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KEYNOTES INTERNATIONAL SYMPOSIUM

polders of the world

Lelystad - The Netherlands - 1982

CONTENTS

INTRODUCTION TO POLDERS OF THE WORLD

.- *W.A. Segeren.*

INTRODUCTION TO POLDERS OF THE WORLD

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Owing to her situation Holland has acquired a lot of experience with polders throughout the centuries. The area where the Dutch are living has been adapted by themselves to the demands made by a populous and prosperous country, such as safety, space to live, to work and for recreation, facilities for the production of food and the preservation of nature. The experience, gained by the Dutch in this field rejoices in a large international interest. This experience is used in different ways in many other countries. Considering the possibilities and the necessity to employ the Dutch experience with design, construction and management of polders elsewhere in the world, it is in fact self-evident that the intention to organise an international Symposium and Exhibition about polders in the world developed in the Netherlands. 1982 seemed especially suitable because several interesting events and anniversaries take place in this year. Most of them are already well-known and have been commemorated with a lot of publicity but in this connection some will yet be mentioned.
On May 28, fifty years ago, the Afsluitdijk was closed and this year interesting events are taking place with regard to the Oosterschelde-dam by placing the 66 columns.
Especially with respect to the IJsselmeerpolders the fortieth anniversary of the Noordoostpolder and the twenty-fifth anniversary of Oostelijk Flevoland can be mentioned.
Moreover, twenty-five years ago the International Institute for Hydraulic and Environmental Engineering has started international

education on water control. This course has been attended by many engineers from all over the world and gives plenty of attention to the lay-out and management of low-lying, flat polder-land with regard to watermanagement.
Finally TNO exists fifty years in 1982. This organisation on practical and applied research has always had plenty of interest in the many aspects of living and working in polder-land in the Netherlands.

Aims

Three aims are being pursued with the Symposium and Exhibition:
1. The exchange of knowledge and experience on polders on international level, to policy-makers and engineers, scientists, managers, builders and politicians alike. For this purpose circulars with a "Call for papers" were sent all over the world. The respons was overwhelming; after selection by a scientific committee, some 150 papers with subjects all in the field of polders, have been printed.
Many papers have been received on certain polder-areas; at the same time there was a large interest in papers on land and water management. Many papers have also been received for the other themes by which it has to be noted that the contributions on socio-economic aspects and physical planning and environmental aspects are mainly of Dutch origin in contrast with the other contributions from all over the world.
The exchange of knowledge and experience will have to take place especially during the Symposium.
Some 400 participants from 60 countries have applied for the Symposium. The fulfilment of this aim will, at any rate, not depend on the number of participants and the countries present.
2. To offer the possibility to the Dutch trade and industry to show her knowledge to the assembled polder-experts of the world both during the Symposium, by means of the papers already mentioned, and at the Exhibition, by means of stands showing information on their trade.
About 40 firms, institutes and services will use this possibility. As a framework for the activities of the Exhibition-participants the organisation has made a separate exposition showing the various aspects

of planning and constructing a polder in different countries, each with their own people's nature, prosperity-level, nature of the soil, climate and such-like. This exposition is also divided in the Symposium themes. It has been built in such a way that it can be used in whole or in part as a framework for an exposition abroad where Dutch trade and industry wish to present themselves. In this way the aim - to advertise the Dutch trade and industry abroad - can be continued after the Symposium.

3. To show the Dutch people in which way other countries have been dealing with the same circumstances, hoping to gain more understanding for the way we live in our own country. That is why many activities, interesting for the Dutch public, are organised all round the Symposium and Exhibition. The Ministry of Transport and Public Works has issued a brochure entitled "Polders of the World". In this brochure many data, collected by the Symposium organisation, have been reproduced easily accessible. Many Dutch and foreign technical journals, papers and other media pay attention to the Symposium. Spontaneously exhibitions of paintings and ceramics, its subjects inspired by polders, will be held in Lelystad from 4 till 10 October. And moreover, a few days the exhibition will be opened for the public. The Exhibition as well as the Symposium will be held in the "Agora" in Lelystad. Lelystad acts already as a centre for the IJsselmeer-polders and will become the capital of the new polder-province.

The meaning of polders to the world

The description of the meaning of polders to the world has to be preceded first by a definition of what is meant by "polders".
In particular prof.ir. A. Volker gives some thoughts to this in the series of articles following hereafter. The starting-point is the following definition:
"A polder is a level area which has originally been subject, permanently or seasonally, to a high water level (groundwater or surface water) and is separated from the surrounding hydrological regime, to be able to control the water levels in the polder (groundwater and surface water)

independently of the surrounding regime ".

The separation from the surrounding hydrological regime and the water level control in the area are the most important characteristics of a polder. They are necessary to be able to use the area in a way that was not possible in the original condition. Other important characteristics of a polder are the flat surface and the fact that almost never big, for agriculture troublesome stones, are found in the soil. The reason for this can be found in the origin of a polder, the deposition of particles eroded elsewhere, by running or stagnant water. The above-mentioned definition and explanation of a polder may lead to many different interpretations.
For instance in this way a paddy-field is a polder just as the flood-plain of a large river protected from floods by an upstream dam with a reservoir.
In general neither of these areas are indicated with the word polder. Anyway, in the framework of "Polders of the World" a practical approach has been chosen for the delimitation of the subject.
For the Symposium those areas are taken as subject where development necessitates the same practices and techniques as the ones used in polders. Level topography and high original water levels are characteristics of that.

In the framework of the Symposium research has been done after areas where "polder know-how" is essential for, especially agricultural, development. The International Soil Museum has derived, from the FAO-UNESCO World Soil Map, the fact that 1200 million hectares are to be found in the world as an absolute maximum of level areas of which the soil is being influenced by groundwater or shows, by its profile, regular flooding.
These soils have mainly developed from alluvial deposits. Of this amount the part without growing season, 109 million hectares, can be excluded at once. From the remaining 1100 million hectares more than half is to be found in areas where, as far as the length of the growing season is concerned, three crops per year are possible. These are the tropical and subtropical regions. It has been assumed that enough water for

for plant growth is available in the form of rainfal, soil moisture or irrigation.

When other criteria are used, such as bearing capacity, germination possibilities, natural fertility, salt content, tillage, rooting capacity etc. another 200 million hectares can be excluded as being not suitable. Of the remaining area, some 900 million hectares, the suitability varies from moderately suitable to good.

In the table below the distribution of these areas is given for the different continents. The name "potential polders" is used because polder know-how is necessary for the development of those areas.

Potential polders in 10.000 ha or 100 km^2.

After: data of the International Soil Museum.

	1 crop	2 crops	3 crops	total
North-America	1695	2054	295	4044
Mexico Centr.America	-	200	1867	2067
South-America	605	2861	12079	15545
Europe	8278	503	-	8781
Africa	-	3036	16161	19197
South-Asia	78	4597	5813	10488
North and Centr.Asia	16458	5231	247	21936
South-East Asia	-	-	5296	5296
Australasia	-	3151	1200	4351
Total	27114	21633	42958	91705

The table clearly shows that in all parts of the world large areas can be found suitable for agriculture. From the table it cannot be read whether these areas are in fact in production and if so, whether the production circumstances require further development or not.

Also not present in the table is, at what cost existing agriculture can be improved and what benefits this will yield. Also no analysis has been made of the regional need for more or improved agricultural lands, the availability of skilled farmers and the social and economic circumstances that have to lead to the optimum use of new or improved land. Finally, our knowledge of the effect on ecology of new impoldering or improvement of existing polder areas, as indicated in the table, is only limited.

Where polderdevelopment is really needed is not known precisely now. This does not alter the fact that the areas, in the table above, clearly shows that polderdevelopment can contribute importantly to the world food supply, especially when being reminded of the fact that in general these areas tend to be fertile.

Three circumstances can be distinguished:

1. Densely populated polder areas, mainly in Asia, Europe, among which the Netherlands, parts of Africa and some areas in North, Central and South-America. In most of these areas the use and administration of the polders is far from being optimum. Improvement of the food production for the local population can only be obtained when starting from integrated rural development. Not only land and water management will have to be adjusted technically. At the same time more attention should be paid to education and extension services, credit facilities, processing and sale of products. Only with a strong participation of the local population this sort of rural development plans have a chance to succeed, together with a wise adoption-pace and project size.

2. Sparsely populated potential polder areas in densely populated regions, mainly in Asia and parts of Africa, in Europe, among which the Netherlands, and some areas in North-, Central- and South-America.

These sparsely populated areas are characterized by their inaccessibility. In general large scale engineering works have to be carried out before the land can be made suitable for agriculture. The reclamation of these areas is taken at hand for relieve of the overpopulation in the region and for the production of food, both for the region and, eventually, for elsewhere too.

The engineering works are large scale. The parcelling of the land can take place on a small scale by giving out the reclaimed land to many small farmers. In general the engineering and land development projects on a large scale require large investments which are often payable in itself but can not be accomplished because of budgetary reasons. The result is that concessions are made on safety and lay-out of the area. At the choice of use of the limited means two criteria should have very high priority.
Firstly, the investment in large engineering and land development projects has to be such that later on, when additional means are available, further lay-out can embroider on what has already been constructed. Therefore a clear picture is needed of the final stage. Secondly, reclamation has to be in such a stage when the farmer starts, that he can grow his first crop without too great a risk. Therefore much attention should be paid to the initial reclamation of the land. Agriculture, financed or even carried out by the government will be almost inevitable during the first years. In developing the new area sufficient attention will have to be paid to the integrated approach for rural areas as given under 1. At determining the place and the scale of the area to be reclaimed ecological factors must play a distinct part.

3. Sparsely populated potential polder-areas in sparsely populated areas, mainly to be found in Central- and South-America, parts of Africa and Australia. In general large engineering and land development projects have to be carried out. The aim for reclamation of these areas has to be a contribution to the world food production. This means that the cost of reclamation and production has to be made up for by the prices of agricultural products which means, in this case, the world market prices. So the cost of reclamation and production will have to be low. This is possible because in these sparsely populated areas, high degrees of mechanisation will be aimed at anyway, for the reclamation activities as well as for the agricultural production itself. Here also the place, the extent and the lay-out of the reclamation have to be chosen in such a way that a maximum of ecological stability is safeguarded. Government, consulting engineers

and contractors in the Netherlands have a lot of experience with the overall development of polder-areas. This experience and knowledge is such that they can give an important contribution to each of the three circumstances mentioned. At the same time they contribute to employment in their own country. The development of the first two categories will often take place on initiative of and conducted by the governments of the countries where the polder-areas are situated. In the areas, mentioned under 3., the Dutch could take the initiative themselves not only by making knowledge and experience available but also by taking care of finance.

Contents of this edition.

To have a clear review of all different aspects of polders of the world a division into five themes for the Symposium has been chosen:

1. land and water management
2. construction
3. agriculture
4. socio-economic and physical planning
5. environment.

For each of these themes two speakers have been invited, one from the Netherlands and one from abroad, mainly working for an international organisation as Worldbank, UNESCO and FAO. The invited speakers give a review on aspects of polders and potential polders in their theme.
Finally two Dutch professors, ir. A. Volker and dr.ir. B. Verhoeven, who have spent an important part of their career in and around polders of the world, will give their view on the past and future of polders.

I wish to express the hope that you will read these keynote with pleasure and that you will get a clear insight in the different aspects of existing and future polders of the world.

LAND AND WATER MANAGEMENT

- *E. Schultz.* From natural to reclaimed land. Land and water management in the polders of the Netherlands
- *K. Pranich.* Land and water management in polders

FROM NATURAL TO RECLAIMED LAND

Land- and water management in the polders of The Netherlands.

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Abstract

This article deals with land and water management in the polders of the Netherlands. It starts with a brief overview, of the history of impoldering. Information concerning meteorological, hydrological and geohydrological data is given. The structure of the water management system is described. Some attention is paid to soil management, wates quality aspects and the main structure of the water management in the Netherlands. Finally some ideas are given for the future of land and water management in the polders of the Netherlands

1 Introduction

The Netherlands is a low lying, densely populated country bordering the North Sea. The major part of the country consists of lagoon and delta type areas. The Dutch have made this area inhabitable by reclamation and protection against the water. But for this creation of their country the Dutch had to fight during centuries against the water, coming from the North Sea, from the rivers, from rainfall, or water from lakes and blown over the adjacent lands during gales.

This article will deal with the different aspects of land and water management in the polders of the Netherlands. First some data about the Netherlands, together with some general information about the polders will be given.

Starting with the past and a brief description of the various works and projects by which the Netherlands was developed, some of the aspects that govern the possibilities to make polders, such as the meteorological, hydrological, geological and geohydrological conditions, will be discussed. Based upon these conditions, a drainage system and a good soil management have to be established in a polder. Aspects of system, lay-out, design norms and means will be discussed. Some attention will be paid to water quality aspects and to the main structure of the water management in the Netherlands.

On basis of the experience gained during centuries of impoldering and recent developments in techniques and way of thinking, some ideas will be given for the future of land and water management in the Netherlands.

2 The Netherlands.

The land area of the Netherlands is 3,400,000 ha. As a result of land-reclamation and subsidence about one third is situated below mean sea level (figure 1). The Netherlands is a very densely populated country, varying from 190 inhabitants per km^2 in the northern part to 915 inhabitants per km^2 in the low lying western part. The cities and industrial areas -8% of the area- are mainly located in the western part. The agricultural lands - 71% of the area - are spread all over the country. The forests and nature reserves - 9% of the area - are located predominantly on the relatively wet soils in the western and northern part and on the sandy soils in the dunes and in the eastern part. (CBS, 1981).

3 Polders, general aspects.

Originally the major part of the Netherlands - some 2,000,000 ha. -, consists of lagoon and delta type areas originating from the delta's

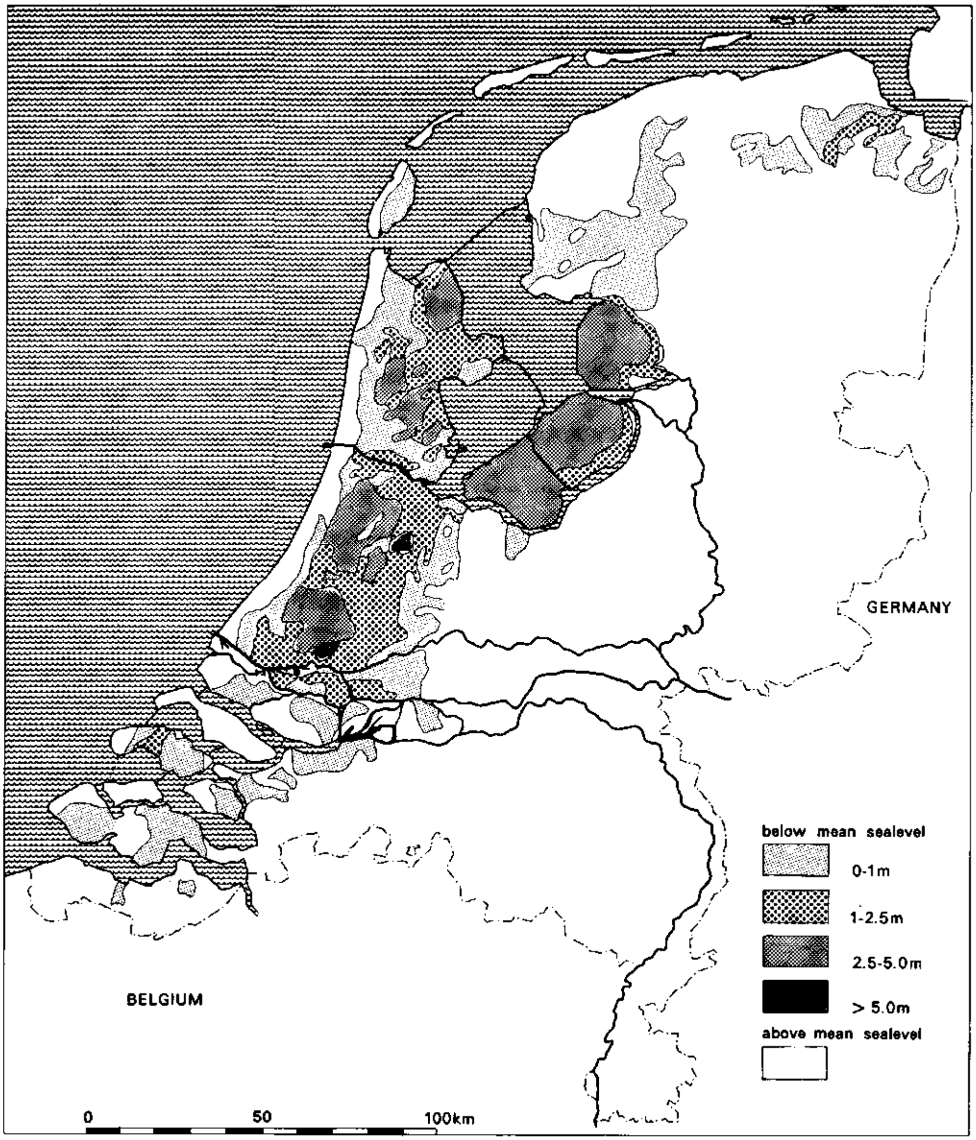

Figure 1. The ground level in the Netherlands.

of the rivers Rhine, Meuse and Scheldt. Owing to the transgressions and regressions of the sea and the different climatological conditions, the land area reduced or extended at regular intervals. Regular flooding of the area occurred owing to high water levels of the North Sea during gales and or owing to high river floods. The people, mainly fishermen and hunters, lived on the river banks unprotected against extreme situations.

As far as is known, the making of protection works against the water started approximately in the third century before Christ when people in the northern part of the Netherlands built artificial mounds to live on. In the first century there was, under the influence of the technical power of the Romans, a beginning of the construction of small dams along the rivers. Later also dams were constructed to connect the several mounds. These dams could resist the regular floods and protected the lands more or less against the water, but they were probably too low to safeguard the land under extreme conditions. Later on the system of dams gradually improved and discharge structures (sluices) were made in the dams. Large activities in dike construction during the seventh and eighth century make it reasonable to suppose that in the eighth century the first polders were made. During the following centuries the protection against the sea and the rivers improved regularly.

Gradually four aspects in relation to the land- and water management became of importance, namely:

- by damming off the various connections with the sea, systems of canals and reservoirs for superfluous polder water - or briefly canal systems - gradually developed These systems have a relatively high water level ($\pm$ 0.40 m. below mean sea level). The polders and higher lands drain their water into these systems, through which the water is then, transported to the sea and discharged during low tide (figure 2);
- owing to subsidence of the reclaimed soils, large areas became gradually below mean sea level;
- there were a lot of lakes. The top soil in the adjacent areas mainly consists of peat. During gales the water of the lakes destroyed the banks as a result of which the lakes extended.

- There are large peat areas. The peat has been used for fuel during centuries. By digging the peat, lakes were created.

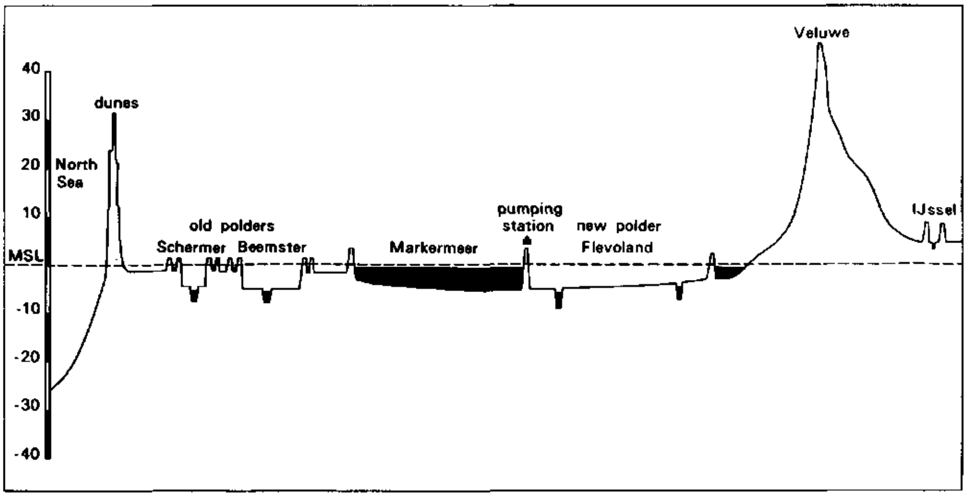

Figure 2. Scheme of the relative levels in the polders, the system of canals and reservoirs for superfluous polderwater and the sea

The improvement of the windmills by the invention of the revolving cap made it possible that from the middle of the sixteenth century lakes were drained. This was particularly so when in the beginning of the seventeenth century it was discovered that to place several windmills in a series (figure 3) large land reclamation works could be executed.

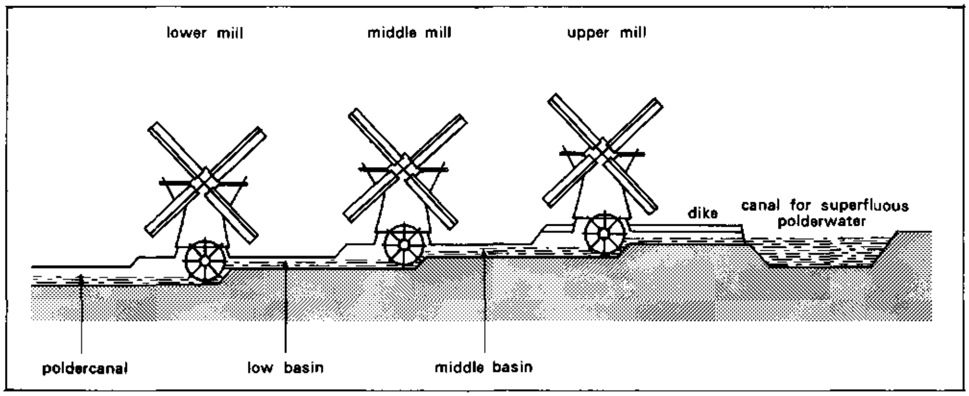

figure 3. Row of three windmills to pump out polder water.

In the beginning of the nineteenth century most polders were made. Besides the winning of lands along the coast, there were two areas left for which plans lived to reclaim them. The first area was the Haarlemmermeer, a lake in the neighbourhood of Amsterdam. This lake had grown from 9,000 ha. in 1250 to 17,000 ha. in 1800 (Ramaer, 1892). During two centuries plans had been made to reclaim the Haarlemmermeer. None of the plans were realized until in Novermber of 1836 a gale blew the water up to Amsterdam and another gale in December blew the water into the streets of Leiden. Altogether 11,000 ha were flooded. It was then that the central government decided that the lake had to be reclaimed.

The second area was the Zuiderzee and as soon as the reclamation of the Haarlemmermeer had been executed, serious plans started to reclaim land in the Zuiderzee. A disaster was necessary to give the final push to start the works. On January 13, 1916, a gale caused floodings in the areas around the Zuiderzee. On June 14, 1918, the act to construct the enclosure dam and reclaim parts of the Zuiderzee passed Parliament. There were three reasons mentioned for the decision:

- greater protection against flooding;
- improved water management;
- the winning of agricultural land.

Up till now, sixty years later, 165,000 ha. former sea bottom have been reclaimed (figure 4). During the execution of the works new ideas about the land use in the polders have been developed. So in the recent polders, apart from the use for agricultural purposes, land is also used for town building, recreational areas and nature reserves.

Not primarily to reclaim new land, but of great importance for the protection against the sea, are the main delta works in the south western part of the Netherlands. In February 1953, in this region 195.000 ha. were flooded and almost 2000 people drowned. In 1958 the Delta Act was accepted, giving way to the building of large dams and other hydraulic contructions and the raising of existing dikes along the North Sea and the main rivers.

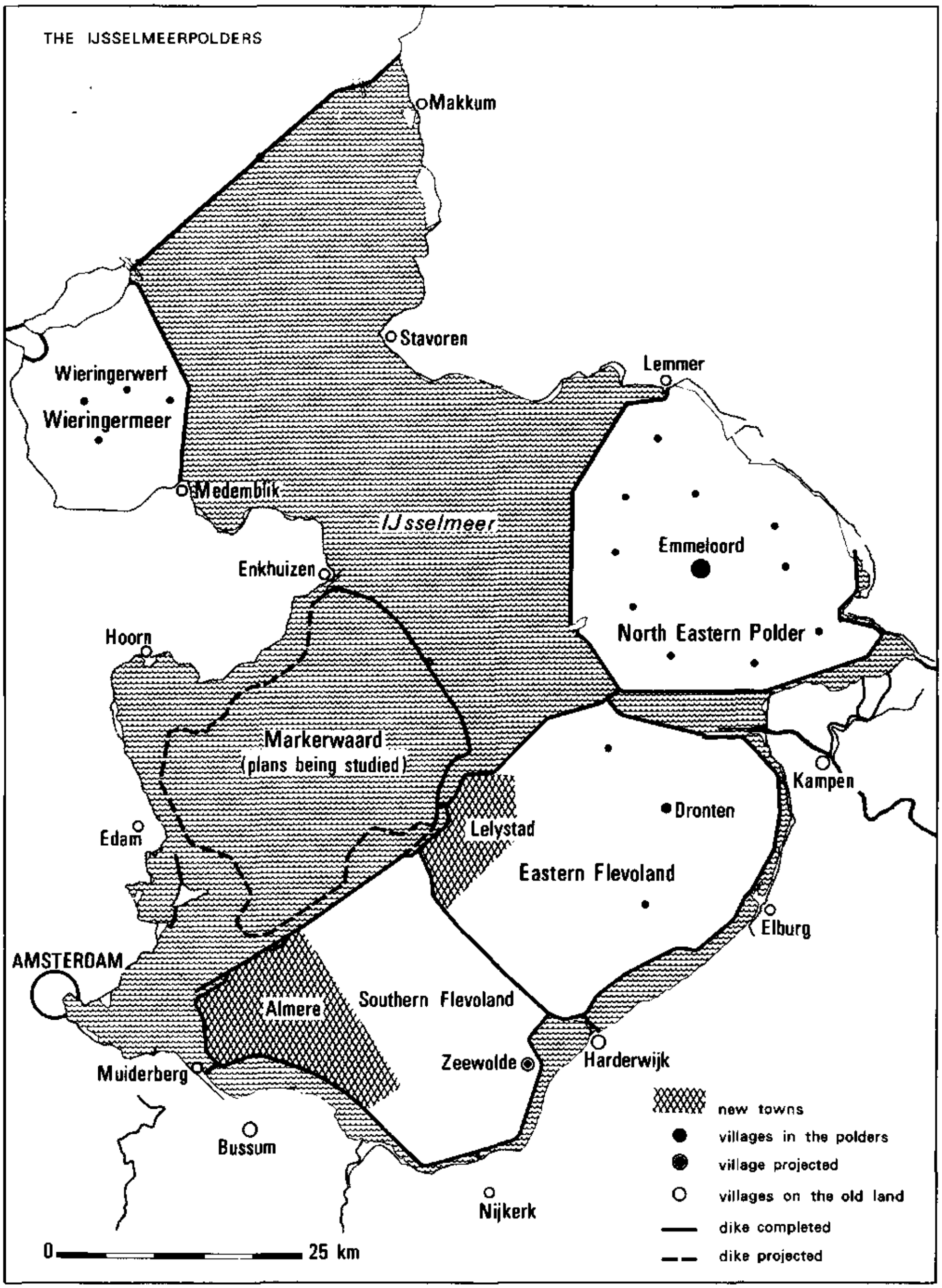

Figure 4. The IJsselmeerpolders.

While the big projects took much attention a lot of works in the polders were also being carried out. Owing to subsidence and to improved norms regarding the water management, improvement works have been regularly executed. Since 1954 when, the Land Consolidation Act was accepted, several land consolidation schemes have been executed.
These schemes have the goal to redistribute the land among the farmers. Within the framework of these schemes, the water management has usually been improved (Van den Hende, 1978).

The land in the polders was normally used for agriculture. On the higher parts the cities and villages have been constructed. The growth of the population, especially after the second world war, made it necessary to find new locations for urban areas. Because all the higher locations were already occupied, it became necessary to house the people in the polders. Altogether about 7 to 8 million people are now living in polders in the Netherlands.

The history of landreclamation in the Netherlands has resulted in the different polder areas:

- Low lying lands	1,335,000 ha.
- Drained lakes	315,000 ha.
- Land won from the sea.	350,000 ha.
Total	2,000,000 ha.

In figure 5 the areas in the Netherlands that need protection are indicated.

But protecting low lying land against the water only makes sense when such an undertaking is economically justified. This means that the output has to surmount the input. The costs of the water management system, like investments for constructions and expenses for maintenance, are influenced by the meteorological situation - especially rainfall and evaporation - the geological and geohydrological conditions and the degree of watercontrol that is required. The aspect that are of importance will be discussed.

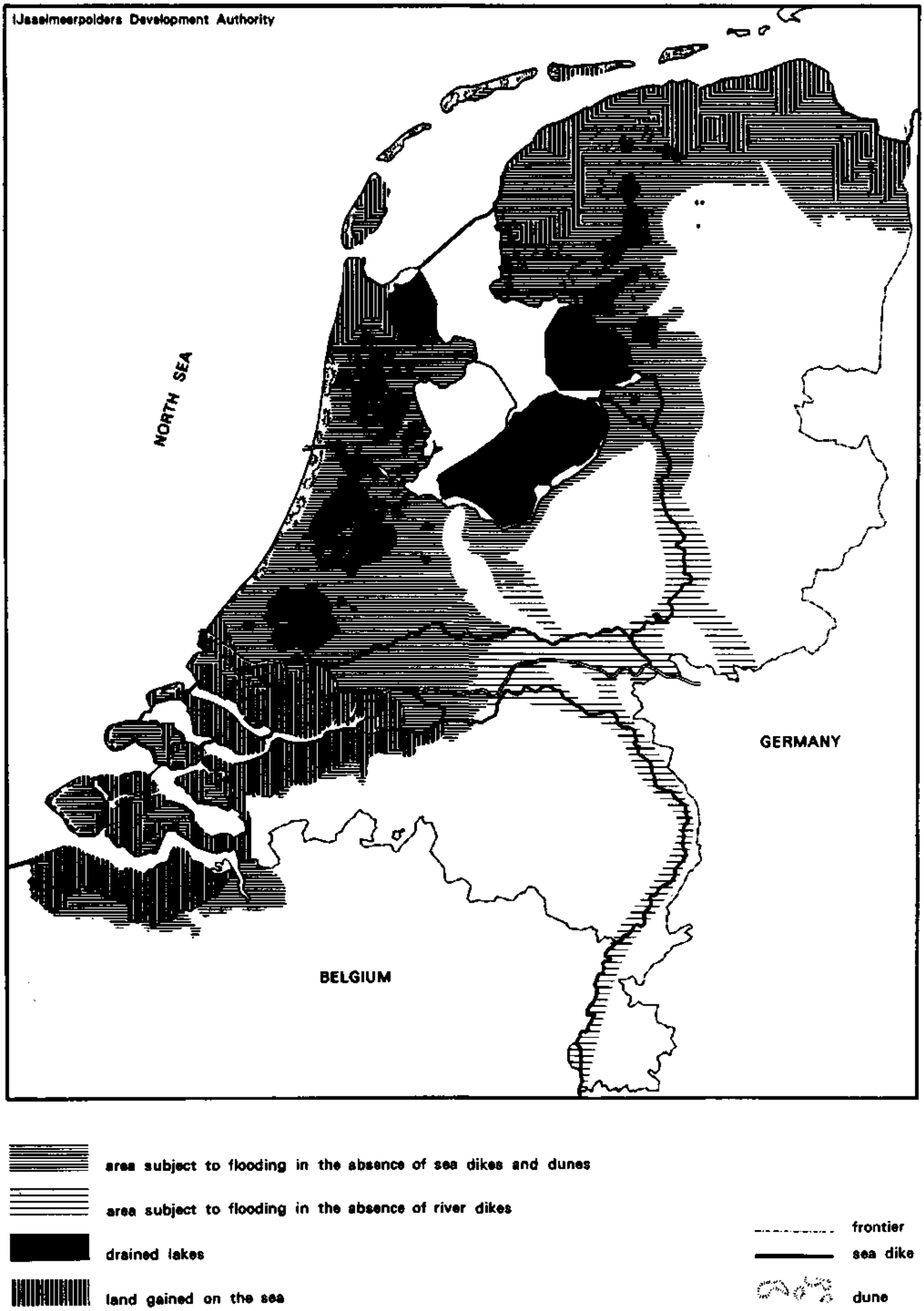

Figure 5. Areas in the Netherlands protected against flooding.

The Netherlands has a temperate maritime climate with a rather even distribution of rainfall over the year. The mean annual rainfall is about 760 mm. The rate of evaporation from open water varies from 0 mm/day in winter to 4 - 5 mm/day in summer. The mean annual evaporation is about 700 mm (figure 6).

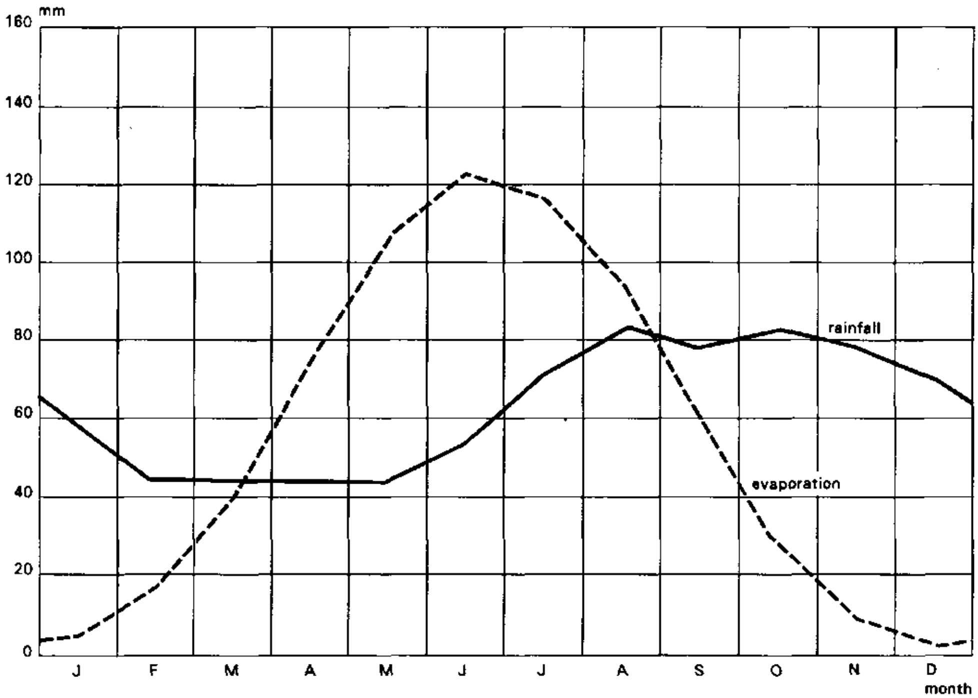

Figure 6. Mean monthly rainfall and evaporation from surface water.
Rainfall data: Hoofddorp 1867-1980.
Evaporation data: De Bilt 1911-1980.
(Royal Meteorological Service, 1867-1980)

Owing to the relatively even distribution of precipitation over the year, the intense potential evapotranspiration during summer and the low potential evapotranspiration in winter, there is under average conditions a rainfall deficit in the summer months amounting to 120 mm and a surplus of rainfall in the winter amounting to an average of 300 mm. In relation to the design of the water management system the short term rainfall intensity is important (figure 7).

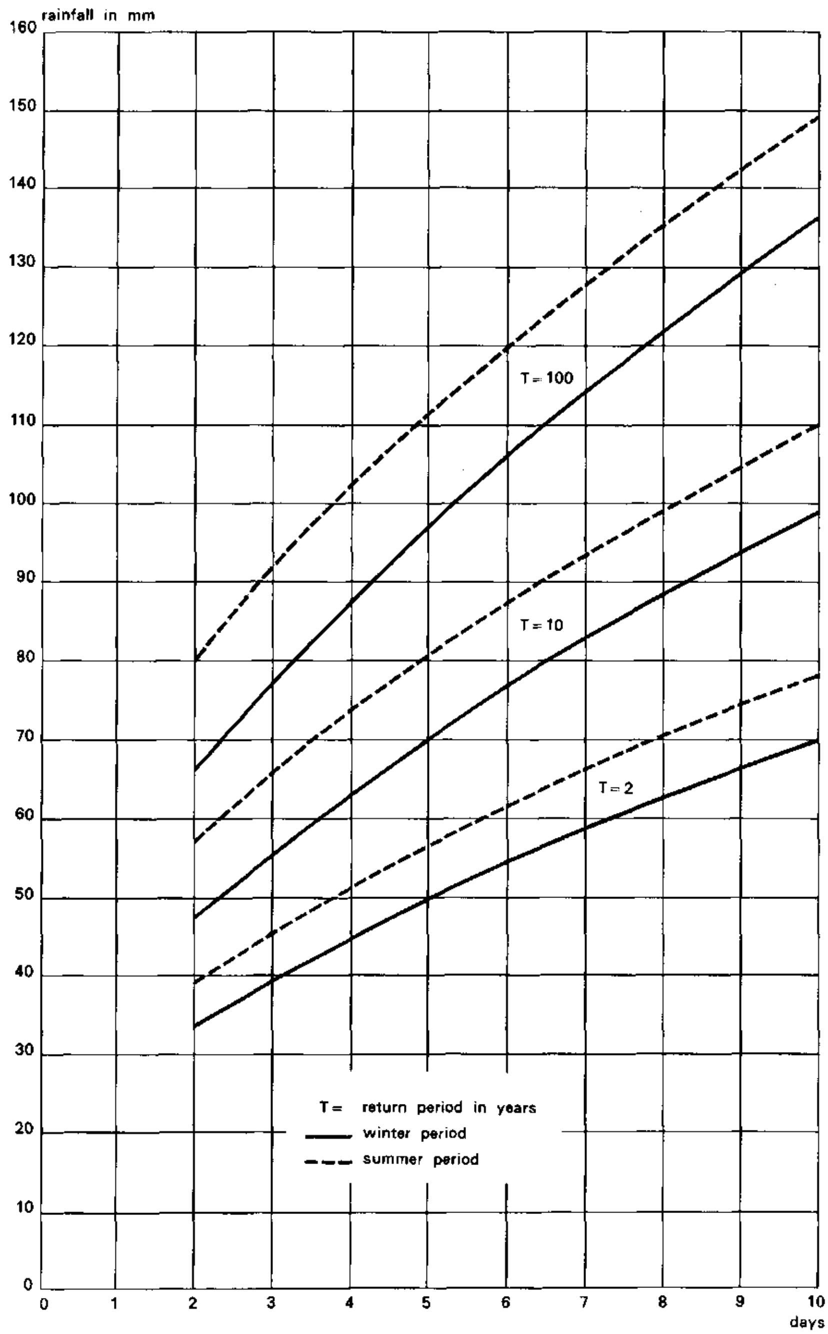

Figure 7. Rainfall intensity-frequency curves.
Hoofddorp, period 1867-1980.

While windmills have played a very important role in the pumping dry of polders, the distribution of the wind velocities has, of course, been of importance too.

5. Hydrological aspects

The discharge of water from a polder has to be realized in a more or less artificial way. For designing discharge structures like discharge sluices or pumping stations it is necessary to have both information about the rainfall surplus and about the possibilities to discharge the water. Water can be discharge to:

- another polder;
- a canal system;
- a river;
- the sea.

When a polder discharges into another polder it is necessary to check the combination of both management systems. The same holds true when a polder discharges into a canal system. The typical aspects of the river regime, in combination with the design periods for the water management system in the polder, are important when a polder discharges into a river. The main rivers in the Netherlands normally have relatively high water in spring. Such a rse in levels can continue for several days or weeks.

When a polder or a canal system discharges into the sea one can make use of the advantage of the tide. During low tide, sluices can be opened. During high tide they have to be closed. Especially during spring and autumn, northwesterly winds can cause relatively high water sea levels during some days.

6. Geohydrological aspects

Important parts of the Netherlands, as a result of land reclamation and subsidence, are nowadays located below mean sea level (figure 1).

The geological profile in the low part of the Netherlands can be briefly summarized as a holocene toplayer consisting of clay and/or peat and a thick pleistocene layer mainly consisting of sand. The thickness of the Holocene toplayer can be up to 20 m.

Due to the location below mean sea level there is seepage in the deeper polders. Normally this seepage amounts to less than 1 mm/day but there are exceptions of up to 20 mm/day.

In the western part of the Netherlands, as a result of transgressions and regressions, the groundwater is brackisch or saline so the seepage water is often brackish. For this reason the water in the canal systems has to be flushed regularly. For this purpose substantial quantities of water are used from the river Rhine and the IJsselmeer. For example, in the western part of the Netherlands, the amount of water used during a summer period, partly for supply and partly for flushing, is about 650×10^6 m^3 which means 290 mm spread over the area.

7 Water management system

Originally only farmers lived in the polders. Most cities were located on the higher ground or where artificial landfill had been applied. The water control system in the polder was therefore designed and constructed according to norms applicable for agricultural areas. This was predominantly the situation until the second world war.

After the second world war intensive urban schemes were executed in existing polders to house the people in the neighbourhood of the cities. Mostly by landfill the area was "depoldered" and drained directly into one of the canal systems. Gradually, for new projects, the lands were only raised to some level above the water level in the polder. In these cases both the water of the rural and the urban areas had to be pumped out. So the design norms for the water management system had to be adapted.

The water management system inside a Dutch polder consists in principle of some or all of the next items (figure 8).

- sluice(s), windmill(s) or pumping station(s);
- canal(s);
- main ditch(es);
- ditches;
- open or closed field drains.

Polders have to be protected by dikes against the water from outside.

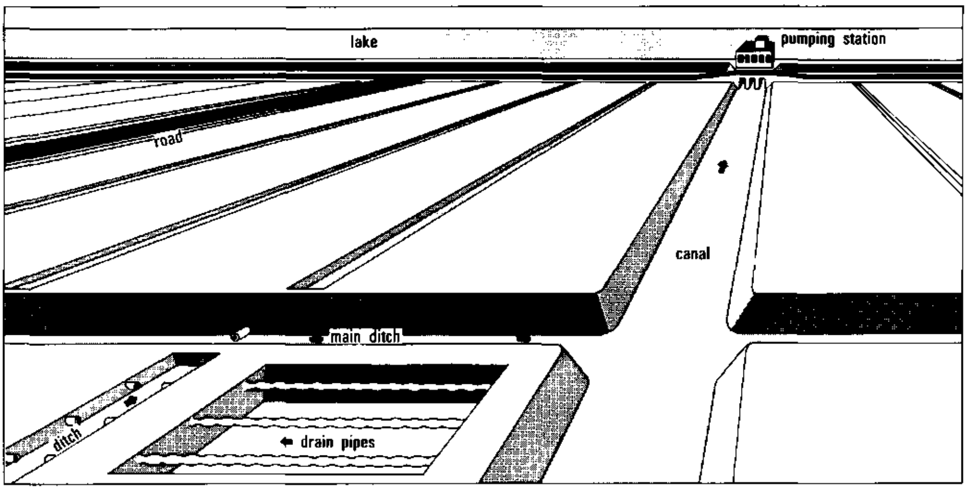

Figure 8. Schematic layout of a polder.

Sluices, windmills and pumping stations

Depending on the relation of the surface level and the level of the receiving water body, sluices or pumping stations have to be installed. In the older polders the discharge of water was mainly achieved by means of sluices. The first windmill for the discharge of water was constructed about 1400. However windmills only became common practice after the invention of the revolving cap and introduction of the idea of placing several windmills in a row (figure 3). In 1770 the first application of the steam engine was tested. The years thereafter steam engines were installed in some polders, but always in combination with windmills. It took about eighty years before a pump driven by a steam engine was trusted in such a way that it was used as the only device to pump out the water. But one of the first applications was a tremendous one, since it was used to pump dry the polder Haarlemmermeer of 18,000 ha (Huet, 1885).

In the beginning of the twentieth century electrical and diesel power were introduced. These sources of energy are, generally speaking, the only ones now being used in the pumping of water from polders. Figure 9 shows the location of pumping stations used for drainage in the Netherlands (Rijkswaterstaat).

For a long period of time the paddle-wheel was the only divece used. It could raise the water up about 2 m. In the middle of the seventeenth century the open Archimedes screw was introduced. With this device the water could be raised up about 4 m. In recent times the screw pump, the screw centrifugal pump and the centrifugal pump have been used. They can realize all normally occurring heights.

Drainage system

The layout of the system of open or closed field drains, ditches, main ditches and canals in polders, is mainly based upon topography, soil conditions and on agricultural economy. Over the centuries the sizes of the plots have been enlarged. In figure 10 some representative systems of parcelling out are given.

The water levels in the canals are determined by the depth of drainage required by the different uses of land. In the older polders the parcelling out is often based on the natural pattern of streams and creeks. In the peat polders, the drained lakes and other newer polders, the ditches run along the long sides of a plot, the main ditches along the short side of a plot.

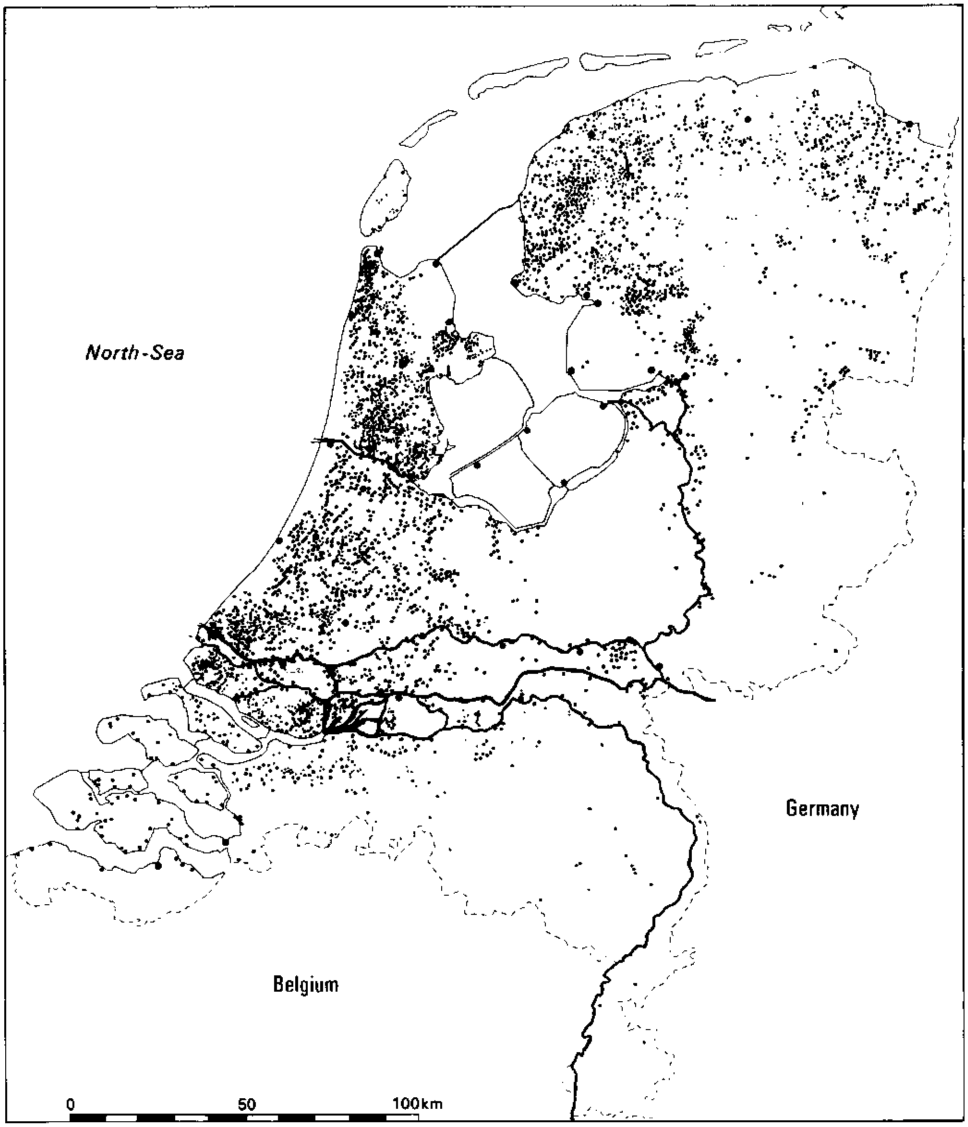

Figure 9. Pumping stations for drainage purposes in the Netherlands. (Rijkswaterstaat).

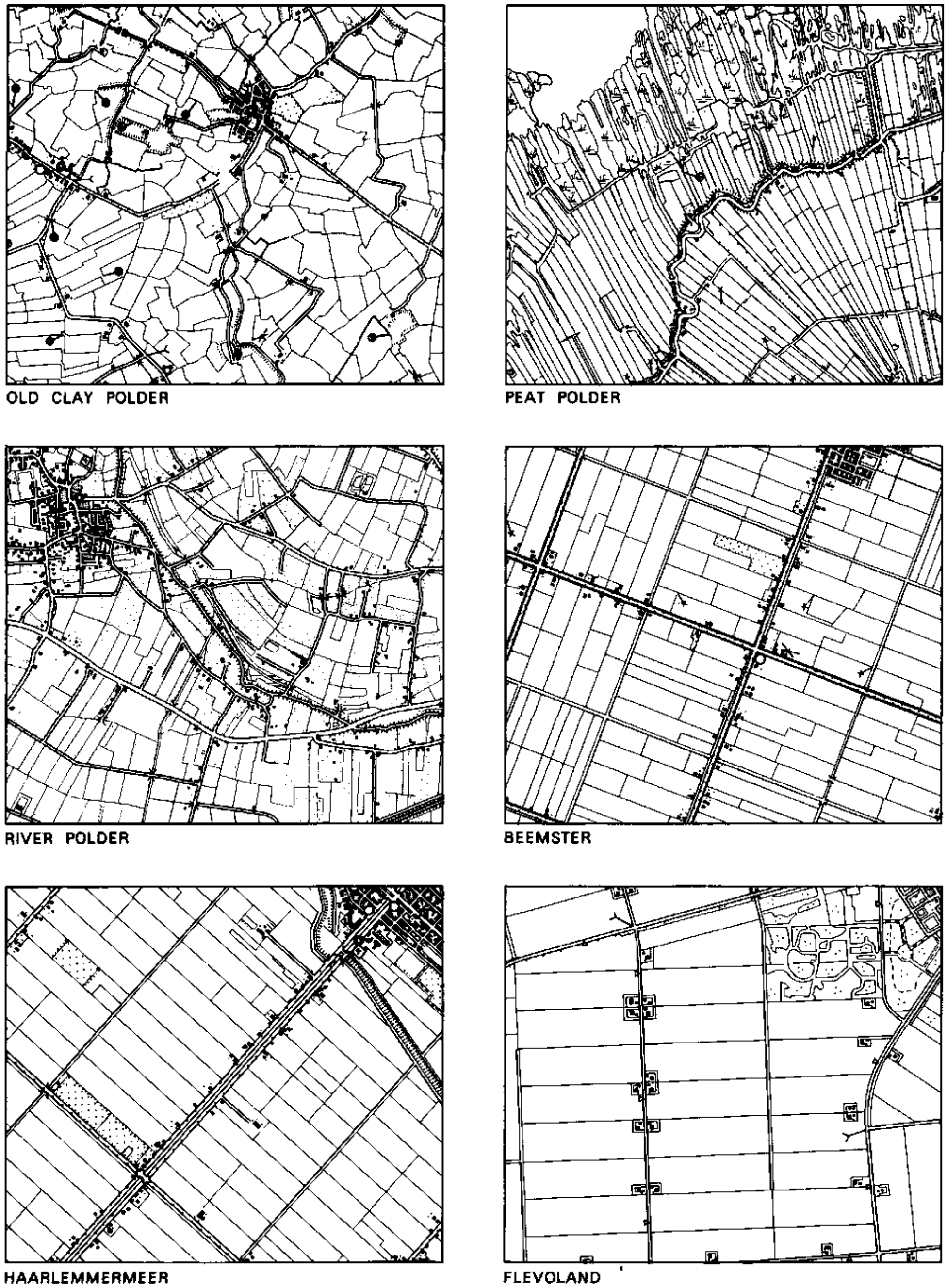

Figure 10. Systems of parcelling out.

Originally, the design of the drainage system had been based on trial and error, but from the thirties empirical steady state formulas could be applied. In these formulas a certain rise in the water level is combined with an accepted frequency and a design discharge. With these formulas an adequate design of the water management system is possible. Nowadays, with the aid of the computers, a more scientific approach is possible. This approach not only leads to an adequate design but also gives the designer a good insight into relevant alternatives.

The plot sizes in new polders are based mainly upon agricultural economy. Figure 11 shows an example of the derivation of optimal plot sizes.

