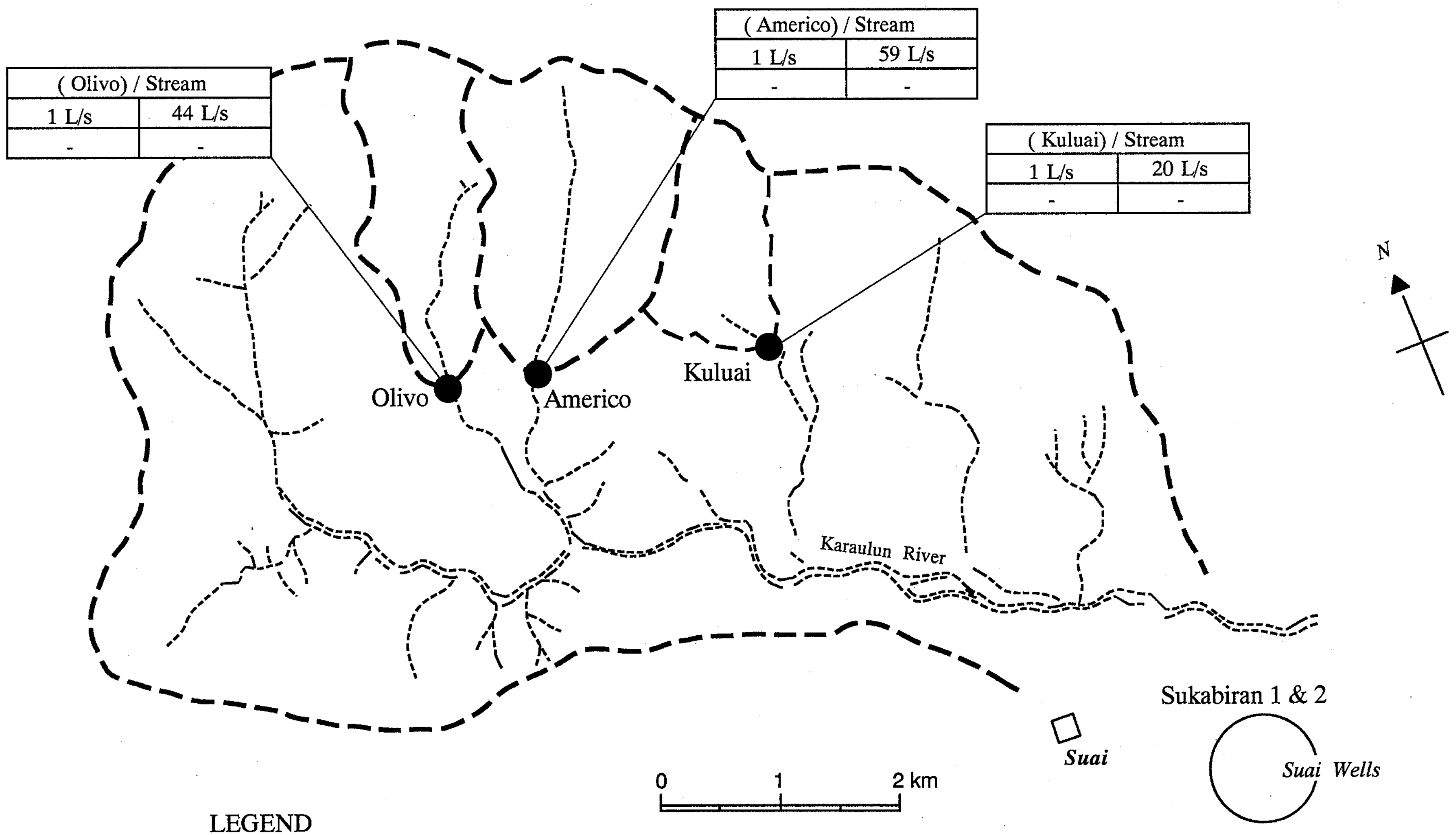
SOURCE(S) OF WATER SUPPLY IN LIQUICA

Figure B - 1.12



LEGEND

Name (popular name) / type of source	
Minimum Discharge in Dry Season	Calculated Potentially Available Water
EC (micro S/m)	Temperature (C)

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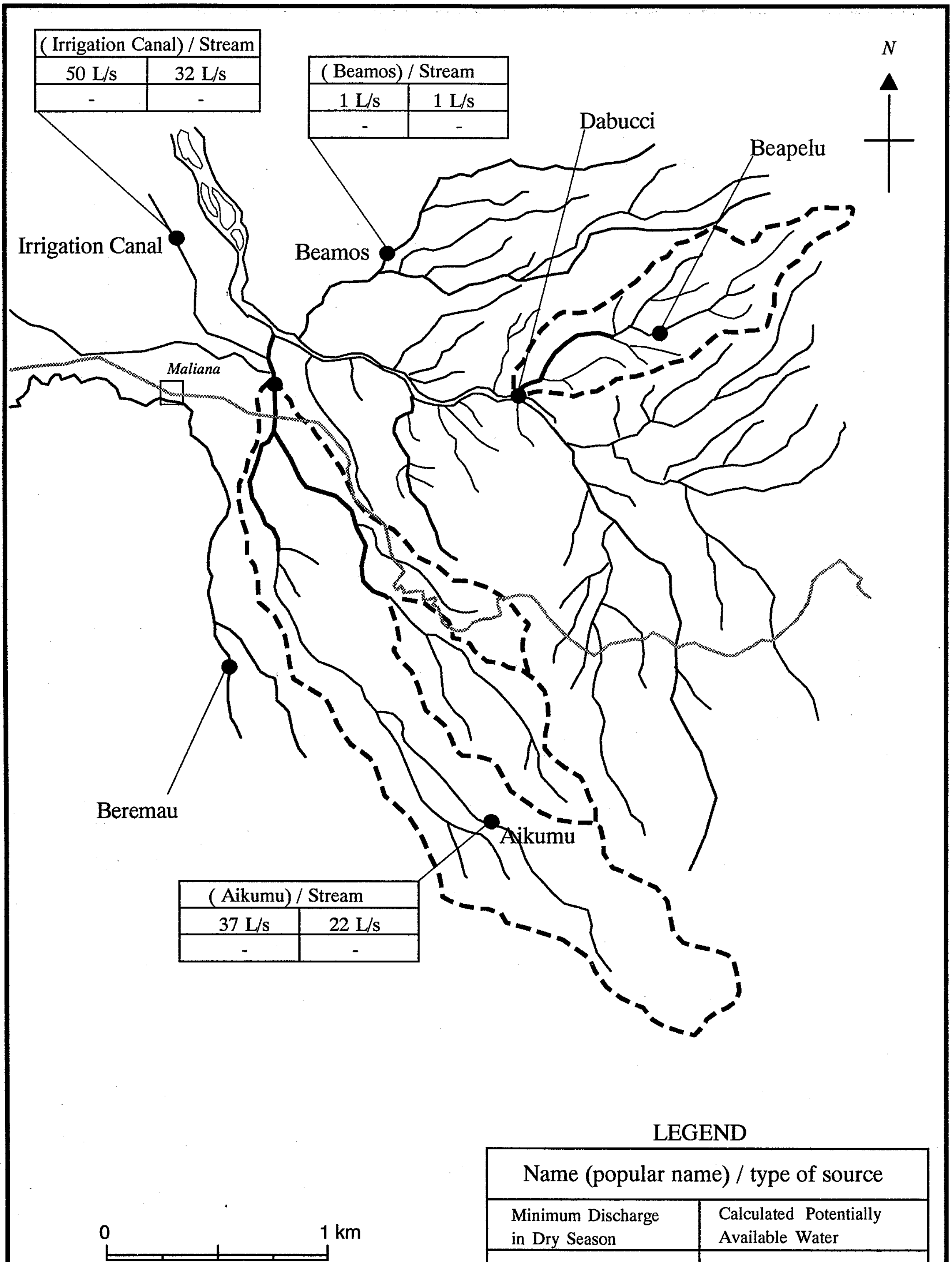
SOURCE(S) OF WATER SUPPLY IN SUAI

Figure

B - 1.13



LEGEND

Name (popular name) / type of source	
Minimum Discharge in Dry Season	Calculated Potentially Available Water
EC (micro S/m)	Temperature (C)

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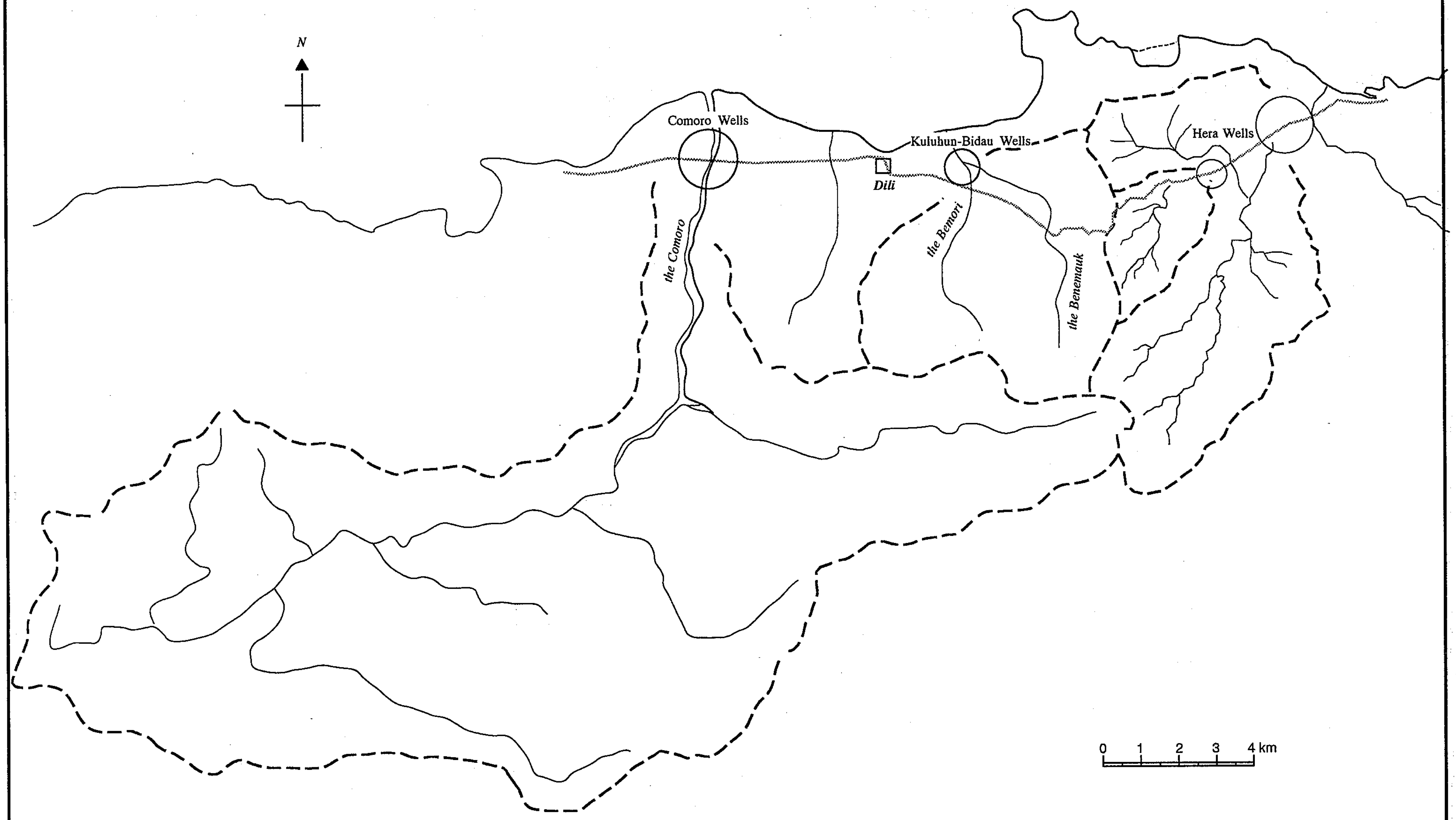
Figure B - 1.14

SOURCE(S) OF WATER SUPPLY IN MALIANA



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LOCATIONS OF WELL FIELD AND THEIR CATCHMENT IN DILI

Figure B - 1.15

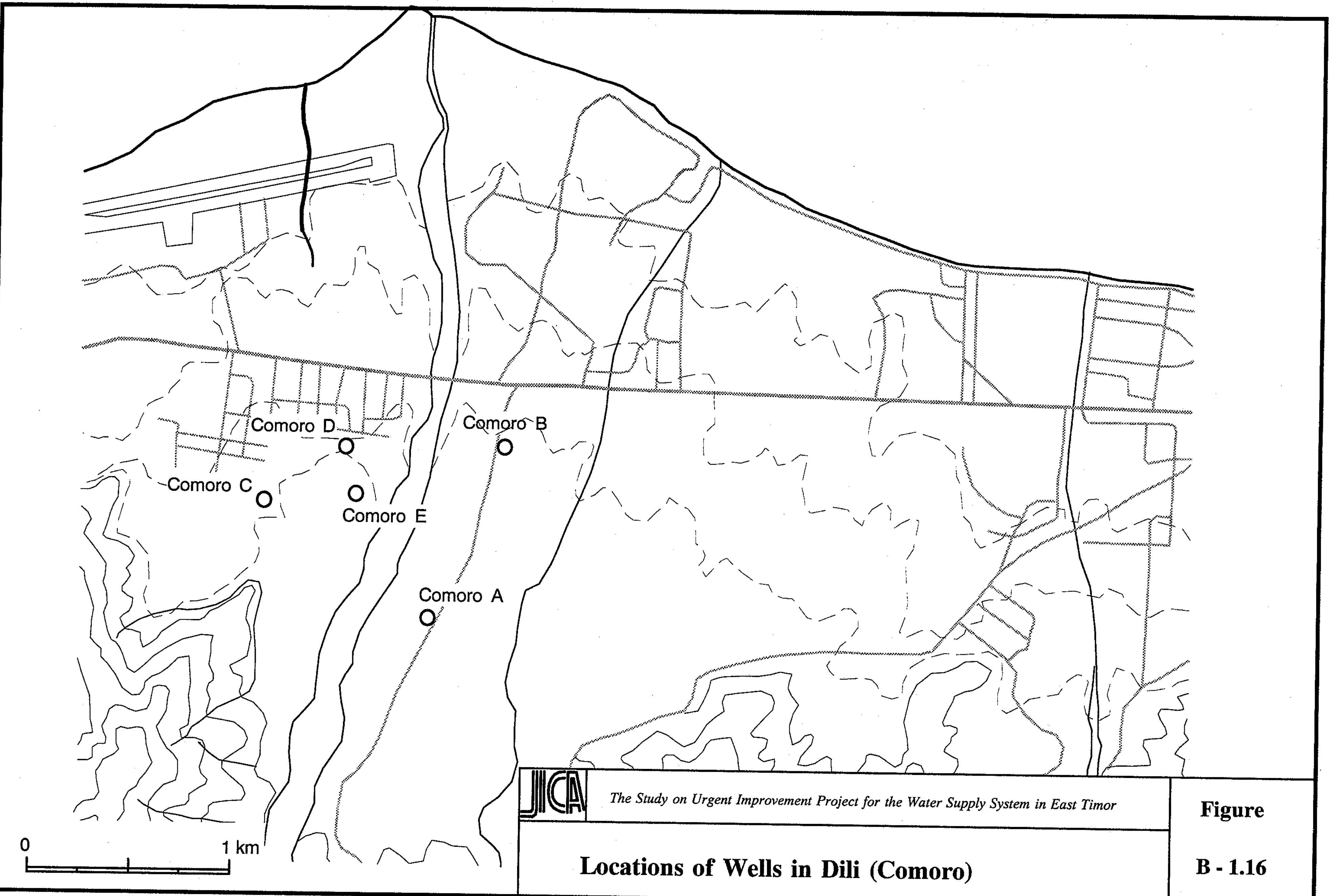

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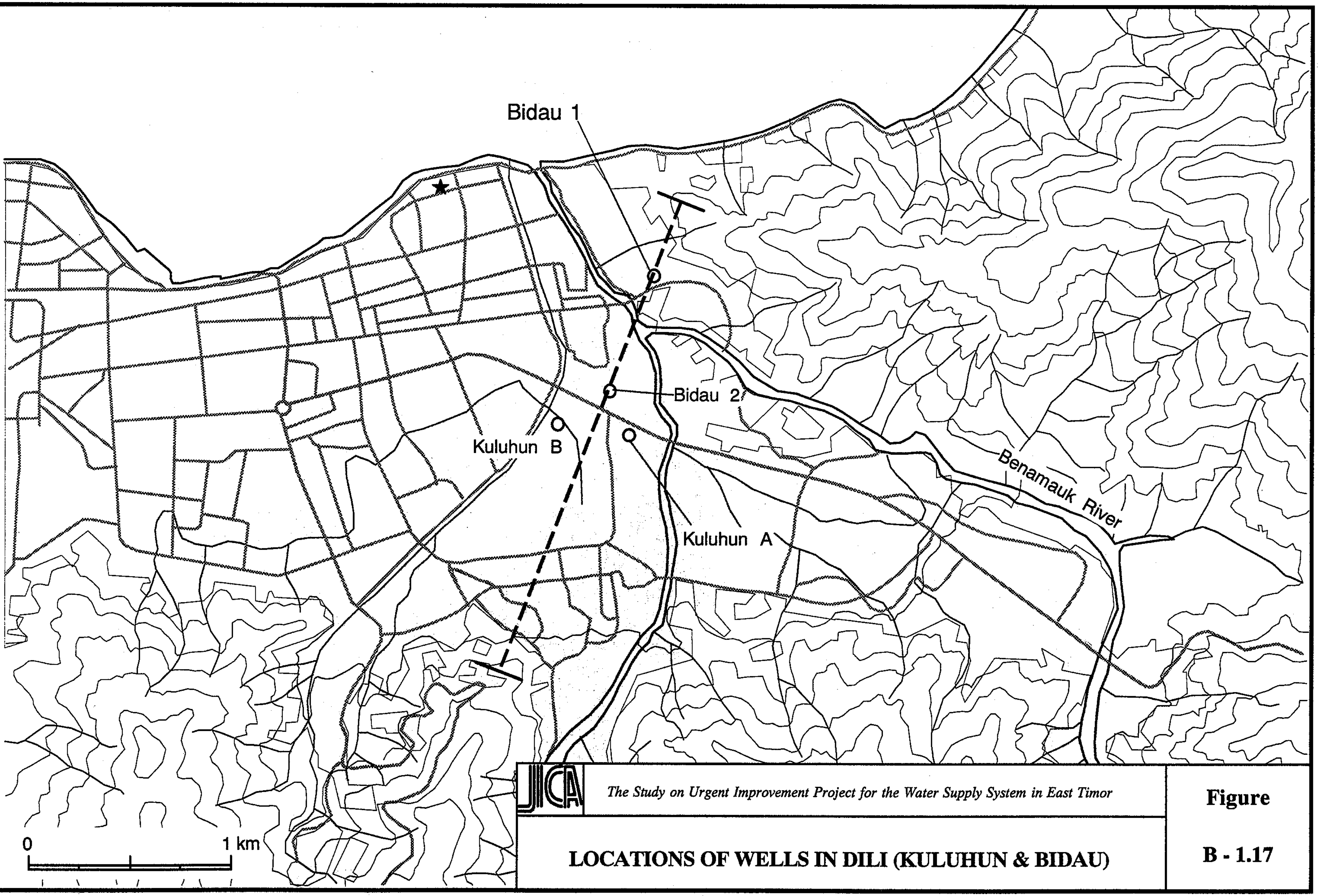
Figure B - 1.16

Locations of Wells in Dili (Comoro)



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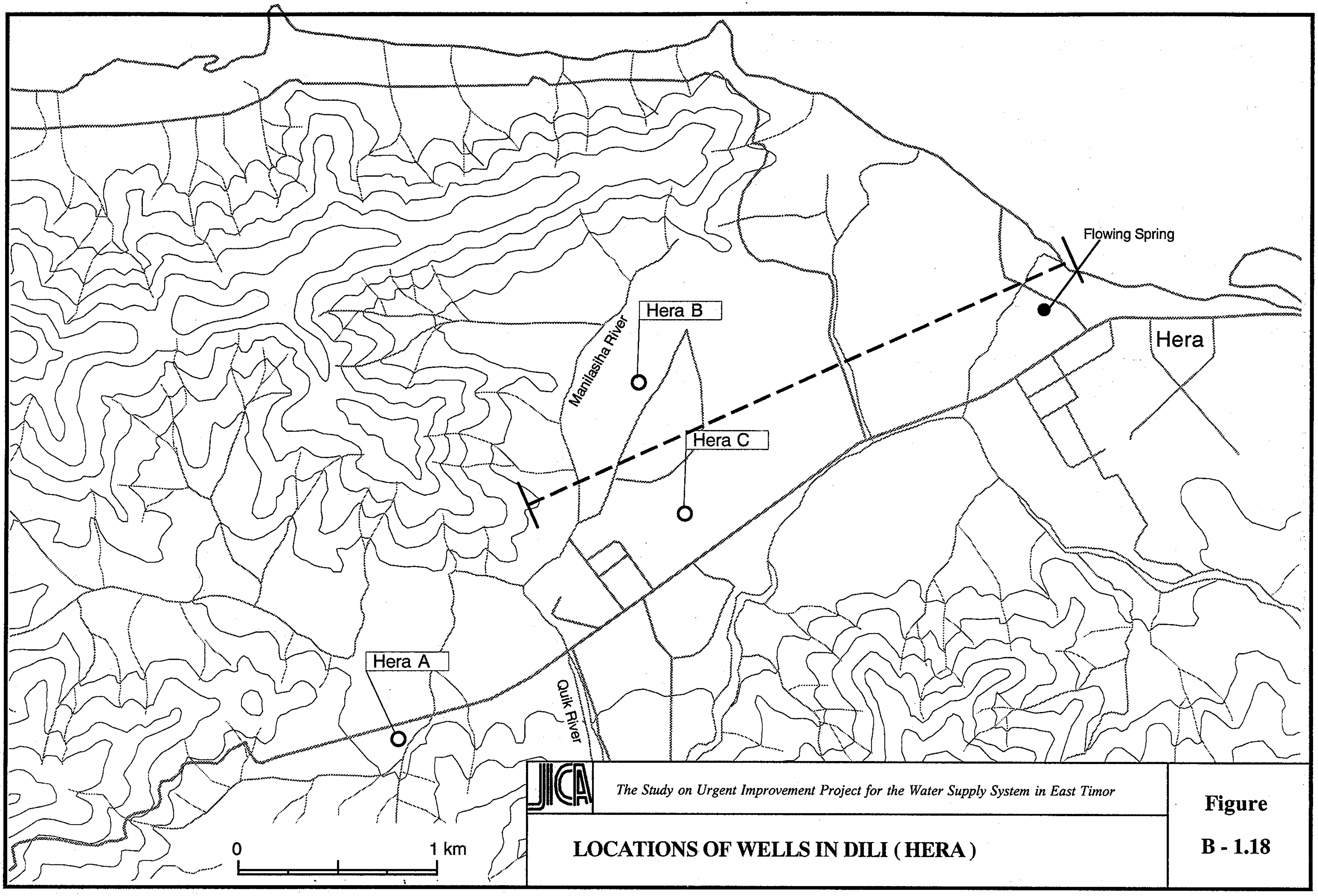
LOCATIONS OF WELLS IN DILI (KULUHUN & BIDAU)

Figure B - 1.17



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LOCATIONS OF WELLS IN DILI (HERA)

Figure
B - 1.18

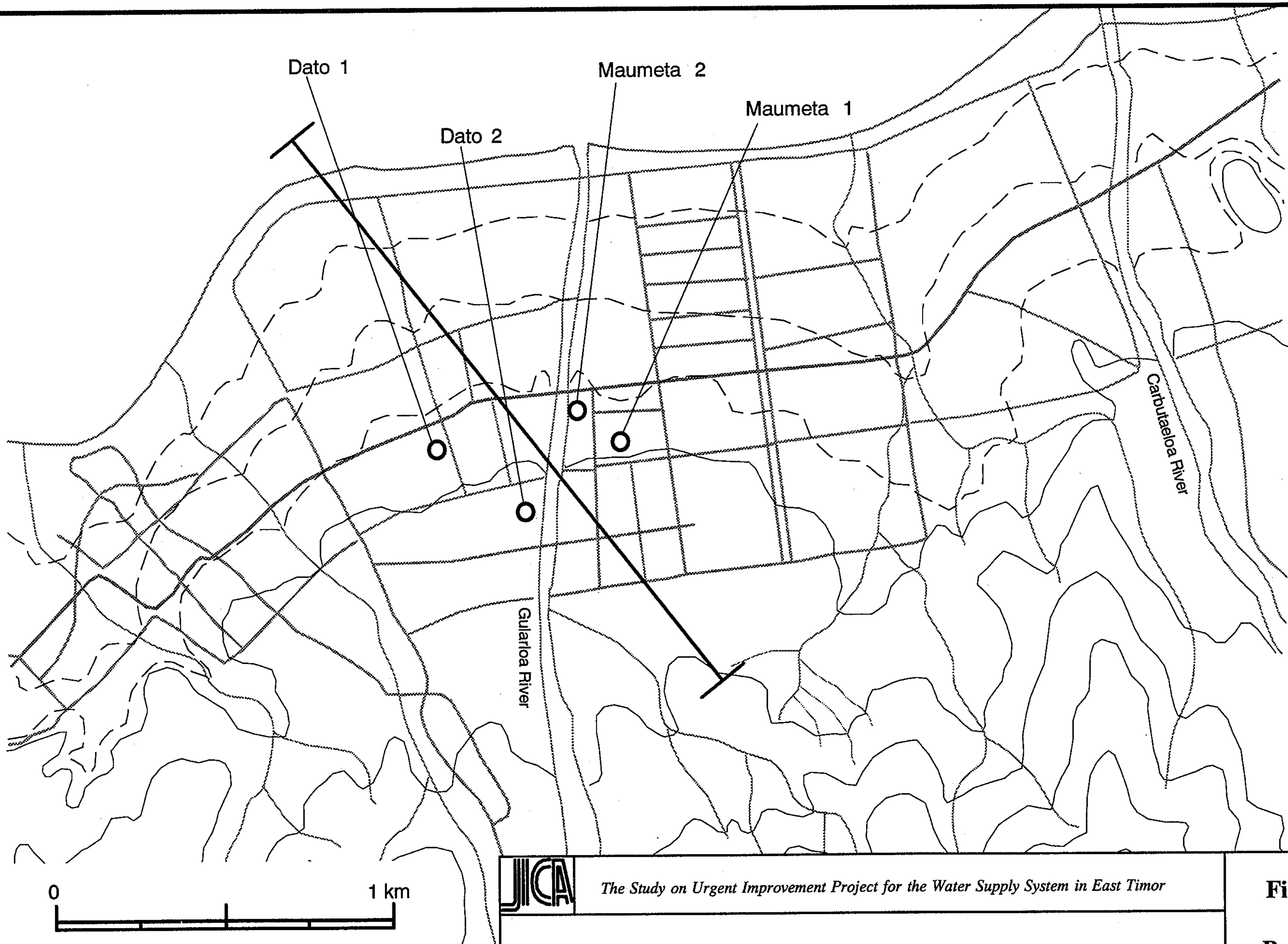

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Figure B - 1.19

LOCATIONS OF WELLS IN LIQUICA

B-2 WATER BALANCE ANALYSIS

B-2.1 Introduction

As a part of the water resource study, water balance analysis was carried out for 15 towns. The result is expected to give an approximate estimate of the amount of water available for exploitation. The calculation was done using the meteorological and hydrological data collected during the study. In spite of the limitation of the data, a tentative calculation was done for every municipal water sources and the results are presented in **Table B.2-1**. The following shows the course of calculation in detail.

a.) General

The hydrologic balance in a drainage basin can be represented by the equation.

Recharge = Discharge + Change in the basin storage

This simple equation can be broken down into the following components, such as,

$$P = E + Rd + Rb + dS$$

where *P* is precipitation, *E* is evapotranspiration, *Rb* is direct runoff that is discharged from the drainage basin shortly after it falls as rain, *Rb* is base flow, and *dS* is change in the drainage basin storage.

The first two elements, *E* and *Rd*, are loss from the basin, while the last two elements, *Rb* and *dS*, can be considered potential available water from the basin. Thus potential available water in a drainage basin; Q, is given by

$$Q = P – E – Rd$$

P, *E*, and *Rd* were estimated as described in the following sections. Then *Q* obtained by the equation is used to evaluate each water source in the study area.

b.) Precipitation, P

The Study Team collected the monthly rainfall data of 14 stations from 1950’s to 1974. The name of the stations and the period of collected data are indicated in **Figure B-2.1** and the collected data are attached at the end of Chapter B. The mean values of monthly and annual rainfall and the locations of observation points are shown in chapter 2 of the main report.

Rainfall and Altitude

The mean annual rainfall varies widely from below 600mm, Manatuto, to more than 2400mm, Vaquia, in place to place. **Figure B-2.2** plotting the mean annual rainfall and altitude of stations, however, shows two types of linear relation between rainfall and altitude, that is, a type of the north of the island and a type of the south of the island.

The values of mean monthly rainfall were also plotted in **Figure B-2.3**. From October to March, the south side does not differ from the north side in the relation between rainfall and altitude, whereas the linear relation is quite different between the north and the south from April to September.

Based on the series of **Figure B-2.3**, the relation between monthly rainfall and altitude is obtained by the following equation.

