HUARMEY DRAINAGE PROJECT, CONCEPTUAL PHASE

Consultancy report to Ground Water International, Lima, Peru

Roland Oosterbaan, agricultural water management specialist
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Abstract

The general situation in alluvial fans/delta's is sketched and it is argued that drainage and reclamation of waterlogged and saline lands at the base of the delta is usually possible without encountering major problems provided that irrigation and socio-economic conditions are favourable.

The feasibility of drainage and land reclamation in a waterlogged and saline area of 150 ha to the south of Huarmey alluvial fan is studied at *conceptual* level.

The area is divided into 5 subareas for which land improvement options and impediments are discussed.

Recommendations include: (1) refrain from land reclamation in the two subareas to the south of the central drain; for mosquito control lateral ditches may be excavated, (2) drainage by lateral ditches in the two areas to the east of the central drain is an option provided that additional information to be collected about the availability of irrigation water and the possibility of socio-economic assistance (e.g. for the operation and maintenance of the drainage system cum pumping station) confirms that these are no major constraints, (3) drainage by shallow wells in the subarea to the east of the central drain is an option provided that the availability of irrigation water does not pose a serious constraint.

1. Introduction

The consultant was invited by David Evans, Senior Hydrogeologist, Principal, Ground Water International (GWI) to advise on the concepts of drainage of waterlogged saline lands within the southern Huarmey valley.

With David Evans, the consultant made a field visit to Huarmey from 13 to 15 July 2008 .

More information was collected at the GWI office in the following days, including:

- Análisis de Sistemas de Riego Adecuados by Ricardo Apaclla N.(not dated)
- Inventario y Evaluación de la Infraestructura Hidráulica Productiva. Sistemas de Riego Existentes by Ricardo Apcalla N., Junio 2008.
- Estudio de Suelos y Potencial Agrícola en el Valle de Huarmey – Ancash by Miguel Remigio M. y Jose Remigio A., Junio 2008.

Reporting was completed on the 18th of July 2008.

Prior to the field visit, the consultant received a copy of the report on the "Hydrogeology Study of Puerto Punta Lobitos Irrigation Areas" and the following terms of reference (section 2).

2. Terms of reference

Approximately 150 ha of land within the Huarmey Valley are affected by waterlogging and salt accumulation in the soils (Figure 1). The water is also brackish due to (1) high evaporation from the high water table, (2) virtually no regular flushing of salts due to the arid climatic conditions; and (3) saline ground water inflow from the Cascajal Valley (an arid valley located south of the Huarmey Valley with a naturally saline aquifer). These conditions have destroyed the fertility of much of these lands of which most have now been abandoned. The productivity of other irrigated lands has likely been reduced due to high water tables and salt accumulation within the root zone.

In addition to these conditions, waterlogging has created conditions in which mosquito species thrive creating uncomfortable living conditions in the area and allowing the potential for the spread of disease.

