IRRIGATION PROJECTS IN GUATEMALA
OBSERVATIONS AND RECOMMENDATIONS

BY

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In cooperation with

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and

Direccion General de Recursos Naturales Renovables
Ministerio de Agricultura

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PURPOSE

This study is a result of an official request from the Guatemalan Government through USAID/Guatemala and AID/Washington (TOAID A-269 and AIDTO A-94) to Utah State University for Technical Assistance in Drainage and Irrigation. The following plan of work was suggested:

A. Evaluate actual drainage and salinization problem in Monjas Irrigation District in southeastern Guatemala.

B. Establish the bases for a general reconnaissance detailed survey of Ministry irrigation operations, and determine the actual status of available information.

C. Develop a scope of work for feasibility studies leading to a national irrigation and drainage plan for 8000 hectares of irrigated land.

PERSONNEL

A. TDY from Utah State University through the Technical Assistance Bureau, AID/W:

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B. Guatemalan counterpart personnel from the Dirección General de Recursos Naturales Renovables, Ministerio de Agricultura:

1. Ing. Agr. Mario R. Vela, Suelos
2. Ing. Oscar G. Espinoza M., Hidráulicos
3. Ing. Agr. Teodoro Engelhardt, Hidráulicos

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The writers want especially to express their thanks to the Vice-Minister of Agriculture, Ing. Agr. Rodolfo Perdomo, for his complete interest in the problems encountered, and for the disposition made by him of the personnel, data, and facilities of the Dirección General de Recursos Naturales Renovables. Without his full-hearted cooperation this study, as limited as it is, could never have been completed in the period of time allotted.

Praise must also be extended to the Guatemalan counterparts who were assigned to shepherd the writers through the country as well as through the maze of data already collected pertaining to the projects visited, namely: Ing. Agr. Mario R. Vela, Ing. Oscar G. Espinoza M., and Ing. Agr. Teodoro Engelhardt. Thsese dedicated engineers unhesitantly met long work schedules, made long trips with us into the field (many times leaving shortly after dawn and returning after dark), and kept us informed and entertained whenever possible.

Also to be recognized is the interest expressed by the Interamerican Development Bank (BID) in the persons of Director Julio Sanjinés and especially Ing. Hugo Bacarreza who accompanied us on two of the field trips.

None of this would have transpired without the full cooperation of Mr. Alphonse C. Chable, Chief, Agricultural and Natural Resources Division, USAID/Guatemala, who acted as intermediary to bring all interested parties together. Also, without the complete disposal to our needs of his office space and secretarial personnel, this report could never have been prepared in such a short time. Mrs. Barbara Kennedy, Mrs. Emilia de Barrios and Mrs. Aura de López were diligent in their efforts to accommodate us in our writing idiosyncracies.

ITINERARY

April 17, 1972	
1620 hrs.	Arrival of Prof. Christiansen in Guatemala
1900 hrs.	Arrival of Dr. Olsen in Guatemala.
April 18	In the company of Mr. Alphonse C. Chable, Chief, Agricultural & Natural Resources Division AID/Guatemala, visited with Ing. Agr. Rodolfo Perdomo, Vice Minister of Agriculture. After this meeting the relief model of Guatemala was visited, and then discussions about the projects and general problems were held at the offices of Recursos Naturales Renovables in La Aurora Zoological Park.
April 19	Visited the director of the National Meteorological Observatory, Sr. José Vassaux, and then traveled with the three counterparts to the Monjas project. Spent the night in Jutiapa.
April 20	Visited Atescatempa Project area and returned to Guatemala in the evening.
April 21	Spent the morning and early afternoon discussing projects in the Aurora offices, and visited with Director Julio Sanjinés and Ing. Hugo Bacarreza of the Interamerican Development Bank (BID).
April 24	Visited the Executive Office and Mr. Joseph S. Courand, Agriculture & Natural Resources Divi ion, USAID/Guatemala and then to the Auro a offices to continue project discussions.

April 25	Traveled to the La Blanca Project with the counterpart personnel as well as Sr. Hugo Bacarreza (BID). Spent the night in Coatepeque.
April 26	Spent the entire day in the La Blanca Project area and returned in the evening to Guatemala.
April 27	Traveled to the Cabañas-Autombran-Reforma and the La Fragua projects. Returned to Guatemala.
April 28	Report writing in hotel.
May 1	Report writing in hotel.
May 2	Collected more data from Aurora offices and continued report writing in USAID offices where secretarial assistance was available.
May 3	Report writing in USAID office.
May 4	Report writing and editing in USAID office.
May 5	Discussion draft of report completed. 1600 hrs. Prof Christiansen and Dr. Olsen departed from Guatemala.

INTRODUCTION

This report is in three basic parts: I, Observations and discussions on subjects that pertain to general conditions that may prevail in more than one specific project; II, Descriptions and discussions that refer only to specific projects; and III, a summary and general recommendations.

General Considerations

The inspections of the five projects that were visited were necessarily very brief and some important aspects may have been overlooked. Also, the time available for a study of the project reports and other important data was very limited. An attempt has been made to note factors that pertain primarily to the suitability of the project area for irrigated agriculture. Especially noted were features that may result in a drainage and/or salinity problem at some later date. From the writers' experience in several Latin American countries as well as in the USA, it is believed that drainage and salinity are the most difficult problems that plague many irrigation projects, and that in many instances conditions have become very bad before any attempt has been made to provide the necessary facilities to correct the problems.

For this reason, a discussion is presented on groundwater observation wells, which are of primary importance in determining just what is happening to the ground water levels as the result of the introduced irrigation as well as the effect of the rainfall following an irrigation season when the water levels may have already been increased by irrigation. For a permanent irrigated agriculture, all of the salt added in the irrigation water must be removed from the root zone by either natural drainage or installed drainage facilities such as open drains, tile drains, or pumped wells. A record of water table conditions is essential for the determination of the adequacy of the drainage.

Since the quality of the irrigation water with respect to the salinity and sodium hazard is also of great importance to an understanding of the problem a discussion of this subject is included. For Guatemala, it has been found that the ground waters in many instances, although low in total salinity, are high with respect to sodium percentage and residual sodium carbonate, and may therefore not be acceptable waters for irrigation. A suggested rating table for irrigation water is included.

GROUND WATER OBSERVATION WELLS

Because of the danger of raising the water table and creating a serious drainage and possibly a salinity problem in any new area that is brought under irrigation, a careful record of the water table levels over the area should be maintained. Where the water table is within 3 meters of the surface before the area is irrigated, special observation wells should be installed before irrigation begins so that the effect of the irrigation on the water table levels can be evaluated. In areas where the water table is initially several meters below ground level, and where natural drainage conditions are favorable, the installation of ground water observation wells may not be justified until there is some evidence of an impending drainage problem.