[Monthly Rainfall in mm] = A x [Altitude in m] + B

Values of A and B are as follows:

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
North	A	0.18	0.18	0.15	0.07	0.06	0.02	0.02	0.013	0.017	0.04	0.14	0.19
	B	154	158	145	85	63	40	18	6	8	15	56	127
South	A				0.58	0.91	0.51	0.27	0.032	0.03			
	B				46	86	93	60	27	25			

The above equation with figures of A and B is used to calculate the rainfall in each drainage basin of water source as explained below.

Northern Part of the Island

A drainage basin is divided into some areas with every 500m in elevation. Area less than 500m of altitude is assumed the mean altitude of 250m. Then the monthly rainfall calculated at the altitude of 250m is concluded the rainfall in the area less than 500m. The area between 500m and 1000m in altitude is assumed the mean altitude of 750m. Then again, the monthly rainfall calculated at the altitude of 750m is concluded the rainfall in the area between 500m to 1000m in altitude. The rainfall of the area more than 1000m is calculated similarly as described above.

The rainfalls in the area divided every 500m are tabulated below.

Rainfall Data in mm

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mm/yr
Less than 500m	199	203	182.5	102.5	78	45	23	9.25	12.25	25	91	174.5	1145
500m - 1000m	289	293	257.5	137.5	108	55	33	15.75	20.75	45	161	269.5	1685
1000m - 1500m	379	383	332.5	172.5	138	65	43	22.25	29.25	65	231	364.5	2225
More than 1500m	469	473	407.5	207.5	168	75	53	28.75	37.75	85	301	459.5	2765

Southern Part of the Island

The rainfall in the area less than 500m in altitude is estimated in the same as the North part. The rainfall in the area between 500m and 750m is considered the value obtained by the equation at the altitude of 500m, and the rainfall in the area more than 750m is assumed the value obtained at the altitude 750m.

The result of the above calculation is tabulated below.

Rainfall Data in mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mm /yr
Less than 500m	199	203	182.5	191	313.5	220.5	127.5	35	32.5	25	91	174.5	1795
500m – 750m	244	248	220	336	541	348	195	43	40	35	126	222	2598
More than 750m	289	293	257.5	481	768.5	475.5	262.5	51	47.5	45	161	269.5	3401

c.) Evapotranspiration, E

Evapotranspiration is calculated by FAO Penman-Monteith equation using the collected meteorological data in Dili. The collected data include mean monthly temperature and mean humidity from 1953 to 1982, wind velocity from 1955 to 1982, and atmospheric pressure from 1977 to 1979. These collected meteorological data are attached in Appendix.

FAO Penman-Monteith equation is shown as below. The estimation, however, is calculated practically by the MS-Excel-program attached in Appendix B-1.

$$ET_o = \frac{0.408\,\Delta(R_n - G) + g\,\dfrac{900}{T+273}\,U_2(e_a - e_d)}{\Delta + g(1 + 0.34U_2)}$$

where:

ET_o	:	reference evapotranspiration [mm d^{-1}]
R_n	:	net radiation at surface [MJ m^{-2} d^{-1}]
G	:	soil heat flux [MJ m^{-2} d^{-1}]
T	:	average temperature [°C]
U_2	:	wind speed measured at 2m height [m s^{-1}]
$(e_a\text{-}e_d)$	:	vapour pressure deficit [kPa]
Δ	:	slope vapour pressure curve [kPa °C^{-1}]
γ	:	psychrometric constant [kPa °C^{-1}]
900	:	conversion factor

The results of the computations are shown in the table below.

Evapotranspiration, E

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mm/ yr
mm/day	3.74	3.79	4.31	4.72	4.69	4.48	4.69	4.90	4.94	4.81	4.44	3.90	
mm/mo.	116	106	134	142	145	134	145	152	148	149	133	121	1626

Then the value of *P-E* is calculated as tabulated below based on the value of *E* and the value of *P* ; rainfall.

P-E (mm/month)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mm/yr
North	Elv. – 500m	83	97	49	0	0	0	0	0	0	0	0	54	282
	500 – 1000m	173	187	124	0	0	0	0	0	0	0	28	149	660
	1000 –1500m	263	277	199	31	0	0	0	0	0	0	98	244	1111
	1500m -	353	367	274	66	23	0	0	0	0	0	168	339	1589
South	Elv. – 500m	83	97	49	49	168	86	0	0	0	0	0	54	586
	500 - 750m	128	142	86	194	396	214	50	0	0	0	0	101	1311
	750m -	173	187	124	339	623	341	117	0	0	0	28	149	2081

d.) Surface Direct Runoff, Rd

The Study Team could not collect continuous observation data of surface runoff in East Timor. Such kind of data might not have been recorded or be lost during the trouble in 1999. Only the table as shown below was obtained. The table summarizes minimum, mean, and maximum monthly runoff of the Comoro River, of which data were explained to be recorded at the point with a catchment of 150km^2.

Run-off **m^3/sec**
River: Comoro **Catchment 150 km^2**

	Min.	Average	Max
Jan	0.01	1.24	15.44
Feb	0.19	5.97	20.19
Mar	4.91	6.01	19.3
Apr	1.36	3.96	15.57
May	0.79	1.73	11.64
Jun	0.49	1.03	13.57
Jul	0.28	0.6	2.34
Aug	0.17	0.36	2.71
Sep	0.11	0.22	7.78
Oct	0.06	0.13	7.60
Nov	0.04	0.08	9.86
Dec	0.02	0.05	14.66
Average	0.70	1.78	11.72

Specific Run-off **l/sec/km^2**
River: Comoro **Catchment 150km^2**

	Min.	Average	Max
Jan	0.07	8.27	102.93
Feb	1.27	39.80	134.60
Mar	32.73	40.07	128.67
Apr	9.07	26.40	103.80
May	5.27	11.53	77.60
Jun	3.27	6.87	90.47
Jul	1.87	4.00	15.60
Aug	1.13	2.40	18.07
Sep	0.73	1.47	51.87
Oct	0.40	0.87	50.67
Nov	0.27	0.53	65.73
Dec	0.13	0.33	97.73
Average	4.68	11.88	78.14

The figures shown in the above table are used to estimate the total runoff, the direct runoff, and the base flow from a drainage basin as explained below.

The mean monthly runoff is considered the total runoff, *R*, and the minimum monthly runoff is considered the base flow, *Rb*, in the month from a drainage basin. Then the difference between *R* and *Rb* is considered the direct runoff, *Rd*, in the month from the drainage basin. The figures of *R*, *Rb*, and *Rd* were calculated based on the specific runoff.

The results are shown in the table below.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	mm /yr
R	**Total Runoff (m^3/sec)**	1.24	5.97	6.01	3.96	1.73	1.03	0.60	0.36	0.22	0.13	0.08	0.05	
	Daily (mm/day)	0.7142	3.4387	3.4618	2.2810	0.9965	0.5933	0.3456	0.2074	0.1267	0.0749	0.0461	0.0288	
	Monthly (mm/month)	22.141	96.284	107.314	68.428	30.891	17.798	10.714	6.428	3.802	2.321	1.382	0.893	368.4
Rb	**Base Flow (m^3/sec)**	0.01	0.19	4.91	1.36	0.79	0.49	0.28	0.17	0.11	0.06	0.04	0.02	
	Daily (mm/day)	0.0058	0.1094	2.8282	0.7834	0.4550	0.2822	0.1613	0.0979	0.0634	0.0346	0.0230	0.0115	
	Monthly (mm/month)	0.179	3.064	87.673	23.501	14.106	8.467	5.000	3.036	1.901	1.071	0.691	0.357	149.0
Rd	**Direct Runoff (mm/month)**	21.963	93.220	19.642	44.928	16.785	9.331	5.714	3.393	1.901	1.250	0.691	0.536	219.4

Where: Rd = R – Rb Catchment Area = 150km^2

e.) Potential Availability of Water

Potentially available water, *Q (=P-E-Rd)*, of each water source is estimated using the values of *P*, *E*, and *Rd* obtained in the previous section. The results of the evaluation are summarized in **Table B-2.1**.

B-2.2 Water Balance Calculation for 15 Towns

The following are the summaries of water balance calculations for each water source. Detailed figures derived from the calculations are presented at the end of this chapter as "calculation of potentially available data".

B-2.2.1 Dili

a) Bemos

The potential available water is estimated at 16.956 Mm^3/year or 537.7L/s. The monthly results are attached in Appendix B-1.

Contour (m)	Area (km^2)
less than 500	1.1
500m – 1000	20.3
above 1000	8.9
Total	30.3

			Mm^3/year	L/s	%
Precipitation in Area	P		55.268		100.0
Evapotranspiration	E		31.665		57.3
	P-E		23.602		42.7
Direct Runoff	Rd	= R – Rb	6.646	210.8	12.0
Potential Available Water	Q	= P - E – Rd	16.956	537.7	30.7

b) Bemori

The potential available water is estimated at 0.808 Mm^3/year or 25.6L/s.

Contour (m)	Area (km^2)
less than 500	0.79
500-1000	1.72
Total	2.51

			Mm^3/year	L/s	%
Precipitation in Area	P		3.803		100.0
Evapotranspiration	E		2.444		64.3
	P-E		1.359		35.7
Direct Runoff	Rd	= R – Rb	0.551	17.5	14.5
Potential Available Water	Q	= P - E - Rd	0.808	25.6	21.3

c) Benemauk

The potential available water is estimated at 2.206 Mm^3/year or 69.9L/s.

Contour (m)	Area (km^2)
less than 500	3.03
500 - 1000	4.57
Total	7.6

			Mm^3/year	L/s	%
Precipitation in Area	P		11.170		100.0
Evapotranspiration	E		7.297		65.3
	P-E		3.873		34.7
Direct Runoff	Rd	= R – Rb	1.667	52.9	14.9
Potential Available Water	Q	= P - E - Rd	2.206	69.9	19.7

d.) Maloa

The potential available water is estimated at 0.022 Mm^3/year or 0.7L/s.

Contour (m)	Area (km^2)
less than 500	0.79
500-1000	1.72
Total	2.51

			Mm^3/year	L/s	%
Precipitation in Area	P		0.305		100.0
Evapotranspiration	E		0.227		74.2
	P-E		0.079		25.8
Direct Runoff	Rd	= R – Rb	0.057	1.8	18.7
Potential Available Water	Q	= P - E - Rd	0.022	0.7	7.1

e.) Comoro (Groundwater)

Groundwater has been developed in Comoro, therefore the equation was modified to estimate groundwater recharge. That is, addition to *Rd*, *Rb*, the base flow from a drainage basin, was deducted from the value of *P-E*.

Then the potential groundwater recharge is estimated at 57.201 Mm^3/year or 1,813.8L/s.

Contour (m)	Area (km^2)
less than 500	39.4
500 – 1000	142.23
above 1000	25.69
Total	207.32

			Mm^3/year	L/s	%
Precipitation in Area	P		341.931		100.0
Evapotranspiration	E		208.354		60.9
	P-E		133.577		39.1
Direct Runoff	Rd	= R – Rb	45.476	1442.0	13.3
Potential Available Water	Q	= P - E - Rd	88.101	2793.7	25.8
Total Runoff	R	= Rd + Rb	76.376	2421.9	22.3
Base Flow	Rb		30.900	979.8	9.0
Groundwater Recharge	Qg	=P-E-(Rd+Rb)	57.201	1813.8	16.7

f.) Kuluhun-Bidau (Groundwater)

The potential groundwater recharge was estimated in the same way as Comoro.

The result was, however, unnaturally low, 0.312 Mm^3/year or 9.9 L/s. The obtained value is only 0.7% of the total rainfall in the area. The total surface runoff may be overestimated. Assuming 10-12% of the total rainfall is recharged to groundwater in the area, the estimated value would be 139-167L/sec.

Contour (m)	Area(km^2)
Less than 500	25.7
500 - 1000	8.64
Total	34.34

			Mm^3/year	L/s	%
Precipitation in Area	P		43.985		100.0
Evapotranspiration	E		31.022		70.5
	P-E		12.963		29.5
Direct Runoff	Rd	= R – Rb	7.533	238.9	17.1
Potential Available Water	Q	= P - E - Rd	5.430	172.2	12.3
Total Runoff	R	= Rd + Rb	12.651	401.2	28.8
Base Flow	Rb		5.118	162.3	11.6
Groundwater Recharge	Qg	= P-E-(Rd+Rb)	0.312	9.9	0.7

g) Hera (Groundwater)

The potential groundwater recharge was estimated in the same way as Comoro.

The obtained value is 3.7% of the total rainfall in the area, 2.148 Mm^3/year or 68.1 L/s, which may be relatively lower than expected. Assuming 10-12% of the total rainfall is recharged to groundwater in the area, the estimated value would be 185-222L/sec.

Contour (m)	Area(km^2)
Less than 500	30.72
500 - 1000	11.09
above 1000	2.09
Total	43.9

			Mm^3/year	L/s	%
Precipitation in Area	P		58.511		100.0
Evapotranspiration	E		40.191		68.7
	P-E		18.320		31.3
Direct Runoff	Rd	= R – Rb	9.630	305.4	16.5
Potential Available Water	Q	= P - E - Rd	8.691	275.6	14.9
Total Runoff	R	= Rd + Rb	16.173	512.8	27.6
Base Flow	Rb		6.543	207.5	11.2
Groundwater Recharge	Qg	= P-E-(Rd+Rb)	2.148	68.1	3.7

B-2.2.2 Atauro

a) Mota Tulai

The potential available water is estimated at 0.0365 Mm^3/year or 11.6L/s.

Contour (m)	Area (km^2)
less than 500	0.33
500 – 1000	0.78
Total	1.11

			Mm^3/year	L/s	%
Precipitation in Area	P		1.692		100.0
Evapotranspiration	E		1.084		64.1
	P-E		0.608		35.9
Direct Runoff	Rd	= R – Rb	0.243	7.7	14.4
Potential Available Water	Q	= P - E - Rd	0.365	11.6	21.6

b) Mota Eklai

The potential available water is estimated at 0.022 Mm^3/year or 0.7L/s.

Contour (m)	Area (km^2)
less than 500	0.063
500 – 1000	0.04
Total	0.103

			Mm^3/year	L/s	%
Precipitation in Area	P		0.140		100.0
Evapotranspiration	E		0.095		68.3
	P-E		0.044		31.7
Direct Runoff	Rd	= R – Rb	0.023	0.7	16.2
Potential Available Water	Q	= P - E - Rd	0.022	0.7	15.5

c) Mota Lampia

The potential available water is estimated at 0.060Mm^3/year or 1.9L/s.

Contour (m)	Area (km^2)
less than 500	0.664
500 – 1000	0.04
Total	0.704

			Mm^3/year	L/s	%
Precipitation in Area	P		0.828		100.0
Evapotranspiration	E		0.614		74.2
	P-E		0.214		25.8
Direct Runoff	Rd	= R – Rb	0.154	4.9	18.7
Potential Available Water	Q	= P - E - Rd	0.060	1.9	7.2

B-2.2.3 Manatuto

a) Manatuto Spring

The potential available water is estimated at 0.153Mm^3/year or 4.9L/s.

Contour (m)	Area (km^2)
Less than 500	2.43
Total	2.43

			Mm^3/year	L/s	%
Precipitation in Area	P		2.782		100.0
Evapotranspiration	E		2.096		75.3
	P-E		0.686		24.7
Direct Runoff	Rd	= R – Rb	0.533	16.9	19.2
Potential Available Water	Q	= P - E - Rd	0.153	4.9	5.5

b) Laclo and Sumasse River

The potential available water is estimated at 58.345Mm^3/year or 1850L/s.

The area used to estimate is only the catchment of the Sumasse River. In fact, the new infiltration gallery constructed by JICA takes water from the Laclo River also. The Laclo River has a drainage basin of 1114km^2.

Contour (m)	Area (km^2)
less than 500	74.1
500 - 1000	65.1
above 1000	28
Total	167.2

			Mm^3/year	L/s	%
Precipitation in Area	P		256.838		100.0
Evapotranspiration	E		161.817		63.0
	P-E		95.021		37.0
Direct Runoff	Rd	= R – Rb	36.676	1163.0	14.3
Potential Available Water	Q	= P - E - Rd	58.345	1850.1	22.7

B-2.2.4 Baucau

The potential groundwater recharge was estimated in the same way as Comoro because the water source is a spring in Baucau. The potential groundwater recharge is estimated at 9.430Mm^3/year or 299L/s, which is 14.5% of the total rainfall in the area. The catchment of the Wailia Spring is the limestone plateau with highly permeable. Actually, there are few surface streams on the plateau. The groundwater recharge ratio may be more than the estimated value.

a.) Wailia Spring

Contour (m)	Area (km^2)
Less than 500	6.4
500 - 1000	34.2

Total	40.6

			Mm³/year	L/sec	%
Precipitation in Area	P		64.955		100.0
Evapotranspiration	E		40.568		62.5
	P-E		24.387		37.5
Direct Runoff	Rd	= R – Rb	8.906	282.4	13.7
Potential Available Water	Q	= P - E - Rd	15.482	490.9	23.8
Total Runoff	R	= Rd + Rb	14.957	474.3	23.0
Base Flow	Rb		6.051	191.9	9.3
Groundwater Recharge	Qg	= P-E-(Rd+Rb)	9.430	299.0	14.5

B-2.2.5 Los Palos

The estimation of P was modified because the elevation of the area does not vary so much. Rainfall in the area less than 500m in altitude is estimated with the mean altitude of 425m and the area more than 500m is estimated with the mean altitude of 500m. Then the potential groundwater recharge was estimated in the same way as Comoro because the water source is a spring in Los palos. The obtained value is 0.790Mm^3/year, 25L/sec, which is only 2.8% of the total rainfall in the area. This is considerably low. The catchment of the Papapa Spring is the limestone plateau with highly permeable as well as Baucau. Suppose the amount deducted the direct runoff from the value of *P-E* infiltrates into ground, the potential value is estimated at 3.965Mm^3/year, 125.7L/sec, which is 13.9% of the total rainfall in the area.

a.) Papapa Spring

Contour (m)	Area (km²)
350 - 500	21.04
500	0.26
Total	21.3

			Mm³/year	L/sec	%
Precipitation in Area	P		28.435		100.0
Evapotranspiration	E		19.798		69.6
	P-E		8.637		30.4
Direct Runoff	Rd	= R – Rb	4.672	148.2	16.4
Potential Available Water	Q	= P - E – Rd	3.965	125.7	13.9
Total Runoff	R	= Rd + Rb	7.847	248.8	27.6
Base Flow	Rb		3.175	100.7	11.2
Groundwater Recharge	Qg	= P-E-(Rd+Rb)	0.790	25.0	2.8

B-2.2.6 Viqueque

The potential groundwater recharge was estimated in the same way as Comoro because the water source is a spring in Viqueque. The potential groundwater recharge is estimated at 11.716Mm^3/year or 371.5L/s. Viqueque is located in the south part of the island.

a.) Builua (Loihunu) Spring

Contour (m)	Area (km^2)
Less than 500	9.46
500 – 750	6.45
750	2.09
Total	18

			Mm^3/year	L/s	%
Precipitation in Area	P		40.846		100.0
Evapotranspiration	E		22.499		55.1
	P-E		18.347		44.9
Direct Runoff	Rd	= R – Rb	3.948	125.2	9.7
Potential Available Water	Q	= P - E – Rd	14.398	456.6	35.3
Total Runoff	R	= Rd + Rb	6.631	210.3	16.2
Base Flow	Rb		2.683	85.1	6.6
Groundwater Recharge	Qg	= P-E-(Rd+Rb)	11.716	371.5	28.7

B-2.2.7 Same

Same is located in the south part of the island.

a) Carbulau (Darelau)

The potential available water is estimated at 1.917 Mm^3/year or 60.8L/s.

Contour (m)	Area (km^2)
750	1.03
Total	1.03

			Mm^3/year	L/s	%
Precipitation in Area	P		3.503		100.0
Evapotranspiration	E		1.360		38.8
	P-E		2.143		61.2
Direct Runoff	Rd	= R – Rb	0.226	7.2	6.4
Potential Available Water	Q	= P - E – Rd	1.917	60.8	54.7

b) Kotalala

The potential available water is estimated at 20.366Mm^3/year or 645.8L/s.

Contour (m)	Area (km^2)
750m	10.94
Total	10.94

			Mm^3/year	L/s	%
Precipitation in Area	P		37.207		100.0
Evapotranspiration	E		14.441		38.8
	P-E		22.766		61.2
Direct Runoff	Rd	= R – Rb	2.400	76.1	6.4
Potential Available Water	Q	= P - E – Rd	20.366	645.8	54.7

c) Mirbute Bituruli

The potential available water is estimated at 0.872 Mm^3/year or 27.6L/s.

Contour (m)	Area (km^2)
500 - 750	0.125
750	0.395
Total	0.52

			Mm^3/year	L/s	%
Precipitation in Area	P		1.668		100.0
Evapotranspiration	E		0.682		40.9
	P-E		0.986		59.1
Direct Runoff	Rd	= R – Rb	0.114	3.6	6.8
Potential Available Water	Q	= P - E – Rd	0.872	27.6	52.3

B-2.2.8 Ainaro

Ainaro is located in the south part of the island. The potential available water is estimated at 16.624 Mm^3/year or 527.1L/s.

a.) Sarai River

Contour (m)	Area (km^2)
750	8.93
Total	8.93

			Mm^3/year	L/s	%
Precipitation in Area	P		30.371		100.0
Evapotranspiration	E		11.788		38.8
	P-E		18.583		61.2
Direct Runoff	Rd	= R - Rb	1.959	62.1	6.4
Potential Available Water	Q	= P - E - Rd	16.624	527.1	54.7

B-2.2.9 Aileu

a) Mantane River

The potential available water is estimated at 53.994 Mm^3/year or 1712 L/s.

Contour (m)	Area (km^2)
500 - 1000	9.99
1000 - 1500	47.5
above 1500	5.28
Total	62.77

			Mm^3/year	L/s	%
Precipitation in Area	P		137.120		100.0
Evapotranspiration	E		69.357		50.6
	P-E		67.763		49.4

Direct Runoff	Rd	= R - Rb	13.769	436.6	10.0
Potential Available Water	Q	= P - E - Rd	53.994	1712.1	39.4

b) Naufaisaran

The potential available water is estimated at 0.111 Mm^3/year or 3.5L/s.

Contour (m)	Area (km^2)
1000 - 1500	0.125
Total	0.125

			Mm^3/year	**L/sec**	**%**
Precipitation in Area	P		0.278		100.0
Evapotranspiration	E		0.139		50.1
	P-E		0.139		49.9
Direct Runoff	Rd	= R - Rb	0.027	0.9	9.9
Potential Available Water	Q	= P - E - Rd	0.111	3.5	40.1

c) Hularema

The potential available water is estimated at 0.321 Mm^3/year or 10.2L/s.

Contour (m)	Area (km^2)
1000 - 1500	0.36
Total	0.36

			Mm^3/year	**L/sec**	**%**
Precipitation in Area	P		0.801		100.0
Evapotranspiration	E		0.401		50.1
	P-E		0.400		49.9
Direct Runoff	Rd	= R - Rb	0.079	2.5	9.9
Potential Available Water	Q	= P - E - Rd	0.321	10.2	40.1

d) Sloi Kraik

The potential available water is estimated at 0.883 Mm^3/year or 28.0L/s.

Contour (m)	Area (km^2)
1000 - 1500	0.99
Total	0.99

			Mm^3/year	**L/s**	**%**
Precipitation in Area	P		2.203		100.0
Evapotranspiration	E		1.103		50.1
	P-E		1.100		49.9
Direct Runoff	Rd	= R - Rb	0.217	6.9	9.9
Potential Available Water	Q	= P – E - Rd	0.883	28.0	40.1

B-2.2.10 Maubisse

a) Raikuak Ulun

The potential available water is estimated at 1.725 Mm^3/year or 54.7L/s.

Contour (m)	Area (km^2)
1500	1.26
Total	1.26

			Mm^3/year	L/s	%
Precipitation in Area	P		3.484		100.0
Evapotranspiration	E		1.482		42.5
	P-E		2.002		57.5
Direct Runoff	Rd	= R - Rb	0.276	8.8	7.9
Potential Available Water	Q	= P – E - Rd	1.725	54.7	49.5

b) Bucana

The potential available water is estimated at 0.644 Mm^3/year or 20.4 L/s.

Contour (m)	Area (km^2)
1500	0.47
Total	0.47

			Mm^3/year	L/s	%
Precipitation in Area	P		1.300		100
Evapotranspiration	E		0.553		42
	P-E		0.747		57.5
Direct Runoff	Rd	= R - Rb	0.103	3.3	7.9
Potential Available Water	Q	= P - E - Rd	0.644	20.4	49.5

c) Filmou

The potential available water is estimated at 0.233 Mm^3/year or 7.4 L/s.

Contour (m)	Area (km^2)
1500	0.17
Total	0.17

			Mm^3/year	L/s	%
Precipitation in Area	P		0.470		100.0
Evapotranspiration	E		0.200		42.5
	P-E		0.270		57.5
Direct Runoff	Rd	= R - Rb	0.037	1.2	7.9
Potential Available Water	Q	= P - E - Rd	0.233	7.4	49.5

d) Erulu

The potential available water is estimated at 0.305 Mm^3/year or 9.7L/s.

Contour (m)	Area (km^2)
1000 - 1500	0.02
above 1500	0.21
Total	0.23

			Mm^3/year	L/s	%
Precipitation in Area	P		0.625		100.0
Evapotranspiration	E		0.269		43.1
	P-E		0.356		56.9
Direct Runoff	Rd	= R - Rb	0.050	1.6	8.1
Potential Available Water	Q	= P - E - Rd	0.305	9.7	48.9

B-2.2.11 Gleno

a) Mota Boot

The potential available water is estimated at 6.178 Mm^3/year or 195.9 L/s.

Contour (m)	Area (km^2)
1000 – 1500	5.53
above 1500	0.91
Total	6.44

			Mm^3/year	L/s	%
Precipitation in Area	P		14.820		100.0
Evapotranspiration	E		7.230		48.8
	P-E		7.590		51.2
Direct Runoff	Rd	= R - Rb	1.413	44.8	9.5
Potential Available Water	Q	= P - E - Rd	6.178	195.9	41.7

b) Mota Kilk

The potential available water is estimated at 0.789Mm^3/year or 25L/s.

Contour (m)	Area (km^2)
1000 – 1500	0.67
above 1500	0.14
Total	0.81

			Mm^3/year	L/s	%
Precipitation in Area	P		1.878		100.0
Evapotranspiration	E		0.911		48.5
	P-E		0.967		51.5
Direct Runoff	Rd	= R - Rb	0.178	5.6	9.5
Potential Available Water	Q	= P - E - Rd	0.789	25.0	42.0

B-2.2.12 Ermera

a) Ersoi

The potential available water is estimated at 0.057Mm^3/year, 1.8L/sec.

Contour (m)	Area (km^2)
1000 - 1500	0.064
Total	0.064

			Mm^3/year	L/s	%
Precipitation in Area	P		0.142		100
Evapotranspiration	E		0.071		50
	P-E		0.071		49.9
Direct Runoff	Rd	= R - Rb	0.014	0.4	9.9
Potential Available Water	Q	= P - E - Rd	0.057	1.8	40.1

b) Mota Bura Spring

The potential available water is estimated at 0.807Mm^3/year or 25.6L/s.

Contour (m)	Area (km^2)
1000 - 1500m	0.905
Total	0.905

			Mm^3/year	L/s	%
Precipitation in Area	P		2.014		100.0
Evapotranspiration	E		1.008		50.1
	P-E		1.006		49.9
Direct Runoff	Rd	= R - Rb	0.199	6.3	9.9
Potential Available Water	Q	= P - E - Rd	0.807	25.6	40.1

B-2.2.13 Liquica

a) Laclo

The potential available water is estimated at 0.522 Mm^3/year or 16.6L/s.

Contour (m)	Area (km^2)
below 500	0.025
500 – 1000	1.05
above 1000	0.065
Total	1.14

			Mm^3/year	L/s	%
Precipitation in Area	P		1.943		100.0
Evapotranspiration	E		1.170		60.2
	P-E		0.773		39.8
Direct Runoff	Rd	= R - Rb	0.250	7.9	12.9
Potential Available Water	Q	= P - E - Rd	0.522	16.6	26.9

b) Lilabu

The potential available water is estimated at 0.137Mm^3/year or 4.3L/sec.

Contour (m)	Area (km^2)
below 500	0.35
500 - 1000	0.26
Total	0.61

			Mm^3/year	L/s	%
Precipitation in Area	P		0.839		100.0
Evapotranspiration	E		0.568		67.8
	P-E		0.271		32.2
Direct Runoff	Rd	= R - Rb	0.134	4.2	16.0
Potential Available Water	Q	= P - E - Rd	0.137	4.3	16.3

c) Narlolo

The potential available water is estimated at 0.115 Mm^3/year or 3.7L/s.

Contour (m)	Area (km^2)
below 500	0.43
500 – 1000	0.2
Total	0.63

			Mm^3/year	L/s	%
Precipitation in Area	P		0.829		100.0
Evapotranspiration	E		0.576		69.4
	P-E		0.253		30.6
Direct Runoff	Rd	= R - Rb	0.138	4.4	16.7
Potential Available Water	Q	= P - E - Rd	0.115	3.7	13.9

d) Daulo

The potential available water is estimated at 4.622 Mm^3/year or 146.6L/s.