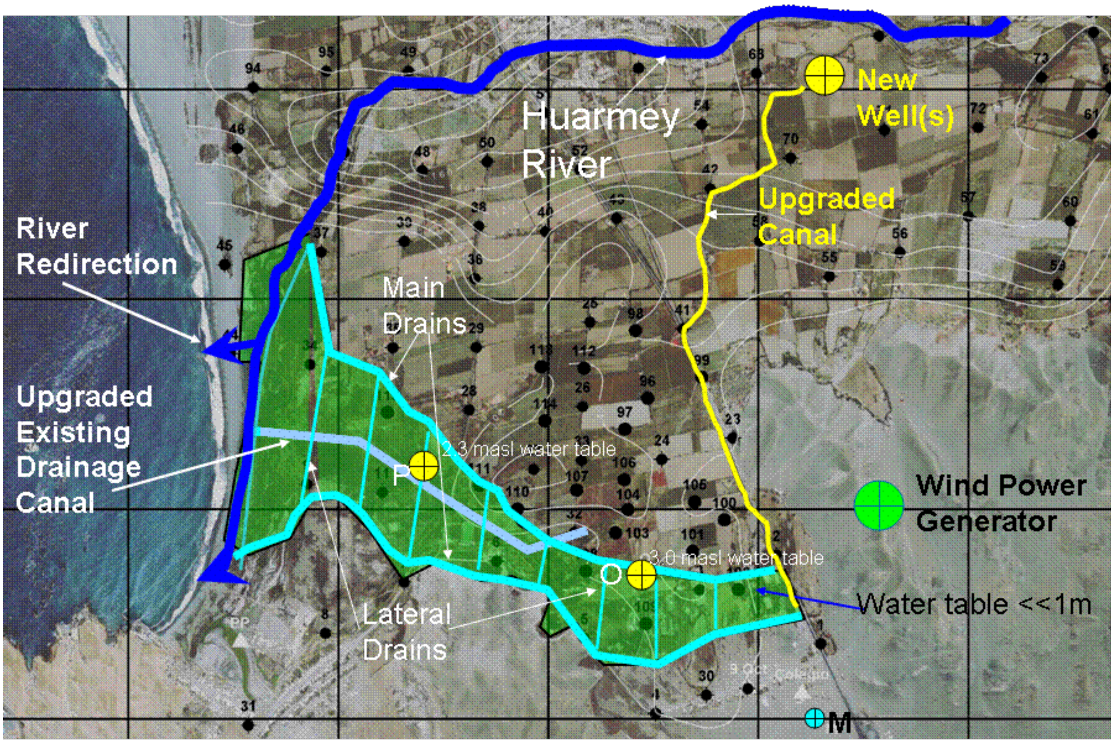

Figure 1. Delineation of the waterlogged area with tentative drainage system

There are several possible reasons for the waterlogging within this area.
The main reasons are provided below:

1. Shallow bedrock. The bedrock is very shallow within the southwest portion of the Huarmey Valley based on recent geophysical surveys. The geophysics has not been confirmed by drilling however. The shallow bedrock is apparently extensive, covering nearly 2 km2 (see Figure X). The bedrock, consisting of volcanics and

intrusives, typically has a much lower permeability than the valley infill sediments and would tend to impede ground water movement in the direction of the sea.

2. Low permeability of soil. The permeabilities of the basin fill deposits along the southern portion of the basin are lower than the deposits central to the basin. The drainability of the soil is directly proportional to its permeability. These finer-grained silts and sands were deposited in lower energy environments along the edge of the basin during flood stages. The permeabilities of the upper soils range between 10-6 to 10-5 m/sec. The permeabilities of the aquifer deposits within the central portion of the valley are approximately 10 to 100 times higher for comparison.

3. River deviation. The river deviates from its typical westerly direction approximately 1km west of the City of Huarmey turning south-southwest and discharging at the south end of the Huarmey Bay (see Figure X). This is likely due to increasing topographic levels close to the ocean due to aeolian deposition. When the river flows high during 3 months of the year it has the potential for impeding ground water movement to the sea due to hydraulic mounding. The hydraulic mounding may take months to dissipate thereby reducing drainage during the alpine dry season which lasts for approximately 8 months. During this time, the velocity of the ground water isn't quick enough to drain the land sufficiently. When the river flows again the cycle continues.

Although the problem has been recognized for many years, the community has not been successful in finding a long-term solution. An open drainage canal was constructed in the past within the mid portion of the waterlogged area, however, the canal was never maintained and became overgrown with vegetation thus drastically reducing its effectiveness. It is unknown if this canal was ever successful in reducing the water levels in this area.

A new drainage scheme would be the only way to reclaim these waterlogged affected areas. Land drainage schemes, consisting of ditches, drain pipes and possibly wells, would help manage ground water levels and improve crop yields. It is unlikely that surface or buried drains would discharge freely to the ocean based on the shallow hydraulic gradients; hence, pumping station(s) would likely be required. We are uncertain if the river would need to be redirected or the feasibility of doing this.

When the land is sufficiently drained, the soils could be flushed with fresh water to desalinize the soils. Fresh water could be pumped from the central paleochannel aquifer and conveyed to the site via canals. The existing canal would likely need upgrading. Eventually the water quality in the drainage canals would change from brackish/saline to fresh after water is drawn in from the north. Also, the flux of saline ground water from the Cascajal aquifer would be cut off by the pump-back system, which is currently being installed. Hence, the water in the canals could be used for the irrigation project reducing the need to pump and convey water from the central aquifer.

3. Waterlogging and soil salinity in coastal alluvial fans/delta's

3.1 General description

Along the coast of Peru, the rivers descending from the Andean mountain range form alluvial fans with a conical shape spreading out towards the sea (Figure 2).

When the alluvial fan is intensively irrigated, there are considerable percolation losses of water to the underground that usually consist of deep and permeable aquifers (Figure 3). The percolation losses, upon reaching the aquifer, spread out through the aquifer towards the coast and the edges of the fan.

The water table in the aquifer cannot drop to below sea level, and therefore it comes closer to the soil surface as the groundwater flow reaches the shoreline. The soil becomes waterlogged. Waterlogged soils cannot be irrigated and the topsoil is dry. Thus, by capillary forces, the groundwater moves up and evaporates whereby the salts dissolved in the groundwater are left behind. Even good quality groundwater contains enough salts to potentially originate soil salination in the long run.