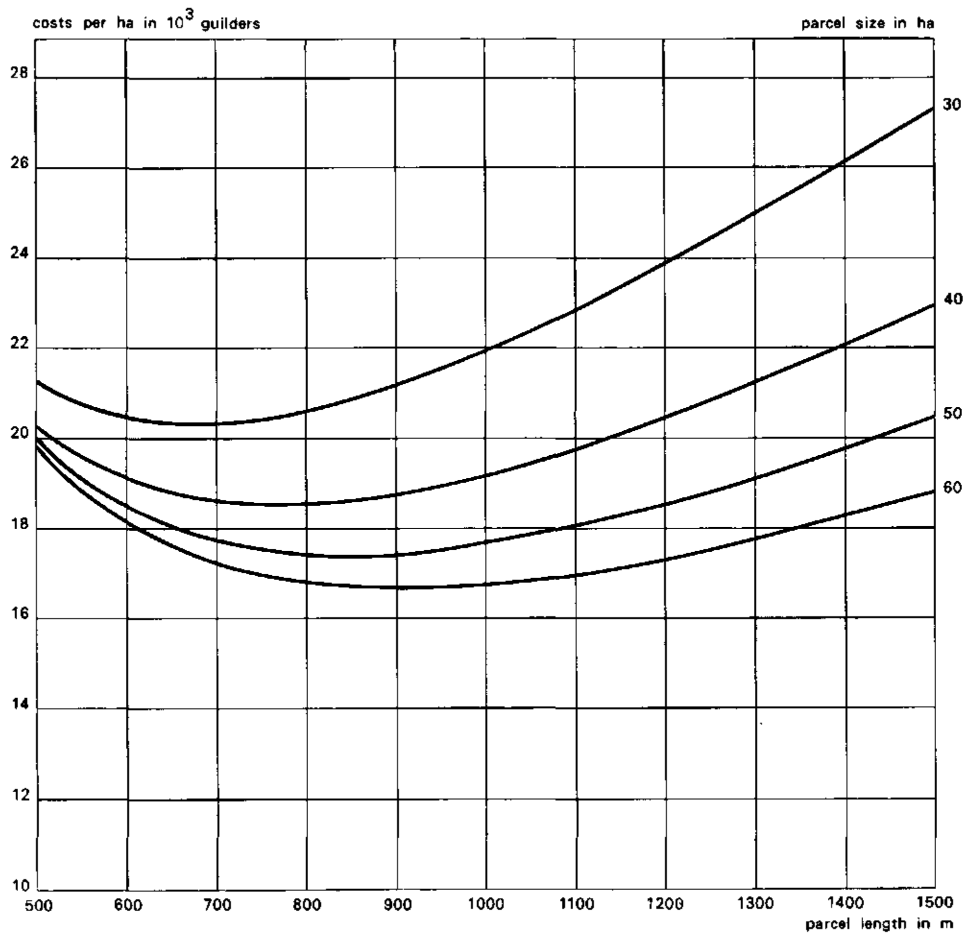

Figure 11. Analysis to calculate optimal plot sizes.

Field drains

Field drains are applied for two successive purposes:

- lowering of the groundwater-table during landreclamation;
- maintaining adequate drainage conditions after reclamation.

For field drains there are two possibilities:

- trenches;
- subsurface drains.

Trenches have been used over centuries. Subsurface drains date from the nineteenth century but have been especially applied since the second world-war. Nowadays, they are usually made of corrugated plastic pipe.

The distance between the drains and their depth have to be chosen in such a way that optimum growth of the crop can be assured. Several drainage formulas have been developed to be used in the various situations. When the recently reclaimed soil has a high pore space, subsidence will occur, particularly in the top-layer. The drains have to be installed at such a depth that after subsidence the soil is still well-drained.

8 Soil management

Originally most soils in the low part of the Netherlands contained brackisch groundwater. The soil was rather saline, especially in lands won from the sea and in a number of the drained lakes. When an adequate drainage system is installed, under the prevailing climatological conditions in the Netherlands, the desalinization of the topsoil is realized within some years. Two processes contribute to this, namely:

- the permeability of the unripened deeper soils is normally very low. The permeability of the ripened top layer is rather high. During winter there is a rainfall surplus so salts are washed out;
- the major part of the seepage flows directly to the ditches and the canals, so the root zone is not affected by this brackish water.

Steps during the reclamation

Especially in the drained lakes when the soils felt dry, they are unaerated and almost impermeable. In the old reclamations this caused a lot of problems to the first farmers that tried to grow their crops on these soils.

In the new IJsselmeerpolders, special measures are taken to let the soils "ripen". These measures consists of drainage measures together with an adapted crop rotation scheme (figure 12). With trenches a first lowering of the groundwater table is established and crack formation in the clay soils starts. These cracks result in an increase in permeability. When after several years the groundwater table is deep enough, the trenches are replaced by subsurface drains. The subsurface drains realise a further lowering of the groundwater table. Because the bearing capacity of the soils during reclamation is very low, only those crops - rape seed and cereals - are grown where the necessary cropping measures have to take place during periods with an evaporation surplus.

Besides the several measures taken during landreclamation, soil improvement measures such as deep ploughing and subsoiling have been taken, depending upon local conditions.

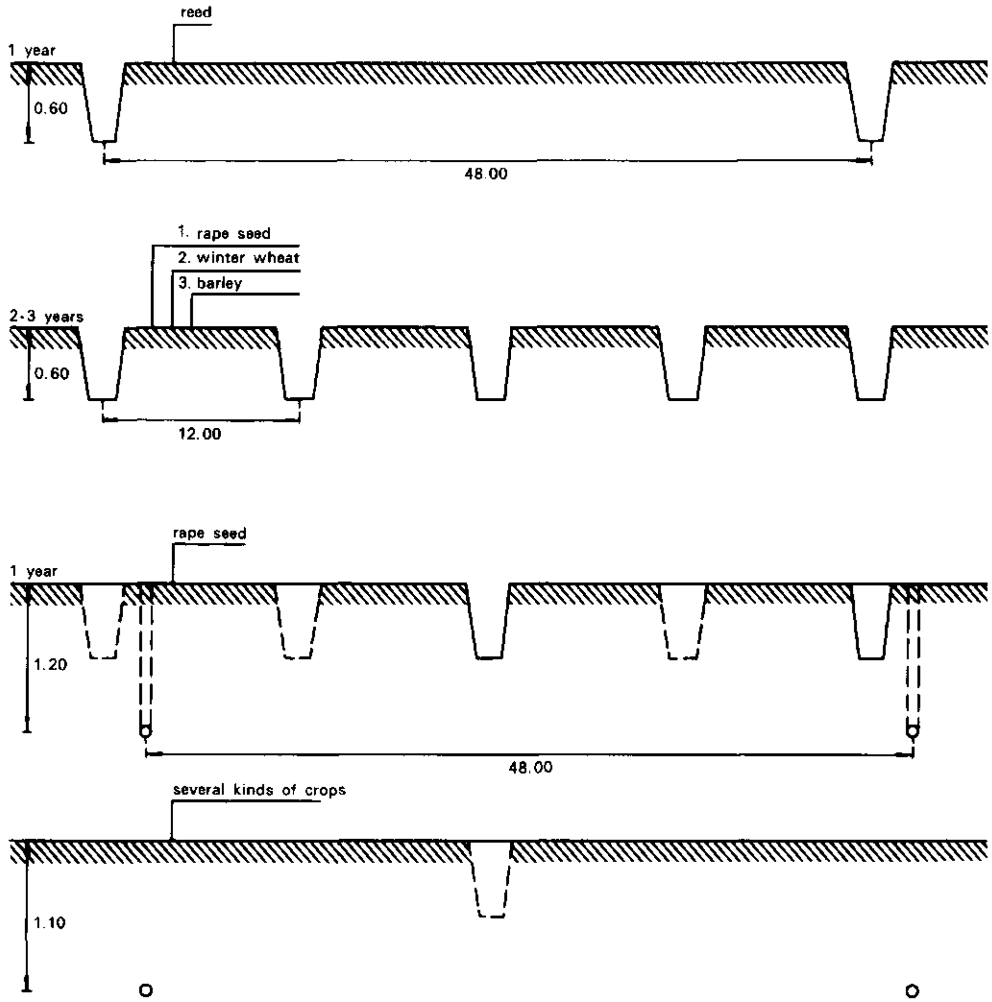

Figure 12. Measures taken during landreclamation in the IJsselmeerpolders

9 Water quality aspects

Over a long period of time one of the main goals of the water management system was the prevention of salinization. Sources for salinization were created by:

- salt water intrusion by sluices;
- saline or brackish seepage.

From the middle of the sixties oter water quality aspects got more emphasis. The reason for this was the changing use of the water, for example for recreation and nature reserves and the increase in production of domestic and industrial waste and cooling water problems. So the control of both water quantity and quality came to the fore and measures had to be taken to control the water quality such as:

- purification plants;
- separate sewer systems;
- flushing of lakes or canals with water with a relatively good quality.

10 Main structure of the water management in the Netherlands

The situation of the water in the Netherlands, with problems of salinization and pollution on the one hand and on increasing demand for drinking, irrigation, cooling and processing water on the other makes it necessary that special attention is paid to the main water structure. Especially the dry summer of 1976 has encouraged the undertaking of studies in relation to the distribution of water over the Netherlands. An intensive study named "Policy Analysis of the Water management in the Netherlands" was made by Rijkswaterstaat and the Rand Corporation (Blumental, 1982). During this study, cost benefit analyses of several development alternatives were checked. The results of this study creates a solid base for the further development of the main water structure in the Netherlands.

11 Evaluation and possibilities for the future

The Netherlands, as it is now, is the result of a history of landreclamation and the loss of land. For the future there are in principle only a few places in the Netherlands where polders can still be made. There are three places for which more or less serious plans have been developed:

- Markerwaard 41.000 ha
- Slufterplan 600 ha
- plan Waterman 2.000 ha

More futuristic possibilities can possibly be found in the North Sea. However it has to be mentioned that possibilities are rather limited while the level of the bottom of the North Sea has such a rapid slope (figure 13). (Rijkswaterstaat).

For the maintaining of the existing land the rise of the sea level of about 0,10 m per century and the subsidence of the land will gradually lead to an increase in saline seepage and the necessity to increase the level of the top of the dikes.

Regarding the design of the water management system the following developments can be excepted.

The drainage system in a polder is now almost at its optimum. There is a good insight into the behaviour of the system and the extreme situations that can be expected. By further mechanization and automatization of the construction and maintenance of the system, it can be made and operated at minimum costs. In a modern polder, on yearly basis, the cost of installation and maintenance of the water management system is 1 to 2% of the existing values of crops, buildings and infrastructure in a polder.

Regarding the subsurface drains, some developments can perhaps be expected regarding the material to be used and in respect of the installation techniques.

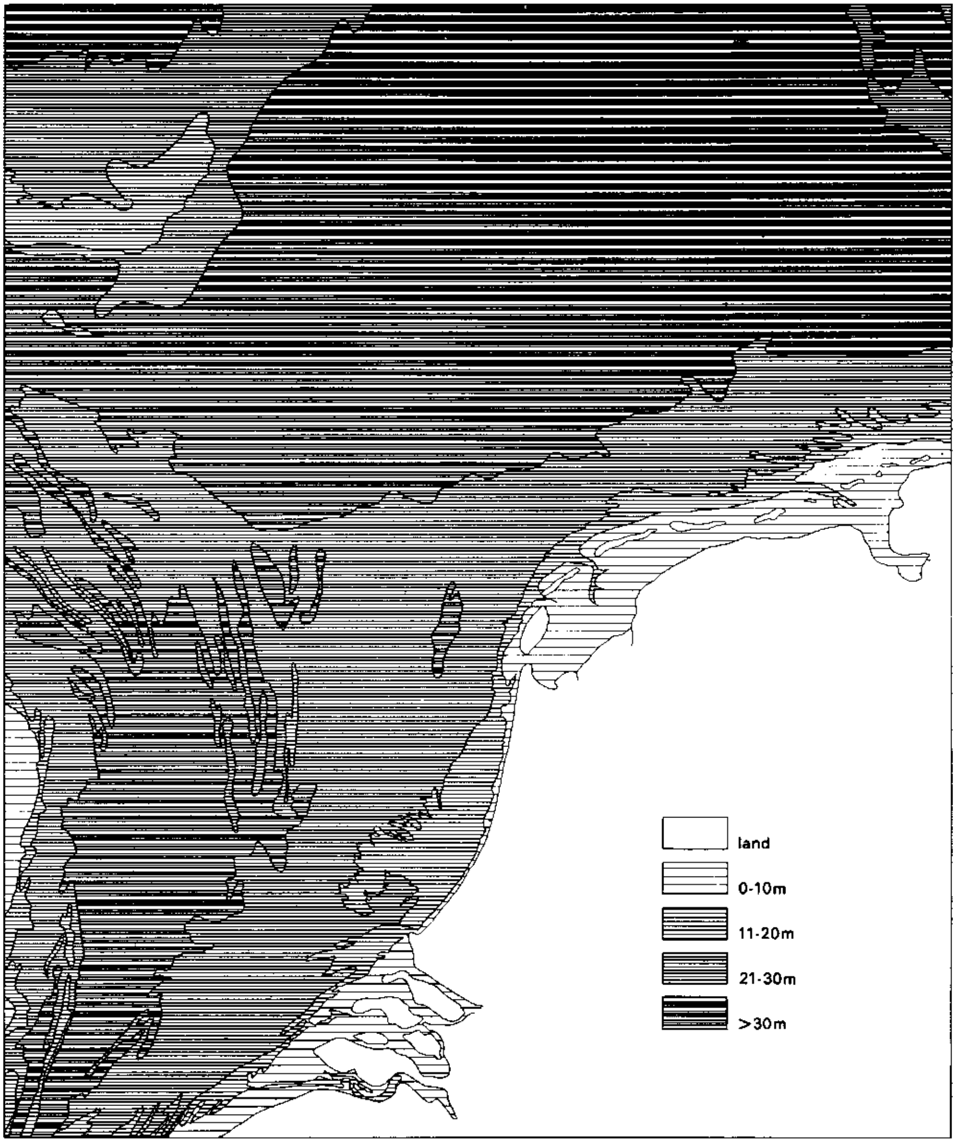

Figure 13. Level of the bottom of the North Sea.

There will be a further development towards a fully controlled water management. That means that to have optimal conditions for the crops during the whole year on a large scale, not only drainage, but also irrigation facilities will be installed.

The pumping out of water can probably be most economically realized by the combination of wind power (back to the past) and another source of energy. In this way the exploitation costs can be lower but investments higher.

There will probably be developments to store the surplus of fresh water in the winter to use this water during dry periods in the summer.

And last but not least I will finish with a saying made by a former president of the United States mr. Lyndon B Johnson who said:

> " A nation that fails to plan intelligently for the development and protection of its precious waters will be condemned to wither because of its shortsightedness. The hard lessons of history are clear, written on the deserted sands and ruins of once proud civilizations".

This statement taken in the context of the history of the Netherlands in the field of water management, brings me to the following:

> " If the Netherlands fails to maintain the protection of its precious land against the water and to keep a strict quality and quantity control of its equally precious waters it will be condemned to new disasters. The hard lessons of history are clear, written on the long list of floodings".

12 Aknowledgement

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LAND AND WATER MANAGEMENT IN POLDERS

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Abstract

By the end of this century, the World's population will exceed six billions. The pressure on land for producing food, for urban development, housing, factories and even for recreation will be so intense than at any time in the history of mankind. In search for appropriate land and related water, people will be compelled not only to moving up the hills but also to encroach into the swamps, flood plains and tidal lands by impoldering and reclaiming them. To reap the full benefit of this latter undertaking, polders will have to be carefully planned and executed. Also, land and water management within the polders will have to be well designed and implemented.
Experience has shown that planning of all aspects of development in the polder such as villages, park, wooded area, industrial estate, irrigation, drainage, fresh water reservoir, farm unit, land parcelling, agriculture, etc, in an integrated manner, is the best way for achieving full benefits, even if the implementation will be carried out in stages. Such planning and implementation require close cooperation and coordinated effort of people of several disciplines working together.

Introduction

The present World population is around 4.5 billion. By the turn of the century, it has been estimated that the population will exceed six billion. The pressure on land for producing food, for urban development, housing, industry and even for recreation will be so intense than at any time in the history of mankind. The need for development will be very real and pressing. People will be compelled to search for more appropriate land and related water. Some will move up to the hills and some will encroach into the swamps, flood plains and tidal lands by filling or impoldering and reclaiming them.

Objectives of Water Management

The objectives of water management is to supply water to meet the need of development, be it for domestic, agriculture, industry or recreation, and to drain off excess water.

In agriculture, supply of the needed quantity of water for plant growth at the right time is essential. Also, drainage is important as it allows oxidation of the soil (by drying up of soils) and percolation of water for oxygen supply and for leaching of toxic compounds into the subsoil, as well as to maintain the proper depth of groundwater below the surface for plant roots development. Except for rice and some other wetland crops, most other crops need good drainage.

Water management for domestic and industrial uses, i.e. to supply water of certain qualities to meet the demand for these uses, is a subject by itself and I feel it is not in the purview of this Symposium, except to say that in planning the polder, the demand for these uses will have to be taken into account. Water brought into the polder will have to provide for adequate supply to satisfy the needs of all activities planned inside the polder.

In the past, recreation was a fringe benefit created after the construction of the polder. Water bodies such as fresh water reservoir, lake, river and canals inside the polder were also used for recreation -- swimming, sailing, fishing, bird sanctuary and the land along their banks as camping grounds or woods. In recent years, this has grown to become the primary user and benefits from recreation even surpassed several other benefits. In other cases, the fresh water reservoir may be used for harbour and as source of cooling water for thermal plant. The case in point is in the Netherlands. Hence, in planning the polder and water management inside, all of these uses have to be considered. In such cases, water level (elevation) and quality as well as the control of aquatic weeds are some of the important aspects. In Taiwan, some polders along the west coast such as the Tseng-Wen Polder was constructed for fish ponds and oyster beds. Undoubtedly, water management in these polders had to be geared to provide water level, quality, degree of salinity, etc., appropriate for the purposes.

Source of Water

The water resources for the polder may be either one of these:

a) river or stream which passes through the polder area or canal carrying water to the polder;

b) fresh groundwater;

c) natural lake or pond;

d) man-made pond or tank;

e) dug wells; or a combination of some of these sources.

When a polder is designed to incorporate a river or a stream running from the upper land through it, a sluice or a regulator is built on the river at the lower end of the embankment to control the discharge, volume and level of the water as well as to conserve water within the river channel (fresh water reservoir) inside the polder. However, in this case the discharge and volume of water entering the polder cannot be effectively controlled. Hence more often than not sluices are built at both the upper and lower end of the embankment to control water entering and leaving the polder. Examples of this latter case are many: Chandpur project in Bangladesh, Chiangrak-Klongdarn project in Thailand, Hachiro-gata project in Japan, and several tidal land development projects in Korea and Taiwan.

An exception to the above are several projects in the middle part of the Irrawaddy delta, where horse-shoe shaped embankments were built leaving the lower end or downstream side of the polder open and sluices were built at the upper end. River floods can enter slowly through this open downstream side but the depth of flooding and the flooded area are smaller than without the open embankment.

In Thailand (Chiangrak-Klong Darn Project), several canals were dug to convey water from the nearby river into the embanked area. These canals are used multi-purposely, as sources of irrigation water, for conservation to store water during the wet season for use during the dry season, and as drainage channels as well.

Some polders are located in the delta or along the sea coast where aquifers bearing fresh groundwater exist. In such a case, tubewells can be sunk to extract the groundwater for use within the polder. However, as soils in the delta and along the sea coast are generally alluvium, excessive pumping will cause land subsidence. Examples of this can be found in the deltas of the Tone River and Nagara River in Japan, and many other places in the World. Also lowering of water level in the aquifer may cause sea water intrusion into the aquifer, in particular for the polders along the sea coast.

In the coastal (embankment) polders of Bangladesh, and several polders in Burma, farmers also use shallow dug wells (5-10 m. depth) as source of water for domestic supply and irrigation.

Natural lakes, ponds of adequate quality of water can and are used as sources of water in the polder. Often man-made ponds or tanks have been built to collect and store water during wet season for use during the dry season.

The source of water for the polder may be either one of the above or a combination thereof.

Drainage

In polders, drainage comes before irrigation and is considered more important. After impoldering is completed, the polder will have to be drained dry. The soils, generally comprises largely of clay and silt with small percentage of sand, have to be ripened 2/, again by means of drainage together with the cultivation of reclamation crops such as rice, barley, wheat, reed or grass. Where climate is suitable, rice is an excellent reclamation crop. It is somewhat salt tolerant. It is grown under flooded condition which allows flushing and leaching process to go on concurrently while land is under cultivation.

Drainage for Reclamation

After the completion of embankments and sluices (and in many cases pumping stations) and the land is completely enclosed, drainage by pumping and sluicing should begin. After that the construction of main drainage canal should be started. Natural creeks or channels may be used as main drain if their elevation and location are suitable. Smaller creeks may be used as secondary drains. Shallow and meandered creeks should be deepened to the required depth and straigthened as appropriate and the excavated soils used for filling up other small creeks and depressions. If the main drain has to be newly excavated, in the initial stage, when the soils are still fully saturated and very soft, the depth may be kept shallow and slide slop flatter. It will be deepened to the final cross section after the soils have been ripened.

Secondary drains may be excavated concurrently with land levelling and filling up of unwanted creeks. Like the main drain, if the soils are soft, they may be dug smaller with flat side slopes first and made deeper with steeper side slopes. The spacing of these drains is designed according to the different kinds of soils and is generally ranged from about 400 m (Thailand Chao Phya Delta - heavy clay) to about 600 m (Japan Hachiro-gata - sandy soils).

For reclamation and ripening of soils, field drains are generally needed. The higher the clay content in the soils will require the smaller spacing between the field drains. In general, the spacing ranges between 20 m to 100 m. After a few years when the soils have been ripened fully, these field drains may be back-filled to gain more land.

Drainage for Agriculture

For good crops growth the groundwater should be kept about 1.4 to 2 m below the land surface. If the groundwater is brackish, the minimum level of 2m should probably be used. This means that the secondary and main drains should be adequately deep to affect such groundwater elevation. However, for rice which is a wetland crop, such condition may not be required so long as there is some movement of water through the root zone. Hence, drainage canals in polders catering only for rice are generally shallower than those in which dryland crops are grown. In general, the land elevation in the polder has to be sufficiently high (more than 1 m above mean sea level) to enable drainage by gravity to be effected through sluices, taking advantage of ebb tide a few hours each day. For lower elevation of land, pumping together with sluicing may be necessary and if the land surface is below mean sea level, drainage has to be effected entirely by pumping. This makes the project more expensive in both the capital and operation costs. In the design of the polders, locations of pumping stations and sluices are important as also the elevation of the sills of sluices. Sluice sills should be placed as low as practicable to improve hydraulic capacity. When the land elevation is low, not only drainage is more difficult but also the construction of embankments, irrigation and land and water management become more complicated and more costly. For this reason, several countries have established land elevation criteria for the development of their tidal lands. In India (Sundarbans), the lowest permissible level of land for reclamation is mid-way between high spring tide and high neap tide. In Indonesia, the land elevation has to be between mean sea level and high tide. In Malaysia, the elevation has to be about 1.2 m above mean sea level. In Sri Lanka, the minimum elevation of the reclaimed coastal areas is about 0.3 m above mean sea level, whereas in Thailand, this elevation is about high neap tide. In Japan (Hachiro-gata), the minimum elevation of land inside the polder is 4.5 m below mean sea level. Elsewhere in Japan, where land for industry and urban development was reclaimed by filling, land as low as -10 to -15 m MSL had been reclaimed. There are certain kinds of soils which call for special kind of drainage and water management. For both Cat Clay (or acid sulphate) and peat soils for different reasons, the groundwater water level should not be lowered too much, - 0.60 to -0.90 m should be sufficient. When soils are drained aeration occurs. For peat soils oxidization and land subsidence will be excessive if the groundwater is lowered too far and, for acid sulphate soils oxidization will accelerate the formation of acid (sulphuric acid) in the soils.

In countries which are subjected to monsoon and typhoon rainfalls and where rice is grown, the paddy fields which generally have low field dikes all around are used to store excess rainfall temporarily, in order to reduce the cost of the drainage system. Paddy can stand submergence of up to 7 days without much effect. In Japan, Hachiro-gata polder in Akita prefecture was designed to store excessive rainwater on the paddy fields temporarily, equivalent to 77 mm or about one-third of the maximum three days rainfall of 220 mm. This reduces the required capacity of pumping stations from 150 m^3/sec down to 80 m^3/sec. In Bangladesh, a drainage criteria of 25 mm per day has been adopted for areas with an annual rainfall of about 1750 mm and for other areas in proportion to this amount, based on the assumption that crops can be submerged to a depth of 150 mm with little damage. In Thailand, the drainage system was designed to drain the three days maximum rainfalls in 7 up to 10 days. For coastal or tidal land polders, the closure of the river mouth or estuary by sluices to create a large fresh water reservoir will help improve drainage and water management within the polder.

If the seepage through the sea dike is excessive, a seepage canal (drain) may be constructed near the toe of the dike to arrest the brackish water or else the seepage will spread further inside the polder and damaging the good land. The canal water can then either be pumped out or drained through sluices or a combination of both, as the case may be.

In the present day, more and more subsoil drainage through tile drains or plastic pipe drains are being used. Although this type of drainage initially costs more than the open or surface drain, it is more effective in controlling the groundwater level and the loss of land is minimal compared to open drain system. The operation and maintenance cost is also lower. In particular, if the groundwater is saline, the adoption of subsoil drains should be encouraged. The average cost of subsoil drainage ranges from about US$750 to US$1500 per hectare, depending on the depth and spacing of the drains as well as the type of soils and the level of groundwater during the installation.

Irrigation

The main principle of irrigation is to provide water according to plants need. When river is the source of water for the polder, the main canal taking water from the river should be located far enough upstream beyond the reach of sea water intrusion. When fresh groundwater is the water source, pumpage has to be limited not to exceed the infiltration rate into the aquifer, so as to prevent land subsidence. As mentioned earlier, natural creeks, ponds and tanks are also used as sources of irrigation water. Also, fresh water reservoir can be created as good source of water by closing the downstream end of the river or creek, or by closing the river mouth or estuary at the impoldering embankment.

Irrigation may be effected by gravity through a system of main and secondary canals and field channels, or by pumping from water source into the gravity system of distributory canals or by pumping through sprinkler system (sprinkling irrigation).

The planning of irrigation and drainage should begin at the farm level and work upstream to the main canal and headworks. Whether irrigation (and drainage) will be effective and efficient depends a great deal in the planning and design of the field irrigation channels and field drains at the farm level.

When land is reclaimed from the sea, after the polder has been drained and the soils ripened, irrigation water has to be supplied for leaching and flushing of salinity from the soils. When soils contain a large percentage of sand, leaching will be very effective and crops like rice can be grown after only a few months of leachings. In Hsin-Chu Tidal Land on the west coast of Taiwan where soils contain 70-90% of sand, rice crop could be grown only after 2-3 months of leaching with fresh water and the yield in the first year would almost be normal. However, if the soils contain large percentage of clay, it will take 1-2 years or may be longer before the intended crops can be grown.

When irrigation is by gravity through canals, the amount of water supplied as determined by crop water requirement or evapo-transpiration, divided by irrigation efficiency to arrive at irrigation water requirement, is generally sufficient for leaching, to keep the soil salinity under check. However, if irrigation is by sprinkler, some additional amount may be needed for leaching. Genelly, if about 10 to 15% of crop water requirement is allowed for this purpose, it will be sufficient. Most soil scientists will agree that if the land comprises of potential cat clay or acid sulphate soil, it is not worth reclaiming. It is difficult and costly to improve the soil as well as to manage the drainage and irrigation, and yet the yield of crops grown will never be high. However, there have been such land in some of the polders. There are several ways of tackling such soil :

a) By the application of lime to neutralize the acidity. However, a large quantity of lime will have to be applied, ranging from 30 up to 2-300 tons per hectare. Also, additional quantity will be required every few years. This makes the method costly and even prohibitive.
b) By puddling the land with fresh water and flushing and draining several times before rice is grown. This method is practiced in Japan and Thailand.
c) By keeping the ground wet or saturated all the time, thus reducing oxidation. In tropical countries this can be done by growing two crops of rice per year or by keeping the groundwater table high (if the groundwater is fresh).
d) By ploughing and flushing the land with sea water and subsequently leaching and flushing it with fresh water. This method is employed in Vietnam and Sierra Leone.

Even with the employment of the above methods, acid tolerant crops should be grown on this soil. Some of these crops are rice and pineapple in the tropics and reeds and grass in the temperate region. Planning of irrigation and drainage systems should start from the farm level up to the headworks or reservoir and not the other way around. Such planning will ensure that the requirement at the farms which are productive units, in particular with respect to the water level in relation to the elevation of the land surface, will be met.

There are various types of layout of farm parcels comprising irrigation and drainage channels and farm roads (and in some cases wind breakers). These layouts are generally designed to suit the topography, soils, hydrometeorology, hydrogeology, agriculture (crop grown) etc. of the polder. However, the governing principle of these layouts is the same that each farm unit should have direct access to the irrigation supply, drainage and a farm road.

Separate or Combined Irrigation and Drainage System

The system comprising separate irrigation and drainage channels at farm level as explained above is the best for agriculture. It gives better and more efficient water control and water management than the combined system. Irrigation or drainage of any one parcel or unit of land can be carried out at any time independently to suit plants need without affecting the other parcels. For agriculture aiming at high intensity of crops of high yields, the separate system is preferred. However, this sytem costs much more than the combined system and the operation and maintenance costs of the system is also higher. Hence, in several developing countries the combined system has been employed. In Japan (Hachiro-gata Project), Korea (Dong Jin Gang, Yong San Gang and Pyongtaek-Kumgang Projects), and Taiwan (West Coast Tidal Land Development Projects), where agricultural development has reached high level with high crop yields, separate systems of irrigation and drainage have been employed. In Burma (Paddyland Development Projects in the Irrawaddy Delta), Bangladesh (Chandpur Project), Sri Lanka (Southwest Coast Drainage and Reclamation Project), where agriculture development is still in the intermediate stage, a combined irrigation and drainage system has been adopted. In these polders, natural streams and creeks have been redredged and closed by sluices to act as reservoirs for water conservation, irrigation canals as well as drains. In all these projects, farmers use small pumps (generally 3-5 hp.) to lift water from the natural streams for irrigating their lands. Moreover, the Chandpur Project in Bangladesh has a large primary pumping station

(34 cu m/sec) at the main sluice to pump water in and out of the polder for effective control of water inside the polder. Farmers in the polder own 1500 pumps of 70 lt/sec for irrigation. A special feature of this project is that farmers were trained in irrigated agriculture by actually doing it before the project was completed. Hence, by the time of project completion they were ready. The project in Sri Lanka also has several medium size pump installed at the main sluices to help improve the control of water, in particular water level, inside the embankments.

Land Consolidation

Unlike the existing agricultural land, the newly reclamimed land can be laid out and subdivided into rectangular farm units ideally appropriate for high production, with each unit served by an irrigation channel and a drain and connected to a farm road for bringing the products and implements in and out of the farm. Hence, it is recommended that land consolidation layout be employed in the newly reclaimed land.
As mentioned earlier, the tidal land reclamation in Japan, Korea and Taiwan, all employed land consolidation. When there is persistent strong wind for a long period of time such as at the tidal land development projects in the west coast of Taiwan, where strong NNE wind averaging 35-40 km per hours prevails from October to March, wind breakers in the form of two rows of trees are grown on both sides of the farm road to protect the crops as well as to reduce water losses in the farm through excessive evaporation. Hence, there are two rows of trees every 4-500 meters. The trees grown are of varieties of which their leaves can also be used as green manure.

Planning of Land and Water Management

The planning of land and water management has to be made at the time of planning the polder. The location and size of village, park, wooded area, industrial area, fresh water reservoir, etc., as well as the size of farm unit, land parcelling, including roads, farm roads, wind breakers, etc., as well as agricultural development should be planned together as an integrated whole, even though their implementation may be divided into stages for short and long-term development.

I have seen polders planned and constructed without proper drainage nor irrigation, and farmers had cut the embankment to let floods caused by rain to drain off. In other case, farmers also cut the embankment to let water backed up by tides to come in the polder for irrigation. No one can blame the farmers in both cases. As the polders were not well planned and executed, farmers had to help themselves.
As the planning and design of the polders is an intricate and complex task, requiring experienced professionals in several fields such as hydrologist, geohydrologist, soil scientist, engineer, agriculturist, economist, etc., it is a must that cooperation of efforts by these specialists be ensured from the start, beginning with collection of data, planning, design till project implementation.
To reap substantial benefits and good return from the polder project, adequate water management is a must, otherwise there may be negative effects to the extent that farmers may cut the embankment as aforementioned.

Footnotes

1/ The views expressed in this paper are the author's own and not necessary of the institution to which he belongs.

2/ To change from mud to firmer soil. The ripening of soils comprises three main processes: decrease in water content, formation of cracks and subsidence of land surface.

CONSTRUCTION ASPECTS

- *P.C. Mazure*. The development of the Dutch polder dikes
- *R. Segers*. From windmill to wind-generator. Development in polder construction
- *M.A. Meyer*. Construction aspects of polders in the world

THE DEVELOPMENT OF THE DUTCH POLDER DIKES

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Abstract

As a result of the variety in the origins of polders several categories of polders have developed in the Netherlands.
The specific development in the construction of sea dikes, river dikes and belt canal dikes is illustrated in the present paper.
In the past the complete design was based on experience collected in a process of trial and error.
Modern design methods utilize knowledge obtained about loads acting on a dike and the strength of the constructional elements of the dike.
In recent years studies have been intensified towards the probabilistic design method. In the future the design will be based on a calculation of the risk of flooding of the protected polder. However at present the results of the studies to date can be used to improve the traditional or deterministic design method until the probabilistic method becomes completely applicable.

1 Introduction

The major part of the Netherlands consists of polders. As a result of the variety in the origins of these polders and variations in local circumstances several categories of polders have developed.
Since medieval times people protected comparatively high level areas along seacoasts and rivers from frequent flooding by building small

dikes. Drainage of these polders took place by gravity through sluices. Soil subsidence in the older polders necessitated a change from gravity drainage to artificial drainage by windmills or pumping stations.
After the development of windmills and pumping stations polders also were constructed in comparatively low level areas, such as lakes and marshes. Many of the lakes were the result of the digging of peat for fuel.
In recent times even parts of the sea and inland seas have been impoldered.

As result of successive impoldering activities a very complicated system of polders and drainage systems has developed (figure 1).

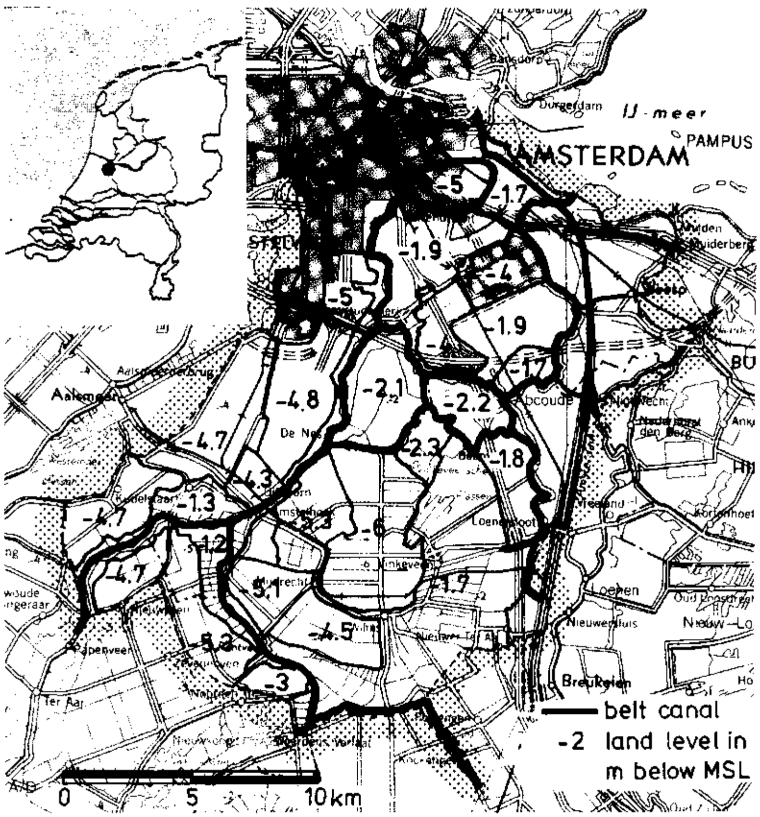


Figure 1. Example of a complicated system of polders and belt canals near Amsterdam

The levels of the various polders range now from 2 m above to 6 m below mean sea level (MSL).
The drainage system for all polders consists of a series of natural waterways and excavated canals, together forming a storage and transport system to conduct superfluous polder water to the sea or to the rivers. This paper deals with specific developments in the construction of sea, river and belt canal dikes resulting from the variety in origin of these dikes.

2 Sea dikes to protect sea polders

Parts of the Dutch North Sea coast are protected naturally against the sea by dunes. Where dunes do not exist or have disappeared because of coastal erosion and also along branches of the sea, low lying areas must be protected against inundation by the sea by approximately three hundred kilometres of sea dikes.
Many of these dikes have grown over centuries from small embankments made of locally excavated materials (mainly clay) into enormous constructions made from materials brought in, especially sand. The local soil was not always ideally suited to the construction of impermeable dikes but in former days transport of large quantities of soil was impossible, especially where these dikes had to be constructed in tidal areas. Hence the slopes of these "old" dikes were made as steep as possible to minimize the quantity of soil. The crest of the dike was determined by the highest flood level people could remember. The steep outer slopes, often almost vertical walls, were protected against wave attack by all kinds of materials like wood, stone (glacial boulders), bricks, rubble and grass-sods (figure 2); even compacted seaweed was used for cofferdam construction along the branch of sea now called the IJsselmeer. Knowledge about the use of these materials was founded on practice under the specific circumstances in different areas of the Netherlands. These areas each had their own specific construction methods, based on local knowledge and available materials. Even today these differences in construction can be seen.

The introduction of mechanically driven bucket and suction dredgers,

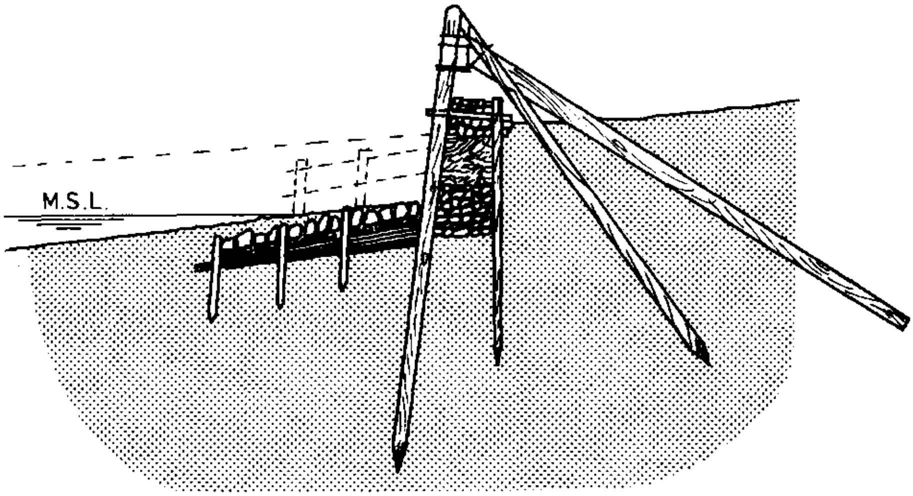


Figure 2. Cross section of an early sea dike

hopper barges and other means of transport in the second half of the nineteenth century facilitated the transport of great quantities of soil over great distance.
This development had a great influence on the shape and construction of dikes, particularly newly built sea dikes and dams. From then on materials could be chosen based on their properties in relation to their function in the construction of the dike because soil could then be obtained in larger quantities and from a greater distance.

The core of a modern dike is made of great quantities of sand, brought into place as hydraulic fill. This sand is covered with a clay layer of a thickness of about 1 m. Side slopes are now chosen at 1:5 to 1:7 on the seaward side and 1:3 to 1:4 on the polder side (figure 3).

As already mentioned the protection of the dike against wave attack was originally constructed of various materials. However since the presence of the teredo worm ruled out the use of wood, protection was provided mainly by turf. Where grass could not grow due to the salinity of the spray on lower levels the slope was covered by a mattress of willow twigs ballasted with stones. From the middle of the 18th Century the

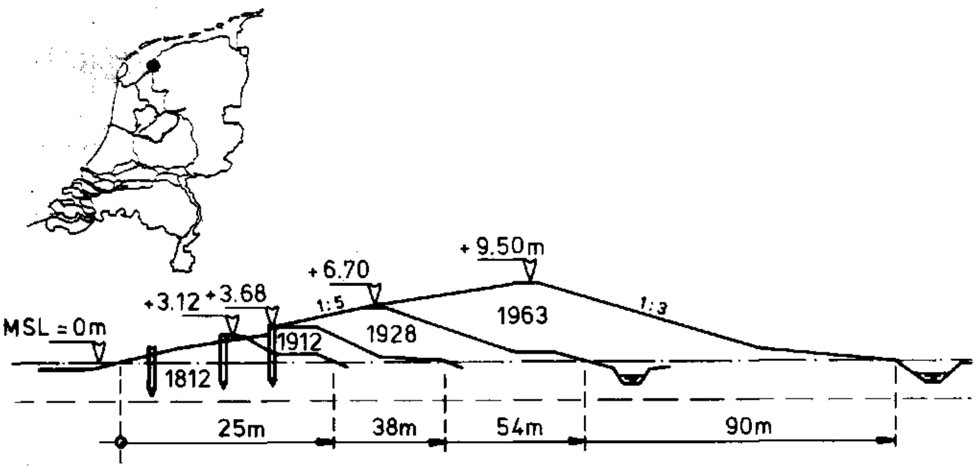


Figure 3. Development in cross section of a sea dike during the period 1812 to 1963

outer slopes were protected, up to 1.5 m above storm flood level, by a revetment of stones imported from foreign countries.

After the Second World War concrete blocks were introduced.

The need to repair great lengths of sea dikes in a short time after the 1953 disaster in the South Western part of the Netherlands, the so called Delta area, lead to the introduction of asphalt revetments. This has necessitated entirely new dike constructions with asphalt revetments overlying directly the sand core (figure 4).

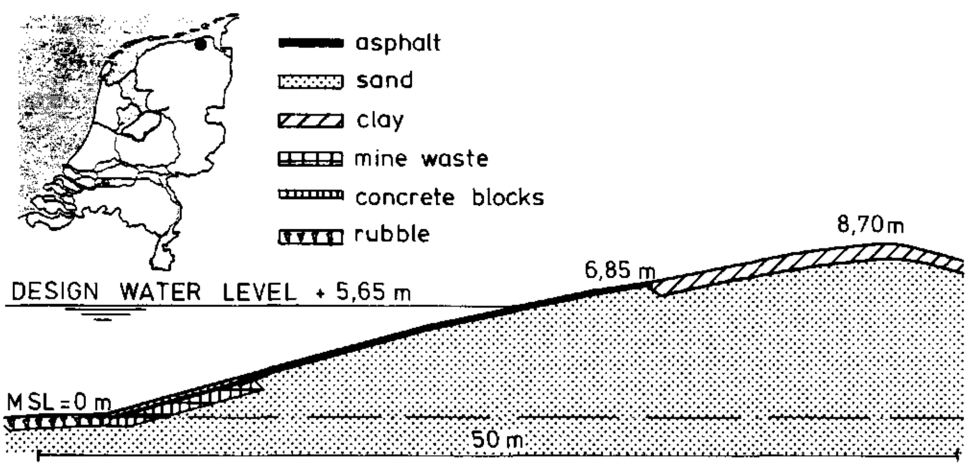


Figure 4. Cross section of a sea dike with asphalt revetments

As mentioned earlier the height of a dike was for many centuries based on the highest known flood level that could be remembered. Consequently after the occurrence of a disaster due to overtopping or overflowing further heightening of a dike became gradually less urgent, over a period of years, especially where a large amount of money was necessary. Generally some limited measures were taken which provided a new yardstick valid for some time until a flood occurred with a level which exceeded the old one.

It is evident that in this way the real risk of damage or the probability of flooding were unknown. Little was known about the relation between the cost to prevent flooding and the cost of the damage that might result from flooding. Economic comparison was not made; people asked for dry feet preferably at no expense. The height that dikes should have was the subject of animated discussion.

In the 20th Century it was found that the occurrence of extremely high water levels at sea could be described adequately in terms of frequency in accordance with the laws of probability calculus. However the curves of extreme water levels, based on a relatively short period of observations, have to be extrapolated into regions far beyond the field of observation (figure 5).

The 1953 disaster provided proof for the theories developed for the probability of exceedance of high water levels. From studies of the Dutch Royal Meteorological Institute, initiated in 1953, it was concluded that considerably higher flood levels than the one observed in 1953 were physically possible and that no practical level could be given which could never be exceeded; therefore there will always be some finite risk. The frequency of the risk of flooding was studied in relation to the economic aspects. This matter will be discussed below. After much discussion it was decided to base the design of all sea dikes fundamentally on a water level with a probability of exceedance of 10^{-4} per annum.

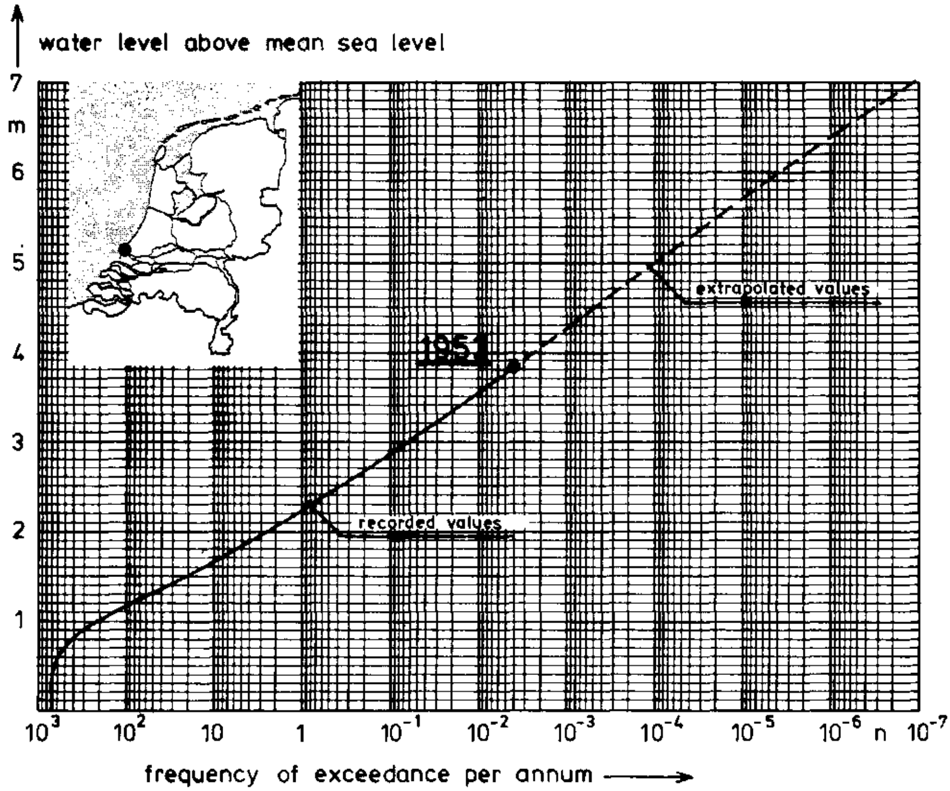


Figure 5. Frequency of exceedance of high water levels at Hook of Holland
For example the storm surge level of 1953, 3.85 m above MSL has a frequency of 1/300 per annum.

Several other elements also play a role in determining the design level of a sea dike:

- wave run-up depending on wave height and period, angle of approach and roughness of the slope,
- an extra margin to the dike height to take into account seiches and gust bumps (single waves resulting from a sudden violent rush of wind),
- a change in chart datum (NAP) or a rise in the mean sea level,
- subsidence of the subsoil and the dike during its life time.

Based on these factors the design level of a sea dike can be determined as shown in table 1. The profile of such a sea dike is shown in figure 3. With the present design criteria the cross section of a modern sea

Table 1. illustration of determining design level

flood level	MSL +	5.00 m
wave run-up		9.90 m
seiches and gust-bump		0.35 m
rising mean sea level (MSL)		0.25 m
settlement		0.25 m
Design level	MSL +	15.75 m

dike is twice as high as the old dike that preceded it before the 1953 disaster with a fourfold increase in volume.

To construct modern dikes the clay of the inner slope of the old dike is generally dug away and stored and the sand of the new dike is filled in against the old dike. Afterwards the stored clay is used to cover the sand core. In the wave attack zone a revetment of stone setts or asphalt is made. Because of the flat slopes now in use slope stability problems will seldom occur. Despite the enormous width of the whole dike construction an impermeable blanket made of clay or asphalt, applied to the seaward slope, or an impermeable core of clay is essential to prevent seepage.

The historical development of the design method can be traced. In the past the complete design was based on experience collected in a process of trial and error.
Developments in mechanics (from 1920 especially soil mechanics) have brought a change in these methods. The modern design method utilizes knowledge of the properties of soil material and subsoil obtained from field and laboratory tests, knowledge of ground water flow and water pressures, knowledge of the behaviour of the dike body and the revetment under the wave attack etc.

3 River dikes

River dikes were made by man to withstand the highest flood levels.

Originally these dikes were only small, positioned along the river banks and carrying roads.
The present form and height of these river dikes was achieved by the heightening of the crest only, using all kinds of locally available soil and as a consequence the inner slope became more and more steep, reaching even 1:1.5 in places (figure 6).

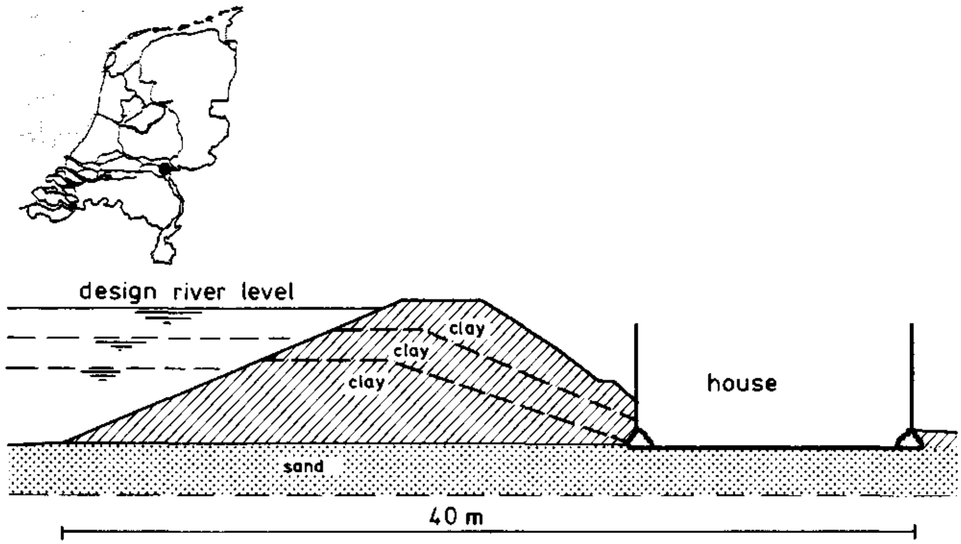


Figure 6. Development in cross section of a river dike in the course of time

As a result the inner slope could become unstable during periods of high river water level.
These river dikes are all overgrown with grass and the slopes protected by a revetment only on places where severe erosion or wave attack can be expected.
Thanks now to better transport facilities more suitable materials are used for reconstruction such as clay for impervious revetments on the outer slopes and sandy clay on the inner slopes making for flatter slopes.

In the past the height of a river dike was determined by the highest flood level that one could remember and only a small allowance was made for wave run-up.
Before 1950 the construction of these dikes was more or less based upon

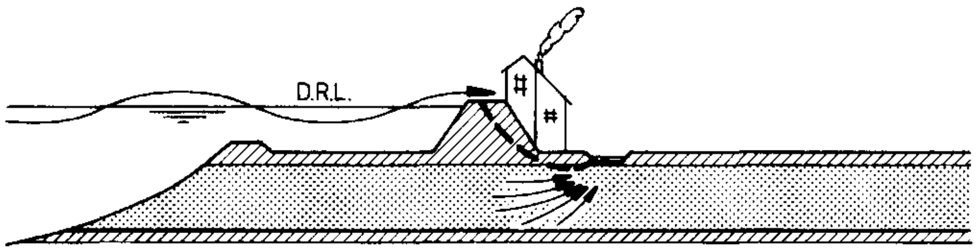
experience and many disasters, caused by inundation and failure, were the result. Inured to inundations, people learned to live with this risk and in general they built their houses near to or on the crest of the dikes. The growing population and changes in agriculture however have made it necessary to house people in the polders as well as on the dikes. Due to this a better protection against inundation has become essential.

Today, the incidence of extreme high water levels can be represented in terms of frequency, using the same philosophy as described above for sea dikes.

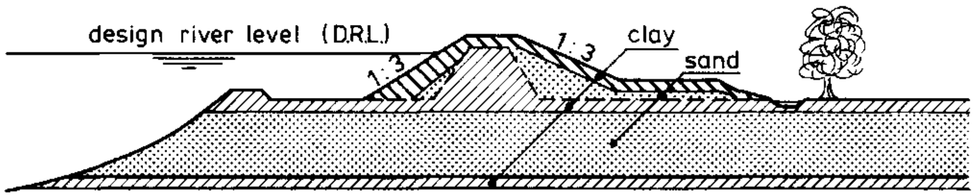
After years of discussion about technical and environmental aspects it was decided to base the design level of the main river dikes on a water level corresponding to a discharge that can be reached or exceeded 8×10^{-4} times per year. At present a reconstruction program is being carried out to strengthen the major part of the four hundred kilometres of river dikes.

Reconstruction of these dikes is especially difficult because of the environmental aspects. The reconstruction often destroys valuable vegetation on the slopes which probably will not return to the new flat slopes. Many houses and farmhouses with historical value, built on or into the dikes have to be demolished or dike reconstruction minimised or executed with very elaborate techniques in order to prevent demolition.

In the eastern part of the Netherlands the subsoil of the river dikes often consists of a clay stratum of a thickness of 2 to 6 m overlying a sand stratum of 20 m or more. On many spots there is an open connection between the sand stratum and the river bed which causes a transmission of the high flood water pressure to the underside of the clay stratum at the toe of the inner slope. This pressure may endanger the stability of the clay stratum and can lead to its break up, followed by internal erosion of the sand (piping). The high water pressure in the sand stratum may threaten the stability of the inner slope, adding to the threat of river water percolating through the dike (figure 7).



failure mechanisms before reconstruction



river dike after reconstruction

Figure 7. Cross section of a river dike before and after reconstruction

In the western part of the Netherlands peat strata in the subsoil can cause considerable subsidence.
Therefore extensive investigations of the subsoil and the soil material used for dike construction must be done before reconstruction to obtain data (mainly soil properties) for design calculations.

