HYDROLOGY AND WATER RESOURCES IN KABUPATEN LUWU

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PROJECT LUWU
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INDONESIA

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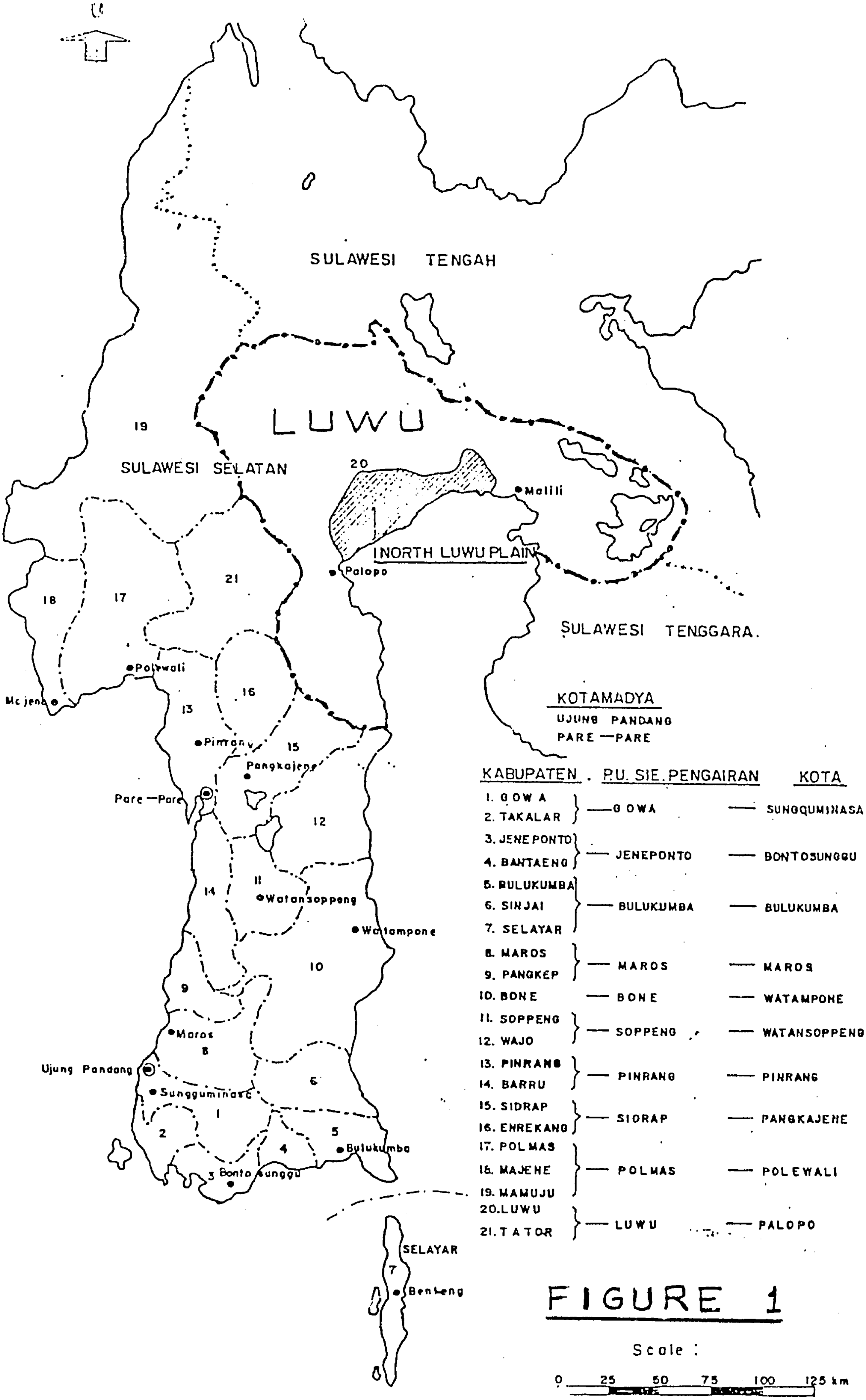

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FIGURE 1

1. INTRODUCTION

Kabupaten Luwu is the largest of the 21 kabupatens which go to make up the Province of South Sulawesi. Kabupaten Luwu occupies the greater part of the northeastern portion of the province. The total area of Kabupaten Luwu is approximately 25,000 Km^2 as shown in Figure 1.

The Luwu Irrigation Project is located in the North Luwu plain, which is part of Kabupaten Luwu. The plain is bounded on the South by the Bay of Bone, on the North by the foothills of the mountain range of central Sulawesi, on the West by the town of Palopo, the administrative center of the Kabupaten and on the East by the nickel mining center of Malili. The total project area is approximately 2,500 Km^2 as shown in Figure 1.

Water resources management within Kabupaten Luwu is presently the responsibility of the Water Resources Section (Bidang Pengairan) of the Public Works Services (Dinas Pekerjaan Umum) of South Sulawesi with the exception of areas where special projects are being performed such as the Luwu Irrigation Project.

The Water Resources Division main office is at Ujung Pandang and consists of the following departments:

Administration
Design
Construction
Rivers and Swamps (Hydrology)
Operation and Maintenance
Logistics and Equipment

For certain large irrigation areas, special projects, with their own staff, have been established. The Luwu Irrigation Project is one of these. These projects are responsible for the design and execution of the irrigation schemes. Upon completion of these special projects they will be turned over to the Water Resources Division, which will then be responsible for the operation and maintenance for the project.

The Luwu Irrigation Project Office is located in Palopo and consists of the following Departments and Branches:

Administration
Technical
- Planning
- Construction
- Operation and Maintenance (Hydrology)
- Equipment

The Hydrology Section is under the control of the Operation and Maintenance Branch.

Hydrological and meteorological activities within Kabupaten Luwu are performed by two different organizations. The Department of Rivers and Swamps, directly under the Water Resources Section is responsibile for most stations and activities within the Kabupaten including some within the limits of Project Luwu. The Luwu Project has its own Hydrology Section which is responsible for stations and activities located only within the limits of Project Luwu.

The objectives of this study were: To review, evaluate and make recommendations for the existing hydrological and meteoroiogical activities in Kabupaten Luwu. The study included assessment of the present organization, station network, effectiveness of data gathering, analysing and reporting procedures for the activities.

To evaluate streamflows for those rivers planned to contribute water to the various irrigation projects as outlined in the Master Plan for North Luwu Plain. Based upon those findings, a comparison assessment was to be made, with the Master Plan conclusions and recommendations, as to the adequacy of river discharges in providing a sufficient quantity of water to meet all irrigation water requirements.

To make assessment of ongoing water resources projects. To provide recommendations for initiating new projects and improving existing projects through appropriate means.

This report is the result of that study. Hydrologic and meteorologic data reviewed and analyzed in the study were provided by the Luwu Irrigation project and the Water Resources Division. Numerous reports from the Luwu Irrigation Project were examined. Field trips were taken to observe physical features and methodology used in the measuring, observing and recording the data.

2. RAINFALL

The topographical and geographic features of Kabupaten Luwu are primarily responsible for the nature of its rainfall. Beginning in early April, the northwest monsoon retreats and variable winds from a southeasterly direction carry air of high humidity towards the East coast. Rainfall peaks, at the eastern coast, are generally observed during the months of April through June. The intensity of the rainfall depends on the location of the area. As the seasons progress, the southeasterly winds become stronger and introduce dry air into the Kabupaten. The northern portion of the Kabupaten is less influenced by these dry winds than the southern portion, whereas the dry season for North Luwu is normally less than for South Luwu. The dry season for North Luwu is normally during the months of August through October. The mountainous areas in the northerly and westerly areas of the Kabupaten cause orographic rainfall resulting from the cooling effects upon moisture-bearing winds traveling up the slopes, producing rainfall on the windward side of the slopes. The leeward slopes receive less rainfall. However, under orographic influences, the heavier rainfall does not totally cease at the crest of the high terrain, but may continue with the same intensity past the crest. This is defined as spill-over effect.

2.1. Rain Gage Network

The density of rain gages varies greatly from country to country and even within the same country. The network density necessary to obtain adequate records varies with the use of the records and the characteristics of the area being studied. A relatively sparse network of stations would suffice for studies covering large areas of level terrain. A more dense network of stations is required in rough or mountainous terrain. Minimum densities of rain gage network have been recommended in certain reference books. However, local physical land conditions and the cost of installing and maintaining the network must be considered. The accessibility of the gage site to an observer is always important to keep in mind. There are techniques which adequacy of rain gages may be calculated for a specific area. However, many times the density of rain gage networks is based on economic reasons than on scientific standards.

There are forty-nine rainfall gage locations in Project Luwu. Thirty-eight locations have one nonrecording gage. Seven locations have one nonrecording gage and one recording gage. At each of the meteorological stations there is one nonrecording gage and one recording gage. (see Table 1).

However most of the rainfall gages are located in limited areas around on-going irrigation projects such as the Lamasi, Bone Bone and the Kalaena areas. Few rainfall gages are located in the mountainous areas which make up the majority of the watersheds for each river.

In many orographic regions it is difficult to install and maintain gages over portions of the area where rainfall may be the heaviest. Rain gages, usually located in the valleys, fail to give a representative idea of the annual and storm rainfall over the whole area. There have been techniques proposed for estimating mean annual rainfall and for estimating storm rainfall in areas which experience orographic rainfall. Each was developed in the United States -- the Parsons method, developed by the Corps of Engineers and the Spreen method.

Table 1

RAIN GAGE NETWORK IN THE NORTH LUWU PLAIN

		Standard Rain Gauge	Automatic Rain Gauge
1.	BK. I Koroncia	X	
2.	BK. XI Mulyosri	X	
3.	Rantetiku	X	
4.	Purwosari	X	
5.	Cendana Hitam	X	
6.	Lembara	X	
7.	Pepuro Utama	X	
8.	Kampung Kalaena	X	
9.	Seriti	X	
10.	Ferangka	X	
11.	Kertahararjo I	X	
12.	BK. VI Margolembo	X	
13.	BK.IX Wonorejo	X	
14.	Kaluku	X	
15.	Katulungan	X	
16.	Lamasi	X	
17.	Banyu Urip	X	
18.	Rante Damai	X	
19.	Sidomakmur	X	
20.	Sukamaju	X	
21.	Mulyorejo I	X	
22.	Lindu	X	
23.	Pembasean	X	
24.	Batusitanduk	X	
25.	Bobokan	X	

		Standard Rain Gauge	Automatic Rain Gauge
26.	Ampana	X	
27.	Balebo	X	
28.	Salu Sapang	X	
29.	Saragi	X	
30.	Lamasi Pantai	X	
31.	Tolemo	X	
32.	Cendana Putih	X	
33.	Mulyrejo III	X	
34.	Sidobinangun	X	
35.	Batang Tengka	X	
36.	Bend. Bone Bone	X	
37.	Sukaraya	X	
38.	Kalaena Kiri II	X	
39.	To'	X	X
40.	Bok	X	X
41.	Tc	X	X
42.	Porodoa	X	X
43.	Mangkulande	X	X
44.	Salu Sambaa	X	X
45.	Passapa (Parara)	X	X
46.	Setiorejo/Lamasi	X	X
47.	Wonorejo/Kalaena	X	X
48.	Sidomukti/Bone Bone	X	X
49.	Baliase	X	X

Rainfall was first recorded in the province of South Sulawesi in 1879. Three rainfall stations were put in operation at that time. In 1907 the first rainfall stations were established in Kabupaten Luwu.

During World War II and a period of unrest after the war these activities ceased and some rainfall stations were abandoned, damaged or destroyed. Many of these old rainfall stations have never been reestablished.

In 1951 rainfall measurements were again started and in 1975 the network was expanded considerably.

Rainfall data has been compiled and published in one volume containing data of many stations from 1879 thru 1980 excluding the period from 1942 thru 1950 when rainfall was not recorded.

Presently, Luwu Irrigation Project publishes a yearly periodical showing daily rainfall depths for each rain gage station. The data, also indicates number of rain days, maximum daily depth and average daily depth. In the yearbook which is also published, rainfall is summarized, monthly bar graphs are shown and a mass curve, for all rain gage stations are shown.

2.2. Rainfall Measurement

Rainfall is measured on the basis of the depth of water which would accumulate on a level surface if all the rainfall remained where it fell. This depth is often expressed in milimeters.

