POLDERS OF THE WORLD

FINAL REPORT

INTERNATIONAL SYMPOSIUM LELYSTAD THE NETHERLANDS 1983

THE SYMPOSIUM ORGANIZATION

- Department of Civil Engineering - Delft University of Technology
- IJsselmeerpolders Development Authority - Ministry of Transport and Public Works
- Committee for Hydrological Research TNO
- Association for Water Management and Land Use Planning

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PREFACE

The International Symposium and Exhibition 'POLDERS OF THE WORLD' was held in Lelystad, The Netherlands, from 4 to 10 October, 1982. The aim of the Symposium was to provide a comprehensive view of the various aspects of polder development and to give scientists, engineers, decision-makers, and managers a forum for a discussion of these aspects and their related problems.

The Symposium was arranged under the themes of land and water management, construction, agriculture, socio-economy and physical planning, and the environment. These were treated in plenary sessions where keynotes were presented and in workshops where papers were discussed. Because of the overwhelming number of papers, general reporters summarized them.

Presented in this FINAL REPORT on Polders of the World, are the keynotes, the General Reports, and the Conclusions, as well as a list of authors and the titles of their papers. The actual papers have been published by ILRI, Wageningen, in a set of three volumes.

I hope that this book will provide its readers with an overall view on polders, polder development, and on what could be concluded because of this first-ever Symposium on 'Polders of the World'.

To get this book into print as quickly as possible, we have decided to forgo the time-consuming task of correcting and editing the English language. We hope our readers will forgive the imperfections.

Delft, June 16, 1983

W. A. Segeren
Chairman
'Polders of the World'

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THE SYMPOSIUM AND EXHIBITION

'Polders of the World' was held from Monday October 4 through Sunday October 10, 1982 in Lelystad, the capital city of the IJsselmeerpolders. The Symposium was host to 426 participants from 52 countries all over the world, developing countries as well as developed countries.
The first three days were mainly devoted to the scientific part of Polders of the World. In the plenary morning sessions twelve keynotes were delivered. The first morning was used for opening addresses and introduction speeches, stating general views on polder development now and in the future. The other morning ten keynotes were presented, dealing the five themes chosen to treat the subject:

- Land and water management;
- Construction aspects;
- Socio-economic and physical planning aspects;
- Environmental aspects.

The Symposium was honoured by the sponsorship of a great many international organizations, as e.g. the Worldbank, FAO, Unesco. These organizations were represented by directors and other staff, presenting keynotes on the just mentioned themes. Also many, more discipline orientated, international organizations granted their support as sponsor.
In the afternoon of the first three days workshops were dedicated to the exchange of views on problems, ideas and solutions in polder-development. The basis for this had been provided by the papers written by many of the participants.
The overwhelming amount of papers (some 140) did not allow every paper to be presented in full. General reports have summarized the papers of

their sessions and risen questions or topics for discussion. The workshops, mostly with more than one reporter, were concluded by the chairmen, who presented their findings and conclusions on Wednesday afternoon, the last plenary session.

Finally the chairman of the Scientific Committee presented the overall conclusions of the Symposium.

Two well known 'polder' professors - A. Volker and B. Verhoeven - were honoured for their many contributions to polder development in the world, on their presenting keynotes with a 'lessons to be learned' character.

The first three days of the Symposium were followed by three days of fieldtrips to: the IJsselmeer polders, the older polders in the mid and west of The Netherlands and the 'Delta Works', the large engineering works in progress at this moment, for the protection of the south-west region of The Netherlands. The participants visited an open air demonstration and exhibition of 'polder equipment and machinery' on the first fieldtrip.

Parallel to the mentioned activities an Exhibition was held (October 4 through 10) in which, next to an introductory part with information on polders all over the world, government services, research institutes and companies could show their ability and know-how with respect to polders. The number of visitors of this Exhibition exceeded expectations and requests have been made for showing this collection of information on polders in various other countries.

Follow up

On the occasion of 'Polders of the World' many data and large amount of knowledge and experience have been collected. During the Symposium I promised the participants to shape and publish this material. Contacts have been established between FAO, World Food Program and the Committee Polders of the World, to deliberate upon a study program towards enlarging the insight in the role of polders in solving the worldwide problem of a growing food demand.

During the Symposium I already extended my views on a repetition of an event alike, as was proposed by many participants. Worldbank, FAO, Unesco and also more discipline orientated organizations as e.g. CGIR and ICID should be more involved in the second Symposium of this nature. Let the conclusion of this Symposium be an incentive to go on with this initiative to, in the end, the benefit of all countries where polders can contribute to prosperity and well-being.

W.A. Segeren
Chairman
'Polders of the World'

KEYNOTES

INTRODUCTION

Prof.ir. W.A. Segeren
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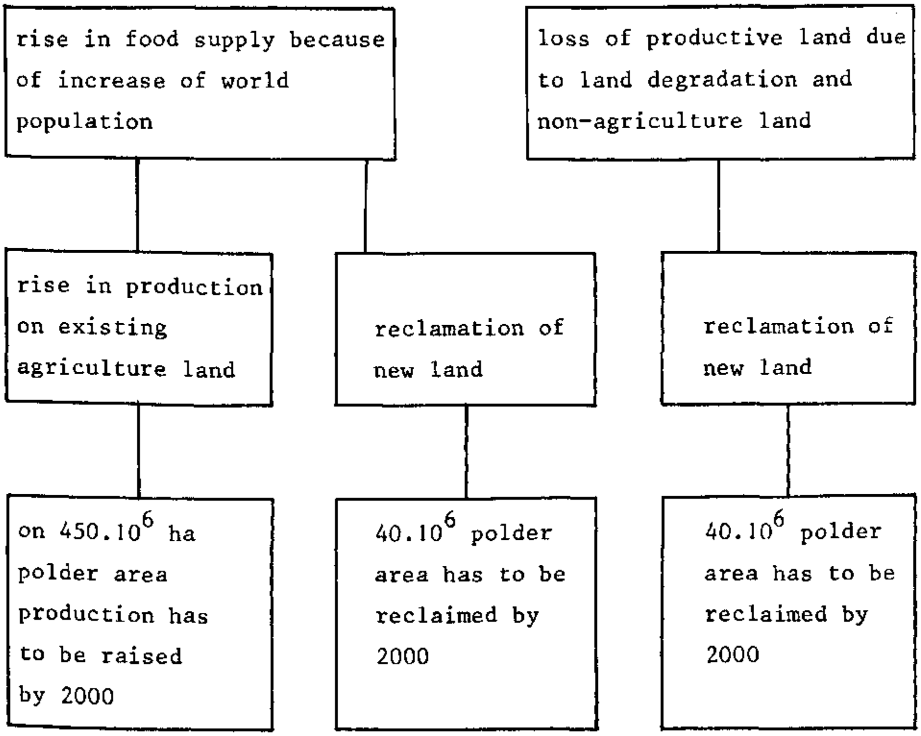
Service for Land and Water Use.

The lesson to be learned is that we should design, build and maintain polders in such a way that it is safe to live in. For this reason government, administrators, land users, consultants and contractors should all work together. These groups are all together here in Lelystad to discuss, for the first time in history, polder development. When we speak of a polder, what exactly do we mean?
As I define it, a polder is a level area which was originally subject to a high water-level, either permanently or seasonally and due to either groundwater or surface water. It becomes a polder when it is separated from the surrounding hydrological regime so that its water-level can be controlled independently of the surrounding regime.
This definition of a polder still leaves room for various interpretations. It allows for instance to call a paddy-field a polder. Or we could refer to a floodplain of a large river protected from an upstream dam as a polder. But in general, neither of these areas is ever called a polder.
For this Symposium, a rather broad definition is deliberately accepted to include all periodically waterlogged or flooded low-lying plains, which need some kind of impoldering to improve their land-use.

Within the framework of the Symposium, a global inventory has been made of the areas which could be made more productive, especially to agriculture, by means of impoldering or impoldering-techniques.
From the FAO-Unesco-world-soil-map, the International Soil Museum has estimated that for some 900 million hectares in the world, food-

production is severely hampered by high groundwater levels and regular flooding. If these areas could be impoldered, a considerable contribution could be achieved.
Let me recall some well-known data to clarify this point.
The world population today is estimated at 4.2 billion people. It is expected by the year 2000 to have increased to 6.6 billion.
This means that within a period of 20 years extra food must be produced for this extra 2.2 billion of people. This assessment assumes that the present world foodproduction is sufficient to meet the needs of the present world population, if the imbalances of the food distribution are corrected. Studies into the world food supply in the coming decennia by the FAO have already been mentioned by Mr. Dudal. Other studies in this field have among others been undertaken by the Worldbank and World Food Study Centre in the Netherlands. Most of the extra food - about 72% of the total - should come from the present 1500 million ha cropland of the world. An overall yield increase of some 40%, even up to 100% in the developing countries, in the coming 20 years are deemed to be necessary. The implications with respect to impoldering will be discussed in a moment. The remaining 28% of the extra food needed by the year 2000 should grow on newly reclaimed cropland according to these studies. The FAO estimates this latter area at 200 million ha. It must also be recognized that every year about 13 million ha of cropland are lost because of erosion, desertification, salinization and urbanization.
An estimated 1700 million ha of land in the world is available for reclamation. The choice is, as is explained by our keynote speaker, Mr. Pranich: 'Do you go up to the hill or down to the sea?'
This can be translated as: are we going to increase our world cropland area by reclaiming the drier, higher lands or by reclaiming the lowlying wetlands.
Very general, one can say that the reclamation of the wet areas, the potential polder-areas, is to be preferred from an economic and technical viewpoint. However, ecologically, the reclamation of the higher and drier soils may often be preferable. If we assume that both these alternatives will contribute in proportion to their availability, then we have calculated that by 2000 some 80 million ha of polderland has to be reclaimed.

Table 1. Need for additional polder land by the year 2000.



The distribution of these areas over the world is depicted in the table. Here by again, the availability in different parts of the world is taken into account.

	Potential polders		Reclaimed by 2000
	10^6 ha	%	10^6 ha
South America	119,3	28,6	22,9
Africa	138,4	33,3	26,6
Asia	85,3	20,5	16,4
North America	35,9	8,6	6,9
Europe	36,8	8,8	7,0

With regard to the polderdevelopment in the future, we can distinguish three different types of potential polders.

1. The first type is polder development in already densely populated areas, mostly small farmers, working under bad conditions of water-management, soils and infrastructure.
2. The second type concerns the development of the sparsely populated level and wet areas, situated in a densely populated region.
3. The third type concerns polder development in sparsely populated, level wet areas, in a sparsely populated region.

Each of these three types of polders has its own problems and requires its own approach.

Type 1.

The densely populated potential polder areas are mainly situated in Asia and in Europe. A good example of this type is Bangladesh as described by Brammer in his keynote.
In my view a rise in food-production by the local farmers can only be achieved by integrated rural development.
Development is not just a matter of improving land- and watermanagement. Attention should also be paid to education, extension services, credit and marketing facilities, agro-processing industries and so on. Only by a cautious pace and with a strong participation of the local population this sort of rural development will have a chance to succeed.

Let me now come back to the calculations of the FAO which indicated that agricultural production in the less developed countries by the year 2000 has to be increased by 100%.
This is obviously a very difficult task, if not impossible, considering that the actual growth of the last 15 years was hardly half of this. Improved land- and water management will always be a first requirement. This means that the 360 million ha of existing wet land has to be improved substantially in the next twenty years.
The task we are confronted with leads me to the conclusion that I can not share the views of some keynote speakers and some authors of papers: They claim that with relatively simple means and only by increasing production on existing land we can cope with the growing demand for food in the coming years.

Type 2.

The potential polders, concerning the sparsely populated areas in densely populated regions. They are mainly found in South Asia and some areas in North, Central and South America. Some of the papers dealing with new reclamations in Indonesia are good examples of these type of polders. A main characteristic of these areas is their inaccessibility. The reclamation of these areas is generally undertaken to relieve over-population in the surrounding region as well as for the production of food, mainly for the region itself.
Large scale engineering works are often necessary, as well as extensive on-farm developments to prepare the reclaimed land for the many small farmers.
In general, these engineering and land-development projects require large investments and although these investments as such are generally quite feasible, finding the necessary funds is often difficult.
Often a choice has to be made how to allocate the limited funds, whereby the following two criteria should have high priority.
Firstly the investment in large engineering and land development projects has to be such that later on, when additional funds are available, further development can build on what has already been constructed without the necessity to do things twice. For this, one needs to have a clear conception of the final stage.

Secondly the land reclamation and the on-farm development should be adequate for the farmer to grow his first crop without too great risks. This will often call for strong government assistance or involvement in the initial development stages, of course the integrated approach for rural areas as mentioned under type 1 also applies to this case. This type of potential polders involves 158 million ha.

Type 3.

The potential polders in the sparsely populated areas in sparsely populated surroundings. They are mainly found in Central and South America, parts of Africa and Australia. These areas should produce mainly for the world market. The cost of reclamation and production has to be made good by the prices of agricultural products on the world market. In generally this implies that recalamation- and production-costs have to be low. The main aim is food production with minimum costs, this in contrast to type (1) and (2), where social consideration often play an important role.
These low costs are possible because in these areas high degrees of mechanization can be applied both for the reclamation activities as well as for the agricultural production itself.
This type of potential polders involves 258 million ha.

The projections I have mentioned were made on a global scale.
For a country and certainly for project-planning much more detailed data must be available.
Not only data on soil or technical aspects; economic factors are important too as the benefit-cost-ratio's will always be an important decission. Once the decission to impolder has been made, social factors will influence the design, construction and management. The distinction into three types of polder development shows this clearly.

Political influence can also be decisive. The calculation and estimates of world food problem were made almost exclusively on a technical basis. However, it is clear that the production of food and its distribution between the urban and rural areas of a country as well as between the countries and even the world regions can be powerful political weapons

and can have farreaching political consequences.
The most important decision factor from most of the recent polder reclamations has emerged only recently. The potential polderareas are very dynamic and productive ecosystems. They are often intensely and closely related with each other so that reclamation works in one area can have consequences in others, even those far away.
No new polder project should be undertaken without a careful assessment of these consequences. Also in the design and layout of new polderprojects one has to consider possible impacts on the natural environment. In keynotes and papers, attention is given to these aspects. Studies in The Netherlands about Markerwaard, Waddensea and Landdevelopmentprojects have given much more insight into this problem. Although the interpretation of the results of ecological studies leads to widely conflicting opinions.

When we review the three types of potential polders identified it is clear that the first two types have many common characteristics. Besides the contribution to the food supply, the contribution to the well-being and well-fare of the local farmers is another important aspect. In this respect, I fully agree with the policy of for instance the Dutch Minister of Development Aid, which emphasizes the economic and social development of the rural populations. Polder projects of the type (1) and (2) fit well into this policy.

Food, however, also has to be produced for areas not capable of producing for their increasing need as I explained before. This is for instance the case with many rapidly growing cities. Here the third type of polder development can make a contribution, becoming the modern graneries of the world.
I am perfectly aware of the many political problems, involved in this policy. But I also hope that these problems can be reconciled in the face of the strongly emerging world-food-crisis.

As the Dutch Minister of Transport and Public Works has just said, in The Netherlands the various Government Services, consulting engineers and contractors have a lot of experience with the overall development of polder areas. This experience and knowledge is relevant to each of

the three different types of potential polder areas.
The development of the first two types is often be initiated and implemented by the government of the countries in which the areas are situated.
The programmes of Worldbank and FAO as well as many bilateral aid programmes attend to the development of these two types of potential polders.
For the development of the third type, the large scale graneries, a more direct approach can often be followed, whereby design, construction and finance are all in the hand of one organisation. I can conceive of a developing country, which is prepared to hand over the entire reclamation and development of such a polder-area to such an organisation provided, that there is an assurance that - after say 15 or 20 years - the reclaimed land, including all infrastructure, will be handed over to the Government or to farmers.
And also if there is the assurance of an efficiently functioning extension programme.
I can also conceive of developed countries prepared to make expertise and funds available to develop polders that will pay a profit over a 15 to 20 years period. In this respect a plea is made for the Dutch Government, consultants, contractors, farmers organisations and banks to cooperate to give the world the food it needs and to promote the export of Dutch polder know-how.

Objectives

The need for the further development of polder areas is the main reason for this symposium and exhibition. That it is being held in The Netherlands and specifically in Lelystad you will understand from the speeches by the Minister and the Mayor. That it is being held in 1982 is because of the many celebrations we have in this country this year. You will have read about these celebrations in the earlier circulars that we sent to you.
The Symposium and Exhibition are being held together to persue three objectives:

1. The first is an international exchange of knowledge and experience

on polders by, and for, policy-makers and engineers, scientists, managers, contractors and politicians alike.
Part of this objective has already been fulfilled. From all over the world we received 150 papers and these have since been printed.
I think that all the information gathered justifies my feeling that the basis for a good symposium exists, especially when one considers that the papers have come from so many countries of the world.
In the light of the previous considerations on the problem of the worldfoodproduction I want to make one general remark about the papers received.
It is remarkable that most papers on the theme environment question impoldering as such. They all conclude that the need for food has to be realized by increase of production on existing land.
Contrary to this, some keynote speakers and many authors of papers, taking a technical and economic point of view, do not conclude that impoldering is needed. They discuss details, very important aspects, but still details. I think that this last group has to realize that a serious debate is going on about the necessity of impoldering in general.
My opinion should be clear; we must increase production on existing cropland as much as possible, but this will not be enough. For this, new impoldering will be necessary. This has to be done with care.
To arrive at good solutions, environmentalists, technicians and economists have to come to serious discussions once again to solve the real problem of foodproduction.

2. A second objective is to offer participants of the Symposium the opportunity to become acquainted with the experience that the Dutch Government and Dutch industry have acquired in the many aspects of impoldering. This statement needs further clarification.
Impoldering is not merely a matter of solving technical, socio-economic and ecological problems. Apart from these more-or-less technical matters, it is of the utmost importance that an organised administrative infrastructure is created not only for the planning and implementation of the polder but also for its management after the works have been completed.
In several centuries of experience in polder development specific

know-how has been built up, both within Government institutes and services and within the private sector (consultants and contractors), and it all rests on the base of a well-organised administration.
To give an insight into the integral Dutch approach to polder development, an exhibition has been set up.
Represented at the exhibition are some fifty Government institutes, services and private firms, which will all be pleased to pass on their accumulated know-how.

Serving as a framework for the Exhibition there is a separate exposition showing how the various aspects of planning and constructing a polder are applied in different countries. Each takes into account the people of that country, their prosperity-level, the soils that occur, the prevailing climate, and so on.
This exposition is arranged in line with the themes of the Symposium. It has been built in such a way that it can be shipped abroad to serve, partially or wholly, as an exposition in any country that may request it.
So, after the close of the Symposium and Exhibition, we are still offering other countries the chance to get acquainted with Dutch knowledge and experience.

3. A third objective is a more philosophical one.
Its aim is to provide understanding of the working and living conditions of people in various countries.
It is my personal experience that by seeing how people in different countries live and work - each with their own cultural back-ground and each with their own organizational infrastructure - I find that we have a deeper understanding, not only of their way of life, but also of our own Dutch way of life. By showing the Dutch people how the people of other countries live and work and how they solve their sometimes local problems, we hope to contribute to a greater understanding between people.
That is why many activities, of interest to the Dutch public, have been organised around the Symposium. And this is also why the Ministry of Transport and Public Works has issued a brochure entitled "Polders of the World".

In this brochure they have reproduced many of the Symposium data to make that information available to a wider public.
Many Dutch and Foreign technical journals, newspapers and other media are focusing attention on the Symposium. Spontaneously, exhibitions of paintings and ceramics, their subjects inspired by polders, will be held.

Ladies and Gentlemen, I wish you, participants, an interesting and fruitful Symposium and you, participants in the Exhibition, a successful week.

LAND AND WATER MANAGEMENT

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, water 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.

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 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

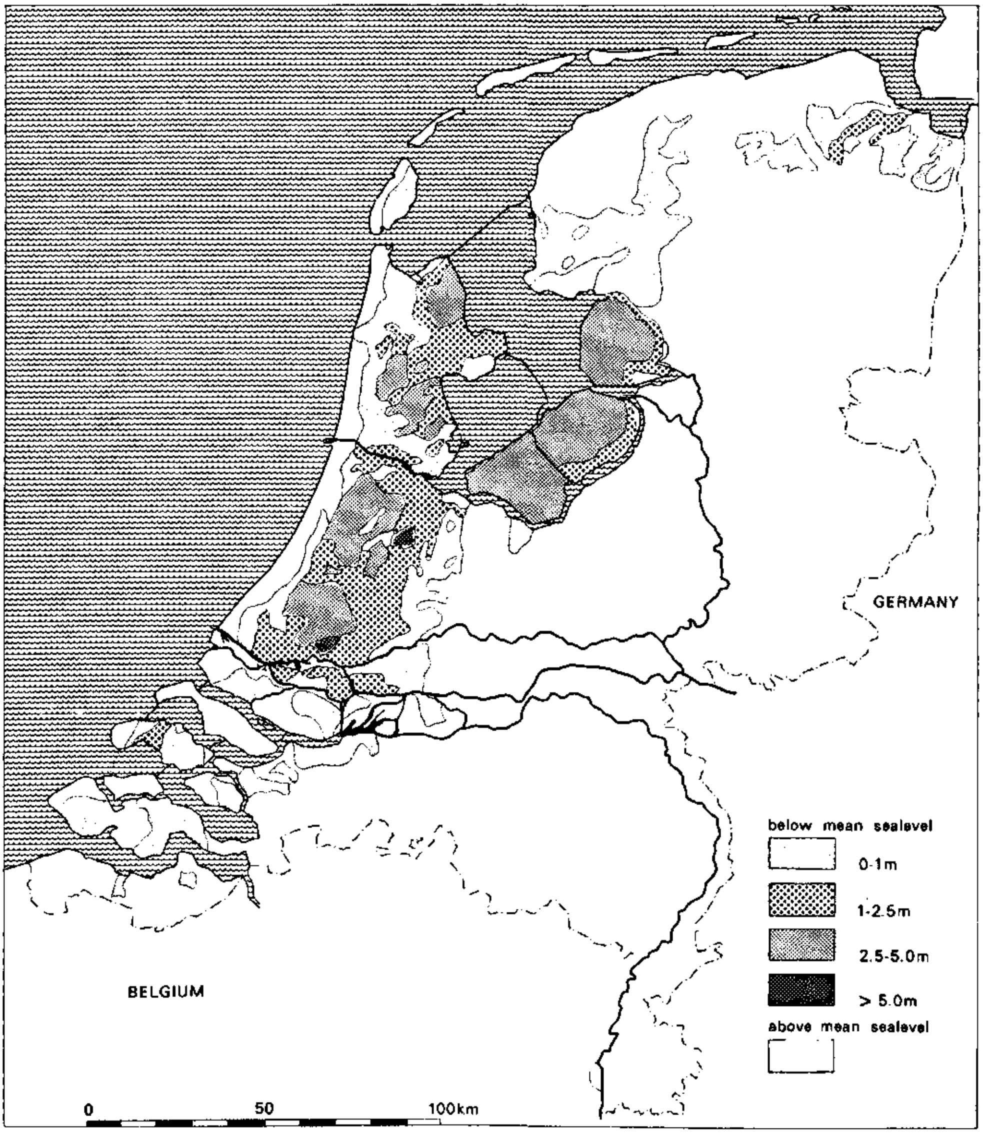

Figure 1. The ground level in the Netherlands.

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.

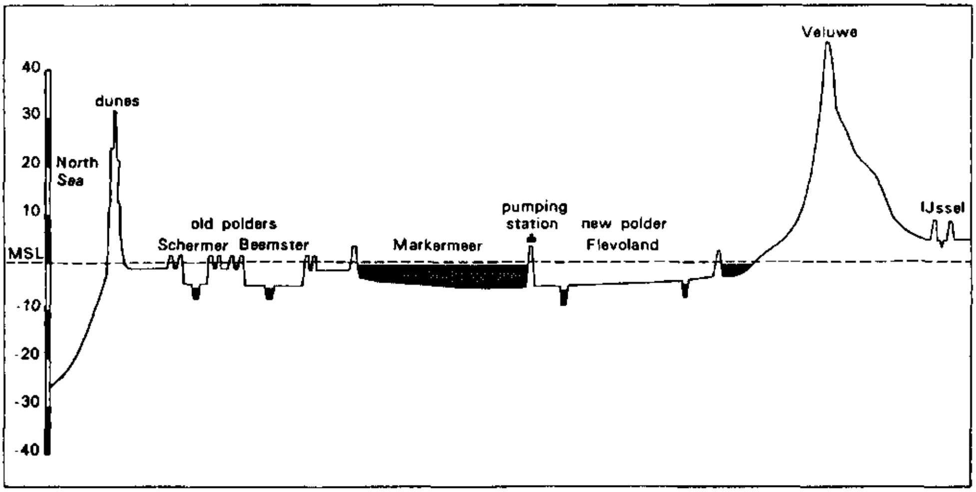

Figure 2. Scheme of the relative levels in the polders, the system of canals and reservoirs for superfluous polderwater and the sea

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.

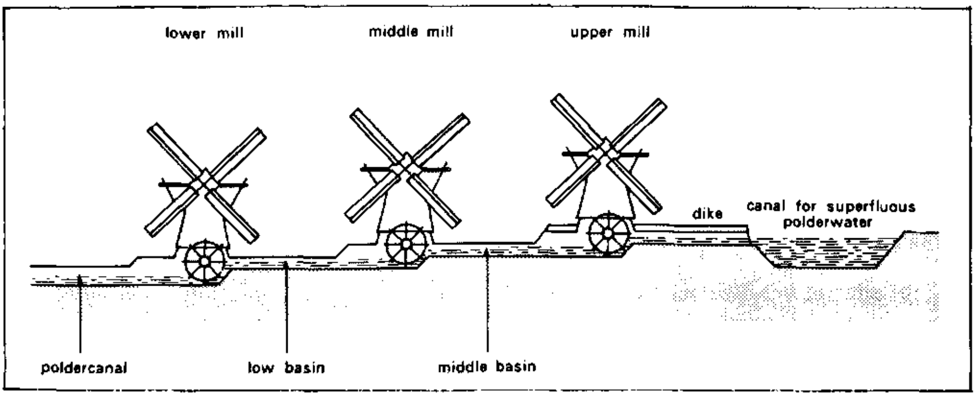

figure 3. Row of three windmills to pump out polder water.

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.

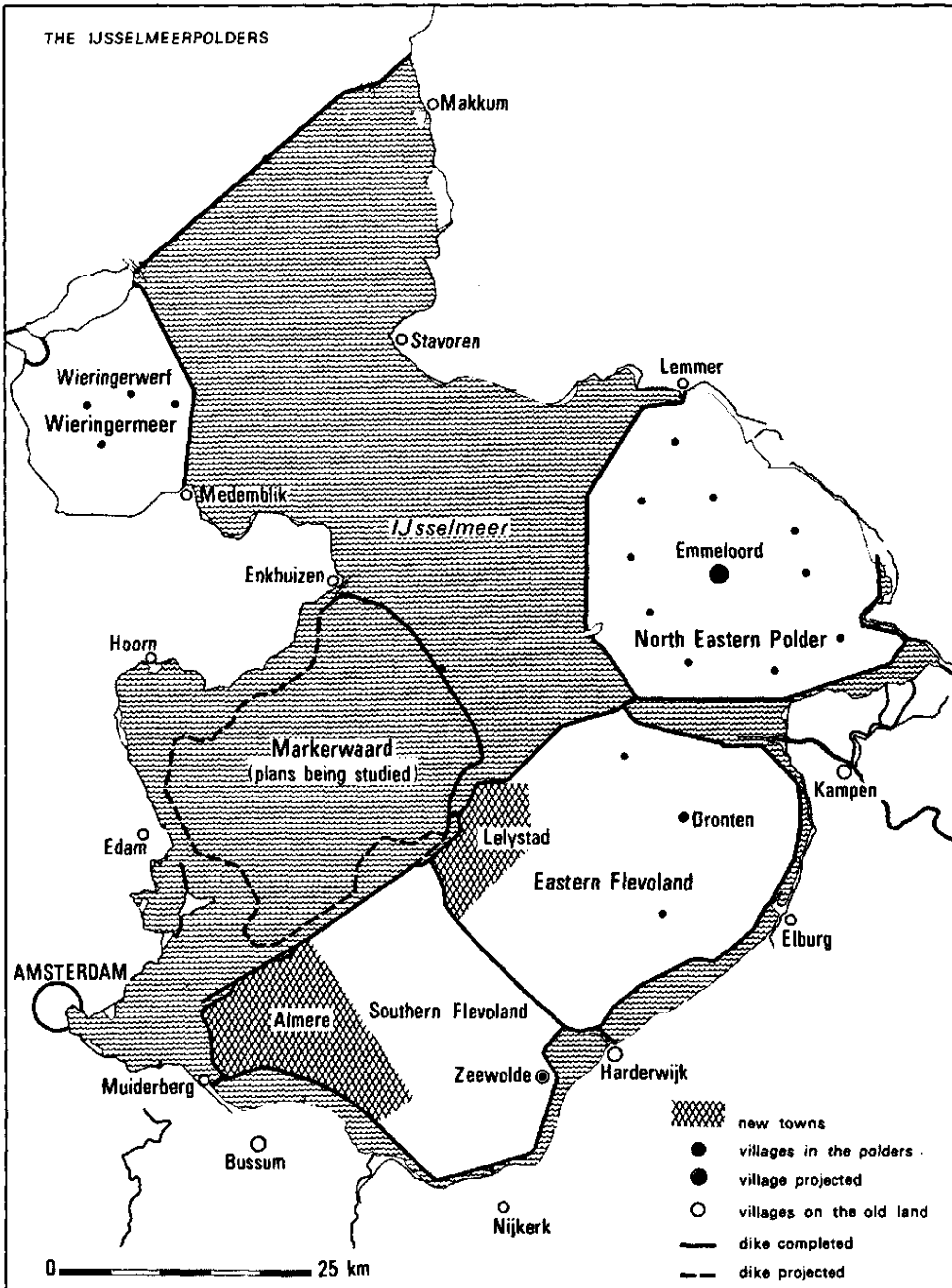

Figure 4. The IJsselmeerpolders.

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.

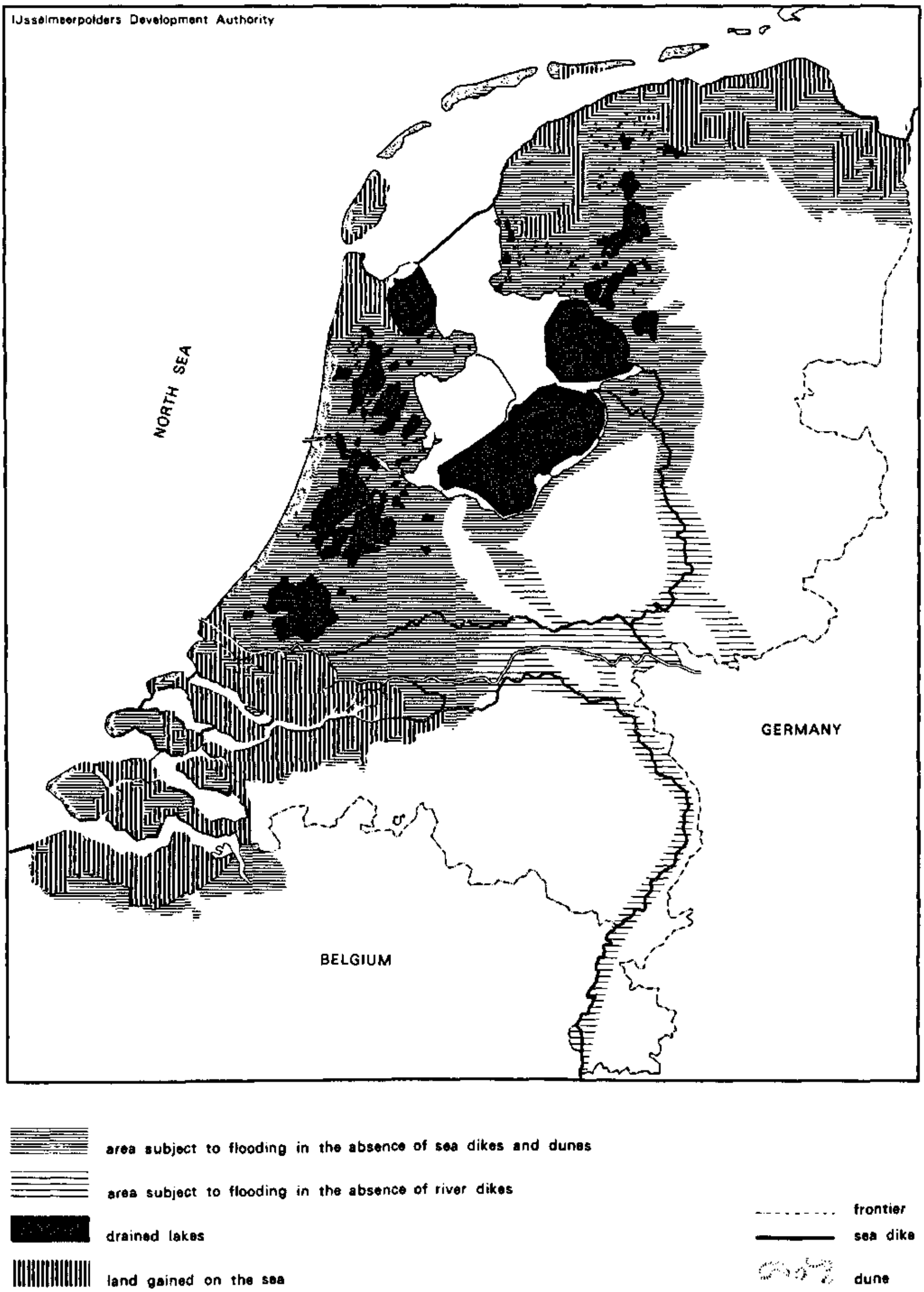

Figure 5. Areas in the Netherlands protected against flooding.

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).

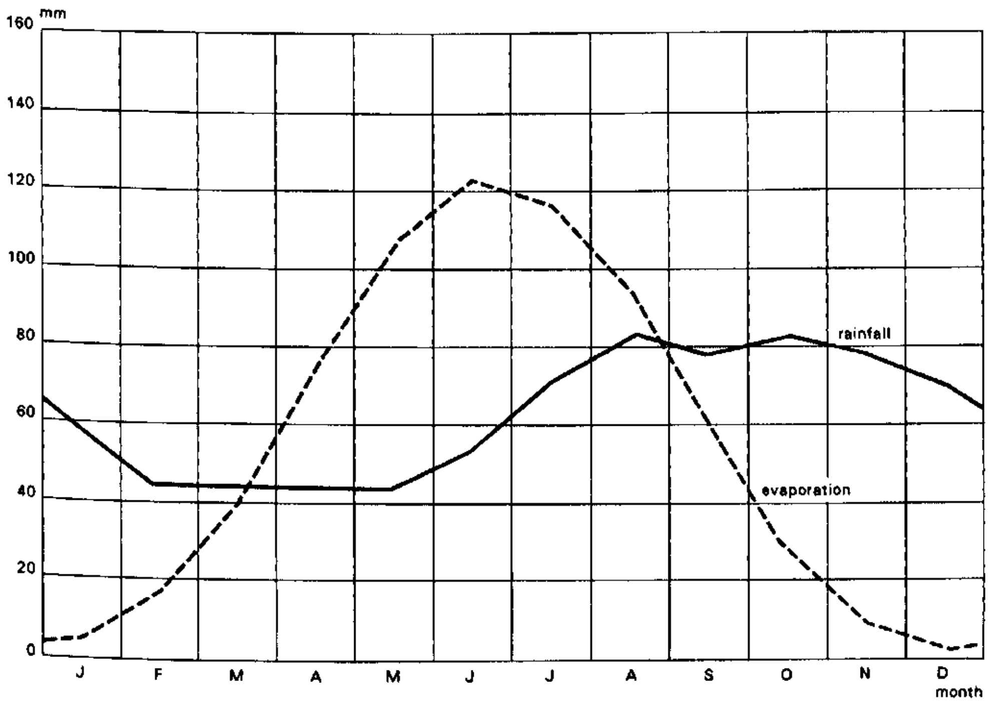

Figure 6. Mean monthly rainfall and evaporation from surface water.
Rainfall data: Hoofddorp 1867-1980.
Evaporation data: De Bilt 1911-1980.
(Royal Meteorological Service, 1867-1980)

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).

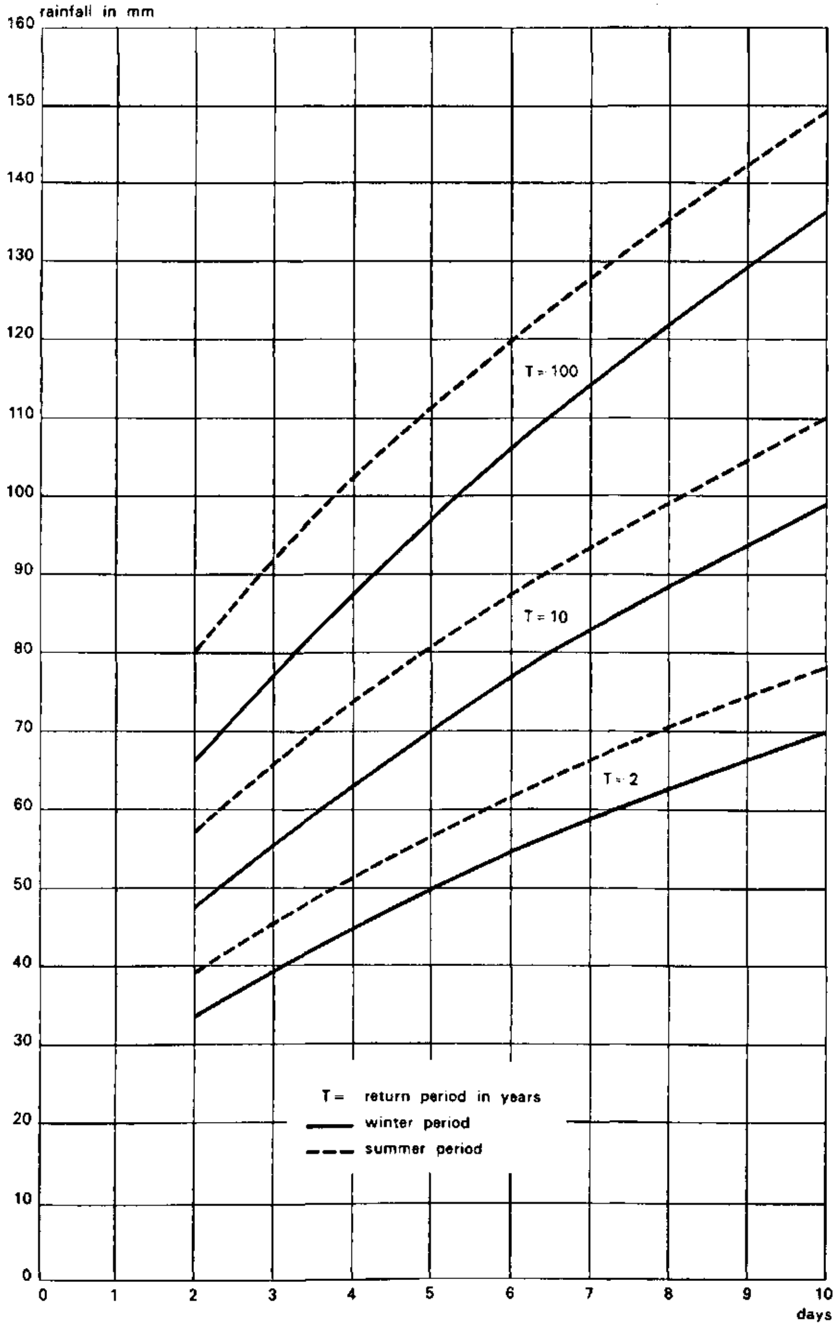

Figure 7. Rainfall intensity-frequency curves.
Hoofddorp, period 1867-1980.

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.

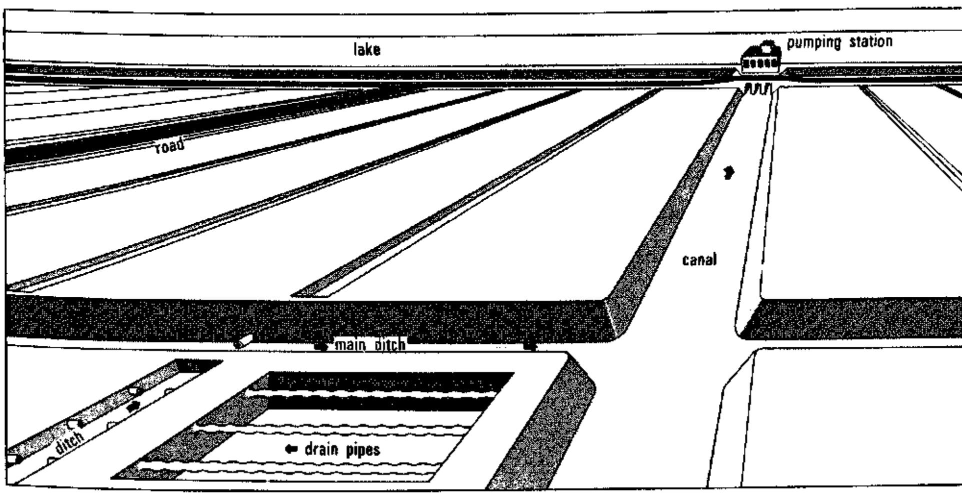

Figure 8. Schematic layout of a polder.

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 system 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.

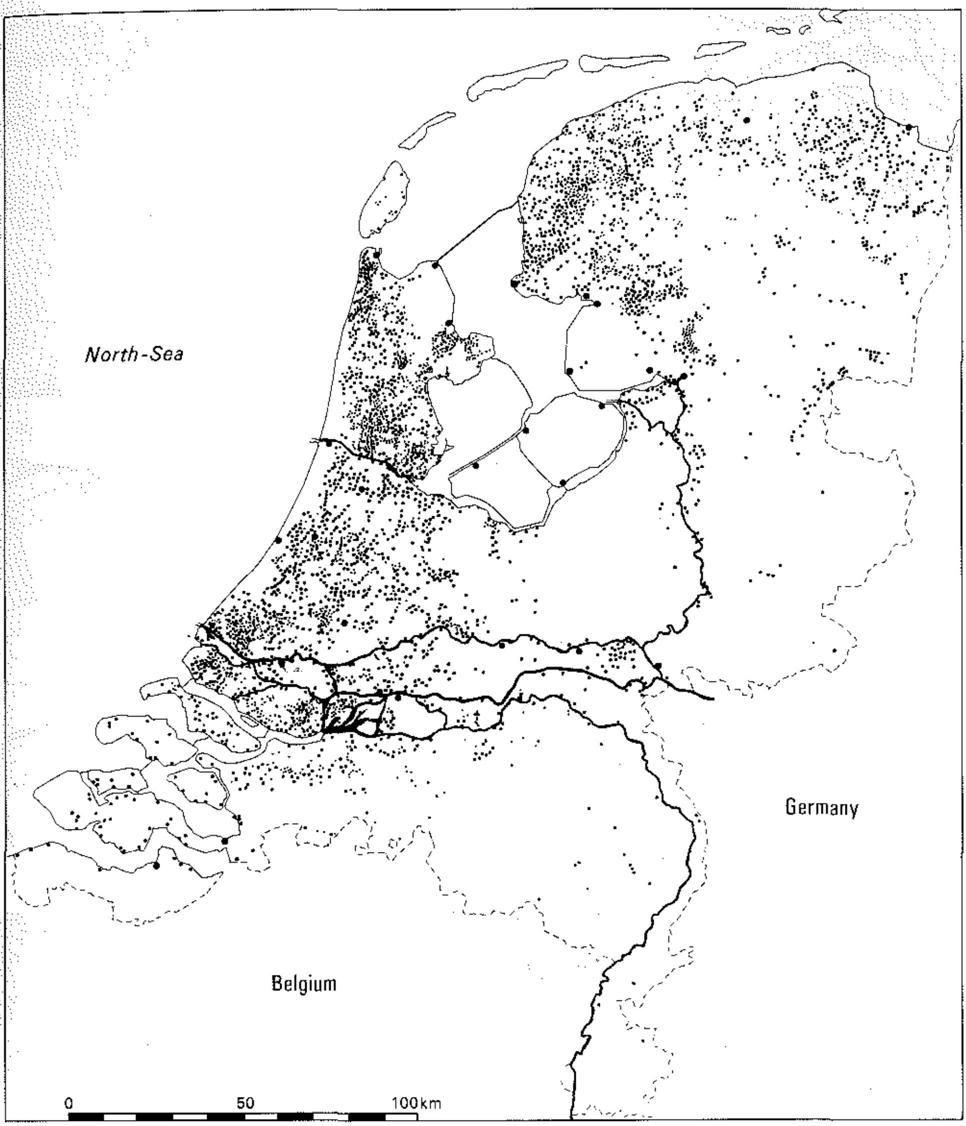

Figure 9. Pumping stations for drainage purposes in the Netherlands. (Rijkswaterstaat).

