

Sea dikes northern part of Vietnam

-Review-



Government of the Socialist Republic of Vietnam
Ministry of Agriculture and Rural Development

Government of The Netherlands
Ministry of Transport, Public Works and Water Management

SEA DIKES NORTHERN PART OF VIET NAM (Red River Delta)

- Review -

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EXECUTIVE SUMMARY

Problem definition

The coastal areas of Vietnam are repeatedly hit by devastating storms and typhoons. Protective sea dikes are overtopped or breached frequently, with the resulting flooding causing damage to agriculture land, loss of life and crops, and destruction of infrastructure.

In the coastal area of the five northern provinces of the Red River Delta, 361 kilometres dikes will be upgraded, assisted by the World Food Program, project number 5325. This project is the follow-up of the WFP project number 4617, which was focused on 7 provinces along the Central Coast.

Scope of the mission

As a result of the strong similarity in physical nature between the Netherlands and Viet Nam on water related issues, the Ministry of Agriculture and Rural Development of the Socialist Republic of Vietnam has requested to the Ministry of Transport, Public Works and Water Management of the Netherlands for technical assistance on flood control issues.

As a first step the Dutch Ministry has sent in November 1995 two representatives, mr. Anne van Urk and mr. Ale van der Hoek, to discuss many flood control and water management issues in Viet Nam, on which cooperation can take place. One of the issues with the highest priority was to get a second opinion on the sea dike designs as to be used in the WFP program.

So as a second step in the program a mission visited Vietnam, from 26 March to 12 April 1996, in order to evaluate the existing designs and execution options for the five coastal provinces of the Red River Delta (RRD).

Design methodology

In order to decide what kind of protective measures should be taken in case of coastal defence problems, different preceding activities must be realized. On the one hand the causes and the extent of the coastal problem should be assessed by means of a study into the boundary conditions and the morphological processes in the area considered. On the other hand an evaluation should be made of the different interests, which may be related to safety, agriculture, environment, economy, etc.

There is a large research potential available in Viet Nam, e.g. Department for Dike Management and Flood Control, Vietnam Institute for Water Resources Research, Marine Hydrometeorological Centre of the Hydrometeorological Service, and Hanoi Water Resources University. However, in order to use this potential effectively in solving of practical coastal problems a more close cooperation between the different parties in the design process should be further stimulated. To achieve this goal some administrative actions should be undertaken by the Ministry of Agriculture and Rural Development.

It should also be considered to develop different possible solutions to a problem and compare these solutions on basis of the interests involved. Even future development on economy and boundary conditions should be considered. Then, the available money and labour can be used in a (more) efficient way. Therefore a so called 'policy analyses study' should be prepared, on province-, district- or project level.

To improve understanding between various institutes and in order to involve the different interests in the design process, the activities related to a certain program (problem or project) should be organized in a form of multidisciplinary project teams and giving proper responsibilities to the project-leader.

Risk level

For a proper design, as a starting point, an acceptable risk level has to be fixed. The present designs for the rehabilitation and upgrading of the sea dikes in the Red River Delta are based on design-circumstances which will occur with a frequency of 5% each year (= 1/20 years). However, the interests to protect vary for the different area. In order to get a balance between the investments for dike improvement and the value of the interests to be protect, it is advised in the future to consider a differentiation in risk level.

From the moment that people realize that the area they inhabit, is protected in a sufficient way, investments will be done. Moreover, the living standard and the economic situation in Vietnam will expand in near future.

Consequently the interests in the area adjacent to the sea will increase and in order to keep the interests and the safety level in the future in balance, the safety level will most probably be upgraded again. Therefore it should be considered to allocate a free strip on the landside of the dike for future improvements.

Natural boundary conditions

Topography and morphology

For a sound planning and design of sea defences it is necessary to know the bottom topography in front of the coast (at least in the zone from 'deep water' to the toe of the dike) and even to make a prediction of the shoreline development for the lifetime of the structure. Such a prediction can be made based on the historical coastline development in combination with a morphological analyses of the coast. In such an analyses the effects of the sediment load of the rivers, longshore and cross shore sediment transports etc are evaluated. Based on the shoreline prediction the design conditions of the sea defence can be determined. Further, decisions can be made to concentrate efforts and investments on for instance eroding shoreline sections.

Waves

Since the bigger part of the coastline of the northern part of Vietnam has a shallow foreshore, in most cases the design wave heights for the sea defences will be depth limited. Based on the present bathymetry and on the predictions for the near future the design wave height for the sea defence design can be calculated. However, it is still important to know the deep water wave climate (wave height, wave period, frequency distribution). Not only for the sea dike design but also for other purposes (morphology).

A reliable deep water wave climate can only be obtained by long term measurements. In this way a reliable set of statistical wave parameters can be defined. This data set should include directional frequency distributions of the wave height and wave period.

Design water level

The design water level is a *dominant* parameter in design of the crest height of the dike. Therefore much attention should be paid to the proper quality of prediction of the design water level and its components: astronomic high tide and storm surge (= wind set-up). Than it is possible to tune the design water level to the acceptable risk level.

Comparing the various sources of information it might be possible that the tidal level which is used in the present calculations already includes the wind set-up. It appears that this value has been derived from a water level exceedance curve and not from the astronomical tide-table figures.

It is recommended to verify and validate the wind set-up formulation. This can be done by comparison of water level measurements and wind set-up computations.

Conclusions and recommendations

The proper quality of input data/hydraulic and geotechnical boundary conditions is of a primary importance for a proper design. An expert working group should prepare a document with boundary conditions for the coast of Viet Nam, which should be used as a basic document for the design process.

With respect to boundary conditions for sea dike design it is recommended to:

- analyze all the relevant available wind, wave, current, water level and bathymetric measurements in order to define the boundary conditions along the entire coast the best as possible. Priority should be given to the water level analysis (required to obtain the design water level) and the bottom topography (required to obtain design wave heights);
- prepare boundary condition guidelines and submit these to the local (provincial) governments. These standards will contain specific values (based on the analyses of measurements) to be applied or standardized procedures to calculate certain design parameters;
- determine priorities for improvement. For example: setting up a long term wave measurement campaign.

Design

Crest height

The subsoil along the line of the dikes to be improved will vary. So the heightening for the dike improvement will be different. Therefore it is recommended, especially in areas with bad soil conditions or with settlement problems, to calculate the expected settlement of the subsoil which will occur due to load of earthfill. If sufficient data are available, it should be supported by geotechnical calculations.

The runup on the dike will be strongly influenced by the slope angle and the roughness and permeability of a revetment. In the present designs there is no distinction for the various types of revetment.

In cases that the runup is calculated for an exceedance of more than 2%, also overtopping of the dike should be calculated including its consequences for the stability of crest and inner slope.

Due to the above mentioned aspects it is recommended to examine the present calculations for the crest height of the dike in according to state-of-the-art design standards, and differentiated for the different dike sections.

Revetments

In the present designs of sea dikes Russian formulas as well as the Hudson formula (USA) are used. All these formulas are originally developed for riprap and/or rubble mound structures (breakwaters), which are based on the weight of elements. However, these formulas have also been applied in the present designs for calculation of thickness of pitched stone and block revetments. The design of block revetments should be based on the thickness of a block and not on the weight of a block.

In general, for new dikes where settlements can be expected, the loose protective units (stone, placed blocks) are preferred instead of interlock blocks, because of their flexibility and re-use possibility after eventual damage.

The existing riprap on various dikes, which is not stable enough for design conditions can still be applied in the zones of less wave attack (e.g. above design water level + $\frac{1}{2} H_s$, and at the toe structure). The toe structure should be strong enough to resist the sliding forces provided by the slope revetment. In all cases proper transitions from the slope protection into the toe protection, and into the crest, are very essential for the stability of the revetment.

As **conclusion**, the actual design approach concerning the stability of the revetments on the sea dikes is not always based on the right formula and is also inconsistent, and can not be accepted as a final design. Also the construction of the transitions should be re-considered.

Foundation

Special attention should be paid to geotechnical aspects of dike design, such as foundation on soft soils, and problems of compaction of clay-earthfill especially during dry and warm periods when the clay is becoming very hard. An important question is "what is the influence of possible cavities between the blocks of clay inside the dike body on the geotechnical stability of the dike?"

Design standards

The actual design standards for coastal protection (including dikes) in Viet Nam should be updated according the actual state-of-the-art of the international knowledge in this field. Therefore new design guidelines should be formulated including the selection of proper design formulas for various revetment types, including stability of sublayers and subsoil, and also including design recommendations concerning toe protection and transitions.

Implementation of knowledge

The existing knowledge on design, construction and maintenance of dikes, especially at districts, needs upgrading. Because of a language problem, the access to the current literature is limited. Therefore training of technical staff is urgently needed.

To improve communication in the field of transfer of know-how from The Netherlands to Viet Nam, the one-year training of at least two young engineers at the International Hydraulic Institute (IHE) in Delft, supplemented by about two months orientation within the specialistic Rijkswaterstaat Divisions is considered as a minimum. It is stressed that for a training in the Netherlands an adequate knowledge of the English language is necessary.

Moreover a short course in Viet Nam for the engineers involved the project should be considered. For the long term it would be important that the (backgrounds of the) standards will be taught at the University.

Seminar

On a seminar on 9th April, attended by representatives of DDMFC, provincial and district design engineers, Hydraulic Institute, Hanoi Water Resources University and Meteorological Service Viet Nam, the Dutch mission has presented the results of the mission. Also a case study was presented on the calculation of crest height and the stability of revetments, based on the state-of-the-art design standards.

Execution

In order to have a reference to check, the detailed specifications of the design and execution and permitted tolerances, should be established in 'execution specifications' and proper drawings. To achieve a proper construction special attention should be paid to the execution of the revetment, the transitions and the compaction of the earthfill.

Surveillance during the execution by a supervisor who is familiar with the design of the structure, and a proper quality control system, are essential for a proper final result of a project.

Operation and maintenance

There should be a clear definition of responsibilities of various management levels resulting in 'short lines' in respect to decision and necessary actions concerning the repair of damages after the storm.

After each storm an inspection report should be prepared. Small damages should be directly repaired by the local authorities and people.

The storm damages should be repaired before the next storm season starts. The unrepaired locations (even with small damages) may lead to the serious damages during the next storm season, which can be very costly to repair.

A check list for post-storm inspection and reporting should be prepared by the Department for Dike Management and Flood Control, as well as the maintenance guidelines and definition of responsibilities.

During the lifetime of the structure the boundary conditions (e.g. due to the morphological changes) and also the strength of the structure can change. Therefore it is recommended to order the local authorities to report periodically the actual state of the dike in respect to fulfilling its defence function.

For realization of this goal it is needed to have a sufficient data base. In the present situation these actions are basically taken place.

General conclusions

From the observations of the mission and the comments as drawn in this report, the following general conclusions can be mentioned:

- In all reviewed designs, each province has used different prediction methods for waves and wave runup, and stability of the revetments. Because of that it is nearly impossible to compare all these designs.
- The applied design water level seems to be too high; on the other hand the calculated wave runup is insufficient. As a preliminary conclusion it can be mentioned that the calculated crest height is sufficient in Nam Ha Province and at some stretches in the other provinces. At most stretches the crest height seems to be insufficient. For a better judgement detailed calculations are inescapable.
- The wave prediction, especially for long and shallow foreshore, and its interaction with dike slope is insufficient. This will have repercussions for the calculated runup and revetment stability. Some prototype measurements on local wave spectrum and interaction with existing dikes, and laboratory investigations of runup with shallow foreshore are recommended.
- The actual design approach concerning the stability of the revetments on the sea dikes is not always based on the right formula and is also inconsistent, and can not be accepted as a final design.
- In most cases the dikes to be improved have a various exposition in relation to the dominant wind direction. From the designs it can be concluded that in each province only one direction is considered.
- Special attention should be paid to the compaction of clay-earthfill
- Feasibility study incl. costs should be done on stability of revetments at lower design frequency of water levels and resulting waves (e.g. 1/50 and 1/100 years). Mostly it is possible to achieve much higher stability of revetments at a little additional cost. It will reduce the amount of future repair costs and will allow additional heightening of dikes without necessity of placement of new revetments.

Preliminary Action Plan

The Dutch mission, based on her observations and conclusions as drawn above, is recommending to undertake the following actions:

Dike program 1996-1997

The designs of dike stretches planned for rehabilitation in 1996 and 1997 should be examined again, as soon as possible (without waiting till the future design guidelines are prepared). The Dutch technical documents [6] and [7], which are provided to the DDMFC, can be of use for this examination. In order to prevent a delay in the WFP-program it is recommended to consider a second opinion of the adapted

designs by the members of the Dutch mission, in the foreseeable future. For this purpose it is necessary to provide the basic data of the dike stretches for realisation in the near future.

The proper quality of input data/hydraulic and geotechnical boundary conditions is of a primary importance for a proper design. An expert working group should prepare a document with boundary conditions for the coast of Viet Nam, which should be used as a basic document for the design process.

It is recommended to organize a semi-permanent help-desk at the Rijkswaterstaat for occurrent technical assistance during realization of this program.

Design guidelines

Project definition and project proposals should be worked-out concerning the preparation of the national design guidelines for sea dikes in the coming two years (1997-1998). For the transfer of the available Dutch know-how on this matter, the appointment of the joint working-team (Viet Nam - The Netherlands) is recommended.

To ensure the effectiveness of such working group, the project should be commissioned by, and realized under direct responsibility of the Vice-Minister of the Ministry of Agriculture and Rural Development. The project-team should consist of representatives of DDMFC, one or two designers from the provinces, representatives from the Hanoi Water Resources University, Institute for Water Resources Research and Meteorological Service. There must be a proper commitment of all these parties to the project and the existing boundaries between various departments should disappear.

Educational program

Parallel with the activities as mentioned above, the short- and long term educational program for technical staff should start.

It should include the following components (steps):

- short course (2 to 3 weeks), for design staff in Viet Nam, preferably in 1996;
- short visit of Vietnamese designers to The Netherlands;
- training of few (young) engineers in The Netherlands, by attending the yearly course at the International Hydraulic Institute in Delft, and including a 1 or 2 months period of orientation within the Rijkswaterstaat Divisions;
- upgrading the teaching program of the Hanoi Water Resources University.

Integrated studies

Feasibility (integrated) studies should be undertaken, concerning the coastal area of Nam Ha Province, with special attention to the erosion problems of the Hai Hau district.

Besides the studies on the physical components, an integrated policy analysis for the coastal area of Nam Ha Province should be prepared (safety/risk analysis, evaluation of local interests, additional coastal protection measures, environmental aspects, etc.). The results of this policy analysis will provide the base for the necessary decisions concerning this area, by the policy-makers.

1 INTRODUCTION

1.1 Background

The coastal areas of Vietnam are repeatedly hit by devastating storms and typhoons. Protective sea dikes are overtopped or breached every year, with the resulting flooding causing damage to agriculture land, loss of life and crops, and destruction of infrastructure.

The overtopping of the sea defences causes salt intrusion which decreases the agricultural productivity. Further the constant risk of flooding discourages farmers to adopt new technology or to invest in other income-generating activities.

Assistance of World Food Program (WFP) will act as an incentive to the population to undertake self-help dike upgrading activities. So, under the WFP project number 5325, in the period of 1996 to 2000, 361 kilometres dikes in the coastal area of the five northern provinces of the densely populated Red River Delta will be assisted by the WFP program and will be upgraded in order to reduce the risk of sea water reaching the areas behind them (see picture I.1).

The Red River Delta is characterised as low lying with a enormous network of river branches with a long line of dikes and sea defences. Most of the sea dikes are built over the centuries mostly due to local initiatives. The sea dikes have generally an inadequate design and are poorly constructed. Due to the bad state of the dikes a significant part of the yearly funds has to be allocated to repairs and maintenance. The length of the coastline is approximately 165 km as the crow flies.

Governmental organization

At the national level the government is organized according to the schematized tree diagram in appendix F1. The country is being led by the governmental council in which Ministers are seated. Each Minister has the responsibility over his ministry or equivalent organization.

The same organization structure as on the national level is also implemented on the lower levels (see appendix F2). These are the provincial level, the district level and the commune level (a cluster of villages). The administration of these levels is called the Peoples Committee of the province, district or commune. At the province and district level there are representatives of all the ministries and equivalent organizations as presented in appendix F1. Each department or representative has the responsibility to report to the higher level. So it is the task of the Representative of the Waterresources Department in the commune to report the condition of the dikes bottom up.

Parallel to the People Committees there is also the structure of the Communist Party which has its national, provincial, district and commune departments and representatives as well. On each level the Party Committee plays an important role in all important decisions. The chairman and people on key positions in the Peoples Committees are usually also seated in the Party Committee. Decisions are therefore made in good agreement between the Party Committee and the Peoples Committee. In general it can be stated that the Peoples Committees are responsible for the daily administration while the Party Committees control the outline of the policy.

The coastal defence system in Viet Nam is in principle the responsibility of the Ministry of Agriculture and Rural Development (MARD). The Ministry is organized according to appendix F3. In this schedule the Department of Dike Management and Flood Control (DDMFC, appendix F4) is in charge of the monitoring, maintenance, improvement, design and funding of projects on the river and sea dikes. The DDMFC manages 5.000 km of river dikes and 3.000 km of coastal and estuarine dikes throughout the whole country. In practice, the Ministry has especially a funding, controlling, managing and supportive function towards the local (province and district level) representatives. The institutional structure for combatting the annual effects of floods and typhoons is presented in appendix F5.

The DDMFC (appendix F5) also runs the Secretariats of the Central Committee for Flood and Storm Control (CCFSC) and the Viet Nam National Committee for the International Decade for Natural Disaster Reduction (VNCIDNDR). The CCFSC is responsible for the emergency responses just before (forecasting and warning), during (coordination) and after the onset of the disastrous event. The VNCIDNDR is responsible for preparing the community and the responsible authorities is cooperation with international organizations (public awareness, emergency preparedness).

1.2 Terms of reference mission

As a result of the strong similarity in physical nature between the Netherlands and Viet Nam on water related issues, the Department of Dike Management en Flood Control (DDMFC) of the Ministry of Agriculture and Rural Development has requested to the Ministry of Transport, Public Works and Water Management of the Netherlands for technical assistance on flood control issues.

As a first step in this program a mission visited Vietnam in order to evaluate the designs and execution options for the five coastal provinces of the Red River Delta.

The Terms of Reference for the mission is as follows:

- a. Review of the existing improvement plans with their status.
- b. Survey and assessment of the dike systems and designs in the provinces including field visits together with the designers.
- c. Evaluation of the hydraulic boundary conditions for the dike design.
- d. Evaluation of other factors affecting the design and stability of the dikes, as coastal erosion, etc.
- e. Introduction of Dutch guidelines for design.
- f. Review of and advice on the incorporation of the specific constructions in the dikes as water discharge sluices etc.
- g. Preliminary Action Plan with Prioritizing; for this issue the results of the VVA study can be used.

Members of the mission:

Ministry of Transport, Public Works and Water Management

* Mr. Krystian W. Pilarczyk, Road and Hydraulic Engineering Division

* Mr. Piet J. Eversdijk, Civil Engineering Division

Viet Nam Vulnerability Assessment project (VVA)

* Mr. Gijsbert Kant

Mr. Kant has assisted the mission in order to provide the necessary information gathered in the scope of the VVA project.

1.3 Results of the mission

During the mission discussions were held with the different parties, which are involved in the program for the improvement of the sea dike system in the RRD, even on Ministry -, Province - and District level. Different documents were examined and site visits gave an impression of the present situation. At one place, a dike improvement under construction was visited.

The impressions, comments and recommendations are described in this report. Moreover, a seminar was held for the people of the different institutes and design offices, involved in the dike improvement program (see also appendix A2, page 10, and picture I.10).

In chapter 2 a short description of a design methodology and a view on the risk level is given.

In chapter 3 the hydraulic boundary conditions as the bottom topography, and the water level and waves in front of the coastline of the Red River Delta, are discussed.

In chapter 4 the present designs are described and also comments to that are given.

The mission paid only limited attention to the execution and maintenance aspects. Nevertheless some topics are mentioned in chapter 5.

In the chapters 6 to 10 more specific remarks for each province are presented.

To give some idea about the more systematic design approach and the sensitivity of the outcome in respect to the input data, in chapter 11 a simplified case study was prepared.

Finally in chapter 12 conclusions are drawn and some recommendations are given, resulting in a preliminary action plan.

The mission wishes to thank the representatives of the different organisations and agencies involved for the open and fruitful discussions and for the great hospitality. Especially, the support of Ms. Pham Thi Hong and Mr. Ton That Vinh should be acknowledged.



Figure 1.1 Dutch delegation during visit of Hanoi University

2 DESIGN PHILOSOPHY

2.1 Design methodology

In order to decide what protective measures should be taken in case of coastal defence problems, different preceding activities must be realized. On the one hand the causes and the extent of the coastal problem should be assessed by means of a study into the boundary conditions and the morphological processes in the area considered. On the other hand an evaluation should be made of the different interests, which may be related to safety, agriculture, recreation, environment, economy, etc.

The general methodology is drawn in figure 2.1.

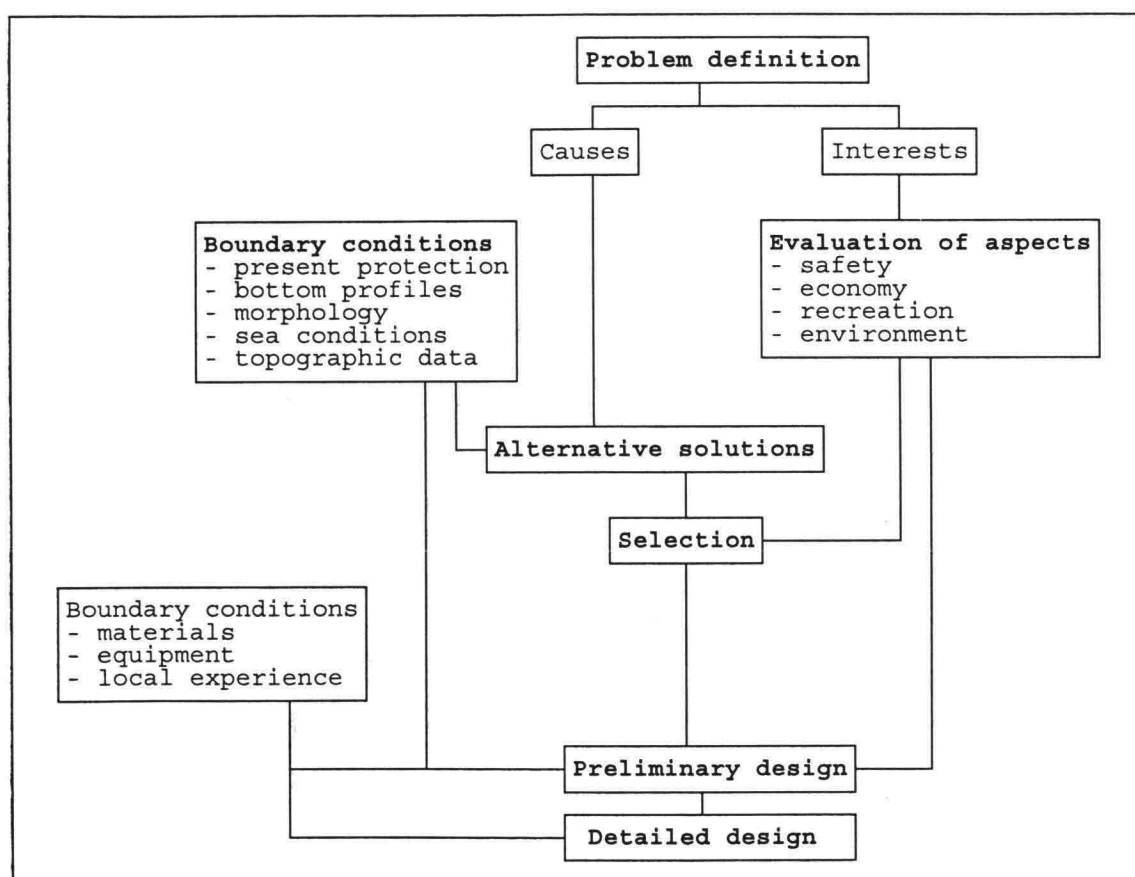


Figure 2.1 Methodology for solving coastal defence problems

Problem definition

An appropriate solution can only be found when the problem is well defined. This does not only include the identification of the actual problem itself, but also why the problem is identified as such.

