TECHNICAL ASSISTANCE IN TIDAL LAND RECLAMATION

DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA

PROJECT FINDINGS AND RECOMMENDATIONS

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

ROME, 1994
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Report prepared for the Government of the Democratic People’s Republic of Korea by the Food and Agriculture Organization of the United Nations acting as executing agency for the United Nations Development Programme

UNITED NATIONS DEVELOPMENT PROGRAMME
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 1994
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1. INTRODUCTION

1.1 PROJECT BACKGROUND

The Democratic People's Republic of Korea has started the reclamation of tidal land along its western coast. The decision to implement this highly ambitious project, which implied the construction of some 1 000 km of sea dikes and the reclamation of 300 000 ha of tidal land, was taken in 1980 at the Sixth Congress of the Workers' Party of Korea. The location of the projects is shown in Figure 1.

The sea dike for the Taegye Do project was closed in 1984, but it had still to be brought to its final profile. The total area enclosed was 8 800 ha, of which 7 300 ha was to be agricultural land and 1 500 ha water and fish ponds. Two discharge sluices had been constructed. While the inner dikes had not yet been constructed, 3 500 ha, located on the higher areas, had been brought under cultivation. The basic layout is given in Figure 2.

For the Ka Do project, construction of the sea dike, with a total length of 16.2 km had started. A total area of 33 500 ha was to be enclosed, of which 27 800 ha would be agricultural land and 5 700 ha water, roads and fish ponds. Three discharge sluices were to be constructed in the dike. The current situation in the Ka Do area is shown in Figure 3.

In some other projects, which were of smaller size, either sea dike construction or polder development was ongoing. In the first of these, the Unryul polder, the sea dike had been closed and some 3 500 ha were to be reclaimed in the near future. In the Kang Ryong project, 5 200 ha had been enclosed, of which 4 200 ha would remain fresh water to be used for irrigation. The other part was to be reclaimed. In the Ryong Mae Do project (4 000 ha) and the 18th September project (3 500 ha), the sea dike had been closed and reclamation had started. In the framework of the tidal land reclamation projects, some 11 700 ha of mussel breeding sites were to be developed.

To accelerate the rate of dike building, considerable increases were needed in the national capability to design and implement dike design and building programmes, and assistance was requested of UNDP, following FAO support in familiarizing government officials with land reclamation programmes and methodologies elsewhere under project TCP/DRK/2201 of the FAO Technical Cooperation Programme.
Figure 1 Location of tidal land reclamation projects in the People's Democratic Republic of Korea
Figure 2
Basic layout of the Taegye Do project
Figure 3  The current situation in the Ka Do area
1.2 OUTLINE OF OFFICIAL ARRANGEMENTS

The Project Document for project DRK/85/005, Technical Assistance in Tidal Land Reclamation, was signed on behalf of the Government on 1 April 1986, on behalf of UNDP on 2 April 1986, and on behalf of FAO, the Executing Agency, on 5 February 1986. The proposed duration was 18 months, with an indicative donor budget of $US 386 000, and a proposed Government contribution-in-kind equivalent to $US 1 365 000.

The counterpart agency responsible for project implementation was the Department of Tidal Land Reclamation, Agricultural Commission of the Democratic People’s Republic of Korea.

In view of the highly technical nature of the support needed, FAO decided that certain work and services in connection with the project be subcontracted to the Ijsselmeerpolders Development Authority under contract no. DP/DRK/85/005-1/AGOF. The Ijsselmeerpolders Development Authority merged on 1 January 1989 with the Directorate Zuiderzee Works to form the new Flevoland Directorate of the Directorate General for Public Works and Water Management, within the Ministry of Transport, Public Works and Water Management of the Netherlands. A list of staff and persons associated with the project is given as Appendix 1.

Subsequently, amendments to the contract were made on 12 March 1988, on 27 May 1988, and on 20 February 1989.

Due to the complexity of the work to be executed and the processes to be expected, it was agreed to extend the project into a second phase, on a reimbursable loan basis.

This terminal report covers both project phases.

The donor budget as finally adjusted was $US 511 000, and the project terminated on 31 December 1993.
1.3 PROJECT OBJECTIVES

The development objective was to assist the Government of the Democratic People’s Republic of Korea in the implementation of a large-scale programme of tidal land reclamation, undertaken to increase the country’s agricultural production area.

The immediate objective was to help improve the methodologies for dike building investigations and the agricultural development of sea-bottom land, particularly through cooperation in the design of a 30 km long ‘model’ dike near Chungsan (west of Pyongyang), and of a pilot agricultural development (polder) area of about 9,000 ha near Taegye Do in the northwestern part of the country.

The immediate objective was later modified, with the project focal point being transferred from Chungsan to Ka Do. The first sea dike sections were constructed there, and discussion and advice regarding ‘model’ dike building concentrated on the Ka Do project.
2. RESULTS AND CONCLUSIONS

2.1 DIKE DESIGN

In designing dikes, the condition of the soil material a dike will be built of, the depth and the condition of the subsoil, the highest tidal water level, expected storm water levels and the height of the waves must all be taken into consideration. The main elements of a dike’s design are alignment, cross-section, and the closure method.

The alignment of a dike depends on the local geology and the water management desired in the area to be reclaimed. The cross-section is defined by the height and width of the crest of the dike, and the gradients and protections of the outer and inner slopes.

The height of the dike must be based on the highest tidal water level, the increase in highest tidal water level caused by typhoons, the height of the waves, wave run up (which is a factor of the gradient of the slope, eventual verges and the roughness of the protecting construction), long-term rise in sea level, and subsidence of the dike during its lifetime.

The stability of the outer slope depends on the gradient of the slope, wave action, construction of the protecting stone revetment (i.e., the size and weight of the stones to be used), the condition of the subsoil and the qualities of the dike-body material. If necessary, the bearing capacity of the subsoil can be improved by removing existing material and replacing it by sand.

The stability of the inner slope depends on the gradient of the slope, seepage through the dike, the condition of the subsoil and the condition of the dike body material.

The seepage through the dike can either be collected with a drainage system in the inner toe of the dike or be reduced by a cut-off wall, or a combination.
2.1.1 Dike-closure methods

During the construction of a dike in a tidal area, current velocities in those gaps remaining open will increase and the slack water period at the turn of the tide will decrease. A bottom consisting of sand, mud or clay does not resist the increasing current, and will sooner or later be washed away, and so some form of bottom protection has to be provided for the last gaps. Such bottom protection can consist of polypropylene sheets covered with stone.

Closure of the last gap becomes very risky, especially as the slack tide period becomes shorter and the current velocity increases. Four closure procedures are possible:

- **horizontal** closure with closed caissons (the construction proposed in this project);
- **sudden** closure with sluice gate caissons;
- **gradual** vertical closure; or
- **gradual** horizontal closure with stone material.

A horizontal closure with closed caissons is quite risky, as the current velocity will increase during the closure operation and the slack water period will decrease.

A sudden closure with sluice gate caissons allows the whole gap to be closed at one go. The caissons are placed during several successive slack water periods and are kept open until all the sluice caissons are placed. When the last caisson has been placed, all sluice gates are closed in the same slack water period. A characteristic feature of a sudden closure by means of sluice gate caissons is to maintain the widest possible effective wet cross-section in the closure gap until all caissons are placed. The increase of the velocity in the gap is limited and consequently the risk is also reduced.

With a gradual vertical closure, the closure gap is built up in horizontal layers. As a consequence the velocity increases and reaches a maximum when, during maximum flow, a *clear overfall* situation is reached. Further heightening of the dike will result in decreasing velocity until the dam has attained its full height. Until the clear overfall situation is attained, the weight of the stones to be used in the successive layers must increase, and must resist the current velocity. As the dam is built up, the total quantity of water flowing over the crest decreases, and the velocities at the bottom become lower and the scouring effect weakens. When the closure dike has been built
up sufficiently to stop the tide, the permanent dam is built around it. The limited current velocity that is a feature of the clear overfall method makes this closure method attractive, but, being dependent on slack tide periods, the closure will take longer than with caissons where the operation is executed with vessels. In case the slack period at turn of tide is too short for a closure with caissons, or for a gradual vertical closure using stone transported by sea vessels, stone-transport using a cableway constructed beforehand remains possible. It is also possible to transport and dump stone with lorries from a temporary bridge, but this is rather expensive.

In a gradual horizontal closure, the gap is closed by constructing the dike from one or both sides. During construction, the current velocity in the gap will increase continuously. Consequently, very heavy stones are required both for the necessary bottom protection and in the dam itself. As the current velocity will increase to very high values, this method is quite risky. However, almost any dike building equipment can be used and the closing is not dependent on slack tide periods. This can minimize the operation time. Where there is rock near to the surface, bottom protection is not required. In this case the method might be attractive.

