A STUDY OF THE TINAJONES WATER SYSTEM, LAMBAYEQUE - PERU */

Summary

*/ This report was prepared by Mr. Julio Guerra Tovar, Consultant for the project on horizontal co-operation in the management of water resources in Latin America and the Caribbean, financed by the Government of the Federal Republic of Germany. The views expressed in this report are the author's and may not agree with those of the organization.

87-10-1479
 CONTENTS

I. BACKGROUND AND PHYSICAL, SOCIAL AND ECONOMIC FEATURES
   OF THE AREA COMPRISING THE TINAJONES WATER SYSTEM ............... 1
   A. BACKGROUND ......................................................... 1
   B. THE CHANCAY BASIN ............................................... 1
   C. CLIMATE .............................................................. 3
   D. SOILS .................................................................. 4
   E. TOPOGRAPHY .......................................................... 4
   F. VEGETATION ............................................................ 4
   G. WATER RESOURCES .................................................. 5
   H. POPULATION, SOCIAL INFRASTRUCTURE AND SERVICES .......... 6
   I. AGRARIAN STRUCTURE, LAND TENANCY AND SIZE OF
      AGRICULTURAL UNITS .............................................. 6
   J. IMPORTANCE OF AGRARIAN ACTIVITY IN LAMBAYEQUE AND
      IN THE NATIONAL ECONOMY ...................................... 7
   K. CURRENT AND POTENTIAL LAND USE IN THE TINAJONES SYSTEM 7
   L. INFRASTRUCTURE FOR AGRICULTURAL PRODUCTION .......... 8
   M. AGROINDUSTRY ....................................................... 9
   N. OTHER ECONOMIC ACTIVITIES .................................... 9

II. DESCRIPTION OF THE MAIN WORKS IN THE TINAJONES WATER SYSTEM ..... 10
   A. TECHNICAL FEATURES OF FIRST-STAGE WORKS .................... 10
      1. Impoundment, channelling and storage .......................... 10
      2. Distribution system .............................................. 11
      3. Drainage works .................................................... 13
   B. REMODELING OF THE IRRIGATION DISTRIBUTION SYSTEM -
      RURAL REORGANIZATION: THE LUXFAQUE PROJECT .............. 13
   C. COST, FINANCING, TIME LIMITS, EXECUTING AGENCY AND
      INTERNATIONAL TECHNICAL CO-OPERATION .................... 14
   D. SECOND-STAGE WORKS .............................................. 14

III. ADMINISTRATION OF THE WATER SYSTEM ................................. 15
   A. OPERATION AND MAINTENANCE OF THE SYSTEM ...................... 15
      1. Planning, use and control of water resources ............... 15
      2. The irrigation district ......................................... 15
      3. Sectorization of the Chancay-Lambayeque
         irrigation district ........................................... 16
      4. Agricultural use register of irrigation subscribers .......... 17
      5. Organization of users ......................................... 17
      6. Cultivation and irrigation plans .............................. 18
      7. Monitoring the distribution and use of water resources .... 19
      8. Water rates ...................................................... 19
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Maintenance and conservation of the water system</td>
<td>20</td>
</tr>
<tr>
<td>10. Public institutions concerned with services</td>
<td>21</td>
</tr>
<tr>
<td>11. Main duties of national, regional and local bodies</td>
<td>22</td>
</tr>
<tr>
<td>B. FINANCIAL RESOURCES OF THE WATER SYSTEM</td>
<td>23</td>
</tr>
<tr>
<td>1. Central government financing for operation and maintenance</td>
<td>23</td>
</tr>
<tr>
<td>2. Amount of water rate and fees</td>
<td>24</td>
</tr>
<tr>
<td>IV. EVALUATION OF THE SYSTEM</td>
<td>25</td>
</tr>
<tr>
<td>A. PHYSICAL ASPECTS OF WORKS</td>
<td>25</td>
</tr>
<tr>
<td>1. Degree of compliance with goals</td>
<td>25</td>
</tr>
<tr>
<td>2. Critical analysis of execution</td>
<td>26</td>
</tr>
<tr>
<td>B. ECONOMIC, SOCIAL AND ENVIRONMENTAL ASPECTS</td>
<td>27</td>
</tr>
<tr>
<td>1. Contribution towards increasing production and productivity</td>
<td>27</td>
</tr>
<tr>
<td>2. Employment</td>
<td>28</td>
</tr>
<tr>
<td>3. Salinization of land</td>
<td>28</td>
</tr>
<tr>
<td>C. OPERATION AND MAINTENANCE</td>
<td>29</td>
</tr>
<tr>
<td>1. Critical analysis of operation and maintenance</td>
<td>29</td>
</tr>
<tr>
<td>V. CONCLUSIONS</td>
<td>37</td>
</tr>
<tr>
<td>VI. RECOMMENDATIONS</td>
<td>40</td>
</tr>
</tbody>
</table>
I. BACKGROUND AND PHYSICAL, SOCIAL AND ECONOMIC FEATURES OF THE AREA COMPRISING THE TINAJONES WATER SYSTEM

A. BACKGROUND

The system is located in the southern coastal area of Peru, in the department of Lambayeque (figure 1).

The valley known as Chancay-Lambayeque is one of the oldest human settlements in Peru. It saw the growth of the prosperous Mochica culture, which practiced intensive irrigation agriculture. This culture, the Chimú culture in the north, and those of Nazca and Paracas in the south represented the poles of political, economic and social development on the Peruvian coast during the pre-Inca (from the third to the thirteenth centuries, A.D.) and Inca periods.

The Spanish conquest and colonization radically changed the course of the economy. From an internal agrarian economy, the region turned to mining for export, and many of the irrigation systems used by the pre-Columbian cultures were abandoned, leading to the decline of the Mochica culture.

Like most of the valleys on the Peruvian coast, Chancay-Lambayeque is subject to the irregular and unseasonable flow of its rivers, which make agriculture an unpredictable economic activity, due to the alternation of wet and dry seasons. This led the Peruvian Government, in 1964, to declare it necessary and in the public interest to execute the Tinajones project, which was designed to improve irrigation on approximately 100,000 ha of arable land by harnessing the Chancay and Chotano rivers and the waters obtained from the Conchano and Llaucano rivers and their tributaries.

B. THE CHANCAY BASIN

This basin covers an area of 5,139 km2, and is located in the departments of Lambayeque and Cajamarca (Chota province).
The Chancay river, on the Pacific watershed, has an irregular course and is made up of the Tacamache and Perlamayo rivers, which have their source in the western Andes range. It is about 170 km long and receives the waters of the Cañar, San Lorenzo, Cirato and Cumbil rivers, among others.

The irrigated area is in the lower and middle section of the basin, at altitudes of between 0 and 150 m above sea level.

The canals and storage facilities and the irrigation and drainage system are in the provinces of Chiclayo, Ferreñafe and Lambayeque.

The Conchano and Chotano rivers, in the department of Cajamarca, Chota and Huálgayoc provinces, are on the Atlantic watershed, at altitudes of between 2 000 and 3 000 m above sea level.

C. CLIMATE

The basin has a variable climate. In the lower section —on the coast— the climate is arid, and is influenced by the cold sea currents (the Humboldt current) which act as regulators of meteorological phenomena.

The annual average temperature is 22° C, ranging between 25° C and 18° C; the extremes go as high as 35° C and as low as 10.5° C.

South and southeast winds are predominant; they are of moderate intensity and cause the relative humidity to reach an annual average of 72%, with a range between 93% and 58%.

Precipitation is minimal; the annual value is lower than 50 mm. Rainfall occurs during the summer.

The El Niño current, which causes increases in temperature and precipitation and damage to agriculture and to the population, occurs at intervals of between 3 and 7 years.

In the upper section of the basin, which has an altitude of over 2 000 m and a broken terrain, the climate is temperate, the temperatures are lower, and the streams flow through sheltered valleys. The days are sunny and warm and the nights cold, except in summer, when there is an increase in cloudiness and relative humidity. The average annual temperature is 17° C; the maximum is 22° C and the minimum, 11.6° C. Precipitation occurs between October and April; March has the highest precipitation (128 mm) and July and August, the lowest (23 mm); average annual precipitation is 680 mm.
All the soils in the valley are azonal, and have two distinct origins: the young alluvial soils account for 96.9% of the area, and aeolian soils cover 3.1%.

The alluvial soils are stratified but do not show edaphogenetic development. They are characterized by great stratigraphic disorder, with sedimentation or sitting on top, caused by flooding and irrigation, consisting of moderately fine or fine calcareous materials. The soils vary considerably in depth and texture, from light and superficial to deep and heavy.

The aeolian soils show a profile composed of non-consolidated marine sediments from the Quaternary; they also contain materials carried by the wind. These are skeletal soils.