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.

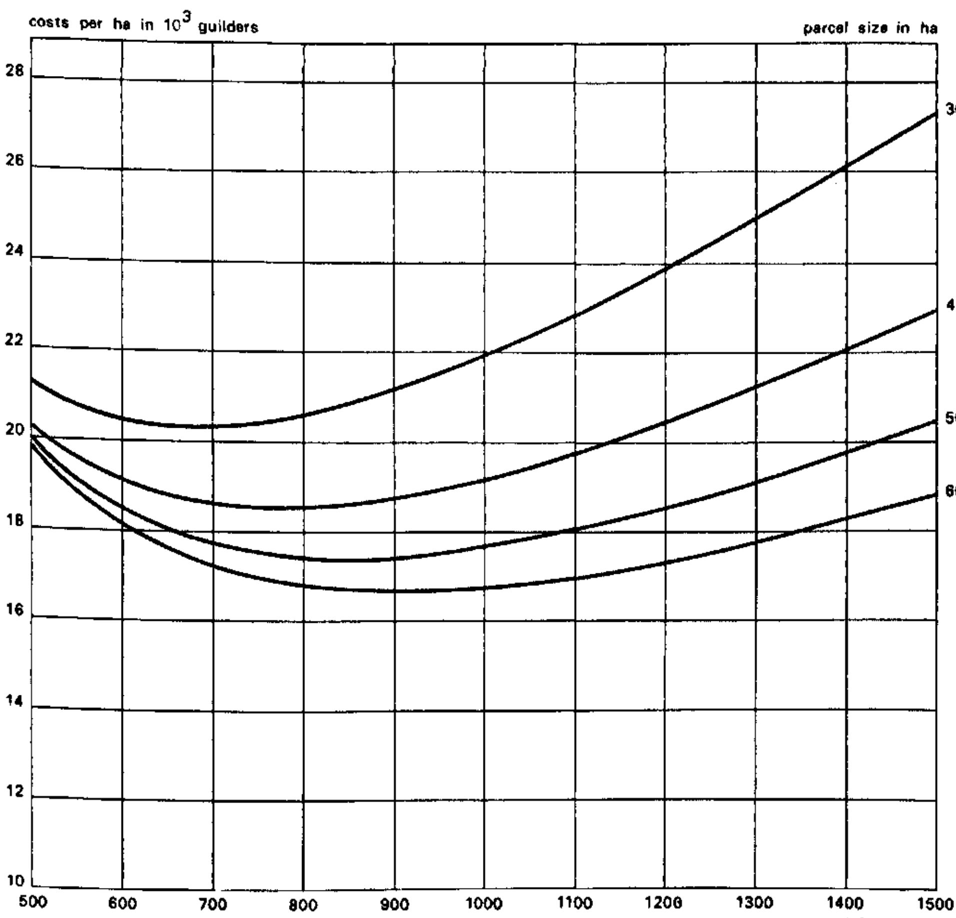

Figure 11. Analysis to calculate optimal plot sizes.

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.

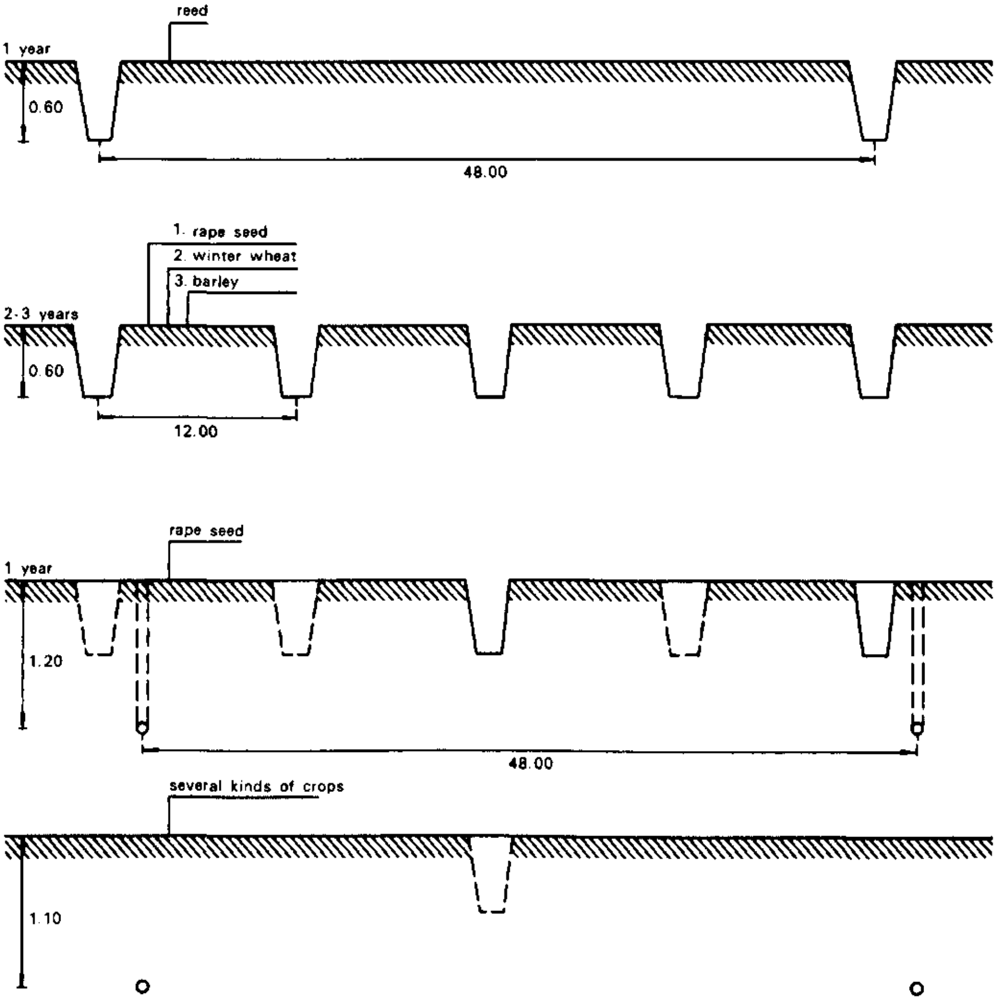

Figure 12. Measures taken during landreclamation in the IJsselmeerpolders

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.

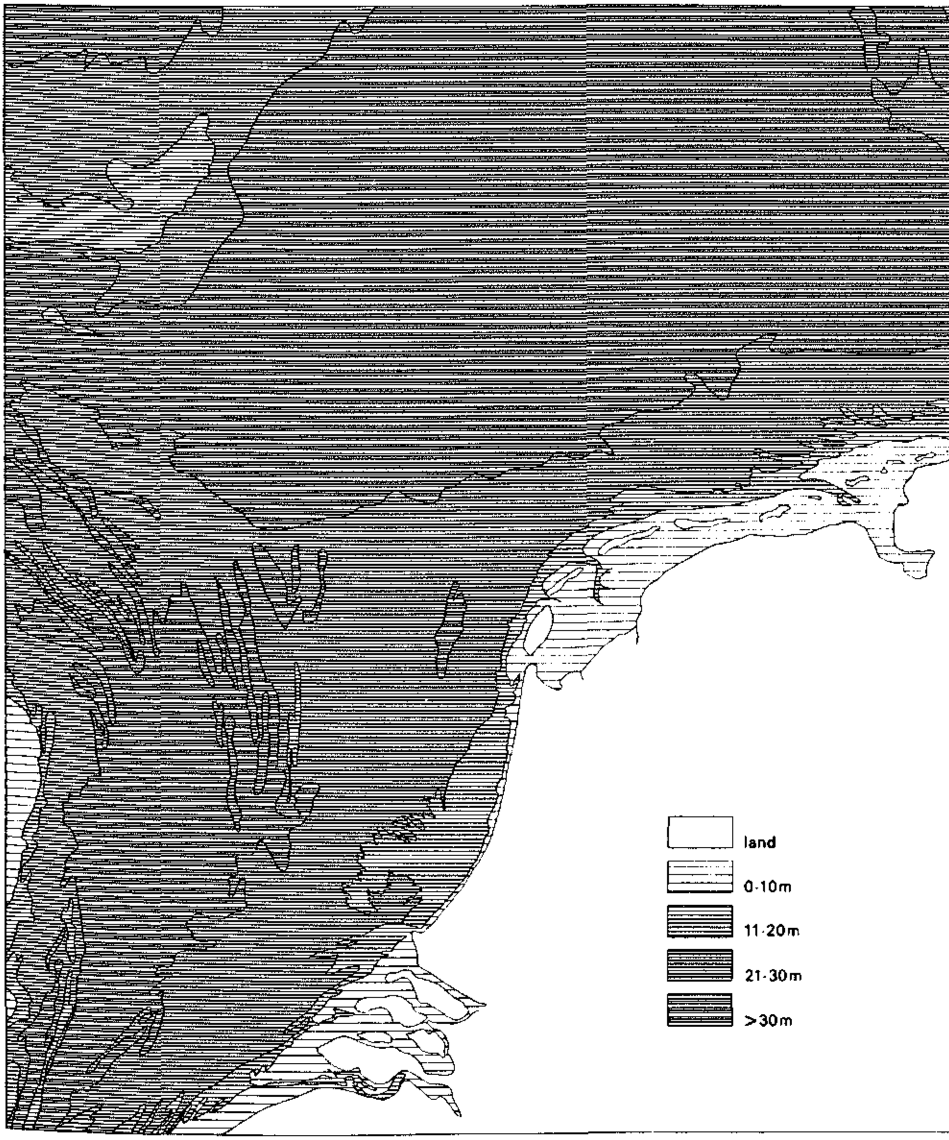

Figure 13. Level of the bottom of the North Sea.

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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13 References

1. Blumental, K.P. 1982. De waterhuishoudkundige infrastructuur van Nederland. PT-Civiele Techniek september nummer.
2. Centraal Bureau voor de Statistiek, 1981. Statistisch zakboek 1981. Staatsuitgeverij, 's Gravenhage.
3. Hende, W.R.J. van der, 1978. Ruilverkavelingswet 1954. Deel I. Vijfde druk. W.E.J. Tjeenk Willink, Zwolle.
4. Huet, 1885. Stoombemaling van polders en boezems. De gebroeders Van Cleef, Den Haag.
5. Royal Meteorological Service, 1867-1980. Maandelijkse overzichten van de weersgesteldheid, De Bilt.
6. Ramaer, J.C., 1892. De omvang van de Haarlemmermeer en de meren waaruit het ontstaan is, op verschillende tijden voor de droogmaking, Johannes Müller, Amsterdam.
7. Rijkswaterstaat. Directie Algemene Dienst, Den Haag.

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. deep 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 side 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.

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 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 was almost 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. Generally, 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

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).

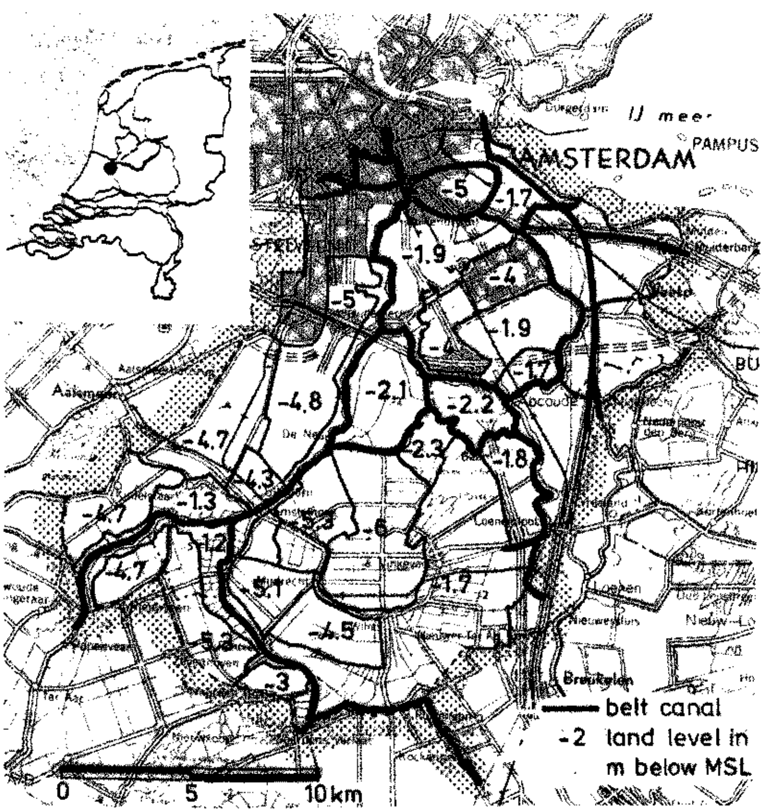

Figure 1. Example of a complicated system of polders and belt canals near Amsterdam

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,

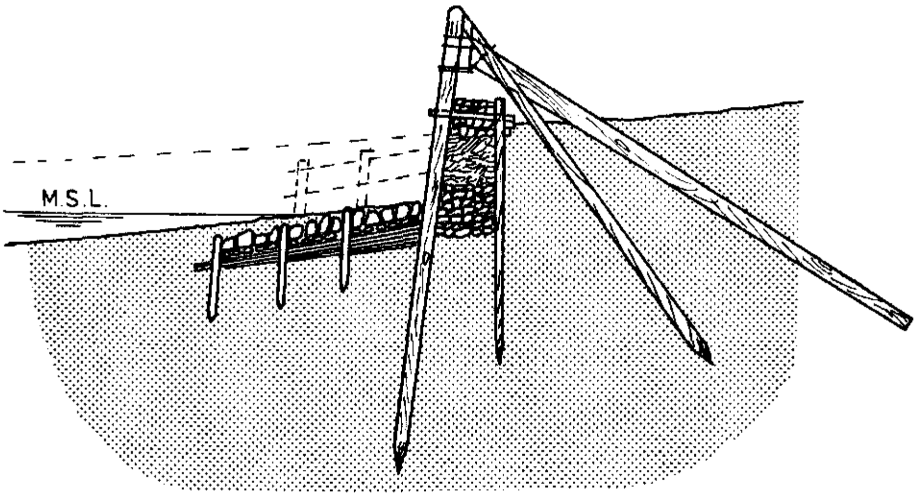

Figure 2. Cross section of an early sea dike

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

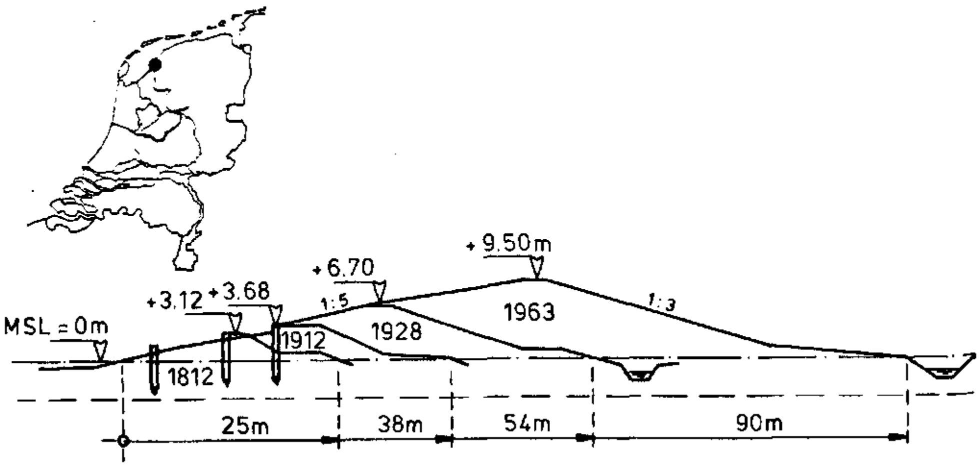

Figure 3. Development in cross section of a sea dike during the period 1812 to 1963

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).

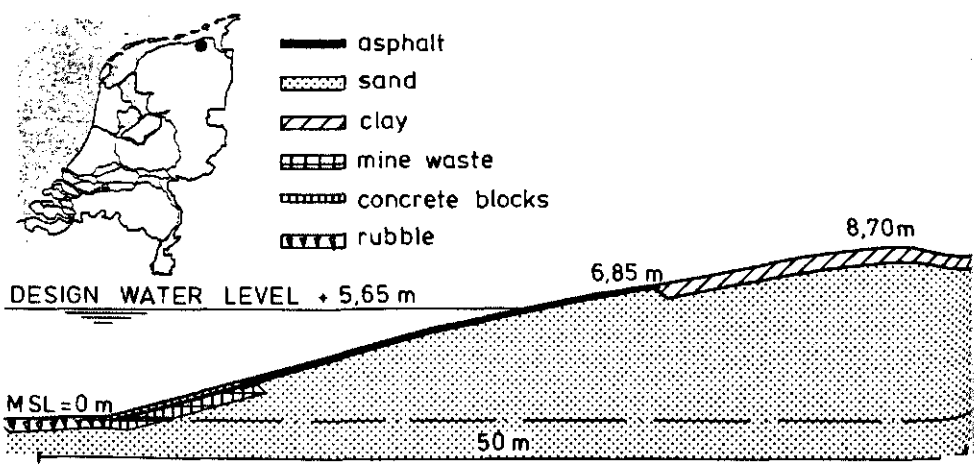

Figure 4. Cross section of a sea dike with asphalt revetments

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.

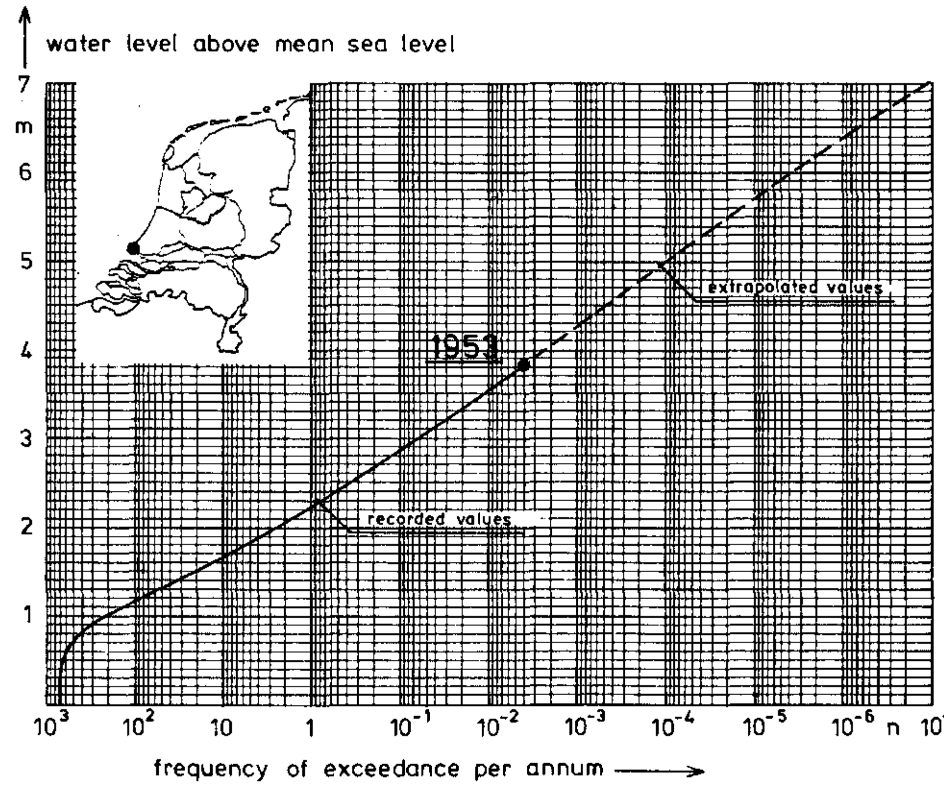

Figure 5. Frequency of exceedance of high water levels at Hook of Holland

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).

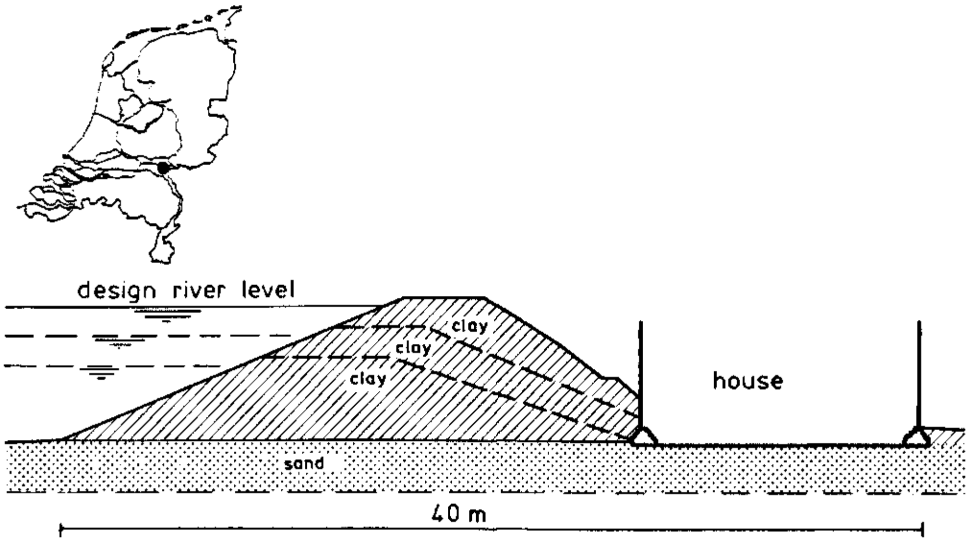

Figure 6. Development in cross section of a river dike in the course of time

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).

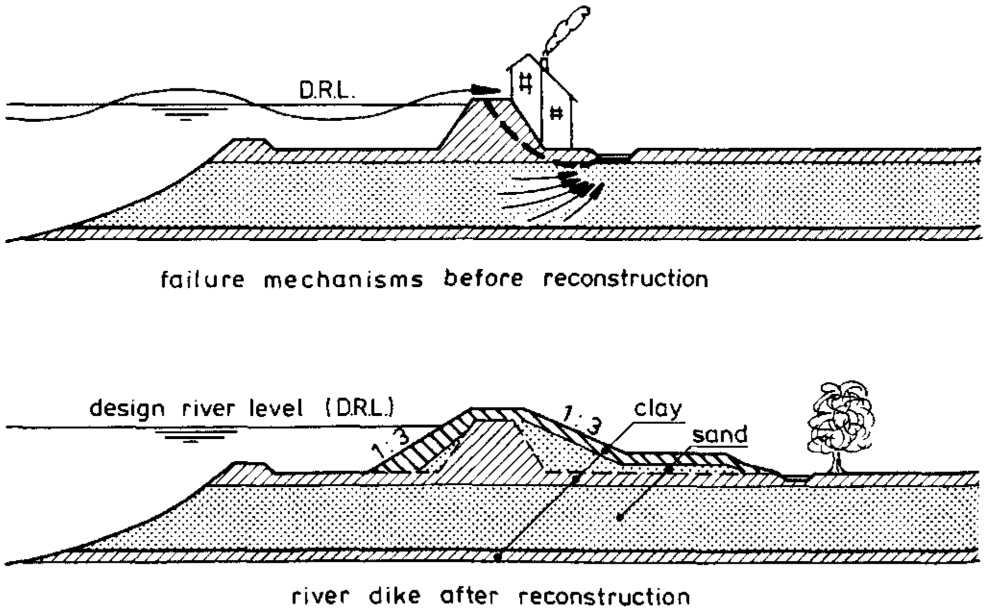

Figure 7. Cross section of a river dike before and after reconstruction

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

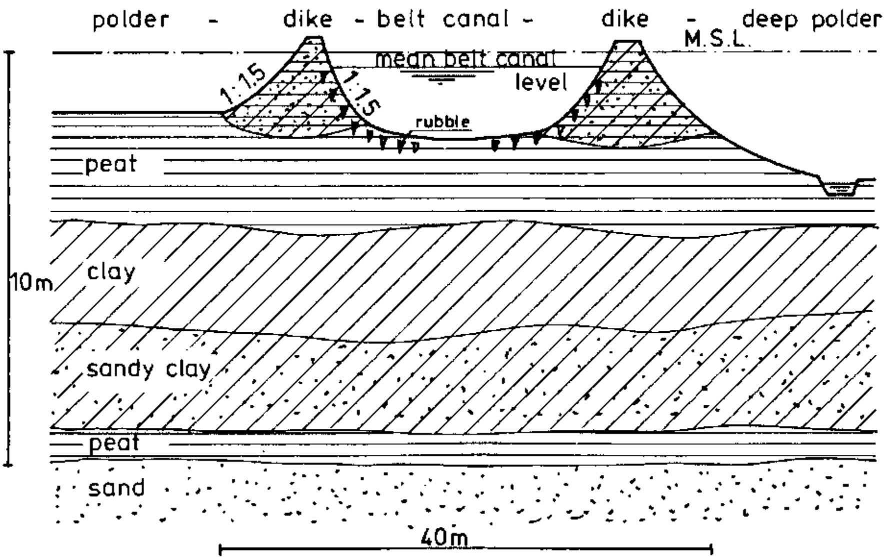

Figure 8. Cross section of a belt canal with dikes

(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.

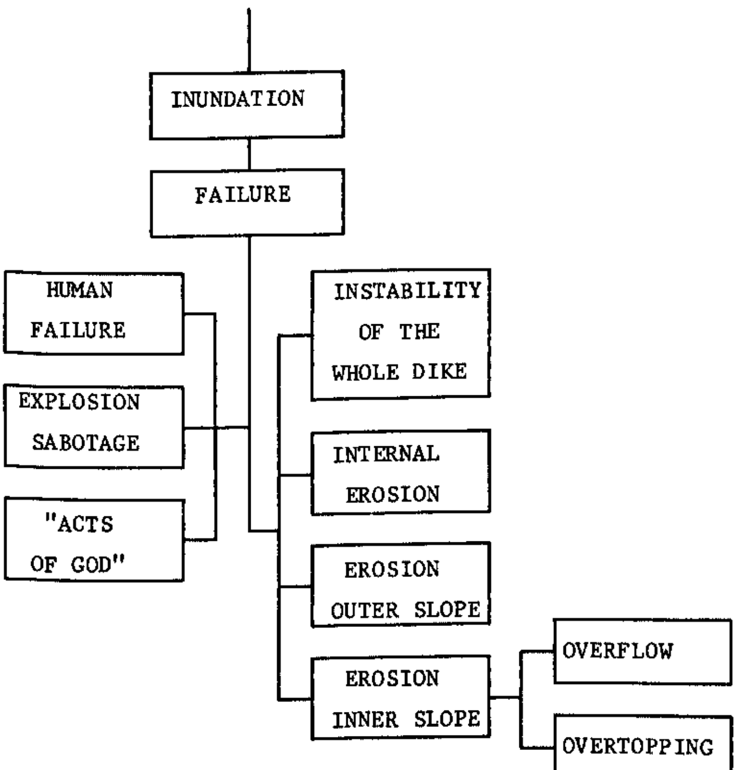

Figure 9. Fault tree

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).

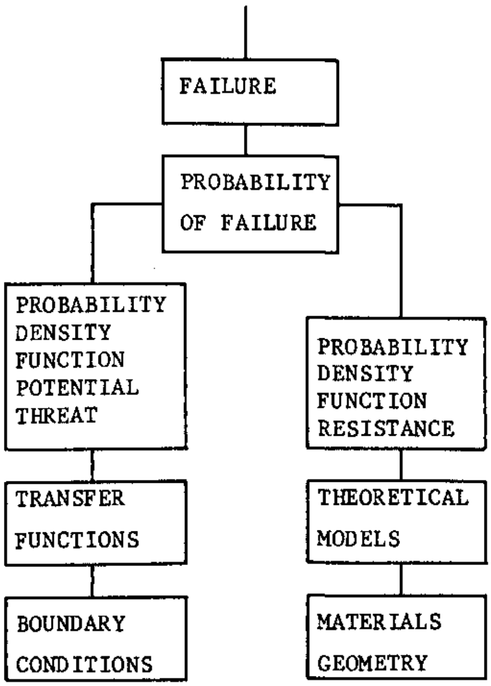

Figure 10. The concept of the ultimate limit state of a failure mechanism

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.

References

Bakker, W.T., J.K. Vrijling 1980. Probabilistic Design of Sea Defences, 17th Coastal Engineering Conference, March 24-28, 1980, Sydney, Australia; pp. 2040-2059.

Wit, J.M. de, J.B. Sellmeijer, A. Penning 1981. Laboratory testing on Piping. Tenth Int. Conf. on Soil Mech. and Found. Eng. June 15-19, 1981, Stockholm, Sweden, pp. 517-520.

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.

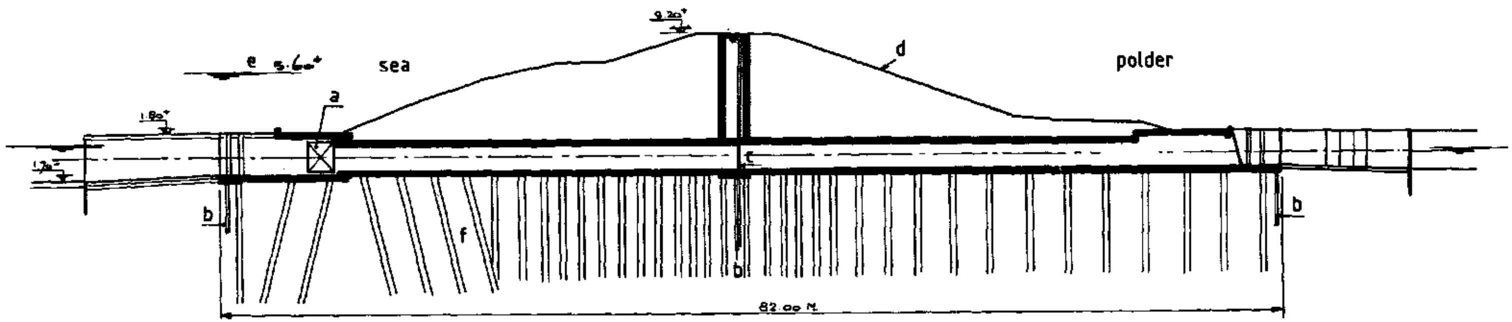

FIG. 1 CONCRETE CULVERT SLUICE. (longitudinal section)

a. one way discharge door

b. sheet pile cut off

c. emergency valve

d. sea dike

e. design water level

f. concrete piles

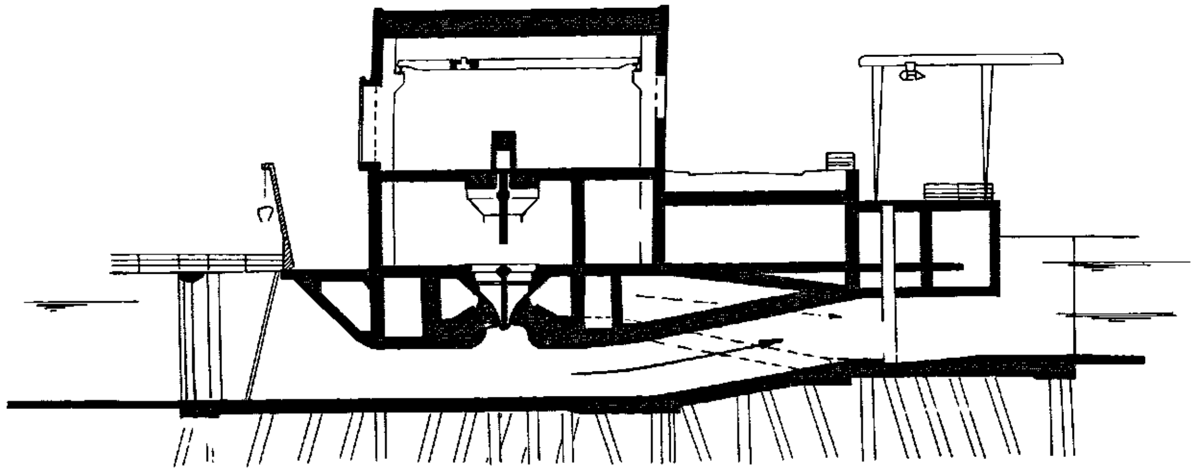

FIG. 2 PUMPHOUSE (longitudinal section)
axial flow pump and sluice

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 pumpin 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.

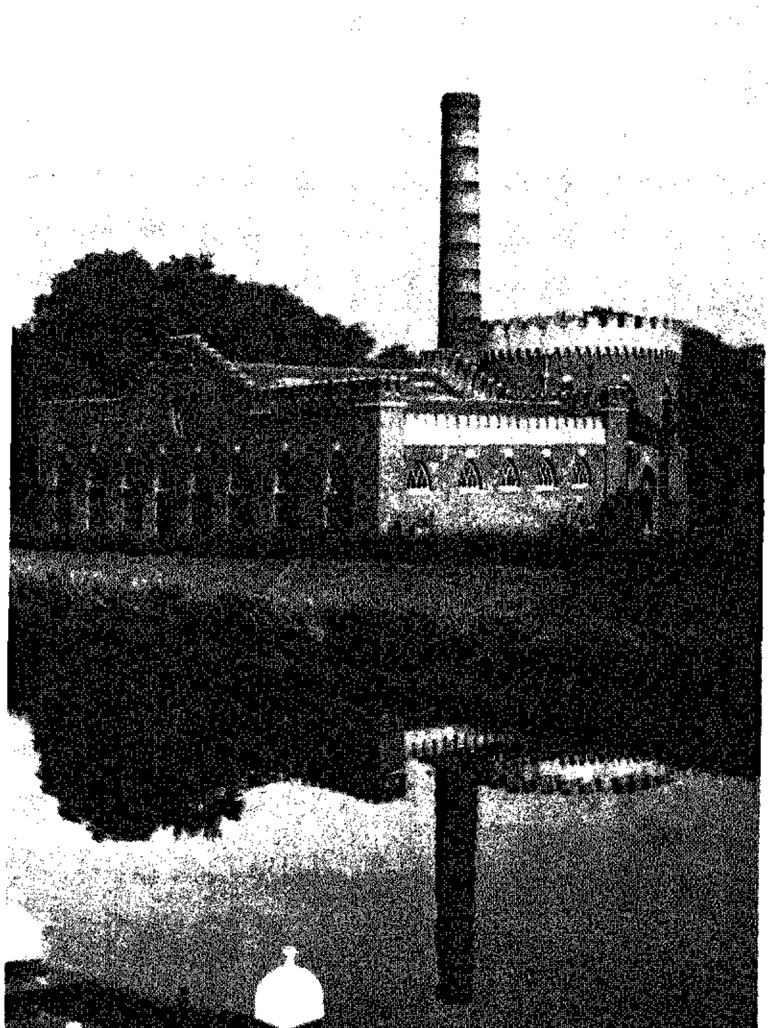

Fig. 3. Pumping station Cruquius

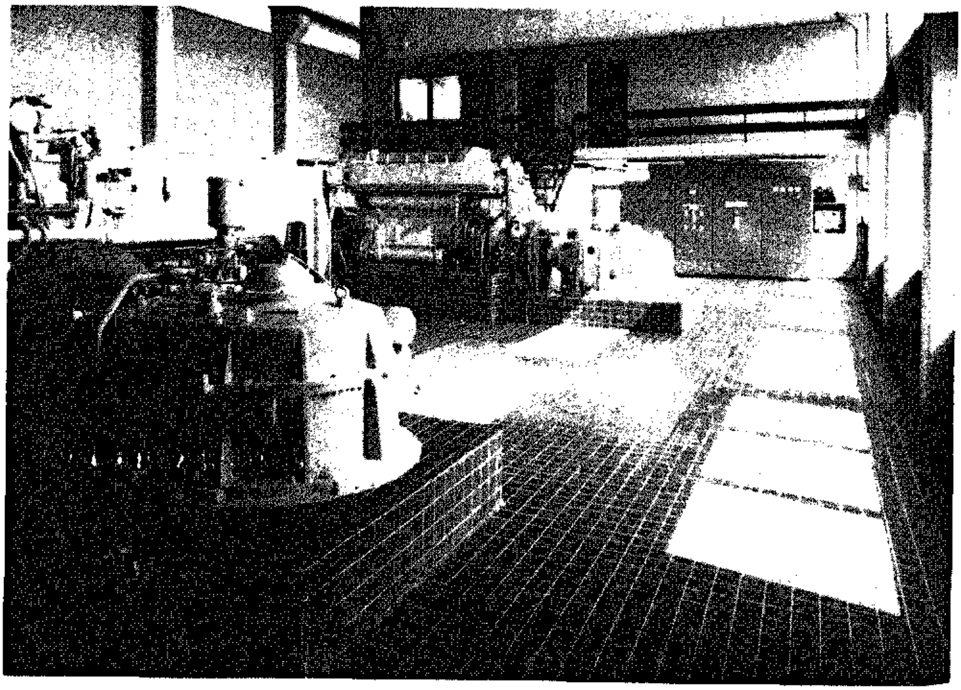

Fig. 4. Pumping station Keizersveer

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).

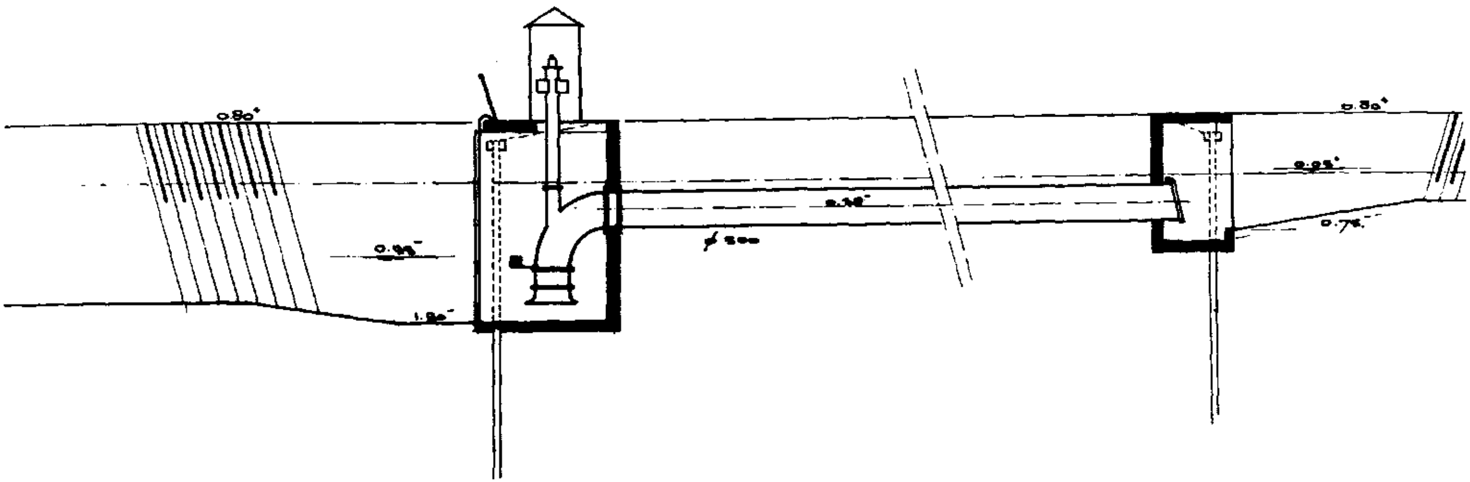

FIG. 5 PREFABRICATED PUMPING STATION

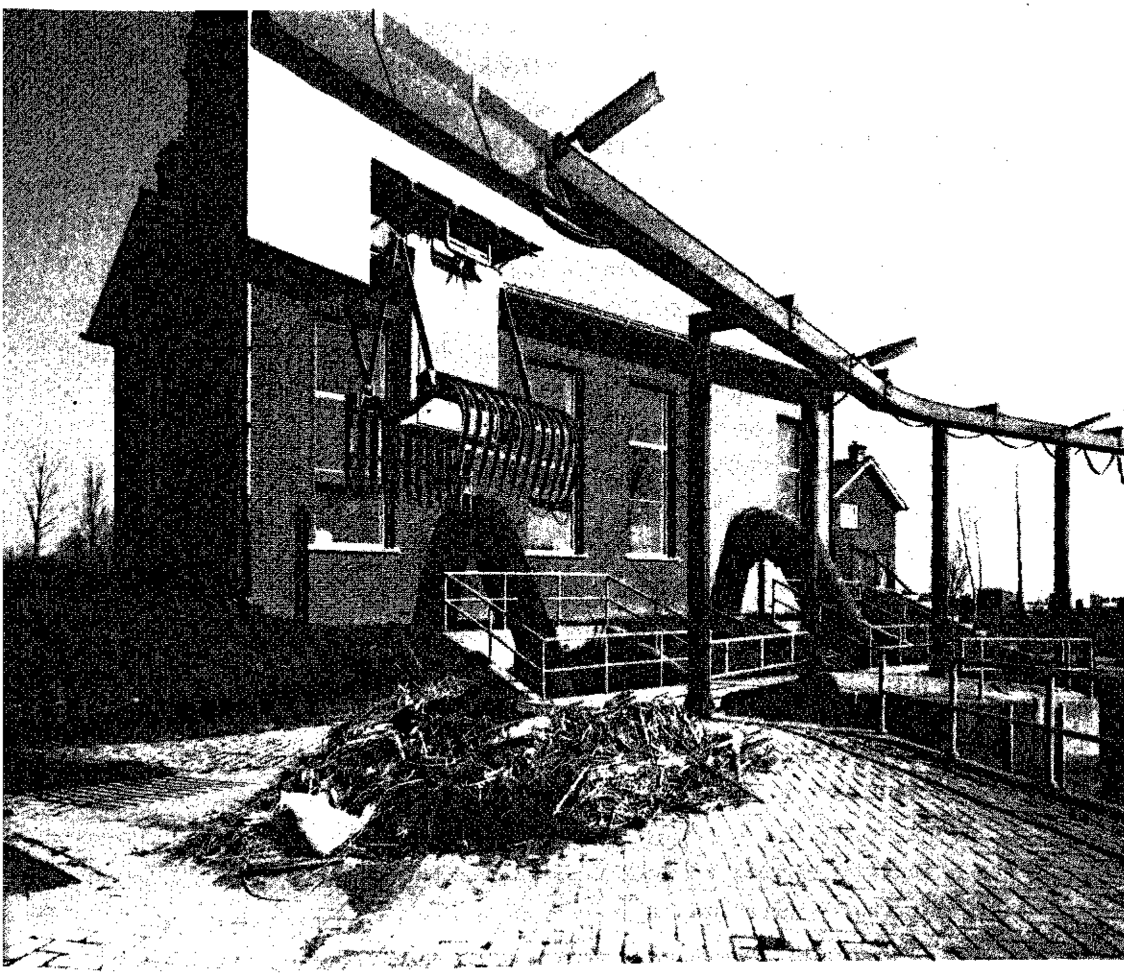

Fig. 6. Completely automatized mechanical trush remover

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

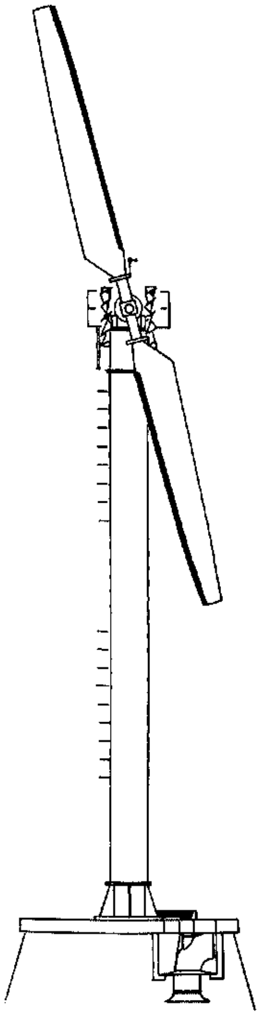

FIG. 7 DRAFT DESIGN
WIND-GENERATOR WITH PUMP

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

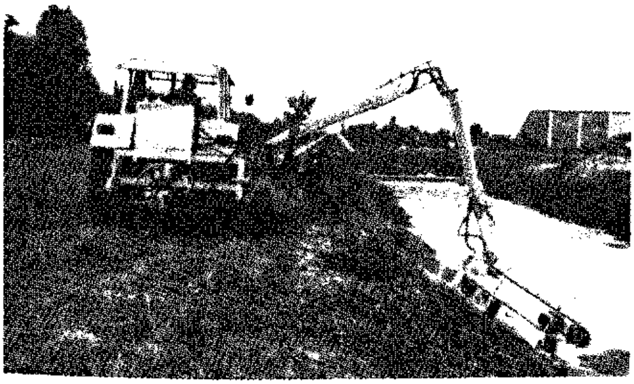

Fig. 8. Maintenance of a water course

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 considerabl 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 import- ance. 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 ord 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 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.