Caissons and polypropylene sheets have to be placed during slack tide. Where the current decreases rapidly to zero and then increases rapidly, so that the slack water period is (too) short, the forces on the caissons and sheets can grow to very high values in a short time, making it very difficult, if not impossible, to handle them. Hence it is important to calculate beforehand, for the different closure procedures, the slack water period at different stages of the closure operation. Based on these calculations, relationships can be derived between the current velocities, the scouring, the stone dimensions and the length and the width of the bottom protection.

A decision on the closure method can be taken based on an analysis of the risks of the different methods, taking into account the various factors involved.

Slack tide periods become very short, especially at the end of the closure activities. The velocity becomes very high and changes very rapidly just before and after slack tide. Under these circumstances, the crest of the sill must be flattened very carefully to prevent slipping, to keep the caissons upright, and to prevent piping underneath the caissons. This all makes the closure process very difficult and risky. A vertical closure, similar to that employed to close the Unryul and the Taegye Do reclamations, seems preferable.
2.1.2 Availability of data related to dike design

At the start of the project, only limited data related to dike design were available. With the equipment purchased during the project, listed in Appendix 3, there is now the possibility to obtain valuable additional information.

Regarding the topography of the areas to be reclaimed, there were maps available showing the then current situation in Taegye Do and Ka Do, including the depth contour lines. Geological data along the sea dike alignment were available to a depth of 20 m below sea bottom. Mud and sand were the usual bottom material, except in the gully between Ka Do and Tan Do, where rubble was encountered at a depth of about 8 m below the sea bottom, which was of mud and sand. Water level recordings were available from 1917 to date. Extreme high water levels (5.20 m above mean sea level (MSL) and 5.30 m above MSL) were recorded in 1948 and 1986. From 1917 until 1960, water levels were observed visually, and, after 1960, automatically on a self-recording gauge. According to the information available, the design wave height was 1.50 m, based on a wind velocity of 28 m/s from the northwest (frequency 1:50) and 3 m based on a wind velocity of 20 m/s from the south. In the pre-construction conditions, the current in different gullies reached a velocity of about 1.7 m/s.

2.1.3 Current dike design

The design of the dike for the Ka Do reclamation was discussed in detail. The proposed alignment of the sea dike for the Ka Do project ran from Chongsa Do to Sinmi Do, connecting the islands in between. After reclamation, the area would consist of 23 300 ha of land lying above 4 m below MSL, and a freshwater lake of 10 200 ha with a lake level of about 1 m below MSL. A shiplock was in discussion. Discharge sluices were projected between Tan Do and Muggung Do. It was the intention to start construction in 1989. The last gap was projected between Ka Do and Tan Do (length 1 150 m), and the last gap but one would be in the western gully between Kom Do and Sari Do (length 3 200 m). Both gaps were to be closed with caissons (18 m × 12 m × 8 m) on a sill construction of stone and stone nets (weight of stone nets ≈ 100 t). The crest of the sill would reach to 5 m below MSL. In the gap in the western gully between Kom Do and Sari Do, bottom protection, consisting of polypropylene sheets, was planned. The width would vary from 300 to 500 m. The dimensions of the sheets
would be $30 \times 50$ m, and would be loaded with stones, each of 50 to 60 kg each, to a loading of 2 to 2.5 t/m$^2$. In the last gap, rubble occurs at a depth of 8 m below sea bottom, so that bottom protection was not proposed. The rest of the dike was to be constructed of stone and stone nets ($\approx 100$ t each) up to 5 m below MSL, on top of which a wall of concrete blocks was planned, with a fill of sand and stone on the polder side. It was recommended that, in addition, a stone fill should be placed also on the sea side, sloping 1:3 to the top of the dike. The top of the dike was designed according to the location, with a maximum crest of 10 m above MSL. Based on information supplied, the overtopping frequency would be 1:10 000, which was an acceptable value.

Sand and stone were available on the adjacent islands, and the dike building material would be transported by vessel across the sea area and with lorries over the completed dike. Velocity of current and slack tide periods during the closure procedures of the two gaps were calculated. Slack tide periods became very short, especially at the end of the closure operation. The velocity would become very high and would change very rapidly just before and after slack tide.

Stability calculations were made. They showed that at some places a loss of stability of the sill construction must be expected as soon as caissons were placed on the crest of the sill. To prevent this loss of stability, gentler slopes would be required for the sill, and variable according to local conditions. Therefore, stability calculations have to be made.

The bottom protection would be placed in an early stage of dike construction. The sheets should overlap each other by 3 m. According to information supplied, it was planned to sink each sheet in such a way as to ensure that the fabric goes down as a whole. However, it is possible, and even probable, that using the method proposed the sheet would go down with some side slippage, and so could end in a wrong location. An alternative method of placing the sheets was presented. It is probable that sheets longer than 50 m could be sunk in this way. To get sufficient, experience some exercise is needed. Location equipment is necessary to sink the sheets at the proper location. After sinking the location of the sheets must be marked, for instance with the help of buoys on the four corners.

As the bottom protection is laid at an early stage of dike construction, and the current velocity increases during dike construction, it is necessary regularly to inspect this bottom protection, including the scour holes at the edges, using an echo-sounder,
for instance once a day. Should the bottom protection be found to be damaged, measures must be taken immediately to rectify the situation.

The sill was to be constructed on top of the bottom protection. The crest of the sill construction must be flattened carefully and inspected on a regular basis with the help of echosounders until the caissons are placed.

The caissons were to be made in a construction pit, and floated from the construction site to the closing gap using movable floatation boxes temporarily fixed in the caissons. The caissons were to be moved and sited with the help of tug boats, and, after placement, the floatation boxes were to be taken away and the caisson filled with stone and sand. With the design adopted, the use of open bottom caissons to get a good connection with the crest of the sill was a good solution.

The development of the construction and implementation processes require the solution of several complicated problems. To assist in solving these problems, several computer programs have been developed in the Netherlands, including programs to forecast current velocity distributions over the area before and during dike construction; to analyse soil mechanical problems; and to plan project execution. These programs were demonstrated during the training courses.

2.1.4 Inner dikes

Inner dikes will have to be built to protect the reclaimed lands against flooding from the inner lake. The inner dikes have to be built before reclamation of the low lying areas is possible. The crest level of the inner dikes would be at 3.50 m above MSL. Details regarding slopes, protection, etc., were not available.

2.1.5 Alternative reclamation possibilities

If dike construction in the Ka Do area becomes too risky or too expensive, other approaches are possible. Two such options are considered here.

The first option would be a three-stage reclamation, involving a Western polder, a Central polder, and an Eastern polder. The dike around the Western polder could run from Chongsa Do, via Ka Do and Tan Do, to Kom Do, and then in a northerly
direction to the coast. The dike around the Eastern polder would run from Io Po to Sinmi Do, and from there in a northerly direction to the coast. The alignment of these dikes must follow the line where two tidal waves meet each other in order to minimize water movement perpendicular to the dike alignment. Consequently the construction of these dikes, especially their closure, should be easy. Most important is that the closure of the last gap of the different polders should not affect the current velocity in the closure gaps of the other polders. Not only the cost of the different alternatives but also the risk of failure must be taken into account. At a later date these dikes could be used as inner dikes.

The second possibility is a two-stage reclamation. In the first stage, only the higher lying parts would be reclaimed. That can be done with relatively simple construction. In a second phase, the lower parts could be enclosed, an area which by then would be silted. In this way, salt seepage problems in the lower parts would be reduced. This could be attractive, especially as the sedimentation rate is high.

2.2 POLDER DEVELOPMENT

In relation to polder development in the tidal lowlands, several factors are of major importance, including the layout and design of the irrigation, drainage and road systems; the location and the design of the drainage pumping stations; measures at field level to counteract damage to crops due to salinity and to promote the de-salinization process; research and training required for soil, (geo)hydrological and soil mechanics investigations; the use of research and survey results for planning and design; slope protection of main drainage canals; soil improvement measures; and the operation, maintenance and management of the cultivated lands. The management of the water level in the inner lake is of particular importance in order to provide in an optimal way the conditions required for irrigation and the conditions required for drainage, and to minimize damage to crops due to salinity, both in the topsoil and the subsoil. As the Taegye Do project was already under reclamation at the time of writing, the different topics have been dealt with in relation to the reclamation and development of that area. In general, they may of course also be applied in coming projects.
2.2.1 Availability of data related to polder development

Data related to polder development may be divided into meteorological data, topographical data, soil physical data, and hydrological data.

Meteorological data have been collected extensively in the Democratic People’s Republic of Korea. Based on the observations, district, region and country data sets were computed. The maximum rainfall, based on 16 years of data, was 1 946 mm/yr, with 50% of the annual precipitation occurring in July and August. The maximum daily precipitation could be as much as 300 mm. Open water evaporation amounted to 1 167 mm/yr on average, and was highest in April, May and June, when it averaged 160 mm/month.