The area which is amenable to irrigation covers 116,259 ha; of this total, 6% of the soils are coarse, 36% are of medium texture, 45% are fine and 13% are of variable texture with an impermeable clay top layer.

The phreatic level of the soil is under 1.60 m; 13% of the soils have a high phreatic level, between 0.50 m and 1.50 m.

In this valley, 15.7% of the soils are very amenable to irrigation (class I), 47.4% are moderately amenable (class II), 18.1% are not very amenable to irrigation. The remainder of the lands are not very amenable to irrigation (15.6%) or are not arable (3.2%).

E. TOPOGRAPHY

The land slopes very little; 82% of the surface is flat or almost flat, with a grade of between 0.1% and 2%, while 17% of the land has a slight grade of between 2.1% and 5%.

As regards microtopography or microrelief, most of the land is flat; less than 0.5% of the surface is slightly broken and less than 0.2% is hilly.

F. VEGETATION

The predominant ecological formation in the lower part of the basin is sub-tropical desert, which is typical of the Peruvian coast.
In the sub-tropical desert-weed formation, at between 200 and 1,000 m above sea level, there are associations of Cereus, Malocactus and opuntia. The humidity of the subsoil causes the growth of perhumid edaphic associations, usually Acacia, Salix, Schinus, Caesalpina and Tessaria. Along the banks of rivers and streams there are associations of woody grasses such as Paredas grass (Bynerium and Cortaderia).

In the area of Chiclayo, the secondary influence of the coastal fogs and drizzle in winter and spring, and the summer rains in the high Andes, lead to the formation of sub-tropical thorny forests, in transition with the sub-tropical desert-weed formation. The predominant vegetation is mesquite (Prosopis juliflora), acacia (Acacia macrocantha), gum (Tabebus sp.) and huautaco (Loxopterygicmu huasango).

In the upper part of the basin, at 2,000 m above sea level, the vegetation is that typical of a savannah, with small shrubs and trees and seasonal grass. The predominant species are caesalpiniaceae plants (Caesalpinia tinctoria), Brazilian rosewood (Jacaranda sp.), acacia (Acacia sp.) and some cacti.

G. WATER RESOURCES

The water resources consist of surface waters of pluvial origin, from the Chancay, Chotano and Conchano rivers; underground waters and surface waters produced by recuperation.

The level of the rivers varies considerably, as it is markedly influenced by the seasons; the greatest percentage of their total volume is concentrated in the period between February and May. The water source is rain. The quality of water is good, as they are free of boron; the risk of sodium is low; salinity level is between low and medium; sedimentation (Chancay) is approximately 500 ppm. Over 90% of the waters are used for agricultural purposes.

There are nearly 500 wells, which produce 150 million m³ per year, 90% of which is used for irrigation. It is estimated that in a normal year, the water resources of the system amount to 1 billion m³.
H. POPULATION, SOCIAL INFRASTRUCTURE AND SERVICES

Lambayeque is one of the ten most populated departments of Peru; the population almost doubled over a period of 20 years. In 1985, the population was 803,500, and the Tinajones system accounted for 92% of this total.

The annual population growth rate is 3%. The urbanization process is proceeding at a fast pace. In 1981, 76.9% of the population lived in urban areas and 23.1%, in rural areas.

The agricultural economic population is the most important and largest, 29%.

The illiteracy rate is 13.5%; in the urban areas, it is 12.9% and in the rural areas, 41.1%.

The social infrastructure (health, education and housing) in the urban area is generally acceptable, while in the rural areas it is deficient. Potable water, sewer and electric power services have serious deficiencies. In 1981, about 60% of the population had access to one or other public utility, while the remainder had none. Most of this group lived in the rural areas.

The high rate of population growth and urbanization has led to the appearance, in the last few decades, of a large number of shantytowns and the proliferation of slums.

I. AGRARIAN STRUCTURE, LAND TENANCY AND SIZE OF AGRICULTURAL UNITS

Before the enactment of the General Agrarian Reform Act, a few individuals owned most of the land, which was concentrated in the haciendas or latifundios. The Pomalca, Patapo-Pucala and Tuman sugar corporations were typical of this form of land tenancy.

With the application of the Act, from 24 June 1968 onwards, substantial changes took place in the size and ownership of land. The large holdings disappeared, and the number of individual owners and minifundio holders increased.

In 1976, there were a total of 9,711 agricultural units in an area of 89,586 ha.

Holdings known as minifundios, i.e., farms of less than 3 ha, account for 55.8% of all holdings and 9.1% of the total land area of the valley.
Small holdings—with areas of between 3 and 15 ha—account for 41.2% of all units and 29.6% of the total area of the valley.

Medium-sized holdings—between 15 and 100 ha—account for 2.6% of all units and 11.2% of the total area.

"Associative enterprises", ranging in size from 66 to 13 800 ha account for 0.4% of all units and 50.2% of the total land area of the valley.

J. IMPORTANCE OF AGRARIAN ACTIVITY IN LAMBAYEQUE AND IN THE NATIONAL ECONOMY

The total cultivated area of Peru is estimated (CONARN, 1982) at 2.7 million ha, which represents 2.1% of the total area of the country; about 1.1 million ha are under irrigation. The coastal region, with an area of 760 000 ha represents the largest irrigated area. Modern agriculture is practiced in the 52 valleys which cross the coastal desert, with the production of cash crops such as cotton, sugar cane, rice, maize, potatoes, legumes and a variety of vegetable and fruit crops. More than 40% of the gross value of agricultural production is generated in this region.

There are four valleys in Lambayeque: Motupe-Olmos, La Leche, Chancay-Lambayeque and Zaña. Taken together, they represent a cultivated area of over 148 000 ha. Chancay-Lambayeque, i.e., the Tinajones water system, has an area of over 97 000 ha, or 65.5% of the area of the department and 12.8% of the irrigated area of the coastal region.

Between 1970 and 1979, the Tinajones area produced between 27 and 35% of the sugar, between 15 and 32% of the rice, between 2 and 15% of the cotton, between 1 and 3% of the maize and up to 16% of the beans produced in the entire country. Stockraising is not economically significant in this area.

K. CURRENT AND POTENTIAL LAND USE IN THE TINAJONES SYSTEM

At present, 97 369 ha are registered as irrigated land. Of this area, 80 064 ha (82.2%) are covered by irrigation "Licenses", i.e., indefinite water-use rights for agricultural purposes; 17 305 ha (17.8%) are covered by "permits", which allow for the use of surplus waters.
The most representative crops are sugar cane, rice, maize, legumes (beans), cotton and pastures. Sugar cane is concentrated in the agroindustrial complexes of Pomalca, Patapo, Pucala and Tuman.

Rice, the most important crop in terms of planted area, is distributed throughout all the irrigation sectors. The largest area of maize and legumes is grown in the Cachicame irrigation sector, and vegetables and pastures are grown in the Monsefu subsector, in Peque.

Except for sugar cane, which is grown in specific zones, the other crops are scattered throughout the valley; this creates serious difficulties when it comes to distributing and ensuring the adequate use of water.

The system has a potential irrigation area of 116 259 ha. Considering that 68.8% of the land (80 064 ha) is covered by irrigation "licenses", one may assume that if additional water resources were available and advanced technologies for the irrigation of arid zones —sprinkling, for example— were applied, the agricultural frontier could be extended by 31.2%, i.e., by over 36 000 ha.

I. INFRASTRUCTURE FOR AGRICULTURAL PRODUCTION

The most significant is the sugar industry, with plants located in the agroindustrial complexes of Pomalca, Patapo-Pucala and Tuman. The evaporated and condensed milk plants and the coffee processing plants, located in Chiclayo, are also important.

Privately-owned rice mills located in the producing zones that only process the rice have a total capacity of 250 000 metric tons per year.

The marketing infrastructure consists, basically, of a central warehouse for rice distribution, located in Chiclayo, with a capacity of 7 200 metric tons. This facility fulfills the functions of collecting and storing the rice and regulating the market.

In Chiclayo there is also a cold storage plant, with a capacity of 500 metric tons, which is used for storage and preservations of perishables.

Transport is facilitated by the existence of the Pan American highway, which is entirely paved, and an adequate system of secondary roads, which lowers transport costs. Lambayeque has 3 036 km of roads, from 2.50 to 6.60 m width.
In the upper part of the basin, the roads are in very poor condition, and the system may be classified as a secondary one. Traffic intensity is low and the system is technically deficient.

There is an airport in Chiclayo, but air transport is not important to agriculture. Sea transport, with ports in Pimentel and Eten, is important, as it is used, especially, for exporting sugar.