An inner slope of 1:3 to 1:3.5 is recommended with an impermeable cover of clay on the outer slope and on the floodplain adjacent to the foot of the slope to prevent the percolation of flood water. A permeable horizontal blanket adjacent to the inner slope will prevent break up and the probable subsequent piping and collapse of the dike. The width of this cover is still designed by empirical methods but in recent years model studies and in situ tests have been carried out to obtain more exact design rules. de Wit et al (1981).

4 Belt canal dikes

For many centuries in the western part of the country the impoldering of lakes was necessary to stop the progressive erosion of the banks. In addition people who dug peat for fuel were obliged to impolder excavated areas which had become artificial lakes. Another process that led to the formation of polders was the drainage and agricultural use of peat marshes. In a few centuries the level of these peatlands became so low that protection by dikes and artificial drainage was essential.

In the excavated areas small canals had been left for water management and for shipping. The small strips of land alongside these canals were used as dikes when drainage started with the pumping of water from the lake into the "belt" canal.
"Belt" canals were excavated around large lakes and with the soil dug from these canals (often peat) a belt canal dike was made between the canal and the lake. These belt canals remained part of the existing system of waterways to transport superfluous water to sea or river and for use by shipping.

During the process of impoldering over the centuries in the western part of our country an interconnected network of belt canals and thousands of kilometres of belt canal dikes have come into being.

The subsoil in this area mainly consists of strata of peat and soft clay. Because of this soil severe subsidence of the dikes has occurred at a rate of up to 0.05 to 0.10 m per annum in some areas. As the water level of the belt canal and the whole system of canals to the sea is kept constant this has necessitated the frequent heightening of the belt canal dikes (up to once every 2 or 3 years). Heightening has usually been carried out using locally available materials. This process has resulted in an inhomogeneous top layer with a thickness of up to 4 to 5 m, consisting of dredged mud, peat, clay, rubble, ashes and sometimes sand (figure 8). Often, the additional weight caused by this heightening has produced further subsidence.

When, by progressive subsidence, layers of rubble, ashes and sand

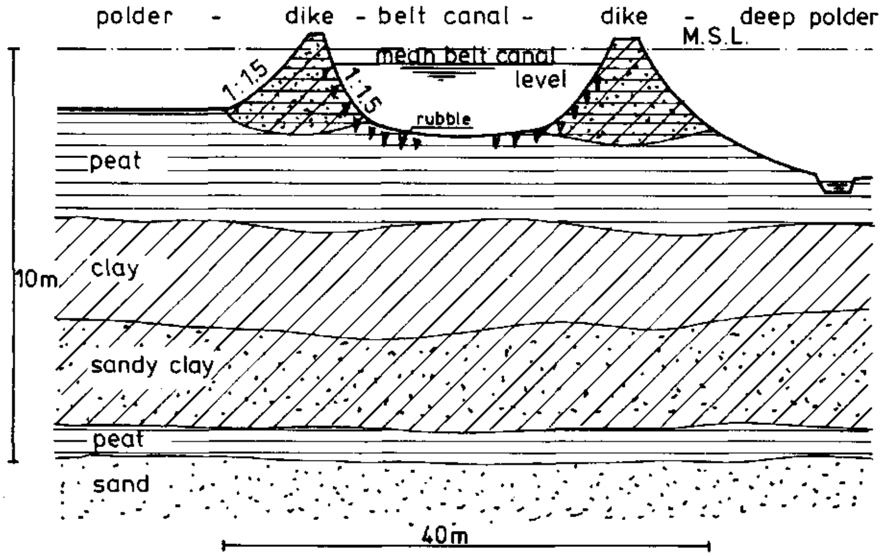


Figure 8. Cross section of a belt canal with dikes

(whether old revetment material or road-metal) disappear under belt canal level they may cause seepage problems. When heightening is done simply by placing a cap of clay on the crest of the dike the inner slope becomes steeper and stability problems may arise in addition to the problems due to the soft subsoil on which it rests.

The quest for safe belt canal dikes has become more important since a growing population and industrialisation has necessitated building in low level polders. Usually people do not realise fully what can happen when a belt canal dike bursts. The low level polder is inundated completely by the large quantity of water stored in the extensive belt canal system and in addition damage can be done which is difficult to repair. The dike burst causes a depression of the level of the adjacent belt canal endangering also the stability of the dikes alongside the canal. Division of the belt canal system by means of emergency weirs limits this effect to a restricted area but may cause more local damage to the belt canal dikes because of the quick fall of the water level in the belt canal.
The belt canal dikes are covered with turf and only protected against stream and wave attack at the water level.

A not so obvious threat comes from animal activities.
Grazing cattle locally destroy the turf on the belt canal dikes and make a quagmire of the outer slope when drinking from the belt canal. There is a growing problem in recent years, due to the presence of muskrats, which infiltrate unchecked into the Western part of the Netherlands with its many small belt canal dikes. Muskrats are far more dangerous because they burrow their holes in ground adjacent to open freshwater, whether dike or not.
As the entrances lie below water level and the tunnels can be very extensive the tracing of this threat is difficult.
The only way of combating this problem now is to catch the muskrats.

The design of belt canal dikes has not changed very much since former times, as the major work on this sort of dike is maintenance. The crest must have a minimum width of 1.5 m, but 3 m is recommended to cater for vehicular transport. The crest must be 0.5 to 0.8 m above the extreme belt canal level.
The belt canal level is regulated by the pumping stations of the polders and the pumping stations and sluices that drain the belt canal into the sea and it varies within certain limits. Though in the course of time the inner slopes became 1:0.8 to 1:1.5 a dip of 1:3 is recommended as maximum slope angle on account of turf maintenance requirements.
Nevertheless the design for a new cross-section must be based on geotechnical investigations and calculations and will often show flatter inner slopes. This sometimes implies realigning ditches immediately adjacent to the inner slope.
The revetments are made of wattlework (willow twigs or hardwood strips) or, simply and cheaply, dumped rubble. Often a reed border growing along the canal bank will suffice to protect the outer slope.
It will be clear that regular inspection is needed for the upkeep of the system of belt canal dikes.
Usually this is done by the polder and provincial authorities. A governmental program of assessment of the stability and safety of the belt canal dikes started 15 years ago after the failure of an important belt canal dike. This is a great aid to the polder authorities, informing them about the conditions of the most important belt canal dikes.

5. New developments in dike design

In recent years the statistical and economic approach to dike design has again become a topic for dabate.
The inundation risk or the probability of failure of a definite dike section are especially in the forefront of the discussion. The immediate reason for this discussion lies in the idea that the design methods available to date are based upon a design level which sometimes leads to unnecessarily high construction expenditure.
The possible loss of areas of outstanding natural, cultural or scenic interest which is almost impossible to value must also be seen as expenditure.
To tackle this problem studies are initiated in two directions:

a) An assessment is made of the "profit" of a higher level of security. A profound understanding must be obtained of the possible damage which can be caused by the failure of a dike, both in terms of money and also the loss of human life and things of cultural interest. In these studies of cause and consequence, historical floodings (including the 1953 flooding of Zeeland) are analysed and scenarios of probable floodings are made.

   The aim of these studies is to fix standards of safety for specific polders in relation to particular defence requirements. It must be realized that a safety standard can be formulated in several ways, for example, an accepted risk of failure of a dike, inundation, drowning or an optimal ratio of costs of dike strengthening to profits gained from a reduction in damage by flooding, (to which also belong various other imponderables).
   The problem of the (political) decision to fix certain safety standards for specific areas has still to be solved.

b) Studies are made to provide a well balanced design for a specific safety standard or risk of failure (based on a political decision). In a modern design the imposition of the load on all the construction elements of the dike should be arranged in such a way that all elements bear the same risk of failure. For example: It might happen that much money, material and land are used to heighten a dike even though there is still a great risk of failure by piping before flood water actually overflows the crest of the dike. Our knowledge of the piping mechanism is still limited. Investigations on this problem have started recently.

The first step in these studies is to analyse all possible causes of dike failure. These causes (as presented in a "fault tree", figure 9) comprise four categories of events that may cause inundation:

- human failure, management faults,
- aggressive human actions such as war or sabotage,
- acts of God, extreme rainstorms, earthquakes and hurricanes,
- technical failure of structural elements.

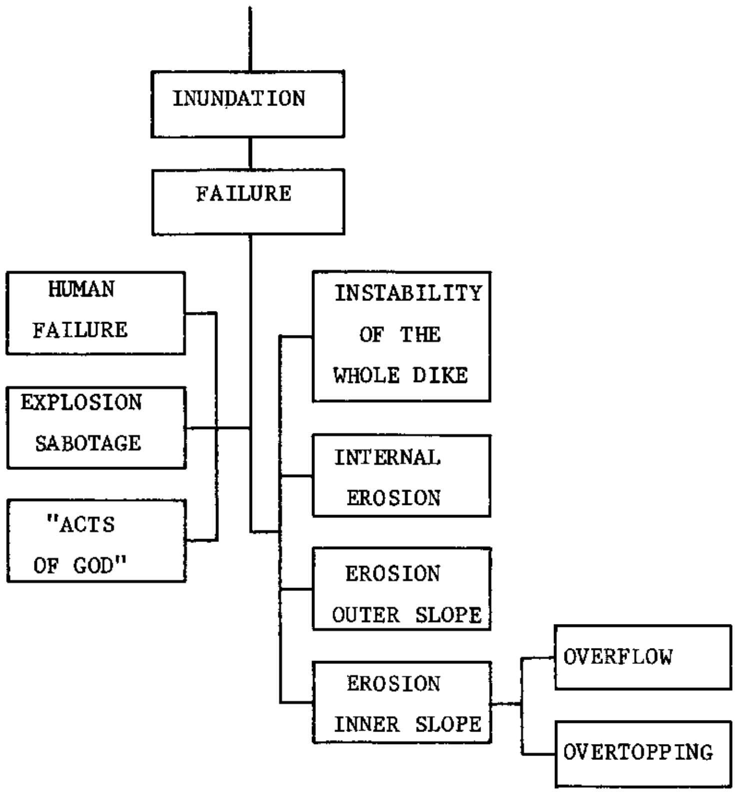


Figure 9. Fault tree

The second step is to analyse the different causes of failure in aparticular category. Only the technical failures are mentioned here:

- overflow or overtopping of the dike,
- erosion of the wetted slope or loss of stability,
- erosion of the inner slope leading to progressive failure,
- instability of the whole dike,
- instability of the foundations and internal erosion.

For all these modes of failure, the situation where the forces acting are just balanced by the strength of the construction (the ultimate limiting state) is considered.
The probability of occurrence of this situation for each technical failure mechanism can be found by employing mathematical and statistical techniques.
In this method , Bakker and Vrijling (1980), the probability-density function of the loads and the dike strength are combined (figure 10).

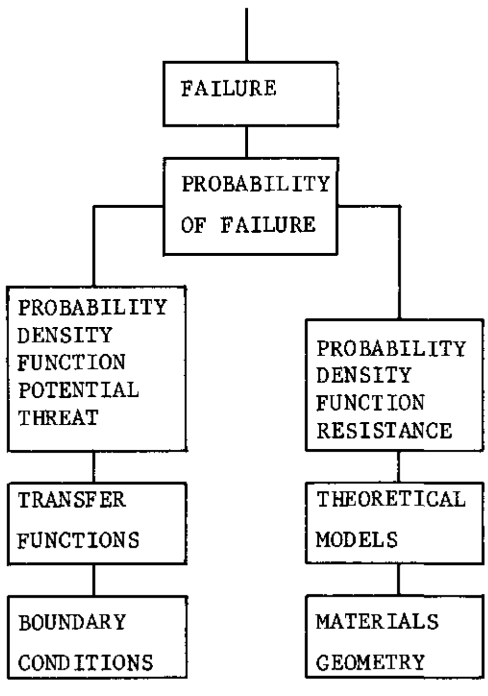


Figure 10. The concept of the ultimate limit state of a failure mechanism

For this purpose more knowledge must be acquired concerning the complex problems associated with the use of theoretical models relating loads

and strength.
Improved knowledge of the theoretical relation between wave attack and the strength of the revetment, of the probability of slope stability related to the various ground parameters, and also of the theory of internal erosion is urgently needed.
Studies have been initiated for all these topics during the last 10 to 15 years and have been intensified in recent years. The results of these studies can be applied immediately to improve the traditional or deterministic design method until such time as more insight is gained concerning the practicability or otherwise of the probabilistic design method.

It is impossible at this moment to predict the results of the studies mentioned above. Also, whether or not the probabilistic design method for dikes is a delusion or a realistic concept has still to be shown.

There is no doubt, that the studies concerning the probabilistic design method result in a growing knowledge about the relative importance of the various failure-mechanisms for the stability of the whole construction. In addition, the results of these studies enlarge our knowledge about dikes and their behaviour under different conditions and also the knowledge about the risks associated with damage and flooding.

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FROM WINDMILL TO WIND-GENERATOR

Development in Polder Construction

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"The things that hath been,
it is that which shall be;
and there is no new thing
under the sun"

1. Introduction

The diversity of construction aspects mentioned in the circular is so extensive, that a choice from the various topics has been made. It is undeniable that irrigation and drainage systems, roads and shipping canals form part of every polder involved. However the most significant structures essential to maintain a polder, are discharge structures. Without sluices and especially pumping stations the major part of the Netherlands would consist of marshes, lakes or sea. So life in these regions depends greatly on the perfect condition of these discharge structures of which the requirement of reliability is of the same importance as the technical operation required. In this presentation several aspects of discharge structures of which the pumping stations form the principle part are dealth with.

2. Sluices

The oldest engineering works to drain rainfall and percolating water from impoldered areas, were sluices. These were constructed of wood and brickwork and were situated at the outlets of small inland waterways into the rivers or directly into the sea. A reliable protection against the tidal movements of the sea was the principle requirement of the inhabitants of the coastal districts at that time. The need for fixed water levels developed gradually over a period of several centuries.

It was obviously practical to combine these oldest sluices with navigation locks.

As a result of the rapid increase in reclamation works there was a comparable increase in the number of drainage sites required. In most of these locations there was no longer any shipping and to improve the safety of dike crossings, the structures were covered over (Figure 1).

Modern sluices are constructed of reinforced concrete with special precautions against seepage along the structure. Discharge through a sluice is controlled by one or two automatically operating doors, which are opened by the pressure head of the inside water level and closed by the pressure head of the outside water level. The doors are constructed of hard wood of tropical origin as a precaution against pile worm. Emergency valves are built into the structure for use in case of a non closure or other troubles.

As a result of ground settlement and the relative raising of the mean sea level, larger discharge structures have become necessary. Gradually sluices have been replaced by pumping stations. Along principle rivers and at some big discharge locations draining directly into the sea, pumping stations have been added to sluices. At low tide and low river levels drainage by gravity is possible by opening the sluices. However at high tide or high river levels the pumping station will become operational (Figure 2).

3. Pumping stations

As the major part of the Netherlands cannot be drained by gravity pumping station are most important structures inside the polders. These pumping stations have to fulfil many conditions, of which reliability is the most important. Reliability can be expressed in three ways and your attention is drawn to the following aspects:

Reliability in design;
Reliability of machinery and its maintenance;
Reliability in energy supply.

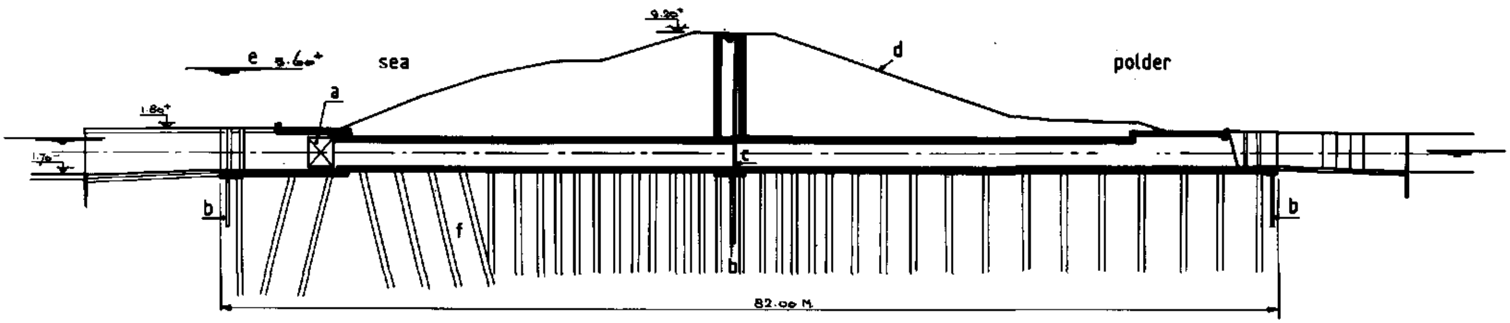

FIG. 1 CONCRETE CULVERT SLUICE. (longitudinal section)

a. one way discharge door

b. sheet pile cut off

c. emergency valve

d. sea dike

e. design water level

f. concrete piles

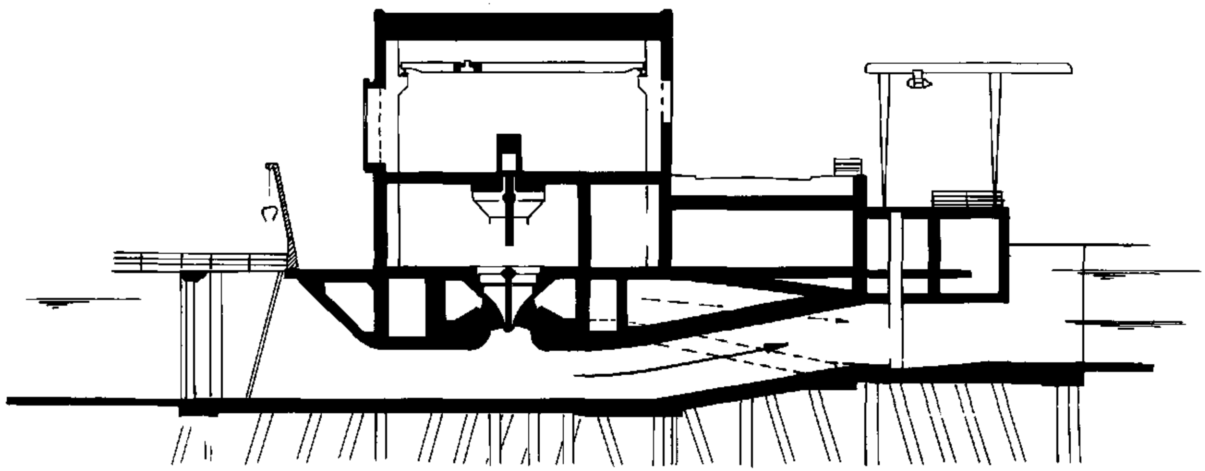

FIG. 2 PUMPHOUSE (longitudinal section)
axial flow pump and sluice

3.1. Design reliability

During the 19th Century windmills were replaced by steam engines and paddle wheels by plunger pumps; this combination of steam engine and plunger pump was used as a weapon against the oldest enemy of the Netherlands, referred to in the past, as the "waterwolf". This way of thinking was expressed in the first designs of pumping stations, which were built like castles with towers and galleries (Figure 3). Afterwards this aggressive element disappeared from the design, but aspects such as solidity and effectiveness remained. The present pumping stations are constructed in a purely functional manner as efficiently and economically as possible (Figure 4). A pumping station is in some way comparable with a small-scale factory, with the exception of the working hours. The average annual discharge required to maintain polder water at an acceptable level can be displaced in about 1,000 hours, operating with full installed capacity. The limited working time required together with the growing possibility of the automation of several specific operations, has resulted in new developments in the construction of small pumping stations.

The traditional way of building pumping stations in-situ has been replaced by the construction of prefabricated pumping stations (Figure 5). In this case the complete concrete substructure, composed of different parts, the mechanical and electrical equipment and the superstructure are supplied and placed by one contractor. At present only smaller stations, up to 100 m3/min, can be built in this way. Automation, together with the distance signalizing of technical troubles has resulted in the reduced supervision of smaller pumping stations. Most pumping stations are situated at lonely spots in the polder and are infrequently attended and are therefore an attraction to uninvited visitors. Sometimes the results of such visits can be harmful and a designer has to take this into account in the design to ensure pumping station security.

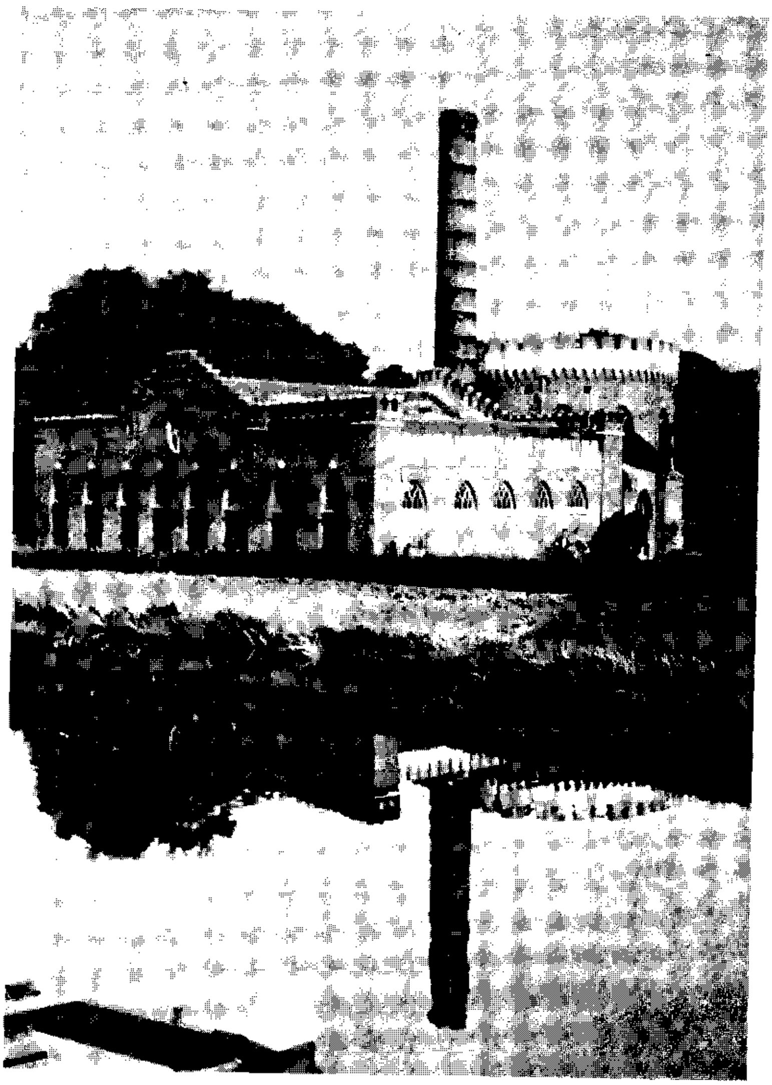

Fig. 3. Pumping station Cruquius

Fig. 4. Pumping station Keizersveer

The accessibility of the various components of the mechanical and electrical equipment, is one of the most important design standards inside the pumping station (Figure 4). Bad accessibility is a principle cause of the neglect of inspection and maintenance of the main components of pumping equipment. Secondly it delays the repair of damage during which time the pumping station is out of order and every engineer must try to shorten this vulnerable period as much as he can. In addition the design has to include protection against climatological influences. A long life is one of the principle objectives pursued by every polder board.

3.2. Machine reliabilty and maintenance

The reliability of the pumping station is expressed in the quality of the pumping equipment and its maintenance. Throughout the ages understanding between suppliers and engineers has grown to a very high standard and as a result the service given by the suppliers is based on giving priority to all the kinds of repairs to be expected with pumping equipment. As a result of this well organised service, pump failures can be repaired in a few days so most pumping stations are equipped with only two identical pumps or Archimedes screws. In the case of very big discharges (say more than 1,000 m3/min) the total discharge is divided into three or more pumps. In this case the method of transportation (by road or ship), determines the dimensions of the pump runners and the diesel or electrical engines.

Protection of the runners against pollution especially against wooden trash in the polder water is provided by trash racks. As a result of the increasing population in the polders, the amount and the kind of pollution is increasing. For ages the pollution was mostly soft vegetable materials; nowadays however domestic rubbish, containing plastics and wood, is a constant threat to the pump runners. Therefore the trash rack is an important part of the equipment. Cleaning of the trash rack is completely automatized and most racks are provided with a mechanical trash remover or grab bucket (Figure 6).

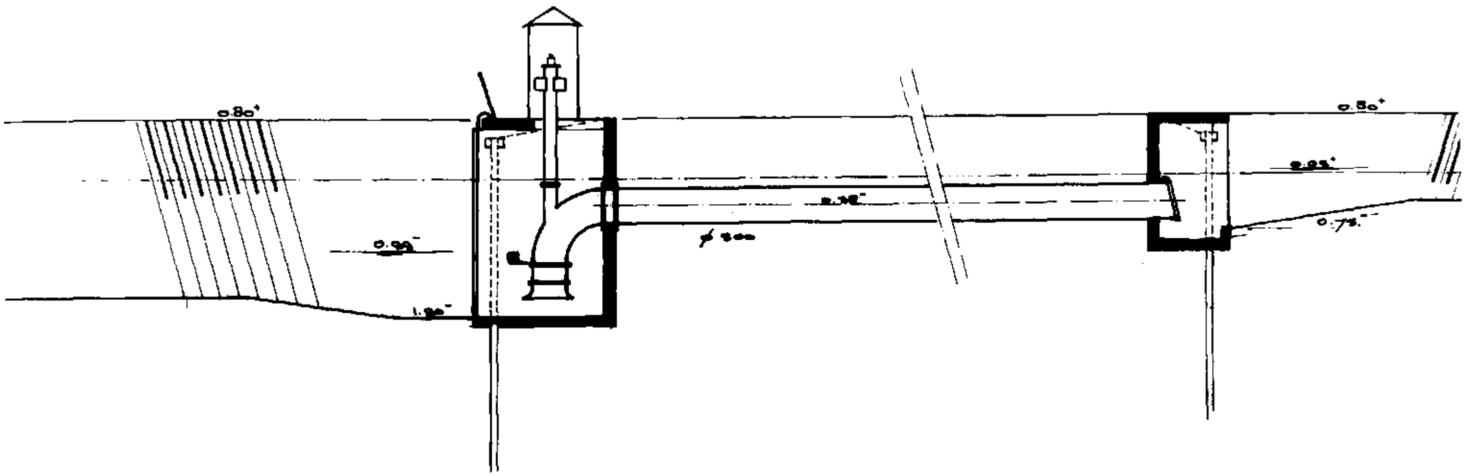

FIG. 5 PREFABRICATED PUMPING STATION

Fig. 6. Completely automatized mechanical trush remover

In addition to the protection of the pumping machinery the inspection and maintenance of all moving parts of the machinery as well as the electrical equipment is essential. At least once a year an inspection of the most vulnerable parts of engines, pumps and auxiliary engines is necessary. When the condition of one or more parts of the machinery is unsatisfactory, the replacement of this particular part must be considered in time to prevent a sudden breakdown.

A well composed scheme of maintenance is as important as inspection. This scheme should be based on routine actions after a fixed number of working hours and should be drawn up by the supplier of the machinery. The better the inspection and maintenance, the longer will be the life of the machinery and the more reliable the pumping station.

3.3. Reliability of energy supply

In order for a pumping station to be reliable it must have a guaranteed energy supply. An estimate of the mean yearly consumption of energy by all pumping stations in the Netherlands together comes to 45×10^6 kWh and although this consumption is only 6% of the total national consumption the delivery has to be assured under all conditions.

The principle sources of energy are electricity and oil and it is striking that natural gas is hardly relevant to pumping station operation. An explanation for this may be that the distribution network of natural gas has been developed in the last 15 year period and its branches are not as fine as the network of electricity. As a consequence connection to the natural gas distribution network would be expensive. Connection to the electricity network is also needed, to operate small auxiliary motors and to illuminate pumping stations, leading to further expenses.

The supply of electricity is guaranteed by the construction of a national distribution network, constructed in such a way that failures of electricty are mostly of a short duration. Failure of electricity supply in the local distribution network can be expected more frequently, but incorporation of the pumping station into an lateral electrical system will solve this problem.

Pumping stations are in general irregular consumers of electricity and in every pumping station a relatively large power supply must be installed in relation to the relatively short working time which leads to the irregular consumption of the local energy supply. Most of the electricity suppliers therefore have made limitations in energy supply by charging extra during the morning and evening peaks. Therefore all pumping stations are equipped with locking contacts so that the off peak time can be bypassed. The costs of connecting the pumping station to the distribution network are variable and are dependent firstly on the location of the pumping station with respect to the distribution network and secondly on the power installed. Sometimes the connection cost can be considerable and this financial consideration combined with the, formerly, low oil cost made it attractive to equip pumping stations with diesel engines. A second advantage of the use of diesel engines is the possibility of changing the speed of revolution within fixed limits. This speed regulation influences the discharge of the pumps and the power of the engines which is particularly important for drainage into the sea. In this situation tidal movement causes varying pressure heads, which results in variable discharges. By raising the speed of revolution, both discharge and engine power will increase, which is attractive for draining during a rising tide.

A combination of diesel and electrical engines may be considered when pumping stations are constructed with three or more pumps. Also when two or more pumping stations are constructed or have to be constructed inside a polder it would be wise to investigate the benefits to be obtained from the use of two energy sources.

When oil is used as a source of energy, a good supply route by land or water is needed. The oil is generally stored in underground storage tanks, which have to meet environmental pollution regulations. Some pumping stations are provided with above ground storage tanks, which are less expensive but more vulnerable.

The total capacity of storage tanks installed at oil-driven pumping stations, is at least 150% of the annual comsumption. Under normal conditions 1/3 of this quantity has to be available at all times, in order to meet the reliability requirements. Only in a state of national emergency is it permitted to use the reserve quantities. The extra cost attached to the installation of this extra storage capacity is mostly paid by the Government, according to the Protection of Civil Works in Wartime Act.

The rising of energy costs in the last few years has resulted in a renewed interest in the application of wind energy, be it with some diffidence. Although the investigations are not finished yet, the interim reports regarding the use of wind generators in pumping stations, are of the opinion that wind energy can be a useful addition to electrical energy (figure 7).

Wind-generators are not operational during calm or strong wind, so a connection to the electrical network would be essential to maintain a fixed waterlevel inside the polder at all times. Absence of such a connection would carry us back to the start of the windmill period, in which the changing water levels could be kept in hand only by creating an adequate water storage capacity inside the polder, an undesirable situation today.

The effective power of the wind-generator is limited. In comparison with ancient windmills however, considerable improvements have been made to increase the efficiency of wind-generators and pumping equipment; both the Archimedes screw and the axial flow pump are of a higher quality as are the paddle wheel and the plunger pump today.

Both the development of the wind-generator and the prefabrication of small-size pumping stations prompt again the always real question about centralizing or decentralizing the total discharge of big drainage areas in newly reclaimed land. As the number of pumping stations is not the only component in the general lay-out of a polder, the answer is not an easy one. It will be clear, that in most cases the initial cost

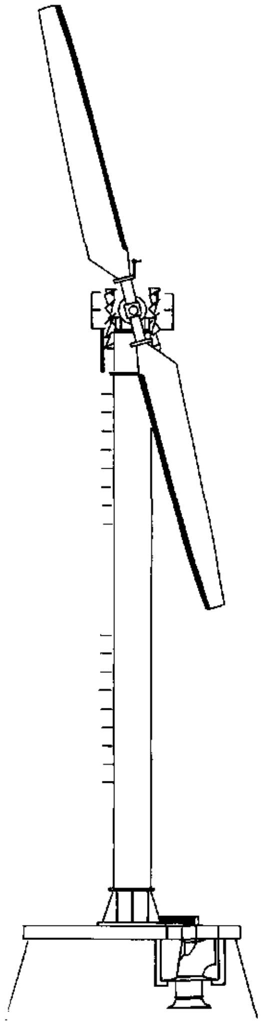

FIG. 7 DRAFT DESIGN

WIND-GENERATOR WITH PUMP

of constructing one pumping station is less than the construction costs of two or more. It is also clear that one central pumping station is always situated on the lowest spot of the polder closest to the dike. However it is also true that the soil excavation for the additional drainage lay-out will depend greatly on the number of pumping stations involved, especially when the lay-out is designed in a more or less undulating terrain. Calculation of the initial cost of some alternative lay-outs, in which the total discharge is divided over more pumping stations, will be essential to make a justified and correct choice. It may be economical to drain small deep-lying isolated areas inside the polder by seperate pumping sub-stations. Doing this will contribute to energy savings.

3.4. Running costs

In addition to the initial cost of the total lay-out, are the running cost of the pumping stations and the cost of maintenance of both the pumping station and the drainage system.

The running cost can be divided into the energy cost and the cost of manpower. Energy costs depend primarily on the annual rainfall, percolating water and evaporation, on the efficiency of the machinery and the construction, and last but not least on the energy prices. All these factors are difficult to influence as the climatological and geological conditions cannot be altered, the efficiency is the highest possible and prices are dictated by third parties. The cost of manpower is however, a subject of economy studies, especially when in the last decade salaries have increased tenfold and more. The employment of engineers and other polder workmen has changed in such a way, that as a result of automation and computer techniques and the development of automatically operating trash-rack removers, more time has become available for new activities, such as the centralized cleaning of drains and ditches and the maintenance of mechanical equipment used for that purpose (figure 8). Ditch cleaning, formerly a land holder's task is done more and more by polder workmen, equipped with a large assortment of selected equipment. For this reason the dimensions of

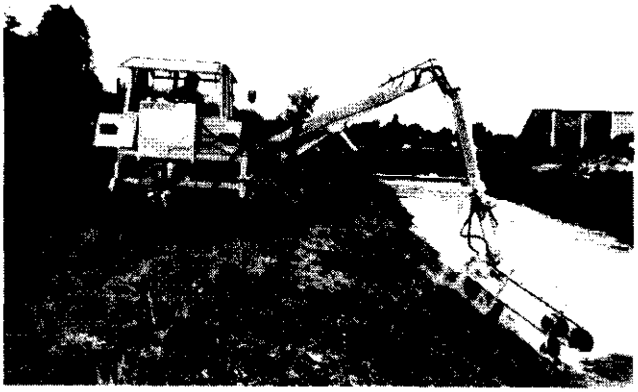

Fig. 8. Maintenance of a water course

culverts are no longer based on discharge only, but also on the dimensions of the water reed cutter. As uninterrupted side strips along the drains enable the possibility for operations with mechanically operated equipment each side ditch has to be bridged or covered over at the inlet into the drain. All these costs, mentioned above are significant in the determination of the number of pumping stations to be constructed in a polder.

Almost five centuries of interesting technical developments are between the construction of the first windmill and the designed wind-generator. Regarding the improvements of machinery and pumping equipment, much has been achieved and as a result both efficiency and solidity are of high standards now. However all technical achievements will be judged according to the requirements of reliability.

At the end of this presentation, a tribute is paid to that small army of unknown millers and engine-drivers. The "Crugius", one of the oldest pumping stations in the Netherlands is now a museum and so are the few windmills that have survived. In this we honour our ancient technicians, who reclaimed polders in the past ages. But the miller and engine-driver, who by night and day was employed on operating the windmill or pumpings-station, are hardly mentioned. He did his job, sometimes grumbling, always dutifully, making life possible for the major part of the people of the Netherlands.

CONSTRUCTION ASPECTS OF POLDERS IN THE WORLD

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Abstract

The construction of polders started outside of Europe on a large scale in the Caribbean area, where works were mainly carried out manually. The physical environment required a special way of reclamation.
At present polders are constructed in quite different ways, requiring 2 important parameters to be taken into consideration against a great number of factors, viz:

- the construction period;
- the costs of the polders.

The polder design, the physical environment, socio-economic circumstances and the political system of the country, do exercise considerable influences upon these two parameters. Examples are quoted of the effects of such influences on the construction.
The degree of mechanisation constitutes another factor of major importance. Country wise, well considered choices will have to be made, in order to arrive at balanced and justified rate between the utilisation of conventional means and modern equipment in the construction. In order to highlight the effects of the factors named, an example is presented of the cost-components of a polder size 3,000 ha, to be constructed in a delta-area covered with tropical rain forest.

1 History

The following presentation is mainly focussed upon the construction of polders in the river delta-areas of tropical South America. Since the problems to be solved are identical to those to be solved elsewhere, what is to be said here, may therefore be attributed universal significance.

In various parts of the world technologies for polder construction were more or less developed independant from each other.

For example, the endikements alongside the larger rivers in China, can be considered as the fore-runners of the technology in that region, of which later developments were derived.

Up till now no integration took place of all the construction techniques developed in the various countries.

This paper aims at a modest contribution to the establishment of one universal theory for the construction of polders.

For the start the polders in Europe and South America were considered. The emergence of the "polder" in Europe was to a large extend also the result of prime endikement of areas adjacent to the larger rivers.

The methodology and technology thereby developed were first used on a large scale outside Europe, after the discovery of the "New World", when Europeans attempted to settle in the Guyana's, the river delta-area between the Amazonas and the Orinoco rivers in the north-eastern section of South-America.

Dutch and English colonists founded ever since the 17th century settlements along the larger rivers in this region. And this explains why the first polders constructed in this area, were exact-copies of well known polders found in the province of Zealand (Holland).

Up to the present the original lay-out of the earliest Zealand polders can be found back in the older plantations alongside the Suriname, Demerary and the Berbice-rivers. However, despite the great similarity in lay-out and construction, the South-American polders were referred to as "plantation", a name which primarily refers to the purpose rather than to the structure of the reclamation effort.

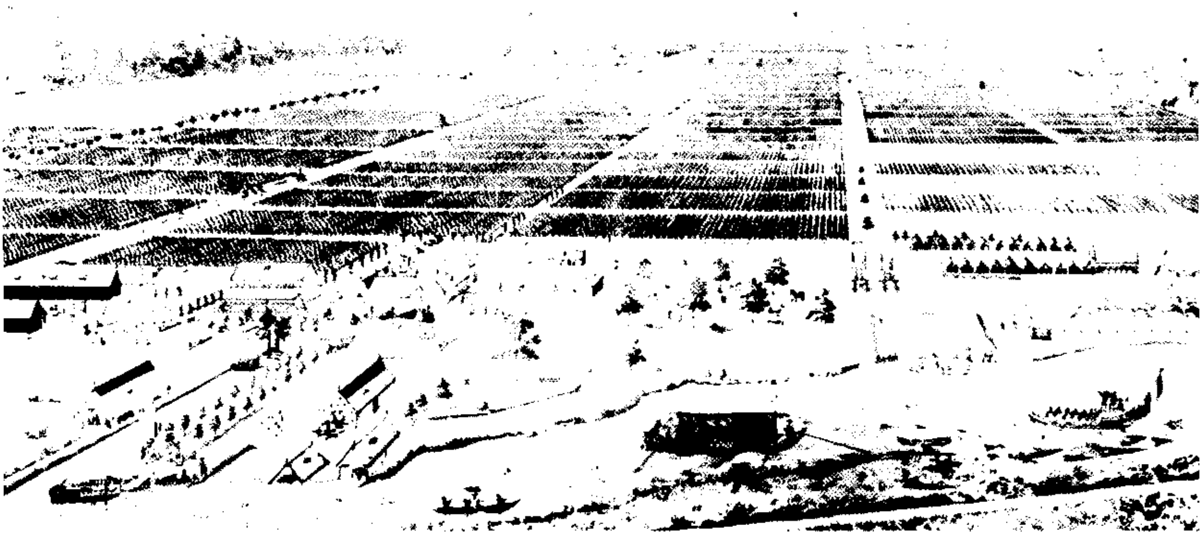


Figure 1. Plantation

Three important differences can be distinguished, when comparing the emergence of polders in South-America with the emergence of polders in Europe.

a) The first European polders, in particular those found in the lowlands of northern Netherlands, originated as the result of the construction of dams, which could facilitate overland communications between neighbouring settlements, situated on land sections above the floodline, named "terps".

The construction of these communication-dams between the terps, led to the complete endikement of the lowlands between these settlements.
Later on impoldering followed, which had the purpose to reclaim floodlands, laying above the average high water mark. Special "quais" were constructed as means to accellerate the silting-up proces.
In the 17th century a third polder-type emerged, the so-called "droogmakerij", which involved the endikement and artificial drainage of marshes and lakes by means of windmills and tide-locks. The construction of this type of polders was based upon economic considerations and took to a certain extend also place, as a means to protect densely

populated or intensively farmed areas from periodical flooding and other inconveniences due to uncontrolled water-movements in the marshes. The famous "Haarlemmermeer polder" can be named as an example which fits this description entirely.

As such three types of polders can be distinguished in the Netherlands and in other European countries, namely:

- polders resulting from the construction of dams for overland communication between settlements;
- polders resulting from endikement of floodlands;
- polders resulting from the drainage of marshes and lakes.

The first type of polder is the result of technical measures primarily taken to satisfy the basic social need for more intensive face to face communication between inhabitants of different settlements. The empoldering of lowland can as such be seen as a "by product" of the fullfillment of a social need.

The endikement of floodlands was a consequence of the increased demand for farmland and settlement area, due to the increase of the population. Some of these endikements were also undertaken as safety-measures, which could prefent the periodic undesired intrusion of water into the settlements.

Social factors as such were of prime importance with respect to the emergence of the polders in Europe. By contrast these factors were entirely absent in the considerations which gave rise to the emergence of polders in South-America. The South-American polders were exclusively constructed on the bases of pure economic reasons.

The South-American polders were primarily constructed for the cultivation of high price tropical products such as sugar, cocao, coffee and cotton, which could not be grown in Europe.

The rivers constituted the only possible way of direct access to areas suitable for the cultivation of these products. And although the rivers offered vast highland areas upstreams, the European settlers preferred settlement in the marshy downstream areas, because of the higher fertility of the clay soils available in the downstreams sections.

The choice for the marshy areas was justified by the fact that despite high costs for the construction of polders, economic profit was larger, because of the higher crop yields obtained from the fertile clay soils.

b) The second important distinction to be made between the emergence of the European polder and the South-American polder, relates to the involvement of manpower and capital in the polder construction. In Europe capital and trained manpower for polder constructions were readily available. Not so in South-America! Most settlers had only limited funds for polder construction, while manpower had to be imported in the form of huge slave-forces, composed of workers with no experience or what so-ever in polder construction-activities.
Despite the fact that several decades earlier, sophisticated equipment such as dredges, excavators and tipping carts were introduced for polder construction in Europe, no use was made of these equipments in the construction of the polders in South-America. Preference was given to manual labor, since slave labor was far less expensive than the exploitation of sophisticated equipments. These two factors have led to an entirely new approach which differs in many ways substantially from the approaches to polder construction used in Europe at that time.
The most significant difference in this respect is to be found in the fact that new technology had to be developed, for the utilisation of cheap manpower in the construction of polders, instead of already known equipment used for the construction of polders in Europe.
The South-American system thus featured capital saving at the expense of manual labor, while in Europe the trend to substitute manpower by means of capital was already well under way.

c) In Europe the size of the impoldered area was not directly geared to one type of production. Impoldered areas were devided into sevetal production units, each of which could be used for a different type of production. The South-American plantation however, was constructed as a single production unit, with a specific production purpose.
What were the procedures followed in the manual construction of polders or plantations in the New World?
At first interested parties were allotted a parcel of land, with a given front-width, measured in "Rhineland Rods" along one of the main rivers. Meanwhile it was thereby also decided that the rear-boundary of the parcel should be established afterwards by the government surveyor of the colony.

The commonly allotted front-width, measured at 50 to 75 Rhineland Rods.[1] This width was established with reference to the desire to facilitate the establishment of as many plantations as possible along the river, since as a matter of fact, the river was the sole means of access to the arable land-areas.

The depth of the parcel was determined by the drainage possibilities. But since there was an entire dependency upon tidal-drainage, it was the front-width which in effect determined the total acreage which could be drained effectively, as we shall see later on.

Each parcel was separately impoldered. The impoldering included the construction of dikes surrounding the parcel and the excavation of one or more drainage-canals. Often two drainage-canals were excavated alongside the depth-borders of the parcel. The polders thus obtained a rectangular form, with the short side bordering the river.

In this way thousands of rectangular polders varying in size between 500 and 1,500 "akkers" (200-600 ha) came into existence along the main rivers in the Guyanas.

The area within the endikement was subdevided into drainage-units of 10-15 "akkers" (4-6 ha). Within the drainage-units ridges were constructed with a length of 100-160 meters and a width of 8 to 12 meters. Of course there was a lot of variation with respect to these dimensions, due to the differences in soil types and permeability of the soils to be drained.

Along the ridges, gullies were drawn (h=0,6-0,9 m) which flowed into the drainage canals along the drainage-unit.

Because of their purpose, drainage canals could not be used as "waterways" for the transportation of products from the field to the processing center of the plantation. Therefore special "navigation-systems" had to be constructed within the polders.

In general the main navigation-canal was excavated lengthwise in the center of the polder. In this canal a water-level was maintained, which was usually higher than the water-levels of the drainage canals, in order to facilitate product transportation by means of barges.

Usually this main navigation canal popular named "BANTAMAS" was given exceptionally large dimensions, not only to facilitate water transportation, but especially to be used as a means to store a sufficient volume of fresh water, for use in the dry season. As such the Bantamas had a

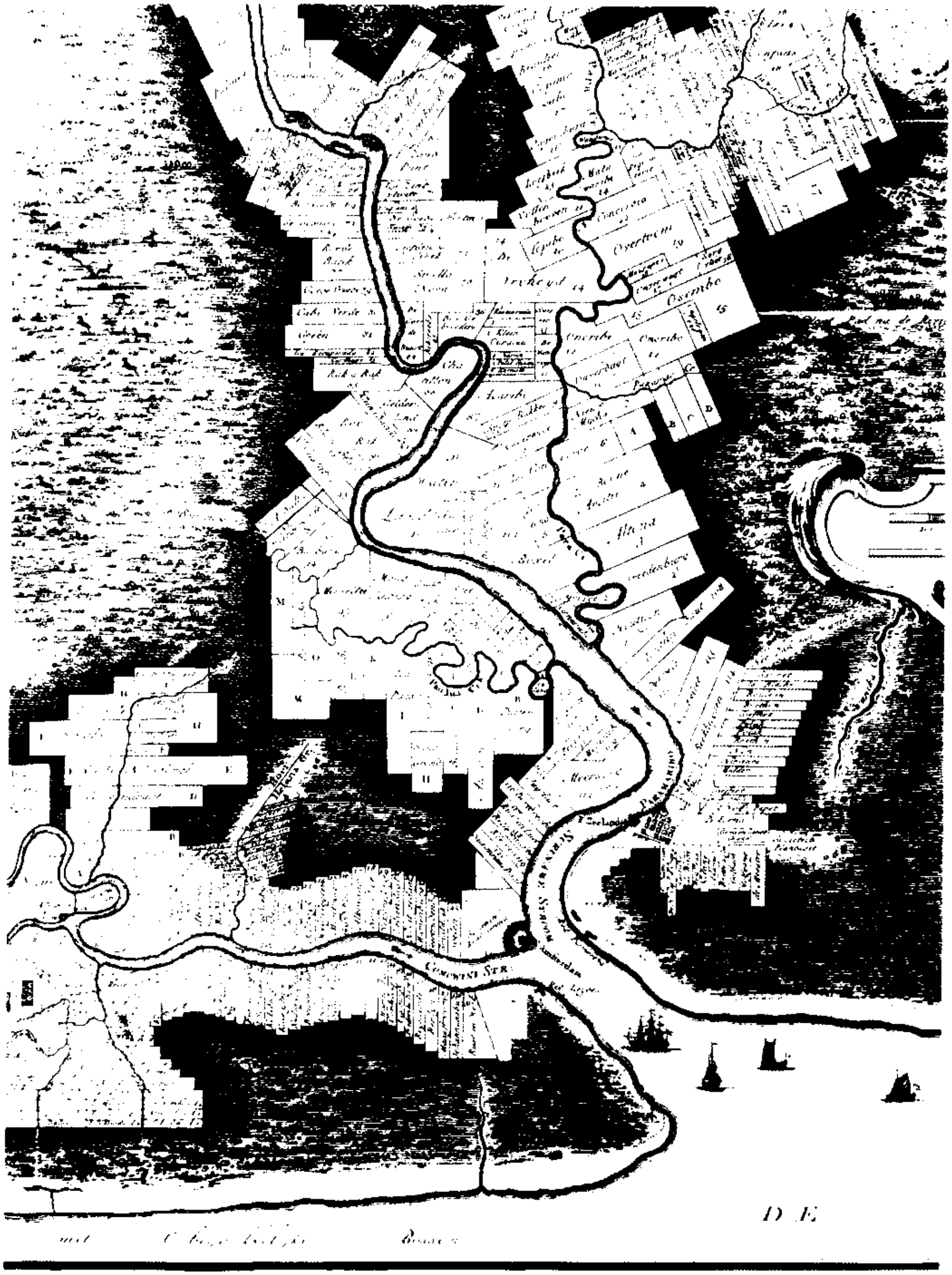


Figure 2. Plantation along a river in South-America

function comparable to that of the Dutch "storage canals" ("boezemvaarten").

In the main drainage canal a tidel lock was constructed. Bricks manufactured in Europe were used as construction materials for these locks. The norms taken into account for the design of the tidal lock were most often based upon sound empirical principles.

For instance, for floodlands flooded during a special period of time, the "sill of the sluice" had to be built on lowest known low tide level, while the width of the lock was a function of the number of "akkers" to be drained, for example one foot of sluice-width per 100 akkers.

The construction of such a plantation was completely carried out in manual labor, according to the following sequence of activities.

- During the dry periods of the year the area was cleared manually. The remnants of the slashed vegetation were stored ridge-wise for a period of 4-6 weeks.
- For the final destruction of these remnants by means of fire, a moment was chosen whereby conditions persisted, which could minimize all possible dangers of damaging the organic topsoils by the burning of the slashed vegetation. The end of the wet season proved to provide the best such moments, since at that time the soil still contained sufficient moisture.
- Within the same year the planter could already make a start with the planting of his first "cash crop", in order to recapture part of the land clearing costs made.

The manual endikement of the allotted parcel was also carried out during the dry season. A very high degree of accurateness and precision was observed in dyke-construction. Especially the "clearing and grubbing" of sections within the construction limits were very carefully carried out.

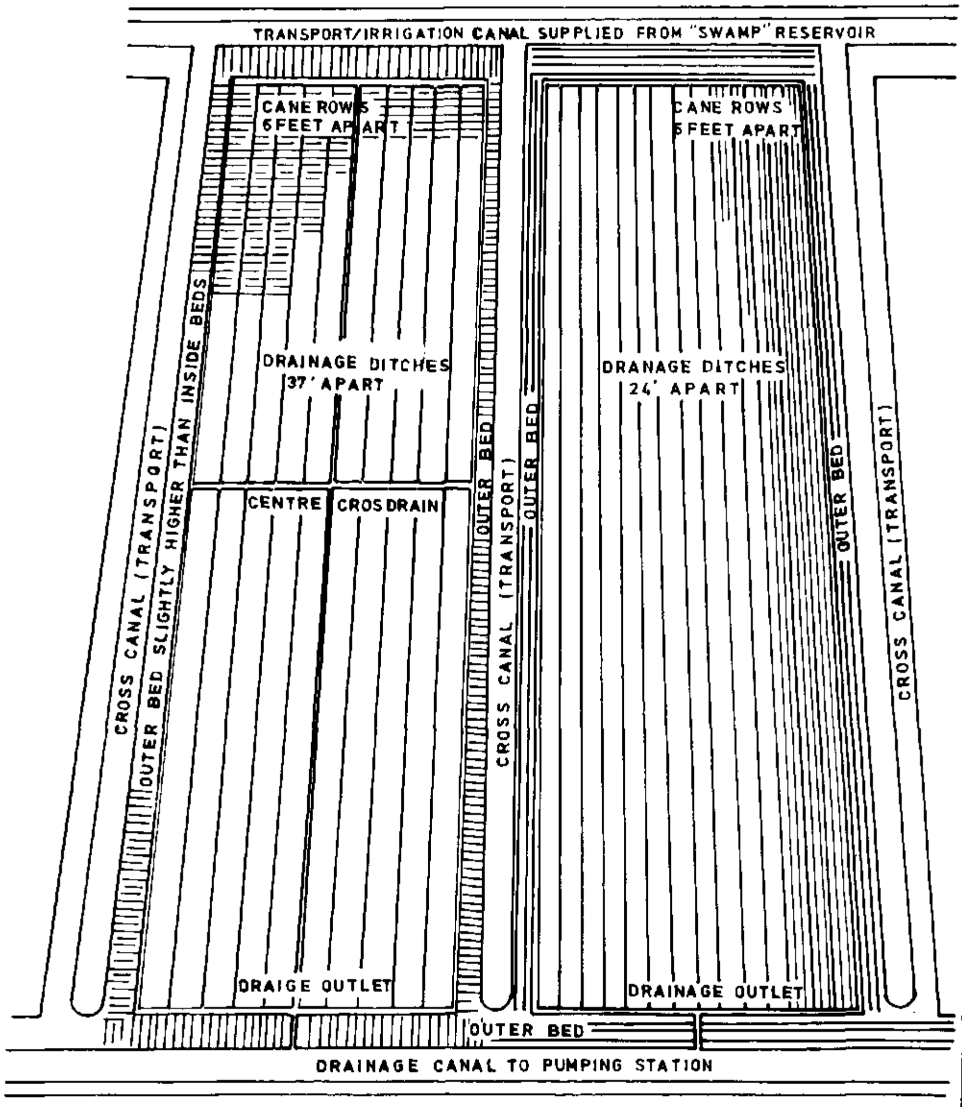
All organic materials such as bagasse, grass, roots and other undesired materials were removed by hand. The dykes were erected with the soil species obtained from the excavation of the canal on the innerside of the polder-dyke.

To prevent seepage a centercore made of pure clay was first laid, around which the dyke was to be erected. This centercore is called the "blinder".