From section 1.1 it can be concluded that in case of the dikes along the Northern coast of Viet Nam (Red River Delta) the problem can be summarized as follows:

- a. The strength of the present dikes is not enough to withstand devastating storms and typhoons
- b. Salt intrusion due to overtopping: crest is too low

From the problem definition a program of requirements can be defined which must be met when designing the alternative solutions.

Boundary conditions

A clear insight into the hydraulic boundary conditions and the morphological processes in the area of interest is necessary to determine the causes of the coastal problem and to choose the right type of protective measures.

The actual design of coastal protections is determined by the local conditions like waves, tides, currents, bottom profiles, morphological processes and the characteristics of sediments and soils.

The knowledge of the hydraulic conditions and the morphological processes can be obtained by careful analysis of the available data. Additional measurements may be necessary.

Not only the present evolution in the coastal zone needs to be known, but also the change which is expected to occur in the future (for instance a rise in sea level, structural erosion, accretion). In fact, the present condition and the future development of the coast should be confronted with the interests involved in order to decide whether protective measures should be taken or not and to which extent.

Aspects

An evaluation of the different interests should be made in order to be able to make a proper decision between the alternative solutions.

First, all relevant aspects should be discerned. Second, the relative importance (weight) of the aspects should have to be determined.

In case of the RRD such aspects as safety, economy, housing, environment, sacral and historical values (see also picture I.2), and agriculture should be considered.

Alternative solutions

Experience and engineering judgement play an important role in applying the design rules in the actual design process of coastal protection measures.

Possible solutions must solve the defined problem(s), taking into account the local boundary conditions and the interests defined. The hydraulic and morphological consequences of the alternatives must be known. The solutions have to be work out to such a level that a comparison of the different alternatives is possible.

In case of the RRD e.g. the following alternatives can be considered:

- retreat or maintain present dike in erosion area
- maintain or replace dike seawards in accretion area
- stabilize the existing foreshore in erosion area eventually in combination with groynes or offshore sills
- different amount of overtopping, in combination with additional measures for overtopped dikes

Selection

A weighing of the relevant aspects against the effectiveness of the alternative solutions can result into a decision on what protective measures should be taken. Therefore a so called 'policy analyses study' should be prepared, on province-, district- or project level.

The weight or relative importance of the various aspects is a matter of policy-makers. By using several sets of weight scores, different points of view can be evaluated. The effectiveness scores can be qualitative (for instance scores like ++, +, 0, -, and --) or quantitative in terms of absolute or relative figures, or by means of ranking.

Ranking of the alternatives can be determined by a summation of the aspect scores.

Table 2.1 gives a simplified example of an evaluation matrix. Safety is in this example the most important aspect. The scores of the alternatives are given by ranking (1 = worst; 5 = best). The highest total score gives the best alternative which is in this example alternative "3".

Aspects	Weight	Alternative solutions				
		1	2	3	4	5
Safety	50 %	5	1	4	2	3
Economy	25 %	1	2	3	5	4
Environment	25 %	2	5	3	4	1
	100 %	3.25	2.25	3.5	3.25	2.75

Table 2.1 Example of an evaluation matrix

Using another viewpoint, for instance safety = 30 %, economy = 60 %, and environment = 10 %, it will give "4" as best alternative with a total score of 4.0.

In this way the optimal solution considering the importance of all the relevant aspects, seen from a certain viewpoint, can be selected in a relatively objective way. However, especially in Viet Nam case, the cost of construction and future maintenance should also be included in this analysis, because the cost will be generally a controlling factor in the final choice of alternative solutions.

Preliminary design

After choosing one or two conceptual designs, these designs must be worked out in detail. At this stage (the preliminary design), more accurate boundary conditions are required to determine the dimensions of the protective measure.

Detailed design (and tender documents)

In the scope of the detailed design all possible failure modes should be examined according to the actual calculation methods. After that the final structural design of the structure according to the actual design criteria can be performed.

This includes, for example, such structural components as:

- dike body and its composition and compaction
- settlement of subsoil
- revetment (if necessary) including filter structure
- transitions and toe protection
- splash area (crest) and inner-slope

The possible execution methods (incl. availability of equipment) and future maintenance should be taken into consideration during the design process. The detailed design should be properly reported including necessary detailed drawings and tender documents.

Summary and recommendations

In order to decide what kind of protective measures should be taken in case of coastal defence problems, different preceding activities must be realized. On the one hand the causes and the extent of the coastal problem should be assessed by means of a study into the boundary conditions and the morphological processes in the area considered. On the other hand an evaluation should be made of the different interests, which may be related to safety, economy, housing, environment, agriculture etc.

There is a large research potential available in Viet Nam, e.g. Department for Dike Management and Flood Control, Vietnam Institute for Water Resources Research, Hydrometeorological Service of the Marine Hydrometeorological Centre and Hanoi Water Resources University. However, to use effectively this potential in solving of practical coastal problems a more closely cooperation between the different parties in the design process should be further stimulated. To achieve this goal some administrative actions should be undertaken by the Ministry of Agriculture and Rural Development. Special attention should be paid to the quality of hydraulic boundary conditions which will strongly influence the final quality of the design.

It should also be considered to develop different possible solutions to a problem and compare these solutions on basis of the interests involved. Also future development on economy and boundary conditions should be considered. Then, the available money and labour can be used in a (more) efficient way. Therefore a so called 'policy analyses study' should be prepared, on province-, district- or project level.

To improve understanding between various institutes and in order to involve the different interests in the design process, the activities related to a certain program (problem or project) should be organized in a form of multidisciplinary project teams. The leaders of such project teams should have sufficient wide, properly defined responsibilities.

2.2 Risk level

Socially acceptable risk-levels for inundation

The first problem in dike-design is to establish an allowable failure frequency of the structure. It has to be decided how often flooding of an area is acceptable. This is normally not a responsibility of a designer, but more an economical and political problem of policy makers. One can imagine that an optimum relation can be found between the cost of dike construction and the value of the protected goods. Higher dikes costs more, but are economic when you have to protect valuable infrastructure in the area protected by the dike. However this problem can not be solved only on a financial basis. Another important question is: 'what is the economic value of a natural reserve and especially of human lives'. So in fact it is a mixture of politics and economics.

Thus the level of safety depends on the willingness of investing money in safety and (of course) on the availability of money.

Because in the Netherlands the building of dikes started by (small) private land-owners working together, they build up a tradition of investing in the property they used to work on.

Determination of design values

After having determined the risk level (and thus the allowable probability of failure), one can determine the strength of a structure and the design load on the structure.

In the Netherlands it was decided to design dikes with a design load with a given probability of occurrence. Under this design load the construction has to be strong enough to ensure an extremely low probability of failure.

Practically this means for the central part of the Netherlands that the design water level is the level with an occurrence of once every 10,000 years (1/10,000). So we design a dike with a design water level (including a storm surge) with a probability of 1/10,000 per year. This water level is determined using extreme value statistics. Together with this design water level we determine the corresponding boundary conditions (like the wave-height, etc.).

Not every place in the Netherlands needs to be protected against a 1/10,000 level. Places where less people live, or with less economic activity, may use a lower design value. For the south-western and northern part of the country a level of 1/4,000 is adopted. For river dikes a level of 1/1250 is accepted.

Practical values

The values of 1/10,000 and 1/4,000 are general values in the Netherlands. These frequencies are reasonable because about a half of the Netherlands will be flooded during severe storms without proper sea defences (dunes, dikes and other structures). It is quite doubtful that in the rest of the world identical values should be used. As indicated above, these values depend on the economic value of the activities in the area, the social acceptance of flooding, the amount of money authorities are willing to spend on flood protection, etc.

In general one can state that high-yield agricultural areas should not be flooded too frequently, especially not by salt water. It also depends on the time of the year when flooding usually occurs. For high-yield agricultural areas which might be flooded by fresh water one should think of a flooding frequency of once every 10 years. When high investments were made in irrigation and drainage, one might decrease the frequency to 1/25. For salt-water flooding one should use frequencies in the order 1/50 to 1/100.

For individual houses a value of 1/50 - 1/100 is a good guideline. In this case it is assumed that the flooding causes considerable damage to the construction of the house. If the flooding only causes some water in the house, the frequency might be in the order of 1/10.

For a complete village the values for damage-causing floods should be in the order of 1/100 to 1/500. For big cities, industrial areas and areas vital for the functioning of the country (airports, railway stations, etc.) the frequency of damage to a protection resulting in a flood should be in the order of 1/500 to 1/1000.

In the above it is assumed that the dikes only protect against a flood, and that after the flood or storm surge the water flows away naturally from the area. If the dikes protect a polder area with a surface level below normal high tide (like it is in the Netherlands), then a tidal flow will remain in the dike breach, even after the storm surge. In that case the frequencies should be at least a factor 10 less.

Of course the above mentioned values are only first estimates. In many cases the selected safety will be a factor 10 more or less. In any case one should compare the risk of flooding with the other risks in the area (problems with chemical industry, earthquakes, volcanos, etc.).

Conclusions for the Red River Delta Viet Nam

For a proper design, as a starting point, an acceptable risk level has to be fixed. The present designs for the rehabilitation and upgrading of the sea dikes in the RRD are based on design-circumstances which will occur with a frequency of 5% each year (1/20 years). However the interests to protect, vary for the different area. In order to get a balance between the investments for dike improvement and the value of the interests to be protect, it is advised to consider a differentiation in risk level.

From the moment that people realize that the area they inhabit, is protected in a sufficient way, investments will be done. Moreover, the living standard and the economic situation in Vietnam will expand in near future. Consequently, the interests in the area adjacent to the sea will increase. In order to keep in balance the future interests and the safety level, the safety level will probably be upgraded again. Therefore it should be considered to allocate a free strip on the landside of the dike for future improvements and/or developments (see also picture I.3).

3 HYDRAULIC BOUNDARY CONDITIONS FOR SEA DIKE DESIGN

3.1 Introduction

In order to achieve an effective planning of the shoreline protection and to achieve sound sea dike designs along the coast a reliable set of statistics which describe the hydraulic boundary conditions acting on the sea defence is essential. A good insight is needed in operational conditions as well as in extreme conditions. Well documented and reliable data will in general lead to a optimal and cost effective defence strategy whereas a lack of data usually results in costly conservative designs or in unexpected high risk levels which may lead to unpredicted losses and high maintenance costs.

In this chapter the most important hydraulic boundary conditions for sea dike design are discussed. Further, a preliminary comparison is made between the boundary conditions used in the sea dike design of the five northern provinces of Vietnam (WFP project 5325) and data gathered during the Vietnam Vulnerability Assessment Project.

Hydraulic boundary conditions are determined by the following parameters. The most important parameters which will be discussed in this chapter are:

- *bottom topography*
- *wind*
- *waves*
- *water levels*
- *currents*

These parameters interact and may act simultaneously. In figure 3.1 the interaction of the various hydraulic boundary conditions is presented.

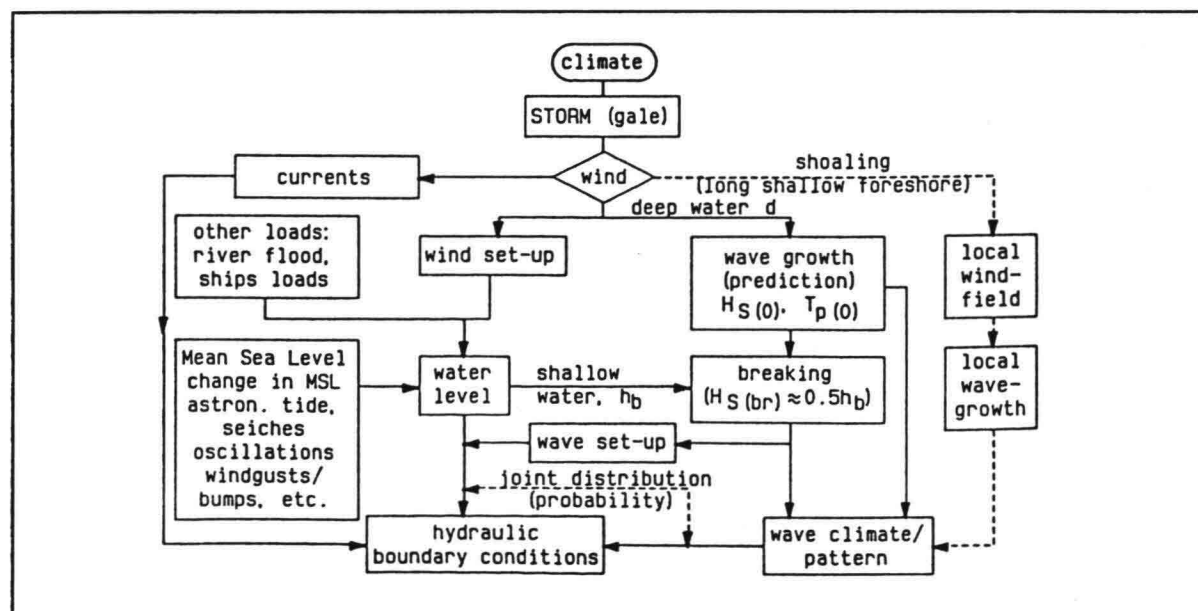


Figure 3.1 Interaction of hydraulic boundary conditions

3.2 Bottom Topography

Knowledge about the bottom topography is important since it determines how the environmental conditions, like for instance waves and currents, act on the dike. Nearshore and offshore boundary conditions usually vary significantly because of the influence of the bottom topography. Shallow areas are for instance vulnerable for a high wind set-up during storms resulting in a high design water level. On the other hand shallow areas force waves to break which will reduce the wave attack and run-up on the dike face.

In the case of a shallow foreshore waves will break in front of the dike. The way that wave breaking occurs depends on the wave characteristics (wave height and wave period), and the local water depth. For example: a solitary wave will break when the wave height becomes bigger than 0.8 times the local water depth.

A shallow foreshore can be very advantageous with respect to the maximum wave forces acting on the dike. Therefore it is of importance to know the bottom topography in front of the dike and also the stability of the foreshore. In case of an eroding coast the water depth in front of the dike will increase in time which will also result in an increasing wave attack. Accretion in front of the dike will result in a decreasing wave attack during the lifetime of the dike. Whether erosion or accretion is expected depends on the morphological behaviour and development of the coastline.

For a sound planning and design of sea defences it is therefore necessary to know the bottom topography in front of the coastline and to make a prediction of the shoreline development for the lifetime of the structure. Such a prediction can be made based on the historical coastline development in combination with a morphological analyses of the coast. In such an analyses the effects of the sediment load of the rivers, longshore and cross-shore sediment transports etc are evaluated. Based on the shoreline prediction the design conditions of the sea defence can be determined. Further, decisions can be made to concentrate efforts and investments on for instance eroding shoreline sections and not on accreting shoreline sections.

3.3 Wind

Wind itself is not a parameter which is needed for a sea defence design. However, wind is the important parameter which governs the wave climate and, to a certain extent, the current climate.

In the study area the wind climate can be divided into a summer and winter monsoon period. During the summer monsoon period moderate winds (average force: 3 Bft) from south westerly direction prevail. In winter the predominant wind direction is north east. The average wind force during the winter monsoon period is about 4 Bft.

On average two typhoons per year hit the coastline of the northern provinces in Vietnam. The typhoon season in this part of the country starts in May and lasts till October. The highest activity of typhoons occurs in the months July and August. According to international standards typhoons develop maximum wind speeds over 32 m/s. Tracks of typhoons are irregular both in propagation speed and in direction. Therefore typhoon generated wave climates are not easy to predict. The best insight in typhoon generated waves will be achieved by means of measurements.

3.4 Waves

As the wind climate, the wave climate can be divided into a summer and winter monsoon period. The average deep water wave height in the summer months is about 1.5 m from south westerly directions. The average wave height in winter is about 2 m coming from the north east.

However, during typhoons the deep water significant wave height may develop up to 10 m. No data on wave periods is available. Most likely wave periods of over 10 sec are to be expected.

Since the bigger part of the coastline of the northern part of Vietnam has a shallow foreshore in most cases the design wave heights for the sea defences will be depth limited. Based on the present bathymetry and on the predictions for the near future the design wave height for the sea defence design can be calculated. However, it is still important to know the deep water wave climate (wave height, wave period, frequency distribution). Not only for the sea dike design but also for other purposes (morphology, coastline development predictions).

As mentioned earlier the reliability of (design)wave predictions using the relationship between wind, fetch length and wave height is questionable especially under typhoon conditions due to the typical strong variations in wind speed and wind direction. This method should at least be verified against measurements for the local circumstances.

A reliable deep water wave climate can only be obtained by long term measurements. In this way a reliable set of statistical wave parameters can be defined. This data set should include directional frequency distributions of the wave height and wave period.

In this respect available measuring equipment (e.g. wave rider buoys) can be used to obtain these long term wave data.

3.5 Water levels

One of the important parameters determining the crest level of the dike is the so called design water level. For the design usually a choice is made on the exceedance probability of the design water level. The water level at the dike is a combination of several effects and processes. The most important are:

- *astronomical tide*
The astronomical tide is a regular periodic vertical water movement, driven by the gravitational forces of the moon and the sun. The astronomical tide can be predicted by use of a harmonic analyses. Results of these analyses are published in tide-tables. Astronomical tides are often measured or published with a datum level which is related to the lowest astronomical tide. For dike design purposes the astronomical tide levels should be transferred to the design datum level (in Vietnam: Mean Sea Level).
- *wind set-up (surge)*
Water level variation due to wind set-up is a result of the friction between the wind and the surface of the water.

- *sea level rise*

Sea level rise is a long term effect which is a result of climatologic changes. As a result the average sea level rises. Based on the lifetime of the new structure the effect of sea level rise can be taken into account. Predictions of this sea level rise vary up to 90 cm per century. However at this moment it is sufficient to take into account approximately 20 cm.

The design water level is determined by a combination of astronomical tide and the wind set-up. Based on the lifetime of the structure a value is added for the predicted sea level rise over this period. For the analyses of the design water level the recordings of the water level (hydrometeorological stations) can be of big help.

Water level recorders measure the water level which actually occurs. Sometimes a special structure is built to filter out short period water level variations (like wind waves, characteristic time scale: seconds). However, wind set-up (characteristic timescale: hours) can not be filtered out and is therefore always included in water level recordings. Further, each recorder measures water levels related to a specific datum level. For design purposes the values should be transferred to for instance mean sea level.

The design water level can be computed via three different paths:

- *water level recording exceedance curve*

The water level recordings of a station (which include astronomical tide and wind set-up) are statistically analyzed. In Vietnam recordings of over 30 years are available. In this way the water level which, for instance, will statistically be exceeded once in every 10 years can be computed. The results of these analyses, in combination with the predicted sea level rise, can then be used as design water level for the sea dike design.

An example of such an analysis is presented in figure 3.2. Maximum yearly water levels of 34 years of measurements are put into a water level exceedance curve. Based on this preliminary analysis the water level (astronomical tide plus wind set-up) with a return period of 20 years would be approximately 2.25 m MSL.

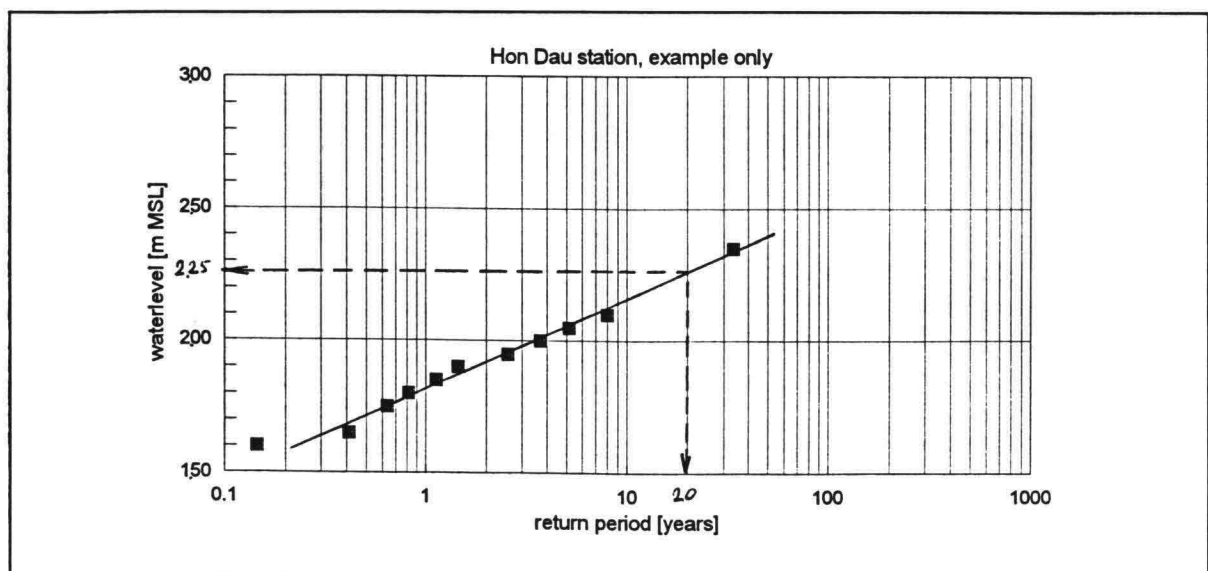


Figure 3.2 Example water level exceedance curve

During the mission the data as presented in table 3.1 was gathered on water levels along the northern coast of Vietnam.

Hon Ngu station	station datum [m]	relative to MSL [m]
maximum recorded water level (30 years)	3.88	1.98
mean sea level	1.90	0.00
minimum recorded water level (30 years)	0.14	-1.76

Hon Dau station (Hai Phong)	station datum [m]	relative to MSL [m]
maximum recorded water level (30 years)	4.21	2.35
maximum astronomical tide level 1992	3.80	1.94
mean sea level	1.86	0.00
minimum recorded water level (30 years)	-0.07	-1.95

Hon Gai station (Quang Ninh)	station datum [m]	relative to MSL [m]
maximum recorded water level (30 years)	4.73	2.67
maximum astronomical tide level 1992	4.20	2.14
mean sea level	2.06	0.00
minimum recorded water level (30 years)	-0.26	-2.32

Cua Ong station (Quang Ninh)	station datum [m]	relative to MSL [m]
maximum recorded water level (30 years)	4.74	2.55
maximum astronomical tide level 1992	4.50	2.31
mean sea level	2.19	0.00
minimum recorded water level (30 years)	0.09	-2.10

Table 3.1 *Data on water levels along the northern coast of Viet Nam; stations presented in Appendix D*

Based on this data it appears that the amplitude of the diurnal astronomical tide increases going from south (Hon Ngu) to north (Cua Ong). Also the wind set-up varies along the coast depending on the water depth and fetch length. It is recommended to analyse the available water level data in more detail in order to specify design water levels throughout the entire coastline. There might well be significant differences in design water level between Ninh Binh province and for instance Quang Ninh province as a result of the difference in tidal amplitude and wind set-up.

