GOVERNMENT OF BANGLADESH   WORLD FOOD PROGRAMME   GOVERNMENT OF THE NETHERLANDS

CHAR DEVELOPMENT AND SETTLEMENT PROJECT II

চর উন্নয়ন ও বসতি স্থাপন প্রকল্প ২

BANGLADESH

Polder Design and Development

(Some Guidelines and References)

Technical Report No. 13

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CONTENTS

1. INTRODUCTION

In this report guidelines and references for *the initial stages* of polder development have been compiled, based on the experience gained within the LRP and CDSP projects. The objective is to get an overview of this knowledge and experience and to make this information accessible to other agencies involved in polder development. Hopefully it will contribute in this way to the on-going process of integrated coastal zone management in Bangladesh (ICZM).

Within the different stages of polder development, as suggested in CDSP Mission Report No. 25 – see text box below -, the main practical physical/ technical aspects of polder development are addressed. This concerns the desired land elevation, the size of the polder and major features of the embankments. In addition guidelines are proposed as to low embankments and the siltation of drainage outfall channels.

STAGE: Site selection, delineation and conceptual design

STAGE: Feasibility level design

STAGE: Environmental impact assessment

STAGE: Detailed design & Construction

STAGE: Institutional aspects

STAGE: Operation & Maintenance - (project) Monitoring & Evaluation

Main stages of polder development

This report builds further on that mission report. However, the resulting guidelines are certainly not all-encompassing and perfect; rather it is an attempt to gather all project results (reports) in the context of polder development, for the purpose of later reference. Hopefully, others, involved in different aspects of polder development than addressed in the present "version" will use the report as a framework for recording new insights and experience. This does not necessarily need to be limited to coastal polders in the southern Meghna Delta but may be extended to more upriver polders as well.

The starting-point for developing guidelines was formed by a preliminary CDSP study:

- CDSPII (2003); *Preliminary study on Polder Design Guidelines.* Technical Report by Md. Noajesh Ali, Sheltech Consultants (Pvt.) Ltd, January 2003;

This report describes the characteristics of the coastal char areas, embankment projects, and polders. A number of guidelines are presented regarding the elevation and size of polders and the alignment and safety of embankments. This, again, is based on many years' experience and current practice of BWDB. The essential points of this report are reflected in the present version of the manual.

The design practice in Bangladesh of water infrastructure is based on the Standard Design Manual of BWDB. The present technical report is obviously *not* an attempt to copy that manual, rather some aspects in earlier (prefeasibility level) stages of polder design are highlighted. The reference for the BWDB Standard Design Manual is:

- BWDB (1999?); *Standard Design Manual*. Standard Design Manual Committee, Bangladesh Water Development Board. Dhaka.

Two other documents on polder development can be mentioned here: the DDP Polder Design Manual and the Preparation Report on the CZWM Programme. The first-mentioned may be outdated on some points and is actually –the BWDB Manual alike - focusing on designers rather than on decision-makers involved in site identification. Nevertheless, its structure and scope are interesting to mention in the context of the matter at hand. The second report is relatively new and is basically a compilation of major projects (and experience) in the water sector in the coastal (waters) zone of Bangladesh. Their references are:

- DDP (1985); *Design Manual* for *Polders in South-West Bangladesh*. Delta Development Project, Bangladesh-Netherlands. Joint Programme under BWDB. Dhaka, November 1985.
- CERP-2 (2000); *Preparation Report for the Proposed Coastal Zone Water Management Programme*. Second Coastal Embankment Rehabilitation Project. Jaako Pöyry Consulting Oy in association with DHV Consultants, Mott MacDonald Group, Devconsultants, Techno Planners, House of Consultants Ltd and Desh Upodesh Ltd. Bangladesh, December 2000.

The outline or relevant parts of the above documents are presented in Appendix A to this report.

The guidelines in the present report focus on the first stage of polder development but partly cover other stages as well. Therefore, and because the many LRP and CDSP references do relate to other stages as well, the outline of the report includes – chapter wise – all six proposed stages of polder development. In this way most LRP and CDSP references could be related to this framework. Furthermore it forms a structured basis for later inputs by other specialists, to ultimately end up as a “complete” set of guidelines resulting from LRP and CDSP.

2. STAGE: SITE SELECTION, DELINEATION AND CONCEPTUAL DESIGN

Main aspects:

Physical environment (location, initial alineation)
Ecological environment
Topography
Geological/ tectonic conditions
Hydraulic and morphological conditions
Geohydrological and soil conditions
Fresh water supply potential
Drainage conditions
Socio-economic conditions
Principal dimensions of the embankment
Intake and outfall structures

2.1 Physical environment (location, initial alineation)

2.1.1 Guidelines

MATURITY OF NEW LAND

In general the decision to empolder coastal lands is taken after a considerable period of time of deltaic growth and natural rising of land, followed by the development of vegetation and the arrival of the first pioneering settlers. The physical environment these first inhabitants have to cope with is harsh and enables, if any, marginal outputs only. Typical threatening environmental factors are:

- frequent high tides and storm surges, sometimes a number of meters above normal tidal water levels;
- saline soils and groundwater;
- fresh water scarcity;
- extremely high wind velocities and intensive rainfall when tropical storms and cyclones cross the area.

Ideally the natural process of accretion and vegetation is not interrupted by premature human settlement. That is actually the reason that in Bangladesh chars emerging from the coastal waters are supposed to be controlled – for the first 20 years of existence – by the Ministry of Forestry to be handed over to the Ministry of Land after that period of time. However, in reality premature settlement often evolves, as soon some sort of marginal existence can be achieved by the pioneering (often hired) farmers.

- Regulation of mangrove cutting and social forestry is to be stimulated in that early stages of development.

DRAINAGE OF ADJACENT AGRICULTURAL AREAS

An important factor to take into account is the drainage of existing agricultural lands forming the land-side boundary of the envisaged polder area. This drainage may be accommodated by existing khals that are kept outside the new polder or, often partly, via the new polder area, crossing its embankments. In general the outside khals will silt up at an increasing rate because the natural tidal flows in the system will reduce due to the construction of the new polder. The table below summarises the options and consequences with respect to this drainage issue.

Drainage of adjacent lands	Consequences
Existing khals, outside the new polder	Increased siltation, water logging in the adjacent areas
New/ upgraded khals inside the new polder	Need of intake and outfall structures
New shortcut(s) to receiving water bodies	Land acquisition, siltation, salination and/or new outfall structure(s)

SET-BACK IN VIEW OF WAVE ATTACK

The river- or seaside boundaries of a polder are exposed to tidal and flood water levels. In addition, wave attack on the fringes of the empoldered area may be a factor of importance. The latter has implications for the position of the embankment: when propagating over the foreshore waves dampen resulting in a reduced wave impact on the embankment. This is one of the reasons to apply a certain set-back, i.e. a distance between the shoreline and the embankment.

How much this set-back should be depends on the wave conditions: the longer the (design) wave period, the larger set-back is required. For example, with a water depth of 5 m on the foreshore and a design wave period of 6 s, the wave length on the foreshore is about 40m.

- It is recommended to adopt a value of about 5 times the wave length for the length of the foreshore, i.e. 5x40=200 m in the above case.

The waves move then over a sufficiently wide foreshore, will adapt to the decreasing water depth and will reduce in wave height. If deeper channels are situated close by the shoreline (a steep foreshore), it is certainly important to apply the above set-back.

The maximum wave height on the foreshore is depth-limited and will be of the order of 0.5 times the water depth, thus about 2.5 m in the above example.

If data on local hydraulic conditions would be available, the above conservative approach could be optimised. However, this is generally not the case, and as a guideline

- a depth-limited wave height can be taken as the design wave height, i.e. the maximum unbroken wave height on the foreshore of the embankment (see the above example).

MANGROVE BELTS TO REDUCE WAVE ATTACK

In order to enhance the above attenuation of waves propagating over the foreshore towards the embankment, mangrove forests should be maintained (sometimes called “herbal protection”). Especially at more moderate storms than design conditions – with lower water levels – the mangrove will be helpful in reducing erosion and scour at the toe of the embankment. Also the wave run-up and overtopping of the crest of the embankment will be reduced by the effect of a mangrove belt. As indicated above, during the stage prior to settlement and empoldering, the chars are under responsibility of the Ministry of Forests. A mangrove fringe bounding the polder should be maintained where possible during the subsequent stages of development, especially because of the absence of any other shore protection works.

- If no mangrove exists it should be planted, on the foreshore of the embankment. In the case that accretion of new land will continue seaward of the polder, an initial mangrove fringe of about 200 to 500 m is considered to be sufficient. At a stable coast a width of 500 m at minimum is recommended.

If shoreline tends to erode, from past experiences plantation of mangrove appears not to be viable. Mangrove will cause the waves to attenuate when propagating over the foreshore, however it will not halt erosive forces driven by large scale morphodynamics.

SET-BACK IN VIEW OF MORPHOLOGY AND SHORELINE EROSION

A set-back of the embankment is also required if the shoreline at the riverside of the polder is retreating. This set-back should be based on

- the morphological dynamics of the adjacent river or coastal area;
- the lifetime of the embankment;
- possible revetment of the outer slope and the toe of the embankment.

The prediction of the future position of the shoreline should be based on a thorough analysis of historical positions of the shoreline. The Standard Design Manual of BWDB recommends adopting a set back that allows for a 10-year period of erosion. Whatever set back is chosen, the increasing cost of repair or even partly reconstruction of the embankment should be included in the cost-benefit analysis of the structure if the retreating shoreline is assumed to reach the structure within the economic lifetime of the embankment.

- Conclusively speaking, no fixed standard for this set-back can be put forward; the agricultural benefits missed due to a more landward position of the embankment should be balanced against the higher cost – investment and maintenance - of a more seaward location. In addition to such cost-benefit considerations the safety of the inhabitants of the polder should be taken into account.

SIZE OF POLDER

The size of the area to be empoldered is usually not free to choose. Rather, geographical and topographical conditions and administrative boundaries determine the area that can be empoldered. Nevertheless, there are some guidelines that can help to decide on the size and shape of a polder.

First of all the delineation of the water catchment area should be considered. This forms the basic guideline for the determination of the size of the polder. In general it is recommendable to include as a first option the whole catchment in the polder.

The economic feasibility of the polder depends on the balance between increased income on the one hand (improved conditions for agriculture) and cost of investment, maintenance and operation of the water infrastructure on the other hand. A favourable (=large) ratio of polder size vs. embankment length will be more economical. This consideration supports large polders with a large area vs. perimeter ratio.

In a later stage of development, when the economic value of the polder has increased significantly, it may be considered to compartmentalise the polder area to reduce the flood risk.

Flooding of small polders will induce less damage but the flooding may be more violent because of the relative small basin and quick filling up in case of a breach of the primary embankment. In large polders the flood will spread out and attenuate because of the large distances along which the floodwater will propagate. Social disruption, loss of life, and other immaterial damages caused by more violent flooding may be another factor to support larger polders.

Another aspect to consider is the fresh water supply. Smaller polders will partly need to rely on fresh water supply from outside because the storage capacity inside the polder is relatively small. The boundaries of small polders will likely intersect the relevant catchment areas and intake structures for fresh water are needed. On the contrary, large polders can accommodate for larger storage areas and do not rely that much on fresh water supply from outside.

Water management in large polders tends to be more complicated because i) the longer drainage (and possibly irrigation) distances and ii) because there is a larger variety in stakeholders in the same polder, putting different demands on the water system. This advocates for polders that are more uniform as to the interests of its inhabitants.

- On the basis of the above considerations the initial areas to be empoldered should cover the whole catchment of the area, within the constraints brought about by land levels and geographical, topographical and administrative conditions. In later stages of development with increased agricultural production compartmentalisation of the polder (and reconsideration of desired safety levels!) may become feasible.

2.1.2 References

GENERAL	NOAKHALI	CHAR BHATIRTEK
CHAR MAJID	SOUTH HATIYA	SOUTH BHOLA
MUHURI		

2.2 Ecological environment

2.2.1 Guidelines

A first identification of the ecological characteristics of the area to be empoldered should be carried out. This will be in terms of a description of the habitats, types, diversity and quantity and viability of the flora and fauna species in the area. Attention should be paid to the autonomous development of the ecosystem - the predicted development without the interference by the envisaged project. First existing information and data should be collected. Next field surveys are needed to complete this first initial inventory.

Based on this initial inventory the outline can be drawn up of a survey programme under the more formal EIA procedure (Environmental Impact Assessment) at a later stage of the polder development.

- The migration potential of the ecosystem that will virtually disappear due to the polder construction needs to be evaluated.

If, for example, a similar ecosystem is likely to develop in the coastal fringe adjacent to the new polder – due to further accretion and development of new chars – then the negative effects of the empoldering will be (partly) compensated by these changes outside the polder.

2.2.2 References

GENERAL	SANDWIP – NOAKHALI CROSSDAM	

2.3 Topography

2.3.1 Guidelines

A most important factor for the decision to empolder is the land level. There is a number of guidelines in this respect. It is generally understood that, in tide-dominated areas, land accretion slows down to almost zero at reached land levels of about Mean High Water in the monsoon season (MHW_mons). At this level it is possible to start crop production. Therefore, MHW_mons can be taken as a sensible guideline for the start of empoldering.

The required land level for empoldering is primarily related to water levels and not to PWD. For different areas different PWD heights will apply for empoldering because tidal water levels (such as Mean Sea Level, Mean High Water, Mean High Water Spring, etc.) vary across the area. Therefore, a rule of thumb like "empoldering should be started not before a land level of PWD + 3m" is dangerous because PWD + 3m can be above Mean High Water Spring in the one place and well below this level in another place. On top of that there is a significant seasonal variation of the water levels in the Lower Meghna Estuary with approximately 0.75 to 1.5 m higher sea levels in the monsoon.

The implication of the above is that tidal water levels should be known in the area of empoldering. This is achieved by collecting water levels and, if possible, by connecting the tidal gauges in the project area to a nearby established tidal station such as a BIWTA tidal gauge. By combining the local tidal observations and the long-term data of the nearest tidal station, the required tidal levels such as MHW_mons can be assessed. It is also possible to carry out harmonic analysis of local tidal measurements covering a period of for example 15 days to assess the relevant tidal constituents and the value of MHW_mons. Standard software is available for that purpose.