Contour (m)	Area (km^2)
below 500	0.46
500 – 1000	5.18
above 1000	2.59
Total	8.23

			Mm^3/year	L/s	%
Precipitation in Area	P		15.018		100.0
Evapotranspiration	E		8.590		57.2
	P-E		6.428		42.8
Direct Runoff	Rd	= R - Rb	1.805	57.2	12.0
Potential Available Water	Q	= P - E - Rd	4.622	146.6	30.8

e) Eanlua

The potential available water is estimated at 0.881Mm^3/year or 27.9L/s.

Contour (m)	Area (km^2)
below 500	0.19
500 - 1000	1.87
1000	0.05
Total	2.11

			Mm³/year	L/s	%
Precipitation in Area	P		3.480		100.0
Evapotranspiration	E		2.136		61.4
	P-E		1.344		38.6
Direct Runoff	Rd	= R - Rb	0.463	14.7	13.3
Potential Available Water	Q	= P - E - Rd	0.881	27.9	25.3

f) Metagou

The potential available water is estimated at 0.129 Mm^3/year or 4.1L/s.

Contour (m)	Area (km^2)
500 – 1000	0.03
1000	0.13
Total	0.16

			Mm³/year	L/s	%
Precipitation in Area	P		0.340		100.0
Evapotranspiration	E		0.176		51.7
	P-E		0.164		48.3
Direct Runoff	Rd	= R - Rb	0.035	1.1	10.3
Potential Available Water	Q	= P - E - Rd	0.129	4.1	38.0

g) Emilaloa

The potential available water is estimated at 2.275 Mm^3/year or 72.1L/s.

Contour (m)	Area (km^2)
below 500	0.32
500 – 1000	2.93
1000	1.08
Total	4.33

			Mm³/year	L/sec	%
Precipitation in Area	P		7.706		100.0
Evapotranspiration	E		4.482		58.2
	P-E		3.225		41.8
Direct Runoff	Rd	= R - Rb	0.950	30.1	12.3
Potential Available Water	Q	= P - E - Rd	2.275	72.1	29.5

h) Dato – Maumeta (Groundwater)

The potential groundwater recharge was estimated in the same way as Comoro. The estimated value is 3.590Mm^3/year or 113.8L/s. Groundwater condition in Liquica will be described in the next section again.

Contour (m)	Area (km^2)
below 500	4.71
500 – 1000	7.76
1000	2.33
Total	14.8

			Mm^3/year	L/s	%
Precipitation in Area	P		23.653		100.0
Evapotranspiration	E		14.610		61.8
	P-E		9.043		38.2
Direct Runoff	Rd	= R – Rb	3.246	102.9	13.7
Potential Available Water	Q	= P - E – Rd	5.796	183.8	24.5
Total Runoff	R	= Rd + Rb	5.452	172.9	23.1
Base Flow	Rb		2.206	69.9	9.3
Groundwater Recharge	Qg	= P-E-(Rd+Rb)	3.590	113.8	15.2

B-2.2.14 Suai

Suai is located in the south part of the island. The locations of water sources were pointed based on the investigation conducted by the local stuff trained by the Study team.

a) Olivio

The potential available water is estimated at 1.397 Mm^3/year or 44.3L/s.

Contour (m)	Area (km^2)
below 500	1.37
500 - 750	0.82
Total	2.19

			Mm^3/year	L/sec	%
Precipitation in Area	P		4.590		100.0
Evapotranspiration	E		2.712		59.1
	P-E		1.878		40.9
Direct Runoff	Rd	= R – Rb	0.480	15.2	10.5
Potential Available Water	Q	= P - E – Rd	1.397	44.3	30.4

b) Ameriko – Maugusu

The potential available water is estimated at 1.87Mm^3/year or 59.3L/s.

Contour (m)	Area (km^2)
below 500	2.69
500 - 750	0.81
Total	3.5

			Mm^3/year	L/sec	%
Precipitation in Area	P		6.933		100.0
Evapotranspiration	E		4.295		61.9
	P-E		2.638		38.1
Direct Runoff	Rd	= R – Rb	0.768	24.3	11.1
Potential Available Water	Q	= P - E – Rd	1.870	59.3	27.0

c) Kuluai

The potential available water is estimated at 0.637Mm^3/year or 20.2L/s.

Contour (m)	Area (km^2)
below 500	1.23
500 - 750	0.17
Total	1.4

			Mm^3/year	L/s	%
Precipitation in Area	P		2.650		100.0
Evapotranspiration	E		1.706		64.4
	P-E		0.944		35.6
Direct Runoff	Rd	= R – Rb	0.307	9.7	11.6
Potential Available Water	Q	= P - E – Rd	0.637	20.2	24.0

d) Sukabilaran 1 & 2 (Groundwater)

Groundwater has been developed in Suia. The potential groundwater recharge was estimated in the same way as Comoro. The estimated value is 10.352Mm^3/year or 328.3L/s. Groundwater condition in Suai will be summarized in the next section again.

Contour (m)	Area (km^2)
below 500	36.48
500 - 750	2.56
Total	39.04

			Mm^3/year	L/s	%
Precipitation in Area	P		72.132		100.0
Evapotranspiration	E		47.398		65.7
	P-E		24.734		34.3
Direct Runoff	Rd	= R – Rb	8.564	271.5	11.9
Potential Available Water	Q	= P - E - Rd	16.170	512.8	22.4
Total Runoff	R	= Rd + Rb	14.382	456.1	19.9
Base Flow	Rb		5.819	184.5	8.1
Groundwater Recharge	Qg	= P-E-(Rd+Rb)	10.352	328.3	14.4

B-2.2.15 Maliana

The locations of water sources were pointed based on the investigation conducted by the local staff trained by the Study team.

a) Dabucci Spring Group

The potential available water is estimated at 1.004Mm^3/year or 31.8L/s.

Contour (m)	Area (km^2)
below 500	0.19
500 - 1000	1.42
above 1000	0.41
Total	2.02

			Mm^3/year	L/s	%
Precipitation in Area	P		3.523		100.0
Evapotranspiration	E		2.076		58.9
	P-E		1.447		41.1
Direct Runoff	Rd	= R – Rb	0.443	14.1	12.6
Potential Available Water	Q	= P - E – Rd	1.004	31.8	28.5

b) Beapelu Spring

The potential available water is estimated at 0.706 Mm^3/year or 22.4 L/s.

Contour (m)	Area (km^2)
500 - 1000	1.4
above 1000	0.1
Total	1.5

			Mm^3/year	L/s	%
Precipitation in Area	P		2.582		100.0
Evapotranspiration	E		1.546		59.9
	P-E		1.035		40.1
Direct Runoff	Rd	= R – Rb	0.329	10.4	12.7
Potential Available Water	Q	= P - E – Rd	0.706	22.4	27.4

c) Beremau Spring

The potential available water is estimated at 0.015 Mm^3/year or 0.5 L/s.

Contour (m)	Area (km^2)
500 - 1000	0.034
Total	0.034

			Mm^3/year	L/s	%
Precipitation in Area	P		0.057		100.0
Evapotranspiration	E		0.035		60.8
	P-E		0.022		39.2
Direct Runoff	Rd	= R – Rb	0.007	0.2	13.0
Potential Available Water	Q	= P - E – Rd	0.015	0.5	26.2

d) Irrigation Canal

The potentially available water is estimated at 4.195Mm^3/year or 133L/s.

<u>Contour (m)</u>	<u>Area (km^2)</u>
below 500	1.57
500 - 1000	4.74
above 1000	2.25
Total	8.56

			Mm^3/year	**L/s**	**%**
Precipitation in Area	P		14.791		100.0
Evapotranspiration	E		8.718		58.9
	P-E		6.073		41.1
Direct Runoff	Rd	= R – Rb	1.878	59.5	12.7
Potential Available Water	Q	= P - E – Rd	4.195	133.0	28.4

Table B - 2.1 Calculated Potentially Available Water

No.	Town		Water Source				Catchment Area	Calculated potentialy available water **
			Name	Label	Type		(km²)	(liter/sec)
1.	Dili	1	Bemos		Stream	1	30.3	537
		2	Bemori		Stream	1	1.49	26
		3	Benemauk		Stream	1	7.6	70
		4	Maloa		Stream	1	3.02	30
		5	Comoro A - E		Borehole	5	207.32	1812
		10	Kuluhun & Bidau		Borehole	5	34.34	(139-167)
		14	Hera A - C		Borehole	5	50.83	(185-222)
2.	Atauro	1	Mota Eklai		Streams	1	0.103	1
		2	Mota Tulai		Spring	3	1.11	12
		3	Mota Lampia		Spring	3	0.704	2
3.	Manatuto		Manatuto		Spring	3	2.43	5
			Laclo River		River	2	1281.2	17895
4.	Baucau		Wailia		Spring	4	40.6	491
5.	Lospalos		Papapa		Spring	4	21.3	126
6.	Viqueque		Builua		Spring	4	18	372
7.	Same	1	Carbulau		Stream	1	1.03	61
		2	Kotalala		Stream	1	10.94	646
		3	Mirbute Bituruli		Spring	3	0.515	28
8.	Ainaro		Sarai		Stream	1	8.93	527
9.	Aileu	1	Mantane		River	2	62.77	1712
		2	Sloi Kraik		Stream	1	0.99	28
		3	Naufaisaran		Spring	3	0.125	4
		4	Hularema		Spring	3	0.365	10
10.	Maubisse	1	Raikuak Ulun		Spring	3	1.26	55
		2	Bucana		Spring	3	0.47	20
		3	Filmou		Spring	3	0.17	7
		4	Erulu		Spring	3	0.23	10
11.	Gleno	1	Mota Boot		Stream	1	6.44	196
		2	Mota Kiik		Stream	1	0.81	25
		3	Ergrogo		Spring	3	0.5	---
12.	Ermera	1	Lubulala		Spring	3	0.064	---
		2	Ersoi		Spring	3	0.064	2
		3	Mota Bura		Spring	3	0.905	26
13.	Liquica	1	Dato & Maumeta		Borehole	5	14.8	114
		5	Laclo	LIQ-WS13	Stream	1	1.14	17
		6	Lilabu	LIQ-WS06	Stream	1	0.61	4
		7	Narlolo	LIQ-WS05	Stream	1	0.63	4
		8	Daulo		Stream	1	8.23	147
		9	Eanlua	LIQ-WS09,10	Stream	1	2.11	28
		10	Raisape		Stream	1	-	-
		11	Metagou	LIQ-WS11,12	Stream	1	0.16	4
		12	Emilaloa	LIQ-WS07	Stream	1	4.33	72
14.	Suai	1	Olivio		Stream	1	2.19	44
		2	Ameriko & Maugusu		Stream	1	3.5	59
		3	Maugusu		Stream	1	-	-
		4	Kuluai		Spring	3	1.4	20
		5	Sukabilaran 1 - 2		Borehole	5	39.04	328
15.	Maliana	1	Beamos		Spring	1	0.03	1
		2	Aikumu		Spring	3	1.50	22
		3	Dabucci		Spring	3	2.02	-
		4	Beapelu		Stream	1	1.50	-
		5	Beremau		Stream	1	0.03	-
		6	Colegio		Stream	1	-	-
		7	Irrigation canal		Stream	1	2.02	32

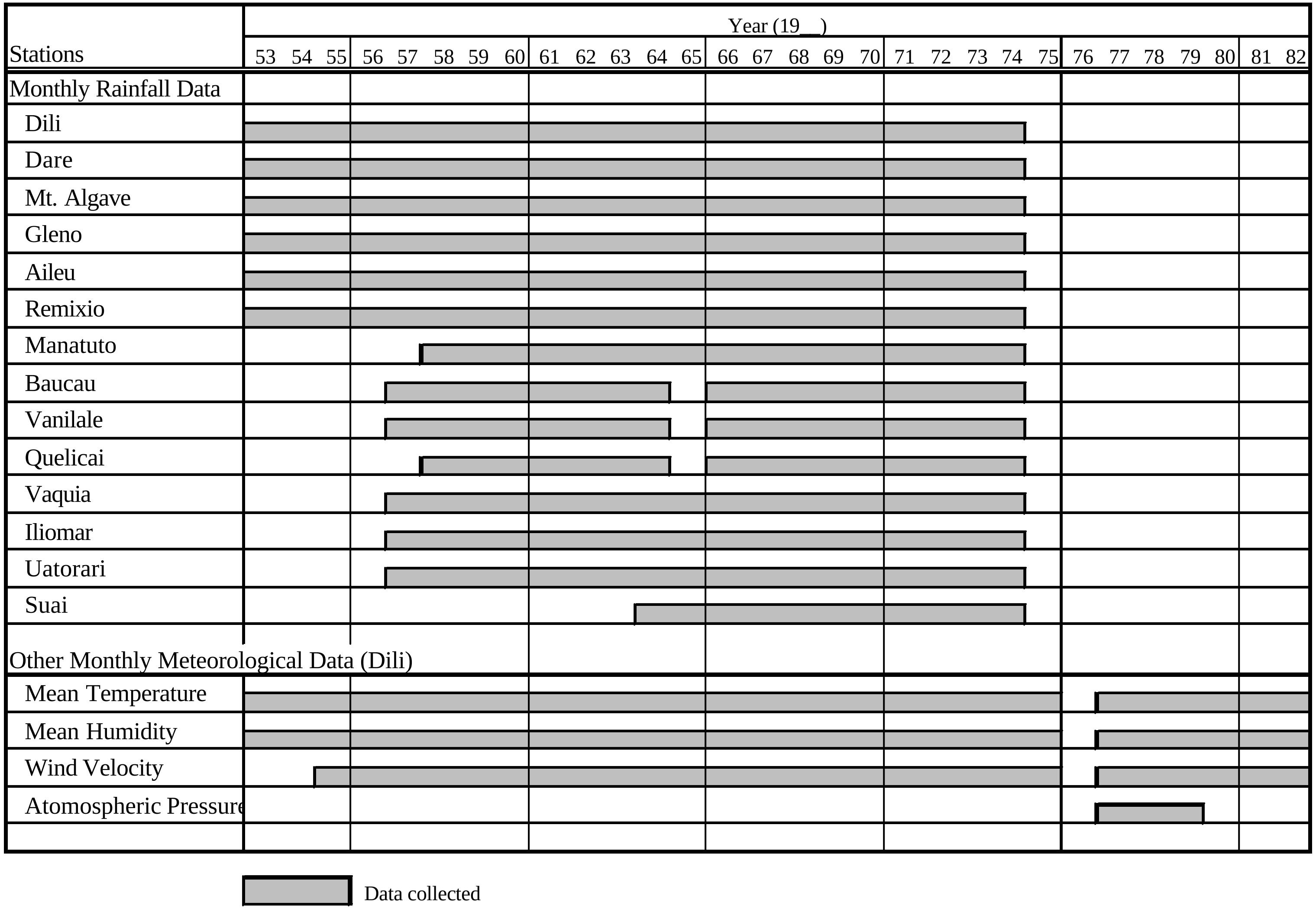

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Figure B2-1

METEOROLOGICAL DATA COLLECTED

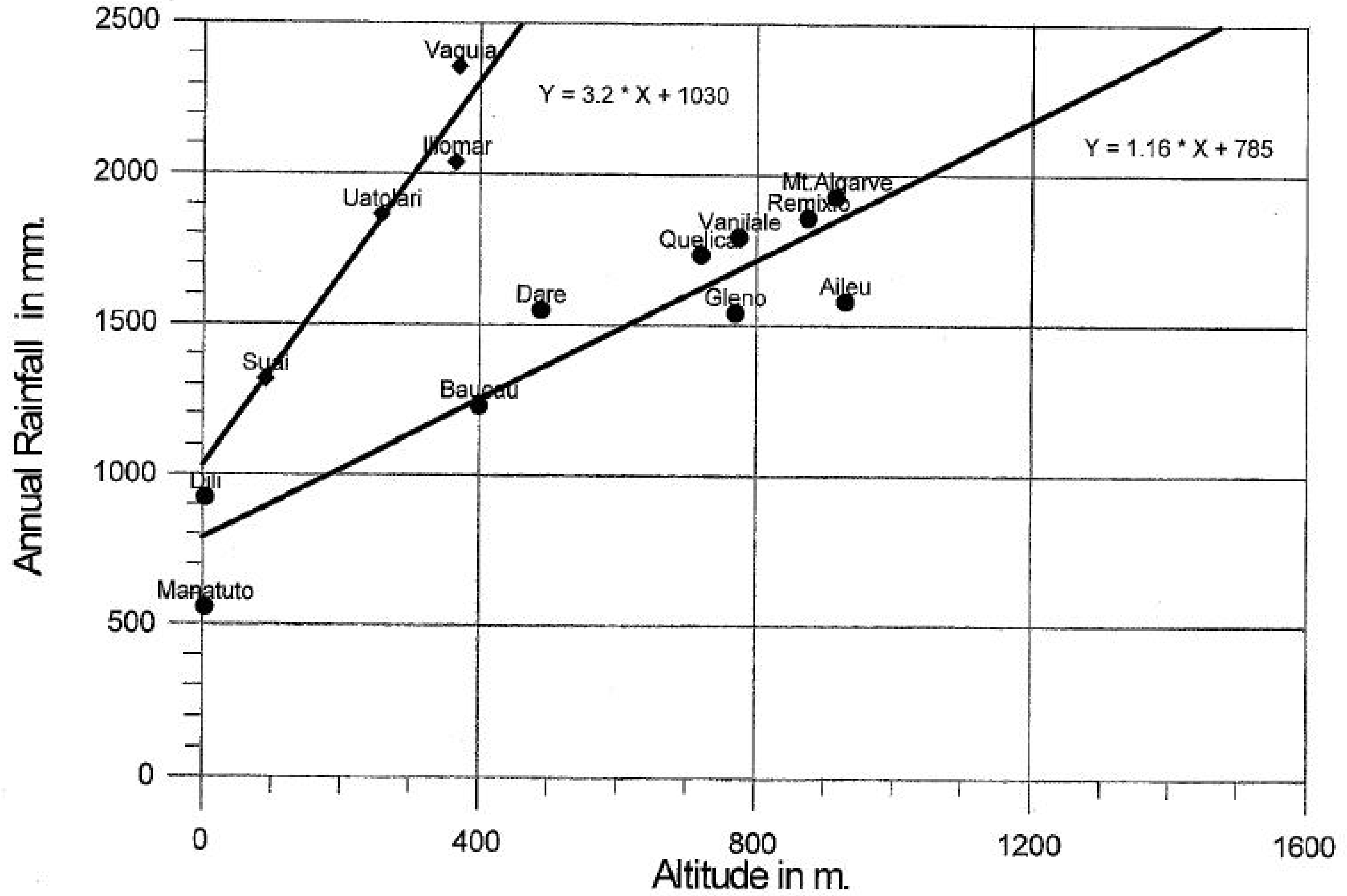

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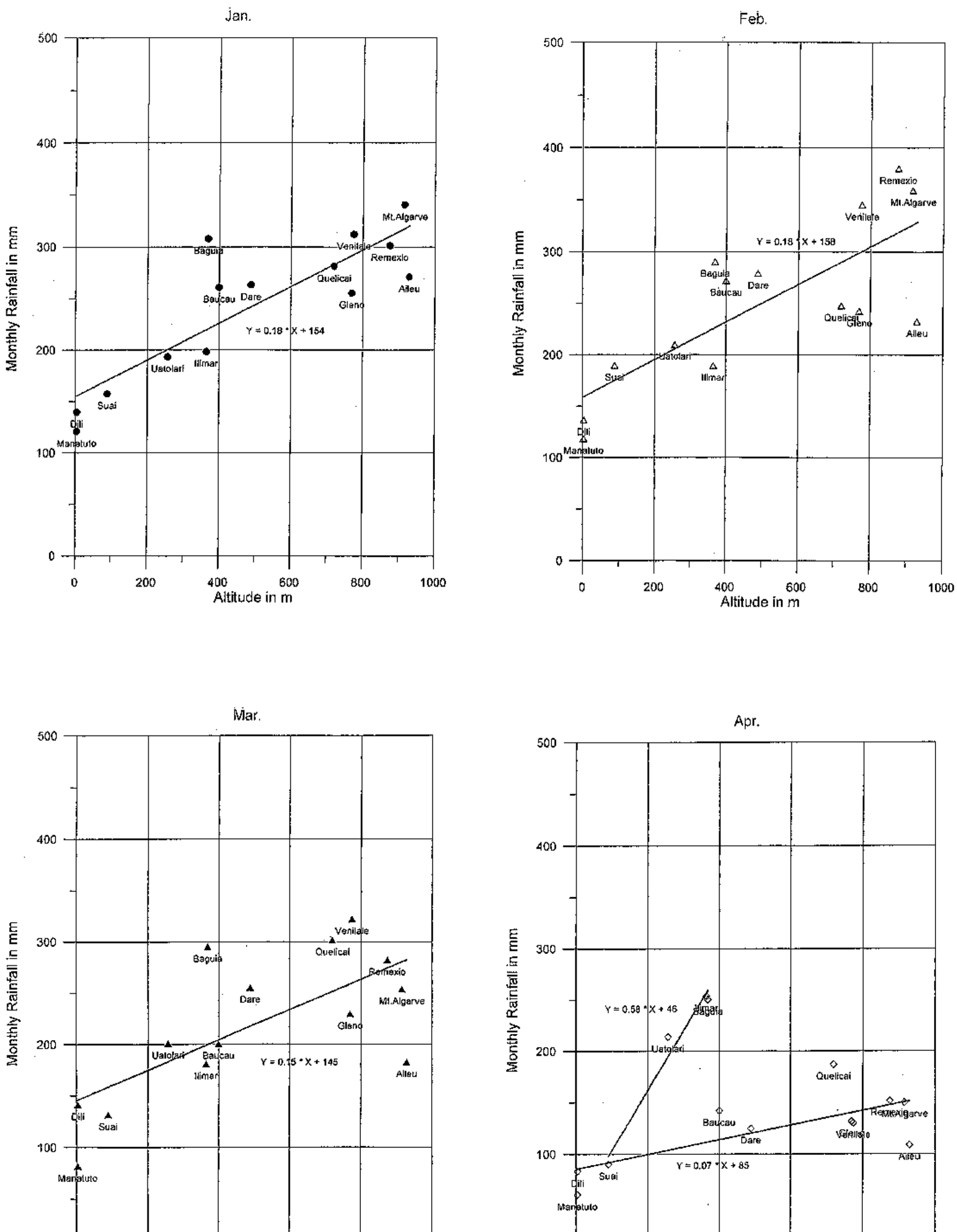
Figure B-2.2

RELATION BETWEEN ANNUAL RAINFALL AND ALTITUDE



The Study onUrgent Improvement Project for the Water Supply System in East Timor	**Figure**
RELATION BETWEEN MONTHLY RAINFALL AND ALTITUDE (Jan.-Apr.)	**B-2.3 (1)**

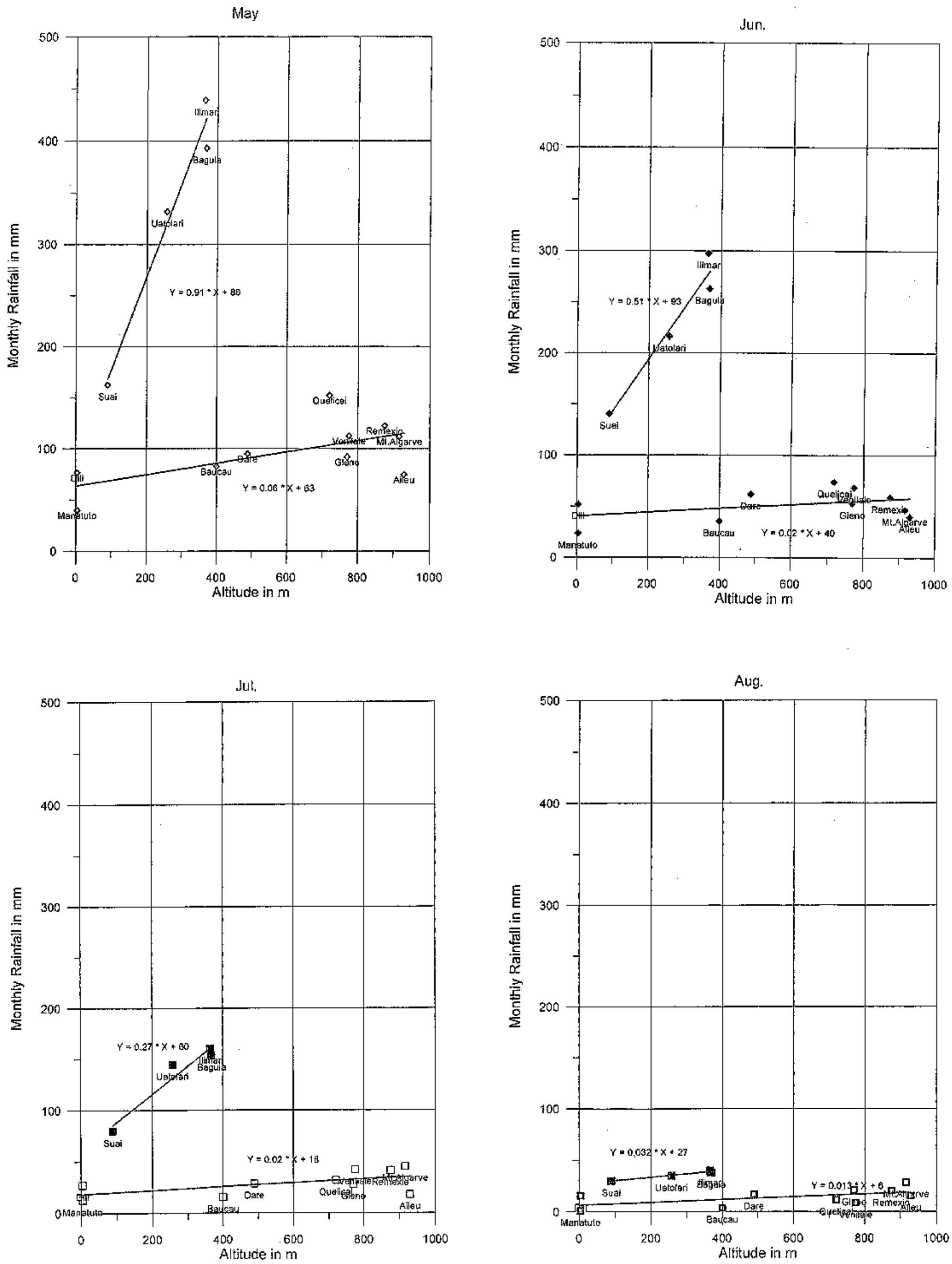


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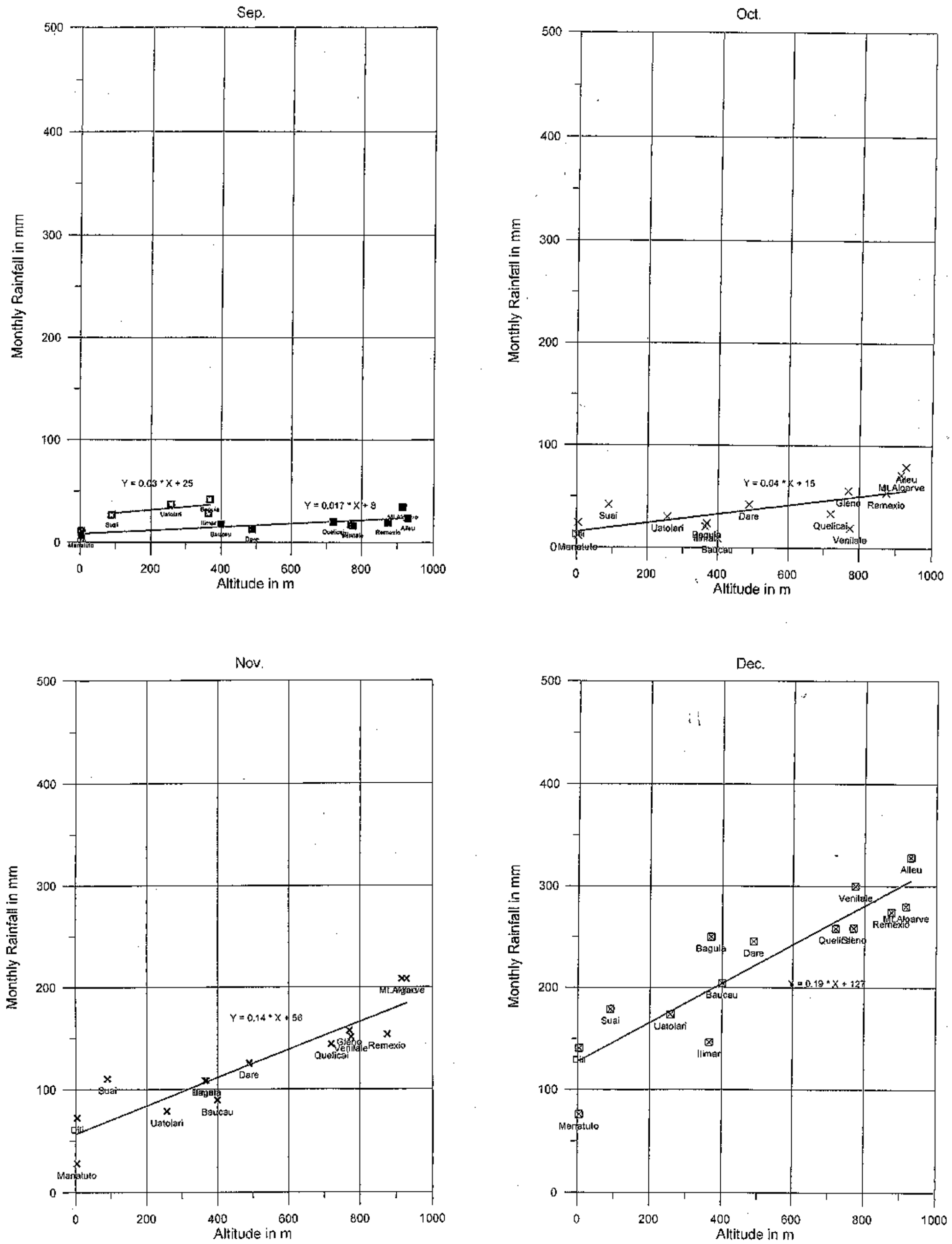
Figure

RELATION BETWEEN MONTHLY RAINFALL AND ALTITUDE (May-Aug.)