To be able to determine the amount of irrigation water that may be required, the rainfall deficit is of importance. To determine the evapotranspiration for a cropped field, a crop factor is applied. For rice in the Democratic People’s Republic of Korea, this crop factor varies between 0.77 and 1.5, depending on the growth stage. Decadal data for the evapotranspiration of rice fields was computed for the period May to September. As a general indicator, the rainfall deficit was determined for the period May to September for rice fields. To design drainage canals and pumping stations, rainfall duration frequency curves are of importance. These curves have been developed for Taegye Do and Ka Do separately. Extreme wind velocities are of importance in dike design, and the design was based on a northwestern wind of 28 m/s which could occur in spring and autumn at a frequency of once in 50 years, and a southern wind of 20 m/s occurring in November, and also with a frequency of 1:50. Data were derived from 80 years of observation.

Topographical maps were made at a scale of 1:3 000, with contours at 0.20 m. Surface slopes were between 1:1 000 and 1:1 500 for areas above MSL, and 1:1 000 or steeper for areas below MSL.

The top layer in Taegye Do could be divided into 3 882 ha clay, 2 618 ha silt and 2 300 ha silty sand. Regarding the vertical distribution, the division was generally clay and silt from 3 m above MSL down to MSL; silty sand and fine sand from MSL down to 3 m below MSL; fine sand and medium sand below 3 m below MSL. At deeper levels there was first coarse sand and then pebbles. In the higher areas (above MSL) the clay layer was more than 3 m thick. Most of the soil was clay and loam.
In the area below MSL, sand predominated. The soils along the former coast contained 0.43% salt by dry weight in clay soils and 0.34% salt by dry weight in silt soils. The mud soils in the area below MSL contained 0.8% salt by weight. Along the rivers the salt content was less.

Four rivers discharged in the Taegye Do area: the Tong Gang, the Gon Dang Chon, the Hey Yon Son, and the Hak San Son. Discharge measurements for these rivers were not available.

In the sea dike of Taegye Do, discharge sluices had been constructed in two blocks, with 6 and 5 sluices respectively. The sluice gate bottoms were at 2 m below MSL. The cross-section of each sluice gate was 4 m × 10 m, with a maximum discharge through the sluices of 510 m³/s. In the sea dikes of Ka Do, 3 blocks of discharge sluices were planned. The sluice gate bottoms would be located at 3 m below MSL.

Due to the construction of the sea dikes and inner dikes in the Taegye Do area, a 1 500 ha lake will be created, to be used for irrigation water supply and temporary storage of river discharge and drainage water. Important levels are:

- normal lake level 1.50 m below MSL;
- maximum lake level 3.00 m above MSL; and
- minimum lake level 1.50 m below MSL.

For the supply of irrigation water to the new tidal land reclamation projects, the construction had started of a canal with a length of 116 km and a capacity of 60 m³/s. The canal was to take water from the Taejong Gang river, which had a minimum discharge of 120 m³/s. The intake dam, the Pak Chong Dam, was under construction. Additional irrigation water for the northern part of the Taegye Do area was to be obtained from the Amnok Kang river.

2.2.2 Irrigation, drainage and road system

Only rice was planned to be grown in the polder in the near future, using basin irrigation. The irrigation system was to consist of an inlet sluice or pumping station; primary and secondary irrigation canals; and field irrigation ditches. Under the current irrigation practices, the sequence of activities in the rice fields during cultivation would be:
• April - ploughing;
• 20 April - 10 May - irrigation to wash out salts;
• 10 - 25 May - direct sowing of rice;
• from 25 September - harvest; and
• October - ploughing.

The design irrigation water requirement was 3.7 l/s/ha, including de-salinization. After de-salinization this value could be reduced to 2.0 l/s/ha. A percolation was expected of 20 mm per 10 days. The irrigation water was to be taken from the freshwater lake between the two polder compartments, and from the rivers. The current hydrological conditions were such that under normal meteorological circumstances sufficient irrigation water would be available in the area to meet annual requirements. The intake of irrigation water would be mainly controlled by pumping stations. On the old coastline, two pumping stations were projected for the supply of irrigation water. There were also inlet sluices for water from the inner lake. Due to the expected high salt content (1 000 mg/l) in the dry period from April to June, the water of the inner lake would not be suitable for irrigation of rice, as the current maximum salt content acceptable for rice growing was 500 mg/l. The total capacity to be installed was expected to be 14 m$^3$/s. In some places, irrigation by gravity through inlet sluices was planned. A total of four irrigation pumping stations were to be constructed. The capacity of each electric powered pump was to be 1 m$^3$/s. The cross-section of the primary irrigation canals was based on a design velocity of 0.35 m/s, with an acceptable highest velocity of 0.5 m/s, and on the area to be supplied and the unit quantity of irrigation water. The secondary irrigation canals had a profile based on the area to be supplied, the design velocity and the unit quantity of irrigation water. The cross-section was to be gradually reduced in a downstream direction. The field irrigation ditches had standard cross-sections.

The drainage system was to consist of field drainage ditches, secondary and primary drainage canals, and discharge sluices or pumping stations. The drainage was based on a design discharge of 100 mm/day. To pump out the drainage water, 12 pumping stations were originally planned. In the areas above MSL, these pumping stations would have to be accompanied by outlet sluices in order to discharge water by gravity at low levels of the inner lake. The polder development authority wished to reduce the number of pumping stations to a maximum of three. Due to this, pumps with a higher capacity (5-10 m$^3$/s) would be required. The head ranged from 3 to 6 m
depending on the surface and design water levels in the inner lake. The design rainfall was 300 mm/day. Based on this rainfall and the accepted water level fluctuations in the rice fields, the design drainage discharge was 11.8 l/s/ha. In the rice fields, it was acceptable that for short periods the rice might be under water for two-thirds of its height. The drainage water was to be discharged to the lake. The field drainage ditches had a standard cross-section. The cross-sections of the primary and secondary drainage canals were based on a design velocity of 0.35 m/s and the area to be drained. The discharge of drainage water would be mainly effected by pumping stations. The total capacity to be installed was expected to be 61 m$^3$/s. The number of drainage pumping stations as well as the required capacity within each station still had to be decided. The pumping stations would have to be built before reclamation of the low lying areas could become possible.

The layout of the polder was based on a basic plot size of 50 m $\times$ 125 m and a basic block size of 500 m $\times$ 500 m. It would be necessary to level the parcels, and it was accepted that the difference in level between adjacent parcels might be 0.30 m. Two types of roads were distinguished: main roads and field roads. All roads on the plan were connected with the old land. As no one was expected to live in the polder, good connections with the old land was necessary. The unpaved main roads were to have a width of 6 m and the field roads a width of 3.5 m.

The basic layout of the irrigation, drainage and road system was in general appropriate for this type of area. Nevertheless, some aspects merited closer attention:

- special machinery with low ground pressure is required for the dominant soil types in tidal land reclamation projects;
- in the longitudinal profile of several irrigation and drainage canals, level differences of more than 1 m occur. This will result in land levelling being required in several places;
- for efficient operation and maintenance of the new projects, modern irrigation and drainage systems – including automatic pumps – are needed. It is felt that more information is necessary about automatic control of pumping stations and sluice gates;
- bulldozers with low pressure crawlers are available. In the areas already reclaimed, the bearing capacity of the soil is 0.8 - 1.0 kg/cm$^2$ at a depth of 0.30 m, and 0.2 - 0.4 kg/cm$^2$ at a depth of 0.80 m. For the low lying areas, it should be borne
in mind that the bearing capacity of the clay and loam soils may be as low as 0.2 kg/cm²;

- the pumping stations were situated around the inner lake, with no provisions made to drain water from higher areas to lower lying areas in periods of extreme rainfall;
- for de-salinization, sand grooves, deep wells and horizontal subsurface drainage systems could be good solutions. A trial could be done after finishing the inner dike and installing a pumping station.

The design criteria that have been used for the different systems are in general appropriate for the conditions that occur in the Democratic People's Republic of Korea, provided that the systems are maintained properly. Having seen the quality of the maintenance of existing agricultural lands in the country, it could be expected that proper maintenance will be forthcoming in the newly reclaimed lands as well.

2.2.3 Soil quality and soil improvement

The presence both of saline and of sandy soils in the area may require soil improvement measures. It had not yet been decided what measures to apply and to what extent. However, for both type of soils, a number of soil improvement measures could be considered. To make a proper estimate of the costs of soil improvement, soil maps will be required.