Type of Observation Well -

The type of ground water observation well recommended consists of a perforated PVC pipe about 1 inch (2.5 cm) diameter installed in an auger hole (about 10 cm diameter) with coarse sand or fine gravel backfilled around the plastic pipe. Such observation wells are the least expensive of any satisfactory type known. They should ordinarily be about 3 meters in depth, but for some high water table conditions, a depth of 2 meters would be adequate. This PVC pipe comes in 6 meter lengths and can, therefore, usually be cut in either 2 or 3 sections with an ordinary hack saw. They can be rapidly perforated with either a hack saw, an electric drill, or with a hammer and nail. Perforations with a saw should be made about 10 cm apart or two sides, staggered so that they are 5 cm. apart. Where drilled or where nail holes are used, several holes should be made in each 10 cm section. Perforations should extend from the bottom to within one meter of the top end. When installed, it is best to have the upper end of the plastic pipe about 20 cm above ground level for ease in measurement. A suitable cap over the top is recommended. It should not be airtight.

Methods of Measuring Water Levels -

Several methods can be used for measuring the water level in these plastic tubes. An electric sounder is most convenient but may not prove entirely satisfactory because it is more expensive and easily damaged. Basically, it consists of an electric circuit with a suitable battery, a high resistance volt meter (or micro ammeter), and a double wire conductor with a special tip that the water shorts when it reaches the water in the tube. Markings in centimeters along the wire conductor facilitate the measurements.

Other means include a tape with a special oxidized steel rod, about 3 mm diameter, attached with a small ring. This rod should be about 50 cm in length. The tape and rod is lowered into the well until the lower end is wet. The dry part of the rod added to the tape reading at the top of the PVC tube gives the water level from the measuring point. The small rod used must be oxidized (rusted) so that it will clearly show the wet part.

An alternative method is to use a plastic tube, not more than 10 mm diameter, weighted with a short section of metal tube at the lower end. This tube can be lowered into the well while blowing on the other end. When the tube reaches the water level, a bubbling sound will be heard. Marking the tube in cm facilitates the readings, although it can be removed and the length in the pipe can be measured with a pocket tape. An alternative method to blowing is to hold the upper end of the tube just below the water level in a small container (cup) and observe when a bubble appears from the tube which occurs when the lower end of the tube reaches the water level in the well.

Location and Spacing of Observation Wells -

The desirable spacing of observation wells will depend somewhat upon the topography, total area to be covered, and the specific purpose for which they are to be used.

Ordinarily, in a small project of less than 1000 hectares a spacing of about 1 Km apart on a square grid will suffice. If the topography is uneven, closer spacings in the lower part of the area would be desirable. The actual location of each well should be selected so that they are spaced as uniformly as possible and yet be convenient for making the readings, especially during the rainy season when some areas may be flooded. Ordinarily they are placed along fence lines along roadways that can be travelled during rainy weather. They should <u>not</u> be placed where they will interfere with cultural practices, or where it is inconvenient to get to them to make the readings.

When observation wells are used for special purposes such as to study the effectiveness of drains, or seepage from canals, they are placed on one or more lines normal to the drain or canal. The center observation well in a line should be placed as near to the center line of the drain or canal as feasible. At least three wells should be located on each side of the center line with the second one spaced about twice as far from the first one as the latter is from the center line. The distance between the second and third wells should again be double the spacing of the previous two wells. For example, to study the effect of a drain on the water table, one might place the first well 10 meters from the drain, the second one about 30 meters, and the third 70 meters from the drain, etc. For studying the effect of a pumped well on the adjacent water table, observation wells might be placed on either 2 or 4 radii at similar distances from the pumped well. Experience with observation wells for such special purposes will indicate what spacings best suit the specific conditions.

Field Notebook -

For each observation well, a small sketch map should be prepared in the field notebook when the well is installed. This sketch map should show the location with respect to local features such as fences, buildings, canals, drains, etc. These maps are very useful in locating wells at a later date by someone other than the person who installed the well.

The elevation of the top of the pipe and the general field level nearby should be determined and permanently recorded in the notebook. The elevation of the water level and the distance below general field level can then be readily computed. It is important that the ground level refers to an average field level in the vicinity of the well and not the ground level right at the well, because when wells are placed along fence lines (so as to be protected from damage and not interfere with farming operations), the ground level at the well may be a half a meter higher (or possibly lower) than the general ground level.

Suggested Notebook Headings -

A field notebook with the following column headings is very convenient for taking the records:

Pozo No. ________ Depth________m. Pipe Elev._____m Ground Elev._____m

Date	Hour	Reading m	Water Elevation m	Depth to water m	Comment

It is best that only the field readings and dates be recorded in the field by the observer. Elevations and depths to water should be computed in the office by a different person so that the consistency of the data can be checked. A space for comments is desirable since this provides space to note rainfall, irrigation, etc.

Frequency of Readings -

The frequency at which readings should be made will also depend on the special conditions. Ordinarily readings at intervals of one or two weeks will suffice, but if one is trying to determine the effect of irrigating adjacent fields on the water table, one might want to make daily readings so that the amount of rise in the water table when the field is irrigated, and the subsequent rate of drop, can be more accurately determined. If it is known just when the fields are to be irrigated, readings just prior to the irrigation, and for several days afterwards, might suffice for the same purpose.

Maps Showing Water Table Conditions -

It is desirable to plot water table data on maps showing the location of the observation wells; physical features such as roadways, canals, drains, and other special features such as buildings for identification. There are two kinds of useful maps. One shows the actual elevation of the water level above a fixed datum (arbitrary or mean sea level), and the other the depth from general ground level to the water table. The first shows the slope and direction of movement of the ground water and often indicates the source of the ground water such as a portion of a canal with high seepage rate. The second shows at a glance the critical areas that are most urgently in need of drainage facilities. Such maps can be colored to advantage with red indicating water levels within 0.5 meters from the surface; orange, from 0.5 to 1.0; brown, 1.0 to 1.5; blue, 1.5 to 2.0; and green, more than 2 meters.

Such maps can be prepared to show conditions on a specific date, but when readings are taken at intervals of 2 weeks or so, and there are noticeable fluctuations in water levels due to irrigation of adjacent fields, maps showing the highest levels as read during a specific period (such as for the rainy period or during the irrigation period) might suffice. Similar maps showing the lowest water levels as observed during the same period will show the magnitude of the fluctuations due to rainfall or irrigation.

Hydrographs -

Charts showing the depth to water in the wells below the general field level plotted against the date are also useful. Charts of this kind are now plotted for 30 observation wells in the Monjas Project. It might be convenient to plot several observation wells on one sheet. The time scale need be such that the changes that occur can be readily understood. For some conditions, one sheet may contain the records for 3 or 4 months, with an entire year contained on not more than four sheets.

A better visual representation of what is actually happening in the well is indicated if the ordinate, as it is presently plotted for the wells in the Monjas Project, is inverted, i.e., zero depth to water should be at the top of the scale with increasing depths plotted downward. In this manner the hydrograph will show a descending line when the water table is falling and will be easier to interpret visually.

QUALITY OF IRRIGATION WATER

General Considerations -

A study of available data on the quality of the waters available for the projects indicates that some waters, especially those from wells in some areas, may be unsatisfactory for irrigation, although the factors that make them so have not been pointed out in any of the reports. For this reason, this section has been prepared and a new rating system is proposed.