All compaction of the added clay took place by means of trampling, using

Fig. 3:

CANEFIELD LAYOUTS IN GUIANA



slaves, cows, donkeys or horses as the tramplers.
The lock in the drainage canal was mostly built a few hundred meters landinward from the riverbank. The lock was connected with the river by means of a canal, the "lock creek" also called "sluice creek". This landinward location of the locks was a safety-measure against wave attacks on the lock as well as a security for the preservation of the lock in case the river started to meander.
The natural riverbank-area, also named "front land" was used as residence-area. The frontlands had separate drainage systems. Due to the location of the frontland area and the type of land utilisation, much more complicated criteria had to be observed in the construction of the frontland drainage systems.
The deforestation of the impoldered area could take place during the whole of the year, regardless of the soil conditions present.
The weakness of the soil and prolonged periods of excessive precipitation did not have the effects on the pace of deforestation, which are at the present time encountered by mechanised deforestation of polder-areas.
At the time of plantation construction only manual labor was used for cutting and fragmenting of trees as well as ridging of the slashed vegetation. And the slaves ordered to do this work, could always work in the fields regardless of the weakness of the soil, they had to work on.
The construction system used, thus facilitated optimal employment of the means of construction and optimal flexibility of the construction-operations, since there were also no differences with respect to the employment of the means of production in the construction of large canals and the digging of smaller ditches and gullies.
The slaves used for the construction, could more-over also immediately be employed for the cultivation of the cropland.
The pace of plantation construction was nevertheless very slow.
The completion of a plantation of about 600 ha required at the average ten years of time. Needless to say that if the slaves were to be paid wages at that time current in Europe, all concerns should be bancrupted by the polder-construction endeavours.
There are only a few records left to us, containing only some of the many empirical principles and practical experiences, obtained during

this high time of polder-construction in South-America.
Because of the sorrow state of our historical records in this respect, only the physical remnants of the plantations in the Guyanas, are left to us as silent, forest rampanted monuments, in memory of a marked era in the history of the polder phenomenon.

2 Consideration for present polder-construction endeavours

In the foregoing we have spent quite some attention to the manually constructed "Polders of the World". In this presentation manual construction of polders is seen as one of the extremes from which the polders phenomenon can be reviewed. The other extreme is to be found in the present way of polder-construction, whereby the job is almost exclusively done by means of heavy equipments.
In between these extremes a lot of varations can be found, using both manual labor and equipments simultaneously, but in different ratios.
In sparsely populated countries mechanisation is often the only alternative, because of the scarsity of manpower. In densely overpopulated countries, such as found in South-East Asia, the utilisation of manual labor must be given considerance for large parts of the impoldering works, as a means to facilitate the population to benefit directly from the construction efforts.
At the same time it must be also considered, that the demand for readily cultivaleable croplands is also extremely large in essentially this type of countries, which may well lead to limitations in the utilisation of the vast amounts of manual labor available, in favour of the optimal utilisation of equipments for certain sections of the job, as a measure to speed up the construction operations and as a measure to satisfy the need for farmland in the shortest possible period of time.
But regardless of the kinds of the considerations to be taken into account, decisions concerning the involvement of manual workers viz equipments, will always have to be made with reference to a context of sound principles, to be observed in order to obtain optimal realisation-efficiency at the lowest costs.
In this section a review is made of the most important elements at play in contemporary polder-construction. The factors to be considered, will

be analysed, using as basic comparative parameters:

a. THE PACE OF CONSTRUCTION;

b. THE COSTS PER AREA-UNIT.

Needless to say that the analysis and comparisons presented here are both far from complete and far from exhaustive.

2.1 The physical environment

It seems quite justified to assume that all over the world, the areas to be impoldered are composed by lands which are more or less permanently submerged. As a consequence the soils of these areas are mostly not fully consolidated and may often be quite young.

The borders of the area to be impoldered, should be determined on the bases of a sound analysis of prevalent hydrological conditions.

Strict observation of the hydrological conditions is the prime and foremost important requirement, to secure a proper pace and least costs of the construction activities.

The random obstruction of the natural drainage of surrounding areas, may cause a lot of complex problems both during the construction period and afterwards.

All efforts should therefore be made to obtain the most accurate insights concerning the natural drainage system and the topographical and vegetational characteristics of the area by means of aerial photograph analysis.

In any case prior to the initiation of the polder-construction a thorough appraisal must be made of the following factors:

- Climate : The course of annual precipitation and the identification of dry and wet periods.
- Hydrography : The location of swamps, creek and river courses, gullies and tidal effects.
- Soil : Topography, presence of soft layers and pervious soils, possible presence of acid sulfate soils.
- Vegetation : An analysis of the various types of vegetation and vegetation layers, to be categorized for example in:

: - dense forest
- medium forest
- scrub vegetation
- herbal vegetation and grasses

- Accessibility : All possible means of access will have to be surveyed with emphasis on the analysis of factors of logistical significance.
- Management : Analysis of anticipated social, economic and technological situations which may affect both polder-construction and polder-maintenance activities as well as decisions concerning centralised or decentralised control.

Although the factors just mentioned may seem rather self-evident affairs in polder-construction, it appears in practice that they are often insufficiently or not at all observed.
Water-annoyance during the construction and subsequent sagging of machines, logistics problems affecting personnel transportations, fuels and food supplies, and poor working conditions due to incorrectly selected campsites are only some of the many problems to be faced, as a consequence of neglecting the forementioned factors.
Quite often the neglect of a proper approach towards the factors mentioned also results in wrong choices of equipments - choosing either too small or too large machines.
Such neglects lead to bad planning, which in many instances results into the escalation of construction costs by hundreds of percents.
Extensive confrontation with such problems and cost-escalations, is one of the most outstanding aspects of polder-construction in the delta-areas of countries as Brazil, Guyana, Venezuela, Thailand, India, Bangladesh, Birma, Vietnam and Indonesia.
It would be erroneous to think that the factors named are not or of less relevance for polder-constructions, which take place in a somewhat different physical environment. The relevance pertains to all the kinds of physical environments of polder-construction.
And to point out another example of a physical environment to which these factors also apply, reference can be made to the Hachiro Gato polders in Northern Japan and to the polders in the Peoples Republic of

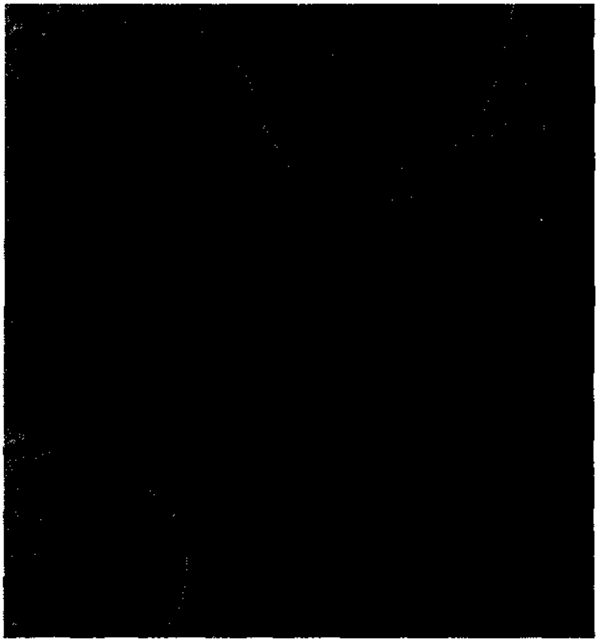


Figure 4.

Aerial photograph of flood lands

Fig. 5:

Rainfall and evapotranspiration in Tropical humid regions

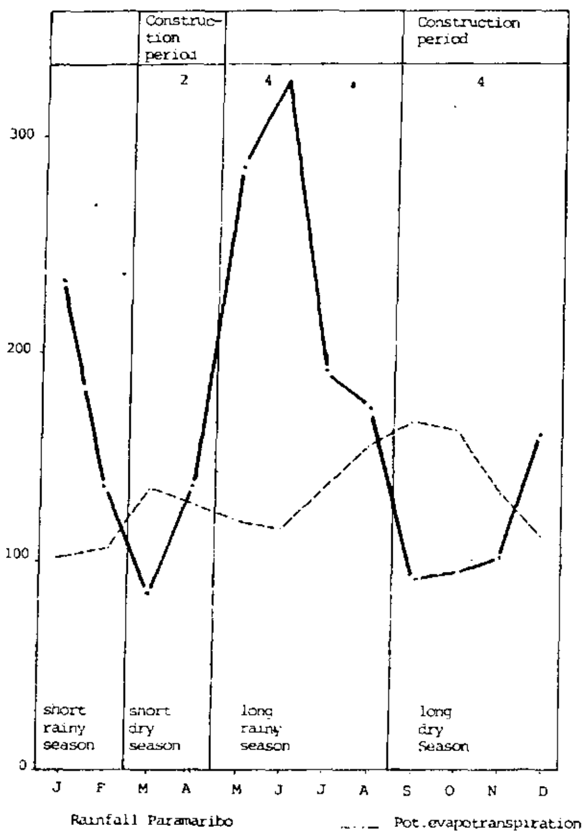


Figure 6.

Deforestrated area

Figure 7.

Equipment in rainy season

Figure 8.

Logistics

(North) Korea. In both countries the polder-constructions were carried out in inland sea-areas.
The water balance in relation to salinity, constituted the most important factor in determining of the size and boundaries of these polders, while as other prime factors to be taken into account in the construction of these polders the following can be named:

- permeability of the soils;
- desalination;
- soil compaction and seepage of soils.

The two types of physical conditions mentioned namely:

- the densely vegetated marshy tropical delta-areas, and
- inland-seas,

can be seen as two extreme types of physical conditions, which despite their differences require the total observance of all factors named.

The carefull examination of the conditions presented by the physical environment, is also of major importance for the choice of polder design, the choice of construction methods and for the determination of the degree of mechanisation of the construction operations.
In the delta-areas proper mechanisation of the operations may be best pursued by the involvement of conventional machines such as bulldozers, draglines and hydraulic excavators, while in the case of inland-seas the main infrastructure can be best realized by the involvement of dredges.

For a proper approach it is of course necessary to take also other aspects into account, which are not directly related to the physical environment of the polder area. Some of the socio-economic aspects to be studied for this purpose will be reviewed by the next section.

2.2 Socio-economic aspects

All over the world, the construction of polders will have to be preceeded by an analysis of the socio-economic conditions, prevalent in the country within which the construction is to take place.
Substantial influences are exercised upon the pace of construction activities and the costs of the polder-construction by factors such as:

- local experiences in polder-construction;
- distribution of technical know-how, skills and experience in machine operating and maintenance;
- employment conditions and customs of employers and employees;
- wage levels and wage structure;
- time-use patterns of skilled and unskilled manual workers.

It is of prime necessity to obtain reliable data of these factors in order to be able to make a proper assessment of social conditions, which affect very seriously both the costs and the duration of the polder-construction, as well as matters such as the degree and level of mechanisation to be applied in the construction. It is therefore no luxury to hire a well trained social scientist with considerable field experiences to do this job.

In case the local experience proves to be limited to manual operations only, or to operations involving traditional equipments, a program must be made for the completion of the project, which has taken these realities into account in the selection of the level of mechanisation to be observed.

If the polder would be constructed in pretty much the same way as done by the population up to that time, only relatively small acreage of arable land would be reclaimed in a given time period. The satisfaction of the need for farmland would as such require an excessively long period of time. By contrast a highly mechanised approach could result in a very high level of arable land realisation. But it is not excluded that such an approach does not concur with the interests of the local population, because of the vast numbers of manual workers that would have to be put off side.

Program planning for polder-construction as such involves quite a lot of exercises in compromising the two social interests named, in relation to factors such as pace of the operations and level of mechanisation.

Solutions for such "conflicting interests" may be found by various forms of division of labor, linking the involvement of modern machines to the construction of larger and more comprehensive works meanwhile assigning the detailments of the construction to manual workers.

Such approaches mag possibly make the achievement of the highest level of mechanisation illusive from a technical point of view. One must however consider that in this way a socially acceptable balance can be found, providing both the timely completion of the construction on the one hand and ample opportunities for employment and training of local workers on the other hand.

In selecting the machines to be involved in the construction, attention must be paid to such factors as post-construction exploitation of the equipment, for example in maintenance activities and possibly also in other construction activities, to be pursued in forthcoming times by the country.

Finally inquires should also be made to determine whether or not, and if so to what extend workers needed for the construction will be available during the seasons most suitable for the realisation of the construction. It may well be that these periods co-incide with other activities of the population, such as planting or harvesting of crops, dwelling construction and the like.

2.3 The relations between polder design and the pace and costs of polder-constructions

The topography of the area to be impoldered constitutes the bases for the polder design. But because of factors such as the pace of construction and the costs per area-unit, other factors, among which the following must also be taken into account.

- dimensions of canals, conduits and parcel-ditches have to be standarized as much as possible;
- cross-profiles of canals etc. have to be atterned to the machines to be used, so to secure the obtainment of the highest level of efficiency;
- the volume of earth species needed for the construction of dams and road foundations, has to be used as determining factor for the establishment of the dimensions of excavations. (This may result in dimensions for the various types of excavations which are not in accordance with the outcomes of hydraulogical calculations.)
- irregularly shapes of parcels must be avoided! (mechanised) crop productions require regular shaped-preferably rectangular parcels, to be obtained by somewhat more of land-levelling if such is necessary.

The final design of a polder is therefore obtained by cross-comparing of the advantages and disadvantages of the following principles.

a) Size of the smallest polder-unit

The costs per area-unit of the polder increase relatively to the average-costs to the extend that the size of the area-units is decreased. This is due to the considerable increase of tertiary infrastructure, which also limits i.e. decreases the pace of the polder-construction. Basically polders of the same size require identical periods of time for construction. Differences in construction time are primarily caused by differences between the parcelling systems.
The smaller the polder the larger the costs per area-unit.
The costs per area-unit (parcel) of the polder increase relatively to average area-unit costs, to the extend that the size of the area-units is dcreased.
This is due to the considerable increase of tertiary infrastructure, which increases construction-costs and decreases the pace of the polder-construction.

b) Overland versus navigational within-polder communications

A choice shall be made between a roadssystem and navigation canals, as means to facilitate the hauling of goods/products to and from the parcels.
In case of choosing for a navigation system, this will meanwhile also require a choice to be made out of either drainage or irrigation canals, to be made suitable for this purpose. In considering these alternatives, comparative evaluations have to be made of the following factors:
- construction and maintenance costs of roads;
- costs of canal adaptations such as raising of quais and bridges, construction of ducts;
- enlargement of the wet profile of canals and subsequent extra excavation costs;
- purpose of the polder (small holdings polder or single estate polder).

c) High level or low level water presentation

The water level to be maintained in the irrigation-canals, will influence the construction and exploitation costs of the polder to a considerable extend.
High level water presentation requires higher dams. This implies that more earth will have to be excavated than necessary, according to hydraulogical calculations. For a low level water presentation less excavating is required because the profile to be constructed will be in closer approximation to the outcomes of the hydraulogical calculations.

A second consideration is the degree of efficient water-utilisation, since the farmers will waste a lot of water in case of high level presentation, which is in contrast with the utilisation if a low level presentation is maintained, whereby pumping costs are to be paid by the farmer.
In the exploitation phase central pumping and high level presentation may prove to be far less expensive than low level presentation and individual pumping.
In the last case the farmers themselves will have to account for the pumping costs, which in effect only implies the shifting of some of the costs.

2.4 Political factors

Next to the various, physical, technical and socio-economic aspects the design and construction of polders is also substantially influenced by various types of political decisions, of state and local governments.
In the densely forested delta-areas the government will have to decide whether or not the farmers will be allotted either readily cultivaleable or partly or wholly forested parcels, to be cleaned up by the farmers individually.
Next to the fact that about 15 to 20 percent of the investment costs are transferred to the farmers, by allotting them partly or wholly forested parcels, other disadvantages of individual land clearing must also be considered. To name a few:

- The period of land improductivity of the impoldered area will be extended substantially, since the farmers can only start with the clearing after the completion of the construction and after completion of the processes of parcelling and allotment. And those processes may take a lot of time, mainly because of extensive political deliberations proceeding them.
- If the polder is delivered during a period of unfavourable weather conditions, the farmers will have to postpone the clearing activities for rather long periods of time.
- The contractor has the opportunity to secure the land clearing in a highly centralized way, the construction period will include several suitable seasons, facilitating the contractor to commence and continue the clearing operations according to weather conditions.
- The clearing costs might be higher in individual clearing of parcels since the clearing has to be pursued by means of workers which are at the time of clearing also much in demand by other activities (harvesting etc.).
- Individual clearing activities may result periodically in over-demands for relatively scarcely available machines and other equipments.
- The farmers loose at least two crop seasons i.c. two crop harvests.
- The interest period of the investments for clearing is extended with at least one or two years.

The decision to allot either forested or cleared parcels to the farmers, is of course influenced by many other political and socio-economic factors.

Next to the financing terms by which funds are allocated for polder construction, it is the prime socio-economic role of the polder, which must be seen as a major important factor with substantial effects upon the decision to be made, concerning the clearing conditions of parcels to be allotted to farmers.

If the polder is constructed primarily as a means for the rapid solution of national food constraints, it appears to be most recommendable to allot readily cultivaleable parcels to the farmers. In this way no harvests are lost, while the effects of the investment can be made readily sensible to major sections of the population.

In countries suffering from foreign currency constraints, allotment of forested parcels may be seen as the only way to finalize the polder-construction, or as a means to save some of the foreign currencies, otherwise to be used for the purchasing of fuels and spareparts for machines.

The considerations should not be limited to only macro-technical financial and social aspects.

The decision concerning the allotment of either forested or cleared parcels to farmers, has also to take into account the socio-economic position of the individual farmers as well as the social effects of each of these two alternatives, in order to avoid problems such as the following:

In an Indonesian land reclamation project, farmers were allotted rice-parcels still containing stumps and trunks of large trees, leaving only a sparse amount of open land for the cultivation of rice.

Because of the almost still too modest parcels allotted in these regions this type of allotment could easily have brought the farmers existence into peril, since the net cultivaleable area of the parcel was in effect reduced far below the minimum proportions of land needed to grow sufficient rice for his personal subsistance. Meanwhile he was also left with the almost impossible task of removing the trunks and stumps, with no means or whatso-ever available for this purpose.

In some of the land reform projects of the Republic of Colombia, only the main infrastructure was put in an area allotted to farmers.

As a consequence of the absence of other provisions the farmers were unable to produce beyond subsistance level.

In other projects of that same country, farmers were allotted readily cultivaleable parcels, which enabled the rapid ascertainment of a decent level of living.

It must be clear that such inconsistent allotment policies can easily result in the emergence of social tensions between the more and the less favoured groups of farmers.

The nature of the terms by which funds are made available, also exercises considerable influences upon political decisions with respect to the approaches to be followed in the realisation of land reclamation projects.

This statement can be very clearly illustrated by a comparison of the policies followed by the cooperative Republic of Guyana and those chosen by its neighbour, the Republic of Suriname.

Land-reclamation in Guyana is almost entirely financed by means of funds obtained at relatively high interest rates from international financing institutes. In Suriname the land-reclamations are financed out of funds, donated free of any charge by the Government of the Kingdom of the Netherlands - the former ruler of this country.

The Guyanese Government has explicitly chosen for an approach, which secures high speed, efficient realisation of the polders.

Two large land-reclamation projects are executed at the same time, each controlled by a separate special appointed authority, with full fledged decision- and operational control.

The M.M.A.-authority is charged with the reclamation of an area of 50,000 ha, situated between the Mahaica, the Mahaicony and the Abarry rivers. At the same time a second large polder - the Black Bush polder - is constructed in the area between the Canje and the Corantyne river, under direct control of a different Government authority.

In the M.M.A.-project, the reclamation works are commissioned to one contractor supervised by one consultant. Both are obliged to complete the total land-reclamation within the shortest possible period of time. The approach results in simple and very straight forward relations between the authorities, the consultant and the contractor, meanwhile also securing high speed and efficient completion of the constructions. In my opinion the Guyanese approach appears to make a lot of good sense.

By contrast to the Guyanese high speed construction endeavour, the approach applied by the Suriname Government in the realisation of the "Multi-Purpose Corantyne Canal Project" - MCP -, features a continuously ongoing concern, to segregate the construction into as many small items as possible, to be commissioned to as many as possible contractors. Control is all but firmly established in the government agency charged with the coordination and supervision of the construction, since several other government institutions are still left a voice in the decision-making process.

Due to these factors the pace of project-realisation is slowed down considerably and because of the too slow and too sluggish pace of realisation, construction costs escalate substantially.

The Suriname Government has now reduced the total area to be impoldered as a measure to keep the project costs in balance with the available capital funds for the project.
With reference to the forementioned aspects and situations, it may be stated that the construction of polders in the developing world, has to take place in such a way that a readily cultivaleable polder can be obtained, by observing all factors of influence upon the costs and the pace of the construction.
This objective will have to be enforced by all circumstances and regardless of the ways in which and the conditions by which funds were obtained for the construction.
In final some broad remarks may be made concerning the execution of the construction activities. Most important in this respect is the choice between involvement of the local population on the one hand or the involvement of a foreign contractor on the other hand.
As the construction of polders requires a very specific know-how, it may be recommendable for countries with no experience in polder-construction to start with foreign contractors rather than taking another approach. After the initial transfer of know-how joint, ventures may be considered as a next step in the switch to the construction of polders by local contractors.
At last but not at least, much attention should be given to promote the willingness of the farmers to adapt themselves to the new production and living circumstances.

3 Financial aspects of polder-construction in a densely forested tropical delta-area

In conclusion of this presentation an example will now be presented of the construction of a middle sized polder in a densely forested, marshy tropical delta-area. The example is fictitious and is only meant to illustrate the costs involved in polder-construction. The assumed polder measures 5,000-6,000 meters.
All too often it occurs at the commencement of such projects, that no more than incomplete costs are presented and that the "disappointments" as mentioned in previous chapters, in fact do result into more extensive

financial consequences than wa assumed at first.
By the following table a review is presented of the costs for the realisation of a polder, generally named "construction costs".

Table of total project costs in %

1	Construction costs		100 %
2	Contingencies	à (15%)	15 %
	Sub-total		115 %
3	Engineering costs	(13%)	14,95%
4	Legal and administrative costs	(3%)	3,45%
	Sub-total		133,40%
5	Financing costs	(3%)	4 %
	Sub-total		137,40%
6	Interest during construction (interest in 1 year)	(6%)	8,24%
	Total project costs		

The table shows that the costs for the so-called "additional elements" can amount to almost 50 percent of the construction costs.
The size of the so-called "contingencies" depends upon the stage of construction of the project at the time that the estimate was prepared.
At entering into the financing or at the application for development aid, reference should be made to the above mentioned cost-alignment, which must be seen as an average, calculated on the bases of data obtained from a larger number of polder-projects.
For each project a separate analysis must be made, to determine the extend of applicability of the items included into the costs-alignment mentioned, because the table presented assumes project realisation by a private contractor.
A more extended eleboration of the "polder-construction costs" shows that there also exist very marked differences between the "direct costs" and the "final costs".
The "direct costs" are named "net costs" in the following and can be specified as follows:

- general preparations;
- plotting costs;

- endikement of total area;
- clearance of tracts and excavation of conduits;
- road constructions (unpaved);
- primary engineering constructions;
- secundary engineering constructions;
- parcelling including deforestation.

To these net (direct) costs, the general costs for the execution after contracting have to be added. The following references may serve a guide lines for the costs to be considered in this context.

Item	Percentage/costs
- net costs	100
- general costs	6.7
- construction costs	6.0
- management costs	3.2
- mobilisation, demobilisation and transportation costs	8.3
Sub-total	124.2
Risks and profits (assumed at 15%)	18.6
TOTAL COSTS	142.8

In the previous table the "construction costs" were assumed at 100%, but in relation to the net costs, construction costs do amount to 1.42 times the estimate. As such the final picture of net costs reveals the following

Net construction	(netto aanleg)	100 %
Net direct costs	(construction costs)	142.83%
Project costs	(1 year construction period)	208.01%

The engineer is therefore compelled to focus his attention at all times, upon the preparation of accurate cost-estimates, which have to present a complete and correct picture of the total costs, in order to avoid his principal to be confronted with embarrassing surprises, at the day of project-delivery.

The following costs-estimate can be presented for the imaginary polder size 3,000 ha, to be constructed in a densely forested, marshy tropical delta-area.
The costs are based upon experiences, obtained in rice polders and banana polder-constructions.

Polder-construction costs in 1982 (example)

Item	Description of work	Costs per ha (gross) in US$
1	General preparations, surveying etc.	250.-
2	Endikements	250.-
3	Tract clearing and conduit excavation	750.-
4	Road pavements (up to the parcels)	750.-
5	Primary engineering constructions (irrigation)	1,000.-
6	Secundary engineering constructions (culverts and bridges)	750.-
7	Deforestation, levelling, clearing/ grubbing	1,500.-
A	Construction costs	5,250.-
B	Project costs including financing, supervision, interest 24%	8,950.-[1]

1 Multiplied by 170.36 due to the accumulation of interest during the four year construction period.

From the previous table it appears that approximately 50% of the costs for the construction of a new polder is absorbed by the deforestation of the area.
These costs are extremely sensitive for effects of the factors mentioned in chapter 2.
The remaining works such as engineering construction, road pavings are less affected by some of those aspects.

Note

1 1 R.R. = 3,6764 m

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AGRICULTURAL ASPECTS

AGRICULTURAL ASPECTS IN POLDER AREAS IN THE NETHERLANDS

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I am glad to have this opportunity, as Chairman of the Landbouwschap, to tell you something about the agricultural aspects of polder areas in this country. First of all, I think I ought to tell you something about the Landbouwschap itself.

The Landbouwschap

The Landbouwschap is the public cooperation of the agricultural employers' and employees' organizations in the Netherlands. We have three employers' organizations - the biggest is the Netherlands Catholic Farmers and Growers Union (K.N.B.T.B.), then there is the General Royal Netherlands Agricultural Committee (K.N.L.C.) followed by the Protestant Farmers' and Growers' Union (C.B.T.B.), of which I myself am also Chairman. Around 80% of the 140.000 farmers and growers in this country are affiliated to one of these organizations. The agricultural employees' are organized in two sectoral unions - the Food Workers' Union F.N.V. and the Food Workers' Union C.N.V. *)
These 5 organizations have a statutory organization - as central agricultural organization, recognized by Dutch Law. The Board of the Landbouwschap is made up of representatives from all 5 organizations. The Chairmanship at present rotates between the Chairman of the three farmers organizations. The members of the agricultural organizations are perfectly satisfied with this unique form of cooperation.
The Landbouwschap acts as a mouthpiece for Dutch agriculture as a whole, and it is indeed recognized as such by Government and Parliament.

*) F.N.V. = the Federation of Netherlands Trade Union
C.N.V. = the Christian Netherlands Trade Union

The position of farming in the Netherlands

This brings me to a few remarks about the position of agriculture in the Netherlands. Our country is small, densely populated and well known for its windmills and cheese. Its total area of agricultural land is about 2 million ha.
Every year some of that area is lost to provide land for other purposes such as housing and recreation, and some is designated as nature area. This loss amounts to about 10.000 ha every year.

In 1950 no fewer than 17% of the Dutch working population were employed in agriculture. Today that figure has fallen to 6%. Nevertheless the significance of the agricultural sector for the Dutch economy has increased. In spite of the reduction in the area of agricultural land and the fall in number of agricultural holdings - we now have 145.000 - agricultural output had risen substantially. A considerable part of this output has to be sold abroad.

Let me give you a few figures to illustrate this. In 1981 the Netherlands exported agricultural products worth 31 milliard guilders. This increased the surplus on the agricultural trade balance to 14.7 milliard guilders. This contribution to the Dutch economy matches that made by the exports of natural gas. Dutch agriculture is small-scale by nature. The average size of the holding - excluding horticulture - is 18 ha. This small-scale character is offset by the large-scale nature of the ancillary, manufacturing and marketing sectors. In this structure of small-scale holdings and highly concentrated marketing lies the great strength of Dutch agriculture.
The agricultural land is used very intensively. The net added value per ha of agricultural land is almost 4.000 guilders. That is over 35.000 guilders for every agricultural worker. And that in turn is 20.000 guilders more than the average figure for the EEC.

Since the 1950s each ha of agricultural land has been used to an increasingly intensive extent. For arable land, the percentage of labour-intensive crops - potatoes and sugar beets - has risen from 24% to over 40%. Since 1960 the number of dairy cows per ha of grassland has increased by 50%. The average stocking rate is currently 1.76 dairy cow per ha. The milk production per ha of grassland has risen by 88% in 20 years and is approching 10.000 kg per ha.

Polder areas in the Netherlands

This brings me to the subject of my talk. Polders in relation to agriculture. Mr. Schultz has already shown you an interesting table explaining the three different kinds of polders to be found in the Netherlands. He told you that of the total 3.4 million ha of Dutch land, 2 million ha are polder land. That is to say, land which is enclosed by a dyke and where the water level is artificially controlled.

The greater part of this land consists of low-lying peat land and the often not easily accessible clay land around the big rivers. The second group consists of former lakes shich have been drained, and which account for 315.000 ha.
The third group is made up of the empoldered parts of the sea, totalling 350.000 ha. The agricultural production potential of this land is closely connected with the way in which the land was empoldered and brought into cultivation.

From this review it is clear that a very large part of Dutch agricultural land lies in polders. The way in which the polder originated, the conditions of water control, distribution of plots, and of course the type of soil are very important determining factors for the production potential for agriculture. I will explain this in greater detail.

The history of Dutch farming has been largely dominated by the struggle against water, the formation of polders and the possibility of controlling the water level in those polders. This history is reflected to this day in the life story of many Dutch farmers. Indeed, I myself can tell such a story.

I was born on a "terp", a dwelling mound, in Friesland. Grew up on a farm in one of the new polders, the North-East Polder, 4.5 m below sealevel, where my father decided to start a new farm, and I have in

fact spent the greater part of my life in a polder.
The "terpen" of the Northern Netherlands are artificial dwelling mounds, which were used as a refuge for the population in times, when storm tides flooded the country, before it was protected by dykes.

What kind of a life did our ancestors lead? They lived in constant struggle with the sea, which provided them with fish and deposited fertile silt, but at the same time represented an ever-present threat as the sea-level rose. If the sea encroached upon the land, the harvest was lost and the land was inundated with salt water. Regular farming only became possible after sea dykes had been constructed.

A sea dyke protects the land from the danger from flooding. However the fact that the building of dykes does not mean that all the dangers have been conquered is proved by the long list of dyke breaches and floods. I need only remind you of the night of 1st February 1953, when the dykes in the South-West of this country were breached and that part of the country was inundated by the North sea. Thousands of people drowned, and many cattle were lost. Hunderds of farms were destroyed. The land was covered with salt water. Years afterwards, the effect of this on the structure of the soil remained noticeable in substandard crop yields. This disastrous night resulted in the rigorous decision to raise the height of all our sea dykes and shorten the length of our coast line. (This amounts to locking the stable door after the horse is stolen. As a matter of fact the Dutch saying is much more appropiate in the context. Literally translated it runs: the well is only filled in after the calf has drowned).

Agriculture in the "low polders"

In the past,the low-lying peat land were surrounded with low dykes or embankments in order to protect them against an excessively high water level. For many centuries, the ground water in these extensive regions was maintained at a very high level by means of wide ditches, because the people were afraid that a lower water level would allow the peat to dry out and become a water-impermeable layer, which would seriously reduce the fertility of those lands. But such a high ground water level

has many disadvantages for the farmer. The softness of the ground means that a lot of grass is lost through being trampled by grazing cattle. This loss is often more than 50%. A Dutch farmer will then say, "my cows graze with 5 mouths". In the spring, grass growth begins late, and in a dry summer it will quickly dry out because of its shallow root system. During the spring and autumn, the more remote parts of the farm are entirely inaccessible without destroying the turf. Such plots are used on a very extensive (as opposed to intensive) basis, often merely as unmanured grassland for hay.
In the extensive areas with river basis clay - between the big rivers - the situation was scarcely any different. Only in the past few decades have these regions improved, agriculturally speaking.
Thanks to intensive research into better drainage-methods, better opening-up of inaccessible areas, and thanks to land consolidation or redistribution of plots, the production conditions of extensive agricultural areas in the Netherlands were so modified that modern farming became possible in those regions as well.

Effect on the population's character

The centuries-long struggle against the water, the often great isolation and the hard life has left its traces in the mental make-up of the population in many parts of the Netherlands. Without going too deeply into this matter, I believe that the independent charavter of many Duthmen, their longing for freedom and independence, their habit of acting in accordance with their own ideas, their courage in tackling problems and their perseverence in conquering adversity has been created to some extent by the constant struggle for existance. The pioneering spirit which characterized the Dutch people in the past, not only in the sense of discovering unknown continents but also in the sense of turning unproductive areas of peat and marsh into fertile land or draining inland lakes in our own country has not yet been extinguished.
That spirit has certainly not been extinguished among the farmers, who were the first to move into the immeasurably large expanse of the new land created by empoldering of the IJssel Lake.

Following the theme of this conference, it is important to draw your specific attention to the great importance of proper agricultural grouping of plots of the empoldered areas. After being reclaimed, the drained land must be brought into cultivation. This involves a number of problems, such as:

- what will the land be used for (farming, forestry, nature reserve, urban area);
- how deep must the ground water level be (that depends on the future use);
- how large must the plots and fields be, how large must the new agricultural holdings be;
- will the land be sold, or leased or operated by the State itself?

You will appreciate that the state in which the land is handed over and the conditions on which the land is made available to the private farmer will be of the utmost importance to him. I should like to explain that to you in broad outline.

The drained lakes

The Beemster - the first large lake drained in the Netherlands - was empoldered between 1608 and 1612 by the legendary Leeghwater with the aid of about 40 windmills, on the instructions of Dirck van Oss, the Director of the East India Company (Verenigde Oost-Indische Compagnie), the cartel of Ansterdam merchants who financed the project. They proved to have progressive ideas, for the plot distribution of the Beemster as it was arranged 350 years ago remains suitable for modern farm management to this day.

Another example is the Haarlemmermeer - which was drained in 1850 after in 225 years 15 plans had been submitted for its drainage, all of which were wrecked for either technical of financial reasons - which also has a form of plot distribution and water control which makes it excellent for present-day farming. The fact that this polder is currently subject to severe erosion by housing, recreation and our national airport means a great loss to agriculture.

As soon as these inland lakes had been drained, the land was sold to

the highest bidder. "Ripe and green" established itself here in a single area. Professor Groenman wrote about this system of free colonisation as follows:
"Although the area appeared richly green from weeds, yet it was still far from ripe to be cultivated with success". It was, in fact, a fight to the death against nature, in which the strongest, the healthiest and the most fortunate could withstand the struggle. Perhaps it was only the wealthiest Ultimately, this system of free colonisation, by means of a process of strict selection, led to a prosperous society. But note the word ultimately! for while the first generation had an extemely difficult, poor and hard life, the second generation benefited from it and the next generation even enjoyed a very decent standard of living, thanks to the efforts of the pioneers.

The new IJssel Lake polders

When the IJssel Lake polders were constructed a completely different policy was followed. The Government itself bore the risks of bringing the drained areas into cultivation, by operating them itself for the first few years. Only after it has become clear that there are no exceptional risks to the private farmer in operating the land individually are the farms which have already been built in the new polder made available to private enterprise. And this method had proved a success.

New land helps the old

In the course of time, the policy relating to the conditions on which the land is made available to farmers had undergone quite a few changes. The first polder was the Wieringermeer, containing 20.000 ha of land. Anybode could apply for a farm. Applicants were selected on the basis of proficiency, financial soundness and good family reputation.

In the North East Polder - which was let out in the period from 1940 to 1962 - certain groups were given priority in the allocation of farms. First came the group of pioneers, who had helped reclaim the polder. Then came farmers from Walcheren, an island in the South West of the Netherlands, which had suffered flooding in the World War as a result

of the dykes being bombed. The farms on Walcheren are very small. By offering these farmers a new farm in the North East Polder, the farms on Walcheren can be enlarged.
So the new land is utillized for the purpose of improving farm structure in older regions. This method of making newly reclaimed land serviceable for the improvement of the production condition on the old land, has been extended to an increasing degree.

In the Flevopolder, half of the farms were allocated to farmers from land consolidation areas, that is to say areas where a plot redistribution programme is being implemented. This releases land in that area enabling the farms to be more efficiently parcelled.
For pasture areas in particular, it is most important that the land should be directly adjacent to the farm buildings. This allows the dairy cattle to be milked in the parlour during the summer as well.
If the farms on the old land are situated too close together, the land of a farmer on the old land can be used to reparcel the surrounding farms by offering him a farm in the new polder. In this way, every ha of new land makes it possible for 5 ha of old land to be reparcelled.

In addition, some of the new holdings in the polder are reserved for farmers forced to leave the old land by urban expancion or road construction. Particularly if the farmer holds the land on lease in the case of expropriation the farmer will no be able to obtain a new leasehold farm elsewhere. In such cases, the best solution is to move into the new polder.

Freehold or leasehold?

A politically important issue is the question of whether the land should be made available to the farmers on a freehold (i.e. private property) basis or on a short or long term (i.e. hereditary) lease. Although Parliament originally voted in favour of all three forms of tenancy, it was decided in practice, under socialist pressure, to retain the land as State Property and let it almost exclusively on a short or long lease. This had made the State into the biggest agricultural landlord in the country. I must add, not always to the full satisfaction of the farming community. And Parliamentary control over the State's behaviour as landlord has proved to be extremely difficult, because the State Land Management is part of the budget of the Ministry of Finance. And, of course, in this particular budget the problems surrounding Government expenditure and financial economies are more important to the financial experts in Parliament than land lease problems in the IJssel Lake Polders!

Size of the farms

Another political issue is the question of whether to allocate large or small farms?

Besides such aspects as economic viability and employment and social acceptability, the main objective that applies her is to provide solutions to problems affecting the old land.
The lesson to be learnt from the past is that what was considered to be a reasonably large arable farm in 1930 - 20 to 25 ha - is now too small. On the basis of this experience, you should really start from a farm size such as to allow a margin to absorb future developments as yet unforeseen. The desire to put the new polder to use in order to solve problems on the old land means that when that farmer moves to the IJssel Lake polders he must be able to continue to farm. And this means that the farm size must be sufficient to make such a move to the polder both mentally and financially possible.

When a farm is accepted in the polder it generally involves a considerable financiel outlay. The old farm has to be sold to the State, then you take over the new farm, either on a short of long term lease. In the case of a short lease, the land comes with a "rump building". The tenant farmer himself has to provide the home as well as the equipment for the shed, surfacing the yard, etc. In the case of a long term lease, the farme has to provide all the buildings himself. The costs involved are around 800.000 to 1 million guilders in the case of a short lease, and from 1 - 1,5 million guilders for a long lease farm. This amount is only economic in the case of holdings which are not smaller than 40 ha.

At this point I would remind you that the average size of Dutch agricultural holdings is 18 ha. By comparison, the farms in the IJssel Lake polders are relatively large, with an optimum location, all the land in one piece around the farmhouse, excellent water control and new farm buildings.

The use of modern holdings, with farmers who are only allocated a farm if they satisfy a number of conditions, for example agricultural efficience, have a significant positive influence on the farmers working the old land.
The polder therefore has a certain exemplary effect. New machines and methods of cultivation are often tried out in the polder first. The relatively favourable business results enhance the willingness among farmers on the old land to make investments and introduce improvements, paricularly as regards reparcelling and water control.

The result is that the importance of good parcelling and water management is brought to the attention of many more farmers. Land consolidation has become a very important policy instrument in the efforts to improve the structure of agricultural and horticultural holdings. This is made evident by the fact that at the present time approximately 40% of our cultivated land is either undergoing or about to undergo a land consolidation project, and that 35% of our land has already been reparcelled. The State is currently investing 5.000 guilders per ha in land consolidation. Part of this money - averaging about 50% - has to be repaid by the farmer or horticulturist after completion. Each year, about 40.000 ha of land are reparcelled and reparcelling starts on a further 40.000.
The entire land consolidation procedure from the beginning to the end takes from 25 to 30 years. Admittedly, it is not possible to achieve the same ideal land distribution as in the new IJssel Lake polders. The ultimate effect depends very much on the question of whether there is sufficient room to allocate every farmer the maximum amount of land immediately adjacent to his farm. The possibility of moving a number of farms to the polder means that the chance of success becomes considerably better. To put it briefly the new capacity of agricultural land in the IJssel Lake polders has a far larger indirect effect on the

old land than is often realised. I hope that I have succeeded in giving you some idea of how important it is to Dutch agriculture as a whole to receive new farmland with modern and efficient farms.

Changing social views

Over the years, there is another factor which influences the organization of our new polders. That factor is the changing views within society as to the value of nature, the countryside and the environment. This has made itself felt in the distribution of land utilization in the new polders.
In the Wieringermeer and the North East Polder, practically all the available land which was not required for building houses, is being used for agricultural purposes. In Eastern Flevoland 75% is agricultural land and in the newest polder, South Flevoland, no more than half of the land is being assigned an agricultural function. In these two areas, besides the space allocated for housing, the areas designated as nature reserves and forest areas are 11% and 18% respectively. In other words, a very significant increase.

The Markerwaard

This change in the appreciation of nature and countryside also finds expression in the discussion concerning the Markerwaard, the last of the IJssel Lake polders. Is it going to be constructed or not? Debate on this subject has been continuing for the past 10 years in political circles in The Hague. Many studies have been carried out by supporters and opponents. Action groups have been formed. In the end, the Government decided to build a 40.000 ha polder surrounded by wide lakes covering 20.000 ha. But, first of all this plan had to be presented to the public for debate. The opponents - headed by the nature conservation organizations - who frequently find it easy to make the newspapers and television, state their argument with persuasive simplicity: intervention in the environment is a crime. An open inland lake of this size suddenly became represented as something unique, unique for recreation and unique for water birds.
It should be not be sacrificed merely for the purpose of making even

more agricultural products, which are already in huge surplus. This fishermen, seeing their livelihood endangered, joined in the campaign. Public opinion was aroused. Certain major political parties voiced their objections to the new polder, others were not so sure. And yet - I consider uncertainty to be absolutely irrelevant to this matter. The main objections which have been raised against the Markerwaard prove upon analysis to be untenable. I base my opinion on a report produced by senior officials responsible for dealing with this matter within the three ministries concerned: Area planning, Traffic and Waterways and Finance.

The main objections which the opponents have raised are:

- loss of jobs in the fishing industry;
- loss of unspoiled open water as a nature reserve;
- risk of even more over-production of agricultural products;
- loss of unique recreation facilities for large yachts.

Let me consider these arguments one by one.

1 The fishing Industry

If the Markerwaard becomes a polder, the fishing industry will lose 40.000 ha of fishing waters. It will retain a remaining 160.000 ha of open water in the IJssel Lake region. The loss to the fishing industry ancillary and manufacturing firms, is estimated by esperts at 26 million guilders in terms of added value per annum. If only half of the Markerwaard is made into agricultural land, that agriculture, including ancillary and manufacturing industry, would yield an added value of 150 million guilders. That is no less than 6 times as much as the loss to fishing. In terms of jobs as well, the loss to the fishing industry is more than compensated by the additional jobs created by agriculture in this polder.

2 The value of the Markerwaard as an open nature reserve

The loss of the large Marker Lake, a large-scale nature reserve, will admittedly be very real if the polder comes about, but that loss is offset by certain gains. Let me mention hust three matters:

1) it will create a considerably longer coastline, that means considerably more food for coastal birds;
2) a new nature reserve is planned opposite the Oostvaarder Lakes. I believe that this possibility alone outweighs the loss of part of the open water.
3) the important indirect effects which are often ignored. Empoldering means that after the year 2000 there will be more space for urban construction in the vicinity of Amsterdam. It means less risk that the green heart of Holland, the extensive pasture areas in the central part of this country, will have to be used for building houses, at the beginning of the next century.
   I would have thought that this factor is not unimportant from the viewpoint of nature conservation. A sevond positive effect for nature conservation is that designated nature reserves which at the present time are still being used by farmers will be able to be purchased more rapidly and cheaply by the State if the farmer is offered a holding in the polder. That means: less risk of losing the natural assets which are already there. In brief the Markerwaard also offers a lot of advantages for nature conservation as well.

3 Recreational aspects

The argument that the Markerwaard should not be built because it will result in loss of recreational space for large yachts or seagoing pleasure boats is a rather elitist argument. Of the 200.000 ha op open water, 160.000 will remain. The resultant wide peripheral lake will offer recreational facilities for far larger numbers of less wealthy recreation seekers. Small boats, wind surfers and that all close to the Randstad, the Western conurbation. What is more, the extended coastline will offer more recreation facilities.

4 Agricultural surpluses of produktion

I will disregard the question of whether, in view of the rate of the population growth and structural decrease in the area of cultivated land, we should not expect a structural food shortage within the EEC by the year 2000. The area of agricultural land in the Markerwaard polder would represent 0,04% of the total area of agricultural land in the EEC.

In the period up to 2000 in the Netherlands alone it is expected that 400.000 ha, i.e. ten times the area of the Markerwaard, is going to be lost for agricultural purposes in the form of housing or nature reserves. Surely this disproves the credibility of talking about the Markerwaard polder resulting in bigger food surpluses.

No: we must have the Markerwaard.

The costs of construction and developing it for cultivation have been estimated at 1.650 million guilders. Temporary utilization and lease revenues over the first 20 years following its drainage can potentially earn 650 million guilders. Therefore the net costs of the drained polder will be 1 million guilders (spread over 20 years).

What do you get for this:

1) 40.000 ha of first class agricultural land. That works out at 25.000 guilders per ha. If the State wanted to sell this land it could do so at a profit.
2) Space for building houses and undertaking other socio-economic activities at the very centre of the country. To build houses the State will not first have to expropriate and prepair good agricultural land elsewhere for house building.

I have already mentioned the benefits in terms of recreation and nature conservation.

For farming, the polder will offer:

20 to 30.000 ha of space for ideally parcelled, ultra-modern agricultural and horticultural holdings. Part of the polder will be particularly suitable for growing bulbs.

This means, directly: - extra jobs (for about 1.500 persons)
- extra added value (about 125 - 150 million guilders/year)

indirectly: the effect on the old land will be even more substantial.

I have already explained how the polder land can be used in order to improve the parcelling of the old land, by making it possible to offer farmers from land consolidation areas a new farm in the polder. This means that the Markerwaard will enable between 6.000 and 8.000 old farms have a better parcellation which will yield a cost saving of 500 guilders per annum for every hectare.

In short:
The Markerwaard will pay for itself so to speak. I am convinced that this investment will bear full fruit. The new Government will have to make a choice. The new polder, new jobs, new space, new economic potential, or it can display the unenterprising spirit which is so often the characteristic of politicians.

I challenge the Government and Parliament to take a positive decision. Admittedly we are short of money, but we can easily afford the Markerwaard. In the East Schelde, we are spending an 6 milliard guilders in order to construct an open stormsurge barrier instead of a closed dam, merely for environmental reasons.
The Markerwaard will cost less than 20% of that amount, spread over a period of 15 - 20 years. We have the knowledge and the experience. The project cannot fail to have major positive effects on employment, space for urban construction, agriculture and recreation.

I have made an attempt to give you some idea of the ways in which, in the past and in the present, new polders are developed for agriculture. And that how the new land is handed over the first agricultural pioneers and the new land is so vitally important.
But also how it can make a contribution to improving the structure of the old land. How the modern holdings in the new polders generate a tremendous spin-off effect on the entire national developments in agriculture in the form of new machines and methods of cultivation. How a polder can also make a social contribution by providing extra opportunities for agriculture, housing, landscape and recreation.

I hope that I have succeeded in making a useful contribution to an interesting discussion on this subject.

AGRICULTURE AND FOOD PRODUCTION IN POLDER AREAS

A case study from Bangladesh

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Abstract

Bangladesh illustrates polder development issues in a densely settled, subtropical, deltaic environment. Six floodplain types - active; meander; estuarine; tidal; piedmont; peat basin - provide different opportunities, needs and problems. A 1964 Master Plan proposed 35 embankment/polder projects covering 5.8 million ha. To-date, about 0.5 million ha have been flood protected and 85,000 ha irrigated, increasing annual rice production by about 1 million tons (net). Slow implementation is due to aid donors' recognition of technical difficulties in constructing embankments and headworks on the unstable Ganges-Brahmaputra rivers and of alternative, quicker, development modes, especially small-scale irrigation. Problems of seepage/waterlogging and uneconomic returns resulting from farmers' slow adoption of planned cropping patterns are partly due to planners' insensitivity to both soil-crop relationships and farmers' crop production capacities. First generation problems also include: low irrigation coverage due to seepage losses; erosion of embankments; optimum economic designs which leave depression sites undrained; and lack of water management in tidal basins. Second generation problems include: siltation of tidal creeks outside polders; waterlogging in canal irrigated areas; zinc and sulphur deficiencies; spread of settlement onto flood-protected land; and breaching of coastal embankments by shrimp producers. Agro-economic surveys and land use regulations are recommended.

Introduction

The organizers of the Symposium on Polders of the World originally requested a paper giving an overview of agricultural aspects of polder development outside the Netherlands. That task proved to be impossible within the time and resources available to the author in Bangladesh. However, it is expected that the Symposium itself will provide such an overview through the combined contributions made by delegates coming from many individual countries.

The author has chosen to speak instead on polder development in Bangladesh. The objective of this is not to provide a detailed description of polder development in Bangladesh but, rather, to use Bangladesh examples as a means to illustrate principles, experience and issues of wider relevance. It must be emphasized that the views expressed are those of the author alone, and do not necessarily reflect the views either of his employer, FAO, or of the Government of Bangladesh which he serves.

Environment and demography

Bangladesh has both the physical and the demographic environments where polders are most needed. Alluvial floodplains which are seasonally or tidally flooded occupy 80 percent of its total land area of 143,000 km^2. Almost the whole of the country's population of over 90 million is crowded onto those floodplains, with densities ranging from less than 500/km^2 in two coastal districts to over 1,000/km^2 in Comilla, the most densely settled rural district. For the whole country, the density now is over 628/km^2. Considering the fact that more than 80 percent of the population is rural and dependent on agriculture, that is a very high population density indeed.

It can be regarded as all the more so when seasonal flooding is taken into account. More than half of Bangladesh goes under water for part of the year. Within the floodplain area, it is estimated from soil surveys that only about 8 percent of the agricultural land lies above normal flood-level. About 17 percent normally is flooded up to 30 cm deep, about 40 percent is flooded 30-90 cm deep, almost 20 percent 90-180 cm deep and about 15 percent deeper than 180 cm. Some land in the north-east is submerged deeper than 5 m. Flooding normally lasts for 3-5 months, depending on topographical position. Most land becomes dry during the dry season, but some depression centres stay wet for part or all of the dry season.

The subtropical monsoon climate allows crops to be grown throughout the year. Annual rainfall ranges from 1,250 mm in the extreme west to more than 5,000 mm in the north-east, concentrated in a summer rainy season lasting 4-7 months. The dry season is divided into a cool winter, during which temperate crops such as wheat and potato can be grown, and a hot, pre-monsoon season during which erratic, high-intensity, thunder showers occur. Coastal districts are periodically ravaged by cyclones (= hurricanes, typhoons) and accompanying storm surges.

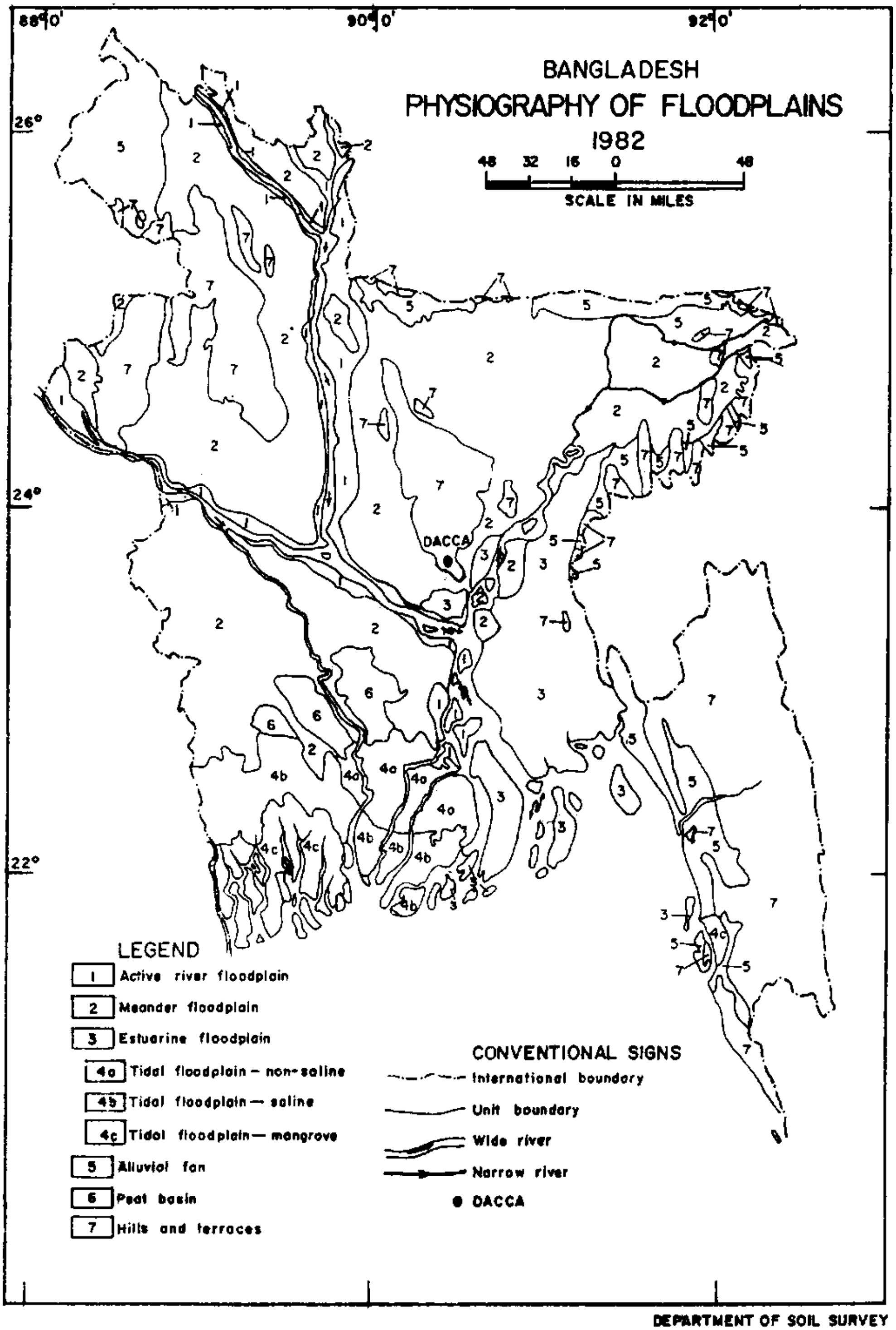
Physiography and soils

Most of the country comprises the combined delta of the Ganges, Brahmaputra and Meghna rivers. This area can be divided into six broad physiographic types (Map).

a) Active and very young floodplains along the major river channels (700,000 ha) which are subject to bank erosion or deposition of new sandy or silty alluvium each flood season. Such unstable land is not suitable for embankment projects.

b) Young and old meander floodplains of the major rivers (5.7 million ha) which are characterized by a ridge and basin topography with 2-5 m local difference in relief. Predominant soils are heavy silts to clays with developed profiles 30-120 cm deep over a stratified substratum. Such land is suitable for polder projects, so long as embankments are set well back from active river channels and there are suitable sites for irrigation/drainage headworks on stable tributary channels. The Ganges-Kobadak (G-K) project, referred to later, is on the Ganges meander floodplain.

c) Young and old estuarine floodplains (3.1 million ha), mainly east of the Meghna river, which are characterized by almost level relief (<2m), few or no natural channels, and deep silty deposits in which soil profiles 20-120 cm deep have developed. Such land is suitable for polder projects, provided that embankments and irrigation/drainage headworks can be sited away from active river channels. The Chandpur and Dacca-Narayanganj-Demra (DND) projects, referred to later, occupy parts of the old and young Meghna estuarine floodplains.