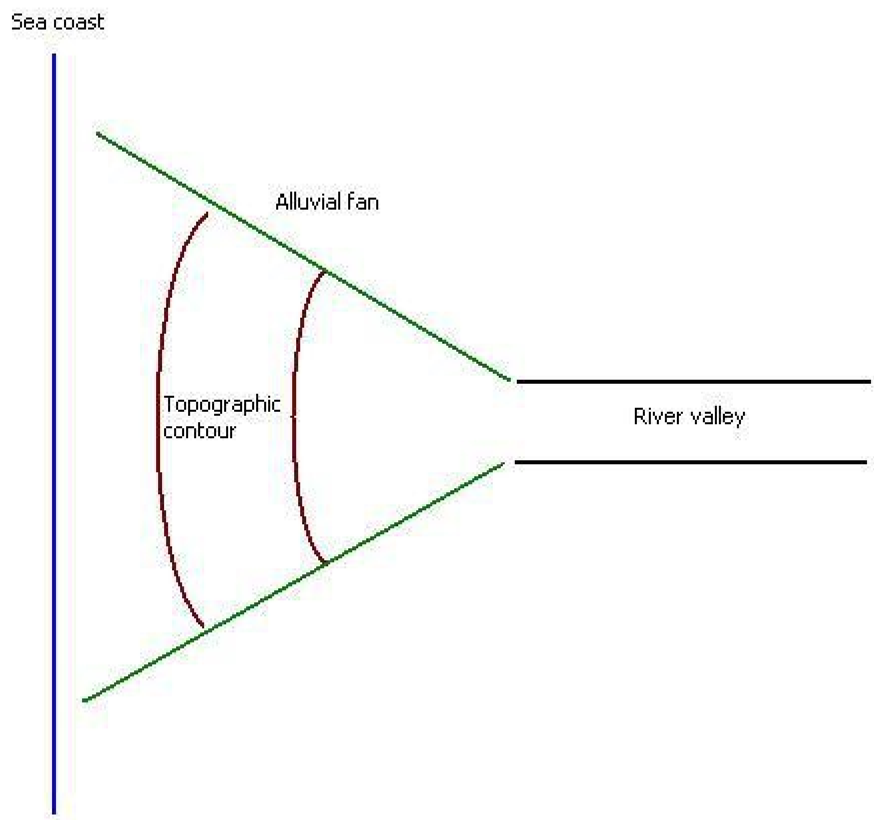

Figure 2. Sketch of a coastal alluvial fan.

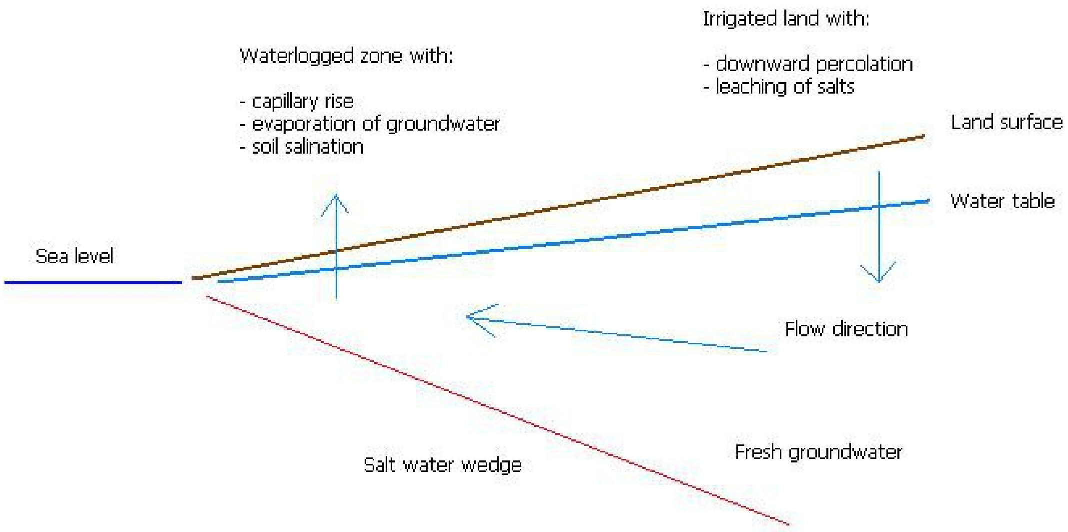

Figure 3. Sketch of a vertical section through a coastal alluvial fan.

In silt and fine sandy soils, the rate of capillary rise in dry soil with a water table at 1 m or less is often in the order of 1 to 3 mm/day and roughly 30 to 50% of the potential evaporation, which is the maximum evaporation that can occur under the local climatic conditions.

The upward flow of groundwater can be reversed installing a subsurface drainage system, consisting either of pumped wells ("vertical drainage"), or ditches and horizontal pipe drains, and irrigating the land. This stops the capillary rise and a small fraction of the irrigation water can now percolate downward to the drainage system whereby the salts are leached from the soil and transported to the drainage outlet. The required amount of leaching water is some 10 to 20% of the irrigation requirement.

Horizontal drainage systems nearby the coast need a pumping station to discharge the water. Such systems are relatively expensive. Further away from the coast, the drains can be made to discharge by gravity.

In the absence of drainage systems in the waterlogged zone one often observes patches of irrigated land intercalated with unused, strongly saline, patches. The unused, permanently fallow patches, assume a drainage function (Figure 4). In some irrigation projects such permanently uncultivated plots are designed on purpose. In Australia this is practice is called sacrificial drainage. Elsewhere it may be called: "dry land drainage".