The Salinity Laboratory classification which uses the conductance in micromhos ($EC \times 10^6$) and the Sodium Adsorption Ratio (SAR) has been used in all reports studied. This classification omits consideration of other important factors, although most of them are discussed in the Salinity Laboratory Handbook 60, "Diagnosis and Improvement of Saline and Alkali Soils" by Richards et al. These additional factors include the sodium percentage (Na%), the residual sodium carbonate (Na_2CO_3), the chloride concentration (Cl^-), the effective salinity (ES) and boron. When these factors are taken into consideration, some of the waters used, and to be used, for irrigation in Guatemala are of questionable value and may be very detrimental to the soils on which they are used. They may disperse the fine textured soils and greatly reduce the infiltration rates. They may also produce "sodic soils" which are very difficult to reclaim.

Suggested Irrigation Water Ratings -

These suggested ratings for irrigation water as given in Table 1 consider all of the important factors which degrade a water with respect to its use for irrigation.

TABLE 1. SUGGESTED RATINGS FOR IRRIGATION WATER

Rating	$ECx10^6$ μ mhos	Na+ %	SAR -	Na_2CO_3 me/l	Cl- me/l	Eff.Sal. me/l	Boron ppm
1	500	40	5	0.5	3	3	0.5
2	1000	60	10	1.0	6	6	1.0
3	2000	70	15	2.0	10	12	2.0
4	3000	80	20	3.0	15	18	3.0
5	> 3000	> 80	>20	> 3.0	> 15	>18	> 3.0

Each detrimental factor is considered separately and no attempt is made at combining these factors into a single classification. The factors considered are those that have been proposed in classification systems by number of authorities including: Eaton, Scofield, Wilcox and Megistad, Thorne and Thorne, Richards et al, and Doneen. No one classification by itself gives a justifiable basis for accepting or rejecting a water for irrigation. The most commonly used classification proposed by Richards et al, in the U.S. Salinity Laboratory Handbook 60, does not consider factors such as effective salinity (Doneen), residual sodium carbonate, Na_2CO_3, (Eaton), boron (Wilcox and Magistad), sodium percentage (Scofield, and Wilcox and Magistad) which are all considered detrimental, and which, with the exception of effective salinity, are discussed separately by Richards et al. The proposed rating simply evaluates each factor separately on a scale of 1 to 5, considering #1 a water of excellent quality with respect to the specific factor, and #5 a water of limited or no value for irrigation, as extremes.

In rating any water for irrigation, one must consider the soils on which it is to be used, the drainage conditions, and the management practices. For example, a water rated as #5 on the basis of conductance, but with a rating of #3 or better on all of the other factors, might be used successfully on coarse textured soils with good drainage as well as for basin or border irrigation with tolerant crops. Such a water would ordinarily not be suitable either for furrow or sprinkler irrigation. Likewise, a water rated #5 on the basis of Na% or residual Na_2CO_3, but with a rating of 1 or 2 on all other factors, might prove very detrimental when used on fine textured soils such as silt and clay loams. Such a water would probably disperse the soils and greatly reduce the infiltration rates. It would make the soils very difficult to manage. From visual evidence, this appears to have happened in the Cabañas and La Fragua projects irrigated with well water.

Comparison of Irrigation Water Analyses -

On the basis of these suggested ratings, a number of irrigation water analyses have been evaluated. Six of these analyses are given by Israelsen and Hansen (1962), page 224. 1/ Others were taken from the report entitled "Estudio de Electrificación y Riego, Vol. 1, Sección de Riego, by Ingenieros Consultores, Sept. 1962, Cuadro IV 22 y IV 24. The suggested ratings are compared in Table 2 from the analyses tnat are given in Table 3.

1/ Israelsen, O.W. and V.E. Hansen. 1962. Irrigation Principles and Practices, Third Edition, John Wiley and Sons, New York.

Table 2. Comparison of Irrigation Water Ratings

Identification	$EC \times 10^6$ µmhos	Na^+ %	SAR -	Na_2CO_3 me/l	Eff Sal me/l	Cl^- me/l	Boron ppm
La Fragua Project							
Pozo ICA #1	2	2	1	4	2	1	-
Pozo ICA #4	2	2	1	4	1	1	-
Pozo ICA #5	1	5	2	4	2	1	-
Rio Grande, P. B.							
Monjas Project							
Laguna del Hoyo	1	4	1	4	1	1	-
Río Güirila	1	1	1	1	1	1	-
Pozo 9	1	1	1	1	1	1	-
Pozo 10	1	1	1	2	1	1	-
Pozo 15	1	2	1	3	1	1	-
	1	1	1	1	1	1	-
Israelsen - Hansen USA							
Río Grande, Colorado	1	1	1	1	1	1	-
Río Grande, N.M.	2	2	1	1	2	1	-
Pecos River, Texas	5	2	3	1	5	5	-
Snake River, Idaho	1	1	1	1	1	1	-
Colorado River, Ariz.	3	1	1	1	3	1	1
Well, Coachella, Calif.	3	5	3	1	5	4	2

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TABLE 3 COMPARISON OF IRRIGATION WATER ANALYSES

IDENTIFICATION	EC $\times 10^6$	CATIONS, me/l Ca	Mg	Na	K	Σ	ANIONS, me/l HCO_3	SO_4	Cl	NO_3	Σ	Na %	SAR	Na_2CO_3 me/l	Eff. Sal.	Boron ppm	SAL LAB CLASSIF.
La Fragua*																	
Pozo ICA 1	595	1.46	1.13	3.90	0.12	6.61	4.70	0.92	0.83	0.10	6.55	59	3.41	2.11	4.02	-	C_2S_1
Pozo ICA 4	550	1.60	1.15	3.17	0.15	6.07	5.23	0.43	0.44	0.14	6.20	52	2.77	2.52	3.32	-	C_2S_1
Pozo ICA 5	415	0.56	0.10	3.46	0.07	4.19	3.27	0.47	0.59	0.04	4.37	83	6.39	2.62	3.53	-	C_2S_1
Rio Grande, P.B.	262	1.56	0.55	0.49	0.07	2.67	2.01	0.48	0.06	0.01	2.56	18	0.48	-	0.65	-	C_2S_1
Monjas*																	
Laguna del Hoyo	420	0.92	2.22	1.18	0.33	4.65	4.73	-	0.19	0.06	4.98	72	0.94	1.59	1.51	-	C_2S_1
Río Güirila	100	0.34	0.24	0.34	0.12	1.04	0.94	0.17	0.16	0.05	1.32	33	0.63	0.36	0.46	-	C_1S_1
Pozo 9	240	0.94	0.70	0.68	0.12	2.44	1.86	0.13	0.29	0.42	2.70	28	0.75	0.22	0.80	-	C_1S_1
Pozo 10	320	1.69	0.84	0.76	0.12	3.41	3.25	0.12	0.08	0.17	3.62	22	0.51	0.72	0.88	-	C_2S_1
Pozo 15	250	0.94	0.17	1.42	0.15	2.68	2.50	0.09	0.13	0.08	2.80	53	1.92	1.39	1.57	-	C_1S_1
ISRAELSEN-HANSEN																	
Rio Grande, Colo.	85	0.56	0.27	0.30	-	1.13	0.70	0.32	0.12	-	1.14	26	0.46	0	0.43	-	C_1S_1
Rio Grande, N.M.	870	3.76	1.34	4.03	-	9.13	2.97	4.69	1.53	-	9.19	44	2.52	0	5.37	-	C_3S_1
Pecos R, Texas	9150	30.62	17.19	53.62	-	101.43	-	44.52	54.00	-	98.52	52	10.92	0	70.81	-	C_5S_4
Snake R, Idaho	250+	2.60	1.80	1.74	0.14	6.28	3.28	1.69	1.18	0.04	6.19	28	1.18	0	3.00	-	C_1S_1
Colorado R, Ariz.	1135	5.08	2.21	4.54	-	11.93	2.56	6.97	2.31	0.04	11.88	35	2.38	0	6.75	0.14	C_3S_1
Well, Coachella	1740	2.14	0.08	12.67	-	14.89	1.02	1.80	12.04	0.14	15.00	85	12.06	0	13.43	0.71	C_3S_3