The determination of the precise – and absolute - elevation of an area of land as such is complicated. Land levelling data are subject to the following potential variations and errors:

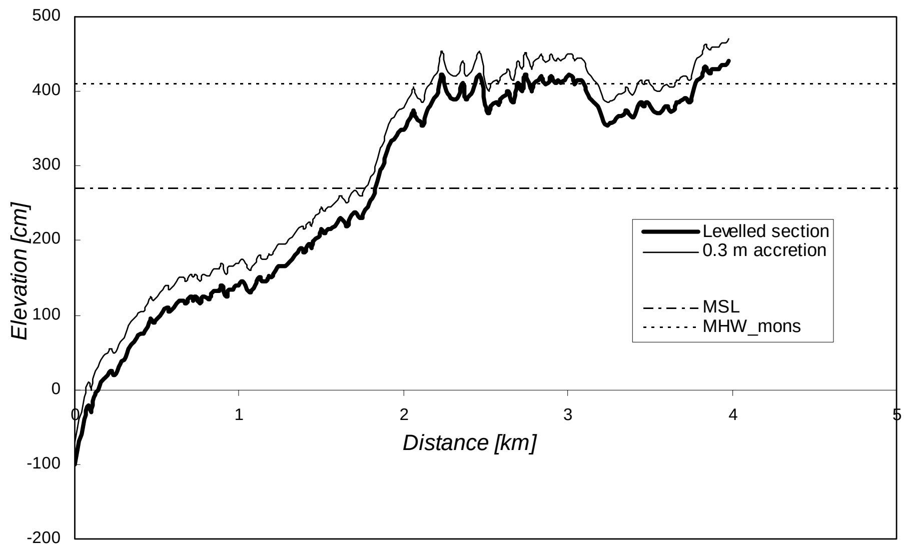
- systematic, instrument-bound, errors
- (human) reading, writing and storing errors
- variations in the exact location of measurements when repeating levelling surveys periodically
- sampling space, i.e. the space between the measurements in a trajectory

Execution of levelling surveys, the related processing of data and controlling the above errors and variations require the skills of geodetic professionals. However, agencies responsible for empoldering land should be aware of the reliability of levelling data and possible variations, both in time and space. Ultimately the question they have to answer is when to start with empoldering.

As mentioned before the monsoon Mean High Water level (MHW_mons) can be taken as the land level mark to start empoldering. Natural rising of land above this level will virtually not take place. However, the actual land profiles should be considered carefully. If there is only a small ridge at MHW_mons height along the outer fringe of a char with large depressions well below MHW_mons inside, empoldering would be premature. If scattered smaller depressions exist, covering - say, not more than 20% - of the area considered, then empoldering may be taken up certainly.

The picture below shows an example of two surveyed trajectories on the same place, with the second one after an additional 30 cm of uniformly distributed siltation. Mean Sea Level (MSL) is assumed at +2.7m PWD and the monsoon Mean High Water tide at +4.1m PWD.

If an embankment is constructed at distance 2.2 km on a land level of about +3.9m PWD, about 60% of the area landward of the embankment is still below MHW_mons. After another 30 cm of natural land accretion this is reduced to about 20 % which may be considered as a sufficient small area of lower levels to take up empoldering.



If the accretion of the envisaged polder areas tends to develop more or less uniformly across the area, it may be considered to mark representative areas of accretion in the field and to monitor the elevation of such areas. A grid of spot height measuring points of well-defined positions should be attached to these accretion areas in order to monitor the rates of accretion in the same points during the years of monitoring. The number of spot heights will determine the reliability of the resulting elevation (the variance of the resulting average height in the accretion area equals the standard deviation of each single measurement divided by the square root of the number of sampling points). Thus a measuring grid of a hundred points will reduce the standard deviation of single heights with a factor 10. Such a procedure is not common practice and not necessary when a topographical survey is (regularly) carried out covering the whole area. Local terrain height fluctuations are then averaged out because of the large number of spot heights.

In conclusion,

- PWD starting levels for empoldering depend on the location because tidal levels vary across the areas;
- a guideline for the start of empoldering is MHW_mons;
- careful consideration of the topography is required; and
- it is recommended that at least 80% of the area to be empoldered has reached MHW_mons level.

2.3.2 References

GENERAL	CHAR BAGGARDONA	CHAR MAJID
CHAR BHATIRTEK	MUHURI ACCRETED AREA	SOUTH HATIYA
BANDARTILA	MORA DONA	GANGCHIL-TORABALI
SANDWIP – NOAKHALI CROSSDAM		

2.4 Geological/ tectonic conditions

2.4.1 Guidelines

The Lower Meghna Delta area is not subject to frequent earthquakes. Bangladesh has been distributed in three seismic zones, with the Lower Meghna Delta situated in Zone I, which is the zone of weakest seismic activity. There have been a number of recent earthquakes along the Chittagong coast that have been smaller than 4 on the Richter scale (the Chittagong coast is situated in Zone II).

In the course of time, land levels in empoldered areas will drop with respect to sea-level because of

- Subsidence
- Settlement of upper layers
- Climate induced sea-level rise

The natural delta system responds to these phenomena by increasing rates of siltation and land accretion. However, empoldered areas are isolated from such accretion mechanisms and will lag behind.

Annual subsidence rates are estimated at 2 to 3 mm in the northern part of the Meghna Estuary and 4 to 6 mm in the southern part. A guideline is to account for subsidence of the above rate when considering the lifetime of the polder. For example, when considering a period of 100 years, land elevation will be reduced by about 0.5 m due to subsidence in the southern parts of the delta.

In addition climate-induced sea-level rise may contribute. Although the progress in knowledge is leading to varying scientific predictions of sea-level rise, a climate-induced sea-level rise of 5 to 10 mm per year could be adopted as scenario. Adding geological subsidence

- a rate of 1 to 1.5 m per century can be adopted as scenario for the sea-level rise relative to empoldered areas.

2.4.2 References

No references are available in CDSP library. The Banglapedia internet site is given under “general”.

GENERAL		

2.5 Hydraulic and morphological conditions

2.5.1 Guidelines

There is a vast amount of knowledge and data about the hydraulic and morphological conditions of the Lower Meghna Estuary. The Meghna Estuary Study (MES) project is the most recent project aimed to analyse and map these conditions. For the preliminary design of empoldering projects tidal water levels, extreme storm surge levels, future changes of water level, wind and wave conditions and future morphological changes are the most important. These quantities form the seaward boundary conditions of the polder to be developed and knowledge thereof is needed for the alignment and the design of embankments and other flood control structures.

There are standard criteria for crest levels of embankments, depending on the type of embankment. These are dealt with under “Principal dimensions of the embankment“.

Tidal water level data are also required for the design of the drainage system of the polder because of the influence on the discharge capacity of drainage outlet structures and channels (see “Drainage conditions“ and “Intake and outfall structures“).

In addition it is important to collect data on salinity. Surface water salinity is important for possible intake of water into the polder. Groundwater and soil salinity are important to determine the agricultural production potentials.

In general hydraulic conditions should be presented in terms of characteristic quantities on the basis of measured data. These are as follows:

water level:
- high and low waters for neap, mean and spring tide
- representative tidal curves (spring, mean, neap) for drainage simulation computations
- extreme storm surge levels with probabilities of occurrence (return periods)

waves
- significant wave heights, wave periods and directions with probabilities of occurrence (return periods)
- nearshore wave conditions

wind
- wind data (frequencies of wind forces, direction and duration) to determine wind set-up and waves

morphology
- accretion and/ or erosion trends in the area of the polder
- position of shorelines and changes thereof.

salinity
- salinity of surface water, ground water and soil

Under the CDSP project a monitoring programme has been carried out to record the most important physical quantities in the various project areas. Three themes of data relevant to polder development projects can be identified from the programme:

a) water levels
b) salinity
c) siltation

Ad a) water levels.
In the project areas long times-series data are scarce. Within the framework of the feasibility study for Baggardona area long term water level recordings at Hatiya were used. This resulted in the following return periods of extreme levels (95% interval of reliability):

Return period	**Water level between**	**and**
1 year	3.2	3.7 m PWD
2	4.1	4.3
5	4.3	4.6
10	4.5	4.8
25	4.6	5.0
50	4.6	5.1
100	4.7	5.2

Within CDSP daily water level observations are taken in 9 stations, beginning in 1997: Char Baggar Dona I and II, Char Majid, Char Bhatirtek, Bamni, Bhuierhat (Steamerghat), Muhuri, South Hatiya and Nijhum Dwip. For three polders some results are presented below.

CHAR MAJID
Monsoon: for Char Majid Polder the high water levels outside the polder reach values of approximately 3.5 m PWD (at spring tide) and 2 to 2.75 m (at neap tide). In general the ground water level, measured in piezometric tubes, are about 0.25 m higher during this part of the year.

Dry season: water levels outside the polder are about 1.5 m lower, as compared to the monsoon. Ground water levels drop then to 0.5 to 1.5 m PWD. In this period the drainage khal outside the sluice often dries up. In order to prevent siltation of the drainage channel as much as possible, a crossdam is (can be) constructed at the outer end of the outfall channel (see also Operation & maintenance).

CHAR BAGGAR DONNA
Monsoon: high water levels outside the polder reach values of approximately 4.75 m PWD (at spring tide) and 3 m (at neap tide). In general ground water levels are about 0,5 to 1 m higher during this part of the year.

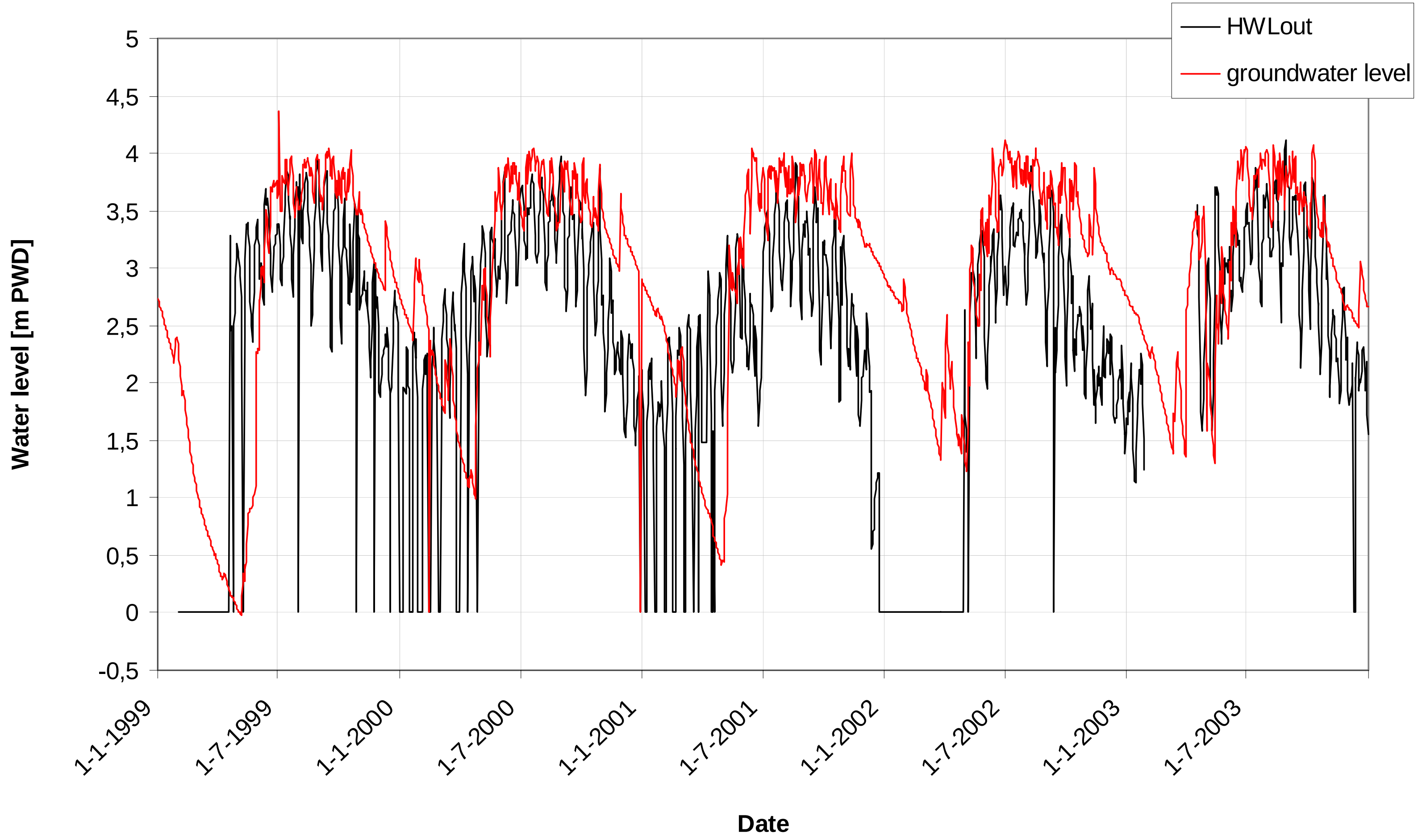
Dry season: water levels outside the polder are about 1.5 m lower, as compared to the monsoon. Ground water levels drop then to 0 to 1 m PWD.