Waterlogged saline soils normally pose no difficulties for their salinity reclamation once a proper irrigation regime is established and the drainage system operates satisfactorily.

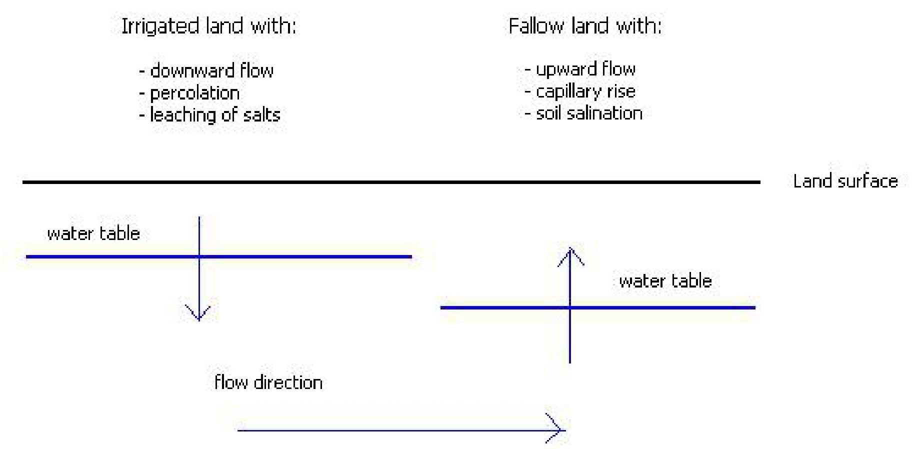

Figure 4. Fallow land assuming a drainage function in waterlogged areas.

Saline soils contain a high amount of sodium chloride and are therefore also called saline-sodic soils. Sodium salts and chlorides are soluble and leach out quickly. The leaching process seldom results in unfavourable alkaline-sodic soils with high pH and low infiltration rates. In the unlikely case that the soil would become alkaline sodic, this would only constitute a major problem in heavy clay soils with potentially swelling properties. Silty and fine sandy soils have no swelling potential. In the Huarmey valley, clay soils are absent.

3.2 Case studies

Consultant has no information on recent land reclamation experiences in Peru, but he has been involved in pilot projects in the period of 1971 to 1974. A summary of the experience follows.

1. Pilot area Pedregal (20 ha) in the Piura valley. The silty soils were waterlogged and very salty. A drainage system consisting of 30 cm clay tiles with a gravel filter was installed. There was a gravity outlet. The water management was done by a research institute and there was plenty irrigation water. The soils were reclaimed within a year and gave excellent cops.

2. Pilot area Chacupe (30 ha) near Chiclayo. The dense clay soils had a low hydraulic conductivity and were waterlogged and very salty. A drainage system consisting of clay tiles was installed. The water management was done by a research institute. As the irrigation water was scarce, it had temporarily to be derived from a nearby cooperative. Initially rice was grown for reclamation purposes. Due to the unfavourable soil properties, the reclamation process lasted 3 years. After that time other crops, like maize, could be grown successfully. Initially there was a fear that the saline soils might be converted into alkaline sodic soils, and therefore some fields

were given a gypsum amendment. Analysis of the effects of the amendment showed that the gypsum application was not really necessary and there appeared to be no danger of soil sodification. After terminating the experiments, the irrigation water was given back to the cooperative which used the water in its own land and the pilot area was abandoned. This example illustrates that the reclamation of waterlogged saline soils is only useful in case of ample availability of irrigation water.

3. Reclamation project Pan de Azucar (150 ha) near Trujillo. The silty and fine sandy soil belonged to a sugar cooperative. The soil was waterlogged and very saline. The cooperative availed of sufficient irrigation water as it had recently increased the irrigation efficiency elsewhere whereby water was saved. A drainage system was designed. The elements consisted of 30 cm clay pipes with a gravel filter. The pipes were produced by the cooperative itself. A gravity outlet was available. The cooperative itself implemented the design and within a year the area was produced a good crop of sugarcane. Since the area received upward seepage of groundwater, the drainage design criteria included the requirement that the cane would not consume groundwater during maturation, otherwise the sugar content of the cane might be too low.

At present flexible corrugated drain pipes are available in coils. The pipes can be pre-wrapped with geotextiles. This development has facilitated drain installation greatly.

4. Numerical Modeling Drainage Evaluation

Consultant received the following information on the drainage modeling, using FEFLOW.

To evaluate the impact of the proposed drainage system on groundwater heads, drain cells were introduced into Layers 1 through 3 of the model. However, before these simulations, new information on the hydrogeology of the southern Huarmey area was incorporated into the model. Part of the low permeability is inferred based on geophysical surveys and the other part is inferred by the presence of a shallow water table. The assumption of lower K is corroborated by the K-testing, which indicates lower values in this area then elsewhere in the Huarmey or Cascajal valley.