The two types of rainfall gages used in Kabupaten Luwu for measuring rainfall are a nonrecording type (standard) and a recording type. The nonrecording type is essentially an open receptacle with vertical sides and certain refinements to permit more accurate observations. It is often important to know not only the total amount of rainfall but its intensity or the amounts for shorter durations than can be obtained by manually read gages. Recording gages are then used that give a continuous pen trace on a clock-driven drum.

Since most hydrologic problems require a knowledge of the average depth of rainfall over a specific area, some procedure must be used to convert the individual gage measuments to areal averages. The simplest procedure is to average arithmetically the amounts measured by each gage within the area. However, the simple averaging of gage measurements sometimes gives unsatisfactory results, because of nonuniform distribution of gages.

A more formal method of computing average depths of rainfall over an area is known as the Thiessen method, which gives weights to the areal distribution of the rainfall gages.

The most accurate method for computing average rainfall is the use of isohyetal maps.

Unfortunately, both the Thiessen method and the isohyetal maps are dependent on accurate location of the gaging stations on maps of reasonable scale. This could impose a problem for areas, such as this area in which the gaging stations have not been field surveyed or where accurate maps are not available.

Table 2

OBSERVED MEAN MONTHLY RAINFALL IN mm
(For all project Luwu nonrecording gages)

	1978	1979	1980	1981	1982	Mean
January	309	247	290	122	282	250
February	261	263	245	162	256	237
March	298	238	184	278	415	283
April	360	361	317	328	429	359
May	282	226	193	338	274	263
June	249	403	164	194	251	252
July	336	244	163	357	60	232
August	191	134	106	47	83	112
September	276	231	47	258	95	181
October	253	79	87	158	108	137
November	221	247	87	285	91	186
December	268	320	144	240	188	232

3. STREAMFLOW

It has been pointed out that streamflow is the only portion of the hydrologic cycle in which water (moisture) is so confined so as to make possible reasonably accurate measurements of the volumes involved.

The first staff gage in Kabupaten Luwu was installed in the Kalaena River in 1919 and was in service until 1932. The Kalaena River and 13 other rivers had staff gages installed and in operation during the period of 1937 to 1940. The water level was observed twice daily and was published in yearbooks.

Prior to the Luwu Irrigation project, new staff gages as well as automatic water level recorders were installed. These stage readings are available for some periods; however, they are of limited value because there was not an adequate correlation between stage and discharge.

Since the beginning of Luwu Irrigation Project a number of automatic water level recorders were installed in the more important rivers which traverse Kabupaten Luwu. The gaged rivers and type gage installed is shown in Table 3. Discharge measurements and sediment transport determinations are performed for 14 of the rivers which are also noted in Table 3.

Luwu Irrigation project publishes a monthly periodical which covers measurements and observed values taken in the procedure for determining river discharge and sediment transport. Computation formats are included to demonstrate how the two items are derived. It also displays a scaled cross-section of each stream at the station where the measurements were taken. It includes daily river stage readings and daily river discharges and has a section on data obtained from the meteorological stations with a format indicating evaporation and evapotranspiration.

Table 3

GAGED RIVERS IN KEBUPATEN LUWU

River	Staff Gage	Automatic Water Level Recorder
North Luwu		
1. Batang*	X	X
2. Lamasi*	X	X
3. Makawa*	X	X
4. Tabu*	X	X
5. Ampak*	X	X
6. Rongkong*	X	X
7. Baebunta	X	
8. Radda	X	X
9. Masamba*	X	X
10. Balaese*	X	X
11. Uraso	X	
12. Lampuuawa	X	X
13. Kanjiro*	X	X
14. Bone Bone*	X	X
15. Bungadidi*	X	X
16. Senggeni*	X	X
17. Tomoni*	X	X
18. Kalaena*	X	X
19. Angkona	X	X
20. Cerekang	X	
South Luwu		
21 Noling/Paremang*	X	X
22. Bajo	X	

Note: Rivers marked with an asterisk have discharge measurements and sediment transport determinations conducted on them.

3.1. Hydrometric Network

The design of a hydrometric network is a problem of meeting statistical area sampling, specific locations where data are most likely to be needed and all too frequently budget constraints.

The selection of rivers to be gaged may be determined by those that may contribute to present or future problems, consideration for development or that they sample the range of hydrologic characteristics in the region.

Once the river is selected, a choice of station location is required. There are four criteria for establishing a hydrometric station.

1. Accessibility - The station should be accessible under all conditions, particularly during floods.

2. Adequacy - The ability of the station to accurately cover the full range of discharge which may occur.

3. Stability - It is very important that the relation between stage and discharge remains reasonably stable.

4. Permanency - The station should be so located that it is not likely to be disturbed either by future work projects or floods.

3.2. <u>Water Stage</u>

The term stage, as used in streamflow measurement, refers to the water-surface elevation above some arbitrary datum.

The two types of gages used in Kabupaten Luwu for measurement of river stage are the staff gage and an automatic water level recorder.

The staff gage is the simplest device for measuring river stage. It is a vertical staff graduated in metres and placed so that a portion of it will be in the water at all times. At Project Luwu, staff gages are read three times each day. The most serious disadvantage of the staff gage is that, without frequent observations, large changes in stage may be inadequately reported.

The automatic water level recorder used in Kabupaten Luwu is the float-actuated type. The float is connected to the recorder by a wire or tape passing over a wheel and counterweighted. As the float moves the wheel is turned and drives a pen on a chart which is turned by a clock mechanism in such a way that a continuous record is provided.

The float type recorder requires a stilling well for the float mechanism and should have a lockable protective shelter house or a lockable box for the recording equipment. Another safety precaution would be to place the shelter or box for the recording equipment at an elevation above estimated higher flood levels.

It is necessary to install a reference staff gage outside the well of each automatic water level recorder. This is done in order to have a means of varifying the recorders readings. Essentially the recorder simply records the staff gage readings continuously on a chart.

A permanent type benchmark should be set a near the gaging station in as safe a location as possible. An accurate survey should tie the staff gage into the benchmark. The record of this datum is important and would permit resetting the staff gage in the event it may be damaged or washed away by a flood.

A permanent gage attendant should be assigned to every gaging station. The gage attendant for a station with automatic water level recorder would be responsible for winding the clock, refilling the ink reservoir of the pen, adjusting the pen to the water level indicating on the adjacent staff gage, changing chart paper and being aware, in general, of items requiring cleaning, repairing or maintenance. The gage attendant for a station having only a staff gage should read the gage at least three time each day at some predetermined fixed times. When the water level exceedes a certain set level, the gage attendant should be instructed to read the gage more frequently in order to record a peak flood stage, if possible. Each gage attendant would be responsible for observing, recording readings and reporting the findings as instructed.

The errors in the records made by properly maintained and attended float operated recorders are generally too small to be of great importance. However, it may be beneficial to look into certain sources of errors in order to recognize them to eliminate them in the future.

All paper is affected by humidity changes. It expands with increasing humidity decreases. The results of these changes are to introduce errors on the charts. In humid climates there is a tendency for the chart paper to expand while the record is being made. When the chart paper is examined in the office the paper has resumed its normal dimensions and there is no indication on the chart paper of the error involved. In many cases where the graph does not check with the staff gage readings the discrepancy may be attributed to this cause.

The human error constitutes the greatest possible source of error. Incorrect gage reading, failure to wind the clock, failure to start clock after winding and inaccurate setting of stylus on chart are only a few things that all too frequently result in erroneous or incomplete records.

The majority of the rivers in Kabupaten Luwu are prefectly suited for the use of automatic water level recorders. Catchment areas are small and the channel gradients are quite steep. These rivers are subject to large fluctuations. A major flood may develop, rise to a peak and drop back to low stages within 24 hours. A manual gage would very unlikely pick up the crest of this flood.

3.3. Discharge Measurements

The cross-sectional area of a stream is determined at the location for the discharge to be taken. For some streams with stable enough channels, the area may remain the same for all practical purposes. The streams here in Project Luwu are subject to scour or sedimentation and therefore, the area must be established at the time of each discharge measurement.

The velocity measurements are accomplished in Project Luwu with a propeller-type current meter. As the current meter depends upon revolutions made by a shaft rotated by the flowing water during a fixed period of time, there must be a calibrated rating table or curve to actually determine the velocity. Normally, the manufacturer prepares the calibration table or curve for each individual meter.

Thus, by knowing the area and the velocity in certain units of measure, the discharge can be determined.

3.4. Stage-Discharge Relation

Periodic meter measurements of discharge and simultaneous stage observations provide the data for a curve called a stage-discharge relation or a rating curve. This establishes a continuous record for discharge. For any stage level, the discharge may be determined just by comparative analysis of the curve. Only occasional discharge measurements are necessary to insure that the curve remains reasonably constant. The additional data should show a minimum dispersion about the curve. If the additional data shows appreciable dispersion, this then indicates that the control has shifted. The shift may be due to scour and sedimentation, water-surface slope at the station, or as the result of backwater from tides, weirs or tributary inflow dowsnstream or that the measurements were not accurately made.

The effects of shifting control on the stage-discharge relation are of great importance in the operation of the station as to useful and accurate data.

There are techniques which minimize the effects of shifting control. One widely used method is simply a program of routine check measurements in order to learn how serious the condition is. Frequently by the additional measurements, necessary corrections may be adequate for the adjustments.

4. METEOROLOGY

There are presently four meteorological stations in operation, in the Project Luwu area, as shown in Table 4.

Table 4

METEOROLOGICAL STATION LOCATIONS

Location	Date Began Operation
1. Setiorejo/Lamasi	May 1977
2. Wonorejo/Kalaena	July 1977
3. Sidomukti/bone Bone	March 1982
4. Balease	October 1982

These stations are well laid out and properly equipped for observing and measuring those paremeters which are necessary for the calculation of the open water evaporation and the potential evapotranspiration. The evapotranspiration is of great importance in the design of irrigation facilities.

Daily observations are performed at:

7:00 am	(7 o'clock in the morning)
1:00 pm	(1 o'clock in the afternoon)
6:00 pm	(6 o'clock in the afternoon)

These observations are entered into a daily record book and subsequently transcribed to a monthly record book.

A copy of the monthly record, along with the rainfall, sunshine and hygrothemograph charts, are collected each month by a person from the Hydrology Section Office in Palopo. These data are processed by the Hydrology Section. Rainfall quantities, relative humidity, dew point and evaporation are determined and the evapotranspiration is calculated from the Penman formula. The copies of the monthly record and charts should be filed for future reference.

Data obtained from the stations are published in a yearbook which provides a format indicating the evaporation and evapotranspiration and the data required for determining them.

4.1. Equipment and Instrumentation

Each of the four stations are equipped with the following items:

1. Stevenson screen which is a protective shelter containing:

   a. One pair of thermometers (maximum and minimum) for recording the highest temperature and the lowest temperature during the observation period.

   b. A psychrometer, consisting of one dry bulb and one wet bulb thermometer for measuring the relative humidity of the air

   c. A hygrothemograph which measures and records both relative humidity and temperature on one continuous chart.

2. An anemoneter which measures the wind speed.

3. A nonrecording (standard) rain gage.

4. A recording rain gage, to learn the intensity of rainfall for shorter durations than can be obtained by manual measurements at a standard rain gage. Recording gages are used that give a continuous pen trace on a clock-driven drum.

5. An instrument for measuring intensity of radiant energy. Setiorejo/Lamasi and Wonorejo/Kalaena are equipped with a Gunn-Bellani radiation integrator. Balease and Sidomukti/Bone Bone each have an actinometer.

6. A Campbell Stokes sunshine recorder which is a self-recording instrument for measuring the duration of sunshine during the day.

7. An evaporation pan of the standard U.S. National Weather Service type with a hook gage installed in a stilling well for measuring the water surface level.

5. EVAPOTRANSPIRATION

5.1. Evaporation

Evaporation is the process by which water is transferred from land and water masses of the earth to the atmosphere. It is a function of solar radiation, differences in vapor pressure between a water surface and the overlying air, temperature, wind, atmospheric pressure and the quality of the evaporating water.

Evaporation is a crucial consideration in water resources planning and management programs, in evaluating the potential for water resources development and in determining water supply requirements of proposed irrigation projects.