Comparing the above presented data to the design reports of the upgrading of the sea dikes of the five northern provinces (summarized in table 4.1) the following remarks, comments and recommendations can be made:

- The design water level has been determined based on a summation of the tidal level (5% exceedance probability) and the wind set-up.
- The design water levels vary from 3.39 m MSL (Hai Phong and Thai Binh) to 2.86 m MSL (Quang Ninh). From the tables presented above can be derived that the maximum recorded water level in 30 years in Hai Phong was 2.35 m MSL and in Quang Ninh 2.67 m MSL. It can be concluded that there appears to be a difference in safety level (risk of flooding) between both provinces.
- Comparing the various sources of information it might be possible that the tidal level which is used in the calculations already includes the wind set-up. It appears that this value has been derived from a water level exceedance curve and not from the astronomical tide-table figures.
- As explained earlier, it is recommended to verify and validate the wind set-up formulation. This can be done by comparison of water level measurements and wind set-up computations.
- Comparing the design water levels for the designs and the above presented maximum recorded water levels for different stations for a 30 year period it can be concluded that the safety standards for the various provinces are not consistent.

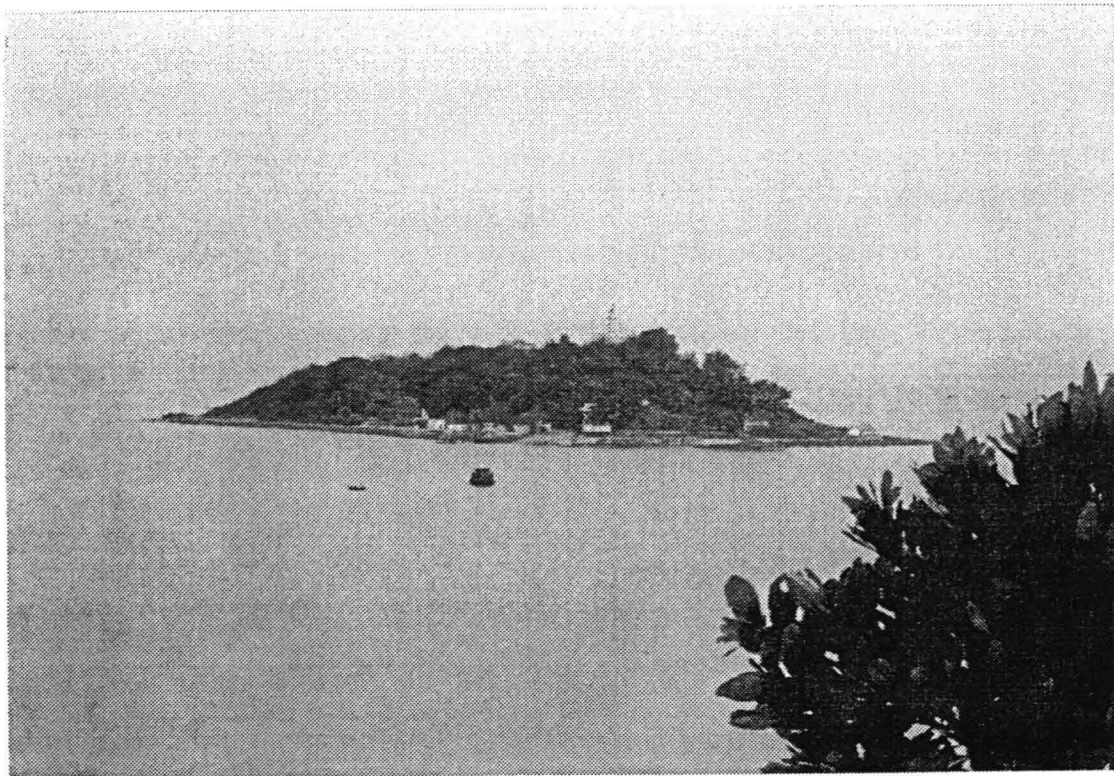


Figure 3.4 View on island with Hon Dau Station

3.6 Currents

Currents are of significant importance with respect to the development of the coastline. The interaction of waves and currents is the important transport mechanism which governs the coastal morphology and development. Therefore it is necessary to have a good insight in the current climate and the current driving forces along the coast. Currents are the result of a superposition of a number of different driving forces. The most important currents are:

- *tide driven current*
the astronomical water level variations along the coast induce tidal currents along the coast. The magnitude of the tidal current depends on the tidal amplitude, the tidal period and the shape of the bathymetry.
- *wind driven current*
Especially when the wind is directional persistent and/or very strong, there will be a significant effect on the surface current. In Vietnam the persistent monsoon winds will have a effect on the (surface) current climate. Typhoons will cause significant impacts on the current, but only for a very limited period of time.
- *wave driven current*
Part of the energy of breaking waves is transformed into the generation of the so-called wave driven current. Especially in the surfzone this current plays an significant contribution to the current climate.
- *river currents*
In the direct vicinity of rivers (estuaries) the effects of river discharges will be noticeable. Especially during peak discharges.

3.7 Recommendations

The following recommendations with respect to boundary conditions for sea dike design have been formulated:

- analyse all the relevant available wind, wave, current, water level and bathymetric measurements in order to define the boundary conditions along the entire coast the best as possible. Priority should be given to the water level analysis (required to obtain the design water level) and the bottom topography (required to obtain design wave heights).
- prepare boundary condition guidelines and submit these to the local (provincial) governments. These standards will contain specific values (based on the analyses of measurements) to be applied or standardized procedures to calculate certain design parameters.
- determine priorities for improvement. For example: setting up a long term wave measurement campaign.

4 TYPES OF DIKES AND DESIGN CALCULATIONS

4.1 Types of protection

In general four types of dikes can be distinguished:

- sea dikes and estuarine-dikes
- river-dikes or levees
- dikes around lakes
- dikes along canals

These four types differ in design and construction method. During the mission only sea dikes and more or less estuary dikes have been considered.

4.2 Dikes and revetments in general

Dikes and revetments are both types of shoreline protection. However, their aim is different. The aim of a **dike** is to prevent flooding and salt intrusion of the area behind the dike. This can be both a temporary flooding or a permanent flooding. Permanent flooding occurs when the land is below normal high water level. Temporary flooding occurs when the land is above normal high water, but below the flood level. In case of a land level between normal low water and normal high water, as it is in the coastal zone of the RRD, the area will be flooded, with the rhythm of the tides. This land is usually called **intertidal** land.

The most important aspects in a dike design are:

- crest level
- stability under design conditions
- watertightness

of which crest level and stability strongly influence the geometry of the dike.

The geometry of the seaward face of the dike or dam can vary. A simple dike has a single slope, the composite dike has two slopes, the upper one being steeper than the lower, and the bermed dike has a horizontal step (berm). The steepness of the slope can be varied.

Revetments have a different aim. Their aim is to prevent loss of land (loss of shore-face) due to erosion. This erosion can be caused by currents, by waves, or by both at the same time. Sometimes this erosion occurs only during storms (like the erosion of dunes).

On a dike one usually also finds a revetment. The aim of such a revetment is the prevention of erosion of the dike-front, due to wave action. This can be both extreme or normal condition wave action. Very often the revetment on a dike is called **slope-protection**. In this way a distinction is made with a **bottom-protection** which has the task to prevent scouring of the bottom under water, in front of a structure.

Types of revetments

There are numerous types of revetments. They can be distinguished in several groups:

- a Loosely deposited material like gravel, riprap, tetrapods or dolosse, etc.
- b Regularly placed concrete elements
 - concrete blocks
 - concrete columns
 - blockmatresses

- c Monolith constructions
 - cement concrete slab
 - (hydraulic) asphaltic concrete
 - riprap (fully or pattern) grouted with an asphaltic mixture (bituminous emulsion)
 - riprap (fully or pattern) grouted with concrete
- d Special structures
 - sandbags or sand sausages filled with sand, gravel, cement, rock, etc.
 - gabions (wire mesh containers with relatively coarse material)
 - gravel
 - grass on a clay layer

Selection of a reliable revetment depends on the following boundary conditions:

- availability and quality of materials
- availability of labour, engines and devices
- experience with the application of the construction technique, and
- costs for transport and apply
- possibilities for re-use in the future

4.3 Calculation of crest height

Formula used

For the calculation of the crest height in the 5 northern provinces of the RRD the following formula is used:

$$H_{dd} = H_t + H_{nd} + H_{sl} + a$$

of which:

- H_{dd} = design crest height (m)
- H_t = design tidal water level corresponding to probability of $P = 5\%$ (m)
- H_{nd} = height of storm surge corresponding to wind of 9B scale (m)
- H_{sl} = height of wave runup (m)
- a = free board

Results

The results of the calculations which were made are summarized in table 4.1.

Province	Quang Ninh	Hai Phong			Thai Binh	Nam Ha	Ninh Binh
H _t (m)	2.56	2.29			2.29	2.29	2.29
H _{nd} (m)	0.30	1.1	0.9	0.8	1.10	1.00	0.95
Design water level (m + MSL)	2.86	3.39	3.19	3.09	3.39	3.29	3.14
H _{sd} (m)	1.77	1.82	1.57	3.09	1.50	2.00	1.48
a (m)	0.30	0.30	0.30	0.20	0.30	0.21	0.25
H _{sd} (m + MSL)	4.94	5.51	5.06	4.46	5.20	5.50	4.97
round	5.00	5.50	5.00	4.50			5.00
in case of mangroves	4.50						
outer slope	1:4	1:3 ÷ 1:4			1:4	1:4	1:4
H _s	2.18	1.82	1.57	1.17	1.56	2.14	1.56

Table 4.1 Summarized results of crest height calculations

Water level and storm surge

In section 3.5 H_t and H_{nd} already have been considered.

Wave runup

In the present design practice in Vietnam various formulas are used for prediction of wave runup. There is no recommendation which formula is the most actual and should be used. In the reviewed design of sea dikes the following two Russian formulas were mostly used:

$$1^0 \quad H_{SL} = (3.8 * h_s) / m * \cos \beta,$$

where h_s = local wave height, $m = \text{ctg} \alpha$ = slope angle, and β = angle of wave front approaching the coast.

$$2^0 \quad H_{SL} = 2 * K_n * (h_s / m) * (\lambda_s / h_s)^{1/3},$$

where K_n = reduction coefficient due to roughness of a slope and λ_s = local wave length.

When using both formulas no indication is given on estimation of local wave length. Even for wave height a number of various formulas is used without indication howfar the formula used is appropriate for conditions under consideration. No effect of the slope roughness is included in the formula (1⁰). The first formula (1⁰) is similar to the 'old'-Dutch formula: $H_{SL} = 8 * H_s * \text{ctg} \alpha$.

However, the numerical coefficient in formula (1⁰) is about a half of the Dutch formula, which has been proved to work satisfactorily for smooth slopes and wave steepness of about 4% (or 3 to 5%). That means that the formula with coefficient 3.8 should only be used for riprap slopes where runup is reduced by factor 0.5. Using this formula for revetments or pitched stone and 2% wave runup the numerical coefficient of about 7.5 should be used (instead of 3.8).

The second formula (2⁰) is a more general formula including effect of slope roughness. (K_n) and wave steepness λ_s / h_s .

Note: in some designs (e.g. Haiphong) the component $(\lambda_s / h_s)^{1/3}$ is also written as $(\lambda_s * h_s)^{1/3}$. It is difficult to judge whether this is a typing mistake or a calculation mistake.

Formula (2⁰) can be rewritten to the form:

$$H_{SL} = 2 * K_n * h_s * \xi * (h_s/\lambda_s)^{1/6}$$

where $\xi = \tan\alpha/(h_s/\lambda_s)^{1/2}$

The component $(h_s/\lambda_s)^{1/6}$ in the range of storm waves, $2 \leq h_s/\lambda_s \leq 5$, provides the numerical values of 0.52 to 0.60.

That results in: $H_{SL} = (1 \div 1.2) * K_n * h_s * \xi$, which can be compared with the formula actually used for design of sea dikes in the Netherlands, namely:

$(H_{SL})_{2\%}/H_s = 1.5 * \xi * \tau_R * \tau_B * \tau_\beta$, for $\xi \leq 2$, and $(H_{SL})_{2\%}/H_s = 3.0 * \tau_R * \tau_B * \tau_\beta$, for $\xi > 2$, where H_s is a wave height and the numerical coefficients 1.5 and 3.0 represent average values (for design purposes the value 1.6 and 3.2 are used), $\tau_R = K_n$ = reduction due to roughness, τ_B = reduction due to berm, τ_β = the angle of approach of wave front.

Because $(H_{SL})_{2\%} \approx 1.4 (H_{SL})_{13\%}$, the formula (2⁰) is probably correct for wave runup with exceedance percentage of about 13%; that means that the crest will be overtopped by about 13% of runups.

Due to the using of various runup formulas, the predicted runup, and thus the predicted crest of the dike are not very consistent. Very often the designers are not really calculating the runup and the crest of the dike, but just concluding that it must be MSL + 5.5 m. The proper recommendation on prediction of runup and crest calculation is very urgent.

Free board

In the present design calculations a freeboard of 20 to 30 cm is applied. It is not clear why these values are applied; in some cases it should be a value for the settlement of the subsoil and/or higher economical values of land protected.

The settlement of the upper layers and dike foundation can be calculated quite accurately when enough geotechnical data are available. The settlement is caused by compression of sublayers due to the weight of the dike. This settlement may vary considerably over the route of the dike.

In the calculations which were made for the improvement of the sea dikes in the RRD a value for the settlement of the subsoil was not considered. Furthermore, it was not clear whether the foundation of the dike sections was stable enough to assure the stability of the dike.

Relative sealevel rise

The subsidence of deep layers is more a geologic phenomenon and is much more difficult to calculate. Because it is quite constant over the whole route of the dike, it is generally combined with the increase of the sea level. The combination of sea-level rise and subsoil subsidence is usually called **relative sealevel rise**. Because the value for this parameter is only minimal (in the order of 10 cm) it is not necessary to be considered in this case.

Comments and conclusions

1. In case of new dikes the additional free board should be added for expected settlement of the subsoil, which will occur due to load of earthfill. Especially in areas with bad soil conditions or with settlement problems, it should be supported by geotechnical calculations for profiles dependent on the differences of the quality of the subsoil.
2. In case of improvement of the existing dikes it should be verified whether the additional settlement can take place or not. It can be a case when the dike is founded on soft soils.
3. The design water level is a *dominant* parameter in design of the crest height. Therefore much attention should be paid to the proper quality of prediction of the design water level (DWL) and its components: astronomic high tide and storm surge (= wind set-up) (see sections 3.2 to 3.5 as well).
It is reasonable to assume that, due to the short duration of the maximum wind speed (say about 2 hours), it is probably not necessary to superpose the maximum storm surge with the maximum

tidal height (durinal tide). Therefore the expected design water levels will probably vary between MSL + (2.0 to 2.5).

Because of the present uncertainty concerning the prediction methodology it seems to be more safe to assume design water level (incl. wind set-up) equal to MSL + 2.5 m (southern provinces) to MSL + 3.0 m (northern provinces), as a first approximation.

4. In most cases, there is a shallow foreshore (beach + foreshore with slopes 1:100 to 1:50). That also means that the associated deep water waves will break on the foreshore few times. The local wave height in front of the dike (in such cases) will be determined by the local water depth, d . The, so called, depth-limited wave height for these conditions can be roughly estimated as $H_{s,max} = 0.5 d$ for significant wave height, and for $H_{max} \approx H_{2\%} = 0.6 d$.

More precisely calculations are possible by using mathematical models.

5. The deepwater wave length is defined as $L_{op} = gT^2/2\pi = 1.56T^2$ (T in sec, L in m). The local wave length (L_s) due to the shoaling effect will be reduced approximately to $L_s = T\sqrt{g \cdot d}$, where T is wave period in deep water and d = local water depth. For long shallow foreshore there will be a combination of waves transformed from the deepwater and the locally developed waves. This will affect the shape of the wave spectrum. The existing runup formulations are based on wave steepness defined by a local wave height H_s and the deepwater wave length L_{op} . For conditions with long shallow foreshore and resulting depth-limited wave height it provides for dike slopes 1 on 3 and 1 on 4, a breakwater-index ξ larger than 2. In such case the wave runup becomes independent of wave period and can be defined as:

$$R_{2\%}/(H_s)_{local} = 3.0 * \tau_R * \tau_B * \tau_\alpha,$$

It is a save (conservative) approximation which can be used for runup calculation as long as no better information on local wave spectrum is available.

Some prototype measurements on local wave spectrum and interaction with existing dikes, and laboratory investigation of runup with shallow foreshore are recommended.

6. The runup on a dike will be strongly influenced by the slope angle ($m = \text{ctg } \alpha$) and the roughness and permeability of a slope (= reduction factor τ_R).

A high roughness and a high permeability of the revetment provide a high reduction of runup. For example, riprap = random dumped stones in 2 layers on a granular sublayer/filter provides a 40% reduction ($\tau_R = 0.6$). Pitched stones and blocks will provide $\tau_R \approx 0.85 \div 0.90$, say 15 % to 10% reduction. The concrete slabs or fully grouted stones provide practically no reduction. The milder slopes (e.i. $m = \text{ctg } \alpha = 4$) provides less runup than steeper slopes (e.i. $m = \text{ctg } \alpha = 3$).

Additional advantage of a milder slope is that the required stone or block size (thickness) for protection against waves is also smaller. However, the length of protection is becoming larger. On the other side, it should be mentioned that the upper part of such a slope, from the level (DWL + $(\frac{1}{2}$ to $1)H_s$) can be protected by smaller units (say 50% smaller) (see appendix G.3).

In case of fully grouting of (unstable) riprap the permeability will be drastically reduced, and also the surface roughness will be reduced, providing as a result of nearly no reduction of runup. In such case the pattern grouting (local grouting) with strips of concrete may somewhat help to increase the permeability, and thus, the reduction of runup (see figure 4.1).

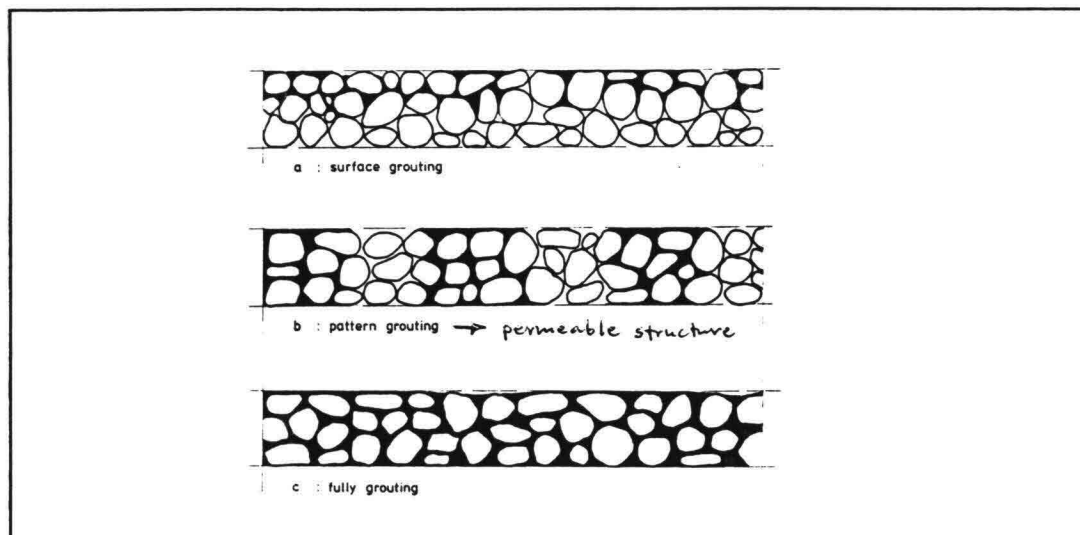


Figure 4.1 Different types of grouting

7. Based on the present designs (outer slope 1:3 to 1:4; block revetment), design water level as mentioned above (see comment 3) and a fore shore level as mentioned in appendix G7 (case study), as a first approximation the crest height of the dike needs to be MSL + 5.5 m (southern provinces) to MSL + 6.5 m (northern provinces). As a preliminary conclusion it can be mentioned that the calculated crest height is sufficient in Nam Ha Province and at some stretches in the other provinces. At most stretches the crest height seems to be insufficient. However for a better judgement detailed calculations are inescapable.
8. It should be considered to stabilize the existing foreshore to a certain extent so that, the existing depth-limited conditions for wave development can be guaranteed for long time.
9. In cases that the runup is calculated for an exceedance of more than 2%, also overtopping of the dike should be calculated including its consequences for the stability of crest and inner slope.
10. The dikes to be improved have a various exposition (direction) in relation to the dominant wind direction. From the designs which has been examined by the mission it can be concluded that in each province only one direction is considered. It is advised to make a separate calculation for each homogeneous section of the dike.
11. See also the remarks in chapter 11: Case study.

4.4 Calculation of revetment

Present designs: thickness of protection layers

Province	Quang Ninh	Hai Phong	Thai Binh	Nam Ha	Ninh Binh
pitched stone (d in m)	0.45	0.35 0.35	0.40	0.50 0.10	0.45
gravel (d in m)	0.20	0.25 0.37	0.15	0.25 0.15	0.30
coarse sand (d in m)	0.15/0.05	0.05 0.12	0.10		
concrete plate (d in m)		0.35/0.25/0.15			
gravel (d in m)		0.25			
coarse sand (d in m)		0.10			
loamy soil				0.70 0.50	
if mangroves					turfing

Table 4.2 Outline of revetments according to the present designs

Comments and conclusions

- In the present designs of sea dikes Russian formulas as well as the Hudson formula (USA) are used. All these formulas are originally developed for riprap and/or rubble mound structures (breakwaters), which are based on the weight of elements. However, these formulas have also been applied in the present designs for calculation of thickness of pitched stone and block revetments. No comparison between the Russian and Hudson formula are made.
 Also, no official recommendations are formulated on the choice of one of these formulas for the design of revetments. The choice of the formula is left up to the designers. However, the designers have no sufficient information on the backgrounds of these formulas, and they are making a choice based on their own individual preference.
 Due to this fact, each design office use different formulas and provides different stability calculations and, as a result, the comparison of various designs is not possible.
- The design of block revetments should be based on the thickness of a block and not on the weight of a block. That provides possibility to produce a concrete block of a high stability but with an acceptable (lower) weight for a handling by individual persons (see also case study).
- When using interlock blocks the stability may increase by a factor 1.5 to 2 in comparison with loose blocks. In such a case, special attention should be paid to a stable design of revetment foundation (sublayers and subsoil). Even small settlement will lead to creating of cavities under the interlocked blocks. These cavities will be not visible (not inspectable) until a damage take place.
- In general, for new dikes where settlements can be expected, the loose protective units (stone, placed blocks) are preferred instead of interlock blocks (grouting of present stone revetments should be forbidden, see also picture I.4, or only allowed as a pattern grouting; see figure 4.1).
 When a certain settlement take place the slope must be re-placed, and the existing loose protective units can be used once again on a slope.
- When using placed concrete blocks the revetment can be strengthened by washing in the interspaces by a coarse sand.
- New design guidelines should be formulated including the selection of proper design formulas for various revetment types, including stability of sublayers and subsoil, and also including design recommendations concerning toe protection and transitions.
- The actual level of knowledge on design of revetments is rather poor. Therefore adequate training of technical staff (design and construction) is recommended.

8. The existing riprap on various dikes, which is not stable enough for design conditions can be still applied in the zones of less wave attack (e.g. above design water level + $(\frac{1}{2}$ to 1) H_s , and at the toe structure.
9. The toe structure should be strong enough to resist the sliding forces provided by the slope revetment.
10. In all cases a proper transition from the slope protection into the toe protection is very essential for the stability of the revetment. This transition must be soil-tight to prevent migration (escaping) of subsoil from the slope through the toe structure.
11. The existing foreshore should be stabilized to a certain extend, so that the existing depth-limited conditions for wave development can be guaranteed on long term.
12. In a number of actual designs of dikes is mentioned the possibility of replacing of granular filter by a geotextile filter. However, it is only possible for revetments exposed to wave attack with waves lower than 1 m. For wave height higher than 1 m there will be necessary to place an additional granular layer with aim to reduce the hydraulic gradients and to prevent the migration of the subsoil along the slope and to avoid local liquefaction, and thus the deformation of a slope.
13. See also the remarks in chapter 11: Case study.