B-2.3 (2)



JICA	*The Study onUrgent Improvement Project for the Water Supply System in East Timor*	**Figure**
RELATION BETWEEN MONTHLY RAINFALL AND ALTITUDE (Sep.-Dec.)		**B-2.3 (3)**

B-3 EVALUATION OF WATER SOURCES

B-3.1 Evaluation of Catchment

The conditions of catchment of a water source affect the quality and quantity of the water to a large extent. In this study observations were made in most water sources to evaluate vegetation and human activity. In the sites where direct observation could not be made, the evaluation was made based on the information obtained from the topographic maps. Note that the evaluation is a qualitative and relative one, thus not based on any measurement or counting.

For vegetation, forest coverage was mainly checked as well as the types of trees and soil exposure. Tentative evaluation results are shown in **Table B-3.1**. The evaluation was made on a scale of A to C where A stands for rich forest coverage, B moderate and C, poor. It is well known that forests in the catchment of a water source serve to retain rainwater. This helps to reduce flood water discharge, making more water available at the intake. Forest coverage also helps reduce soil erosion that makes the water turbid and sometimes clog pipes and paralyzes treatment plants.

In East Timor, while the overall vegetation may not be very bad, few mountain slopes (except very steep ones) are free from human activity. They are either inhabited by small groups of people or frequented by people for firewood and farm products.

For human activity, existence of houses, roads and artificial pollution sources were checked at the sites. Tentative evaluation results are shown in **Table B-3.1**. The evaluation was made on a scale of A to C where A stands for trace of human activity, B moderate and C, intensive human activity. The intensity of human activity greatly affects the vegetation in the area. People cut down trees for firewood and burn bushes for farming. In addition, animal and human droppings in streams or near intake sites contaminate the water. In places where unpaved roads cut through steep mountain slopes, erosion of soil or small-scale landslides occur. According to the observation of a study team member, water flashed pit latrine is commonly used in populated areas while in areas where houses are isolated, people just go out in bush or often to a stream. At some intake site, people do washing and bathing right around the intake (usually downstream) using the water overflowing or coming out near the intake. This may contaminate water extracted at the intake as well as the water that can be used downstream by other groups of people.

B-3.2 Evaluation of Water Source's Potential

The potential availability of water at a water source is defined principally by incoming and outgoing water in the catchment for the water source. The study team estimated the values by carrying out a water balance analysis as already presented in chapter B-3. The calculated values are considered to be the maximum amount of water that can be theoretically extracted from the water sources, thus the actual amount that can be extracted with a practical technique and reasonable cost will be far smaller. The results are shown in **Table B-3.2** for every water sources in 15 towns. Note that the figures in the table are annual total values and monthly fluctuations are leveled off.

In reality there is a large seasonal difference in rainfall, river flow and groundwater level. The study team measured flow rate of rivers and springs and estimated the annual minimum flow for the water sources as described in chapter B-1. Since the data basically came from actual measurement, it is expected to reflect real conditions and, on the other hand, can be influenced by annual fluctuations of the weather. On the contrary, the theoretical potential data has been derived based on long-term meteorological data and such fluctuations have been eliminated. The result is shown in **Table B-3.2** along with the theoretical potential data (potential availability) for comparison.

Both data should be given due consideration in the case of future water resources development planning.

Table B - 3.1 Evaluation of Catchment of Water Sources

No.	Town		Water Source: Name	Label	Type		Catchment Area (km2)	Vegetation	Human Activity
1.	Dili	1	Bemos		Stream	1	30.3	B	B
		2	Bemori		Stream	1	1.49	C	B
		3	Benemauk		Stream	1	7.6	C	B
		4	Maloa		Stream	1	0.26	C	B
		5	Comoro Wells		Borehole	5	207.32	B	B
		10	Kuluhun, Bidau Wells		Borehole	5	34.34	C	C
		14	Hera A		Borehole	5	6.87	C	B
2.	Atauro	1	Mota Eklai		Streams	1	0.103	A	A
		2	Mota Tulai		Spring		1.11	A	A
		3	Mota Lampia		Spring	1	0.704	A	A
3.	Manatuto	1	Manatuto		Spring	3	2.43	B	B
		2	Laclo River		River		1281.2	A	A
4.	Baucau	1	Wailia		Spring	4	40.6	C	B
5.	Lospalos	1	Papapa		Spring	4	21.3	C	B
6.	Viqueque	1	Builua		Spring	4	18	A	A
7.	Same	1	Carbulau		Stream	1	1.03	B	A
		2	Kotalala		Stream	1	10.94	A	A
		3	Mirbute Bituruli		Spring	3	0.515	A	A
8.	Ainaro	1	Sarai		Stream	1	8.93	A	A
9.	Aileu	1	Mantane		River	2	62.77	B	B
		2	Sloi Kraik		Stream	1	0.99	A	A
		3	Naufaisaran		Spring	3	0.125	A	A
		4	Hularema		Spring	3	0.365	B	B
10.	Maubisse	1	Raikuak Ulun		Spring	3	1.26	C	B
		2	Bucana		Spring	3	0.47	C	B
		3	Filmou		Spring	3	0.17	C	B
		4	Erulu		Spring	3	0.23	B	C
11.	Gleno	1	Mota Boot		Stream	1	6.44	A	B
		2	Mota Kiik		Stream	1	0.81	A	A
		3	Ergrogo		Spring	3	0.5	A	A
12.	Ermera	1	Lubulala		Spring	3	0.064	B	B
		2	Ersoi		Spring		0.064	B	B
		3	Mota Bura		Spring	3	0.905	B	B
13.	Liquica	1	Dato 1& Maumeta Wells		Borehole	5	14.8	B	A
		5	Laclo	LIQ-WS13	Stream	1	1.14	A	B
		6	Lilabu	LIQ-WS06	Stream	1	0.61	B	B
		7	Narlolo	LIQ-WS05	Stream	1	0.63	B	B
		8	Daulo		Stream	1	8.23	A	B
		9	Eanlua	LIQ-WS09,10	Stream	1	2.11	B	B
		10	Raisape		Stream	1	-	-	-
		11	Metagou	LIQ-WS11,12	Stream	1	0.16	A	A
		12	Emilaloa	LIQ-WS07	Stream	1	4.33	B	B
14.	Suai	1	Olivio		Stream	1	2.19	-	-
		2	Ameriko & Maugusu		Stream	1	3.5	-	-
		3	Maugusu		Stream		-	-	-
		4	Kuluai		Spring		1.4	-	-
		5	Sukabilaran 1		Borehole	5	39.04	-	-
		6	Sukabilaran 2		Borehole	5		-	-
15.	Maliana	1	Beamos		Spring	1	0.03	-	-
		2	Aikumu		Spring	3	1.50	-	-
		3	Dabucci		Spring	3	2.02	-	-
		4	Beapelu		Stream	1	1.50	-	-
		5	Beremau		Stream	1	0.03	-	-
		6	Colegio		Stream	1	-	-	-
		7	Irrigation canal		Stream	3	8.56	-	-

Note 1) Vegetation: A - Rich, B - Moderate, C - Poor
2) Human Activity : A - Trace, B - Moderate, C - Intense
Numbers in parenthesis indicate the figure is based on a second hand data

Table B-3.2 Water Sources Evaluation (1/2)

No.	Town	Water Source						Catchment Area	**Estimated Minimum Discharge in Dry Season***	Calculated potentialy available water **	Remarks
			Name	Label	Type		**Observed Discharge (late Oct. to late Nov.)**				
							(liter/sec)	(km2)	(liter/sec)	(liter/sec)	
1.	Dili	1	Bemos		Stream	1	282	30.3	197	537	
		2	Bemori		Stream	1	29	1.49	20	26	
		3	Benemauk		Stream	1	45	7.6	32	70	
		4	Maloa		Stream	1	13	3.02	7	30	
		5	Comoro A		Borehole	5	40	207.32	40	1812	
		6	Comoro B		Borehole	5	(35)		35		
		7	Comoro C		Borehole	5	---		---		
		8	Comoro D		Borehole	5	31		31		
		9	Comoro E		Borehole	5	(20)		20		
		10	Kuluhun A		Borehole	5	16	34.34	16	(139-167)	
		11	Kuluhun B		Borehole	5	36		36		
		12	Bidau 1		Borehole	5	---		---		
		13	Bidau 2		Borehole	5	---		---		
		14	Hera A		Borehole	5	---	6.87	5	(185-222)	
		15	Hera B		Borehole	5	---	16.04	3		
		16	Hera C		Borehole	5	---	27.92	5		
2.	Atauro	1	Mota Eklai		Streams	1	1	0.103	1.0	1	
		2	Mota Tulai		Spring		2	1.11	1.0	12	
		3	Mota Lampia		Spring	1	(2)	0.704	0.0	2	
3.	Manatuto		Manatuto		Spring	3	116	2.43	104	5	
			Laclo River		River		7900	1281.2	3950.0	17895	at the infiltration gallary
4.	Baucau		Wailia		Spring	4	55	40.6	44.0	491	at least (water through pipe estimated at 15 liter)
5.	Lospalos		Papapa		Spring	4	99	21.3	99.0	126	
6.	Viqueque		Builua		Spring	4	121	18	121.0	372	
7.	Same	1	Carbulau		Stream	1	20	1.03	10.0	61	
		2	Kotalala		Stream	1	1120	10.94	280.0	646	All the streams in the visinity
		3	Mirbute Bituruli		Spring	3	3	0.515	1.5	28	only spring water considered
8.	Ainaro		Sarai		Stream	1	1130	8.93	160.0	527	
9.	Aileu	1	Mantane		River	2	370, 864	62.77	370.0	1712	
		2	Sloi Kraik		Stream	1	4.0	0.99	2.0	28	
		3	Naufaisaran		Spring	3	1.2	0.125	1.0	4	
		4	Hularema		Spring	3	0.5	0.365	0.5	10	

Table B-3.2 Water Sources Evaluation (2/2)

No.	Town		Water Source Name	Label	Type		Observed Discharge (late Oct. to late Nov.) (liter/sec)	Catchment Area (km2)	Estimated Minimum Discharge in Dry Season* (liter/sec)	Calculated potentialy available water ** (liter/sec)	Remarks
10.	Maubisse	1	Raikuak Ulun		Spring	3	1.5	1.26	0.8	55	
		2	Bucana		Spring	3	2.0	0.47	2.0	20	
		3	Filmou		Spring	3	0.2	0.17	0.2	7	
		4	Erulu		Spring	3	0.5	0.23	0.5	10	
11.	Gleno	1	Mota Boot		Stream	1	1300.0	6.44	325.0	196	
		2	Mota Kiik		Stream	1	80.0	0.81	10.0	25	
		3	Ergrogo		Spring	3	10.0	0.5	7.0	---	
12.	Ermera	1	Lubulala		Spring	3	0.1	0.064	0.1	---	
		2	Ersoi		Spring		0.6	0.064	0.6	2	
		3	Mota Bura		Spring	3	1.0	0.905	1.0	26	
13.	Liquica	1	Dato 1		Borehole	5	---	14.8	---	114	
		2	Dato 2		Borehole	5	---		---		
		3	Maumeta 1		Borehole	5	---		---		
		4	Maumeta 2		Borehole	5	---		---		
		5	Laclo	LIQ-WS13	Stream	1	2.3	1.14	2.0	17	
		6	Lilabu	LIQ-WS06	Stream	1	2.0	0.61	1.5	4	
		7	Narlolo	LIQ-WS05	Stream	1	0.7	0.63	0.5	4	
		8	Daulo		Stream	1	15.0	8.23	10.5	147	
		9	Eanlua	LIQ-WS09,10	Stream	1	3.8	2.11	3.0	28	
		10	Raisape		Stream	1	5.0	-	(5)	-	
		11	Metagou	LIQ-WS11,12	Stream	1	2.0	0.16	1.5	4	
		12	Emilaloa	LIQ-WS07	Stream	1	20.0	4.33	10.0	72	
14.	Suai	1	Olivio		Stream	1	(1)	2.19	(1)	44	
		2	Ameriko & Maugusu		Stream	1	(1)	3.5	(1)	59	
		3	Maugusu		Stream	1		-		-	
		4	Kuluai		Spring	3	(1)	1.4	(1)	20	
		5	Sukabilaran 1		Borehole	5		39.04	6	328	
		6	Sukabilaran 2		Borehole	5			6		
15.	Maliana	1	Beamos		Spring	1	(1)	0.03	(1)	1	
		2	Aikumu		Spring	3	(150)	1.50	(37)	22	Group of springs
		3	Dabucci		Spring	3		2.02		-	Group of springs
		4	Beapelu		Stream	1		1.50		-	
		5	Beremau		Stream	1		0.03		-	
		6	Colegio		Stream	1		-		-	
		7	Irrigation canal		Stream	1	(200)	2.02	(50)	32	

Note * : Estimation based on the measured flow rate and interview with local people
** : Theoretically calculated based on the existing data in the course of water balance calculation
Numbers in parenthesis indicate the figure is based on a second hand data

B-4 GROUNDWATER IN DILI, LIQUICA AND SUAI

Groundwater has been developed as source for water supply system in three cities, Dili, Liquica, and Suai, out of 15 study areas.

B-4.1 Existing Wells

Dili

Production wells for water the supply system have been constructed in Comoro, Kuluhun – Bidau, and Hera, as described already.

Comoro

The table below shows the groundwater withdrawal rate from the Comoro Wells from August to October in 2000.

	Pumping Rate (L/s)			
	Aug.	**Sep.**	**Oct.**	**Average**
Comoro A	32.5	35.6	34.3	34.2
Comoro B	52.4	52.6	45.7	50.2
Comoro D	31.9	31.1	27.6	30.2
Comoro E	8.9	8.0	-	8.5

Comoro C has been abandoned. Comoro A and D have been used for the water supply system in Dili. Comoro B is used for the PKF at all times. Comoro E is used for the PKF on occasion. Therefore, the recorded pumping rate is low in Comoro E.

The maximum yield of Comoro A was theoretically estimated at 200L/s and practically 42 to 47L/s based on a pumping test (Hydrogeology of Dili and Suai, 1993, L.W.Drury). The maximum extraction capacity of Comoro B was also estimated at 42 – 47L/s operating at heads up to 70m. At present the water from Comoro B is pumped up to tanks just on the ground and the pumping water level is about 12m below G.L. The safe yield of Comoro D seems to be evaluated at 23L/s by a drilling contractor according to obtained information. It is reported that the drawdown of 1.05m occurred in Comoro E after 44 hours pumping with the constant discharge rate of 28L/s. (Comoro E was mentioned as Comoro C2 in a drilling report.)

Storage of the aquifer was estimated at $36Mm^3$ based on the following assumptions; an aquifer area of $3km^2$, an aquifer thickness of 40m, and porosity of 0.3 (L. W. Drury, 1993). The assumptions are considered reasonable.

L.W. Drury (1993) also estimated natural groundwater through-flow at from 202L/s to 3010L/sec. This is based on transmissivity of 6000 - $13000m^2$/day, hydraulic gradient of 0.0027 – 0.01, and width of aquifer of 1000 – 2000m. The study team recalculated it based on the transmissivity of $13000m^2$/day, hydraulic gradient of 0.0045, and width of aquifer of 2000m. The Hydraulic gradient was obtained with measurement of water level and surveyed elevations during the study. The result is 1350L/sec.

The groundwater recharge in the Comoro basin is estimated at about 1800L/sec as described already in the water balance analysis.

Kuluhun – Bidau

The extraction of Kuluhun wells is shown in the table below.

	Pumping Rate (L/s)			
	Aug. 2000	**Sep. 2000**	**Oct. 2000**	**Average**
Kuluhun A	16.3	14.6	12.6	14.5
Kuluhun B	26.3	31.5	32.4	30.1

Groundwater storage in the eastern Dili was estimated at 27m^3 based on an aquifer area of 3km^3, an aquifer thickness of 30m, and porosity of 0.3 (L.W.Drury 1993).
The groundwater through-flow is estimated at 280L/s. This is based on a transmissivity of 3800m^2/day, hydraulic gradient of 0.0042, and width of aquifer of 1500m. The transmissivity was calculated based on the constant discharge test conducted on 21, May 1998.

Suppose the 10-12% of the total rainfall recharge groundwater in the area, the estimated recharge will be 139-167L/sec.

Hera

There are three wells, Hera A, B, and C, that had been used for water supply in the past. No wells, however, are in operation at present.

According to a drilling report, the drawdown in the well (Hera C) was 0.64m after pumping with a discharge rate of 10.24L/s for 72 hours. (The Study team received this report from ADB-PMU. The report describes the construction work of the well named Hera B. The location map in the report, however, indicates that the well is actually Hera C.)

The geophysical survey conducted by the Study team indicates that the effective porosity, or specific yield, of aquifer is comparatively low. Suppose that 10-12% of the total rainfall recharge groundwater in the area, the estimated recharge will be 185-222L/sec.

Liquica

No wells are being operated at present while four wells were constructed for the water supply system of the town. The designed pumping rate is reported to range from 2.5 to 10L/s. However, there is no information whether the designed rate was attained during the operating. It is reported the pumping rate was only 1-2L/s during Oxfam's trial to reactivate the well of which designed rate was reported at10L/s.

The geophysical survey by the Study team indicates that the hydrogeological condition varies place to place in Maumeta and Dato area. The potential groundwater recharge is estimated to be 3.590 Mm^3/year, 113.8L/sec, by the water balance analysis.

Suai

It has been reported that there are some wells, of which potential yield ranges from 6 L/sec to 15L/sec or more. Two of them; Sukabilaran 1 & 2 have an yield of 6L/sec. The potential groundwater recharge is estimated 10.352 Mm^3/year, 328.3L/sec, by the water balance analysis.

B-4.2 HYDROLOGICAL CHARACTERISTICS OF AQUIFERS

In this chapter the hydrogeological characteristics of 4 major well fields of Comoro, Kuluhun & Bidau, Hera and Liquica are briefly discussed based on the findings of the resistivity survey and drilling work and also on some reports obtained during the study.

a.) Comoro Well Field

Aquifer

The following information mainly comes from a report titled "Hydrogeology of Dili and Suai, 1993" issued under the Indonesian government. According to the report, the vertical thickness of the alluvial fan deposit is at least 82m and 130m at Comoro B. The thickness of the deposit seems to increase to the north. The report says the aquifers in the deposit are semi-confined. The judgement seems to be based on the well construction information and general knowledge of this kind. The judgment seems to be reasonable. The statement "Bedrock appears to be a highly micaceous clay" indicates that the top of the bedrock is highly weathered mica schist which is common in the area. This means that the upper part (perhaps up to 50 m) of the hard basement rock is highly weathered with cracks and contains some water.

Water Level

The observation of undercurrent which reportedly had a flow rate of 80 liter/s and dropped in flow at the end of a dry season suggest that the groundwater discharge is directly affected by the rainfall although precise relation is yet to be clarified. The static water levels of the two wells of Comoro A and B (April 1993) were reported to be 8.9m and 3.15m respectively while a measurement made by the study team in Nov. 2000 recorded a water level of 18.79 and 11.22m respectively. The latter value is a dynamic one with the pump working at a rate of about 35 liter/s. Since the performance of Comoro B well is remarkably good, the drawdown is probably no more than 2m. The difference also indicates a great seasonal change in water level.

b.) Kuluhun and Bidau Well Field

Aquifer

The report "Hydrogeology of Dili and Suai, 1993" describes that the coastal plain and the elevated terraces in central Dili consist of recent alluvial deposits of various grain-size. The report describes the sediments as "The grain sizes in the colluvium and overlapping alluvial fans decrease from cobble and boulder at the base of the hills to coarse sand and gravel near the sea. Silt and clay are exposed toward the backwaters and levees away from the fans indicate that the alluvial fans consist predominantly of coarse sediment with numerous thin clay lenses which appear to increase in thickness and become dominant away from the braided systems." This is a typical Structure of an alluvial fan and seems to fit reasonably to the alluvial deposit of the area although the development of fans is not very good. The actual sediment size may be smaller and silty sediment may be dominant in Kuluhun area.

According to other studies conducted in the 80's, the aquifer system is quite complicated with existence of confined, semi-confined and unconfined aquifers. Many resistivity surveys carried out in the past could not satisfactorily clarify the subsurface structure of the area because of conflicting interpretations. This seems to imply a limit in use of resistivity survey for the investigation of underground structure. The result of geophysical survey conducted by the Study team indicates that the aquifer thickness is getting thinner towards east, the skirts of the mountain.

In the drilling of Bidau new well, the bedrock was encountered at a depth of 52m below which lies altered phyllite. The basement rock is the same as that of Comoro due to the proximity of the two areas. Schematic cross-section of the area is shown in **Figure B-4.1**.

Water Level

The report says there are many shallow dug wells and spearpoints have a depth of around 12 to 13m. The study team observed some of them and found that the static water levels of those wells are within a few meters from the ground level. On the other hand, the observed water levels of deep boreholes are from4 to 12m. Seasonal variation seems to be limited within a range of a 3 to 4m. The static water level in Bidau new well was found to be 2m.

The results of the pumping test at Bidau new well are as follows. Detailed discribtion and data is presented as Chapter B-7 "Well Rehabilitation/ Construction Project" in the Annex.

The maximum drawdown observed during the continuous pumping test was approximately 22m after 1400 min from the start of the pumping with a pumping rate of 7L/sec. The aquifer constants are calculated in the following way using the Jacob's method (See **Table B-4.3**). Note that in this case the observation well is taken to be the pumping well for convenience.

Transmissivity:

$$T = \frac{2.3\,Q}{4\pi\,\Delta s}$$

Hydraulic Conductivity:

$$K = \frac{2.3\,Q}{4\pi D\,\Delta s}$$

where Q = pumping rate = 7.0 liter/s
Δs= one cycle of bellow figure s-log(t) curve = 8.4m
D=thickness of aquifer =12m
T= 1.52×10^{-4} m^2/s = 13.13 (m^2/d)
K=1.27×10^{-5} (m/sec) = 1.27×10^{-3} (cm/sec)

c.) Hera Well Field

Aquifer

The surface topography and river morphology suggest that the area is covered with alluvial flood plain deposit of the Quiarsitequi River and the outer fan deposit of the Quik River. Two of the existing wells, Hera B and Hera C were drilled through this deposit. Hera A well was drilled at the exit of a valley, which has the smallest catchment area in Hera. The alluvial deposit at Hera A well is probably less thick compared with the Hera B and C. The occurrence of flowing well or spring in the port of Hera indicates the existence of widespread clay layer in the deposit. The bedrock was detected at only two points on the foot of the hills at both ends of the survey line passing near Hera B and C. In this area, some meta-sandstone (medium to fine grained) outcrops are observed along with highly deformed black schist. The survey must have detected that sandstone. According to another report on Hera C well written in Indonesian, the bedrock was encountered at the well site at a depth of 64 m below ground level. A schematic cross-section of the area is shown in **Figure B-4.1**.

Water Level

A short report on the rehabilitation of Hera B well shows that the static water level of the well is 2.5m. The study team carried out a step-drawdown pumping test at each well and found out the following. Hera B well (as of 4 Dec. 2000) has a static water level of 5.13m and a dynamic water level of about 29m when pumped at a rate of 4 liter/s. Hera C well had a static water level of 12.9m and a dynamic water level of 13.3m with the pumping rate of 8.3 liter/s.

d.) Liquica Well Field

Aquifer

There is little information available on hydrogeological conditions in the area. Judging from the topography, alluvial fan deposit is dominant in this area and the existing four wells are all drilled through the mid-fan of the Gularloa River up to a depth of around 84m. Although the general components and structure of the alluvial sediment are relatively similar to those of Comoro and Dili central, the deposit is made up of coarser materials with less silty lenses. The Permian Aileu formation underlies the alluvial sediment in Liquica as well. Although a distribution of green rock is observed to the east of the area, the rocks observed in the upper reach are exclusively black slate and phyllite with thin lamina of fine sandstone. The resistiviy survey could not detect this bedrock clearly in this area either. In the borehole of new Liquica 1 and 2 drilled by the study team the bedrock was encountered at 54 to 56m. A schematic cross-section of the area is shown in **Figure B-4.2**.

Water Level

The rehabilitation of Maumeta 2 well by OXFAM failed and they have learned that the static water level of the well is as low as about 37.8m. Moreover, the GS casing pipe was corroded with rusty surface as to have some halls below the water level. An attempt to rehabilitate Maumeta 1 well was also made by the JICA study team but the water level was as low as 46m and the well was filled with stones. These observations indicate the fan is made up of relatively thick and permeable layers of sand with gravel that let the water pass through its bottom. The drilling of the two wells which are about 280m apart confirmed that the water table in Liquica is low (22.6 m at Liquica 1) and flat being only 3.5m above the sea level.

As for the cause of the casing pipe corrosion, it may be related to the alteration of the bedrock observed in the Carbutaeloa River. It will be necessary to analyze the water sample from both chemical and bacteriological aspects to clarify the nature of this corrosive water and to take a protective measure.

The results of the pumping test at both new wells are briefly discussed below. Detailed discribtion and data is presented as Chapter B-7 "Well Rehabilitation/ Construction Project" in the Annex.

The maximum drawdown observed during the continuous pumping test at Liquica 1 was approximately 31.8m after 1440 min from the start of the pumping with a pumping rate of 4.15L/sec. That for Liquica 2 is 18.6m after 1440min with a discharge of 3 liter/s. The aquifer constants were calculated in the following manner using the Jacob's method (See **Table B-4.3**). Note that in this case the observation well is taken to be the pumping well for convenience.

Transmissivity:

$$\boldsymbol{T} = \frac{2.3\,Q}{4\pi\,\Delta s}$$

Hydraulic Conductivity:

$$\boldsymbol{K} = \frac{2.3\,Q}{4\pi D\,\Delta s}$$

<Liquica 1>

where Q = pumping rate = 4.15 liter/s
Δs = one cycle of bellow figure s-log(t) curve = 1.7m
D = thickness of aquifer =12m

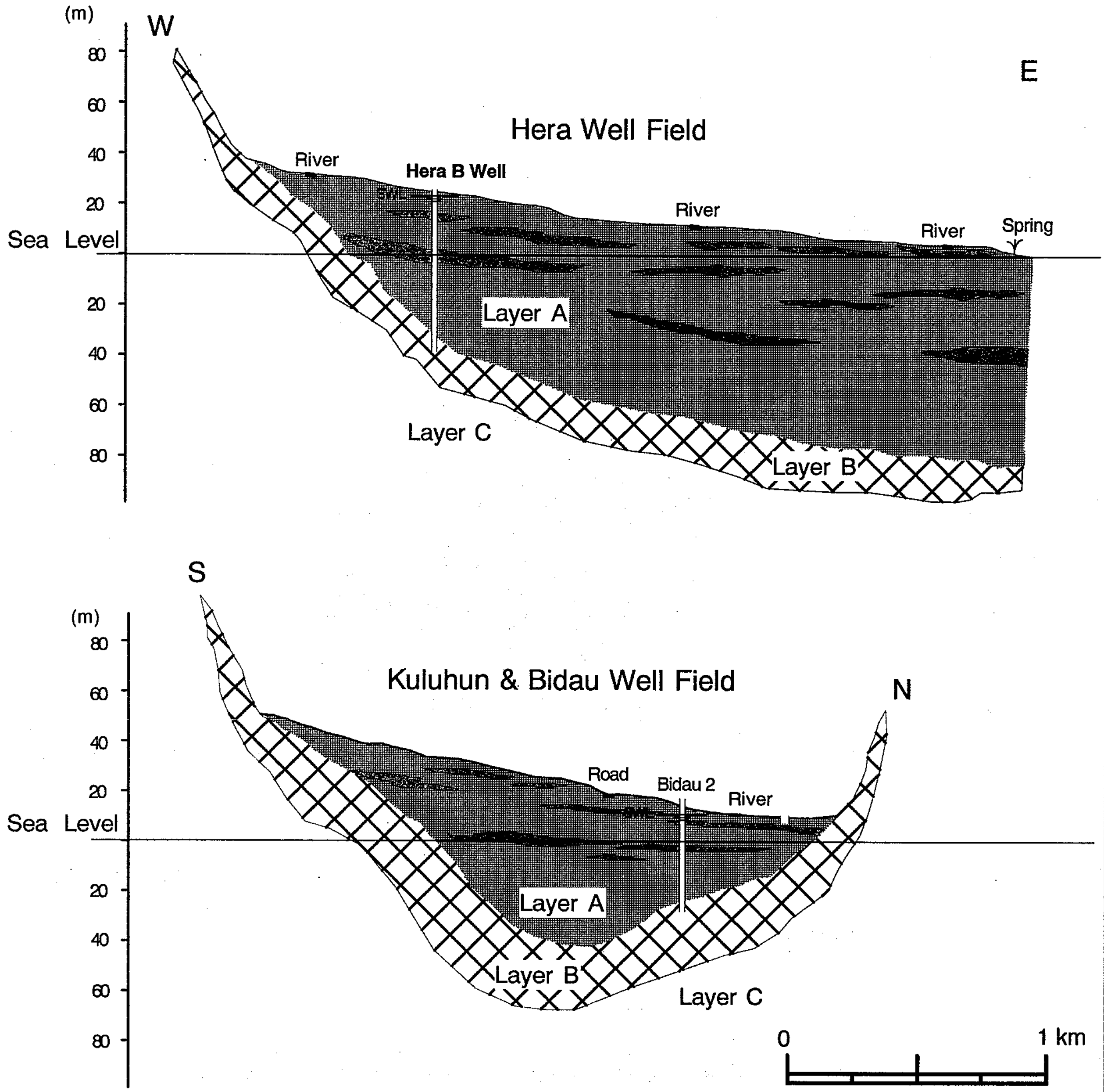
$\boldsymbol{T}$= 4.47 x 10^{-4} (m^2/s) = 38.6 (m^2/d)
$\boldsymbol{K}$=3.72 x 10^{-5} (m/sec) = 3.72 x 10^{-3} (cm/sec)

<Liquica 1>

where Q = pumping rate = 3.0 liter/s
Δs = one cycle of bellow figure s-log(t) curve = 0.048m
D = thickness of aquifer =15m

$\boldsymbol{T}$= 1.14 x 10^{-2} (m^2/s) = 988.3 (m^2/d)
$\boldsymbol{K}$=7.6 x 10^{-4} (m/sec) = 7.6 x 10^{-2} (cm/sec)

These calculated constants indicate rather favorable results themselves. However the fact that the water table is as low as 3.5m above the sea level suggests that the groundwater potential of this area is not as good as it appears from the figures. The topic is discussed in more detail in the Annex Chapter B-7 "Well Rehabilitation/ Construction Project" in the Annex.