The present practice of salt leaching by using large amounts of irrigation water may only be effective in the higher parts, such as those areas above MSL. In the lower parts, this system probably will not work satisfactorily for two reasons. First, due to upward seepage, infiltration may be almost zero, so it will be very difficult to create freshwater conditions in the root zone, and, second, surplus irrigation water will have to be pumped out to the lake, which is energy intensive and costly. A large part of the area to be reclaimed lies rather low (down to 2 m below MSL). In the Ka Do project, reclamation was planned up to 4 m below MSL. With the aid of pumping stations for drainage this would be possible. Nevertheless, special attention would be required, with measures taken to prevent harmful effects from saline seepage.

For sandy soils, the grain size and the thickness of the sandy layer are important. Coarse sand and thick layers diminish the water holding capacity of a soil,
and a sandy soil has a lower natural fertility than a soil with a significant clay fraction. Firmly packed sandy layers can hamper root growth. If the sandy top layer is thin (<0.5 m) it can be improved by deep ploughing or mixing. Heavily packed layers can be broken by an underground breaker. For a number of crops, in particular for vegetables, the low fertility of sandy soils is no problem as this can be improved by manure or artificial fertiliser. The high bearing capacity of sandy soils allows a high degree of mechanization.

The possibility of de-salinization of saline soils depends primarily on both the availability of fresh water and the hydraulic conductivity of the soil. If the hydraulic conductivity is high and an adequate (subsurface) drainage system exists, it should be possible to pass sufficient amount of water through the profile to effect de-salinization. Sandy soils generally have high hydraulic conductivity, and so natural de-salinization by rainfall would be high and could be improved by a good drainage system. De-salinization of a clay soil is a time consuming process, but would be speeded up by a good drainage system. To preserve the internal structure of the clay minerals, the lime content of the clay soil must remain sufficiently high. Initially the sea clay profiles would have a high lime content and severe problems would not be expected at first. To prevent transport of salt by the seepage of salt water, measures must be taken to reduce seepage. This can be done by reduction of the evapotranspiration at the surface and by reducing the piezometric head of the salt or brackish groundwater by installing a drainage system.

2.2.4 Seepage

Seepage through the sea dike is a matter of concern. This seepage can be forecast by computation based on analytical formulae. The Taegye Do area can be described as a situation with impermeable rock in the subsoil, covered with a permeable layer of sand and a semi-permeable layer of clay. For different lake levels and permeability data, the seepage through the sea dike can be computed based on MSL existing on the outer side.

There is a lot of fossil saline groundwater in the Taegye Do area. Besides seepage due to the low surface and water level in the lower polder areas, there will be a permanent seepage flow to these areas. Part of this water may originate from the sea. The amount of flow will be strongly influenced by the differences in head, and the
permeability of the subsoil. In this case, the groundwater flow can be computed with numerical computer models by which the groundwater flow in an area can be simulated based on the finite elements method. These models are generally written in Fortran, and compute geo-hydrological parameters like piezometric head and flux in a grid system. The present capacity of personal computers is sufficient to simulate the situation in large areas. These models are well tested and reliable, and their applicability to the Taegye Do area has been discussed. Their accuracy depends on the quality of the input data.

2.2.5 **Design of drainage pumping stations**

Drainage pumping stations are normally costly elements in the water management of polder areas. In the location and the design of these stations a number of factors come into the picture, including the amount of water that can be removed by gravity through discharge sluices, the required capacity of the drainage pumping stations in order to remove surplus water based on the agreed design criteria, the average annual amount of water that has to be removed by the drainage pumping stations, and the number and location of the stations.

The surface level in the Taegye Do area is such that, with proper management of the water level in the inner lake, a substantial part of the water can be drained by gravity, for example from the area with a surface level above MSL. Detailed computations of the lake level fluctuations to be expected and the amounts of water that can be drained by gravity can be executed with the water balance program provided during the project.

During the project the location and capacity of pumps for the Taegye Do polder were determined, together with any other drainage that would minimize the pumping required. For this purpose, the whole design process was discussed extensively with the Korean specialists. Items discussed included the availability and validity of the basic data for rainfall, evaporation and discharges of rivers, the exceeding frequency of the water levels of the rivers, criteria for the location and capacity of pumping stations and methods, such as the use of buffer reservoirs, for reducing the pump capacity required.
The overall water management system of the Taegye Do polder was discussed, with the main point of discussion being the water level in the inner lake. The water balance program was used to analyse the options. Simulations based on the physical properties of the area indicated that during average weather conditions the water level in the inner lake could be maintained at a level of 1.5 m below MSL. A higher level might hamper the natural drainage of higher lying areas; a lower level would increase salt seepage and be difficult to achieved because of the short time available at low tide. For adequate de-watering, the level should be between 1 and 2 m below MSL. In those circumstances, natural drainage should easily be attained through the outlet sluices from the higher lying areas - above MSL - and salt seepage would be limited. Careful operation of the outlet sluices to the sea will be needed to ensure this.

For the Taegye Do polder, a water management system was discussed and agreed. It consists of a combination of outlet sluices in the areas above MSL and pumping stations for the deeper lying areas. As there are three main areas in the Taegye Do polder, separated by rivers, three pumping stations and three outlet sluices will be necessary. An initial proposal was to pump away the design rainfall by using pumping stations with a capacity of 100 mm/day. As the average rainfall surplus in the months of July, August and September should be only about 215 mm/day, these pumping stations would work about 50 hours per year. This implies a very high investment for a short working period. In the Netherlands, pumping stations operate 1 000 to 2 000 hours per year. In the water management system now proposed, a capacity of 300 mm/day is foreseen for the outlet sluices, and a pump capacity for the pumping stations of 70 mm/day, combined with a buffer of 10% of the polder area. This buffer area must be able to store 1 m (1 000 mm) of water and could consist of a reservoir or a part of the deep lying area that would be allowed to flood. In this way results could be achieved comparable to pump capacity of 100 mm/day for the whole polder. This is a reduction in the pump capacity required, to an average of about 40 mm/day taking into account the surface area of the whole polder. A further reduction in the required pump capacity could be achieved if a range of allowable water levels in the rice fields were accepted instead of a fixed level of 100 mm. Were a range of 100 to 150 mm water in level to be acceptable, this would create a buffer capacity of 50 mm in the rice fields themselves.

The above design requires that the operation of the outlet sluices to the sea is such that in the rainy season the water level in the inner lake must be maintained at
between 1 m and 1.5 m below MSL. This would require adequate operation of the outlet sluices on a 24 hour per day basis. Precautions would have to be taken to ensure proper functioning of the outlet sluices.

It is advisable that overflow structures be installed both at the discharge sluices and at the higher pumping stations. In this way, during extreme conditions, only the lowest spots would inundate.

A final decision on the number of drainage pumping stations in each individual polder could be based on cost analyses in which both construction and operation costs are taken into account.

With respect to the number of pumping stations in the Taegye Do area and their location, the following are proposed:

- Polder I: one pumping station with 4 pumps of 3.5 m³/s at a manometric head of 4 m; minimum manometric head 2 m; maximum manometric head 8 m.
- Polder II: one pumping station with 2 pumps of 1.7 m³/s; same manometric heads as Polder I; and
- Polder III: one pumping station with 4 pumps of 3.5 m³/s; same manometric heads as Polder I.

Each of the pumping stations would be located at the deepest point of the polder, near the dike separating the polder from the inner lake.

A preliminary selection was made of pump type. Development work and model tests need consider only one type of pump, since the 3.5 m³/s and the 1.7 m³/s pumps are hydraulically comparable. Pumps of this size are fitted, in general, with a metal housing. The Tidal Land Reclamation General Bureau, however, expressed a wish to develop a concrete volute pump in Korea. Such pumps are in use in the Netherlands on a large scale for water management purposes.

The possibilities were evaluated of developing a low head, large discharge pump in-country. Such water management pumps are in common use, specifically for irrigation purposes, and are of the medium to high head, centrifugal type. Such pumps have been built in the country, and some have been running for more than 30 years with no problems. It can be concluded that local knowledge and experience are available to design, fabricate, operate and maintain pumps in general. The possibilities of manufacturing larger sized pumps were studied. The equipment available for the
machining of large parts was adequate. If the design were available, at least one industrial complex was capable of manufacturing the pumps required. In designing the pumps, specific hydraulic development work on impellers and housings and overall technical pump design should be taken into account. Test facilities available were capable of testing pump models. Preparations for the start of the development work on both low head centrifugal and axial-flow pumps had already been made.

The overall technical design has to consider mechanical engineering aspects. With some additional training both in-country and in the Netherlands, there is no doubt that low head, large discharge pumps could be developed within a short time.