The measurement of evaporation can be based on the water-budget (water-balance) method, energy budget, mass transfer techniques or pan evaporation. Usually, instrumentation for energy budget and mass transfer methods is quite expensive and the cost to maintain observation is substantial. For these reasons, the water budget methods and use of evaporation pans are more common. Further, the water budget method is simple in theory, but application rarely produces reliable results. The pan method is the least expensive and will provide good estimates of annual evaporation.

5.2. Transpiration

Plants remove water from soil through their root systems, use a small portion of it and discharge the remaining into the atmosphere through pores in their leaves and by lesser mechanisms.

Transpiration may be measured in the laboratory, but applying it to field conditions might result in unreliable data. Therefore, rates of transpiration are considered to be about the same as rates of evaporation from a free water surface.

5.3. Evapotranspiration Values

Evapotranspiration, often referred to as consumptive use in irrigation practice, is the evaporation from all water, soil, vegetation and other surfaces plus transpiration.

There are several methods of estimating potential evapotranspiration.

The Penman formula is based on the most complete theoretical approach, showing that evapotranspiration is directly related to the amount of radiative energy gained by the surface. This formula has been widely accepted and is presently used in Project Luwu for determination of open water evaporation and the potential evapotranspiration.

The required data for the use of the Pernman formula is obtained from the Meteorologic Stations. The reflection coefficient (albedo) values used in this area are for open water evaporation, r = o.05 and for the potential evapotranspiration of grass, r = o.25.

Table 5 indicates evapotranspiration data from the 4 Meteorologic Station listed in Table 4. The data are monthly averages of the 4 stations during a 5 year period.

Numbers shown in parentheses in Table 5 represent evapotranspiration values which were transferred from Semarang and used in the Master Plan for determination of gross irrigation requirements.

Table 5

EVAPOTRANSPIRATION mm/DAY

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3.4	3.1	3.3	3.4	2.9	2.7	2.8	3.0	3.2	3.4	3.5	3.4
(5.0)	(5.1)	(5.2)	(5.5)	(4.8)	(4.8)	(5.4)	(5.6)	(5.6)	(6.3)	(5.7)	(4.9)

6. SEDIMENT TRANSPORT

The transport of sediment in natural watercourses and the resulting changes in the configuration of the bed are of great interest to designers for the development of river systems. This analogy extends to man-made construction such as diversionary facilities and canal systems used in irrigation practice. In order to reduce or eliminate the sediment problem, the sedimentation process must be studied.

Sediment orgininates in watershed areas from various means and is principally carried to a channel system by overland flow. When the sediment enters a stream, the sediment moves as suspended sediment (load) in the flowing water and as bed load which slides or rolls along the stream bed.

6.1. Sediment measurements and Sampling

Most recent developments in sampling devices for sediment loads have been directed toward an integrating technique. When integrating samplers are held at a constant depth while the sample is being collected, a time-integrated measurement is obtained.

The sediment sampler used in Project Luwu for sediment loads is the Delft Bottle which is an integrating type and utilizes the time integrated technique for measurement.

The collected sediment load sample is taken from the Delft Bottle and placed in a milliliter graduate for direct measurement. The volume of water that passes through the Delft Bottle during sampling can be calculated from recording the measuring time, flow velocity of the stream and the area of the nozzle used on the sampler. This ratio of sediment to water is usually expressed in parts per million (PPM)

No practical device for field measurement of bed load is now in use. A number of formulas have been presented for the calculation of bed load movement. The formulas may use as a basis for the computations size distribution of material, stream bed measurement and characteristics, and flow.

Presently, sediment sampling in Project Luwu is performed along with taking of discharge measurements. These measurements are taken once a month, from January through June, for all rivers listed in Table 3 and twice a month, from July through December, for the Battang, Lamasi, Makawa, Masamba, Bone Bone and the Kalaena rivers.

Table 6

OBSERVED SEDIMENT LOAD (PPM)

River	1978	1979	1980	1981	1982
Battang	10.9	12.0	8.8	3.2	3.0
Lamasi	8.1	13.0	5.8	3.4	1.6
Makawa	9.0	3.0	5.1	2.9	2.7
Tubu	2.2	2.0	1.5	2.1	2.1
Ampak	6.8	5.7	3.4	3.2	3.4
Rongkong	18.0	22.5	4.0	3.0	1.7
Masamba	11.2	15.3	298.0	50.8	60.6
Balease	22.7	52.3	8.4	2.6	2.7
Kanjiro	8.4	34.2	23.0	4.6	3.1
Bone Bone	4.2	6.3	8.6	2.4	2.2
Bungadidi	23.7	31.2	25.4	4.3	2.9
Senggeni	11.8	24.1	19.6	4.6	4.0
Tomoni	47.9	53.3	48.2	3.7	3.7
Kalaena	7.4	4.8	21.1	4.5	3.1

6.2. Sediment - Rating Curves

A sediment - rating curve, relating suspended load and water discharge, is often used to estimate sediment load on days when no measurements are available. Caution must always be exercised when using sediment-rating curves because such relationships are only approximate. A given flowrate may result from rains of different intensity and a different sediment load would result in each case. Areal distribution of runoff may be a factor if different parts of a watershed are more prolific sediment sources than others. However, when sediment-rating curves are used to estimate mean annual sediment yield, the errots in the sediment rating will tend to compensate and the resulting answer should be reasonably satisfactory, provided a sufficiently long record is used. Results have been quite good when the curves are applied to small and relatively homogenerous watershed which seem to fit most of the rivers in Kabupaten Luwu.

7. IRRIGATION

Sufficient justification was found to select Kabupaten Luwu for a rural development project, which included irrigation. It appears that certain orginal objectives of the plan have been partially realized. Apparently, the projects have to date created new farmland and have opened up other areas, that up until now have been underutilized, providing productive land for transmigrants.

During this initial period of implementation it might have been noted that irrigation development is quite complicated and requires much effort, accurate data, high standards and experienced, competent personnel in order to achieve optimum potential from the projects.

Ongoing irrigation construction projects which are partially operable are Bone Bone and Kalaena. Two other ongoing irrigation construction projects which are not operable are Kanjiro and Lamasi.

7.1. Irrigation Planning

The hydrologic considerations in irrigation design vary with the size and type of the project. No two irrigation projects are identical and no absolute outline of procedure for project design is practical.

A first step in planning an irrigation project is to establish the capability of the land. The topography of the land is important in that it can be irrigated without excessive pumping or transmission costs and that the removal of excess water from the surface and the root zone can be accomplished effectively. The soil must meet a relatively high criteria for successful irrigation farming.

Having established the suitability of the soil for an area, the next step is the determination of water requirements, water availability and water quality.

7.2. Basic Data

These basic data were utilized in preparation of the Master Plan for the North Luwu Plain. They are reproduced in this report as a means of conforming to the same criteria in order to form a comparison between certain data available at the time the Master Plan was prepared and more current data actually recorded in Kabupaten Luwu.

a) Cropping Pattern:

Two crops per year are proposed -- the first crop from the middle of December to the middle of June and the second crop from the end of June to the middle of November. Land preparation -- the first crop 60 days and second crop 52 days for the overall project. Transplanting period is estimated to be 45 days.

b) Area:

For the calculation of the irrigation demand, net irrigable area is used. The estimated average crop coverage is 95 percent in the wet season and 90 percent in the dry season.

c) Irrigation efficiency for the overall project is estimated to be 70 percent.

d) Water needs apart from evapotranspiration.
Land preparation: 200 mm for presaturation and water layer.
Transplanting: 50 mm for water layer.

e) Evapotranspiration:

The estimated actual evapotranspiration is based on a reference evapotranspiration calculated with the Penman formula for short grass (elbedo 0.25) which is to be multiplied by a crop factor. (The evatranspiration data mentioned above and used in the calculations for the Master Plan were from Semarang, Central Java. The crop factors mentioned above were proposed in Prosida report for both wet and dry season and for the 1st month, 1.10; 2nd month, 1.35; 3rd month, 1.30 and 4th month, 1.05. For evapotranspiration values, see Table 5.

f) Dependable Rainfall

Part of the water needs is covered by rainfall and a certain amount of the actual rainfall can be taken into account for the design: the dependable minimum rainfall.

For the Luwu area the design rainfall is calculated from the monthly averages by means

of the following formula:
$R_d = 0.7 \times 1/30 \times R\ (\text{month})_5$ in mm/day
with $R(\text{months})_5$ the once in 5 years dry month rainfall.

g) Percolation:

Losses caused by percolation in the Luwu area are estimated to be 3 mm/day for the overall project. Measurements in the area have shown values of 2 to 8 mm/day. The sawah areas are presently only developed in the higher areas and it is suspected that percolation in lower elevations will be less due to a high groundwater table which is likely to developed. As soils in the Luwu area are generally lighter than the soils in most of the Prosida area, the percolation rate is estimated higher in the Luwu Plain. With adequate puddling and irrigation over large areas the percolation is expected to be not larger than the estimated 3 mm/day.

7.3. Project Luwu Dependable Rainfall

A certain amount of the actual rainfall, the dependable minimum rainfall, can be deducted from the irrigation water requirements.

For the Luwu area, the dependable rainfall has been calculated from the monthly average by means of the formula given below:

$R_d = 0.7 \times 1/30 \times R\ (\text{month})_5$
R_d is dependable rainfall in mm/day
R (month)5 is the rainfall which falls in the dryest month in a period of 5 years.

For calculations, the rainfall data of 49 stations in the Luwu Plain have been used. Locations of stations are shown in table 1. The minimum monthly rainfalls with a return period of 5 years for the 49 stations have been averaged. The values thus found have been multiplied by 0.7 in order to arrive at the dependable rainfall for each month. The results are shown in Table 7.

Table 7

DEPENDABLE RAINFALL (R_d) FOR LUWU AREA (mm/Day)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.7	1.4	1.7	2.7	1.9	1.6	1.4	0.7	0.9	0.5	0.8	0.8
(3.8)	(4.1)	(5.0)	(6.0)	(5.5)	(4.9)	(2.9)	(2.0)	(1.0)	(1.0)	(2.0)	(3.6)

Numbers shown in parentheses in Table 7 represent values of dependable rainfall used in preparation of the Master Plan. In the calculations for the dependable rainfall, the rainfall data of Bajondo, Lamasi and Masamba rain gage stations were used.

7.4. Water Requirement

In preparing the master Plan for the North Luwu Plain, irrigation water requirements were determined from data available at that time. The methods of calculation adhered to computations of irrigation water requirements for wet paddy by Nedeco, September 1973. These methods were, also, followed in this study to permit forming a conclusion that would be more comparative with the original data.

Utilizing data observed and measured in the North Luwu Plain and substituting these data in the equations from the Nedeco method of calculations, it was found that the gross water requirement for the project area was less than those indicated in the Master Plan. This comparison may be noted in Table 8 for the three critical months of August, September and October.

Table 8

COMPARATIVE GROSS IRRIGATION REQUIREMENTS

	Gross Water Requirements			
	Master Plan Data		Project Luwu Data	
Period of the Year	mm/day	l/Sec/ha	mm/day	l/Sec/ha
1 - 15 August	11.9	1.37	8.9	1.03
16 - 31 August	11.9	1.37	8.9	1.03
1 - 15 September	11.3	1.31	7.9	0.91
16 - 30 September	8.4	0.98	5.9	0.68
1 - 15 October	3.0	0.34	2.1	0.25

7.5. Water Availability

In the design of an irrigation system, it is important to know the minimum flow for the river(s) which will supply the water. In irrigation practices the minimum flow is often defined as the mean monthly discharge that is exceed in 4 out of 5 years. This mean monthly discharge only gives an indication of the available water; however, it has been found that flows during shorter periods in the dry spells of the growing season are more accurate for that purpose. This flow is known to be less and is estimated to be about 80 per cent of the minimum mean monthly river flows. This flow is defined as the dependable river flow.

At the time the Master Plan was being prepared, discharge records for the Luwu area were minimal. The only long term discharge record available was for the Kalaena River. Therefore, the minimum flow of the other rivers for the Luwu area were determined by using simulation techniques.

Since work began on Project Luwu, a hydrometric network was established and the recording of stage and river discharges for most major rivers commenced.

From the mean monthly discharges, the dependable river flows were determined and tested against the gross irrigation water requirements. As indicated in Table 8, there is a difference between the gross irrigation water requirements computed from data derived from Project Luwu and the Master Plan. This is demonstrated more clearly in Table 9 where the dependable river discharges for the Master Plan and Project Luwu data are shown.