M. AGROINDUSTRY

Agroindustry is still incipient. The main agroindustrial inputs are imported from other areas; thus, the evaporated and condensed milk industry (Chiclayo) uses milk production from Cajamarca; the coffee products industry (Chiclayo) processes coffee grown in Jaén, Bagua and other regions of the country; the beer industry (Motupe) uses inputs from other regions.

The inputs produced within the region are sugar cane, rice and cotton. Sugar cane and rice give rise to a semi-agroindustry and cotton, with its by-product, cottonseed, is an input for the oil agroindustry (Lambayeque).

N. OTHER ECONOMIC ACTIVITIES

Crafts: This is an important complementary activity in the Monsefu sector, although it is not very well supported. The main products are straw hats and different types of woven articles (tablecloths, ponchos, saddlebags, etc.).

Fishing: The hydrobiological potential of the sea, mainly fish, accounts for considerable activity. In 1981, it generated 3.2% of the regional product. In the same year, at Santa Rosa and San José and the Port of Pimentel, 31,440 metric tons (21% of national production) of marine species for direct consumption were landed: 17,111 metric tons for canning, fish meal and oil, and 1,291 metric tons for salting.
II. DESCRIPTION OF THE MAIN WORKS IN THE TINAJONES WATER SYSTEM

A. TECHNICAL FEATURES OF FIRST-STAGE WORKS

1. Impoundment, channelling and storage

   a) Conchano tunnel. The Conchano river belongs to the Llauccano river basin, on the Atlantic watershed. It has a uniform flow, between 100 and 120 million m³/year.

   The connection works are the following:
   - The intake, located 2 375 m above sea level, 2 km south of the town of Conchano (Cajamarca department).
   - The feeder canal, 57 km long, surfaced with stonework, with a capacity of 13 m³/sec.
   - The free water level tunnel, 4 213 m long, with a capacity for a maximum streamflow of 13 m³/sec; the circular section has a diameter of 2.50 m and is surfaced with concrete.

   These works were begun in 1973 and completed in 1983.

   b) Chotano tunnel. This structure allows for the waters of the Chotano and Conchano rivers to flow into the Chancay river; in the second stage, the Llauccano river will also be included.

   It was built during the 1950s; after seven years of work, it was put into service in 1956.

   The Chotano river belongs to the Atlantic watershed. It contributes an average flow of 100 million m³/year.

   A typical section of the tunnels (horseshoe section) measures approximately 9.7 m² and has a concave floor; it is surfaced with simple concrete, 35 cm thick. The tunnel discharges 31 m³/sec.

   This tunnel was repaired between 1980 and 1982.

   c) Raca Rumi intake. This is the main intake on the Chancay river. It is located in the district of Llana, Chota province, Cajamarca department. It takes in up to 75 m³/sec from the Chancay river.
d) **Feeder or head canal.** This channels waters from the Chancay river through the Raca Rumi intake to the Tinajones reservoir. It is 16 km long, and has a maximum capacity of 70 m³/sec and a 1% grade. Its typical section is trapezoidal, and its sides are surfaced with stonework.

e) **Tinajones reservoir.** This is a lateral type reservoir; it was built taking advantage of a depression in the bed of the Arequipeña tributary, to store the surplus waters of the system and return them to the Chancay river, for subsequent distribution in the valley. It consists of: i) the main dam and secondary dikes; ii) a floodway, and iii) outlet tunnel and discharge canal.

**Main dam:**
- Capacity of reservoir: 320 million m³.
- Area of reservoir: 20 km².
- Level of crest: 216.50 m above sea level.
- Maximum level of reservoir: 214 m above sea level.
- Normal level of reservoir: 212.50 m above sea level.
- Minimum level of reservoir: 185 m above sea level.

**Outlet tunnel.** Located on the right buttress of the main dam and consisting of: intake hole; metallic structure, tunnel with concrete surfacing and steel lining; outlet with pressure chamber for hydraulic lifting of segment-type gate; valve house for operations and stilling pool for dissipating the energy of the water.

**Discharge canal.** This canal connects the outlet of the reservoir with the Chancay river. It is 3.9 km long and it is surfaced with stonework. It has a capacity of 70 m³/sec and a 1% grade.

The Tinajones reservoir and related works, including the intake, were built in 48 months, between 1965 and 1968.

2. **Distribution system**

a) **Chancay river.** In the upper part of the distribution system, in the Chongoyape irrigation sector —downstream from the Raca Rumi intake to the La Puntilla division box— the cultivated lands (8.1% of the valley) are irrigated by the Chancay river itself, by means of direct intakes.
Upstream from the Racac Rumi intake, between the mouth of the Cumbil river and the Chancay river, is the Carniche Alto intake, which irrigates cultivated lands belonging to the non-regulated sector of the Chancay-Lambayeque valley.

b) La Puntilla division box. This is a reinforced concrete structure which has been in operation since 1918. It was remodeled between 1971 and 1973 to improve its intake capacity, taking into account the new topographic features of the river. It divides the waters of the Chancay into the Reque river and the Lambayeque canal, which later on feeds into the Taymi canal.

The structure is designed for a maximum intake of 93 m$^3$/sec. Downstream there is a sand trap designed for a flow of 80 m$^3$/sec. The cleaning canal to the Reque river is 1,320 m long and has a 3.3% grade.

c) Reque river. This is the extension of the Chancay river and the only part of the distribution system which empties into the Pacific Ocean. It serves 11.4% of the cultivated land and also serves as a receiver of unused irrigation water from the middle part of the valley. Its length from the La Puntilla division box (km 42 + 200) to the sea is 71.80 km.

d) Lambayeque canal. This is another of the waterways in the primary system; it serves 26% of the cultivated land in the valley.

It is a dirt canal and has not been remodeled as planned. It is 41.65 km long. It has a maximum capacity of 40 m$^3$/sec at the upper end, 12 m$^3$/sec in the middle and a grade of between 0.5 and 2.5%. Seepage is estimated at between 12 and 15%.

e) Taymi canal. This is the main primary canal for distribution of irrigation waters in the valley, as it serves more than 37% of the irrigated area.

It is a new canal, built parallel to the old one.

Construction was carried out between 1970 and 1975. Its characteristics are as follows: length, 48.9 km; telescopic canal of variable capacity: 65 to 25 m$^3$/sec; trapezoidal sections, stonework slopes and concrete floor. The canal has 14 secondary intakes, with sub-canals and lateral canals, with capacities ranging between 2.0 and 12.6 m$^3$/sec.
f) Measurement structures. At strategic points in the system, the volume of water discharged is controlled and measured; this is done at 46 permanent gaging stations equipped with stream gages and measuring decks.

The Tinajones reservoir has a sophisticated system for determining its volume, monitoring seepage, the water table downstream from the dam and volume of discharge.

3. Drainage works

Drainage system. Even before the Tinajones project was built, there was, in the lower part of the old valley (1965), a trunk network of six open-cut drainage systems (92.4 km) for evacuating to the sea the surface waters left over from irrigation and percolation waters from the lands located in the middle and the lower parts of the valley, as well as for drying up a series of small swamps which had formed in depressions adjacent to the farmlands.

In 1979, construction was begun on the new drainage system, which includes the Valle Nuevo sector. These works are not yet completed; it is expected they will be finished in 1987. The valley will have 321.5 km of main return ditches, 87.8 km of secondary ones and 57 km of piped drains. This system will allow for adequate drainage of the cultivated lands in the Chancay-Lambayeque Valley.

B. REMODELING OF THE IRRIGATION DISTRIBUTION SYSTEM - RURAL REORGANIZATION: THE LUZFAQUE PROJECT

The plans for the first stage of the Tinajones project envisaged improving the entire irrigation system up to the individual farm intake level; however, for a variety of reasons, this was not done.

Action aimed at concentrating the scattered land ownership pattern and eliminating the minifundio only covered an area of 1 200 ha in the Ferreñafe (Luzfaque) irrigation sector, and this model was abandoned because it was not economically and socially viable.
C. COST, FINANCING, TIME LIMITS, EXECUTING AGENCY AND INTERNATIONAL TECHNICAL CO-OPERATION

In 1983, the final cost of the works to be carried out during the first stage were estimated by the Ministry of Economic Co-operation of the Federal Republic of Germany, at 150.5 billion soles (constant 1983 value). This figure has increased, compared with the original, by more than 43%.

The estimated and final time limits were also extended, and in many cases (Conchano and Taymi) were tripled.

The works have been financed with five loans granted by the Government of the Federal Republic of Germany, totaling DM 150 million, and with funds from the Public Treasury of the Peruvian Government.

The Executive Commission for the Ticajones Project, now the Directorate, was created in 1964 as an autonomous State agency, to be in charge of the execution, implementation and operation of the project.

All the first-stage works have been supervised by the German firm Salzgitter Consult GmbH (previously 2.Salzgitter Industriebau GmbH).