Recently, designs have been made by local specialists for an Archimedean screw pump and a mixed flow pump with concrete volute. The Archimedean screw pump can be considered a quasi-static water lifting device. Dimensioning is mainly based upon rules of thumb, although a theoretical basis does exist, and an experienced mechanical engineer should be able to design this type of pump. Once the principles are understood, the designer does not need hydraulic model investigations. The design presented was based on Dutch designs for such pumps. Bearings, lubrication, and the complete drive train were discussed in detail, and the manufacturing of the screw was subject to extensive discussions. The manufacturing method used in the Netherlands and shown to the Korean specialists during their 1990 visit, would require considerable development within the Democratic People’s Republic of Korea, since in the Netherlands the production process is based extensively on the use of specialist machine tools. Since the choices made in the design correspond in general with Dutch practice, the pump could be expected to operate as expected.

Compared to the Archimedean screw pump, the development of a mixed flow pump is to be considered high technology, as it requires a thorough knowledge of hydraulics, of the technical literature, model development, model testing and advanced calculation methods. The design presented represented a first attempt, and certainly required improvement. With respect to structural elements, improvements were still possible. Several sets of model tests had been run with only one model of impeller, which had double curved blades, but showed insufficient axial effect. As a result, the pump had a wide range of operation, but its maximum efficiency point was between 6 and 8 m of head, which was higher than the required head, which is in the order of 3 to 5 m. Moreover, the newly designed pump could suffer from cavitation when running
under lower head operating conditions. It appeared that no investigations had been carried out on the cavitation behaviour of the pump. The design of the pump clearly showed that the *Stork BSV* pump series had been taken as its starting-point. For unknown reasons, some good elements of this type of pump were not used in the design, and instead some new elements had been introduced, more specifically, constructional elements like bearings, seals and lubricating facilities. The Korean pump design engineers were advised to continue the development of models, run more model tests at a wide range of operating conditions, and - with emphasis on improving efficiency – investigate cavitation behaviour and experiment with alternative bearings and bearing materials.

The design of the pumping stations for the polders currently under construction had not started, design work having been restricted to the design of a pilot pumping station. Drawings of the pilot pumping station were discussed, and based upon these drawings, some important recommendations could be given for improvements to be realized in the final pumping station designs. The importance was stressed of taking into account all energy losses which occur in improperly designed approach and discharge channels of these low head large discharge pumping stations. Many questions remained regarding foundations, quality of concrete, and the use of special mortars and of epoxy glues. It was felt that there was unawareness of the qualities of materials available in the country, and of how to adapt the design to the materials available. In addition, real cooperation had still to be developed between all parties involved. This kind of project cannot nowadays be realized without a multidisciplinary approach, and the principle of a coordinated approach in project management was explained.

The pilot pumping station was located at Wang Am, in Hang Ju county, North Hwanghae Province. A rock foundation was available at that location. This was of importance, since an earlier attempt to build a pumping station failed as a result of subsidence caused by poor soil conditions. Drawings of the pilot pumping station revealed that in one pumping station, two different pump types were to be installed. Some assistance was given in improving the general layout in order to attain optimal conditions and efficiencies for both pumps. Both pumps were to be fed from a common sump connected to the main polder drainage canal via an inlet structure with trash rack. Both pumps were to discharge into the Jae Ryong river. The mixed-flow pump was said to have been designed for a discharge of 1.3 m$^3$/s at a manometric head of 3.70 m; this was slightly more than the head to be expected. The pump will discharge into the
river \textit{via} a siphon, but neither a non-return valve nor a sluice had been provided. The Archimedean screw pump was designed for a discharge of 1 m$^3$/s at a static head of 2 m, with discharge into the river by free fall \textit{via} an open culvert. The pumping station was expected to become operational in July 1993. The expected usage of the pumping stations in the Democratic People's Republic of Korea are not directly comparable with the Dutch situation. It is expected that the pump installations in the Democratic People's Republic of Korea will run more or less continuously during the summer months, with only incidental operation expected during the rest of the year. The expected operating time for each pump would be about 2 000 running hours per year. From a technical point of view, long idle periods are detrimental for pumping stations if proper measures are not taken. However, the long periods without pumping requirements can suitably be used for maintenance. At the time of writing, it was not clear how control and operation of the pumping stations would be organized. The Dutch system was explained, but a proper adaption to the local situation would still have to be made.

2.3 LAKE LEVEL MANAGEMENT

The water level of the inner lake is determined by the balance between inflow, outflow and storage. Rainfall, evaporation and river discharges are stochastic processes. Irrigation and drainage are partly stochastic and partly influenced by man. The discharge sluices may be more or less completely controlled by man. The capacity of these discharge sluices was such that under the design conditions of a 1:100 year event, the water level in the inner lake could rise to 2 m above MSL.

The one per 1 000 year discharge of the river into the inner lake is 1475 m$^3$/s. This would result in a water level in the inner lake of 2.5 m above MSL for a period of 2 hours. After completion of the inner dikes, the water level of the inner lake should be kept as low as possible. Due to its high salt content, the water of the inner lake would not be usable for irrigation; however it could be used for an initial flushing of the rice fields before planting the rice in order to save good quality irrigation water.

During spring, the major part of the irrigation water will be required, while during summer the major part of the drainage water will have to be discharged. In winter, the level should be kept low to prevent damage to the dikes by ice. In the final
decision on the preferred water level in the inner lake during the year, seepage through 
both the sea dike and the subsoil will have to be taken into account in order to keep the 
lake water as fresh as possible.

Based on the above and discussions on the required water levels, some critical 
dates and corresponding lake levels were identified for the Taegye Do area:

- beginning of May – 1.2 m above MSL;
- by the beginning of July – a reduction in lake water level to 1.5 m below MSL due 
to take-off of irrigation water;
- during July and August – operation of the discharge sluices in such a way that the 
lake level is kept as low as possible so as to drain the surrounding land as much 
as possible by gravity;
- during September – the water level in the lake is allowed to rise so that by the first 
of October the water level is at MSL;
- during the winter, from October to February – the discharge sluices in the sea dike 
would be kept closed, and the expected river discharge would gradually raise the 
water level to 1.2 m above MSL at the beginning of May.

Water balance computations will be needed to check the probability of these lake levels 
being reached. In order to facilitate such computations, a water balance computation 
program was made available, allowing simulation of various practical situations.

The water in the inner lake must be fresh when the water is to be used for 
irrigation, which means the period from late April to the end of June. In the other 
months, some increase in the salinity of in the inner lake could be accepted, provided 
that by the April of the next year the water would be fresh again. The difficult 
elements in this calculation are the seepage calculations.

2.4 SURVEY EQUIPMENT

The survey equipment listed in Appendix 3 was supplied under the project, and arrived 
in good order. The laboratory equipment and computers were sent to the Design 
Institute, in Sariwon, where they were installed, demonstrated, and instruction given 
to those who were work with it. The low water pressure in Sariwon gave some 
inconveniences during installation, but all equipment worked satisfactorily in the end. 
The deviation of the normal voltage of the mains was from time to time more than the
allowable 10\%, and at low voltages the equipment could be unreliable. The field equipment was sent to Taegye Do by the Technical Department of the Tidal Land Reclamation Bureau. The step gauge and the triaxial apparatus were slightly damaged during transport. The field equipment was installed and demonstrated near Taegye Do. A post had previously been installed near Kachar Do for the attachment of the step gauge.

2.5 TRAINING

Transfer of knowledge formed an important part of the technical assistance. Eight local specialists visited the Netherlands for training in dike building and polder development. The training had four main elements: lectures by and discussions with specialists in the Netherlands; field visits to projects; practical training with the research and survey equipment to be purchased, as well as with other equipment; and practical exercises on dike and polder design. The training was held in part as separate programmes for the dike building engineers and for the polder development engineers, and in part as a joint programme for general discussions. A list of the participants of the training courses in the Netherlands is given in Appendix 2, and in the in-country training course, in Appendix 5.

During the installation and testing of the equipment purchased, handling of the equipment was practised and discussions held on its use. Special attention was given to computer training, which consisted of three parts: general discussions about the functioning and use of personal computers; training in use of software packages; and training in use of the water balance program. The three components of the training were mixed, and several topics were discussed each day. Discussions were also held on the use of the triaxial apparatus and the tape reading apparatus of the underwater current meter. A special program was developed to compute the breakpoint for soils in triaxial tests, and also a program to read out the tapes of the underwater current meter. Many aspects of computer programming, including graphics, data communication, sub-routine development and functions were involved in these programs. The use of the programs was extensively practised and the significant parts of the programs were explained. This should allow the Korean specialists to modify the programs if so required. A very important part of the training was to discuss the concepts involved in using computer models for simulating real world processes, and
especially the difficult task of transforming physical values into model equivalents. At the end of the training it was felt that local training at the computer training centre in Pyongyang would be very useful. At a later stage, the specialists now working with the computers could train others. For training in the use of computer models, contacts with foreign institutions and universities could be very useful.