Dependable river discharges, with a return period of 5 years, are equivalent to 80 per cent of the low monthly flow, with a return period of 5 years, with all flows in m^3/sec. Dependable river discharges thusly calculated are valid only when a permanent weir is provided. Dependable river discharges must be decreased by 25 per cent when free river intakes are used and then only when the diversion of the river is done in a proper manner.

7.6. Water Quality

The quality of water used for irrigation is well recognized as an important factor in productivity and quality of the irrigated crops. Irrigation water generally requires water with a low salt content and in the salts present a low proportion of sodium and chloride ions. A certain amount of calcium, magnesium and potassium ions is be favorable.

Presently, there is no irrigation water quality program operated in Kabupaten Luwu.

Table 9

PROJECT LUWU SUBPROJECTS AND DEPENDABLE RIVER DISCHARGES

Sub-Project	Area No.	Areas In ha: Gross Commandable	Areas In ha: Nett Irrigable	River Structure		Master Plan Data: August (1.37)	Master Plan Data: Sept. (1.15)	Master Plan Data: Oct. (0.34)	Project Luwu Data: August (1.03)	Project Luwu Data: Sept. (0.80)	Project Luwu Data: Oct. (0.25)
Lamasi	A 1	500	430	Lamasi weir	(1)	14.4	8.0	7.0	21.6	19.8	19.4
	A 2	5,000	4,600		(2)	(1.67)	(0.93)	(0.81)	(2.51)	(2.30)	(2.26)
	A 3	4,100	3,490	Lamasi weir + Batang free-intake		16.9	9.4	8.2	23.6	20.9	20.0
	A	10,100	8,600			(1.97)	(1.09)	(0.95)	(2.74)	(2.43)	(2.33)
Makawi	B 1	1,900	1,500	Masawa		3.8	2.2	1.8	2.8	3.3	1.8
	B 2	1,400	1,100	Makawa weir		(1.46)	(0.85)	(0.69)	(1.08)	(1.27)	(0.67)
	B	3,300	2,600								
Tabu + Ampak	C	2,200	1,600	Tabu free-intake +		2.2	1.4	1.0	2.4	1.8	2.2
				Ampak free-intake		(1.38)	(0.88)	(0.63)	(1.50)	(1.13)	(1.38)
Rongkong	D 1	40,500	29,200	Rongkong weir		49.6	43.2	39.2	39.4	27.2	24.3
	D 2	3,000	2,200			(1.58)	(1.38)	(1.25)	(1.25)	(0.86)	(0.77)
	D	43,500	31,400								
Balease	E 1	2,800	2,250	Balease weir		44.0	38.4	34.4	29.0	23.4	21.1
	E 2	4,100	3,150			(1.53)	(1.33)	(1.19)	(1.01)	(0.81)	(0.73)
	E 3	8,700	6,500								
	E 4	17,500	14,000								
	E 5	3,600	2,900								
	E	36,700	28,800								

Sub-Project	Area No.	Areas In ha: Gross Commandable	Areas In ha: Nett Irrigable	River Structure		Master Plan Data: August (1.37)	Master Plan Data: Sept. (1.15)	Master Plan Data: Oct. (0.34)	Project Luwu Data: August (1.03)	Project Luwu Data: Sept. (0.80)	Project Luwu Data: Oct. (0.25)
Kanjiro	F	1,500	1,200	Kajiro free-intake	(1)	3.7	2.1	1.8	2.5	1.8	1.6
					(2)	(3.08)	(1.75)	(1.50)	(2.08)	(1.50)	(1.33)
Bone Bone	G	1,900	1,600	Bone Bone weir		1.7	1.0	0.8	2.2	1.6	1.3
						(1.06)	(0.63)	(0.50)	(1.38)	1.00)	(0.81)
Lauwo (Bungadidi)	H	5,000	3,500	Lauwo weir		4.1	2.3	2.0	3.8	3.5	2.9
						(1.17)	(0.66)	(0.57)	(1.09)	(1.00)	(0.83)
Senggeni	K	2,000	1,400	Senggeni		2.8	1.5	1.4	2.1	1.7	1.2
						(2.00)	(1.07)	(1.00)	(1.50)	(1.21)	(0.86)
Tomoi	L	1,500	1,200	Tomoni free-intake		5.2	2.9	2.5	5.0	4.0	3.7
						(4.33)	(2.42)	(2.08)	(4.17)	(3.33)	(3.08)
Kelaena	M 1	11,000	9,000	Kelaena weir		29.6	19.2	16.0	34.0	24.9	22.8
	M 2	6,200	4,600			(1.64)	(1.06)	(0.88)	(1.88)	(1.38)	(1.26)
(L.B)	M 3	6,000	4,500								
	M	23,300	18,100								
Total		131,000	100,000								

Note: 1. Minimum mean discharges with return periods of 5 years have been multiplied by 0.8 in case a weir will be constructed in the river.
2. For the case of a free-intake 25 per cent has been subtracted from the value as found above.
3. Numbers in parentheses shown immediately under the name of the month is the gross irrigation requirement
4. (1) Dep. river disch in m^3/sec
(2) Available in l/sec. ha.

7.7. Operations and Maintenance

The permanent operations and maintenance phase of an irrigation project begins almost simultaneously with the turnover of the project, if not before. After the turnover, the responsibilities of the operation and maintenance activities are handled by the Water Resources Section.

Prior to that time, it is the responsibility of the Contractor to insure that all work is of good quality, free from faults and defects and in conformity with the contract documents. If the Contractor fails to maintain or repair the work to properly adhere to the contract documents, payment should be withheld until the deficiencies have been corrected to comply with the drawings and specifications.

7.8. Construction Inspection and Materials Testing

It has been consistently noted of the lack of control by Luwu Irrigation Project inspectors. Their experience appears to be negligible and without the proper training, they are unable to conduct on-site inspections of the work in progress to determine compliance with the contract documents.

As important as materials testing is to ongoing construction projects, there seems little evidence of an effective testing program on any of the projects which have been observed during this study.

8. WATER RESOURCES DEVELOPMENT APPLICATIONS

This section presents a brief outline of several important types of water resources applications which may be appropriate for Kabupaten Luwu at this time and in the near future.

No attempt has been made to describe detailed technical procedures for the various applications. The items are listed to attract the attention of those interested in water resources as to the broad field of influence through water resources.

A master plan attempts to define the most desirable future planning pattern for an area. Unfortunately subsequent changes in technology, economic and social development, and higher level planning goals often make a master plan obsolete. Any plan is based on assumptions regarding the future and if these assumptions are not realized, the plan must be revised. Master plans may have to be modified periodically in order to consider any of the above changes and as more current data is provided.

Most decisions regarding water resouces development are based on estimates of a quantity of water or the rate of flow. Therefore, hydrology is basic to the planning of water resources projects and to the subsequent operation and maintenance of these projects.

8.1. Groundwater

Referring to groundwater in a separate section should not be construed as indicating that groundwater and surface water are independent of each other. On the contrary, many surface stream receive a large portion of their flow from groundwater. While elsewhere, water from surface streams may serve as a main source of recharge for the groundwater. The two sources of supply are definitely interrelated and the use of one may affect the water available from the other source. Both surface water and groundwater problems should be considered in plans for water resources development.

A large number of persons living in Kabupaten Luwu are fortunate that they have relatively easy access to a natural stream or a man-made canal from which to obtain their water requirements. This study does not advocate this means of obtaining a water supply for a family unit. When it is necessary proper precaution must be exercised along with appropriate treatment, such as boiling, for all human intake purposes. Those who are not quite that fortunate and live a greater distance from a stream or a canal seem to have little difficulty in striking sufficient water at a minimum depth with a shallow dug well.

In the future, water will become more and more of a scarce resource. Water will have to be allocated for domestic and industrial consumption, which will have to be deducted from the potential amount of water available for irrigation. As a result, the Water Resource Section will have to turn its attention from projects solely geared to irrigation. More and more it will have to direct time and effort to a continuous and comprehensive management of all water reources including groundwater.

The majority of the rivers in Kabupaten Luwu are not of the storage type, consequently if water from streams is to be the principal source, storage reserviors, pumping facilities and supply pipelines will have to be constructed and installed to satisfy water requirements in some areas. This will be expensive.

An attractive alternative would be groundwater. At this time there is a minimum of data available on groundwater resources which is even more reason to search for a method to explore this means of available water. If studies indicated that groundwater in certain areas was probably inadequate to provide sufficient water for future planned requirements, this would enable priority to be given to strengthing other known water source availabili- ty then being carried out or planned.

8.1.1. Location and Development of Groundwater Suppplies

The location and development of groundwater supply can be expensive operations, particularly if the water is at considerable depth. In order to receive optium benefit from the operation costs, it is important that the site be carefully selected and that the wells be properly developed.

The most direct method of prospecting for water is the driving of small-diameter test holes in the area of interest. The area tested should be selected on the basis of geograhysical exploration.

There are a number of equally good methods of exploring for water. All should be carried out in the presence of experienced personnel. Two of the more satisfactory methods commonly used are the seismic and resistivity methods with the resistivity method being used more often for small projects.

Since groundwater resources are exhaustible, the development of groundwater should be based on careful studies. If the various natural types of recharge balance the water withdrawn from an aquifer over a long period of time, no difficulity will be encountered in utilizing the aquifer as a water source. The yield of an acquifer can be maintained, extended or increased, as necessary by artifical recharge.

8.1.2. Groundwater Fluctuations

Variations in groundwater levels may be caused by:

a) Seasonal effects - Wet or dry years in which rainfall is above or below the mean.

b) Streamflow effect - Relative water levels may permit flow from groundwater to the stream or the reverse.

c) Evapotranspiration - Water table near the ground surface frequently exhibit diurnal fluctuations resulting from evaporation and/or transpiration.

d) Tidal effects - Groundwater levels in coastal aquifers fluctuate in response to the ocean tides.

8.1.3. Seawater Intrusion

Kabupaten Luwu's comparatively long coastline makes it particularly susceptible to the intrusion of seawater in the coastal acquifers. Seawater usually enters acquifers through submarine outcrops. Special surface situations may be conducive to intrusion such as sea-level canals and streamflows which permit seawater to progress inland.

Once intrusion develops in a coastal acquifer, it is not easy to control. Many satisfactory methods are highly expensive. However, to remove the seawater contamination might require years under natural conditions. As long as the total rate of pumping is confined to the safe yield of the acquifer, in order to stabilize the fresh-saltwater interface, the intrusion problem should be eliminated or highly reduced. Using shallow wells rather than deep wells might also eliminate the intrusion problem.

8.2. Watershed

This subject appears in this report mainly to emphasize the importance that watersheds play in water resources development.

A study, entitled "Watershed Management in Kabupaten Luwu", July 1983, Checchi/DMJM, Project Luwu is a more definitive work on this subject and should be consulted as a reference.

Watersheds play an important role in nearly every aspect of water resources development, consequently proper watershed management should have a high priority in control and improvement in order to maintain a high order of capability in achieving its functional purpose.

It was noted during this study that there are differences of opinion concerning the areas of the various watersheds. Areas must be measured from maps or aerial photographs. Differing scales and cartographic standards may result in values which tend to be diverse, often substantially. The watershed areas indicated in Table 10. Seem to be generally accepted.

From the hydrologic point of view the watersheds in Project Luwu possess distinct characteristics classified as flashy. They appear to be very sensitive to high-intensity rainfalls of short durations. The surface runoff is rapid and flood peaks occur soon after the end of the rain storm.

Table 10

CHARACTERISTICS OF MAJOR RIVERS

River	Watershed in Km^2	River Length in Km	River Slops in Per Cent
Batang	115	15	4.8
Lamasi	365	42	4.2
Makawa	108	15	7.7
Tubu	29	10	12.8
Ampak	29	9	9.9
Rongkong	1,030	52	3.5
Masamba	105	17	7.2
Balease	855	38	4.3
Kanjiro	120	19	12.6
Bone Bone	46	10	10.2
Bungadidi	83	16	11.0
Senggeni	85	18	9.3
Tomoni	190	33	7.5
Kalaena	1,070	53	4.5

8.3. Flood - Damage Mitigation

A flood is the result of runoff from rainfall in quantities too great to be confined in the normal channels of streams. Absolute control over floods is rarely practical either physically or economically. We can only reduce flood damage to a minimum consistent with the cost involved.