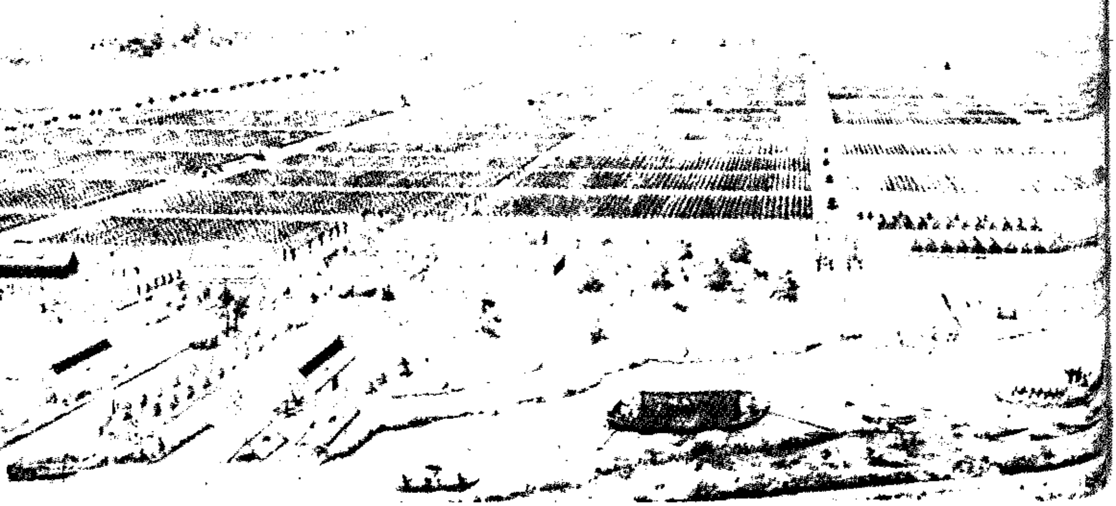


Figure 1. Plantation

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

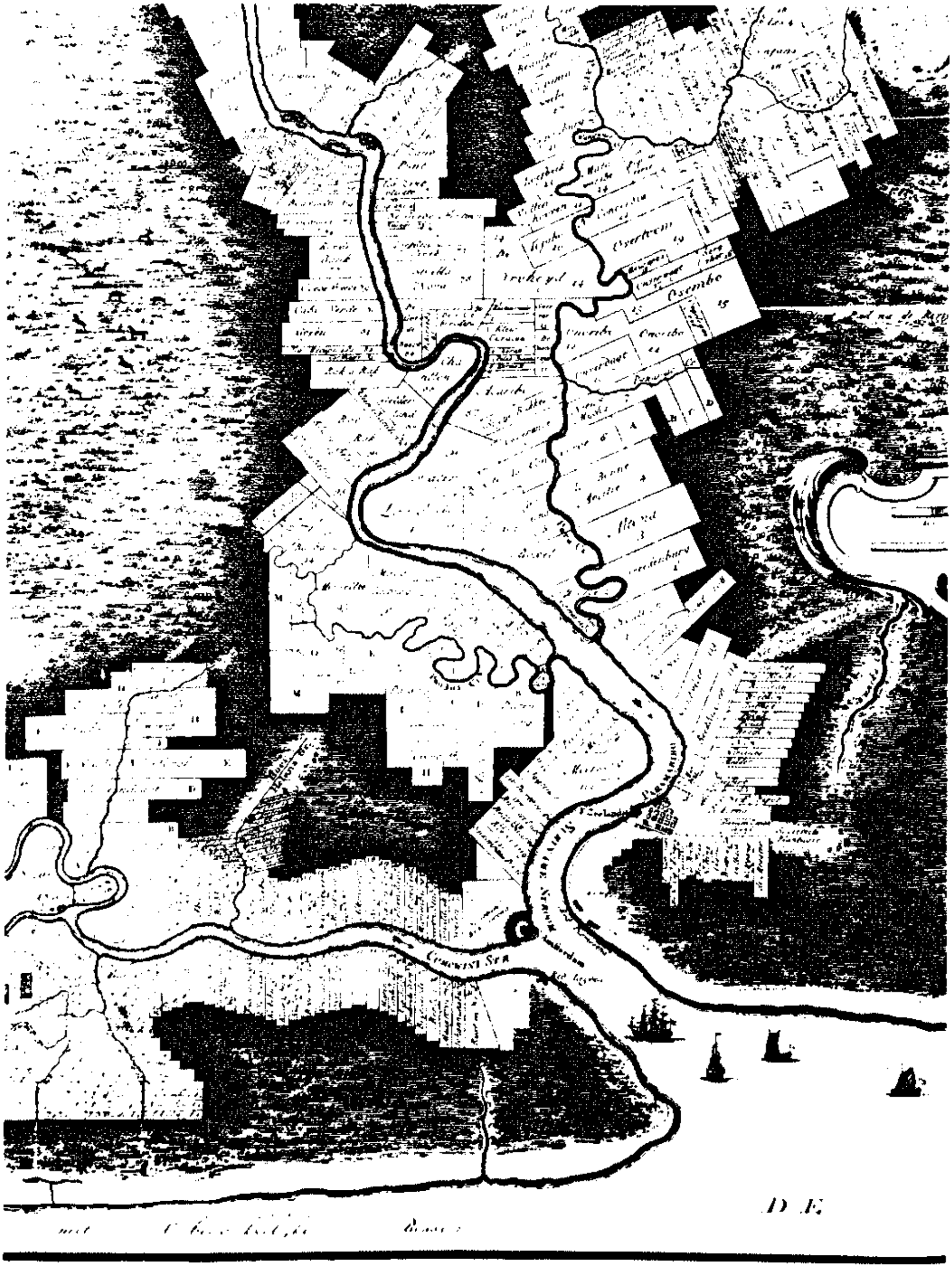


Figure 2. Plantation along a river in South-America

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.

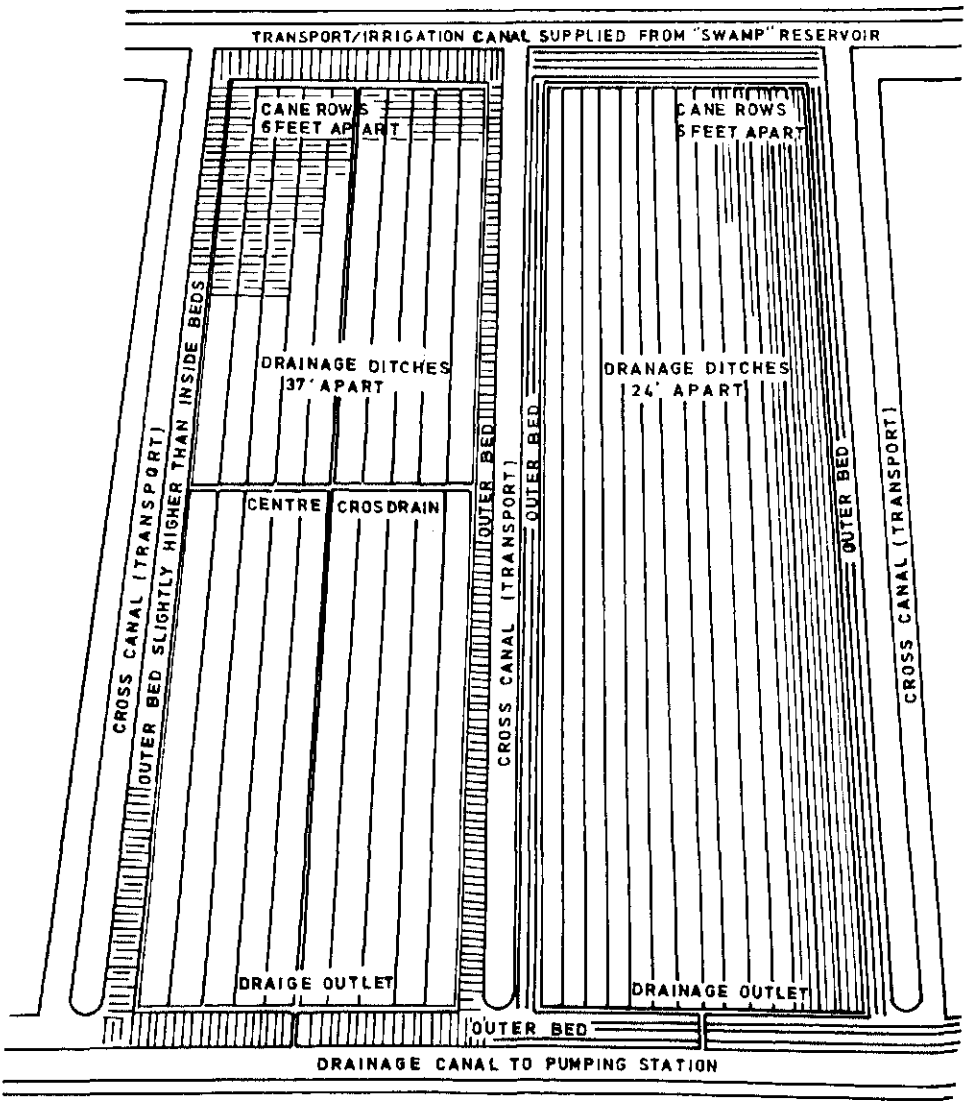
All organic materials such as bagasse, grass, roots and other undesired materials were removed by hand. The dykes were erected with the soil species obtained from the excavation of the canal on the innerside of the polder-dyke.

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

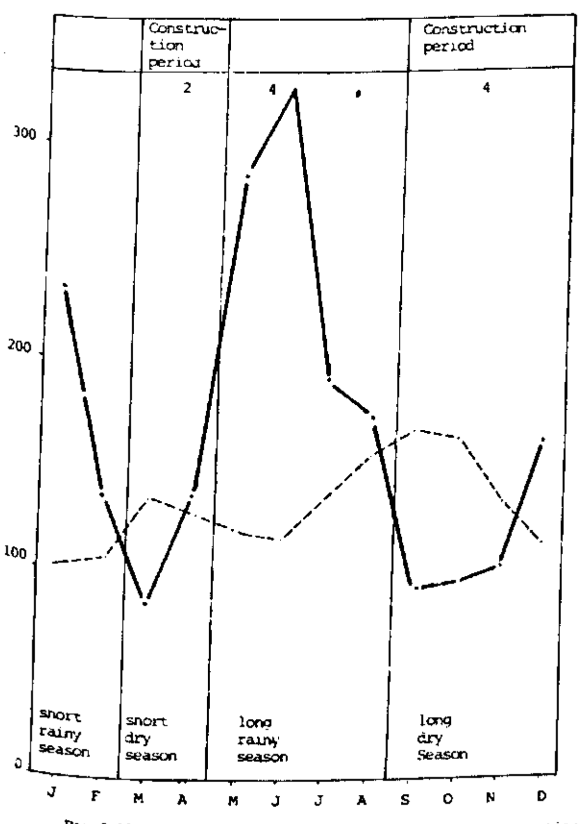


Figure 6.

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

References

Benjamin, dr. H.D. and Joh. F. Snelleman, 1914, Leiden
Encyclopedie van Nederlands West-Indië

Consortium M.C.P., 1978, "Multi-Purpose Corantijn-Projekt,
Voorbereiding FASE I

Consortium M.C.P., 1982, Adviezen B1-B8,
definitief projekt

F.A.O., 1988, Survey of the Canje Reservoir Scheme
Guyana

Lier, prof. R. van, 1971,
Samenleving in een grensgebied

Rodney, Walter, 1979, Guyanese Sugar Plantation in the
late 19th century

Surinaamsche Historische Kring, juli 1968,
Uit Suriname's historie

Surgroma N.V., 1977, Vooronderzoek bevloeiingsmogelijkheden
Regio 2 - Suriname

Teenstra, M.D., 1833, De landbouw in de kolonie
Suriname

Traa, mr. A. van, 1946
Suriname 1900-1940

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 smallscale 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 tot 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, is 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 physocal and the demographic environments where polders are most needed. Alluvial floodplains occupy 80 percent of the totoal land area of 143,000 km^2. It is estimated from soil surveys that about 75 percent of the floodplain area is flooded deeper than 30 cm for 3 - 5 months in the rainy season. In addition, about 1 million hectares near the coast formerly were subjects to tidal flooding with salt water before embanments were built.

Most of the country's population of over 90 million lives in floodplain areas. The average population density is 628/km^2; regionally it varies from more than 1,000/km^2 in Comilla the most densely settled rural district, to less than 500/km^2 in two coastal districts. Considering the fact that more than 80 percent of the country's total population is rural, that is a very high population indeed.

Unlike the Netherlands, Bangladesh does not have major areas where new land for settlement or agricultural production could be reclained from the sea by empolderment. The purpose of making polders in Bangladesh is mainly to protect existing settled agricultural land from deep flooding or from tidal flooding with salt water, so that improved crops can safely be grown in the monsoon season. Often, irrigation is provided at the same time , partly so as to compensate farmers for the loss of soil moisture derived from seasonal flooding, partly to enable farmers to grow improved crops in the dry season also.

Agriculture and food production

Bangladesh's economy is predominantly agricultural. Agriculture contributes about 55 percent of the GNP and supports, directly or indirectly, about 75 percent of the work force. The major cash crop jute provides about 70 percent of the country's export earnings.

Rice is the principal crop, occupying about 80 percent of the net cropped area, spread over three growing seasons. The two rainy season crops are mainly dependent on rainfall and seasonal flooding, but almost all the dry season rice crop is irrigated. Almost 2 million hectares of the rainy season crop are occupied by deepwater rice varieties which can withstand flooding depths greater than 30 cm. Average rice yields are low: 1.35 tons/ha. This reflects the relatively low adoption rate of modern technology, as illustrated by average fertilizer rates (for all crops) of around 100 kg/ha (= < 50 kg/ha nutrients) per annum, spread over three seasons.

The average size of farm holding is 1.4 ha. However, it would be wrong to infer from this that Bangladesh is a country of predominantly small peasant farmers. That is because land ownership is badly skewed. In 1978, the 8.5 percent of rural land owners who possessed 2 ha or more held 48.4 percent of the land; on the other hand, 50.4 percent of rural households owned less than 0.2 ha (including those with no agricultural land at all); (reference 1). Land owners with more than about 2 ha generally use share-croppers or hired labour to cultivate their land; often they are absentee owners. In the past, such big land owners have generally shown little interest in using modern technology to increase production, although there are indications that a change may be taking place in some areas.

Progressive small farmers are found mainly in the south-east and centre of the country.

Bangladesh currently produces 14-15 million tons of foodgrains annually, depending on whether harvests are good or bad. The population of 92 million needs an estimated 14.5 million tons. A further 1.5 million tons are needed to cover seed, feed and waste. That leaves a deficit of 1-2 million tons. Each year, too, population growth adds a further 400,000 tons to the requirement.

In it's Second Five Year Plan (1980-81 to 1984-85), the Government of Bangladesh aims to achieve national self-sufficiency in foodgrain production and to expand the production of other food and cash crops, including sugarcane, banana, jute, cotton, pulses, oilseeds, potato, vegetables and spices. The foodgrain production target by 1984-85 is 18-20 million tons, including provision for building up a reserve food stock. In order to achieve these ambitious targets, it is planned to double the area under irrigation, from 1.47 million ha in 1980 to 2.88 million ha in 1984-85, and to provide flood protection and drainage to an additional 600,000 ha. Therefore, although priority is given to small-scale irrigation, polders also have an important role to play in this planned development.

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 (< 2 m), 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 Dhaka-Narayanganj-Demra (DND) projects, referred to later, occupy parts of the old and young Meghna estuarine floodplains.

d) Tidal floodplains occurring mainly in the south-west, locally in the south-east. They are characterized by almost level, saucer-chaped, 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 flood-plains. 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 texture 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 soil 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 in 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 floodplain 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 30 kg/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 than in silty floodwater. Therefore, the construction of polder embankments will not necessarily 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 length of the rainy season and the depth and duration of seasonal flooding. 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 in order to increase security ot 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 also 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 totale 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 damage by 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 flood-water 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 East Pakistan Water and Power 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 reasin 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 since they were built and many sluices either were not installed or have subsequenly 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. That is because, for most projects areas, it cannot be assumed that, without the project, land use would have remained in the preproject 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 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 by major projects to about half a million ha and irrigation to about 85,000 ha. The direct benefits in terms of increased floodgrain 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 a civil engineering plan .

It is not an agricultural development plan[1). 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 dealy the implementation of that plan. The major cause has been the reluctance of international aid 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 the 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 can take 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 have been expressed, also, on the advisability of double embanking rivers as big and active as the Brahmaputra and the Ganges.

[1)] In Bangladesh, as in many developing countries, irrigation and drainage projects generally are planned, executed and operated by engineers with a background in civil or mechanical engineering, not in agricultural or irrigation engineering.

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 1960's 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 40,000 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 from the hazardous monsoon season 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/1000 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 influence 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 rather 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 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, of 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 pressure - 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!

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 areas 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 - but they are unlined. Also two transplanted rice crops a year are irrigated, even on permeable soils, mainly because the very low or no irrigation charges do not give farmers any incentive to use water more efficiently. 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 Dhaka (or from a donor's headquaters).

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 in the area 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 resonable 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 permenently, 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, prompt 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 satifying 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 risk 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 situation 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 watertable 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 alleriation, 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 is has been made available, to the extent that a consultant examining the problem early in 1982 was able to find little visible evidence of zinc 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 in 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.

Peat basins in the transition zone between the Ganges meander and tidal floodplains have not yet been empoldered, so problems of subsidence of the land surface due to drainage have not yet arisen on a large scale. However, extensive parts of these peat basins are included within the proposed Satla-Baghda and Faridpur projects. Problems arising from subsidence can be expected to develop in these project areas unless the original plans made for draining the basins are modified so as to keep the peat wet (or to bury it with alluvium dredged from adjoining rivers).

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 in Bangladesh showed that in gene settlement and related non-agricultural land use expanded by only 0.8 percent (in total) 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 floodlevel, 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 Dhaka, 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 Dhaka. 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 covert 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 subsequent soil either prevents the farmers from growing their traditional, single, aman crop, or it greatly reduces aman yields and production. Is 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

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 periode 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 continuous to grow at current rates - doubling in about 30 years - then major polder projects (perhaps including eatuary closures) will eventually be needed so as to enable high yielding transplanted <u>aus</u> and <u>aman</u> to be grown on most of the floodplain land, 70 percent of which currently is too deeply flooded for them to be grown reliably during the monsoon season. Irrigation will also be needed to expand HYV crop cultivation in the dry season and to make production more reliable in the monsoon season. By the year 2000 A.D., it is estimated that annual floodgrain 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[1].

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[1] Since this paper was drafted, the Government of Bangladesh has sought assistance from UNDP in preparing a Master Plan for Water Resources Development. The prospectus for this study is more fully comprehensive than that provided by the 1964 Master Plan .

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, where necessary,appropriate changes should be 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 to control forms of land use which conflict with project objectives.

SOCIO-ECONOMIC AND PHYSICAL PLANNING ASPECTS

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 successfull.

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 IJsselmeerpoldersproject 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 recreationareas 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 not doing things, not 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.

The formation of waterboards in the Netherlands')

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.

') 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).

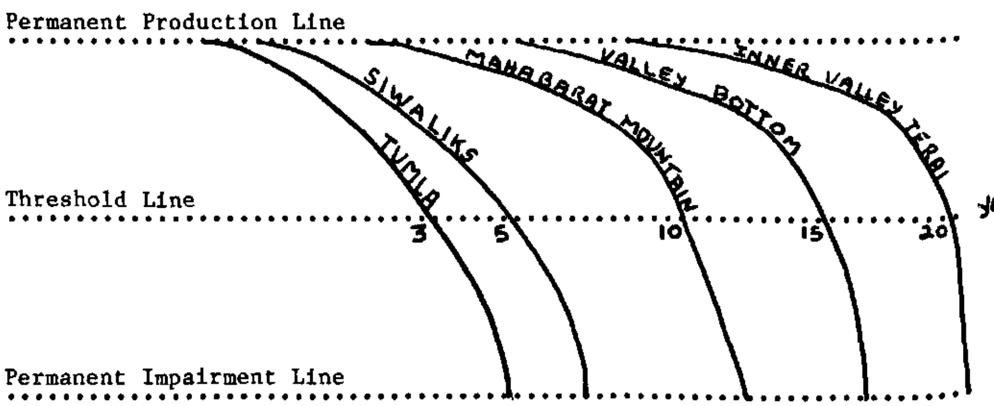

Figure 1. Time period for a given land area to exceed the threshold with a given technique

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 <u>per se</u> 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.

References

[1] Bogetteau-Verlinden, E. 1980. Study on impact of windbreaks in Majjia Valley, Niger. Agricultural U., Wageningen, The Netherlands.

[2] Bromley, D.W. 1980. The political economy of private resource-use decisions affecting soil productivity. Comments prepared for workshop on "Soil Transformation and Productivity."

[3] Ciriacy-Wantrup, S.V. 1968. Resource conservation: economic and policy. U. of California, 3rd Ed.

[4] FAO. 1980. Soil and conservation, Committee on Agriculture, GOAG/81/8, Rome.

[5] Fleming, W.M. 1980. Phewa Tal catchment management program, Nepal: forestry and soil and water conservation. Unpublished manuscript.

[6] Fleming, W.M. 1979. Environmental and economic impacts of watershed conservation on a MAPS reservoirs project in Ecuador. Unpublished paper. Westwater Research Center, U. of British Columbia, Vancouver.

[7] Gupta, S.B. Lal, R. Prasad, and R.K. Paudey. 1973. An economic evaluation of soil conservation in Varanasi District, Uttar Pradesh. Indian Jour. of Agric. Econ., 28, 4:205-211.

[8] Hudson, N. 1981. Soil conservation. Cornell U. Press, Ithaca, NY, 2nd Ed.

[9] Kohnke, H., and A.R. Bertrand. 1959. Soil conservation. McGraw-Hill Book Co., New York.

[10] Lee, L.K. 1980. The impact of landownership factors on soil conservation, Amer. Jour. of Agric. Econ., pp. 1070-1076.

[11] National Association of Conservation Districts. 1980. Soil Degradation: Effects on Agricultural Productivity. National Agricultural Lands Study. Interim Report No. 4. Washington, D.C., Oct.

[12] Seitz, W.D. et al. 1979. Economic impact of soil erosion. Land Economics, 55, 1, Feb.

[13] Sharp, B. and D.W. Bromley. 1979. Soil as an economic resource. U. of Wisconsin, Madison, Oct.

[14] Shaxson, T.F. 1981. Land conservation measures and related costs. FAO, Workshop on Econ. Aspects of Land Cons. under Humid and Semi-Humid Tropical Conditions, Rome, 30 June-3 July.

[15] Stevens, M.E. 1978. Land use pattern for marginal land and erosion. Draft unpublished paper.

[16] U.S. Department of Agriculture. 1962. Shelterbelt influence on Great Plains field environment and crops. Forest Service Production Research Report No. 62, Washington, D.C., Oct.

[17] U.S. Department of Agriculture. 1964. Tree windbreaks for the Central Great Plains. Forest Service Agricultural Handbook No. 250.

ENVIRONMENTAL ASPECTS

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,

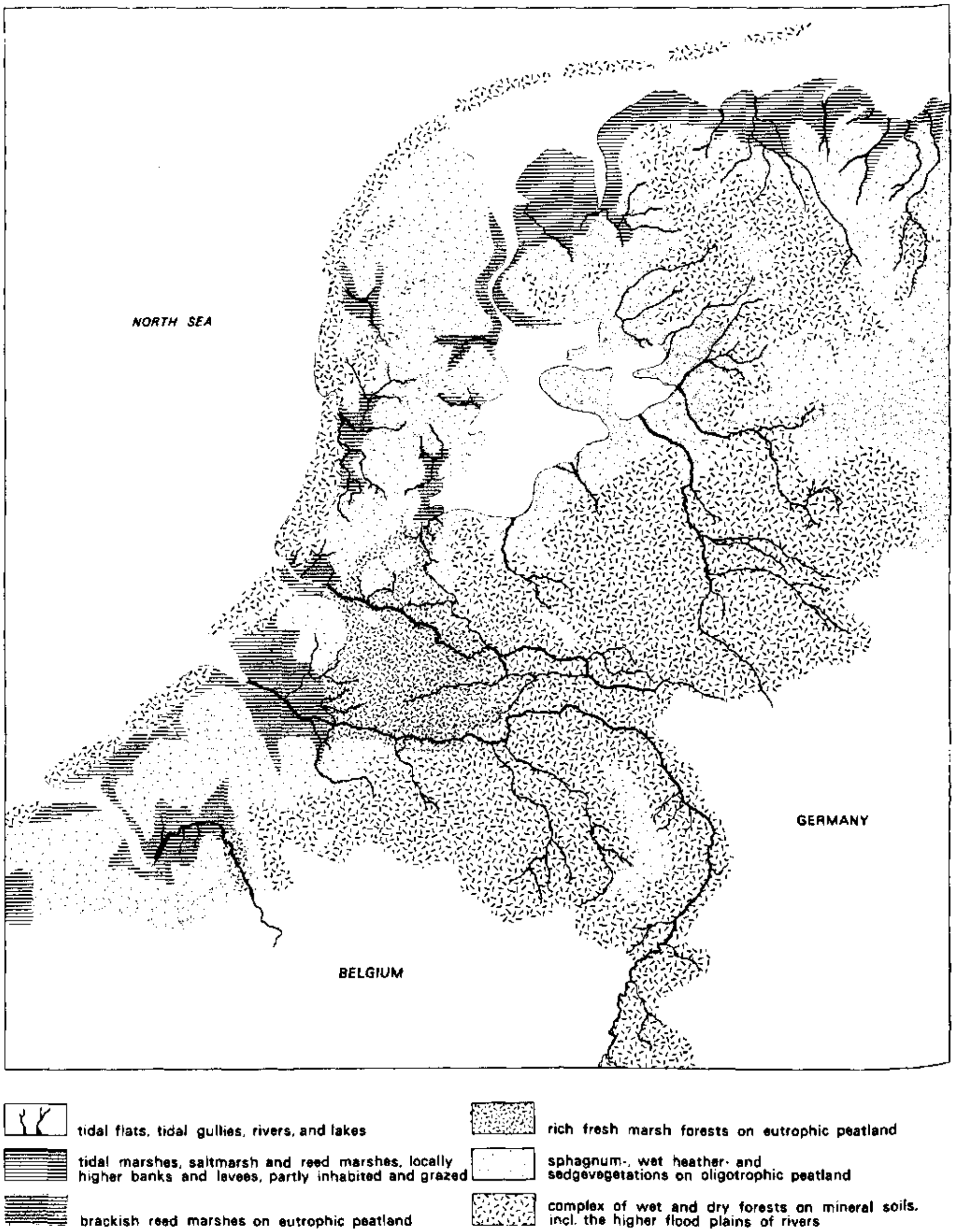

Fig. 1. A reconstruction of the ecological situation of the Netherlands in Roman times (after Pons, 1974).

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.

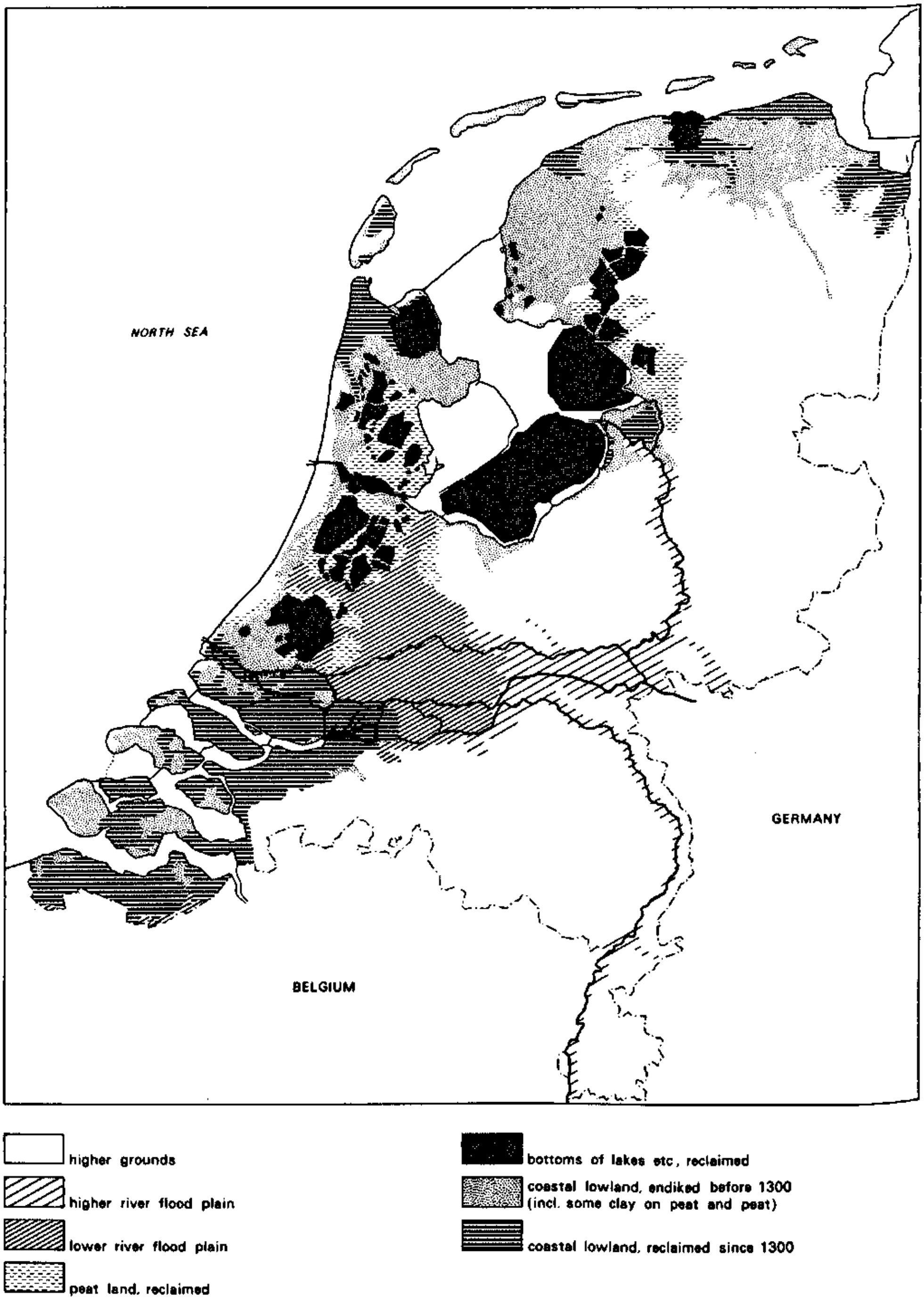

Fig. 2. The location of the polders in downstream flat river catchment areas, in peat areas, of polders made by draining lakes and of polders made by coastal embankments in the Netherlands.

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.

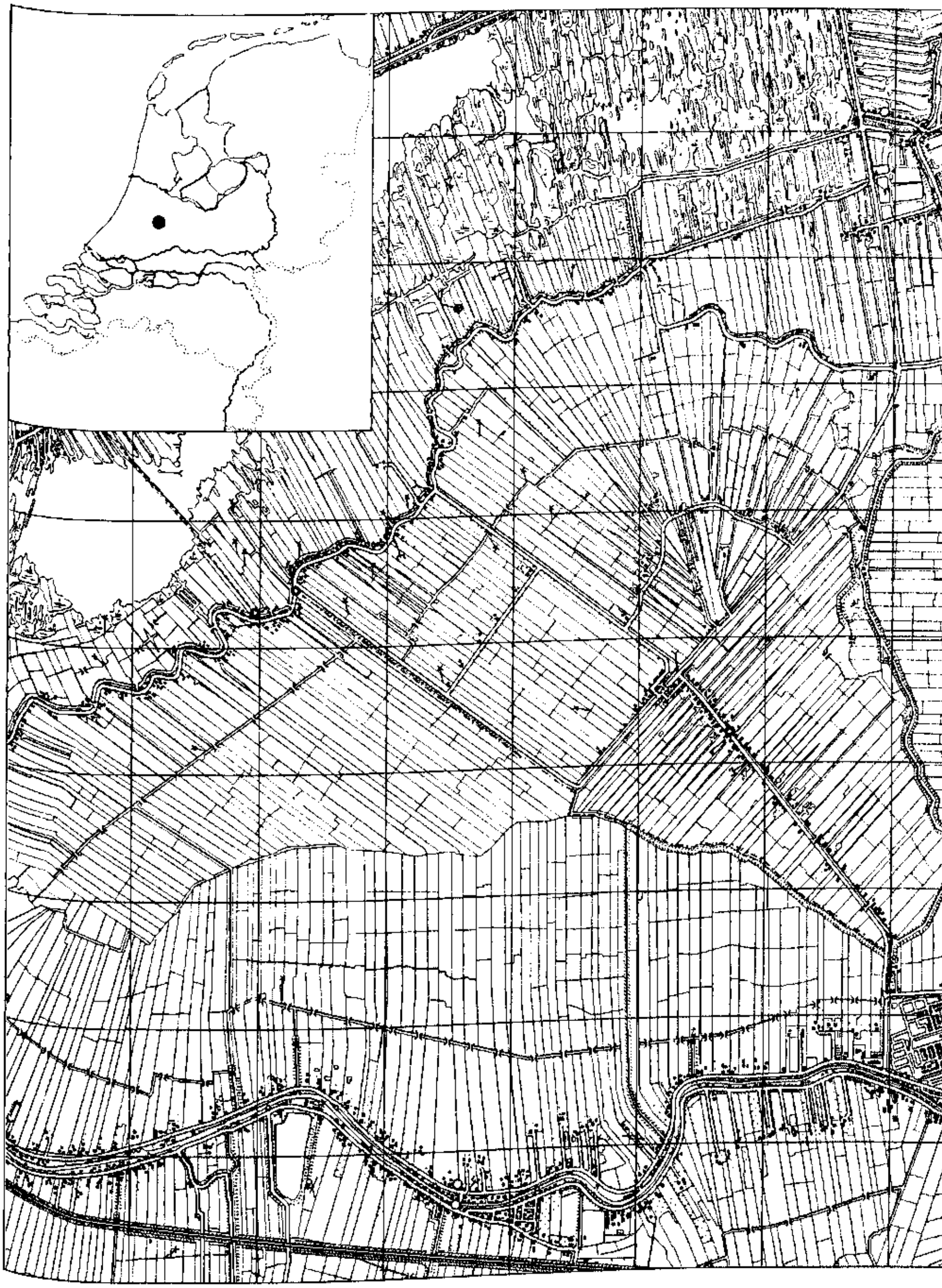

Fig. 3. A typical example of the long stretched parcelling in the peat reclamation areas in the western part of the Netherlands (Holland - Utrecht region).

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

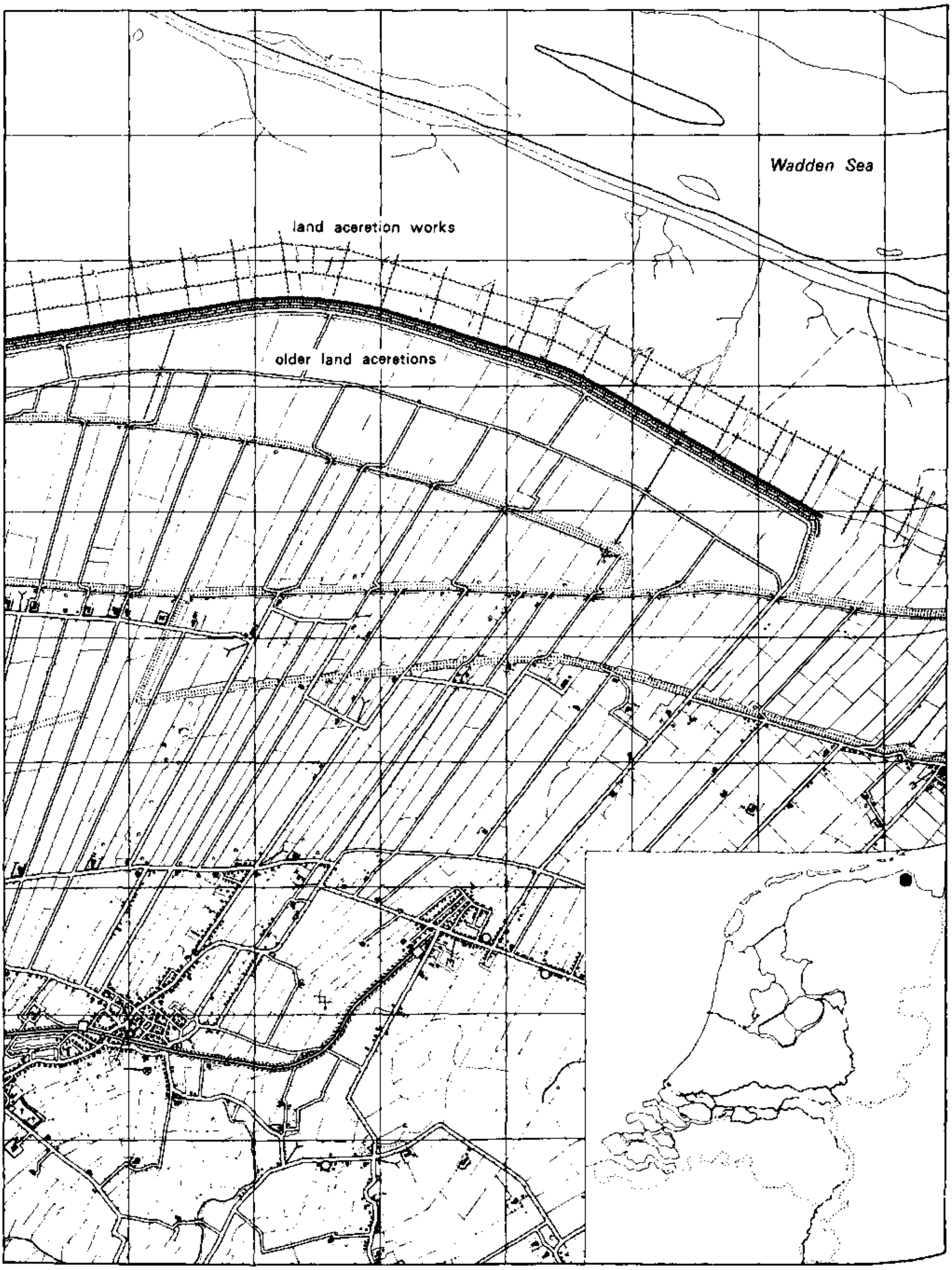

Fig. 5. Land accretion works in the Waddensea region.

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.

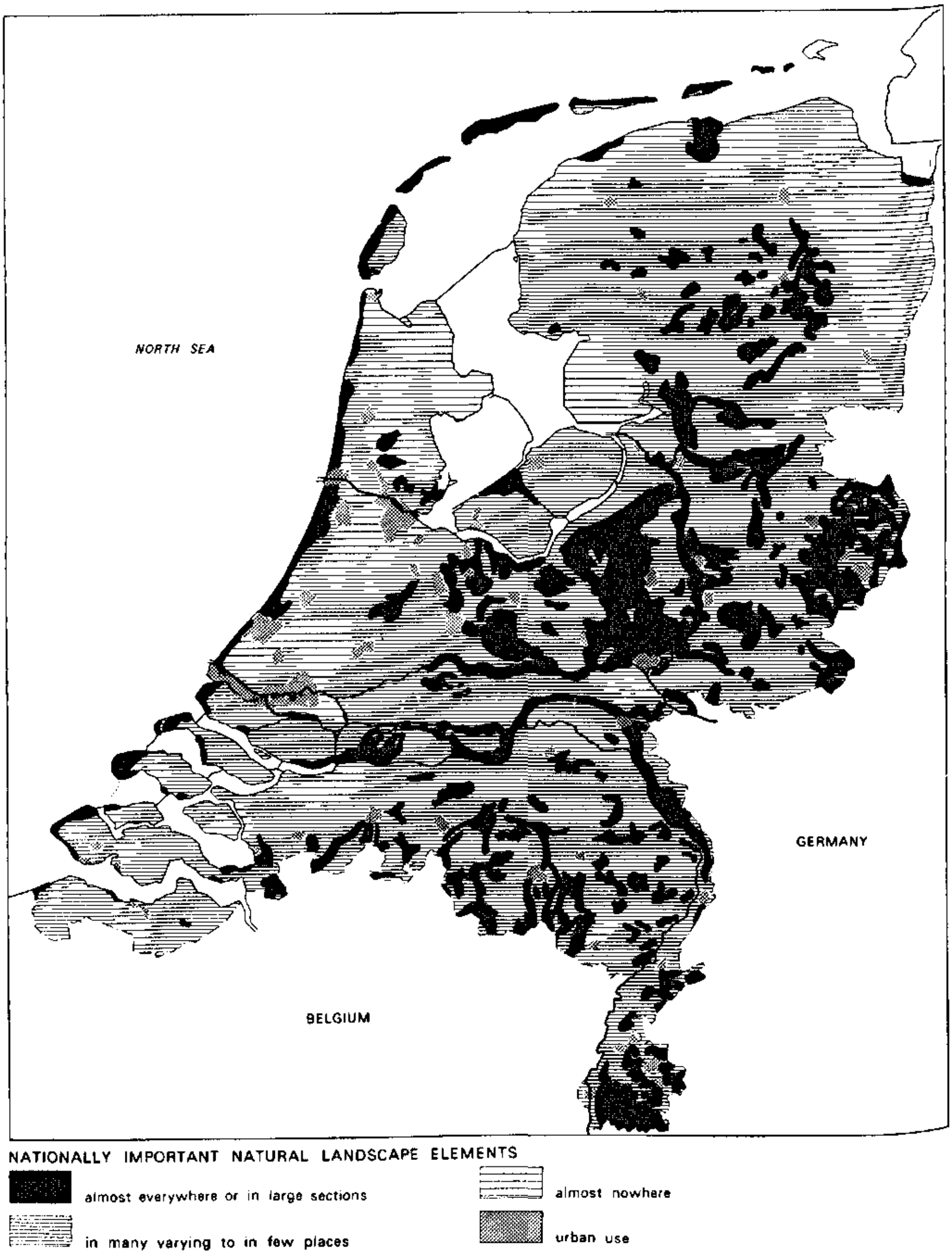

Fig. 6. The ecological situation of the Netherlands around 1975 (after Atlas van Nederland).

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).

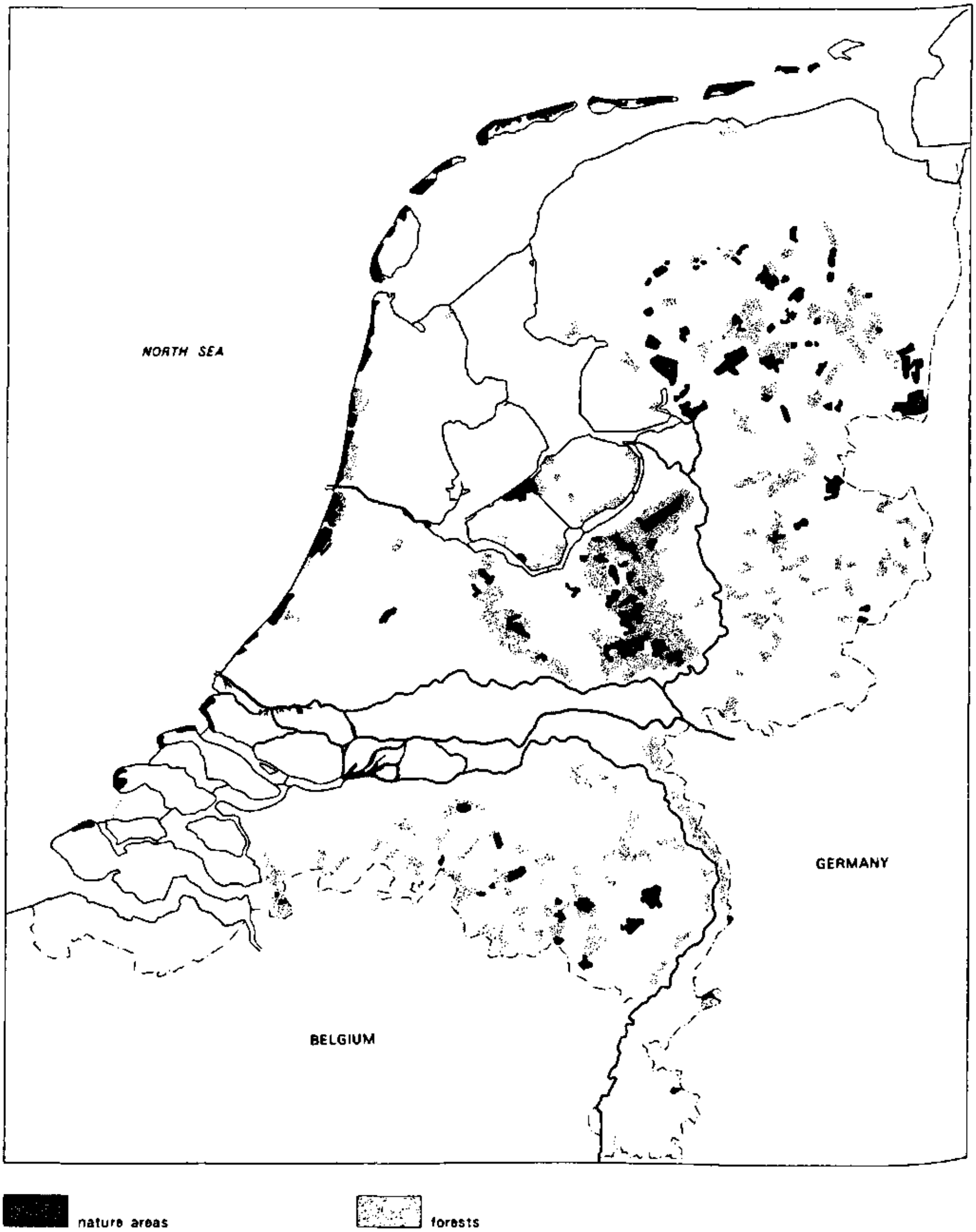

Fig. 7. Nature reserves and forest areas in the Netherlands around 1975 (after Atlas van Nederland).