As **conclusion**, the actual design approach concerning the stability of the revetments on the sea dikes is very inconsistent, and can not be accepted for a final design.

The attention should be paid to:

- re-use of materials in general
- transition between revetment and crest

When designing slope protection (revetments) it should be taken into consideration the future (possible) increase of safety requirements. The placement of revetments is a very expensive post of the project (dike strengthening). It is often (on long-term) cheaper to provide a stronger revetment than required for design conditions. It will limit the damage and the necessary repair due to the storms exceeding the design conditions. It will also allow to increase the dike height (when necessary) without the necessity of placement of new revetments. For this purpose the dimensions of revetments should be calculated also for water levels, and resulting waves, with frequency of exceedance of 2% (1/50 years) and 1% (1/100 years).

Based on the level of additional cost the proper choice of revetment size can be made. Mostly with relatively low extra cost a much higher safety level of protection can be achieved.

4.5 Geotechnical aspects

Special attention should be paid to geotechnical aspects of dike design, such as foundation on soft soils, and problems of compaction of clay-earthfill especially during dry and warm periods when the clay is becoming very hard. The question is "what is the influence of possible cavities between the blocks of clay inside the dike body on the geotechnical stability of the dike?" (see picture I.3).

5 EXECUTION AND MAINTENANCE

5.1 Execution

It is recommended to define the requirements, specifications and tolerances (e.g. quality of concrete, dimensions and gravity of rock), which are permitted in 'execution specifications'. Also proper design drawings should be made. In order to achieve a proper construction special attention should be paid to the execution of the revetment and the transitions (e.g. toe construction) and the compaction of the earthfill (especially in dry season).

During the mission only one sea dike under construction is visited. During this visit earth filling by means of clay-hulks was going on (see picture I.9). Special attention should be given in periods with high temperatures. Then the clay will petrify and compaction will be very problematic. As a result there is a risk of spaces (cavities) between the clay hulks in which rainwater can infiltrate and instability of the dike can occur (e.g. sliding).

Because the earth is excavated and transported by manpower, it is logic that the earth is mined in the area adjacent to the dike. It should be stressed that a strip along the inner toe of the dike should be reserved for the reason of stability of the present dike and as a reservation for future improvements (also including a strip due to stability).

The implementation of a quality assurance programme is beneficial. For quality assurance to be effective it is necessary to define the purpose of the scheme, the conditions of use, the expected lifetime and the serviceability. A proper monitoring program is essential.



Figure 5.1 Earthfill of clay: difficult to compact

Supervision during the execution by a experienced technician who knows something about the design of the construction, and a proper quality control system, are essential for a proper final result of a project, especially when the execution is done by unskilled and unexperienced voluntary labour.

Special attention should be given to the following elements/aspects:

- toe construction (width, lining, transition with revetment)
- compaction of the earthfill
- location of mining
- dimensions (e.g. slope steepness, height and width of crest)
- revetment type and dimensions
- filterlayers
- quality of materials (rock, concrete, gravel)
- work termination at the end of the season (protection of the last part of the work)
- execution schedule, planning, phasing, measurements

Conclusions

The implementation of a quality assurance programme is beneficial. In order to have a reference to check on detailed specifications of the design and execution should be established.

5.2 Operation and maintenance

Because of the substantial investments for the upgrading of the sea dikes it is extremely important to establish a (management) system to ensure a proper repair and maintenance of these dikes. Such a system may not fully rely on voluntary labour provided by the farming families living in the protected areas. Instead of that, a cost-sharing arrangement should be defined between central and local government, and the people benefiting from the improved dikes.

It should be stressed that also the designers must think about 'how to maintain the construction'.

A clear definition of responsibilities of various management levels is needed. There should be short lines in respect to decision and necessary actions concerning the repair of damages after the storm. After each storm an inspection report should be prepared. Small damages should be directly repaired by the local authorities and people.

The storm damages should be repaired before the next storm season starts. The unrepaired locations (even with small damages) may lead to the serious damages during the next storm season, which can be very costly to repair.

During the mission various examples of damages have been observed. A check list for post-storm inspection and reporting should be prepared by the Department for Dike Management and Flood Control, as well as the maintenance guidelines and definition of responsibilities.

Set-up of a management system

A management scheme for a sea-defence system, including revetments and bottom protection, must satisfy and fulfil needs of the responsible public authority (districts or regional council) so that maximum value for the invested capital is achieved (social output).

All relevant data of the sea-defence (risk level, boundary conditions, shape of the dike, revetment) should be recorded in a database (or register). The system has to provide basic information on the maintenance plan, the annual budget estimates, the annual accountancy and justification reports.

During the lifetime of the structure the boundary conditions (e.g. due to the morphological changes) and the strength of the structure can change. Therefore it is recommended to order the local authorities to report periodically, e.i. each 5 years, the actual state of the dike in respect to fulfilling its defence function.

For realization of this goal it is needed to have:

- update design standards and criteria
- updated boundary conditions
- an accurate data base of the dike

Conclusion

To ensure a proper repair and maintenance of the (improved) dikes it is recommended to set-up a management plan. Also it should be considered to establish a policy to order the local authorities e.g. each 5 year to prove that the dike in the concerned area is in a good shape and can fulfil its function in the coming period.

6 REVIEW QUANG NINH PROVINCE

Reference [1] and appendix A2, page 9 (site visit); pictures I.1, I.3 and I.9

Outcome of study:

- * length of coastline 250 km
- * length of sea dikes appr. 300 km
- * to be improved under WFP km, in 10 dike sections, with different exposition
- * used: tidal water level MSL + 2.56 m (probability of 5%)
- * storm surge calculated by formula (+ 0,3 m)
- * design water level MSL + 2.86 m
- * wave runup: used only one angel for the wind direction to the direction of the dike; $H_s=2.18$ m
- * freeboard 0.3 m
- * calculated crest height MSL + 5.00 m and MSL + 4.50 m at the locations where mangrove planting is foreseen (calculation method see section 4.3)
- * dike profile: seaside slope 1:3; landside slope 1:2; crestwidth 2 m
- * pitched stone revetment in Yen Hung Zone, thickness 45 cm (no calculation found)
- * other zones: calculated riprap (used Russian formula); $d=22$ cm; thickness of layer 45 cm; on drawings pitched stone and block revetment!
- * layer of gravel (20 cm) and layer of sand (5 cm)

Comments

- The transition of the revetment and the clay-layer on the crest is insufficient; due to rainfall and overtopping of water, clay will erode to respectively stonelayer (in case of riprap slope protection) and filter construction (in case of pitched stone revetment).
 - Toe protection:
 - * filter construction under riprap is lacked
 - * in case of pitched stone slope protection, the transition between revetment and toe protection is insufficient; due to movements of the stonelayer also the pitched stones will move and the filterlayer will erode and consequently the revetment will damage.
- Conclusion: toe protections are poorly designed.
- A sufficient layer of clay with a vegetation of grass is important to prevent damage due to overtopping.
 - Only one calculation of crest height and revetment for the different sections; differentiation recommended.
 - It would be useful to control once again the prediction of the wave height which seems to be on the high side. Use bottom bathymetry and compare with other prediction methods where the depth of water is included.
 - The calculated stone size by using Russian formula (for $H_s = 2.18$ m) seems to be too low. Calculation with the Hudson formula is not included.
No distinction is made between estuary and exposed sea dikes. The differences in the various existing foreshores (with or without mangroves) are not taken into account in the design.
 - Calculations were made for riprap while in drawings a pitched stone is shown.
 - During our visit to Quang Ninh we have discovered that the proposed pitched stone will be grouted by concrete. This is not mentioned in the design report. Because of bad experience up to now with grouted stone (see pictures I.4 and I.5), it should be recommended to look for a better solution.

Questions

- What does it mean in report [1], "reduction of stone size by 25%", when calculating stone size?

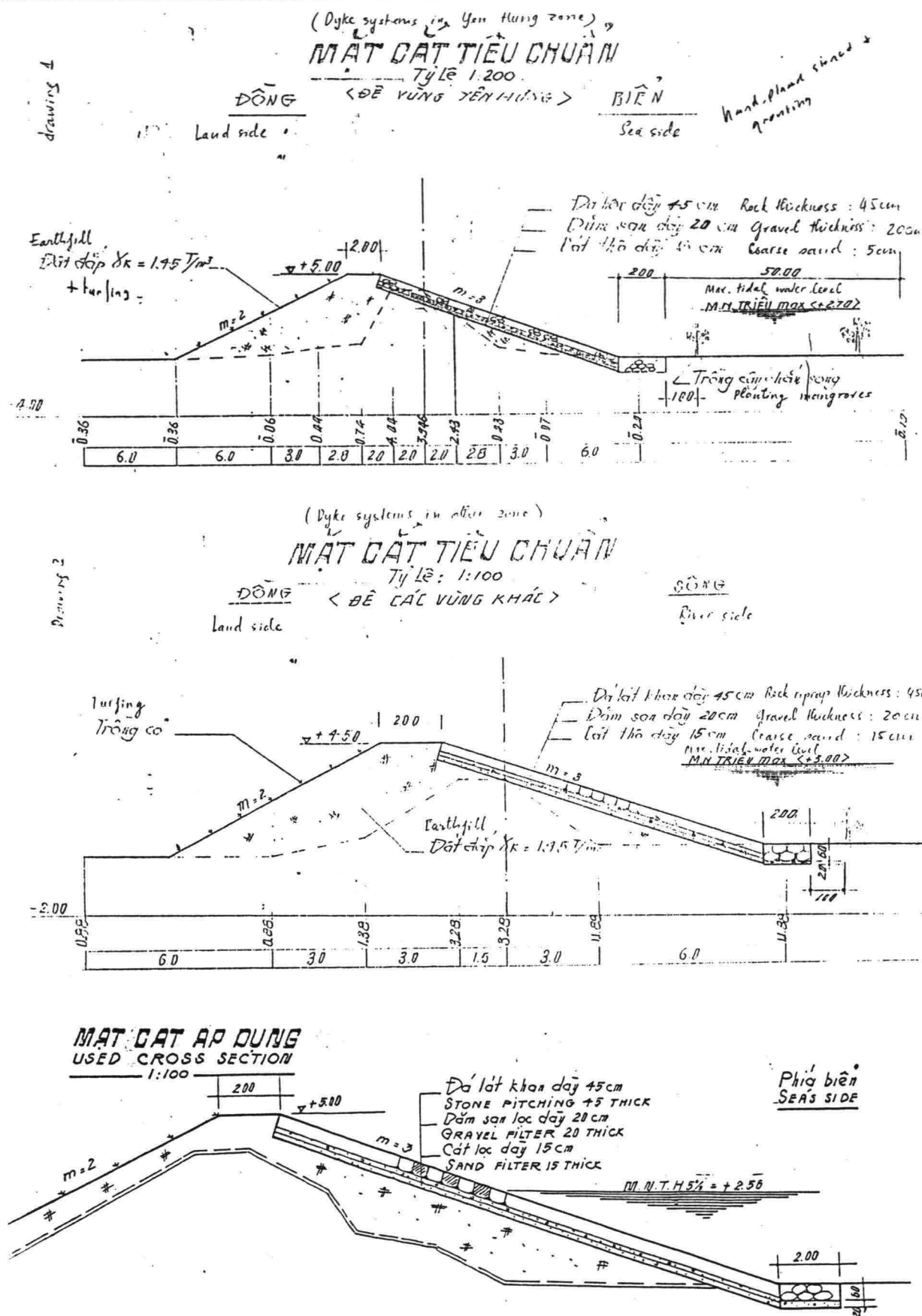


Figure 6.1 Design Cross-sections in Quang Ninh Province

7 REVIEW HAI PHONG PROVINCE

Reference [2] and appendix A2, pages 8 and 9 (site visit); pictures I.6, I.7 and I.8

Results

- * length of sea dikes 93 km; to be improved under WFP 81 km
- * tidal difference 3 - 4 m; tidal characteristics: one high and one low tide each day
- * design tidal water level MSL + 2.29 m (probability of 5%)
- * distinguished routes: sea dikes I, II and III; Trang Cat; Bach Dang
- * storm surge calculated by formula (respectively 1.1, 0.9 and 0.8 m)
- * design water level respectively MSL + 3.39, 3.19 and 3.09 m
- * wave runup: used only one angle for the wind direction to the direction of the dike; respectively $H_s = 1.82, 1.57$ and 1.17 m
- * crest height respectively MSL + 5.5 m, 5.0 and 4.5 m; at the location where mangrove planting is possible: MSL + 4.5 m (calculation method see section 4.3)

Dike line	$H_{5\%}$ (m)	Storm-surge (m)	Runup (m)	Freeboard (m)	Crest height (m)
- Dike I, II, III	+ 2.29	1.10	1.82	0.30	+ 5.50
- Trang Cat	+ 2.29	0.90	1.57	0.30	+ 5.00
- Bach Dang	+ 2.29	0.80	1.17	0.20	+ 4.50

Table 7.1 Summarized results of crest height calculations for Hai Phong Province

- * dike profile: seaside slope 1:3.5 - 4; landside slope 1:2; crest with 3 - 5 m
- * slope protection: pitched stone and concrete slab calculated according to Russian formula and Hudson
- * layer of gravel (25 - 37 cm) and layer of sand (5 - 10 cm)

Comments

- Prediction of hydraulic boundary conditions (tidal level, storm surge, wave height, etc.) is not clear. The calculated wave heights and wave length are probably not correct and should be examined once again (including influence of various foreshore types).
- The calculation of the revetment sizes is also not clear. There is no argumentation for use high values of K_D (=5.8 and 7) in the Hudson formula.
- Application of concrete slabs or concrete grouting, because of bed experience with these systems up to now, should not be recommended.
- The transition between the revetment and the layer of clay on the crest is insufficient; due to rainfall and overtopping water clay will erode to filter construction under pitched stone revetment).
- A sufficient layer of clay with a vegetation of grass on the crest and the inner slope is important to prevent damage due to overtopping.
- Above the calculated crest height an extra size is needed due to settlement of the subsoil which will occur due to load of earthfill.
- The design drawings, especially concerning toe protection, need further improvement. The present toe construction seems to be insufficient.
- Proper specifications for execution should be prepared.
- Extra attention should be given to the execution of the transition between the two revetment types.

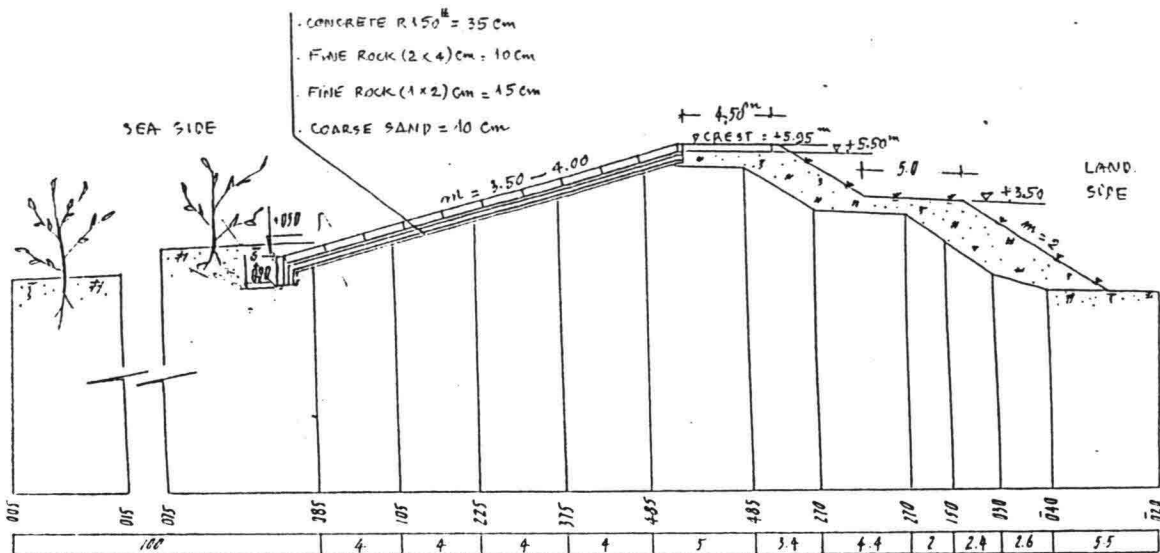


Figure 7.1 Typical cross-section of sea-dike no. I - Hai-Phong Province

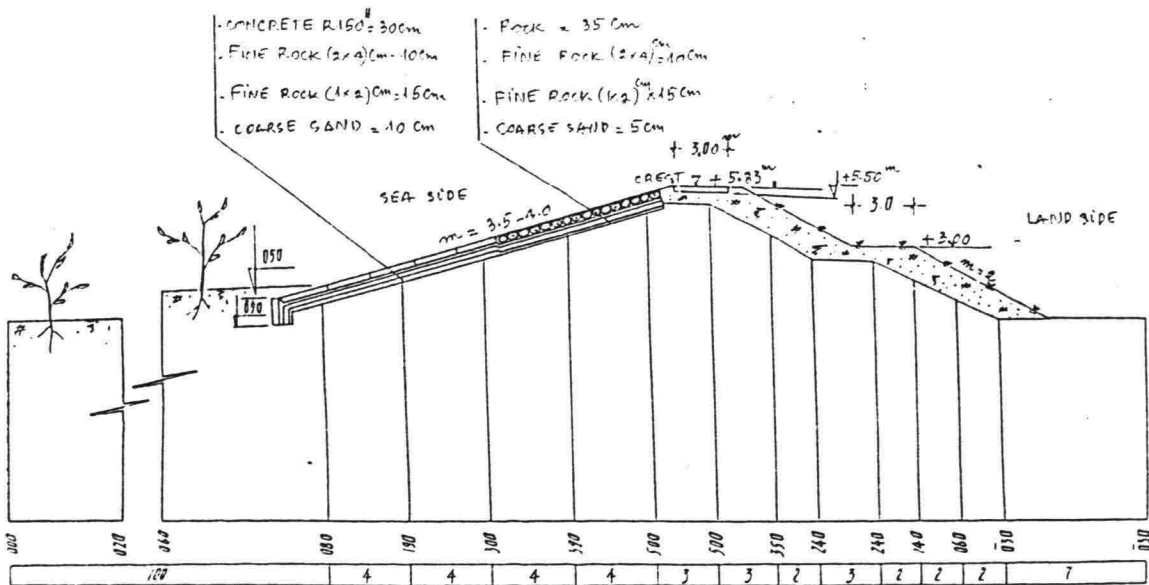
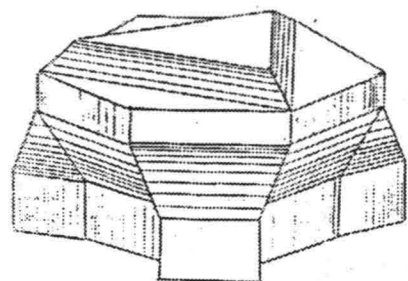


Figure 7.2 Typical cross-section of sea-dike no. II - Hai-Phong Province



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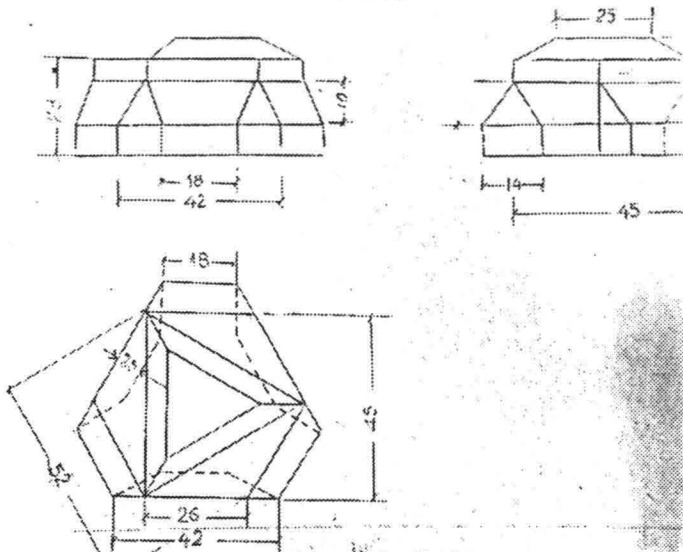


Figure 7.6 Interlock blocks

8 REVIEW THAI BINH PROVINCE

Reference [3]

- * 3 districts located along the coast: from north to south, Thai Thuy, Dong Hung and Tien Hai.

Results

- * length of coastline as the crow flies 40 km
- * the coastline is divided into four sections of equal length of about 10 km by five branches of the Red River
- * length of sea dikes 152 km; to be improved under WFP km, divided in a lot of sections, various located to the direction of wave attack
- * design tidal water level MSL + 2.29 m (probability of 5%)
- * storm surge calculated by formula (+ 1.1 m)
- * design water level MSL + 3.39 m
- * $H_s = 1.5$ m
- * wave runup: only one angle is used for the wind direction
- * freeboard 0.3 m
- * calculated crest height MSL + 5.20 m (slope 1:4) (calculation method see section 4.3)
- * dike profile: seaside slope 1:4; landside slope 1:2; crestwidth 4 m
- * pitched stone revetment, thickness 40 cm (calculated with the formula for riprap)
- * layer of gravel (15 cm) and layer of coarse sand (10 cm)
- * if mangrove planting: turfing revetment

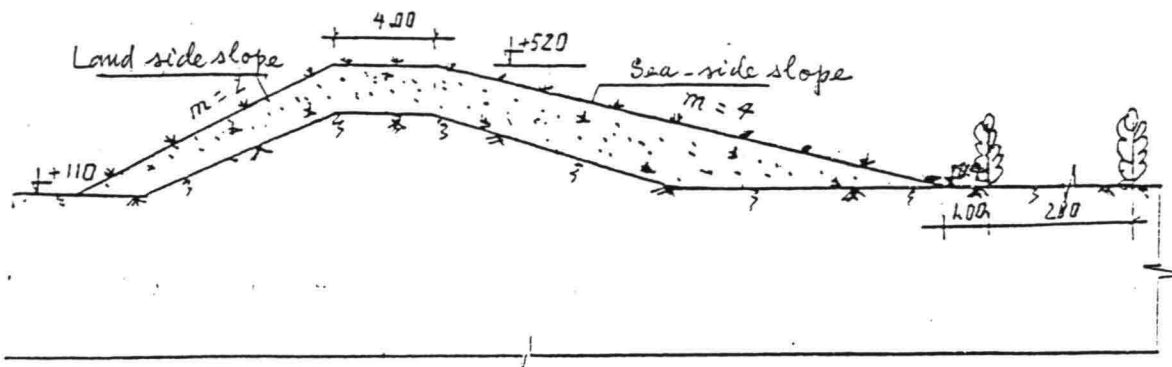
Comments

- The connection between the revetment and the layer of clay on the crest is insufficient; due to rainfall and overtopping water clay will erode to filter construction under pitched stone revetment).
- Construction of toe protection in lit 1 only vaguely conveyed. The construction appears to be insufficient.
- A sufficient layer of clay with a vegetation of grass is important to prevent damage due to overtopping.
- Above the calculated crest height an extra size is needed due to settlement of the subsoil which will occur due to load of earthfill.
- Because uncertainties concerning calculation of the wave height, the calculated stone size is also uncertain.
- In the report [3] riprap is calculated while on the drawings a pitched stone is shown! It must be clear what is applied: riprap or pitched stones. These are two different revetments which should be calculated by separate methods.