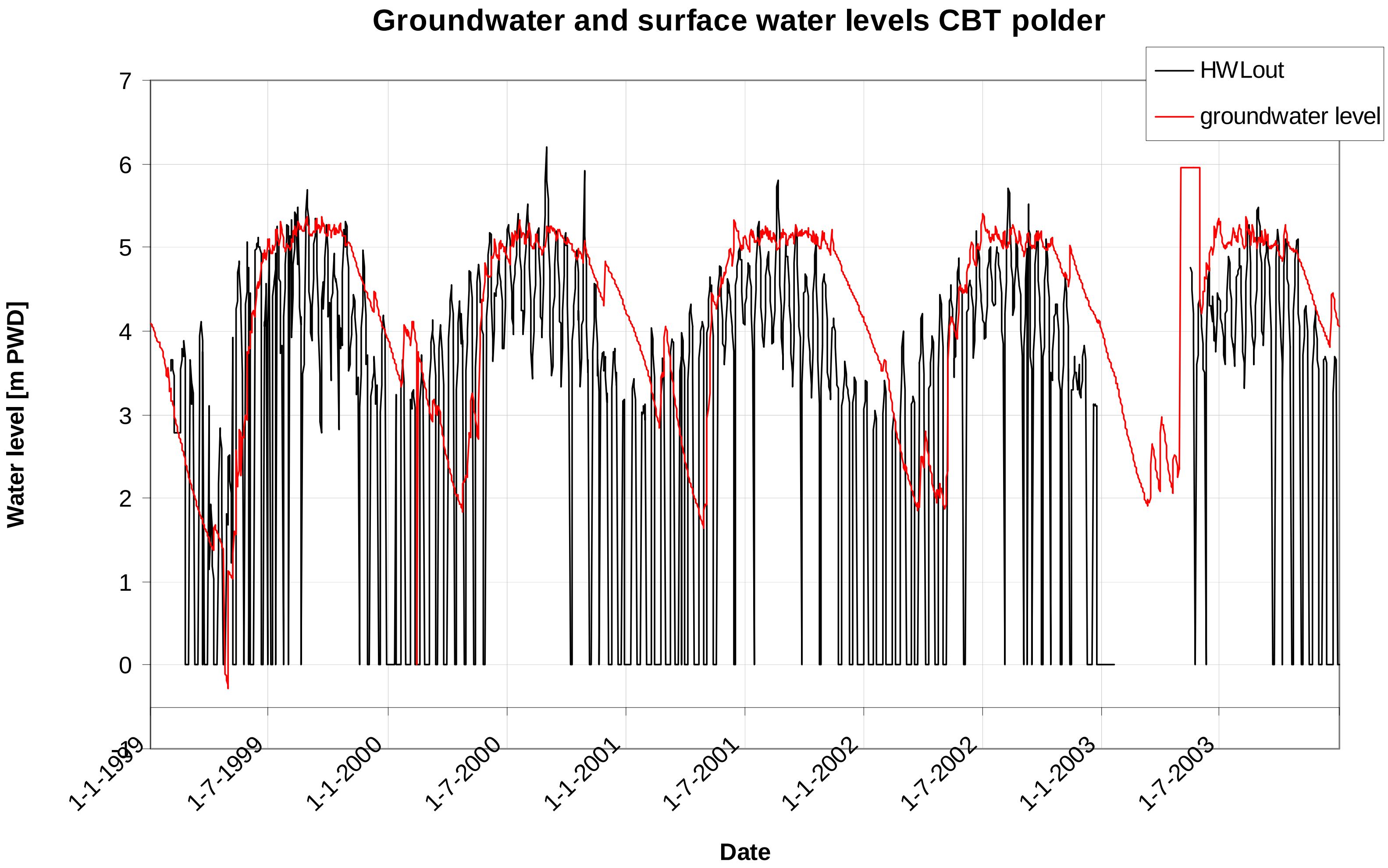
CHAR BATIR TEK
Monsoon: high water levels outside the polder reach values of approximately 5 m PWD (at spring tide) and 4 m (at neap tide). In general ground water levels are about 5 m PWD, more or less the same as the spring tide levels outside the sluice.

Dry season: water levels outside the polder are again about 1.5 m lower, as compared to the monsoon. Ground water levels drop then to about 2 m PWD.

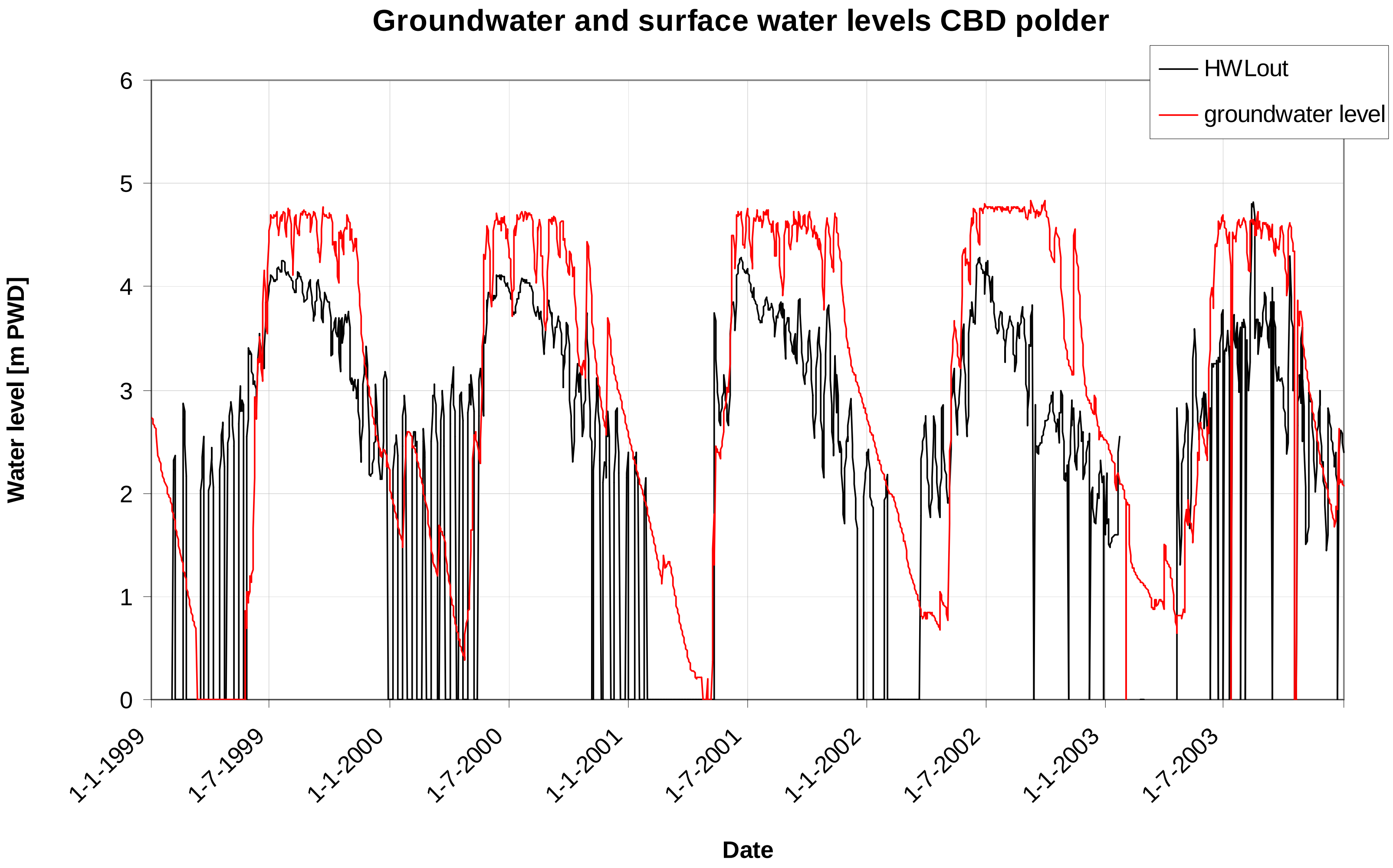
The figures below show the above recordings. It should be realised that dry season data are often absent or unreliable because the khals are frequently drying up then. In the figures the high water levels outside the sluice are indicated by HWLout.

Groundwater and surface water levels CM polder





Groundwater and surface water levels CBT polder
HWLout
groundwater level
Water level [m PWD]
7
6
5
4
3
2
1
0
1-1-1999
1-7-1999
1-1-2000
1-7-2000
1-1-2001
1-7-2001
1-1-2002
1-7-2002
1-1-2003
1-7-2003
Date


Groundwater and surface water levels CBD polder
HWLout
groundwater level
Water level [m PWD]
0
1
2
3
4
5
6
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1-7-1999
1-1-2000
1-7-2000
1-1-2001
1-7-2001
1-1-2002
1-7-2002
1-1-2003
1-7-2003
Date

Ad b) Salinity

Salinity of the waters outside the polders varies with the seasons: maximum values are reached in the pre-monsoon (April, May) and vary between 20 and 30 mS/cm (12-19 ppt) which is more or less equal to sea water salinity. It seems that at Char Batik Tek such levels are reached earlier than at Char Baggar Dona and Char Majid. There the peak levels are observed in the period October - January. This is understandable because the major upland fresh water flow passes the receiving waters of this polder.

The value of 2 mS/cm, which is critical for irrigation purpose is mostly reached in October or November. However, sometimes is this earlier (Char Batik Tek, September), sometimes later (Char Baggar Dona, December).

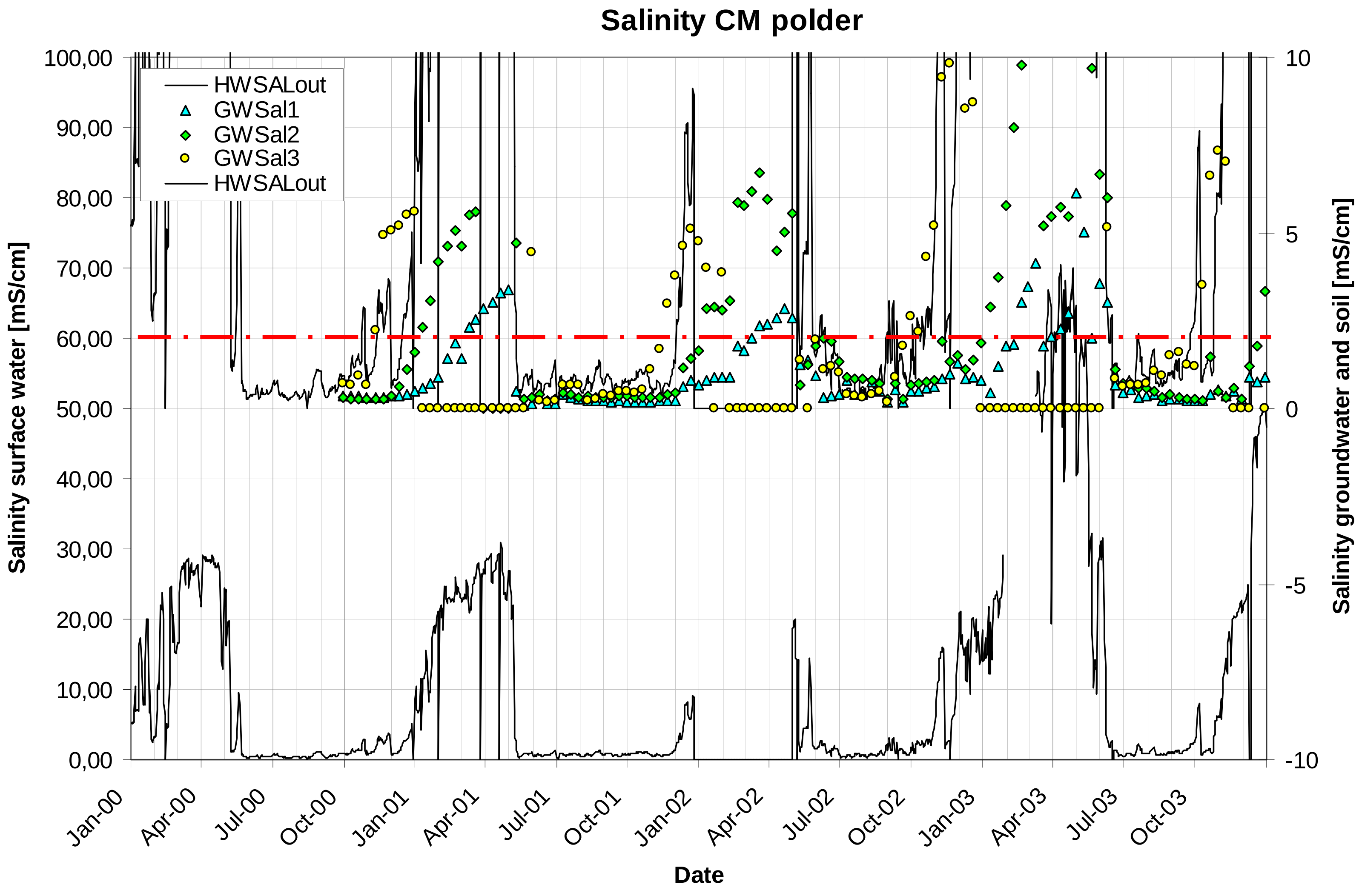
Inside the polder the salinity of the water in the khal is close to zero in the monsoon and increases in the dry season to measured values of 10 to 30 mS/cm in Char Majid and 10 mS/cm in Char Baggar Dona and Char Batir Trek. It is noted that by that time the khals contain little water. Therefore, evaporation certainly contributes to the measured high rates of salinity.

Groundwater salinity is measured in three piezometric tubes (mostly 5, 3 and 1.5 m in length) at some distance from the drainage sluices: Char Majid about 1.5 km, Char Baggar Dona about 2.5 km and Char Batir Tek about 3 km.

Groundwater salinity levels are close to zero throughout the dry season. They start to rise in the period October – January. Peak levels are of the order of 2 mS/cm (Char Baggar Dona 2 to 3; Char Batir Tek below 2). In Char Majid some more variation occurs in peak levels: the 3 m piezometric tube shows peak values of about 4 mS/cm, reached in May, the 2 m long tube peak values of 6 mS/cm and the shortest 1.5 m tube values from 5 to over 10 mS/cm across the 4 years monitoring period.

The plots below depict the observed values. On the bottom part the outside salinity is plotted against the left axis. The upper part of the figure shows again the outside salinity levels, plotted against the (up scaled) right axis. The critical level for intake water (2 mS/cm) is indicated by the horizontal red (dashed) line. Here groundwater salinities have been added.

- when planning salinity measurements of the waters outside regulator sluices, care should be taken to sample in the tidal water which is not always near the sluice. With a cross dam in the drainage outfall channel, the enclosed water is subject to evaporation, resulting in continually increasing levels of salinity. This explains most likely unrealistic high values of the salinity outside the sluices.
- Possible intake for agricultural purposes – which is not common practice – should be realized before it has reached salinity levels of about 2 mS/cm.