A second training course - on Water Management and Design of Pumping Stations - was given in the Netherlands for five specialists from the Democratic People’s Republic of Korea. The main contents of that course were the design and production of pumps, and aspects of drainage and land reclamation. The documents prepared in connection with the training courses are given in Appendix 4.
3. RECOMMENDATIONS

3.1 DIKE DESIGN

The closure method plays a very important role in dike design. It is recommended that detailed plans be finalized based on closure methods using closed or sluice gate caissons as well as vertical closure with stone and stone nets. The design calculations must take into consideration velocity and slack tide periods during the closure operation, and be based on laboratory tests concerning the transport and placing of the caissons.

According to information available, it was the intention to start dike construction in 1989 and to finish it in 1993. To implement such an ambitious plan, an operational planning scenario must be made, taking into account the time schedule for each part of the dike construction; the required construction equipment, including, if necessary, specially designed equipment and inspection equipment such as current meters and echosounders; and the dike building materials required. If the necessary dike building equipment or materials are not available at the due time, the consequence could be total failure.

In connection with various details of dike design, the following actions are recommended:

• make velocity calculations for different places at varied stages of dike construction;
• repeat these calculations during dike construction;
• make stability calculations;
• inspect regularly the velocity of the water at different sites during construction;
• inspect the location of the sheets as soon as possible after sinking;
• with the help of echo soundings, make daily inspections of the bottom protection, including the scour holes;
• inspect the flatness of the crest of the sill;
• finish the closure operation as soon as possible after starting in order to prevent passing the winter with a small gap;
• make an operational management plan with a clear and realistic time schedule, indicating for each element of the project:
  * the dike construction equipment required, including, if necessary, specially designed equipment; and
the dike building materials required;

- monitor the level of the crest of the dike to see whether any settlement occurs, and take prompt remedial action if settlement occurs;
- protect the inner slope against erosion, for instance by sowing grass. To begin with, a temporary straw protection will suffice until the grass has grown;
- place, as soon as possible, a stone fill on the sea side of the dike slope; and
- during dike construction, take velocity measurements at regular intervals in the gaps and compare them with the calculated values.

Under the current plan, large enclosed areas will be relatively low, e.g., below MSL. Based on available information, there is a high rate of sedimentation along the west coast of Korea. This could be exploited by reclaiming as a first step the relatively higher parts, and, later, the lower parts in a second step, as it will in the meantime have silted up. Dike building should become much easier and less risky, and would minimize the salt seepage problems.

3.2 POLDER DEVELOPMENT

Although the conclusions and recommendations on 'model' polder development refer mainly to the Taegye Do project, they may, in general, also be applied to coming projects.

Appropriate measures at field scale to counteract damage to crops due to salinity during and after the reclamation process are strongly dependent on the local conditions. Therefore they have to be investigated by field research. It is recommended that such field research be carried out in a low-lying spot as soon as the inner dike is closed and the water has been pumped out.

Relatively sandy spots are expected at several places in the lower parts of the Taegye Do area. If no soil improvement measures are taken, the potential for agriculture on these soils will be relatively low. The effect of soil improvement measures depends strongly on local conditions. It is recommended that various possible soil improvement measures be included in the field research.

It is the intention that most of the irrigation water will be pumped in and most of the drainage water will be pumped out. With the amounts of water involved (more than 75 million m³/year) it would be of great advantage to supply irrigation water and
to discharge drainage water as much as possible by gravity. To this end it is recommended that
• the pumping stations be combined with respective inlet or outlet sluices at those
  places where supply or discharge of water by gravity is possible; and
• by appropriate operation of the sea dike sluices, the water level in the lake be
  managed in such a way that an optimum balance is reached between irrigation
  requirements and drainage requirements so as to minimize crop damage due to
  salinity, both in the topsoil and the subsoil.

It is recommended that meteorological and hydrological data be collected on a
regular and systematic basis.

It is recommended that the condition of the different elements of the systems be
monitored systematically for some years after installation in order to get a clear insight
into their actual functioning. If the data collected indicated the need for modification
of the existing design criteria, new systems can then be designed according to these new
criteria. Point of special interest will probably be the quantities of irrigation and
drainage water entering and leaving the polders by gravity, in relation to the total water
flow. In addition, optimization of the design criteria in relation to soil types should be
considered.

It is recommended that trials with sub-surface drainage or other means to de-
salinate the soil be carried out as soon as possible. The results of the trials can then
be applied in the remaining part of the Taegye Do polder. This polder in its turn can
be seen as a pilot project for a larger and deeper lying polder, such as Ka Do.
Leaching of the lower areas (above MSL) could be established by subsurface drainage
pipes. Such a trial on the June the Third research farm at Onchon was not very
successful. Bearing in mind both the importance of a rapid and permanent de-saliniza-
tion of the root zone, and the soil textural differences between the Taegye Do and the
June the Third research farm, a modified field trial was proposed.

It is clear that, at the time of writing, only a start had been made to designing
and building the low head pumping stations. A lot of experience still had to be
acquired. Specifically, the evaluation of the first results of the pilot pumping station
would seem to be of major importance before further steps are taken in the development
of low head pumping stations for tidal land reclamation projects. There is an urgent
need for reliable pumping stations for the new polders under construction, since up to
now only those parts which can be drained by gravity are usable for cultivation. Moreover, there is no experience in the Democratic People's Republic of Korea in the control and maintenance of low head pumping stations. Therefore it would be extremely useful to draw up a plan for control and maintenance reflecting the Korean situation. Aspects still to be solved involve:

- evaluation of pump design and manufacturing;
- further pump development for polder application and preparation of the construction of larger pumps; and
- drawing up a programme for control and maintenance of low head pumping stations with different types of pumps.

It is strongly recommended that every effort be made to achieve effective cooperation between engineering institutes and industry for the realization of new pump design. It was noticed that, in fact, all knowledge – to a greater or lesser extent – was available in the country, but that cooperation was not apparent, despite the fact that the experience gained from the testing of water turbines could be applied to the testing and developing of pumps, and similarly in manufacturing.

In particular during the reclamation process, water management and de-salination of soils require special measures. It is recommended that a special State farm be in charge of farming during the first years of development of the new areas. This farm should have a research branch in charge of research, surveys and advice in the field relating to:

- measures to promote de-salinization;
- research to contribute to improved irrigation and drainage systems for future projects;
- day-to-day advice, primarily regarding the construction, operation and maintenance of the drainage system, but also lake level management;
- field trials on drainage techniques and materials; and
- agricultural advice in relation to soil types.

This special State Farm could also be used for demonstrations of highly mechanized rice farming for both the Cooperative and State farms, as well as elsewhere in the Democratic People's Republic of Korea. When the soils have been de-salinated and all reclamation works have been finished on a substantial area, the lands could be handed over to an ordinary State or Cooperative farm.
## Appendix 1

### STAFF ASSOCIATED WITH THE PROJECT

<table>
<thead>
<tr>
<th>Name</th>
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<td>F.J. Rmerij</td>
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<td><strong>National Staff</strong></td>
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<td>National Project Director</td>
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<td><strong>Staff of National Institutions closely associated with the Project</strong></td>
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<td>Chon Myong Su</td>
<td>Head of Mechanical Section, Design Institute, Sariwon</td>
<td></td>
</tr>
<tr>
<td>Chon Son Ae</td>
<td>Official interpreter</td>
<td></td>
</tr>
<tr>
<td>Gon Jong Pal</td>
<td>Engineer, Design Institute, Sariwon</td>
<td></td>
</tr>
</tbody>
</table>
Gon Mong Su  Head of the Mechanical Section, Design Institute, Sariwon
Gon Won U  Engineer, Design Institute, Sariwon
Han Gong Ok  Involved in dike building equipment
Han Gong Ik  Chief engineer of Fourth Sub-enterprise of the Dike Building in Chol San County, North Pyongan Province
Han Yong Sik  Teacher in Farm Instruments
Hen Dong Son  Involved in polder development survey equipment
Ho Gwang Hun  Chief Engineer in Soil Survey, Design Institute, Sariwon
Ho Zum Bom  Head of Polder Development, Design Institute, Sariwon
Hyen Dong Son  Head of Soil Survey section, Design Institute, Sariwon
Kang Jwa Yong  Head of Hydraulic Structure Department, Hydraulic Engineering Institute
Kil Chang Hun  Director of Technical Department
Kim Chang Sik  Chief, Design Institute, Sariwon
Kim Chang Sik  Head, Design Institute, Sariwon
Kim Ik Su  Assistant Director, Pumps Section, Hydraulic Engineering Institute
Kim Tae Sik  Head of Inspection, Civil and Mechanical Engineering, Design Institute, Sariwon
Kim Yang Su  Chief of Engineering, South Hwang He Mechanical Construction Enterprise
Kim Yong Hu  Deputy Director, Hydraulic Engineering Institute
Kim Yong Sok  Designer, Hwang Hae Province Polder Enterprise
Jon Won U  Civil engineer, designer of dikes
Ju Chol Ung  Engineer, Design Institute, Sariwon
Lee Chung Do  Mechanical engineer, manufacturing, South Hwang He Mechanical Construction Enterprise
Li Do  Chief Engineer, Fifth Enterprise, North Pyongyang Province
Li Dok Gjun  Head of Pump Section, Hydrological Engineering Institute
Li Lyon Lyob  Guide, General Bureau
Li Gong Yeon  Soil survey engineer, Design Institute, Sariwon
Li Gong Ren  Engineer, Design Institute, Sariwon
Hen Dong Son  Head of Soil Survey, Design Institute, Sariwon
Ho Zum Bom  Head of Polder Development, Design Institute, Sariwon
Mrs Li Gong Yeon  Soil survey engineer, Design Institute, Sariwon
Li Mu Il  Head, Instrumentation Section, Hydrological Engineering Institute,
Li Song Gu  Deputy Director General
Li Yang Su  Engineer, Design Institute, Sariwon
Li Yong Gyem  Chief Engineer, Enterprises in North Pyongyang Province
Pak Byong Lek  Official guide
Pak Hong So  Computer operator, Design Institute, Sariwon
Pak In Su  Engineer, Mechanical Section, Design Institute, Sariwon
Ri Gyong Bok  Engineer, Hydraulic Design Institute
Ro Dong Ung  Engineer, Hydraulic Design Institute
Son U Yong  Computer operator, Design Institute, Sariwon
Um Lin Hyok  Senior engineer of the Polder Design Institute, in charge of the Ka Do project
Institutions and staff involved in the Netherlands during project implementation