The hydraulic conductivity in Layer 2 was reduced from the previously calibrated value of 3x10-4 m/s to 1x10-5 m/s. The overall model calibration statistics remained essentially unchanged, with the normalized root mean square error increasing somewhat from 8.28% to 8.29%.

After inclusion of the lower permeability zone, groundwater drains were installed in Layers 1 through 3 of the model. The drains were assigned a drain conductance of 9 d-1. The water table in the model was reduced by 1 m in the area of Well O. The results are shown in Figure 5.

The figure shows the steady state heads for the case without drains (dotted line), with only the main drain (dashed line) and with the entire drain system (three main drains and lateral drains (solid line). The yellow head contours are the 1m contour, the green indicate 2 m, and the blue are the 3 m head contours.

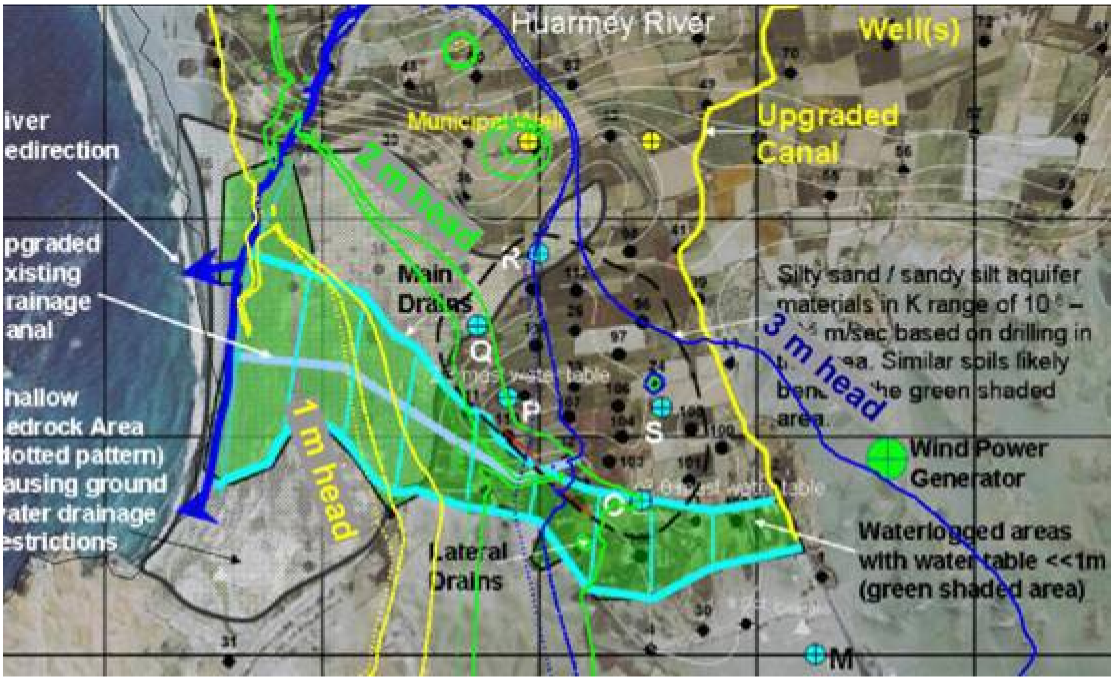

Figure 5. Simulation of groundwater levels after implementing a drainage system using FEFLOW

Comments

In the absence of a topographic map, the groundwater contours cannot be translated into water table depths, needed to develop agricultural drainage criteria.

The simulated lowering of the groundwater levels has probably been obtained by maintaining a sufficiently deep water level in the main drains at their outlet. This would require the presence of pumping stations.

The simulated lowering of the groundwater contours needs to be tested under an increased supply of irrigation water when the lands are reclaimed.

The projected northern and southern border drains will probably not be required as the lateral drains can discharge into the existing central drain, unless a topographic map overrules this statement. The extension of the central drain to the east (along the eastern part of the northern border drain), however, will be necessary to provide an outlet to the eastern lateral drains if they are installed.

To obtain sufficient depth of the water table, the required spacing of lateral drains in irrigated sandy soils with upward seeping groundwater will probably be in the order of 50m, as the drains have to cope with the discharge of both the groundwater seepage and the field irrigation losses.

Excavated drains in waterlogged silty or fine sandy soils are usually very effective in lowering the water table, but they need gentle side slopes, say 3 (horizontal) : 1 (vertical), as these soils are unstable. In addition they need assured annual maintenance to restore the cross-section and remove the abundant vegetation.

The limited fertility of the land, the prevailing low market values of most crops, and the limited financial resources of the small farmers for agricultural inputs, such as fertilizers and crop protection chemicals, will probably not economically justify the more costly installation of buried pipe drains instead of lateral ditches.