Salinity CM polder
Salinity surface water [mS/cm]
Salinity groundwater and soil [mS/cm]
HWSALout
GWSal1
GWSal2
GWSal3
HWSALout
100,00
90,00
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
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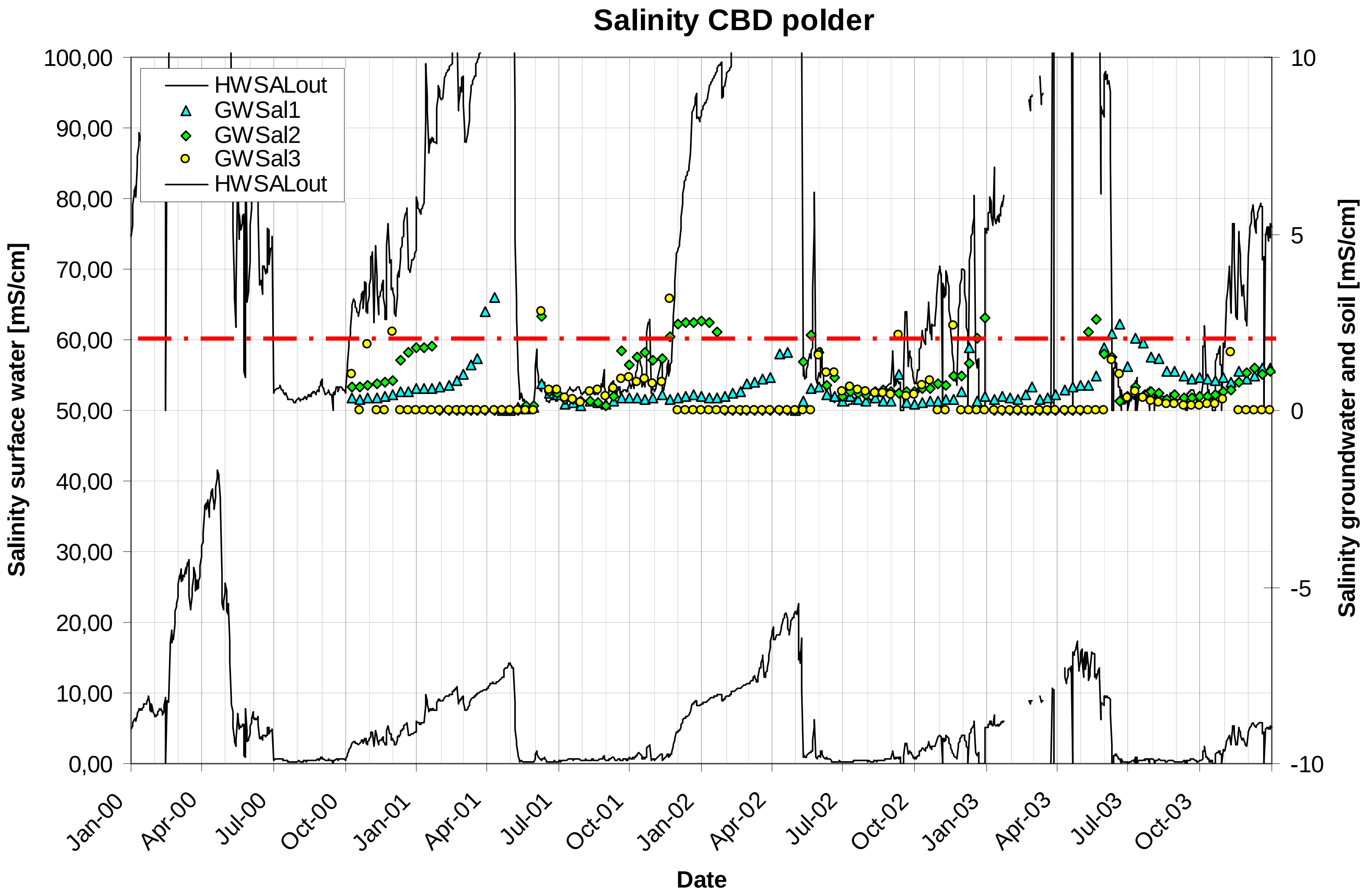
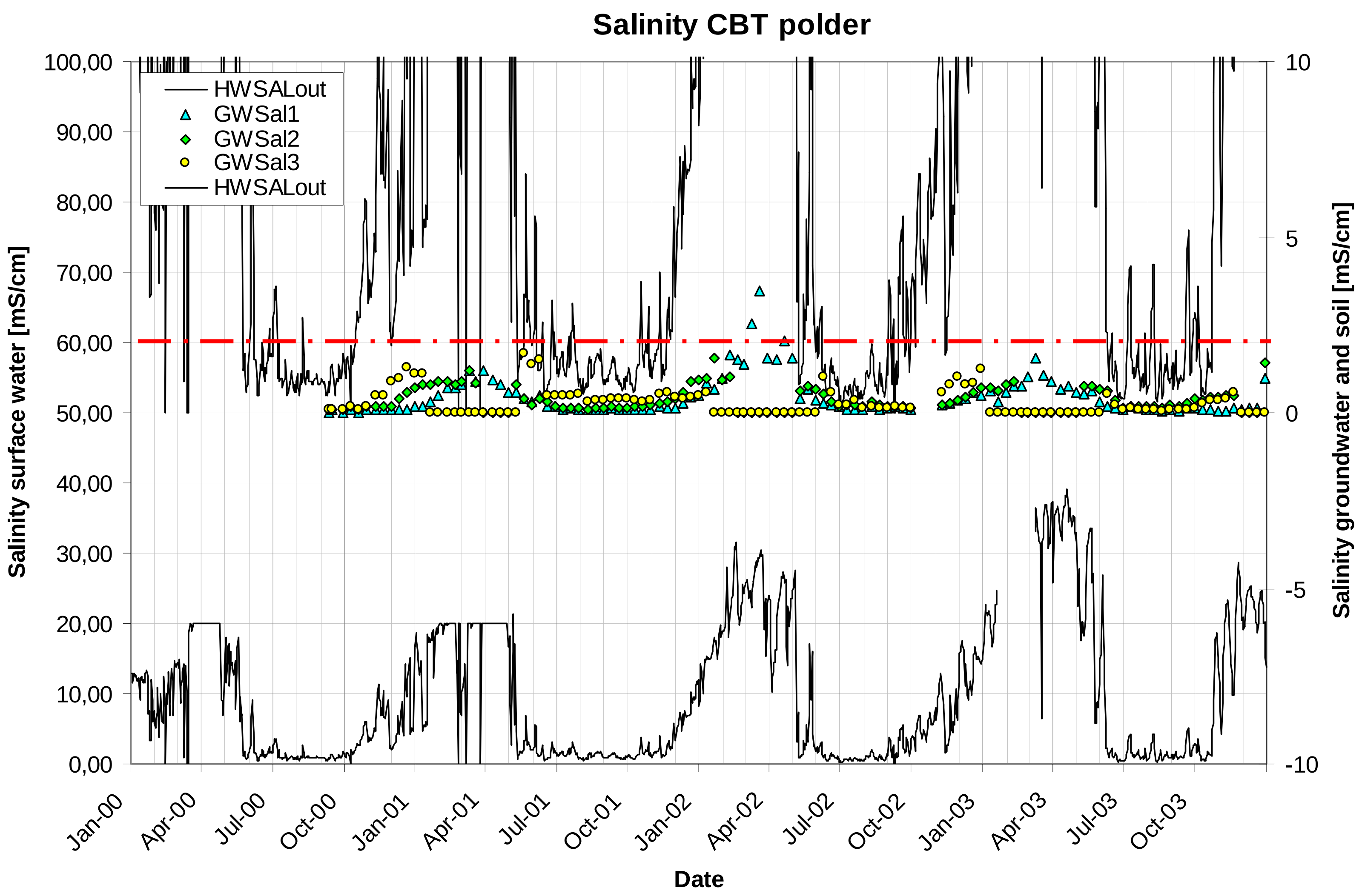

Salinity CBD polder
HWSALout
GWSal1
GWSal2
GWSal3
HWSALout
100,00
90,00
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
0,00
10
5
0
-5
-10
Salinity surface water [mS/cm]
Salinity groundwater and soil [mS/cm]
Jan-00
Apr-00
Jul-00
Oct-00
Jan-01
Apr-01
Jul-01
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Date



Salinity CBT polder
HWSALout
GWSal1
GWSal2
GWSal3
HWSALout
Salinity surface water [mS/cm]
Salinity groundwater and soil [mS/cm]
Date
100,00
90,00
80,00
70,00
60,00
50,00
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Oct-02
Jan-03
Apr-03
Jul-03
Oct-03

Ad c) Siltation
Siltation is a well-known problem in drainage outfalls, mostly occurring in the dry season when the gates are closed. Detailed monitoring of siltation of the Bashkali Khal – the drainage outfall channel of Char Majid – has been undertaken in 1999/ 2000. However, rates of siltation vary strongly and depend on the location. The construction of temporary cross-bunds to prevent siltation is discussed in many reports and put in this report under Operation & maintenance.

2.5.2 References

GENERAL	WATER LEVELS	FLOW DATA
SEDIMENT LOAD AND SALINITY	MORPHOLOGY	

2.6 Geohydrological and soil conditions

2.6.1 Guidelines

Future soil salinity is a most important aspect as it poses an important agricultural constraint. It is not possible to precisely predict the rate of desalinisation after empoldering. Roughly speaking the development of soil salinity will depend on three mechanisms, i) deep drainage of saline ground water to the drainage basin, ii) leaching of the upper soil due to rainfall, and iii) resalinisation due to capillary rise in the upper soil (stimulated by evaporation and evapotranspiration) and flooding by saline water.

Deep natural groundwater drainage has reportedly been overestimated in the past. The deep drainage flow may even be reversed in the dry season if the groundwater table is below the drainage base. Shallow groundwater drainage is also not a factor of importance because of the very scarce drainage facilities. Surface drainage is limited to periods of excessive rainfall and most likely not important for salt removal.

However, leaching of topsoils in char areas contributes substantially to desalination. The downward flux of fresh monsoon rainwater, and upward capillary rise prevailing in the dry season, causes a cyclic, seasonal up and down movement of the shallow ground water table. All in all the main factors for slow or insufficient desalinisation are

- limited gradient of ground water to the shallow drainage base; and
- high evaporation and strong capillary rise, causing a drop in the groundwater level and possibly a reversal of the deep drainage.

Therefore, first of all it is recommended

- to take up empoldering with land levels as high as possible (see “Topography“).
- Secondly, working the upper soils and ploughing as soon as possible in the post-monsoon

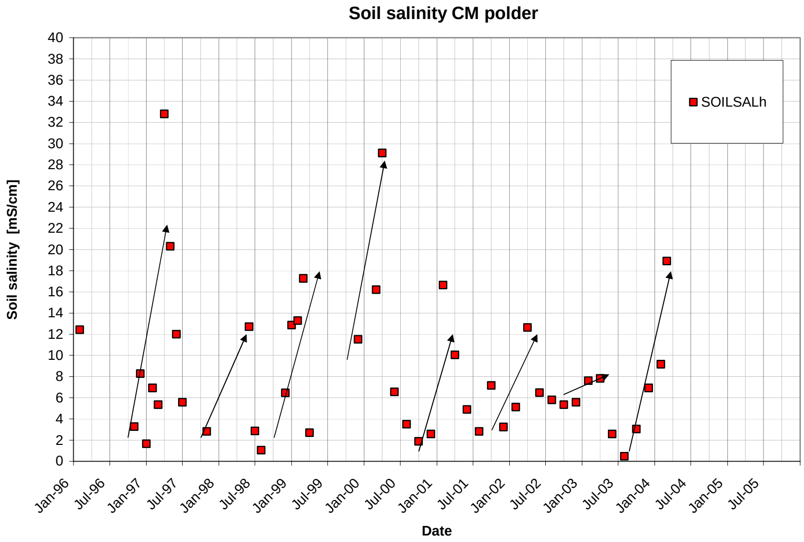
will isolate the top soil from the layers beneath and forming a blockade against capillary rise in the subsequent dry period.

It is often observed that the farmers themselves do adopt the best practice of farming to reduce resalinisation to the extent possible, either deliberately or intuitively.

It is recommended to collect existing information and to map the geohydrological and soil conditions in order to analyse the desalinisation potential of the envisaged areas. This can be done by comparative analysis, using data on desalinisation of similar areas.

The CDSP polders start to show a stabilisation of the soil salinity. Since the measurements of 1996 no significant overall reduction of soil salinities seems to appear and the pattern of strongly increasing salinity levels during the dry season and lowered values in the monsoon do persist throughout the various polders albeit to a different extent. Char Baggar Dona shows a more mild regime compared to Char Majid and Char Batir Tek.

However, linear trend lines through the various the data series show in most cases a small decline. The pictures below show the sample measuring series for the Char Majid, Char Baggar Dona and Char Batir Tek polders. First a series of plots with one single category of soil salinity data is shown (the “high“ series of samples - SOILSALh).The strong increase in the (yellow) dry season is high-lighted by the arrows. The second series of plots shows all the data (“low”, “medium” and “high” samples – resp. SOILSALl, SOILSALm and SOILSALh) with the trend lines added. Full details are written up in the relevant CDSP reports on agriculture.