The project was part of a technical assistance programme carried out by the German Government between 1967 and 1984.

D. SECOND-STAGE WORKS

The second stage has not been started; it is currently in the financing process. This stage includes:

a) Connection from the Llaucano to the Chotano river
b) Llaucano reservoir
c) Connection from Shugar and Chonta streams to the Llaucano river
d) Connection from the Jadibamba river to the Llaucano river
e) Connection from Tondora stream
f) Hydroelectric power use
g) Expansion of works designed to improve the irrigation water distribution and drainage systems and continuation of agricultural programmes initiated during the first stage.
III. ADMINISTRATION OF THE WATER SYSTEM

A. OPERATION AND MAINTENANCE OF THE SYSTEM

1. Planning, use and control of water resources

During the 1970s, water was distributed according to concessions and rights acquired under the Water Code of 1902. Private control over waters was considered a right of ownership. There was no plan in the valley; the resource was distributed according to the daily supply from the river and on the basis of percentages that had already been established in terms of the acquired rights for each farm.

With the enactment of the General Water Act, decree law No. 17752 of 24 June 1969, a profound transformation began, throughout Peru, with regard to the planning, administration and use of water resources. These activities fell within the competence of the agricultural sector.

The law provides for the justified and rational use of water based on the social interests and the development of the country. It establishes certain basic principles, such as the following:

- There is no such thing as private ownership of or acquired rights over water resources.

- All waters, riverbeds and waterways belong to the State, which has inalienable and imprescriptible control over them.

- It is a "public necessity and of public utility" to conserve, preserve and increase water resources; standardize regulations governing water resources in order to ensure their rational, efficient, economic and multiple use; promote, finance and carry out investigations, research and other studies needed to achieve these ends.

- Volumetric measurement (m³/sec) is the general norm for all uses; users are required to pay rates per unit of volume.

- The irrigation district is the unit to be used for distribution and administration of waters.

2. The irrigation district

The criterion for defining an irrigation district is that it must cover a hydrographic basin and include at least one area in which the resource water
is used for agricultural or stockraising purposes. It may include one or more irrigation systems served by the same source or by different sources of water (rivers, lakes, underground waters).

In this area, water resources are evaluated, planned, administered and monitored; the relevant infrastructure is implemented, operated and maintained, and the organization and participation of water users is promoted and recognized; training is provided for the administration, operation and maintenance of the irrigation and drainage systems; and activities are carried out in connection with the organization, protection and conservation of the hydrographic basin or basins.

The action mentioned above is carried out through several institutional mechanisms, to wit: the water authority, the agricultural use register, the board of users and the irrigation users commission, the planting and irrigation plan, and the water rates.

3. Sectorization of the Chancay-Lambayeque irrigation district

For purposes of administration and distribution of the waters, the district has been subdivided into subdistricts, irrigation sectors and subsectors, as follows:

a) **Chancay-Lambayeque regulated irrigation subdistrict**

   This is the middle and lower part of the basin. It includes the lands located downstream from the Raca Rumi intake up to the area near the coast. The irrigation sectors are the following:

   i) **Chongoyape**, the upmost part of the valley, between the Raca Rumi intake and the part upstream from the La Puntilla division box. The irrigation subsectors are: Chongoyape, and direct intakes.

   ii) **Reque**, which is the extension of the Chancay-Lambayeque riverbed, with the irrigation subsectors of Reque, direct intakes, Monsefu and Eten.

   iii) **Lambayeque**, downstream from La Puntilla, with the Lambayeque, Chiclayo and direct intake subsectors.

   iv) **Taymi**, downstream from La Puntilla, with the direct intakes and Ferreñafe subsectors.

   v) **Cachinche**, downstream from the Cachinche distribution centre, with the Muy Finca, Tucume, Mochumi, Sasape and Morrope subsectors.
b) **Non-regulated irrigation subdistrict**

This covers the middle and upper part of the basin, and includes the lands located east of the confluence of the Cumbil and Chancay rivers, with part of the Chotano river basin, from its sources (Chancay) up to the intake (Raca Rumi intake).

The irrigation sectors are: i) Cumbil; ii) Santa Cruz, and iii) Chota.

4. **Agricultural use register of irrigation subscribers**

This is the official register in which a record is kept of the farms and the users who use the water for agricultural purposes. Entries include the total area and irrigated area on each farm and specify whether the areas are under the license (indefinite term) and/or permit (specific time limit) system. No individual or legal entity, whether private or public, may use water for irrigation purposes unless they fulfill this requirement.

According to this register, the cultivated area covers 97,369 ha, and over 82% have irrigation licenses, with the remainder only using surplus water during the "flood" months.

5. **Organization of users**

a) **The board of users**

This board represents all water users, regardless of the purpose, at the irrigation district or subdistrict level. It is made up of delegates of the irrigation user commissions and delegates representing non-agricultural users in the area. Its purpose is to ensure the active participation of users in the development, preservation, conservation and use of water and soil resources, as well as in the implementation and maintenance of the irrigation infrastructure within its jurisdiction.

b) **The irrigation user commission**

This body represents users of water for agricultural and stock-raising purposes, organized at the level of irrigation sector or subsector. Its board of directors includes representatives of associative agricultural enterprises, peasant communities, and medium-scale and small-scale farmers. Its functions are similar to those of the board of users; some of its most important duties are to ensure that members maintain their canals at the farm level in good
condition and that the communal infrastructure is kept in optimum condition; to make available to the water authority the personnel it needs for distribution and monitoring of waters; to participate in the formulation, execution and monitoring of cultivation and irrigation plans, and to advise users who are members of the commission, and to propose the fee to be charged users in order to finance the annual budgets of the commission, of the board of users and of the irrigation user committees.

c) Irrigation user committees

These are set up within an irrigation user commission, on which they are represented by delegates. Their main duties are to support, promote and carry out the cleaning and maintenance of irrigation canals; to support the technical administration and the commissions by helping them to enforce their regulations, and to nominate their delegate to the irrigation user commission.

These committees have no economic resources of their own, but are subsidized by the irrigation users commissions and, in some cases, by the board of users.

The board of users, the commissions and the committees, which have an indefinite duration, are recognized by the technical administrator. The boards and the commissions have status as legal entities.

6. Cultivation and irrigation plans

This is one of the basic mechanisms used to optimize the use and distribution of water. In drawing up these plans, consideration is given to a set of interrelated factors, such as the availability and quality of natural resources, the water requirements of crops, the State's production policy, the interests of the producers, and the availability of credit and the potential market for the crops concerned.

The cultivation plan is based primarily on a prognosis of surface waters and their distribution over the 12 months of the agricultural season. The water forecast is calculated at 75% persistence.

In general, two or more alternative cultivation and irrigation plans are drawn up, based on the characteristics, fluctuations and availability of water resources, which are analysed statistically.
The water authority is responsible for the formulation, implementation, monitoring, adjustment and evaluation of the cultivation and irrigation plans. It is required to co-ordinate its work with the board of users and with the competent authorities at the regional level.

7. Monitoring the distribution and use of water resources

The system established consists of the following steps: i) distribution report, broken down to the agricultural unit or farm level; ii) irrigation order, by which the volume of water required (m³/sec) is made available to the applicant; iii) daily irrigation service report, drawn up by the canal inspector, which lists the users served and the volumes delivered, for accounting purposes and for purposes of collecting water rates; iv) monthly irrigation service report, for purposes of monitoring volumes delivered and appraising them; v) crop control cards, which list crops and areas that have been established and those undergoing preparation and irrigation for planting.

The monthly reports and the crop control cards provide the basic information needed to make adjustments or adopt alternatives by increasing or reducing delivery with respect to the plan drawn up at 75% persistence.

8. Water rates

The 1972 Rates and Fee Regulations were in force up to the beginning of the 1980s. Calculations were based on three components: i) water use, ii) service, and iii) amortization.

The new Water Rates Regulations, approved on 10 July 1981, establish different rates according to type of use, i.e., agrarian or non-agrarian. The rate for water used for agrarian purposes is calculated on the basis of i) board of users income, ii) water rate, and iii) amortization.

The board-of-users-income component is that part of the rate which is used to cover overhead costs and the cost of developing the water resource for irrigation purposes; this income is used to finance the budget at the level of activities scheduled by the boards of users. The funds collected are assigned as follows:

i) Ten per cent for execution of studies on the protection of hydrographic basins.
ii) The remaining 90% for:
- Management and distribution of water;
- Conservation and improvement of waterways and other irrigation and drainage infrastructures in common use;
- Costs of collecting water rates pertaining to agricultural use;
- Operating and payroll costs of the board of users;
- Costs of irrigation water studies and/or studies of groundwater, aimed at improving the supply of agricultural water;
- The amount necessary to maintain a reserve fund for emergencies caused by natural phenomena.