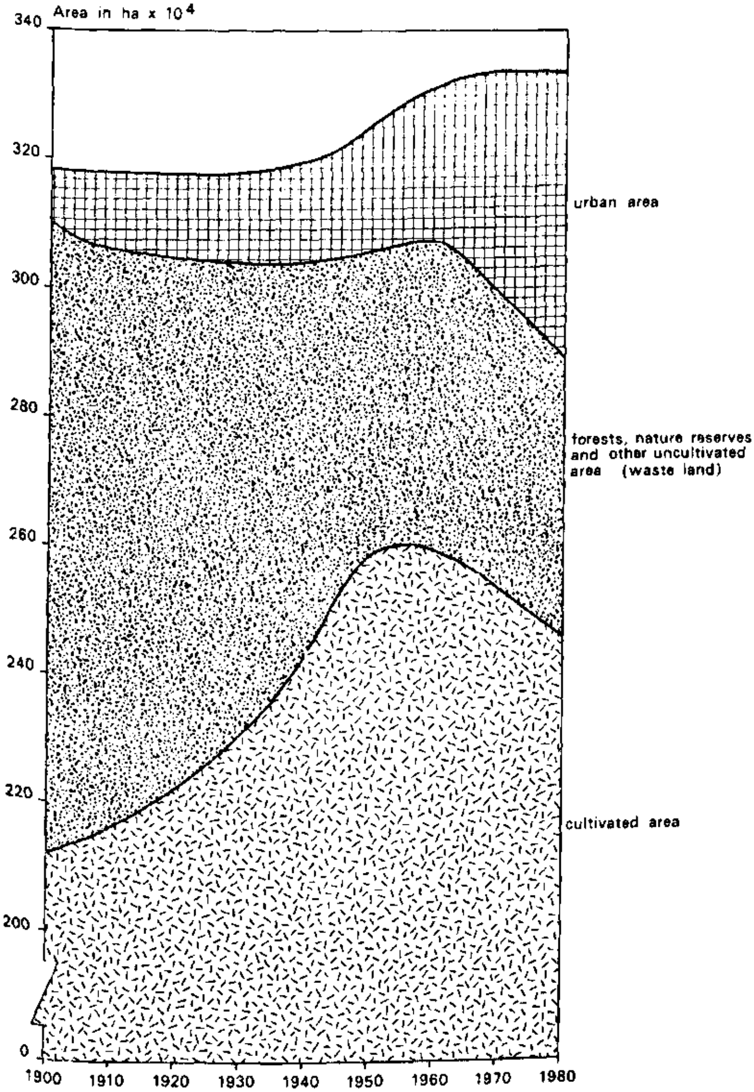

Fig. 8. The development in the land uses in the Netherlands during the 20th century.

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

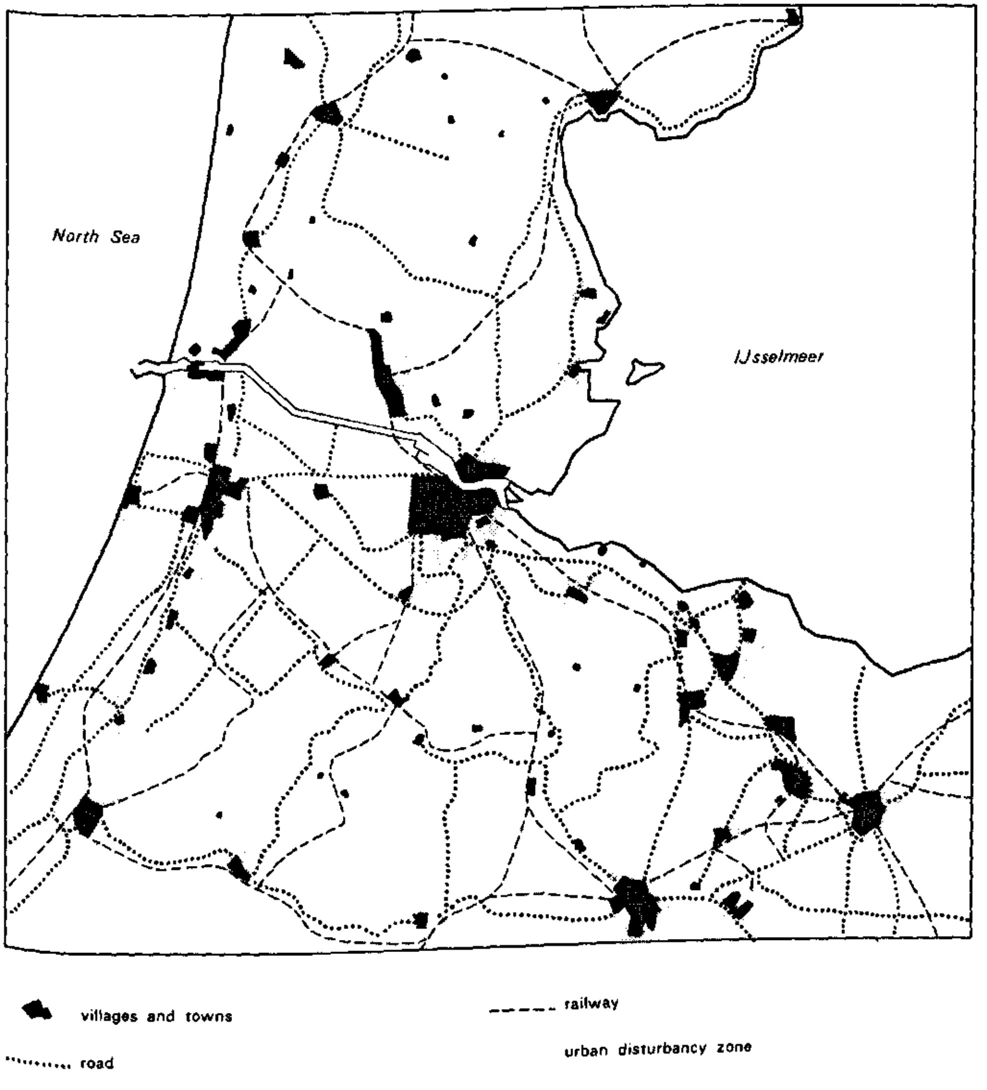

Fig. 9. The urbanisation in the Amsterdam region in the Netherlands in 1930 and the urban disturbancy zones (arbitraraly set at 1.5 km in 1930).

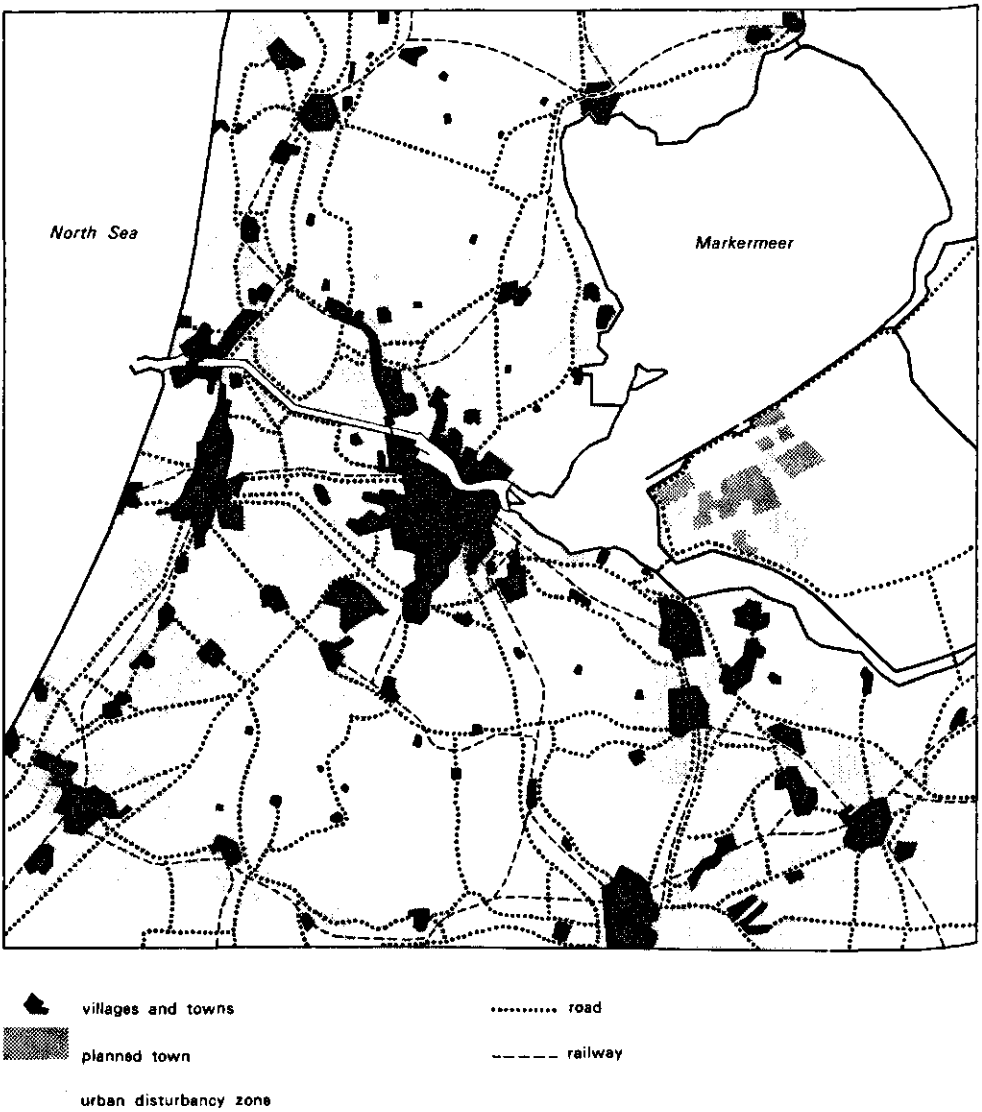

Fig. 10. The urbanisation in the Amsterdam region in the Netherlands in 1975 and the urban disturbancy zones at that time (arbitraraly set at 4 km in 1980).

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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References

Linden, H. van der. History of the reclamation of the western fenlands and of the organizations to keep them drained. In: Proceedings of the symposium on peat lands below sea level, ed. by H. de Bakker and M.W. van den Berg. ILRI publication no. 30, Wageningen, 1982.

Pons, L.J. Ecological map of the Netherlands in Roman times (1974). In: Leven met bomen en bossen, J.F. Wolterson, 1974.

Poorter, E.P.R. De zilverreigers van de Oostvaardersplassen. In: De Lepelaar, no. 66, 23-25, 1980.

Rooth, J. a.o. Numbers and distribution of wild geese in the Netherlands 1974-1979. In: Wildfowl, december 1981.

Saeijs, H.L.F. and H.J.M. Baptist. Evaluatie van Westeuropese overwinteringsgebieden van watervogels. Deltadienst nota 78-10, 1978.

- Atlas van de broedvogels van West-Nederland.
- Atlas van Nederland.

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 do's and don'ts.

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 Mirim 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 Penaeus indicus. 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

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.

6. References

1. History of tidal land reclamation carried out by the Higo Clan.
   Toshisane Shibuya.
   Kumamota Year-Book (1954 edition).
   Translated by the Ministry of Agriculture and Forestry, Japan.

2. De agrarische geschiedenis van West-Europa 500-1850.
   Bernard Slicher van Bath.
   Het Spectrum, Antwerpen, 1960.

3. Irrigation in the world - Comparative developments.
   Hitsohi Fukuda.
   University of Tokyo Press, Tokyo 1976.

4. Rice in Asia.
   The Association of Japanese Agricultural Scientific Societs.
   University of Tokyo Press, Tokyo 1975.

5. Sur les orignies de l'agriculture hydraulique.
   Jacques Bethemont.
   XIe Congrès I.C.I.D. Grenoble 1981.

6. Land development and improvement projects in Japan.
   Shiro Sasaki.
   Agricultural Development Series 3. Agriculture, Forestry and Fisheries Productivity Conference, Tokyo 1959.

7. Dredge, Drain, Reclaim - The art of a nation.
   Joh. van Veen.
   Martinus Nijhoff, The Hague 1948.

8. Land below sea level _ Holland in its age - long fight against the waters.
   Joh. van Veen.
   N.V. Drukkerij Trio, The Hague 1953.

9. History of Hydrology.
   Asit K. Biswas.
   North-Holland Publishing Company, Amsterdam 1970.

10. History of Hydraulics.
Hunter Rouse and Simon Ince.
Dover Publications, New-York 1957.

11. A history of Dams.
Norman Smith.
Peter Davies, London 1971.

12. Japan - A short cultural history.
Sir George B. Sansom.
The Cresset Press London 1952.

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 <u>virgin</u> land because millions of hectares of <u>cultivated</u> 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.

Literature

Early Implementation Projects for Flood Control and Irrigation in Bangladesh. First interim report, 1978. Euroconsult, Arnhem.

Glopper, R.J. de, Aspects of reclamation plans. Land and Water Intern. 24, 6-13, 1974.

Grijm, W., Man and Science in the Development of Water Resources. Newsletter IHE, 13, 22-26, 1980.

Horst, L., Alternative Development Concepts in Potential Polder Areas in Developing Countries, 1982. This symposium.

Liere, W.J. van, Southeast Asia - Potential World Food Basket, Neth. J. Agr. Sc. 25, 14-25, 1977.

Odum, E.P., The role of tidal marshes in estuarine production. The Conservationist 15 (6), 12-15, 1961.

Ohling, J., (ed). Ostfriesland in Schutze des Deiches. Krummhorn, 1969.

Veen, J. van, Dredge, Drain, Reclaim.- The art of a nation. The Hague, 1948.

Volker, A., History and future of impoldering in the world, 1982. This symposium.

GENERAL REPORTS AND CONCLUSIONS PER THEME

THEME A: POLDER PROJECTS

SUB-THEME: VARIOUS ASPECTS OF POLDERS IN A CERTAIN AREA

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Abstract

What is the essential feature of a polder?

We hear ten answers to this question. All are quite different, but all are equally valid.

From the Netherlands we have two answers: it is reclamation of the sea bed for agricultural, urban and recreational use; it is also the protection of dense populations from accidental inundation.

In West Germany it is the avoidance of false political and sociological goals.

In Hungary it is the attainment of the optimum balance between minerals, water and air in a soil.

In Romania it is the protection of a part of the flood plain of a great river from too-frequent inundation.

In Spain, Thailand and Vietnam, the correct management of water to combat toxic ions in the soil is the central feature of reclamation.

In Guinea Bissau, it is the adaption of modern techniques of reclamation to methods appropriate for an African social structure.

In Suriname, supplies direct from tropical rivers must be combined with water collected from the swamps themselves to give the best management of reclaimed lands.

The papers are fascinating in their variety; impressive in the unity of resolve the authors show in overcoming the problems with which they are confronted.

Introduction

Answers to the question 'What is the essential feature of a polder? come to us from different parts of the world, and, although the answers are so different, all are good and correct answers, because the authors have started from the same fundamental unspoken assumption. It is that the earth, which often appears so hostile, can be transformed into a home in which men and women should live in peace, and free from drudgery and want. From this common assumption, the contributors have provided a set of highly individual answers. They are not easy to summarize together for each goes to the heart of the local problem which has to be solved for that area. A sketch of the main features of each paper there fore follows. Finally a table lists and reclamations and compares important elements in their design.

THE NETHERLANDS -- The Ysselmeer Polders -- Constandse, de Jong and Pinkers.

The former Zuyder Zee became the Ysselmeer or Yssel lake after 1932 when a barrier dam separated it from the North Sea. Four polders have been reclaimed in the lake. A fifth is under discussion. Total reclaimed area will be 200 000 ha. In winter, rainfall exceeds evaporation but in summer this is reversed. A large part of the Netherlands (40%) depends on artificial drainage. Soil types vary over the area, but a large proportion are very fertile loams.

Reclamation of the polders is only part of a plan made in 1890 and approved in 1918, which had the following objectives:-

a) Shortening of the coastline to give more effective safety against storm surges in the North Sea.

b) Reclamation of high quality agricultural land.

c) Improved water management with better control of level and salinity.

d) Improved road systems.

As construction has been under way for 60 years, new objectives have been set in the field of urban development, forestry, nature conservation and recreation.

Three state organisations supervise the development:-

a) Zuyder Zee Works Agency designs and constructs large scale civil engineering works e.g. dikes, pumping stations, bridges, canals, roads

b) The Public Body of the Yssel Lake Polders is in charge of local government

c) The Ysselmeer Polders Development Authority prepares the newly reclaimed land for its final use, including social and economic development.

Reclamation works proceed through the following stages:-

1. Construction of enclosing dike, pumping stations and drainage canals following by pumping dry of the polder
2. Mud surface is sown with reed seeds from aircraft
3. Smaller drains are dug, land is sub divided into fields and roads are built over a 10 year period
4. Cultivation starts with burning-off of reed beds and preparation of land for cropping.
5. Land is farmed for 5 years by Government
6. Subsurface drain-pipes are installed and farm buildings constructed. Water, electricity and telephone services are installed. Villages are built.
7. Land is allocated in holdings needing 1-4 workers. The occupiers of the land live on their farms.
8. Landscaping, forestry and recreational areas are given attention.
9. Finally, when all works are complete, maintenance is handed over to a Polder Board, and local government takes over the administration.

The land is divided into rectangular fields about 500 m x 1200 m, each with road access and boundary canal. A labour force of about 700 men cultivate an area of about 20,000 ha. during the first five years. Thereafter, the land is let out to farmers. There are many more applicants than farms so a selection procedure is necessary. The average size of farm is 40 ha, varying between 20 and 90 ha.

In the first two polders, agricultural development was of prime importance and only the poorest soils were reserved for other use. In the course of time, urban development has become more important along with associated recreational facilities. In the recent polders, even good agricultural soils are being allocated for these purposes. Two large

new towns are under construction - Lelystad in Eastern Flevoland for 100,000 inhabitants and Almere in Southern Flevoland for 125,000.
In the early polders is was assumed that each farm should be within cycling distance of a village (max. 7 Km) so that shops, schools and churches should be within easy reach. Consequently, a relatively large number of small villages (500-2000 inhabitants) was built. In present circumstances, with greatly increased productivity, the number of farm workers has diminished, and with greater motorization the distance between farms and village is no longer a problem. A village is now considered to require 3000 inhabitants to farm a viable unit and therefore the number of villages planned for Eastern Flevoland has been reduced from the original fourteen, to only three. In Southern Flevoland, there will be the large polynuclear town of Almere for 125000 to 250000 inhabitants, plus only one local service centre called Zeewolde.
Recreational facilities have been provided on the lakes bordering the polders and in the areas set aside for forestry. Nature reserves have been established to preserve and extend habitats for plant and bird life.

THE NETHERLANDS - Protecting the North Holland Polder Area against Flooding -- Vernimmen and Heyligers.

The province of North Holland occupies the flat coastal area north of Amsterdam. In the Middle Ages there were a number of lakes in the area in open connection with the Zuyder Zee. In the 16th Century the major estuaries were closed and in the 17th Century nearly all the lakes were drained. The method was to surround the lake by an embankment called the 'boezem' embankment in such a way as to leave a strip of water known as the ring canal between the embankment and the border of the lake. The water of the lake was pumped into the ring canal. The ring canals were connected with each other and with other canals in the area to form a maze of water courses all at the same level, called a 'boezem' system.
On either side of the canals, several metres lower are the polders.

These are tracts of land surrounded by dikes with artifical water level control, very fertile soil and numerous towns and villages with some millions of inhabitants.

Sea walls must be capable of standing up to extreme gale-swept floods, but these boezem embankments need only rise a small amount above normal water level because the range of variation in boezem water level is only a few decimetres. On the other hand, the embankment must be capable of withstanding the difference in level between boezem water and polder water (up to 5m.) Investigations have recently shown that many of the embankments do not have a sufficient degree of stability to meet present-day standards.

Although the same banks can be reinforced by placing sand on the polder side, it is still possible for bursts to occur due to undetected weak spots, pipeline fractures, burrowing animals or acts of war.

If a boezem dike bursts, the damage is often very severe. Usually it will not be possible to close the breach until the water levels have equalised. There is the danger of loss of life, damage to buildings and services, disruption of industry. etc. A rapid fall in boezem water level can also cause considerable damage to banks.

A dike burst occurred in 1960 in North Holland in the embankment of a small polder lying on a large boezem and 2600 homes were flooded and 1100 inhabitants had to be evacuated.

The consequences of dike bursts may be restricted in two ways:-

- by reducing the area that can be inundated
- by reducing the quality of water that can flow from the boezem into the polder.

The first method would imply the construction of a great many additional embankments within the polders, and therefore the second method has been used very widely.

It was decided to create a facility for dividing the boezem into sections by means of sluice gates. The project comprised the construction of 37 new sluices and 23 are now complete. Emphasis has been placed on isolating major bodies of water , such as lakes, from the remainder of the boezem network.

Various types of sluice have been considered, depending on the circumstances at each site. For use in the wider watercourses, an inflatable weir has been developed. This weir consists of a flat steel box lying on the bed of the canal, containing a folded envelope made of nylon-reinforced rubber. The weir is operated by pumping water into the folded envelope. It then emerges from the box and retains the boezem water as a solid rubber dam. The system incorporates an automatic monitoring and warning system. At important locations, flow meters have been installed whereby the rate of flow and direction can be scanned electronically If for a certain period, the velocity exceeds a certain preset value, an alarm is activated. In this way, a high degree of protection against flooding is preserved for the densely populated and low-lying polder land in the western Netherlands

WEST GERMANY - The Origin and Early Stages of the Hermann Goring Polder (Tumlauer Koog) in Schleswig Holstein. -- J.C. Smit.

In 1931 a plan was drawn up to shorten the coastline on the west coast of Schleswig-Holstein, reclaim the mudflats behind the dikes and establish new villages in the area. By 1945 most of the plan had been realised: 7 polders on former mud flats had been reclaimed, varying in size from 500 to 1300 ha.
The best known polders were originally called the Adolf Hitler Koog and the Hermann Goring Koog, named after the two men who initiated them in 1935. They are now known as Dieksander Koog and Tumlauer Koog.
When the National Socialists took power in 1933, they decided that reclamation could serve some of the main objectives of their policies eg. increasing home food production in Germany, strengthening of agricultural communities, selection of settlers with supposed favourable racial characteristics.
Throughout the course of development of the Tumlauer Koog, each stage was marked by differences of opinion between the parties involved. A settlement company was formed to carry out the development and select the new settlers, but its views were often at variance with government agencies. For example, the Company wanted dispersed settlement throughout the polders, but the Government wanted concentrated settlements.
Farm buildings were constructed in the traditional style of farms in the neighbouring old land, with thatched roofs because there was a lot of propaganda for this style in the time of National Socialism. Initially

34 settlers came to live in the Tumlauer Koog (500 ha.) Many were selected because of party affiliations.
Soils were much heavier than the settlers had expected and cultivation was very laborious, harvests were disappointing and the government had to provide subsidies to preserve the propaganda- value of the project. After the war, a new generation gradually took over. Farms have merged and the average farm size has grown from 14 ha. to 31 ha. The initial ideological aims of the reclamation have now disappeared and farming has adapted itself to the pattern in the rest of the surrounding land.

HUNGARY - Hydroamelioration of Agricultural Lands in Hungary -- M. Szinay

Hydroamelioration is defined as the branch of science and technology which deals with improvement of the natural condition of soil for plant growth, by controlling the soil moisture budget. The aim of hydroamelioration is to manage the soil moisture in such a manner as to allow plants to grow at their optimal rate. The key factor which will ultimately control agricultural development in Hungary, and in most of the rest of the world, is water supply. Agriculture can progress in two ways:- 1) 'extensive' - ie, bringing into cultivation new tracts of land for example in semi-arid zones. 2) 'intensive' ie gaining better crops from existing cultivated land, by providing optimal moisture conditions at each stage of plant growth. In either case, hydroamelioration is expected to perform two basic functions, namely the removal of excess water by drainage and the supply of water to cover shortages by irrigation.
In Hungary there is an area of 5 million ha. in which soil fertility is impaired and which can be corrected by proper water management in the soil. In applying the principles of water control it is important to remember that the soil is a 3 phase system of minerals, water and air, and when any one element in the system is changed, the others are also affected. For example, saline soils exist over 1 million ha. in Hungary, most of which could be improved by leaching with irrigation water

ROMANIA - Some of the Danube Floodplain Polder Project Criteria - I. Mihnea and M. Clarian

In Romania, the area below river flood levels is about 3.5 million ha. and of this 2.2 million ha. is agricultural land. There is therefore a long history of embankment schemes alongside the Danube and other major rivers, which aim at the protection of polder areas in the flood plain. At first most of the land was protected only by low submersible dikes, some 3m. above land level, with a crest width of 5 m. These gave a standard of protection up to about the once-in-ten-year flood. More recently, new polders have been reclaimed by constructing dikes up to the once-in-a-hundred year flood level plus a 1m. safety margin.
In 1962 a decision was taken to reclaim 450,000 ha. in the Danube floodplain in this way. An area of 290,000 ha divided into 17 polders is included in the first stage of this scheme. The dikes are built about 200m. from the outer limit of the river bed with a crest width of 5m. Drainage channels and pumping stations are provided to evacuate excess water in the polders themselves. Field drainage is provided by means of open ditches with a minimum spacing of 400m. The capacity is calculated to give a rate of discharge of 5 to 6 mm/day. In some places lakes for fish farming were integrated into the reclamation plan. The need for irrigation is also incorporated in the design of the drainage works. In the reclaimed areas it has been found that groundwater levels have declined to a level 4-5 m. below ground and this has had a beneficial effect on soil aeration. The cost of the reclamation works have been fully justified by the increased crop production which has been obtained.

SPAIN — Basic Information about the Marshes at the Lower Guadalquivir River — R. Bellas Rivera

At the mouth of the Guadalquivir River in South West Spain there is a large area of marshland covering 136,000 ha. at about the level of high tide, 3.6 m above mean sea level. In summer, evaporation far exceeds rainfall and irrigation is required to sustain crop growth. Moreover, groundwater is saline and slightly alkaline and these salts must be kept out of the rooting zone. Reclamation work is therefore seen as having four aims:-

1) Prevent inundation by impoldering.
2) Provide a drainage network which allows rain or irrigation water to pass through the soil, washing out injurious salts
3) Maintain a water table which allows roots to develop and does not allow capillary rise to the surface.
4) Loosen the soil by cultivation to increase permeability.

Success has been achieved in decreasing salinity and increasing agricultural yields up to levels obtained in the surrounding districts which do not have salinity problems.

GUINEA-BISSAU - Natural and Social Constraints to Polder Development in Guinea Bissau -- R.J. Oosterbaan.

Guinea-Bissau is a coastal state in the extreme west of Africa with an area of 36,000 Km^2. There are coastal mudflats extending to 400,000 ha, and 100,000 ha. have beem empoldered. The remaining area is covered by mangrove forest, but as there is a need to increase rice production, the Government is considering extension of the reclaimed area.

The traditional method of reclamation is to construct dikes 1.5 to 2m. high alongside the tidal creeks, although more recently dams have been built across the creeks and this reduces the length of dike required. By custom the men construct and maintain the polders whilst the women cultivate the rice.

Water supply in the polders is entirely dependent on incident rainfall and no irrigation water from outside is used. A system of cultivation in ridges is followed and this seems to be very beneficial in controlling the presence of noxious elements in the acid-sulphate soils, and in using the available moisture to the best advantage. Drainage of the area is by means of surface drains and these are also used to retain water.

There has been a failure to bring some of the newly reclaimed land into cultivation, and it is thought that emphasis should now be placed on improvement of existing polders rather than on reclamation of new areas.

THAILAND - Land Reclamation in Thailand - Ruanglek, Chaveesuk and Poolsup

The Klongdarn Drainage Project was carried out between 1921 and 1931 as an irrigation scheme covering 200,000 ha. close to Bangkok. Now it is intended to reclaim 24,000 ha. of marine clay as part of the same project. In 60% of this area, soils are saline, and the aim is to make these soils suitable for cultivation of rice. The methods used is to provide surface drainage and allow irrigation by flooding during the dry season to flush the salts down beyond the rooting depth of the rice (20 - 30 cm.) Evaporation and upward movement of salts from saline groundwater must be kept to a minimum by double cropping. It is hoped to produce 2.5 tonnes/ha. in the dry season.
A sea dike has been constructed along the southern edge of the area to keep out sea water. In the dike there are associated discharge sluices and bridges. Irrigation water is conveyed to the area from the north along the Raphiphat Canal. Drainage channels are designed to discharge at a rate of 46 mm/day, and irrigation canals are provided with a capacity of 7 mm/day.

VIETNAM - The Experimental Polder for Research on Acid Sulphate Soils in the Mekong Delta -- E. Stamhuis.

In the delta of the Mekong River in Vietnam there is a very flat area of 4 million ha. Half of this area has acid sulphate soils and a method is being sought of managing these soils in such a way as to give increased production of rice.
Land is not embanked, and when rivers overflow in the wet season, fields are inundated to a depth of 1.5 - 2m. This is of value to the soil moisture budget. Higher yields of rice have been attempted by using shallow drainage systems to give improved leaching of topsoil, by planting acid-tolerant varieties of rice and by the use of fertil-

isers, but usually these methods are too expensive and large areas remain with low yields.

An experimental polder has therefore been set up by the University at Can Tho, with assistance from the Dutch University of Wageningen. The area, 8 ha. in extent, has been surrounded by a clay dike. It has been provided with drainage and irrigation channels and sub divided into small plots. Within each plot, drainage and inundation depth can be controlled. The pH value of the irrigation water can also be varied as required. Tillage depth and rate of fertiliser application are further variables to be investigated. From these trials it is expected that improved techniques can be devised for the management of polders in the Mekong Delta, and that agricultural yield of the area can be increased.

SURINAME - Present state of Water Resources Development in N.W. Suriname -- A. Spier

The extent of reclaimed swampland in N.W. Suriname has grown rapidly since 1950 to an area of about 40,000 ha. mainly used for the cultivation of rice. A much greater area (180,000 ha.) of very fertile soil is potentially available. Much technical data has been collected, but the most difficult problems are concerned with land ownership and its legal and social implications.

Water for irrigation can be made available by means of low banks to build up the level of water seeping across the land towards the coast. This traditional method is still used but more efficient ways of water resource management are now being sought.

The most promising method of development seems to lie in an integrated system of river water intakes and canals to cut off seepage from swamps. On the Corentyne River work has started on a multi-purpose project. Some water must be left to prevent saline intrusion, but 50cu.m./sec can be withdrawn by a pumping station and conveyed along a canal 67 Km in length. This will allow reclamation of 12,500 ha. of new polders and provide irrigation water for 33,000 ha. The yield could be increased by:-

a) Installation of extra pumping capacity to operate only at low tide.

b) Flow regulation by means of a dam to be constructed upstream for hydropower.

c) Collecting water which seeps from the Nanni and Coronie swamps.

The latter option is most promising. Care must be taken not to lower the water level in the swamps by too much because only the top most layers of soil (mainly peat) are permeable. By combining the yield of the river with the yield of the swamp, an integrated resource can be developed, which has a combined yield greater than the sum of the component parts. In this way the total polder area can be increased to 57,000 ha.

VARIOUS ASPECTS OF POLDERS IN CERTAIN AREAS.

LIST OF AREAS DESCRIBED, AND MAIN DESIGN FEATURES

Region	Authors	Subject & Main Theme	Design Parameters*
Netherlands, Ysselmeer	Constandse de Jong Pinkers	Comprehensive agricultural and urban development	R=750 E=680 A1=166 A2=41 A3=207
Netherlands, N. Holland	Vernimmen Heyligers	Flood protection: Safety from accidental inundation	
W. Germany, Schleswig-Holstein	Smit	Effects of social policy on origin of polders	A1=0.5 (Typical polder)
Hungary	Szinay	Hydroamelioration: optimisation of soil moisture budget	R=580 A3=5000
Romania, Danube	Mihnea Clarian	Planning polders in floodplain of large river	D=5 to 6 A1=29 A2=426 A3=455
Spain, Guadalquivir Marshes	Bellas-Rivera	Improvement of saline alkaline soils	R=570 E=430 A3=136
Guinea-Bissau	Oosterbaan	Constraints on development: finding appropriate technology	R=2300 A1=100 A2=300 A3=400
Thailand	S.Ruanglek S.Chaveesuk M.Poolsup	Regulation of quantity and quality of soil moisture	R=1200 E=712 D=46 I=7 A1=184 A2=24 A3=208
Vietnam, Mekong Delta	Stamhuis	Experimental polder: control of acid sulphate soils	D=86 I=20 to 35 A3=4000
Suriname	Spier	Water from swamps integrated with river abstraction	A1=40 A2=12 A3=57

*R=Annual rainfall in mm. E=Evaporation

D=Design rate for drainage mm/day I=Design rate for irrigation

A=Areas in 1000's ha. A1=Complete. A2=Proceeding. A3=Ultimate.

SUB-THEME: VARIOUS ASPECTS OF POLDERS IN A CERTAIN AREA (CONTINUED)

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Abstract

This General Report deals with ten papers, nine of which describe aspects of the construction, amelioration and management of polders while the remaining one pictures the disposal of dredged sediments in deep polders.

Four papers discuss the large (13.500 km^2) delta development and reclamation projects in the densely populated and naturally hazardous coastal provinces of Bangladesh. Smaller, but pursueing similar purposes, is the amelioration scheme of the Lezíria Grande in Portugal.
Designs of new polders are the subject of papers on the Tana River Project in Kenya and the Hadejia Vally Project in Nigeria; both situated in a semi-arid climate.
A Dutch paper surveys the four types of polders that have developed during the past ten centuries above and below sea level in the low and slowly subsiding coastal Netherlands. The works required to combat the effects of subsidence caused by excessive use of ground water are the subject of a paper from Taiwan.
A paper from Rotterdam describes the methods of disposal of the large quantities of (partly heavily polluted) dredged material from the harbours in polders and the environmental aspects of this use of polders.

The wide range of natural, economic and social conditions encountered in the project areas lead to interesting comparisons of ways polders are laid out and operated. Dutch consultants were involved in most of the projects.

1 General observations

Definitions of polders all contain the elements of land and water and their joint management in a well defined area. This separation from the surroundings is a direct consequence of the control of processes within the polder and the exclusion of external influences.

The element "land" leads to various aspects such as location, geology, soils and land use while water leads to associations with climate, hydrology and water control. The joint management presupposes a goal which must be feasible and which leads to a technical design and an organisational structure for the operation and maintenance. These aspects of polders are the subjects of the ten papers to be reviewed in this Report.

The location not only points to a place on our globe but even more to the vertical position of the polder with respect to the surrounding water level. Differences of a few decimetres in altitude can have far reaching consequences for the technical realisation of the supply and evacuation of water. The development of hydraulic machinery with increasing head and capacity multiplied the range of lands suitable for reclamation as a polder. In the Netherlands, with drainage as the main problem, the successive steps in the conquest of the water were (see de Bakker and Kooistra).

- construction of dwelling mounds (2000-1000 BP);
- embankment of the surrounding high grounds (1000-1500 AD);
- embankment of naturally accreted areas (1200-present);
- drainage of lakes up to 6 m below sea level (1450-present), and
- reclamation of large areas of sea bottom (since 1930).

The first three could still do with gravity flow but the latter two types required the power of wind, steam, combustion engines and electricity. Notwithstanding the availability of this range of technical means, there is an understandable (economy, reliability) tendency to solutions with the sole use of gravity (see Brouwer).

2 The papers; location and climate

The ten papers, which are the subject of this General Report, can be classified, according to their location and the climate, into five categories.

1) Bangladesh.

- Delta development in Bangladesh by *Shafiqul Haq*
- Polder development in Bangladesh
  - I Past and present by *Md. Mohsin Uddin and S. Islam*
  - II The land reclamation project by *A.T. Chowdhury*
  - III The delta development project by *Md. Abu Quassem*

all pertaining to 13.500 km^2 along the estuaries and the coast of the delta of the rivers Ganges and Brahmaputra with a tropical monsoon climate: precipitation 1500-3000 mm; evaporation 1200 mm.

2) Taiwan.

- Problems in stratum settlement due to ground water exhanstion by Sih Mong-Hsiung.

About an area of 40 km^2 in the south of the island of Taiwan in a sub-tropical humid climate: P = 1300-3000 mm from July to October.

3) The Netherlands.

- Marine polders in the Netherlands by H. de Bakker and M.J. Kooistra.
- Polders as a disposal site for dredged material from Rotterdam by H.J. Groenewegen.

Pertinent to about 10.000 km^2 (one third of the country) in the coastal part of the Netherlands in a temperate marine climate: P = 760 mm; E = 690 mm.

4) Portugal.

- Land reclamation and agricultural development of the Lezíria Grande (Portugal) by L. Santos Pereira and M.G. Bos.

130 km^2 in the estuary of the Tagus River and in a dry sub-tropical climate P = 400-1100 mm; E = 1200 mm.

All these polders are situated in tidal areas. In most cases, the land surface is above the mean sea level or even above mean high water but below the highest floods caused by the tides, the spates of a river or storms. The polders in Taiwan are gradually subsiding and some of the Dutch polders are dry lake bottoms up to 6 m below sea level.

5) Africa.
   - Irrigated rice polders in the delta of the Tana River, Kenya by H.W. Appel and M.M. Vierhout.
   - Hadejia valley irrigation and drainage project, Nigeria by R. Brouwer.

   Areas of 100 and 200 km^2 respectively near the Indian Ocean in Kenya and in the North of Nigeria in a semi-arid tropical climate: P = 600-700 mm; E = 2000-2500 mm.

Both project areas are situated in the flood plains of rivers some tens of metres above the ocean and Lake Chad. They are subject to seasonal flooding.

3 Objectives

In all cases, the construction of a polder means protection of the land against inundation:

- by embankments (bunds) against intrusion from the outside by floods of fresh river water and tides, and surges of saline sea water, and
- by a drainage system against an excess of local precipitation and seepage.

Contrary, an often temporary shortage of water is met by irrigation in Africa, Portugal and Bangladesh. An excess of salt, which mainly occurs in coastal areas (Bangladesh, Portugal, Netherlands) is fought by the prevention of inundation by salt water and by flushing with fresh (irrigation) water.

In most cases, the empoldering of an area is an offensive act: land is withdrawn from "Nature" and made to (a better) use. Along the Dutch coast and on Taiwan also defensive aspects are important because subsidence of the area increases the natural dangers.
Generally, the protection of inhabitants, property and crops against the various catastrophes is expected to increase the usability of the land or of the bottom of a lake or sea.

Most of the reclaimed or improved land is used for agriculture. An increase of the production of (better) food is the main objective of the projects in Bangladesh, Portugal and Africa. Other expected benifits are: better living conditions (safety, economy) for the local people, more room in a densely populated contry (Bangladesh, the Netherlands), a better infra-structure of the area, changes of the social structure (land tenure, co-operatives) as in Bangladesh and Portugal.

Pilot areas, such as being developed in Bangladesh, are expected to yield experience with certain techniques to be used in the future development of the whole project and they are meant to be examples for a larger area.

An exception are the deep polders around Rotterdam to be filled in order to dispose of the great quantities of (partly polluted) dredged material from the harbours.

4 Geology and soils

Because land improvement is a main objective of the construction of a polder, the geology of the area and the properties of the soils are of great interest. The latter should be "suitable or highly suitable" in order to make projects, as designed in Bangladesh, Africa and Portugal, feasible.
Control of water level requires a relatively flat area and the availability of water. These requirements point to recent coastal plains and alluvial plains along rivers and lead away from mountains and deserts. From the discussed areas the ones in Bangladesh, Taiwan, Portugal and the Netherlands are situated along coasts and estuaries while the polders in Nigeria and Kenya are projected in flood plains of rivers.
Also in view of the water control, the vertical movements of the soil surface are of mayor importance. The relative rise of the sea level along the coast of the Netherlands, caused by a eustatic rise of the mean sea level (1 mm/year), a tectonic subsidence and compaction of the subsoil (1 mm/year), compaction of (local) recent sediments and various types of erosion of the surface, has mounted up to almost half the tidal range since the Dutch started building embankments. Probably the same occurs

in Bangladesh. Artificial subsidence, caused by the mining of natural gas and ground water add to the problems in the Netherlands and are the main subject of the paper about Taiwan.

The complex process of deposition and the subsequent soil formation generally lead to a very complicated soil map. The one of the Lezíria Grande in Portugal is a good example.

The soils of the coastal, lagoonal and estuarine areas of Bangladesh, Taiwan, Portugal and the Netherlands are generally described as clays, sands and some peat. The salinity of the soils is one of the problems to be solved by their empoldering. The soils are more or less calcareous depending on their formation. Older marine non-calcareous soils tend to develop into acid sulphate soils (cat clay).

The soils in the projects in Nigeria and Kenya are alluvial and aeolian deposits of clays and sands. Some of the terrace soils in Kenya are saline.

5 Land use

In all cases agriculture is the main use of the land. Details depend on location, climate and soil conditions, a brief review shows the great variety.

- Bangladesh: 60% is under cultivation with crops as rice, betelnut, jute, fruit, vegetables, condiments, pulses, sugarcane, oil seeds, tobacco and sesame; the rest is waste land, forestry, shrimps and salt production.
- Taiwan: not specified except fish farming.
- Kenya: mechanised rice production.
- Nigeria: sorghum, millet, cow peas, maize, ground nuts, wheat, cotton, vegetables and rice.
- Portugal: presently 50% fodder and pasture; the rest wheat, other cereals, tomatos, melon, etc.; the production of irrigated rice will be promoted.
- The Netherlands: pasture land, arable land, horticulture and fruit.

Generally some of the land is used for the infra-structure such as roads, canals, towns, industry, etc. Specially mentioned are recreation, natural reserves and the dumping of dredge spoil.

6 Hydrology and water management

The purpose of water management in a polder is to influence the local hydrologic phenomena in a favourable way. Briefly, the following means are available (or not):

- precipitation, evaporation and seepage within the polder can hardly be influenced;
- supply from outside can be controlled within the limits of the source (rivers, ground water);
- drainage to the outside depends on external conditions, and
- the storage in the polder (soil and open water) is given with the design.

Irrigation and drainage can be aided by technical means. They are the main instruments of the management. Irrigation is needed when the storage is insufficient to fill the gap between evaporation and precipitation (and seepage) during a dry period and drainage should remove an excess; both within a reasonable time. Such measures are meant to safeguard a crop or even to allow for an extra crop.

With these observations in mind, and in vieuw of the great variety in climate and land use, it is no wonder that the polders described in the papers show great differences in the water management. From the three elements - flood protection, drainage and irrigation - the first two appear in all areas under consideration.

River floods occur in the project areas in Nigeria (once a year) and Kenya (twice a year). High tides and storm surges are the main problem in Taiwan and the Netherlands. Both are met with in Bangladesh and Portugal. In all cases embankments are expected to protect the polders against floods of which the recurrence period varies between 20 years (Bangladesh) and 10.000 years (the Netherlands).

Most of the described polder areas are drained by gravity flow into the river or (at low tide) into tidal water. In the Nigerian case a special buffer, in the lower part of the polder provides storage capacity to facilitate a proper drainage to the river and to a lower flood plain; avoiding a pumping station. Such stations are indispensable in the very deep polders in the Netherlands and in the subsided area on Taiwan. They are considered in the amelioration scheme for the Lezíria Grande in Portugal.

Irrigation is not very common in the Netherlands with an evenly distributed precipitation, relatively little evaporation and a large storage capacity of most soils. In Bangladesh, where 90% of the annual rain falls in the monsoon from mid May to mid October irrigation is applied in some areas for the flushing of salt. In all other schemes, irrigation is an important aspect.

- On Taiwan, especially the fish ponds need vast quantities of water; also outside the rainy season which lasts from July to October only. The use of ground water for this purpose caused a shortage and severe subsidence of the area.
- In Kenya, the two wet seasons around April and December are too weak and need assistance by irrigation to facilitate the growth of two crops. Water can be taken from the Tana River.
- In Nigeria, the precipitation of 700 mm in concentrated squalls from August to October must be supplemented by irrigation from the Hadejia River in which water is retained by a series of reservoirs upstream from the project.
- In Portugal, the period of low precipitation and high evaporation during the summer will be bridged by irrigation from the Tagus river. This will facilitate the growth of rice. Pumping stations will bring the water into and through the northern half of the polder.