88°0'
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BANGLADESH
PHYSIOGRAPHY OF FLOODPLAINS
1982
48 32 16 0 48
SCALE IN MILES
DACCA
LEGEND
1 Active river floodplain
2 Meander floodplain
3 Estuarine floodplain
4a Tidal floodplain – non-saline
4b Tidal floodplain – saline
4c Tidal floodplain – mangrove
5 Alluvial fan
6 Peat basin
7 Hills and terraces
CONVENTIONAL SIGNS
International boundary
Unit boundary
Wide river
Narrow river
DACCA
DEPARTMENT OF SOIL SURVEY

d) Tidal floodplains occur mainly in the south-west, locally in the south-east. They are characterized by almost level, saucer-shaped, basins with <1 m local difference in elevation, and numerous tidal creeks. Clay soils predominate. About 400,000 ha is non-saline; about 600,000 ha is saline, (most of it only in the dry season). The Coastal Embankment project occupies most of the saline tidal floodplain land, and the Barisal Irrigation Project (which includes embankments) occupies a part of the non-saline Ganges tidal floodplain.

e) Alluvial fans and piedmont plains (1.1 million ha) occurring partly in the north-west near the foot of the Himalayas, the rest mainly adjoining the eastern and northern hills. Relief often is irregular, and soils vary from sands to clays. The embankment of hill-foot rivers provides difficult problems because of the deposition of sediments within embankments following flash floods and the constant risk of embankments being breached. The Manu, Muhuri and Karnafuli projects occupy hill-foot sites.

f) Peats (200,000 ha) occur most extensively in the transition zone between the Ganges meander and tidal floodplains in the south-west. The empolderment of peat basins is suitable so long as they are not deeply drained, which would allow the peat to shrink and oxidize. The land should be kept permanently wet or moist.

On all floodplains, there is a characteristic pattern of permeable, usually loamy, soils on the highest parts and impermeable, usually clay, soils on the lower parts. The proportions between light and heavy soils differ both between major floodplains and within them. Generally, heavy soils occupy most of the landscape. Rapidly permeable soils occur mainly on high floodplain ridges, some piedmont fans (especially that in the north-west), and some temporary islands on active floodplains. The most extensive soils are Fluvaquentic Haplaquepts (Eutric and Calcaric Fluvisols in the FAO/Unesco system).

Ganges river alluvium contains lime; so does young Meghna estuarine alluvium, although only in small amounts. Ganges tidal, Brahmaputra river and old Meghna estuarine alluvia are neutral to moderately alkaline in reaction, but not calcareous. Alluvial fans and Meghna river deposits are usually slightly to moderately acid.

Because of the seasonal cycle of flooding and drying out, soil development usually is rapid. The seasonal changes cause rapid development of structure (where textures are suitable) and the development of iron oxidation mottles. Alluvial stratification is quickly broken up by biological activity down to the permanently saturated zone. Biological activity (roots, soil fauna) also increases subsoil porosity, aeration, permeability and moisture holding capacity. On the other hand, cultivation tends to destroy topsoil structure and to create a slowly permeable ploughpan, especially in soils deliberately puddled for transplanting rice.

Soil fertility

The seasonal reduction and oxidation of the topsoil - which usually is cultivated, and often puddled - quickly decalcifies or acidifies this layer, except in loamy soils where biological activity constantly brings subsoil material to the surface and where the deposition of new alluvium neutralizes such chemical changes. However, whether topsoils are acid or alkaline in the dry season, they become neutral in reaction when submerged and reduced.

The rapid leaching of most floodplain topsoils confirms field observations that most river and estuarine floodplains are not flooded by river water. They are flooded with rainwater or the raised groundwater table derived from the heavy monsoon rainfall which is ponded on the land by high monsoon season river levels. Silty floodwater mainly deposits new alluvium on active floodplains and the immediately adjoining land, on unembanked tidal floodplains, and on alluvial fans (piedmont plains) at the foot of hills.

This has important implications for embankment projects. Farmers (and lay officials) believe that the fertility of floodplain soils is maintained by an annual deposit of alluvium from the seasonal floods. Since most floodplain areas do not receive such annual deposits, and yet clearly are at least as productive as those that do - e.g., large areas of the Brahmaputra and Ganges floodplains are triple cropped, without irrigation and with little or no use of fertilizers - the self-evident fertility of these soils must be derived from some other source.

The ready availability of phosphorus and potash can be accounted for by the seasonal cycle of reduction and oxidation in these mineral-rich soils. However, this phenomenon cannot provide nitrogen, and many cultivated soils contain little organic matter as a nitrogen source. It now appears certain that the nitrogen fertility of Bangladesh's flood-plain soils is provided by biological activity in the floodwater itself, especially that of blue-green algae. It is probable that such organisms can provide up to 30kg/ha of Nitrogen annually, perhaps even more on deeply flooded land where deepwater aman is grown. Since these organisms are dependent on light for photosynthesis, it is probable that they produce more Nitrogen in clear water than in silty floodwater. Therefore, the construction of embankments will not cut off farmers from these sources of plant nutrition, at least on land where wetland rice continues to be grown.

That should not be taken to imply that Bangladesh's floodplain soils do not need or respond to fertilizers. Without fertilizers or manure, the natural fertility maintains production at only a low or moderate equilibrium level. For increased yields, particularly for HYVs and irrigated crops, it is necessary to add N and P fertilizers regularly, and sometimes potash fertilizers also. As will be described later, there is also increasing evidence of zinc and sulphur deficiency in some places.

Cropping patterns

Under natural conditions - i.e., without artificial drainage or irrigation - farmers' cropping patterns on floodplain land are determined largely by the depth and duration of seasonal flooding, and the length of the rainy season. Soil permeability, soil moisture holding capacity and the presence or absence of salinity are also important, particularly for dry season crops grown with or without irrigation. Because of the characteristic floodplain relief of ridges and basins, variations in soils, depth of flooding and flood duration occur on a local scale, even within the area of a village. Cropping patterns often are complex, therefore.

Rice occupies about 10 million ha, which is about 80 percent of the cropped area. It can be grown in three seasons:

- aus, sown in the pre-monsoon season and harvested in the monsoon season;
- aman (which is photo-period sensitive), sown before or in the monsoon season and harvested at the beginning of the dry season; and
- boro, sown in the first half of the dry season and harvested just before or early in the monsoon season.

Aus and aman are mainly grown without irrigation, although irrigation is expanding in both seasons, either to increase security or to allow both crops to be grown in western areas where the 4-month rainy season is insufficient to support more than one rainfed crop. Boro traditionally was grown in depressions which stay wet for most or all of the dry season, but it is now grown widely with irrigation on relatively higher land.

Within the three broad rice groups, farmers have selected many thousands of rice varieties to suit their specific micro-environmental conditions, especially for the aman crop. Aman includes varieties with different maturity periods, tolerant of different degrees of salinity, zinc deficiency and iron toxicity, and adapted to different depths and duration of seasonal flooding. Some deepwater aman varieties can elongate their stems to as much as 4-5 metres.

High yielding varieties (HYVs) of rice which have been introduced in the last 15 years are not adapted to a wide range of Bangladesh environments. In order to give high yields, they require good water control to provide a very shallow water depth, and relatively high fertilizer doses. The farmer will only invest in the latter where he feels there is sufficient security to ensure a reliable return on his investment. For that reason, the HYVs have spread to only an estimated 15 percent of the total rice area. About half of this is boro, grown with irrigation in the dry season. The rest is about equally divided between aus and aman, grown both with and without irrigation on relatively heavy soils on land where the risk of damaging floods is low.

It is in this context that polders are important for agricultural development in Bangladesh. About 75 percent of the floodplain land - about 8.5 million ha gross - is too deeply flooded for existing HYVs of rice to be grown in the monsoon season. Also, some of that land cannot be used for irrigated HYV boro in the dry season, either because floodwater recedes too slowly or because the risk of early, pre-monsoon floods is too high. A further area of shallowly flooded tidal land near the coast has soils or water which are too saline in the dry season for boro rice to be grown.

Master Plan

The Master Plan for water development drawn up by the present Bangladesh Water Development Board in 1964 envisaged polder development extending eventually over a gross area of 5.8 million ha. Three kinds of project were envisaged: flood embankments with gravity drainage in meander floodplain and piedmont plain areas; flood embankments with tidal sluice drainage; and flood embankments with pump drainage. For most of the schemes, provision of irrigation was also envisaged, sometimes as a second stage. Priority was given to flood protection. Eighteen years later, only seven of the 35 major flood protection and irrigation projects envisaged in the Master Plan have been wholly or mainly completed. For a variety of reasons it is difficult to quantify the benefits which they have provided.

One major reason for that derives from the meaning of the word 'completed'. Project authorities tend to use the term to indicate that construction works have been completed. That does not necessarily mean that project benefits have been brought to all the project command area. A particular problem arises in the case of the 'completed' Coastal Embankment project, which supposedly protects 1.08 million ha from saline tidal flooding. Many sections of embankments have been eroded or breached, and many sluices either were not installed or have subsequently been damaged, so that many polders are now polders only in name. It is probable that only about one-third (or possibly less) of the 'completed' project area is, in fact, receiving the full project benefits of protection from saline floodwater.

A further problem is provided by the lack of reliable crop production statistics. Even where project authorities make estimates of crop acreage and production within project command areas, it is difficult to estimate the net increase in production attributable to the project, especially in the case of relatively older projects, such as the G-K project. That is because, for most project areas, it cannot be assumed that, without the project, land use would have remained in the pre-project condition. In the case of the G-K project, for example, where transplanted improved aus and aman varieties have replaced the former broadcast, traditional aus and aman varieties (and some jute), the comparison should be made with areas of similar land adjoining the project. Undoubtedly, there have been significant changes in land use outside the project area during the years since the project started: in addition to the traditional aus and aman still grown in the monsoon season, there has been a considerable expansion of wheat, tobacco, cotton and sugarcane production, part of it with small-scale irrigation. Because of the difference in crops grown, a realistic comparison could be made only on the basis of economic returns per hectare. Unfortunately, reliable data are not available for this purpose. Moreover, analysis would be complicated by the different levels of input subsidies provided within and outside the project area.

On the basis of existing information, the author's best guess is that flood protection may actually have been provided to about half a million ha and irrigation to about 85,000 ha. The direct benefits in terms of increased foodgrain production may be about 1 million tons annually (net). In addition, because of the greater security which flood protection provides, farmers have been able to provide or obtain small-scale irrigation from surface water or groundwater sources, as well as to grow additional or better dry-season crops without irrigation in some areas. Unfortunately, reliable data are not available to enable such benefits to be quantified.

Plan defects

Important though the direct benefits have been, they have been much less than was envisaged when the Master Plan was prepared. It is instructive to examine the reasons why polder development has been so slow. There are lessons in this not only for Bangladesh but probably also for other countries.

The first reason undoubtedly is because the Master Plan and its component projects were too narrow in concept and focus. The Master

Plan is primarily an engineering plan. It is not an agricultural development plan. With the benefit of hindsight, one can understand why that should be so. The origins of the Water Development Board and the Master Plan lie in the serious floods which ravaged what is now Bangladesh in the 1950's. Flood protection was then seen as a priority for providing security to crop production. Irrigation usually was a secondary consideration. Alternative possibilities for agricultural development were not considered at all. The engineering projects in the Master Plan were considered to provide a panacea for the country's agricultural development.

Three main factors have combined to delay the implementation of that Plan. The major cause has been the reluctance of international donors to finance some of the major proposed projects because of the technical difficulty of siting headworks on such major rivers as the Ganges and Brahmaputra, whose banks can erode or recede by as much as 600 metres in a single year, and where intake or outlet canals can silt up in a single flood season. On the G-K project, for example, it takes six dredgers up to three months to desilt the 1,000 m intake canal to the main pumphouse before irrigation can begin each year; and on the Chandpur project, 20 km of river embankments had to be rebuilt before the project had even been completed, because of actual or threatened breaches in the original embankment. Reservations were expressed, also, on the advisability of double embanking rivers as big and active as the Brahmaputra and Ganges. The lack of international agreements on water use in rivers originating outside the country was a further constraint on obtaining funds for projects involving irrigation as well as embankment.

A second factor - and one also influencing donor funding - was the growing recognition during the second half of the 1960s that there were alternative - and cheaper - ways to increase crop production than through costly embankment and canal irrigation projects. By 1970, about 24,000 small low-lift pumps and 1,000 tubewells had been installed, irrigating an estimated 370,000 ha. By 1981-82, that number had grown to about 41,000 low-lift pumps, 12,000 deep tube-wells and over 50,000 shallow tube-wells, as well as more than 200,000 hand pumps, together irrigating an estimated 1.27 million ha. That figure compares with only about 85,000 ha irrigated within major irrigation projects in 1981-82. Although the limit of easily available surface water usable by small pumps has almost been reached, there remains considerable scope to expand irrigation from groundwater. The development of small-scale irrigation has greatly expanded crop production in the dry season, thus reducing the urgency for flood protection and drainage in many seasonally flooded areas. The emphasis in crop production has been switched to the relatively safe dry season.

A third delaying factor has been the difficulty and expense of acquiring land for the construction of embankments and irrigation/drainage canals. In a country where the average farm holding is only 1.4 ha and where the average population density is more than 600 per km^2 - and exceeds 1,000/km^2 in some floodplain areas - the reluctance of farmers to give up their land, and to sell it only at a high price, is understandable. This factor also has influenced donors' decisions, and it has led to changed designs which minimize the amount of land needed for irrigation distribution systems. Preference now is given to the use of many small pumps along existing or improved internal channels rather than to the construction of new, gravity-flow, channels.

Farmers' alternatives

During the eighteen years that have intervened since the Master Plan was prepared, there has been a slowly growing recognition that technical and physical factors are not the only considerations to be taken into account in agricultural development. In the Master Plan, it was naively assumed that land which remained uncultivated in the dry season did so because it was too dry; some planners and policy makers still express such views. Planners also naively assumed that, with the provision of flood protection and irrigation, farmers would quickly adopt improved methods of cultivation and grow two or three high yielding crops a year. Project planners - and assertive aid donors - calculated benefit: cost ratios accordingly, showing attractive rates of return on proposed investments.

Two things have happened to upset those early assumptions. One is that there has been a considerable increase in double cropping and triple cropping of land, even without flood protection, drainage or irrigation.

The second is that, in irrigation and drainage project areas, farmers have either not adopted the cropping patterns designed for them by the project planners, or they have done so more slowly than was projected.

In the first case, soil surveyors have confirmed what farmers obviously knew already: namely, that many floodplain soils store sufficient moisture after the floods and rainy season to support a satisfactory crop of wheat, pulses or oilseeds without irrigation during the cool winter months. The changes from single to double cropping, and from double to triple cropping, have resulted more from population - and hence economic - pressure than from the provision of modern technology. Much land still remains fallow in the dry season or in the aus season in areas with relatively low population density, even though conditions may be suitable for growing crops during those periods. Big farmers using share-croppers can obtain a sufficient surplus from one crop per year, with little or no management or investment, so that there is little incentive for them to grow a second crop or to invest in increased production. That is particularly so in the case of absentee land owners.

In the second case, farmers have been much slower to adopt intensive cropping patterns and HYVs than project planners assumed. Figure 1 gives examples of the rates of adoption of HYVs in the boro/aus and aman seasons in the G-K and DND project areas. Both areas have controlled drainage and irrigation, and have soils which are suitable for HYV rice with irrigation. Yet, in the G-K area (Phase I), it took more than 10 years for HYVs to cover even 50 percent of the area, although the trend has been continuously upward. In the DND area, it took only two years to reach 50 percent HYVs in the boro season and eight years to reach 90 percent HYVs, at which level the proportion seems to have plateaued; but in the aman season, progress has been erratic, and seems to have plateaued at 70 percent.

Two lessons can be drawn from this experience. One is that drainage and irrigation projects should be regarded primarily as agricultural development projects, not as engineering projects. Therefore, agronomists and soil scientists need to be given a stronger voice in the planning and implementation of such projects - and that voice should be listened to !

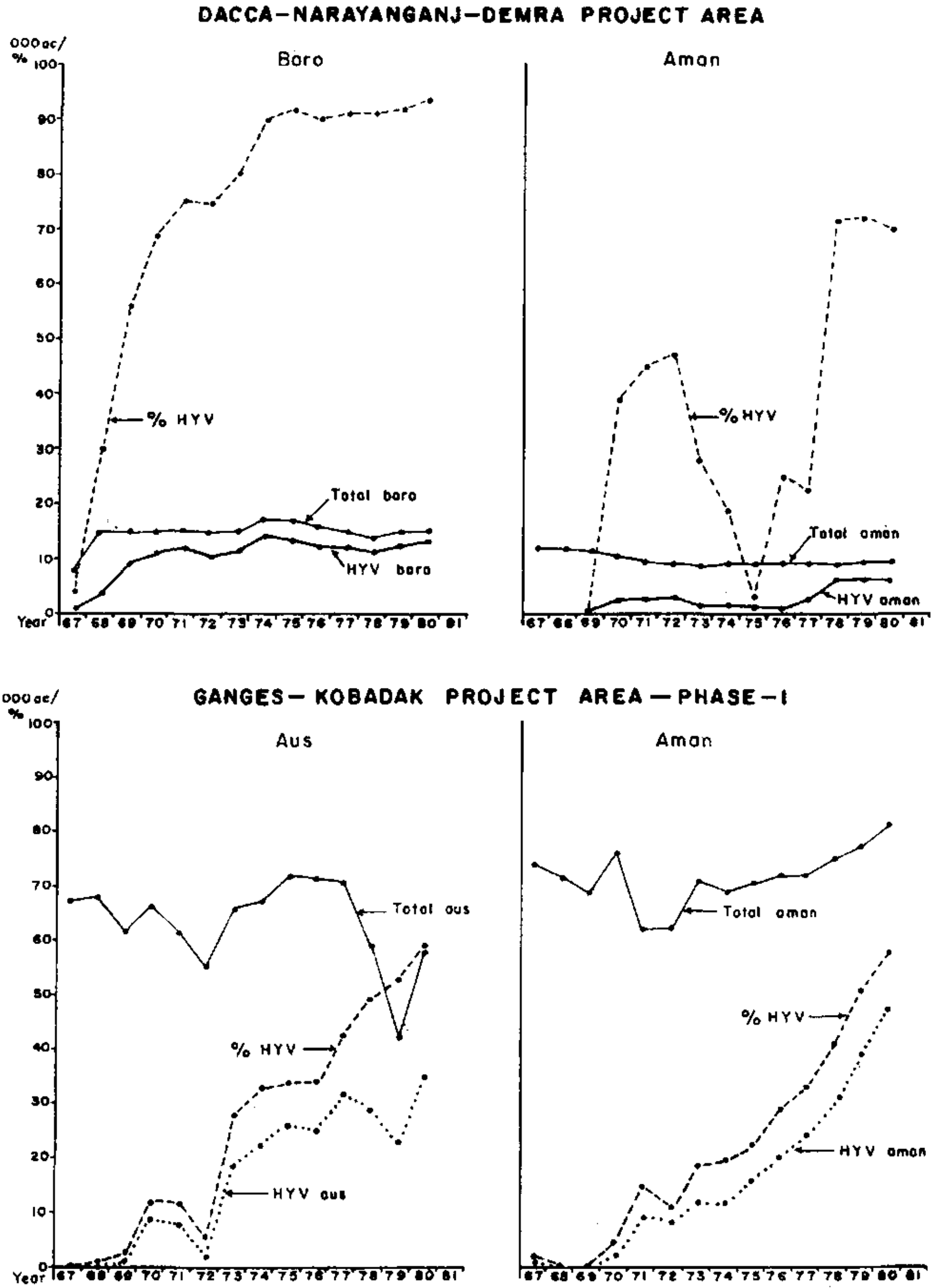

Figure 1. Spread of HYV rice in two flood protected and irrigated areas

The second lesson is that agricultural development involves farmers. Therefore, farmers should be consulted about the practicality and acceptability of the plans being prepared for them. It is the policy makers or planners, not the farmers or Extension officials, who should be blamed if ambitious project targets are not met. In the case of both the G-K and DND projects in Bangladesh, the project authority - comprising administrators and engineers - has planned three HYV cereal crops a year for the projects, without finding out whether that is what the farmers want to do or whether such cropping patterns are practical for them to adopt.

Recent investigations indicate that such intensive cereal cropping patterns do not suit all farmers. In the G-K project area, for example, the average size of farm holding is 2 ha and the majority of farmers are dependent on hired, migrant labour for transplanting and harvesting the aus and aman rice crops. Harvesting and threshing (by bullocks) takes 1-2 months or more, which prevents the quick turn-around which the addition of a third HYV crop per year would require. Moreover, the production of two HYV rice crops per year gives farmers owning 2 ha or more a huge grain surplus, about 5-6 times their family consumption needs. There is no incentive for them to grow a third crop per year merely to satisfy the plans of the project authority.

The experience of the G-K project and the Chandpur project illustrates another common weakness in planning: i.e., ignoring the soil factors which influence farmers' choice of crops. In the former case, the soil survey report carried out for the project indicates 20 percent of the area as being unsuitable for irrigated rice because of rapidly permeable soils. Even if that were not apparent from the soil survey report - which, admittedly, like many reports of its time was more descriptive than prescriptive - it should have become obvious from site examinations along the proposed canal alignments. Yet the irrigation layout and cropping pattern adopted totally ignore that information. The main distribution channels are aligned along the most permeable soils, because they occupy the highest part of the landscape, as is required for a gravity distribution system; and two transplanted rice crops a year are irrigated. Not surprisingly, water does not reach tail-end areas, and only about 55 percent of the supposed command area actually receives irrigation.

The Chandpur project plan expected farmers to grow two (or three) HYV rice crops a year. In fact, within the command area of almost 30,000 ha, farmers grew only 18,783 ha of boro rice in the 1981-82 dry season. They grew 3,507 ha of irrigated wheat and other dry-season crops; and a further 6,347 ha of dry-season crops (mainly chillies) were grown without using irrigation. This reflects the fact - known to the farmers, and described in the soil survey reports - that a substantial area within the project boundaries has light-textured, permeable soils which are not well suited to irrigated rice cultivation in the dry season. Under pre-project conditions, some of those soils were intensively used for dry-season crops without irrigation, especially for chillies, which formed the area's most important cash crop. Obviously, farmers find it more economic to continue growing chillies (and other dryland crops) on such soils, without using irrigation, rather than to follow project plans blue-printed over their heads from Dacca (or from a donor's headquarters).

Agro-socio-economic surveys

In this, the farmers are right. Projects should be tailored to suit farmers, not vice versa. However, it often appears as though project planners first calculate an economic rate of return which will justify investment in a project, and then fabricate an intensive cropping pattern to provide that rate of return. Admittedly, the planner's task is difficult. But it could be made easier if agricultural and socio-economic surveys were made in advance, and if project plans were then based on a realistic assessment of the findings. Project planners raise no question regarding the need for detailed site surveys when dams and headworks are being designed. There needs to be a similar recognition of the need for detailed agricultural and socio-economic site surveys to be made before costly agricultural projects are designed.

Agricultural surveys should provide information on the following subjects:

a) soil patterns in relation to topography and hydrology, because most floodplain land is neither level nor uniform in soils;

b) physical soil properties (actual or predicted) in relation to irrigation, drainage and natural moisture storage;
c) crops and cropping patterns in relation to soils, including evidence from crops presently grown with irrigation;
d) farm sizes and tenancy conditions;
e) seasonal availability and cost of labour;
f) preferred staple and cash crops, crop price relationships (including HYV versus traditional varieties), and relative production costs and returns, etc.;
g) opinions of big, medium and small farmers on which crops they would prefer to grow with the proposed project improvements, and what additional inputs or services might be needed; and
h) objections, if any, from those whose livelihood might suffer as a result of project implementation: e.g., fishermen; farmers on relatively high land who might suffer from prevention of flooding; and farmers in depressions which might become perennially waterlogged after installation of dry season irrigation.

If the findings of such a survey indicate that the proposed project would not be economic, then so much the better: the funds can be better spent elsewhere. How many projects must there be around the world by now that represent a drain on national economies because their plans were not based on a realistic study and appraisal of the agro-socio-economic factors ? In such a situation, project planners (or Government policy makers) have four alternatives:

a) accept the findings that the proposed project would not be economic, and divert the proposed funds to a more economic investment (preferably within the same area);
b) accept the findings and design/redesign the project to suit the physical, social and economic conditions found;
c) accept the findings, and consider whether by intensive extension activity, price incentives, improved markets, etc., farmers could be persuaded within a reasonable period to adopt cropping patterns which would make the project economic; in this respect, a pilot scheme can be useful, both for the farmers and the project planners;
d) accept the findings that the project, as proposed, will not be profitable, and proceed with it in the knowledge that it will need

to be subsidized, temporarily or permanently, in the national interest.

First generation problems

The low irrigation coverage in the G-K project area due to seepage losses, and the erosion of sections of the embankments in the Chandpur and Brahmaputra Right Bank projects, can both be regarded as first generation problems: i.e., they result directly from the project design itself. Another example is the cutting of embankments by farmers or fishermen who feel that the project is adversely affecting their livelihood. In the latter case, advance public education about the effects of the proposed project, payment of compensation or a modification of project design could help to avoid the problem.

Another example is provided by project designs which, in seeking to optimize economic rates of return, prevent project benefits from being provided to a substantial number of farmers within the project boundaries. Both the DND and Chandpur projects provide examples of this. In the DND area, the optimum economic pump drainage design left about 10 percent of the polder area, in depression sites, subject to deep flooding for a week or more after sustained, heavy, monsoon rainfall, such that farmers on such land cannot risk growing transplanted aman (including HYV aman) or using costly inputs on their monsoon season crops. Sustained, heavy, pre-monsoon rainfall in 1980-81 also caused flooding which destroyed about one-third of the HYV boro crop in the Chandpur project area and prevented farmers from growing HYV aus in low lying areas. The solution would seem to be to design projects so that they optimize the benefits to farmers, even if this requires accepting a lower rate of return on project investment. That principle would seem to be particularly important in areas where small farmers predominate; (in the Chandpur project area, for example, the average size of farm holding is only 0.4 ha).

The difficulty of satisfying the needs of all farmers within the Coastal Embankment project polders can also be regarded as a first generation problem which could have been anticipated. The tidal landscape comprises shallow basins with raised rims along creeks. Although the difference in elevation between the highest and lowest points may be no more than

60–100 cm, such differences can be critical for rice farmers, especially for those who wish to grow dwarf HYVs. Tidal sluices in the embankments provide drainage of local run-off following monsoon season rainfall. The problem is, how to regulate the drainage. If the basins are drained to leave the optimum depth of water on them for transplanted aman seedlings, the higher fields do not retain enough water. On the other hand, if water is retained to satisfy the needs of farmers on the higher margins, then the basin land stays too deeply flooded. A possible solution would be to construct low interior embankments to retain water on land at different levels, but experiments to test or demonstrate this practice have proved unsuccessful so far, because of lack of cooperation from big land-owners.

Second generation problems

A number of problems has arisen in embankment projects some time after they have become operational. These can be regarded as second generation problems which it may or may not have been possible to predict during project design.

The first problem of which the author became aware was the rapid siltation of creeks outside some of the coastal embankments. Under natural conditions, tidal water flooding the land twice a day flows slowly off the land again as the tide falls, thus keeping the creeks flushed. After embankments have been completed, sluice gates prevent tidal water from entering the polder at high tide. Water in the creeks stagnates at high tide, therefore, and drops some of it silt load which the slow flow of the falling tide is insufficient to pick up again. Some creeks silted up within three years of embankments being closed. That not only restricted navigation on the creeks, which formerly had been important, but it also caused waterlogging in the adjoining polders because of the restricted outflow during monsoon season rains. Hydraulic studies are needed to provide a solution to this problem.

A second early problem to develop was perennial waterlogging of some depression sites in the G-K project area. That resulted from excessive seepage losses from neighbouring irrigation channels located, as described earlier, on permeable floodplain ridges. This problem could become more serious and extensive if full-scale irrigation were to be introduced in the dry season; so far, the project has mainly provided supplementary irrigation in the pre-monsoon and monsoon seasons, allowing the water-table to fall during the first half of the dry season. If the problem were to become more serious - and it is, of course, already serious for farmers whose land is affected - it might be necessary to introduce two measures to reduce waterlogging: lining of irrigation channels along sections where seepage losses are most serious; and if this did not provide a sufficient alleviation, the installation of tube-wells to lower the water-table.

Within the last 3-4 years, there has been a growing awareness of zinc (and sometimes sulphur) deficiency in rice crops grown in the DND, Chandpur, Barisal and G-K project areas. Recent studies suggest that sulphur deficiency might eventually become the more widespread of the two. The symptoms develop where the rate of removal of soil nutrients has been increased due to the cultivation of one or more HYV rice crops per year, and where the provision of irrigation for growing boro rice keeps the soils wet for most or all of the dry season in addition to the monsoon season.

Farmers have found two solutions. One is to grow a quick maturing winter crop - e.g., mustard or pulses - before planting boro. That helps the topsoil to dry out and become oxidized for a time, which increases zinc and sulphur availability. The second solution is to add zinc sulphate fertilizer. The use of this fertilizer has increased remarkably within the first 18 months that it has been made available, to the extent that a consultant examining the problem early in 1982 was able to find little visible evidence of the deficiency in the DND and Chandpur project areas: most farmers appeared to be using the fertilizer. Farmers clearly are much less conservative about adopting new practices than they are popularly condemned as being, at least when there are obvious and simple remedies available.

Acid sulphate soils, fortunately, provide a relatively minor problem in Bangladesh. Such soils occur patchily on the saline tidal floodplains. The acidity problem is most severe and extensive in the south-east, where some soils have gone out of cultivation. However, a substantial area of such empoldered soils is highly productive for making salt. On the Ganges tidal floodplain, the acid sulphate problem is less serious because Ganges silt in the rivers during the flood season contains lime which could be used to neutralize the acidity, if necessary.

Land use regulation

Two other second generation problems have recently been identified: encroachment of settlement onto flood-protected land; and the conversion of polders from agricultural use to shrimp farming.
A recent FAO consultant's study of seven, scattered, rural areas showed that, in general, settlement and related non-agricultural land use expanded by only 0.8 percent between 1952 and 1974, even though the human population expanded by an average of 58 percent during that period. Examination of airphotos showed that the population had expanded almost entirely within existing settlements, by reducing the area under trees and waste land. That was partly explained by the seasonal flooding, which makes it costly to build a new earthen platform above flood-level, and partly by the farmers' natural inclination to preserve their land for agricultural production. However, in the first 10 years following the completion of the DND polder outside Dacca, the area under settlement and industry doubled, and the trend obviously is continuing rapidly as farmers (and suburban non-farmers) build individual houses, scattered over the whole area instead of within existing settlements. Within the next 10-20 years, it is probable that the polder will no longer be a viable agricultural project; it will be a suburb of Dacca.

There is a danger that a similar sprawl of settlement could eventually negate the objectives of other polder project areas. (Even pre-project, 28 percent of the Chandpur project area was occupied by settlements). There is the risk, too, that the spread of settlement on the flat (i.e., without making high platforms) could lead to catastrophic loss of life and property if, for any reason, a polder embankment were to be breached during the flood season. It seems essential, therefore, that the spread of settlements (and industry) within flood protected areas should be regulated so that the minimum amount of valuable agricultural land is transferred to non-agricultural uses, and so as to minimize the risk of catastrophic casualties and property damage if an embankment is breached. At present, the Government of Bangladesh has no practical legal means to regulate land use. That is an omission which needs to be rectified without delay.

The same lack of land use regulations is permitting powerful businessmen and land owners to convert agricultural polders in parts of the Coastal Embankment project area to shrimp farms. The process is simple. The embankment is breached, allowing brackish water to flood the land and shrimps to enter for breeding and growth. The salinity either prevents the farmers from growing their traditional, single, aman crop, or it greatly reduces aman yields and production. It is estimated that more than 4,000 ha of land have so far been lost to agriculture in this way in south-western polders; no figures are readily available for losses in the south-east.

Shrimp farming is highly profitable to the powerful individuals who control it. Shrimp exports also earn the country valuable foreign exchange. But the effect on small farmers and agricultural labourers can be disastrous, and the breaching of the embankments negates the purpose for which they were constructed. A thorough socio-economic study is needed to determine the net social and economic gains and losses. Technical studies also are needed to determine whether shrimp farming and crop production can be combined or can be practised on separate land. Whatever the findings might be, it seems essential that either the project authority, a locally elected council or central government should have the power to regulate land use in the polders in the greater public interest.

Future needs

Bangladesh's population of 92 million is estimated to need 14.5 million tons of foodgrains per annum. Taking into account seed, feed and waste, about 16 million tons are needed. Each year, population growth adds a further 400,000 tons to the requirement. By 1984-85, the target foodgrain production is 18-20 million tons, including provision for building up reserve stocks.

The country presently produces 14-15 million tons annually. The range in figures given reflects annual fluctuations in production due to good and bad harvests. Production is about 10 percent below requirements; in the past 5 years, annual imports have averaged 1.5 million tons. In addition, a wide range of other food and cash crops is grown, mainly without irrigation. Such crops include jute, sugarcane, banana, tea, potato, pulses, oilseeds and spices.

To-date, major embankment projects have contributed an estimated 1 million tons (net) to annual foodgrain production. That is much less than was expected when the projects were planned. It also is much less than the 2.5 million tons (net) annually which small-scale pump and tube-well irrigation schemes probably have contributed.

The major embankment projects included in the 1964 Master Plan have been slow to attract donor investment. Apart from technical problems described in the text above, donors have been reluctant to take up such projects because of the high capital costs and the long gestation period before benefits appear. Small-scale projects have therefore attracted more support because of the lower investment cost per hectare, the quicker returns and the more widespread distribution of benefits. Included in those small projects are a number of so-called early implementation projects, usually providing flood protection and/or irrigation (but usually not polders) to areas of up to 6,000 ha.

Undoubtedly, if the country's population continues to grow at current rates - doubling in about 30 years - then major polder projects (perhaps including estuary closures) will eventually be needed so as to enable high yielding transplanted aus and aman to be grown on most of the floodplain land, 70 percent of which currently is too deeply flooded for them to be grown during the monsoon season. Irrigation will also be needed to extend HYV cultivation in the dry season and make production more reliable in the monsoon season. By the year 2000 A.D., it is estimated that production must increase to 25 million tons to satisfy the population's consumption needs.

Regarding such projects, the next 5-10 years during which attention is concentrated on small-scale methods need to be used to make an exhaustive study of experience gained from polder projects which have been completed. Those studies should include not only engineering considerations, but - at least equally important - agricultural, social and economic considerations: what has succeeded; what has failed. Armed with more comprehensive information, planners should then be able to design more realistic and profitable projects which are better tailored to the farmers' needs. That will require the recognition that engineering works are not an end in themselves. They are a means to an end. In Bangladesh, that end is agricultural development, as reflected in optimum improved land use and a well fed population.

Conclusions

Bangladesh's experience with major embankment projects suggests a number of principles which may be of wider relevance, especially in developing tropical countries.

1. Where embankment projects are undertaken primarily to increase agricultural production, they should be regarded primarily as agricultural development projects rather than primarily as engineering projects. That implies that:

a) soil scientists, agronomists, agro-economists and agricultural extension specialists should be given a more responsible role in project identification, design, appraisal and implementation;

b) in areas which already are cultivated, the opinions of a representative range of farmers in proposed project areas should be sought in advance regarding feasible cropping patterns with proposed project inputs;

c) where a project would greatly alter existing agro-ecological conditions, (as usually will be the case with embankment projects), possible new crops or cropping patterns should be tested and demonstrated in pilot areas before the full project is implemented; and

d) objections from those whose livelihood might suffer as a result of project implementation should be considered with a view either to modifying the project design so as to remove their objections or to provide them with adequate alternatives or compensation.

2. Because embankment projects usually are expensive, especially when they include pump drainage and irrigation, they should be regarded as a development mode of last resort. That means that Governments should examine and use alternative, cheaper, agricultural development modes wherever possible, until embankment, etc., becomes the most economic mode remaining available.

3. Geomorphological, hydrological and hydraulic studies should be made to determine the optimum location of project embankments and irrigation/

drainage headworks along active river channels and in tidal floodplains, taking into account the predicted effects of project works on river flow and sedimentation outside embankments and on drainage within embankments.

4. Irrigation channels should be sited and designed so as to minimize seepage losses which might cause waterlogging and prevent irrigation benefits from being provided to tail-end areas.

5. Especially in areas where small farmers predominate, projects should be designed so as to minimize land acquisition for project works and so as to maximize the number of farmers who benefit, even if that means accepting a suboptimum economic rate of return.

6. Soil and crop conditions on different agro-ecological land types within project areas should be monitored regularly so as to provide early warnings of any physical, chemical or biological problems which may develop. Relevant studies should be made to find practical solutions, including solutions which might require the modification of project design or operation. Similarly, agro-economic surveys should be made regularly, and appropriate changes made in project design, operation or charges so as to ensure that both farmers and project authorities can achieve profitable returns.

7. Either at national or at project level, land use regulations should be made and enforced which will ensure that settlement and industry do not spread unnecessarily onto valuable agricultural land or onto sites where disastrous losses of life and property might occur in the event of an embankment being breached by floods; also, so as to prevent or control forms of land use which conflict with project objectives.

SOCIO-ECONOMIC AND PHYSICAL PLANNING ASPECTS

- *A.K. Constandse.* From spontaneous settlement to integrated planning and development
- *J.H.M. Kienhuis.* The management of polders in the Netherlands
- *A. Sfeir-Younis.* Economic aspects of soil conservation programs in LDC's

FROM SPONTANEOUS SETTLEMENT TO INTEGRATED PLANNING AND DEVELOPMENT

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Abstract

The reclamation of new land, which is uninhabited, involves internal colonization implying the establishment of a new society. In the beginning the reclamation projects were carried out by private corporations and there was no clear settlement policy. Even when in the 19th century the State took responsibility for the operations no settlement policy of any importance was developed. During the execution of the IJsselmeerpolders-project in this century a planning and development system was built up, however, that takes care of detailed integrated plans, takes responsibility for the preparation of the land, for settlement patterns, for construction, for the guiding of immigration, the creation of jobs, and the harmonious integration of the plan in the national planning goals.

The origin of polders is to be found in the human attempts to protect land against flooding, with the aim to make land that could be used temporarily only, into land that could be occupied permanently and safely. In the Netherlands these attempts started about one millennium ago.

Why these heroic efforts with primitive tools in such a dangerous half-drowned country were made is an interesting question, but will not be answered here. Not the causes but the effects are relevant in this context. Out of this co-ordinated moving of earth which enabled the people to control the moving of water, technical as well as organizational skills were developed, which created a selfconsciousness in matters of watercontrol that formed the necessary basis for the development of plans for drainage of new land, land that was not occupied before. In small-scale reclamations this did not always imply new human settlement: the reclaimed land was just used to enlarge the existing farms or estates. In the North of the country it is usual, up to the present, that the borderlines of a farm, standing perpendicularly on the coastline, are elongated into the water and all the land that will eventually be reclaimed, lying between those lines, belongs in principle to that farm. Even if a concerted effort was necessary, such as the drainage of a lake, for which windmills had to be built for pumping the water out, it might well be that the reclaimed land was farmed by the people living on the border of the former lake.

When the drainage projects became larger and technically more sophisticated, considerable investments where necessary, which could not come from local sources. As a consequence the projects came into the hands of managers, planners, and were considered as ends in itself. Farms were established, villages came into existence, people from elsewhere were moved in, sometimes from adjoining areas, sometimes from larger distance, sometimes individually, sometimes in groups.

Although the inhabitants of the new land did not come from very far, most often from within the Netherlands, which is a rather small country, a fact is that these people came together in new circumstances, where everything had to be built up from scratch, where a new society had to be formed. As such, the name 'internal colonization' which has been given to such processes is quite adequate. Also the name 'pioneer' attributed to the first settlers was not an exaggeration, because the life of the first and sometimes even the second generation was not an easy one. In the 17th century the companies which undertook the works were formed by merchants, urban people, who wanted land but who did not know how to work it and sometimes appointed unskilled people to continue the exploitation of the land after drainage. Furthermore the land was often badly drained, as a consequence bad harvests came about.

People were struck by diseases, like malaria, in unhealthy conditions at the beginning.

In the 19th century, when some large drainage schemes, with modern techniques (steam engines instead of windmills) were carried out by the State and not by private companies, the living-conditions for the people were not at all good in the beginning. The State carried out the works for reasons of safety-protection of the areas surrounding the lakes - and was not interested in the exploitation of the land. After initial drainage and a rough parcelization the acquired land was sold as soon as was possible and no attention was given to what happened further. This was the case with one of the largest developments in this country, the Haarlemmermeer, an area of 20.000 ha, in which now Schiphol-airport is located. Prosperous as the region is now, very poor it has been in the first twenty years of its existence, because of bad drainage, lack of good organization of the building of the new society, resulting in bad health-care, formal education, housing and transportation.

When in this century the Dutch government decided to carry out the largest reclamation project ever undertaken, it was understood, on basis of the aforementioned experiences, that as the goal should be to develop not only new land, but also a prosperous and harmonious society, it should take full responsibility for the development process as a whole, not only for the technical, but also for the social and economic aspects. This idea of more intensive intervention by the State was not only inspired by the idea that the mistakes of the previous century should be avoided now, but was also an expression of the coming of the welfare-state.

The State had to play in this way a dual role. As owner of the new land, developed with public funds, it had the duty to strive after good economic management of the area. It should, just as any private entrepreneur try to make profit. As guardian of the welfare-state it had to protect the inhabitants against misfortune and to promote public welfare. These two roles are not always easy to combine.

The first role was in the beginning considered as the most important one. The land was made ready for normal cultivation by the Development Authority. A land allocation plan was made, with fixed sizes and types of farms. The land remained property of the State, the farm buildings were constructed by the State. The farmers were carefully selected in order to be sure that a very capable group of people would till the land in the new area. If the main aim of a reclamation project is to increase the agricultural production, then this is a good policy. It is the same policy as would be applied by a private landowner: try to find the best tenants. This policy made it unnecessary to make extensive educational and training programmes for the settlers. They were ready for the job. This is stated so explicitely because in many foreign cases the main problem is how to teach people to make the best use of the new opportunities. In those cases the people are not selected: they are the ones who are entitled for some reason to receive a piece of land.

The second role, being the guardian of welfare, is less easy to describe. Even on the matter of the farms itself, the basis of the economy, there were next to economical also socio-political factors that played a role in decision-making. From a purely economical viewpoint it would have been possible to calculate which type of farm would give the highest profit. But this would not give necessarily the highest socio-economic advantage on the national level. For that reason a rather complicated system was developed, resulting in a mix of smaller and larger farms, giving opportunities to different kinds of farmers.

But outside the direct sector of farming the planning became also more 'human', more directed to the building of a society than to the economic development only. The farming population should not only have good farms, but there should be also service-centres, good housing for the workers, there should be shops, schools, churches, medical services, recreation facilities, libraries. And all the personel employed in these services should have a good basis for existence and the services should have a good quality.

In retrospect this sounds logical and simple. At the time of the first development in the IJsselmeerpoldersproject, half a century ago now, it meant that all kinds of relations between social facts had to be studied and quantified: how many customers does a baker need to make a living; how often does an average person borrow a book and how many kilometers he will travel to get such a book; young lovers need some wood to make walks in: how many hectares of wood should be planted to

satisfy the needs of a certain quantity of lovers?
This did not only provoke research needs, but it also encouraged, even necessitated, government-interference in a number of fields that had always belonged to the private sphere. Standards and norms had to be found for a number of immeasurable things.
Of course research and normsetting had imperfactions, not in the last place because social change remained for a large part unpredictable, but an advantage of all this research-work and striving after integrated, comprehensive planning was, that the understanding about interdependencies in matters of societal development was improved and that because of that better planning systems could be designed.
From the single goal, how to keep the area dry and safe, the goal to make profit from agriculture, now the goal was to give people a good life.

As agricultural areas the polders could be considered as being an end in itself. Of course the internal colonization had also as a goal to solve problems on the main land: farmers leaving for the polders freed space for other forms of landuse, or for improving the farm-structure in overcrowded areas. The policy of selection of applicants for a farm in the polders was in later years even geared to that purpose. But the developments within the project were nevertheless happenings in a more or less closed regional-economic system.
Because in other parts of the world, in many or most cases, polders are developed for agricultural purposes, some more attention will be given to that part of the history of the IJsselmeerpolders.
If agriculture is the main source of production, the changes in agriculture have far-reaching influences on the socio-spatial system. In our case the main change was that the response of agriculture to the cost-price squeeze was the replacement of labour by machines, which meant that there were less people on the land. Less people on the land means a lower demand for services.
This lower demand for services was quite problematic, because it was only quantitatively lower, qualitatively it became higher. Good schools were wanted, shops with a variety of wares were requested. This problem could within the closed system only be solved by reducing the number

of central places and accepting the larger distances from the periphery of the catchment areas to the core. Because of the fact that the farmers were in the position that they could possess one or more private cars the increase in distance was acceptable, but of course not ideal.
The remarkable thing about the project of the IJsselmeerpolders is that it is possible to see the effects of socio-economic change and of development in planning, real life, because the polders have been constructed one after one, with time-lags long enough to see change clearly: years of drainage being 1930, 1942, 1957 and 1968. In the first polder the main effort has been put into a good landuseplan for agriculture: rectangular lots, good roadconnections, in some parts even waterconnections. But a plan for a balanced settlement pattern was not made. It was expected that like in the past at roadcrossings services would spring up. Of course this would have happened, but not in the orderly way and without personal dramas as was the norm in this era. Therefore, later the government took care of the establishment of villages. In the second polder the lesson was taken at heart: next to the careful planning of the agricultural landuse, the settlement pattern was designed on basis of extensive studies on catchment areas of different kinds of functions and on distances from the periphery of a village area to the centre which would be acceptable. The result was a hierarchical pattern of a regional centre in the geographical point of gravity and a circle of ten villages around it.
Already during the period of execution of the plan it became clear that the dynamism of societal development was underestimated and that the system was too static: the villages remained too small, the services could not function in the proper way for that reason, and because of an immense increase in private motorization distances counted much less as a limiting factor, which caused that the regional centre grew faster than was expected. A parallel of this way of planning in a closed system can be found in the Lakhish region in Israel (not a polder but a former desert). The same hierarchical pattern set up in about the same time and now a prospering regional centre - Kyriat Gat - has grown while the villages have hardly a function.

In the third polder the results of the changes are clearly demonstrated. Again a regional centre was planned. The number of villages was, in comparison with the former polder, greatly reduced, four instead of ten and of these four only two would be built. The average size of the farms was increased, the number of people employed in agriculture went down and down and soon it was realized that the system of enlargement of scale could not go on forever. The closed system was broken up by the decision not to build houses for local demand only in the two villages that were realized, but just to build and allow people from elsewhere, who were not economically tied to the area, to buy or rent a house. Because of a shortage of houses and the desire of many people to live outside the big cities in a quiet rural environment, this policy was quite success-full.

It would be interesting to know how this process would have developed in the following polders if agricultural use would have been remained the main function.

But this was not so. Around the year 1960 the period of the IJsselmeer-poldersproject as an isolated agricultural project ended. The polders coming nearer to the urban concentrations in the West of the country (the Randstad or Rim City) were more and more regarded as a compensation for the scarcity of space in the urban areas. The borderlakes, designed at first for geohydrological reasons only, became in a short time recreation-areas of national importance, for swimming, for sailing, developing a demand behind the dykes for areas where campings and holiday-bungalows could be built.

Of much more importance has been the decision to choose the polders as the location of two new towns. The first one, Lelystad, could be regarded as an expanded town because the polders would have needed a larger centre, a kind of provincial capital, anyway. Without the 'task' to grow out to 100.000 inhabitants, some 30.000 would have lived in the place if the regional system had remained closed.

The second one, Almere, designed for 250.000 people, is a pure satellite of Amsterdam, but is playing role of course in the polders.

In a rather short period changes have taken place which have a tremendous effect. Where as a continuation of a thousand years old tradition the agricultural space of the Netherlands would be increased with about 10 percent, now the region is seen as the habitat for half a million of people.

In the Dutch terms half a million of people is a sufficient number for

forming a new province, but this is probably not of great interest for a foreign audience.
Of more importance may be that the agricultural function, which has been the most important during the period of reclamation, is now being attacked by a third new element: nature. In this crowded, urbanized and industrialized country there is a general fear that natural areas, typical for the lowlands, will disappear. Therefore, there is a strong (political) movement that wants to keep parts of the drained land as it is after reclamation and does not want that the fifth and last polder is made, because as a lake this part of the territory has more value than as land.
Some people state that <u>not</u> doing things, <u>not</u> transforming the environment is the ultimate wisdom after a period of ruthless destruction in order to make profit. Others think that this attitude is the result of a state of such high prosperity, that people think they can afford to leave things as they are. Probably there is some truth in both statements. Anyway, it is a curious phenomenon to see that there is such a resistance to the attempt to create new space for human life so near to an area where six million people live and who have a shortage of space. Of course the water as such is also space for human use and this is recognized by the fact that the borderlakes of the polders are designed wider than is necessary for hydrological purposes.

So, as has been said: each polder is an expression of the time in which it has been constructed, even the last one by not being constructed yet! It shows that the main value of this technique of draining is the acquisition of space, which can be used for many purposes. This is demonstrated in the Netherlands very clearly, because this is such a densely populated country. Also the older polders, which have originally been made for the acquisition of agricultural land, are often used now for other purposes: industry, residential quarters of the town, or airports. The fact that these polders are so clearly a product of their time is probably typical for polders as such, because polders are flat, are rather undifferentiated, have hardly any historical landmarks, and give therefore the planners a high degree of freedom for designing. This is in itself fascinating, but it gives also a heavy responsibility and the absence of guidelines present in the existing environment, causes decision-making to be often laborious.

On the other hand the freedom of the planners is limited by the wishes and needs of the immigrants. If improvements of a certain kind are wanted, then they can be realized - within reason - in the new polders, but if the immigrants want to maintain or reproduce their culture in the new environment, then there will be no fundamental innovation. Although there is much societal change, this change attracts so much attention and is described at such lenght, that there is hardly any awareness of continuity. If one studies the so-called new society on the new land than it is surprising to see how much continuity there is. For a part this will be because a number of cultural elements function so well that there is no need for change; for another part it may be explained by tradition (which can be rational as well). Remarkable is the continuity in the system of agriculture. There is an enormous change in techniques, the production and the productivity have grown, but the types of farms, even the size and form of the farms show a resemblance which is striking, whether one looks in the sixteenth century Beemster, the eighteenth century Haarlemmermeer or the present days IJsselmeerpolders.

This internal logic of the design and development of the first polders disappeared with the coming of the new towns. The number of inhabitants was no longer the result of the productivity of the land, but became a target in itself and the result of decisions and developments outside the region. This made the planning process more complicated and more a part of the national planning.

The task of the developer was no longer only to equip a region with the necessary system of services and amenities, but also to promote and create the resources for making a living as well: by replacement of activities and jobs from elseweher (overspill from the cities) or establishment of new activities. Although this building of new towns was started by the same organization that developed the polders as a whole, this activity is in fact no longer typical for polders, except that the start had to be made from scratch: no infrastructure of any kind available in the beginning. Because these new towns with their fast growth involve a large building activity, new ways of financing had to be found, the funds coming from different and mostly private sources. This meant that more people and institutions were going to

participate in the decision-making process. This made matters more complex and the timing in the system of networkplanning more vulnerable.
As building of highways, construction of a railway, the budget for housing etc. are all subject to different spheres of decision-making and have their own sequences of priorities, regional comprehensive planning becomes difficult.
Looking at this complex situation it becomes all the more clear what the adventages are of the formula of the IJsselmeerpoldersproject: ownership of the land, planning, development and management in the initial stage in one hand.
Of course a good organization is not a guarantee for success in all respects. The general economic situation in a country, the political climate, the changes in value-orientation, have quite an influence, especially on long-term planning and a development-organization has to take these factors as data. This can be seen in the present: it is possible to build a new town, to develop a new society on new land, but if unemployment is growing in the country and in neighbouring countries also, it cannot be avoided that this phenomenon occurs also in the new towns.
But the interesting fact remains that polders as such, by providing space, have always a value. That is true for the old polders, it will also be true for the new. It is quite possible that there will be no need for more new towns in the future. Then it is good to realize that we did not make polders in order to have space for new towns, but that we found a place for new towns because there were new polders. It is quite probable that in the last polder to be made, agriculture will form the main activity.
In that case we can under again new circumstances, with new techniques perhaps, but with old experience, continue this work that started over 1000 years ago.