Layer A : Alluvial fan and flood plain deposit

Layer B : Weathered bedrock

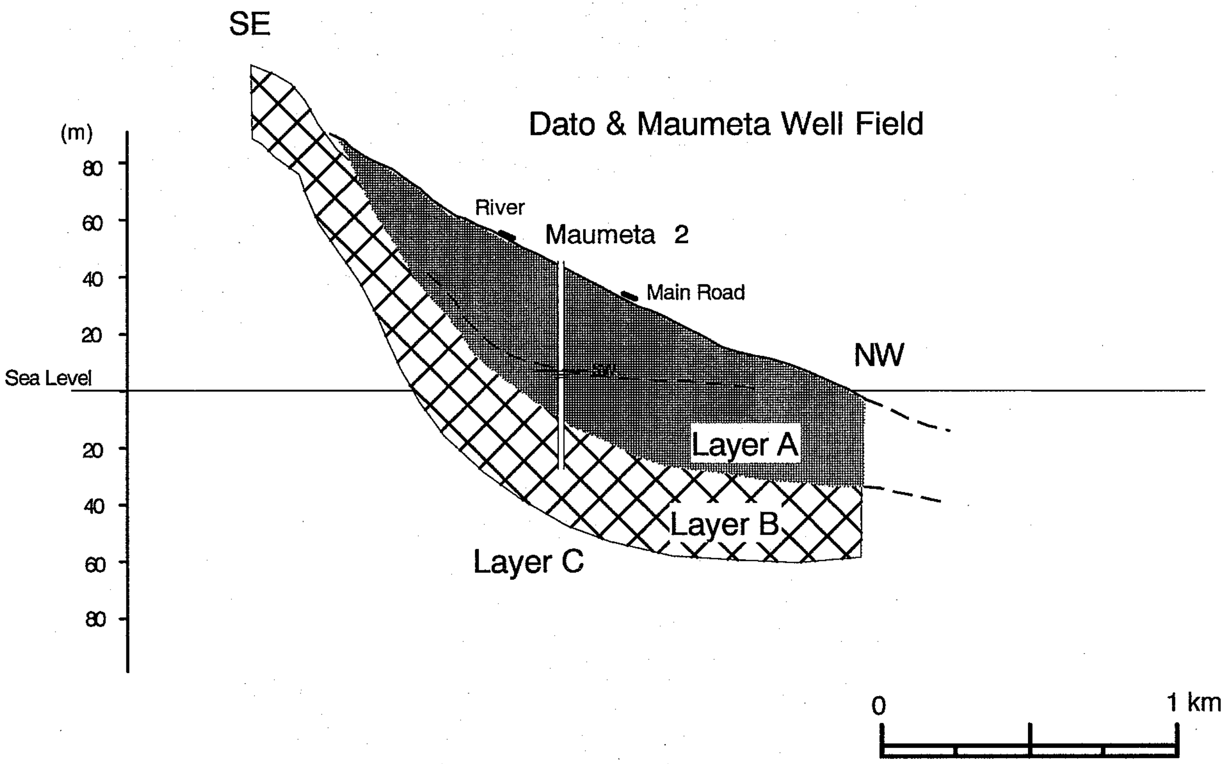
Layer C : Fresh bedrock

Permeable deposit (sand with gravel)

Impermeable deposit (silt, clayey silt)

JICA | *The Study on Urgent Improvement Project for the Water Supply System in East Timor* | **Figure**

SCHEMATIC CROSS-SECTION OF WELL FIELD IN DILI | **B - 4.1**



Layer A : Alluvial fan deposit

Layer B : Weathered bedrock

Layer C : Fresh bedrock

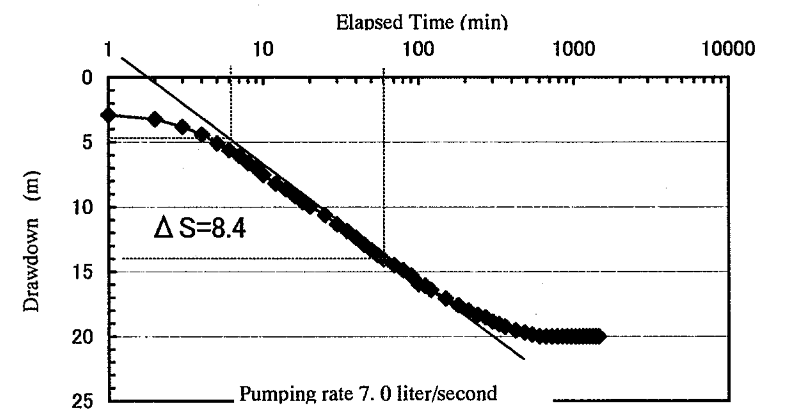
Permeable deposit (sand and gravel with some silt)

The Study on Urgent Improvement Project for the Water Supply System in East Timor

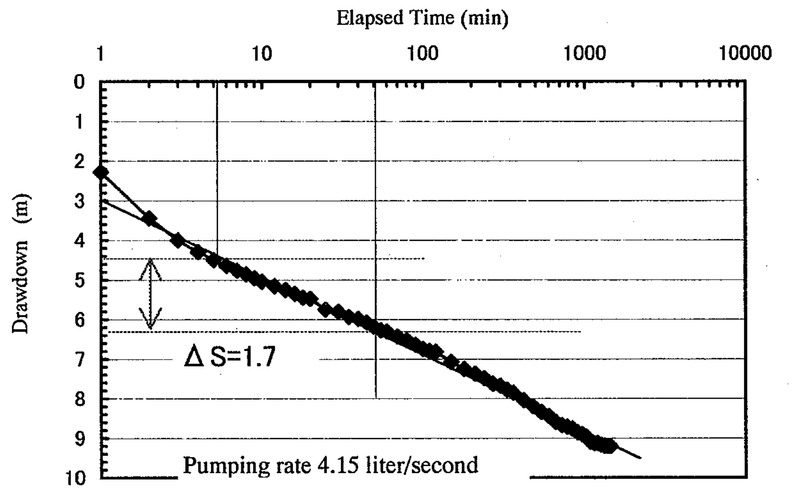
Figure B - 4.2

SCHEMATIC CROSS-SECTION OF WELL FIELD IN LIQUICA

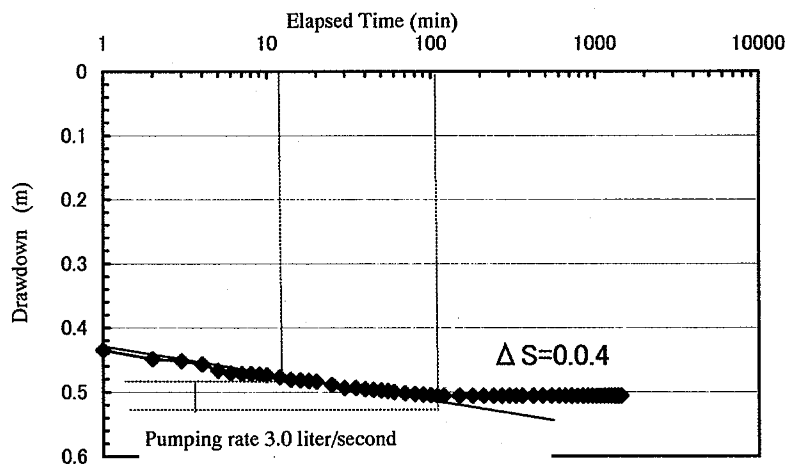
Pumping test, Bidau-1



Pumping test, Liquica-1



Pumping test, Liquica-2



JICA	*The Study onUrgent Improvement Project for the Water Supply System in East Timor*	**Figure**
SEMILOG TIME-DRAWDOWN PLOT OF CONTINUOUS PUMPING TEST		**B-4.3**

B-5 RECOMMENDATIONS

B-5.1 Protection of Water Sources

As already explained in the end of chapter 2, condition of a catchment in terms of vegetation greatly affects the quantity and quality of the flow in the stream. Occurrence of turbid water in streams are caused by inflow of eroded top soil that is widely exposed in places where trees have been cut down and grassed burned. Reduction in forest coverage in catchment will also raise the peak flow in the stream. This will result in frequent flooding downstream and in less available surface water.

A number of people live on mountain slopes exploiting the trees and the land in East Timor. While the situations in the local towns are not serious, it is getting serious in Dili. The recent migration of people into the capital and consequent urban sprawl in future will lead to further destruction of vegetation in the surrounding areas.

Contamination of water is another threat. The study team observed, in many places, that people use detergent to do washing at the water source. Although this usually happen downstream side of the intake points, there seem to be no distinction of water usage. Contamination by detergents or human/animal excretion does not usually cause serious problems unless it happens directly upstream an intake because these matters are normally filtered through soil and sediment layers before going into a stream. However, the filtration process does not work effectively in the areas of limestone. contaminant can easily and quickly go into the underground steam and pollute the water.

In order to avoid above problems, it is recommended that major catchments of water sources be designated as protection areas where human activities such as farming and construction of roads are kept minimum.

B-5.2 Regular Measurement of Meteorological and Hydrological Data.

The meteorological data is a basic data that should be recorded regularly. The data will be indispensable in many fields in future. Especially a water resources management plan, a comprehensive plan for the strategic use of water resources in an area, should be based on a long-term meteorological record. At present there is only one meteorological observatory is in operation. It should be increased to cover all the major towns and several high-altitude areas in consideration of increase in rainfall with altitude. In those observatories, short-term rainfall record (hourly) and their change should also be recorded.

In this study the only hydrological data (discharge measurement data) obtained was that of the Comoro River, recorded by the government of Indonesia. River discharge data is one of the basic data for flood control planing or water resources planning. In order to grasp the long-term and short-term fluctuation of flow rate at major intakes, it is recommended that a structure to measure flow be constructed at the intakes.

In the case of a mountain stream, a weir with a notch be constructed as a part of intake structure. The flow rate can be easily converted from the depth of water overflowing the notch once it is properly calibrated. This doesn't require power or special maintenance and easy to build. The intake maintenance staff should keep the record of the water level every time they visit the intakes for cleaning.

In the case of large rivers such as the Laclo River in Manatuto another type of structure will be needed. Considering its low water level and wide river course of such rivers in East Timor, a monitoring point should be set in a narrow a narrowest course. The stream should be as straight as possible with no obstacles so that a uniform and steady flow can be measured. If necessary the river course has to be shaped. Easiest way of monitoring the river flow is by installing a pillar with a scale in the stream. With a fixed cross-section, the flow can be represented by the water level measured with the scale. Another more sophisticated way is to construct a water level observation well on the river bank. It is a concrete structure similar to an collector well with an infiltration gallery. The difference is that no filtration through the pipe is necessary and water has to flow into the vertical shaft of the well as smoothly as possible. An automatic water level recorder can be placed to keep the record of water level.

B-5.3 Recommendation for Conservation and Optimum Management of Groundwater

The limit of a regional groundwater extraction is determined by the amount of natural recharge to the aquifer. Therefore, grasping and understanding the accurate condition of recharge, discharge, and storage of the groundwater will form the basis of planning conservation and optimum management of groundwater resources.

Hydrological observation is essential to obtain more information about the amount and condition of recharge to the aquifer. The pumping rate record of wells is the basic data to grasp discharge from the aquifer. And the observation of the water level fluctuation is the most important information to assess the change in groundwater storage.

The water level of each intake well should be recorded periodically. The level decreases in dry season and increases in rainy season naturally. If the water level continues to decrease for long period of time, it may mean that the storage also decreases gradually. The construction of a new observation borehole is recommended in each well field to observe the spatial effect of drawdown in a pumping well.

The monitoring of water quality is also a fundamental part of aquifer management. A kind of pollution such as saline water intrusion and induced filtration may be cause by over pumping from a well.

The data as described above is the basis of the future development of the aquifer.

Annex

B-6 Geophysical Survey

ANNEX

B-6 GEOPHYSICAL SURVEY

Resistivity Survey

B-6.1 General

Resistivity sounding survey has been carried out from October 6, 2000 to November 20, 2000 using McOHM (one of the sounding devices). The purpose of sounding was to determine ground water sources and to grasp subsurface geological structure.

The sounding was performed by Wenner Method electrode array. The intended depth of sounding was set to be 200 m from ground level and the intervals of survey points were taken to be 150 m to 600 m depending on the location. A single survey line consisted of 6 to 8 survey points, except AD-sounding line in Liquica.

B-6.2 Location of Survey area

The survey areas are the following three areas in the city of Dili and the Town of Liquica; Bidau-Dili, Becora-Dili, Hera-Dili and Liquica.

1) Bidau-Dili

Survey was carried out at only 1 (one) point in Bidau, near the existing well No. Bidau-1. The locations of survey point is show in **Figure B-6.1.**

2) Hera-Dili

Survey was carried out with 2 (two) sounding lines in Hera area as follows.

A-line and B-line consisting of 16 (sixteen) sounding points and
3 (three) points near the existing wells.

The direction of sounding line was as follows.

A-line: north to South from the foot of the mountain Saratotu and to the foot of mountain Lacasa for.
A-line: between the foots of the Airoma and Sidukun mountains.

Location of survey lines and survey points are presented **Figure B-6.2.**

3) Liquica

Survey was performed in the following 3 (three) sounding lines in the vicinity of the existing 4 (four) wells.

A-line, B-line and AD-line consisting of 19 (nineteen) sounding points. Directions of sounding lines were from west to east.

The locations of survey points are presented **Figure B-6.3**.

4) Becora

Survey was carried out in 1 (one) sounding line consists of 8 (eight) points near the existing wells of. Kuluhun A and B. The sounding line is along the Becora road. Detail of sounding points are presented in **Figure B-6.1**.

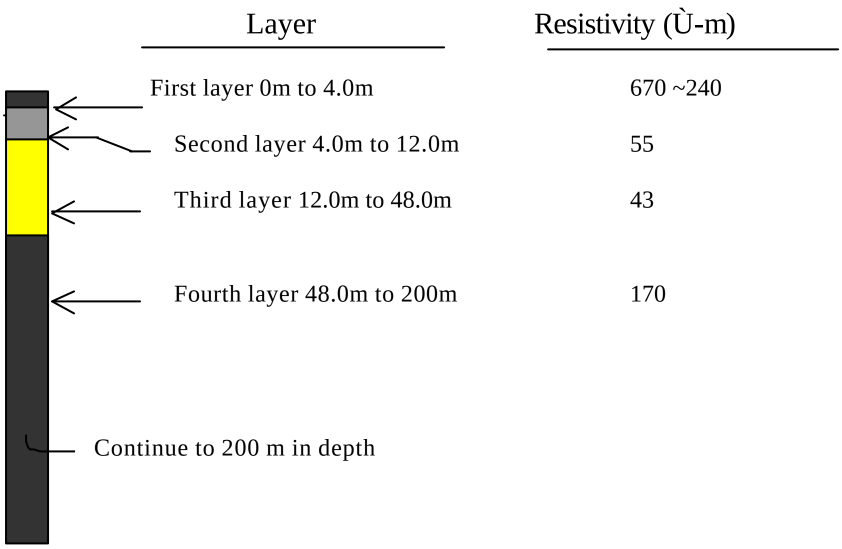
Number of survey points and survey lines in each area are shown in the table below.

Quantity of work

Area	Sounding point	Sounding line
Bidau Dili	1	-
Becora Dili	8	1
Hera Dili	19	2
Liquica	19	3

B-6.3 Result of the survey

B-6.3.1. Result of the survey at Bidau is shown below.



B-6.3.2. Result of survey in Hera is presented below

The Sounding result of A-line showed three distinct patterns. Based on this finding, the survey line can be classified into three basic categories "Zone A-1", "Zone A-2" and "Zone A-3".

Zone A-1 is located in the south between 300 m to 550 m from the shoreline.
Zone A-2 is located in the south between about 550 m to 1,550 m from the shoreline.
Zone A-3 is located in the south between about 1,550 m to 2,400 m from the seashore line.

The result of sounding B-line showed four distinct patterns. On the basis of the finding, the survey line can be classified into four basic categories "Zone B-1", "Zone B-2" "Zone B-3" and "Zone B-4".

Zone B-1 is located in the south between 0 m to 350 m from existing well No. Hera-B.

Zone B-2 is located in the south between about 350 m to 1250 m from existing well No. Hera-B.

Zone B-3 is located in the south between about 1250 m to 1,800 m from existing well No. Hera-B.

Zone B-4 is located in the south between about 18,00 to 2,000m from existing well No. Hera-B. Details each zone is show in **Figure B-6.2**.

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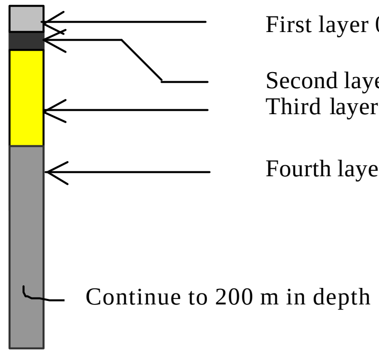
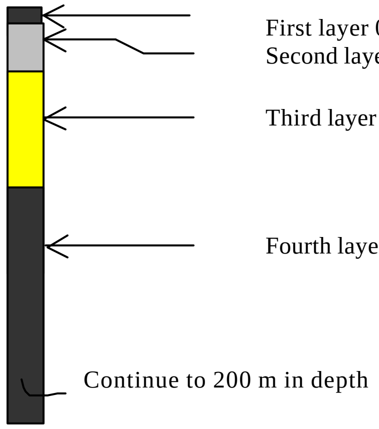
The result of the survey in Hera is presented below.

Typical Sounding Log “Zone A-1”



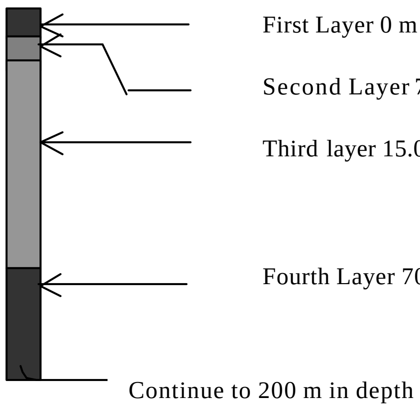
Layer	Resistivity (Ù-m)
First layer 0 m to 5.0 m	20 ~ 30
Second layer 5.0 m to 10.0 m	30 ~ 33
Third layer 10.0 m to 50.0 m	28 ~ 35
Fourth layer 50.0 m to 200 m	36 ~45

Typical Sounding Log “Zone A-2”



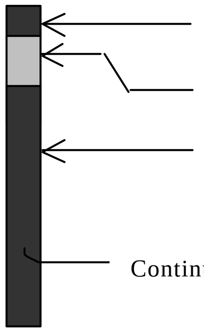
Layer	Resistivity (Ù-m)
First layer 0 m to 6 .0 m	25 ~ 35
Second layer 6.0 m to 20.0 m	35 ~ 40
Third layer 20.0 m to 70 .0 m	40 ~ 50
Fourth layer 70.0 m to 200 m	45 ~ 80

Typical sounding log “Zone A-3”



Layer	Resistivity (Ù-m)
First Layer 0 m to 7.0 m	500 ~ 300
Second Layer 7.0 m to 15.0 m	300 ~170
Third layer 15.0 m to 70.0 m	170 ~60
Fourth Layer 70.0 m to 200 m	60 ~100

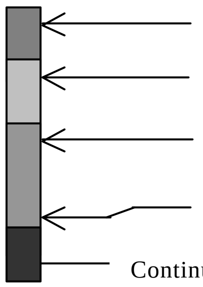
Typical sounding log “Zone B-1”



Layer	Resistivity (Ù-m)
First Layer 0 m to 6.0 m	150 ~ 50
Second Layer 6.0 m to 26.0 m	20 ~ 30
Third layer 26.0 m to 200 m	100 ~250

Continue to 200 m in depth

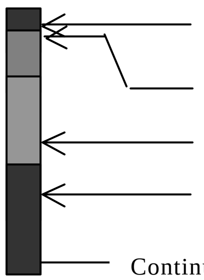
Typical sounding log “Zone B-2”



Layer	Resistivity (Ù-m)
First Layer 0 m to 18.0 m	300 ~ 100
Second Layer 18.0 m ~ 42.0 m	100 ~ 60
Third layer 42.0 m ~ 90.0 m	50 ~ 60
Fourth layer 90.0 m ~ 200 m	48 ~ 55

Continue to 200m in depth

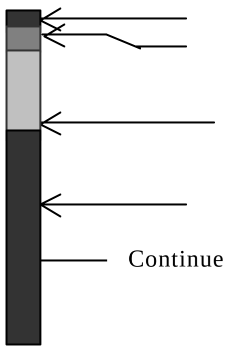
Typical sounding log “Zone B-3”



Layer	Resistivity (Ù-m)
First Layer 0 m to 10.0 m	480 ~ 270
Second layer 10.0 m to 25.0 m	200 ~ 100
Third layer 25.0 m to 65.0 m	110 ~ 73
Fourth layer 65.0 m to 200 m	100 ~ 50

Continue to 200 m in depth

Typical sounding log “Zone B-4”



Layer	Resistivity (Ù-m)
First Layer 0 m to 3.0 m	610 ~ 330
Second Layer 3.0 m to 10.2 m	60 ~ 70
Third layer 10.3 m to 30.0 m	142
Fourth layer 30.0 m ~ 200 m	60 ~ 80

Continue to 200m in depth

B-6.3.3. Result of survey in Liquica is presented below.

In terms of resistivity characteristics Liquica area can be classified into two basic categories “Area 1” and “Area 2”.

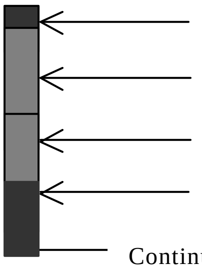
Area 1 covers both villages of Dato and Maumeta.

Area 2 covers a tiny area in the eastern corner of Maumeta village along the Enela River.

Details are shown in **Figure B-6.3**.

The detailed result of each area is presents below.

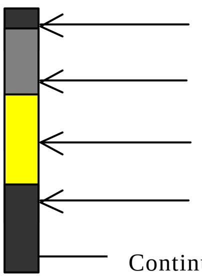
Typical sounding log of “Area 1” at Liquica



Layer	Resistivity (Ù-m)
First Layer 0 m to 10.0 m	670 ~ 220
Second layer 10.0 m to 40.0 m	190 ~ 170
Third layer 40.0 m to 70.0 m	190 ~ 270
Fourth layer 70.0 m to 200 m	150 ~ 80

Continue to 200 m in depth

Typical sounding log “Area 2” at Liquica



Layer	Resistivity (Ù-m)
First Layer 0 m to 10.0 m	330 ~ 130
Second Layer 10.0 m to 30.0 m	48 ~ 18
Third layer 30.0 m to 70.0 m	18 ~ 25
Fourth layer 70.0 m ~ 200 m	20 ~ 30

Continue to 200m in depth

B-6.3.4. Result of survey in Becora, Dili is presents below

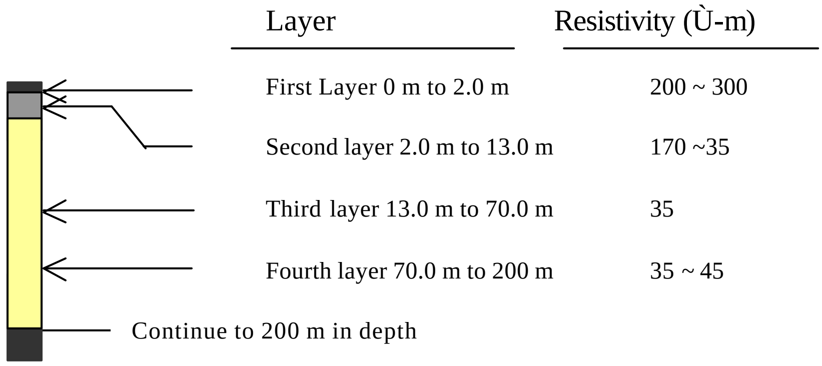
Based on the survey result, Becora-line can be classified into two basic categories “Zone 1, “Zone 2”. See **Figure B-6.1** for the location.

Zone 1 covers the western part of Santana River, Kuruhun village and eastern part of Bemoli village.

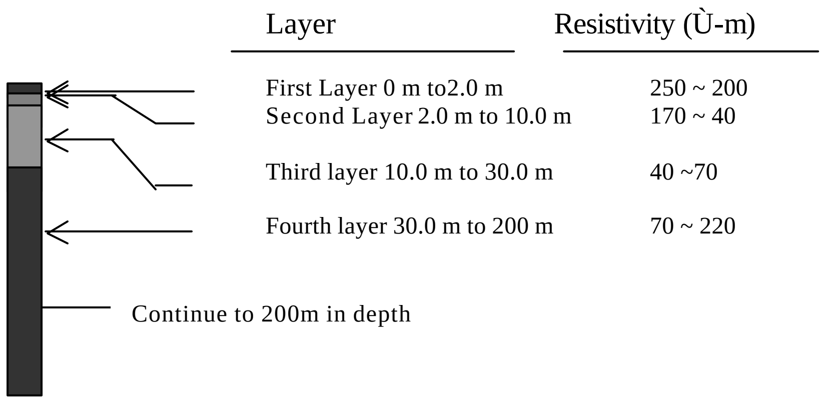
Zone 2 covers the eastern of Santana River, Becora village.

Result of each zone is presented below

Typical sounding log of “Zone 1” at Becora line



Typical sounding log “Zone 2” at Becora line

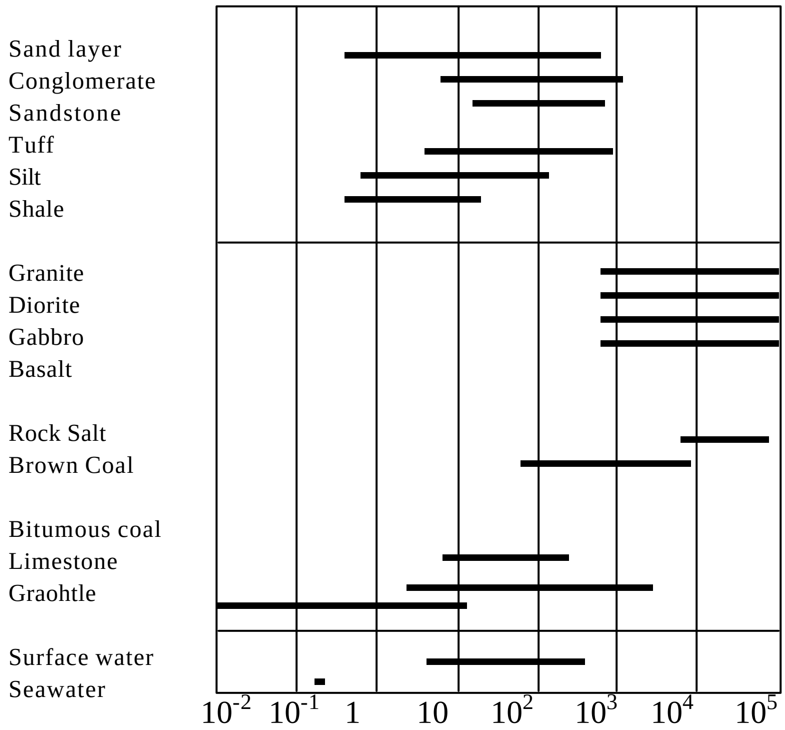


B-6.4. Analysis of the result

In the surveyed area, the base rock is expected to be made of mostly schist with some meta-sandstone judging from the surface geology. It is relatively easy to detect base rock in places where sandstone is dominant. On the other hand, in places where schist, which is basically metamorphosed mudstone, is dominant it is very difficult to detect a base rock. This is because schist generally has as low resistivity as ordinary sediments. For this reason, the analysis of subsurface geology by geophysical survey in Dili and Liquica is very difficult.