5. Findings from the field visit in Huarmey

5.1 Existing drains

The central drain was recently upgraded, after apparently a long period of neglect. According to local farmers the upgrading was done by the ministry of agriculture. At the same time a new lateral was excavated (Figure 5).

The cross-section of the central drain is now wide and deep. At the bridge, approximately halfway the drain, there is a small drop of a few decimeters (Photo 1) and the drain discharge was estimated at 10 l/s.

As the zone of influence of the drain upstream of the bridge is less than 50 ha, the drain discharge was more than 0.2 l/s per ha, which is almost 2 mm/day. At the time of the visit the area had probably not been irrigated for a period of more than a month, which indicates that the drain is intercepting upward seeping groundwater effectively. It remains to be seen how effective the drain will be when the lands are being irrigated.

The soil excavated from the central drain was dumped in heaps along the drain without any leveling and no attempt to create an even spoil bank to serve as an inspection road.

The lateral drain is narrow and has vertical walls that showed signs of caving in (Photo 2). Also here, the excavated earth was dumped in heaps and not spread. The discharge could not be assessed.

In the downstream reaches of the central drain the water level is too high to permit properly functioning lateral drains (Photo 3).

5.2 Area characteristics

A rapid visual inspection of the proposed project area has led to a division into 5 subareas distinguishable according to differences of agricultural water management conditions in the subareas (Figure 6).

Subarea I is flat, saline and waterlogged and shows no traces of previous cultivation. It is far away from surface water resources and the availability of exploitable groundwater resources of reasonable quality for irrigation is doubtful so close by the sea. The soils appear to be silty and/or fine sandy, which will have to be verified by a soil survey.

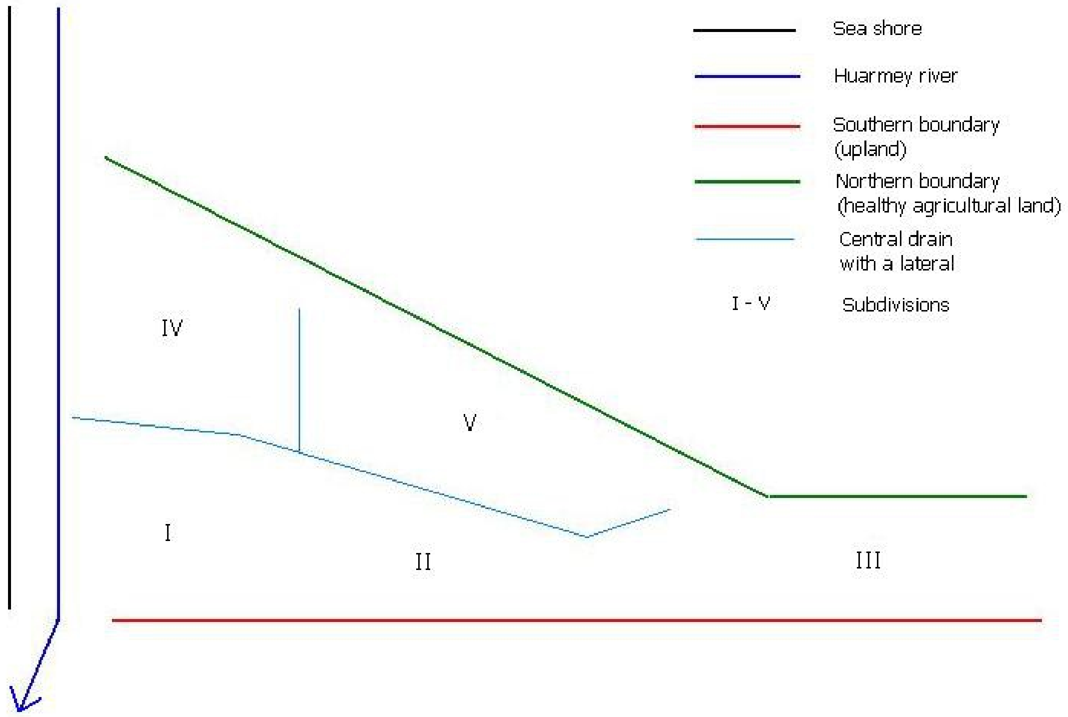

Figure 6. Sketch of the waterlogged area identified in Figure 1, divided in 5 subareas.

Subarea II is consists of small dunes, stabilized by salt tolerant plants (Photo 4). It has never been cultivated. Like subarea I, it is far away from surface water resources and the availability of exploitable groundwater resources of reasonable quality for irrigation is doubtful.

Subarea III shows patches of irrigated land intercalated with fallow lands (Photo 5) that show signs of agricultural use in the past. In this subarea, the farm of Victor has fields with maize and alfalfa to provide fodder for his dairy cattle (Photo 6). A considerable part of his land is fallow. The irrigation water is supplied by a canal that receives water derived from the Huarmey river. The canal appears to be connected to an outlet for excess water. The crop stands are poor. There is a dug well on the farm for household purposes. Victor lives on the farm with his family and derives his main income from work elsewhere. The family experiences a mosquito problem.