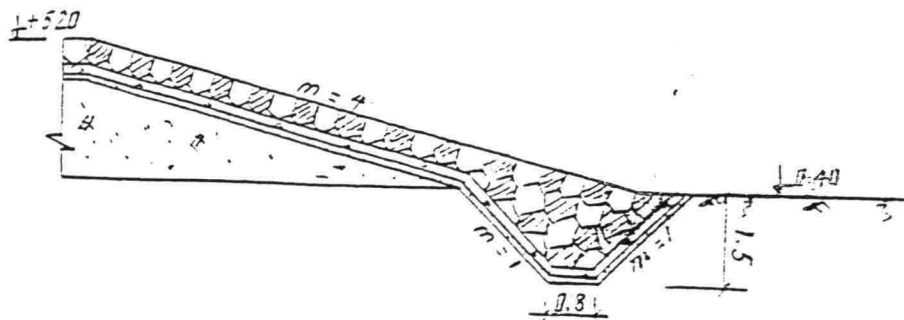
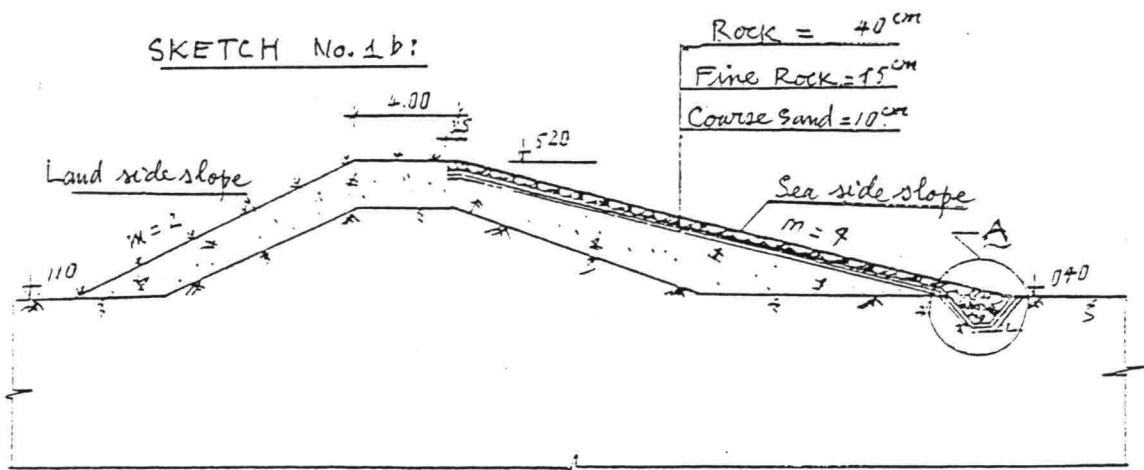
Questions

- How is it possible that you get such low wave height of about 1.5 m for wind of 24 m/s and fetch length of 300 km? It is only possible when the depth of the sea bottom is about 5 m, which we don't think it is!

SKETCH No. 1a:



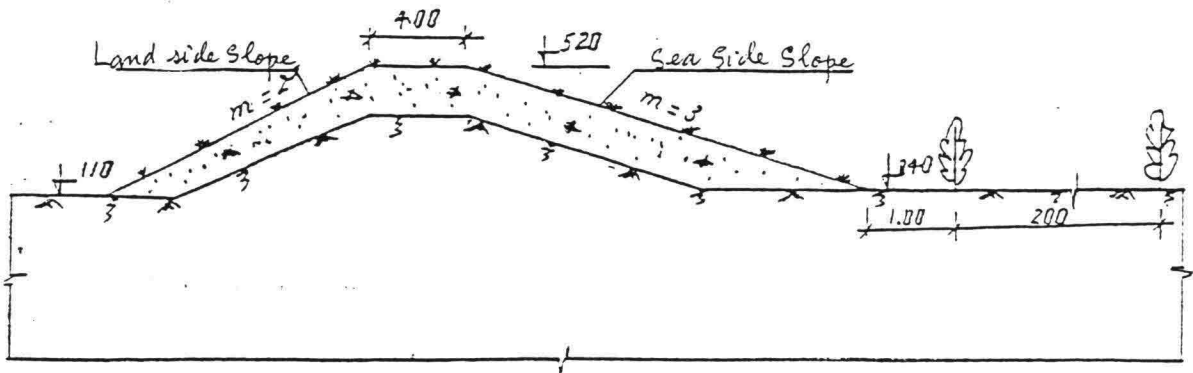
SKETCH No. 1b:



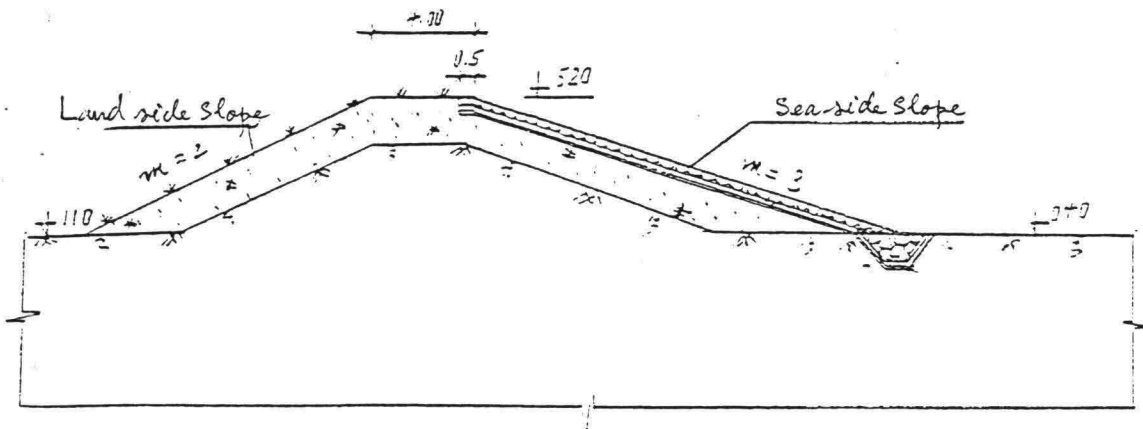
DETAIL "A"

Figure 8.1 Cross-section dike Thai Binh Province; sketches Ia, Ib and detail A

SKETCH No. 2a



SKETCH No. 2b



SKETCH No. 3

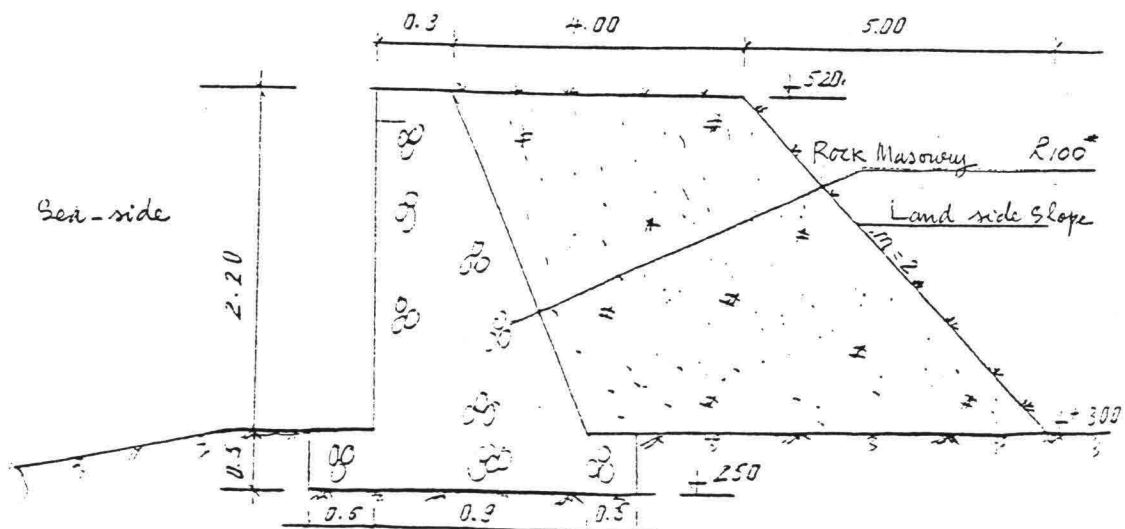
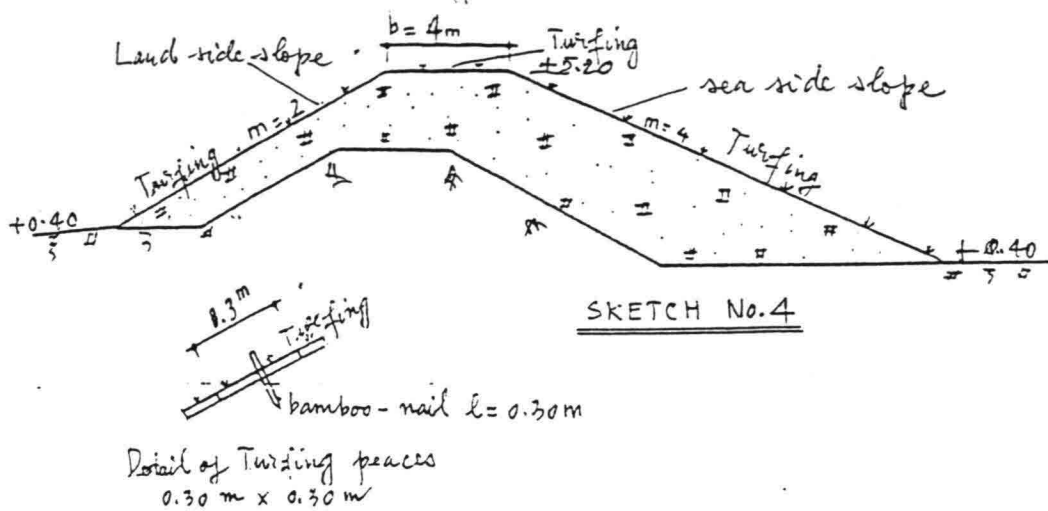


Figure 8.2 Cross-section dike Thai Binh Province; sketches 2a, 2b and 3

Twisting:
 Twisting on slopes and top of sea dike is illustrating
 in sketch No.4:



Tree-planting:
 Tree-planting of shelter-belt was illustrated in
 sketch No. 5.

- Density of tree planting : 10,000 trees / Ha
- Distance from tree to tree : $l = 1 \text{ m}$
- Width of shelter belt : $B = 200 \text{ m}$

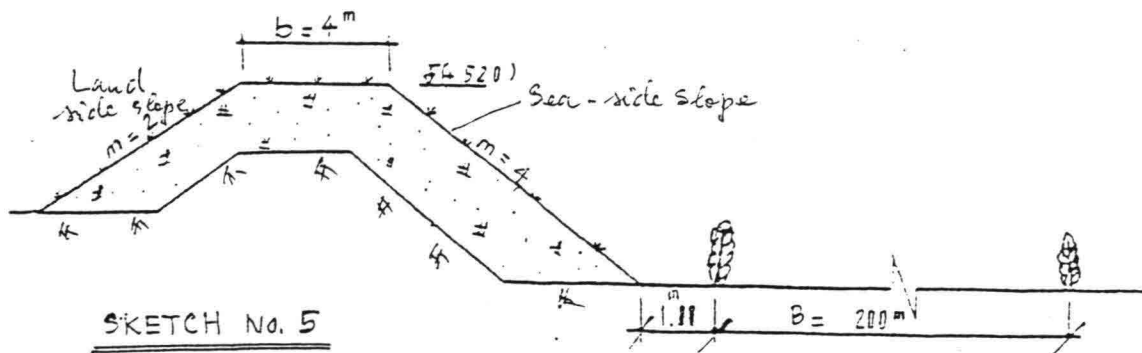


Figure 8.3 Cross-section dike Thai Binh Province; sketches 4 and 5

9 REVIEW NAM HA PROVINCE

Reference [4] and appendix A2, pages 7 and 8 (site visit); pictures I.2, I.4 and I.5

Results

- * length of coastline 70 km
- * three coastal districts (with length of sea dikes): Xuan Thuy (32 km), Hai Hau (33 km) and Nghia Hung (26 km)
- * to be improved sea dikes under WFP km, divided in different sections, various located to the direction of wave attack
- * design tidal water level MSL + 2.29 m (probability of 5%)
- * storm surge from calculations by formula and observations (+ 1.0 m)
- * design water level MSL + 3.29 m
- * compared submerged groyne to mangrove planting; normative: $H_s = 2.14$ m
- * wave runup: 2.0 m (slope 1:4)
- * freeboard 0.21 m
- * calculated crest height MSL + 5.50 m (slope 1:4) (calculation method see section 4.3)
- * dike profile: seaside slope 1:4; landside slope 1:2; crestwidth 4 m
- * pitched stone revetment:
 - below MSL + 3.5 m: thickness 45 cm (calculated formula for rock revetment); block dimensions 0.50 x 0.50 x 0.45 (appr. 250 kg)
 - above MSL + 3.5 m: thickness 0.30
- * layer of gravel (25 and 15 cm) and layer of loamy soil (70 and 50 cm)

Comments

- Prediction of the hydraulic boundary conditions should be controlled according to the updated input data.
- It is not clear which wave height is used for prediction of runup (how do you get runup of 2 m?)
- Also for runup and stability calculations of revetments should be using more actual formulas (separately for riprap and for block revetments).
- Design drawings must also contain detailed drawings suitable for a proper execution, supported by a proper specifications.
- The transition between the revetment and the layer of clay on the crest is insufficient; due to rainfall and overtopping water clay will erode to filter construction under pitched stone revetment
- Construction of toe protection seems to be insufficient
- A sufficient layer of clay with a vegetation of grass is important to prevent damage due to overtopping
- above the calculated crest height an extra size is needed due to settlement of the subsoil which will occur due to load of earthfill.
- Re-use of stone from the 'first dike' for the improvement of the 'second dike' is recommended.

General remarks

The central part of the coast in Nam Ha Province is highly eroding. It is decided to offer the first defence line and to improve the dike lying in the second defence line. Stone from the first dike can be re-used on dikes to be improved, in the zones of less wave attack (upper slope and toe, and foreshore stabilization). The progress of erosion of the foreshore should be carefully studied to be able to make a proper prediction for future development, and its consequences for the new dike. At certain moment the existing foreshore should be stabilized to prevent increase of wave attack due to deepening of the foreshore.

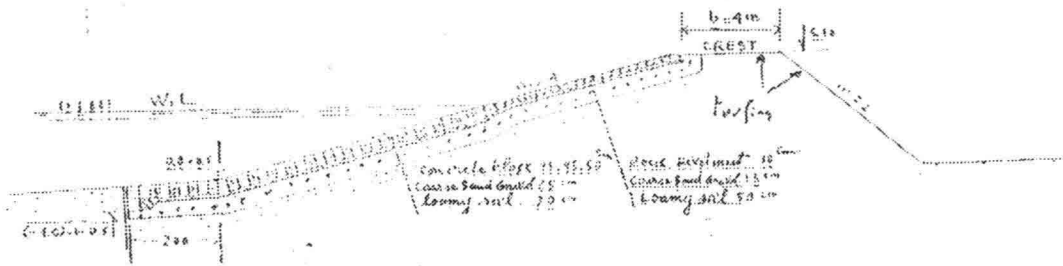


Figure 9.1 Standard cross-section of sea dike in Nam Ha Province



Figure 9.2 Discharge sluice; Hai Hau District

10 REVIEW NINH BINH PROVINCE

Reference [5]

Results

- * length of coastline km
- * length of sea dikes 16 km; to be improved under WFP km
- * design tidal water level MSL + 2.29 m (probability of 5%)
- * storm surge 0.95 m
- * design water level MSL + 3.14 m
- * $H_s = 1.5$ m
- * wave runup: perpendicular to the coastline: 1.48 m
- * freeboard 0.25 m
- * calculated crest height MSL + 5.0 m (calculation method see section 4.3)
- * dike profile estuary dike: seaside slope 1:3; landside slope 1:2; crestwidth 4.5 m; pitched stone revetment, thickness 45 cm (calculated formula for rock revetment and filter layer (30 cm) (gravel and coarse sand?))
- * sea dike: mangrove planting; slope 1:4; slope protection: turfing

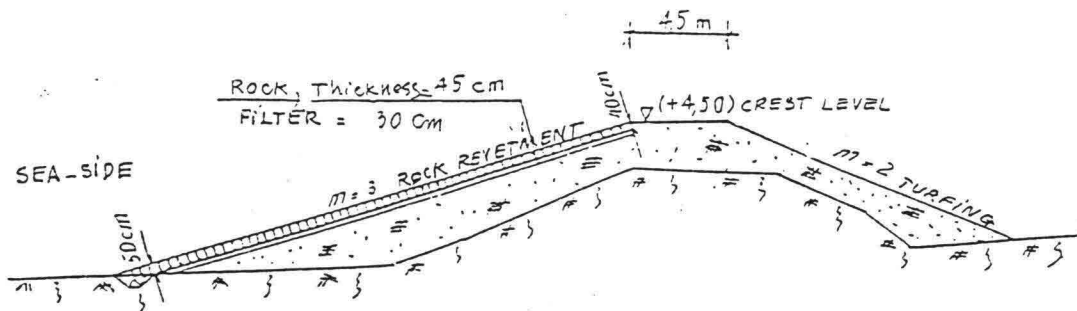
Comments

- The connection between the revetment and the layer of clay on the crest is insufficient; due to rainfall and overtopping water clay will erode to filter construction under pitched stone revetment).
- Construction of toe protection in lit 1 only vaguely conveyed. The construction seems to be insufficient.
- A sufficient layer of clay with a vegetation of grass is important to prevent damage due to overtopping.
- Above the calculated crest height an extra size is needed due to settlement of the subsoil which will occur due to load of earthfill.
- The prediction of the wave height should be examined once again taking into account the bathymetry of the foreshore.
For estuary dikes the wave height will probably about 1 m. Therefore, the actually calculated weight of stone is too big. Probably a riprap with stone size of about 30 cm will be sufficient.
- The crest height of the estuary dike is reduced by 0.5 m, "based on experience". Probably when the calculations are done properly one gets a lower crest height for estuary dikes in comparison with the crest height of the sea dikes, without introducing this kind of reduction.
- The remark given in the report [5] that "in case of using geotextile, we can replace conventional filter layer by geotextile", is only true for waves lower than 1, thus for estuary dikes.
For high waves often an additional granular layer is needed between the toplayer and geotextile, to reduce the hydraulic gradients at the interface with a sandy subsoil below the critical values.
- In the report [5] riprap is calculated while on the drawings a pitched stone is shown! It must be clear what is applied: riprap or pitched stones. These have two different revetments which should be calculated by separate methods. Moreover, the details of the toe protection are not reworked sufficiently.

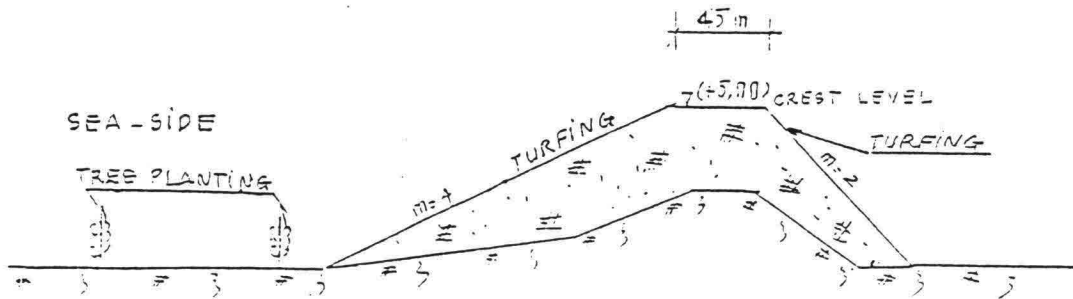
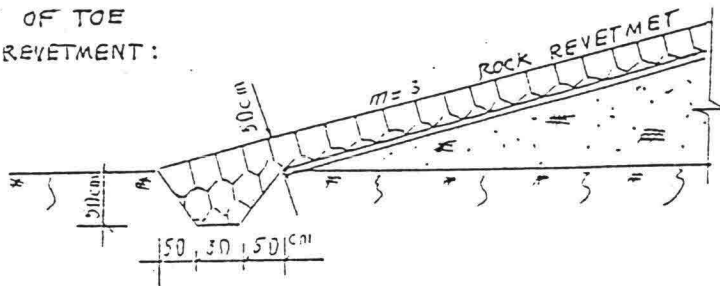
Questions

- Wave height is calculated with wind speed of 24 m/s for sea dikes with fetch length of 300 km and for estuary dikes with fetch of 3 km. How is it possible that the result is: $H_s = 1.56$ m for fetch of 300 km (sea dike) and $H_s = 1.59$ m for fetch of 3 km (estuary dike)? The wave height for a sea dike is probably too low, and the wave height for estuary dikes is probably too high!

DESIGNING CROSS-SECTION OF SEA DIKE AT ESTUARIES:



DETAILS OF TOE
OF ROCK REVETMENT:



DESIGNING CROSS-SECTION OF SEA DIKE AT PORTIONS
"FACED" DIRECTLY TO THE SEA.

Figure 10.2 Designing cross sections of sea dike in Ninh Binh Province

11 CASE STUDY

In all reviewed designs, each province has used different prediction methods for waves and wave runup, and stability of the revetments. Because of that it is nearly impossible to compare all these designs. Very often for the same wind speed (about 25 m/s), nearly the same wave height was predicted for the fetch length of 3, 10 or 300 km. It is obvious that the wrong prediction of waves will have repercussions for the calculated runup and revetment stability.

To give some idea about the more systematic approach and the sensitivity of the outcome in respect to the input data, a simplified case study was prepared for conditions similar to those of the northern coast of Viet Nam. Both the crest height of the dike and the stability of the revetment were calculated.

As input to the calculations the following variables were assumed:

- windspeed 25 m/s and associated deep water conditions ($H_{OS} = 5$ m, $T_p = 8$ sec) for the fetch length of 100 km
- various types of foreshore
- design water level (including high tide plus storm surge) equal to MSL +3.0 m

It is assumed that a new dike is build as an improvement (strengthening) of the existing dike, where no additional settlement of the subsoil is expected (otherwise, the calculated settlement should be added to the design crest height).

Two slopes of a dike are considered: $m = \text{ctg } \alpha = 3$ and 4.

Three types of slope revetments are assumed: smooth slope (e.g. grouted stone or concrete slabs), block revetment and riprap (2 layers of random placed stones on thick granular filter). However, the combination of geotextile and granular filter layer can be considered as an alternative material for filter structure.

The results of this case study were presented on the seminar of 9 th April, attended by representatives of Dike Department, provincial and district design engineers, Hydraulic Institute, Hanoi Water Resources University and Meteorological Service Viet Nam.

The results are included in Appendix G: Case study on calculation of the crest height and Appendix H: Case study on calculation of stability of revetments.

12 CONCLUSIONS AND RECOMMENDATIONS

12.1 Conclusions and recommendations

From the discussions which were held and from the impressions of the site visits the following conclusions and recommendations can be given:

Design methodology

- In the scope of the design of the dike improvements in some cases (e.g. erosion and accretion area) it should be considered to develop different possible solutions and compare these solutions, on basis of the interests involved. Also future development on economy and boundary conditions should be considered. Then, the available money and labour can be used in a (more) efficient way. Therefore a so called 'policy analyses study' should be prepared, on province-, district- or project level.
- There is a large research potential available in Viet Nam. However, in order to use this potential effectively, in solving of practical coastal problems a more close cooperation between the different parties in the design process should be further stimulated. To achieve this goal some administrative actions should be undertaken by the Ministry of Agriculture and Rural Development.
- To improve understanding between various institutes and in order to involve the different interests in the design process, the activities related to a certain program (problem or project) should be organized in a form of multidisciplinary project teams and giving proper responsibilities to the project-leader.
- To be able to predict the future development in the Hai Hau area of Nam Ha Province, a policy analysis study (including all interests) should be undertaken in the near future. This subject is very suitable for a pilot project where also the already achieved results in the scope of the 'Vietnam Vulnerability Assessment' project can be implemented and further extended.