General resistivity values of rocks and sediments are shown in the Table below. As shown in the figure, the resistivity range of shale (considered similar to schist) corresponds to the lower range of sand layer and silt.

Table; RESISTIVITY OF ROCK AND SOIL



Resistivity (Ù-m)
(Daknov, Geophysical Well logging, 1959 in Russian)

Bidau, The first layer to the third layer are composed of alluvial deposit. Natural ground water level is found in the second layer around 5 to 6 m in depth. A sand layer aquifer may be expected in the third layer. However thickness of the third layer is only about 36 m and may not be thick enough to have a high potential of ground water. The fourth layer is certainly a bedrock with its top around 50 m in depth. The Aquifer may not be expected in the fourth layer.

Well No. Hera-A, from surface to 8m is topsoil with a resistivity between 180 ~108 (Ù-m). The second layer is from 8 m ~ 30 m in depth with a resistivity between 120 ~100 (Ù-m). The third layer is from 30 m to 55 m in depth, with a resistivity 100 ~ 80 (Ù-m). These three layers are composed of alluvial deposit. The forth layer is from 55 to 200 m in depth with a resistivity between 55 ~70 (Ù-m), bedrock may be encountered at around 60 m in depth. Expected natural ground water level is at around 8 m in depth. An aquifer of sand layer is expected in the second layer and third layer.

Well No. Hera-C, from surface to 6 m is topsoil with a resistivity between 300 ~ 100 (Ù-m). The second layer is from 6 m to 15 m in depth with a resistivity between 90 ~80 (Ù-m). The third layer is from 15 m to 60 m in depth with a resistivity 80 ~ 40 (Ù-m). These three layers are composed of alluvial deposit. The forth layer is probably the bedrock. The natural ground water level is at around 6 m in depth.

Hera “Zone A-1”, The first layer to the third layer are composed alluvial deposit. Natural ground water level is probably found within the upper part of the second layer. The bedrock may be encountered in the fourth layer.

Hera “Zone A-2”, the first layer to the third layer are composed of alluvial deposit. Expected natural ground water level is found within the upper part of the second layer. The bedrock will be encountered around 75 m in depth.

Hera “Zone A-3, first layer, the second layer and the third layer are talus deposit. Expected natural ground water level is within the third layer. The forth layer is the bedrock.

Hera “Zone B-1”, this location is close to well No. Hera B. The first layer and second layer are composed alluvial deposit. Expected natural ground water level is around 8 m in depth. The second layer may be expected to be an aquifer of sand layer but the thickness of this layer is about 20 m. Therefore it may not have a high potential of the ground water. The forth layer is the bedrock around 26 m below the third layer. It may not be expected to serve as a potential aquifer.

Hera “Zone B-2”, the first layer, second layer and third layer are composed of alluvial deposit. Bedrock is assumed to be encountered around 90 m in depth; it is the uppermost part of the forth layer.

Hera “Zone” B-3”, the first layer, second layer and third layer are composed of alluvial deposit. Expected depth of the bedrock is around 65 m; it is the uppermost part of the forth layer.

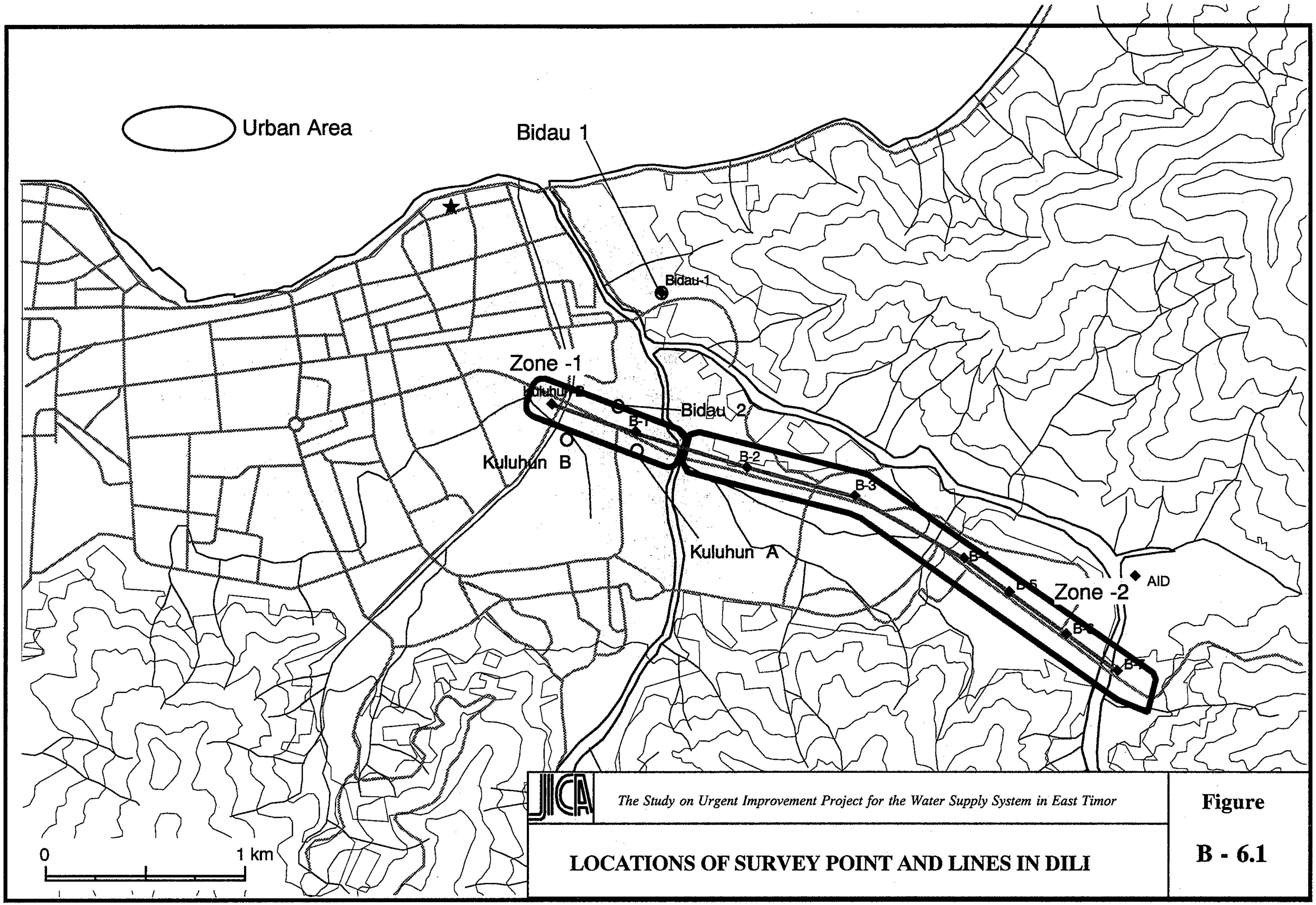
Heara “Zone B-4”, the first layer, second layer and third layer are talus deposit. Expected depth of bedrock is around 30 m; it is the uppermost part of the forth layer.

Liquica “Area-1”, the first layer is talus deposit with cobbles and boulders, thickness of the layer is about 10 m. This dry layer can not be an aquifer. The second layer, up to the depth about 40 m, is assumed to be made of talus deposit and clayey material with sand and some gravel. This layer has no potential of being an aquifer and. The third layer may be made of mixture of sand and clay, up to the depth around 70 m. The layer may not have a high aquifer potential. Natural ground water level is about 38m to 45 m in depth. The forth layer may be the bedrock. However, overall groundwater potential of this area is low.

Liquica “Area-2”, the first layer is talus deposit with cobbles and boulders. The thickness of the layer is about 10 m. This dry layer can not form an aquifer. The second layer, up to 30m, is assumed to be layers of clay and sand mixture. This layer has no potential either. The third layer is expected to be an aquifer of sand layer. The layer has some potential for water sources with a resistivity of 18 to 25 (Ù-m). The thickness of the third layer is about 30 to 40 m. The bedrock may be encountered right below the third layer.

Becora “Zone-1”; from surface to 2.0 m is topsoil. The second layer is sand and clay mixture with 11m of thickness. Natural ground water level in this layer is at around 5 to 7 m in depth. The third layer is composed of sandy material from 13 m to 70 m in depth. The layer has high potential of yielding water. Base rock is encountered below the third layer.

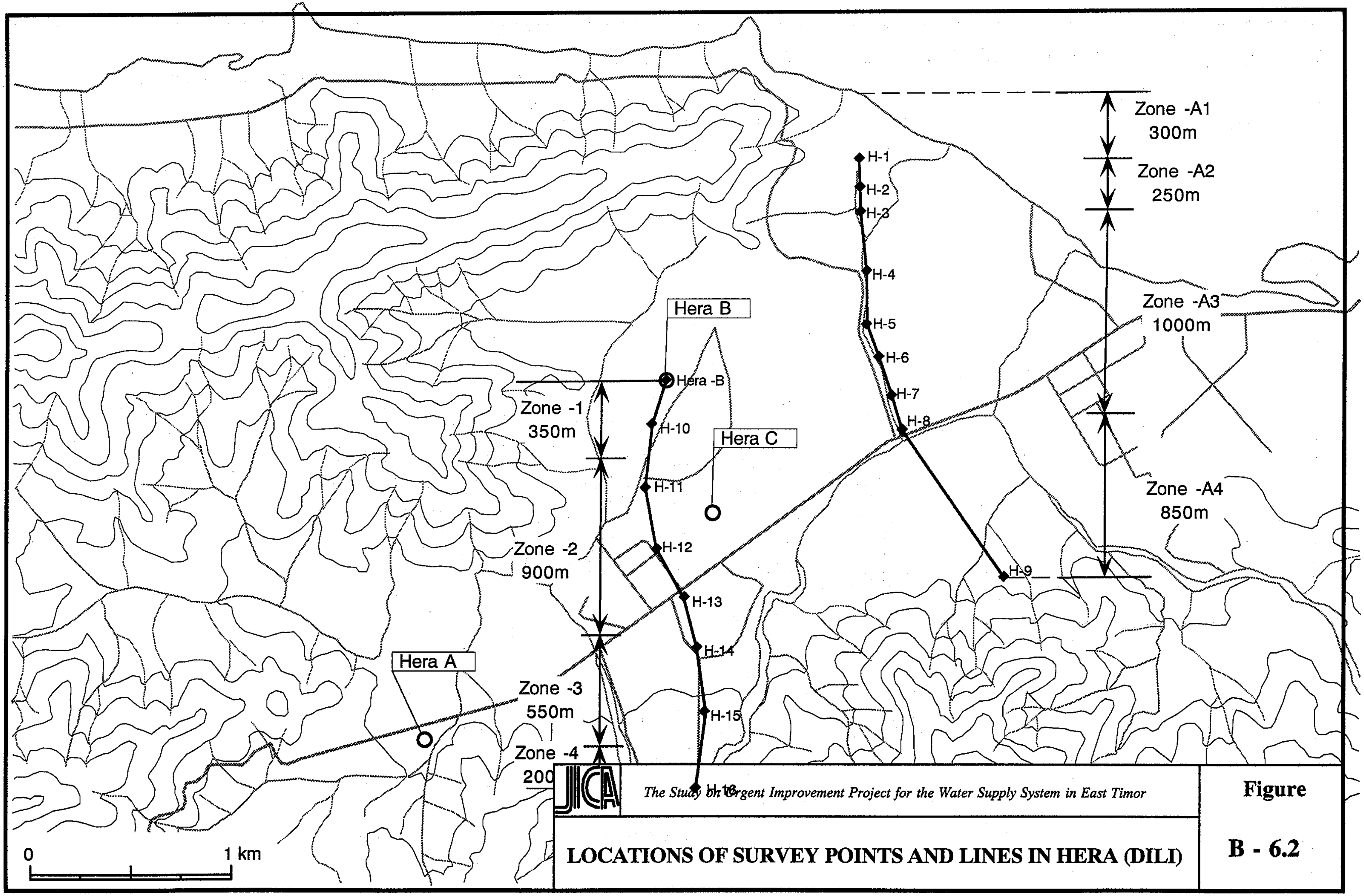
Becora "Zone-2" from surface to 2.0 m is topsoil. The second layer is from 2.0 m to 10.0 m in depth. The third layer may have some potential of yielding groundwater. The Forth layer may be the bedrock from 30 m deep.



The Study on Urgent Improvement Project for the Water Supply System in East Timor

LOCATIONS OF SURVEY POINT AND LINES IN DILI

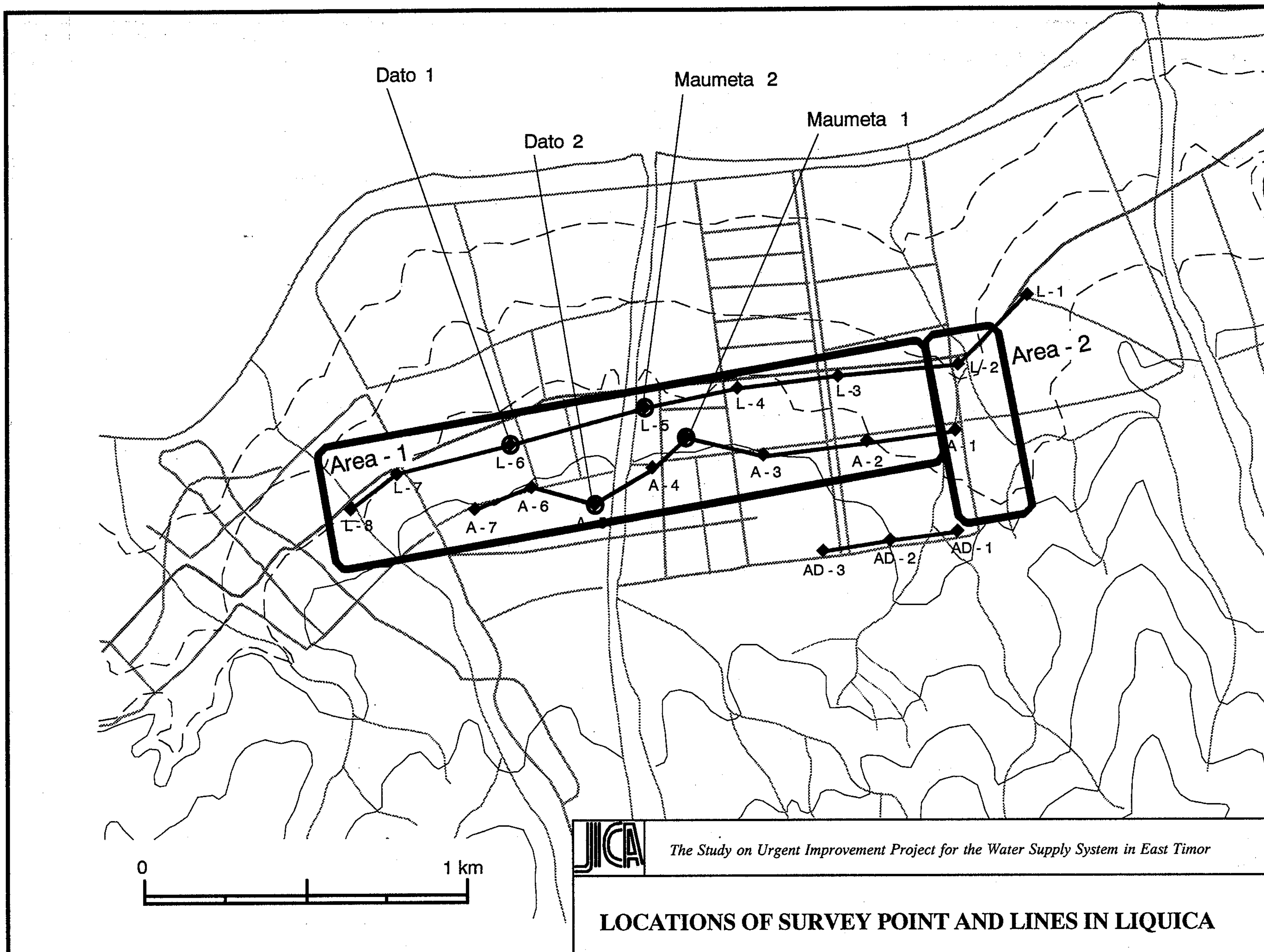
Figure B - 6.1



The Study on Urgent Improvement Project for the Water Supply System in East Timor

LOCATIONS OF SURVEY POINTS AND LINES IN HERA (DILI)

Figure B - 6.2



The Study on Urgent Improvement Project for the Water Supply System in East Timor

LOCATIONS OF SURVEY POINT AND LINES IN LIQUICA

Figure B - 6.3

Annex

B-7 Well Rehabilitation / Construction Project

ANNEX

B-7 WELL REHABILITATION/WELL CONSTRUCTION PROJECTS

Introduction

According to the terms of contract and technical specifications agreed on by the JICA Study Team and the contractor, the rehabilitation of six wells in the city of Dili and in the town of Liquica was carried out.

This report aims to explore hydrogeological conditions and groundwater potential in three well fields where the rehabilitation was carried out. The data obtained in the course of the rehabilitation work was used to analyze the aquifer characteristics of the areas.

B-7.1 Outline of the rehabilitation

As a result of rehabilitation work, 3 out of 6 wells were successfully rehabilitated. The rest of the 3 wells could not restore their potential yield thus one well for each site was newly drilled. The locations of the wells are shown in **Figure B-1.16 to B-1.19**. Schematic borehole logs of the wells are shown in **Figure B-7.1** to B-7.5 for easy comparison of "before and after conditions" of the wells. The following is the summary of rehabilitation work.

Rehabilitation Result for the 6 Wells

	Name of well / town	Result	Remarks
1	Bidau 1 / Dili	Not conducted	Due to land access problem
2	Hera A / Dili	Successful	SWL at 22.4m, Well depth: 54m, PWL: 23m at 9L/s
3	Hera B / Dili	Successful	SWL at 5.5 m. Well depth 59.2. PWL 12.4m at 4.2L/s
4	Hera C / Dili	Successful	SWL at 37.8 m. Well depth: 64m, PWL : 13.3m at 8.3 L/s
5	Maumeta 1 / Liquica	Failed	The borehole was dry and filled with stones up to 27m.
6	Maumeta 2 / Liquica	Failed	SWL at 37.8 m. Well bottom up to 48 m. Little water abstracted by air lifting.

* SWL: Static Water level, PWL: Pumping Water Level

Actual rehabilitation procedures and results are briefly described by site in the following section.

Bidau 1 in Dili

The well is located in a privately owned plot with pumps and discharge pipe installed. The project was explained beforehand to the landowner in the middle of November and verbal agreement was obtained. However, when the study team visited the site for inspection for the second time in December, the landowner asked for compensation that the study team could not afford. The matter was later taken over by the UNTAET water supply office. Several discussions were held between the water supply staff and the landowner who insisted on compensation in monetary terms and they couldn't reach an agreement. The water supply office eventually proposed to the Study Team that a new well should be drilled in the adjacent area instead of rehabilitating the Bidau 1 well. The Study Team Accepted the proposal.

Hera A

The well has been left unused for a few years in a grassy corner of a farm on the main road to Dili. The well was equipped with a submersible pump and rising pipe of small diameter.

Rehabilitation measures and results at Hera - A

1	Checking the Static Water Level and casing configuration The static water level was found to be at 22.4 m. There was no reduction of the casing diameter. The depth of the borehole was 48 m.
2	Cleaning the borehole by bailing for 10 hours Some sediment was removed.
3	Cleaning the borehole by air-blowing for 20 hours The end of air line was set at 46 m. The air blowing was conducted by gradually lowering the pipe up to 53 m. All the sediment was removed and the well depth was 54 m.
4	Air lifting test for 10 hours The air lifting was conducted for 10 hours after the end of air line set at 45 m. The discharge was about 150L/s.
5	Pumping test with submersible pump Five steps at 5L/s, 6L/s and 7L/s, 8 L/s, 9 L/s. The maximum drawdown of 0.6 m was observed after 10 hours from the pumping at the highest rate.
6	Water Level measurement After withdrawing the pipe, the water level was checked and recorded a static water level of 5.5m.

The rehabilitation was successfully completed. Although the maximum pumping rate in the pumping test was only 9 L/s due to the pump capacity, the maximum possible yield of the well can be far more than this value.

Hera B

The well had been reportedly left unused for a few years before the rehabilitation attempt was made by the Study Team. The well was just abandoned in a grassy front yard of a house without a pump nor a cap to cover the opening. The Study Team observed a water level of 0.5m below ground seven months before the rehabilitation was conducted.

The JICA Study Team rehabilitated the well successfully in the following manner.

Rehabilitation measures and results at Hera - B

1	Checking the Static Water Level and casing configuration The static water level was found to be at 5.5m. The casing was reduced from 8 inch to 6 inch at 42m. The depth of the borehole was 46.6m.
2	Cleaning the borehole by bailing for 6 hours Some sediment was removed.
3	Cleaning the borehole by air-blowing for 20 hours The end of air line was set at 46.5 m. The air blowing was conducted by gradually lowering the pipe up to 59.2m. All the sediment was removed.
4	Air lifting test for 10 hours The air lifting was conducted for 3 hours after with the end of air line set at 45 m. The discharge was about 300L/s.
5	Pumping test with submersible pump A submersible pump was installed to carry out more accurate pumping test. Three steps at 1.38L/s, 2.77L/s and 4.166L/s. The maximum drawdown of 6.93m was observed after 6 hours from the pumping at the highest rate.

6	Water Level measurement After withdrawing the pipe, the water level was checked and recorded a static water level of 5.5m.

Although the rehabilitation was successfully carried out, the Study Team recognized the following problems.
About 12m from the bottom of the borehole was filled with fine sediment and the water was still turbid because of finer materials even during the pumping test.
The ground around the casing pipe gradually caved in during the cleaning by air lifting.

These two incidents indicate that the well development was not properly done at the time of its construction. In specific, the gravel packing was insufficient and/or screens were not appropriately installed. These conditions often result in sand pumping or plugging of screen slots and surrounding aquifer. The situation seems to have improved and stabilized after the rehabilitation. It is still necessary to keep track of suspended sediments in the water sample in the course of actual operation of the well.

Hera C
The well had been reportedly left unused for a few years before the rehabilitation attempt was made by the Study Team. The well was located next to a house with a pump and a small house to shelter the control panel. During the phase 2 field survey, the Study Team found that the pump had been removed and observed a water level of 11.5m below ground. It was also reported, at that time, that the well could produce water only if the control panel was repaired.
The JICA Study Team rehabilitated the well successfully in the following manner.

Rehabilitation measures and results at Hera - C

1	Checking the Static Water Level and casing configuration The static water level was found to be at 12.87m. The casing was reduced from 8 inch to 6 inch at 56m. The depth of the borehole was 64m.
2	Cleaning the borehole by bailing for 6 hours Some sediment was removed.
3	Cleaning the borehole by air-blowing for 10 hours The end of air line was set at 60 m. The air blowing was conducted. Four meters of sediment was removed.
4	Air lifting test for 13 hour The air lifting was conducted for 3 hours after with the end of air line set at 45 m. The discharge was about 300L/s.
5	Installation of submersible pump and preliminary pump test A preliminary pump test was conducted for 3 hours to determine the discharge rates for step pump test.
6	Pumping test with submersible pump Pump test was conducted with three steps at 2.77L/s, 5.55L/s and 8.3L/s. The maximum drawdown of 0.43m was observed after 6 hours from the pumping at the highest rate.
7	Water Level measurement After withdrawing the pipe, the water level was checked and recorded a static water level of 12.87m.

Although some sand was pumped up during the initial stage of the pumping test, the total sediment deposit in the bottom of the casing was only 4m. The value is far smaller than that for Hera B and no caving in around the casing occurred. There seem to be no imminent problem anticipated. The maximum pumping rate was raised only up to 8.3L/s because of the limit of the pump capacity and the recorded drawdown was a negligible amount. The well has much greater potential of production.

Maumeta 1

The JICA Study Team also tried to rehabilitate the well in the following manner.

Rehabilitation measures and results at Maumeta - 1

1	Cleaning the borehole by bailing for 2 hours No water observed in the borehole
2	Cleaning the borehole by air-blowing for 4 hours The end of air line was at 27 m. The deposit (probably gravel) in the bottom could not be effectively removed. No water recovery after an hour. The air blowing was terminated.
3	Water Level measurement After withdrawing the pipe, the water level was checked and recorded no water.

The well had been left unused without a pump for some time after the rehabilitation attempts by OXFAM.

Maumeta 2

At least two attempts were made to restore the yield of the well. One by OXFAM and the other by a Bangladesh contractor. In spite of these trials the well didn't recover the yield. It seems that the both rehabilitation works were not well-organized considering the fact that no written report on the rehabilitation works was produced.
After the failures of the two rehabilitation attempts, the JICA Study Team also tried to rehabilitate the well in the following manner.

Rehabilitation measures and results at Maumeta - 2

1	Removal of the submersible pump the pump was covered and filled with silt and mud.
2	Cleaning the borehole by bailing for 10 hours Static water level was found to be at 37.8 m
3	Cleaning the borehole by air-blowing for 3 hours The end of air line was at 48 m (borehole bottom). The fine sediments deposited in the bottom could not be effectively removed
4	Air lifting test for 1 hour The air lifting was continued for another hour after lowering the discharge pipe but little water was extracted. The pumping was terminated.
5	Water Level measurement After withdrawing the pipe, the water level was checked and recorded 40m.

It appears that the considerable part of the borehole had already been filled with silt and clay that are adhesive and difficult to remove once they are settled. The well was suspected to have been drilled until some 80m and the primary aquifer lies under 40m. This is one reason why the well did not recover yield. Another reason is probably the poor development of the well; inappropriate screen locations and insufficient gravel packing. A local resident reported that the well was producing water only in rainy season. This statement implies that the either the pump was set too shallow or the borehole was not deep enough.

B-7.2 Drilling of New Wells

A total of three wells were newly constructed to complement Bidau 1, Maumeta –1 and Maumeta –2. The locations of the new wells are shown in **Figure B-7.6 and B-7.7.** The configuration and log data of the wells are presented in **Figure B-7.8 to B-7.10** attached to the end of this chapter. The samples were taken during the pumping test and the analysis result was presented in **Table B-7.1**.

First Well to replace Maumeta 1 (Liquica 1)
The location of the new well was carefully decided based on the resistivity survey data and field observations. The failed rehabilitation at Maumeta 1 and 2 that are drilled just on the right bank of the Gularloa river implied that the water level can be considerably low in the area. The resistivity survey data also did not show apparent water bearing layer in this area while the data indicated existence of water bearing layer about 1 km to the east around a small stream (see resistvity survey report). Thus the new well was drilled at this point in spite of relatively small catchment area the site can make use of. At first the water supply office in Liquica proposed a well name "JICA Maumeta 1" to the Study Team. However it was later changed to Liquica 1 for some reason.

The bed rock of black schist was struck around 55m below ground level according to the observation of the drill cuttings. The bed rock seems to have a lot of quartz veins. The overlaying sediment is mostly sand with some silt layers and gravel layers. There seem to be few confining clay layers in the area.

During the pumping test, the static water level was found to be 22.618m below ground and the maximum drawdown was 10.3m with a discharge of 8.3L/s. In terms of the specific capacity the well has a high potential. However, it should be stressed that the on site water quality test indicated relatively high electric conductivity value of 1466Ù-s/m, which implies the slight influence of the sea water.

<Aquifer characteristics>
The findings from the drilling of the two boreholes confirmed the descriptions of the aquifer characteristics in the main report made largely on the basis of the rehabilitation and field survey results. The water table is almost flat throughout the Dato –Maumeta well field and the area of new wells. The water table (static) is as low as about 3.5m above sea level even at the existing wells located about 1000m away from the shoreline, where the water level is nearly 39m below ground. This peculiar condition can be attributed to the following.

The thick alluvial fans develop in the coastal area and the lower part of the fans is submerged in the sea, which allows groundwater go deeper into the ground until it meets the sea water wedge and comes to balance.

The fan deposit is made up of very course materials with few confining layers, which also allows quick infiltration of the surface water through the deposit into the sea, resulting in little amount of groundwater storage. The high groundwater temperature (32.9C) indicates that the surface water is heated while flowing along the stream or near the ground surface and rapidly go deeper into the ground maintaining the temperature.
The well fields have relatively small catchment area, which limits the amount of recharge.

The water table observed this time is considered to be that of dry season and probably the lowest. The water table is expected to rise during the rainy season but it will be perhaps only by a few meters. Special attentions should be paid in the operation of the pumps to avoid pumping up of saline water. The basic principle is to maintain the pumping water level above the sea level.

Second Well to replace Maumeta 2 (Liquica New 2)
Following the success of Liquica 1 well and failed rehabilitation at Maumeta 2, the Study Team decided to drill another well to complement Maumeta 2. The drilling location was decided based on the same data and observations. The outline of the well is illustrated in **Figure B-7.10.**

The bedrock of black schist was struck around 56m below ground level according to the observation of the drill cuttings. The bed rock seems to contain some quartz veins. The overlaying sediment is mostly sand with some silt layers and gravel layers around the top.

During the pumping test, the static water level was found to be 18m below ground and the maximum drawdown was 18.6m with a discharge of 3 L/s. In terms of the specific capacity, the well has a high potential. However, it should be noted that the on site water quality test indicated relatively high electric conductivity value of around 4000 Ù-s/m, which implies the influence of the sea water. Therefore the operator should pay special attention be the salinity of water during operation. It is recommend that the electric conductivity should be monitored continuously and the pumping rate be as low as possible to keep the drawdown minimum (preferably within 3.5m).