Soil salinity CM polder
Soil salinity [mS/cm]
Date
SOILSALh
Jan-96
Jul-96
Jan-97
Jul-97
Jan-98
Jul-98
Jan-99
Jul-99
Jan-00
Jul-00
Jan-01
Jul-01
Jan-02
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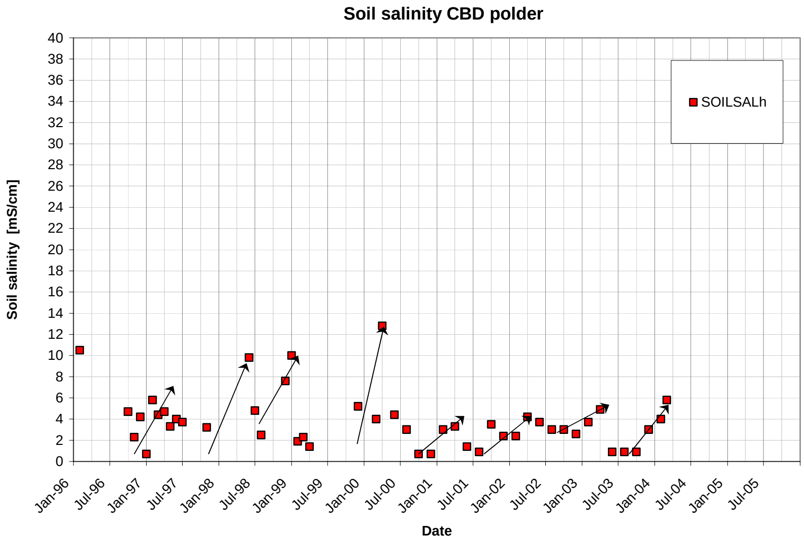
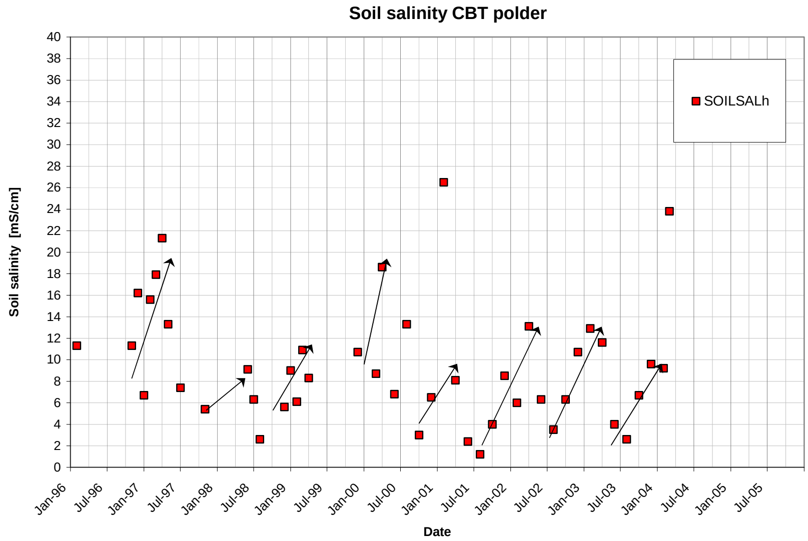
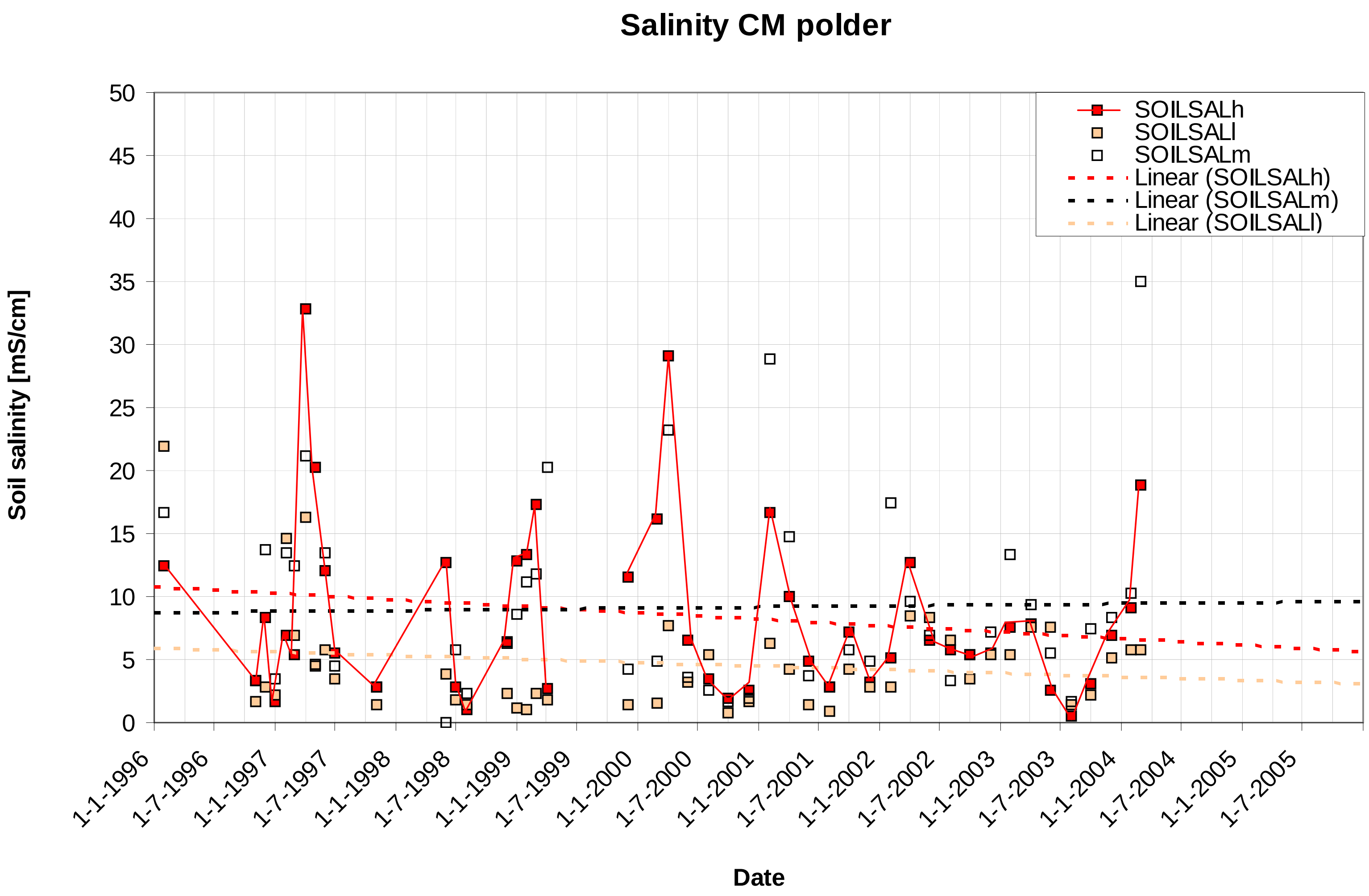
Jul-04
Jan-05
Jul-05


Soil salinity CBD polder
Soil salinity [mS/cm]
Date
SOILSALh


Soil salinity CBT polder
Soil salinity [mS/cm]
Date
SOILSALh


Salinity CM polder
Soil salinity [mS/cm]
50
45
40
35
30
25
20
15
10
5
0
SOILSALh
SOILSALl
SOILSALm
Linear (SOILSALh)
Linear (SOILSALm)
Linear (SOILSALl)
1-1-1996
1-7-1996
1-1-1997
1-7-1997
1-1-1998
1-7-1998
1-1-1999
1-7-1999
1-1-2000
1-7-2000
1-1-2001
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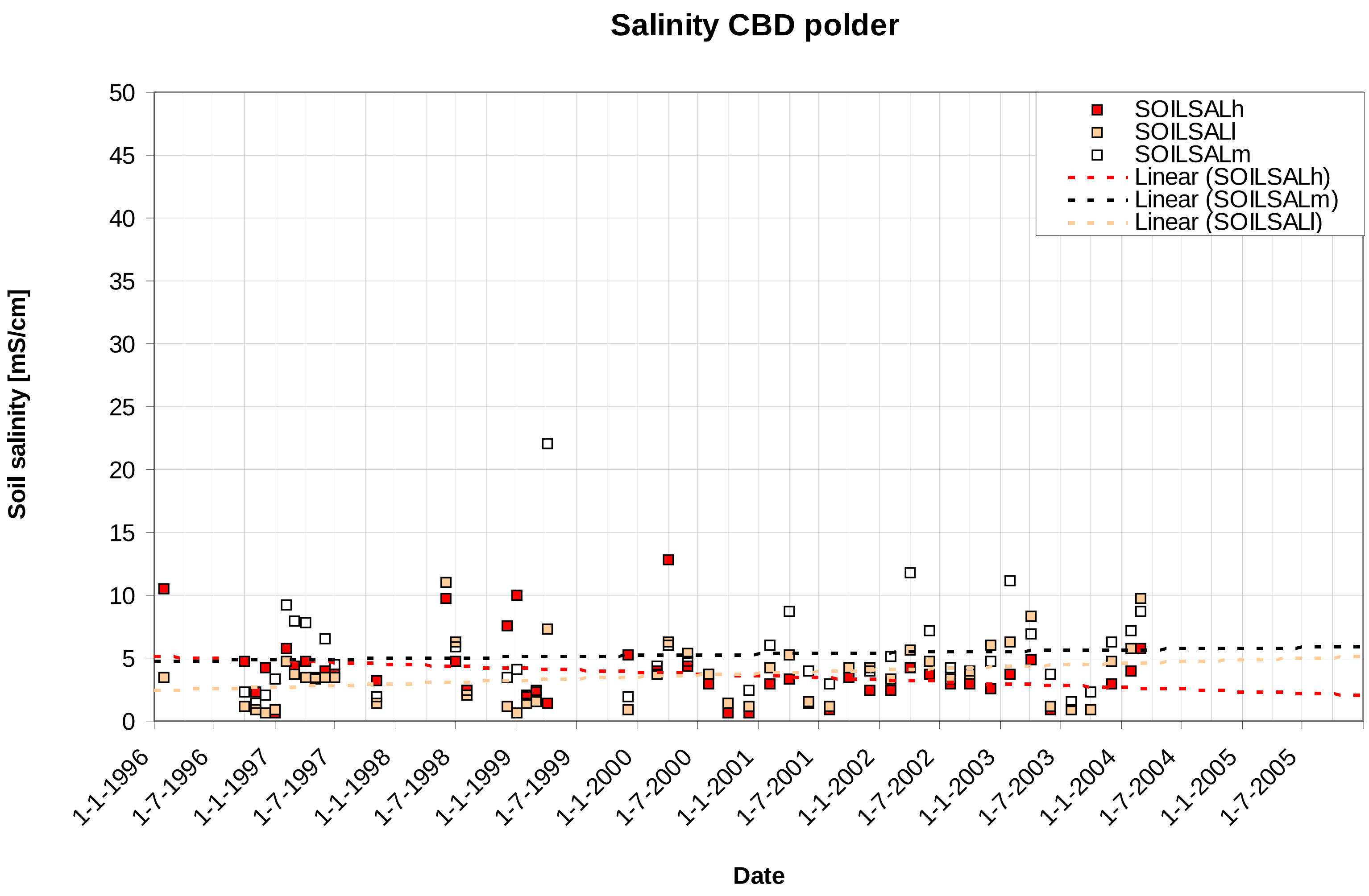
1-1-2005
1-7-2005
Date


Salinity CBD polder
Soil salinity [mS/cm]
50
45
40
35
30
25
20
15
10
5
0
1-1-1996
1-7-1996
1-1-1997
1-7-1997
1-1-1998
1-7-1998
1-1-1999
1-7-1999
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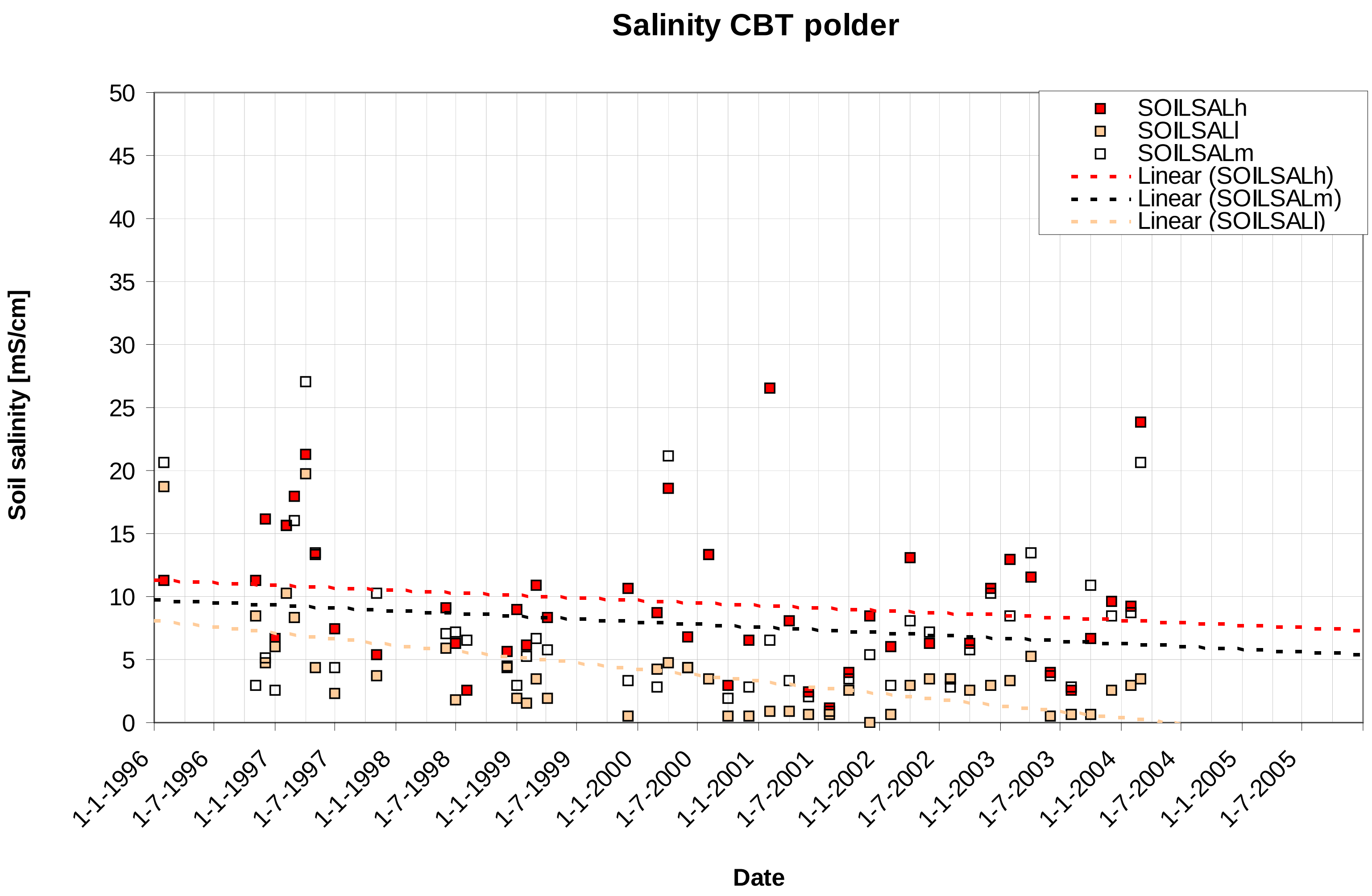
1-1-2002
1-7-2002
1-1-2003
1-7-2003
1-1-2004
1-7-2004
1-1-2005
1-7-2005
Date
SOILSALh
SOILSALl
SOILSALm
Linear (SOILSALh)
Linear (SOILSALm)
Linear (SOILSALl)



Salinity CBT polder
Soil salinity [mS/cm]
Date
SOILSALh
SOILSALl
SOILSALm
Linear (SOILSALh)
Linear (SOILSALm)
Linear (SOILSALl)
50
45
40
35
30
25
20
15
10
5
0
1-1-1996
1-7-1996
1-1-1997
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1-1-2002
1-7-2002
1-1-2003
1-7-2003
1-1-2004
1-7-2004
1-1-2005
1-7-2005

2.6.2 References

General	Char Baggar Dona	Sudharam Upazila

2.7 Fresh water supply potential

2.7.1 Guidelines

At this stage, potential sources of fresh water should be analysed. Information and data on ground water resources should be collected from adjacent and comparative areas, in addition to data from the envisaged polder area itself.

- In general, large scale groundwater extraction from aquifers within 200 m from the ground level does not seem feasible, because of the small number of potential locations and the quality of the groundwater. This has appeared from earlier studies.
- The installation of deep tube wells may be possible, although the economic feasibility has not been assessed yet. Environmental risks (subsidence, saline water intrusion) are to be incorporated in such an assessment.