Ministry of Transport, Public Works and Water Management
Directorate General for Public Works and Water Management, Directorate Flevoland

J. Abrahamse  Educational expert
F.W. Alberts  Lauwerszее Division
B. Balgobind  Transport Department
G.J. Bijkerk  Water Management Division
A. ten Brinke  Soil science expert
W. Boxsem  Operations and Management Research Division
R. Buursink  Enclosure Dam Division
K.S. Feitsma  Land Use Sub-division, Scientific Division
B. Fokkens  Director, Land Use Department
D.H. Frieling  Deputy Director General, IJsselmeerpolders Development Authority
R.J. de Glopper  Soil science expert
K.P. Groen  Water management specialist
C.A.M. ter Haak  Course assistant
A.J. Hebbink  Water management specialist
D. van Hoorn  Waterways and Water Management Department
J.H. van Kampen  Director, Land Use Department, IJsselmeerpolders Development Authority
J. Kuit  Water management expert
G.A.M. Menting  Water management specialist
J. Middelburg  Specialist in dike building
J. Penninkhof  Operations and Management Research Division
J. Scholten  Water management expert
E. Schultz  Water management specialist, (Project Manager)
H. Slager  Water Management Sub-division, Scientific Division
M. Spierings  Land Use Division
R.G.T. Staverman  Centre for Integrated New Land Development
F.J. Stegeman  Course assistant
M.A. Viergever  Soil Mechanics and Foundation Division
J. Visser  Water management specialist
C. Visscher  Laboratory technician
H. Visscher  Delta Division
J.P.M. Vink  Soil science expert
J. de Vos  Head of the workshop, IJsselmeerpolders Development Authority
C.D. van der Wildt  Director General
H.J. Winkels  Soil science expert
Witteveen  Water management specialist
H. Wolters  Water management specialist
Ministry of Transport, Public Works and Water Management
Directorate General for Public Works and Water Management, Civil Engineering Division
Tj. Visser    Director General
J. van Westen  Dike building expert
J. Boot        Construction Division
Ebbens        van Dijke
M.R. v.d. Does de Bye
Droppert      Hernandez
den Hoed      J.C. Huis in 't Veld  Dike design specialist
Jansen        J.L.M. Konter    Dike design specialist
A.J.G.M. van Roermond  Dike design specialist
Struik        Termaat         Hydraulic structures specialist
D. Verhagen   v.d. Vlugt      J.K. Vrijling  Probabilistic design specialist
C.J. van Westen  Dike design specialist

Ministry of Transport, Public Works and Water Management
Directorate General for Public Works and Water Management, Engineering and Construction Division
H.A. van Aller  Electrical engineering department
G. Boogert     Mechanical engineer, pump expert
G.J.M. Hertogh Mechanical engineer, pump expert
F.J. Remerij    Mechanical engineer, pump expert
M. v.d. Schaft Civil engineering department
M.M.P. Steinebach  Mechanical engineering department
D. Stroosma    Mechanical engineering, pump expert

Ministry of Transport, Public Works and Water Management
Directorate General for Public Works and Water Management, Directorate Zeeland
J.P.A.A. van Gorp  Public Relations Department
T. Jumelet       Instrumentation specialist

Waterboard Fleverwaard
K. Snabel        Water management expert
Appendix 2

FELLOWSHIPS AND STUDY TOURS

A2.1 FELLOWSHIPS

<table>
<thead>
<tr>
<th>Participants</th>
<th>Purpose</th>
<th>Location</th>
<th>Dates</th>
</tr>
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<tbody>
<tr>
<td>Li Yong Bom</td>
<td>Attendance at training</td>
<td>The Netherlands</td>
<td>7 March 1988</td>
</tr>
<tr>
<td>Em Lin Hyok</td>
<td>course on Dike Design and Polder Development</td>
<td></td>
<td>- 31 March 1988</td>
</tr>
<tr>
<td>Se Byong Hwa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kil Chang Hun</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kim Gab Sik</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>He Jun Bom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Chong Won Chan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Li Song Gu</td>
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<td></td>
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<tr>
<td>Kil Chang Hun</td>
<td>Attendance at a Technical Training</td>
<td>The Netherlands</td>
<td>8 Sept. 1990</td>
</tr>
<tr>
<td>Kim Ik Su</td>
<td>Course on Water Management and Design</td>
<td></td>
<td>- 30 Sept. 1990</td>
</tr>
<tr>
<td>Kang Jwa Yong</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Kim Yok Sok</td>
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<td></td>
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<tr>
<td>An Chang Do</td>
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</tbody>
</table>

A2.2 STUDY TOURS

There were no study tours under this project.
### Appendix 3

**MAJOR ITEMS OF EQUIPMENT SUPPLIED**

| Quantity | Item                                                      | Cost  
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Electric stepgauge, including receiving station</td>
<td>44,900</td>
</tr>
<tr>
<td></td>
<td>Self-recording current meter</td>
<td>13,100</td>
</tr>
<tr>
<td></td>
<td>Echo sounder</td>
<td>10,890</td>
</tr>
<tr>
<td></td>
<td>Wave rider</td>
<td>22,175</td>
</tr>
<tr>
<td></td>
<td>Wave pressure meter</td>
<td>12,100</td>
</tr>
<tr>
<td>1 set</td>
<td>Soil physical research laboratory equipment</td>
<td>36,750</td>
</tr>
<tr>
<td>1 ea.</td>
<td>Computer, Printer and associated software</td>
<td>15,125</td>
</tr>
<tr>
<td></td>
<td>Voltage stabilizer</td>
<td>2,925</td>
</tr>
<tr>
<td></td>
<td>Spare parts</td>
<td>2,750</td>
</tr>
<tr>
<td>1</td>
<td>Laser range-finder (Atlas LR 90/205)</td>
<td>10,350</td>
</tr>
<tr>
<td>1 set</td>
<td>Prism holder and 3 prisms</td>
<td>1,067</td>
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<tr>
<td>1</td>
<td>Echo sounder (DE 719C)</td>
<td>4,400</td>
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<tr>
<td>1</td>
<td>Theodolite (TH NE2)</td>
<td>2,221</td>
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<tr>
<td>1 set</td>
<td>Computer upgrade hardware</td>
<td>2,823</td>
</tr>
</tbody>
</table>
Appendix 4

DOCUMENTS PREPARED DURING THE PROJECT

TECHNICAL DOCUMENTS

Papers for the *Training Course on Dike Design and Polder Development* held in Lelystad, The Netherlands, from 7 - 31 March 1988, for Technicians of the Democratic People's Republic of Korea.

Appendix 5

IN-COUNTRY TRAINING COURSES

A Technical Training Course of a general nature was held 19 - 20 May 1993 during the visit of the consultant, F.J. Remerij.