POLDER MANAGEMENT IN THE NETHERLANDS

THE MANAGEMENT OF POLDERS IN THE NETHERLANDS

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1 Introduction

The title of my paper could perhaps give the impression that polders in the Netherlands have a different type of management to the rest of the country. In a certain sense this is true for the new IJsselmeer-polders, for example the Flevopolder. For the initial functioning of the polders, during the construction and commissioning periods, there is in fact a management organization which differs from the general pattern. We do not intend to talk about this rather short-term type of management today, but rather about the management system which has operated for centuries in existing polders. In these polders the system of management is principally similar to that found generally throughout the country. Why then do we want to talk specifically about polder management? Well it is because the polder, as a water management identity for centuries has also had a management/legal identity: the polder as waterboard. The Institute of Waterboards which has a history of many centuries in the Netherlands, has not been limited to the polder alone. This will be shown in the remainder of this introduction. Polder management forms a typical example of this management system.

Water management developed in lower parts of the Netherlands during the Middle Ages. In this the existing, mainly agrarian, local communities - referred to as "buurschappen" - played an important role. From monastry records it is known that, during the 12th century, low-lying areas became increasingly subjected to surge and river flooding which, in addition to the tempory flooding also lead to a more permanent loss of land. These events demonstrated the need for defence on a much larger than local scale. Dams were constructed at various places and at the same time drainage systems were constructed to remove excess water from the hinterland. Around 1200 and in the first half of the 13th century (between 1200 and 1350) regional water management activities increased both in number and extent. In many districts it was obvious that extension and/or further extension of local dikes to protect larger areas, was essential. To ensure that these dams and dikes had a long-lasting effect, maintenance controlled by regulations, was indispensable. In this work, clearly, local communities played an important role. The organization of these regional water managements works was generally based on cooperation between the interested communities. Depending on the area there were various forms of cooperation practiced. Generally it involved a very loose kind of management. This was not the case however for large works such as dams (whether or not fitted with sluices). Then maintenance had to be organized to ensure that the work (on both sides) was coordinated. For this work a supervisional authority was essential to guarantee that maintenance was carried out to the required standard. Out of this came the regional waterboards, which developed as separate governing bodies, responsible for regional water management. As time went by, these regional waterboards gradually got a set place in public authorities.

Since the 15th century they have had, in addition to a representative body, a board with a management and judicial identity.

In the long run, this board became the supreme, also legislative, organ of the regional waterboard.

In the meantime things were happening at a local level. Already in the 12th and 13th centuries an increasing number of communities were constructing or extending embankments. By the end of the 12th century news of "polres" and "kogen" had spread to the delta in the south from the north of North-Holland. Locally these words meant mudflats or foreshore on which embankments were constructed. This was the beginning, in a technical-water management sense of polders in Dutch history. In the 13th and 14th centuries data on poldering became more widespread. Slowly but surely at various places along the coast and the larger rivers the habitable areas were extended. This process of poldering and land-winning continues today. Polder construction has not been limited to only the coast, estuaries and larger rivers. At the end of the 13th century this process was also used in the hinterland where the need became urgent with the bed settlement "inklinking" which occurred. This phenomenon occurs in relatively uncompacted cultivated ground when it is drained bij streams and ditches - a common situation in the low-lying Netherlands. The settling process is accentuated by the shrinkage which results from oxydation of the upper layers used for agriculture.
Eventually, natural drainage was locally inadequate and then the only solution was to excavate special water courses to areas with a low waterlevel. In addition to drainage, one can also lower the average waterlevel in a small river by damming the upstream section. Just as the whole drainage situation was becoming precarious there was a spectacular invention - the windmill. Early in the 15th century the windmill was successfully applied to drainage. With further improvements in the 16th century it became possible to drain relatively shallow lakes. Subsequent improvements lead ultimately, under the influence of Dutch merchants, who appreciated a possible good investment, to the drainage of large lakes, especially in northern Holland in the 17th and 18th centuries.

Initially, especially in the cases of land-winning, the supervision of polder works was the responsibility of the local community. Sometimes, especially with polder construction and the construction of embankments, slices and so on on old established land lying between two or more local cummunities, there was one communal set of regulations, governing the works. Ultimately, the most general legal system for poldering was the waterboard: the polder in the administrative-legal sense; referred to hereafter as the "polder". This was in addition to the regional waterboard, the second type of waterboard that developed in the Dutch lowlands. Characteristically a group or "board" of selected people were given the authority to:

- draw up regulations for the management and maintenance duties of the landowners concerned;
- try cases of negligence and
- fix the charges to be paid by the landowners: tax assessments etc.

Every year the board, as polder administrators, had to account to a meeting of landowners called "de vergadering van ingelanden". Naturally the precise form of polder management varied from region to region, which at this time were strongly seperated. There were differences but the basic pattern was that, outlined above. This basically simple and logical management system for the polders, has generally been applied until present times.

The object of the present paper is to show how the waterboard system in the Netherlands developed from local community organizations into a specific administration, responsible for the needs of local and regional water management. In this part of the introduction only an outline description can be given and many interesting details must be omitted, one of which being the interference by the "higher" authorities with the waterboards. Neither did we go into the matter of how, in the 19th century and the beginning of the 20th century, the provincial authorities introduced the waterboards to improve water-control for the benefit of agrarian use of the soil.
Neither can be explained into detail the way in which, during the last few decades, water-quality management was appointed to existing regional waterboards or to new, large waterboards exclusively charged with this task. The intention is that this description will be sufficient for a good understanding of the origins of the association of Dutch waterboards in particular the polder management system.

3 The present Dutch waterboard system

The attention paid by the State to water, that is the guaranteeing of safety against river and sea flooding, and the control of water quality and the quantity of surface water forms, as in the past, for the Netherlands, a low-lying land bordering the sea, an essential condition for life and survival. Without the continuing attention of the State to dams along the coast and rivers, half of our country would be flooded by the sea. The functioning and habitability of this low country hinges on a tight control of rainwater drainage and the waterlevel in watercourses. The maintenance of surface water quality, evident especially in recent times, is essential to living-conditions, both for the population and also flora and fauna. The exercising of the essential care and attention is, in our land, the responsibility of the waterboards.

By public law the waterboard, together with the municipality belongs to the lower public administrative body of the so-named third management level, that is the management level nearest to those actually being administered to. The Province is the second management level, and finally the State is the first. The waterboard can be considered to be a form of functional decentralisation within the Dutch state. The waterboard, as a functional body, cannot take responsibility for public administrative matters, as does the municipality - the general administrative body - unless specifically decided by law. In principal the municipality is responsible for economic, cultural and educational affairs etc. The waterboard's responsibilities are limited to tasks related to water management matters which are specifically stated in its regulations. The waterboard and the municipality work in coordination but the municipality cannot work independently in those "areas" for which the waterboard has prime responsibility.
The function of the waterboard, as a public administrative body, can only be in the field of water management matters. This can be: either separately or in combination:

- care and attention to hydraulic structures along the coast and rivers;
- attention to control of water quantities;
- attention to water quality and
- attention to associated roads.

In principal more than one waterboard can operate in one territory. For example water quality control in the areas of several waterboards can be the responsibility of one particular board. Similarily the control of water quantity, watercourses and excess-water reservoirs can be exercised by one waterboard for other waterboards in the region. These, in turn, could be generally responsible for the control of embankments and roads. In other words the waterboard system is flexible and can be adjusted to meet the needs of the region. The provincial government is, in the first instance, responsible for the organization and operation of the waterboards in its province. The provincial government can found and dissolve waterboards, give them authority and also controls the correct exercising of their duties. The Crown, that is to say, the Head of State with the minister responsible, in this case the Minister of Transport and Public Works in turn has overall responsibility for the work of the provinces with respect to the waterboards.

It should be noted that the provinces and the State in addition to the waterboards also have management responsibilities in the field of water management. The State, for example, the large waterways, the IJsselmeer and the Zeeland and South Holland channels. In different provinces the provincial governments manage the water quantities in certain rivers, for example, the ones used primarily for navigation. In certain provinces the provincial governments have retained the responsibility for water quality control and have not given it over to the waterboards. In general it can be said that from early times in the Netherlands, the responsibility for local and regional water management has rested with the waterboards, taking into account the fact that it is ideally suited for the duties and also decentralised - a characteristic of the Dutch state system - represents, and has done for ages, a pre-eminent management system.

The present waterboard comprises a general administrative body: representatives of the management "board", a general management, a day-to-day management and a chairman, kwown generally as a Dike Reeve. The composition of the general and day-to-day management varies, depending on the tasks and local and regional situation of a particular waterboard. A general characteristic is that they are all composed on a functional basis and representative of the different interest groups directly involved in the tasks of the waterboard. For the hydraulic structures, water quantity management and roads, there are generally two interested groups: the "ongebouwd", unbuilt-group comprising owners and other legal users of unbuilt property and the "gebouwd", built group comprising owners and other legal users of developed property. These groups have to pay for water management services in the form of a water management tax, in proportion to their interests. The costs incured in water management must be paid by the interested parties. The waterboards have no fixed financial relationship with the State, unlike the provincial and municipal governments. This does not prevent, however, the State giving the waterboards financial assistance, on occasions, for example after the floods of 1953 for the strengthening of hydraulic structures on the coast and the large rivers. The costs for water quality management are paid on the basis of the polluter pays. Domestic/industrial polluters pay in relation to the amount of their pollution with a pollution tax.

Basic interests are central to waterboard management and go with the composition of the management, hand in hand, with payment and control. It is these three - basic interest, payment and control - which form the basis of the composition of the waterboard management. It is important to consider the task of the provincial government in this respect, which is to allow the number of seats and their categories within a certain waterboard. Representatives of these categories are chosen either by a direct or an indirect system of election. The aim of the elections is not to fix the relative importance of the categories as is the case with political elections.

The proportion, by which, for each category a number of seats is guaranteed, is fixed in the regulations and it is not true to say that the category paying the most, has the most seats. It is, however, a valid point that, because of the essential interest in good water control, of farmers and market gardeners, these - as owners of undeveloped land - have a right to a relatively strong representation.
It is striking that unlike the provinces and municipalities which have provincial/municipal laws, the waterboards have no direct waterboard laws. This can be explained mainly by the primacy of the provincial government in the past with respect to the waterboards in the province. Some years ago parliament decided, on the Government proposal, that such a law should be made for the waterboards. With the increasing significance in our society of the responsibilities for water management and the waterboard institute it was considered that the waterboards should no longer remain solely within the autonomous power of the provincial government. The waterboard law preparation, which has involved much hard work, will in a few years consist of the legal rules by which the provincial governments will exercise their continuing primary responsibility for the waterboard system.

4 The increase in scale/concentration

A dense network of independent polder administration, varying in size from tens to thousands of hectares, covered, until recently, the low-lying parts of the Netherlands. Characteristic of these administrations was the direct involvement of those being administrated to, especially farmers and market gardeners, with the working of the polder. A management apparatus, and, in fact, a building was generally missing. The work of the chairman and secretary was generally undertaken for a limited reimbursement bij trustyworthy people living in the polder. The personnel consisted mainly of maintenance workers and machine operators for drainage equipment, sluices and weirs and also workers for the execution of particular control and maintenance activities. Day-to-day administration was generally carried out from the village hall, or some such suitable establishment or the home of the chairman or secretary. Some larger polders had a small polder administration building with the associated staff. An important event in the polder administration was the periodical inspection to check if adjacent owners had carried out their obligatory maintenance duties. These duties comprised clearing plants from water courses and maintaining the water management works. In case of negligence the polder administration was empowered to force the owner responsible to carry out the necessary work. Alternatively the polder administration could itself carry out the work to the cost of the owner. The property formed - and continues to form - the surety against non-payment of tax and other costs.

During the last 20 to 25 years small scale waterboards have almost completely vanished. Social developments have led to increases in scale which have not left untouched the waterboard and polder administration system. Much higher demands have been placed on the tasks of the waterboards, especially by developments in agriculture and market gardening and by an increase in the number of related activities under the authorities care in management, professional, technical and administrative matters. The management, professional, and financial facilities of the existing waterboards could no longer cope with the demands created by the changing times. In recent years there has been much discussion on what the response to this should be. There were those of the opinion that after so much time the waterboard system no longer had a role to play. Others supported new forms of functional management. There were also those who thought there was little reason to change and preferred the present system. Particularly in polder management these people were attached to their own polder and were very reluctant to let go their own interests and join with bigger associations. Ultimately parliament agreed, with one accord, that the waterboard system should be maintained. The price of its maintenance was paid in an increase in scale and a reduction in number - these changes to be effected by the provincial governments. The former 2500 large and small waterboards have now been reduced to about 250, ranging in size from very big large parts of provinces to waterboards of at least 10.000 ha. Small scale waterboards and polder administrations are now only to be found in certain parts of the country: these are shortly to be absorbed. The polder, in a technical waterboard sense, has not vanished and, as in earlier times, still requires the continuing specialised attention to guarantee the water management interests particularly of the farmers and market gardeners within the polder. It is still important to maintain and even strengthen the involvement of the people living in the polder areas. There are different possibilities which must be considered from case to case, two merit attention:

- within the concentrated waterboard there can be a certain, more or less far reaching form of decentralisation into departments which have their own departmental administration with certain rights, for instance with respect to their budget;
- election districts are selected and given certain day-to-day administrative responsibilities under the ultimate responsibility of the day-to-day management. These district administrations together with the landowners can be consulted on budget matters, waterboard affairs etc; thus keeping alive the involvement of the local people with water management matters.

5 Conclusions

In the Netherlands because of its physical origins and its location by the sea - with a delta and large rivers - a special management organization has developed over the ages which brings together and cares for the special interests connected with water management in a particular area. The Institute of Waterboards has at its source the care for, i.e. promotion of, local and regional interests in water management. It has, as it were, grown out of the community and

a typical outcome was the formation of the polders. To date, the Institute of Waterboards has been able to fulfil its duties and to do this had, necessarily, undergone a rigorous increase in scale. One of the fundamental characteristics of the Institute:
the decentralised promotion of interests within the framework of an independent management body and in close relationship with the different interested parties, has been maintained. Although water management in a technical sense remains, the polders in an administrative/ legal sense have gone. Perhaps "have gone" when looked at closely is too strong. In the process of the increase in scale of the waterboards, one tries as much as possible to allow the water management "unity" concept - the polder in a technical/administrative sense - to play a role. The recent discussions in parliament have indicated that it is fully appreciated that, particularly in relation to the various interests involved, the waterboards must be administered effectively. Polders are pre-eminently of essential significance to life and living in the Netherlands lowlands. The way that society has developed has had a strong influence on the functioning of the waterboard system especially of the polders. In spite of recent changes, the pre-requisite that regional and local interests are brought together to achieve responsible water management, continues and this under the auspices of a specific, caring, administrative organization.

[1]) This paragraph has for a large part been abstracted from a publication of Professor H. van der Linden, Head of the Ancient History Law Department of the Free University of Amsterdam and Dike Reeve of the "Groot-Waterschap" of Woerden.

ECONOMIC ASPECTS OF SOIL CONSERVATION PROGRAMS IN LDCs

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Abstract

This paper is about the economic aspects of soil conservation. It is well known that millions of hectares are being irreversibly lost for agricultural production or for other economic activities. FAO has estimated that historical soil losses amount to 2 billion ha and that 5-7 million ha are being completely lost every year through soil degradation. The economic evaluation of soil conservation projects seem to pose some difficulties both to the natural scientist and the economist. To find a common ground between those problems related to the natural environment and economic decision system, the paper is outlined in a self-contained way. After describing, very succinctly, the characteristics of soil erosion, some of the salient economic aspects of soil conservation are defined. The paper also describes a few approaches for the economic appraisal of this type of project and reviews several case studies within this context. The final sections deal with problems in implementing this type of program in the developing countries and with the most salient policy issues.

1 Introduction

1.1 Some Hightlights

Despite the fact that soil is one of the most important natural resources in developing countries, no statistics are available on the precise extent of soil erosion damages around the world. However, it is well known that millions of hectares are being irreversibly lost for agricultural production or for other economic activities. FAO has estimated that historical soil losses amount to 2 billion hectares and that 5-7 million hectares are being completely lost every year through soil degradation. This is a phenomenon which affects both developed as well as developing nations. For example, losses of productive topsoils in the United States amount to 7.4 tons per ha per year. Similary, total area affected in Africa adds up to 35% and in the Near East up to nearly 61%. Countries densely populated and highly dependent on agricultural production, like India and Nepal, have several millions of hectares affected by water and soil erosion, salinity and floods. In India, 90 million ha are affected by water erosion, 90 million ha by wind erosion, 7 million ha by salinity and 20 million ha by flooding. In Nepal, it has been estimated that nearly 8.5 million ft^3 of soil are lost annually; these are translated into productivity losses of 1% per year or an equivalent of US$10 million per year. In middle-income countries, like Argentina, this is also a critical problem: 13% of the land is affected by water erosion and 16% by wind erosion [4, 15].

To bring lands back to their productive capacity requires in many cases sizable amounts of investments. Few countries have systematically dealt with this issue due to the nature of the problem (social and institutional) and the types of investment needed. In many developing countries, the areas which are going through heavy soil damages coincide with areas of high population density, particularly of low-income groups. Because these people are poor, their need to exploit the land to its limits--in most cases to produce only a subsistence crops--poses a serious environmental threat to many areas of the world. In addition, investment packages for these soil conservation programs are usually expensive, and their potential benefits are expected to come far in the future (this is particularly true when land reclamation takes place). Also, with often unstable political systems, decision makers are mostly concerned with investment decisions of high visibility (e.g., large infrastructures, tunnels, reservoirs) or of quick returns. These are not characteristics of soil conservation programs. In the final analysis, one finds many LDCs suffering from serious environmental degradation but where very little is done to alleviate the problem.

The paper focuses on the economics of soil conservation programs. Because of the nature of the problem addressed here, and the audience for which the paper is intended, the approach followed is believed to keep the subject relatively comprehensive for both the natural scientist and the economist. Before getting into the main topic, the remainder of this section will outline very briefly the nature and role of the World Bank.

Although the conference focuses on polders around the world, this paper does not specifically address the engineering aspects or all possible economic aspects of polders. Several reasons account for this: first, the Bank's lending program has only a few polder projects, most of which were designed to deal more with soil erosion and conservation than with land reclamation. And second, it was thought useful to focus on the analytic framework for the evaluation of projects affecting soil quality; this applies to both polders and other projects (e.g., irrigation, forestry, agricultural development). Sections 5.1 and 5.2 make specific reference to polders.[1]

1.2 The World Bank

The World Bank is the largest provider of loans for agricultural development in the developing countries of the world. Over the past five years, 1977-81, the Bank has committed more than $17 billion for agricultural development; this investment has elicited $2 billion in co-financing and $20 billion from local sources or a total of $39 billion. This is a very substantial sum indeed, but most experts on the subject agree that total investment in agriculture falls considerably below the requirements for the sustained long-term increases in production that will be needed over the next 20 years or so.

The World Bank is an intergovernmental lending agency that is owned by its 134 member countries. The Bank is governed by its Executive

Directors whose votes are weighted by their contributions to the Bank's capital stock. The largest stockholder is the United States, followed by the United Kingdom, Germany, France, and Japan. The Bank is a multinational institution, and it has a multinational staff drawn from all its member countries. The overall task is to provide technical and financial resources to stimulate soundly based economic growth primarily through project lending to member countries. No less important is our commitment to protect the resources entrusted by the countries who subscribe capital and by those who buy IBRD bonds. To this end, Bank projects must be financially viable, technically feasible, managerially sound, and yield a rate of return at least equal to average returns from other investment in the borrowing country.

The Bank's organization and structure has evolved since it was established immediately after World War II. It now includes three distinct legal entities (IBRD, IDA, IFC), each with separate assets, liabilities and capitalization.

1.2.1 The International Bank for Reconstruction and Development (IBRD)

This entity uses the equity entrusted to it by member governments and earnings retained from 35 years of profits to borrow in the world capital markets and relend to developing countries. Loan terms are repayment over 18 years, a 5-year grace period, and interest rates reflecting the full cost of our borrowings and administration at a current rate of 11.6%. This is about 40% less than the average cost of recent borrowings in the U.S. and Eurocurrency markets by developing countries such as Brazil. IBRD bonds are rated AAA and are held by investors in over 90 countries. In its 30-year history there have been no defaults. It has recently been agreed that the Bank would double its capital from US$40 billion to US$80 billion. There are now 134 member countries of the IBRD and current annual commitments are about $9 billion.

1.2.2 The International Development Association (IDA)

IDA was created in 1960 when it became apparent that the cost of servicing external debts was becoming unmanageable by the poorest countries. IDA was therefore set up to recycle funds from richer member countries, including Brazil, and IBRD profits. Project credits from IDA are provided only to poorer countries, primarily in Africa and Asia, where the GNP per capita is less than US$320 (1977 prices). Lending terms of these credits are noncommercial with a repayment period of up to 50 years, no interest charges, and a service charge of 0.75% per annum. The IBRD and IDA are administered by the same personnel, and projects meet the same criteria. IDA has 121 members. Commitments are running at a current annual rate of about $3.5 billion.

1.2.3 The International Finance Corporation (IFC)

IFC was created in 1956 to foster the growth of the private sector equity financing in developing countries. IFC obtains funds largely from member country subscriptions and the IBRD itself. It has 109 members. The IFC collaborates with the private sector in directing resources, both domestic and foreign, into productive investment in member countries. It organized $3,340 million worth of capital for LDC enterprises in FY1981 in addition to other important activities developing the domestic financial markets of those countries.

It is important to emphasize that the Bank's charter calls for loans to be made on the basis of economic criteria. The emphasis on economics is essential, because the Bank's members include countries with a wide range of political spectra: central market economies as well as countries with free market economies. Most of our poorer and more populous member countries, though, are in the tropics--a factor which has special significance in agricultural development.

1.2.4 The Basic Approach

The rest of the paper is divided into the following sections:

- characteristics of soil erosion
- economic aspects of soil conservation
- approaches for economic appraisal
- case studies
- implementation problems
- private sector and fiscal impacts; and
- policy issues.

The merit in writing a short paper lies more in the synthesis of issues it requires than on the array of answers it provides. The literature is diverse and focuses on a countless set of technical, economic, institutional, social and cultural issues. A substantial portion of the economic literature has been devoted to test behavioral relationships with the aim to assess the beneficial impacts of soil conservation practices. Variables such as security of land tenure, farm size, intensity in crop production, replacement or substitution among crops, and increases in the use of inputs are some of them. In addition, some economists have attempted to assess the impacts of such policies as taxes, subsidies, changes in land use patterns and other regulations on soil conservation practices, mostly in the context of developed countries. Finally, an important part of the literature deals with the planning process, particularly with regard to land classification and land use policies of which very little is said here.

The examples used to illustrate some of the issues are not generalizable. One could easily find counter-examples, which often exist because of the nature of the problem.

Long-term environmental considerations and the corresponding decision-making process involve plenty of value judgments. Intergenerational and interpersonal equity issues, compensation of potential losers (e.g., programs which require postponement in production), choice of discount rates, and choices of shadow prices, all involve value judgments which relate more to political and institutional choices than to economics.

2 Characteristics of Soil Erosion[2]

2.1 Types of Soil Erosion

Soil erosion is a process which usually includes two different steps: the removal of soil particles and the transportation of them to some place in the system. Several types of soil erosion have been distinguished, depending on the agent that causes the removal and transport. The most widely known are water and wind erosion. When water provokes the uniform removal of a thin layer of soil, it is usually identified as sheet erosion. In contrast to sheet erosion, when detachment and transport result from significant masses of water supply, it is usually identified as channel erosion (i.e., rill erosion, gully erosion). Streambank erosion is a form of channel erosion, and it may occur on the farm, within an irrigation distribution system or in rivers. In water erosion, detachment of soils usually occurs due to rainfall [8, 9], except in streambank erosion where channel flows provide large amounts of detaching energy. The transportation of particles is mostly a function of runoff--the difference between total rainfall and the amount that can possibly be stored. Infiltration rates (amount of water entering into the soil) and percolation rates (downward movement of water) will greatly affect the runoff rates.

Other forms of soil degradation should also be mentioned: desertification and salinity.

Several factors significantly affect soil erosion. The most important are: uncontrolled deforestation, unsatisfied wood fuel energy demands, certain forms of intensive agriculture, improper agricultural practices, shifting cultivation, overgrazing, fires, demographic and regional factors. Denuded soils left as a result of those activities are at great risk.

The amount of erosion produced by those activities depend on several factors: soil properties (e.g., permeability, texture, structure), natural vegetation (e.g., type, extent), rainfall patterns (e.g., distribution, amount), slope of soils, and cultural practices. There are also some socioeconomic (e.g., high population density, poverty), political, and institutional factors (e.g., land tenure, size of the farm) which affect soil erosion rates. These factors are present both in developed and developing countries. For example, a study in the U.S.A. [10] concluded that "the relationship between net farm income and mean levels of erosion appeared to depend on the tenure category of the landowners ... full owner operated ... were associated with lower rates of erosion" (p. 1073).

2.2 Soil Erosion Effects

Several types of negative effects will appear when soil conservation practices are not followed, e.g., land going out of production, deficiency in nutrient levels of existing lands, and human and physical capital deterioration. It may be convenient to classify soil erosion effects into three main categories: (a) intrafarm effects, e.g., loss in fertility, decrease in area cropped, decrease in cultivation intensity; (b) interfarm effects, e.g., silt, sedimentation, increase or decrease in water runoff, decrease in the productivity of groundwater supplies; and (c) interarea or downstream effects, e.g., sedimentation of river basins, siltation of reservoirs (decrease in economic life of projects), clogging of irrigation canals (decreasing operation efficiency), and increases in the probability of flooding. While the financial analysis should be able to show if there is enough incentive to the individual farmers for investing in soil conservation programs, the economic analysis should shed some light in assessing the impacts of externalities, i.e., interfarm and downstream effects (the fiscal impact will also be very instrumental).

Although differences between intra- and interfarm household effects are rather arbitrary (definition of a boundary), this classification proves useful from an institutional and organizational viewpoint. It is convenient for identifying important benefits and costs, avoiding double counting and assessing the institutional feasibility of programs.

Institutionally, when trying to reverse intrafarm households effects, one needs to focus on decisions by one individual farmer; in interfarm household effects, one needs to deal with farmers associations and their working rules (e.g., irrigating forestry); and in downstream effects, one usually deals with the complexities of public interventions. An example may illustrate these complexities. In many cases, the effectiveness of soil conservation practices and programs (e.g., reforestation) depends on the performance of such social institutions as tenure, the private or common property of resources or, in other circumstances, the existing tribal groups arrangements. Each of these institutional options require different treatment.[3]

2.3 Soil Conservation Methods

To remove or alleviate the major causes of soil erosion, policymakers may design investment programs or institutional changes (regulation) or both. Most investment programs include components that may be classified in two groups: engineering or mechanical protection methods and biologicial protection methods. Although this classification is rather arbitrary, it helps to identify the source of benefits and costs of soil conservation projects. Among the most well-known engineering-related practices in soil conservation, one can mention: bench and channel terraces, contour-bunds, mulching, diversion ditches or drains, polders, and tiered ridging.

Most of the biological-related methods refer to pasture and forest plantations and management, alternative choice of cropping system, strip cropping, plantation of wind breaks, and sand dune stabilization. In general, one can classify different land-use groups by their relative efficiency of crop cover to protect the soil from erosion. A classification of this nature must be region- and soil-type-specific. For example, in regions with specific environmental characteristics, permanent vegetation could be more efficient in protecting existing soils than certain row crops. With regard to cropping practices, different forms of tillage, planting methods, fertilizer, and harvesting methods (e.g., removal of both crops and roots) will greatly affect the productivity of soils.

Each of these methods or a combination of them will generate important benefits and costs to farmers. An important task for an economist is to quantify the monetary value of potential benefits (section 4).

3 Economics of Soil Conservation

3.1 Concepts and Definitions

The use of benefit-cost analysis (BCA) provides useful information for economic decision making. Planners should choose soil conservation projects which show net present values (NPV) of incremental benefits greater than zero when discounted at the opportunity cost of capital. This criterion also applies when selecting mutually exclusive projects. Certainly, one has to recognize that decisions of this nature should include many other technical and institutional aspects. In particular, because of intergenerational equity considerations for example, decision makers may decide to take projects with negative NPVs.

Soil is a natural resource. It is a complex resource because it includes a composite of many stock and flow resources.[4] Most of the relevant flow resources have a critical zone of exploitation below which irreversible damage may occur. This composite of resources is affected (i.e., consumed) by agricultural production systems--most of which is in demand through plant growth. Because of this complementarity in demand, most scientists find it convenient to measure soil quality in terms of land productivity or crop production. The loss in productivity occurs through a reduction in root-zone depth, losses in plant nutrients (the subsoil left contains less nutrients), degradation of the soil structure (changes in infiltration rates), and the like.

However, changes in the productivity of soils are not necessarily correlated with soil conservation, and the lack of such correlation presents, as stated next, a particular set of problems. A decrease in soil productivity, due to resource use but not beyond the critical zone of the corresponding flow resources (e.g., plant nutrients), may be improved with the use of economically and financially viable development programs (e.g., purchase and application of nitrogen fertilizer). However, when resource use has surpassed that critical zone (e.g., deep gullies), a return to the original or even an acceptable level of soil productivity may be economically prohibitive (i.e., irreversible process).[5]

Conservation of soil resources needs to be defined in terms of an assessment of intertemporal distribution of use rates [3]. Conservation means or requires redistribution of use rates in the directions of the future, while depletion results from a redistribution of use rates in the direction of the present (this either results from human actions or nature). Thus, conservation requires making comparisons of two or more time distributions of use rates.

To measure the state of conservation of soil resources or of any other composite type of resource is difficult since it would require measuring the redistribution of use rates and assessing complex interactions of several stock and flow resources (e.g., plant nutrients, water, texture). These measurements are even more complex if one admits that some plants or cropping patterns may be "conserving" soils under one system while "depleting" soils under others.

As stated earlier, crop yields are usually used to measure different types of soil productivity. However, such an indicator obscures the issue, particularly when other exogenous factors are believed to be more important in causing such productivity changes (e.g., weather, increase in input use) while disappearance of organic matters, leaching of plant nutrients, and other depleting factors may be taking place.

In addition, monitoring of soil quality is further clouded by the accepted definition of the relationship between conservation and agriculture investments (i.e., projects). Investments are often identified as a source of depletion (e.g., increase in livestock investments in pasture lands), while disinvestment (e.g., reduced stocking) is believed to lead toward conservation. This is not always the case. This paper mainly focuses on investments and actions that will hopefully change the distribution of use rates toward the future or that would avoid irreversible situations. The analysis of physical investments or technologies, however, is incomplete or meaningless without focusing on the array of institutions that go with them.

A specific example may illustrate this point. Stevens [15], using the case of Nepal, defines the "critical zone" as the point beyond which nutrients become unavailable to plant growth (for land cropped year after year without applying fertilizers). Beyond this point it becomes uneconomical for farmers to recuperate the land. The critical zone varies depending on the environmental characteristics of soils. As noted in Figure 1 [15], two dimensions of the problem are used:

- three levels of productivity (i.e., permanent production, threshold line, and permanent impairment), and
- time (in years).

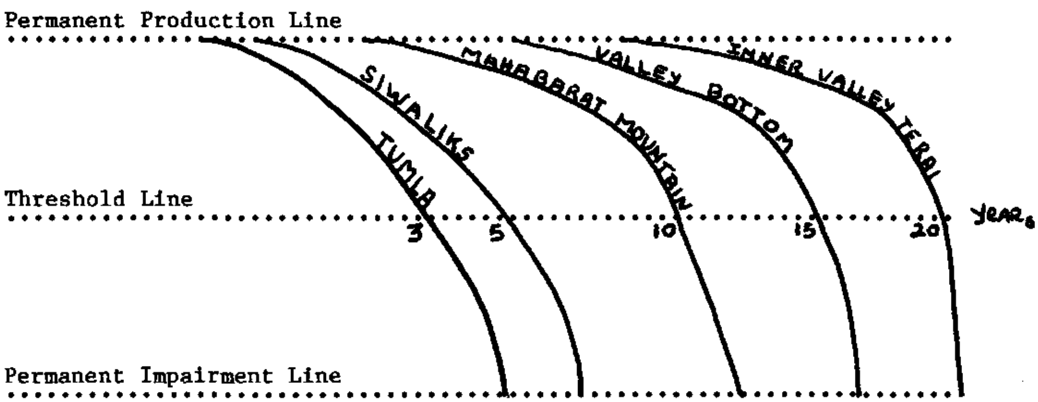

Figure 1. Time period for a given land area to exceed the threshold with a given technique

As referred to in a section later on, redistribution of use rates--toward the present or future--may also result from changes in institutional arrangements (i.e., land tenure, taxes, subsidies), with investment being held constant. Consequently, soil conservation programs and policies need to be meaningful and easy to grasp by policymakers; otherwise, a large portion of our effort will be lost.

3.2 Conservation Decisions [2]

Since there are many causes that might redistribute use rates of soils toward soil depletion, conservation decisions are complex. Individual farm households are the decision-making unit at the micro level. Using a rather simple framework for describing farmers' soil conservation decisions, one may assume that such decisions depend on income, institutions, and the planning horizon. For example, low-income farmers would be less willing to postpone consumption--and release the pressure on intensively cultivating lands which are quickly eroding--than higher-income farmers.

Several types of imbalances--biological, technological, supply and demand (for inputs and outputs), private versus social costs, social time preference and institutional--cause changes in farmers' behavior. Several farming systems show some of these imbalances: shifting cultivation, range burning, lack of fire protection, overgrazing, and uncontrolled tree cutting, all of which become depleting factors of the basic soil-carrying capacities. In addition, such economic and institutional variables as prices (in favor of "crop depleting" practices), investments, uncertainty in land tenure, too small farm sizes (making it uneconomic to adopt soil conservation programs), lack of public services (e.g., extension, research) and input supply of several flow resources (e.g., fertilizers), structure of taxation, income levels, and farmers personal time preferences (the need to consumers today, e.g., fuelwood), all affect farmers behavior.

3.3 Economic Characteristics of Soil Conservation Programs [7]

Is there any characteristic that makes soil conservation programs unique when compared to other projects? With the exception of a few, the use of benefit-cost analysis (BCA) is as easy or complicated as in any other project. This section first highlights the most salient economic aspects of soil conservation projects and, second, outlines alternative appraisal frameworks.

There are several characteristics that make soil conservation projects rather unique. First, soil conservation programs are multiproduct in nature. Namely, besides their impacts on the ecology of soils, these programs produce several other joint products (e.g., forestry programs produce fuelwood, timber, fruits, wood poles, fodder, water catchment protection, flood control, shade). The nature and structure of the demand, as it affects relative prices across products, will affect the extent to which a program is effective in the conservation of soils.

Second, assignment of monetary value to some of the expected benefits and costs may be difficult. This is particularly true for environmental effects. Valuation problems are compounded by the nature of soil conservation monitoring, the lack of data, the absence of adequate market signals, the set of transaction costs, and the like.

Third, externalities are present. This will require focusing on costs that are not revealed by farmers production functions (i.e., interfarm and downstream effects). These externalities might result from the existing tenure system--where extraction costs are not totally absorbed by farmers, thereby affecting the cost of every other user--the difference between private and public sector risks, and the alternative perceptions with regard to uncertainty. Therefore, most often, land market prices do not reflect changes in soil quality.

Fourth, the presence of irreversibilities complicates the process of valuation. The value of land, equivalent to the discounted value of all future income streams from that land, does not take into account the value that society assigns to each hectare lost to erosion. Land seems to have a value in stock. This value changes over time as a function of the existing stock of land available.

Finally, intergenerational equity issues are involved adding new complexities. Soil conservation programs result sometimes in benefits (or costs) which are accrued very far in the future: by future generations. The planning horizon of today's farmers may significantly differ from society's, all of which leads to conflicts in terms of allocations and use of soils. This "myopia" of today's generation may also be considered a form of negative externality.

As an example of the valuation problem, let us focus on forestry projects as a soil conservation project. Only some of the joint products in forestry have market prices (e.g., lumber) while for others sometimes there is none (e.g., fuelwood). Whatever the shadow price used for fuelwood in the economic analysis, it should reflect not only the need for energy but also the expected effects on soil depletion. To come up with useful estimates of fuelwood prices, one needs to study rural markets much more, apply new methods for determining willingness to pay, and advance the use of proxy pricing (section 4.5). Moreover, downstream effects of forests, like preventing siltation of reservoirs, or interfarm effects, like preventing the clogging of canals (i.e., decrease in operational efficiency), demand data which are seldom available.

4 Approaches for Economic Appraisal

Several benefit-cost valuation methods may be used depending on the characteristics of future "with" and "without" the project situations. Before outlining the nature of each method and in order to define and understand the nature of project benefits, one must understand the relationship between the natural system under study and the economic decision framework.

Because the economic analysis often begins with an estimate of land productivity, economists tend to forget that several steps have been followed to compute yields. For example, one may need to know how losses in topsoil affect farm productivity (e.g., measured in crop yields). This would require first recognition that there is a relationship between losses of topsoil and losses of nutrients, and between losses of nutrients and changes in yields. The Universal Soil Loss Equation is often used to quantify potential losses in topsoil. There is a statistical relationship between soil loss and such factors as rainfall, slope, soil erodibility, crop management, and erosion control determine the correlation between loss in topsoil and crop yields. This is often estimated by correlating soil depth with losses in soil nitrogen, and then those are correlated with output. There are other formulae (e.g., soil erosion and wind velocity) that may be used to illustrate this point.

Many economists do not grasp these ecological relationships. For them it is difficult to identify benefits other than the usual crop production (regardless of how one assigns values to those benefits). Many projects end up having "marginal" economic returns because not all the benefits have been accounted for. This also applies when identifying effects of soil conservation programs; most projects consider only one type of effect, e.g., intrafarm effects.

The choice of valuation method--as a next step in the appraisal of projects--has to be properly done. In many instances, one makes mistakes in choosing an adequate set of prices because no analysis has been done on present and future "with" and "without" project situations. This analysis (i.e., economist's judgment) will define which methods to be used.

4.1 Consumer/Producer Surplus Approach

At a microeconomic level, many soil conservation programs have been evaluated using this method under the assumption that the market will reflect the nature of the problem. This approach uses information provided by supply and demand functions. The absence of a soil conservation program ("without" project) would shift the supply curve for commodities upward due to a decrease in land productivity. Producers may gain from a price effect. However, this gain may be outweighed by increase in production costs (land held as a fixed factor). In the presence of a soil conservation program (additional costs), gains may result from increase in production which may be outweighed by an expected decrease in prices (supply curve shifts downwards). On the other hand, in the absence of a conservation program, consumers may lose due to a decrease in supply of products. However, with a conservation program, consumers may gain by an increase in the available quantity of products. Time as a factor will play a very important role [12].

4.2 Property Value Approach

Two procedures need to be distinguished: (i) market value and (ii) assessed value (or income forgone approach). Both approaches imply that land rent or land values reflect to some extent future income streams (i.e., productivity) from the land. Soil erosion will affect the quality of land, and, thereby, it is expected to be reflected in land values. If land markets are perfect, both approaches should give the same results.

The market value approach also applies the willingness-to-pay principle. Demand functions are usually estimated using econometric methods. The market value approach is limitated when applied in LDCs due to the imperfections in the land markets of rural areas and due to the fact that land prices will reflect several factors other than soil productivity: land is purchased also for security reasons, for land speculation, and for increasing one's stock of wealth.

In the absence of a market value, many projects calculate an implicit value of land by determining its production (e.g., alternative cropping patterns) capacity "with" and "without" the project (net benefits being defined by the difference between the two). This value only reflects our estimate of land flow effects, and therefore crop production estimates will tend to underestimate land values. In the traditional BCA, no stock effects are accounted for in assessing the opportunity cost of land. The presence of soil erosion and the real risk of irreversible damage will also affect the stock value of land.[6]

The land value approach operates under a set of specific assumptions, not all of which are realistic in the context of developing countries. First, it assumes that changes in the quality of land is visible by consumers, and, therefore, the price of land will change in a continuum with changes in land quality. This continuum does not always exist either, because people in LDCs are attached to the land and few transactions take place or because quality is not a dominant factor in the process of land prices formation. Another factor which limits the extent to which land prices reflect changes in quality is the excessive segmentation of rural land markets.

4.3 Replacement Value Approach

Soil erosion results in downstream effects usually captured by changes in the economic life, for example, of irrigation infrastructure, groundwater development, or other economic activities like agriculture and fisheries (these important social costs need to be considered). Siltation of reservoirs reduces their economic life, depending upon the existing siltation rate. Soil conservation programs will decrease such siltation rate, expanding the useful life of infrastructures. If no program is adopted (future "without" the project), the economy will have to replace such infrastructure (i.e., shadow project) sooner than expected. The cost of replacement could be used to estimate potential benefits (i.e, "cost saving benefits"). By the same token, replacement of tubewells or differential pumping costs could be accounted for as benefits of soil conservation projects which would prevent further deterioration of existing aquifers. This approach may also be used when changes in the economic life of soils is appraised.

4.4 Travel Cost Approach to Recreational Benefit

In some cases soil erosion affects recreational facilities through decreasing the fishing productivity of lakes and reservoirs, increasing turbidity in waters, creating fetid odors in waters used for recreational purposes, and others. Recreational benefits may be measured by estimating consumers' willingness to pay revealed by expenditures associated with travel time and distance. Since this does not seem to play a major role in rural areas, no further analysis is given.

4.5 Other Approaches and Proxy Values

First, estimation of social demand curves has been proven useful when one is able to identify how much society is willing to pay to avoid violating a safe minimum standard of soil conservation. This approach has been used in the Bank to evaluate nutrition intervention programs. Second, the use of social accounting matrices may prove useful when one tries to allocate benefits and costs and their incidence. The Bank has used this approach in sector work. Finally, proxy value may be used to estimate the implicit price of commodities whose markets do not reveal prices.

An example in the use of proxy methods is the valuation of fuelwood.[7] The most frequently used proxy method--directly linked to soil conservation decisions--is to determine what type of products that affect soil productivity at the margin will substitute for fuelwood as an energy source. In rural areas, lack of fuelwood is satisfied by burning cow dung or crop residues. In particular, Bank projects have used the value of crop productivity that society loses by substituting fuelwood for cow dung (or agriculture residues) when fuelwood is not available. The implicit assumption here is that elasticities of substitution between fuelwood and cow dung are high, while the price elasticities of substitution of fuelwood with regard to other sources of energy is assumed to be very low or zero.[8]

This proxy method cannot be used indiscriminately, since to advocate such substitution, one would require a thorough analysis of the supply and demand structure for energy "with" and "without" the project. In some projects we have assumed that all these cross-partial price elasticities are zero ("one must supply only fuelwood"), while in others we have assumed that these elasticities are high with respect to several other alternative sources of energy (i.e. coal, kerosine). The basic task here is to determine the opportunity cost of fuelwood so as not to over- or underestimate a project's benefits.

5 Project Appraisal: Few Case Studies

5.1 Economic Evaluation of Polders

Until now, this paper has not focused much on polders. Most World Bank-financed polder projects reviewed for this paper were designed to control streambank erosion and to prevent floods. Only one Bank-financed project from a sample of several projects considers the construction of a polder like the ones in the Netherlands, namely, where land is actually reclaimed from the sea.

The construction of polders is assumed to have several important benefits besides those benefits stemming from land reclamation. Intrafarm effects include the increase in land productivity by enabling the land, subject to floods, to be cultivated during the whole cropping year and by controlling salinity. Interfarm effects include land reclamation and the control of streambank or riverbank erosion within the project area. Downstream effects include prevention of flood damages (e.g., land, houses, capital stock), siltation of reservoirs, and decrease in the productivity of other rural sector activities (e.g., freshwater fisheries).

The most important external effect introduced by the construction of polders is the change in the productivity of existing freshwater fisheries. Polders and embankments to control floods and streambank erosion would change the habitat's quality of fish growth through changes in salinity, water temperature, and spawning habits. These rather negative effects have been avoided by providing the necessary changes in project design (e.g., fish ladders) or by financing fish hatcheries (i.e., the "shadow project"). If such investments are not provided, important losses in income would occur through both fish production (i.e., fishermen's catch will decline) and animal protein consumption.

5.1.1 Yong San Gang II Project

The project is the second stage of a plan for irrigation, drainage, and land development in the lower reaches of the Yong San Gang River. The project is designed to benefit 20,700 ha through irrigation of the entire area, reclamation of 5,500 ha uncultivated tidal flats, and land development on 11,900 ha. The project finances the construction of an estuary dam across the mouth of the Yong San Gang; construction of a 4,000 m long sea polder; construction of irrigation facilities; reclamation of tidal land development and consolidation; project building, access roads and a temporary pier; and connecting services.

The polder, extending downstream of the estuary dam along the left bank of the river, would be constructed to reclaim 830 ha of tidal flats. The polder will be 4,000 m long and about 8 m high. The body of the polder would be compacted earth with a rock zone on the seaward face. A sluice would be constructed at the downstream end of the polder to permit drainage of the reclaimed area at low tides.

The total project cost was estimated at US$167.0 million, where the polder would cost US$2.0 million and the sluice gates US$10.7 million.

The major beneficial environmental effect would be to improve water quality in the lower reaches through elimination of seawater intrusion. Two downstream effects could be expected: sedimentation in Mok Po Harbor and reduced fisheries. A survey shows that about 800 households in the vicinity of the project engage in fishing to supplement farm income, but nearly all of the fishing is in shallow coastal waters. Therefore, construction is expected to have no significant effect on fisheries (i.e., income forgone is zero). As regards effects on Mok Po Harbor, a study by an expert in sedimentation concluded that the estuary dam would not increase, and might, in fact, reduce, the annual dredging requirements (about 130,000 m^3) in the harbor.

The economic benefit and justification procedures did not include two additional downstream effects: road link with other towns, and reduced levels of salinity allowing to allocate some of the water into the municipal areas and industries. The main benefits quantified in the analysis are on-farm: land reclamation and land development. The project's overall rate of return would be 13%.

5.2 Other Examples

5.2.1 Phewa Tal Catchment Management Program: A Land Value Approach

The Phewa Tal catchment is located in Kaira District, some 140 km from Kathmandu. The catchment has an area of 113 km^2 and drains Lake Phewa Tal. The climate is humid subtropical, with an annual precipitation of 3,700 mm. Because of intensive agriculture and grazing in the catchment, only about a quarter of the original forest remains; this land is owned by the Government of Nepal. Subsistence agriculture is the resource base of the catchment with cultivation of rice, corn, millet, wheat, potatoes, and other vegetables. Most families keep 4 or 5 large animals for production of manure, milk, and for plowing. Forests supply fuelwood and timber for building. Several resource management problems exist, namely water supply shortages, water quality, erosion problems (grazing lands being the most critical), sedimentation in Phewa Lake, grazing management (e.g., number of livestock, fodder productivity of grazing land and development alternatives--keep animals off--and legal jurisdiction), and forest and agricultural management (cultural practices, nutrient depletion). The proposed program includes plantation maintenance, forest protection, pasture establishment and protection, gully control, stall feeding, and training and technical assistance.

The appraisal approach draws comparisons on differentials in potential land values "without" and "with" the proposed programs. Values are defined by varying degrees of land productivity over time, which is assumed to change depending on expected output foregone. For grazing land, different conversion factors into animal feed and for animal feed into the production of milk and fertilizer (net of production and other costs) were estimated. The fertilizer and milk values of the grass were estimated at NRs 11/ha/yr and 72/ha/yr, respectively. For pasture land, it was estimated that its productivity would be approximately five times that of open grazing land (for the same commodities). For scrub land, the analysis assumed that each hectare would produce 500 kg of grass, 1,500 kg of fodder leaves and 4 m^3 of wood. The economic values of grass and fodder were calculated as before but 96 m^3 of fuelwood were added. For unmanaged forests, a productivity was estimated equivalent to 3,000 kg of leaf fodder and 12 m^3 of fuelwood per hectare. Finally, for plantation forestry and managed forests, coefficients on fodder and fuelwood were estimated as before. Benefits were added up and compared to the cost of the program; a B/C = 1.7.

5.2.2 Economic Benefits of Shelterbelt.[9]

Several benefits have been identified with the planting of shelterbelts or, often called, windbreak. Among the benefits one can mention:

- reducing wind velocity and soil erosion,
- modifying air and soil temperatures,
- reducing evaporation and transportation,
- improving distribution of snow and soil moisture,
- improving distribution of water in sprinkler irrigation,
- reducing windburn and wilting of crop plants,
- protecing newly needed crops from blowout, and
- protecting mature crops from lodging.

In terms of specific economic benefits, depending on circumstances, one may account reduction in energy requirement, building maintenance, reducing mortality in livestock, improving the production and quality of crops and fodder, controlling soil erosion, providing shade, and many others [1, 16, 17].

The Bank tried to estimate the effects of shelterbelts on land productivity; it has been estimated that for certain crops the presence of shelterbelts would double existing productivity. These data come from experiments and several studies around the world. In Niger [13], it was estimated that yields of millet would progressively increase with the height of the windbreak up to a certain point; the average increase in yields was found to be 29%. The Niger report concluded furthermore that as a result from shelterbelts wind erosion is reduced considerably and soil moisture and yield were higher than those crops left in the open. In the U.S. [17], a functional relationship has been estimated between distance from the shelterbelt and yields (as a percentage of normal yields). It is shown that between 1.3 m and 12 m, yield would be above the norm; the highest yield (over 50%) is reached with a shelterbelt of 5 m.

5.2.3 Indonesia Watershed Project Appraisal of Downstream Effect

The Bank has done some crude calculations for appraising the economic value of reducing soil erosion and siltation of streams. Here, only down stream effects have been clearly singled out. It was estimated that only 50% of all the silt which enters the riverbasin would cause quantifiable damage downstream; this includes siltation of dams, canals, fishponds, ports, floodways, and other structures. The study assumes that damage costs are at least as large as the economic cost of removal or alleviation (replacement costs). Impacts on the economic life of reservoirs and other structures were also studied.

5.2.4 Tunisia-Northwest Rural Development: Intra- and Interfarm Household Effects

This project recommended financing a 4-year time slice of a 15-year development program for 311,000 ha of Tunisia's 1.46 million ha Northwest Region. Project actions will be undertaken on 162,000 ha within the area subject to soil erosion or susceptible to crop production increases. The project area was divided into 2,000 ha microzones distinguished by types of land ownership and use, and by topographical and agriculture characteristics. The project components include

- measures to decrease soil erosion,
- agricultural development,
- forestry production,
- livestock development,
- production infrastructure (e.g., roads),
- social infrastructure, and
- technical assistance.

The soil erosion production program includes changes in cultivation practices (contour farming, continous cropping of cultivable land, introduction of different crops on alternative parcels down hillsides to reduce water runoff); contour banking systems and planting or maintenance of permanent pastures, and planting of forest in areas where cultivation must be stopped and conditions do not permit pastures to prevent erosion; and fencing off, supervised grazing, water control works, and afforestation on land surrounding gullies and riverbeds (overgrazing and water runoffs causing the erosion).

Most benefits and costs were appraised as the activity affects crop and livestock production. Changes in crop production to some superior crops, increase in milk production, fuelwood and forest products, overall increase in yields of food crops, and beef products. After including all costs, a financial analsyis was carried out to see the extent to which farmers had any incentive to participate (other things being equal). The financial rates of return to farm models fluctuated between 22% and 62%. Such returns were not positively correlated with farm size. However, it was found, as one would expect, that the project's rate of return was positively correlated with the planning horizon or the time slice, achieving an optimum when considering a program of 15 years (i.e., ERR = 16%).

5.2.5 Ethiopia - Wolamo Agricultural Development: Intrafarm Household Approach

In this project, soil conservation measures include bunding and contour cultivation, gully control and land rehabilitation, water development, and program monitoring. Two elements were defined in order to carry out the economic analysis: (a) a net value of production figure Br 150 per ha and (b) a decrease in soil productivity in the absence of this project and a 5% drop in production. Under these assumptions, the economic rate of return was estimated at 11%. No attempt was made to quantify benefits of gully control and land rehabilitation, though their benefits were also expected to be significant.

5.2.6 Watershed Conservation in Ecuador: Economic Life Approach [6]

The Poza Honda Watershed is a humid, subtropical watershed of 175 km^2 located 2,000 km southwest of Quito in the coastal province of Manabi, Ecuador. The watershed varies between 100-500 m in elevation and is steep, with 60% of the area having slopes greater than 25%. Land use analysis indicates that 55% of the watershed area is still in natural forest, while 6% consists of cultivated coffee and cocoa trees. Grazing land covers 22% of the watershed and 3/4 of this land is subject to sheet erosion during the dry season. Mixed farming and grazing takes place on 14% of the land. The reservoir occupies the remaining 3% of the watershed.

The existing reservoir has many problems due to sedimentation, to climate, and to intensive land use in certain areas. Sedimentation surveys have indicated that 20% of the original volume of the reservoir was filled with sediment; with 4% per year after 5 years, one expects the reservoir to be filled in 25 years. In addition, the reservoir suffered from a dense blue-green algae, causing fetid odors in the water. Under these circumstances, a program including reforestation, construction of terraces on steep and erodable land suitable for cultivation, grazing control and rehabilitation, and forest protection programs were suggested.

Estimation of project benefits focused on a reduction of the sedimentation rate from 4% to 2%. Such reduction was expected to increase the economic life of the reservoir from 25 to 50 years. The benefits were estimated to come mainly from irrigation. The analysis concluded that with a longer-life reservoir the economy would achieve a B/C = 1.433, while with a shorter-life reservoir the economy achieves a B/C = .67.[10] Net incremental benefits to society were estimated at US$30.7 million.