The board-of-users-income component is approved annually by the Regional Directorate, on the proposal of the local co-ordination committee and the board of users.

The water rate component is that part of the rate which is paid to the State as a tax on the use of water as a public utility. This income goes into the Public Treasury and it consists of 10% of the board-of-users-income component.

The amortization component is that part of the rate which is paid to the State to reimburse public investment in irrigation works, and in works designed to improve irrigation and/or drainage; it is income for the Public Treasury and its value is calculated annually by the Executive Office for the Tinajones Project (DEPTI) and approved by a resolution of the ministry responsible for the sector.

9. Maintenance and conservation of the water system

The system's administration works on the basis of operation and maintenance regulations. The technical specifications contained in these regulations, and the field requirements serve as the basis for drawing up the annual maintenance programme, which must be approved by the technical administration and the board of users or irrigation subscribers commission, as the case may be.

The programme sets forth those structures which are to be maintained by the technical administration and those which are to be maintained by the users. The source of financing for the water system is determined according to
whether the works in question belong to: i) the primary system, or ii) the secondary system.

a) **Primary irrigation system**

This includes the connecting tunnels (Chotano-Conchano), the reservoir system, direct intakes located on the Chancay-Reque and Taymi rivers, the drain system, the Lambayeque and Taymi main canals and the main drainage ditches; it also includes monitoring and measuring structures, roads and guard houses, dwellings, staff offices, machinery, equipment, shops and others.

The board of users is responsible for maintenance of the greater irrigation system, except for the Tinajones reservoir and related works.

The maintenance work is carried out during the low-water season (July to September). It is financed by charging a fee based on the total budget and the total volume of water delivered to the irrigation subdistrict during the previous agricultural year.

The technical administration is responsible for maintenance of the reservoir and related works, as well as for the plants and other facilities. This work is financed with resources from the Public Treasury, through the annual operating budget.

b) **The secondary irrigation and drainage system**

This system includes the second- and third-order irrigation and drainage canals, structures pertaining to monitoring, measurement and distribution in these areas, and roads used for inspection purposes. Maintenance is carried out, with the active participation of irrigation users commissions, during the months of August and September. In this case, the budget is covered by the users through work assignments; daily wages are calculated on the basis of hectares irrigated and/or fees determined by the irrigation users commission, taking into account the total budget and the total volume of water delivered to the user during the previous agricultural year.

10. **Public institutions concerned with services**

a) National Office for Evaluation of Natural Resources (Oficina Nacional de Evaluación de Recursos Naturales - ONERN), which carries out the necessary
studies in order to draw up and inventory and classify and evaluate the current and potential use of resources.

b) National Weather and Water Service (Servicio Nacional de Meteorología e Hidrología - SENAMHI), which conducts and updates hydrological, meteorological, glaciological and limnological studies of all the watersheds in the country.

c) The Ministry of Agriculture, which draws up and executes projects relating to irrigation, standardization and improvement and conservation and increase of water resources and protection against erosion; it also grants water use rights.

d) The Ministry of Health, which limits its action to preserving waters against contamination and pollution, conducting studies and inventories, and qualifying, classifying and evaluating mining and medicinal waters; it also grants licenses for therapeutic, industrial and tourism uses of water resources.

e) The Ministry of Housing, which is concerned with all matters pertaining to the promotion, administration and supply of potable water and sewer services.

Ministry of Agriculture: This is the public agency which plays the most important role and participates directly in the planning, use and control of water resources for agricultural purposes. It carries out its activities through: i) the General Directorate for Water, Soils and Irrigation (national level); ii) the Regional Directorate and the Regional Directorate for Water and Soils (regional level); and iii) the Technical Administration of the Irrigation District (local level).

11. Main duties of national, regional and local bodies

a) Central line agency (national level)

i) General Directorate for Water, Soils and Irrigation. This body regulates, supervises and evaluates all activities pertaining to protection of hydrographic basins; conservation, preservation, regulation and use of water resources; organization of users; preparation and execution of cultivation and irrigation plans; operation and maintenance of irrigation systems, and administration, operation and implementation of irrigation districts.
b) **Deconcentrated line agencies (regional level)**

ii) **Regional Directorate.** This body proposes policy alternatives to the Deputy Minister of Agriculture, administers water resources and the conservation and use of soils, grants temporary water-use authorizations and permits for studies and works for the irrigation of areas up to 200 ha.

The Directorate for Water and Soils, which carries out supervisory and support services, operates at this level.

c) **Executive agency (local level)**

iii) **Technical Administration.** This body is responsible for managing the Tinajones system and is the primary local water authority. Its most important duties are:

- To settle, as the administrative body of first instance, questions and claims pertaining to the General Water Act.
- To draw up and implement programmes for the maintenance and conservation of the irrigation and drainage infrastructure.
- To draw up and propose the preliminary budget proposal for the Technical Administration.
- To administrate the water resources of the system.
- To draw up and implement cultivation and irrigation plans in coordination with the board of users and the Chief of the Agrarian office.
- To determine, along with the board of users, the amount of the board-of-users-income component of the rate charged for agricultural use, to collect it and to keep the books on and supervise the use of the funds collected.
- To monitor the execution of activities pertaining to the management and protection of hydrographic basins.
- To preside over the general meetings of the user organizations.

**B. FINANCIAL RESOURCES OF THE WATER SYSTEM**

1. **Central government financing for operation and maintenance**

Between 1969 and 1974, DEPTI was in charge of operating the impoundment and storage structures and maintaining these and the return ditches. During this time, these activities were carried out satisfactorily, inasmuch as DEPTI had
sufficient human and budgetary resources and enjoyed a certain degree of independence, which enabled it to solve problems without the bottlenecks and delays inherent in the traditional bureaucratic apparatus.

When the Organic Law for the Agrarian Sector was enacted, the works that had been completed (the reservoir and related works, Taymi canal, etc.) were transferred to the Agrarian region - Technical Administration of the Chancay-Lambayeque Irrigation District (1974), which assumed responsibility for the operation and maintenance of the Tinajones system.

Since 1975, the resources made available for the system have not only been limited and delayed, but they have declined to the point where the budgets for these activities mostly cover only wages and social benefits for the staff directly assigned to the services. As a result, these activities -- operation and maintenance -- are carried out with only limited efficiency.

2. Amount of water rate and fees

The rate applied within the system does not provide a means for recovering the investment made in the Tinajones project; the amount charged and the income generated do not even cover operating and maintenance expenses. In addition, the inadequate collection schedule and the factor of delays in payments mean that, in an unstable economy with a high annual cumulative inflation rate (124.9% in 1983), the real value received is negligible and may be considered purely symbolic.

Up to 1978, the rate was equivalent to 0.01 sol per cubic metre. From 1979 on, it has been increased, and in 1985 it was 5.70 soles per cubic metre.

Fees. This is a self-imposed fee established by the users; the amount per cubic metre of water used is approved annually by the Technical Administrator. Seventy-five per cent of the funds collected are used to finance cleaning and maintenance of the irrigation canals; this work is carried out with the support and supervision of the irrigation user committees. The remaining 25% is used to finance the budgets of the board of users and the irrigation user commissions.

The amount fixed for the fee is similar to that set for the rate. In some cases (1985), the fee has been almost double the rate (S/. 11.30/m3). The two amounts (rates plus fees) represent the actual contribution of users to the Tinajones system.
IV. EVALUATION OF THE SYSTEM

A. PHYSICAL ASPECTS OF WORKS

1. Degree of compliance with goals

The analysis of original plans and of works actually implemented, made in order to determine the degree of compliance with the goals and objectives of the project, leads to the following conclusions:

a) Substantial deviations from the original conception of the project

The time schedule for works and investments (May 1967) envisaged the construction of the impoundment and storage works and of the Conchano tunnel, the repairing of the Chotano tunnel, the remodeling of the irrigation system up to the farm intake level and the reorganization of farms (goals were not included).

Of this package, the following works were not executed:

- Remodeling of canals and irrigation structures up to the farm intake level (Valle Nuevo and Valle Viejo, including the Taymi sector).
- Farm reorganization was only carried out partially, in a small area (Luzfaque).
- Remodeling of the Taymi canal was replaced by the construction of a new canal.

b) Inconsistency in planning and execution of works and activities

The first-stage works were presented as a package of interrelated investments, i.e., the idea was that they would be carried out simultaneously. The results show that they were carried out separately, without any order of priorities or any logical sequence for achieving objectives.