<Aquifer characteristics >
This well is only 280m away from the first well and the hydrogeological condition is similar to that of the first well. The bedrock was encountered at 56m below ground.

Bidau 1 New
The new well was drilled on the eastern side of the Santana River about 10m from the river course that is usually dry. The drilling site was decided through discussion with the water supply office. The outline of the well is illustrated in **Figure B-7.8.**

The bedrock of black schist was struck around 52m below ground level according to the observation of the drill cuttings and drilling bit load. The bedrock seems to contain some quartz veins. The overlaying sediment is mostly sand with some silt layers around the top.

During the pumping test, the static water level was found to be 2 m below ground and the maximum drawdown was 20m with a discharge of 7 L/s after 24 hours from the start of the pumping.

Table B-7.1 Water Quality Analisis Data Sheet (1/2)

Sampled and tested by: Alvaro Godinho, Mario Soares, WSS laboratory and T.ISHIHARA, JICA Study Team

No.	Sampling Point	sampling		Test	pH	Temp.	Cond.	TDS	Salinity	Turbid.	Alkali.	Hdns.	NH_3-N	NO_3-N	NO_2-N	Fe	Fluoride	Mn	SO_4^{2-}	T.Coli	G.Bac
		Date	Time	Date		(°C)	(μ S/cm)	(mg/L)	(‰)	(NTU)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	CFU	CFU
Timor Loro sa'e Guidelines					6.5-8.5	NS	NS	1000	NS	5.0	NS	200	1.5	10	1	0.3	1.5	0.5	250	0	0
	Bidau 1	28-Dec-00	18:02	2-Jan-01	7.0	28.5	398.0	188.0	0.2	5.5	188.0	183.0	0.7	0.7	0.005	0.02	0.33	NT	-	NT	NT
	Bidau 1	28-Dec-00	19:00	2-Jan-01	7.0	28.4	405.0	192.0	0.2	4.8	184.0	160.0	0.2	0.6	0.013	0.0	0.33	NT	-	NT	NT
	Bidau 1	28-Dec-00	0:00	1-Feb-01	7.0	27.5	413.0	196.0	0.2	4.8	187.0	157.0	0.6	0.8	0.007	0.03	0.29	NT	-	NT	NT
	Bidau 1	29-Dec-00	6:00	2-Jan-00	7.0	27.0	407.0	194.0	0.2	3.7	183.0	178.0	0.5	0.8	0.006	0.03	0.48	NT	-	NT	NT
	Bidau 1	29-Dec-00	12:00	2-Jan-01	7.0	31.3	384.0	178.0	0.2	1.5	200.0	190.0	0.9	0.8	0.006	0.02	0.31	NT	-	NT	NT
	Bidau 1	29-Dec-00	18:00	2-Jan-01	7.0	29.9	384.0	780.0	0.2	0.5	190.0	184.0	0.5	0.8	0.008	0.03	0.31	NT	NT	NT	NT
	Hera-A	10-Jan-01	9:02	11-Jan-01	7.7	29.1	990.0	486.0	0.5	4.9	460.0	156.0	0.7	0.3	0.010	0.04	1.51	0.3	-	NT	NT
	Hera-A	10-Jan-01	11:00	11-Jan-01	7.6	29.0	790.0	386.0	0.4	3.6	386.0	178.0	0.7	0.3	0.011	0.03	1.30	0.4	-	NT	NT
	Hera-A	10-Jan-01	13:00	11-Jan-01	7.5	28.7	760.0	371.0	0.4	3.0	388.0	156.0	0.8	0.5	0.012	0.02	1.29	0.6	-	NT	NT
	Hera-A	10-Jan-01	15:00	11-Jan-01	7.5	28.3	724.0	353.0	0.4	2.5	360.0	140.0	0.7	0.3	0.013	0.02	1.25	0.3	-	NT	NT
	Hera-A	10-Jan-01	17:00	11-Jan-01	7.5	28.0	716.0	349.0	0.3	2.4	352.0	124.0	0.8	0.4	0.012	0.03	1.18	0.5	-	NT	NT
	Hera-B	8-Dec-00	14:02		7.3	26.7	590.0	286.0	0.3	0.6	250.0	180	0.6	0.4	0.006	0.01	NT	NT	-	NT	NT
	Hera-B	8-Dec-00	16:00		7.2	26.5	585	284	0.3	0.6	260	210	0.6	0.4	0.006	0.02	NT	NT	-	NT	NT
	Hera-B	8-Dec-00	18:02		7.2	26.3	562	272.0	0.3	0.4	260.0	188.0	0.3	0.7	0.005	0.05	NT	NT	-	NT	NT
	Hera-B	8-Dec-00	20:00		7.3	26.6	593.0	288.0	0.3	0.3	261.0	210	0.7	0.6	0.005	0.04	NT	NT	-	NT	NT
	Hera-C	11-Dec-00	10:02	11-Dec-00	7.0	27.9	289	137.0	0.1	<1	148.0	127.0	ND	0.2	0.005	0.01	NT	NT	-	NT	NT
	Hera-C	11-Dec-00	12:00	11-Dec-00	7.6	28.0	272	130.0	0.1	1.0	142.0	128.0	0.3	0.2	0.006	ND	NT	NT	-	NT	NT
	Hera-C	11-Dec-00	14:02	11-Dec-00	7.7	28.1	241	137.0	0.1	1.3	138	116	0.5	0.2	0.006	0.01	NT	NT	-	NT	NT
	Hera-C	11-Dec-00	16:00	11-Dec-00	7.5	29.6	284.0	135.0	0.1	0.6	149.0	118.0	2.0	0.2	0.0	ND	NT	NT	-	NT	NT

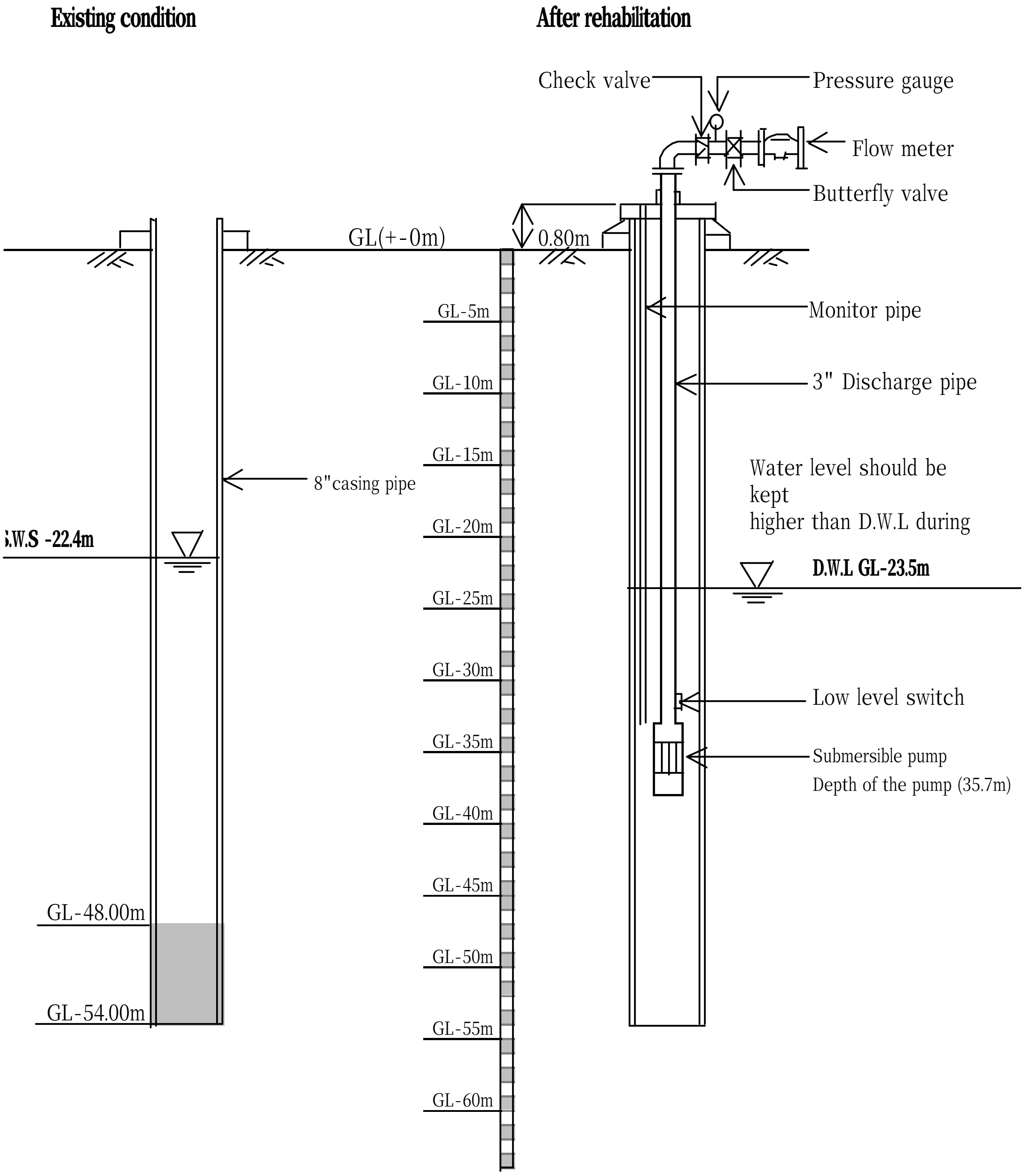
Table B-7.1 Water Quality Analisis Data Sheet (2/2)

No.	Sampling Point	sampling		Test	pH	Temp.	Cond.	TDS	Salinity	Turbid.	Alkali.	Hdns.	NH_3-N	NO_3-N	NO_2-N	Fe	Fluoride	Mn	SO_4^{2-}	T.Coli	G.Bac
		Date	Time	Date		(°C)	(μ S/cm)	(mg/L)	(‰)	(NTU)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	CFU	CFU
Timor Loro sa'e Guidelines					6.5-8.5	NS	NS	1000	NS	5.0	NS	200	1.5	10	1	0.3	1.5	0.5	250	0	0
	Liquica-New1	15-Dec-00	11:02		7.6	27.3	1751.0	895.0	0.9	-	437.0	617.0	ND	0.4	0.007	0.04	NT	NT	-	NT	NT
	Liquica-New1	15-Dec-00	12:00		7.6	27.3	1747	873.0	0.9	-	439	600	ND	0.4	0.007	0.03	NT	NT	NT	NT	NT
	Liquica-New1	15-Dec-00	17:00		7.5	27.1	1744	871.0	0.9	-	432	606	ND	0.5	0.005	0.03	NT	NT	NT	NT	NT
	Liquica-New1	15-Dec-00	23:00		7.5	27.1	1753	876.0	0.9	-	442.0	604.0	ND	0.5	0.009	0.04	NT	NT	NT	NT	NT
	Liquica-New1	16-Dec-00	5:00		7.5	27.2	1747	873.0	0.9	-	439.0	606.0	ND	0.5	0.005	0.04	NT	NT	NT	NT	NT
	Liquica-New1	16-Nov-00	11:00		7.5	27.3	1759.0	879.0	0.9	-	429.0	610.0	ND	0.5	0.005	0.05	NT	NT	NT	NT	NT
	Liquica-New2	21-Dec-00	11:02		7.0	32.4	588.0	4160.0	4.3	1.4	468.0	714.0	1.0	0.1	0.006	0.14	1.29	NT	-	NT	NT
	Liquica-New2	21-Dec-00	12:00		7.0	32.7	579	3920.0	4.0	0.6	469	714	ND	ND	0.005	0.09	1.42	NT	-	NT	NT
	Liquica-New2	21-Dec-00	17:00		7.0	32.4	598	4180.0	3.5	0.5	470	730	1.4	ND	0.005	0.06	1.29	NT	-	NT	NT
	Liquica-New2	22-Dec-00	0:00		7.0	30.9	577	3060.0	3.3	0.4	470.0	711.0	0.4	ND	0.005	0.08	1.37	NT	-	NT	NT
	Liquica-New2	22-Dec-00	5:00		7.0	30.3	576.0	3100.0	3.5	0.5	475.0	700.0	0.8	0.1	0.005	0.08	1.32	NT	-	NT	NT
	Liquica-New2	22-Dec-00	11:00		7.0	31.6	3090.0	580.0	3.3	0.5	479.0	700.0	0.6	0.1	0.006	0.07	1.14	NT	-	TND	NT

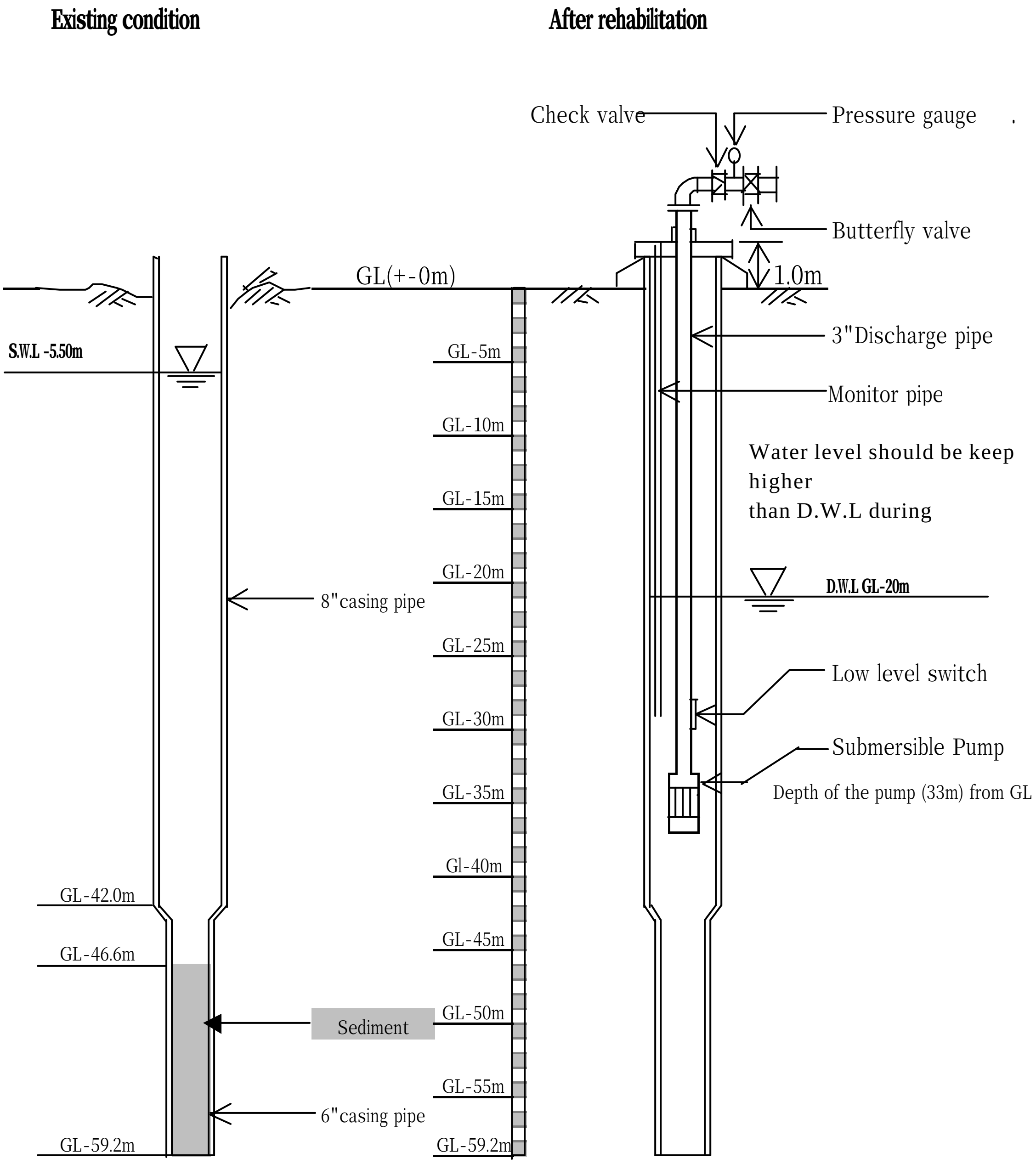
Legend:

ND: not detectable NT: not tested NS: not set CFU: colony formed unit;

*Sample points of DL-17, 19, 24 and DL-25 would be converted the different palces after this sampling.



The Study Improvement Project for the Water Supply System in East Timor	**Figure**
REHABILITATION FOR WELL No. HERA-A, HERA, DILI	**B-7.1**

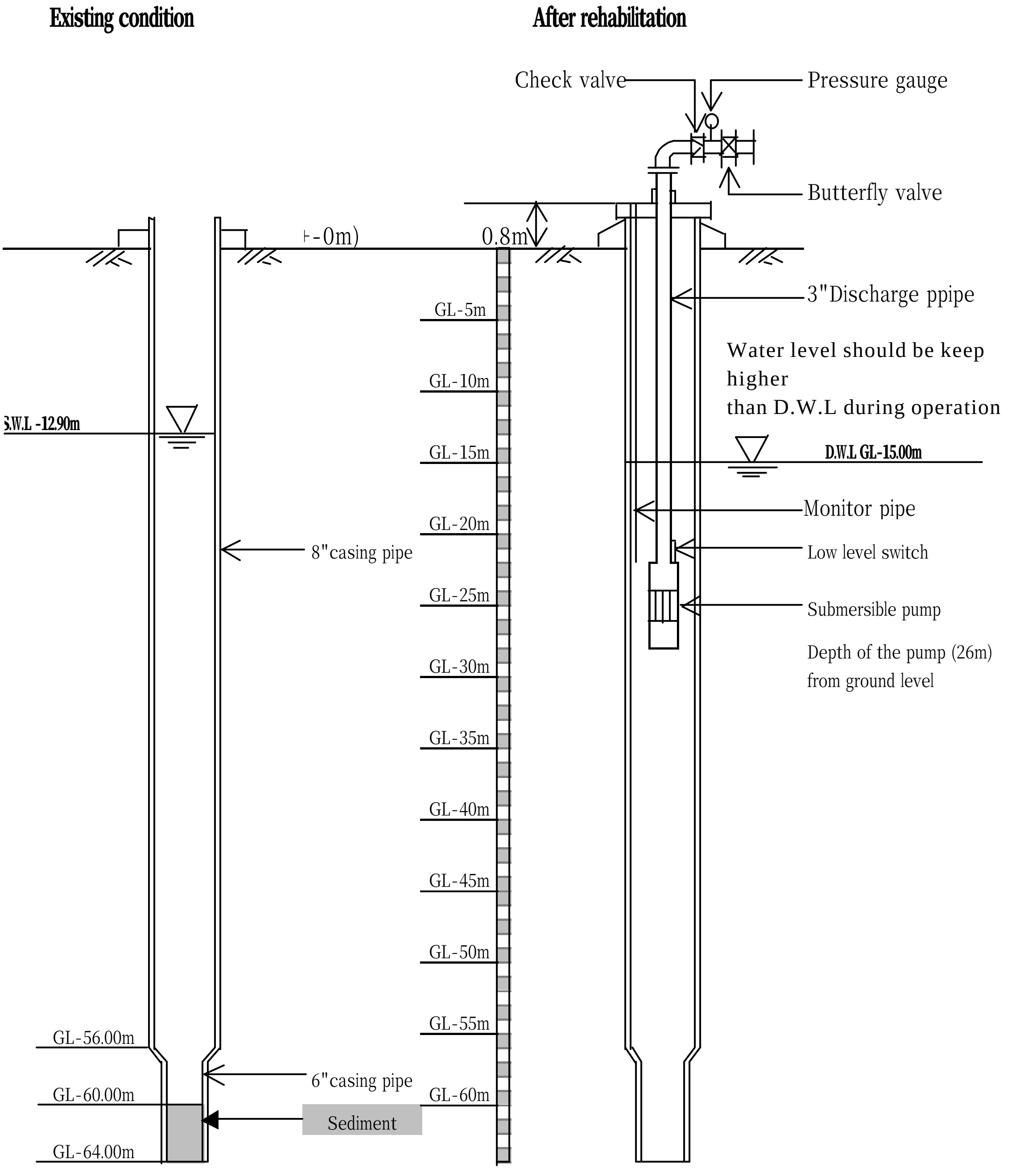


The Study onUrgent Improvement Project for the Water Supply System in East Timor

Figure

REHABILITATION FOR WELL No. HERA-B, HERA, DILI

B-7.2



The Study onUrgent Improvement Project for the Water Supply System in East Timor	**Figure**
REHABILITAITON FOR WELL No. HERA-C, HERA, DILI	**B-7.3**

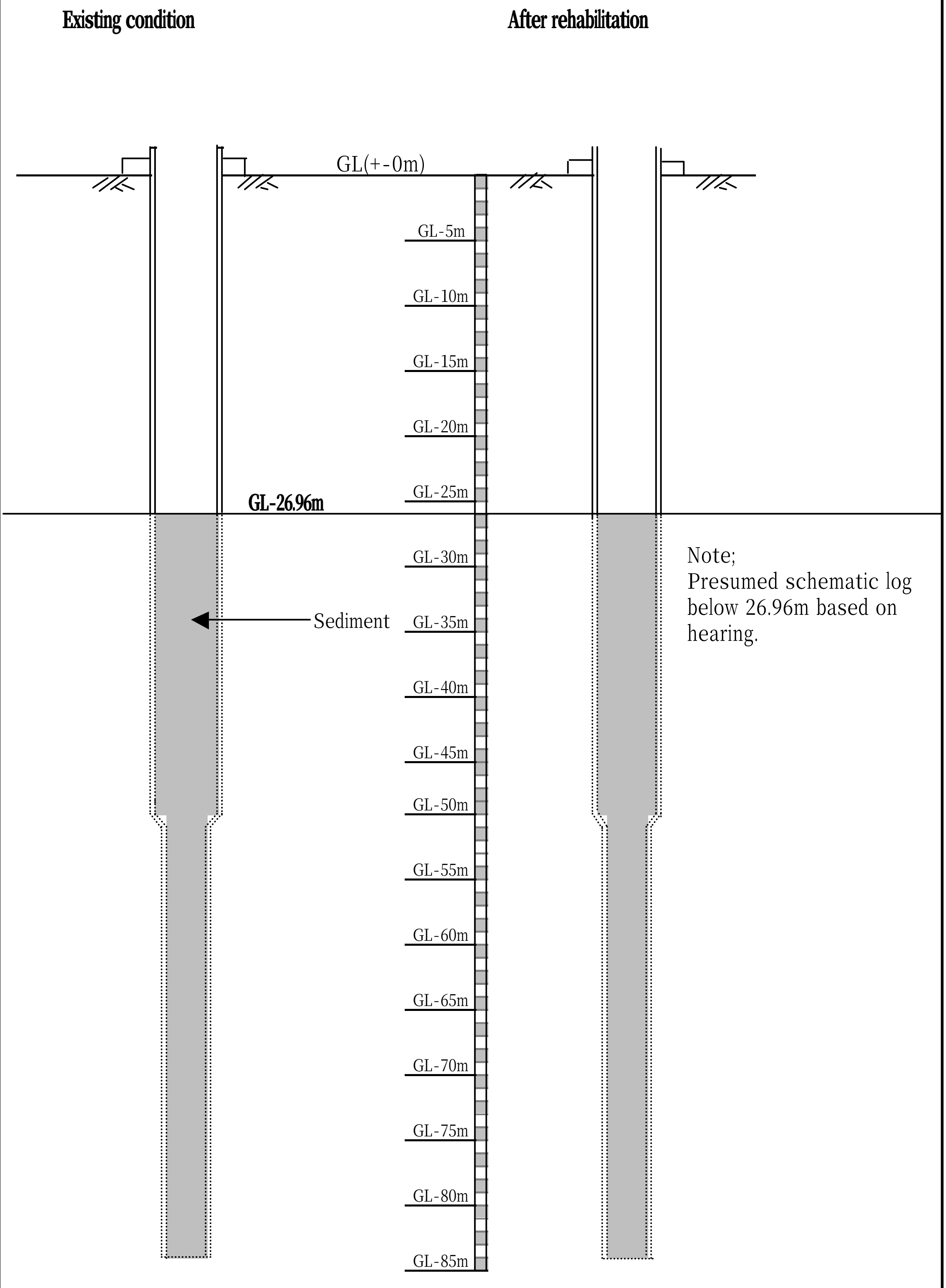


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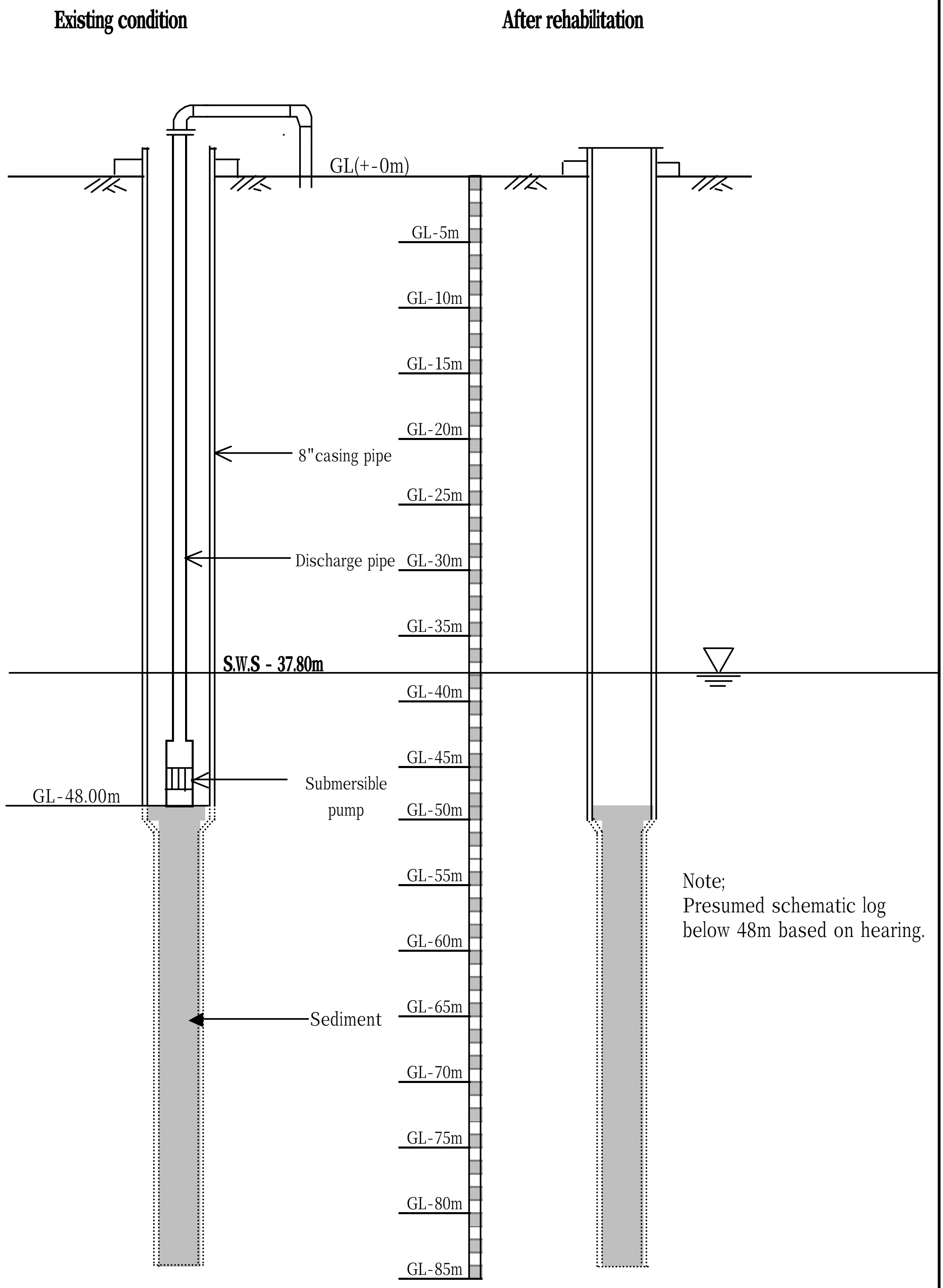
Figure B-7.4