6 Problems in Implementing Soil Conservation Projects and Programs

Though sound economic and financial analysis provide useful information for decision makers it is only one of the necessary conditions for the successful implementation of soil conservation projects. Some of the sufficient conditions are outlined below.

First, it would be ideal that the timing of production practices leading toward conservation coincide with people's short term needs. But, as it is well known, this is not the case everywhere. This issue is particularly acute in areas where it may be advisable even to stop production ("let the soil rest for a while"); however, this is socially unfeasible and, many times, politically unacceptable.

Second, there are such considerable informational gaps that the whole process may become unmanageable. In many instances, experiments with soil conservation programs that will provide the necessary information have to be carried out together with production programs. Under these circumstances, great distortions occur particularly when the data is capturing changes in variables other than those associated with changes in natural systems (e.g., management of individual farms).

Third, monitoring of projects, if done adequately is difficult and expensive--soil losses take a long time before one sees the real effects. Farmers do not opt for soil conservation program because they do not see the immediate need for them.

Fourth, soil conservation programs put severe stress on local institutions: most programs require the enforcement of rights, changes in farming practices, and changes in cultural habits. These changes may be difficult to achieve.

Fifth, markets do not always provide adequate signals to farmers when adopting soil depletion practices. Market values of land or changes in crop yields do not provide the appropriate signals to reflect losses in soil quality and, therefore, seldom account for the total economic cost of production.

Sixth, soil conservation practices *per se* will not be sufficient to alter soil quality or to change farmers' production practices. One may need to adopt income policies; these would affect the rate of social time preferences or farmers' biases in favor of crop-depleting systems.

Seventh, a financial and economically viable soil conservation program may need changes in land tenure to enable farmers to expand the size of their lands. In several countries this is socially or politically unacceptable.

Eighth, integration of soil conservation planning and implementation with development planning in general is a must in order to have self-sustained soil conservation programs.

Finally, there is a lack of appropriate administration for implementing such programs. Under the best of all circumstances, these programs are fragmented (e.g., Ministry of Agriculture, Public Works, Irrigation).

7 Private and Public Sector Finances

7.1 Financial Analysis

Financial analysis of soil conservation is important, since it is the individual farmer who carries out the projects. This presents problems in areas of subsistence farming, since soil conservation decisions are clearly affected by the need to achieve subsistence first and conservation later (i.e., lexicographic decision making). Do farmers have enough incentives to carry out soil conservation programs? For example, the financial analysis of such programs as forestry needs to consider carefully: (i) competitive uses of land (e.g., foodcrops) and labor (e.g., for planting and maintenance); and (ii) tree species and tree planting modes of maximum financial returns to farmers. Also one should consider the land tenure structure as it affects farmers' adoption of conservation practices (i.e., land size may be too small for farmers to adopt these programs). Finally, financial performance depends on, e.g., the organization of farmers, input delivery systems, credit extension.

7.2 Fiscal Impacts

The state budget may be affected in several ways:

- compensating farmers to forgo certain benefits or providing cash to farmers for implementing the program (e.g., village forestry schemes);
- having to afford substantial recurrent cost expenditures since these programs demand little foreign exchange; and
- changing the tax structure system. A good fiscal impact statement is a necessity if one expects any sustained success of this type of program.

A good fiscal impact statement is a necessity if one expects any sustained success of this type of program.

Most conservation programs require local currencies and resources. The majority of rural government authorities lack appropriate funds to carry out conservation programs. One reason for such gap is the fact that soil conservation planning is not integrated into overall development planning.

Finally, with regard to taxation changes in the quality of land will correspondingly change the capacity to pay of this land. Consequently, governments should, in principle, get increasing resources as the conservation project develops. Due to institutional and other factors, however, these tax structures are very rigid, thereby not correlating (positively) with increases in land quality. This is a problem one will have to live with it.

8 Policy Issues

Before closing, it would be important to identify some major policy issues which need further research.

8.1 Soil Conservation Planning vs. Development Planning

Isolated attempts to deal with soil conservation are bound to fail. The environmental sustainability of soil resources, and of land in general, should be a central subject of any development plan. Given the nature of soil conservation programs, it is difficult to see how this integration would take place, particularly in light of too many development objectives.

8.2 Macro vs. Micro Variables

A development policy framework needs to be developed; this should take into account the macro- and the microeconomic variables. With regard to macroeconomic variables, the most important is the sustained increase in the demand for agricultural products. This expanded demand would continue to build substantial pressure on the development of both the extensive as well as the intensive margins of agricultural lands. The expansion in the supply of crop lands will require developing the margins of agriculture. In this case, if no coordinated policies really exist, the risk of soil degradation is rather great, because marginal lands are often more fragile and subject to higher risks of soil erosion.

With regard to microeconomic variables, the most important variable to be recognized at the policy level is the profit motive of farmers. Farmers will be reluctant to adopt soil conservation practices that are financially and economically unattractive. This is extremely important in the policy context, since to be able to have more program effectiveness, a balance must be reached between public and private investments. Neither the public sector nor the private sector alone will be able to accomplish the policy objectives outlined in this paper.

Because the development objectives of the public and private sector may differ, an effort should be made to recognize the underlying behavior of each sector. This is certainly true for augmenting the private sector's adoption of new technologies. As stated earlier, the development of conservation technologies, to be adopted by the farmers, should be profitable.

8.3 Time Element: Intergenerational Equity

Although this represents the core of the conservation problem, no solution has been found yet. Benefits of conservation programs are usually materialized far in the future. The use of today's generation's opportunity cost and shadow prices, within existing discounting techniques, weigh very heavily against benefits received far in the future. Several approaches have been suggested, e.g., variable and decreasing discount factors, no discount at all, use of variable shadow prices, use of an opportunity cost of land in the presence of irreversibilities, changes in the BCA objective function, and others. None of them are fully satisfactory.

8.4 Administration of Conservation Programs

Experience shows that the degree of success with soil conservation programs is highly correlated with quality in program administration. This issue has many facets. First, there is a need to create public awareness about the soil erosion problem, both among policymakers and citizens. Since this awareness does not exist, public funds are not channeled at the appropriate rates into soil conservation programs. Fiscal reforms are needed.

Second, soil conservation should be conceived as capital investment programs: investment in the land. This seldom happens and, therefore, money available for those programs often come from the income savings account of the government rather than from the capital accounts. The main implication is that funds are not earmarked for soil conservation activities, and most of them are underfunded.

Finally, there is an increasing need for farmers to participate and for the government to provide extension services. The general idea of "soil conservation districts" in the U.S.A. should be considered as a plausible system in developing countries. This system will enable farmers to participate more actively in soil conservation efforts. However, an important component is an adequate extension service. Unfortunately, most extension systems have focused mostly on agricultural productivity, with very little emphasis on environmentally sound practices. This needs a change.

Notes

1 The term "polder" is used to refer to different things. In many projects, polders are used as synonym for embankment to control streambank erosion and reclaim land partially or totally flooded. In a few projects (section 5.2), the term polder is used in the accepted context of sea soil reclamation.

2 Sections 2.1-2.3 are very preliminary in nature. Each type and method needs to be explored in much detail than presented here. Section 2 relies heavily on [8, 9, 11].

3 Experience in the Bank's financial Gujarat Social Forestry Project has shown that reforestation programs in Panchayat lands have been much less than expected at appraisal.

4 Stock resources include, for example, texture, depth of soil and line zone, and clay pans. Flow resources may be associated to changeable features like salinity levels, pH levels, bush and tree cover, and rock cover.

5 The presence of irreversibility in decision making is another specific characteristic of investment projects that affect natural environments. Shaxson [14] makes an interesting distinction between soil conservation (i.e., build up the nutrient capacity) and soil reclamation (i.e., bringing back to its original stage the nature of a stock resource component like texture).

6 This subject needs to be explored in much more detail. The implications are that land not only preserves a value in use (flow), but it also has a wealth in stock value. This phenomenon will affect the

way in which projects calculate the opportunity cost of land.

7 Increase in relative prices of energy is causing uncontrolled use of fuelwood forests in rural areas. This process has great effect on oil erosion not only because of depletion of forests but also because the bulk of fuelwood is causing losses in agriculture production.

8 Other important factors that may constrain substitution at the margin are tastes, technology, lack of roads, inefficient distribution systems, and prohibitive transaction costs.

9 It is important to note that here we are only describing increases in yield "with" the project situation. In the BCA of shelterbelts, one needs to subtract the "without" project situation.

10 The difference in B/C "with" and "without" the project reflects in addition to the change in the economic life of the reservoir, the expected increase in land productivity resulting from the proposed soil conservation practices.

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ENVIRONMENTAL ASPECTS

- *J. de Jong and A.J. Wiggers*. Polders and their environment in the Netherlands
- *M. Vannucci*. Ecological values of potential polder areas

POLDERS AND THEIR ENVIRONMENT IN THE NETHERLANDS

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Abstract

The environment of polders in the Netherlands is reviewed from two points of view. The historical development of the polder areas during many centuries and the changes in the natural environment are described.
In time this has meant a gradual transformation of natural dry and wet forests, peat areas and lakes in polders used for agricultural purposes with all the associated environmental losses and gains.
Thereafter attention is paid to developments in the use of the available space, both of land and water, in the Netherlands during the 20th century. The changing of an agricultural society into an urbanized industrial society and the developments in agriculture itself (mechanization, artificial fertilizers and chemical control of pests and diseases) have had and still have a profound influence on the environment in the dutch polder regions and play a role in the process of decision making about constructing and developing new polders.

Introduction

In this paper, which deals with polders and their environment in the Netherlands two major aspects will be reviewed.
Attention will be paid to the historical development of Dutch polder areas and of their environment and afterwards the development during this century in the use of the available space, both of land and water,

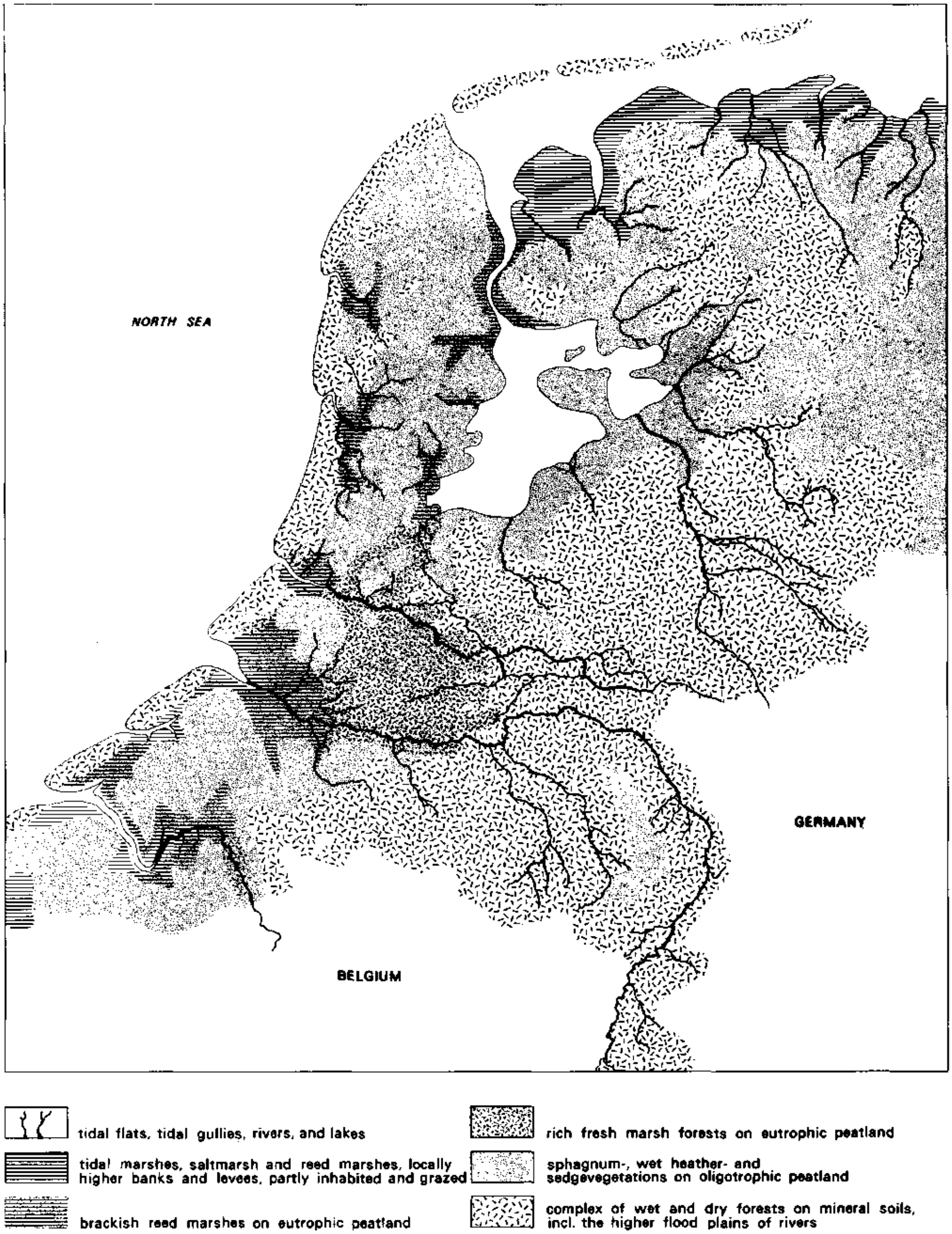

Fig. 1. A reconstruction of the ecological situation of the Netherlands in Roman times (after Pons, 1974).

in the Netherlands and its consequences for polder areas will be discussed.

Historical development

In Roman times (that means in the Netherlands about the beginning of this era) the ecological situation of the Netherlands can be described as follows (fig. 1).
On the nutrient poor Pleistocene sandy soil forests, marsh forests and oligotrophic peat forming vegetations could be found.
On the coastal dunes and islands, forests existed on the sandy soils.
In a large area behind the coastline, areas with peat forming vegetations existed together with reedmarshes and marsh forests. Along the rivers forests on nutrient rich alluvial soils existed as well as marsh forests and reed marshes downstream.
In the northern region behind the islands a wadden region, tidal flats, existed changing landwards into saltings and reed marshes.

From this original situation man made polder areas have been developed. They can be distinguished in four major groups: polders in the downstream flat river catchment areas, polders in peat areas, polders on the bottom of drained lakes and polders created by coastal embankments (fig. 2).

In the river catchment areas upper and lower parts have to be distinguished. In the upper part on the levees forests grew on rich mineral soils and in the backswamps marshes and forests were present, in the lower part marshes and forests were dominating.

Inhabitation started on the river banks, and already in carlovingian times settlements grew and small horse shoe-shaped polders were constructed discharging their water either into the river or behind the river banks using the backswamps and the slope of the land towards the sea.
In the 12th and 13th century people were ordered by means of "dike letters" to tie the dikes along the rivers together and combined polders were created.

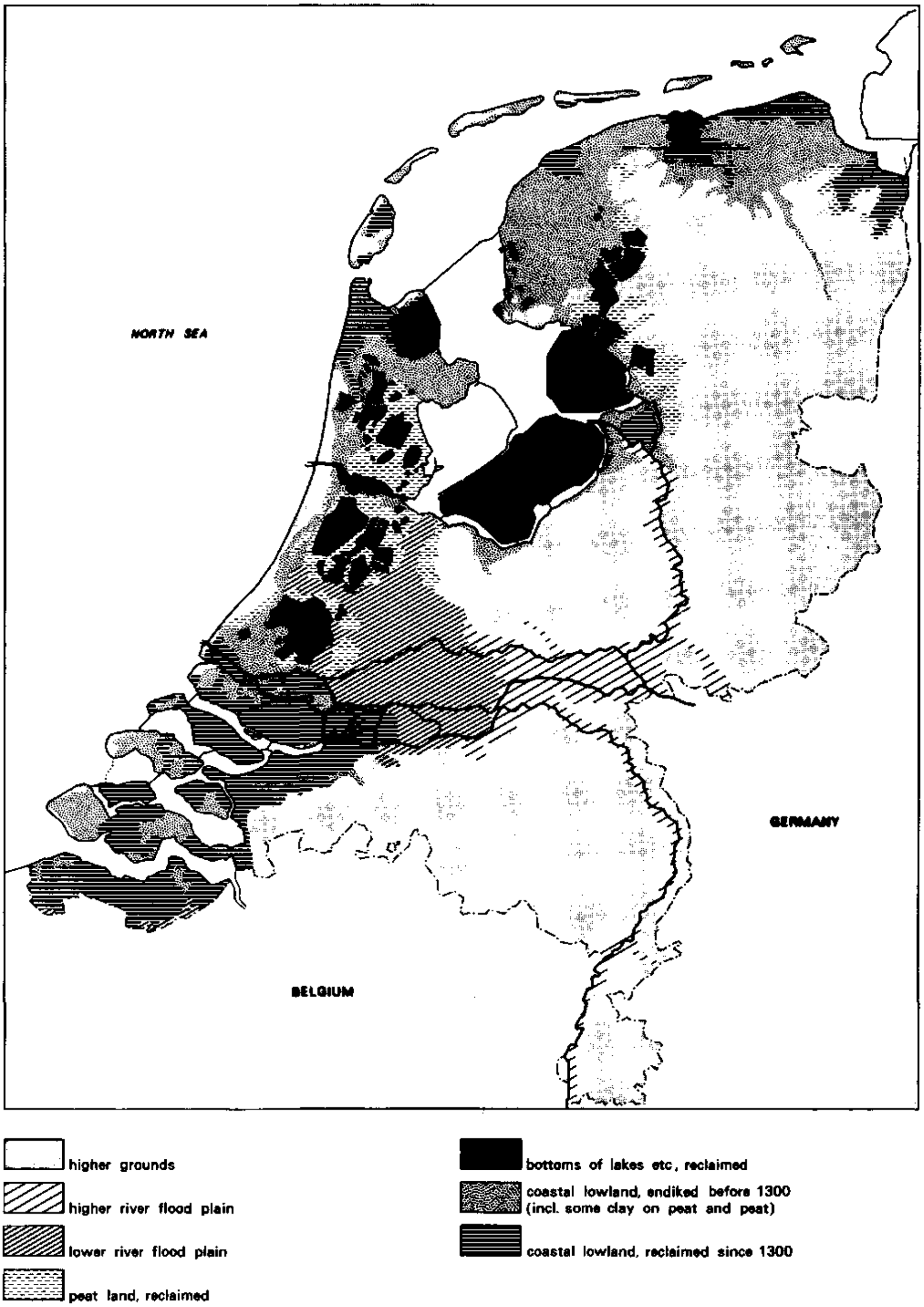

Fig. 2. The location of the polders in downstream flat river catchment areas, in peat areas, of polders made by draining lakes and of polders made by coastal embankments in the Netherlands.

By the construction of these dikes and the development of an artificial water management system these areas were more and more transformed into agricultural land and the original vegetation of forests was more and more destroyed. Initially the land use aimed at cereal production combined with dairy farming and fishing. As time proceeded the land became less suitable for cereal production and mainly dairy farming and fishery remained.
In the lower part of the river catchment the marshes and marsh forests were also gradually reclaimed. The original marsh habitat was transformed into a habitat of wet grasslands (on the dikes along the rivers special vegetation developed that still, though often partially, exists). With the destruction of the tidal marshes birds like the Great white egret, the Nightheron, the Dalmatican pelican and the Squacco herron lost their habitat to a large extent.

A major part of dutch polder areas consists of peat soils. The reclamation of these areas sometimes dates from the eleventh century but the major part has been reclaimed during the thirteenth century and later. In these peat areas, peat of various thickness overlays mainly loamy or clayey soils. The peat was originally reclaimed for cereal production. As time passed by, due to oxydation and shrinkage, the construction of an artificial water management system was necessary to save the land from flooding. Under those conditions the land could only be used for dairy farming. Grassland polder areas providing mainly wet grasslands, formed the habitat for water and meadow fowl.

In these areas the major and decisive step from an environmental point of view is the first i.e. the reclamation of the soil. This meant the destruction of the original vegetation on the peat soils and turning it, after a major temporary use for cereal production, into grassland.
The other result of the construction of polder areas is a decrease in the frequency of flooding of various areas and control of the water level, both of the open water and of the ground water.
The reclamation of the land often started from a bank of a river and penetrated by means of long stretched parcels into the area to be reclaimed. The origin of the formation of these long stretched parcels is due to the central government that was already present at that time.

Due to legislation a farmer could only rent a certain (limited) length of land along a bank for reclamation perpendicular to that bank. This resulted in a difference in the intensity of the agricultural use, forced upon the farmer by both distance and soil conditions. In the often naturally well drained areas near the basis of the reclamation (and mostly near the farm) the land was much more intensively used than the remote, somewhat wetter parts at the other end of the reclamation parcels. They were only used for hay cropping. Such hay-lands were and are from an ecological point of view valuable. They provide good living conditions for many species of meadow birds, but are also important from a floristic point of view. In these regions birds like the Corncrake, the Baillon's crake, the White stork were common although they have now almost completely disappeared from these areas.

Figure 3 shows a typical example of this parcelling which can still be found in the Netherlands.
However due to the improvement of farming conditions by e.g. lowering of the water levels, the application of artificial fertilizer and reallotment of farms, much of this parcelling has disappeared. From an ecological point of view this is especially reflected in a decrease in the number of meadow birds, rails, White storks, birds of prey like harriers but also in the diminishing floral values of these areas.

The third group of polders in the Netherlands consists of drained lakes. Natural lakes were present in the peat areas but they have also been formed by man using the peat as fuel because of lack of wood or coal. In the western and northern part of our country this resulted in the creation of lakes and a system of open waters with many small, long islands on which the peat was dried (fig. 4). In a number of cases the combined action of wind and waves resulted in erosion of the small islands and the formation of increasingly larger lakes, threatening the lands around them.
These areas where lakes, small canals, small islands and hay-lands in various combinations were present were important for both herbivorous and carnivorous birds of wetlands.

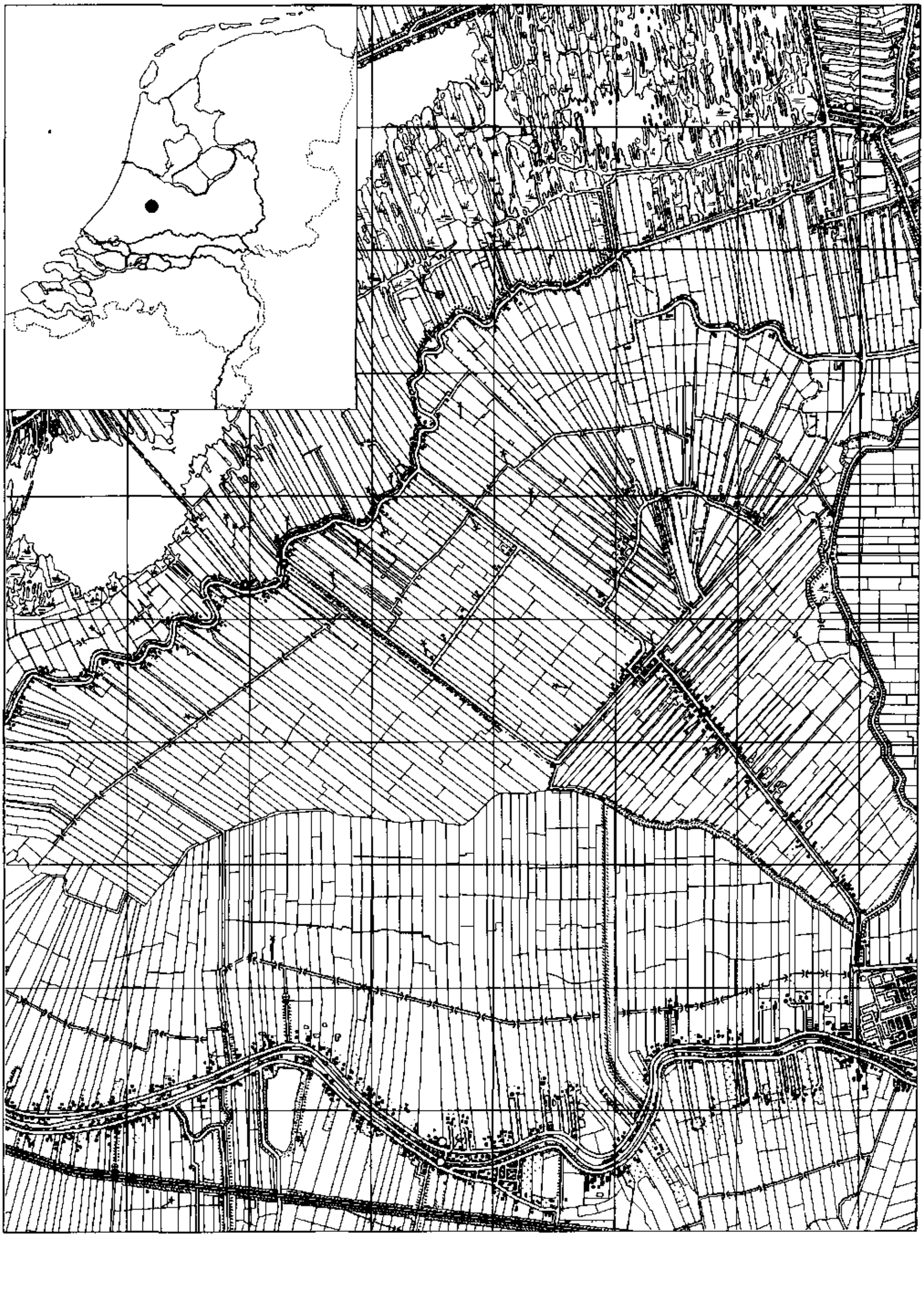

Fig. 3. A typical example of the long stretched parcelling in the peat reclamation areas in the western part of the Netherlands (Holland - Utrecht region).

Fig. 4. An example of the system of long stretched waters and islands resulting from peat digging for fuel production.

The invention of the revolving turret windmill enabled the lakes to be reclaimed. The first lake was drained in the first half of the sixteenth century and especially in the western part of the Netherlands many lakes have been drained in following centuries. The main purpose of these works was the reclamation of fertile clay soils suitable for cereal production, as well as for the increase of safety against devastation of the surrounding peat area, reducing shore line and improvement of water management. In time the emphasis on these aspects has varied, but they are still valid.
The ecological result was a destruction of the habitat for many water fowl and birds of marsh land, but also for mammals like the Otter and the Beaver.

In the area of the coastal polders a different situation is found. Here the polders have been reclaimed from the saltings. Coastal accretion could be enhanced by making special sedimentation provisions which still can be observed in the Wadden-sea (fig. 5). The higher parts of the saltings were first turned into salty grasslands providing food for many herbivorous waterfowl like ducks and geese.
After embankment the coastal polders were predominantly used as arable land. Nowadays the land accretion areas have proved to be of very high ecological value for both the marine ecosystem of the North-sea as well as for waterfowl and waders.
The shallow, intertidal and sometimes brackish areas proved to be of such ecological value that, in recent years, it has been decided not to execute embankment in such zones even though plans were advocated.

The largest land reclamation project in the Netherlands is the Zuyder-zeeproject. Plans for this project were already advocated in 1657 by Henric Stevin, a Dutch engineer, but it was not untill the middle of the nineteenth century before technical developments made the plans feasible. It took many years of discussion, research and planning before the final decision to execute the plan was taken, in 1918, by passing the Zuyder-zee act in parliament.
The basic aims of the plan were to shorten the primary coast line by the construction of a barrier dam, to increase food production by the reclamation of approximately 200,000 ha of new land (160,000 ha now

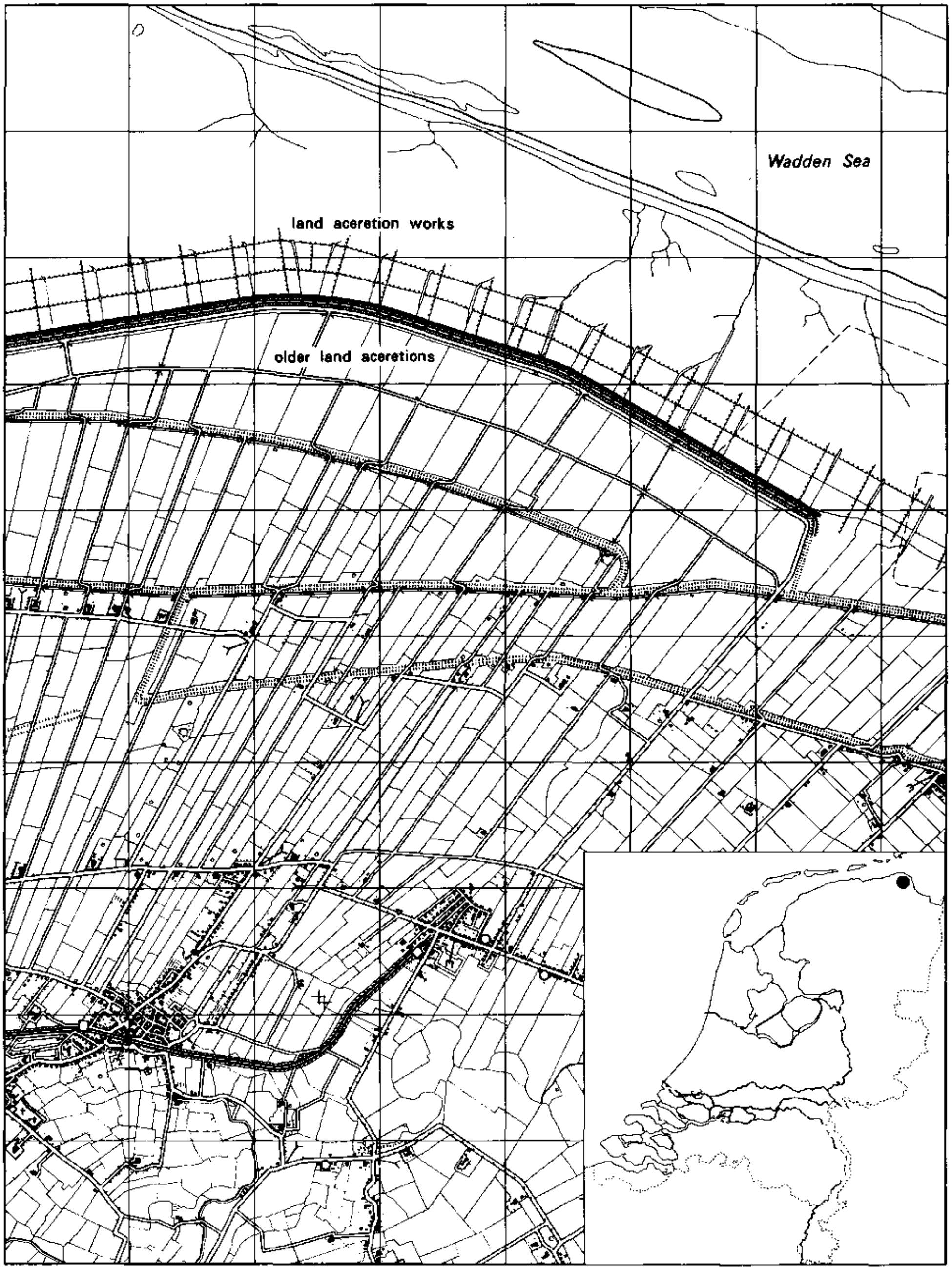

Fig. 5. Land accretion works in the Waddensea region.

realized) and an improvement of the water management of adjacent regions, subjected to saline seepage from the sea, by turning in the former Zuyderzee into the fresh water lake: Lake IJssel (IJsselmeer) by means of the Rhine distributary the IJssel.
The execution of the project has had and still has ecological and environmental consequences.
A major ecological consequence is the change from the almost saline and brackish system of the Zuyderzee into a fresh water system of the Lake IJssel. This meant for example the disappearance of the typical Zuyderzee herring, the anchovy and of waterfowl living and feeding along the coastline and in shallow waters like the Brentgoose.
On the other hand there are gains too.
The water in Lake IJssel is eutrophic and, although under influence of the Rhine, still not heavily polluted. Due to its eutrophic character the large lakes in this system are rich in food for waterfowl feeding on fish or benthos. Nowadays the mollusc, Dreissena polymorpha, which was only first observed here in 1937, is the basic food for benthos feeding ducks. The Smelt is the basic food for many fish eating waterfowl. The area ranks very high on the list of valuable west european areas for waterfowl.
Also in the polders part of the new land nowadays is saved for ecological developments; marshes, grasslands, woods and forests are and will be developed providing habitats for waterfowl, birds of meadow land and various rare or endangered species such as harriers, spoonbills and herons. In the polder Southern Flevoland, which is now under development approximately 15,000 ha of nature sanctuary and forest will be realized in a polder of 43,000 ha. These developments have to be considered in relation to the role environmental and ecological aspects have played in physical planning in the Netherlands during the last decennia. Which brings us to the second part of this paper, after concluding this part with a map of the present day ecological situation of the Netherlands as it is nowadays (fig. 6).

In the Netherlands during the 20th century a number of developments took place, resulting (as in many other countries) in a strong awareness of the importance of the maintenance of a good quality of the environment and the preservation of nature as valuable elements for the welfare of mankind.

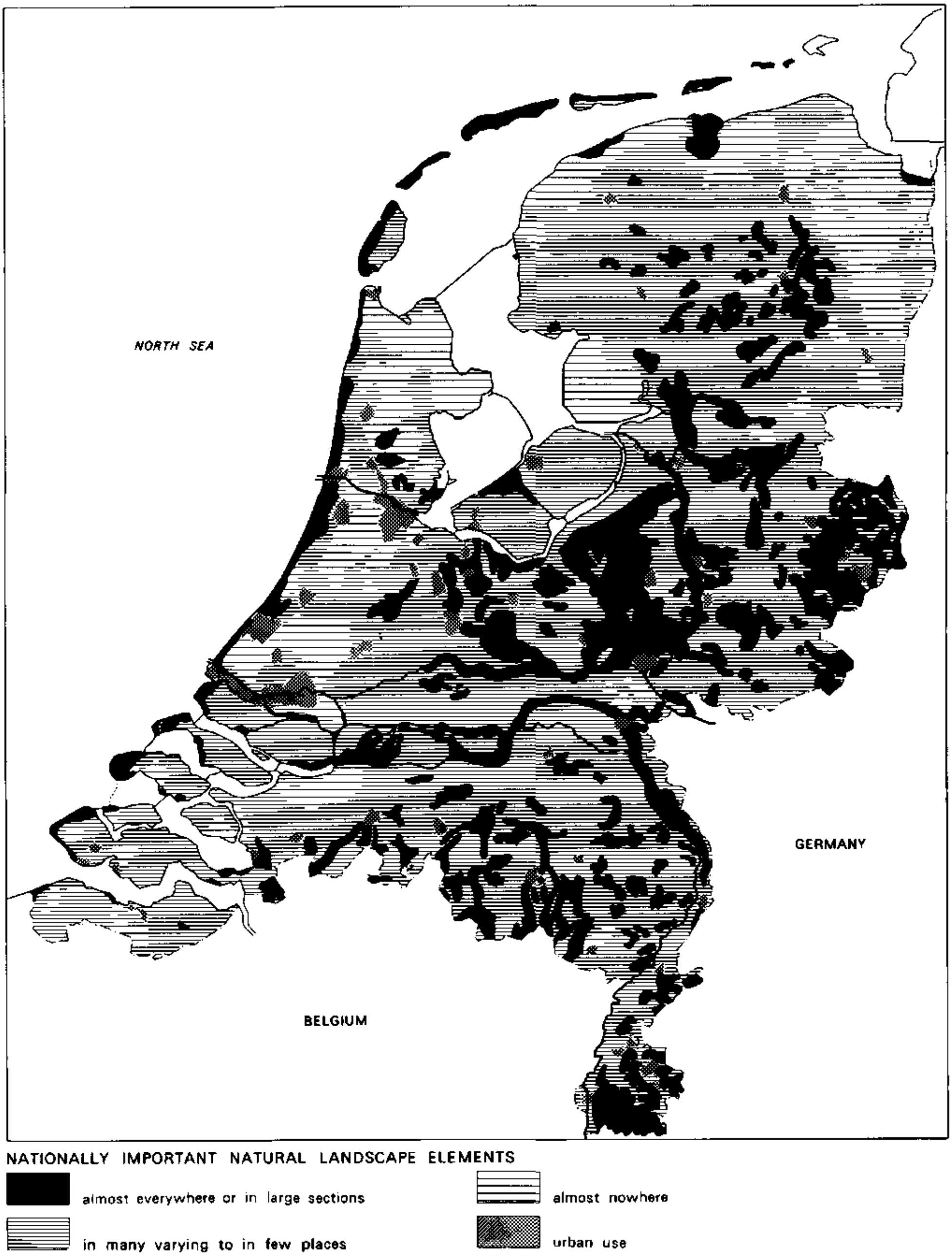

Fig. 6. The ecological situation of the Netherlands around 1975 (after Atlas van Nederland).

Developments in the 20th century

The change of an agricultural society into a modern industrialized and urban community together with a large increase in population and a still continuing mechanization in agriculture are important in this respect. The awareness of the preservation of nature originated from urban areas as well as the recognition of the importance of good environmental conditions and the need to reduce the various causes of pollution. Already in the beginning of the 20th century (by private initiatives) the first nature sanctuary, the Naardermeer, was purchased. Earlier efforts to reclaim the lake had failed and it was then planned to be filled with urban waste. Starting with the Naardermeer, the private and government organizations for nature preservation acquired 136,000 ha of nature sanctuary of different types and sizes throughout the country, together with 293,000 ha of forests (fig. 7).

The environmental movements, begun by books such as "Silent spring" by Rachel Carson, stressed the importance of combating pollution in just such an industrial society such as the Netherlands had become. Pollution of water, soil, air, groundwater, but also noise etc. had to be reduced. New legislations in this field have been developed in the past decennia and progress is being made, but still many problems have to be solved, in the urban as well as in the rural areas of our country.
Prior to the legislation concerning the environment, the legislation concerning the physical planning within the country was more developed and elaborated. Starting from national planning for urbanization and the development of the rural areas, regional and local planning was adjusted to one to the other. At the same time the process of planning was gradually being democratized.
Recently a law concerning environmental impact assessment for new projects has been proposed to the parliament, bridging and covering both physical planning and environmental planning.
However, in spite of this development of an elaborate legislation in the field of both planning and environmental protection, there has been and is still damage being done to the environment of the polder areas. This can be illustrated by considering the developments in the land use in our country during this century (fig. 8).

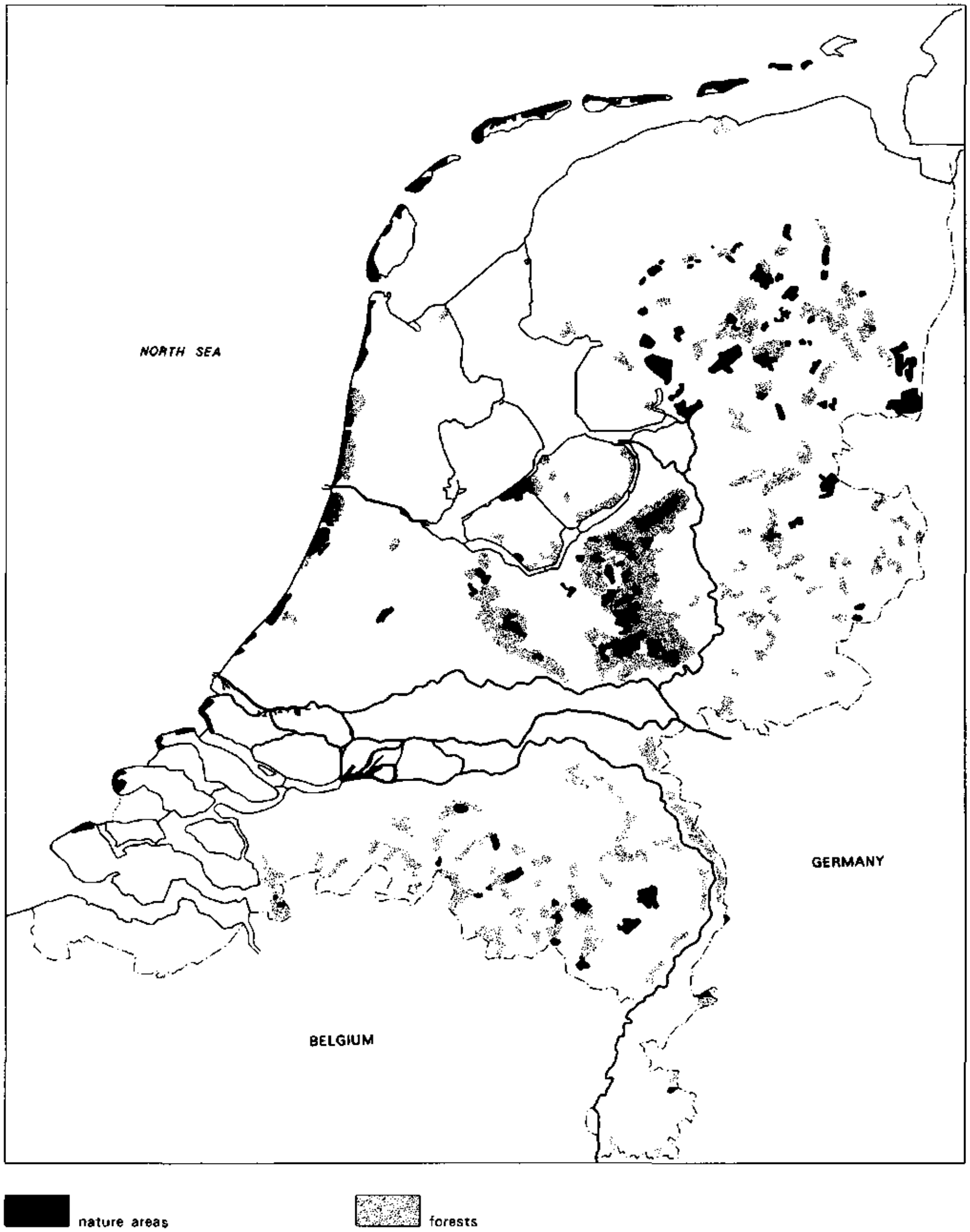

Fig. 7. Nature reserves and forest areas in the Netherlands around 1975 (after Atlas van Nederland).

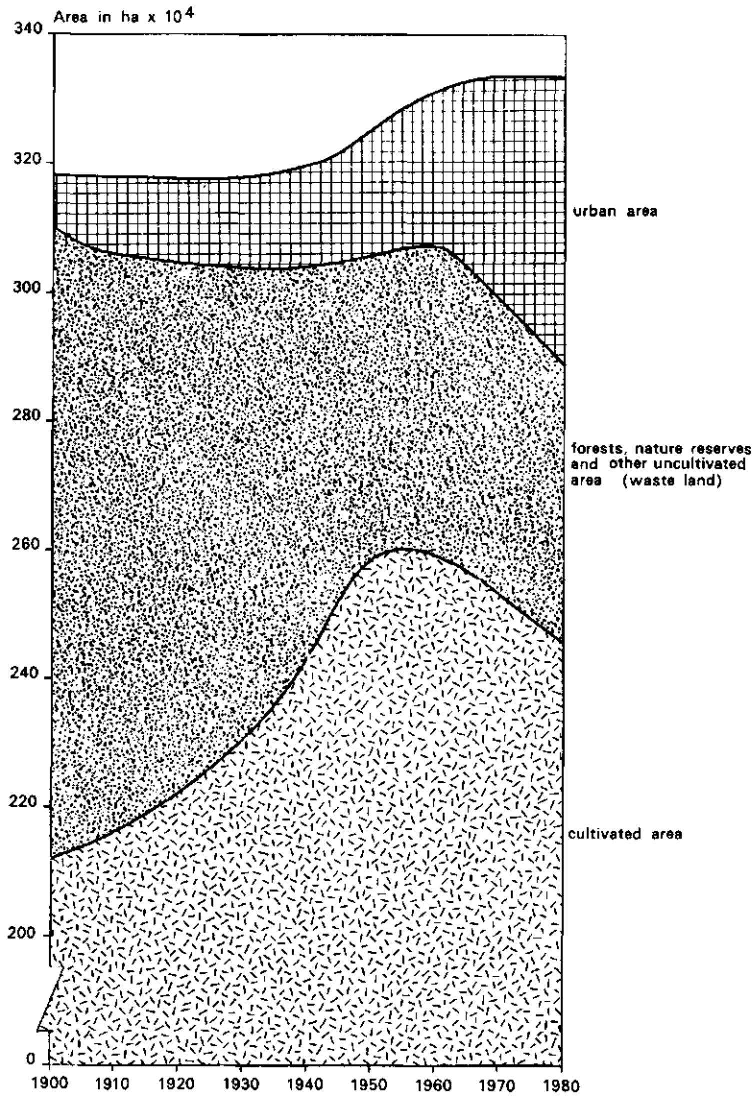

Fig. 8. The development in the land uses in the Netherlands during the 20th century.

As can be seen the total area of the land in the Netherlands has increased from almost 3.2 million hectares to over 3.3 million hectares. This is mainly due to the reclamation of the large Zuyderzee polders. During the first fifty years of the 20th century the total area of forest and waste land decreased from approximately one million hectares to about half a million hectares mostly by exploiting the waste land. The major causes were the introduction of artificial fertilizers, large unemployment in the thirties and food shortages. During the last three decennia no significant changes can be observed.
However, important changes can be observed in the size of the urban area. Due to a very strong increase of the population, 6 million around 1900, 8.5 million in 1945 and over 14 million in 1981, together with an increase in the use of the available space per person, resulted in a growth of the urban areas from about 80,000 hectares around 1900 to about 450,000 ha in 1980. It can be seen that during the last decennia, the urban expansion was realised at the expense of the area of agricultural land. The average rate of this process is nowadays about 13,000 hectares per year.
Such a process affects many polder areas, since the major part of the Dutch population lives in the western parts of the country, where predominantly polder areas exist. The impact that such a spreading urbanization and the related infrastructure can have, can be realised by considering maps of the urbanization in the region around Amsterdam in 1930 and 1975. Next to the towns and villages themselves, there is an increase in the zones of disturbancy around them by increased mobility of the people. By setting these disturbancy zones arbitrarely at 1.5 km in 1930 and 4 km in 1980, from the urban border one can see the increase of the effect of urbanization upon the region (fig. 9 and 10).

Next to this urbanization process, developments in agriculture itself such as increasing mechanization, the use of artificial fertilizers, of pesticides, the improvement of water management and the execution of large scale reallotment plans resulted in a decreasing ecological value of especially the grasslands. Their vegetation became more and more uniform. The more intensive use of the land caused the destruction of many nests of meadow birds, although some species compensated by starting

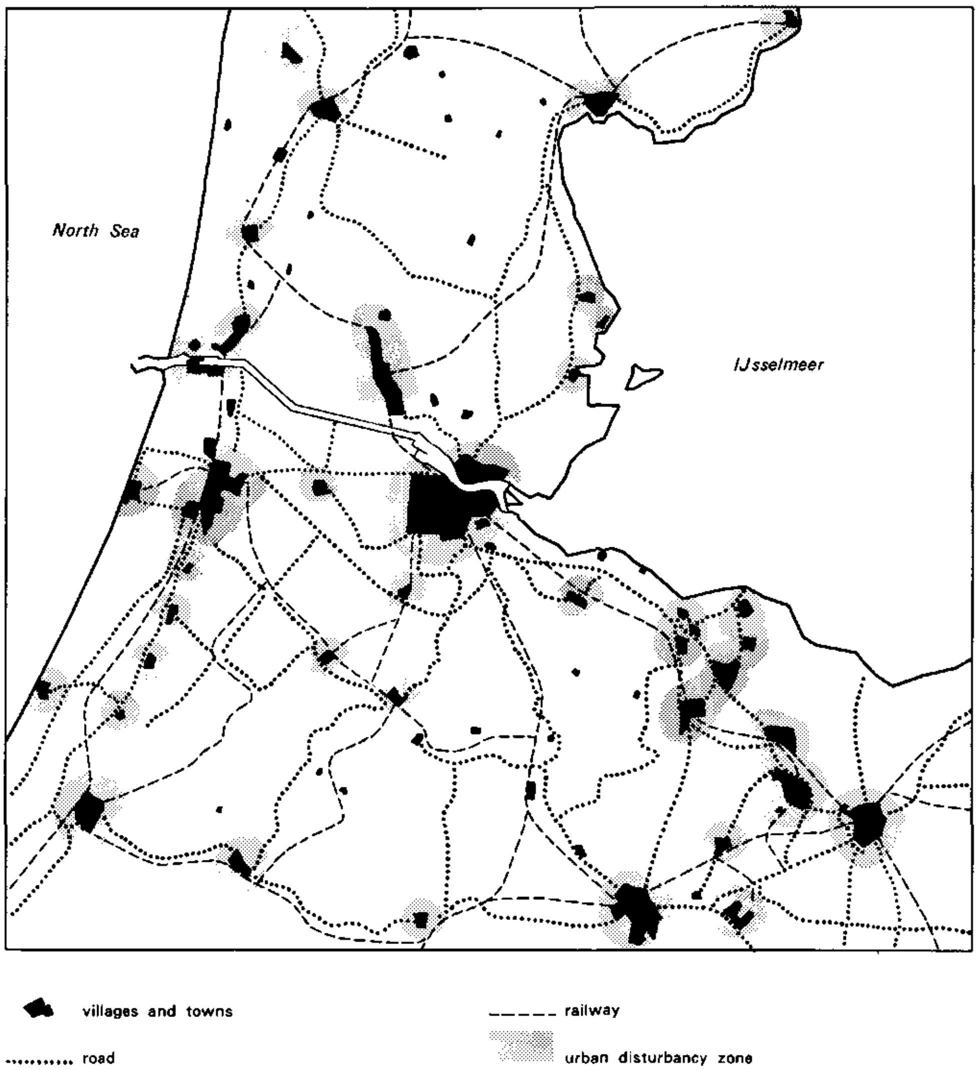

Fig. 9. The urbanisation in the Amsterdam region in the Netherlands in 1930 and the urban disturbancy zones (arbitraraly set at 1.5 km in 1930).

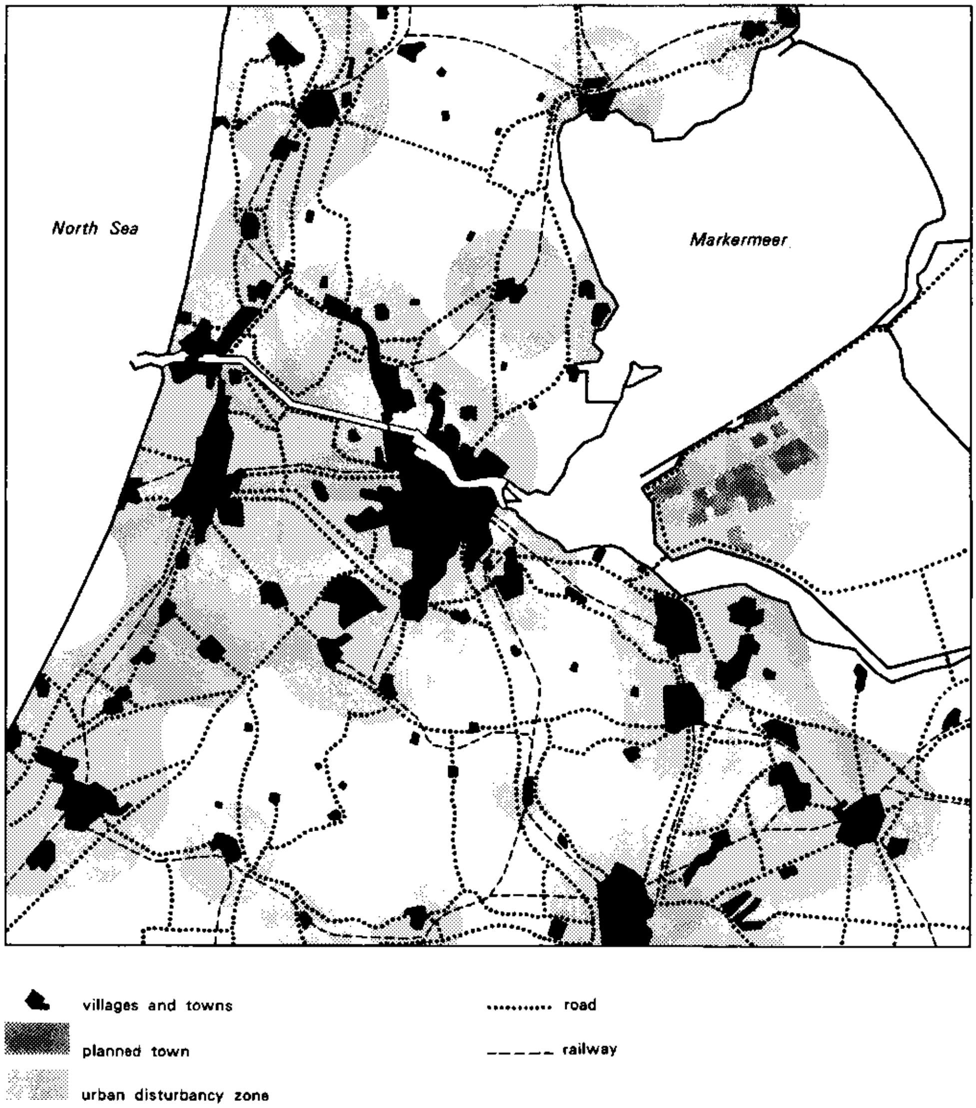

Fig. 10. The urbanisation in the Amsterdam region in the Netherlands in 1975 and the urban disturbancy zones at that time (arbitraraly set at 4 km in 1980).

breeding earlier.
Excessive use of fertilizers caused eutrophication of canals and lakes and the changing of the aquatic habitat.
The use of pesticides, such as DDT and others, resulted in the introduction of poisons in food webs, as does the discharge of urban and industrial wastewater and effluents.
Only in recent years has the effect of dumping industrial and urban wastes in polder areas become evident. Sometimes urban extensions have been realized in such regions. Afterwards it was observed that soil, groundwater and sometimes even surface waters were heavily polluted by, for example, carcinogenic solvents such as benzene and other aromatics. Very expensive soil improvement plans have already been realized in the regions near Rotterdam, resulting in costs amounting to over hundreds of millions of Dutch guilders.
In other locations, such as in the Volgermeer polder near Amsterdam, the dumped industrial waste was recently found to contain the very toxic dioxine, threatening the environment of both the city and the adjacent nature reserves.