Risk level

- In the present designs for the rehabilitation and upgrading of the sea dikes in the Red River Delta no differentiation in design-circumstances is adopted. However, the interests to protect vary for the different areas. In order to get a balance between the investments for dike improvement and the value of the interests to be protect, it is advised in the future to consider a differentiation in risk level.
- From the moment that people realize that the area they inhabit is protected in a sufficient way investments will be done. Moreover, the living standard and the economic situation in Viet Nam will expand in near future. Consequently the interests in the area adjacent to the sea will increase and in order to keep the interests and the safety level in the future in balance, the safety level will most probably be upgraded again. Therefore it should be considered to allocate a free strip on the landside of the dike for future improvements.

Natural boundary conditions

Topography and morphology

- In order to calculate the wave height in front of the dike it is necessary to know the bottom topography, at least in the zone from 'deep water' to the toe of the dike.
- Also a forecast of erosion and accretion must be done. In this respect special attention should be paid to the area of Hai Pong Province and Hai Hau District, where erosion rate is observed.
- It should be considered to stabilize the existing foreshore to a certain extent so that, the existing depth-limited conditions for wave development can be guaranteed for long time.

Wave heights

- In most cases there is a shallow foreshore. In such cases for the determination of the crest height the so called depth limited wave can be used. That also means that the dependent deep water waves will break on the foreshore few times. More precisely calculations are possible by using mathematical models.
- The calculated wave heights according to the present designs are not calculated in accordance with the above mentioned method. Therefore it is advised to make new calculations. Then also the wave length has to be considered.
- Moreover the present prediction of wave heights is not documented properly and should be examined by wave experts.

Design water level

The design water level should be determined based on a summation of the tidal level, the wind set-up and the sealevel rise. Comparing the various sources of information it might be possible that the tidal level which is used in the calculations already includes the wind set-up.

Conclusion

An expert working group should prepare a document with boundary conditions for the coast of Viet Nam, which should be used as a basic document for in the design process.

Design

Crest height

- The subsoil along the line of the dikes to be improved will vary. So the heightening for the dike improvement will be different. Therefore it is recommended, especially in areas with bad soil conditions, to calculate the expected settlement of the subsoil which will occur due to load of earthfill. If sufficient data are available it should be supported by geotechnical calculations.
- The runup on the dike will be strongly influenced by the slope angle and the roughness and permeability of a revetment. In the present designs there is no distinction for the various types of revetment.
- Due to the above mentioned aspects it is recommended to examine the present calculations for the crest height of the dike in according to the updated standards, even more differentiated for the different dike sections.
- In cases that the runup is calculated for an exceedance of more than 2%, also overtopping of the dike should be calculated including its consequences for the stability of crest and inner slope.
- The dikes to be improved have a various exposition (direction) in relation to the dominant wind direction. From the designs which has been examined by the mission it can be concluded that in each province only one direction is considered. It is advised to make a calculation for each homogeneous section of the dike.

Revetments

- In the present designs of sea dikes the Russian formulas as well as a Hudson formula (USA) are used. All these formulas are originally developed for riprap and/or rubble mound structures (breakwaters), which are based on the weight of elements. However, these formulas have also been applied in the present designs for calculation of thickness of pitched stone and block revetments.
- The choice of the formula is left up to the designers; each design office use different formulas and with different stability calculations and, as a result, the comparison of various designs is not possible.
- The design of block revetments should be based on the thickness of a block and not on the weight of a block.

- When using interlock blocks the stability may increase by a factor 1.5 to 2 in comparison with loose blocks. In such a case, special attention should be paid to a stable design of revetment foundation (sublayers and subsoil).
- In general, for new dikes where settlements can be expected, the loose protective units are preferred instead of interlock blocks.
- Grouting of stones should be forbidden, or only allowed as a pattern grouting.
- When using placed concrete blocks the revetment can be strengthened by washing in the interspaces by a coarse sand.
- The existing riprap on various dikes, which is not stable enough for design conditions, can be still applied in the zones of less wave attack.
- The toe structure should be strong enough to resist the sliding forces provided by the slope revetment.
- In all cases a proper transition from the slope protection into the toe protection is very essential for the stability of the revetment. This transition must be soil-tight to prevent migration (escaping) of subsoil from the slope through the toe structure.
- In a number of actual designs of dikes the possibility of replacing of granular filter by a geotextile filter is mentioned. However, it is only possible for revetments exposed to wave attack with waves lower than 1 m. For wave height higher than 1 m there will be necessary to place an additional granular layer with aim to reduce the hydraulic gradients and to prevent the migration of the subsoil along the slope and to avoid local liquefaction, and thus the deformation of a slope.
- The attention should be paid to re-use of materials in general and the transition between revetment and crest.

Geotechnical aspects

Special attention should be paid to geotechnical aspects of dike design, such as foundation on soft soils, and problems of compaction of clay-earthfill, especially during dry and warm periods when the clay is becoming very hard.

As conclusion, the actual design approach concerning the stability of the revetments on the sea dikes is very inconsistent, and can not be accepted for a final design.

Design standards

The actual design standards for coastal protection (including dikes) in Viet Nam should be updated according the actual state-of-the-art of the international knowledge in this field. Therefore new design guidelines should be formulated including the selection of proper design formulas for various revetment types, including stability of sublayers and subsoil, and also including design recommendations concerning toe protection and transitions between different constructions.

Implementation of knowledge

- The existing knowledge on design, construction and maintenance of dikes, especially at districts, needs upgrading.
- Therefore, the preparing of the updated design guidelines and training of technical staff is greatly needed.
- It is recommended that The Netherlands will help to prepare new design standards, suited to the situation in Viet Nam.
- To improve communication in the field of transfer of know-how from The Netherlands to Viet Nam, the one-year training of at least two (young) engineers at the International Hydraulic Institute (IHE) in Delft, supplemented by about two months orientation within the specialistic Rijkswaterstaat Divisions is considered as a minimum. It is stressed that for a training in the Netherlands an adequate knowledge of the English language is necessary.
- Moreover a short course in Viet Nam for the engineers involved the project should be considered.

- For the long term it would be important that the (backgrounds of the) standards will be taught at the University.

Execution

- In order to have a reference to check, the detailed specifications of the design and execution should be established in 'execution specifications' and detailed drawings. To achieve a proper construction special attention should be paid to the execution of the revetment, the transitions and the compaction of the earthfill.
- Surveillance during the execution by a supervisor who is familiar with the design of the structure, and a proper quality control system, are essential for a proper final result of a project.
- Also the implementation of a quality assurance program would be beneficial.

Operation and maintenance

- There should be a clear definition of responsibilities of various management levels resulting in short-lines in respect to decision and necessary actions concerning the repair of damages after the storm.
- After each storm an inspection report should be prepared. Small damages should be directly repaired by the local authorities and people.
- All storm damages should be repaired before the next storm season starts. The unrepaired locations (even with small damages) may lead to the serious damages during the next storm season, which can be very costly to repair.
- A check list for post-storm inspection and reporting should be prepared by the Department for Dike Management and Flood Control, as well as the maintenance guidelines and definition of responsibilities.
- During the lifetime of the structure the boundary conditions (e.g. due to the morphological changes) and the strength of the structure can change. Therefore it is recommended to order the local authorities to report periodically the actual state of the dike in respect to fulfilling its defence function. For realization of this goal it is needed to have a sufficient data base.

12.2 Preliminary Action Plan

The Dutch mission, based on her observations and conclusions as drawn above, is recommending to undertake the following actions:

1) Dike program 1996-1997

The designs of dike stretches planned for rehabilitation in 1996 and 1997 should be examined again, as soon as possible (without waiting till the future design guidelines are prepared). The Dutch technical documents [6] and [7], which are provided to the DDMFC, can be of use for this examination.

In order to prevent a delay in the WFP-program it is recommended to consider a second opinion of the adapted designs by the members of the Dutch mission in the foreseeable future. For this purpose it is necessary to provide the basic data of the dike stretches for realisation in the near future.

The proper quality of input data/hydraulic and geotechnical boundary conditions is of a primary importance for a proper design. An expert working group should prepare a document with boundary conditions for the coast of Viet Nam, which should be used as a basic document for the design process.

It is recommended to organize a semi-permanent help-desk at the Rijkswaterstaat for occurrent technical assistance during realization of this program.

2) Design guidelines

Project definition and project proposals should be worked-out concerning the preparation of the national design guidelines for sea dikes in the coming two years (1997-1998). For the transfer of the available Dutch know-how on this matter, the appointment of the joint working-team (Viet Nam - The Netherlands) is recommended.

To ensure the effectiveness of such working group, the project should be commissioned by, and realized under direct responsibility of the Vice-Minister of the Ministry of Agriculture and Rural Development. The project-team should consist of representatives of DDMFC, one or two designers from the provinces, representatives from the Hanoi Water Resources University, Institute for Water Resources Research and Meteorological Service. There must be a proper commitment of all these parties to the project and the existing boundaries between various departments should disappear.

3) Parallel with the activities mentioned under 2), the short- and long term educational program for technical staff should start.

It should include the following components (steps):

- short course (2 to 3 weeks), for design staff in Viet Nam, preferably in 1996;
- short visit of Vietnamese designers to The Netherlands;
- training of few young engineers in The Netherlands, by attending the yearly course at the International Hydraulic Institute in Delft, and including a 1 or 2 months period of orientation within the Rijkswaterstaat Divisions;
- upgrading the teaching program of the Hanoi Water Resources University.

4) Feasibility (integrated) studies should be undertaken, concerning the coastal area of Nam Ha Province, with special attention to the erosion problems of the Hai Hau district.

Besides the studies on the physical components, a integrated policy analysis for the coastal area of Nam Ha Province should be prepared (safety/risk analysis, evaluation of local interests, additional coastal protection measures, environmental aspects, etc.)

The results of this policy analysis will provide the base for the necessary decisions concerning this area, by the policy-makers.

Possibly this project can be carried out as a pilot project, in a close cooperation with the current VVA project.

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6. Centre for Civil engineering Research and Codes, and Rijkswaterstaat/Road and Hydraulic Engineering
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Design manual for pitched slope protection
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7. Centre for Civil Engineering Research and Codes, and Rijkswaterstaat/Road and Hydraulic engineering
Division
Manual on use of rock in hydraulic engineering
1995, The Netherlands.

APPENDICES

Appendix A1: Itinerary in brief

Monday 25 March

Departure from Schiphol airport

Tuesday 26 March

- Arrival at Hanoi airport
- Arrival in the Hoa Binh Hotel

Wednesday 27 March

Attending the 3rd scientific meeting of the Vietnam Vulnerability Assessment Project (VVA project)

Thursday 28 March

- Ministry of Agriculture and Rural Development (MARD); discussion and agreement on the objectives and the program of the mission
- Meeting at World Food Program (WFP)
- Ministry of Agriculture and Rural Development, DDMFC; presentation and discussions on design of dike systems in Vietnam

Friday 29 March

- Ministry of Agriculture and Rural Development, DDMFC; discussions on dike design, construction and maintenance
- Vietnam Institute for Water Resources Research; introduction on tasks of Institute, presentations and visit of the laboratory

Saturday 30 March

- Hanoi Water Resources University; introductions, explanation on the activities of the University, discussions, visit of the university and campus
- Working session at the hotel.

Sunday 31 March

free

Monday 1 April

Visit to the flood control diversion structures in the Red River, 30 km north west of Hanoi, site visit of river dikes on the southern bank of the Red River

Tuesday 2 April

- Travel and visit to the Provincial Hydraulic Service of the Nam Ha Province in Nam Dinh; presentation, discussions on dike design
- Visit to the Peoples Committee of the Hai Hau district; presentation

Wednesday 3 April

- site visit to the Hai Hau sea dike system
- return to Hanoi

Thursday 4 April

- Travel and visit to the Provincial Hydraulic Service of the Hai Phong Province in Hai Phong; introduction, -Site visit to a block factory and dike section

- Visit of Rock Hills with view on island with Hon Dau station (meteorological station, water level recording station)
- Visit to fishing harbour and neighbouring dike (planned for rehabilitation)

Friday 5 April

- Meeting with the Hydraulic Service of the Hai Phong Province; discussions
- Travel to Quang Ninh Province
- Visit to Halong Bay

Saturday 6 April

- Meeting with Provincial Hydraulic service of the Quang Ninh Province
- Meeting at the peoples committee of the Yen Hung district
- Site visit to an estuary dike under construction
- Return to Hanoi

Sunday 7 April

Working session in the hotel

Monday 8 April

- Meeting with Mr. Uong and Ms. Huong
- Working session in the hotel and at the VVA project office

Tuesday 9 April

- Seminar on the findings of the mission at the Ministry of Agriculture and Rural Development; lectures and discussions

Wednesday 10 April

- G. Kant: return to The Netherlands
- Working session in the hotel
- Briefing Netherlands Embassy

Thursday 11 April

- Working session in the hotel
- Meeting at the Ministry of Agriculture and Rural Development (MARD); discussions on further assistance by The Netherlands in the field of (sea) dikes
- Reception in the Sophia Restaurant

Friday 12 April

K.W. Pilarczyk and P.J. Eversdijk return to The Netherlands

Saturday 13 April

Arrival in The Netherlands

Appendix A2: Extensive itinerary

Monday 25 March

Departure from Schiphol airport

Tuesday 26 March

Arrival at Hanoi airport, collected by Ms Huong, Ministry of Agriculture and Rural Development

Arrival in the Hoa Binh Hotel

Preliminary discussions with:

- Gijsbert Kant and Geoff Toms (VVA/Frederic R. Harris BV)
- Cees Hulsbergen and Frank Hoozemans (VVA/Delft Hydraulics)
- Ryszard Zeidler and Thomas Okroj (VVA/IBW-PAN, Polish Academy of Sciences)

Wednesday 27 March

Attending the 3rd scientific meeting of the Vietnam Vulnerability Assessment Project (VVA project); discussions held with (among others):

- Frans van der Knaap (VVA/WL)
- Marshall Silver (United Nations Development Programme, UNDP)
- Felix Hoogveld (Netherlands embassy)
- Eric Evers (Vietnam-Holland Dredging)
- Wim Klein (Rook Revetment)
- Abraham de Kock (World Food Program, WFP)
- Anne van Urk (RIKZ)

Thursday 28 March

Morning:

Ministry of Agriculture and Rural Development (MARD)

Attendants:

- Mr. Nguyen Cat Giao, Director International Cooperation Department
- Mr. Doan The Uong, Deputy Director Department of International Cooperation
- Ms. Pham Thi Hong, Department of International Cooperation
- Mr. Nguyen Sy Nuoi, Deputy Director DDMFC
- Mr. Ton That Vinh, Chief Engineer DDMFC
- Dr. Quan Ngoc An, Division head, Vietnam Institute for Water Resources Research
- Representative University of Hanoi
- Anne van Urk (RIKZ)

Discussion and agreement on the objectives of the visit.

Discussion and agreement on the program of the mission.

World Food Program (WFP)

Attendants:

- Mr. Julian Lefevre, Country Director WFP
- Mr. Abraham de Kock, WFP
- Mr. Joost Martens, SNV
- Anne van Urk (RIKZ)

Explanation on the WFP involvement in two dike rehabilitation projects in the central and northern provinces of Vietnam. The collaboration between the WFP, UNDP and the Vietnamese Government was explained. Project in five northern provinces of Vietnam is scheduled for 1996 to 2000. Second opinion on designs was provided by Mr. Minetti (Italian Consultant).

Discussions were held on the implementation of VVA results in the WFP (in relation to boundary conditions and selection of dikes to be upgraded).

Afternoon

Ministry of Agriculture and Rural Development, DDMFC

Attendants:

- Dr. Doan The Uong, Deputy Director Department of International Cooperation
- Mr. Nguyen Sy Nuoi, Deputy Director DDMFC
- Mr. Ton That Vinh, Chief Engineer DDMFC
- others

After a brief introduction by Dr. Nuoi a presentation was held by Mr. Vinh on the boundary conditions and the dike systems in Vietnam. Followed by discussions on boundary conditions and design formulae. WFP sea dike designs for the five northern provinces: Ninh Binh, Nam Ha, Thai Binh, Hai Phong and Quang Ninh Province, were made available for review purposes.

Friday 29 March

Morning

Ministry of Agriculture and Rural Development, DDMFC

Attendants:

- Mr. Ton That Vinh Chief Engineer
- Mr. Phan Duc Tac, Engineer
- Mr. Nguyen Thi Hien, Engineer
- Ms. Bui Thi Kha, Engineer

Discussions were held on dike design, construction and maintenance. Mr. Pilarczyk gave an introduction to the attendants on present Dutch design techniques. Subjects: breaker type, toe protection, subsoil, damages, crest level, crest and back side protection, revetment types. Mr Vinh showed us the interlocking blocks which were developed and tested in the Vietnam Institute for Water Resources Research (within MARD). According to Mr. Vinh the required budget for dike improvement is US\$ 500/m. However, the available budget from the WFP (25 million from WFP and 15 million US\$ from the Vietnamese government) is only 40 million US\$ for 360 km of sea dike. This means that there is about US\$ 100/m available for dike improvement.

Afternoon

Vietnam Institute for Water Resources Research

Attendants:

- Prof. Nguyen Thanh Nga, Director Vietnam Institute for Water Resources Research
- Dr. Tran Xuan Thai, Director River and Coastal Engineering Research Centre
- Dr. Quan Ngoc An, Division head, Vietnam Institute for Water Resources Research
- Dr. Dao Xuan Son
- Mr. Ton That Vinh, Chief Engineer, DDMFC
- Mr. Phan Duc Tac, Engineer, DDMFC

Dr. An gave an introduction on the tasks of the Institute. Further he presented some results of the National Program for Marine Research titled: 'Erosion problems at the coast of Vietnam and technical solutions for the most urgent places' (hot spots: north, Hai Phong and Nam Ha; central, Qung Binh and Ninh Thuan; south, Tian Giang). After discussions about the Nam Ha coastline and about the introduction of new design standards the laboratory was visited. The physical testing facilities comprise a wave model facility installed by HR Wallingford and a physical model of the Red River. Also two Wave Rider buoys donated by the Norwegian Government were shown.

Saturday 30 March

Morning

Hanoi Water Resources University

Attendants:

- Prof. Ngo Tri Vieng, Vice Rector Hanoi Water Resources University
- Prof. Nguyen Cong Man, Deputy head of the ministry research program
- Assoc. Prof. Do Van Hua, Head Department of Science and International Cooperation
- Assoc. Prof. Do Tat Tuc, Deputy Dean of the faculty of Hydrology
- Dr. Le Dinh Chung, Deputy dean of the faculty of Hydraulic Engineering
- Mr. Le Van Uoc, Deputy dean of the Postgraduate Training Faculty
- Mr. Ho Sy Minh, Lecturer on coastal engineering
- Dr. Vu Nhu Hoan, Centre of Ocean Meteorology
- Dr. Nguyen Ba Quy, Member of the research project (hydrology)
- Mr. Vu Minh Cat, Member of the research subject
- Mr. Luu Van Lam, Secretary of research subject (Hydraulic engineering)
- Mr. Nguyen Mai Dang, Member of the Centre of Hydrology
- Prof. Dr. Nguyen Dich Dy, Natural Centre of Natural Science and Technology
- Mr. Dinh Van Thuan, member of National Centre of Natural Science and Technology
- Prof. Ngo Dinh Tuan, Director of Hydrology and Environment
- Mr. Ton That Vinh, Chief Engineer, DDMFC
- Anne van Urk (RIKZ)

After introductions of both sides Mr. Cat explained on the activities of the University. The University is involved in the study of the morphological behaviour of two provinces, Quang Minh and Hai Phong. Mr. Cat is also involved in the UNDP project Sea Dike Engineering Services. The University assisted in the dike design of the central provinces for the WFP. Professor Man presented the research project called 'Master Plan Sea Dikes in Vietnam'. In this project the following tasks are being executed (proceedings were handed over): (i) evaluation of existing sea dike system, (ii) evaluation of site conditions (geology, hydrology, morphology, boundary conditions), (iii) impacts of reclamations on the coastline, (iv) socio-economic analyses. These tasks must lead to a sound evaluation of safety standards.

Discussions were held on design methods, design philosophy, need for education, and surge levels. Mr. Pilarczyk stressed the need for the introduction and use of the same state of the art design standards throughout the country.

Prof. Man proposed a joint project by the Hanoi University, DDMFC and the Dutch Government. The title would be 'Master Plan of Sea Dikes in Vietnam' and will need to be sponsored by the Dutch Government. Mr. van Urk welcomed the proposal and will take this under consideration.

The visit was finished with a short walk through the university and campus.

Afternoon

Working session at the hotel.

Sunday 31 March

free

Monday 1 April

Morning and Afternoon

Visit to the flood control diversion structures in the Red River, 30 km north west of Hanoi.

Attendants:

- Mr. Le Tin, Director Flood Control Diversion Management
- Mr. Ton That Vinh, Chief Engineer DDMFC

Mr. Tin presented the principles and history of the flood diversion structures in the Red River and its tributaries. The strategy has been developed in order to reduce risk of floods near Hanoi in the case of extreme discharges through the Red River. In the old days the extreme water levels in were fought by blowing dikes in the Da River (one of the three tributaries to the Red River). In this way the (extreme) water level in the Red River could be somewhat reduced.

In 1934 the French constructed the flood control diversion structure (floating weir principle, design discharge 2200 m³/sec). In the case of extreme high water levels water can be discharged into the Day River, which flows directly to the Gulf of Tonkin. In this way the water level in the red River can be somewhat influenced. After its construction the structure was used 5 times, during the flood seasons of 1940, 1945, 1947, 1969 and 1971. However, the operation and maintenance of the structure was not satisfactory. In 1977 it was replaced by the present structure (mechanical weir operation, design discharge 5000 m³/sec). The structure was used once; in 1986. In this year also the construction of the Hoa Binh Reservoir Dam was completed (in the Da River). From then on floods coming from this tributary can also be influenced by means of this dam.

Before water from the Red River can reach the diversion structure the water must pass the sluice structure near Van Coc, on the southern bank of the Red River. In case of a flood this structure is opened and nearby river dikes will overtop. In this way water will reach the diversion structure and will be discharged through the Day River to the sea.

The flood diversion structure, the sluice near Van Coc as well as river dikes on the southern bank of the Red River were visited during the remainder of the day.

Tuesday 2 April

Morning

Travel and visit to the Provincial Hydraulic Service of the Nam Ha Province, seated in Nam Dinh, the capital of the province.

Attendants:

- Mr. Pham Hap, Director of Nam Ha Hydraulic Service
- Mr. Nguyen Ngoc Thanh, Chief of Dike management division
- Mr. Nguyen Van Tiem, Director of Hydraulic Design Department
- Mr. Dang Vu Chu, Deputy director Hydraulic Design Department
- Mr. Ton That Vinh, Chief Engineer, DDMFC
- Mr. Nguyen Sy Nuoi, Deputy Director DDMFC
- Dr. Quan Ngoc An, Division head, Vietnam Institute for Water Resources Research

Mt. Thanh welcomes the mission and presents the situation of the sea dikes in Nam Ha Province. Nam Ha province (250.000 ha) consists of 13 districts of which three are coastal. Nam Ha counts 2.6 million inhabitants. The total population in the three coastal provinces is about 850.000 people. 70 km of coastline, 90 km sea dike. In Hai Hau district the coastline is retreating for at least a century. Estimated erosion rates:

1900 - 1953	35 - 50	m/year
1953 - 1973	15 - 20	m/year
1973 - 1990	8 - 10	m/year
1990 - 1996	5	m/year

Locally the total coastline retreat has reached up to 3 km in this century.

In the period 1890-1992, 23 heavy storms passed the province. In the years 1892, 1905, 1925, 1944 (7 days, 3 successively storms), 1956, 1968, 1971, 1975, 1982 and 1986 the sea dikes were severely damaged. The averaged capitalized damage for the province is calculated on $2.1 * 10^6$ US\$/year (loss of live, houses, boats, cultivated area, damage to structures, earth fill loss, revetment loss, loss of crops etc.)