* From "Estudio de Electrificación y Riego - Vol. 1 Sección de Riego", Guatemala, Sept.1962
\+ Estimated From Analysis

On the basis of the Salinity Laboratory Classification all 3 wells in La Fragua would rate as C_2S_1, indicating no sodium hazard. On the suggested rating scale, they would rate as #2 and #1 on EC, #2 and #5 on Na%, and #4 on Na_2CO_3. Some of the waters from the USA would rate worse on all factors except residual sodium carbonate for which all would rate #1. The primary difference, therefore, is that these well waters in La Fragua do have residual sodium carbonate in excessive amounts, and they probably should not have been considered as suitable for irrigation.

The water from the Laguna del Hoyo, as sampled in 1961, is also of questionable quality. However, after filling the Laguna with water from the Río Güirila a few times it may be satisfactory. Analyses of this water periodically is recommended.

Climate

The annual precipitation is estimated to average about 1770 mm and occurs mostly during the period May through October. The mean annual temperature is 27°C, with a minimum of 20°C and a maximum of 36°C. There are no official weather stations within the project area. The estimates given above were reported to have been interpolated from other stations. An inspection of the data from the low elevation climatological stations (elevation less than 50 meters) in the Departments of Retalhuleu and San Marcos for 1970 and 1971 would indicate that the mean annual precipitation would be somewhat less than the 1770 mm indicated in the report. The available precipiation data are as given in Table 4.

Table 4 - PRECIPITATION AT LOW ELEVATION STATIONS IN DEPARTMENTS RETALHULEU AND SAN MARCOS

Station		Tecún Umán	Los Limones	Champerico PHC	Champerico FEGUA	Agro Santa Sofía
Elevation m.		28	14	3	5	25
Apr.	70	41	--	5	0	--
	71	12	--	2	0	--
May	70	15	--	79	10	--
	71	133	--	95	15	--
June	70	199	--	289	93	--
	71	182	188	--	149	--
July	69	352	--	244	43	--
	71	277	270	--	130	140
Aug.	70	279	--	225	81	--
	71	366	259	--	107	--
Sept.	70	345	--	233	210	--
	71	287	315	--	109	249
Oct.	70	215	--	168	127	--
	71	29	--	309	6	386
Nov.	70	91	--	23	2	--
	71	60	29	2	10	15
Total	70	1537	--	1266	566	--
	71	1346	--	--	526	--
MEAN		1442			546	

Soils and Classification

The soils of the rea are classified mostly as silt and clay loams with some areas near the River as sandy loam. Some 92% of the 1800 hectares within the project is given a rating of Class 1. The remainder is Class 3 because it occupies old stream channels that lie at an elevation from 1 to 2 meters below the general ground level. In general these soils are well adapted to irrigation agriculture, having a suitable texture and water holding capacity. The principal problem will be with respect to drainage.

Topography

All of the area in the project lies at an elevation below about 16 meters above sea level. The area has very flat slopes in general, but there is some micro relief that may make irrigation by surface methods (furrow and flooding) somewhat difficult without appreciable land grading in many places.

Land Grading

The project plans call for parallel laterals spaced at 400 meters along property boundaries. To cover the highest areas without considerable land grading, these laterals will have to be built on embankments or berms of one meter or more in height in many places.

The writers believe that it would be better, if possible, to first make detailed topographic maps of the entire area at a scale of about 1:5,000 or 1:10,000 and having a contour interval of not more than 20 cm. From such maps the laterals could be laid out so as to follow contour grades with water levels in the canals only about 20 centimeters above the ground surface in most places. Likewise, the open drains could then follow natural low depressions where possible. The land could then be re-subdivided to conform with the irrigation and drainage channels with slightly variable areas, rather than into rectangular tracts that do not conform with the topography. Since the land is already in private ownership, however, this suggestion may not be practical; but where new land, not in private ownership, is to be brought under irrigation, this procedure is both most desirable and economical.

Heavy grading of most soils to achieve uniform slopes of desirable gradients is generally detrimental. It removes top soil in many places and exposes the less fertile and often compacted subsoils. The least amount of grading possible is generally most desirable, but for surface irrigation depressions must be filled and a somewhat uniform gradient in the direction of the run (border or furrows) must be achieved. Actually, however, a somewhat concave profile rather than a uniform gradient is most desirable from the standpoint of uniformity of application of water, with a nearly zero gradient at the lower end of the run.

Drainage Facilities

This project will undoubtedly require drainage facilities which should be provided to some minimum extent in the initial construction plans. Major open drains can often be located satisfactorily from detailed contour maps, considering also farm boundaries, roadways, and irrigation canals. In the La Blanca Project, some of the main drainage channels should follow and connect the old river channels where the soil surface is now from 1 to 2 meters below ground levels. This will save appreciably on excavation costs, but is not always feasible unless adjustments in farm boundaries and location of irrigation canals are also possible. Farms should not be bisected by deep drains except where absolutely necessary and considerable. savings in cost of excavation can thereby be achieved.

Although an open drainage network should be planned and constructed at an early date, the writers would not recommend the installation of a network of tile 1/ drains at this time.

1/ The term "tile" is used to include all types of buried tubing for subsurface drainage.

The need for, and required spacing of, such a system of tile drains can better be determined after the effectiveness of the open drains is better understood. The cost of anticipated tile drains should be estimated where possible, and funds for their construction should be provided and set aside for future use. In areas such as the Imperial Valley of California, tile drains are required at spacings of about 150 feet (50 meters) in most places. Such systems cost from $250 to $400 per hectare, using plastic drain tubing. This is in addition to the cost of a network of open drains spaced either one-half mile or one mile apart to serve as outlets for the tile drains. Drainage is expensive, but often absolutely essential to the success of an irrigation project.