8.3.1. Measurable Features of Floods

The stage of a flood is of interest to those planning to construct structures along or across streams. The area inundated is of interest to those planning to occupy in any manner the flood plains adjacent to a stream. The peak discharge is of interest to those designing spillways, bridges, culverts and flood channels. The volume of flow is of interest to those designing storage works for irrigation, water supply and flood control.

The elements of floods to be measured, described above, clearly indicate the degree of importance in obtaining as much accurate basic hydrologic and meteorologic data possible and the need for analyzing these data for every need.

8.3.2. Design Flood

A design flood is the flood adopted for the design of a structure or project after consideration of economic and hydrologic factors. Pertinent facts are obtained from stream flow records and records of floods. It is seldom economically practicable to design for the maximum probable flood and often not for the maximum flood of record.

In agricultural areas where failure of protective works would result in the flooding of crops, a design flood of much lesser magnitute would be selected than if the area were thickly populated or develped.

8.3.3. Measures for Reducing Flood Damage

The commonly accepted measures for reducing flood damage are:

1. Reduction of peak flow by reservoirs.

2. Confinement of the flow within a predetermined channel by levees or flood walls.

3. Reduction of peak stage by increase velocities resulting from channel improvement.

4. Diversion of flood waters through bypasses to other channels and streams.

5. Reduction of flood runoff through land management.

6. Temporary evacuation of flood threatened areas on the basis of flood warnings.

8.3.4. Levees

One of the oldest and most widely used methods of protecting land from flood water is to erect a levee adjacent to the river to confine the water within reasonable limits. The channel width between levees must be sufficiently wide to pass the flood flows with a reasonable freeboard against wave action. Levees are most frequently used for flood mitigation, because they can be constructed at relatively low cost and usually utilize materials available at the site. Normally there is no suitable material for a core and most levees are homogeneous embankments. Levee cross sections must be adjusted to fit the site and the available material. Top width of levees is usually determined by the future use with a minimum width of about three metres to permit movement of maintenance equipment. The slopes should be protected against erosion by sodding, plantings and use of riprap. The importance of bank protection work and channel improvements associated with the levee construction cannot be overemphasized.

Levees restict the channel width by preventing flow on the flood plain and this results in increased stages in the leveed channel. Channel improvements, which usually accompany levee construction, increase velocity and may offset some or all of this increase. The net result of levee construction depends very much on the physical characteristics of the situation. Usually levee construction and associated flood-mitigation works results in a general increase in flood stages along a river unless reservoirs or extensive channel improvements are provided. The increase in stage following levee construction has sometimes led to unfortunate consequences.

The best program of flood mitigation for a river will be obtained if a master plan is developed at an early date and if this program reserves a considerable amount of flood plain for a flood channel. Excessive encroachment on the flood plain initiates a cycle of higher stages which may lead to levee damage and frequently levee failure.

8.4. Multiple - Purpose Projects

The wealth of technical and economic data on the subject of multiple - purpose projects are so extensive that it deserves a report just on its own merit.

Meticulous studies of benefits and costs for different flows, sizes, capacities and types of structures and works, along with the inclusion or exclusion of each of the several services, must be made in order to obtain an optimum economic and physical balance.

The basic factor in multiple-purpose design is compromise. A working plan must be devised which permits reasonably efficient operation for each purpose although maximum efficiency is not necessarily attained for any one single purpose. The physical elements of a multiple-purpose project differ in no way from those for a single-purpose project. The unique feature in multiple-purpose design is the selection of physical works and an operation plan which is an effective compromise between the various uses.

8.4.1. Compatibility of Multiple-Purpose Use

Irrigation and water supply require a volume of water which cannot be jointly used. Since power development is not a consumptive use of water, water from power development can be released for other purposes after the water has been used. However, whether the power plant is of a storage type or runof-river type would determine how compatible it would be with other uses. Flood mitigation, with its requirement for empty storage space, is the least compatible.

Requirements for other uses e.g., recreation, fish and wildlife, pollution control and navigation would have to be properly assessed in order to consider the ways in which these uses might be coordinated.

8.4.2. Hydrologic Factors

Vitally important to practical multipler-use projects is an accurate water forcast system. Reliable estimates of expected low flows with flood forcasts are essential. If for any reason the quantity of water differ appreciably from the forcast, the planned operations cannot be carried out as intended and the multipler-purpose use fails.

8.5. Land Drainage

Land drainage removes excess surface water from an area, lowers the ground water below the root zone to improve plant growth and reduce the accumulation of soil salts. Open ditches are widely used for the drainage of surface water at a considerable saving in cost over that of buried pipes.

Land drainage speeds up the runoff of water and consequently increases peak flow downstreams of the drained area. The results of this increase should be considered in the planning of the drainage systems. Wetlands are important biological areas. They may serve waterflow and as nursery grounds for some species of aquatic life in coastal areas. The consequence of draining such lands requires careful evaluation.

The hydrologic considerations in land drainage design vary with the size and type of project. Sediment inflows are often troublesome and are usually caused by erosion on upstream areas rather than on the land being drained. Hydraulic determination in the ditch design includes:.

1. Determining the most desirable hydraulic grade line.

2. Selection of ditch cross section to match required depths.

3. Developing profiles of ditch bottoms for the hydraulic grade line selected.

Long experience shows many failures of drainage projects. Difficulties in many cases, were due to poor planning, poor construction or lack of proper maintenance.

8.6. Water Quality

Water quality is one of the hydrologic data elements required for the planning of certain water resources developments. Water quality is normally required for projects which involve domestic and industrial water supply, irrigation, recreational use of water, fish and wildlife conservation and aquiculture.

Three primary factors control the usefulness of the data obtained in determining the quality of water. Confusion and misinterpretation of data is possible when these factors are not clearly understood.

1. Sampling Techniques

The basic consideration in determining the water quality characteristics of a supply is obtaining a sample or series of samples which are representative of the supply. In developing a water quality sampling program, the techniques to be used and the extent of such a program depend on the specific use of the water.

2. Analytical Procedures

The actual determinations of the specific water quality characteristics are based on procedures and techniques developed through the years. Analyses and the related field and laboratory procedures should conform to the standard methods prescribed by appropriate associations and agencies.

3. Units of Expression

Various units are used to report water quality data. The proper interpretation and correlation of data depend on knowing exactly what units the data are reported in. Many substances are generally expressed as concentrations. Concentrations may be expressed in several ways.

One of the most common expressions of concentration by Weight per Weight unit is parts per million (PPM) or milligram per kilogram (mg/kg). When Weight per Volume unit is use, it might be reported as milligrams per liter (mg/liter). The concentration of materials in flowing streams is often reported as kilograms or tons per day.

8.6.1. Water Quality Requirements for Specific Uses

Water supplied for domestic purposes should meet recognized established water quality standards relating to bacterial, physical, radiological and chemical characteristics.

Industrial water quality requirements cover a wide range. Operation of such industries from food and beverage to textile and pharmaceuticals involve quite large differences in requirements of the various uses.

Not all water is suitable for irrigation use. Unsatisfactory water may contain chemicals toxic to plants or to persons and animals using the plants as food, chemicals which react with the soil to produce unsatisfactory moisture characteristics and bacteria which may be dangerous to persons or animals eating the plants. Bacterial contamination of water is normally less serious than other contaminants from an irrigation viewpoint unless the contaminated water is used on crops which are eaten uncooked.

8.6.2. Water Quality Deterioration

Much of the pollution of water is the direct result of man's activities and a great deal of study must be devoted to the problems involved.

Municipal wastes, which may be broadly termed sewage, includes normal domestic wastes, wastes from commercial establishments, hotels, hospitals, schools and other institutions.

Industrial wastes are extremely complex and variable. They may contain organic matter, acid, chemicals and even poisonous substances. Mining practices contribute large amounts of pollutants to nearby streams.

Agricultural wastes are commonly asociated with agricultural development and the increasing use of water for irrigation. The increased concentration of dissolved minerals in the return flow from irrigated areas has long been recognized.

8.6.3. Public Health

Public health, per se, is not a responsibility of water resources planning. However, in a social oriented dvelopment domestic water availability and quality should be considered at this time, even for only long term planning.

A large number of residents of Kabupaten Luwu obtain their water requirements dirctly from nearby streams, supplemented perhaps by rain water. These streams are intensely used for every means of daily living including waste disposal.

It is appropriate at this time to include domestic water requirements in planning.

The quality of water for domestic use can, to a large extent, influence the general health situation in Kabupaten

Luwu. The incidence rate of a number of infectuous diseases is directly affected by the quality of the water supply.

Improving sanitation is an essential factor in protecting the safe water supply. In the absence of proper sanitation facilities, water resources and conveyance facilities might become polluted to such an extent they pose a very serious health hazard.

8.7. Hydroelectric Power

With the exception of the element of water requirements for power generation are quite similar to that of irrigation practices. However, in contrast to irrigation usage, power water requirements normally cannot tolerate noticeable seasonal variation in flow. A more uniform delivery of water is necessary for successful hydroelectric power operation.

In March 1979, "Reconnaissance Report, Balease Hydropower" was published. The report concluded that a run-of-river type hydropower plant on the Balease River at the location designated was technically possible and economically feasible. In the report's preliminary concept of the Project Plan, it was planned to combine the hydropower intake with the irrigation intake in order that the water released from the turbines might be immediately available for irrigation use.

As the basis for the design, a discharge of 57 m^3/sec was found necessary to produce sufficient electric power to satisfy the area's estimated power consumption.

The report also mentioned providing a network to include the diesel generator plants at Bone Bone and Palopo. In this manner the hydropower plant would be used to provide the base load and the diesel generating plants might increase the supply for the peak loads.

It was learned through the Rantepao Office of P.T. Aneka Tambang that a study is planned for the feasibility of a dam and hydroelectric power project at Malea near Kakale in Kabupaten Tana Toraja. The site on the Sadang River was said to have a capability of generating a power capacity of 190 MW and could supply power to much of the northern part of South Sulawesi including Kabupaten Luwu.

Studies have been planned for an hydroelectric project on the Larona River for supplying a nickel processing plant.

Perhaps there might be an opportunity for obtaining any available excess power from this source.

The Ministry of Mining and Energy has a great interest in hydropower on specific rivers. The possibilities of small hydropower project studies should gain their attention for assessing their requirements in a manner that they would help support studies and if feasible, contribute their cooperation for construction projects.

8.8. Electronic Computers in Hydrology

The electronic computer has become the most important tool of modern research and practicing hydrologists. The principal reason for this is that hydrologic analysis and design require processing such large amounts of quantitative data. Theoretical approaches have been benefically introduced into hydrology and such approaches involve complicated mathematical procedures and models which can be solved practically only by high-speed computers. Today computers are being utilized for all phases of hydrology and it will have far-reaching implications in the future development.

It has always been difficult to estimate the accuracy to be expected when a hydrologic procedure is applied to a specific investigation. If the procedure is used to simulate flows where an existing record of some length is available, it is reasonably simple to compare observed and simulated flows in order to determine the accuracy of the simulation. However, usually hydrologic procedures are applied to watersheds with at the best a short record and in many cases no record at all. The accuracy of these estimates must rely on the judgement of the user relative to the comparability with studies made on watersheds in which actual data were available.

The accuracy of simulation depends on three factors - accuracy of input data, effectiveness of parameter evaluation and inherent errors in the model.

Numerous mathematical models have been developed for the purpose of simulating various hydrologic phenomena and systems.

The Directorate of Hydraulic Engineering (DPMA) in Bandung possesses computer capability. They use a major hydrologic simulation model for continuous streamflow called Streamflow Synthesis and Reservoir Regulation Model (SSARR). This model was one of the earliest continuous streamflow simulation models using a lumped parameter representation and has its primary strength in its verified accuracy indicated by tests conducted in several large drainage basins including the Columbia River Basin in the United States and the Mekong River Basin in South Vietnam. This model was developed by the U.S. Corps of Engineers and is widely used world-wide.

8.9. Environmental Considerations in Water Resources Planning

Too often water resources studies are conducted without serious consideration to the environment. It is a fairly simple matter to decide what should have been done upon completion of a project that may have caused long-term and perhaps irreversible damage to flora and fauna and possible danger to man. It is far more difficult to make the decisions which might give assurance that the natural landscape would be altered by a minimum amount and that the project would not bring about extinction of some species of flora and fauna.