Afternoon

Continuation of discussions with above listed attendants.

The toe level of the sea dikes is in general +0.5 m MSL in the Nam Ha Province. Discussions about boundary conditions, toe protection, revetment type, inner slope protection, geotechnical stability etc. Discussions about the double dike strategy, as being adopted in the Hai Hau district.

Visit to the Peoples Committee of the Hai Hau district.

Attendants:

- Mr. Oang, Chairman of the Hai Hau People Committee
- Mr. Thang, Vice Chairman of the Hai Hau People Committee
- Mr. Pham Hap, Director of Nam Ha Hydraulic Service
- Mr. Nguyen Van Tiem, Director of Hydraulic Design Department
- Mr. Hien, Vice Deputy of the Hydraulic Service of Hai Hau District
- Mr. Tho, Director of Construction Company

Mr. Dang gave a short presentation of his district. Beside the general issues of the district he stressed his concern about the problems related to the coast erosion.

The Hai Hau district is encircled by 33 km of sea dike and by 47 km of river dike. Population: 330.000 people. 45 % of the inhabitants has the catholic religion. 133 churches. Total area 266 km². The limestone which is being used for the revetment of the sea dikes has to be transported over 100 km. During this transport the means of transportation changes 7 times.

Mr. Hap proposes to the mission to start up a joint pilot project for the coast of Hai Hau District. The project would comprise the morphological study of the coastline development, sea dike design, construction and maintenance. Support from the Netherlands, both technically as financially, is requested.

Wednesday 3 April

Morning

Breakfast, followed by a site visit to the Hai Hau sea dike system. Almost the entire coastline of the Hai Hau district was visited. On many places the results of the strong erosion could clearly be observed. On many places heavily damaged revetments were inspected. Visits to the improved sea dike sections with interlocking blocks and square placed blocks. Mr. Vinh commented upon the situation and showed the dikes which will be improved by the World Food Program (in general the second dike).

Afternoon

Lunch and return to Hanoi.

Thursday 4 April

Morning

Travel and visit to the Provincial Hydraulic Service of the Hai Phong Province, seated in Hai Phong, the capital of the province.

Attendants:

- Mr. Le Huu Ban, Vice Director Hydraulic Service
- Mr. Le Tue Tien, Chief Division of Dike Management Hydraulic Service
- Mr. Do Trung Thoai, Director of Dike Management Board
- Mr. Duong Van Gang, Deputy Chief Division of Dike Management of Hydraulic Service
- Mr. Nguyen Van Miul, Senior Technical Expert Dike Management
- Mr. Vu Thi Bao, Deputy Director Design Company Hydraulic Service
- Mr. Tran Xuan Hop, Chief of Division Design Company

Mr. Tien gave a brief introduction on general issues of the province. In total Hai Phong Province has 93 km of sea dike of which 81 km will be upgraded by the WFP.

Afternoon

Mr. Hien continues his presentation. Sea dike system protects 40.000 ha land. Dikes are in general built on soft soil (silt). The bed level in front of the dike is in general between 0 - +0.5 m MSL. Beach is not stable: even erosion and accretion.

Within the dike system are 55 sluices for drainage purposes. For about 25 % of the dikes the wave action is reduced due to the presence of mangroves. Present crest level: +4 - +4.5 m MSL. Protection systems used: rock, concrete plates, interlocking blocks. Crest level after WFP upgrading: +5 - +5.5 m MSL.

Site visit:

A visit was made to a block factory where the interlocking blocks were produced. Figures: 8 blocks/man/day; 25 blocks/m³ concrete; 150 blocks/day. Use of interlocking blocks is 8 times more expensive than the traditional rock protection.

Visit of damaged dike section (concrete plate revetment).

A recently constructed dike section was visited (interlocking blocks, next to placed rock) outer slope 1:3.5; rock D=20 -30 cm (40-200 kg)

Visit of Rock Hills with view on island with Hon Dau station (meteorological station, water level recording station) and visit to fishing harbour and neighbouring dike (planned for rehabilitation)

Friday 5 April

Morning

Meeting with the Hydraulic Service of the Hai Phong Province. Discussions about foreshore, boundary conditions and design formulae. Mr. Tien explained on the confusion with respect to design formulae and parameters to be used in these formulae. Mr. Pilarczyk stressed the importance of understanding of the processes and boundary conditions. Further he advised on the use, design and calculation of concrete plates, toe protections, filter layers, settlements, transitions, interlock systems, reuse of old revetments, geotextiles, quality control, maintenance, importance of repair and damage reporting.

A request was made to the mission to provide support for the integrated introduction of design standards, maintenance standards, and quality control standards in Vietnam.

Afternoon

Travel to Quang Ninh Province; visit to Halong Bay (coast with a great number of rocky islands).

Saturday 6 April

Morning

Meeting with Provincial Hydraulic service of the Quang Ninh Province.

Attendants:

- Mr. Dang Quang Nhi, Director Quang Ninh Hydraulic Service
- others (list via Ms. Huong)

General introduction by Mr. Nhi. Brief discussions on boundary conditions (tide, surge and wave conditions). Subsoil layers of the dikes is usually soft. 250 km coastline; 373 km dikes, of which 300 km (?) sea dikes in 10 different sections. HHWS: difference between north and south of Quang Ninh 10 to 30 cm.

Meeting at the peoples committee of the Yen Hung district

Site visit to an estuary dike under construction which was funded by the World Food Program (project Vietnam 5325).

Afternoon

Return to Hanoi.

Sunday 7 April

Working session in the hotel

Monday 8 April

Meeting in the hotel; attendants:

- Mr. Doan The Uong
- Ms. Pham Thi Hong
- Mr. Pilarczyk and Mr. Eversdijk

Discussions on the proposal of a 'project' for (technical) assistance by The Netherlands; subjects:

- Design guidelines and technical norms
- Training/courses both in The Netherlands and in Viet Nam
- Standards and guidelines for operation and maintenance
- Equipment for design (computers) and field survey
- Pilot study Nam Ha (and evt. Hai Hau)

Working session in the hotel and at the VVA project office.

Tuesday 9 April

Seminar on the findings of the mission at the Ministry of Agriculture and Rural Development; lectures and discussions.

Attendants:

- 25 to 30 representatives of different departments, institutes and the university

Morning

Welcome	Mr. Tu Mao, Director General of DDMFC
Opening	Mr. Nguyen Sy Nuoi
Introduction	Mr. P.J. Eversdijk
The coastline of the Netherlands	Mr. P.J. Eversdijk
Boundary conditions	Mr. G. Kant

Afternoon

Design methodology	Mr. K.W. Pilarczyk
Design practice in the Netherlands	Mr. K.W. Pilarczyk
Runup calculations, berms	Mr. K.W. Pilarczyk
Revetment types	Mr. K.W. Pilarczyk
Revetment stability calculations	Mr. K.W. Pilarczyk

Wednesday 10 April

Morning

G. Kant: return to The Netherlands
Working session in the hotel

Afternoon

Briefing Netherlands Embassy

Attendants:

- Mr. D.A.V.E. Ader, Her Majesty's Ambassador
- Mr. Robert van Embden, First Secretary
- Mr. Pilarczyk and Mr. Eversdijk

Thursday 11 April

Morning

Working session in the hotel

Afternoon

Ministry of Agriculture and Rural Development (MARD)

- Mr. Prof. Dr. Vu Trong Hong, Vice-Minister, Ministry of Agriculture and Rural Development
 - Mr. Tu Mao, Director General of DDMFC
 - Mr. Doan The Uong, Deputy Director Department of International Cooperation
 - Ms. Pham Thi Hong, Department of International Cooperation
 - Mr. Nguyen Sy Nuoi, Deputy Director DDMFC
 - Mr. Ton That Vinh, Chief Engineer DDMFC
 - Mr. D.A.V.E. Ader, Her Majesty's Ambassador
 - Mr. Pilarczyk and Mr. Eversdijk
 - others
- Introductions by mr. Hong and Mr. Ader
- Discussions on the help of The Netherlands in general
- Briefing of the mission; topics:
- * cooperation between departments and institutes involved
 - * differentiation in safety standard should be considered on basis of costs/benefits study
 - * different alternatives should be considered: policy analysis study
 - * updating of design-tools
 - * transfer of knowledge from The Netherlands to Viet Nam
 - * study of the natural boundary conditions
- * for training in The Netherlands, knowledge of the English language is very important
- Proposal of a 'project' for (technical) assistance by The Netherlands in the field of (sea) dikes:
- * Introducing new design guidelines/standards
 - * Training of staff: courses in both The Netherlands and Viet Nam
 - * Arrange a visit to The Netherlands for Policy makers and technicians
 - * Standards and guidelines for operation and maintenance
 - * Equipment for the collection of field information
 - * Pilot-/feasibility study Hai Hau (Nam Ha)

Conclusion: Viet Nam will send a proposal to Her Majesty's Ambassador, for assistance by The Netherlands in the field of sea dikes, except the 'equipment item'; Dutch side will help with formulation of a project.

Evening

Reception "on the occasion of working visit of Ministry of Transport, Public Works and Water Management of The Netherlands", in the Sophia Restaurant

Attendants:

- Mr. Prof. Dr. Vu Trong Hong
- Mr. Tu Mao
- Mr. Doan The Uong
- Ms. Pham Thi Hong
- Mr. Nguyen Sy Nuoi
- Mr. Ton That Vinh
- Mr. Quan Ngoc An
- Mr. Lambert Grijns, Second Secretary of Netherlands Embassy
- Mr. Pilarczyk and Mr. Eversdijk

Friday 12 April

K.W. Pilarczyk and P.J. Eversdijk return to The Netherlands

Saturday 13 April

Arrival in The Netherlands

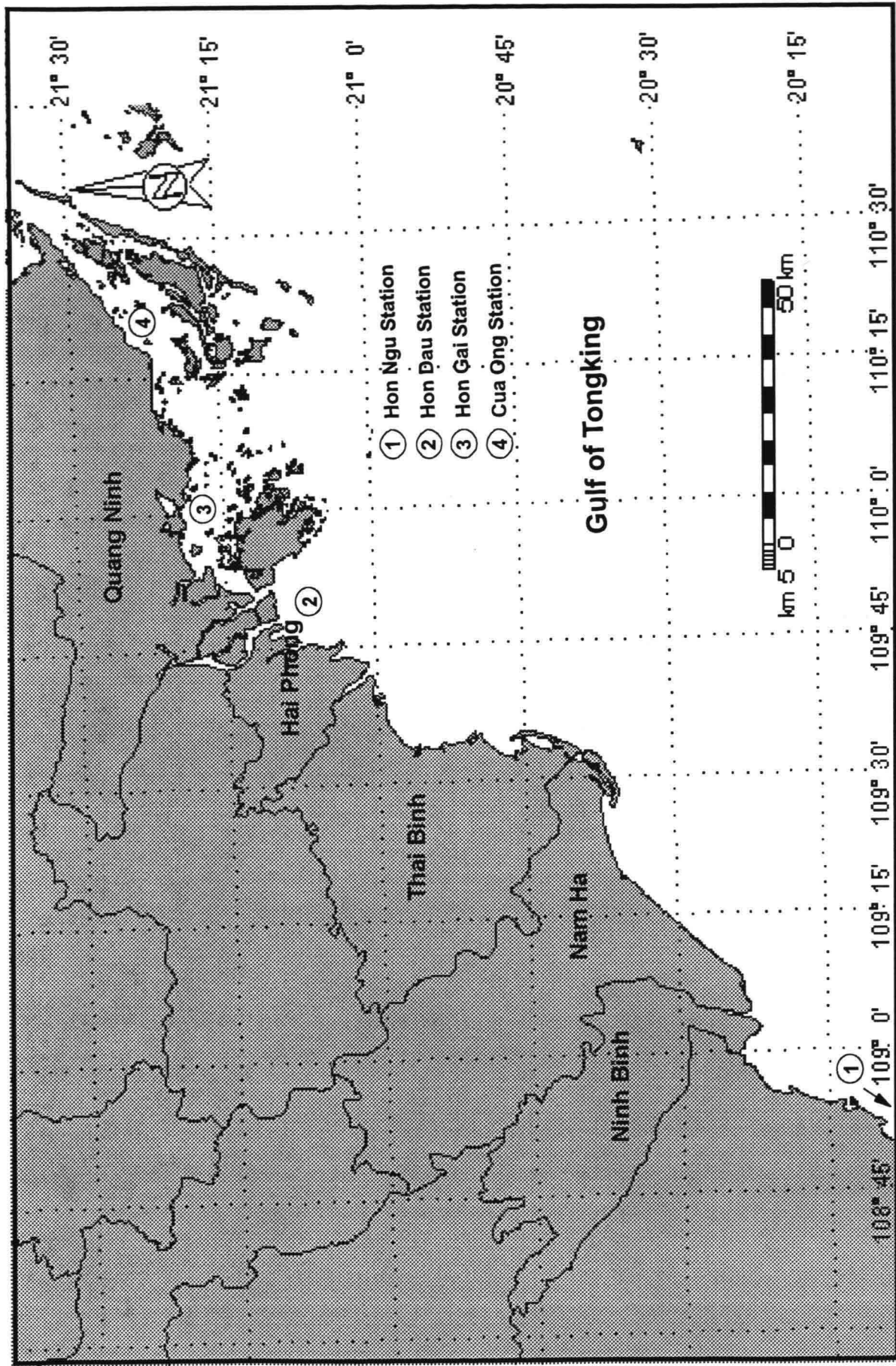
Appendix B: List of Abbreviations

CCFSC	Central Committee for Flood and Storm Control
DDMFC	Department of Dike Management and Flood Control
DWL	Design Water Level
HHWS	High High Water Spring
HWRU	Hanoi Water Resources University
HMS	Hydro Meteorological Service of Viet Nam
LAT	Lowest Astronomical Tide
LLWS	Low Low Water Spring
MARD	Ministry of Agriculture and Rural Development
MSL	Mean Sea Level
RRD	Red River Delta
RWS	Rijkswaterstaat (Directorate General of Public Works and Water Management of the Ministry of Transport, Public Works and Water Management)
UNDP	United Nations Development Program
VNCIDNDR	The Viet Nam National Committee for the International Decade for Natural Disaster Reduction
VVA	Vietnam Vulnerability Assessment
WFP	World Food Program

Appendix C: Glossary

Acceptable risk	Degree of loss that is perceived by the community, as acceptable
Breaking index	Relationship between the maximum wave height (with respect to breaking) and the water depth
Design water level	Maximum water level calculated in the design of hydraulic structures of dams, dikes etc
Failure modes	Various mechanisms of water-soil-structure interactions, which may lead to failure of structure
Fetch length	Length of sea or estuary, in the direction from which the wind comes
Flood	The inundation of a normally dry land, by water
Geotechnical instability	Collective name for related geotechnical failure mechanisms, e.g.: deformation of the filter and/or base material into S-profile or slip circle, soil movement in the subsoil, and sliding of the cover layer or dike body
Geotextile	Plastic fabric applied, for example, to sand or clay to prevent them being washed into the filter
Grouted systems	Stone or blocks, grouted by binding material (concrete, asphalt); if fully grouted, they are similar to slabs/plates
Hydraulic gradient	Change in hydraulic pressure head per unit length (pressure head gradient)
Hydraulic loads	Wave heights (or pressure head differences on the cover layer or in the filter, or in the subsoil) which threaten the stability of the structure
Interlocked blocks	Prefabricated blocks which, because of their shape, lock together providing a higher stability
Internal stability	Migration of the fine fraction of a filter layer or subsoil, through the pores of filter and/or toplayer
Loose blocks	Blocks in the revetment which are only in contact with the row of blocks immediately below and which can be lifted out by a force which is only slightly greater than their own weight
One percent probability flood	The flood with an annual exceedance probability of one percent
Pitched stone	One layer of stones regularly placed with the longest axis perpendicular to the slope

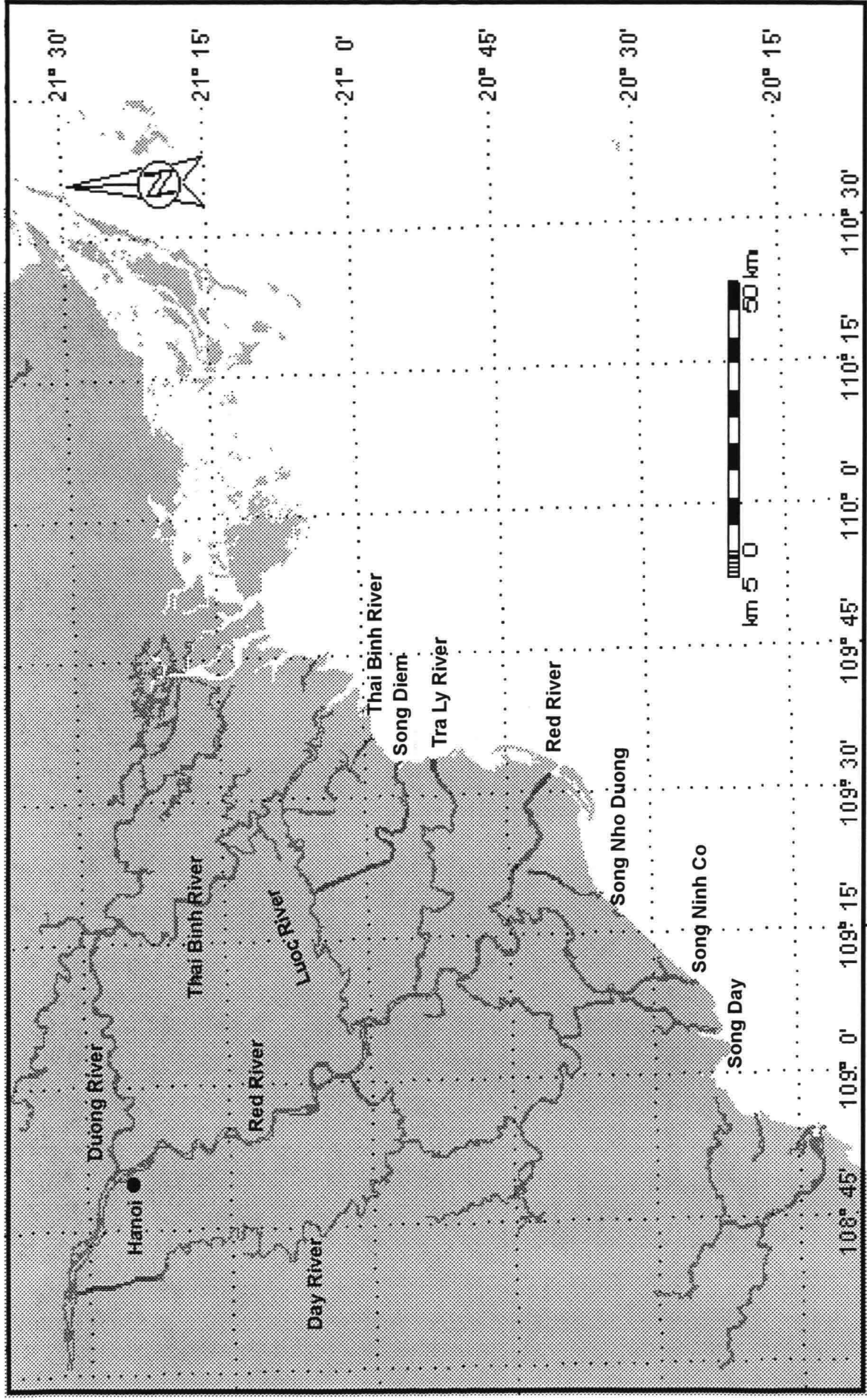
Revetment structure	All the layers which protect the dike core of sand/clay against erosion by water movement, comprising a cover layer with (possibly) filter layers and/or geotextile
Riprap	At least two layers of random dumped stones
Runup	The height of water level on a slope, relative to the still water level, due to the interaction between waves and structure
Shoaling	Change in wave height as function of bottom topography (waterdepth)
Storm surge	A rise in water level in the open coast due to action of wind stress as well as atmospheric pressure on the sea surface.
Subsoil	Sand or clay underneath a granular filter or a geotextile
Sustainable development	Development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.
Toe structure	Structure at the bottom of the slope forming a transition between the foreshore or a supporting berm
Transition structure	Structure designed to join together two different types of revetment
Vulnerability	Expected degree of loss (as a percentage) resulting from a potentially damaging phenomenon.
Wave set-up	Increase in water level as a result of windwaves
Wave steepness	Relationship between wave height and wave length
Wind set-up	The temporary rise of the sea level at the coast by the friction between the wind and the water surface