Almost all the technical effort and most of the investment were concentrated on the Tinajones reservoir and complementary works. Thus, it was completed in a shorter time than originally envisaged. When it went on stream (October 1968), work on the Taymi canal and remodeling of the La Puntilla division box were only at the bidding stage. Hardly any progress was made on the digging of return ditches. Repairs on the Chotano tunnel were also delayed.
In addition, there was non-compliance with the schedule of activities pertaining to the operation and administration of the water system, i.e., updating of the register of users; approval of operation and maintenance regulations; proposal and approval of water rates; research, extension and training in irrigation, and proposal and approval of specific legal means aimed at facilitating the execution of drainage works and preventing the invasion of lands (Taymi canal and other sectors) and extension of the irrigated area in the Chancay-Lambayeque valley.

c) Slow pace of execution of works

With the exception of the reservoir and complementary works, the other works were considerably delayed and, in some cases, this involved substantial increases in costs.

The extremely long time taken to build the drainage system (25 years) is without precedent in the country. Work on the return ditches began before the creation of the Executive Commission for the Tinajones Project (CEPTI) (1961) and was completed in 1972. During this period (1961-1972), a series of problems arose which hindered the normal progress of work, namely: failure to conduct studies at the execution level, resistance of farmer-owners to works which would affect their farming lands, annual budgetary deficits, deficient logistical support, and lack of interest on the part of authorities in increasing economic resources for the programme in order to expedite work.

2. Critical analysis of execution

The failure to comply with goals, the increase in costs and the delays in execution were due to several negative factors, including the following: i) deficiencies in the studies at the execution level, such as the lack of geological research (Chotano tunnel), poor design of some hydraulic structures, and underestimation of costs; ii) the failure to carry out detailed research of a technical, economic and social nature (remodeling of irrigation systems and farm reorganization); failure to envisage solutions in advance (expropriation of lands, relocation of minifundio owners, etc.); administrative difficulties (absence of a comprehensive development plan and of a system for evaluation and follow-up), and financial problems (bad timing and cutback of national counterpart funds).
B. ECONOMIC, SOCIAL AND ENVIRONMENTAL ASPECTS

1. Contribution towards increasing production and productivity

One of the most important effects on agriculture of the execution of the project is the excessive area devoted to rice growing.

The schedule of crops envisaged for the first stage of Tinajones provided for a ceiling of 20,000 ha; however, several unusually rainy years (1970-1976) led people to stop considering water as a scarce resource and instead to consider it as a freely available one and to use it indiscriminately. This situation was further encouraged by the existence of the reservoir, which had adequate volumes of water, more than enough to meet any demand in the event of a temporary decrease in the volumes supplied by the Chancay and Chotano rivers.

The area planted was increased by 76%, production rose by 146%, and productivity rose by 40% (1960 vs. 1976).

As time has passed, not only have the years of abundant water supply encouraged the production of rice, but so have certain other favourable factors, including:

i) The National Rice Programme, which is responsible for research, promotion and expansion of areas devoted to this crop. Technological changes have made it possible to replace traditional varieties with others of greater productive potential.

ii) The Agrarian Bank, which assigns a major portion of its financial resources to this crop.

iii) A growing demand, arising from exogenous changes in the consumption habits of the population (sierra region). Per capita consumption of rice rose from 24 kg in 1979 to 32 kg in 1984 (a 33% increase), while the national income fell by more than 13% during the same period. The increased consumption of rice may be explained by its favourable price compared with other products (bread, noodles, beans) and by an increase in the urban population, which consumes more rice.

In order to prevent the consumer price of rice from rising in line with the prices of the other products mentioned, it has been necessary to implement the subsidy policy initiated in 1972.
iv) State intervention in marketing, whereby the producer is assured that all his crop of rice in the hull will be purchased; prices are fixed in advance, with the participation of producers, by the Ministry of Economy and Finance.

v) The predominant role, at the national level, of the Rice Producers Committee, considered one of the most powerful and efficient organizations in the country.

These factors, taken together, and with the decisive support of regional authorities responsible for implementing State policies, have allowed for the exorbitant growth of this crop.

The area planted in sugar cane has also increased, by an average of 8,000 ha in relation to the "no project" situation. Although the volume of sugar production has also increased (16.6%), unit yields in recent years have remained stable, as a result of major administrative and technical shortcomings in the farm co-operatives (CAP's).

2. Employment

The high labour component involved in rice growing, including preparation of the land, seed beds, transplanting, weeding and other intermediate activities up to the harvest (138 workdays/hectare) has led to a significant increase of employment in the area covered by the system; labour represents more than 35% of total cost. However, the production of rice also gives rise to: i) a very marked disequilibrium in the market of the economically active population, with peak-season demand exceeding supply by over 106% (transplanting season) and almost no work between July and September; ii) inadequate management and use of water, with the mass of water utilized being concentrated into four months (81% of the yearly total), thus canceling out the regulatory function of the Tinajones reservoir.

3. Salinization of land

This is the most serious environmental problem which has arisen in the middle and lower part of the valley. The deficient and inadequate drainage system which existed before the project, and the unjustified delay in completing the current system, poor water management practices, the constant increase in the area planted in rice and the existence of slowly permeable to impermeable
strata of subsoil have led to a serious increase in the salinization of the irrigation areas.

Field evaluations carried out in 1963, 1968, 1975 and 1980 have confirmed that there has been a gradual salinization of the farmlands; of nearly 106,000 ha studied, 13%, 32%, 40% and 30% were found to be affected during the years mentioned, in that order. The latter percentage is attributed to normal hydrological years (1975-1980), the drought of the 1979-1980 agricultural season, and the effect of construction of new return ditches and other drainage facilities (Ferreñafe, Lambayeque and Reque).

C. OPERATION AND MAINTENANCE

1. Critical analysis of operation and maintenance

The problems which most hinder normal operation and maintenance procedures are the following:

a) Specific problems affecting the operation of the system

1. Exogenous problems

Division of agricultural units. Legislative Decree No. 02 of 1981 opened the way for members of the farm co-operatives to change their entrepreneurial model; as a result, there was a growing trend, within the system, to divide the land into family plots.

This phenomenon may be the result of certain conflicts of a technical, economic and social nature which arose from poor management of the enterprises resulting from lack of State support (technical assistance and credit) and the impact of the economic crisis brought on by natural causes (droughts and floods) and the fall in prices of export commodities.

Although it has not been possible to establish how many agricultural units belong to beneficiaries who decided to take advantage of this new status, such action may be reflected partly in the fact that there was an increase in water rate receipts (1137) in 1984 by comparison with the previous year.

Social and political aspects: squatters and irrigation of new lands. The agricultural frontier has continued to expand, to the detriment of the water supply, despite the serious and repeated opposition of the General Directorate
for Water, Soils and Irrigation and the local authorities. All along the new Taymi canal, an unknown number of squatters are illegally taking water, using modern pumping systems. In addition, political pressures have led officials at the higher levels to grant new "permits" or provisional authorizations to take water to irrigate new lands. In all these developments, there is evidence of constant interference with the duties of the Technical Administrator. It is estimated that as a result of squatter activity, the agricultural frontier has been extended by 1200 ha.

Lack of a comprehensive resource management system. Constant reorganizations of the agrarian sector have given rise, among other things, to certain changes of jurisdiction: the current Third Agrarian Region (formerly the Second Agrarian Region) coincides with the boundaries of Lambayeque department; thus, it has lost jurisdiction and control over the natural resources of the upper part of the basin (regulated irrigation subdistrict of Chota, Santa Cruz and Qumil). The original orientation of an irrigation district as being defined in terms of a hydrographic basin, or basins, and as a basic planning unit has been lost; rather, these districts have been divided according to other demarcation criteria. In this case, water acts as an independent, dissociating factor giving rise to a lack of harmony in project development and to many disputes, mainly because of the proliferation of water authorities and the resulting anarchy in the utilization, management and preservation of this resource.

2. Endogenous problems
   i) Non-compliance with cultivation plans

Failure to monitor cultivation plans has made it possible for users to sow larger areas than planned (rice), thus causing a significant distortion of irrigation plans, as well as alterations --arising from hidden demand-- in the distribution of the resource.

The hidden demand is usually "solved" by the users themselves, who take the resource illegally, and/or by some of the technical staff responsible for water distribution, who infringe the regulations. Fines are minimal and are hardly ever paid.

ii) Scattering of crops

Except for the single-crop sectors devoted to sugar cane and rice in Chongoyape, in the other irrigation sectors, a wide diversity of crops are
planted, all with different water requirements; this is further aggravated by
the different growing seasons of the crops concerned (different planting
dates). This "mosaic" of different crops and staggered planting, which gives
rise to a complete disarray in the pattern of demand for, application and
frequency of irrigation, requires the use of an excessively large network of
canals, with excessive capacity. This reduces efficiency of operation, as
there are considerable conveyance and distribution losses, especially in the
irrigation subsectors of Cachinche (Tuoume, Morrope and Sasape), where
distribution canals show conveyance losses of over 40%.