Salt, which poses problems in Bangladesh, Taiwan, Kenya (only locally), Portugal and the Netherlands, is generally expected to be combated via the drainage of excess rain water during the wet seasons.

A special feature of the Land Reclamation Project in Bangladesh are large ponds to be used for the storage of drinking water for villages. They will be filled by wind mills.

7 Environmental aspects

The reclamation of land, by its nature, changes the hydrology (surface and underground), the flora and the fauna within and probably also outside the area. Relatively little attention is paid to this aspect in the papers.

An exception is the paper of Groenewegen which, however, deals more with the environmental problems of the disposal of heavily polluted dredged material than with the effects of a polder. It discusses the paths and the effects of a multitude of contaminants in the soil and in the ground water within and outside the dumps. Various effects on water quality, flora, fauna and structures were studied.

8 Feasibility; economic and social

The economic feasibility is briefly discussed by a few of the authors. The very large (14,000 km^2, 86 polders) project in Bangladesh caps everything with an estimated cost of about US $ 0.25 billion. Benefit cost ratios of 2.35/1 and 3.88/1 are mentioned for specific parts of the project. For the Tana River project (100 km^2, 3 polders) the cost per net ha is estimated at US $ 6,670 with running costs at US $ 970 per annum. Various alternatives lead to internal rates of return of 10.5% to 13.8%. The final evaluation (on farm level and on the national level) of the Lezíria Grande project in Portugal encompassed four reclamation alternatives and three farm structure alternatives. The adopted plan is expected to have an internal rate of return of 8%.

The social aspects of the projects appear in some more papers. Structures and objectives vary greatly.

- In Bangladesh the system of (absentee) landlords is proposed to shift to small land-ownership with an organisation of farmers in co-operatives. Also other changes in the social structure of villages and of the whole area are expected to result from the scheme.
- In Portugal the ownership of the project area is in the hand of the "Companhia das Lezírias" which also is a large agricultural company.

It is proposed to maintain the present structure but to promote the settlement of small farmers on plots of 12 to 100 ha. depending on the type of crop.

- In the Netherlands much of the old land was empoldered and managed by associations of landowners. The empolderings of lake bottoms were private enterprises under charter from the Government. The Zuiderzee-polders were constructed and reclained by the Government and for the greater part rented in parcels of 12 to 60 ha to farmers.
- In Kenya the three polders in the Tana River project will be owned and run as a state enterprise.

9 Design, areal planning and details

The areal planning is a well considered composition of all elements constituting a polder such as the drainage system, the farm plots, the irrigation system, roads, villages, etc.; all taking into account the natural conditions. Technical skills have greatly improved in the course of history; just to mention the Archimedean screw, the wind mill, various pumps, modern power sources, automotive transport, fertilizers and modern farming equipment. These developments are reflected in the areal planning of the successive polders in the Netherlands (de Bakker and Kooistra) as well as in the amelioration schemes for the polders in Bangladesh and Portugal. For the latter case, the author gives some details of the alternative drainage and irrigation schemes. Tertiary units of 30-40 ha. with 25 to 30 farming families, living in a typical circular village, are contemplated in a pilot polder in Bangladesh.

The technical design of the projects is sparsely mentioned in the papers. The most important aspect is the flood protection. The project in Bangladesh provides for 4050 km of bunds of three types viz. sea dikes, river dikes and marginal dikes. Each has its own design based upon the hydraulic conditions on the coast, in the estuaries and along lesser canals, and to be constructed from locally available materials. In the Tana River project (Kenya), the flood embankments are combined with a main drain; detials (also of a main canal) are given in the paper.

Drainage sluices of a special type were designed in Bangladesh; the number of vents (1,5 x 1,8 m^2 each) to be adapted to the local conditions. The use of bamboo field drains is mentioned.

A special case is the description of the construction of dredged material dumps around Rotterdam: The deposition in settling basins, the stimulation of the ripening process and the drainage of the water from the transportation of the sediments, from the compaction process and from normal precipitation.

10 Management and operation

Some aspects of the general management have already been mentioned as points of social development. The management and operation of the drainage and irrigation systems are often in the hands of public bodies in which the farmers have a say. In Bangladesh a polder committee (consisting of representatives of the project, the co-operatives and the agricultural department) will oversee the main system assisted by sub committees for the sluices and local canals as well as for the water control in the tertiary units. In Kenya the estate management authority will be responsible for everything. On Taiwan, a Provincial Water Conservancy Bureau maintains the drainage and irrigation systems as well as the sea-wall. The same aspects are looked after by the "Associação de Defesa" in the Lezíria Grande in Portugal. In the Netherlands, the water management and the flood protection is in the hands of water boards in which the committee is chosen by the landowners and which operate under supervision and co-ordination of provincial authorities.

SUB-THEME: GENERAL DESCRIPTION OF POLDER PROJECTS

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1 Introduction

The eleven papers describe general features of polders in areas as widely separated as Canada and Indonesia, for objectives as diverse as the development of prime agricultural land (U.K.) to the flood protection of densely populated urban areas in South East Asia.
In essence, polders aim to isolate areas of land hydrologically from their surroundings whilst controlling the hydrological processes within, to enable the desired human activity to proceed. They are usually situated on low lying lands adjacent to a major element of the regional open water system, i.e. the sea and/or a river estuary where the construction of dykes lessens the incidence of flooding.
Soils in lands bordering such areas are often highly fertile, comprising the products of erosion carried down from higher lands. Their evenness, fertility and ease of access make them highly attractive for development either for agriculture or urban development, the two competing uses not always in harmony.
In estuaries, progressive raising of marsh levels by deposition creates conditions well suited to small step by step impoldering and their continued successful development is usually assured by the presence of a firm existing agricultural foundation. Elsewhere, large new polders are developed mainly by the state either to extend existing agricultural strengths as in Spain or to create new strengths as in Egypt.
The papers reveal that urban and agricultural polder developments

create conflicts concerning the desirable degree of control to be exerted on the external and internal hydrology. Cities near or within polders provide a ready market for produce whilst creating problems of pollution and waste disposal. They also tend to draw people away from the land to the urban environment. The papers also reveal that impoldering involves major changes in the natural ecology of areas and increasing concern about the preservation of natural habitats is making it increasingly difficult to continue to create further polders in Europe purely for agricultural development.

The papers cover a number of interesting problems and for reporting, have been grouped around linking themes. The first group is a very general description of four polders. The second group describes polders within peat lands whilst the third group concerns polders mainly within developing countries. A further challenging paper (Kafue Flats) questions the philosophy behind the large scale introduction of what are seen to be fairly sophisticated polder systems into developing countries.

The final group of papers deal with a polder specifically established to assist in a population relocation programme whilst two deal with most unusual and interesting technical problems. The first of these deals with the problems occurring in a polder subject to large scale differential subsidence and lying within an earthquake prone area (Venezuela). The second and final paper explains how the problems of a densely populated polder area in Jakarta involving water management and waste disposal were overcome.

2 Papers describing general details of polders

2.1 Reclamation of land on the Eastern Coast of England

by P.D. Cook

The paper describes the reclamation of prime agricultural land from the marshes bordering the shores of the Wash, a broad and shallow estuary in Eastern England. The level of the seaward marsh progressively rises due to the deposition of sediments accelerated by the marshes vegetative cover. The area is reclaimed by constructing a dyke as far out into the marsh as possible. Later, the prime silt soils are under-drained by pipe drains.

The reclamation is privately financed by the farmers bordering the reclamation and for this reason the minimum width of 'economic' reclamation tends to be about 400 m. The dyke is constructed from the locally available silty material and is protected from wave action firstly by preserving sufficient protective marsh to seaward and secondly, by covering the dyke by a thick grass sward. On a recent reclamation the failure to establish a sward rapidly and unusually high tide levels (1978), resulted in damage to the dyke costing approximately 50% of its construction cost in 1977. In recent years, pressures to maintain the marshes in their natural state as a sanctuary for wildlife are making it increasingly difficult to consider future reclamation.

2.2 Dykelands (Polders) along the Bay of Fundy, Canada by C. Desplanque

In the maritime provinces of Canada, large areas of grassland, in particular bordering the Bay of Fundy, were endiked by French settlers in the sixteenth century. Today, much of this area lies below the existing seaward marsh which has, like the Wash areas of U.K., continued to rise due to deposition of sediments. This suggests that the endiked areas could be progressively extended as in the Wash. The land is surface drained by a system of cambered beds leading to shallow drainage channels, this method being chosen because of the high rainfall intensity in autumn (20 $cm.day^{-1}$) and because of ice formation which blocks open channels preventing groundwater drainage by pipes discharging into open collectors. Since the 1950's, dykes have been raised in certain areas whilst tidal sluices have been installed in others to restrict the flow of water and hence control the rise in tide level thus reducing the need to raise the dykes. It would be of interest to learn how the decision to opt for the sluice or the raising of the dykes was made and to know whether the installation of tidal sluices has increased problems due to deposition elsewhere in the Bay.

2.3 Polders of the Vistula River

by P.J. Kowalik

Large areas of land bordering the Vistula River have been reclaimed over the centuries by impoldering. In recent years, the tendancy has been to amalgamate areas and even to install intermediate pumping stations thus creating polders within polders. The close proximity of urban areas (Gdansk) has provided a ready market for produce, though this advantage has been countered by the drift of population from the land to the town and by the environmental impact of the town causing water and air pollution and problems of waste disposal.
In Figure 2, a detailed graph is presented relating predicted grassland yield to water table depth and nitrogen fertilizer. It would be helpful to learn whether these predictions have been tested in the field and how the information is used in practise.

2.4 The soils and water table properties of the polder area "Castillo De Doña Blanca"

by V. Gomez-Miguel *et al*

The fourth paper describes soils and climatological data for a polder development bordering the Guadalete River near Cadiz in Spain. The area is to be irrigated using low to moderately saline river water. Two minor points require elaboration.
Firstly, Figure 2 depicts an annual water balance showing periods of excess and water deficit. The excess which it is stated gives occasional efficient leaching of the soil, presumably depends upon the deficit being made good by irrigation. The reporter would like this to be confirmed, to know whether a parallel salt balance has been developed, and how salinity is to be controlled within the polder.
Secondly, the significance of the comment "the level of the river bed is more than two metres in the dam called La Corta, 5 Km upstream from the E limit of the polder" is not clear.

3 Paper involving the reclamation of peat soils

3.1 Peatland polders of North-West Germany

by R. Eggelsmann

This paper is broadly a restatement of the considerable body of knowledge gained in the development of peat lands in Lower Saxony. The restatement of existing knowledge on the shrinkage and oxidation of peat is justified and timely in view of the potential developments in such soils in the tropics where these processes are accelerated.

3.2 Drainage of peat soils in the polder of Pega-Olivar Alicante, Spain

by I.G. Sánchez and J. Martínez Beltrán

This paper is a good example of the extent to which sound hydrophysical survey (Figures 2, 3, 4 and 5) combined with a stepwise approach to reclamation and drainage can lead to sound drainage measures. The soil in the area is characterised by a clay layer 0.5 m deep underlain by layers of peat (up to 3.0 m thickness) sand and clay. Trials with subsurface drains have indicated a preference for drain depths up to 1.8 m deep.

In view of the first paper, it seems that the peat will shrink and oxidise and so some elaboration on this possibility and its effects on the project would be relevant.

In 1976, a socio-economic survey was undertaken. This indicated that benefits were virtually double the costs. The reporter would like this evaluation to be elaborated, particularly bearing the following factors in mind. Does this evaluation include all the costs or just some and to which group of participants in the polder development do the figures relate, the farmers, the development authority, etc.? Also, to what extent have cost evaluations and changes since 1976 altered this projection?

3.3 Reclaiming Muturajawela, Sri Lanka
by S.H.C. de Silva

This paper deals with the possibilities for reclaiming Muturajawela swamp temptingly close to Colombo, the capital of Sri Lanka. This 2400 ha swamp runs parallel to the coast for 10 Km immediately North of Colombo. The swamp consists of aquatic vegetation overlying substantial depths of peat (3-10 m) overlying sand. The swamps surface lies below mean sea level whilst its perimeter is ringed by canals and roads. Up to the present day, the sheer costs have prevented reclamation. The possibilities investigated are:

1) sand pumping to raise the land above mean sea level
2) replacement of peat by sand
3) impoldering and lowering of the water table

The high development cost mitigates against its sole use for agriculture and so urban development seems to be the most likely justification for any real developments. It would be of interest to know what uses the mined peat, obtained as part of the second proposal would have been put to and whether a time scale for shrinkage and oxidation had been included in the third proposal. Also, it would be helpful if the authors could elaborate on the strength of the arguments in favour of keeping the swamp in its present form.

4 Kafue Flats, Zambia : Flood plain planning on a crossroads
by W.T. de Groot and M. Marchand

This stimulating paper concerns an environmental study of developments in the Kafue River flood plain near Lusaka, capital of Zambia. In the natural state, the plain is shallowly flooded for several months annually. The flooded area supports a rare Antelope, the Lek, whose ability to graze in the flooded lands makes it uniquely able to exploit their grazing potential whilst the reduction of herbage that would otherwise decay, enhances and supports the inundated areas abundant fishlife. The area also supports a traditional human society dependent upon cattle grazing the drylands, fishing and small scale dryland

agriculture.
In recent years, the Kafue River has been regulated by means of dams for hydro-power generation resulting in considerably reduced areas of annual flooding and an increase in the permanently inundated areas. Cattle now have access to grasslands throughout the year, whilst the areas suitable for Lek have been severly curtailed.
Within Kafue Flats up to 70,000 ha of land could be impoldered and developed. However, the main contention of the paper is that it is in the nature of polders to strengthen the arm of the central organising body, in this case the State, and at least in a developing country, weaken the existing pattern of life. This phenomenon is ambiguously described as the centre-periphery complex.
The paper argues that polders should develop organically, that is to say, in small units based upon existing agricultural strengths as happened traditionally in the Netherlands and still occurs in the Wash area of the U.K.
The paper also points out that economic analysis can be targeted to produce answers ranging from the optimistic highly profitable to a pessimistic annual loss. It is in the nature of development to feel persuaded to the most optimistic forecasts although in the reporter's view, realistic ends to the economic spectrum should be identified before final decisions are made. Furthermore, in viewing Kafue Flats, one might question the value of traditional accounting to such a complex situation. How is the cost of the existing situation and social order to be deduced and can accounting allow for the reality that many large projects in developing countries fail to realise the aspirations of Northern hemisphere planners? Perhaps the time has come to invest finance wisely though not necessarily economically in developments that will build strengths without disrupting the status quo; that will succeed albeit on a small scale where larger schems would fail.

5

The final three papers deal with impoldering as part of a transmigration programme (Egypt), with a polder on land that is differentially subsiding (Venezuela) and land which is subsiding rather less but entails impoldering a densely populated urban area (Jakarta)

5.1 Polder areas of Northern localities of the Nile Delta, Egypt

by M. Sh Diab

This large polder lies right at the Northern base of the Nile Delta in an area of predominantly heavy clay soils of low hydraulic conductivity. The elevation of the land is at approximately -0.6 m below mean sea level, the groundwateris at shallow depth, 1-1.5 m below ground level and it and the overlying soil are highly saline. Though not stated, it would seem that these levels are indicative of inseepage via the deep sandy aquifer. The area which is required for resettlement of peoples from densely populated Southern areas is to be irrigated and drained. The planned drainage relies on parallel open ditches some 25 m apart at 1 m depth.

The reporter would like further elaboration on the potential for reclaiming and controlling salinity in these soils. Also, what incentives and plans have been made to attract the migrants to stay and work what are evidently difficult soils in what to them, must be an alien environment.

5.2 Polders and Dykes of the Bolivar Coast, Venezuela

by J. Abi-Saab Soto et al

In Venezuela oil extraction from beneath Lake Maracaibo and its surrounding low lying polder areas has caused progressive subsidence, up to 4.5 m in certain areas.

The subsidence decreases with distance from the extraction zones and creates severe cracking of the land at the points of greatest curvature, i.e. the edges of the areas of subsidence. The cracking clearly poses hazards of piping and failure in the impoldering dykes whilst the settlement causes problems for any rigid structure, i.e pipelines, passing through the dyke. In addition, the area lies within

an earthquake zone so that the accelerations and consequent stresses resulting from earthquakes pose major stability hazards.
The dykes have been progressively increased in height as the land level, though not the lake, has subsided. The increasing depth of water on the lake side of the dyke has sharpened the risks of wave attack whilst the original use of rigid concrete revetments against wave attack has been discontinued in favour of flexible rip-rap which is more able to adjust to differential settlements. Nowadays, pipelines and jetties have to pass freely over the dykes to avoid settlement problems within the dyke. An additional problem is that the drainage within the polder continues to change as levels change differentially. A finite element analysis has been developed to identify the probable sequence of stress patterns in the dykes during a design earthquake. Consideration of the effect of these cyclic stresses on undrained samples in a triaxial test apparatus has suggested that the dyke is prone to liquefaction in the sand layers at the upstream and downstream toes of the dykes.
Further elaboration of studies underway into the 'field significance' of these findings would be of interest. Also, it would be of interest to find out how and by whom, the costs of the remedial works for the polders are met. One point of detail requiring further explanation concerns the comment that the soil is unlikely to crack, i.e. in the dykes, if the capillary zone is less than 3 m thick. The reporter was unsure whether this referred to the depth of the water table within the dykes in general, or the depth of that part of the dyke above lake level.

5.3 The "Pluit" urban polder
by J.H. Kop et al

The final paper deals in a most comprehensive way with the design and operation of the "Pluit Urban Polder" in Jakarta, 2760 ha of low lying land containing a population of 1.5 million people. The acute problems posed by the area include high rainfall, a largely impervious surface area, the need to also use open channels to dispose of foul water containing large quantities of garbage and debris.

The main outfall drain leading to a pump station is now refrehsed daily. Automatic screens at the station remove the worst debris whilst storms and floods are handled by a combination of external diversion canals and, within, pumps assisted by temporary retention reservoirs. The system depends upon sophisticated operation and maintenance and it would be of general interest for the authors to elaborate on the organisational framework established to implement these measures. Also, it would be of interest to know what provision has been made for stand-by pump or generator capacity.

CONCLUSIONS BY THE CHAIRMEN OF THE THEMES.

THEME A: VARIOUS ASPECTS OF A CERTAIN AREA OR PROJECT.

General reports by:
Mr. D.S. Heslam
Ir. E. Allersma
Dr. D.W. Rycroft

Conclusions by Prof.dr. I. Mihnea, chairman.

The discussions during the working sessions dealt mainly with construction, improvement and management of polders although some social, economic and environmental aspects were discussed too. Both the reclamation of new areas and the improvement of existing polders received attention.

The conclusions can be summarized as follows:

1. Investments for making new polders or the improvement of existing polders can be made only if the economic and social analysis justify such projects.
2. Polder projects must be based on local data covering natural, social, economic and environmental aspects while applying local standards.
3. The decision to make a new polder or to improve an existing polder should be taken by the local government since this government knows exactly the needs, and controls the investments.
4. Polders require considerable investment which can only be repaid by a substantive leap in agricultural production. This invariably requires a sophisticated technological response which may be beyond the capacities of the farmers concerned. This constraint can be a major obstacle to successful polder development.
   Consideration should be given in these circumstances to increasing the farmers technological capabilities and crop yields by other means before necessarily embarking on new polders.

5. Experiments and pilot projects are recommended at an early stage of the study when major difficulties and constraints in the technical and/or social fields are expected.
6. Special attention should be given to the maintenance of polders. This is an important task for the local organizations and the farmers. The farmers should be instructed accordingly.
7. All possible sources of energy, including wind, sunshine, and tidal energy can be considered for use in polders.

THEME B 1: LAND AND WATER MANAGEMENT

SUB-THEME: WATER MANAGEMENT SYSTEMS AND DESIGN CRITERIA

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Abstract

The water management of polder areas is essentially a multidisciplinary activity, involving among others elements of civil engineering, hydrology, agriculture and economics. Systems analysis provides a convenient framework within which to consider alternative strategies for providing drainage and irrigation systems that are optimal according to a specified design criterion. Such criteria may be expressed in terms of the costs and benefits of the scheme, but invariably the economic factors are implicit rather than explicit owing to the use of objective functions such as the maximisation of crop yields or the minimisation of irrigation water supplies. The economic performance of the scheme must also be considered at farm level as well as project level. As the power of small micro-computer systems continues to increase, the use of management techniques based upon systems analysis is likely to become more prevalent.

1 Introduction

In what is perhaps the most general definition of the term, a polder may be considered as a well-delineated areal unit whose resources of land and water may be managed independently of other adjacent units. The size and complexity of a polder may vary widely, from the simplicity of a small, bunded rice paddy to the sophistication and

areal extent of the Ijsselmeer polders. Yet despite this diversity, their management invokes common principles. As with many facets of water resources analysis, polder management has benefited from, and could take further advantage of, the flexibility and potential afforded by the digital computer in its various forms. The majority of the papers which form the subject of this Report provide confirmation of this trend, with their reliance on mathematical modelling and their emphasis, implicitly or explicitly, on the search for some optimal solution to a design problem.
An important consequence of the well-defined physical nature of a polder is the extent to which the hydrological inputs and outputs can be either measured, controlled or estimated to an acceptable degree of accuracy. However, in terms of land and water management, the hydrology of the polder is only one pertinent aspect of its behaviour. The response of a given crop to soil moisture levels (or standing water levels in the case of lowland rice), particularly with regard to the reductions in yield that accrue from failure to meet the optimum requirements at different stages of growth, is equally if not more important in economic terms. The subsequent analysis of costs and benefits is another essential ingredient of resource management and serves to emphasise the interdisciplinary nature of the exercise.

As with many similar resource allocation problems, polder management is amenable to a systems analysis approach. This theme is developed in Section 2, along with a generalised representation of a polder water management system. The latter provides a framework within which to review the eleven papers that form the subject of this Report in Section 3. The Report concludes in Section 4 with some general observations on the role of computers in the water management of polder areas

2 Systems approach to polder water management

In its broadest sense, a system is a set of components that collectively transform an input into an output. The system may vary in its complexity, and both inputs and outputs may assume a wide variety of forms, depending upon the problem under study. In practical terms, the components of the system and their inter-relationships are described by a series of mathematical and logical statements which are readily translated into a computer-compatible form. The analysis of a system is generally carried out either by simulation or optimisation. The former approach is particularly relevant where a high level of detail on system behaviour is required. A simulation model provides the time series of outputs produced by the system operating on a given series of inputs according to a predetermined strategy. This approach tends to place large demands on computer core storage, and the location of an optimum operating policy has to be undertaken on a trial-and-error basis, which can prove both expensive and time-consuming and carries no guarantee of absolute success. In contrast, optimisation is highly appropriate for determining a strategy that is the "best" according to some specified criterion. This approach may also be demanding on core storage, but less so than simulation. In addition, care must be taken in defining the system in order to ensure that the problem is amenable to treatment by a standard solution procedure. For example, where all relationships describing the system are linear, the technique of linear programming may be employed.

A schematic representation of a polder water management system is presented in Figure 1. The core of the system may be seen to consist of two mathematical models, one of which describes the hydrological and hydraulic component and the other the economic component. In its simplest form, the hydrological model may consist of a single equation which accounts for all inputs and outputs during successive time increments. This water balance may be described in compatible units by an equation of the form:

$$H\ (n+1) = H(n) + (RF+IRR) - (ET+INF+DR) \tag{1}$$

where

H (n) = soil moisture (or water) level at the end of the nth time increment

RF = precipitation

IRR = amount of irrigation

ET = evaporation

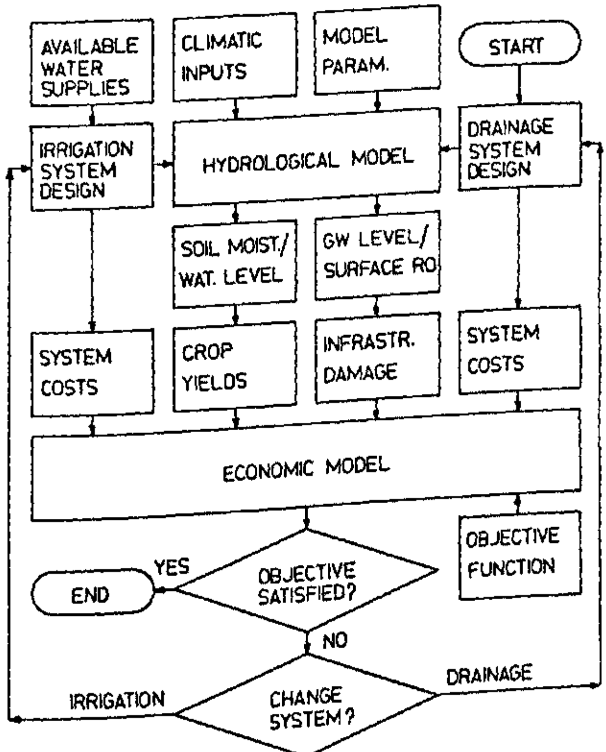

Figure 1. Schematic representation of a polder water management system

INF = seepage loss

DR = amount of drainage

Of these variables, RF and ET may be derived from climatological observations, but IRR and DR are design variables and INF must either be chosen on the basis of experience or determined by experiment.

Whereas equation (1) may be adequate to describe the water balance of a precisely delineated cropped area, such as a rice paddy, this model is obviously inadequate to deal with more complex problems. For example, in order to describe the behaviour of the drainage system serving several such land parcels, account must be taken of both saturated and unsaturated groundwater flow as well as free surface flows in the major arteries of the channel network. A distributed, layered conceptual catchment model would then provide a more appropriate representation of this system component.
Having produced a time series of soil moisture or water levels corres-

ponding to a given drainage modulus or configuration of drainage system, these data become the inputs to the economic model forming the second major system component. The moisture status throughout the growing season is a principal determinant of crop yield. Similarly, if supplementary information is available on groundwater and surface water levels, estimates can also be made of any infrastructure damage resulting from periods of excessive flows. These benefits and costs may be combined with the installation and maintenance costs of the drainage system and (if provided) the irrigation system, and discounted to a common economic basis.

The adequacy of the outcome of these computations is dependent upon the form of the criterion of optimality, or objective function, under which the study is being performed. The possible forms of objective function are many and various, but the most commonly applied would appear to be minimum annual costs or maximum difference between benefits and costs. Frequently, these criteria are implicit rather than explicit. The design variables may be continually updated until the objective function is satisfied.

Having met the criterion of optimality, a further, but equally important, phase of the computation is entered in which the sensitivity of the outcome to the basic assumptions and design variables can be tested. In its simplest form, such sensitivity tests may consist of repeated application of the systems model with individual design variables set to different values with all other variables held constant. Such an exercise may often provide insight into the level of detail to which each system component needs to be represented. For example, the relative importance of the individual terms in equation (1) in relation to the magnitude of the crop yield may be evaluated in this manner. By drawing attention to such issues, the systems approach is able to isolate those aspects of a problem where additional information will yield the maximum dividend. In particular, crop water/yield relationships, which form an important linkage between the hydrological and economic components of the system model, would appear to be a fruitful area for further investigation.

3 Review of papers

The group of papers under review deal with a range of diverse problems, but all are concerned with some aspect of design criteria for polder water management systems. The contributions may be broadly divided into two groups, the first of which addresses problems of rice cultivation and the second the design of polder drainage systems.

Three of the authors treat the problem of rice paddy drainage on the basis of the model described by equation (1). Whereas both Buijs and Dahmen rely on a computer-aided recursive solution procedure, Garzon has opted for a statistical approach in which the change in surface storage (equivalent to a combined term H(n+1)-H(n)+INF) is used as the independent variable in a series of linear regression analyses for groundwater table elevation and groundwater flow. The comparatively poor explained variances obtained for these equations, particularly in comparison with those for groundwater table elevation in terms of lagged rainfalls and numbers of days since the opening or closing of the irrigation system, raises the question as to whether a more physically-based approach, taking into account the water movement in the upper soil horizons, would not have produced a more reliable model.

According to Buijs, the cultivation of rice in Suriname is based upon a strict water management schedule that apparently takes little account of growing season rainfall and therefore results in a large drainage requirement. The return flows are large compared with the discharges in the rivers to which they drain, but can be reused, subject to certain water quality considerations. This "recycling" assists in maximising the use of the available water supplies and bringing the largest possible area into cultivation.

The paper by Dahmen, in treating the more general problem of determining the drainage modulus which minimises the variations in crop yields, is notable for its emphasis on the importance of economic considerations, both at the farm level as well as project and sub-project levels. The procedure which the author outlines is readily identifiable in the general framework of Figure 1. In addition, a timely warning is sounded on the need to assess the reliability of the available climatological information prior to undertaking any analysis.

Rice production is also the topic discussed by Wiersinga and Sudibjo, who describe the reclamation of a tidal swamp area in Indonesia for the cultivation of rainfed crops. This project gave rise to a series of design objectives, including the drainage of excess water and noxious compounds; the maintenance of adequate water and soil moisture levels in the croplands; protection against saline flooding; and the provision of access and effective transportation within the developed area. Those authors describe the structural measures that were devised to meet these objectives and outline the management practices that are to be followed within the developed area. The latter are heavily reliant on the operation of structures with flap gates and stoplogs, which are notoriously subject to human error.

The second group of papers, which deal with various aspects of polder drainage, is notable for the wide spectrum of design problems that is discussed. In some cases, the design criteria are largely qualitative. For example, Hebbink provides a detailed discussion of the different types of subsurface drainage systems that have been installed in the Flevoland polders, and elaborates on their advantages and disadvantages. Current advice on preferred systems would appear to place greater emphasis on avoidance of disruption than on minimising installation and maintenance costs.

A more quantitative approach to polder drainage design is provided by Dorai. Again, the crop is rice, and the design criterion for the drainage system is the minimisation of periods of inundation. This objective is achieved by varying the dimensions of the main outfall sluice, subject to downstream tidal variations. In minimising the duration of submergence of the rice plants, the economic component of the systems model (Figure 1) is implicit rather than explicit.

A similar implicit criterion is evident in the work of Kuroda and Cho. Those authors describe the management problems of an irrigation scheme in a low-lying delta area in which creeks are used as buffer storages which even out the irrigation water demands placed on the main canal system. Dynamic programming is employed to optimise the time series of canal water supplies and creek water levels in order to minimise the irrigation water intake.

An automatic optimisation procedure is also used by Schultz to determine the values of five design variables that together characterise a polder drainage system. This contribution provides a clear example of the application of the systems approach. The hydrological and economic components are comprehensively described, and the objective function, which involves the minimisation of annual costs is explicit. Furthermore, the author presents in his Figure 4 the results of a sensitivity analysis which reveals the importance of avoiding the underestimation of subsurface drain depth and water level.

Each of the above-mentioned contributions relates to polder areas having a single agricultural land use. The reminder provided by van de Ven and Ven of the contrasts in storm runoff response that exist between rural and urban areas is therefore apposite. The effects of the enhanced peak discharges from the urban areas are mitigated by the effective use of the associated urban canal systems as detention storages. Determination of the dimensions of the latter, including the crest width of the outfall weir and the surface area of the canal, also constitutes an optimisation problem in which the objective function involves the limitation of the magnitude of the flood lift to that associated with a specified frequency of occurrence.
By virtue of their physical characteristics, polder areas are invariably located in low-lying areas adjacent to a coastline. In these circumstances, the wind fetch from certain points of the compass may be considerable. The elongated open water bodies that comprise the polder drainage system may therefore be subjected to wind set-up. This problem is treated comprehensively by Bouwknegt and Kroon. Whereas the latter authors employ a computational hydraulic model based upon the Saint Venant equations, Tanaka and Shikasho treat the problem of forecasting the depth of unsteady open channel flow by an approximate method involving the extended Kalman filter.

4 Concluding remarks

Several of the papers reviewed in Section 3 above have described analytical approaches to the solution of a water management problem.

These contributions have demonstrated a variety of techniques, ranging from sequential solutions to the water balance equation to automatic optimisation techniques and numerical solutions to the Saint Venant equations. While much can be accomplished with hand-held programmable calculators, as aptly illustrated by Dahmen, the demands on core storage made by the more sophisticated modelling procedures inevitably involve the use of a larger computer. Unfortunately, access to the larger mini and mainframe computers is far more restricted in the developing countries than in the developed parts of the world. In these circumstances, more consideration should perhaps be given to the transferability of techniques. The authors may care to reflect on how dependent their approaches were on the availability of a particular type and size of computer.

In terms of an appropriate level of computing at which to disseminate analytical techniques to advantage, the different types of micro-computer that have become available within the last 3-5 years would appear to have much to offer. Many makes are now capable of handling mathematical programming problems with 40-50 variables and as many constraints (see Annesley et al, 1982), and several of the problems considered in the papers under discussion would fall within their scope. As their capital cost continues to decrease as their size in terms of random access memory increases, micro-computers would appear to provide a highly versatile tool for future water managers.

Reference

Annesley, T.J., M.J. Hall and N.A. Hill 1982. A master water resources and agricultural development plan for the State of Qatar. 2. The systems model and its application. Water Supply and Management, in the press.

Papers reviewed

Bouwknegt, J., and L.J.M. Kroon. Wind influences on the water movement in open channel networks.

Buijs, J. Irrigation requirement of rice, return flows and their effect on the irrigation capacity of a river.

Dahmen, E. Drainage and irrigation requirements: an integrated approach.

Dorai, M. Design considerations for the drainage of padi polders.

Garzon, R.S. The influence of shallow groundwater on the drainage problem of the Kabacan River irrigation scheme

Hebbink, A.J. Drainage of urban areas in the Flevopolders.

Kuroda, M., and T. Cho. Water management and operation of irrigation system in low lying delta area with creeks.

Schultz, E. A model to determine optimal sizes for the drainage system in a polder.

Tanaka, K., and S. Shikasho. Application of the extended Kalman filter for forecasting the channel flow.

Ven, F.H.M. van de, and G.A. Ven. A comparison between the runoff from a rural and an urban basin in Flevoland.

Wiersinga, R. Th., and S. Sudibjo. Land and water management in tidal swamp land development projects in Indonesia.

SUB-THEME: WATER MANAGEMENT SYSTEMS AND DESIGN CRITERIA (CONTINUED)

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Abstract

The paper summarizes 11 submitted articles dealing with traditional and new approaches in the design and watermanagement procedures of polders and pumped catchments. The review goes from the classical agrohydrological experiments, resulting into drainage criteria and watermanagement concepts, through the definition of design levels and pumping capacities based on the statistical processing of hydrological data collected over a long period of years. Both approaches assume in their design steady flow conditions. Often the criteria as the design procedure are modified to engineer's experience and/or to the failure of existing systems. According to the increasing need of reducing the investment and operation costs of water control works for the agricultural improvement of low-lying parts of river basins in deltaic and coastal areas, new techniques have been introduced for the refinement of design and management. To those belongs the technique of modelling which allows to simulate the water level in existing or designed arterial drain networks of pumped catchments in function of a rain event with given characteristics. This powerful approach, based on the modelling of the unsteady flow conditions in polders permits to examine alternative design concepts, management and maintenace schedules in terms of level control, quality control of the boezem waters and cost estimates. According to some of the reviewed papers, the general application of simulation models offer consi-

derable scope for the refinement of the design and maintenance policies of pumped and free drainage networks, reflecting into an optimization of the economic accounting of the engineering works needed.

1 Considerations of existing design procedures for in-field drainage systems

Low-lying parts of river basins, in deltaic and coastal areas are continuously or frequently subjected to waterlogging conditions, either by seepage, flooding or through the discharge of water from the surrounding uplands, limiting agricultural development of this areas. In addition salinized soils may be formed if the seepage or flood water is brackish in composition. Lowering of the groundwatertable may also be necessarily in irrigated agriculture in order to control the salt balance of the rootzone.
As generally accepted in engineering works the benefits of the engineering measures should be balanced against the costs of the water control works. Drainage and water control (dikes, canals, pumping stations, etc.) measures require rather high investment costs per ha, of which a relatively exact estimate can be made. However details of the benefits to be anticipated from flood control and drainage works are not that clear. The adverse effect of poor drainage, temporarily inundations, salinity, etc., on crop growth is complex, depending on the timing and the duration of the crop stress. Additionally, waterlogging may hamper soil tillage, transport of machines, leading to the detoriation of the structural conditions of the soil.
Rather few data are available of crop response on waterlogging. Increasing efforts have been made recently to express the benefit of drainage in increased land workability. From irrigation studies a large number of criteria have been forwarded of crop tolerance levels for salinity. Among the papers to review one paper (DONKOR) dealt with the experimental determination of the salinity-yield relationship of rice. The experiments were run in the coastal area of Suriname on clayey soils of marine origin, with very little percolation especially when in an unripened state. Leaching on these soils seems to be only adchieved through intensive drainage together with sprinkling irrigation. Peak yields

occured at salinity levels around 0.4 mmho (EC-values were measured on 1:5 soil water extracts, and converted to standard EC-values), a relatively decrease in rice yield occured over the EC range 0.4 - 1.15 mmhos, and at EC-values more than 1.15 mmhos, rice yield fell sharply. According to the author the salinity-yield relationship is influenced by other factors as type of land preparation and pH-level of the soil.
Until recently most of the field drainage experiments were run to establish field drainage criteria. A classical example of such a study is given by VIEIRA et al. The agrohydrological experiments were run on some experimental plots situated in Leziria Grande, an island of 13074 ha in the lower Tejo Valley, 25 km upstream from Lisbon. The soils of the area are mostly heavy, saline and alkali. Based on the results of a detailed investigation of the potential drainage area three experimental plots were installed in the Southern part of the Leziria Grande. The plots differing in composition, permeability and groundwater regime were surface drained with 60 cm deep ditches installed every 20 m; subsurface drained with corrugated PVC pipes, 5 cm in diameter, installed at an average depth of 1.20 m at a varying drain spacing of 10, 15 and 20 m. In addition half of the plots received a gypsum treatment in quantities varying from 10 to 40 ton per ha depending from the ESP-value. Gypsum was applied to verify its effect on the alkali condition, and indirectly on the internal drainage capacity of the soil. From rainfall, drain discharge, EC-values of drainage water and watertable level measurements following drainage criteria and design recommendations for the agricultural exploitation of the area were derived by the authors:

- Subsurface drainage controls the watertable better than surface drainage. Narrow drain spacings are more effective and gypsum applications favourises watertable control by improving soil structure through sodium replacement by calcium.
- The leaching of salts in surface drained plots was remarkable inferior to tile drained plots. Salt leaching seems not to be influenced by drain spacing and as could be expected gypsum effects positively on desalinization.
- A drain spacing of 20 m and drain depth of 1.20 m is recommended for the marine soils of Leziria Grande. The heavy and poorly drained fluvial soils needs a drain spacing of 30 m. For the fluvial soils with intermediate conditions a drain spacing of 60 m is recommended, while

the sandy and loamy soils with high elevation do not need drainage.

- The drain discharges derived are 2.5 $l.s^{-1}.ha^{-1}$ for the marine soils with surface drainage, 2.0 $l.s^{-1}.ha^{-1}$ for the marine soils with subsurface drainage and 1.0 $l.s^{-1}.ha^{-1}$ for the fluvial soils with subsurface drainage.

For the improvement of the drainage and salinity problems in the Leziria Grande future drainage works should consist of subsurface PVC drain pipes (which does not or slightly interfer with the existing irrigation network), concrete collectors and open secondary and main canals, served by pumping stations. Drain pipes should be installed at an average depth of 1.20 m, while the water level in open ditches and canals must be 1.50 m below ground level. The field drainage system should be complemented by land levelling and by gypsum application.

An analogous agrohydrological experiment was run in Jarikaba (Suriname) from 1966 to 1972 in order to derive the drainage criteria for banana plantations in the coastal plain. The conclusions of this research as reported by SOE AGNIE's paper are: a positive correlation between rooting and drainage depth; a greater effect in yield decrease with age with decreasing drainage depth, and an increase in optimum lifetime of the plantation with increasing drainage depth. The optimal field lay-out for heavy clay soils with a permeability between 1.5 and 2.0 $m.day^{-1}$ is a cambered bed system with six meter wide depths, with a groundwatertable level at 80 to 90 cm below surface in combination with a discharge capacity of 2.3 $l.s^{-1}.ha^{-1}$. Farm management treatments on the agrohydrological plots revealed that no soil tillage is allowed on those low-permeability, low-stability, young clayey, marine soils. Use of machinery is not permitted for the same reason of risk of unreversible compactation and physical degradation even for clearing the forest after empoldering, for the maintenance of the drainage system, as well as for the transport of fruits at harvest.

Having defined for a given region the drainage discharge criteria, the design watertable level, a variety of equations for predicting drain spacings, based on the soil hydraulic conductivity and geometry of the flow domain have been developed. The most widely used drain spacing equations are of the steady state type assuming equilibrium between drain discharge and design rainfall. However, even for circumstances, where drains are installed primarly to cope with winter rainfall, which often is rarely uniform long enough to establish a steady state, drainage design is mostly based on the use of the steady state equations. The alternative use of transient equations has been explored by ARMSTRONG. But still the unsteady approach has not yet been developed to a procedure that can be used routinely. The limited application of transient equations is due to the costs of the investigatory work needed for scientific drainage design, the spatial variation in soil properties and cropping practices. Because of this, ARMSTRONG and others developed a rational drainage design procedure suited for the drainage of the English fenlands. Their approach is based on a design rainfall rate (taking into consideration climate, cropping and drainage type), on soil profile examination and experience. According to them the experience of advisors and contractors is not to be despised. In some cases the dogmatic insistence of close spacings could be wipped out through the application of the rational drainage design concept. For a field varying in soil composition they advice to make the design for the dominant soil type, and to modify it in relation to any included soil variation. As for example a dominantly peat soil would normally be drained at fairly wide spacings (in excess of 20 m), which may be decreased to say 15 or 10 m in the presence of clay layers.

The drainage design of the peat soils, as present in the fenlands of Eastern-England, should take into consideration specific problems as the lowering of the surface by shrinkage and oxidation of the organic matter when drained. As a consequence the drains tends to become shallower and risk to loose their grading. If the outfall cannot be deepened the soils have to be redrained periodically at successively greater depths, the pumping requirements to be increased and if after some time the underlaying clay will become exposed the drainage characteristics have to be adapted.

Beside peat wastage blocking of field drains by iron deposits and siltation can cause total failure of drainage schemes. In the U.K. siltation of drainage pipes seems according to ARMSTRONG not of national significance and can be circumvented by the use of pipe filters, while iron deposition seems to be a common fact in peat soils. Once it occurs, remedial works are paricularly difficult, and the only solution according to ARMSTRONG's paper seems to be a programme of repeated drainage until the store of iron is exhausted. In addition, the use of drain lines to supply water to the plant in the summer months has recently been investigated. Technically it seems to be possible to maintain the watertable in the fenlands at a specified level by reversed drainage, but to be effective for agriculture the land should be levelled, which is not only expensive, but may also expose unripened subsoil material. Most of the problems encountered in draining the fenlands, however have not yet resulted into a firm set of recommended procedures. As for other areas, it is rather impossible to base the design to a large extent upon equations, either of steady or non-steady state. Local knowledge and skill, suggests ARMSTRONG, will always be essential for a proper dealing of the particular set of problems encountered locally.

Due to the traditional approach of poldering, rendering optimal conditions for habitation and agriculture, polder development often results into high technical requirements; high investment costs, high organizational requirements, low rate of implementation, social and environmental repercussions, incompatible with local economic, social and environmental conditions of the developing countries. HORST in his contribution advocates strongly that other development concepts generating a greater participation of peasants, resulting into a lower investment cost per ha, corresponding better with the traditional farming systems, causing less disturbance to the ecological equilibrium should be explored. Some possible alternatives that are worthwile to be considered are improved drainage only, improved drainage plus submersible dikes, complete diking without pumping and/or with low pumping capacity, the practice of horse shoe dikes, the introduction of floating rice or deep water rice in the flood period, etc. The effect of those alternatives on the possible length of the growing season is been illustrated graphically by HORST in his paper. It is self evident that the applicability of those alternative forms of water control will depend on land use, on the local topographical and hydrological situation.