It is important to determine whether irrigation water will be needed to enter the future polder via intake structures. (see also “Physical environment (location, initial alineation)”).

- In coastal areas it may be considered to take in tidal water in the post-monsoon, when there is already some scarcity of fresh water. This could be done in October at the latest (see “Hydraulic and morphological conditions”). Potential storage of fresh water in the polder may be enhanced by enlarging the khals. Guidelines on the structural adaptations of existing drainage sluices can be found in Water infrastructure & water management.

Fresh water ponds are wide-spread in the coastal communities. Analysis of the water use from such ponds indicate unaccounted water losses, possibly due to leakage and seepage to the subsoil.

- Therefore cause of these losses should be investigated and possible mitigating measures like sealing the bottom of ponds should be evaluated.
- Manual irrigation and hand-operated tube wells generally contribute significantly to homestead production of for example chilli and potatoes. Salinity surveys are needed to judge the suitability of such potential water sources. In order to prevent resalination due to evaporation such irrigation should be practised with sufficient quantities of water at once and not more frequently with small additional amounts, a fact the farmers are well aware of.

2.7.2 References

General		

2.8 Drainage conditions

2.8.1 Guidelines

For the conceptual design of the drainage system the pattern of natural arterial drainage should be mapped. Drainage requirements for the new polder are based on design criteria such as suggested and practised by BWDB. In general a 10-days rainfall period with a return period of 10 years is taken for the analysis of required drainage capacity.

Drainage of the new polder lands should be considered carefully. The natural drainage system should be taken as the basis because it reflects the natural topography and land slopes. An important consideration is the (possible) need and planning of drainage regulator sluices. The various functions of such structures are mentioned under “Intake and outfall structures”.

An open drainage system, without regulator sluices, should be considered as well.

- Careful consideration should be made regarding the risks and damages due to the intrusion of saline water, sediments and also due to entering of river floods or storm surges.

Because of the propagation of tidal water through the open drainage system the outfall channel will be less subject to siltation. In case a regulator sluice is constructed, the outfall channel at the river side of the sluice is mostly subject to rapid siltation in the dry season. Guidelines concerning this topic are presented in “Operation & maintenance”

- Drainage conditions of the new polder should not only be evaluated for the situation upon completion of the polder, but also for future circumstances.

Very often natural accretion of coastal lands will continue outside the polder, which may cause drainage distances to lengthen and, consequently, drainage capacities to reduce. Intervention measures to rehabilitate the drainage function may be required then, the cost of which is to be included in the overall economic evaluation.

2.8.2 References

NOAKHALI	BAGGAR DONA	SUDHARAM UPAZILA

2.9 Socio-economic conditions

2.9.1 Guidelines

A description of the present socio-economic conditions, the type and degree of social organisation, the autonomous developments (without project) and the possible changes due to the envisaged empoldering should be started already in the present conceptual/ prefeasibility stage. This should be based on existing information, documents and initial pilot surveys.

Because the development of a polder requires land and space for infrastructure, land acquisition is an important issue at polder development. It is recommended to identify already in the early stage of development – this “STAGE: Site selection, delineation and conceptual design” - the possibilities of land acquisition and of sufficient compensation in case land dispossession is required for the realisation of the required infrastructure.

In addition to the above some other key-issues are mentioned here:

- conflicting claims on land property
- possible livelyhood of inhabitants who will happen to live at the river side of the embankments (for example social forestry, the construction of mounds to live on)
- conflicting interests from land use; i.e. shrimp farming vs. agriculture
- reduction or even elimination of natural fresh water fishing activities and options for substituting economic activities (culture fishery in ponds)
- type and level of organisation in water management, operation and maintenance of the water system

2.9.2 References

GENERAL	CHAR JABBAR	CHAR BAGGAR DONA

2.10 **Principal dimensions of the embankment**

2.10.1 Guidelines

Sea-dykes and river embankments are essential elements of a polder design: they safeguard the inhabitants, their properties and the public infrastructure from flood disasters. The embankment should be sufficiently

- *high* to limit wave overtopping and prevent overflowing; and
- *stable* in order to withstand the forces (under design conditions), induced by wind, waves, currents and water levels.

Guidelines for the design of flood embankments and sea dikes are found in the Design Manual of BWDB. A number of aspects are highlighted in the following.

CREST LEVEL

In addition to the required set-back of the embankments (see “Physical environment (location, initial alineation)”), the crest level and cross section can be *indicated* at this stage. This depends on the required level of safety for floods and storm surges.

The BWDB Design Manual presents the following criteria for the design flood frequency:

- 1:20 years flood where agricultural damage is predominant;
- 1:100 years flood where loss of human lives, properties and installations are predominant. This holds, in general, for embankments along Jamuna, Padma and Meghna rivers.

Obviously, at the early stage of polder development agriculture is the main sector of economic activities. Therefore, following the BWDB design rules, a 1:20 frequency can be chosen. However, the BWDB rules are not necessarily compulsory. The CERP-II project proposed (December, 2000) to classify embankments as follows:

Class I: high protection

Class II: intermediate protection

Class III: basic protection

In addition a distinction is made between sea-facing, river-facing and transition embankments, the latter forming the transition between the first two mentioned.

The proposed water level return periods are as follows:

	Class I	**Class II**	**Class III**	**Remarks**
Sea-facing	> 20 yrs	15 yrs	10 yrs	Storm surges
River-facing	> 25 yrs	20 yrs	10 yrs	Monsoon river flows
Transition	Combination	Combination	Combination	Combination

A freeboard height should be added to the above design levels to count for:

- wave run-up (normally on the basis of the 2% wave height of a design storm)
- wind set-up *(comment: if not included in the water level statistics for the above design levels*)
- settlement
- desired safety margin

In general a minimum value for the freeboard is applied, viz. 5 feet for sea-facing embankments and 3 feet for river facing embankments.

In a later design stage a more detailed procedure may be followed to determine the required crest elevation, accounting for sea-level rise, local subsidence, settlement of the structure and the subsoil. Also the stability of the dike will be evaluated at that stage. The BWDB Standard Design Manual assumes a return period of about 25 years as design condition for the (in)stability of the various classes of embankments.

CREST WIDTH

The BWDB Standard Design Manual gives the following criteria:

- minimum crest width is 2.50 m.
- in case an inspection road is provided on the embankment, the minimum crest width is 4.30 m.
- if the embankment is used as a road, the crest width is found from the relevant class of road plus 1.00 m shoulder on both sides.

CROSS-SECTION

The side slopes are to be based on the soil mechanical stability of the embankment. The following values can be assumed:

	r/s slope	**c/s slope**
Sea-facing	7/1	2/1
River-facing	3/1	2/1
Transition	between	2/1

In practice the above values are being adopted without further detailed analysis and considerations. However, in a later design stage, the assumed values should be verified on the basis of soil-mechanical data and analysis. Standardised computation procedures are available to support the stage of detailed design.

Borrow pits

Borrow pits for the construction of embankments are generally situated close to the embankment. At extreme water levels, the phreatic line inside the country-side of the embankment may have a downward tendency if the borrow pits, forming a lateral canal, are situated at the country side of the embankment. In addition seepage water can be drained off through such a lateral channel. This will enhance the stability of the embankment.

A borrow pit at the riverside may disturb wave action and cause undesired scour at the toe of the embankment. Therefore, if a borrow pit is necessarily to be placed at the riverside, the distance to the toe of the embankment should be about 40 m at minimum (- estimated - order of magnitude of the wave length under design conditions).

An inside lateral canal may be used for fresh water storage, may serve fish culture and could be used as a collector drain.

On the basis of the above considerations

- it is preferable to situate borrow pits at the countryside of the embankment.

Low embankments

Low-crested, submersible embankments are meant to prevent premonsoon flooding but to allow for monsoon flooding. The frequency of flooding is determined by the crest level. However, it should always be realised that overtopping may induce severe erosion of the crest and leeward slope of the embankment. Therefore more severe requirements need to be put on these parts of the structure in order to prevent failure and collapse.

A low-crest embankment will induce an increase in agricultural benefits compared to the unprotected situation because of the reduced flood frequency.

Low-crest embankments – if applied – should not be constructed on land that has not yet reached the required elevation for empoldering. Otherwise, the accretion of the protected area is slowed down and the desired levels for “normal” empoldering will not be reached anymore, that is at about monsoon mean high tide level (MHW_mons). This means that in the long run, when the low-crest embankment would be upgraded to the normal standard, the protected area will be lower compared to the situation with a standard embankment.

This is an undesired situation in view of the long-term soil salinity and monsoon drainage congestion. Although it has appeared that the peak values of the soil salinity at the end of the dry season do not tend to reduce, lower land is always more unfavourable than higher land. Moreover, when a low-crest embanked is flooded, salt water will be contained for a longer period of time in the polder, compared to the original situation without embankment, contributing to soil salinity.

Frequent overtopping and overflowing will put high demands on the quality of the low-crest embankment. This refers especially to the quality of the top layers on the crest (should be well compacted and impermeable to prevent infiltration) and inner slope that should not be steeper than about 1/3 and actually be well covered by vegetation to increase erosion resistance.

The application of low-crest embankments may raise false perceptions of safety for flooding, which are not realistic. This puts ethical questions to the application of low-crest embankments. In practice it will be hard to prevent people from settling outside the low-crest embankment.

- Conclusively speaking, a low-crest embankment is, in general, not recommended in coastal areas because i) soil salinity will be higher, ii) frequent overtopping and overflowing of the crest of the embankment endangers the stability of the crest and inner slope, and iii) false perceptions of safety for flooding may prevail.

2.10.2 References

GENERAL	CHAR BAGGAR DONA	SANDWIP
HATIYA		

2.11 Intake and outfall structures

2.11.1 Guidelines

Intake and outfall structures are needed to control the water system of the polder. In the prefeasibility stage it is indicated where these structures can be located (conceptual design). In a later stage the design will be completed, normally first on feasibility level and next on detailed level.

Intake structures are needed if the empoldered area needs fresh water supply from areas outside the polder and if outside drainage water will be conveyed through the polder to its receiving water body. Normally an intake structure will facilitate a controlled inflow of water into the polder. The intake structure needs a closing device if it is situated in a flood protection embankment. In order to suit agricultural purposes, the salinity of the irrigation water should not exceed a level of about 2 mS/cm.

A drainage outfall structure has different functions:

- it should regulate drainage of excess water from the polder
- it prevents undesired intrusion of sediments and saline water from outside into the polder
- it is mostly situated in a main flood embankment or sea dyke and should therefore be able to withstand extreme water levels and wave attack from outside the polder
- it serves as a water retaining device in the dry season, enabling the storage of fresh water.
- it may enhance possible navigation in the new polder, because of the above water retention function

These aspects should be taken into account when considering, at the prefeasibility stage, the water system of the area and the need for drainage outfall structures.

2.11.2 References

3. STAGE: FEASIBILITY LEVEL DESIGN

In this stage the same main aspects as in STAGE: Site selection, delineation and conceptual design need to be addressed but more in detail. In addition the following main aspects will be subject to more detailed technical and economical analysis in a feasibility study:

Alternative lay-outs of the water system
Flood protection system
Design of flood protection works
Water infrastructure & water management
Water Supply & Sanitation
Transportation infrastructure
Settlement infrastructure
Power supply
Public facilities
Land productivity and outputs
Aforestation
Social analysis
Economic analysis

In the following we briefly address the water-related aspects, viz. *Alternative lay-outs of the water* system, *Flood protection system*, *Design of flood protection works* and *Water infrastructure & water management*. The other aspects are beyond the scope of this report, although the available references from LRP and CDSP have been included.

3.1 Alternative lay-outs of the water system

3.1.1 Guidelines

OBJECTIVES

The objectives of the project should be formulated clearly and explicitly at this stage. In addition, the different alternatives or options to achieve these objectives should be presented here, each with its specific advantages and disadvantages.

ALTERNATIVES

During the feasibility study the design of the preferred option will be worked out. However, it is important that, prior to further focus on a single, chosen option, the justification of this choice is made clear. Therefore the various options which can be considered should be screened and elaborated to a level of detail which makes a sound comparison possible. This is the reason that we call this main aspect “Alternative lay-outs of the water system”. An example of different alternatives in a polder design is included in the feasibility study on the development of the catchment area of Baggar Dona river. Another example is the consideration whether a drainage system should be equipped or not with drainage regulators.

Possibly additional data need to be collected for further definition and comparison of alternatives. Data on landownership, existing land use, and geotechnical data may be needed for a thorough comparison of the alternatives.

PRESENT SITUATION AND AUTONOMOUS DEVELOPMENT

A project is aimed at improving certain things. In order to compare these proposed improvements a reference is needed: a description of the present situation and autonomous development should the project not be implemented. For this reason,

- a clear description of such a reference situation should be presented.

CRITERIA OF JUDGEMENT

When comparing alternatives, a yardstick is needed:

- a set of criteria to judge the alternatives.

Investment cost, maintenance requirements, flood risk, population (“human lives at stake”) and environmental impacts are typical criteria to compare the alternatives proposed. The definition of such criteria of judgement before the actual evaluation is useful because it structures and supports an unbiased evaluation of the alternatives and their impacts.

MODELLING

Hydraulic modelling of the water system is often needed to study the performance of the different options: the lay-out and dimensions of canals, khals and structures. This is important because the water infrastructure of the new polder generally comprises an important investment component.

- One-dimensional models of non-steady/ non-permanent flow will suit for that purpose.

SCENARIO’S

The autonomous development can normally not be predicted exactly, we have to deal with uncertainties. Therefore a scenario-approach is often adopted, i.e. different predictions of future developments are formulated. Population growth, economic growth and sea-level rise are typical examples of variables which can be estimated only and which can be incorporated in the analysis by assumptions - adopting values for certain combinations of these variables or scenario’s Obviously an alternative may “behave” differently for different scenario’s.

3.1.2 References

BAGGAR DONA		

3.2 Flood protection system

3.2.1 Guidelines

The alignment of the flood embankments, sea dykes and other flood protection infrastructure has been discussed earlier, partly in the first stage STAGE: Site selection, delineation and conceptual design and, to a greater level of detail at the present stage, at the elaboration of the chosen alternative (at the preceding main aspect: "Alternative lay-outs of the water system")

The flood and storm surge protection system of the new polder area should be designed to withstand river peak flows and – in coastal areas - storm surges and waves. Data collection, hydraulic modelling and analysis are needed to establish the water levels and waves under design conditions. Guidelines for design criteria of embankments have also been put forward at the preceding stage. At this stage

- the hydraulic boundary conditions and design criteria should be assessed.