The participants were:

Chon Myong Su  Head, Mechanical Section, Design Institute, Sariwon
Pak In Sok  Designer, Mechanical Section, Design Institute, Sariwon
Meng Chong Kil  Designer, Mechanical Section, Irrigation Design Office, Pyongyang
Ju Jae Il  Designer, Electric Section, Irrigation Design Office, Pyongyang
Pek Sung Il  Mechanical designer, Pump Design Office, Sin An Ju
Kim Sang Chol  Mechanical designer, Pump Design Office, Sin An Ju
Pek Ku Sun  Mechanical designer, 9.18 Machine Factory, Sin An Ju
Kim Ik Su  Assistant Director, Pumps Section, Hydraulic Engineering Institute, Pyongyang
Kim Kyong Bok  Hydraulic Engineering Institute, Pyongyang
Jang Gi Yng  Hydraulic Engineering Institute, Pyongyang
Li Dong Chan  Hydraulic Engineering Institute, Pyongyang
Li Kwang Ho  Hydraulic Engineering Institute, Pyongyang
Han Sun Gum  Hydraulic Engineering Institute, Pyongyang
Kil Chand Hun  Director, Technical Department, Tidal Land Reclamation General Bureau
Li Lyon Lyob  Tidal Land Reclamation General Bureau
Kim Haeng Ryoil  Member, State Agricultural Commission
Kyang Jwa Yong  Head, Hydraulic Structures Department, Hydraulic Engineering Institute, Pyongyang
Saemangum Comprehensive Development Project

Chollabuk-do Province
Republic of Korea
Saemangum Comprehensive Development Project

□ Saemangum Project Area

□ Project Summary

- Project Area: Kunsan city, Kimje city & Puan-gun county
- Total Area: 99,087 acre
  - Freshwater reservoir: 29,158 acre
  - Industrial Land Area: 69,929 acre
- Sea Dike Length: 20.5 miles (33km)
- Hydraulic Radial Gate: 2 places, 656m
- Project Cost: 1,868 Billion Won (US$2.1 Billion)
- Project Period: 1991 ~ 2004
Dike Construction

‘91 ~ ‘96: 7.6 miles

‘97 Plan: 0.8 miles

After ‘98: 12.2 miles

Vision and Purpose of Internal Development

Development Model: SMART City
(Saemangum Manufacturing Agricultural Research Technopolis)

Total Area: 69,929 acre

Project Cost: 13,581 Billion Won (US$15.1 Billion)

Development Period: Year 2001 ~ 2026

Key Organization Group: Local Government, Central Government, Government Investment Institute, Private Companies, The 3rd Sector

Major Functions
- Industrial Zone: 13,591 acre (19.4%)
- Asia Maritime Tourism Zone: 4,151 acre (5.9%)
- High-Tech Farming Site: 29,652 acre (42.4%)
- Distribution Center: 1,186 acre (1.8%)
- New Port of Saemangum: 5,347 acre
  Total of 54 Berths with the Port Length of 7.2 miles
- Saemangum International Airport: 2,768 acre (4.0%)
- Eco-Intelligent Satellite City: 14,332 acre (20.5%)
- Others: 4,250 acre (6.0%)
The Analysis of Major Functions

1) Industrial Zone (13,591 acre)
   - Providing a low cost, competitive industrial site
   - Providing a strategic base to develop underdeveloped area
   - Attracting foreign hi-tech investment
   - Encouraging the Processing/Assembling industry of air-aerospace industry & automobile industry and Hi-Tech industry of mechatronics industry, new material industry, precision chemical industry & biology industry

   Effect expected: Generating about 49,380 Billion Won (US$54.87 Billion) and Creating almost 170,000 jobs

   Key Organization Group: Local Government, Central Government, Government Investment Institute, Private Companies, The 3rd Sector

2) Asia Maritime Tourism Zone (4,151 acre)
   - Why is it needed?
     - International tourism has posted fast growth since the late of 1980s when the world economy started to recover.
     - Local tourism demand is soaring due to high per capita income, improved tourist information networks and transportation services.
     - The goal is to develop Saemangum into an integral link in a channel linking the West Coast and the West Sea Rim to tap opportunities opened up by globalization.

   Demand Estimate
   - By 2020, when the tourism zone will be completed, the number of tourists is expected to increase to 18.27 million.
Development Methods

- Developing as part of the Large Tourism Area encompassing Kogunsan Archipelago, Pyonsan Peninsula National Park and Kunsan city.
- Developing Sunyoo Island as a maritime attraction for aqua-sports, sight-seeing of places renowned for natural beauty and boat tours.
- Developing Pyonsan Peninsula as a major mountain and seaside leisure destination.
- Developing Saemangum area as an urban & general recreational destination.
- Developing a world-class theme park and recreational resort accommodations.
- Developing circular waterways within Fresh-water Lake complete with ferry and tour boats facilities.

3) High-Tech Farming Site

Why is it needed?

- Introduction of sophisticated facilities will allow local agricultural producers to move up in the value-added chain from simple production to processing and distribution.
- Generating High-tech Farming industries by R&D activities in genetics and bio-engineering.

Demand Forecast

- 28,293 acre of new rice paddies is needed by 2011 if Korea is to maintain acceptable level of self-sufficiency. This means 69,756 acre of new rice paddies will be needed by 2026.
Development Method
- To maintain acceptable level of self-sufficiency in main crop supplies, competitive farms are needed.
- Land for major crops and green-house horticulture production is better located in shallow areas near waterlines and areas whose surroundings are unsuitable for industrial facilities.

4) Distribution Center (1,186 acre)
Why is it needed?
- The need to respond to the rapid increase of goods movement
- The need to encourage investment
- The need to improve competitiveness through a reduction of high distributing cost.

Conditions for Location
- Access to transportation network: easy access to national highway, secondary roads, railroads, terminals.

Demand Outlook
- The demand of distribution center for Kunsan and Janghang area is projected to be around 339.5 acre between 1997 and 2011, which will take 8.7% of all distribution center around the nation.
- It is roughly estimated that 300.2 acre of comprehensive distribution zone will be enough to absorb the commodity movement in this region by 2026.

Direction of Development
- Utilizing the methods of public management, co-development between private and public sectors, and public sectors development.
Major Functions and Facilities
- Maintaining a transshipment site as their basic function and diversify their function to the storage, process and assembly of commodities.
- Other supporting facilities will be introduced besides the facilities of distribution center which connects to the airport and port.

5) New Port of Saemangum

- Why is it needed?
  - Growing Northeast Asian and Chinese Economies
  - Inadequate Sea Port Facilities
  - Industrial Complex Development Promises to increase Shipment

- Direction of Development
  - High-Tech, All-encompassing International Port
  - Contribution to Local Development
  - Sufficient Area of Land for Port Development and Future Expansion

- Tonnage Estimates
  - 6.08 million in 2011, 19.50 million in 2021, and 34.85 million in 2031

- Development Plans & Methods
  - Inviting private capital investment in service facilities for port users that have relatively high rates of returns on investment. The government will be responsible for Basic Port Facilities.
6) Saemangum International Airport

Why is it needed?
- The construction is needed because of international demand for airline services which will follow the formation of large industrial zones in the project area, tourism sites connected to Kogunsan and Pyunsan peninsula, distribution center and Saemangum port.
- The importance of air transportation will increase even more in the 21st century.

Conditions for Location
- No obstacles interfering with flying and selecting the airport location by planning, therefore no worry of civilian complaining the noise.
- Annual average of 38.1 foggy days.

Demand Forecast
- According to forecast of the International Air Transport Association, the Asia and Pacific region in Korea belongs is showing an annual growth rate of more than 7%, and the rate account for world airline service markets is expected to increase from 31.2% in 1990 to 51.5% in 2010.
- It is expected that the demand growth rate of airline passengers in Korea will be higher than the rate of the Asia/Pacific region and higher than the world's growth rate.

Basic Direction of Development
- Developing with the most advanced technology available in order to prepare for the condition changes of environmental concerns and customer satisfaction factors like speed, pleasantness, and convenience.
- Accepting advanced technology and using it in the international airport facilities.
- Being developed to maximize the efficiency of connections with other means transportation like highways, railroads and ports.
- Being constructed to minimized noise and environmental pollution.

7) Eco-Intelligent Satellite City

- Concepts
  - Defining as an environmentally friendly information city, being a combination of the words ecology and intelligent.

- Why is it needed?
  - Needs to satisfy the demand for an environmentally friendly, human-oriented, information-oriented, and culture-oriented city.

- Conditions for Location
  - Since the reclaimed land surrounding Saemangum is farming area, the land should be developed so that the rural and city areas can coexist.
  - It can be developed to take advantage of the water front because the region is surrounded by the rivers.

- Direction of Development
  - Building the Saemangum satellite city’s general facilities and their functions to be environmentally friendly and information-intensive.
  - Conforming to the land utilization plan like basic factors or standards for the quality of water, green tracts of land, the altitude of buildings, landscaped roads, an exterior view of buildings, parking lots, pedestrian networks.
MEMO
INFORMATION

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Chonju, Chollabuk-do 560-761
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The Office of International Policy
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Fax: (82 652) 85 - 4233

Department of Provincial Economy & Trade
Tel: (82 652) 80 - 3200
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