The situation of the rice growers is similar. Even the smallest producers
have their own seedbeds. Under such circumstances (75% of the farmers growing
rice), it is technically impossible to achieve adequate efficiency in the
operation of the system.

iii) Ability and attitudes of users

Water management at the farm level continues to be a limiting factor,
since most of the farmers are not familiar with the basic concepts of
irrigation and the role of water in production; irrigation by wells and by
border checks is widespread. This method of surface irrigation is also
frequently used for cotton, maize and legumes, even during times of greatest
shortage; this is the case during the current season (1985/1986), when,
because of water shortages in the system, rice was replaced by maize.

Farmers usually do not monitor irrigation during the night, and this
leads to considerable losses by seepage and/or evacuation of surplus water to
drains.

During holidays, the farmers' presence in the fields is minimal. During
the last few agricultural seasons, certain leaders of the agroindustrial
complexes and of the co-operatives have adopted a very negative attitude,
refusing to agree to have the surpluses distributed during flood seasons
(February/April) included in the bookkeeping of their irrigation plans and in
rate calculations.

Farmers also lack awareness of the social and economic benefits of water.
This is shown, for example, by the fact that users do not participate enough
in the cleaning of canals and other basic water-saving practices which only
entail the opportunity cost of their free time.
iv) Deficiency and/or lack of hydraulic structures and equipment

For several years, but especially since 1980, there has been a decline in the operational efficiency of the irrigation water distribution system.

These shortcomings may be attributed to the lack of monitoring structures, the lack or obsolescence of measurement, communications and transportation equipment. The lack of a plan for rehabilitating gates which have been deteriorated by use further aggravates the situation.

v) Lack of an adequate basic statistical data system

Existing data are scattered, outdated and incomplete; this detracts from the efficiency of the service, as well as from the periodic evaluation of results.

The study made shows that procedures and standards are only partially complied with. It is not known, with any degree of reliability, how many users and how much land area is subject to the régime pertaining to the temporary use of surface waters; what is the volume of water delivered and whether this régime is maintained during dry seasons; how many squatters there are and where they are located, how much land is irrigated and how much water is taken illegally; how many new concessions have been granted, and so forth. Nor is any detailed information available on actual volume distributed by the main canals and on actual losses; such data would make it possible to determine indirectly how accurate are the estimates of the volume of water attributed to users or whether some of them benefit from this lack of control.

The lack of adequate records concerning the condition of hydraulic structures, measuring equipment, transportation equipment, and others, is another problem which hinders activities relating to the operation of the system.

vi) Research - training

There has been a decline in research on irrigation and drainage, which before the application of the agrarian reform had concentrated on the former sugar plantations. Experiments and research, sponsored mainly by Pedro Ruiz Gallo University, are carried out by students as part of their degree requirements; hence, they are sporadic, highly academic and not very useful in practice.

Farmers have not accumulated enough technological experience in water management. They usually do not calculate the plants' water requirements; rather, the tendency is to use the entire amount of water assigned to the
farm, flooding crops and using up all the water, without taking into account the fact that flooded water filters into the soil, taking nutrients with it and harming vegetative growth. Moreover, they do not realize that saving water would provide them with surpluses which could be used at a more opportune time or could be applied to expand the planted area.

The above situation is further aggravated by the fact that the Agricultural Extension Service does not, at present, plan to provide extension services in irrigation. In addition, there is no training programme nor have agroeconomic studies been made to show that a change in the planting schedule could increase profitability by allowing for optimum use of resources.

vii) Internal training

The staff of the technical administration are not aware of the objectives of the system, the specific techniques and operating standards required, programming concepts and methods pertaining to individual and team work, the structure and functions of the organization, communications, or the controls and authority that are required.

The technical administration should view the internal --non-academic-- training of the staff as essential to the creation of a positive attitude towards their jobs, the selection of qualified personnel and, finally, the awareness, on the part of each employee, of his role within the organization.

b) Specific problems affecting maintenance of the system

1. Exogenous problems

Lack of experience of the Chancay-Lambayeque Valley Technical Conservation Company (Empresa Técnica de Conservación del Valle Chancay-Lambayeque - EMTECO). This corporation was created in 1982 on the initiative of the farmers; it is partly responsible for the irrigation service.

The corporation operates with resources from the revenues of the Chancay-Lambayeque board-of-users component (25%) and the water fees (75%). It is responsible for the maintenance --except for the reservoir and related works-- of the entire hydraulic infrastructure, including the Chotano tunnel system. However, it appears that, because of its scanty funding (6 709 million soles for 1986) and the inexperience of its meagre staff, it is not able to handle the enormous and complex tasks assigned to it. Moreover, it is getting involved in activities which do not properly fall within its scope, as it has
rented a substantial part of its equipment and machinery to private corporations for the excavation of return ditches, under the pretext of increasing its income with "resources of its own".

Changes in the weather. The El Niño current, which appears at intervals of between 3 and 7 years, causes increases in temperature and precipitation. Some years, such as in 1983, the floods caused serious damage, including damage to the irrigation infrastructure, thus making maintenance more difficult.

2. Endogenous problems

Lack of a comprehensive maintenance plan. Since 1980, maintenance has been concentrated mainly on cleaning waterways and major irrigation structures (Paca Rumi intake and related works), while the maintenance and conservation of measurement structures, gaging stations, gates, measuring equipment, communications and transportation equipment and the cleaning of streams have been neglected. Thus, this infrastructure already shows signs of deterioration. Many of the gates are in need of repair or out of service, and do not close properly, causing the loss of large quantities of water, as in La Puntilla; failure to clean strategically located streams and sewers has already caused considerable damage, e.g., in several sections of Tayni canal in 1983, as a result of rains and floods.

c) General problems which commonly affect the operation and maintenance of the system

1. Exogenous problems

Organizational and functional aspects. The latest reorganizations of the agrarian sector have failed to take into account the principle of the primary role of the Water Authority, carried out through two fundamental bodies, i.e., the Technical Administration and the General Directorate for Water, Soils and Irrigation. The current institutional scheme governing the administration of waters and the operation and maintenance of the irrigation districts is not in line with the precepts underlying the relevant law; the current system is based on an agricultural management approach, which tends to neglect the management of water, even though it is such as important input for development.
Thus, the Regional Director has been designated by the relevant Ministry to carry out certain specific functions pertaining to water. These functions, which are executive in nature, are exercised through the Agrarian Agencies; under these is the Technical Administrator of the Irrigation District, who therefore has a low rank within the regional and local hierarchies. As a result, his authority is either diminished or taken away from him.

Under this institution set-up, the Technical Administrator is responsible to two different bodies: hierarchically, he is under the Director of the Agrarian Region, through the Chief of the Agrarian office; from the technical and regulatory standpoint, he is under the General Director for Water, Soil and Irrigation, through the Director for Water and Soil (at the regional level).

The General Directorate for Water, Soils and Irrigation performs a regulatory role, and its relations with the Agrarian Regions are purely nominal, entailing no authority or power to intervene, despite its being the line body at the national level which is responsible for carrying out regulatory activities, in accordance with the pertinent legislation. It has also lost the power it previously had to promote and rotate the staff of the Technical Administration, including its Chief, according to their abilities and experience.

This disorder at the governmental level hampers efforts at efficient operational management of the irrigation districts, inasmuch as, because of the misapplication of sectoral decentralization, the Water authority suffers constant interference in its duties from the excessive number of authorities at the regional level. Under such circumstances, it is only to be expected that the Technical Administrator does not always comply with the orders issued by the General Directorate for Water.

Economic and financial aspects:

1) Financial resources of the State

The economic resources assigned by the State are increasingly inadequate, as they have been steadily decreasing, in absolute values, because of the phenomenon of devaluation-inflation. To this must be added the fact that State funds are decentralized and there are delays in their utilization; neither the General Directorate for Water nor the Technical Administration has access to these funds, which are distributed by the relevant Office of Administration.
A recent study has confirmed that the investment of the sector, during the period 1975-1982, was concentrated on irrigation (96%) and that almost the entire amount so invested was used for irrigation works, preferably long-term projects (80%) (Chira-Piura, Tinajones, Majes, etc.), with hardly any investment being made for operation and maintenance of the irrigation districts. This erroneous policy has had several negative effects:

- The structural bodies at the national (General Directorate for Water, Soils and Irrigation), regional (Directorate for Water and Soils) and local (Technical Administration of the Irrigation District) levels have serious weaknesses in the following areas: lack of qualified staff; problems of mobility, engineering equipment, monitoring, measurement and communications, and lack of office supplies and office facilities.

- An increasing "brain drain", because of low salaries compared with other sectors.