This provides the actual starting point for more detailed design work, first at this stage on feasibility study level, and after that on detailed design level.

3.2.2 References

SOUTH HATIYA CROSSDAM	SOUTH-HATIYA	

3.3 Design of flood protection works

3.3.1 Guidelines

The flood protection system outlined in the preceding steps forms the basis for the detailed design and cost estimate. In addition to the main dimensions established so far geotechnical data should be collected for more detailed design work.

The required level of detail includes:

- the dimensions, materials used, foundation, plan view, front and side views of the structure should be made clear by drawings and descriptions
- the execution and phasing of the works should be defined
- a cost estimate should be made

The BWDB Design Manual provides the necessary guidelines and criteria to complete the feasibility level design of the flood protection works.

Flood embankments and sea-dykes are obviously under control of the BWDB. Preferably a zone at both sides of the embankment should remain under control of BWDB as well, in order to make reservations for later adaptations. Obviously it should not be the intention of BWDB to lease out such adjacent zones for other purposes that may jeopardize the safety of the dyke. Above all, it is important that the cross-sectional profile of the dyke remains intact. The digging of fish ponds adjacent to the dyke and (!) cutting of the inner dyke slope as has been done in the Muhuri polder area endangers the stability of the dyke and should be prohibited.

3.3.2 References

GENERAL	SANDWIP – NOAKHALI CROSSDAM	SOUTH HATIYA CROSSDAM
CHAR BAGGAR DONA	CHAR MAJID	CHAR BATIR TEK
MUHURI		

3.4 Water infrastructure & water management

3.4.1 Guidelines

The water infrastructure of the polder normally consists of a system of canals and khals for water supply and drainage. The water level is controlled by weirs, cross-bunds, lifting-gates and regulator sluices. The whole system may be designed by means of hydraulic modelling. As with the preceding stages, attention should be paid to data collection and model calibration. Typical points of interest are:

- water levels and flow velocities;
- salinity level of intake water;
- sediment transport and siltation;
- salinity intrusion; and
- frequency of flooding and areas flooded.

Standard design rules and criteria are applied for dimensioning the water system including the required structures. Such criteria are given in the BWDB design manual.

In general, feasibility studies hardly pay any attention to the functioning of the system on the long run. In practice, the interior drainage system, for example, often deteriorates rapidly because of the lack of maintenance. With the modelling tools nowadays applied in feasibility studies, it is relatively easy to explicitly show the consequences of bad maintenance, simply by modelling reduced channel dimensions and re-run the relevant simulations. The same procedure can be followed for simulating mal-functioning of drainage sluices, etc. The inclusion of this kind of risk analysis in the feasibility study will contribute to the insight in the sensitivity to maintenance and the sustainability of the water system. Therefore

- substantial attention should be paid to the risks (and costs) due to lack of maintenance.

If it would be considered to use drainage sluices for intake of water in the early post-monsoon, proper structural adaptations should be made. Then fresh water can be let in during the early pre-monsoon when there is already some scarcity of water. Obviously, the seasonal salinity levels at the drainage outfall should be known in order to judge the feasibility of the above fresh water intake. Conclusively,

- the possibility of taking in fresh water through drainage sluices should be addressed in the feasibility study.

3.4.2 References

GENERAL	NOAKHALI	CHAR BAGGAR DONA
HATIYA		

3.5 Water Supply & Sanitation

3.5.1 Guidelines

- As mentioned in the first stage, deep groundwater extraction must be carefully planned.
- Ponds are an important fresh water source. In order to analyse their performance data should be available regarding to the subsoil conditions. Also water retention in the system of khals and channels is an important issue to be dealt with in the feasibility study.
- Finally rain water harvesting should be stimulated for domestic fresh water use.

3.5.2 References

GENERAL		

3.6 Transportation infrastructure

3.6.1 Guidelines

3.6.2 References

3.7 Settlement infrastructure

3.7.1 Guidelines

3.7.2 References

3.8 Power supply

3.8.1 Guidelines

3.8.2 References

GENERAL		

3.9 Public facilities

3.9.1 Guidelines

3.9.2 References

3.10 Land productivity and outputs

3.10.1 Guidelines

3.10.2 References

GENERAL	CHAR BAGGAR DONA	SOUTH-HATIYA

3.11 Aforestation

3.11.1 Guidelines

3.11.2 References

GENERAL		

3.12 Social analysis

3.12.1 Guidelines

3.12.2 References

GENERAL	NOAKHALI	CHAR BAGGAR DONA

3.13 Economic analysis

3.13.1 Guidelines

The procedure for analysis of the feasibility of an empoldering project is outlined in "Guidelines for Project Assessment" (Flood Plan Coordination Organization – FPCO- , Dhaka. CDSP Technical Report 26 (1999) deals with some most important issues in the cost-benefit analysis for char development projects, i.e. the economic benefits (agriculture, fish, homestead gardening) and the financial and economic pricing of paddy and labour.

It appears that the outcome of the analysis (feasible or not) is very sensitive to basic assumptions and price fluctuations. Financially spoken the development of chars looks hardly feasible with a marginal net benefit. However economic analysis and the inclusion of indirect benefits leads to a more favourable picture. If social benefits are added, the outcome seems to be robust and positive.

Another outcome of the analysis is the crucial role of O&M. Empoldering projects which are feasible under design conditions may easily turn non-feasible if proper operation and maintenance is ignored or omitted.

3.13.2 References

GENERAL	SANDWIP – NOAKHALI CROSSDAM	HATIYA
NOAKHALI		

4. STAGE: ENVIRONMENTAL IMPACT ASSESSMENT

In this stage the essential steps are presented of the environmental assessment process [Halcrow et al., 2001], developed under the 'National Water Management Plan Project' (refer to the Mission report No. 26 of Frank Keukelaar; also ://www.warpo.org). People's participation should be included as an important element of this process throughout the various steps mentioned. Screening, reviewing and approval procedures by the Department of Environment are not mentioned here but need obviously to be passed through. The definitive version of the above guidelines is still to be established.

Review of Project Proposals and Alternatives
Background Data Collection and Baseline Description
Scoping and Bounding
Field Investigations
Impact Assessment of Project and Alternatives
Environmental Management Plan
Environmental Assessment Report

4.1 Review of Project Proposals and Alternatives

4.2 Background Data Collection and Baseline Description

- Existing situation and autonomous development

4.3 Scoping and Bounding

4.4 Field Investigations

4.5 Impact Assessment of Project and Alternatives

4.6 Environmental Management Plan

- Measures to minimise environmental damages
- Monitoring plan

4.7 Environmental Assessment Report

4.7.1 References

GENERAL	SOUTH HATIYA	

5. STAGE: DETAILED DESIGN & CONSTRUCTION

Major water and internal infrastructure

5.1 Major water and internal infrastructure

Two categories of physical infrastructures have to be designed for an empoldered area:

- Major water infrastructures (cross-dams, sea dykes, river embankments, drainage sluices, irrigation inlet structures, channel system for irrigation and drainage)
- Internal polder water and civil infrastructures (rural roads, bridges, culverts, cyclone shelters, community buildings, schools, cluster villages complexes, etc.

5.1.1 Guidelines

In general the major infrastructure works are designed on the basis of standard design criteria supplied by BWDB. For internal polder infrastructures the design criteria from LGED are normally applied.

In the following some guidelines are added concerning to drainage sluices.

DRAINAGE SLUICES

Designs of structures are not fully documented and therefore it is difficult to evaluate the existing construction of sluices and outfalls channels. Therefore it is advocated to

- fully document new designs and to make the design process transparent for later references.

Existing designs of drainage sluices can be considerably improved by taking into consideration the encountered problems and experience in the coastal zone during the last 20 years. Typical points of improvement are:

- More clearance between the flap gates and the stop log grooves. The stop logs can be used then as a silt barrier in the dry season in order to prevent the accumulation of sediment against the flap gates.
- Possible simplification and improvement of the robustness of the hoisting mechanism of the lifting gates and the hinges and sealing of flap gates
- Explicit mentioning of required maintenance in the design document

5.1.2 References

GENERAL	CHAR MAJID	

6. STAGE: INSTITUTIONAL ASPECTS

Institution building
Land property
Water management organization
Cooperatives
Training

6.1 Institution building

6.1.1 Guidelines

6.1.2 References

GENERAL	BAGGAR DONA	MUHURI AREA
HATIYA		

6.2 Land property

6.2.1 Guidelines

The issue of land property and allocation of khash lands to landless people is complicated and cannot (should not) be resolved by a project. It is a matter of the Government and relevant governmental agencies. However, a CDSP-like project can contribute to the process of land settlement by monitoring, identifying and registering the status of the new lands covered by the project. In addition dissemination of information and liasing with relevant government institutions may contribute as well.

6.2.2 References

GENERAL		

6.3 Water management organization

6.3.1 Guidelines

- Information campaigns and rapid water management appraisal are the initial activities essential in the developing of the Water Management Organization (WMO).
- The Water Management Committees (WMC) are the grass root level of WMO and are formed by a series of meetings and sessions involving all stakeholders of the area. Both male and female members represent in WMC equally.

In this respect it is noted that GPWM – the Government's Guidelines for Participatory Water Management – arranges water management responsibilities as follows:

- Schemes over 5000 ha managed either by private leasing or by joint-management by BWDB/ LGI/ WMO. Ownership remains with BWDB
- Schemes up to 5000 ha managed by WMO's. Ownership remains with BWDB
- Schemes up to 1000 ha managed by WMO's. Ownership gradually transferred to LGI's.

Guidelines for the sluice operation under control of Water Management Committees are given under Operation & maintenance. As regards the formation of Water Management Committees CDSP applies following guidelines:

- WMC's should evolve from a formation process that ensures peoples'participation
- Women should be represented in the WMC's and take 50% of the seats.
- WMC's are put together on the basis of sluice-wise catchment areas, the so-called Water Management Systems
- No formal organization of smaller hydrological units – Water Management Areas - than the Water Management System, controlled by the WMC
- WMC's in CDSP areas have not been registered with Cooperative department as a legal entity. However, this is a subject of further consideration

WMC's, finally, are commissioned following tasks (briefly– elaborated discussion and summing can be found in one of the references: CDSPII, Technical Report 14 (2004):

- addressing and resolving stakeholder issues and conflicts
- establishing season-wise target water levels and sluice management
- planning (long-term, annual) and executing required maintenance works
- monitoring the performance of the water system
- fund raising and financial management
- collecting (in kind) contributions from beneficiaries and stakeholders
- liasing relevant agencies
- assisting, coordinating and arranging involvement and services from other (implementing) agencies

6.3.2 References

GENERAL	CHAR BAGGAR DONA	

6.4 Cooperatives

6.4.1 Guidelines

6.4.2 References

CHAR BAGGAR DONA	CHAR JABBAR	

6.5 **Training**

6.5.1 Guidelines

6.5.2 References

GENERAL		

7. STAGE: OPERATION & MAINTENANCE - (PROJECT) MONITORING & EVALUATION

Operation & maintenance

(Project) Monitoring & Evaluation

7.1 Operation & maintenance

7.1.1 Guidelines

Operation & maintenance of the water infrastructure is important to maximise the benefits accruing from the polder system. This holds both for the water supply and for drainage. In the following some guidelines are given for preventing and solving frequently occurring drainage problems.

First three major receiving waters are described, each with its own characteristics. Next some guidelines are presented for drainage outfall channels, and finally for drainage sluices.

NOAKHALI KHAL

Noakhali Khal is reportedly subject to sedimentation. However, the river still (2003) seems to perform its drainage function reasonably well even though, by the end of 1999, BWDB predicted that drainage through Nabragam sluice and later on through other, more southerly, sluices such as the sluice in Algir Khal and Ganchil Khal, would be hampered in the short run.

When there is evidence that the river can no longer convey the required drainage water, the first measure to consider is to restore the drainage capacity by dredging. By that time river - as long as this river is to serve as a carrier of drainage water - cross sections, water levels and discharges should be measured in Noakhali Khal and its mouth. This information can be used for quantifying the remaining discharge capacity and the required excavation quantities.

HATIA RIVER

Hatia River has, under the present conditions, sufficient capacity to drain off the water from Char Majid Polder.

This capacity may reduce in the future due to increasing sedimentation if Jarirdona River takes over the drainage of upper areas and Hatia River will be closed off upstream of the outfall channel from Char Majid.

Monitoring water levels and cross-sectional levelling of critical outfall channels and Hatia River should taken up to assess the present conditions (baseline), and to be able to observe possible influences of intervention works in Jarirdona River later on. The Baggar Dona Catchment Area Feasibility Study accounts for drainage of the Char Majid Polder via a new channel crossing Boyer Char which is envisaged to be empoldered.

LOWER MEGHNA BETWEEN SOUTH OF RAMGATI AND HATIA RIVER OUTFALL

The embankments of the Lower Meghna River are eroding in this area and there is no reason to expect any hampering of drainage due to sedimentation. The erosion in this area is estimated to be of the order of hundred meter per year, based on satellite images from the last 20 years (1974 – 1996). Near the outfall of Hatia River the bankline erosion is about 60 m/y on the average over the last 40 years. The latest analysis of bankline movement has been carried out by the MES project.

The 1988 LRP report on drainage of Noakhali [LRP, 1988] presents 1969 and 1987 bank lines in this area (across Gazaria Char), from aerial photographs and bankline measurements. Roughly the width of Lower Meghna River increased from 12 to 18 km, which implies an average widening of 300 m per year. Of course such figures are approximate because of the nature of observations and equipment used[1]. However, it shows that reported erosion rates may differ significantly and should be treated with care.

When planning drainage outfall structures in the above type of areas, sufficient set-back should be taken into account in view of the erosion hazard. This set-back depends on:

- the envisaged lifetime of the structure
- the reliability of given rates of shoreline erosion

DRAINAGE OUTFALLS

In general tidal motion causes sedimentation in the drainage outfall channels in the dry season. Silt bars form, the channel profile narrows and quite often sediment blocks the flap gates. The rate of sedimentation varies from place to place and tends to increase with increasing length of the outfall channel. It is recommended to regularly monitor the condition of the outfall channel, not necessarily by costly survey work, but rather by field inspection and here and there checking of the channel cross sections.

During the monsoon the drainage outfall channel is flushed by the excess drainage water from the polder, which may cause removal of part or all sediments deposited during the dry season. This occurs if the flushing capacity is sufficient.