REHABILITATION FOR WELL No.MAUMETA-1, MAUMETA, LIQUICA

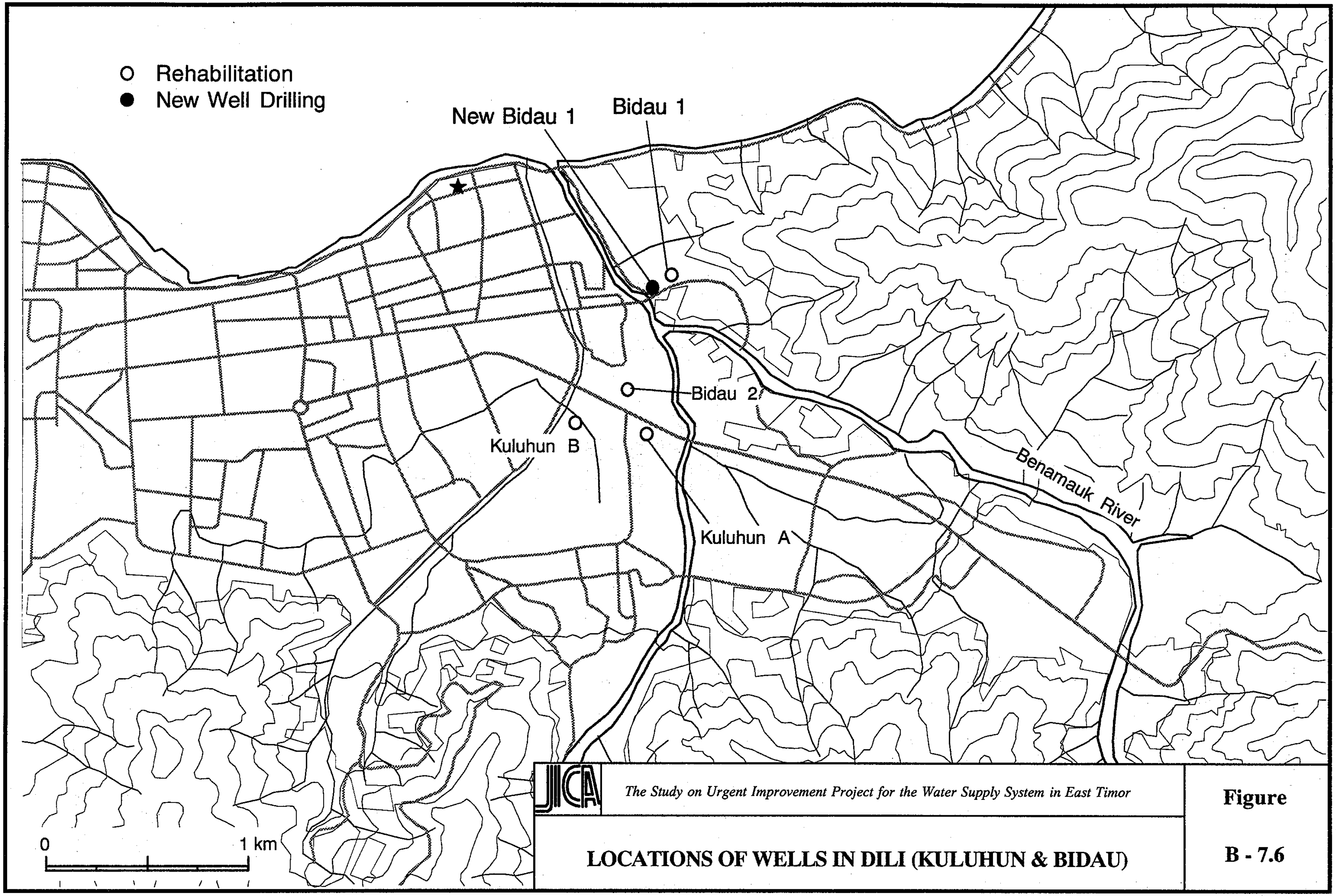


The Study Improvement Project for the Water Supply System in East Timor

Figure

REHABILITATION FOR WELL No.MAUMETA-2, MAUMETA, LIQUICA

B-7.5

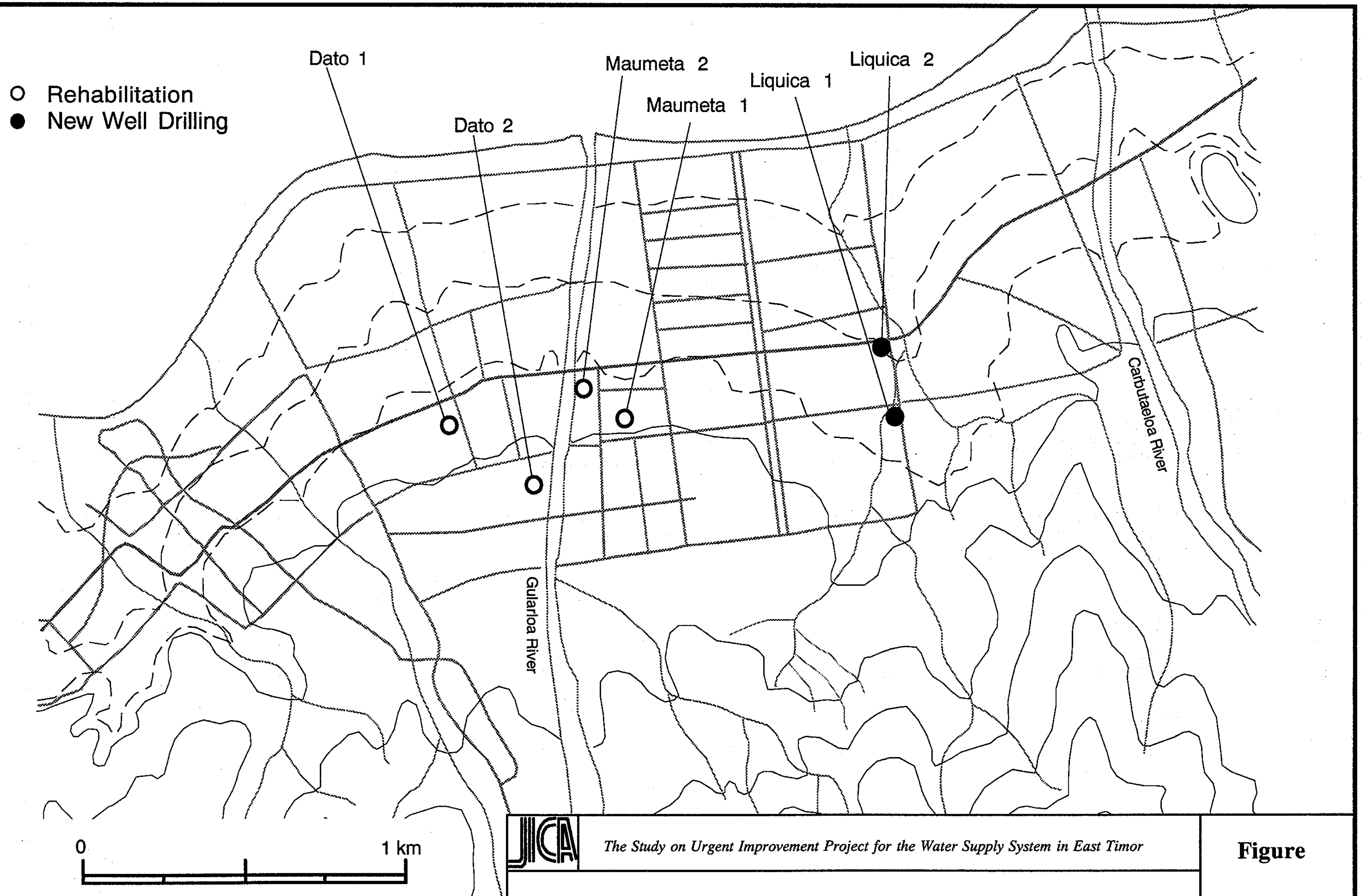


The Study on Urgent Improvement Project for the Water Supply System in East Timor

Figure

B - 7.6

LOCATIONS OF WELLS IN DILI (KULUHUN & BIDAU)



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LOCATIONS OF WELLS IN LIQUICA

Figure B - 7.7

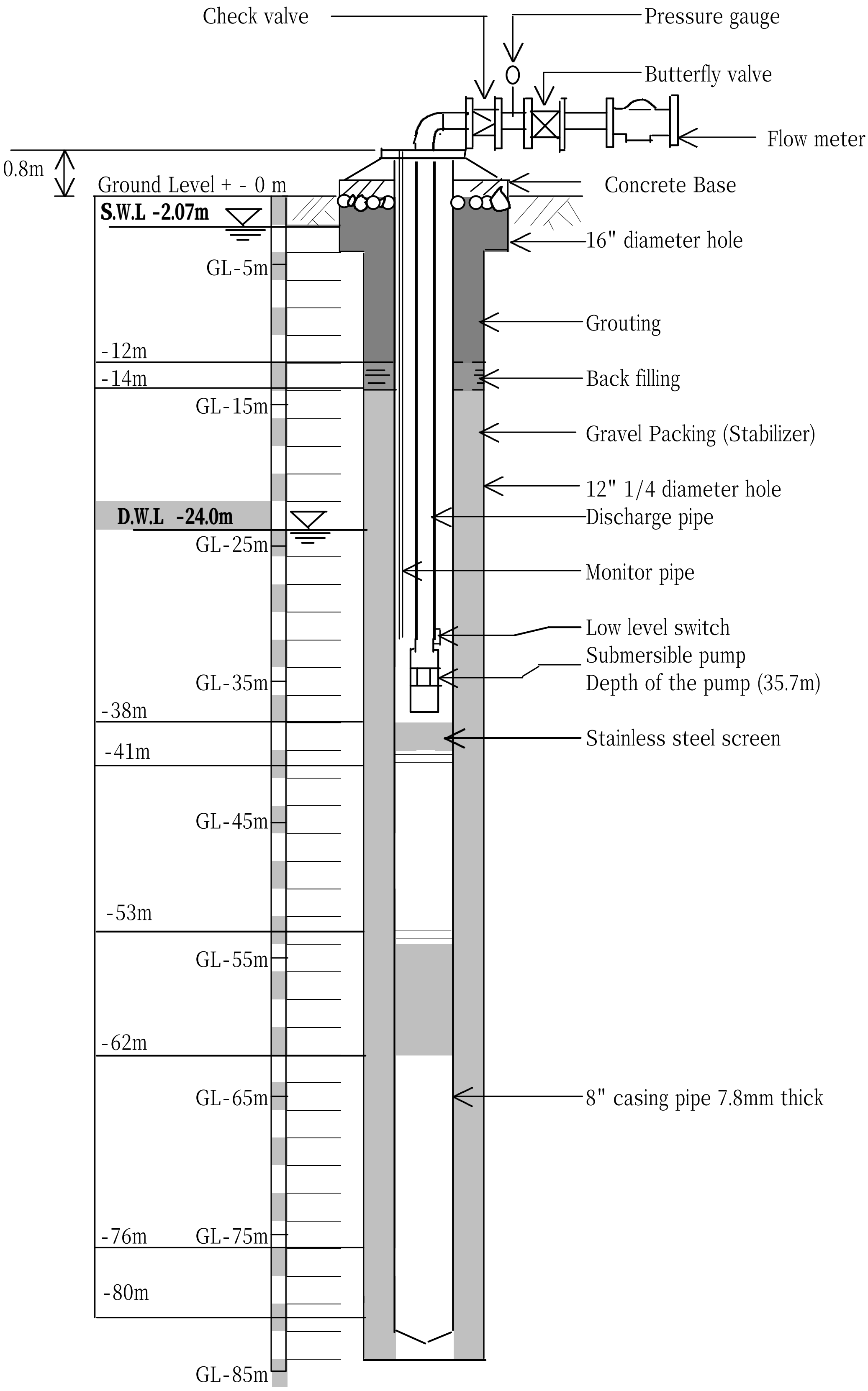

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Figure

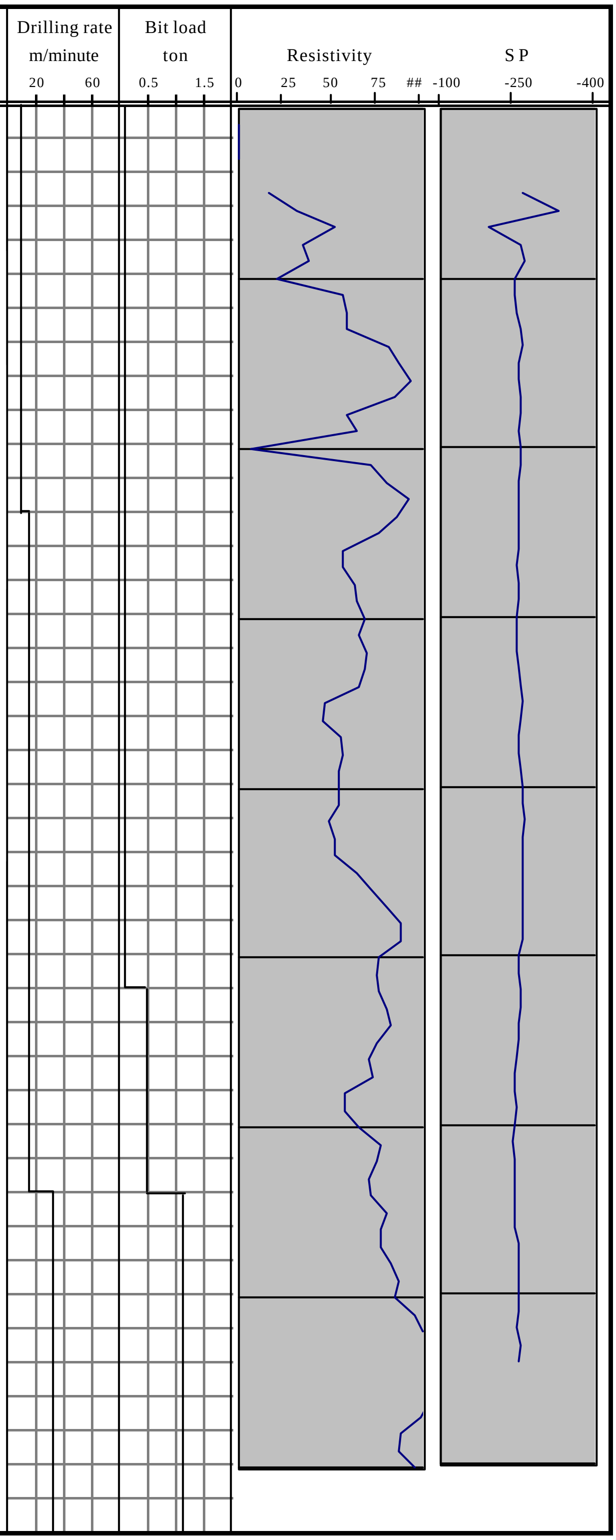
NEW WELL CONSTRUCTION, WELL No. BIDAU NEW-1

B-7.8 (1)

WELL LOG

WELL No. **Bidau New-1** **DATE.** **18 Dec. ~ 21 Dec. 2000**
LOCATION. **Bidau, Dili**

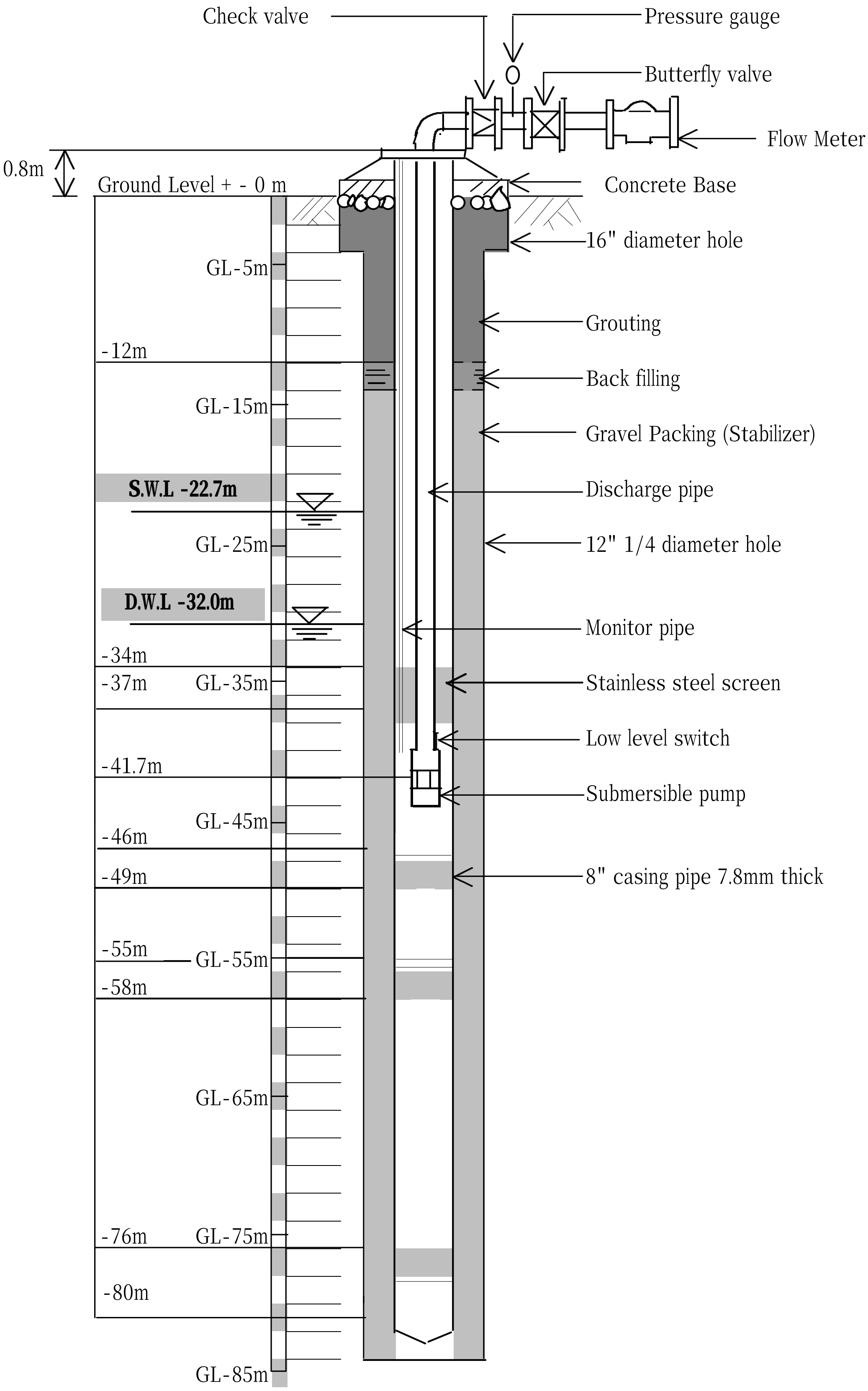
Depth (m)	Symbol	Description	Water Level (m)	Bit type
2		Top Soil	∇	Direct circulation drill by Tricone bit
24		Yellowish brown, Silty Clay with fragments of calluvium.		
52		Dark gray and brown color mixture, Slaty Shale. Moderately to highly weathered, some quartz vein.		
64		Brown and dark gray mixture, Slaty Shale. Fractured zone.		
		Dark gray Slaty Shale phyllite.		



The Study onUrgent Improvement Project for the Water Supply System in East Timor

Figure B-7.8 (2)

WELL LOG OF BIDAU NEW-1



The Study onUrgent Improvement Project for the Water Supply System in East Timor

Figure

NEW WELL CONSTRUCTION, WELL No. LIQUICA-1

B-7.9 (1)

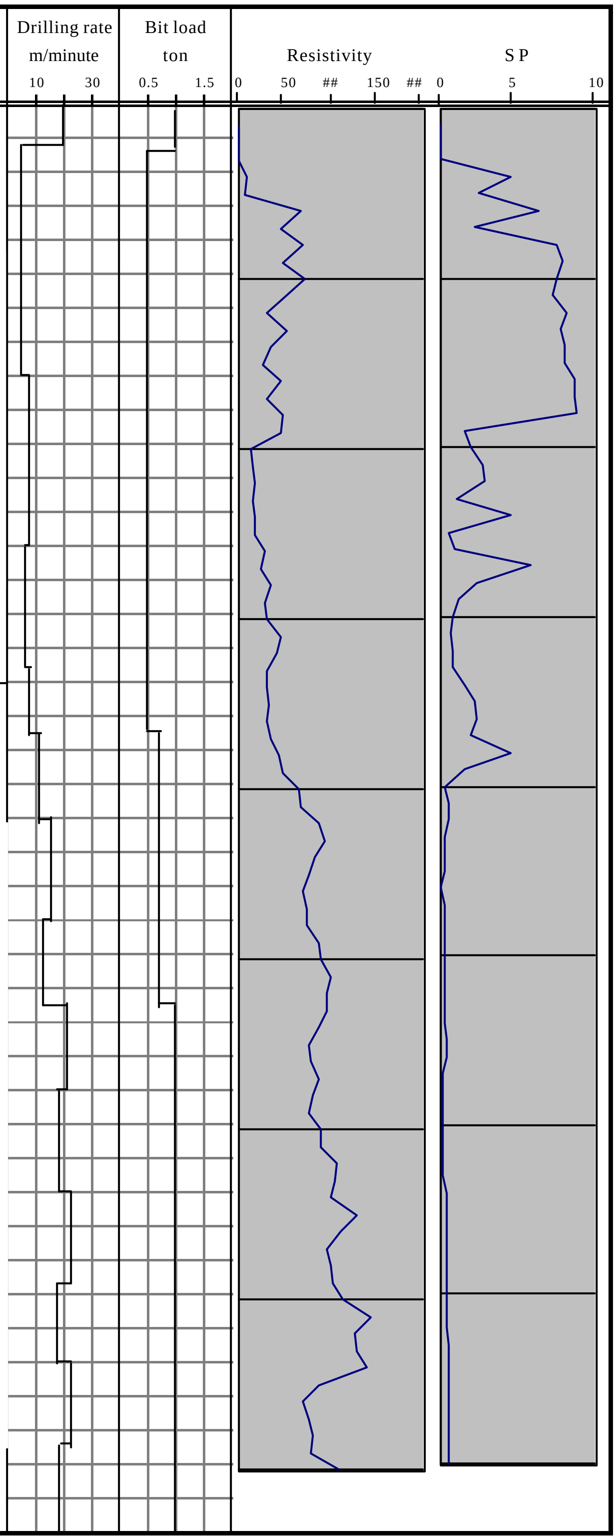
WELL LOG

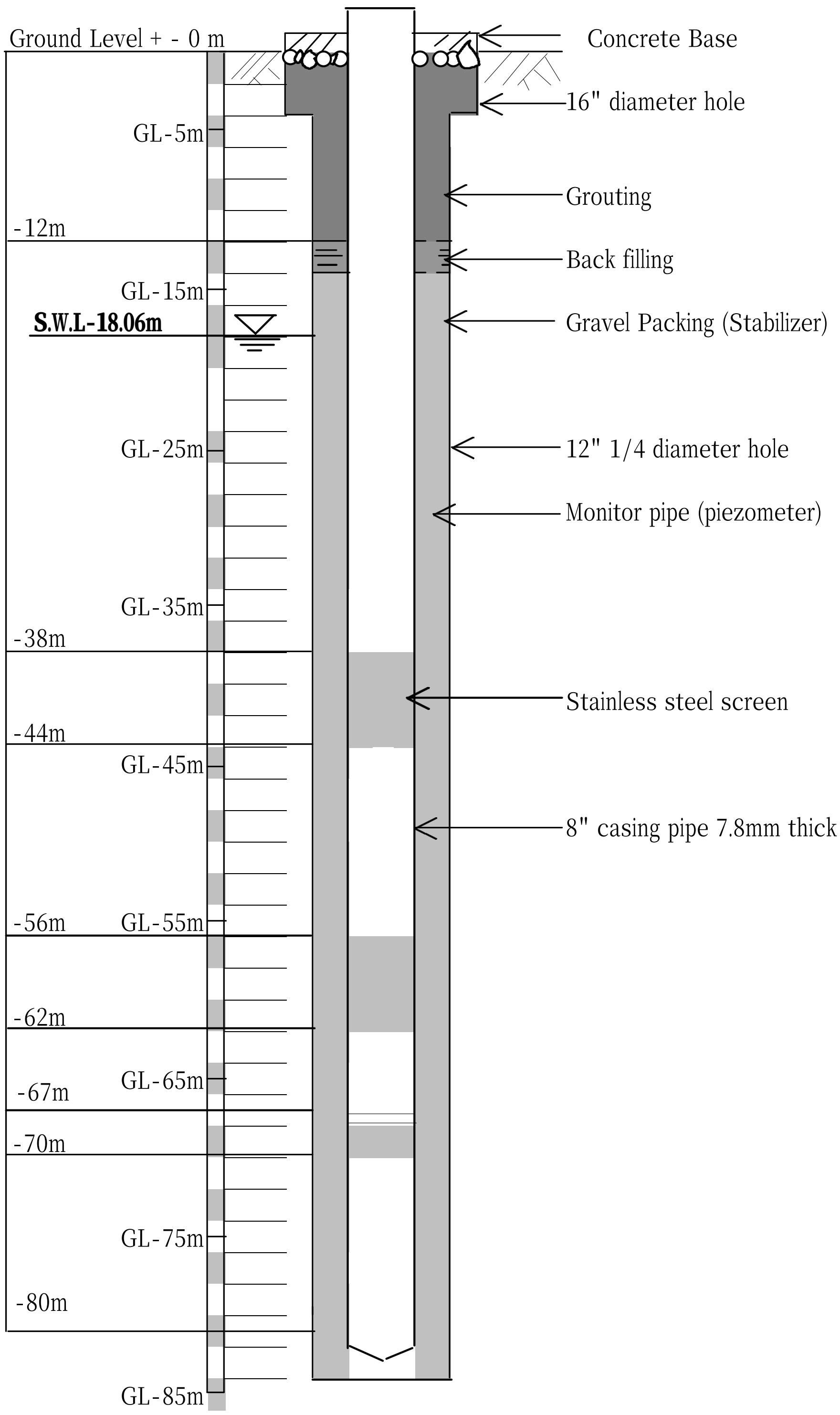
WELL No. New well, Liquica-1 **DATE.** 27 Nov ~ 3 Dec 2000

LOCATION. Maumeta, Liquica, East Timor

Depth (m)	Description	Water Level (m)	Bit type
0–8	Talus material of Sand and Silt mixture with cobble and boulder in upper part.		Down the hole hammer (0–34)
8–18	Dark brown, medium to coarse Sand with silt.		
18–30	Dark brown, medium to coarse Sand and Silt mixture	22.71	
30–54	Dark brown, medium to coarse Sand with same silt. Hole collapse around 35m in depth, with some quartz grain.		Direct circulation drill by Tricone bit (34–)
54–60	Dark gray,Phyllite Schist, cuttings medium to coarse.		
60–	Dark gray, Base rock of Schist, cuttings coarse with quartz grain.		

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80





JICA

The Study Improvement Project for the Water Supply System in East Timor

Figure

NEW WELL CONSTRUCTION, WELL No. LIQUICA-2

B-7.10 (1)

WELL LOG

WELL No. New well, Liquica-2 **DATE.** 4 Dec ~ 8 Dec 2000

LOCATION. Maumeta, Liquica, East Timor

Depth (m)	Description	Water Level (m)	Bit type
0 – 10	Dark gray top soil first 1m. Yellowish brown Sand and Silt mixture.		Direct circulation drill by Tricone bit
10 – 16	Light brown, Sand and Silt mixture.		
16 – 32 (20, 30)	Yellowish brown to dark brown, medium to coarse Sand with silt.	18	
32 – 56 (40, 50)	Brownish gray, medium to coarse Sand.		
56 – (60, 70, 80)	Dark gray, phyllite Schist, Cuttings medium to coarse, some quartz grain		

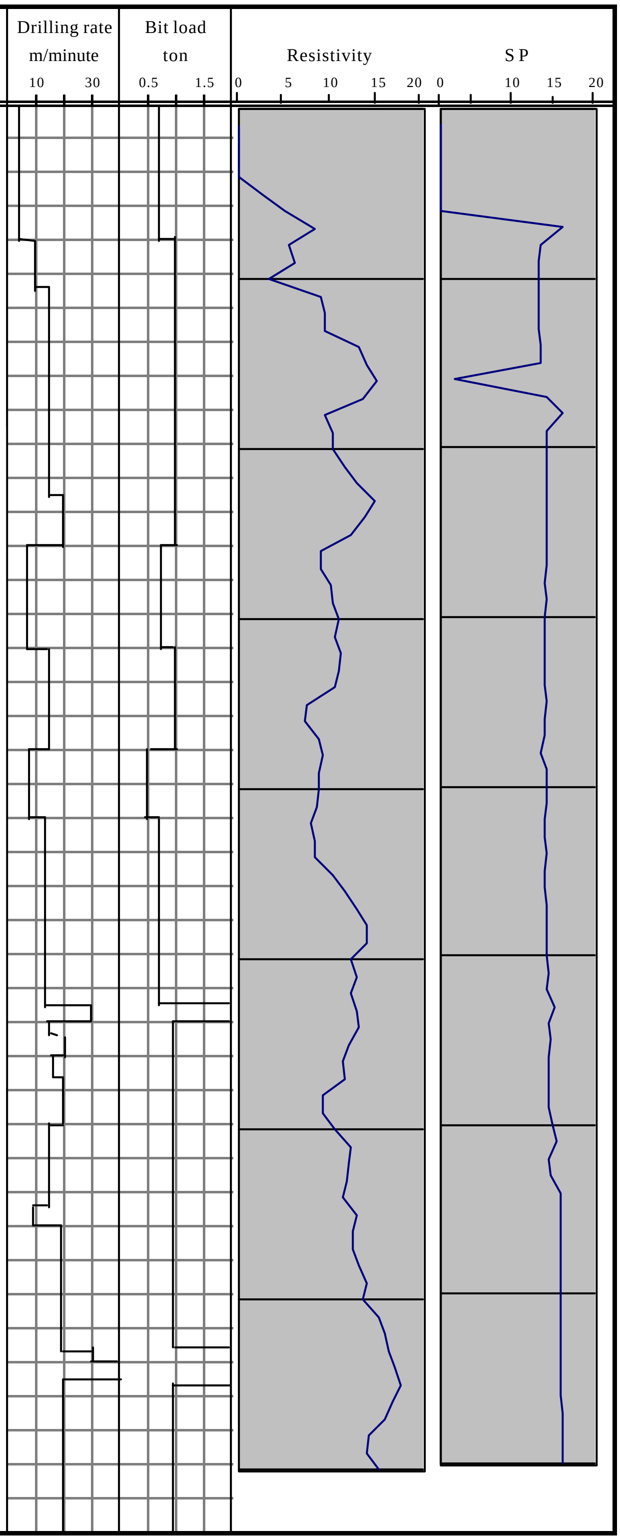


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Figure

WELL LOG OF LIQUICA-2

B-7.10 (2)