2 Design considerations of pumping plants

Traditionally it is accepted that 6 to 13 mm.day^{-1} should be discharged from polders. For the IJsellakepolders a general accepted starting point for the estimation of the pumping capacity was the demand that 40 mm of

rainfall during five consecutive days within the same period should be discharged. If the land is used for the production of high valued crops discharge rates are taken in some cases even equal to 18 $mm.day^{-1}$ (BERAN).
It would be preferable if the design of pumping stations could be based on the runoff behaviour of polders or pumped catchments similar in size, composition and land use. Slightly the collection of hydrological data becomes a matter of routine. In his paper DIJKSTRA is analysing the yearly total runoff volumes of the Wieringermeer and northeast-polder, collected during a large number of years. The pump capacities of the different polder sections analysed ranges from 8.4 to 17 $mm.day^{-1}$. The mean pumping capacity of the IJsellakepolders is close to 12 $mm.day^{-1}$. From the mean value of the total runoff during a year it could be concluded that the entire installed capacity of approximately 12 $mm.day^{-1}$ is operating appears to be 1440 hours during a year. From the analysis of long time series of recorded water levels it could be verified if the pumping capacity of 12 $mm.day^{-1}$ be on average sufficient to maintain the water level in the ditches within permissible limits. According to DIJKSTRA following conclusions could be drawn from the frequency of occurence of extreme water levels: the design assumption of the pumping station is or is not in accordance with the statistical distribution of the water rise; the effect of increase in pumping capacity on the diminish of extreme levels can be estimated, as well as the effect of increase of open water storage on the return period of certain levels.
While DIJKSTRA's study was devoted to large polder areas, BERAN tried to formulate flood frequency curves for smaller areas, 100 to 15000 ha large, situated in the fenlands of the U.K. His findings are based on the processing of daily discharge data collected on 15 pumped areas for at minimum 5 years. From the flood frequency curves, i.e. the relationship between a certain magnitude of runoff and its return period, the degree of utilization of the installed pumping capacities could be derived. As a result a 10 mm pump capacity seems to have a 20 year return period protection in the East Anglian fens but no more than a 5 year return period protection elsewhere. The current design standard of 12.5 mm, as imposed by pump technology, will provide even a 30 year protection at the East Anglian stations.
One of the pumped areas have been studied more intensively by BERAN in

order to establish the catchmant response to storm rainfall. Therefore water levels, rainfall and soil moisture status have been recorded simultaneously at several locations. The most notable feature of this research was the tendency for all points in the catchment a long the arterial drain to march together suggesting that the lag-time of the field drain response may be equated with the lag-time of the basin as a whole. The runoff coefficients from rainfall events so far studied range from 5 to 40 % and the variations seem to be related to the soil type of the catchment, the catchmant wetness, and the storm precipitation. The author suggests further that research should be continued to identify the factors controlling the runoff coefficient. Confirmatory studies are also needed on the slope of flood frequency relationships, including the aspect of seasonal dependency. Those results will help in defining more precisely pump size.

3 Modelling as a design and management aid

Up to now most of the design criteria being used are based on the result of agrohydrological studies of polder and/or pumped catchment areas. In addition these criteria were modified to the engineer's experience and adapted to the failure of existing systems. Recently hydrological studies have tried through a statistical treatment of existing level and pumping data to establish the frequency with which different extreme levels and volumes of pumping within different periods of time have been experienced. However, the existing design procedure for pumped catchments with its assumptions of steady flow and an extreme arbitrary frequency of exceedance of water levels seems to be inadequate for refined economic design. As a result complementary studies have been aimed at modelling the whole of a pumped drainage system deterministically. The hydrodynamic model approach permits to assess how a given drainage network together with its pumping station performs during an unsteady event occuring with a given frequency. Modelling permits to simulate the effect of small changes to the basic design of the arterial drains and of changes in the maintenance schedules on the frequency and duration of water level exceedance in the network. This fine tuning, done with deterministic models has proven to reduce significantly savings in construction, operation and maintenance costs of drainage networks.

Of the papers in the subtheme B 1.2, I had to review 4 papers that were dealing with the development of model concepts for the computation of total water demands for level control and control of chloride concentration, for the hydrodynamic simulation of flows and salt distribution in boezem systems in pumped catchment areas and in tide-driven drainage networks. In most of these papers various design alternatives were compared in terms of specific impacts on water and salinity level, flow conditions in the canals, pumping performance, costs of construction, operation and maintenace.

VAN BOHEEMEN describes in his contribution a numerical model to calculate the water supply needed for level control during the growing season, April 1 to October 1. The water requirements are calculated per timestep of 10 days and per bloc of 25 ha. To each of the distinguished blocs, in which the polder districts have been subdivided a representative land use, soil type, and various hydrological characteristics have been given. For each timestep data have been collected on precipitation, global radiation, and potential evapotranspiration. Then the water requirement of each bloc of 25 ha is calculated. For five different types of land use a separate method has been developed to compute the water requirement. In a next step the water requirements of the blocs are added to obtain the water supply of the entire area.

A validation has been made for two polder districts, the polder district of Rijnland: 106,300 ha large and Delfland: 35,875 ha in size. As validation criteria the simulated water supply was compared to the actual one. The comparison has been made for the summer periods 1975 through 1978. In general the model results are slightly higher than the actual values. According to VAN BOHEEMEN the differences are due to following model assumptions: shortages and surplusses are replenished, respectively discharged immediately so that no fluctuations in open water level occur; an optimal water supply sytem and a full-grown crop being present during the entire summer.

Due to the presence of large scale glass house horticulture in the polder districts in the Netherlands and to the water supply for level control, an additional water supply for water quality control became of growing importance, with special emphasis on the chloride content of the polder and boezem water. GRIJSEN et al. carried out a study to assess the additional water needs for flushing the internal and external salt load

of polders. In addition they analysed various technical alternatives of water supply systems to Delfland. Among the alternatives compared, comprised such possibilities as the construction of a new canal, reconstruction of existing canals, construction of pipelines and syphons, construction of a reservoir and use of purified waste water.
With a hydrological model, comparible to the one described in VAN BOHEEMEN's paper, the water demands for level control were computed for each decade of the summer half years in the period 1911 to 1978, both for the present land use pattern in the region as well as for the one anticipated for the year 2000. In a next step the water demands for flushing were computed for each decade. Hereto the hydrodynamic model, ABOPOL (Analyzing a BOezem POLdersystem) was used. This model calculates the chloride distribution in the boezems and the additional water demand for keeping the salt level of the boezem water below the standard for salt concentration.
In a following step the yearly extreme water demand figures were subjected to a frequency analysis using the Gumbel distribution. Water demands with a return period of 35 years were taken as design flow for the water supply systems. The present study resulted to a total water demand of the region for level and chloride control of only 73 % of earlier made estimates. Previous improvement in the estimate of total water demand was possible since in a dynamic approach the same quantities of water serve various purposes at the same time and since the numerical description of the polder regime became far more detailed and comprehensive as before.
Since in the model ABOPOL the schematization of the project area, of the canals and the boezems has to be imputed, it was possible to check the effect of alternative water supply systems in terms of the chloride level. The cost estimates of the alternative projects ranged from 54 to 224 million dutch guilders compared to the estimated 137 million guilders for the original planned water supply canal. Which of the studied alternatives should be realised depends however from many other non-technical aspects, which cannot be considered with ABOPOL.
From the concern that any investment in improved drainage should be made properly, PRICE et al. of the U.K., argue in their contribution that we should get rid of the semi-empirical design procedure for pumps (= are based on runoff of 0.34 $m^3.s^{-1}.km^{-2}$) and ditches (= a fall of 10 cm per

km and water velocities up to 0.3 $m.s^{-1}$), with its assumption of steady flow and an extreme arbitrary frequency of exceedance of water levels. As a result, a comprehensive procedure for the design and analysis of pumped drainage systems have been worked out and presented in PRICE et al's paper. The procedure is based on the simultaneous use of two models: the first to design the dimensions of the arterial drains, which is regarded as a dentritic network and the second model aims to simulate the performance of the complete system, the operation of the pumping station included.

The hydraulic design of the arterial drains is optimised in such a way that the costs of excavating and of the land lost for agricultural purposes be minimal. A discrete differential dynamic programming method is used to obtain a minimum value of the cost function. From a test of the model on the Newborough catchment was found that : the optimal design corresponded with the critical slope that is, the smallest gradient defined by the maximum permitted water level at the upstream end of any drain and the water level at the downstream end of the branch; the maximum velocity constraint is a critical factor in determining the geometry of the drains.

A simulation model was developed for the description of the unsteady flow in a pumped drainage network. The model is applicable on a designed or existing system and permits to experiment with various alternative changes in terms of the capacity of the arterial drains to store runoff, pump capacities, settings of the pumps, etc. The simulation model is being used to simulate the performance of these alternative changes in design, operation and maintenance schedules on the water level at several locations of the drainage network for any arbitrary rainfall storm, which might be characterised by a given duration, intensity and return period.

In a last paper YANES et al. presented a simulation model for the improvement of the watermanagement of tide-driven drainage networks, with application on the Guara island, situated in the delta of the Orinoco river. Guara like all other islands in the delta, have their lowest land levels towards the center and embankments towards the periphery. The main drains were designed to discharge into the river channels surrounding the island, driven by the water slope produced during low tide in the river channels.

The simulation model, described in YANES et al. 's paper, for the optimization of the management policies has been based on the application of the Saint-Venant type equations. Via the combination of the conservation of mass and momentum equation, using Manning's expression to define the frictional slope, a system of non-linear equations is formed, where the unknowns are the stages (water levels) at the discretization points and the knowns are formed according to the boundary conditions imposed. The system of equations is solved using the Newton-Raphson algorithm. The simulation is simplified by fixing the upstream boundary condition as a slowly varying hydrograph given by the stage of a reservoir. At the downstream boundary a varying tidal stage hydrograph of 12 hours periodicity is taken. A stage-discharge function has been used to describe the downstream discharge through the one way tide control gate.
The rapid growth of aquatic macrophytes was taken into consideration in the hydraulic model by increasing the roughness coefficient in a way which depends on density and plant structure. It has been observed namely that three of the most abundant species display very striking differences in increasing the roughness coefficient. The paper shows the discharge of the island Guara versus time as obtained by computer for a complete tidel period. Besides that the authors claim that the model can serve to analyse alternative management strategies and to optimize water levels.

References

Armstrong, A.C., 1982. The design of in-field drainage systems in the English fenlands. 10 p.

Beran, M.A., 1982. Aspects of flood hydrology of the pumped fenland cathments of Britain. 10 p.

Boheemen, P.J.M. van, 1982. A model for the computation of water requirement for level control of polder areas. 13 p.

Dijkstra, J., 1982. Watermanagement in the IJssellakepolders. 11p.

Donker, S.M.K., 1982. The influence of soil salinity on rice yields in the Wageningen polder, Suriname. 11 p.

Grijsen, J.G. and G. Miedema, 1982. Water supply to the mid-west of the Netherlands. 12 p.

Horst, L., 1982. Alternative development concepts in potential polder areas. 6 p.

Price, R.K. and J.E. Slade, 1982. A model for the design, analysis and operation of pumped drainage systems. 11 p.

Soe Agnie, I.E., 1982. Land and water management in banana cultivation in Suriname. 9 p.

Vieira, D.B., A.E. Pissarra and J.G. Pombo, 1982. Drainage and desalinization studies and design in Leziria Grande, Portugal. 12 p.

Yanes, A.G. and M.F.L. Acevedo, 1982. Tide-drainage networks: the case of Guara island. 11 p.

SUB-THEME: WATER QUALITY, GEOHYDROLOGY AND SOILS

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Abstract

This report discusses papers on water quality and changes in soil properties and their influence on water management. A total of seven papers from Australia, Egypt, Iraq, Japan (2x), the Netherlands and from FAO (Rome) was received.
The latter paper deals with planning programs for irrigated areas with emphasis on the effects on water quality of drainage water from irrigated areas.
The Australian paper describes the water management problems in relation to river water quality of the Murray river in South Australia.
The Egyptian paper discusses the problems encountered by reclaiming and irrigating a strip of desert land of some 17,500 ha.
The Iraqi and Dutch paper treat changes in soil physical properties as a consequence of reclaiming saline land and polders respectively. The latter paper gives a model to simulate the soil ripening to be expected in future.
The two Japanese papers deal with desalinization of newly reclaimed land along Tokyo Bay and the design of fresh water lakes along the sea respectively.

1 Introduction

The papers falling under the congress theme B1 (land and water management) that included the topics water quality, geohydrology, soil ripening, - subsidence, - physics and - improvement could be divided into three groups namely:

- papers dealing with seepage problems in polder areas;
- papers discussing water quality aspects in irrigated areas;
- papers on changes in soil physical properties during and after reclamation of polders and saline soils in irrigated areas.

The report on papers falling in the first category is given by Romijn, the papers falling in the latter two categories are discussed in this report.

Although irrigated areas are not always polders in the original sense of the word, they have many things in common with polders, the main point being the autonomous water management system. Both reclamation of polders and saline soils in irrigated areas have in common that they form the cause of changes in soil properties that are necessary to make the soil suitable for cultivation and the growth of agricultural crops. These changes are of utmost importance for the water management systems to be applied.

Water management problems in irrigated areas

Introduction of irrigation in arid regions inevitably brings about a rise of the groundwater, an increased salt load in the groundwater and a deterioration of the downstream surface water, due to the disposal of drainage water from the irrigated areas themselves.

Because of the ever increasing demand for food there is a world wide tendency to enlarge the productive agricultural area by introducing irrigation. In many areas good quality of irrigation water is scarce. Moreover, agriculture has often to compete with domestic and industrial water demands in the distribution of the scarce resource.

Control of water quality leads to cleaner water and an increase in agricultural production. It may provide extra water to meet additional demands by agriculture, industry and population and it can reduce energy consumption. Improving water management practices can diminish the salt load from agricultural areas, leaving a better water quality for the downstream sections of the river and saving water for use in these areas. A better water quality itself can increase crop production considerably and reduce the hazard of soil salinization. Prevention of soil salinization in turn can save large amounts of water otherwise needed for reclamation of soils once salinized.

Kadry (1) in his paper warns that too often reclamation and irrigation projects in arid and semi-arid regions are designed without considering the effects of implementation of these projects on other regions. He advocates a careful analysis of water quality problems in all the areas of a river system. Such an analysis should start with an inflow-outflow analysis of surface water and groundwater for all the subareas. On the basis of this analysis water and salt balances should be set up to detect the magnitude and sources of salinity. Next one should consider on-farm water use systems to obtain appropriate solutions for minimum salinization of soil and water. From these possibilities acceptable practical solutions should be chosen on which a cost-effectiveness analysis has to be applied to arrive at the best management practice for salinity control in a river basin.

The paper gives planning frameworks for developing best management practices in subbasins and in river basins, but does not go into detail as far as it concerns necessary data or research to obtain them, that are needed for implementation. In that respect the paper leaves a number of questions to be answered. To mention some:

- For implementation of plans and application of technologies partici-pation of the farmers is necessary. The author chooses for the solu-tion of this problem training and field demonstrations. Could cooper-ation of the farmers not better be sought in participation of them in irrigation districts?
- The author points several times to the necessity of systematic moni-toring of flows and water quality parameters, but does not indicate who must organize this and take responsibility for. Moreover, moni-toring alone is not sufficient. Who takes action when results indi-cate problems?
- The author states that remote sensing techniques can be useful to guide the selection of measuring points, the carrying out of soil surveys and land evaluation activities, but does not indicate how this should be done.

- How far wants the author to go with respect to costs of design and accompanied research, say expressed as a percentage of the total investment costs of a project?
- What organizational framework is necessary to realize the planning frameworks included in the paper?

An example of the many problems that appear in water management and the control of salinity is given in the paper of Schrale and Desmier (2). They discuss the problems of the water management of the Murray river in South Australia. This river delivers 90% of the irrigation water in South Australia and is used as a source for drinking water for Adelaide.

Due to return flow of irrigation water and underground seepage of groundwater the salinity of the river water is increasing. Annual costs for urban water users increase with $A 79 200 for each additional EC-unit while irrigation farmers loose $A 18 100 for each additional mg salt per litre. Polders along the river are used as pasture land with a potential production of 27.5 tonnes dry matter pro ha. The actual production is less than 50% and is decreasing due to salinization and water logging of the soil causing changes in composition of the grass-land.

Analyses of return flow volumes revealed that irrigation efficiency is only about 50%, but also that the amounts of salts removed are 2 to 5 times as high as the inlet amounts. This leads the authors to the conclusion that the main reason for the increasing salinity of the river is groundwater seepage. Measurements of groundwater seepage during the nonirrigation season showed that seepage intensities are between 0.1 and 14.2 mm per day with an electrical conductivity up to 34.2 mS per cm. Further research on improved drainage and irrigation combined with resowing of the grass should lead to the solution of the problem in the polders themselves while alternative methods of drainage water disposal have to be considered after reduction of its volume as a solution for eliminating the effect of the drainage water on the river water salinity.

The paper gives interesting data on the effect of salinity for both drinking water and agriculture. An actual production of grassland of about 13 tonnes per ha dry matter is very reasonable. A potential production of 27.5 tonnes in a nine month growing season is comparable with Dutch data of about 16 tonnes for a five to six month season. Taking a transpiration ratio of 30 kg DM per mm of water would demand roughly 900 mm of water. Subtracting the underground seepage from this demand, it becomes clear that the irrigation method must be the main source of the trouble as far as it concerns waterlogging and the accompanying salinization of the soils in the polders. Drainage may solve this problem, but is not a remedy for the underground seepage. Peculiarly the authors do not mention further research on this subject as a possibility to find a solution for the increasing salinity of the river water.

A second example of water management and salinity problems is given by Korany and Hussein (3). It pertains to a 17 500 ha area of desert land west of the river Nile in Egypt.
The authors give a description of the geohydrological and climatological conditions in the area. There is a 67 to 100 metres thick aquifer of Holocene material underlain by impermeable Tertiary formations from Pliocene, Miocene and Eocene origin. Rainfall is restricted to 22 to 45 mm per annum and high temperatures are accompanied by relatively strong winds. Potential evaporation in the area is estimated to be 1450 to 1840 mm per year.
Water brought into the area and originating from the river Nile is of excellent quality. After reclamation of the area in 1965 groundwater levels rose to 19.6 metres and in some spots even to 0.1 m below surface. The groundwater is somewhat brackish but mixed with surface water it gives 25% of the total amount of irrigation water applied in the area. The authors report on results of pumping tests and groundwater maps indicating the direction of groundwater flow.
Unfortunately they do not go into further detail on the results of their findings. Some remarks on this paper could be:

- The authors report that the k-value in the aquifer ranges from 15.4 to 32 m per day. Taking an average of 25 m per day, a gradient of 0.2 m per km (data mentioned are 0.15-0.26 m per km) and a thickness of the aquifer of 75 m, one arrives at an underground loss of 0.38 m^2 per day. For a boundary length of 80 km this comes to 30 400 m^3 per day or 0.5 m^3 per second.

- A potential evaporation of 1650 mm a year as an average leads to a water requirement of 9.14 m^3 per sec. while the authors mention 10,273 + 10,846 = 21,119 m^3 per sec. Therefore seepage losses from conveyance canals must be of utmost importance in determining the water need unless the underground seepage out of the area is highly underestimated.
- The mentioned water requirement means a total irrigation of 3850 mm per annum. From this roughly 40% evaporates. Since the concentration of the surface water is given as 555 ppm this would give a salt content in the groundwater of $2\frac{1}{2} \times 555 \approx 1400$ ppm. The authors give values between 1467 and 4789 ppm. Apparently fossile salts in the profile play an important role and the question is what will happen with both the groundwater table and the salt content of the groundwater in the future under prolongued irrigation. So what do the authors expect that will happen with the future salinization of the soil and the possible seepage losses from the area?

Changes in soil physical properties

As mentioned earlier both reclamation of saline soils and reclamation of polders imply changes in soil properties that are of utmost importance for both water management and water quality.

Okazaki (4) reports on the land reclamation in the eastern part of Tokyo Bay. Here land is reclaimed from the sea by heightening the soil with the aid of sand pumping from the sea.

The soil in the land obtained is saline due to the seawater from the dredging activities. When the material is sandy, leaching by natural rain is rapid enough to allow after some time tree planting and construction works. Many areas reclaimed with finer material had a too poor drainage to be used. In addition, unequal shrinkage of the land leads to depressions that are very saline.

Shrinkage was found to be highly dependent on soil material and started with crack-formation upon drying, the largest cracks occurring at high clay contents. In places with fine-textured subsoil and lighter topsoils, no cracks occurred. Due to the low permeability of the subsoil layers leaching of salts did not occur. Salts accumulated then on the edge of

the depressions due to evaporation.
Movement of chloride was found to be easier than that of sodium, causing differences in pH. This was one of the reasons for differences in the halophytic vegetation found on the land.

From the standpoint of soil formation and the relation between salinity and vegetation type the conditions prevailing in the reclaimed land are very interesting. Technically it is well-known that sand pumping leads to very heterogeneous soil profiles, the heterogeneity depending on the speed of pumping, type of sediment, drainage etc. A solution for the problem that soils are not leached therefore has to be found at least partly in developing better techniques for depositing the soil material during the sand pumping.
Al-ani et al. (5) report on experiments concerning the effect of sodium salts on the permeability of soils.
Salts in water do not only change their physical and chemical properties, but bring into contact with soils such solutions that are liable to exchange of chemicals with the adsorption complex of the soil. Therefore changes may occur in soil properties and water movement in the soil.
The authors saturated undisturbed soil samples of a nonsaline silty clay soil with solutions of sodium chloride, sodium sulphate, sodium carbonate and calcium chloride. Next permeability tests were carried out with the same solutions until constant values were obtained. As a next step the experiments were proceeded using tap water to see which changes took place. The ratio of the values found was used as an indication for the changes in hydraulic conductivity that may occur during leaching of saline soils.
Authors found that especially high concentrations of sodium salts in the soil will reduce the hydraulic conductivity upon leaching. On the other hand the presence of calcium and magnesium salts does not show this effect.
The authors point out that although the results of the experiments cannot be used for direct application in leaching procedures, they give an idea about what can be expected upon the time of leaching of saline soils.

A complete different problem of soil formation, namely the ripening of newly reclaimed polders in the Netherlands is reported by Rijniersce (6). Soil ripening is necessary to obtain enough bearing strength and to make growth of plants possible. In the Dutch practice of reclamation of polders reed is seeded as a pioneer crop to obtain moisture extraction from the soil as a start for the ripening. After some years, when the soil is dried sufficiently to allow the construction of a furrow drainage system, this vegetation is removed and replaced by agricultural crops. The soil ripening is important for the design of the required drainage and to predict the rate of subsidence of the land that has to be taken into account for construction of canals, ditches, roads, buildings, etc.
The author gives the principles of a numerical simulation model for physical soil ripening. The soil profile is divided into a number of layers ranging from 0.5 cm in the topsoil to 5 cm in the subsoil. The water movement in the soil is then simulated to obtain soil water contents and accompanying shrinkage and cracking.
Open water evaporation (Penman) corrected for soil cover is used as evaporative demand. Transport of water through the profile (both upward and downward) is then computed for every period of ten days. Computed soil water suctions are next transferred into a moisture profile with the aid of relations between organic matter content and bulk density on one side and water contents at given soil water suctions on the other hand.
A modified Terzaghi formula is used to find the compaction due to the load excerted by the drying soil layers. This gives the increase in bulk density upon drying. The increased bulk density results into subsidence and crack formation. By means of a distribution factor changes in bulk density are distributed over subsidence and cracking. The model finally predicts the subsidence, the depth of the cracks and the amount of water stored in the soil profile. Examples of comparisons between computed and measured data show that the model gives a reasonable prediction.
The model offers the possibility to obtain data on soil ripening in a relatively simple way. It uses a number of relations between parameters derived for conditions in the Dutch IJsselmeerpolders. This implies that the available model cannot be used for other conditions without proper adaptions as the author points out in his paper.

Water quality in reservoirs

A paper that is somewhat beyond the topics of this report is that of Tohara (7). It describes the water quality in a reservoir that is separated from the sea by an enclosure dam provided with a drainage syphon to let water out. Due to seepage through the enclosure dam salt water accumulates in the reservoir below the level of the outlet while the top layer has fresh water. Under the influence of wind the diffusion of salt from the bottom layer into the top layer is accellerated. The author gives a mathematical description of this phenomenon and discusses the various parameters included.

On the basis of this theory he developes a simulation model for the case that the horizontal distribution of salt in the reservoir is homogeneous. By dividing the depth into a number of layers and applying the finite difference method, both vertical velocity and salinity changes caused by it, can be found numerically. In order to maintain the water quality in the reservoir the amount of water causing the salt movement has to be counterbalanced by an equal amount of fresh water.

From experiments and simulations the author finds that in order to keep the chloride content in a reservoir with surface area A (ha) below 500 ppm, the amount of water Q required is $Q/A = 123H^{-1.8}$ ($m^3.ha^{-1}.d^{-1}$). Under wind velocities $u > 5\ m.s^{-1}$ the critical depth of the reservoir to prevent mixing of salts is $H_c = 0.74u - 2.6$. Under practical conditions in Japan one generally uses $H_c = 5 \log u - 1.0$.

This paper is interesting for problems where fresh water reservoirs close to the sea are used for water intake by for instance agriculture or for the production of drinking water.

References

1. Kadry, L.T. Soil water salinity relationship environmental factors of land reclamation.
2. Schrale, G. and R.E. Desmier. Saline groundwater inflow into irrigated polders along the Murray River, South Australia.

3. Korany, E.A. and S.A. Hussein. Geohydrological status and control of land and water management in the reclaimed desert areas, West of the Nile Valley, Egypt.
4. Okazaki, M. Accumulation and evaluation of salts in soils of reclaimed land along Eastern part of Tokyo Bay.
5. Al-ani, A.F., S.R. Daghistani and B.A. Takessian. Effect of different salts on the hydraulic conductivity of soil.
6. Rijniersce, K. A simulation model for physical soil ripening in the IJsselmeerpolders.
7. Tohara, Y. Water quality management of a desalted reservoir.

SUB-THEME: WATER QUALITY, GEOHYDROLOGY AND SOILS

(CONTINUED) E. Romijn

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Abstract

Seepage problems in polder areas have been a major hydrological research item for many years, especially in The Netherlands. They stimulated the development of geohydrology of semi-confined aquifers.

The papers of Kochev & Yovkov and of Diankov deal with the problems of river polders along the Danube in Bulgaria. Both analytical and numerical model techniques are used for drainage design.

In order to design the most economic and effective drainage system, the fluctuations of the river level and the seasonal precipitation excess must be taken into account.

Barends calculates with an analytical formula the response of a step function in the river level outside the polder, with steady state as a starting point. The leakage factor λ has become time dependent, increasing with time to the limit $\sqrt{KDc}$ after several years.

On the other side the total seepage into the polder increases with time until the maximum value at steady state is reached.

Wesseling's paper deals with an extensive study in the province North-Holland. As a result of the hydrological computations the contribution of various sources to the surface water quality could be calculated namely from the saline underground (deep) seepage, effluents of industry and households, artificial gas-wells, inlet water, agriculture and rain water and salt used in winter against ice on roads.

The paper of Kirkham falls somewhat beyond the subject of this report.

The writer has developed a potential theory for the shape of the cone of depression for the classical problem of an unconfined well centered in a circular island.

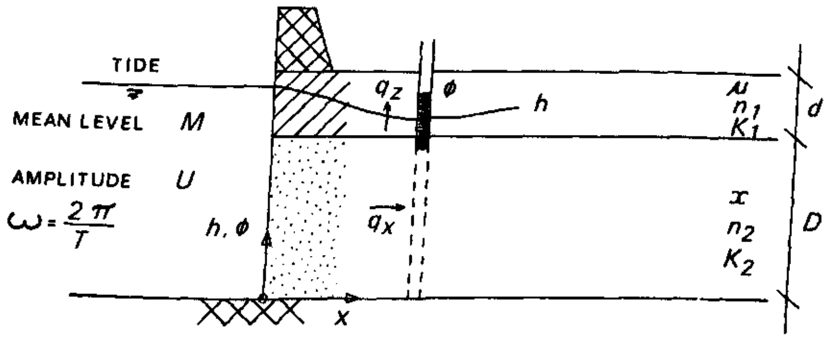
Introduction

Seepage problems in polder areas have been a major hydrological research item for many years, especially in the Netherlands. They stimulated the development of geohydrology of semi-confined aquifers. The hydrogeological scheme, consisting of a sandy aquifer above an "impervious" clay layer and covered by a "semi-pervious" claypeat complex (the aquitard) is often called the Dutch Polder Profile. Because of the refraction of the streamlines of the ground water flow at the boundary of the aquitard and the aquifer, for simplicity the flow is assumed to be vertical in the aquitard and horizontal in the aquifer. Further basic assumptions are:

- Darcy's law
- the law of conservation of mass
- a specific set of equations of state with respect to density and viscosity of the system as a function of pressure, temperature and chemical composition

In all the papers presented, temperature effects are neglected, the water is incompressible, the pressure only effects the soil and the permeability of the soil is time independent.

As an example let us examine the transmission of tidal waves in an extensive Dutch Profile. Case studies of this type were in the Netherlands already described by e.g. Steggewentz in 1933, Bosch in 1951 and Wesseling in 1959. Taking into account the compressibility of the aquifer, and using symbols as in next Figure, the following equations hold



- Darcy's law

$$q_x = -K_2\ \partial\phi/\partial x \qquad q_z = (\phi-h)/c$$

- Mass balance

$$D\ \mathrm{div}\ q_x + q_z = -D\partial n_2/\partial t = -S\partial\phi/\partial t - Z\partial L/\partial t$$

$$q_z = \mu\partial h/\partial t$$

with $c = d/K_1$ (hydraulic resistance), $S = \rho g D\alpha$ (storage coefficient), $Z = \rho g D n_1 \alpha$, α as compressibility coefficient of the soil matrix, μ the drainable pore space, n the porosity, K the hydraulic conductivity.

The flow equations become

$$(\phi-h)/c = \mu\partial h/\partial t, \quad KD\partial^2\phi/\partial x^2 = S\partial\phi/\partial t + (\mu-Z)\partial h/\partial t$$

with boundary conditions

$$x = 0 \qquad \phi = h = M + U \sin \omega t; \quad x = \infty \qquad \partial\phi/\partial t = 0$$

The formula for the piezometric head is

$$\phi = M + U \exp(-Px) \sin(\omega t - Qx)$$

$$P^2-Q^2 = \frac{\mu c(\mu-Z)\omega^2}{(1+\mu^2c^2\omega^2)KD} \quad , \quad 2PQ = \frac{\omega(\mu+S-Z+\mu^2c^2S\omega^2)}{(1+\mu^2c^2\omega^2)KD}$$

which illustrates that at distance x the piezometric head Φ shows a reduction of amplitude exp (-Px) and a phase shift Qx.

Discussion on the papers presented

The papers of Kochev & Yovkov and of Diankov deal with the problems of river polders along the Danube in Bulgaria. Both analytical and numerical model techniques are used for drainage design.
In order to design the most economic and effective drainage system, the fluctuations of the river level and the seasonal precipitation excess must be taken into account.
Kochev & Yovkov define a critical drain spacing such that the phreatic level mid between the drains is just at the level of the piezometric surface of the underlaying aquifer. Their drainage formula for steady flow takes into account the radial flow near the drains, a horizontal flow component and a vertical one due to the piezometric head in the underlaying aquifer. The piezometric head itself is calculated with a finite element model. Also subirrigation was studied.
Diankov's model has in addition a horizontal ground water inflow from the higher parts near the river polder. His results show very clearly the attenuation of the amplitude and the phase shift of the piezometric head mentioned earlier.

Barends extends the theory as illustrated in paragraph 1 with the compressibility and subsidence of the semi-pervious layer. Recall that under steady conditions the total seepage into an extensive Dutch Polder Profile is equal to

$$Q = (M-h_o)\sqrt{KD/c}$$

with M as the steady water level outside the polder and h_o the controlled polder level, whereas

$$\phi - h_o = (M - h_o) \exp(-x/\lambda), \quad \lambda = \sqrt{KDc}$$

Barends calculates with an analytical formula the response of a stepfunction in the river level outside the polder, with steady state as starting point. At the base of the covering semi-pervious layer, a formula for $(\phi - h_o)$ quite comparable to the above mentioned holds, only the leakage factor λ has become time dependent, increasing with time to the limit $\sqrt{KDc}$ after several years. On the other side the total seepage into the polder increases with time until the maximum value at steady state is reached. One may ask however whether in this case the assumption of time independency of the permeability of the semi-pervious layer holds. Consolidation of the claypeat layers may result after several years in a higher c value and a lower total seepage into the polder.

Wesseling's paper deals with an extensive study in the province North-Holland. The hydrogeological scheme consists of three leaky aquifers above each other, covered by the claypeat complex. The resistance of the separating silt layers was calibrated with the aid of water balance studies and piezometric data. As a result of the hydrological computations the contribution of various sources to the surface water quality could be calculated namely from the saline underground (deep) seepage, effluents of industry and households, artificial gas-wells, inlet water, agriculture and rainwater and salt used in winter against ice on roads. Main contributors for chloride are seepage (62%) and inlet water (21%), for nitrogen natural leaching plus fertilizers (35%) inlet water (23%) and seepage (18%) and for phosphorus: households (46%) natural leaching plus fertilizers (28%) and seepage (10%), stressing the important influence of seepage on water quality. It should be noted that leaching from soil and loss of fertilizers combined were obtained as closing entry of the balance and not by direct measurements.

The paper of Kirkham falls somewhat beyond the subject of this report. The writer has developed a potential theory for the shape of the cone of depression for the classical problem of an unconfined well centered in a circular island. At the well face, where ground water leaves the aquifer, a seepage surface exists, nevertheless the formula of Dupuit for the well discharge is correct which can be easily seen by considering the function

$$\Phi = \int_0^{h_r} \phi(r,z)\,dz - \tfrac{1}{2}h_r^2$$

with h_r as phreatic level, $\phi(r,h_r) = h_r$,
giving

$$\frac{d\Phi}{dr} = \int_0^{h_r} \frac{\partial\phi}{\partial r}\,dz = \frac{-Q_w}{2\pi K r}$$

with boundary conditions filled out and integrated

$$\Phi_r = \tfrac{1}{2}h_R^2 + (Q_w/2\pi K)\ln R/r$$

$$Q_w = -\pi K \frac{h_R^2 - h_w^2}{\ln(R/r_w)}$$

Kirkham compares his results with laboratory model data of Hall (La Houille Blanche, 1955)

References

Kochev, K & Yovkov, B. Some methods for selecting and designing of a proper drainage system in a river polder

Diankov, Z.I. Groundwater flow dynamics in Bulgarian riverside polders - a numerical model investigation

Barends, F.B.J. Seepage induced surface leakage in and around polders

Wesseling, J. Hydrological conditions and their influence on surface water quality in the Dutch polder region

Kirkham, D. Free surface potential theory for a gravity well

THEME B

SUB-THEME B1: LAND AND WATER MANAGEMENT ASPECTS

General reports by:
Prof.dr. J.J.A. Feyen
Dr. M.J. Hall
Drs. E. Romijn
Dr.ir. J. Wesseling

Conclusions by Prof.Em. D. Kirkham,
chairman.

The two sessions in this sub-theme dealt with watermanagement systems and design criteria respectively water quality, geohydrology and soils.

The reporters reviewed 37 papers, submitted by authors from 15 countries: Australia, Bulgaria, Egypt, England, Indonesia, Iraq, Japan, Malaysia, the Netherlands, the People's Republic of China, the Philippines, Portugal, Surinam, the United States and Venezuela and from F.A.O.

The subjects of the papers included a wide range.
Some of the studies were:
- the design of polder drainage systems;
- rice and banana cultivation;
- sources of water pollution in the province of North Holland;
- compression and subsidence of the semi-pervious layer;
- development of potential theory for the shape of the cone of depression for an unconfined well with the theory applicable to upward seeping water;
- the relationship of soil water salinity to the environmental factors of land reclamation;
- the effect of different salts on the hydraulic conductivity of soils;
- water quality management of a desalted reservoir where wind influences salt diffusion;
- a study recommending drainage methods that fit with traditional farming systems and ecological equilibrium;

- modelling studies done in England, the Netherlands and Venezuela;
- drainage and irrigation problems of certain regions, such as: the fenlands of England; the Murray River of South Australia; reclaimed desert areas west of the Nile valley in Egypt; polders along the Danube River in Bulgaria; the Lezire Grande polder of Portugal; reclaimed land along the Eastern part of Tokyo Bay; soil ripening in the IJsselmeerpolders; growth of beach land and reclamation at Pearl River Estuary in China; reclaiming against Qiantang Bore, also in China.

Methods of research described in the papers varied from classical agrohydrological experiments, through systems analysis and modelling. Sometimes there was a combination of both methods.

The major conclusions that can be drawn from the papers and discussions are:

1. Water management of polder areas is a multidisciplinary activity, involving elements of civil engineering, hydrology, agriculture and economics.
2. Knowledge and techniques on water management should be transferred internationally.
3. Microcomputers are now becoming of low enough cost, so that they may, in some cases, be used instead of pocket computers.
4. To aid in polder design, physical models of water management should be constructed and solved, with real data supplied, as far as possible, for input.
5. Those people involved in systems analysis used in polder design and those people involved in gathering physical data should learn each other's language and objectives, as an essential aid to their effective cooperation.
6. Often financial resources to do enough research are lacking. Therefore it is of utmost importance to bring together any available information. To do this requires cooperative sharing of data collected by all departments of a government.
7. In many cases irrigation causes underground seepage of saline water toward other regions. Therefore in polder and water management design one should not restrict himself to the project inself, but also consider the neighbourhood.

8. Polder technology as practiced in semi-humid climates must be strongly modified for the tropics, because of torrential rainstorms.
9. Concerning modelling, this design method may be used in data-scarce situations, provided that it is used with a sensitivity analysis. Results of sensitivity analysis can assist in designing future data collection programs. Results also can show deficiencies of existing models and point out directions for future research.
10. Water quality is a major item to be dealt with in water management. Salinity from ocean seepage or from excess evaporation of water from the soil can be a major source of pollution. Sediment in water is also pollution.

    An interesting table was presented in a study of water quality of the polder area of the province of North Holland. This table shows the amounts of chlorine, nitrogen and phosphorus from the following sources: inlet water, households, industries, gas-wells, rainfall, traffic, seepage, natural leaching and fertilizers, and leakage through dikes.

THEME B 2: CONSTRUCTION ASPECTS

SUB-THEME: DIKES AND EMBANKMENTS

J. van Duivendijk

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Abstract

There are many thousand kilometres of dikes surrounding polders all over the world. Very high overall costs are involved in investment and maintenance. It is encouraging to see that the scientific base for dike design, construction and maintenance is broadening because in the long run this will result in savings to the people living in these polders while also their safety will increase.

Fourteen*) papers were submitted on this sub-theme. Subjects treated in the papers concerned design as well as construction and maintenance. Major features highlighted by the papers are:

- a better scientific approach of problems in the hydro-geological and geo-technical field than practiced in the past;
- a growing understanding of the need for regular inspection and maintenance of dikes using modern geo-technical equipment;
- introduction of scientific design of revetments in sea defences.

*) As four papers are dealt with by Mr.Hammond the overall total for Theme B is 20.

1 Introduction

The outsider looking at the sometimes somewhat shapeless ridges of earth surrounding a new polder or at the tree lined friendly looking low embankments covered by grass and wild flowers which are typical for old polders will not see these "structures" as dikes performing a necessary function. Most probably this outsider would laugh if you told him that there is much engineering involved in designing, aligning, building and maintaining these dikes. Nevertheless, the engineering of dikes is the subject of this report and, looking at the many interesting reports submitted, one can say that many engineers with dedication are daily devoting their time and skill to the matter.

Why do people build dikes around their polders? A general answer is easy to give: to keep the water out.But as usual a general answer is never completely correct. It would appear that there are four reasons why people build dikes around polders:

1) To prevent flooding of the reclaimed land due to:
   - high astronomical tides in estuaries and along the coast;
   - wind set-up caused by storm surges;
   - high river discharges caused by rainfall on the catchment.
2) To prevent saline water intrusion along estuarine and sea/oceanic coasts.
3) To limit seepage from outside to inside of a polder.
4) To prevent a further regression of the coastline or meandering of the riverbank.

In short: a dike is a protective device against the forces of nature, the latter being demonstrated in the behaviour and consequences of the tides, the rainfall and the wind.

2 Design requirements and subjects to be studied

The authorities anxious to have such an embankment built, generally have three requirements in mind:

a) the above mentioned reasons 1) to 4) inclusive must be borne in mind and the design developed accordingly;

b) the design must be "economical", i.e. as much as possible use must be made of locally available materials while the design criteria must be met without "over-designing" the embankment profile.
Moreover, an economic evaluation must be made of investment and maintenance costs for alternative designs in order to select the least cost solution;

c) a general human feeling of safety must be established through design and safety margin (freeboard, safety factor) and, subsequently maintained through regular inspection and maintenance.

Bearing these three basic design requirements in mind a process of design, construction, management, operation and maintenance of polder dikes can start. In order to do this a number of different subjects asks our attention. We will list seven here (Table 1) but the number can easily be extended by listing less relevant ones or by sub-dividing the original seven subjects. Most of the subjects have a bearing on the various stages of an embankment project (design, etc., up to maintenance).
How important all these subjects and aspects are in relation to each other is not known as their relative importance varies from project to project and as it are in fact the local circumstances which determine for each project the major issues to be looked into. However, one thing must be very clear: though the subjects are listed as separate items the design process requires the integration of all subjects and aspects. This means that during the design process continuous adaptation of parts of the design is necessary in order to arrive at an optimum solution without "conflicting" parts. As such this process of iteration is a typical engineering method which is not always found in or appreciated by other disciplines involved in polderization.

Table 1: Seven subjects to be studied in the course of design and implementation of an embankment project

Subject	Aspects involved
1 Coastal and river hydraulics, hydrology and morphology.	- waves - frequency of high water levels - erosion/sedimentation - wind set-up - local rainfall
2 Hydro-geological and soil-mechanical characteristics of sub-soil and embankment materials.	- seepage underneath and through dyke body - stability - embankment profile to be selected - construction method
3 Availability of construction materials for:	- dambody - revetment - toeprotection - closure works
4 Structural design of revetment.	- wave impact - perviousness - flexibility versus differential settlements of dambody - construction in tidal zone
5 Environmental issues.	- road-rail connections - erosion of foreshore, meandering - urban and rural settlements - ecology - landscaping
6 Construction methods.	- closure works (if any) - manual labour versus equipment - dry/wet construction
7 Management structure, operation and maintenance.	- inspection procedures - data collection and processing - flood warning system - maintenance

In the following sections we will deal with each of the seven subjects mentioned and see how they are treated in the papers presented for this sub-theme.

3 Papers submitted

On the subject of dikes a total of 14 papers was submitted. For convenience sake four papers (nos 94, 96, 142 and 329) are dealt with in Mr.Hammonds Report. These four papers will therefore only ask for some global remarks from our side. All fourteen papers are listed in Table 2.

Table 2: Papers submitted on design and construction of polder dikes

Ref. no	Authors and their country of origin	Title of paper	Country where project(s) situated
88	Sadami Kuwano (Japan)	Effective protection of polder dike.	Japan
94*	L.S.A.van Elzen and H.L.Jansen (Netherlands)	Possibilities of dike enlargements increased by Colbond vertical drainage system.	Netherlands
96*	G.J.Flórián and H.J.Vinkers (Netherlands)	Calculation of hydraulic head for river embankment design using a numerical groundwater method.	Netherlands
142*	J.van Duivendijk and J.R.Pieters (Netherlands)	Design and construction of the sea defences of Guyana.	Guyana
144	J.J.L.M.Enneking and M.M.Vierhout (Netherlands)	Design and construction of flood control dikes around 43000 HA of irrigation areas in the Rharb Plain, Morocco.	Morocco
151	G.W. Beetstra and P.V.F.S.Krajíček (Netherlands)	Reliability of Dutch Polderdikes.	Netherlands
152	W.Broeders, J.Huis in 't Veld, J.Stuip (Netherlands)	Strategics and methods for closing dyke breaches.	Netherlands

Table 2 (continued)

Ref. no	Authors and their country of origin	Title of paper	Country where project(s) situated
161a	F.Smith (Netherlands	Management of catchwater embankments in "De Oude Veenen" drainage district.	Netherlands
187	R.Dresnack, E.B.Golub, J.R.Pfafflin (U.S.A.)	Statistical risk assessment of polder protection structures.	U.S.A.
209	G.P.Bourgùignon (Netherlands)	Reclamation in deltaic regions.	Various
287	Dr.Béla Hajós (Hungary)	Use of hydromechanization for hydraulic earthworks in Hungary.	Hungary
296	A.M.van Nispen tot Pannerden (Netherlands)	The Zuiderzee project; construction of dikes.	Netherlands
329*	D.L.Gudgeon and M.E.Hannah (United Kingdom)	The raising of the defences of Convey island to resist a one in 1000 year tidal surge.	United Kingdom
501	B.Wesseling (Netherlands) and Ir.Madsalim (Indonesia)	Labour-intensive polder construction in Indonesia	Indonesia

*) These reports are dealt with by Mr.Hammond in his Report.

4 Contents of papers in relation to subjects to be studied

In Table 1 (Section 2) seven subjects were given which normally require our attention when designing and constructing a dike. In the following sub-sections we will review what the authors of the papers have said about each of these subjects.

4.1 Coastal and river hydraulics, hydrology, morphology

Though this subject is as important for dike design as the other six, only a few authors refer to it. This is understandable as both coastal and river hydraulics as well as hydrology and morphology are the subject of periodic congresses, conferences and seminars which are held all over the world and during which all aspects mentioned under this subject are discussed in detail.

This is probably the reason why the authors of papers 142, 144, 296 and 329 only briefly touch this subject. One may say that the outcome of hydraulic and hydrological calculations and considerations are considered by the dike designers (mainly civil engineers) as a boundary limit, a condition imposed by others.