- Finally, a lack of funds which means that most of the staff of the Technical Administration are in the offices and not in the field.

ii) Financial resources of users

The establishment of the water rate as a compulsory payment, to be used mainly to pay for operating and maintenance costs, has not yet produced the desired results. The negligible amount of the rate, slowness in collection and constant delays in payment are negative factors which must be corrected.

At the national and regional level, there is a consensus that the rate must be increased annually. Several economic studies on the matter support this position; nevertheless, the political decision has not yet been taken. This may be due to the Government's concern for avoiding increases in the prices of agricultural products. Nevertheless, it may objectively be said that an increase in the water rate would not have a major impact. One may ask why farmers outside the Tinajones area (Motupe, Pacora, Jayanca), using groundwater (at 160 soles per cubic metre) and applying similar cultivation schedules and prices, receive an adequate return. The answer is obvious: they have the efficiency which could easily be achieved through the water rate.
V. CONCLUSIONS

1. In the execution of the Tinajones irrigation project, there has been considerable delay in the construction of works and a significant increase in their cost. The execution of the first stage will have taken more than 22 years (1965-1987). During this period, new technical considerations have arisen which have led to serious deviations from the original conception of the project: the works have been carried out in isolation from each other, without providing for any interrelationship among them and without any comprehensive pattern; the technical effort and most of the investment have been concentrated on the major civil engineering works, neglecting complementarity of action. These problems may be attributed to: deficiencies in the studies at the execution level, and failure to provide for solutions in advance; administrative, economic and financial difficulties, as well as political ones —agrarian reform— which to some extent diverted resources and attention from this project.

2. The accelerated construction —with ample political support— of the Tinajones reservoir associated with additional volumes of water and the unjustified delay in the construction of the drainage system, because of indecisiveness and lack of support, as well as the lack of regulations designed to restrict the expansion of the rice-growing frontier, gave rise to serious environmental problems in the geophysical system, including the gradual acceleration of salinization of farmlands in the valley (estimated at 40%). This problem, to some extent, is holding back efforts to increase agricultural productivity and enhance the benefits of the Tinajones system. The construction of the reservoir should have been subject to the completion of the drainage system and the prior training of users; this would have made it possible to achieve an adequate level of efficiency in the utilization of water and soil resources.

3. Although the General Water Act provides for comprehensive and interrelated management of natural resources, through the creation of the Irrigation District, this is not implemented in the case of the Chancay-Lambayeque District, which is the sphere of influence of the Tinajones water system, because the hydrographic basin has been subdivided to fit jurisdictional boundaries. This erroneous political decision has led to a curtailment of activities in the upper part of the system, so that management
and conservation of the upper basin have been completely neglected; co-ordination between the regional authorities (Lambayeque-Cajamarca) is sporadic and ineffective.

4. The administration of the system through the Technical Administrator is supported by a set of rules and regulations provided for by the Act, and this allows for planning, use and monitoring of water resources. Cultivation and irrigation plans, the water rate and the user organizations are mechanisms which could facilitate fulfillment of these purposes. In practice, however, there are serious distortions in the execution of plans, illegal appropriation of water, blatant irresponsibility in the payment of rates, and a lack of participation of users in operating and maintenance activities. Under such circumstances, what is needed is a monitoring system that is not only effective but also dynamic. In addition, there is a pressing need to rehabilitate gates which have been deteriorated through use and to replace measurement and communications equipment, as well as vehicles.

5. The creation of higher-level bodies over the Technical Administrator has meant that he has lost the authority delegated to him in connection with the management of the Tinajones water system. His office is subject to interferences and conflicts of duties; his powers are restricted as regards the removal, promotion and hiring of personnel; his participation in decisions and action regarding expenditures is minimal. Because the Minister has delegated his representation to the Regional Directors, there has been a weakening of the direct link which formerly existed between the General Direction for Water and the Technical Administration, which had enabled the Technical Administrator to supervise and enforce compliance with norms, regulations, execution of plans and programmes and the removal and promotion of personnel.

6. The system suffers from serious neglect in the maintenance of its infrastructure; this is due to the lack of economic and financial resources, a situation which is aggravated by the lack of awareness among users of the contribution they can make to this end. The amounts set for water rates, which vary from year to year, would not be enough to cover the actual cost of administration, operation and maintenance of the water system even if a 100% collection rate could be achieved. Many interesting studies show conclusively that the water rate could be increased without any major increase in the cost of production; if new rates were updated annually, the services could become
financially self-sufficient. The State's contribution to the operation of the system, which is lower and lower every year, is used to finance overhead costs, the greatest expenditure of which is to be found in the item "remunerations" (91%). Very little is assigned for "Goods" and "Services", which represent only 2.7% of allocations; this is why the staff spend most of their time in the office, thus neglecting the field work which they should be doing.

7. The Chancay-Lambayeque Valley Technical Conservation Company (EMTECO), created on the initiative of the farmers (1982), still shows weaknesses in its organization and equipment; at present, it is not able to handle the enormous and complex tasks of maintaining the system. It needs constant supervision, support and advice from the Technical Administration.

8. The current cultivation schedule, the attitude of users who wish to further expand their rice-growing area, the constant increase in the number of squatters and the granting of concessions for irrigating new lands make it impossible to achieve efficiency in the operation of the system. The greatest volume and mass of water used (81%) is concentrated in four months (January-April); hence, the Tinajones reservoir does not fulfill its regulatory function. The possibility of optimizing water-soil-labour resources is even more remote.

9. Water management at the farm level continues to be a limiting factor; surface irrigation with wells and border checks is widespread; farmers are not aware of the social and economic benefit of this resource. There is hardly any research, promotion or extension in irrigation at the regional level.

10. The low pay and lack of economic incentives resulting from the country's economic and financial difficulties have led to an exodus of qualified personnel from the system; many of these staff members have been replaced by young and inexperienced professionals and technicians who are not yet able to perform satisfactorily. A programme of constant training, both external and internal, would help improve this situation.

11. The existing information and statistical data are very scattered, inconsistent and outdated; this is the case, for example, with the register of users. An intentional fire which occurred two years ago caused the loss of a very valuable file which should be restored by compiling data existing in other public offices. Efforts should be made to design an appropriate statistical data system.
VI. RECOMMENDATIONS

1. In any irrigation project, priority should be given to the problem of salinity of farmlands, which is widespread in the coastal valleys of Peru, and is caused by deficiencies in or the lack of drainage systems. Construction of such systems should be initiated before any other water works, in order to guarantee the efficiency of the infrastructure and the achievement of the benefits envisaged.

2. It is essential that users' obligations, in the form of water rates and fees, be reassessed as regards the amounts to be paid, forms of payment and policies on this matter; the efficiency of administrative, operational and maintenance services depends on this income. One suitable way to deal with this would be for the competent authorities of the sector to apply one of the many alternatives that have already been proposed; this is the only way the system can become self-sufficient financially and improve its services.

3. The existing user organizations, i.e., the board of users and the irrigation subscribers commissions and committees, should be supported, strengthened and encouraged in order that they may create a real awareness of the role and importance of water in the country's development and, especially, in their own economic activity. There is an urgent need for a small specialized agency to provide permanent practical training in resource management for farmers.

4. Since only a limited amount of water is available for the development of irrigation agriculture, State efforts should be directed towards strengthening research, promotion and extension in irrigation, as well as watershed management and conservation, all of which have been seriously neglected. This would make it possible to establish guidelines for achieving a gradual change in crops and introducing new systems for using water efficiently.

5. The authorities of the Ministry of Agriculture should restore the regulatory function of the Tinajones reservoir, which is its main purpose, in order to ensure efficiency in the use of all the factors involved in production. One possibility would be to carry out a comprehensive study with the active participation of the farmers.

6. The role of the system's Administrator, which currently is very weak, must be restored, and he must be given the full authority established by law.
7. Because the State has made such a substantial investment in this irrigation system, and because of its complexity, it is fitting that its professional and technical staff members should receive a constant flow of know-how that would enable them to innovate and improve their efficiency. This can be achieved through periodic training and participation in seminars and similar activities.

8. It is also essential to restore the morale, dedication and productivity of the staff of the Technical Administration. Internal training should be considered an essential part of administration, with a view to imbuing the staff with the ethics and the values of the organization, their individual and collective roles, and so forth. Only thus will the staff be proud of being part of this important work.

9. The experience gained by the Administration of this system, reflected in the formulation and application of the cultivation and irrigation plans and the pragmatic distribution of water at the farm level in sectors having no measuring equipment and, in some cases, with a very large number of very small properties (Monsefu), is very valuable and could be useful to other, similar irrigation systems. The same is true of the standards and regulations developed in connection with the planning, administration and use of water resources.