Careful use of water based on a knowledge of actual evapotranspiration and continuous monitoring of the water table levels can often substantially reduce the cost of drainage by increasing the spacing of the drains. Drainage can often best be provided by scheduling the construction over a period of many years, constructing the most urgently needed drains first, and studying the effectiveness of each drain as it is excavated.

Water Requirements

According to the Project Report (Proyecto de Riego La Blanca, Abril, 1972) the water requirement has been estimated by the Blaney-Criddle formula (page 41). The computations in the table are apparently in error (the values of P, percent of daylight hours, are all incorrect for the latitude of the project). No values of the monthly K factors are given, but for 10 of the months they compute to be 0.96 using the corrected values of U.C. For June and July they compute to be 0.52 and 1.34. Hargreaves 1/ has estimated the potential evapotransporation at Champerico. A comparison of the U.C. values from the report, and Hargreaves' ETP values are given in Table 5. The Blaney-Criddle F values for the corrected P values are also given for comparison.

Table 5 - Comparison of Blaney-Criddle U.C. (La Blanca Report), Corrected Blaney-Criddle F Factors, and Hargreaves'ETP

Month	U.C. (B-C) mm	F mm	ETP (Harg.) mm	Month	U.C. (B-C) mm	F mm	ETP (Harg.) mm
Jan.	166	159	106	July	128	185	118
Feb.	166	149	98	Aug.	131	180	122
Mar.	143	176	125	Sept.	113	187	104
Apr.	134	178	129	Oct.	123	168	101
May	111	189	140	Nov.	153	156	94
June	95	180	121	Dec.	155	159	94
TOTAL					1618	2066	1352

1/ Personal communication from George H. Hargreaves, Utah State University, April,1972.

The comparisons show that for most of the months, Hargreaves' ETP is less than the reported values of UC. The exceptions were for May and June. Hargreaves' formula uses temperature, humidity, and theoretical radiation. The Blaney-Criddle formula uses theoretical radiation. The Blaney-Criddle formula uses theoretical day length and temperatures only. The corrected F factors multiplied by the proper K factor would give the correct UC for the Blaney-Criddle formula.

Table 4, page 42, of the aforementioned report, gives the estimated monthly water requirement as the difference between the reported mean monthly UC value and the precipitation. Our studies show that the probable precipitation that occurs 75 per cent of the time (3 years out of 4 years) is only about 50 to 70% of the mean monthly value. The mean monthly precipitation is not a reliable value for use in estimating irrigation water requirements.

Actual Need for Irrigation

There may be some questions as to the actual need for irrigation for most of the crops to be grown. Experience in Venezuela and Colombia indicates that when the mean annual rainfall exceeds about 1000 to 1500 mm and when it is distributed over 7 or 8 months, farmers generally do not want to irrigate during the dry season as they can grow one and sometimes two crops a year without irrigation. On one project in Venezuela for which irrigation water has been available for about 10 years, only about 15 per cent of the area is irrigated although no charge is made for the irrigation water. Another example is a project in Peru where less than 50 percent of the project areas was irrigated after about 10 years.

From the appearance of the crops now growing near the end of the dry season, it appears that the stored soil moisture has been sufficient for most crops including platanos, the major crop. Since there is a potential drainage problem in this area because of the flat terrain and relatively heavy soils, this problem could easily be aggravated by bringing water into the area and raising the water table during the dry season when it normally drops to its lowest level. It is believed that some caution should be exercised with respect to these problems, especially since the estimated rainfall and water requirements may be appreciably in error.

Pilot Project

A suggested alternative would be to delay construction of this project until the need for, and results from ,irrigation could be more accurately determined. This might be done by installing a pumping plant to pump water directly from the Rio Naranjo to irrigate from 100 to 200 hectares of mature platanos and other crops that might benefit from irrigation. The effects or irrigation on water table conditions as well as on production should be determined. Research of this kind over a period of 5 years or more should prove of great value in determining the actual need for irrigation and the economic feasibility of the project.

Irrigation of Rice

Rice is one of the crops that is proposed for the project. Rice would require irrigation, but it should not be planted in areas devoted to other crops. When rice fields are kept flooded, as is usual for rice culture, the water table rises to near the ground surface in adjacent fields. These fields often become saline due to increased evaporation from the wet soil surface, even where the irrigation water is of good quality. Examples of rather bad experiences in mixing rice with other crops have been seen in several countries including Perú and Spain. It is believed that if rice is to be grown, it should be grown only in the lowest part of the area nearest the coast. No other crops requiring an aerated root zone should be grown in this area. Only limited drainage is required for rice and then only to control salinity.

MONJAS PROJECT

Brief Description

Location -

This is a small project to irrigate about 450 Hectares. It is located about 70 km. due east of Guatemala City in the Department of Jalapa. The project lies at an approximate latitude of 14°29'N, and longitude 89°52'W. It is approximately 3 km south of Monjas.

Water Supply -

During the rainy season water is diverted from the Río Güirila and the Quebrada Quintanilla through a concrete lined canal 3.7 km in length to the Laguna del Hoyo, a volcanic crater. The water passes through a tunnel at an elevation of about 977 meters above sea level. The original water level in the Laguna has been used as elevation 958.5, which corresponds with the level recorded on May 4, 1965. Records indicate that the natural level fluctuated from 958.5 in May 1965 to 964 in June 1967 with peaks in Oct. 1965 and Sept. 1966 of 964 and 973, respectively. Storage is from elevation 959 to 976. When water is needed for irrigation during the dry season, it is pumped to the tunnel entrance in the crater by 1 to 4 pumps mounted on a float. The water flows by gravity to the distribution system which consists of two main canals, the Canal Norte and the Canal Este. Each canal has several concrete lined laterals.

Soils -

Of the 450 hectares within the project area 67% have been defined as being composed of Class I soils and the remaining 33% as Class III. The Class I soils are generally deep with a medium to fine texture. Because of the volcanic origin of these soils, the structure is very granular and they are very permeable to surface water.

The Class III soils are generally lower in surface elevation than the Class I soils. These soils are also medium to fine textured (clay to clay loam), but have a much more impermeable structure. They are relatively shallow (35 cm.) underlain by a heavy clay layer. In the Class III area poor surface drainage generally exists and the water table is closer to the surface.

Drainage Conditions -

One of the principal problems at this project is the high water table in the lower part of the irrigated area. The natural drainage from the area is through the Quebrada Quintanilla which joins the Río Güirila just south of Monjas. The Quebrada Quintanilla and its tributaries which originate in the project area are very shallow and when the area was visited on April 19, 1972, the water was at the ground surface in the natural drainage channels at the lower part of the area to be irrigated.

Climate -

There are no climatological stations in the project area or the vicinity of Monjas. The report entitled "Laguna del Hoyo" gives the monthly rainfall as varying from zero for January through April, then increasing from 24 mm for May to 126 mm for September, then decreasing to 3 and 5 mm for November and December with an annual total of 498 mm. At La Ceibita, which is reported to be at latitude 14°30'N and longitude 89°52'W with an elevation of 961, the total precipitation for 1971 was 1151 mm. There appears to be a question as to whether the reported location or elevation of this station is correct, and whether this station is near the Monjas project. The mean annual temperature is reported to be 21.2°C with low of 19.5° for December and January and a high of 22.5°C for April.