Subarea IV, like subarea III shows patches of irrigated intercalated with fallow land. Contrary to subarea III, the fallow land does not show signs of cultivation in the past. Two farmers were visited here, an elderly man and an elderly woman (Photo 7) who live there alone. They cultivate asparagus. The irrigation water is bought from an small association of farmers (at a cost of 70 soles/hr) who operate a tube well collectively. The woman obtained the land through the Reforma Agraria and she seems to continue to pay a contribution.

The farmers complained about mosquitoes. In their opinion the outlet of the Huarmey river to the sea needed more excavation to lower the water level in the river and subsequently in the central drain to reduce the mosquito plague and better drain their land.

Subarea V is for a large part uncultivated, but the fallow land shows signs of previous cultivation. During the visit no information could be gathered about the socio-economic conditions of the landowners.

5.3 Land reclamation options and recommendations

5.3.1 Subarea I

To reclaim subarea I it will be required to bring *irrigation wate*r from the Huarmey surface irrigation system. This would have to be arranged with the water user association. Alternatively, irrigation water could be obtained from an existing tube well south of Huarmey city or else a new tube well may be developed. The local groundwater reserves are probably limited and the their quality may be poor due to salinity, hence the new tube well would have to be located more towards the centre of the alluvial fan.

Next a sub*surface drainage system* is to be installed. This might consist of open ditches of 1.5 m depth, spaced at about 50 m, discharging into the central drain or into a new main drain as shown in Figure 5. As the central drain is already present, the construction of a new main drain is not strictly necessary.

As the soils are silty to fine sandy (to be verified from the *soil survey data*) the desalinization of the soil will be a speedy process that can be completed within one year, provided a proper irrigation regime is established and the drainage system operates satisfactorily.

Given the low level of the land, to be verified from a *topographic map*, it may be necessary to *pump* the water from the field ditches into the central or main drain or, alternatively, provide a *pumping station* at the outlet point of the main drains.

For the sustained operation of the drainage system, an annual maintenance program will have to be devised and a *budget for pumping costs* is to be foreseen. It might be required to contact the ministry of agriculture about the *maintenance* of the central drain and reach an agreement on this.

It is to be expected that the development costs of subarea I will be relatively high. In this respect it may be advisable to obtain *assurances* from the landowners that they will make every effort to execute the necessary land preparation activities, start the cropping and irrigation activities and render the land productive. Otherwise the reclamation efforts will be a waste of resources.

It may be considered to let the landowners *share* to some extent the development costs.

<u>Recommendations</u>

Subarea I has never been put into agricultural use. The following factors constitute impediments to its reclamation:

- the limited fertility of the land
- the prevailing low market values of most crops
- the limited financial resources of the small farmers for agricultural inputs, such as fertilizers and crop protection chemicals
- the high costs of providing irrigation water to this remote area
- the high costs of pumping the saline drainage water out of the area

It is therefore *not recommended* to attempt a conversion of subarea I into agricultural land.

However, to control the mosquito population, one could excavate lateral drains, spaced at 50 to 100 m, through the area towards the central drain with the aim to dry the *stagnant pockets* of water on the soil surface. As an alternative one might study the possibility of mosquito eradication by spraying insecticides.

5.3.2 Subarea II

Most of what has been stated about the reclamation of subarea I also holds for subarea II. In addition it would be important to fysiographically assess the small but numerous dune formations (Photo 1) to obtain more information on the feasibility of land levelling. Such information cannot be found in the soil map.

Recommendations

The recommendations for subarea II are the same as for subarea I.

5.3.3 Subarea III

Option 1

Contrary to the previous subareas, it seems attractive to explore the possibility to perform subsurface drainage in subarea III by shallow tube wells at a density of say one well per property. Each landowner would then be responsible for maintenance and operation of the well.

The well water, when saline, may be discharged through a small surface drain connected to the existing central drain. As many of the parcels in subarea III are presently not in use it might be possible to identify suitable courses of the surface drains without disputes between landowners. Alternatively, the well water may be discharged using the tail ends of irrigation canals, provided they have an outlet to a drain.

After the initial desalination of the land, during periods of water shortage, the well water may be used for supplemental irrigation even when it is slightly salty. The extra salts accumulating in the soil owing to this practice can be leached during the following irrigation season without difficulty.

A disadvantage of this method is that a farmer who operates his well diligently may be draining all or part of the land of his neighbour who does not use the well but might take advantage of it without sharing the costs.

Option 2

Alternatively subarea III could be drained by a series of lateral ditch drains discharging into the extension of the central drain (see section 4 under comments).

Recommendations

Consultant recommends option 1.

As irrigation is *essential* to the success of the reclamation efforts, the possibility of acquiring more irrigation water than used hitherto needs to be explored before deciding to implement a drainage scheme. This holds for both above options.