Planners of the future must be innovative. They should not rely solely on a showing of economic benefits. Innovation may take the form of devising ways to lower water requirements, encouraging nonstructural solutions in flood mitigation and finding better means of disposing of wastes.

Water projects required to maintain public health and safety and the accepted amenies must be continued to be sited and constructed. The planner will have to be more alert to alternatives than ever before.

A partial list of environmental consequences of water resource projects might include:

1. Damage to stream bank vegetation by alteration of flow patterns in a stream.

2. Damage to fish by passage through pumps or turbines or over spillways and weirs.

3. Altering aquatic species by increased turbidity from erosion.

4. Change in water quality as a result of drainage from an irrigation project.

5. Drainage of swamps and wetlands, decreasing the opportunity for survival of aquatic or amphibious animals or waterflow.

6. Destruction of fish spawning beds by channel dredging and lining.

9. SOUTH LUWU WATER RESOURCES

South Luwu is generally considered as the area between Palopo and Siwa. This area has received much less attention than North Luwu which is probably attributable to South Luwu not being included in Project Luwu.

The mean annual rainfall of South Luwu is less uniformly distributed than the North Luwu Plain and of lesser amounts.

It is believed that South Luwu presently has the largest percentage of their area in agricultural use at this time. Their cropping pattern has been established to take advantage of normal rainfall and a reliance on small scheme irrigation practices.

Considerable attention is now being directed to the Padang Sappa area to posibly construct a medium irrigation system relying on the Norling River as the primary irrigation water supply. It is believed that the World Bank is interested in the potentiality of larger scale irrigation projects for this area.

A medium irrigation system has also been envisaged for the Bajo area.

No field preparations of any type, have been commenced at either Padang Sappa or Bajo. It is necessary to make assessments of the topography, soil characteristics and cropping patterns as well as acquiring hydrologic data for the determination of water availability. Obtaining useful hydrologic and meteorologic data could prove to be quite a problem because records will be for short periods of time.

It is planned for simple systems to be introduced into 3 separate areas during the next 5 years for South Luwu.

10. CONCLUSIONS

10.1. Water Resources Management

The establishment of Project Luwu in Kabupaten Luwu as a separate entity having its own regulatory authority influenced a division of certain water resources management responsibilities between the Provincial Public Works organization and Project Luwu.

The Water Resources Division, directly under the Public Works of South Sulawesi, is a permanent organization and is undoubtedly as close as you can get to a kabupaten oriented operating department at this time.

Project Luwu is a semipermanent organization, sensitive only to the Central Government of which all or portions of it might remain in place for a considerable length of time.

Essentially there are two different agencies doing approximately the same tasks in identical areas. This does not impose an inherent problem in itself; however, this arangement is susceptible to a number of unavoidable and quite serious problems.

Maintaining the separate sections in separate agencies would result in higher unit costs for performing the work; duplication in personnel, tasks, tools, equipment and materials; untimeliness of reports and a much greater effort to accomplish coordination. This arrangement might also prevent the development of programs for increasing the effectiveness of each of the two sections.

10.1.1. Hydrology

One activity, directly related to water resources, and affected by the thinly defined lines of responsibility, is the Hydrology Section.

Presently the hydrological and meteorological activities in Kabupaten Luwu are not well coordinated. Overlapping of certain tasks and areas of operation occur. For some portions of the work this situation might be considered only a nuisance; however, there are other functions which might suffer from a difference of procedure and, of greater importance, a difference of standards for the finished product.

The sections operate independently of one another. Each Section seems to accomplish its assigned tasks in a a reasonable manner. The Sections do not seem to participate in the selection of their tasks nor do they appear to be given sufficient control to develop their own activities and establish their own priorities. It also appears that in spite of the Sections being highly regulated by the office above them requirements of manpower and budget to enable them to work more effectively, go unrecognized.

In the past this arrangement may have provided adequate data and information to satisfy requests made upon the system. However, Kabupaten Luwu is rapidly approaching a phase of development which will certaily overwhelm the present capabilities of each of the two sections interested in these areas of work.

10.1.2. Data Measurements, Reporting and Processing

While field measurement practices are reasonbly adequate, they are carried out at a low level of accuracy. Field procedures lack some tools and equipment which might make the work easier, more accurate and reduce the time required to accomplish the tasks. Yet, it is unlikely that the productivity and the accuracy of the field data would improve, in spite of obtaining items to improve mechanical operations, without including the indispensable process of training. A trained person will more likely understand the importance of reporting as pure data as possible. The training would permit the person to identify data as being inadequate or deficient and to take measures to explain the defectiveness in reporting the data, and when appropriate supply supplementary data as correction. Trained personnel would be able to use judgement in recognizing methods to improve operating procedures and to eliminate effort which was not productive.

Processing hydrologic and meteorologic data is tedious. As data are composed primarily of numerals and frequently with decimal points, errors are produced quite easily. The only accurate method for eliminating errors is by inspection. Also, the inspection method seems to improve somewhat if the person doing the inspection is not the same person who produced the original record.

In handling and examining many records produced by Luwu Irrigation hydrology Section, numerous errors were detected during the present of this study. There is little doubt that many of the errors would have been noticed even if only a cursory check had been performed.

One of the major functions in processing hydrologic and meteorologic data is selecting certain pertinent portions to be published. Luwu Irrigation Project Publishes a yearbook and two monthly periodicals. One of the dangers in producing data publications is that sometimes the publication, whose purpose should be a means to an end, in reality becomes the end itself.

The hydrologic and meteorologic data presently being published appear to lack a comprehensive program. The publications seem to contain a majority of tabulated raw data, graphs and diagrams. As they do not include an introduction, commentary, analysis explanation or summary, they seem to be more suitable for local office reference. Certain portions of the data should be distributed among those who have a need for it. However, much of the data is most useful to the field office as working files. The system fails to include a method of updating or amending previously issued publications if erroneous data is found to have been included in the publication.

10.1.3. <u>Hydrologic Networks</u>

The present rainfall gage network for Kabupaten Luwu is densely clustered essentially three major locations; Lamasi, Bone Bone and Kalaena. They are predominantly in the flat downstream areas with almost none in the upstream mountainous terrain which go to make up the majority of the individual river catchment areas. The present network fails to represent a large portion of the catchment areas which casts suspicion on any streamflow analysis derived from these rainfall data.

The present river stage network appears to reasonably adhere to basic criteria for the selection of hydrometric stations. A more effective network could be developed by increating the number of rivers gaged which would also enlarge the sample of gaged catchments.

10.1.4. <u>Operation and Maintenance</u>

There is an unquestionable lack of attention given to proper operation and maintenance of hydrologic and meteorologic instruments and equipment. Some instruments and pieces of equipment remain out-of-order for unreasonably long periods of time. The lapse in data information will certainly weaken the record and if the interval of unrecorded information is too great, the record may be unusable for its intended purpose.

10.2. Meteorological Stations

The four meteorogical stations presently operating in the Luwu Irrigation Project are well sited and creditably equipped. The data gathered from these sources are of great importance to the expanding irrigation systems and will be of equal importance in the future to other water resources planning and applications.

However, for these installations to remain benefical, a more serious attitude in operation and maintenance must be developed. Perhaps to untrained attendants some of the equipment may appear to require little attention. Also they may see little need to note that an instrument may read out of adjustment. In order to insure the most effective operation which contributes the most useful and accurate data, trained attendants must be employed or a training program implemented.

It was learned that problems have arisen in the use of the Gunn-Bellani radiation integrator. The instrument has a glass portion and is susceptible to easy breakage. As spare instruments or spare parts are not maintained, an instrument might be out-of-order for a considerable length of time. Replacing spare parts can be expensive and inconvenient. The Gunn-Bellani instrument requires careful calibration for it to operate properly. Taking readings from the instrument is rather awkard and this can easily introduce errors in the readings. It is felt the Gunn-Bellani instrument should be replaced with an actinometer.

10.3. Irrigation

Irrigation construction activities, under USAID loan agreements, have moved along continuously since 1976.

Some of the problems encountered have been inaccuracies of surveys in many areas of the project, adequacy of soils information, lack of qualified contractors, lack of control by Luwu Irrigation project inspectors, lack of material testing capability and lack of proper operation and maintenance.

10.3.1. Water Availability

Evapotranspiration values which were directly measured in the Project Luwu area for the years 1978 through 1982 were found to be considerably lower than the evapotranspiration values proposed in the Msater Plan which utilized data from the Semarang area.

Dependable rainfall calculated from data directly measured in the Project Luwu area for the years 1978 through 1982 was found to be sustantially lower than the dependable rainfall indicated in the Master Plan, which was calculated from data obtained from rainfall stations at Bajondo, Lamasi, and Masamba.

The evapotranspiration values and the dependable rainfall values derived from Project Luwu data were used in conjunction with the Basic Data as outlined in the Master Plan, Section 7.2., for determining the gross irrigation requirements. The results for the critical months of August, September and Octoberare shown in Table 8.

10.3.2. Determination of Water Adequacy

The method of determining water adequacy from the Master Plan is to compare the dependable river discharge with the gross irrigation requirement as shown in Table 9. If the dependable river discharge is less than the gross irrigation requirement, a shortage of water will occur and conversely, when the dependable river discharge is found to be greater than the gross irrigation requirement, ample water is available.

Utilizing discharge measurements from Project Luwu records it was found that flows from this study for the Battang, Lamasi and Kalaena Rivers were higher than the flows shown in the Master Plan for the same rivers. Flows for the Rongkong and Balease Rivers from this study were found to be less than the flows for these rivers in the Master Plan. Flows for the Makawa, Tubu/Ampak, Kanjiro, Bone Bone, Bungadidi, Senggeni and the Tomoni Rivers were found to be relatively the same in both the study and the Master Plan.

The discharge of the Balease river was found to be slightly less than the gross irrigation requirement for August, somewhat more than the gross irrigation requirement for September and sufficient to meet the gross irrigation requirement for October. However, the deficiency in August marginally as it was but occurring adjacent to a month showing such a small quantity of discharge more than the gross irrigation requirement, as for September, might indicate a strong possibility that discharge might fail to meet the gross irrigation requirement for August and September.

The discharge of the Rongkong River was found to be a little more favorable, for the month of August, than the

Balease, but the discharge for September decreased to just a small amount more than the Balease. When consideration is given to the size of the net irrigable area assigned to the Rongkong, it would seem suitable to place the Rongkong in the same category as the Balease.

It was found that the Battang, Lamasi,Makawa, Tubu/Ampak, Kanjiro, Bone Bone, Bungadidi (Lauwo), Senggeni, Tomoni and Kalaena rivers can supply sufficient water to meet the gross irrigation requirement.

Particular attention should be given to the adequacy of low flows in the rivers. The weather pattern is extremely variable from month to month and year-to-year. This variation is not so noticeable when looking at monthly averages, but they can be highly deceptive in that dry conditions can develop even in the wet seasons.

The majority of the hydrologic data reviewed for this study was collected during the years 1978 through 1982. This is considered a short record for analyzing data by most hydrological standards.

Some of the data reviewed had more than the customary errors. Many of the errors were inadvertent mathematical results or typographical. Each of these types of errors is difficult to detect unless the specific number is isolated for a definite purpose.

Some field data had numeous omissions attributable to instruments or equipment that was out-of-order and a lack of diligence on the part of the untrained attendants.

Nevertheless, it should be remembered that there is existing method of discharge determination which can be equally accurate as a reliable meter measurement or even a series of properly conducted surface velocity observations made by timing a float.

10.3.3. Construction Inspection

The need for consistant field inspection for irrigation projects in Project Luwu is imperative if the projects are to achieve a high standard of construction to be completed within the time stipulated to have minimum cost overruns and to perform the function for which they were dsigned.

10.4. Training and Schooling

There is a great need for a Career Advancement Program. This might include lectures and on-the-job-training within the departments, visits to similar departments in either kabupate nor provinces, formal schools in-country and sending personnel abroad to study. This would be by far the greatest influence as a motivating force in successfully implementing all other recommendations.

10.5. Water Resources Development Applications

The Water Resources Section will have to shift its attention from projects solely related to irrigation. It will have to share its time and effort to a continuous and comprehensive management program of all water resources. This will require future increases of manpower in both numbers of persons and varying disciplines and skills. The enlargement of the full program will necessitate establishing different and newer methods and procedures and the obtaining of instruments, equipment and tools commensurate with the assigned tasks.