Ground Water Levels -

Beginning on November 2, 1971, the water levels have been measured daily in 30 farm-house wells in and along the eastern border of the project. These measurements have been continued until the present time, but records are available only until March 31, 1972. In general, the water levels were highest at the beginning of this period, November 2, and have declined more or less steadily since then. Some of the wells appear to have been pumped for short periods, and a few appear to have been affected slightly by the irrigation of nearby fields.

The water level measurements are summarized in Table 6. There appears to be no defined relationship between the water level elevation in the Laguna del Hoyo and the ground water levels. The water level in the Laguna rose steadily until October 15 when it reached a maximum level of 17.0 meters above the datum then declined steadily until March 31. The pumping from the Laguna appeared to have only a minor effect on the rate of drop of the water level in the Laguna.

Water Quality -

The quality of the irrigation water for the Monjas project was reported in the consultants report entitled, "Estudio de Electrificación y Riego", República de Guatemala, Sept. 1962. They give analyses for the Laguna del Hoyo, Río Güirila, the Quebrada Quintanilla, Río El Ovejero, Nacimiento Río Ovejero, Ojo de Agua and 11 pozos. According to the Salinity Laboratory classification all of these waters would rate as C_1S_1, C_2S_1, or C_3S_1

Table 6 **Depth to Water Levels below Ground Surface**

Well No.	Depth to Water Table, Meters					
	1971		1972			
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	2-21	1-31	1-31	1-29	1-31	
1	3.7-4.2	3.9-4.2	4.3-4.5	4.5-4.4	4.4-4.5	
2	1.2-1.7	1.8-2.1	1.9-2.1	1.9-2.1	2.1-2.2	
3	3.8-4.2	4.3-4.8	3.7-4.5	4.6-5.3	5.2-5.5	
4	2.1-2.6	3.1-3.5	3.8-4.1	4.0-4.4	4.3-4.6	
5	2.2-2.7	3.1-3.4	3.7-4.0	3.9-4.1	4.1-4.3	
6	3.6-3.8	4.4-4.0	4.0-4.9	4.9-5.1	5.1-5.3	
7	5.8-6.5	6.4-6.8	6.8-7.0	6.8-6.3	6.4-6.7	
8	6.0-6.3	6.4-6.9	6.8-7.0	6.8-7.1	7.1-7.3	
9	5.3-6.0	5.9-6.4	6.5-6.6	6.6-6.9	6.9-7.0	
10	2.2-5.7	5.9-6.2	5.5-6.8	5.4-5.5	5.5-5.8-6.7	
11	4.0-4.8	4.9-5.2	5.3-5.8	5.8-6.0	6.0-6.3	
12	1.0-1.3	1.4-2.1	2.1-2.6	2.6-2.9	2.9-3.1	
13	1.0-1.2	1.4-1.9	1.9-2.3	2.3-2.7	2.4-2.7	
14	0.9-1.2	1.3-1.9	1.9-2.3	2.2-2.4	2.4-2.6	
15	1.1-1.3	1.8-2.0	2.0-2.2	2.2-2.5	2.4-2.6	
16	0.8-1.2	1.4-1.9	2.0-2.1	2.0-2.2	2.1-2.3	
17	0.6-1.0	1.2-1.5	1.5-1.9	1.7-2.0	2.0-2.2	
18	0.9-1.2	1.3-1.5	1.5-1.8	1.8-2.0	1.8-2.2	
19	0.9-1.1	1.3-1.5	1.7-1.7	1.7-2.0	2.0-1.8-2.0	
20	1.0-1.1	1.4-1.8	1.8-1.9	1.9-2.1	2.0-1.6-1.9	
21	0.9-1.2	1.7-1.8	1.8-2.6	2.5-1.2	1.3-2.3	
22	0.9-1.2	1.3-1.5	1.5-1.7	1.6-1.9	1.9-1.7	
23	1.0-1.7	1.3-1.5	1.5-1.7	1.7-1.9	1.9-1.8	
24	1.0-1.3	1.5-1.8	1.7-2.0	1.9-2.0	2.0-2.3	
25	0.9-1.2	1.5-1.8	1.7-2.0	1.9-2.1	2.0-2.3	
26	0.3-0.7	0.8-1.0	1.0-1.2	1.1-1.3	2.1-1.0	
27	0.4-0.8	0.8-1.0	1.0-1.2	1.2-1.3	1.2-1.0	
28	0.2-0.4	0.6-0.8	0.8-0.9	0.9-1.0	1.0-1.0	
29	0.3-0.7	0.7-0.9	0.9-1.1	1.0-1.2	1.1-1.2	
30	0.1-0.5	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0	
Laguna del Hoyo*						
Elev. above datum on first day of month	16.1	14.1	11.9	9.8	7.4	5.3

*Levels rose steadily from 4.5 on July 11 to maximum of 17.0 on October 15, then began declining.

with only 2 wells in the latter classification. They would presumably all be acceptable waters for irrigation, but upon closer examination, it appears that they all contain some residual sodium carbonate and some have high sodium percentages. Five of these analyses are given in Table 3 under the general section on Water Quality. According to the suggested rating scale (also found in the aforementioned section), the water from the Laguna del Hoyo would rate as 4 on Na% and residual sodium carbonate. Wells 10 and 15 would rate as 1 or 2 and 2 or 3 on these same factors. The water from the Río Güirila, the main source of supply for the project, is of excellent quality rating a 1 on all factors considered. It appears that when this water is mixed with the water in the Laguna del Hoyo for a few years, the mixed water pumped from the Laguna may be entirely satisfactory. The water pumped from the Laguna should be sampled periodically and analyzed to determine the Na% and residual sodium carbonate, Na_2CO_3.

Water samples were collected from three wells within the project area and their conductance measurements indicated a range of 275 to 310 micromhos which would indicate a satisfactory water from the standpoint of total salinity. Complete analyses were to be made on these samples but the results are not yet available.

Ground Water Development -

Ground water development in the Monjas area may provide a solution to the drainage problem and provide water for additional land that is suitable for irrigation. It is understood that more than 1,000 hectares of additional land could be irrigated if a water supply were available.

Before any decision with respect to the development of ground water is made two factors should be carefully considered: the quality and suitability of the pumped water for irrigation, and the cost of pumped water on a unit basis(per m^3) compared with the total cost of surface water on the same unit basis. Costs and benefits for drainage should be included in the above analysis for both sources of water.

As noted in the section on Water Quality, some of the shallow wells tested had questionable amounts of residual sodium carbonate and fairly high sodium percentages. The water from shallow wells may not be representative of water pumped from deep wells. A test well should be drilled, and after pumping for some time, the water should be sampled and completely analyzed, especially for sodium percentage and residual sodium carbonate.