The land users in subarea III may generate enough extra income from the improved conditions to be able to assume the costs of operation and maintenance of the wells.

5.3.4 Subarea IV

The main difference between subarea I and subarea IV is that subarea IV is less remote from Huarmey city, that it is partly cultivated, and that there are signs of previous, but abandoned, efforts to grow crops. This proves that the landowners have an interest in agriculture.

Drainage by wells, as described under option 1, subarea III, is not advisable as the area is close to the sea, and the groundwater is salty.

<u>Recommendations</u>

If the subarea IV is to be reclaimed, it is recommended to excavate a number of lateral ditch drains that discharge into the central drain. The ditches would need to be approximately 1.5 m deep with gentle side slopes and spaced at about 50 m. The field drainage system will also help in controlling the mosquito population.

The central drain would have to be equipped with a *pumping station* to discharge the drainage water into the Huarmey river. Measures will have to be taken to *guarantee* the operation and maintenance of the pumping station.

The landowners will require *assistance* with the acquisition of additional irrigation water and other agricultural inputs as well as with the maintenance of the drains.

5.3.5 Subarea V

The conditions in subarea V are intermediate between those of subarea III and IV. The recommended drainage systems of the subareas III and IV would both be applicable.

<u>Recommendations</u>

Consultant expresses his slight preference for the recommended drainage system of subarea IV, i.e. the construction of *lateral drains*, instead of wells. Otherwise the drainage system of subarea IV would stand isolated. Further, it would be logical to profit of the presence of the central drain.

All other reclamation recommendations for subarea IV are *equally valid* here.

6. Photographs

Photo 1. The recently cleaned central drain is discharging about 10 l/s.

Photo 2. The recently excavated lateral drain collapses due to steep side slopes.

Photo 3. In the lower reaches of the central drain the water level is too high to permit properly functioning lateral drainage systems. A pumping station is required.

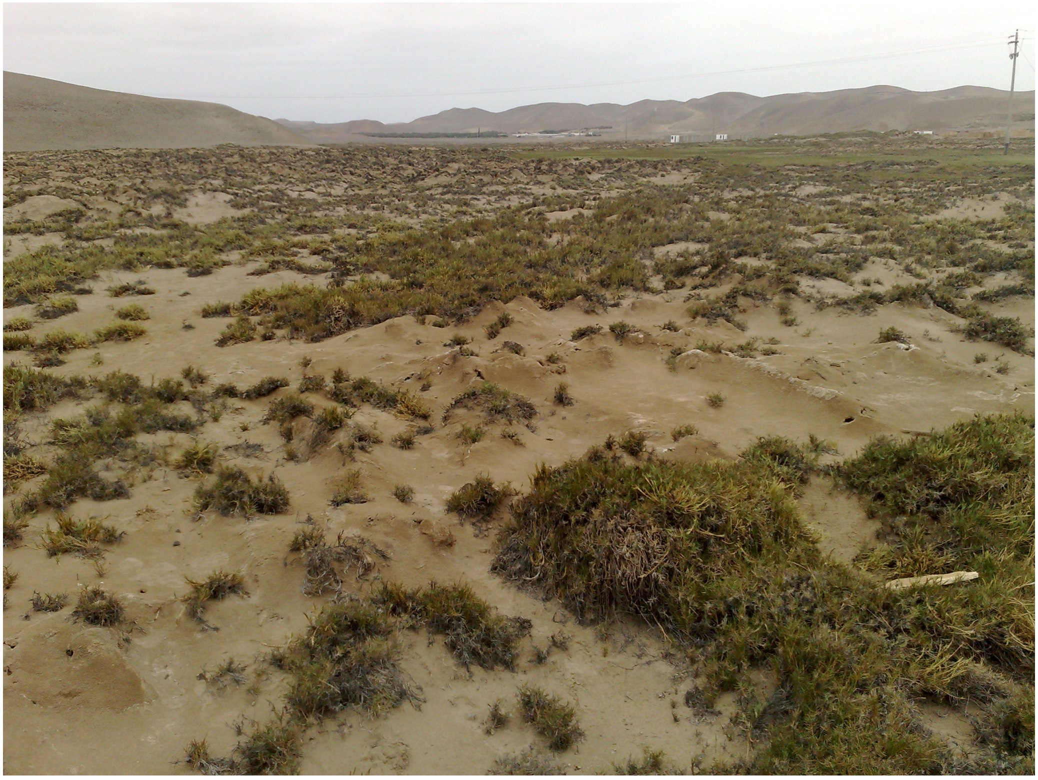

Photo 4. Miniature dunes in subarea II

Photo 5. Unused land in subarea III, waterlogged and saline.

Photo 6. Stunted growth in the alfalfa field of farmer Victor in subarea III. The maize crop to the right, used as fodder, is also growing poorly.

Photo 7. Female farmer in subarea IV. She manages the asparagus field in the background. Beyond that field, another field is seen, which is presently not cropped but it was cropped in the past.