Trained personnel and training and schooling programs, as outlined in Section 11.4, would be essential for the proper operation and maintenance of this type and size of program.

10.5.1. Groundwater

Groundwater is a vital source of water supply. The study of groundwater is a very important branch of hydrology, but because of the geological aspects of the groundwater problem is very specialized and complex.

Kabupaten Luwu will have to give attention to its rural single-family units and even rural group water supplies. Water wells will no doubt serve this purpose adequately. Water wells serve primarily as the most common and efficient manner of extracting groundwater.

Groundwater is superior, in many respects, to surface water. The most important advantage of groundwater as a source of domestic supply is its comparative freedom from bacterial pollution.

In widely spread rural areas, self-supplied industrial water supplies must rely on water wells.

A groundwater program would provide much information as to direct groundwater supplies and would provide information related to rainfall, runoff, river discharges and saltwater intrusion along coastlines.

10.5.2. Watershed

The objectives of watershed management are to protect the land against all forms of soil deterioration, stabilize critical sediment-producing areas, improve grasslands and woodlands, provide required drainage and irrigation and to reduce flood danger. These objectives can be attained by the application of land-treatment practices and water control structures.

Watershed programs use a wide range of control measures and the extent of the hydrologic investigation necessary varies accordingly.

From the sediment transport determinations, as shown in Table 6, the Masamba river is the only river which does indicate high sediment loads. Consequently, the low sediment content of all rivers, except the Masamba, indicate that the watersheds which contributes to the rivers are in relatively good condition.

Therefore, a watershed program, whether it is ongoing or a new program will provide an excellent opportunity to maintain the watersheds to prevent their deterioration in the future.

10.5.3. Flood-Damage Mitigation

Approximate floodmarks were observed on several rivers in Kabupaten Luwu. The height of the flood in relation to the adjacent land, in some cases, must have inundated an awesome area of land. Apparently most of the floods on Luwu rivers have a flood peak of short duration, usually indicating a relatively small volume of flow. Had the volume of flow been large enormous damage would have been done.

The present use of levees offers a positive method of reducing or eliminating flood damage.

There will be a need for river forcasting in the near future.

10.5.4. Multiple-Purpose Projects

Multiple-purpose projects are selected as a means to conserve water or to attempt to reuse water for an economic advantage.

Reservoirs are a natural consideration in multiple-use planning. Were reservoirs to be used in the downstream areas, much highly productive farm land might be permanently flooded and agricultural activities forced to use less productive hillside land with a considerable disruption to the local economy.

Multiple-purpose projects have obvious advantages in economy and efficiency, but these advantages bring with them a far more complex problem in design and operation.

For multiple-purpose projects a working plan must be devised which permits reasonably efficient operation for each purpose although maximum efficiency is not necessarily attained for any single purpose.

The success which can be obtained in multiple-purpose projects is in achieving joint use of storage space which is directly dependent upon the extent to which the various purposes are compatible.

10.5.5. Land Drainage

Drainage is advantageously utilized in Kabupaten Luwu in support of the increasing irrigation farming.

Drainage is also found in some land reclamation uses which should do much to increase the value of the land reclaimed.

It has been noticed that an unusually large amount of land in the vicinity of the main road from Palopo to Siwa is in need of varying amounts of drainage work.

Drainage work in Kabupaten Luwu, seems to suffer from poor construction and a lack of maintenance.

10.5.6. Water Quality

Water quality has long been a misunderstood element of water resources. A majority of people relate this term to only determining standards for potable drinking water. Little do they realize that this vague term plays a decidedly important role in water resources. They overlook the fact that many water resources functions depend heavily on certain standards of water quality for their operation e.g., irrigation, aquaculture, factories requiring boiler water.

There is a lack of a water quality program in Kabupaten Luwu. This should be corrected as soon as possible.

Kabupaten Luwu is endowed with many valuable minerals and ores. The INCO operation is only the beginning. It was learned that consideration is being given to a palm oil plant on the Bungadidi River and final exploration for copper is taking place on the Lamasi River. These industries will use considerable water and will produce various types of waste water which may be disposed of by draining into the nearest stream.

The Water Resources Section will have to evaluate the effects these activities will have on the river water quality and low flows.

There is no water quality program at present. This should be corrected as soon as practical.

10.5.7. Hydroelectric Power

The "Reconnaissance Report Balease Hydropower", March 1979, gave rise to bright prospects in one of the conclusive sentences which stated, in part: ".... the hydropower development is technically possible;".

The discharge of the Balease required to produce the estimated required power is higher than discharge measurements indicated on Luwu Irrigation Projects records for the years 1978 through 1982.

Luwu Irrigation Project records show that there are no rivers in Project Luwu that have a sustained flow during the drier months which might provide water for the plant.

10.5.8. Electronic Computer in Hydrology

As electronic devices for processing and storing data become less expensive and easier to operate they will become available at every level of work.

It will become highly important that data collected be recorded in such a form to be easily computerized.

Special procedures are required to arrange the data in such a manner so as to allow for their electronic processing and storing. These procedures vary from the various pieces of equipment to the type of softwear utilized.

In preparation for assembling the data, the proper method for arranging the data would have to be obtained.

The time is rapidly approching when every hydrology group that collects and/or processes hydrologic data will have trained personnel to arrange data, operate terminals and transact normal exchanges of computer data with others in the same field.

This approaching situation requires that measures be taken at an early stage for training personnel.

10.5.9. Environmental Considerations in Water Resources Planning

The greatest exposure that Kabupaten Luwu might experiencein respect to unbalancing the ecology would be to totally ignore proper control of the watershed areas.

Good watershed management and its effect on stream channels is directly related to a well balanced environmental program.

Some aspects of poor land drainage and in more severe conditions, flood control can be substantially detrimenal to the natural environnment.

The Water Resources Section should accept at least a portion of environmental protection responsibilities along with other coordinating agencies.

10.6. South Luwu Water Resources

South Luwu is poorly equipped for determination of its hydrological potentials. An effective rain gaging and river gaging network is lacking. There is not a meteorological station in the entire southern portion of the Kabupaten.

If there are to be irrigation projects proposed for South Luwu, necessary infrastructure must be put in place to accomplish the studies for determining if the proposals are feasible. And if the projects were continue, there would be an even greater need for this type of data in the planning and design phases.

There should be a careful evaluation of the need for semi-technical and technical irrigation systems in South Luwu. Perhaps, this time, effort and funds might be more effectively used in the improvement and necessary guidance and assistance in the operation and maintenance of the ongoing small scheme organization.

Water resources management should become as active in South Luwu as they are in the North Luwu Plain.

11. RECOMMENDATIONS

11.1. Water Resources Management

11.1.1. Hydrology

There seem to be adequate hydrology organization in both the Water Resources Section and Luwu Irrigation Project for carrying out ongoing programs. However, neither section seemingly has the capability for contribution to long term programs or for improving their present working levels. It appears that each section is in a position to expand its objectives and responsibilities to permit timely responsiveness for increased water resources development demands. However, this would require the staff and budget to be increased.

A special coordination comittee should be appointed composed of persons knowledgeable on the hydrology sections activities and of a significant level of authority to make decisions within the framework of the local organizations. The committee would evaluate tasks, activities and work areas now assigned to each of the sections. A transfer of the various elements of work from one section to the other would be made with an effort to equalize the tasks and to consolidate work locations when possible. This should give the Luwu section an opportunity to formulate a more cohesive and effective data gathering and reporting system. On the other hand, this balance of work loads would give the Water Resources Section the opportunity to become involved in other water resources applications in the Kabupaten. Also, this might give the Water Resources Section more time and energy to devote to the South Luwu Plain.

By transferring certain responsibilities from one section to the other, in contract to establishing a new section, a number of favorable functions and services can be taken advantage of. Existing office space, tools, equipment and transportation will suffice for the present and the near future and would assure that there would not be the customary delay, as for a new section, in fulfilling the planned assignments.

The size and compostion of each section would be dependent on the changes which may have taken place for each section.

11.1.2. Data Measurements, Reporting and Processing

The measurements for acquiring data is presently hampered by lack of trained personnel. Departmental training programs, for presently employed personnel and all persons newly hired, would create a vast inprovement for the entire sequence of observing and physically making the measurements.

Were the field attendants properly trained, the field data submitted to the office for processing would be in a more reliable state. This would save much time. However, all field data should receive both a cursory inspection for obvious omissions and missing data. This would be a pre-tabulation inspection only. When the data was found to be acceptable by eye inspection, then an exhaustive calculation check should be made.

There should be a definite systematic routing of the field data and checking should be signed-off and dated by the checker. All changes made to the field date should be initialled by the checker and the old number lightly ruled out so as not to obliterate it.

Processing hydrologic data, to be truly useful, must indicate the personality of the river or the runoff area, etc. This may be accomplished by comparing past data, of daily, monthly and annual records to discover trends for that particular item. Noting the physical measurements, even approximate, and their changes can give an insight into what occurs under certain conditions.

Publishing hydrogical data can become so voluminous that it actully loses its usefulness. A basic data publishing program should be initiated and coordinated with all related offices. A selective list of organizations and officers should be eligible to receive them. A selection of data to be published should be made. Certain data is only useful to certain persons. Perhaps certain data could be published in a less frequent manner to satisfy some cooperating offices.

All data should be available from the Hydrology Section on a need-to-known-basis.

Data maintained in libraries and archires can only provide adequate information when they are periodically updated.

11.1.3. Hydrologic Networks

In order to expand the existing rain gage networks so as to create a more representative and effective network, it would be necessary to increase both the nonrecording (standard) and the recording rain gages. The new locations for the gages would be in the areas of the Lamasi (1), Tubu/Ampak (1), Noling (2) and Bajo (1) rivers. Numerals in parentheses indicate the number of recording rain gages to be located.

The existing stage gage network should be strengthened by installing an Automatic Water Level Recorder for the Baebunta, Cerekang, Lampuawa, Radda and Uraso rivers.

To improve the river flow sampling and the sediment transport determination, those measurements should be taken more frequently. By increasing the number of measurements taken, this will give a clearer picture, specially during the wet months. The increase would include one additional set of measurements for 8 rivers for 6 months.

11.1.4. Operation and Maintenance

The importance of operation and maintenance functions for hydrologic instruments and equipment is as great as maintaining accurate data collecting.

An effective program must be developed for this phase of the work and a reasonable budget should be assigned.

At present, there are large number of instruments and other comparable pieces of equipment used in hydrologic and meteorologic activities throughout Kabupaten Luwu. The addition of more and of a more highly sophisticated type, envisaged in the future, might serve as an incentive for the Water Resources Section to investigate the adoption of an in-house means of properly servicing the instruments and equipment.

11.2. Meteorology

Training for the meteorological station attendants should include operational information for making readings, taking measurements, recording and reporting data, making adjustments, insure equal readings between certain instruments and equipment and to notice any leaks, broken items and items which do not function properly. Very basic ideas could be covered so as they might learn the purpose for gathering the data. Items often not considered to be worthy of much attention, but which are important to keep clean, are the evaporation pan, rain gage collector or funnel and especially so for the recording rain gage and sunshine recorder glass sphere. All of the items must be cleaned at regular intervals. In order to record reliable data the evaporation pan requires more regular cleaning than any of the other equipment.

Fundamentals in processing the field data should be given to the attendants, but it would be more appropriate for the processing of the field data to be accomplished in the office.

The proposed replacement of the Gunn-Bellani instruments with an actinometer at two of the meteorological station is sound and consideration should be given to carrying out this plan. At the time of this study, one meteorological station was having the necessary construction performed for installing the actinometer.

11.3. Irrigation

11.3.1. Water Available

The Balease River appears to possess the most unfavorable condition in providing adequate water to satisfy its gross irrigation reaquirements. If the Balease was consistently unable to meet its water requirements, the Masamba River, which at this time does not have a demand on it, should be capable of supplying sufficient water to the Balease to make up any deficiency which was occurring.

The Rongkong River has a more favorable outlook than the Balease and by way of carry over, from one month to the next, could have some excess water after meeting its requirements. The Baebunta River, which does not have a discharge record at this time, and considering that any demand on it in the future would still permit the Baebunta to supply some water to the Rongkong, if it become necessary to do so.

The other rivers should not experience any problems in their satisfying their allocation of water for irrigation.