This well should be pumped with a test pump to determine its specific capacity, the discharge divided by the drawdown. Such a test should be made at several flow rates after the well has been pumped for several days. The effect of the pumping on the water levels in nearby wells, or in especially installed ground water observation wells, should be noted. The discharge should be plotted against the drawdown to establish a well capacity curve. Such a curve is often a straight line relationship, but for some formations the drawdown increases more rapidly than the discharge. From these data, together with the cost of drilling and the cost of pumping equipment, the optimum pumping level can be determined and the actual cost of pumped water can be estimated. The economics of pumping water should be carefully studied before final decisions are made with respect to drilling additional wells.

Drainage -

From the ground water well records it appears that the lower part of the area has a very high water table at the end of the rainy season, less than 0.5 meter in some places. For irrigated areas, it is generally considered beneficial to keep water table levels below 2 meters where salinity may be a problem and below 1 or 1.5 meters where the rainfall is adequate to prevent a build up of soluble salts in the soil.

From general observations which indicate that the soils are quite permeable, it is believed that considerable benefit could be obtained by deepening the natural drainage channels that extend into the area. These include the Quebrada Quintanilla and some tributaries. The depth to which these channels might be deepened will depend on the outlet elevation at the Rio Güirila near Monjas. A depth of 1.5 to 2.0 meters below the general ground level would be desirable, and these channels should have a gradient of 50 cm per kilometer or more, if possible. From the Topographic map it would appear that four channels might be extended into the area from the North. No consideration need be given to the required spacing of additional open or tile drains until the effectiveness of the deepening of the natural channels has been determined. It appears likely that these deepened channels may satisfactorily control the water table.

ATESCATEMPA PROJECT

General Description and Location -

This project is located in the south east part of Guatemala near the El Salvador border south of Laguna Atescatempa. It includes about 300 hectares to be irrigated from a diversion on the Río Atescatempa. A concrete diversion dam with an overflow spillway diverts the water into a concrete lined canal 1.23 Km. in length with concrete lined laterals totaling 7.93 Km. in length. One 8" well 118 feet deep has been drilled along the canal to supplement the flow from the river when required. This well has not yet been equipped with a pump. The construction is otherwise complete and the system has been used to a limited extent during the past dry season.

Soils and Topography -

The soils range from sandy loam to clay loam near the Laguna. The topography is fairly uniform with the steeper slopes near the canal, flattening to very low slopes nearer the Laguna. The water level in the Laguna is now at a higher than normal level due to excessive precipitation and runoff during the last rainy season. Consequently, some of the project area is submerged or in a swampy condition.

Some additional area above the canal might possibly be irrigated from wells if the economics of such a development prove feasible, and the quality of the ground water is satisfactory. One farm above the canal was being irrigated from a spring and there was an excellent crop of peppers.

Drainage Conditions -

It would appear that because of the available slopes and soil conditions, that the area nearest the canal would have sufficient natural drainage if the water was used conservatively. The flatter land nearer the Laguna would be difficult to drain by any means because it is subject to overflow at times and there would be no natural outlet other than the lake. The water table levels could not be lowered economically below the lake level as levees and pumping would otherwise be required and the cost would be prohibitive for such a small area.

The best apparent solution would be to use the lower areas for crops requiring a minimum of drainage such as pasture and possibly rice, and to use the better drained soils for the other crops.

Groundwater Development -

Before decisions are made to develop an additional area by supplying water from wells, the well already drilled should be tested to determine its economic capacity. Also, the quality of the ground water should be thoroughly examined, especially with respect to the sodium percentage and residual sodium carbonate.

Samples of the water from the Río Atescatempa and from the Laguna were collected and conductance measurements were made in the field. They showed a range of from 220 to 260 micromhos which indicates excellent quality with respect to salinity. Results of chemical analyses are not yet available, but most surface waters have been found to be entirely satisfactory and it is assumed that this will be the case here.

CABAÑAS - ANTOMBRAN - REFORMA PROJECT

Description and Location

This project is located in the Department of Zacapa on the south bank of the Río Motagua at a latitude of 14°58'N and longitude 89°45'W. It extends from 1 km. west of Cabañas eastward for a distance of about 14 kms. to the vicinity of San José. The elevation is about 250 meters above sea level. It has an area of 1,000 hectares.

Climate

The climate might be described as hot and semi-arid. The mean annual temperature is reported to be 30°C, and the annual precipitation 980 mm with most of it occurring during the months June to September. The highest temperatures occur during March, April and May and the minimum during December and January. There are no official climatological stations within the project area.

At La Fragua, about 20 kms east of Cabañas, the mean annual precipitation was 720 mm., and the mean temperature 26.8° for a 5 year period of record. The mean wind velocity was about 12 kms. per hour for January through May, which is higher than for most of Guatemala. The mean relative humidity ranges from a low of 61 percent for March to 73 percent for July with a mean annual value of 66 percent.

Soils

The soils are highly variable with medium textures dominant. Some of the soils are stoney. The permeabilities of the soils are variable but most of them appear to be satisfactory for irrigation.

Forty percent of the soils are given a rating of Class 1, 20% Class 2, and 40% Class 3. The soils have been carefully mapped and laboratory tests conducted on a large number of samples to depths of 150 cm.

Topography

The topography is variable. The area lying below the main canal is quite flat and appears to be well suited for irrigation. The area served by the upper canal, which is approximately 35 meters above the lower canal, is more variable. The areas selected for irrigation in the upper section have slopes of less than 1.5 percent.

Drainage Conditions

From our observations, it appears that most of the area would have fair to good natural drainage. Some of the lower areas may require drainage facilities. If heavy applications of water are made on the upper terraces, it may have a detrimental effect on the water table conditions in the lower areas. There appears to be no water table data available. Since very little of the area has been irrigated, high water table conditions should not be expected at this time although they may occur in some places after irrigation begins.

Water Supply -

The water supply is from a gravity diversion from the Río Motagua about 2 km west of Cabañas. The water is diverted into a tunnel which extends across the flood plain into a concrete lined canal with a capacity of about 1.8 m^3 per second.

Data on the quality of this water have not been inspected, but from a general knowledge of the quality of water from the larger rivers, it is believed that this water is of excellent quality and would rate #1 for all factors.

Some of the land within the project has been irrigated from one or more deep wells. The quality of this water is questionable from the standpoint of sodium percentage and residual sodium carbonate, and it may have had a detrimental effect on the permeability of the soils irrigated.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS --

General -

No attempt is made here to evaluate the economic feasibility of any of the projects visited. Rather, the objective has been to point out some of the problems that have occurred, or may occur, especially with respect to salinity and the formation of sodic soils. Some questions have been raised with respect to the economic feasibility of projects where there appears to be ample or excessive precipitation for a period of 7 months or more. Some additional research on this problem is suggested.

Water Quality -

Data available on the quality of waters used, or to be used, for irrigation indicate that:

1. Surface supplies from rivers are of good quality with respect to overall salinity, but some may have small amounts of residual sodium carbonate. In no instance were excessive amounts found in surface water samples.