The authors of paper 187 are in fact the only ones who discuss in detail one of the aspects related to this subject i.e. the fitting of data (water levels) to the proper statistical distribution. They state that it is possible to super impose an extreme value distribution of storm surges over a normal distribution of astronomically generated tides.

Because of the interrelationship of crest elevation of dikes, (determined in first instance by hydraulic/hydrological considerations) construction cost and maintenance requirements it is recommended to discuss this aspect during the afternoon session on October 4th. Then also related political, social and safety implications can be discussed.

4.2 Hydro-geological and soil mechanical characteristics of subsoil and embankment materials

Not less than eight papers (88, 94, 96, 142, 144, 209, 296, 329) discuss one or more aspects of this subject. Papers 94, 96, 142 and 329 are reviewed in Mr.Hammonds Report to which reference is made.

The other papers are now briefly summarized.

Paper 88 presents an interesting case of measures carried out in Japan for decreasing the seepage through a dike built up of rather coarse material. By driving 19.0 m long steel sheetpiles into the centre line of the dike over a length of approx. 600 metres the daily seepage of 10 000 m^3 decreased to 200 m^3.

It would be interesting to know the cost of these remedial works in relation to the original construction cost of the polder dike and what extra initial construction cost would have been needed to prevent the leakage all together.

The Reporter is happy to note that the authors were willing to present in detail a case of something which went wrong. We, engineers normally learn most of mistakes either made by ourselves or by others and any discussion on such mistakes and subsequent remedial measures taken is very welcome.

Paper 144 describes in some detail the development of the cross-section of dikes in the Rharb plain in Morocco on the basis of two kinds of available material. It is interesting to hear about the special problems posed by the use of montmorillonitic clay and what experiments were carried out in this respect before a decision was made about the cross-section to be adopted.

In Paper 209 it is pointed out that settlement of the soft subsoil underlying a dike body may have serious consequences and what measures can be considered to reduce this settlement as much as possible.

Paper 296 provides an overall picture of the design and construction of the dikes of the Zuiderzee (now called IJsellake) including the dikes around the polder in which the "Polders of the World" seminar is held. These dikes were built over a period of 50 years and their total length amounts to several hundreds of kilometres while their height in places exceeds 15 metres which in turn signifies them as "large dams" *). For the construction of the polder dikes soft layers in the

*) According to the definition of ICOLD.

sub-soil were removed first and replaced by sand to avoid stability and settlement problems.
For many centuries the design and construction of polder dikes has been based mainly on emperical data. It is encouraging to note that more recently the establishment of a sound geo-technical base of investigations, tests and calculations is becoming a general feature of dike design and construction.

4.3 Availability of construction materials

In fact only a few authors (papers 88, 142, 144, 287, 296) indicate that the availability of a certain construction material in the neighbourhood of the dike's alignment has been a factor of importance in the establishment of the dike design. It can nevertheless be confirmed that in daily practice the designer first looks around to see what is available and then ensures that his design and construction are matched to the properties of these available construction materials. This practice is followd also for large earth- and rockfill dams and it would appear to be a must for economical engineering. It is however pointed out that use of large dredging equipment may sometimes allow to divert from this principle (Paper 296) while such diversion may also be comtemplated for other reasons (recreational constraints, only limited loading of subsoil possible, etc.).

4.4 Structural design of revetment

Generally speaking a revetment is only required when the seaward/ riverward/lake side slope is subjected to continuous wave action. This is certainly not the case for many dikes built for non-frequent high waters or along rivers. Consequently, only typical sea defences (Papers 88, 142, 209, 329) and the dikes bordering large lakes like the IJsellake (Paper 296) require revetments. Also here for many centuries and until 30 years ago the revetments consisted of open type revetments: open filters, stone pitching, rip rap while also concrete

was used with differing results. Thickness of layers and size/weight of individual units was purely a matter of experience and of availability of materials (Papers 142, 209, 296, 329).
Nowadays, an effort is made to really design the revetment with the aid of wave formules and model tests while at the same time bitumen is introduced (Paper 88, 142).

In general, modern revetment design is considered to be a part of coastal engineering and it is therefore understood that only limited attention is given to this subject in the papers presented by the authors.

4.5 Environmental issues

Only two papers (144, 329) indicate that the environment may play a role in design or re-design of the polder dyke. Most probably there is more on this subject in the papers submitted under Theme B-5 ("Environmental aspects").

4.6 Construction methods

4.6.1 Closure works

wnen a polder is constructed in an area of tidal currents (a swamp on the coast, an island in a river delta or a sandbank in an estuarium) it might be necessary to employ elaborate methods for closing the last tidal channel by means of a dike. Such a closure will also be necessary when the dikes of low-lying polders are breached during storm surges and so-called flow gaps develop (Paper 152).
In The Netherlands and also elsewhere (Bangladesh) various more or less elaborate methods have been developed through the centuries to close tidal channels of various sizes.
Papers 152 and 209 summarize these methods. As, again, this subject is considered by the Reporter as belonging to the field of coastal engineering he will not treat this subject in further detail. Provided

the dikes of a polder are safe (no overtopping, no collapse) closure works will only ask for attention during initial construction and not again during its lifetime of many centuries.

4.6.2 *Equipment and labour*

The authors of Paper 501 give an interesting review of labour-intensive construction of polder works in Indonesia. They conclude that although manual execution was slightly more expensive than mechanical execution the quality of the manually constructed embankments was considerably better than that of the embankments constructed by heavy equipment. The additional cost was also justified by increased employment opportunities.
The other papers touching the subject of construction methods (144, 287, 296) invariably refer to the use of equipment for construction of earthworks.

Papers 287 and 296 both refer to the placing of fill by hydraulic means. Paper 296 was already briefly reviewed in Section 4.2 to which reference is made. Paper 287 describes the placing of fill borrowed from the river bed in flood control embankments along the rivers in Hungary. The author states that not less than 4200 kilometres of dikes are involved. He describes in detail the planning of actual fill placing and the advantages and disadvantages of various methods.
It would be interesting to hear from the authors of both Papers 287 and 296 more specific information on weekly production rates, pipe diametres used, grain size of material, capacity and type of dredgers used, transport distances, etc.

4.7 Management structure, operation and maintenance

Designers, in general, have a tendency not to worry too much about maintenance. Firstly, the cost of maintenance does not count much in economic

evaluations (because of the conventional discounting method used and the application of high interest rates) and, secondly, most designers do not see what they can contribute towards this subject anyhow.
A third reason is that only during the last 30 years adequate means (instrumentation, geo-technical equipment) have been developed to actually inspect embankments other than possible by means of visual observations.
The Reporter would like to ask more attention for the relationship initial design/maintenance and on the need for good regular inspections. A good design and costly initial construction may save on future maintenance costs while a cheap design and bad construction may result in very high maintenace costs. The whole matter would be easy if dike behaviour could be predicted. Practice is however that dikes because of their length are subjected to a statistical process of deterioration caused by loading, quality of construction, damage by man and animal, properties of construction materials and subsoil condition; each of these reaching values which are a function of time and place.
Only regular and thorough inspections may bring to light what is wrong and when (Paper 151) and where action is urgently needed (Paper 161a).

The Reporter assumes that many thousands kilometres of polder dikes are in operation all over the world. He knows that for instance large dams in some countries are already inspected regularly to prevent serious accidents. It would be interesting to hear during the seminar what is being done outside The Netherlands on the regular inspection of polder dikes.

SUB-THEME: MISCELLANEOUS CONSTRUCTION ASPECTS

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Abstract

Report on papers dealing with miscellaneous construction aspects of Polders of the World. This group of 10 papers deals with geotechnical, hydrogeological aspects of polder development together with papers on the control and testing of polder pumping equipment. The papers range widely from schemes dealing with the protection of polders from sea attack to the possibilities of the use of underground storage of water in suitable geological formations for irrigation. The engineering approach in all these papers is innovative and interesting to those engaged in construction.

List of papers

Theme B2: Construction Aspects

	Authors	Title	Location
142	J. van Duivendijk & J.R. Pieters (Netherlands)	Design and Construction of Sea Defences	Guyana
329	D.L. Gudgeon & M.E. Hannah (UK)	Raising of the Defences of Canvey Island	UK
39	L. van't Leven (Suriname)	Construction of Polders	Suriname

11	M.A. Viergever (Netherlands)	Foundation on Soft Marine Deposits in a Recently Reclaimed Polder	Netherlands
94	L.W.A. van den Elzen & H.L. Jansen (Netherlands)	Possibilities of Dike Enlargements increased by use of the Colbond Vertical Drainage System	Netherlands
96	G.J. Flórián & H.J. Vinkers (Netherlands)	Calculation of Hydraulic Head for a River Embankment Design using a Numerical Groundwater Model	Netherlands
503	Peter H. Reiter (Finland)	Test Runs and Acceptance Tests of Polder Pumping Stations	Finland
132	D. Dejas, A. Reinhard & W. Trzeciak (Poland)	Control of Pumping Aggregates and Measurement of Discharge in Polder Pumping Stations	Poland
23	Arata Masumoto (Japan)	Possibility of Using Underground Dams to Irrigate Polders in Tropical Areas	S.E. Asia
108	Antonino Vázquez Guzmán (Spain)	Construction Aspects in the Polders of the Left Bank at the Low Quadalquivir Marshes	Spain

In the group of papers on construction aspects of polders, two relate to the protection of land from the sea in the difficult foundation conditions found in estuaries; four papers relate to the drainage and consolidation of embankments and their stability problems; two papers deal with the provision of pumping plant and its control; one paper gives an interesting insight to the possibilities of underground storage of water necessary for polder irrigation and the last paper deals with the construction of a polder development in South Western Spain.

The first paper on the design and construction of the sea defences at Guyana by van Duivendijk and Pieters deals with the design methods adopted for constructing sea defences in an exposed coastal area of Guyana where erosion of protective mud banks is subjecting the coastline to heavy wave attack and higher wave run-up. The author sets out the inter-dependence of the parameters causing erosion and the reasons which led to the selection of a new sea defence line inshore of the original embankments. This new alignment gave the engineers an opportunity of designing a sea defence system which would stand up for a minimum of 100 years without major repair. The paper details wave observations, the design of slopes for wave run-up, surge etc. and the model testing which was carried out, gives an explanation of the possible reasons for the previous failures and the steps proposed to ensure the security of the new defences on the exposed Guyanian coast.

The problems in Guyana are repeated on the Thames estuary where a paper by Gudgeon and Hannah sets out the methods adopted to protect the Canvey Island area of the north eastern Thames estuary against the continuing ground settlement and increase in tidal levels in this corner of the UK together with the increasing frequency and height of surge tides in the North Sea. The very weak clays underlying the embankments in both Guyana and Canvey Island pose the greatest problems to the engineer. It is interesting to see how these problems have been solved. In the case of Guyana, the use of sheet piling driven at the toe of the embankment has been discontinued, whereas at Canvey Island the piling is used to create a new raised core on the centreline of the embankment. This core is cantilevered to act as a toe to the raised downstream embankment.

In Guyana an embankment profile is used with a substantial berm located at low water and then relatively steep excavation at the face of the berm provides the fill for the embankment. At Canvey Island an alternative arrangement using pulverised fuel ash from local power stations was considered for the upstream segment of the raised embankment, backed by sandfill, both protected by suitable drainage layers. The methods at Canvey are more elaborate than those at Guyana and this no doubt is justified by the need to protect a relatively large population living on the island and the associated major industrial base. The Guyana protection is tailored in some respects to the value of the polders protected and of the likely consequences of failure. Judgment of the value of protection works is difficult and in the end must be subjective.

The next group of papers relate to the problems of poor foundations, drainage and consolidation met with during construction.
The paper "Construction of polders in Suriname" by van't Leven gives an interesting description of the conditions found during polder construction in the inland coastal region of Suriname. It describes the methods adopted to enable drainage canals to be excavated in riverine jungle where the bearing capacity of the soil is so low and the forest so dense that normal construction equipment cannot be brought into use initially. The step by step approach sets out the methods used, first to provide access and then to dewater the zone to be excavated, and the final consolidation of embankments. The load bearing capacity of the soil and presence of non-cohesive layers in the excavation itself coupled with a high external groundwater table make the problem of the stability of channel sides a major one. The gradual approach on excavation adopted and the method developed to work with nature paid off so that the cost of new construction was kept to a minimum and the project properly programmed to completion.
The paper by Viergever entitled "Foundations on soft marine deposits in a recently reclaimed polder" deals with similar settlement and stability problems encountered on work in Holland. The author sets out the methods adopted to adapt the fixed structures, such as bridges, pipelines, buildings, etc. to the high settlements encountered in newly reclaimed land. He deals with the problem of taking pipelines or sewers into relatively stable areas from a zone in which movement is continuing. Some examples of methods developed for overcoming differential settlement are set out as are the investigations necessary to give the engineer an indication of the deformations to be expected and the likely magnitude of settlement and subsidence.
The paper by van den Elzen and Jansen covers a specific method of enabling existing embankments to be raised where they have settled or new embankments constructed on poor foundations by utilizing drainage methods which reduce foundation pore pressures by the introduction of a

proprietary "Colbond" vertical drainage system. Vertical holes are first augered, reamed or driven into the foundation to a fixed depth and the drainage membrane consisting of an outer filter jacket and an inner central core which allows the free release of water is then slipped into the hole. The vertical holes are interconnected by a horizontal drainage layer before the surcharge of the embankment is placed. The consolidation occurring from the pore pressure reductions due to drainage can be calculated by the Terzaghi formulae and the eventual stability of any embankment raising carried out on the drained foundations can be established. The "Colbond" system is formed from polyester fibres for both the coarse inner layer and the external porous filter. This type of proprietary vertical drain is used in place of the more conventional sand drain and is a commercial application of this well known technique.

The paper by Florian and Vinkers deals with the calculation of the hydraulic head acting under an embankment, the foundation of which is connected by a pervious layer to the higher head in an adjacent river. The method used adapts a numerical groundwater model to determine head loss. In the case studied, a permeable coarse sand and gravel layer is intersected by a river but continues as a confined aquifer underneath adjacent continuous surface clay deposits. The head in the river thus exerts uplift pressures on the clay on which construction of embankments was to take place. The slip circle analysis of the stability of these embankments had to take into account the uplift pressures occurring beneath them. These uplift pressures were reduced by the head loss occurring in the pervious strata interconnected with the river. The two dimensional groundwater flow model has been developed so that the figures obtained from the model can be utilized in the conventional stability analysis of the embankment. An interesting contour projection has been made showing the calculated hydraulic heads to be expected from the pervious layer and the zones in which these heads could prove critical.

Of the papers dealing with pumping plant at polder pumping stations, the first by Reiter details the methods used to measure the discharges from polder pumps and the problems to be overcome in the method of measurement of large quantities pumped at relatively low heads. Reiter details the information required and the range of accuracies which can be expected and which must be taken into account in assessing the ability of the pump to meet contract guarantees. The author sets out a number of suggestions for suitable measurement equipment and points out the additional requirements to test to ensure that cavitation is not taking place and that the power input meets specified limits.

The paper on the control of pumping aggregates and the measurements of discharge in polder pumping stations by Dejas, Reinhard and Trzeciak describes a method of measurement developed in Poland to achieve the automatic control of the quantity pumped by utilizing a system of electrodes in the pumping well linked with measurement of the pump flows from venturi system. The automatic control system has been working for two years in three pumping stations with satisfactory results. The method outlined in the paper is simple and appears relatively robust and can be adapted to meet the requirements of a number of differing inputs and outputs required from a polder pumping station.

The paper by Masumoto deals with the possibility of constructing underground dams in pervious formations to provide storage of irrigation water for polders in tropical areas. The paper gives some details of the experience obtained on the construction of underground storage in the permeable area underlying Myako Island on Okinawa and suggests that this method of operation could be adopted in other parts of the world. The author suggests that the large limestone or permeable volcanic zones underlying irrigation areas in Indonesia offer such possibilities. If potable water can be held in these permeable areas rather than allowing free discharge to the sea, the reservoir created can reduce the need to take water for irrigation from slightly saline estuaries and so improve rice yield. The methods used at Myako are set out in some detail including the methods used to restrain groundwater outflow to the sea by the construction of grouted membranes in the permeable layer. The author suggests the provision of an underground spillway to restrict the retention of water in the aquifer to an acceptable level. The author sets out the means by which underground water supplies can be conserved and augmented in areas of high intensity rainfall and long droughts. He suggests that this approach could prove useful in a number of tropical areas, particularly on islands where pervious zones such as coral are present. Similar work to that described at Myako has also been successfully carried out in the south of France in cavernous limestone areas adjacent to the sea. The provision of storage by the construction of underground dams is interesting and unusual and the extension of this method to the corals and volcanic ashes in tropical countries deserves further attention.

The paper by Guzman on the construction aspects of polders on the left bank at the Low Quadalquivir Marshes in Seville gives a very brief description of the methods used in construction of the polders and the irrigation system installed. The paper outlines the drainage methods adopted to control salinity and gives some details of the access arrangements to the polder zones. The paper as submitted is in general terms and it is hoped that the author will be able to expand his written paper at discussion and thus give more information at the Symposium.

Conclusion

The ten papers reviewed in this section on the construction of polders are varied and interesting and it is hoped that they will stimulate discussion.

THEME B

SUB-THEME B2: CONSTRUCTION ASPECTS

General reports by:
Ir. J. van Duivendijk
Mr. T.G. Hammond

Conclusions by Dr.ir. H.S. Adhin,
chairman

Twenty-one papers were submitted on "Construction aspects". Most of these papers (15) dealt with one or more aspects of dikes and embankments. Others concerned design and construction issues related to the water-management systems of a polder, such as pumping stations and drainage canals, or with the particular problems posed by the founding of structures on recently reclaimed marine deposits.

From the discussions held during two afternoon sessions the following conclusions can be drawn:

1. A more detailed and more scientific approach is nowadays being used in the design and for solving construction problems in the fields of hydrogeology and geotechnics.
2. There is a need for better integration of all factors involved in the determination of the crest elevation of an embankment. These factors form part of disciplines as hydrology, hydraulics and civil engineering, but also factors like envisaged operation and maintenance procedures should be integrated into the design.
3. Though local circumstances will to a large extent determine the design of earthworks and structures, a number of generally applicable principles and criteria cannot be disregarded when designing and constructing polders.
4. It was apparent from the reports that a wide range of return periods is being used for determining the crest elevation of dykes. In fact, design water levels are selected in such a manner that, in some cases, exceedance can take place once in 20 years and in other cases only once in 10,000 years. For the selection of a crest elevation the relationship between economics on the one hand and psychologically acceptable safety margins on the other hand clearly needs to be considered in further detail.

THEME B 3: AGRICULTURAL ASPECTS

AGRICULTURAL ASPECTS

J.W. van Hoorn
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Abstract

Polders possess some characteristics that make them different from other agricultural areas: soils of high fertility that are drained systematically and often better than elsewhere, plot dimensions designed to obtain low costs, and selected farmers. The combination of these characteristics may well lead to higher yields.

Introduction

The major aim of reclaiming polders is agriculture and, indeed, farming is the main activity in polders in The Netherlands and in other countries of the world. Hoeve's paper on the significance of agriculture in the Dutch IJsselmeer polders shows the changes in land use in four polders reclaimed in succession over a period of forty years. Even in the most recently reclaimed polder, more than 50 per cent of the land is used for agriculture, the rest being reserved for urbanization, forestry and recreation.

Only relatively few papers have been presented on agricultural aspects of polders, warranting the assumption either that the number of papers is inversely proportional to the importance of the topic or that agriculture in polders is not particularly different from agriculture elsewhere.

Indeed none of the papers reveal any systematic difference between polders and other areas, in crops, soil tillage, sowing, crop protection, and harvesting. As elsewhere, parts of polders can be used for forestry. In the early IJsselmeer polders, forestry was limited to soils unsuitable for agriculture, but in the later polders forestry covers a larger area because planners are devoting more attention to recreational needs.

Nevertheless the papers presented at this symposium show that there are some significant agricultural differences due to the intrinsic nature of polders.

Soils

Soils in polders are alluvial in origin, either marine or fluvial, so their topography is flat. Since the watertable is already shallow under natural conditions, artificial drainage is always necessary. With the systematic application of field drainage, watertable control in polders is usually better than elsewhere. The drainage systems are either surface or subsurface systems.

Surface drainage is generally applied in tropical regions, e.g. in Surinam and Indonesia. There are several reasons for this: high rainfall intensity, low permeability of clay soils, or no need for a deep watertable in areas where rice is grown. The paper of da Costa, 'Agricultural aspects of banana cultivation in polders in Surinam', underlines the need for drain maintenance, notwithstanding its high cost, since epxerience has shown that a deterioration of the drainage system results in a rapid decline in production. In Westerhout's paper, 'Agricultural development of tidal lands in Indonesia', water management is considered the key factor for successful development. Acid sulphate soils pose a special problem. They require a careful, gradual lowering of the watertable to control the acidification and the removal of acids.

Traditionally, surface drainage was also applied in Dutch polders. Gradually, on arable land, it was replaced by subsurface drainage, whereas on grassland it continued to be applied for a longer time. The rapid development of high-intensity dairy farming in the past thirty years required improved water management to increase the bearing capacity of grassland and to minimize the damage caused by poaching. This explains the tendency of lowering the water level in the ditches and of replacing surface drainage by subsurface drainage. In the IJsselmeer polders subsurface drainage is applied everywhere, on grassland as well as on arable land.

Polder soils are normally fertile soils. Where peat soils occur, oxidation of organic matter releases a considerable amount of nitrogen for the crops but is also the main cause of subsidence. As pointed out by van Wallenburg and Westerveld in their paper 'Peat polders in the western part of The Netherlands', maintenance of the ditches by dredging and deposition of the mud mixed with manure gradually changed the composition of the top soil by increasing the mineral components, sand and clay, and in this way led to a change in land use suitability.

Crops

The choice of the crops in polders depends on watertable control. In shallow watertable areas, grass is the main crop in a temperate humid climate and rice in a tropical humid climate owing to their shallow root systems. Arable crops and tree crops require a deep watertable. The paper presented by van Goor, Groenhuis, and Jacobs: 'Forestry and forestry research' shows the importance of the poplar as a pioneer species in the IJsselmeer polders.

Plot dimensions

Newly reclaimed land offers the opportunity of choosing optimum plot dimensions.
As pointed out by Moens in his paper 'Agricultural mechanization and plot dimensions in polder development projects', plot dimensions have an impact on yield levels, on the cost of constructing and maintaining road and drainage systems, and on the cost of agricultural production. The problem in planning consists in deciding on plot dimensions that offer the best solution for the immediate future but do not impede long-term developments in farm size and mechanization. Van Dijk, Erdman, and Idoe, in their paper 'Mechanized rice production in Surinam', show the effect of large mechanized estates on the mechanization level of small farms.

Farmers

In the selection of farmers for the IJsselmeer polders, technical skills, financial means, and personal qualities such as leadership are taken into account.

Westerhout's paper on 'Agricultural development of tidal lands in Indonesia' mentions spontaneous and transmigrant settlers, but no selection criteria are applied. The aim of this development is to provide landless rural people and poor farmers with a piece of land. One may, however, assume that only the most active among landless people and poor farmers are willing to transmigrate and thus form the majority of the new farmers. This means that here, too, the farmers in the polder are a selected group.

Yield level

Young polders often show a higher yield level than elsewhere. For example, the yields in Eastern Flevoland, one of the IJsselmeer polders, are 20 to 50 per cent higher than the average for The Netherlands, winter wheat showing the smallest difference and potatoes the largest. Van der Zaag, comparing Eastern Flevoland with older polders in The Netherlands in his paper 'Yield and quality of potatoes produced in the new polders in The Netherlands', points out that not only is the yield better but also the quality. He ascribes the difference to a better water supply, which, in turn, leads to greater root activity and deeper rooting of the crops.

On the other hand, shortcomings in the water management may cause serious drawbacks in further developing agriculture in polders.
Van Boheemen et al., in their paper 'Effects of fresh water supply of Schouwen Duiveland, The Netherlands' discuss a model that allows the need for fresh-water supply in a polder to be determined. They provide data of the effect that supplying fresh surface water to a polder may have on the agricultural production. An important item of this type of forecasting is the possibility for the farmers to change their cropping patterns by including in them crops with high market values. When fresh water is available, even under humid climatic conditions, farmers can thus raise their income.

References

Boheemen, P.J.M. van, P.J. Kusse, C. Maas and J.W. Wesseling. Effects of fresh water supply of Schouwen Duiveland, The Netherlands.

Da Costa, I.Chs. Agricultural aspects of banana cultivation in polders Suriname.

Dijk, A.D. van, J.W. Erdman and M.J. Idoe. Mechanized rice production in Suriname.

Goor, C.P. van, B. Groenhuis and L. Jacobs. Forestry and forestry research.

Hoeve, H. The significance of agriculture in the Dutch IJsselmeer-polders.

Hoeve, H. Criteria for the determination of the moment of suitability for private agricultural land use of clay and loamy clay soils in the Dutch IJsselmeerpolders.

Moens, A. Agricultural mechanization and plot dimensions in polder development projects.

Wallenburg, C. van and G.J.W. Westerveld. Peat polders in the western part of The Netherlands.

Westerhout, J. Agricultural development of tidal lands in Indonesia.

Zaag, D.E. van der. Yield and quality of potatoes produced in the new polders in The Netherlands.

THEME B

SUB-THEME B3: AGRICULTURAL ASPECTS

General report by:
Dr.ir. J.W. van Hoorn

Conclusions by Dr. R.J.A. Dudal,
chairman

Notwithstanding the fact that only a limited number of papers on specific agricultural aspects of polders was presented, it was still possible to arrive at a number of important conclusions and recommendations.

1. The major aim of polder reclamation is agriculture. This implies that polder projects should be regarded primarily as agricultural development projects and that soil scientists, agronomists, agricultural economists, agricultural extension specialists should be given a more responsible role in project identification, design, appraisal and implementation.
2. Though agricultural practices in polders are not particularly different from those on other farmland it should be realized that for the farmers the polder environment is often strikingly different from the conditions of the lands where they came from. Possible new crops or cropping patterns should be tested and demonstrated in pilot areas and farmers should be given full support to adapt to the new conditions.
3. In areas which are already cultivated, the opinions of a representative range of farmers should be sought in advance regarding the future farm management with the proposed project inputs. It should especially be assessed if larger farm sizes and projected intensification are within their reach.
4. With the transfer of technologies it should be taken into account that polders and lands to be reclaimed occur under very different agro-ecological conditions in various parts of the world, not only with regard to soils, climate, micro-fauna, water quality, which all have an influence on project design and mode of development. Through land evaluation one should appraise the type(s) of landuse to be

recommended in accordance with the production potential.

5. In developed polders soil and crop conditions on the 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 (e.g. deterioration of soil structure, acidification, subsidence, salinity). Practical solutions will have to be applied, possibly including solutions which might require the modification of project design or operation.
6. Agricultural aspects of polder development should not be separated from socio-economic aspects such as the establishment of services and institutions, credit and market facilities, mobilization of human resources and pricing policies so as to ensure that both farmers and investors can achieve profitable returns. Concurrently a selection of the settlers may be desirable in order to obtain an optimum response and promote a collective approach.
7. It is suggested that a number of criteria be developed, from the angle of agriculture, to rationally determine desirable cropping patterns, farm management systems, labour inputs, levels of technology, needs for training and research, to be applied in a specific polder development site. Such criteria could be tested by studying these factors in succesful polders and in polders which have failed. Such criteria could also be used as indicators to monitor progress in newly developed areas and to initiate adjustments where needed.

THEME B 4: SOCIO-ECONOMIC AND PHYSICAL PLANNING ASPECTS

SUB-THEME: PHYSICAL PLANNING

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1 Introduction

Relating to the development of the Dutch IJsselmeerpolders Constandse states: "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" (Constandse, 1982).
This statement clearly marks the features of the challenging task peculiar to planning in newly reclaimed polders. Moreover it applies to the planning task to be executed in large reclamation projects, not necessarily comprising polders as such, examples of which can be found throughout the world, e.g. the extensive transmigration schemes in Indonesia as well as the desert-reclamation-projects in Egypt.
Therefore it should be borne in mind, that the papers presented in this report, as well as the discussion points evoked, in principle do have significance concerning these polderless projects.

Considering the statement cited above as marking the specific features of physical planning in polders it appears that only three out of the eight papers presented within this theme directly deal with the subject involved. These papers will be discussed in par. 2.
More indirectly covering some of the features presented are two papers,

to be presented in par. 3.
Physical planning and polders appear to be put together in a rather different way, in the other three papers received.
This papers actually deal with the process of physical planning at the national level, putting up the relation between (aspects of), the national policy and the development - or non-development - of the IJsselmeerpolders. They will be dealt with in par. 4, using the last IJsselmeerpolder-to-be (Markerwaard) as an illustrative case.

2 Physical planning in polders, methodologies used

Within the past millenary of Dutch polder-development major changes have taken place (Constandse, 1982)

- successive scale-enlargement
  Starting from small-scale reclamations in order to enlarge one's own land, large polders up to hundreds of square kilometres have been reclaimed

- monofunctional to multifunctional
  From pure agricultural use to complex use as housing, industry, agriculture, recreation and natural areas.

- growing state-involvement
  While enlarging scale of the polders and mostly due to the growing complexity of the goals set, involvement of the state to develop a comprehensively planned society became indispensable.

Considering (polder-)reclamation projects throughout the world one may observe that in most countries the first two changes did occur in little time or no time at all, while appropriate state involvement within the task of comprehensive planning isn't a matter of course, mostly due to lack of "planning history".
The papers reported upon in this paragraph do offer some valuable history-based experiences which may be applicable in current reclamation projects.

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Rijpert in "Shops and shopping centres in the IJsselmeerpolders" deals with the approach developed to obtain a balanced retail trade composition within the IJsselmeerpolders. Although directed, specifically, to the retail trade sector, this approach in an adapted way may be of use in planning other sectors in a reclamation area.

Rijpert goes through the shopping history of the 20th-century Dutch polders seeing with respect to the Wieringermeerpolder (1930).

"The only statement was to be found on the allocation of shopping facilities in the new polders said that it was to be expected that settlements of people would arise on the main crossings of roads and canals and that possibilities had to be created for the establishment of shops. And that was all there was said to it".

The planning effort confined itself to the monofunctional agricultural purpose of the polder and due to non-planning the retail trade sector shopkeepers without enough professional knowledge could open a large amount of shops and "for a long period of time there was a chaotic situation during which supply and demand were completely out of balance".

Concerning the North-East Polder (± 1946) it is pointed out that a, theoretical demand and supply model has been applied - looking at things after the event simple and imperfect, but at the time 20 years ahead of common use in the Netherlands - being "effective in the sense that the chaotic and unbalanced situations of the Wieringermeer did not exist" and developments could be kept in sight and regulated to a great extent. A crucial role in the model's implementation was played by the Development Authority, which built a certain amount of shops and thoroughly selected the shopkeepers.

At first only based on general experience, the theoretical side of the model used, was built upon the practical experiences of shopkeepers and customers, this being the starting point of distribution planning "Gradually a policy was developed to establish retail trade facilities in a responsible way based on theoretical principles".

And during the colonization of Eastern Flevoland (± 1967) this model - outlines presented by Rijpert - was used to "determine at any moment in the future the amount of square metres necessary for shopping facilities in the defined area". Rijpert in his paper more in detail discusses the regular surveys, carried out, to adjust the model applied. Concluding this report I would like to put forward some more general theses:

- To establish a well functioning retail trade (or any other) sector in a new polder (reclamation area) careful selection, or adapted education of tenants is needed. A state-owned Development Authority is the best way to do so.
- Planning developments in a polder (reclamation area) - forced by the special circumstances - are commonly far ahead of the developments in this field on a national scale. (Rijpert presents evidence to this thesis, with respect to the planning of retail trade).
- It has to be attempted to adjust the experience based Dutch polder-planning for appliance in countries, confronted with relatively sudden, large scale, multifunctional impoldering (reclamation) projects.

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In their paper "Land evaluation for agricultural development in Leziria Grande, Portugal", Reis, Perdigao and Perdigao present a case in which the F.A.O. Land evaluation methodology was applied in Portugal for the first time. In this project the following goals had to be reached: "increasing land productivity, providing more employment opportunities, obtaining more export produces and avoiding imported ones, as well as promoting a better income distribution".

As the authors already signal the nearly impossible task to clearly present the methodology in their limited paper - however actually succeeded in trying this - I won't try to do so in an even more restricted way. Their conclusion however is worth to be cited as by using the methodology described it appeared that: "the present productive capacity of Leziria is very much below its potentialities. With the land improvements some of the limitations can be totally or partially removed, resulting in higher yields, landuse intensification, increasing irrigated area as well as introduction of new crops and landuse systems".

In spite of the formulated multifunctional goals, the description of the methodology used as well as the conclusion drawn, do give the impression

of a rather monofunctional (agriculture) macro economic approach. In the history of Dutch polder planning on the contrary gradually next to economical, sociopolitical factors have been taken into account, while multifunctionality replaced monofunctionality.
In my view both approaches are valuable up to a certain "moment". The question is however, which features do indicate this "moment". Is it the size of the reclamation project, the distance to the nearby already structured "old land", the structure of the old land as such, the country's available planning capacity, the origin of the future population, the regional or national market conditions? Or do other features play a role and how should the desired extensiveness be deter-mined of the approach to be applied.

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"Qualitative spatial planning models for new urban fringe areas" are presented in Wezenaar's so-called paper. This paper actually reflects the planners' high degree of freedom in designing and the laborious decision making process in polder planning.
With respect to Almere's Buitenruimte (Outer Area) Wezenaar sketches the sheer infinite opportunities presented by the site itself, while on the other hand the absence of guidelines in the existing environment and the inexperience with the planned rate of growth do hamper the planning task.

The planning philosophy, with respect to the Buitenruimte - based upon the principles of coherence and diversity - is elaborated. The future users being involved in the planning process, by playing a so-called preference budget game. This involvement - in which the future inhabitant is asked to select a number of attractive environments, considering a limited purchase capacity - appears to be a success both to participants as well as to planners.
"For future urban fringe areas where not yet a development like afforestation took place, another elaboration of the general development strategy was handled. Reason for this was the preference budget game model being based upon certain recreaction designations. It gives no clue for all possible urban fringe elements of non-recreational character. So a structural theme, a "leitbild" is needed. The following concept has

been chosen: the phenomenological orientation with regard to the town. It has to organize the spatial planning on micro level. The base for this concept is the idea that cities are artifacts and worlds of artifice placed at varying distances from human conditions close to nature".

Wezenaar extensively deals with this model and finally concludes "The described model has been tried out in four historical old land urban fringe areas. Because the model matches the real situation it can also be used outside the polders".

Another evidence of the innovative potentialities of the challenging task of "polder planning"?

3 Opportunities and restrictions

Braaksma in "Polders and landfills as alternative sites for major airports" briefly considers the opportunities of polders and landfills in locating space-consuming airports. This because of "many of the major cities of the world are located adjacent to bodies of water".

The landfill concept appears to be applied for several airport extensions while also parts of new airports have been based upon landfills. Several examples are sketched.

"The polder concept can be used where the depth of water, or the availability of fill precludes the construction of a landfill alternative". Although several feasibility studies have been performed - depths from < 5 to 40 metres below sea-level-"to date the polder concept has not been used .....".

Presenting (off-shore) site evaluation criteria, a summary of (dis-) advantages is given, but actually Braaksma's last conclusion totally explains the present-day situation. "Economically, offshore airports appear to be difficult to justify. They require huge capital investments. In the light of the current economic state of the world it is therefore not surprising to note that very few offshore airports have been built".

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In "Do polders adapt to their environment" Bos states "it must be clear that a new entity, e.g. a polder, has got its own spatial identity and that is fully appreciated. But life can at any scale make social, functional and through these also spatial links between old and new, making old and new one divers but organic pattern". Examples of different scale are presented. With respect to the Haarlemmermeer ".... the suburbanization pressure of these two cities (Amsterdam and Haarlem) was such that new residential areas were being planned in the polder ....". The North Eastpolder: "..... East of the polder the area is of poor agricultural value and poorly populated, but of high touristic value. This caused the two woods along the east border to become centres for recreational activity" and "..... three villages in the south east section of the polder attract quite a few people, commutors from the old land .....".

Thus Bos shows that "through quite a few functions old and new land mutually influence each other, thus integrating the polder in its environment".

With respect to Singapore and Almere it is shown that city planning techniques are quite able to transcend the border line.

I can endorse Bos' answer "they should" to his own posed question with respect to the social and functional linkage of old and new land.

But in my view, no convincing arguments - at least on the larger scale - have been put forward to endorse this answer with respect to the spatial linkage, although from the examples given it is obvious that polders "could" adapt to their environment. Can't a sharp bordering line give as much spatial satisfaction as an integrated one?

4 The Markerwaard case

At the Barrier Dam of the IJsselmeer there is a monument on which is sculptured the famous slogan "A nation that is alive, builds for its future". Reclamation of the Markerwaard - the last part of the Zuiderzee project - at the moment however is no longer a matter of course.

The Markerwaard, being the main issue in the Netherlands, when discussing polders and physical planning on a nation wide scale is discussed in three papers.

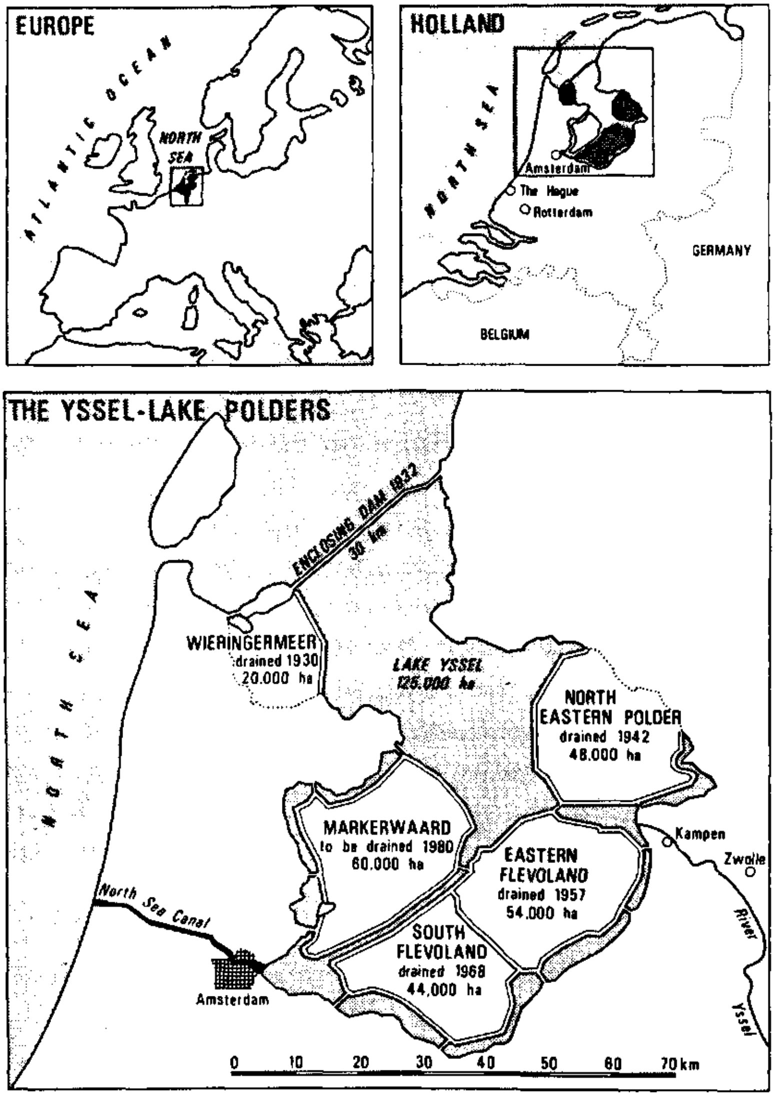

Figure 1: Realised part of the Zuiderzee project and the planned Markerwaard alternative.

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Spierings in "Urbanization in Dutch polders; the evolution of the Randstad conception" only incidentally mentions the Markerwaard, however his paper is important when trying to retrace the development in the role of the polders, with respect to the national physical planning policy, within the past twenty years.

In a very compact way Spierings deals with the "continuing contest between contracting and widening forces" within Dutch physical planning policy.

With respect to the role of the polders in this policy he shows the significant change in goals which has taken place. After the publication of the first "Report on physical planning in the Netherlands" (1961), this policy was implemented in the long-term planning of the IJsselmeer region "A structure plan for the Southern IJsselmeerpolders" (1961). In this plan Lelystad "being designed as the regional centre of the Noordoostpolder, the Markerwaard and both parts of Flevoland (intended number of inhabitants 30.000), its function and size had been put moreover in relation to the urbanization process in view in the northern Randstad (new target: about 100.000 inh.)".

The original widening trend in physical policy, turned into a contracting trend in the seventies and ".....recommended adequate housing production and urban renewal, so advertised more concentration of all urban functions within certain areas, the agglomerations and the near vicinity". The polders did offer opportunities to meet this challenges Lelystad (target: 100.000 inh.) and Almere (target - as being a pure satellite of Amsterdam -: 250.000 inh.) actually reflect the tremendous change in physical policy designating polders originally meant for agricultural use to areas as a habitat for about half a million of people.

Spierings does present - without stating so explicitly - the ability of the southern IJsselmeerpolders to fit within the changing physical planning policy - due to their very own nature of rather unrestricted opportunities. With respect to the last polder to be reclaimed he concludes "As far as the reclaiming of the Markerwaard is concerned, the future developments on spatial policy and practice will influence deeply the functions of this last polder in the IJssellake region, designed in the 19th century, when it will be drained".

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In "The IJsselmeer area: The protection of a natural fresh water area of international importance" van Grondelle calls attention to the importance of the process of " reorientation on the necessity of reclaiming the Markermeer". In his view the reclamation scheme for this lake - as proposed by the Dutch government - "is a clear violation of the Wetlands Convention (1972; ratified by the Dutch government) according to which the conservation and careful management of this wetland of international importance should prevail". Moreover he states "In view of this development - the change of physical planning policy to a much stranger concentration of urban development (see Spierings' papers) - one can understand that serious doubts arise about the necessity of the Markerwaard polder". Continuing he adds "To build the new polder would be to fight the symptoms instead of the true reasons.....will mean a free hand to the space-wasting process which increases the problems.....is therefore contrary to the government policy on physical planning".
His major point of critism concerning the decision-making process is the lack of alternatives in the government's draft decision for reclamation, especially "the lack of an elaborated alternative for the development of the IJsselmeer area without the Markerwaard polder". He presents a short sketch for this development defining "the values of ecology, landscape and cultural history of this area as the basic values", combining these with other functions of the area.
Concluding he states "in my opinion, it is necessary together with every proposal for reclamation - where ever it may be in the world - to also seriously consider the alternative: development without reclamation".

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Goverde in "Decision criteria: differences and shifts between insiders and outsiders in Dutch polder decision making" attempts, by using the Markerwaard case, to illustrate his theoretical proposition that "there is a strong relation between the competition of individuals, groups and institutions for better power positions and the decision criteria which will be used in the final decision taking".

In my view, within the Markerwaard decision process during the last decade, the decision criteria did not change, but the set of criteria used, has been completed by outsiders and a considerable change of importancy level of the criteria considered has taken place. However renouncing discussion on this matter of definitions, I would like to put forward some important features of the decision process, as presented by Goverde.

In 1972 the minister of Traffic and Waterstaat publishes a discussion nota concerning the Markerwaard. Six reclamation options (including the non-reclaiming one are presented.

These six options are put to public participation, while in the meantime one alternative is elaborated by the Development Authority and added into the participation process, already being on its way.

Partly due to the arguments added by the public participation it appears that some advisory boards are largely divided, large minorities not (yet) being convinced of the desirability of the new polder.

The Cabinet decides to a more extensive and formally regulated public participation procedure. Only one (large scale) reclamation scheme (the one elaborated by the D.A.) can be discussed upon. During the participation process a substantial amount of "new" alternatives emerges.

Actually the problem setting as a whole did change. Formally the government still poses one option, but pressure is put upon alternatives.

This profound change took place because, as Goverde states, the accessibility of the decision takers to the insiders of the Markerwaard opposition did fairly increase, and the once exclusive support for the pro-Markerwaard position (scientific research, planning procedures, symbols) is now also used by the opponents. "In summary the power balance sheet was slightly shifted toward the anti-Markerwaard position..... For the decision takers, however, the present-day condition of the power balance sheet is an uncomfortable one. Therefore the most likely prospect for the future will be a deliberate policy of non-decision making".

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To complete the Markerwaard picture - as far as possible within this brief context - I will present some main features of the 1980 government's draft decision.

Reclaiming the Markerwaard offers opportunities to a number of space consuming activities. The value of a Markerwaard with respect to the spatial development of the Netherlands as a whole however is more important, than the value to specific activities. (Corresponding with the ability of adjusting to changes in physical policy as shown by Spierings).

Due to its geographical position and the nature of its underground the Markerwaard offers specific opportunities to several sectors like urbanization, agriculture, forestry, recreation (with exception of large scale shipping) a second national airport, a large military training ground.