A significant factor concerning the comparative results in the review of the Master Plan is the need for continuation of reviewing the hydrologic data and in analyzing and evaluating it, furnishing advice as to the status of available water and other parameters, as required, for irrigation and other water resources applications taking place at that time.

In this study, the mean daily flows were utilized. The picture presented by mean daily flows depends entirely on the chance relation between storm occurrence and the time it occured. The daily flows can differ substantially from the mean daily flows. There could be short periods of time that shortages developed and the rivers would be unable to satisfy their requirements. This could especially affect the Bungadidi and possible the Bone Bone.

There is also the factor of setting limits on crop growth periods, river flow periods and rainfall periods. This is very restrictive. It is understood that some form of criteria must be developed for isolating data in procedures for interpretation. However, when the data is derived from natural phenomena, there is likely to be a carry over or a delayed beginning which causes these set limits to move.

In the event there is a shortage of water during the dry season and it is decided not to transport water from elsewhere, a number of alternatives may be employed: the cropping intensity may be reduced, short duration varieties may be planted,or the risk of crop loss, during dry years, could possibly be accepted. Another possibility would be to grow which need les water.

11.3.2. Construction Inspection

A sufficient number of competent field inspectors are required. A satisfactory job site office for the construction inspectors should be available with space, equipment and conditions adequate for the functions they are required to perform.

It should be made obvious to the Contractor that he is totally responsible for all work being in full compliance with the contract documents up to the point of acceptance by the owner. Full payment should not be made until all requirements are properly met.

When certain portions of the work are completed and ready for turnover, the proper acceptance of the work should be made without under delay and payment for the work made promptly as specified.

A result of much irrigation work is a need for maintenance to help perserve the work. The proper acceptance of the work in a timely manner can prevent some problems from arising as to whose responsibility the maintenance work may actually be.

A more effective materials testing program is urgently required for the ongoing construction. The program should have available a competent, experienced person in charge. The proper tools, equipment and materials should be acquired and adequate work space provided for office and laboratory.

11.4. Training and Schooling

With the ever increasing progress in technology, it is essential that schooling and training be accelerated simply to maintain a static position iin the advancing state-of-the-art knowledge for hydrology and meteorology.

Promotion, higher salary, privileges and acceptance from ones peers are effects of advancement programs and help induce people to improve productivity.

11.4.1. Departmental Training

Site Training

This would include station attendants, field personnel those office personnel who participate in field work.

The material covered might be duties of the persons attending, basic procedures for observing, recording and reporting data, operation and maintenance for instruments and equipment and introductory-type hydrology and meteorology.

To fill a void between the sections main office in Palopo and the station attendants, there would be three Area Coordinators for Luwu Irrigation Project and three Area Coordinators for the Water Resources Section. Their duties would include but not be limited to, making periodic inspections for ascertaining the condition of the stations, noting methodology used in observing and recording data, the keeping attendants supplied with forms, chart paper and other expendable supplies, collecting data and forwarding instructions to attendants and passing collected data to main office in Palopo. Coordination areas might be Lamasi, Bone Bone and Kalaena.

There would be a need for additional personnel in the main office of each section to permit a more effective data examination, processing and publishing procedure. This would help insure that data were thoroughly checked for accuracy. There would be three additional persons assigned to the Luwu Irrigation Project and three additional person assigned to the Water Resources Section.

Office Training

This would included staff persons, including administrative personnel.

The course of study might be similar to the Site Training course, except greater emphasis would be placed on hydrology and meteorology along with details for proper examining, adjusting and analyzing data.

11.4.2. Interprovince Training

This course of training is envisaged to be for 2 staff persons to attend training programs every year at Bandung and Ujung Pandang for a minimum of one month.

11.4.3. Formal In-Country Schooling

This phase of the program would be to permit one staff engineer to attend Diponegoro University at Semarang for a period of 3 years.

11.4.4. Formal Schooling Aboard

A staff member would be permitted to go abroad for two years and fullfill the requirements for a Master degree, which might.

11.5. Water Resources Development Applications

11.5.1. Groundwater

It is felt Kabupaten Luwu has sufficient surface water so is unlikely it would ever have to rely on groundwater sources. However, it must be used an advantageous manner.

Groundwater studies supplement and enhance hydrologic investigations. It frequently helps to clarify problem areas related to runoff and river discharges. It provides a great deal of data on saltwater intrusion. Well logging alone accounts for a wealth of invaluable data.

A comprehensive groundwater program should be studied and outlined. Actual working activities should be commenced as additional duties for personnel assigned to the hydrology sections, until such time full time personnel are required to administer the program. This type of beginning is quite suitable for phased organizational growth.

11.5.2. Watershed

It is appropriate to advise the use of a recently prepared study entitled "Watershed Management in Kabupaten Luwu", July 1983, Checchi/DMJM, Project Luwu as a reference, in this subject.

It is importance to have an organization (s) with sufficient authority to fully control all major activities within the watershed. Anything less will prevent persons assigned control duties from effectively accomplishing their tasks.

11.5.3. Flood-Damage Mitigation

As areas build up and population increases there is a greater need for accurate flood forcasting. At the very best, flood forcasting is extreamly difficult. This would be magnified in Kabupaten Luwu due to the small watesheds and the flashy type streams.

The basic techniques used in river forcasting are the same as those used in other fields of hydrology. However, the flood forecast problem differs from that of other forcasts in that flood forcasting must include not only a predicted flood or stage, but its anticipated time of occurrence.

Hydrology sections are prepared for this type of work in having their regular reporting stations. The only addition they would require is the procedure.

11.5.4. Multiple-Purpose Projects

Multiple-purpose projects would have to be a modified version of the usual definition. Reservoirs become a natural consideration in multiple-use planning. The configuration of the majority of downstream terrain, easily accessable, fails to meet economic criteria for reservoirs.

Without a reliable source of stored water, many water uses cannot operate without an assured water supply basis.

The use of water is an important factor in selecting compatibility of serving two or more purposes. Irrigation is a consumptive water user, where as hydropower generation is not. A run-of-river type plant could efficiently precede an irrigation diversion box, but a storage type hydropower plant may elect to release water when it fails to consider with the requirements of the irrigation diversion box. Flood control requires empty storage. Many water purposes will be in conflict to some degree, while others may be diametrically opposed.

Therefore, meticulous studies, of numerous items must be considered in planning a multiple-purpose project.

Difficulties for planning multiple-use projects may be greatly aggravated by the uncertainty of the stream flows and the problem in locating reservoirs.

11.5.5. Land Drainage

A proper field inspection program must be developed for this area of work.

Either trained, experienced personnel should be employed or a training program commenced in order for the inspectors to be able to conduct on-site inspections of the work as a basis to determine compliance with the contract documents.

A suitable office should be provided with sufficient space to permit any required material testing activities to be carried out.

11.5.6. Water Quality

A water quality unit can normally conform to almost any type of organizational structure. Usually it can operate satisfactorily with minimum personnel, office and laboratory space and transportation. However, by the nature of their work, trained and experienced personnel are necessary and they do require some specialized tools and equipment.

A trained, sufficiently equipped, well organized unit can be very beneficial to a water resources activity, with a requirement for their type of services.

Water quality sampling and analysis programs can provide useful information on such diversified subjects as irrigation water, stream pollution, effects on evaporation and sediment transport.

Water quality's predominant role is the field of domestic water supply and use. This offers a totally different and challenging aspect of water resources apllication.

It is inevitable that a domestic water quality program will be essential in Kabupaten Luwu in the near future. Economic constraints may retard it, but the pressing need for this service will have to be provided.

A water quality program should be formulated and the work program merged gradually into the hydrology section's schedule of work.

11.5.7. Hydroelectric Power

River discharge records derived from meter measurements during the years of 1978 through 1982 indicate that rivers gaged and reported cannot provide the sustained flows during dry seasons required by run-of-river type hydroelectric plant as planned in the Balease report.

This does not infer that a suitable arrangement of turbines and generators cannot be designed to accommodate the lower flows for Luwu rivers.

There is a possibility that sites further upstream would be desirable for the operation of storage type or pumped-storage type plants.

Accurate topographical maps and aerial photographs would have to be used in locating promising sites and then field trips would have to be arranged as to obtain reasonable field survey and stream data and photographs in order to properly ascertain the suitability for further investigation.

Alternatives would be to investigate very thoroughly the planned studies for hydroelectric power projects at Malea in Kabupáten Tana Toraja and on the Larona River.

11.5.8. Electronic Computers in Hydrology

In-country training programs would probably be able to satisfy the needs of Provincial organizations, at least, at this time and in the near future for computerizing data.

The Directorate of Hydraulic Engineering in Bandung would seem to be in an excellent position to provide very personal training programs including hands-on experience in their own computer operation.

Possibilities for sharing machine-time with organizations within the province should be investigated.

Selected qualified personnel should be permitted to participate in the training programs.

11.5.9. Environmental Considerations in Water Resources Planning

This subject can be approached by management levels initiating a program that would cause all appropriate departments to become fully aware of this topic. The departments should be instructed to include recognition of this matter in their studies, programs, design materials, standards and contract documents.

The program should extend to cooperative measures with other organizations and agencies.

11.6. South Luwu Water Resources

If there are indications that medium scale irrigation projects are feasible for South Luwu, the Water Resources Section will have no choice but to immediately expand their activities in this area. They will have to respond to the requirements for data in every phase of the work, from design through construction on to operation and maintenance of the completed projects.

However, if plans for larger irrigation systems are not found to be suitable for South Luwu, there are still ample needs for Water Resources Section support.

South Luwu requires a rain gage network, hydrometric station network and a meteorological station to be located in that area.

Due to the configuration of the South Luwu area properly planned drainage systems might be equally important as irrigation, for some areas. While other areas drainage problems have increased in severity until now they require flood protection.

12. Program Costs

During the preparation of this study, there were ample opportunities to becom acutely aware of manpower and budget constraints within the organizations whose responsibilities include hydrology and water resources functions.

It may be noted that no new organization was considered necessary to achieve more comphehensive and effective working groups.

Consultants were deliberately omitted, since this type of advisors are being proposed for similar work categories, within essentially these same organizations, in subsequent reports.

Where costs are not given for specific tasks, which they might occur, it has been assumed that the present organization would support these items from existing budgets.

No attempt has been made to separate costs for various items, which may exceed budget capability, and which may require assistance from donor participation.

Basic budget estimate data for recurring costs are shown in Table 10, and in Table 11 for all other costs.

BASIC BUDGET ESTIMATE
(5-YEAR PLAN)

RECURRING COSS

Staff	Annual Cost (000 Rp)	
Technical 6 @ Rp. 100,000/month	7,200	
Skilled 6 @ Rp. 80,000/month	5,760	
Unskilled 3 @ Rp. 10,000/month	360	
21 @ Rp. 7,500/month	1,890	
Total Staff Costs		15,210
Departmental Training	2,000	
Interprovince Training	1,500	
Total Training Cost		3,500
Additional Measurements for River Discharge and Sediment Transport (includes Operation & Maintenance)	1,700	
		1,700
Total Annual Recurring Costs		20,410

Table 11

BASIC BUDGET ESTIMATE
(5-YEAR PLAN)

ALL OTHER COSTS
(000 RP)

Item	1984-1985	1985-1986	1986-1987	1987-1988	1988-1989	Total 5-Year Plan Cost
Hydrology						
5-Automatic Water Level Recorders	3,000	13,000	13,000	16,000	20,000	65,000
5-Standard Rain Gages	500	1,500	2,000	1,000		5,000
5-Automatic Rain Gages	4,000	8,000	4,000	4,000		20,000
Relocate AWLR at Tomoni River	6,000					6,000
Meteorology						
Construct Meteorological Station in Bajo Area	3,600	30,000	6,000			39,600
Replace Gunn-Bellani with Actinometer	2,500					2,500

Item	1984-1985	1985-1986	1986-1987	1987-1988	1988-1989	Total 5-Year Plan Cost
<u>Training & Scheduling</u>						
Formal In-Country Schooling		1,900	1,900	1,900		5,700
Formal Schooling Abroad		15,000	15,000	15,000	15,000	60,000
Operation and Maintenance	200	950	3,100	3,750	2,750	10.750
Total	19,800	70,350	45,000	41,650	37,750	214,550
Total from Table 10	20,410	20,410	20,410	20,410	20,410	102,050
Total Estimated Budget	40,210	90,760	65,410	62,060	58,160	316,600