2. Groundwaters generally had questionable amounts of residual sodium carbonate and often relatively high sodium percentages. From the standpoint of total salinity, they were of good to fair quality, and were rated C_2C_1 according to the Salinity Laboratory classification. The detrimental effects of residual sodium carbonate and high sodium percentages were apparently

overlooked in all reports examined.

Development of Ground Water Supplies -

Consideration has been given by the Ministry to the development of ground water supplies in some projects to supplement surface supplies and enlarge the projects to include additional areas that might be irrigated. This would be highly desirable if the ground water was found to be of acceptable quality, but such developments should not be undertaken until the question of quality is fully resolved.

Another factor that should be thoroughly investigated with respect to ground water development is the comparative economic feasibility of such developments. Ideally, in any irrigation project if ground water is of good quality, and where wells of satisfactory capacity can be obtained, the ground water should be developed to the extent of controlling the water table and eliminating high water table conditions. This, in most cases, completely solves the drainage problem by providing better drainage than can be obtained with open and tile drains. At the same time, this provides additional water for irrigation.

The important points to be thoroughly investigated before decisions are made to develop ground water for either additional water supplies or drainage are:

1. The quality of the water as previously discussed.

2. The availability of suitable aquifers from which water can be pumped economically. This involves drilling test wells to determine:
   (a) The discharge-drawdown relationships.
   (b) The unit cost of pumped water as compared with surface supplies, on a unit volume basis, considering all costs involved.
   (c) The unit cost of pumped water as compared with the cost of removing excess water from an area by means of open and tile drains.

In many places it has been found that it is more economical to pump water from wells for both irrigation and drainage than to use only surface supplies and conventional drainage systems.

Water Table Studies -

Consideration should be given to procedures for measuring the depth to the water table in projects where drainage is or may be required. Suggestions are made for the installation of observation wells and for the measurement and presentation of the data required. Such data are essential to the understanding of, and the solution of, drainage and salinity problems.

Salinity and Sodic Problems -

Salinity in irrigation projects almost always results from inadequate drainage and the evaporation of water from the wet areas where the water table is near the ground surface. Salinity conditions are exaggerated where the irrigation water is of poor quality with respect to total salt concentrations as indicated by conductance measurements. In the absence of adequate drainage, sodic conditions result when the irrigation water contains residual sodium carbonate. Dispersed soils and low infiltration rates may result from high sodium percentages, even though residual sodium carbonate may not be present.

Drainage Systems -

Good drainage, as evaluated by the maintenance of the water table at a depth of 1.5 meters or more below the soils surface, is especially important when the irrigation water is of poor or questionable quality, or where annual precipitation is less than 1000 mm per year.

When the water table is not maintained at such a depth below the surface by natural drainage and the evapotranspiration from the area, a drainage system should be provided. Consideration should always be given to pumped wells, but in many instances this is not feasible for reasons mentioned previously, and open drains and/or combinations of open and tile drains must be used. Because of the highly variable permeability of soils from place to place, it is necessary to obtain adequate information on the effectiveness of drains before proceeding with a design of a drainage system.

The topography of an area, and available outlets for the drains, will suggest where one or more main drains should be located. These drains should be excavated and used to determine the effectiveness of such drains before decisions with respect to depth and spacings can be decided intelligently. The use of properly located observation wells is essential in such drainage studies. Special technical assistance may be reqired for these studies.

Engineering Procedures and Accuracy of Data and Reports -

In the study of data and perusal of reports many errors have been noted. Good engineering procedures require that all calculations be checked independently by another engineer. He will watch especially for inconsistencies in the data and errors in computations.

Errors in readings of water levels and electric meters have been noted. Some additional training of personnel assigned to this work would be helpful. Their notes should be carefully checked by the supervisory staff and inconsistencies and possible errors called to their attention. Incorrect data are often worse than no data. Typed copies of all data and reports should be carefully proofread before being released.

Increasing Competence of Engineering and Technical Personnel -

Because of the short period that the Guatemalan Government has been engaged in the development of water and soils resources through irrigation and drainage, the engineering and technical staff, in most instances, have had rather limited practical experience. The competence of the staff might be increased through implementing any or all of the following suggestions:

1. Obtain the services, for a period of two years or more, of an engineering advisor experienced in the planning, design, and construction of farm irrigation and drainage systems as well as development of land for irrigation. Such an engineer should, preferably, have had experience in Latin America and should speak Spanish. Experience of the kind one might have gained with the U.S. Soil Conservation Service would be highly desirable. Such an advisor should work closely with counterparts assigned to him and provide training.

2. Send engineering and soils personnel to study outside of Guatemala for advanced degrees. Consideration should be given to available programs in other Latin American countries in addition to those available in the United States and Europe.

3. Send participants to international and/or national short courses on water resource development including irrigation and drainage. Such courses have been offered by CIDIAT in Venezuela and other countries.

4. Request the assistance of USAID, FAO, OAS, CIDIAT, or other such organizations in the planning and presentation of short courses on specific subject matter in Guatemala.

5. Provide counterparts to work with all foreign professionals that are assigned to work in Guatemala by agencies such as those mentioned above.

Meterological Stations -

In some of the areas or valleys where projects are located, there are either no meterological stations, or only limited data such as precipitation are being collected. Efforts should be made to establish adequate climatic stations in these areas. Cooperation of the World Meterological Organization might be requested. The basic information collected should include temperature (mean, maximum, and minimum), relative humidity, wind velocities at a specified height above ground level, hours of sunshine and/or incoming solar radiation, and evaporation with a Class A pan and/or evaporimeter of the Wild type, such as the Fuess evaporimeter.

Pilot Projects and Research and Demonstration Stations -

In some areas there are special problems that need research or special study before the project should be approved for construction, or before the fullest use can be made of the irrigation facilities provided.

The use of pilot projects and/or research and demonstration stations to thoroughly study such problems before final decisions are made would be advisable in some instances. For example: Are irrigation projects in some areas with annual precipitation in excess of 1000 to 1200 mm per year economically justified on the basis of the benefit to be obtained? Will irrigation in such areas increase the drainage problems, and will the available irrigation water be used by the farmers? A pilot project using water pumped from a nearby river might answer some of these questions before large sums are spent to construct a system requiring storage and/or expensive diversion dams and distribution systems.

In some areas where the construction is completed or underway, there may be problems that can only be solved through the establishment of a pilot project and/or research or demonstration stations. Such projects or stations need be set up only where there are known to be specific needs for them.

Operation and Management of Irrigation and Drainage Systems -

No matter how well designed and constructed, an irrigation system will not prove successful unless it is properly managed and maintained.

Adequate maintenance of irrigation and drainage systems is very often lacking because of issuficient funds and a lack of understanding of the importance of good maintenance.

The manager of such a project faces many problems and he should be given training and assistance in carrying out his duties. Records must be kept of the water diverted from the streams and delivered to the farmers. This requires the construction and use of suitable water-measuring devices, a certain amount of record-keeping, and the analyses of these records by supervisory personnel.

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