Regarding the developments indicated above, it is not at all surprising that in the discussions about the final stage of the realization of the Zuyderzeeproject, the Markerwaard polder, ecological and environmental aspects play an important role in the difficult and already 10 years duration process of decision making. The final decision to construct the polder has still to be taken by the government and to be approved by parliament. Great efforts have been made to give reliable and quantitative predictions of the ecological and environmental consequences for both the aquatic ecosystem, that becomes smaller, and the increasing possibilities for nature in the future polder. The insight has grown. What has remained is the impossibility of weighing the two ecological alternatives, although more quantified than ever.

As a whole, throughout the country, the increase of the population, the increase of industrial activity and the urban expansion result in a spatial consumption of polder areas and hence a destruction of remaining ecological values. On the other hand the awareness of these processes and a policy aimed at preservation, reconstruction and newly developments

of nature and its integration into other means of land use, can help to prevent complete destruction.
As a result it has been observed that the number of geese staying in the Netherlands in wintertime shows a marked increase during the last ten years. Investigations in western Netherlands during the last ten years showed that the number of bird species breeding there has increased together with the actual number of breeding birds. An exception were the typical meadow birds and herons. They decreased in number of species and number of breeding birds for reasons mentioned above.
These losses have been, although partially, compensated for in the new polders.

As already mentioned, there is still a possibility for the construction of coastal polders especially in the Wadden sea. Although a number of plans are advocated in the Netherlands, as well as in Germany and Denmark it is very unlikely that they will be executed in the Netherlands and Denmark. Whether this also holds for Germany is doubtful.
In the Netherlands, it is realized that this Wadden region is too important for the food provision for many birds and for the ecosystem of the Northsea and that it is too important for shrimp fishery and shellfish fishery to be embarked upon.

At the present time there is a tendency in our densely populated country to realise a scheme of physical planning on a national level that will reduce the rate of urban expansion. It is more and more appreciated that the available space, both of land and water, is limited and scarce. The struggle and competition between various land uses can not offer solutions where available space is permanently lacking. It is to be expected that on a national level agreement will evolve about the distribution of the area over the major uses of the available space: agriculture, nature, urbanization (including recreation), forests and water. When this general agreement is reached and accepted, the integration of other functions within the principal one will help to differentiate the environment on a regional or local scale, while on the national level the destruction of the quality of the environment can be prevented.

Acknowledgements

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ECOLOGICAL VALUES OF POTENTIAL POLDER AREAS

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"If we are able to bring about in each country a proper blend of ecological economics and economic ecology, one will find that the work ..... will turn from the present mood of agony into one of enduring ecstasy" - Dr. M.S. Swaminathan, Meeting of ICSU Special Survival Committee. New Delhi. 19-2-81.

From the point of view of the environment - or the world we live in - the two principal consequences of what are usually called the "scientific and the industrial revolution" are: (1) unchecked human population growth, and (2) dwindling natural resources, including decreasing genetic diversity. The problems created by these two phenomona are compounded by ever growing demands for improved standards of living conditions, which are in turn possible thanks to the continuing scientific-technological growth and more powerful information and communication systems.

Many natural resources were, until recently, considered to be available in unlimited quantities, but it has finally been realized that none, absolutely none is so. The ocean cannot be used as a bottomless sewage sink, nor is fresh water inexhaustible; equally finite on a world wide scale is the food, fiber and energy production potential. Each and every ecosystem, every subsystem, whether a river basin, a mountain range, a forest, a village or a polder, is only part of the major Ecosystem Earth. Ecology is the study of ecosystems, where by definition and actual fact, everything is related to everything else; step by step, whatever happens in the Yssel-lake polders may have repercussions far and wide, in unpredictable manner and with unpredictable consequences.

Long gone by are the times when Europe or America could ignore the vagaries of the Monsoon in South Asia and whether millions would starve to death or survive and reproduce.

There are, of course, two possible attitudes in relation to the environment; a passive one saying: "let things be as they are and we shall see what will become", or, if you wish: "let the avalanche come as it may, we hope to run somewhere, fast enough to save our skins". But there is also another attitude which is more Manly and rational, and this is: "let us do something about it and let us avoid doing what should not be done". This attitude of do and don't man shares with some other animals, like beavers, or some birds, but typically human is the willingness to accept and face a challenge, which leads to drawing plans where all factors must be considered on a long term perspective. On steering the perilous course between the Scylla and Carybdis of development or conservation, man in the long run faces failures that are as numerous, to say the least, as success stories. In the perspective of the present symposium, it was this attitude thad led the Venetii to occupy the marshlands on the delta of the Adige and build up Venezia and the Venetian civilization; or the Frisians, who slightly later started on their first attempts to build dikes on the Frisian islands; or the people from Kerala in India who have been known to tame their brackish waters in a game of take and give with the sea since an unprecised many centuries ago.

There are some very peculiar aspects to the land/sea interface ecosystems. They are intensively dynamic systems, usually highly productive, specially in those areas where fresh water from land drainage enter into the system. They are also very variable in space and time, a condition that requires the development of special adaptive features by living organisms. Man's interference in coastal (land/sea interface) ecosystems, has invariably been one of tuning the system by reducing the variability of its parameters, both abiotic and biotic. This type of management is unavoidable, because it means preparedness against natural calamities such as unusually high tides, or floods from land drainage and rains, or, nowadays, the threats of pollution; this type of management, however, may also bring with it unexpected and undesirable consequences;

consequences in a way comprable to those of agricultural practices, enhanced by modern technologies, such as monocultures, intensive use of pesticides, fertilisers and so on.

The building up of a polder, ecologically speaking, is the reverse of conservation activities. It is, for instance, the opposite of establishing a biosphere reserve. When we establish a reserve, by definition we avoid introducing changes of any sort, since the system is to be left undisturbed in order that the natural transfer of matter and energy among components within the system and between the system and the adjoining ones may proceed according to the systems' own laws. On the other hand, when a polder is built, very often it begins from scratch. Entirely new soil is accumulated, then turned into agricultural, urban or industrial land. This is what the Aztecs, for instance, had done when they built the floating gardens, which were literally floating on rafts in the lake of Texcoco because they needed soil in which to plant their vegetables (the remains may still be seen at Ochimilco, where the floating rafts have become islands, through trees that have grown tall and taken root). Similarly the Maldivians enlarge their small coral reef islands for more space on which to live by building sea walls and groins to trap sand. Polders and reclaimed land in general, are new systems that need to be managed by appropriate <u>do's</u> and <u>don'ts</u>.

The building up of polders inevitably takes space away from adjoining systems, the consequences of which must also be considered in the long term planning, to maken a cost/benefit assessment; certainly the "robbed" systems also had a structure and dynamics of their own and a production potential that should be known. If a tiny coral reef island is enlarged, area wise it will be less than a speck of dust in the immensity of the oceans, but may cost a serious environmental impoverishment if the enlargement is at the cost of destroying slow growing corals and the rich fauna associated with them.

Polders are man made systems, in which, according to place and circumstances, the biological element by rank as of primary importance, or may, perhaps, be totally neglected except for the convenience of the single species. Man, who needs a place in which to live and space for recreation. In other parts, of the world, however, polders are considered entirely for agricultural production, including in this perhaps also aquaculture, and they include many different species, in addition to man the plunderer, the species for whose exclusive benefit the polders are being built. There are, therefore contrasting requirements - or values, if you wish - according to the place and purpose for which polders are being built. The parameters to be selected, measured and quantified for a sound management vary in essence and magnitude. What may become a "don't" in one area, could very well be the main "do" in another. Since purposes vary, and so do values, "do" and "don't" must be defined anew in each case.

In the management of polders, like in other systems, probably the general aim would be to bring about what Swaminathan called "a proper blend of Ecological economics and economic ecology". Ecological economics has a very difficult task to perform, because ecological values are hard to define and qunatify in terms such as would be accepted by economists, but it also is a challenge to the human mind that is fascinated by difficulties to be conquered. The imponderables that determine the quality of life for man and that contribute in no small measure to make of any endeavour of this kind a success or a failure case are only too often left out of the picture and only a posteriori it is found out that such factor or other really should have been taken into account because it plays an important previously unsuspected role in, let us say, the food chain or in the transmission of diseases. In fact, everything is important, every species and every association of species, because if it did not play an essential role, it would have long since been weeded out of the system by its natural evolution.

Since it is impossible to obtain total information on everything and since we are characteriscally always in a hurry, we cannot wait to have complete information on everything before taking action, a compromise is sought and .... let us hope for the best.

Almost all life suport systems, almost every where in the world, are nowadays under stress, if the building of polders is carried out with a single purpose in mind, as for instance added space for man, or economic development through industrial growth, it could become a disastrous enterprise. Monotonous ecosystems are fragile, it is diversity that gives stability to ecosystems, whether natural or man made. Potential polder areas may be found all over the world, at low or higher latitudes, especially low lying coastal areas with sand bars, or coastal lagoons, mangrove swamps or forests, wetlands and marshy areas and along estuaries and deltas. Sand bars are in fact usually the starting place where engineering works for reshaping the landscape begin, by building dikes and water level control devices by sluice gates or spillways. Often the impounded area, after water is drained off, is lying below sea level, also in many places in the tropics. Coastal lagoons are admirably suited and innumerable could be cited. For instance, along the 8000 km long coast of Brazil, the Lagôa dos Patos and Lagôa Mírim cover hundreds of square kms. Extensive reclamation has been carried out all along its history in the Baía da Guanabara (Rio de Janeiro) and many of the coastal lagoons are under intensive aquaculture (ex. Lagôa de Maricá, north of Rio de Janeiro) through managed impoundments of brackish water, a practice introduced in the early XVII century for the Portuguese, who had inherited the know-how from the Romans and used the same methods. Even now, grey mullet ponds in the area of, for instance, Recife, are comparable to the acquaculture impoundments in the Campania, and other places in south Italy, where methods are still very much what they were almost 2000 years ago. Values, however, have changed and works which were carried out mainly to manage the natural system to put it to a higher production level for those items of interest to man, like fish, have now given way to works for expanding traffic areas and improve communications, build airstrips and airports or enlarge the industrial area. This was done very often in a hurried manner, without due consideration to local physiographic conditions, specially water circulation and major problems of pollution have cropped up. Times have changed, so have needs and the means to satisfy them.

In Asia, the practice of building dikes for impounding water and developing low lying areas is a practice that goes back to remote times. The people of the Moenjo-Daro/Harappan civilisation built canals and harbours in which the flow of water was regulated according to the needs of navigation of their large covered two-three deck ships as early as the laste fourth millenium BC. In present day India there are 2 million hectares of backwaters, 30,000 hct of which are under aquaculture, mainly for prawns. These include the deltas and estuaries of major rivers as well as coastal lagoons and lakes. Low cost, labour intensive, simple technologies are still in use even where extensive engineering works are involved. Traditional methods and techniques, that have proven their worth over centuries are still in use often in contrast in the same areas, with modern technologies. Thus in the Cochin backwaters (Malagar coast, southeast India), the bund across the Vembanad Lake is being built over a span of decades while further north, in the same backwaters several polders and new waterways were recently built in only a few years for the development of Cochin port and Cochin shipyard. The Cochin backwaters are a particularly interesting example. It is a vast area that extends from about 9^{o} lat. N. to less than 7^{o} lat. N. Extensive "bunding" (dike building, where dikes may be simple mud walls 50-100 cm high above mean water level and repaired yearly after the SW monsoon or major structures built with rocks and other materials) has turned an area that includes many taluds of three districts into a polder lying below sea level. In this area fields are managed for rice cropping and aquaculture all in one. A special variety of paddy was developed over the years which is salinity tolerant, brakish water is admitted during the intermonsoon period, for aquaculture purposes. The management of this area has characteristics of its own and problems of all sorts, not least of them those of land and water use taxation and social relations that become acute now and then. The Kuttanad area is to this day the rice bowl of the State of Kerala. In other places, in the same backwaters and outside of the Vembanad Lake protective bund, small areas which collectively cover some 500^{2} km are individually diked off into fields flooded during the SW monsoon for paddy cultivation and some fish also are reared along with paddy. After reaping the rice, when monsoon fresh water from rains and land drainage have ceased to pour in, brakish water gradually inundates the backwaters where maximum salinity reaches 31-32% at most. During this period, the sluice gates, provided with special nettings are opened during the incoming tide to admit into the fields the larvae of prawns, mainly <u>Penaeus indicus</u>. The larvae grow in the same fields where paddy grew during the monsoon under 1-2% salinity. The prawns (chemmeen) are harvested before the onset of the next monsoon, when, if they could escape, they would migrate back to sea to metamorphose into adults and assemble at a certain distance and depth offshore, where those that had not been trapped, are able to mate and reproduce.

The bunds that make up the checkerboard of fields are planted with coconuts and chinese overhang the major canals. The waterways are, in addition, the major ways of communication, transport of goods and passengers as well as mail. Most of the traffic was done until recently and still vastly so at present, by "village" craft, unmotorised and propelled by oars and poles. The owners of the fields do the planning of the paddy and harvest the coconuts, but fields are leased to fishermen who do the prawn cultivation and weed them from carnivorous fish, allowing only the growth of harmless species of fish in addition to prawns. The success or failure of the prawn harvest is almost entirely due to the ability and expertise of the elder fisherman who operates the sluice gates at the appropriate time to let in the larvae which he cannot see and does not know they exist. No fertilisers are used except human, fish and prawn excreta. The productivity in fish and prawn averages 2,300 kg/hct/season. It could well be increased by modern techniques.

The reason why I have dealt at some length with this particular example is, first, I am familiar with the area and have first hand information but there are many more similar systems in India and Asia; second, it is a good example of wise tradional use of natural ecosystem, and the human and ecological values attached to it. The Cochin backwaters must undoubtedly have been a major mangrove area in the remote past. Small, isolated pockets may still be found. The conversion of a mangrove ecosystem, which is a highly productive one, although of reduced direct utility to man, into a different ecosystem with a much higher production rate of crops of direct use to man, was achieved gradually, over centuries of hard labour and through the accumulated wisdom of people who live in close communion with the system of which they are also an important component. I would presume that, as they were until a couple of decades ago, the Cochin backwaters have reached their maximum production potential, except for improvements that could have been introduced through modern agricultural practices. Troubles, however, started when fertilisers and pesticides were used upstream and were flushed through the system with monsoon land drainage water. At the same time, other polluting agents also set in, such as oil, increased siltation, increasing sewage discharge from growing human settlements and towns and the tampering of the natural hydrographical pattern of circulation due to the construction of harbours, shipyards, airstrips, jetties and the like. In addition, labour has become more expensive while hard work is necessary to keep the structure of the system in proper order throughout the year, including desilting of canals, repair of bunds, sluice gates, nets, plowing, the fields mud flats, tending the coconut trees and so on. Much of the labour done by local traditional experts was taken over by the Land Development Corporation that uses mechanised methods that can do the job quicker but perhaps less well. The excessive use of fertilisers upstream caused eutrophication of the "lake" waters and much of the backwaters have become covered by water hyacinth, hampering navigation and causing all sorts of troubles. In "old times" appropriate drainage canals removed excess salinity from the below sea level areas and the monsoon rains could wash off the sulphides and the acidity produced during the period of stagnant waters. Paradoxically, improvements introduced through modern technologies have created previously unknown problems and one reason is that a natural ecosystem, even if already domesticated ant tamed by man, cannot take abrupt changes; it needs a period of adaptation and acclimatization to the new conditions. At present, a lot of money is being spent on research and survey in order to correct the imbalances produced. The Netherlands themselves have a scheme in the Kuttanad area and UNESCO may help in conducting some research projects. We might, perhaps, close the circle and come to the conclusion that it could not be better than what centuries of experience had achieved.

If we try to compare the Dutch polders, the achievements and problems in this country, with, perhaps, the Cochin backwater system, we would perhaps conclude that no parallel is possible. We would be comparing systems with totally disparaging ecological values and the conclusion is thus unavoidable that each case is unique and merits a special study. Special studies that will and do, in practice, increase our understanding of estuarine, deltaic, and low lying coastal areas in general. The type of reclamation that may be advisable for a territorially small country as Holland may be the only solution to big problems of space and agriculture, even at the cost of sacrificing important "ecological values". They may, however, well be totally inadvisable in other areas where these same ecological values, including human values, take the precedence, since the whole system has already evolved over the centuries to such a level of perfection that the only likely improvements would be the use of modern methods to increase the production level. Under this I would include the production of higher yielding varieties of paddy, starting from those varieties that are already adapted to the conditions at large, the same for coconut, prawns and other species of fish and molluscs. The bunds could be improved materially, the hydrography better understood and the manoeuvering of the doors (or gates) should be based on a scientific understanding and explanation of the ancient empirical wisdom.

The problem would always remain of drinking water supply. Typically, in the reclaimed areas behind the Vembanad Lake bund, tubewells only bring up foul smelling water, obviously due as expected, to the high content of sulphides.

In conclusion I would like to say that in keeping our eyes open to the fact no total conservation is possible, we should, as is now being done in the Netherlands, try to analyse all factors carefully, work out cost/benefit budget analyses and try to find out all the important factors that may perhaps not appear to be such at first sight, that may be difficult to quantify and that may remain in disguise and unperceived for a long time even if in the long run they will turn out to be decivive in determining the quality of life of the people.

SPECIAL KEYNOTES

- *A. Volker*. Lessons from the history of impoldering in the world
- *B. Verhoeven*. Polders of the future

LESSONS FROM THE HISTORY OF IMPOLDERING IN THE WORLD

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The history of impoldering in the world is of interest to the hydraulic engineer provided that technical problems were solved under different conditions with the means available during different historical periods.

The history of impoldering in the world is of interest to the history of the human civilization provided that an analysis is made of the factors which in different societies and at different times in history were determinant for impoldering. History can be instrumental in better understanding the present conditions and in indentifying the factors which played a role in history and which will continue to play a role in the future.

The history of impoldering cannot be divorced from the history of the topics of flood protection, drainage and irrigation. Indeed, impoldering is a special form of integral reclamation and involves a combination of flood protection, artificial drainage and often irrigation.
The history of flood protection, drainage and irrigation is, most unfortunately, a little explored area.

In this essay an attempt will be made to analyze the facts from the history of impoldering so that some factors can be indicated which have been determinant in the past and which will also play a role in the in the future.

1. Ancient polders

In this section some facts will be presented about early impoldering activities. An analysis of the technical and socio-economic factors, which were conducive to impoldering, will be elaborated in section 4.

Impoldering is a special type of land reclamation applied to specific landscapes. It comprises flood protection, artificial drainage and often irrigation and for this reason the history of impoldering is a part of the history of hydraulic and agricultural engineering for achieving flood protection, drainage and irrigation. Unfortunately: "engineers have made history, they have even changed the face of the earth, but they failed to record it". The history of flood proctection, drainage and irrigation is an almost unexplored field and it is only recently that the "International Commission on Irrigation and Drainage" (I.C.I.D.) decided to solicit international co-operation for writing that history.

Professor Hitoshi Fukuda from Japan (1976) considers the embanked flood basins which in ancient Egypt were used as retention basins, and in the saturated soil of which a crop was grown after the Nile flood, as "polders". These basins do have some common characteristics with the systems which are usually called polders and as exist to-day, als in Egypt, in the reclaimed lakes in the northern part of the Nile delta, but which function in an entirely different way. If the definition of Professor Fukuda is accepted, the oldest "polders" in the world were reclaimed in Egypt some five thousand years ago.

If however these Nile basins are not considered as polders one has to look at those ancient civilizations where the control of water played a predominant role and which were denoted by K. Wittfogel (1957) as hydraulic societies with a hydraulic agriculture. Many thousands of years ago embankments as means of flood protection and irrigation canals were built in Egypt, Mesopotamia, in the valleys of the Indus and the Ganges and in China, Peru and Central America, but it is not certain whether the works can be defined as impoldering as it is understood to-day.

Paul Wagret (1959) has drawn attention to the reclamation during the fourth millennium of the marshy low-lying areas of Mesopotamia by the Sumerians. They skilfully maintained these prehistoric polders which are criss-crossed by ditches and canals. A Sumerian text tells of the farmer Enkimdu, "Lord of the ditch and the dyke". The fact that the ditches are so expressively mentioned may indicate that the works comprised more than flood protection. Indeed reclamation of marshes nearly always involved impoldering.

So far as Europe is concerned Wagret considers the reclamation by the Etruscans of the Pontine marshes in Italy some twenty-five centuries ago as the beginning of impoldering in Europe. The Etruscans were renowned as great engineers and may have acquired the science of hydraulics through trading connections with Mesopotamia. The works feel in disuse after the third century B.C. and were not restored during the Roman Empire.

For the purpose of this study the mere question of senority or antiquity is not so important. More can be learnt form cases where information is available as to the technology and the socio-economic framework in which impoldering was carried out. Thus two countries, the Netherlands and Japan, come to the fore where the eminent role they have played in the history of impoldering dates back to the last thousand years only.

In both cases the origin of impoldering and tidal land reclamation is obscure and one has to wait to the 16th and 17th centuries A.D. before it can be clearly seen under what conditions impoldering was carried out and why. Nevertheless the earlier history is still of some significance for the purpose.

2. History of recent impoldering in the Netherlands

Long before the beginning of the Christian era people had settled on the coastal marshlands of the Netherlands. There were no sea dikes and during periods with abnormally high sea levels caused by storm surges in winter they sought refuge from flooding on artificial hillocks ("terpen" or dwelling mounds). Shortly after A.D. 800 this system of passive defence against the sea floods was gradually replaced by a more active defence in the form of coastal embankments, first as dikes connecting the dwelling mounds, later as dikes encircling land areas destined for grazing and growing crops so in more offensive way. In the period 1000-1200, many dams with sluices in the creeks were built enabling some degree of water control in the embanked areas, thus creating the first real polders in the Netherlands. In the same period inland marshes were reclaimed thus creating inland polders.

Why did people do all this? Because of increase in population and the associated need for more food? (Malthus). Because of a rise of the sea level accompanied by land subsidence *) (challenge and response). Because of cultural aspirations and the desire to create cities where life would be more enjoyable and which would made it necessary to reclaim nearby for food production? One is not sure about it but these incitements played a role in many recent cases of land reclamation.

That people did settle on the coastal marshes more than two thousand years ago is understandable because these lands offered better possibilities for a living than many poor sandy and dry lands in the immediate vicinity. They could not foresee that their situation would deteriorate in the course of time and that their successors would have to face enormous problems with respect to safety, drainage, foundations of structures, sea water intrusion and water quality. Perhaps, they did not worry as much about the future, as many people nowadays think we should do. If one wants in engineering circles in this country to show its intelligence, one should state that if two thousand years ago there had been a physical planning institute in Europe, the low-lying part of the Netherlands would never have been identified as one of the most promising areas for human settlement and intensive economic development. Actually our distant predecessors took the right decision independently

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*) The relative subsidence was mentioned for the first time in a session of the Court of Holland as early as 1570. In 1730 the subsidence was estimated at 30 centimetres in 100 years, a figure which is not too far from the correct one.

of the physical planners in after years and that decision was to impolder and to accept all the side effects and consequences of that decision. Towards the beginning of the 16th century a technical innovation is appearing on the historic scene acting as a "vector" or vehicle for the transfer form one technical era to another. It is the windmill which was made suitable for driving drainage pumps by providing the mill with a revolving cap so that the wings could be turned according to the direction of the wind.

Up till then, like in other parts of the world, drainage had been effectuated by gravity flow using, in the coastal areas, the tidal variations. Where no gravity flow was possible, various types of pumps were used for drainage as well as for irrigation driven by human or animal power. This technology has its obvious limitations and the reclamation by drying up of normally submerged lands, like lakes, lagoons and tidal inlets could only be achieved by using wind power which, in the Netherlands, is readily available. The time of acceptance of this new form of energy was more than a century and the environmentalists of that time opposed the innovation on the grounds that the repidly rotating heavy wings would be very dangerous to man and that the birds would stop laying their eggs.

Another technical innovation, meeting less opposition, was the introduction of the so-called mud mill, the forerunner of the bucket dredger, enabling to move earth under water. Also the first manual or textbook on civil and agricultural engineering aspects of tidal land reclamation was published. So the technical vectors were there but this condition is not sufficient to explain what happened in the Netherlands towards the end of th 16th century and during the better part of the 17th century when reclamation by impoldering was carried out of many inland lakes and tidal forelands and which form one of the peak periods in the history of impoldering in this country.

In fact this period was also the "Golden Age" of the Netherlands, a period with overseas trade, succesful war against England and - at least till the latter part of the century- friendly relations of a "Real-Politik"-type with France. A new social class of self conscious

rich merchants came to the fore, business men who were looking for oppertunities for capital investments.
Professor Slicher van Bath, who studied the agrarian history of Western Europe in the period 500-1850, has drawn the attention to the price revolution in the years 1550-1650 which he attributed to an increase of population and an increase of (gold) currency. The first repercussion was a rise in prices of food stuff, in the first place of cereals. This created favourable economic conditions for agriculture and for an expansion of the arable area. Reclamation of new land was undertaken not only in the Netherlands, or "United Provinces", as they were called at that time, but also in England, France and Italy. As far as this was carried out by impoldering Dutch experts were often invited to participate and there have even been cases of capital supply by Dutch business houses.

Slicher van Bath has shown that there exists a close correlation between the index prices of wheat and the acreage of reclamation by impoldering in the Netherlands during the period 1500-1900. The most striking feature is the sudden drop of the latter around 1675 and the small activity during the 18th century. This goes along with a drop of the wheat prices but was this the only reason? There had been around that date an important change in the political relations with France. Louis XIV (+ 1715) had abandoned the realistic policy of his predecessors like Cardinal Mazarin and Cardinal Richelieu who had maintained business-like relations with the United Provinces. Misled by his ambitions Louis XIV waged war with the United Provinces who suffered a serious defeat in 1672, a blow from which, according to an English historian, the United Provinces never fully recovered. During the next century and during the Napoleonic era very little was achieved in the field of impoldering.

The most important activity during the nineteenth century was the drying up of the Haarlemmer Lake in 1852, where nowadays Schiphol Airport is located. Again a decisive technical vector appeared in the form of the steam engines for driving water pumps. It was justified on the grounds that the lake threatened the adjacent land areas by wave erosion. The cultivation of the dried up lands almost became a failure because of too little interest in the socio-economic aspects of the undertaking.

In this century the largest impoldering scheme in the history of the Netherlands has been implemented and almost completed. It is the Zuiderzee project, the enclosure and partial reclamation of the Zuiderzee. It differs from previous schemes not only because of its size but also because of its nature: it is a typical multi-purpose scheme aiming at an increase in safety against floods, gain of arable land, siting for new cities and industries, halting salt water intrusion, storage of fresh water, improvement of drainage, shortening of road communications, etc. This is recent history and we could, perhaps, not yet take sufficient time distance to be able to give a historic evaluation. Some essential independent variables, however, are easily identifiable: availability of powerful technical equipment, response to the defeat caused by the storm surge of 1916, damage due to salt water intrusion, need for more arable land, etc. Yet one may doubt whether in another case the input of these variables would have produced a similar output. Is there still another variable then which - so far - has not been met on the historic scene?

It appears to the author that this variable was the high degree of authority and self-confidence of Government and Parliament who in 1917 took the formidable decision to implement the Zuiderzee scheme which would change the geography of a large part of the country for many centuries to come. This in spite of the opposition of the environmentalists of that time. One may doubt whether the present generation and its political representation would have the courage and the power to take a decision of that scope to-day. Fear of pressure groups and lack of vision are the two variables producing nowadays negative effects.

3. History of recent impoldering in Japan.

Impoldering is an ancient technique in Japan. It was carried out in a physical and cultural setting entirely different from that of the Netherlands. For about two centuries development took place independently from the techniques of the western world. Nevertheless there exists a striking parallelism between Japan and the Netherlands with respect to the factors that were determinant for impoldering.

In Japan paddy fields were cultivated more than 2000 years ago and also tidal and land reclamation by the farmers is an centuries old practice, although not as old as in China. Unfortunately little is known about technology and other variables that conditioned the reclamation by impoldering. In annals the year A.D. 1284 is mentioned as date of the first tidal land reclamation near Kawajiri, but this may have been development of land raised by river deposits and tectonic movements. More is known about the more recent period of the end of the 16th and beginning of the 17th century, a period of great activity in the field of impoldering, a period coinciding remarkably with the peak period of reclamation in the Netherlands. This fact and the fact that the Dutch East Indies Company was allowed from 1600 onward to exploit a commercial house at Nagasaki, Kyushu, very close to the site where tidal land reclamation was carried out, have led some people to the belief, that Japanese technology of impoldering of that time was influenced by a transfer of Dutch technology. It may be questioned whether this is true: when studying on location traditional methods of tidal land reclamation in Japan the author could not find any indication for such a transfer. In his opinion Japanese impoldering technology developed independently from the European technology which renders it all the more interesting. However, things changed completely shortly after the Meiji Restoration of 1868 and again after World War II.

The years around 1600 mark a period of profound changes in the Japanse political and economic system. The system was - and would remain till 1868 - a feudal system with daimyō or barons governing their fiefs with only a nominal vassalage under the Emperor. In the absence of a powerful central government the clans and lords of castles were fighting each other to conquer land and to increase their possessions. The country was pacified in 1615 by two generallissimos, Hideoyoshi and Tokugawa Ieyasu (+ 1616) who succeeded in establishing a central power, the so-called Tokugawa Shōgunate at Yedo (Tōkyō) while the Emperor continued to reside at Kyōtō. Whereas the daimyō remained in possession of their fiefs they were no longer allowed to wage war and the only posibility to increase their territory would be to gain land on the sea.

The decision of the Tokugawa Shōguns to perpetuate the military organization of the country in times of peace, as Sansom expresses it, entailed an economic problem of considerable magnitude. The local economy with payments, also of taxes, in kind had to be changed into a monetary economy. The expenses of the Shōguns and the daimyō increased rapidly in consequence of the civil works of the Shōgunate, impacts of calamities, attendance at the court of the Shōgun at Yedo and double luxurious livelihood in Yedo and in their own fiefs on the part of the daimyo. Thus both parties were gradually driven to economic stringency. To cope with the situation various measures were taken, one of these being the development of new land.

In the same time as one sees in Holland a gifted builder of windmills, Leeghwater, in charge of impoldering works, in Japan a talented man appeared on the impoldering scene: Kato Kiyomasa. He was not originally an artisan, like Leeghwater, but a daimyō, and he is known in the history of Japan as a general and as an architect of fortified castles. It was perhaps through him that the traditional design of the Japanese polder dikes was developed consisting of a stone wall with a steep facing at the outside, a clay fill and another stone retaining wall at the land side. It is said that he started his engineering activities when he was still young and that he supervised the works personally spurring his favorite horse. The Japanese engineers acquired a special skill in building heavy stone walls on a very soft subsoil.

A second important stimulus for the impoldering was the way in which the works were carried out. The daimyō commandeered farmers to do the work and - as a compensation - the new lands were handed out among them when the works were completed. When the lands became productive more land-taxes could be collected and in this way both parties benefitted from the impoldering works. Thus - just like in the Netherlands - the 17 th century became a peak period of the history of impoldering in Japan. In a later stage, when rice prices jumped up, tidal land reclamation was also undertaken by trades men although, in general, this type of investment was not considered as a very attractive one owing to the risk of destruction by the typhoons.

In the same period, in France, King Henry IV (+ 1610), the most popular king in the history of France, succeeded in about the same manner as the

Shoguns in Japan to halt the wars between the feudal lords, to unify the country and to undertake many schemes of land reclamation including impoldering of marshes.
The Meiji restoration in Japen (1868) which changed the history of the country even more than the Tokugawa Shōgunate of 1615 had also a profound effect on impoldering, especially on its technological aspects. In 1870 a group of Dutch engineers including artisans sailed to Japan to work there for 10 or 20 years. They introduced the western technology in the field of hydraulic engineering which was so to speak super-imposed on the traditional and indigenous technology. Mention should be made especially of the project for the enclosure and partial reclamation of Kojima Bay near Okayama, a scheme similar to that of the Zuiderzeeworks in the Netherlands which - at that time - had not yet started. The enclosing dam of Kojima Bay was not completed before 1956 but the polders were reclaimed earlier.

Unlike in the Netherlands, in Japan, in the years twenty and in the thirties of this century, the political conditions were not favourable for impoldering. Things changed completely after World War II when Japan saw itself confronted with a shortage of food and the necessity to find a livelihood for repatriating farmers. Peaceful conquest of new land from the sea was taken up again and contacts with the western engineering world re-established.

Two facts of historical significance emerge from this postwar period. The first is the technical feasibility of impoldering of land which is normally by several metres under conditions of heavy tropical rainfall. The survival of the deep polders created under these conditions depends on the proper functioning of the protection dike and the pumping devices to keep out the surrounding waters and to drain off excess water from local rainfall. With the drying up the lagoon Hachiro-Gata in 1966 Japan joined the group of countries where such deep polders had been reclaimed previously or came into existence by subsidence: the Netherlands, Poland, Denmark, India (Kerala State), U.S.A. (California) and Egypt.

The second fact refers to the economic justification of sophisticated polder projects. According to the commonly used methods of economic evalution a comparison is made between the costs and the benefits of the project discounted according to an interest rate to the present-day values. With the present high rates of interest this means that benefits obtained in say 20 to 25 years from now represent very little money to-day. However most of the hydraulic works of a polder like embankments, canals and sluices are serving for many hundreds of years. But in the standard economic evalution it does not make any difference whether after 20 or 25 years these works would still exist or not. This is a paradox indicating, that the commonly used methods of economic evalution are not suitable for projects like irrigation, drainage and impoldering. They may be appropriate for appraising industrial investments where machines do become absolete after such a short period of time.

All large scale impoldering projects, carried out during the past decades in countries like Bangladesh, the Netherlands and Japan, are not economically feasible according the standard criteria of benefit-cost ratio. Yet their implementation and financing were decided upon by the governments concerned because of their significance for the future of the country.

4. Analysis of the history of impoldering

The study of the history of impoldering in the Netherlands and Japan has produced a wealth of historic facts and some consideration of factors that have been determinant in that history. These factors or variables are of various nature: technical, economic, social, political and psychological. This leads to the conclusion that this history has been a complex matter, a fact which also applies to other fields of history.

Recently the French geographer Bethemont made a classification of these variables as an approach to a new theory on the generating factors of irrigation, drainage and flood control. Since the same factors must have been active in the history of impoldering his study, presented in the framework of the I.C.I.D.-project mentioned earlier, is of particular relevance.

Bethemont classifies the "independent variables" in three main groups, viz.: the incitements for a change, the existence of favourable "vectors" and a society which is favourable and receptive to changes. He considers these variables as necessary but not sufficient for the "genesis of hydraulic environments".

The incitements comprise factors already encountered in the analysis of the history of impoldering in the Netherlands and Japan such as: population increase, economic perspectives and crisis and changes in the natural environment but also factors like succession of dry years and cultural aspirations. Some of the incitements can be indicated as the "challenge and response" group.

Under the vectors appear the technological stimuli, also mentioned earlier, and also the traditional staple crops often associated with various forms of religious cultes like wet rice in South East Asia and mais in South America.

The societal group comprises the requirements of a minimum of stratification and coherence for the establishment of an organization for the implementation and operation of hydraulic schemes. Also the existence of a class of technicians. He concludes that at a certain stage of spatial development and technical evolution the essential element in the development of hydraulic environments is the existence of strong social structures capable to impose technical constraints like the collective management of the systems and also to assume a joint defence of the reclaimed area.

The work of Bethemont represents an important step in the integration of the history of irrigation, drainage and flood control into the general history of mankind.

There is one group of incitements which has played a particularly relevant role in the history of impoldering. It is the group related to challenge and response. Polders along certain sea coasts and certain rivers are very vulnerable and natural disasters caused by storm surges at sea and river floods are likely to occur. What will be the response of man and what factors determine that response?

There is a psychological aspect of that question as well as a technical point. Man is naturally inclined to forget about disasters and factual experience on it is only to a small extent transferable from one generation to the next one. But nature gives no respite and sooner and later the blow comes, man wakes up and, with the idea in mind that it should never happen again, asks himself what to do against it. Whether this will be followed by an actual and vigorous response depends on his technical capabilities and financial possibilities. The technical aspect of the challenge and response situation is that experience has shown, that in the fight against the floods a counter-offensive is more effective than a restoration of the status quo. There will always be higher floods than before, higher requirements with respect to safety and water control, the embankments have entailed higher flood levels, river beds have gone up, etc. New lines of defence have to be created to make head against the enemy in new situations.

A few examples of recent disasters in polder areas will show the significance of challenge response factors.

On the first of February 1953 the southwestern part of the Netherlands was hit by a storm surge. The sea level rose to levels higher than ever recorded before and in tens of places the sea dikes were breached. Nearly 2000 people lost their lives and considerable damage was inflicted to the economy. The response was a counter offensive, known as the Delta Works, and consisting of a closure of the tidal estuaries by dams.

Shortly later, on September 26, 1959 Japan suffered from a sereve typhoon, the Ise Bay typhoon, which hit an area near Nagoya and caused flooding of many polders. The number of casualties and the amount of damage were serveral times larger than those of the 1963-disaster in the Netherlands. The vigorous response was the same as in the Netherlands: damming off of estuaries not only near Nagoya but also in other places in Japan.

Still some years later, on November 11th, 1970 Bangladesh was hit by a cyclone on the Bay of Bengal. The maximum sea level exceeded the crest level of the vulnerable "bunds" by several metres. The result was a terrible calamity, perhaps the worst natural disaster in the history of mankind with more than 500,000 casualties. It passed by, almost unnoticed, in the outer world. The response of the country was weak and more passive than offensive. A number of "kilas" was built similar to the dwelling mounds in the Netherlands erected more than two thousand years earlier. The response in the case of Bangladesh was weak because of the very tense political situation in 1970 and the very poor economic conditions.

5. Prospects of impoldering in the world

With the analysis just presented some factors which will be determinant in the future can be indicated. On a short term the prospects in the Netherlands and in Japan do not look very bright. In both countries there is no shortage of food; cereals and meat can be imported at low prices from the Americas. In Japan, where there is now a surplus of rice, reclamation of tidal land is continuing not for agricultural but for industrial purposes, applying the method of hydraulic fill. In the Netherlands the process of decision on further impoldering has been paralysed, like in other sectors of her society.

Elsewhere in this world conditions are entirely different. The only way to relieve the food situation of poverty stricken countries like Bangladesh and West Bengal is to improve the water management in the existing polders and to transform other upland areas into polders with complete or partial water control. What applies to the delta of the Ganges also applies to many other large deltas and other prospective polder areas of the Third World. High costs of construction, deficient methods of economic evaluation neglecting benefits to the national economy and low prices of cereals act for the time being as negative incitements but history shows that things can change rapidly.

There is one form of impoldering in quite a few of the deltas and other low-lying areas which has met a considerable success even from the point of view of private economy. It is the reclamation of small polders in the vicinity of large cities for the purpose of supply of vegetables and fruits. Cities like Bangkok, Calcutta, Saigon, Jakarta, etc. offer a ready consuming market for these products which can only be grown in polders in the immediate vicinity with a perfect water control and flood protection.

In the opinion of the author also large-scale impoldering will be taken up again because of the necessity to increase food production and the consideration that as long as man will be on earth the same factors that were acting in the past will also determine our future.

The hope is expressed that this Symposium has made a contribution to the transfer of technology in the field of impoldering.

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POLDERS OF THE FUTURE

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Most of the larger terrestrial mammals don't live far from some source of fresh water. Man did not form an exception to this general rule. As a matter of fact, he can nowadays pump water over long distances to his dwelling places. Nomadic tribes moved about, each time the water ran short around their quarters and they still continue to do so. However, after having collected food for a few million years, man was bound to become a more or less sedentary being from the very moment that he started to practice crop growing. Indeed, some crop growers remained semi-nomads, e.g. roaming about during the period between sowing and harvesting, but most farmers settled down and became highly dependent upon sources providing fresh water throughout the year. It is obvious that the lowlands offered excellent opportunities for supplying the people, their domestic animals and their crops with water.

Indeed some people even succeeded in creating living conditions far away from open water, by digging deep wells (Northern Sahara), collecting water in tanks on mountain slopes (Sri Lanka) or by transporting seepage water from the foothills through subterraneous passages of considerable length to their fields (Iran). However, those who lived in the lowlands had easiest access to water. Good soils and excellent fishing and hunting grounds were usually found in these areas. Moreover the traffic by boat was far easier than moving on bad or almost non-existent tracks. We found, for example, that the former Zuiderzee was at that time more a link than a barrier between the towns and villages on both sides of the bay. Finally water - in particular rivers - was always a widely used receptacle for all kinds of wastes. Not that waste disposal formed a major problem in those old days.

One particular disadvantage is peculiar to most lowlands: the water table can fluctuate considerably. The water, however essential it may be, becomes a danger when it rises too fast or too high. The inhabitants of the alluvial plains adapted their way of life to this - usually seasonal - danger. They built their dwellings just outside the valleys on the upland, on high river banks, on protruding outcrops of older strata or they simply left the lowlands during the periode of flood hazard. They constructed dikes to guide the water safely to downstream river tracts, built their houses on poles and even piled up earth to make dwelling mounds ("terpen"); small ones for solitary farms and huge ones for complete villages. They had boats at hand and locally they made raised roads or even footbridges to interconnect the villages and hamlets in those periods when the land was flooded. In large parts of the world comparable situations still exist.

Assuming that the houses were more or less free from deep flooding, it nevertheless remained troublesome that the fields were out of use during the flooding period. Even more detrimental were the brackish and sometimes saline floodings in the downstream part of deltaic plains. Harm was also caused by the fact that the floods did not come every year at the same time. Late floods could postpone the sowing time and early floods could destroy the standing crop. The farmers tried as best as they could to adapt their agricultural practices to the risks. The foregoing sentences have been written in the past tense, but once more: the statements made are still hard reality for many millions of people.

Ladies and Gentlemen. In the second or third century a small dike was built on the terp of Feddersen (Weserland, Germany). It protected one house. We don't know whether this was the first polder, but is was no doubt an early one. Gradually more low dikes were constructed to protect small family terpen and the houses on them and sometimes also part of the adjacent, often relatively high, land. All these dikes were small and very local structures because only the smallest communities showed enough coherence to enable concerted dike building activity. The co-operation needed for dealing with larger dike projects was found not earlier than 6 to 7 centuries after the first small dike came into being. However, the Lex Frisonum does not contain any mention of dikes in the year 800. It may be that the low density of the coastal population during the post-Roman transgression and the social changes during the migration of the nations caused the stunted development of dike building. Some think that the long and fierce fights against the repeatedly invading Vikings unified the freedom-loving Friesians but maybe this is only a war-glorifying conception. Whatever the case may be, it was only in the tenth century that a better cooperation enabled them to tackle the huge job of protecting large fields, until then liable to flooding, by means of dikes. It took indeed another two or three centuries before the "golden rings" surrounded the whole of the lowlands. Yet local people still did not place too much confidence in the results of their common work; for another 100 years they continued the heigtening of the "terpen". Anyway, from the end of the 10th century, the whole cultivated lowland of Belgium, the Netherlands and Germany was embanked within a few centuries, thanks to the incredible zeal and perseverance of the inhabitants.

Obviously, the strong co-operation needed for the building of the larger dikes also applied to the strong changes in social structure. The small farming communities lost influence in favour of village and parish organizations with their more numerous memberships. However, small units still existed locally till far in the 18th century, (guaranteeing), for example, mutual help in case of fire or funerals.

In order to achieve an efficient large-scale defence against the sea, rules had to be drawn up and accepted by the population. The building of the dikes was a collective activity of a well-structured society of free people. The work was, as a rule, organized by parishes. Monasteries and, later on, polder boards, also took part in dike building, the latter using hired labour or even contractors. Initially the maintenance and small repairs were the duty of the landowners. They could shift off this burden to the tenants, but they kept the eventual responsibility for the upkeep of the dike.
Major repairs were the task of the polder boards, which in the event of

calamities could even get help from neighbouring polders. In case of emergency everyone was bound to personal participation in the dikework and in many places the nobility was not exempted from this duty. The importance of dikework was recognized; being occupied by strengthening a dike was one of the few valid reasons for not appearing in court, for example.

Arrangements had to be made for the financial contribution of those farmers who were less endangered by flooding because they were living far from the sea or on higher tracts of land. The maintenance of drainage ditches and canals had to be organized. It took centuries before well-considered rules like the Rustringer rules were recorded and polder boards with well-defined tasks were functioning. After that the rules had to be adapted time after to new social and technical developments. Sometimes social abuses crept in, especially when the polder boards became a closed group and incapable and corrupt board members inherited the chairs from their fathers.

Attention is always paid to the later periods during which the cultivated land was extended by embankment of vegetated coastal accretions and by pumping dry lakes. Moreover, peat areas had to be impoldered because they reached a low level due to subsidence, which in turn resulted from the cultivation of the peat. Technical skills and means developed: windmills with revolving caps, steam-driven pumping stations fuelled by coal or peat and, later on, diesel engines and electromotors as sources of power.

Spades became replaced by draglines, bulldozers and dredgers. Manual transport was superseded by, in succession, horse and cart, narrow gauge railways and trucks. Tidal creeks in dike sites were successively closed by a fast supply of clay, by sinking a ship in the gap, by a simultaneous lowering of a row of sliding panels and even by using caissons. Due to all this technical firework, we easily forget that the later growth of the lowland plains by new embankments was by far less than the area which the old coastal people had protected so to say in one go, by building the "golden rings" as they called these long encircling dikes. We tend to forget that between the first primitive dike and the full protection of the - by gravity drained - lands, nearly 1200 years passed away, whereas the last centuries of this period should be seen as a most instructive epoch because most of the dike-building was concentrated in those ages. It was during these few hundreds of years that, after a prolonged and slow start, a changing society went with a growing collaboration between the lowland people, which co-operation enabled the beginning, the execution and the completion of such a gigantic work with such primitive means; even the wheelbarrow had not yet been invented! As a matter of fact, the later developments of polders and polder management form an indispensable basis for thoughts on polders of the future in Europe, but we will see hereafter that polders of the future are essentially a matter for the third world and for that reason we have to keep in mind these very early days of polder history.

Coming to this future, two more or less inter-related basic questions are: where can the polders of the future be expected and what will they look like?
In the first place: the present polders will form a non-negligible part of future polders. We assume that losses due to earthquakes, stormsurges, landslides etc, etc. will be very small and that nuclear weapons will be abolished before they wipe out such vulnerable items as polders. In fact, existing polders will be modernized. For example, the power usually needed for keeping polders dry will be provided, at least in part, by wind energy. Studies of this possibility have already shown promising results. Maybe other renewable sources of energy can be considered too. In industrialized regions in particular improved control of irrigation water quality will lead to e.g. the use of seepage water or even the construction of storage reservoirs for seepage and precipitation water in order to reduce the intake of polluted river water. The control of aquatic and bank vegetation will have been improved by the introduction of adjusted ditch profiles and appropriate mowing rules, by more careful handling of fertilizers and by stocking the canals with herbivorous fishes.

But enough about the future of the old polders. More interesting are the new ones. Where can we expect them? Hardly anywhere here in

North-Western Europe. On most places the growth of coastal accretions stopped because the process of sedimentation came to an and. Moreover the salt marshes that were still present about 40 years ago have been embanked for the greater part. However, the vis inertiae also rules here. There are still powers active to get coastal foreland (including low-lying sand- and mudflats) embanked, using alleged arguments as need for improved defence against the sea, better drainage of the hinterland, creation of harbour and industrial sites, extension of recreational facilities and wildlife sanctuaries and even the lack of farmland. But heightening of the dikes provides the required safety as well; upstream storage will decrease drainage problems, the growth of industry stagnates and moreover some modern industries don't ask for a site near deep shipping channels. In a densely populated regio the development of new recreational facilities in a nature area usually means the loss of existing, more distinguished, forms of recreation (like sailing). And it seems hypocritical to look for new farmland when governmental policy is to decrease the number of existing farms as quickly as possible.

However, the most decisive objection to new polders came from the biologists. They were able to demonstrate that the high ecological value of this foreland outweighed the advantages of making even minor changes in the present status. The same holds for most of the scarce lakes and swamps that could be considered for impoldering.

Nevertheless, the future will bring plenty of new polders, not here, but in the third world where they are badly needed for raising the food production and where, after all, vast areas are awaiting better water management systems.

Actually, some people say that for the time being no real food shortage had to exist; that hunger is more a matter of poverty than of a too-low level of food production and that banishing malnutrition and under-nourishment is a political issue than a technical problem. Whatever the case may be, a strong increase in food supply will be needed in the near future anyway, in view of the continuing increase in world population. The phenomenon of large families fades very slowly. In order to increase the supply of food, various means can be considered such as: cutting down harvest and storage losses, replacing industrial and fodder crops by food crops, increasing yields per unit of cultivated land and cultivating new land.

Limiting losses could indeed increase substantially the quantity of food available; substitution of non-food crops can at least locally be of some importance too, but both subjects are beyond the scope of this symposium. In densely populated regions, the bringing under cultivation of virgin land is less influential. Large tracts are unsuitable for any form of agriculture or have to be preserved in their present state for some reason or other (e.g. forests). Moreover, the possible extension of cultivated land by impoldering in order to increase food production, forms only a minor track.

Even this narrow path is often ineffective either because the soils prove to be of an inferior quality, the diking is too expensive or even because the scarce local population makes the best use of the natural environment and cannot be removed since they attain a reasonable standard of living. However, the most serious objection to impoldering is that these wetlands in their natural state often prove to be too valuable in the long term to the survival of mankind to be brought under cultivation.

Fortunately there still remains one other method of increasing food production: raising yields per hectare. And in this approach impoldering plays an, important part. In some regions it is - at least for the time being - not even necessary to reclaim virgin land because millions of hectares of cultivated land are awaiting impoldering. Here we still find conditions comparable with the situation in the Netherlands one millennium ago. The people live on higher spots in or near the lowlands, but their field are not protected against flooding, have only very simple drainage facilities and yields are precarious. In such areas a better water management is a prerequisite for the introduction of modern crop varieties double rice cropping and other new crop rotations, a more advanced use of fertilizers and pesticides. Yields can be increased substantially and over vast areas. Here the polders of the future will be established.

A problem may be that for politicians the gaining of new land often seems more rewarding and less troublesome than the improvement of existing agricultural land.
The regions of the new polders being assessed, there still remains the question how to plan them and how te get them constructed? Reclaiming new land means the irreversible elimination of one or more biotopes, but impoldering cultivated land is also a radical measure. It means the definite termination of a geological development, because it stops sedimentation. Impoldering has hydrological consequences, such as rise of flood levels in the river. It has - even in the case of cultivated land - a strong influence on flora and fauna and, as a rule, society changes. It is moreover very costly. The possible changes have to be studied beforehand, but predictions about what will happen are often difficult, in particular with respect to social developments.
As a matter of fact large but flexible overall schemes are usually indispensable, but a slow, step by step execution of such a scheme is preferable so that each small project can serve as a technical and social experience for the next one.

It is not necessary and maybe not even wise, to start with one small dike protecting one house only - as in the case of the terp of Feddersen 1800 years ago - and it is not possible, in view of the food scarcity, to take several hundreds of years as the old Friesians did before the land is properly protected. But it must be clear whether land users are able te organize in one way or another the maintenance of dikes, structures and canals of at least a small polder and how they can cope with repairs. It must be known whether the farmers will match agricultural practices with the new hydrological situation. It has to be studied whether the effect of the new polder will be such that the rich landowners become richer and the small tenants become landless and unemployed labourers. In general social commotion is not a phenomenon that needs development.

Until a short while ago, impoldering was easy: make a ringdike, as far as possible on a level or other strip of highlying land, choose a site far upstream for an intake structure, build a drainage device on a downstream spot, lay down some canals and roads and that is that.

Nowadays we often consider it better not to start with the total elimination of the floods, but with a regulation of the time and rate of flooding. To begin with, the higher parts of the area liable to flooding can be protected. For the water management of the lower parts, different courses can be pursued depending on the height of the land. Among these courses can be included the lowering of the surface inflow from the higher parts by catch canals; controlled flooding by submersible dikes; accelerated drainage; construction of storage basins, etc. etc.

Such a differentiation in intensity of water control requires various adapted forms of land use, fishponds etc. etc. In the river dikes overflows can be constructed so that in case of high river levels some water can flow off through depressions in the polders.

In the course of the years water management can be adjusted to changing demands of agriculture and in some places the development mag end with a polder "Dutch style". In other places maybe everyone will keep his own little "polder". But not only does water management have to be subtle and modern: new ways also have to be found for the energy supply. Attention must be given to techniques for producing energy for the pumps from renewable resources. Solutions will differ from place to place but low-head turbines, windmills, motors driven by burning biogas or wastes from wood of form other agricultural products are in use or will be in use soon.

Maybe the greatest advantage of step by step development of the water management of existing agricultural areas is that the farmers are themselves involved in the establishment of the projects and that they learn to set up a water board for small hydrological units with a relatively simple task. In this way big and expensive centralized organisations can be avoided and the small water boards can serve the purpose of increasing yields without disturbing the social structure and the well-being of the local population.

In short: plenty of work is waiting for all those civil and agricultural engineers, sociologists and ecologists, who are dealing in one way or another with land and water management. We urgently need sound flood control, efficient irrigation systems and adequate drainage facilities, which all combined may lead to polders. And these polders will meet the requirements of the future. Requirements related to an economic use of energy and water; to the development of a decent society and the preservation of a healthy environment. Requirements guaranteeing an existence for many coming generations of plants, animals and human beings. We will need all our resourcefulness to reach this goal. It is time we put our minds to the next symposium dedicated completely to the future aspects of various types of polderlike units on agricultural land.

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