To avoid such sedimentation of the outfall channels and blocking of flap gates in long outfalls (longer than about 500 m) it is recommended to construct an earthern cross-dam at the downstream end of the outfall channel.

The cross-dam should be constructed at beginning of the dry season but not before sedimentation levels downstream of sluice have reached a level between the floor of the stilling basin and the invert level of the vents. This is required to reduce further scouring of the bed of the outfall channel later on in the beginning of the monsoon, when high discharges of excess rainfall run-off from the polder may coincide with low tide in the outfall channel. Before the first rains are about to start the cross-dams should have been removed again.

[1] *In 1987 the Decca positioning system was used.*

To avoid blocking of flap gates by sediment deposition in a short outfall (shorter than about 500 m) it is recommended to remove the silt and mud hampering and blocking the flap gates by water jetting, deploying portable irrigation pumps with a capacity of about 100 l/s.

DRAINAGE SLUICES: MAINTENANCE

<u>There is an overall lack of maintenance of the structures</u>. No facilities are available to store basic tools, lubricants, spare parts and stop logs. Symptomatically, stop logs are not present at all. For an area, depending that much on water, maintenance of the water-related infrastructure is of crucial importance. Since preventive maintenance of the drainage sluices is under the responsibility of WMO's (which could be a WMA, WMC or WMF), these organisations need to undertake the following:

- Stop logs, basic mechanical spare parts and tools should be kept available at the sluice site in a shed under control of the WMC.
- Lubricants, grease should be kept available at the sluice site.
- Sluices should be inspected once a year, with special attention to
  - all moving parts;
  - condition of paintwork;
  - silt and debris, hampering the sluice;
  - condition of slope protection works, both country and river side;
  - condition of downstream apron and possible scour holes
  - symptoms of seepage

A sustainable source of income is required, which could partly be in-kind, to finance these activities.

See also Water management organization and Training at the STAGE: Institutional aspects

DRAINAGE SLUICES: OPERATION

The control of the sluices shall be defined in the operational water management rules that are, in turn, the outcome of an integrated water management plan or schedule of the relevant polders under auspices of the relevant Water Management Committee. Most importantly the WMC decides on the (target) water levels throughout the different seasons.

Responsibility of the sluice operation lies with the WMC. THe WMC employs a sluice operator to actually operate the sluice.

It is recommended to monitor the performance of the drainage regulator by measuring daily maximum and minimum water levels outside the sluice, to take the inside water levels at corresponding times, to record the gate operation and to collect data from a nearby rainfall gauge station. Such measurements can be executed throughout the first full year of operation, and next during the periods of actual operation only. By relating the factual data on sluice operation to the observed pattern of flooding and drainage in the fields, chronicled in the drainage journal (see below) sluice operation can be improved

In some cases drainage sluices can be used to take in fresh water. Also this should be based on the rules of sluice management.

CDSP composed following set of guidelines for sluice operation:

Regular sluice operation:

- pre-monsoon gate operation as per need
- removal of obstacles like cross-dams etc.
- monsoon gates normally open, incidental closure
- post-monsoon possible intake of fresh water
- decision on dry season closure
- no concessions to fishermen in dry season

Emergencies:

- weather forecasting should be observed
- WMC should convene at unusual weather forecasting and/ or immediate action should be taken by the president of the WMC
- WMC will supervise the sluice operator during dangerous or emergency situations

Maintenance:

- WMC is responsible for the coordination of the maintenance of the water management infrastructure
- Funding arrangements will jointly be made by WMC, UP and BWDB whereby BWDB will remain responsible for major maintenance work and interventions
- Problem identification and prioritisation will be done by the WMC
- Maintenance plans are jointly assessed by WMC, BWDB, LGED and UP.

DRAINAGE OF THE LAND

The interior drainage system should be well-maintained in order not to jeopardize the drainage capacity and not to cause drainage congestion. For example, in the early post-monsoon it may be beneficial to drain off the remaining water on the fields in order to start seeding rabi crops. The maintenance should be based on the WMC-journals of the flood and drainage situation of the respective areas (see (Project) Monitoring & Evaluation)

7.1.2 References

GENERAL		

7.2 (Project) Monitoring & Evaluation

7.2.1 Guidelines

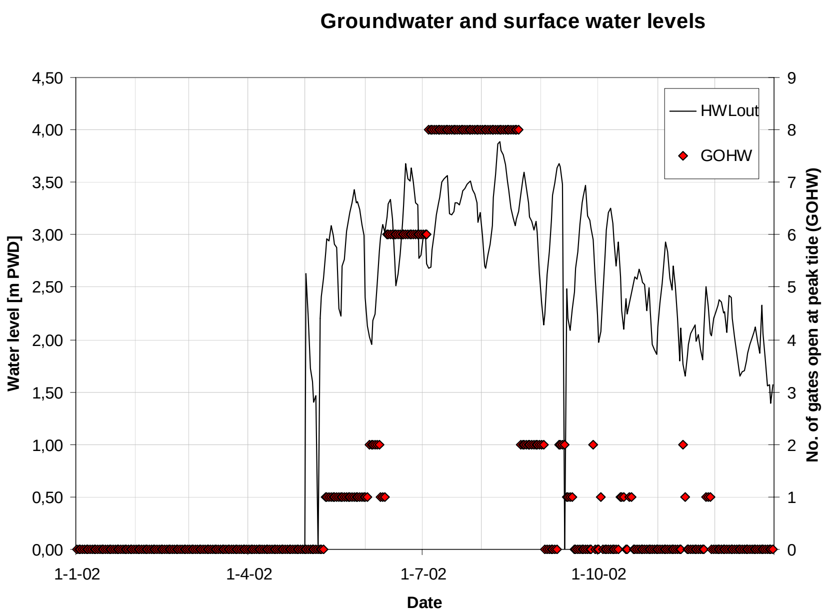
MONITORING ACTIVITIES WITHIN THE PROJECT

In order to continuously improve the polder development a monitoring and evaluation programme should be designed and implemented. Monitoring refers to physical parameters, infrastructure, institutional development, agricultural practice, water management, etc. There are a considerable number of reports produced by LRP and CDSP on this topic. Most of these reports have been referenced under the preceding stages and topics of these guidelines. There are a few specific points which are brought up here:

- establishing and maintaining one common baseline set of data on which the project is based. This includes thematic data (physical, environmental, social, etc.) and maps. The baseline data should be properly referenced and maintained in a shape suitable for dissemination to other users or projects in the coastal zone (ICZM-process).
- monitoring/ mapping of agricultural activities and outputs;
- monitoring/ mapping of soil conditions;
- monitoring of the physical water system (level and salinity of tidal waters outside the polder, same for polder water and ground water);
- monitoring of the water infrastructure (operation of sluices, state of maintenance);
- monitoring of the water management (institutional);

  The seasonal pattern of flooding, drainage, irrigation, etc. should be systematically recorded in a drainage journal under the responsibility of the relevant WMC. This needs to be synthesized with other monitoring results (of soil conditions, water system, performance of the water infrastructure).
- Delineation and mapping of zones of different agricultural potential (PDZ-maps).

The picture below shows an example of the operation of the Char Majid sluices throughout 2002. The number of gates that were lifted is plotted on the right axis. The lines show the outside and inside (the sluice) peak tidal level.



MONITORING OF THE PROJECT AS A WHOLE

A different kind of monitoring is executed by the agencies who release the required project funds (both national agencies and donor countries) and who are responsible for the project. Their decisions regarding the project are normally based on their own findings and conclusions, recorded in evaluation reports. These reports are referenced here because they comprise a valuable outside view on the project.

7.2.2 References

GENERAL	CHAR BAGGAR DONA	

APPENDIX A

Outline of other manuals

BWDB (1999?); *Standard Design Manual*. Standard Design Manual Committee, Bangladesh Water Development Board. Dhaka.

Volume I

Chapter 1: General Hydrologic Design for drainage structures

Chapter 2: General Hydraulic Design

Chapter 3: Structural Design of R.C.C. Members

Chapter 4: Prestressed Concrete

Chapter 5: General Foundation Design

Chapter 6: Design Criteria for Irrigation Structures

Chapter 7: Design Criteria for Embankment

Chapter 8: Pipe Structures

Chapter 9: Road Structures

Chapter 10: Bank Protection and River Training Works

Chapter 11: Design Criteria of Gates and Hoist

Other volumes contain standard design of structural elements (Vol. II), standard lay-out plan of hydraulic structures (Vol. III), drafting and detailed standard (Vol. IV) and standard drawings of hydraulic gate (Vol. V).

DDP (1985); Design Manual for Polders in South-West Bangladesh. Delta Development Project, Bangladesh-Netherlands. Joint Programme under BWDB. Dhaka, November 1985.

The design manual published by the DDP project [DDP, 1985] contains much material on the different design aspects of a polder, tailored to the Bangladeshi situation. Although some parts may be subject to adaptations based on new understanding, it may still serve as a useful tool when taking up new areas for empoldering, albeit on engineering level rather than on the level of site identification.. CDSP experience in the construction of embankments may be used to introduce such adaptations.

Design steps:

1. General: reading explanation

2. Design of embankments
2.1 Data collection
2.1 a) topographic maps
2.1 b) aerial photographs
2.1 c) erosion rates / set back of embankments
2.1 d) topographic survey alignment embankment
2.1 e) bathymetric surveys
2.1 f) flow measurements
2.1 g) water levels
2.1 h) soil borings
2.1 i) wind climate
2.2 Embankment profile
2.2 a) design flood level
2.2 b) wind set-up
2.2 c) wave run-up
2.2 d) design crest height
2.2 e) slopes (r/s and c/s)
2.2 f) crest width
2.3 Alignment
2.3 a) quantity of earth work
2.3 b) set-back
2.3 c) soil conditions
2.3 d) establish alignment
2.3 e) redesign where set-back is insufficient
2.4 Height
2.5 Revetment
2.5 a) water levels
2.5 b) flow velocities and waves
2.5 c) protection layer
2.5 d) filter structure
2.5 e) slope stability

3. Design of Closuredam
3.1 Site selection
3.2 Data collection
3.2 a) see 2.1 above
3.2 b) detailed flow velocities
3.2 c) tidal discharge measurements
3.2 d) semi-detailed hydrographic survey
3.2 e) soil borings and laboratory testing
3.3 Design final section
3.4 Method of closure operations
3.4 a) Established maximum velocities in closure gap
3.5 Scenario for closure operation
3.6 Bottom and sill protection

4. Design of Drainage and Irrigation System
4.1 Data collection
4.1 a) descriptive report
4.1 b) topographical maps
4.1 c) aerial photographs
4.1 d) additional topographic measurements
4.1 e) meteorological data
4.1 f) water level data
4.1 g) salinity data
4.1 h) field visit
4.2 Data evaluation, design of lay-out
4.2 a) agricultural conditions/ potentials; and
possibility of combining irrigation and drainage canals
4.2 b) lay-out irrigation and drainage system
4.3 Irrigation design of an irrigation unit
4.3 a) cropping possibilities
4.3 b) crop water requirement

4.3 c) effective rainfall
4.3 d) net irrigation requirement
4.3 e) field irrigation requirement and conveyance losses
4.3 f) irrigation supply requirement
4.3 g) design irrigation channel system
4.4 Drainage design of the polder
4.4 a) drainage modules
4.4 b) sluice discharges
4.4 c) design drainage channel discharges
4.4 d) surface area of main and secondary drainage channels
4.4 e) sluice location
4.4 f) section –wise schematisation of drainage channel
4.4 g) back water curve main drainage channel
4.4 h) delivery curves drainage channel

5. <u>Design of Drainage Sluice</u>
5.1 a) design drainage discharge
5.1 b) water level boundary conditions
5.1 c) invert level
5.1 d) sluice width
5.1 e) check discharges and flow assumptions
5.1 f) height sluice barrel
5.1 g) sketch lay-out
5.1 h) maximum velocities, wingwall flaring
5.1 i) transition apron – channel
5.1 j) maximum velocities
5.1 k) energy dissipation
5.1 l) transition sluice – outfall channel
5.1 m)flood routing

6. <u>Design of Tidal Inlet Structure</u>
6.1 a) irrigation requirements
6.1 b) tide curve
6.1 c) irrigation supply level
6.1 d) discharge capacity
6.1 e) location

7. <u>Design of Foundation</u>
7.1 Construction pit
7.2 Weights and loads
7.2 a) vertical load
7.2 b) lateral earth pressures
7.2 c) uplift pressures
7.3 Stability of structure
7.4 Foundation pressures
7.5 Arranging soil data
7.6 Bearing capacity
7.7 Settlements
7.8 Pile foundation
7.8 a) resulting loads
7.8 b) lay-out pile system
7.8 c) bearing capacity
7.8 d) pile group action
7.9 Seepage

<u>The “body” of the manual where the above topics are found is structured as follows:</u>

Part 1:
Vol I Introduction and summary of design procedures
Vol II Survey and measurements
Vol III Design of embankments, closure dams
Vol IV Irrigation and drainage requirements – Design criteria
Annex: Comments and discussion Design Circle-I

Part 2:
Vol V Hydraulic computations
Vol VI Foundation design
Vol VII General and structural design aspects

Part 3:
Vol VIII Basic design drawings

Part 4:
Vol IX Worked-out example

CERP-2 (2000); *Preparation Report for the Proposed Coastal Zone Water* Management *Programme*. Second Coastal Embankment Rehabilitation Project. Jaako Pöyry Consulting Oy in association with DHV Consultants, Mott MacDonald Group, Devconsultants, Techno Planners, House of Consultants Ltd and Desh Upodesh Ltd. Bangladesh, December 2000.

In a preparation report for the Coastal Zone Water Management Programme, a lot of information and lessons learnt have been compiled again, including new perceptions and understanding as compared to earlier work. Following annexes contain relevant information:

Annex G: Suggested Planning Framework,
describing the different stages, relations and decision analysis in the planning process;

Annex I: Polder Information and Monitoring system,
giving an outline for data and information collection, processing, storing and presentation;

Annex K: Environmental Considerations,
presents guidelines for environmental appraisal, interference and evaluation;

Annex M: Engineering,
elaborates on design guidelines;

Annex N: Protective Vegetation,
elaborates on vegetation on embankments; and

Annex Q: Institutions, Implementation and O&M in the Polders,
gives an outline of institutional arrangements in a polder area.

###

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STAGE: Site selection, delineation and conceptual design

Physical environment (location, initial alineation)

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LRP, Technical Report no 8: Sedimentation fields, January 1982

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Ecological environment

GENERAL

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