An essential element in weighing the need for reclamation is the expectation that physical pressure in the Netherlands keeps increasing. As first use of a polder can only be made 13-15 years after the start of reclamation, in view of increasing spatial pressure reclamation has to start pretty soon. For the same reason of time-span detailed planning at the moment isn't possible.

The reclamation scheme proposed, does give enough remaining opportunities to sectors which will be affected by the reclamation as fishery, nature conservation, landscape and cultural history.

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It is difficult to extract general features of the Markerwaard issue, worth to be discussed by a foreign audience. Therefore I would confine myself to some reflections. not necessarily comprising the key features of the issue, but meant as incentives for discussion (and not necessarily reflecting the author's opinion).

- During a long term reclamation process the Development Authority involved, acquires a lot of specific experience and knowledge. In a continued planning process this may lead to technocratic planning principles for prestigeous self invented objects, as decision takers are no longer able to demand a neutral problem setting. In a reclamation process possibly to be terminated the Authority's need to survive may also obscure the problem setting. The question arises whether Development Authorities do need a specific democratic control, and if so in which way this should be realised.
- The first Dutch polders were reclaimed, without considering alternatives. Usefulness or even necessity of reclamations was obvious.

Nowadays in many countries the same situation applies to most reclamation projects. Grondelle however actually does plead for a worldwide considering of the non reclamation option. Questions arise such as, from which scale alternatives have to be considered or even can be considered and to which extent alternatives have to be considered (e.g. within the total national physical policy).

- Uncertainty nowadays is a keyword in Dutch polder decision making. The Flevopolders afterward appeared to offer important opportunities in realising the changing physical policy advocated. Timespan needed to reclaim the Markerwaard is about 15 years and uncertainty exists with respect to the future situation. Is it responsible to rely - as the government does - upon the Markerwaardpolder playing a corresponding role in the year 2000. Even if all existing options fail to exist, at least a large natural area has been created?

5 Conclusion

From the papers presented it has to be concluded that the theme physical planning in polders does have many facets. Most of these facets equally being applicable to reclamation projects in general.
This report only deals with very little of the relevant facets. Many reclamation/impoldering projects throughout the world are on their way, each undoubtedly confronting a complex task in the field of planning. Therefore appropriate ways have to be found to transfer the large amount of experience-based knowledge and expertise from where it has been gathered, to where itis needed.

Reference

Constandse, A.K., 1982. From Spontaneous Settlement to Integrated Planning and Development. Paper to be presented at "Polders in the World", October 4-10-1982, Lelystad, The Netherlands.

SUB-THEME: SOCIO-ECONOMIC ASPECTS

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1 INTRODUCTION

For the discussion in the workshop socio-economic aspects of polder development, 14 papers were made available to the reporters. Ten of the papers focus on the IJsselmeerpolders or at least on The Netherlands and four are dealing with settlement activities in other countries, be it not only polders. It is clear that through this set of papers not a balanced picture is presented on the socio-economic problems with regard to polders in the world.

The papers have been divided into two main categories.

1 papers dealing with polders and settlements outside The Netherlands (Awan and Latif; Oyedipe; Smit; Steenwinkel).

2 The IJsselmeerpolders (Netherlands)

   Papers in this category are rather arbitrarily organised in four groups.:

   a sociological and historical aspects (Constandse; Hoeve; Schenk)
   b management and administration (Den Hertog; van der Spek)
   c role of new centres and employment (Fels; Scherjon and Verhoef)
   d landuse and recreation (Ter Haar; Hengeveld; Hoeve)

A short abstract of the fourteen papers is is given hereafter.

2 SHORT ABSTRACT OF THE PAPERS

2.1 Papers on polders and settlements outside The Netherlands

- The paper of Awan and Latif deals with *'Socio-economic aspects of water management of salinity control and reclamation project no. 1 in Pakistan: a case study'*. The results of the pre- and post-project evaluation and the socio-economic impact of the project are discussed. In this pilot project of 0.5 million hectares in the Indus-plain tubewells are installed who should lower the very high groundwatertable, decrease water logging, help to reclaim salt-affected soils and provide more irrigation water. Although the high investment in the tubewells was justified in terms of higher cropping intensity and expected higher yields, the results show quite a different picture. Due to the high capacity of the tubewells installed and their positioning, combined with inadequate and irregular organization of water allocation, operation and maintenance, irrigation water supply to the farmers is not reliable and insufficient. An increase in cropping intensity is only due to the additional installation of private tubewells. In 1981 the yields are only 50-60% of the expect ones. A result, the benefit cost ratio is less than one and the internal rate of return is only 5.7%.

The farmers who often have salt-affected lands, are hardly able to pay their waterfees: loans and the selling of animals must fill in the gaps.

- Oyedipe describes in his paper *"Innovative potentials of Kainji Lake Basin for Fadama farming: a study of three settlements'* the situation in three settlement villages. He explains the role and functions of the 'chief farmers' in relation to the World Bank promoted training and visit system for extension service. He concludes 'that meaningfull change for development has to come from outside the rural areas'. and that innovations have to be administered carefully.
- In the paper *'The origin and early stages of the Herman Göring polder (Tümlauer Koog) in Schleswig-Holstein, Germany'*, Smit stresses the influence politics and ideology can have on polder development. In the case discussed the need for a quick political success led to a hasty implementation of the empolderment and the construction of (farm) houses which resulted in many technical problems. Conflicting political views and institutional interests can be perceived in the layout of the new land, the architectural design and the selection of settlers. Due to the fact that the settlers had to start under poor natural and social conditions and had to depend heavily on each other in the early stages, a considerable amount of solidarity and community-spirit was developed. Even after handing over their farms to the second generation of farmers and often living outside the polder, they stick together. Under the second generation the ideological character of the polder, both social and economic, has disappeared.
- Steenwinkel's paper *'Policy and settlement aspects of tidal swamp land development in Indonesia'*, discusses some of the problems concerned with the reclamation of the last remaining land resources of this nation.

  Indicated are the concequences of high and low costs development and the possibilities to combine four main policy options: 1) A fast and certain increase of rice production; 2) a maximum income for farmer from 2 ha; 3) maximizing the transmigration from Java and Bali to the Outer Islands; 4) keeping development cost per ha at minimum level. Furtheron, criteria are indicated for settlement planning, such as the location of houses, the services to be provided on basic, primary and secondary level, and its location.

2.2 Papers on the IJsselmeerpolders (Netherlands)

a. Sociological and historical aspects

- Constandse in his paper *'From spontaneous settlements to integrated planning and development'* indicates the changes in character of land reclamation and its settlement in The Netherlands. Initially the aim of polders was to protect the land against flooding and occupy it permanently and safely. During the next phase investment considerations of rich urban merchants were the reasons for polder construction. From the 19th century on the state intervened in polder construction. This state intervention was at the beginning a very minimal and purely technical assistance: settlers were really pioneers. Gradually the state-intervention became more and more comprehensive until it reached its present-day all-comprehensive character.

  The character of the various IJsselmeer-polders that were constructed during several decades, reflect the changes in Dutch society, through differences in landuse, agricultural layout, settlement pattern, service centres and recreational facilities: each polder is an expression of the time just before its construction.
- The paper of Hoeve *'Allocation of land to agricultural uses in the Dutch IJsselmeerpolders'* indicates that since 1910 there is a trend to allocate more of the land that through reclamation becomes available, to urban use, recreation and natural reserve. Furtheron the paper indicates the trend of further specialization in agriculture, the great increase in farmsize and plotsize, the criteria for settler selection and the two legal forms of land lease to settlers and special agriculture-related enterprises.
- In his paper *'New structures in newly reclaimed land? The development of social structures in Flevoland, (IJsselmeerpolder) The Netherlands,'* Schonk pays attention to the three main tasks sociologists can have in helping to build a new community, 1) make a thourough study of the intention and aims of the polder in connection with the social structure of the future population; 2) advising in land use and service building in order to improve the quality of life; 3) evaluation of the quality of life and following and explaining, the social changes that occur.

He focusses his attention on the two main cities in the polder: Lelystad and Almere. Lelystad was started by a small group of 'colonists' who in both working and leisure time were strongly involved in building the town and the community.
The atmosphere of 'participation' changes, when the commuters of Amsterdam settled, whose main reasons to move were to find better houses in a safer surrounding and with more outdoor recreation facilities. In Almere Haven the same process took place but in Almere stad no 'colonists' mentality was developed. This made the start of community life much more difficult. Without special and guided efforts the immaterial aspects of the quality of life of the new settlers will not be any better than the situation where they are coming from: new and more integrative social structures do not come autmatically into existence to replace the social luggage settlers took with them to their new environment.

b. Management and administration

- Den Hertog in his paper *'The Zuiderzee project in The Netherlands'* describes some of the administrative changes that took place with regard to several polders. Once the decision was taken that it should be the central government to finance and carry out the Zuiderzee polders, specialised authorities were created by law to carry out the work and for the further development of the polders (IJsselmeer Polders Development Authority), both under the Ministry of Transport and Public Works. After completion of the polders and before the start of settlement, different organizational arrangements with different degrees of autonomy were founded for the various polders to incorperate them (provisionally) into the normal administrative structure. However, it is only in the case of the Wieringermeerpolder authority that it governs settlement plus management and water control. In the North East polder, initially a commissioner was appointed as sole manager with the power of a municipal council and its executives. With the increase of the number of inhabitants, four municipalities were formed up till now. Conclusive arrangements for watercontrol (volume), waterdefences and the provincial structure for the polders are still pending.

- The paper of van der Spek *'Management as a task, polder administration as a means for an integral management of rural areas'* makes the suggestion to extend the responsibility of the present polder-administration unit. Quality and quantity of water and its level influence strongly certain valuable ecosystems. Canals and embankments are or can become important recreation areas with only minor adaptions to be made (slightly higher bridges for the passing of canoes, etc.; simple pavement of inspection roads to make them attractive for fisherman, walkers and cyclers etc.) Due to the close interrelationship between control of water for agricultural purposes, nature management, landscape management and recreation in rural areas, an integrated management via the polder administration units is advocated.

c. Role of new centres and employment

- Fels in his paper *'Employment planning in new towns in the IJsselmeerpolders'* describes the influence changes in the economy and new insights with regard to the role of new towns can have an employment forecasts Emmeloord and Dronten, planned as agricultural centres show now an employment structure where the service sector and manufacturing industry dominates.
  Lelystad changed it position of new town, from regional economic centre to overflow town with employment growth lagging behind demand. Almere has reasonally fulfilled its employment targets in 1981 but the composition of the labour force is different from what was planned. Instead of the manufacturing sector it is especially the wholesale sector which shows particular interest in moving from the Amsterdam-region to Almere. Employment planning is supported by attractive services, low-costs facilities and tax-stimulants to encourage enterprises to start their business there.
- Scherjon and Verhoef in their paper *The regional economic policy in the new towns Almere and Lelystad'* discuss the functions those two towns have to fulfill in the national framework of The Netherlands. The main function was to relieve the overcrowded conditions of the Randstad by offering housing facilities and to create at the same time a living environment that could meet both housing and jobneeds.

Due to two developments this policy had to be reconsidered 1) There was a failure in matching jobs and skills. This forces polders resistent to commute to the Randstad for jobs 2) The present recession in the economy, makes firms hesistant to move from one place to another.
But the authors claim that these towns have comparative advantages for small and medium sized enterprises.

d. Land use and recreation

- Ter Haar's paper *'Recreation in new areas. The IJsselmeerpolders as a case-study'*, shows a considerable change in the attention given to open-air recreation since the first polders were started. In the planning of the first polders attention was only given to open-air recreation of the 'following type': small forests and parks, central open spaces in villages, swimming pools etc. were clearly meant for the recreation of the local residents. With the construction of the subsequent polders, the responsable authorities were surprised by the enormous interest of one-day tourists for the new borderlakes with their freshwater beaches and watersport facilities. The polder area itself turned out to be a tourist goal as well.
  In response to this interest it was decided upon in the early sixties to consider open-air recreation as a stimulating factor for regional development: both 'following' and 'stimulating' type of open-air recreation facilities were included in the regional physical planning. Areas around and close to borderlakes have been arranged in such a way that they now attract and can absorb many tourists from all over the country and even from outside the national boundaries.
- Hengeveld's paper on *'land evaluation for urban development in the Netherlands'* indicates that applications of land evaluation procedures for urban development can provide important information for planning and design of urban area development.
  Since soil- and hydrological surveys are necessary for local urban development anyway, such a land evaluation should be done at the beginning of the planning process, when it can be done without extra costs.

- In his paper *'Cost benefit analysis for a planned part of the IJsselmeerpolders project'* Hoeve shows first of all that there are many practical and theoretical problems related to cost-benefit analysis, because one has to do with direct and indirect - material and immaterial effects. Furtheron the paper makes clear that cost-benefit analysis is wide open to political and other types of manipulation.

3 SOME COMMENTS AND SUGGESTED THEMES FOR DISCUSSION

It was laudable that the organisers of the international symposium on *'Polders in the World'* have made room for the human being in these polders. After all, polders are made by people for people (Schonk).
However we are faced now with the question what it is in polders that influences human behaviour in such a way that it is different from other areas.
One element that clearly makes a difference is the influence of the eternal fight against the water on human character and society. Without following all the way long Huntington's opinion in his book *'The climatic factor' (1914)* it cannot be denied that the habitant has a profound influence on society (Forde; Habitat, Economy and Society, 1934).
In a polder - environment a community must necessarily find an internal organization form in such a way that it effectively can protect itself from the potential calamity that in one night could destroy the community (like what happended in The Netherlands in 1953). A fairly high degree of internal organization of the polder population and polder management is necessary not only with a view to eventual calamities but also to cope with the daily operation and maintenance of the rather complex watersystem and waterdefences. As compared to large irrigation projects there is a vital need for adequate maintenance and operation.
Another possible difference in polders compared to other areas is that once man has driven out the water, he has land that is tabula rasa, both physically and socially. This gives the opportunity to create a physical environment that is completely man-made at a specific point in time and requires hardly any adaptation (Constandse; Steenwinkel).

Polders therefore reflect very clearly the social and even the political situation at the time they were created (Smit and other authors). However, the latter point is not specific for polders. One has only to think about the Geziria-scheme in Sudan. Which means that in fact the social problems encountered in polders during their initial stages of settling the 'colonists' and later on during the growth of a new society are basically the same as those met in (large) settlement schemes in empty areas all over the world.
Our conclusion is that polders represent a special form of settlement-scheme in empty land with high requirements for drainage facilities (and irrigation eventually) and for internal organization and management.

Of the papers presented, several of them are dealing with subjects that are not specific at all for polders or even for settlements in general. Most of the contributions to this section of the symposium are of a descriptive nature; they supply us with interesting information but do not compare their information with experiences from elsewhere. Neither are we supplied with efforts towards a more general or systematic approach based on information the authors might have, as was for instance done by R. Chambers his book *'Settlement schemes in tropical Africa'* (Routledge and Kegan Paul 1969), by G.B. Palmer in his article *'The agricultural settlement scheme: a review of cases and theories'* (in Antropology and Social Change in Rural Areas, B. Berdichewsky ed, Mouton 1979) or by C. Takes in *'Land settlement and resettlement projects'*, ILRI 1975.
Nevertheless, in many papers directly or indirectly themes are indicated that are encountered all over the world where large scale polders or settlement schemes are planned and implemented. Some of these themes will be mentioned here.

- The influence of politics, ideology and the national image on the start, the layout and the speed of implemention of polders and irrigation and settlement schemes. It is often related to a catastrophe or the threatening of it that the political will becomes strong enough to devote considerable shares of public funds to realize schemes that have lingered often for a long time on the drawing boards of the civil engineers. The Netherlands is a case in point.
  For political purposes polders and schemes must be inaugurated at a

specific time. Since this time in many cases is earlier than desirable, the speeding up often has a detrimental effect on the quality of the technical works and affects the level of living and its quality for the new inhabitants for many years in an adverse way. Smit's paper presents a clear example on this item. The same phenomena is happening on a much larger scale in the Mahaweli Ganga Scheme in Sri Lanka.
An example of political motives to revise the civil engineering design is presented by the Syrian Government who required a cheaper and higher design of the Euphrates dam because it wanted to have the highest dam in the region (higher than Egypt's high dam). Consequently, settlement was delayed.
It is interesting to find out how instrumental or how dysfunctional political forces have been in the start, design and speed of development of polders and other settlement schemes.

- Large polders and settlement schemes require a specific type of organisation that is powerfull and can coordinate the many different types of activities that are involved in such works. The 'authority' is a well known and preferred type of institution for these activities. They have considerable advantages but also disadvantages. To create an organization is easy but once its task is over or declining in size and importance, it is so far more difficult to diminish it in size or to liquidate it.
  Could it be that the slow integration of the new areas in the political system of the Netherlands (municipal, provincial system). (Den Hertog) was also partly due to some hesitance of the IJsselmeer Development Autority to lose some of its influence?
- One of the most interesting sociological aspects of polders and large settlement schemes in empty areas is the creation of new communities. Several important issues can be distinghuished.
  • First their is the selection of settlers with such problems as the question whether to given prefence to highly qualified settlers in order to make the polder/settlement an economic success or to give chance to poorer farmers from the old land (Steenwinkel, Smit). Should selection be done on an individual basis, often resulting in a deformed demographic structure with serious concequences for the school and health systems, or should one take whole communities or parts of them in order to have at least some basis for the develop-

ment of 'new' community. In the latter case it is likely that the 'social luggage' (Schonk) will survive longer and can retard modernisation.
Often, due to the excisting social and political structure, selection of settlers is also based on certain quota's with regard to specific groups in the society. A specific distribution over religious groups has strongly influenced the society in the North East Polder. The same kind of distribution took place in Suriname with regard to racial groups and in Africa with regard to tribal groups.
Another interesting aspect in how far the settlement agency should take care of all aspects: what efforts can be expected from the settlers themselves. Apart from the economic and financial aspects (often of great importance in developing countries) there are also some interesting consequences that have to be taken into account by making this decision. There is for example the community spirit. From several papers (among others Schonk, Smit, Scherjon and Verhoef) one can draw the conclusion that a settlement agency preferably should not take care of everything but instead should leave the settlers with building and organizing a part of their new environment. These common activities, often to be carried out under difficult conditions, enhances a colonisers' spirit that makes the building of a new community and the integration of settlers in it, much easier. When the 'late' settler arrives most things have already been organised and found its place, and communication patterns have been established, which make his integration in the young community much more difficult. People are making polders for people (Schonk) but what is the say of the settlers in the physical and social environment in which they and their children have to live? In other words is there any room for participation (and what kind of participation) of settlers in the design and implementation of polders and settlement schemes?

- It is quite normal that the governments' objectives leading to the construction of a polder, are revised during the construction period which extends over a number of years. Pressing problems and new insights might lead to revised wishes like higher demands for urban development and industrial facilities, or for a modified type of agricultural exploitation and related settlement. The IJsselmeerpolder Authority, under sometimes heavy political pressure, has been able to adapt its plans for the physical infrastructure to accommodate the new wishes. It is an interesting question how much flexibility can be built into the initial plans for layout and physical infrastructure that might come up during later stages of planning and implementation. How far in the planning procedure could flexibilities be maintained at what extra cost? These questions are not only relevant to polders and settlement-schemes, but do apply to irrigation projects in new areas or in already populated areas as well. Giving room for new insights in regional development, in farm economics and for settler-participation looks worthwile to be considered.

- From theoretical point of view it is interesting to discuss under which social, economic and ecological conditions polders are/were constructed. Under the social conditions one could imagine a high population pressure, the fear for a calamity, an adequate level of technology, a fairly high degree of internal organization and differentation plus a sufficiently strong central government to allocate the necessary funds and required manpower for the construction and operation (Wittfogels' hydraulic society?). The economic conditions require a.o. such a high surplus production that the investment capital can be supplied and that future demands for the high cost agricultural and industrial goods or facilities to be produced in the polder, is high enough to justify the investment as compared to investing it in further intensification on the existing land. Ecological conditions could be that the prevailing (agricultural) production system fits into the polder environment, and that the creation of the polder does not interfere too much with the natural conditions necessary for food production and healthy living conditions in other parts of the country.

It is clear that only some of the themes mentioned by the various authors of the papers have been indicated: the selection of the themes indicated above is strongly influenced by the experiences and interests of the reporters.

THEME B

SUB-THEME B4: SOCIO-ECONOMIC ASPECTS AND PHYSICAL PLANNING

General reports by:
Prof.dr.ir. D.B.W.M. van Dusseldorp
Ir. H.J. Groenewegen

Conclusions by Prof.dr. A. Constandse, chairman

Socio-economic aspects pertaining to polders and polder development were discussed without arriving at pertinent conclusions: a wish, rather, was expressed to continue to deepen the insight into socio-economic factors.

A major issue was: the economic and political aspects of decision making. Measuring or weighing the pro's and con's of imponderable values, in particular with regard to the competition between nature and agriculture is, in the end, not a scientific but a political problem.

A second major point was also raised during this symposium: should the poorest members of society be helped first, for instance by giving them land in polders, or should polders serve to increase the production of food and fibre, so that there will no longer be any poor and hungry people in the future?

A third point that kept reappearing was the order of priority in the attempts to satisfy the wishes and needs of people. The one extreme is to give people just land to satisfy their first needs, food and income. The other extreme is not to start the operations before ensuring that everything is taken care of, and well organized, so that new disasters are avoided.

Other topics were discussed too, such as the problem of uncertainty, the irreversibility of developments, the statement "small is beautiful", the significance of people's participation and the levels in the decision making process where this participation takes place.

THEME B 5: ENVIRONMENTAL ASPECTS

ENVIRONMENTAL ASPECTS

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Abstract

Eleven papers were presented to this theme. Nine of them are from The Netherlands, one is from Suriname and one deals with the protection of the city of Venice and its Lagoon. Three papers deal with general aspects of polder environment, its functions and influences. Developments in the Ysselmeer-polders and the Wadden Sea area are described. For part of the latter region, a project assessment study was discussed. The ecological effects of a proposed reclamation project were quantified for use in a cost-benefit analysis. Another project assessment was related to a land consolidation project. The methodology of these assessment studies should be given widespread use. Similarly, the use of modeling techniques, as presented in a paper on eutrophication processes, can help to understand effect-cause relationships and to take the right decisions on safe-guarding or improving our environment.

1 Classification of papers

Eleven papers have been submitted to the theme B5 "Environmental aspects". Nine papers are describing polder environments in the Netherlands, one paper is from Suriname and one deals with the protection of the city of Venice and its lagoon. All papers are listed in Table 1. If the title did not give full information about its subject or area, additional information has been given in the column "Remarks".

A classification of the papers was made as follows :

A General aspects

in the Netherlands

Paper 1 by De Jong and Wiggers

Paper 2 by Klein

in Suriname

Paper 3 by De Jong

B Developments in the Ysselmeerpolders

Paper 4 by Driebergen

Paper 5 by Polman

C Developments in the Wadden Sea area

Paper 6 by Drijver

Paper 7 by Joenje

D Project assessment

Paper 8 by Dankers

Paper 9 by Asjes

E Water quality

Paper 10 by Bernardi et al.

Paper 11 by Smits and De Rooij

Paper 8 could be also classified under the heading C. Each paper will be summarized and discussed according to the aforementioned classification but cross-references will be made to the other papers whenever appropriate.

2 Summary and discussion of papers

A General aspects

Paper 1 by De Jong and Wiggers is mainly a descriptive review of the historical development of the four main polder areas in The Netherlands : 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 (Figure 2). The authors describe how the original habitat was changed in each of these areas and how land use and parcelling was affected by the type of reclamation (Figures 3, 4 and 5). Improvement of farming conditions has often resulted in a decrease of bird species and floreal va-

lue (see Paper 2). The land accreation areas along the coast are recognized as having a very high ecological value. New embankment constructions in the Wadden Sea are therefore unlikely to be executed (see Papers 7 and 8). But it is also noted that large parts of the new polders have been developed into nature sanctuaries and forests (see Papers 4 and 5). The authors briefly discuss the change in land use since 1900 (Figure 8) i.e. the decrease in agricultural land, estimated nowadays at ca. 13000 ha per year, lost by urban expansion. They introduce so-called disturbancy zones around towns and villages in order to assess the effect of urbanization upon the region (Figures 9 and 10). Pollution effects, such as eutrophication of canals and lakes and waste dumping, are mentioned (see also Papers 10 and 11).
This paper gives the general reader an interesting overview on the subject of this session. It is in fact an introduction to many of the other papers of this session. Detailed information, e.g. about increase or decrease of number of bird species, etc. ..., can probably be found in the literature listed at the end of the paper.
For easy reference, however, it would have been preferable, if the literature cited had been also quoted in the text. Maybe the authors could specify during the discussion how they define "disturbancy zones".

Paper 2 by Klein details about the ecological developments and relationships in new polder areas. The author discusses briefly the soil ripening, the influence of the hydrological conditions (leaching processes and capillary rise) and the microbial development. The vegetation development is affected by dispersal, spatial differentiation and prevailing wind direction. Management measures, e.g. the sowing of reed, help to establish favorable conditions. Human interference, by reclamation activities and road building, etc... offer opportunities to study the spatial dynamics of various species.
It is surprising to note that plants spread more rapidly

than animals.
Nature conservation and nature-engineering or habitat-building is discussed (see also Papers 4, 5 and 7). Detailed inventory prior to embankment and development and regular surveys are strongly recommended. The use of remote sensing techniques is suggested.
This paper points rightly to the extraordinary possibilities for research on ecology in new polder areas. These studies form the base for environmental impact studies (see Paper 8). As most of the referenced literature is from Dutch origin, the author indicates the need for more research elsewhere in the world. Would it be useful to draw minimum criteria for this kind of research ?
Finally, it is worthwhile to note that 53 references have been collected by means of an online search using computerized literature data bases : a method to be promoted.
Paper 3 by De Jong may be seen as an answer to the request of Klein, urging for more research on new polder areas elsewhere in the world. The estuarine area of Suriname has a high natural fish productivity. Reclamation of the area for rice production will enhance very important effects on the ecology of the environment. Among these effects are decreased fresh water runoff, alteration of the forest habitat which is very important for fish populations, contamination of drainage water by pesticides.
It is recommended that the whole estuarine zone should become a Special Management Area and that planning assessment should be performed prior to development. The reference list includes local research on the ecological effects.
The reporter missed a map of the region involved and an indication about its size.

B Developments in the Ysselmeerpolders

Both papers 4 and 5, respectively by Driebergen and by Polman, deal with so-called shallow borderlakes of the Ysselmeerpolders. These lakes have been designed for multiple water management purposes. Drontermeer and Veluwemeer, discussed by Driebergen, have a closed water management system since 1956. During the period 1957-1961 a rich and varied plant and animal life developed. During the sixties and the seventies the transparancy indicator decreased drastically from 1 m to 0.2 m. The cause is the pollution by domestic and agricultural waste waters. The high contents of nitrates and phosphates increase algae growth, especially Blue-green algae which limit severely development of other plants and animal life. The original rich environment deteriorated rapidly. Several steps have been taken to limit the phosphate content of the waters discharged into the lakes from 0.5 to 1.5 grams per m^2 per annum. The estimated load in 1975 was 3.7 grams per m^2 per annum. These steps are often very costly. Therefore, results of this type are very useful. A reference list at the end of the paper would have improved the interest of this paper.

The Oostvaardersplassen (Paper 5 by Polman) in Southern Flevoland are just south of Lelystad and have been planned as a nature reserve of 5500 ha. The original area developed in a natural way into a very important resting, foraging and breeding area for numerous species of birds. Therefore, it was decided to further develop the area as a nature reserve, especially for waterfowl. An artificial water level has to be maintained by embankment and by artificial water supply in dry years or water discharge in wet years.

This extensive paper gives a detailed account about experiences, discussions and targets of both the original area and the new development. A main technical point is the water level in winter and summer. My question is : what is the cost benefit relationship for developing and maintaining these artificial ecosystems.

C Developments in the Wadden Sea area

Paper 6 by Drijver lists the recent reclamation projects in the Wadden Sea region, either completed, rejected or planned in Denmark, Germany and The Netherlands. The author stresses the irreplaceable role of the existing salt marshes and mud flats for the biological life. Efforts are made to express this role both quantitatively and economically and to incorporate the total environment of the Wadden Sea area with its connection to the North Sea. The author's arguments are impressive, but do they imply the rejection of all diking projects in the area ?

Paper 7 by Joenje, at the other hand, discusses the ecological developments in new embanked polder areas in the same area, which "... however, by no means (compensate) the losses of saltmarsh and wadden ecosystems ..." (quotation by the author).
The case of the 9100 ha Lauwerszee-polder , embanked in 1969, is described.The general question, whether nature management should be a "laissez-faire" or some mode of nature exploitation, is answered in favor for some "active"management.. But even then, different and conflicting options may exist. Moreover, some management methods may be limited by cost considerations. The nature reserve in the Lauwerszee-polder has several management programmes side by side in different zones. They are still very much a matter of trial and error. This study holds a challenge for many years to come, as stated by the author.

D Project assessment

Paper 8 by Dankers gives an account about an ecological study of the Balg-zand tidal flats made in such a way that the information could be used in a cost-benefit analysis of a proposed reclamation project. The author lists 25 functions of the Wadden Sea area and discusses their interaction. I think that this list is a very useful one and should be an example for all studies on environmental impact assessment. The environmental effects are divided into primary, secondary and tertiary effects. They are called a "factor train".

The description of this factor train is again a very welcome step towards a more rational and methodological approach of this type of studies. The author recognizes that some functions cannot readily be quantified. Could he explain how they have been introduced into the analysis ?

Paper 9 by Asjes treats the subject of land consolidation in an older polder area versus conservation of nature areas and landscape. The assessment method made a comparison between several variants of land consolidation schemes and their effects on agricultural development, nature value and landscape value. The conservation of nature value was measured by the number of meadow birds. The size of a bird sanctuary was taken variable. Likewise the number of farm resettlements was a variable versus the openness of the land scenery. The increase in renumeration for the farmers and the internal rate of returns were the base for comparison. It is clear that conflicting interests exist. Could the author discuss how the decisionmaking process will use the information resulting from this assessment method ?

E Water quality

Since water is one of the main substances of the environment, it is not surprising that two papers are essentially related to water quality s.s. Paper 10 by Bernardi et al. presents the problem of monitoring water quality of the fresh water discharged into the Lagoon of Venice. The large number of inflow channels does not allow a full control. Moreover, the tidal flow with its salt wedge and changing water depth necessitates monitoring at several depths and different hours. Symptotic values of total water, salt and heat flow are derived. An even more complex problem is the exchange of matter with the bottom sediments of the Lagoon. A circulation model is being developed. The authors could maybe give some more details about present state of the project.

The last paper of this session (Paper 11 by Smits and de Rooij) is an extensive one about eutrophication processes and their modeling in the Westeinder Plassen, a lake of 9 km² and average depth of 2.9 m, situated in the Rijnland Polder system. The authors describe the model CHARON-BLOOM II where CHARON stands for the chemical part and BLOOM II for the phytoplankton part. Both models as well as the coupled version have been applied elsewhere in The Netherlands. Calibration results for the years 1977/1978 are satisfying the authors. I would like to know somewhat more details about the calibration method : how was the procedure to adjust equation coefficients ? Was a residue analysis applied systematically ? The literature cited will certainly give answers to these questions ? This modeling study resulted in an important conclusion: phosphate is far from limiting for phytoplankton growth. Therefore a decrease of phosphate load will be only effective if the reduction is very substantial. This result is probably a very exemplary one in showing the usefulness of careful modeling techniques.

2 Conclusions

Reporting on theme B "Environmental aspects" has been a most profitable exercise for the reporter. All papers have aroused my interest and widened my knowledge. Many introduced methods or definitions which, in my opinion, are most useful and should become standard procedures in these studies.
One author reghtly concluded that new polder areas are excellent opportunities to study developing ecosystems. Another author pointed out that relatively few studies on polder environments are known outside The Netherlands. May this session be a step towards increasing interest into these studies which should be the strong base for preserving or managing nature while serving humanity.

Table 1. List of papers

Paper No.	Authors	Title	Remarks
1	Jong and Wiggers	Polders and their environment in The Netherlands	review of the historical development of the polders in The Netherlands and the changes in the natural environment and land use
2	Klein	Flying or creeping : the immigration of organisms between reclamation and cultivation	development and relationships of populations of plants, animals and microbes in new polder areas
3	De Jong	Ecological impacts of polderconstruction in Suriname	
4	Driebergen	Environmental developments in two of the borderlakes of the Ysselmeerpolders in The Netherlands	
5	Polman	The Oostvaardersplassen, the developing of marshy ecosystems especially for waterfowl	The Netherlands - Ysselmeer
6	Drijver	Cumulative ecological consequences of diking projects in the Wadden Sea area	significance of salt marches and mud flats for biological life
7	Joenje	Nature in new Wadden-polders conservation by exploitation	plant colonisation, management practices and wildlife protection in a new nature reserve in the Lauwerszee-polder

8	Dankers	Quantifying the loss of functions of a natural area as a means of impact assessment for reclamation projects	environmental aspects of the (abandonned) plans of the development of a deep sea harbour and adjacent industrial area in the Balgzand tidal flats of the Wadden Sea
9	Asjes	The assessment of the land consolidation project Eemland	planning and assessment of alternative plans for safeguarding nature areas, landscape and improvement of agricultural structure
10	Bernardi et al.	Protection of the city of Venice and its lagoon : flow of fresh water and pollutants into the lagoon	
11	Smits and de Rooij	Modeling eutrophication processes in a polder area	The Netherlands-Rijnland (Westeinder Plassen)

THEME B

SUB-THEME B5: ENVIRONMENTAL ASPECTS

General report by:
Prof.dr.ir. A. Van der Beken

Conclusions by Dr. M. Vannucci,
chairman

Owing to the subdivision of the broad subject of polders in themes of an interdependent character participants faced a series of choices. Perhaps the discussions would have been enriched if the array of possibilities had not been all simultaneous.

A good number of authors of papers on environmental aspects was present (9 out of 15). Yet there was no representative of a developing country in the group. Thus it was not possible to pursue the very far lines of thought established by the keynote speakers Meyer and Brammer. This was regretted since their papers had so profound a sense of multi-objective planning, interdisciplinary research and cooperative human effect.

The session on environmental aspects reviewed 11 papers divided by subjects as follows:

- General aspects (3 papers)
- Developments in the IJsselmeerpolders (2 papers)
- Developments in the Wadden Sea area (2 papers)
- Project assessment (4 papers)

All the papers except three were by Dutch authors on Dutch conditions and problems. Two were by Italian authors dealing with the city of Venice and Venice Lagoon problems. One paper was by a Dutch author on polder construction in Surinam.

The problems of the Venice Lagoon are being solved by methods other than polder construction. From the papers it emerged that the Netherlands system of planning and making environmental impact assessments has been tested in many complex situations from which lessons were continually being drawn. The tension between the conservation of nature and the justifiable use of natural resources was well recognized.

It was the consensus of the group that:

1. Polders give special opportunities for studying ecosystems.
2. New methods, new criteria and new definitions for the study and monitoring of polders and waters should be developed and standardized.
3. Analysis of polder ecology should aim at establishing easily quantifiable factors in reclamation projects.
4. The use to which the information gained should be put should reflect different types of values for the cost-benefit analysis, some of the values being expressed in terms of money, others not.
5. An environmental impact assessment should be made before any inpoldering is undertaken.
6. Pollution and ecological development should be monitored for a long time after the completion of new polders.

Furthermore there was a number of questions about environment, society and economies in regard to impoldering in developing countries and the group recognized that these questions needed a broader framework for their appraisal.

Finally it was recognized that the political evaluation of the variables in the management of polders was a matter for fine judgment. The Dutch decision-making process appeared to cope satisfactorily with the need to balance factors in the perspective of the future.

CONCLUSIONS

FINAL CONCLUSIONS

Prof.dr.ir. J.C. van Dam
Chairman of the Scientific Sub-committee

Mr. Chairman, Ladies and Gentlemen,

After listening to so many excellent speakers during the past three days it is a heavy task for me to speak as the last speaker but one. It is also difficult to summarize the findings of this symposium in a balanced way. We listened to a great number of interesting lectures and there were so many papers that even with the chosen system of presentation by means of general reports we had a full programme, if not too full. It will still take us a long time to digest it and to have the full benefit of it. The printed lectures, papers and reports are valuable material for reference and study when back home. I will now try to summarize what, in my opinion, is at this moment the balance of our activities during the past three days.
There exist several definitions and interpretations of the word "polder". This is no wonder as indeed there is a great variety of polders in the world. I will not try to formulate a definition at the end of this symposium. I am only too happy that we did not stick to too strict a definition when accepting papers. So we had not only a large number of papers, but these papers deal with many different conditions, aspects, and solutions.
Much of the knowledge and know-how presented here can also be used in and for other areas than polders.
This symposium on polders has widened our outlook and insight into new possibilities, into all kinds of problems and into the ways they have been tried to solve.

Instead of worrying about a definition one might ask oneself: In what respect differ polders from the rest of the land ? In terms of the five sub-themes of this symposium it is certainly the water management aspect, rather the water control of polders which makes them so special. This in turn can be attributed to the topography of the areas where the polders are located. Closely related to the topography of polders or prospective polder areas the soil properties make them suitable for agriculture in many cases.
The topographical features, in most cases, necessitate the construction of dikes and embankments together with sluices and pumping stations for the control of water.
The construction of a polder means a radical transformation of the original landscape, often in a natural state, into an area liable to serve the requirements of mankind. So it is clear that polder construction implies a huge impact on the original environment. This asks for due consideration.
The great step from natural environment to a developed polder area can not be made without physical planning, based on the prevailing socio-economic conditions.

Almost at the end of this symposium one might ask oneself why this unique happening was held in a small country as the Netherlands. Several answers are possible, such as

- the initiative was born here;
- the Netherlands have a long and impressive polder-history and new polderland is and will be reclaimed here, now and in the near future.

  In this context it is nice to mention that our new Dfl. 50,-- banknote is printed with a colourful map of the IJsselmeer polders on its back.
- the ratio of the polder area to the total land area of the country is extremely high, because this country is so small.

After these introductory remarks I now come to the formulation of my impressions of this symposium.
We received a wealth of papers dealing with polders all over the world. When projecting the polders dealt with in these papers on the world polder map as presented during this symposium we can conclude

that the papers give a good coverage of all continents.
The papers were certainly also useful contributions to the preparation of the world polder map. However, I am convinced that despite all research efforts the map will, sooner or later, need updating.
The exhibition, consisting of two parts, scientific and demonstrative, was very interesting. Like me, you might have wished to be able to spend more time on this important item of our symposium.
The films and Surinam session contributed even more to the extent and variety of the information presented in this symposium.
The value of a symposium like this lies partly in the printed papers, including the general reports and the invited lectures, but perhaps even more in the personal contacts. These contacts are particularly important because we met here not only with people from different parts of the world. The participants have different disciplines and work at various levels, such as decision makers, scientists involved in investigations and study, engineers involved in design and execution, university professors for the education of the next generation of polder engineers. There are also participants whose interest arose from the mere fact that they live in a polder.
The general reports were different in nature, partly due to the freedom which was necessarily given to the reporters, partly because of the different degrees of heterogeneity of the papers to be dealt with by the individual reporters. Most of the reporters provoked the authors of papers and the audience by means of interesting questions. This gave rise to lively discussions.
During the afternoon sessions we discussed the general papers and the papers in the five sub-themes well known to all of us. Remarkably the number of papers on the important sub-themes "agricultural aspects" and "environmental aspects" was smaller than the numbers in the other themes. Nevertheless the relevant sessions were attended by good audiences. For the agricultural aspects holds that many of these aspects can be interpreted as land- and water management aspects and indeed we had many papers and a very great audience on that sub-theme. Another striking feature is that several papers on "environmental aspects" were written by a great number of co-authors (up to seven). This may be an indication of the interdisciplinary character of some papers on environmental aspects. There were only few papers dealing with

"environmental aspects" in developing countries.
The papers in both these sub-themes - "agricultural aspects" and "environmental aspects" - were also very diverse in nature and contents. This made it even more difficult for the reporters of these sub-themes to present us a picture of what is going on in these aspects.
Like in many symposia, and also in literature, there is hardly any paper dealing with failures. This is understandable, but also regrettable as one can learn much from such cases and thus prevent a repetition of such a failure.

So far my concluding remarks were related to the symposium with all its sessions and the exhibition. What conclusions can now be drawn and what lessons can now be learned from this symposium on polders ? Many ! Let us try to formulate them:

1. Construction of polders is a peaceful means of enlarging the land area and/or to make productive land. More productive land for the same population, as distinct from making war, where in the end, fewer people live in the same land area.

2. In consequence of the rapidly growing population of this world there is a growing need for land where people can live and produce the food and fibre they need. Part of the land to be reclaimed will be in polders.

3. Besides the reclamation of new land the improvement of existing land, whether in polders or not, can also contribute to a greater agricultural production.

4. People living in many polders of the world do not appear to be afraid of flooding. They must either have great confidence in the skill of the engineers or they do not even realize that their lives are protected by dikes, because dikebursts have not occurred there for a long time, due to the construction of safe dikes and embankments.

5. The design and operation of polders depend greatly on the climate. Not only the dimensions, but even the concept can be different in different climates.

6. The geological features of polders have had relatively little

attention. This is possible because the importance of the geologic conditions is sometimes underrated.
Due attention should also be given to future sea-level rises.

7. Considerable progress has been made in the past few decades in:
   - scientific knowledge;
   - practical know-how;
   - development of equipment needed for polder construction, development and maintenance.

8. As in many other fields, modern methods as system analysis, modelling and optimization techniques have also been applied - and with success - in the design and operation of polder projects.

9. In the sub-theme "construction aspects" much attention was given to the construction of dikes and embankments and the many recent developments therein.

10. Despite the progress made there are still limits to the possibilities of polder construction. These limits may be and often are of a technical nature. For example, the hydraulic capacity of tidal inlets is too great to enable a closure with the technical means locally available. Many times there are also economic restrictions. For example storm surges can be so high that the cost of a safe dike are even prohibitive.

11. After the sequence: investigation and study, planning, decision making, design and construction follows: operation and maintenance. The operation and maintenance aspects are often neglected in practice. Improper operation can lead to considerable reduction of the profits of the investments. It is true that the cost of maintenance can be high, but when neglecting it the consequences can be disastrous. Not only are these aspects neglected in practice; also for the papers maintenance was apparently not an attractive aspect. There was not too much information about maintenance in them.

12. It is true that polder construction and development can have, and in many cases do have, a tremendous impact on the original environment. In many cases it means even a complete transformation from the original state into a different new state.

This transformation is an irreversible process. Therefore due consideration must be given to all foreseeable and possible consequences. This has been done since long, but in present times the concern for our environment, both the natural environment and men's living environment is greater than ever before. At present there is also much more knowledge and experience available than in the past.

Practice has learned that too often unforeseen consequences appear later.

Newly created environments can also be most valuable or attractive. When creating new polders there is often great freedom in the design and due attention can be paid to measures to compensate or minimize damage to the original environment.

It is highly desirable that the environmental objectives are specified in terms of quantities rather than being expressed in a descriptive way only; they could then be better incorporated in the planning process.

There are a few examples where the so-called irreversible transformation was not for ever. In a few cases men gave up and abandoned a polder for technical or economic reasons. In other cases nature took revenge, for example by inundation after the occurrence of dike bursts.

13. The rentability of new works is commonly judged on the basis of the internal rate of return. This figure depends on the estimated life time of the works. In such a calculation the later years contribute less than the first. The life time of polders is almost for ever. This means that the benefits of such an enterprise continue long after the period of usually some tens of years which count in the calculation of the internal rate of return.

14. It appears that in the past new polders were often constructed and developed as an investment in times of prosperity. In times of economic depression there was generally less activity in the creation of new polders.

15. History teaches that often long time spans elapse between the moment the first initiatives are launched and their realization. After making the necessary studies, planning and design it is often

a long way with ups and downs in the political spheres.

16. In recent times new methods have been developed for the evaluation of projects and plans. Multi-criteria analysis methods are now available for the evaluation where the benefits and drawbacks cannot be expressed in one common unit as e.g. money. These new methods are a mighty tool for decision makers. The consequences of various decisions can now be looked over clearly in advance. However, in the end the decision makers, often the politicians, still have to assign weights to the various elements in their choice problem.

17. Another observation from the past is that often some natural disasters as flooding are the impulses for making the decision to perform the necessary works. These are the hard lessons from nature which are so lightly forgotten by mankind.

After all these conclusions some recommendations can now be formulated.

1. More land must be reclaimed, part of which will be in the form of polders. This is in order to cope with the growing demand for space to live and for the production of food and fibre.

2. Because of the long periods that usually elapse between the first initiative and the beginning of operation the necessary studies should start as early as possible. This may be right now.

3. Apart from the necessity to undertake polder projects for our near future needs it is also recommendable to undertake them right now in this period of economic depression as a contribution to the solution of the problem of unemployment.

There is still much work to be done.

Let us begin !

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