- ① Hon Ngu Station
- ② Hon Dau Station
- ③ Hon Gai Station
- ④ Cua Ong Station

Sea Dikes Northern Part of Vietnam; review

Coastal Provinces and Waterlevel Stations

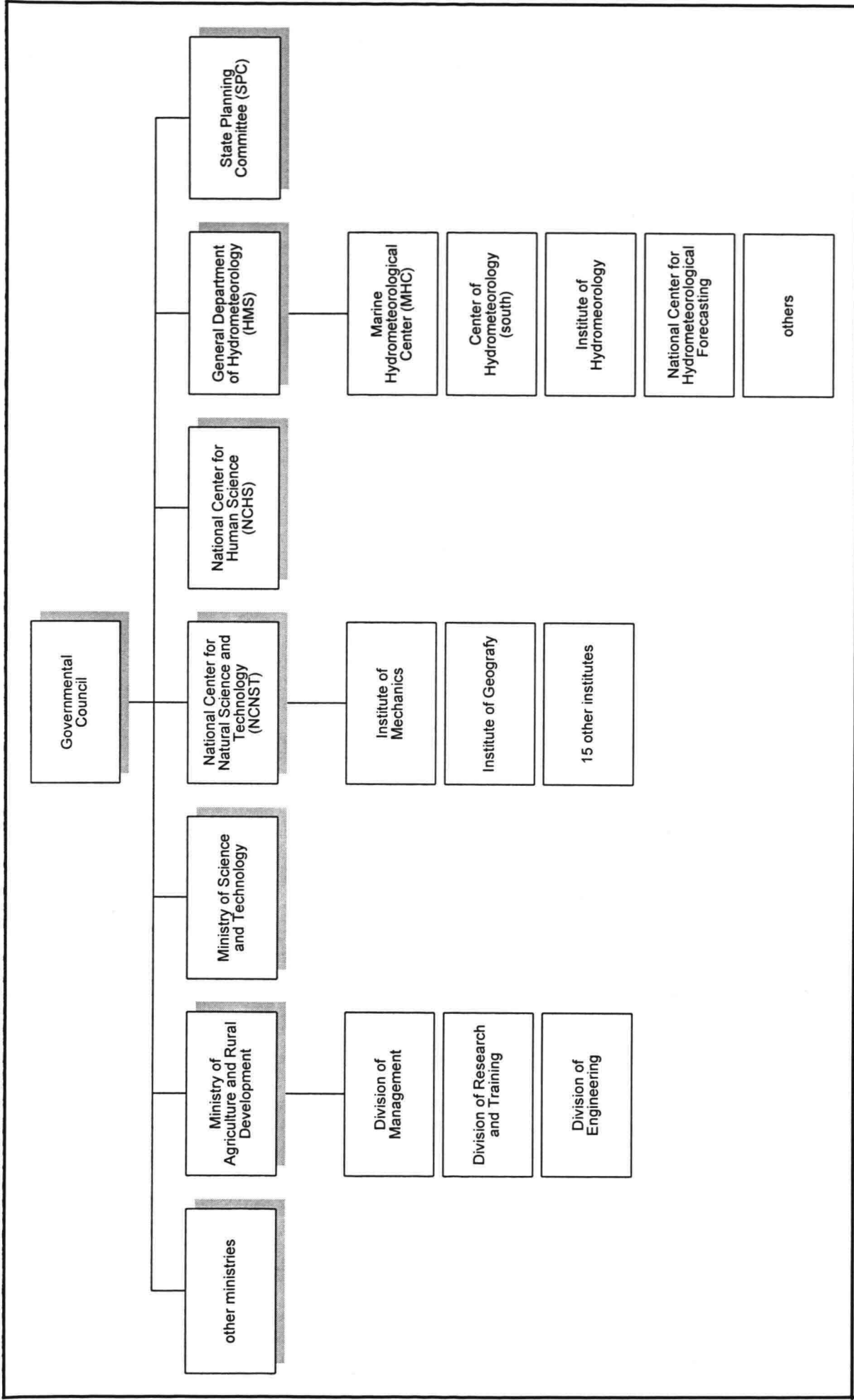


River branches Red River Delta

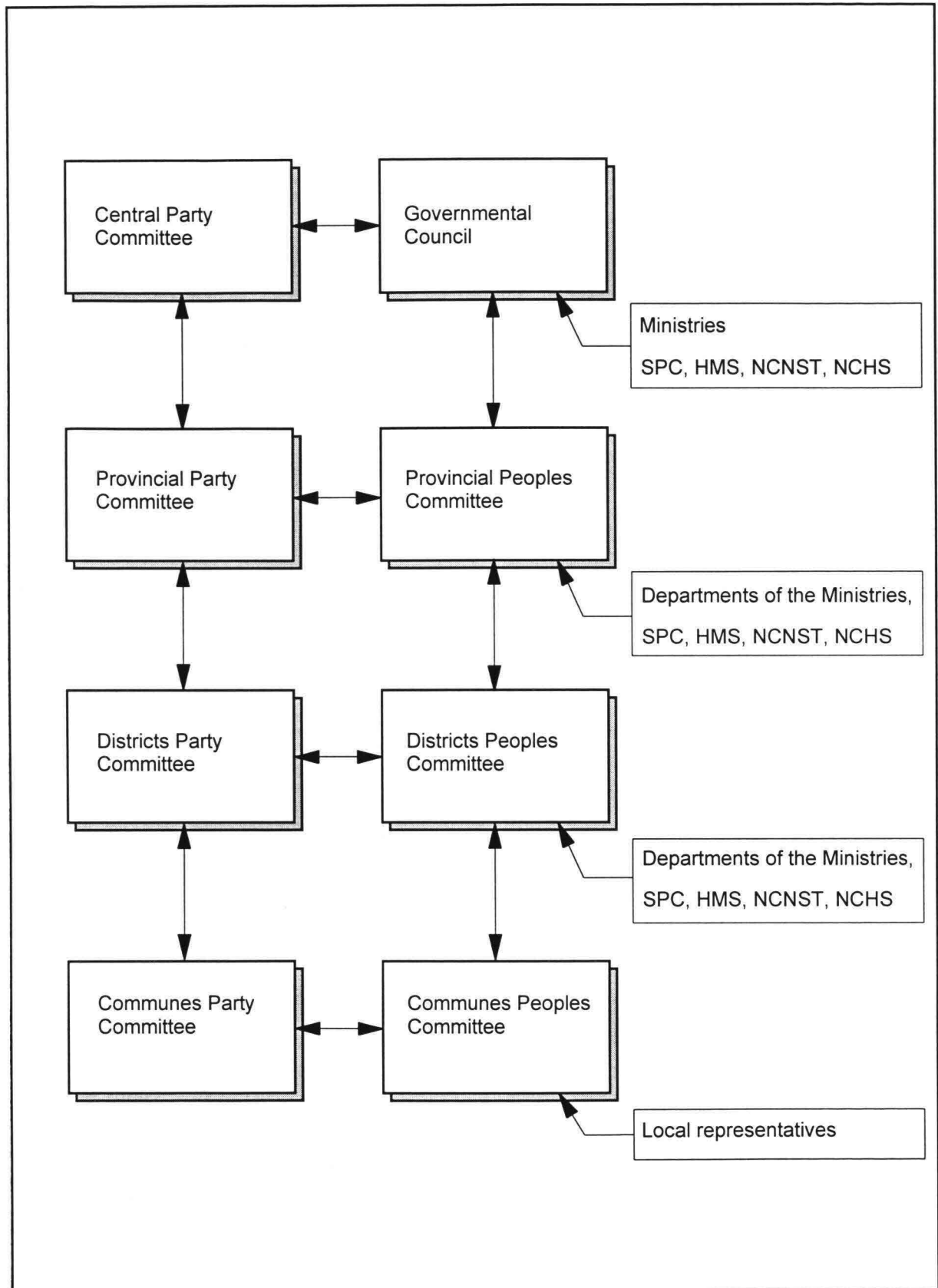
Sea dikes northern part of Vietnam; review

Appendix E

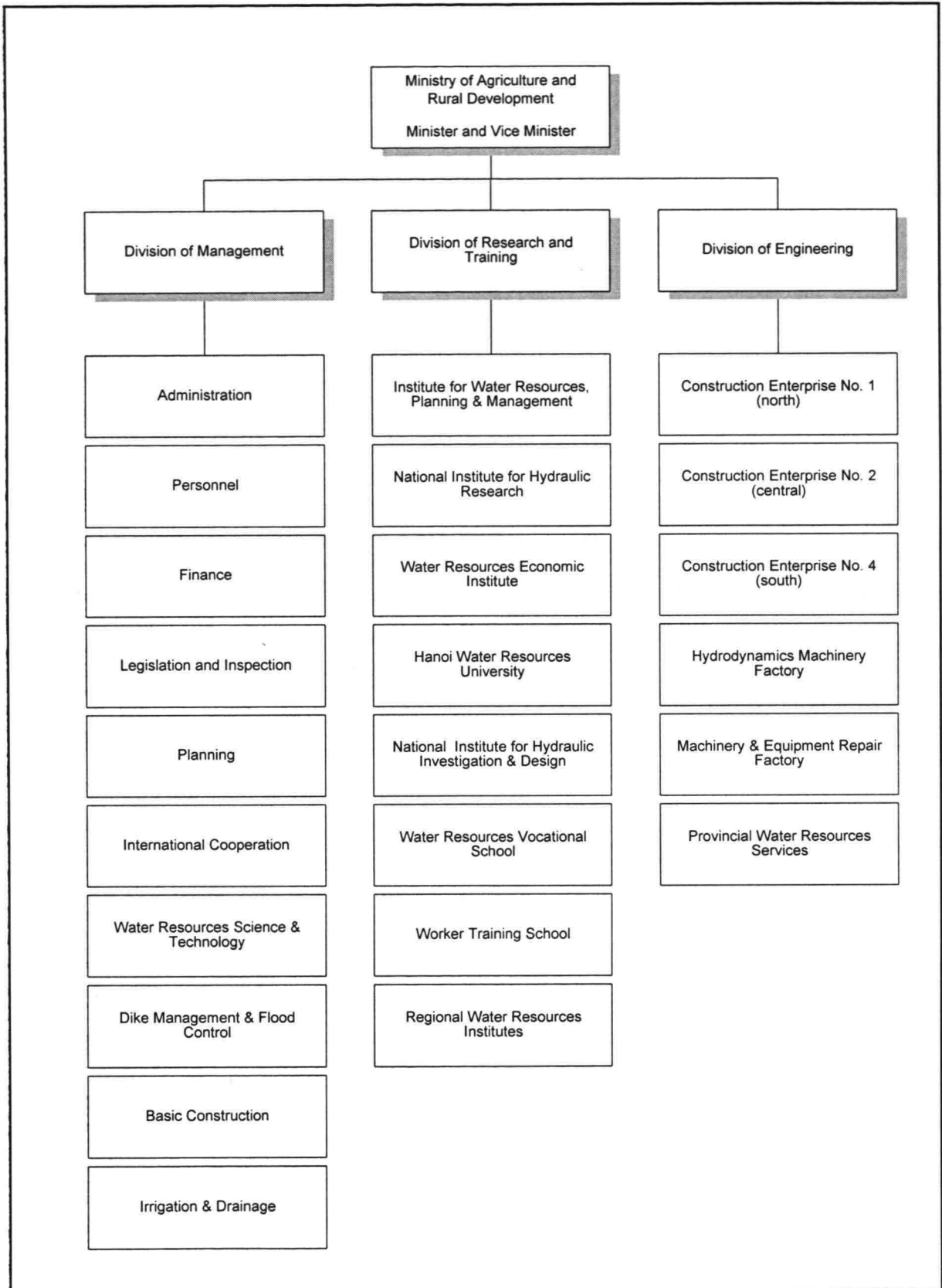
Appendix F: Organisation schemes



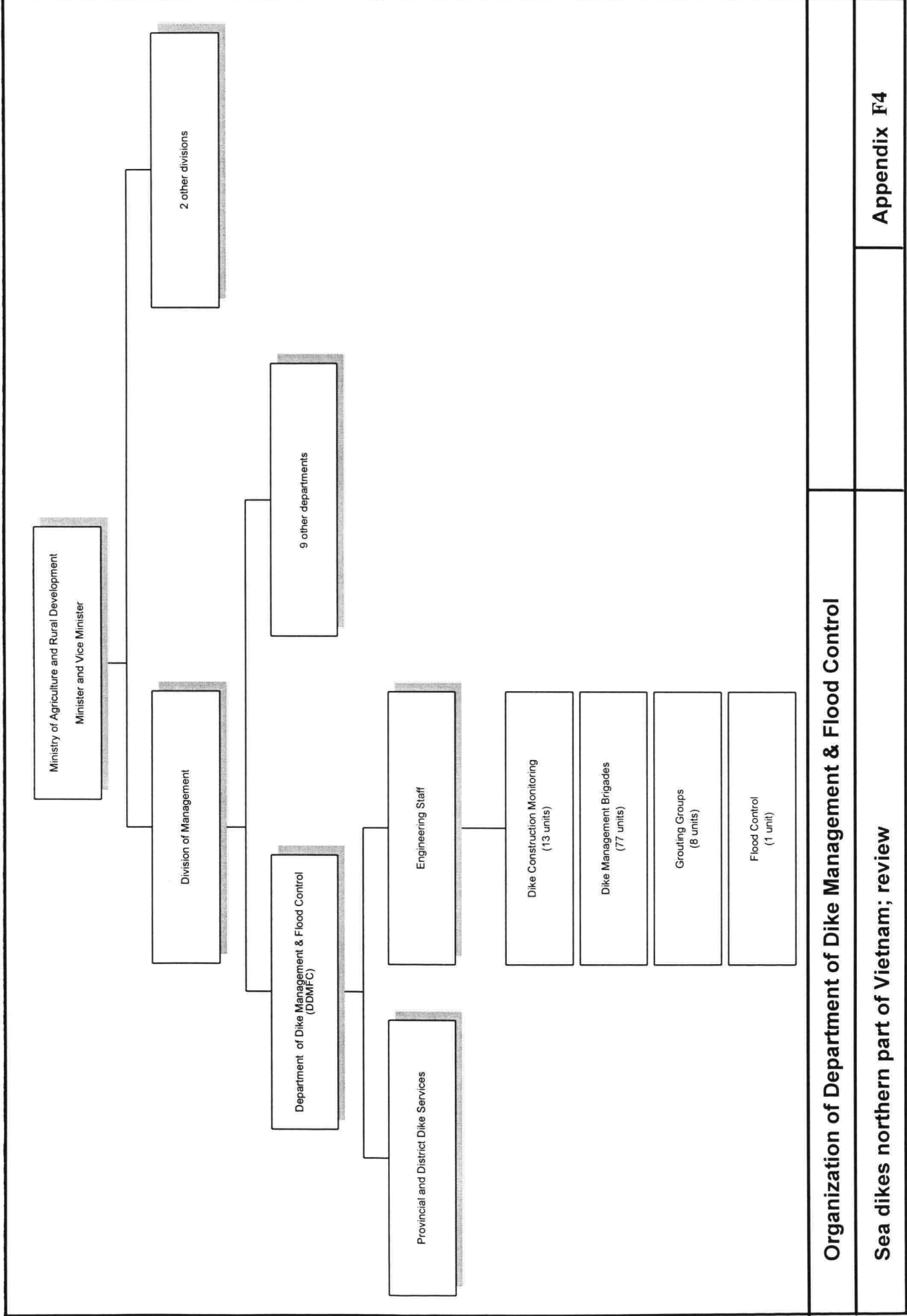
Governmental organization at national level	
	Appendix F1
Sea dikes northern part of Vietnam; review	



Governmental organization		
Sea dikes northern part of Vietnam; review		Appendix F2

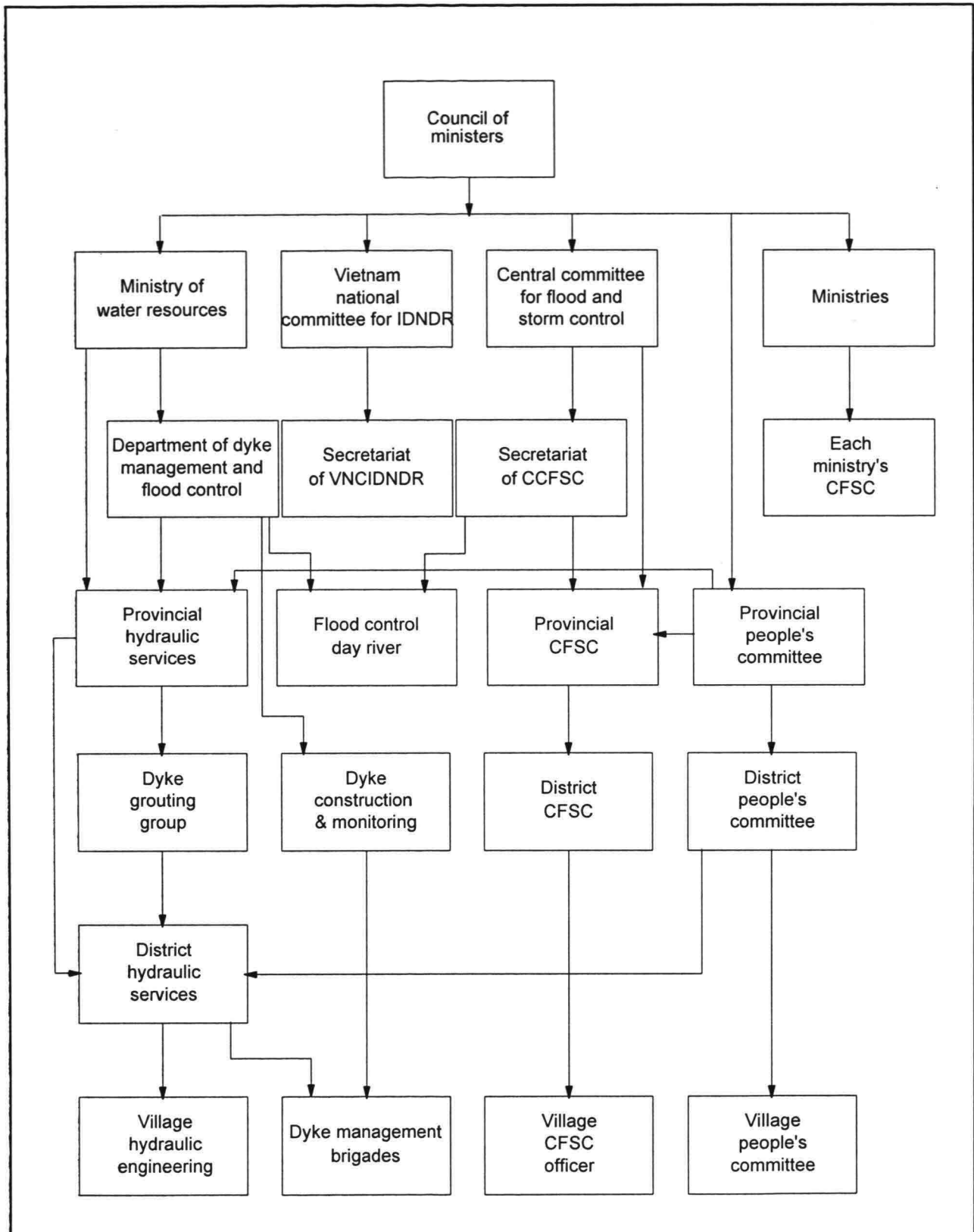


Organization of Ministry of Agriculture and Rural Development		
Sea dikes northern part of Vietnam; review		Appendix F3



Organization of Department of Dike Management & Flood Control

Sea dikes northern part of Vietnam; review



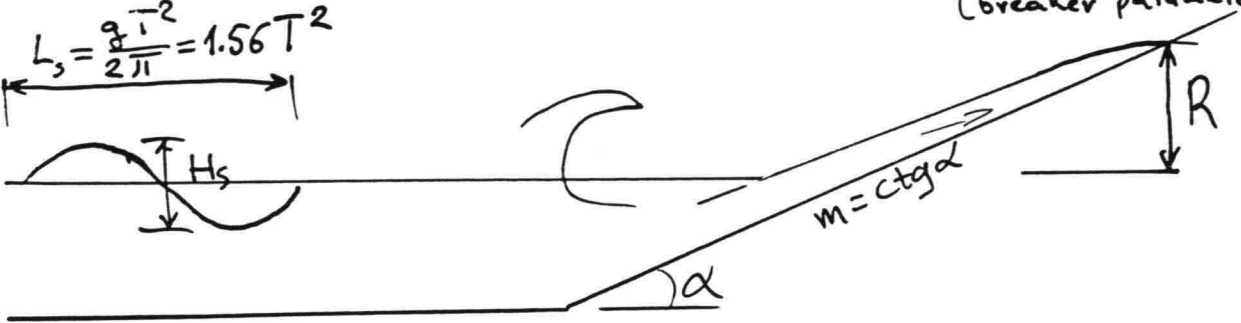
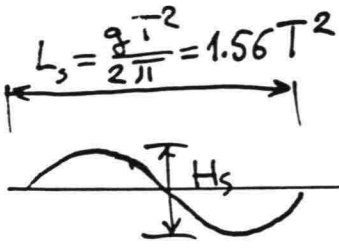
from: Strategy and Action Plan for Mitigating Water Disasters in Vietnam, DHA, UNDP and MWR, Hanoi 1994 [lit 6]

Institutional structure for combating the annual effects of floods and typhoons		
Sea dikes northern part of Vietnam; review		Appendix F5

Appendix G: Results case study on calculation of crest height

Runup and stability as function of ' ξ '

(breaker parameter)



$$\xi = \frac{\tan \alpha}{\sqrt{H_s/L_s}} = \frac{\text{slope steepness (gradient)}}{\sqrt{\text{wave steepness}}}$$

Runup

$$\frac{R_{uz\%}}{H_s} = 1.5 \xi \quad (\text{smooth slope})$$

for $\xi < 2$ to 2.5

- factor 1.5 = average value
- for design 1.6 is used (in the Netherlands)

Stability of revetment

$$\frac{H_s}{\Delta D} = \frac{\varphi}{\xi b}$$

$b = 0.5$ riprap

$b \approx 2/3$ block revetment

General design formula

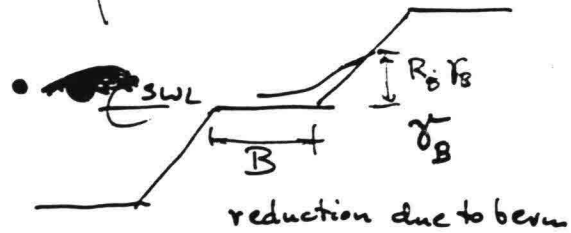
$$\frac{R_{uz\%}}{H_s} = 1.5 \xi \cdot \gamma_R \cdot \gamma_B \cdot \gamma_\beta$$

(1.6)

γ_R = reduction factor due to roughness and permeability

γ_B = reduction factor due to berm

γ_β = reduction factor for oblique wave attack



$$R_{uz\%} = 1.4 R_{us} \rightarrow R_{us} = \frac{R_{uz\%}}{1.4} \quad (R_{us} = \text{significant wave runup} = 13\% \text{ of exceedance})$$

Optimum berm at SWL: $\frac{B}{H_s} = \frac{4}{3} \text{ctg} \alpha \rightarrow \gamma_B = 0.6$ (max reduction)

NB. also wave overtopping is dependant on ξ

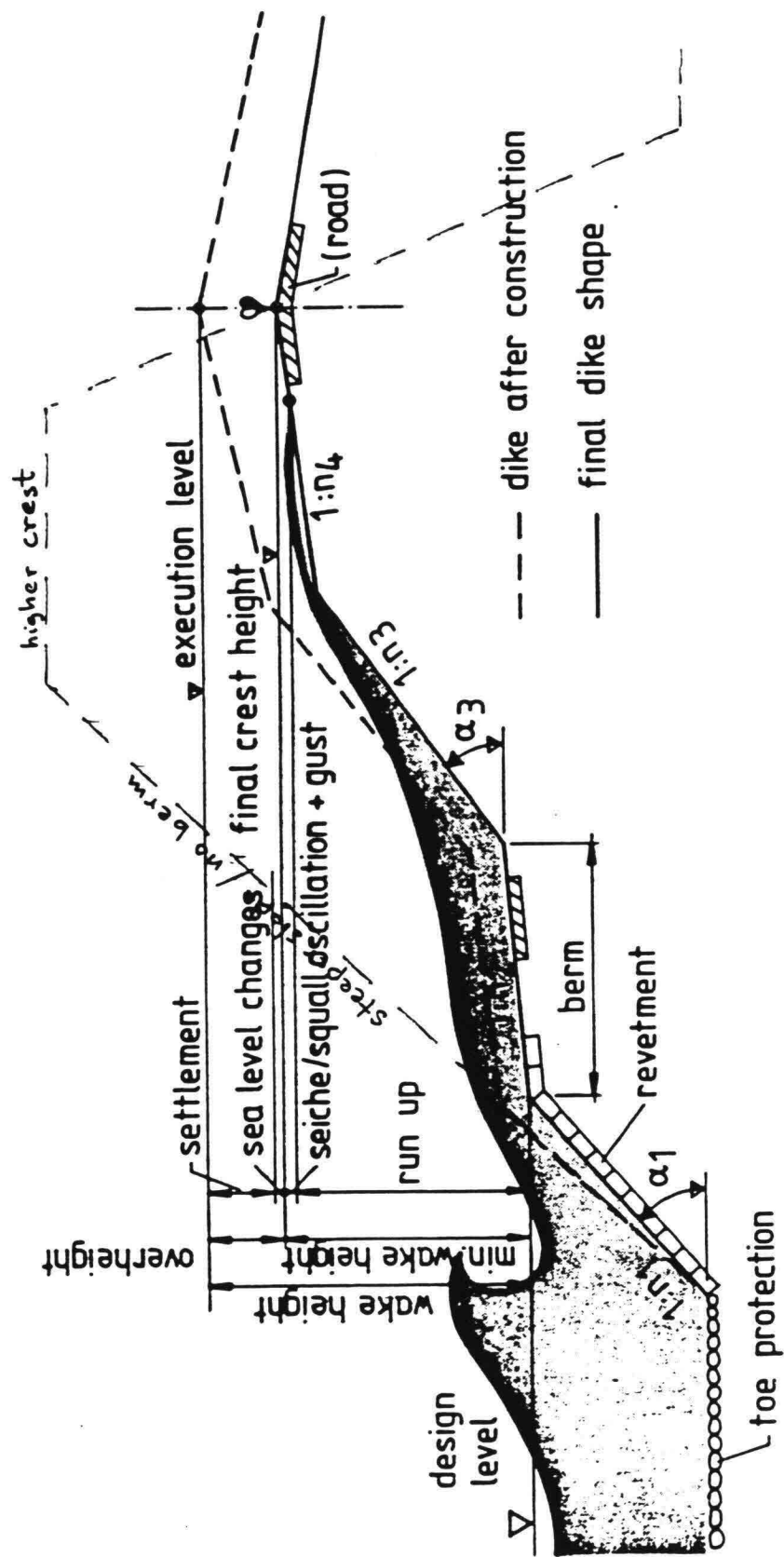
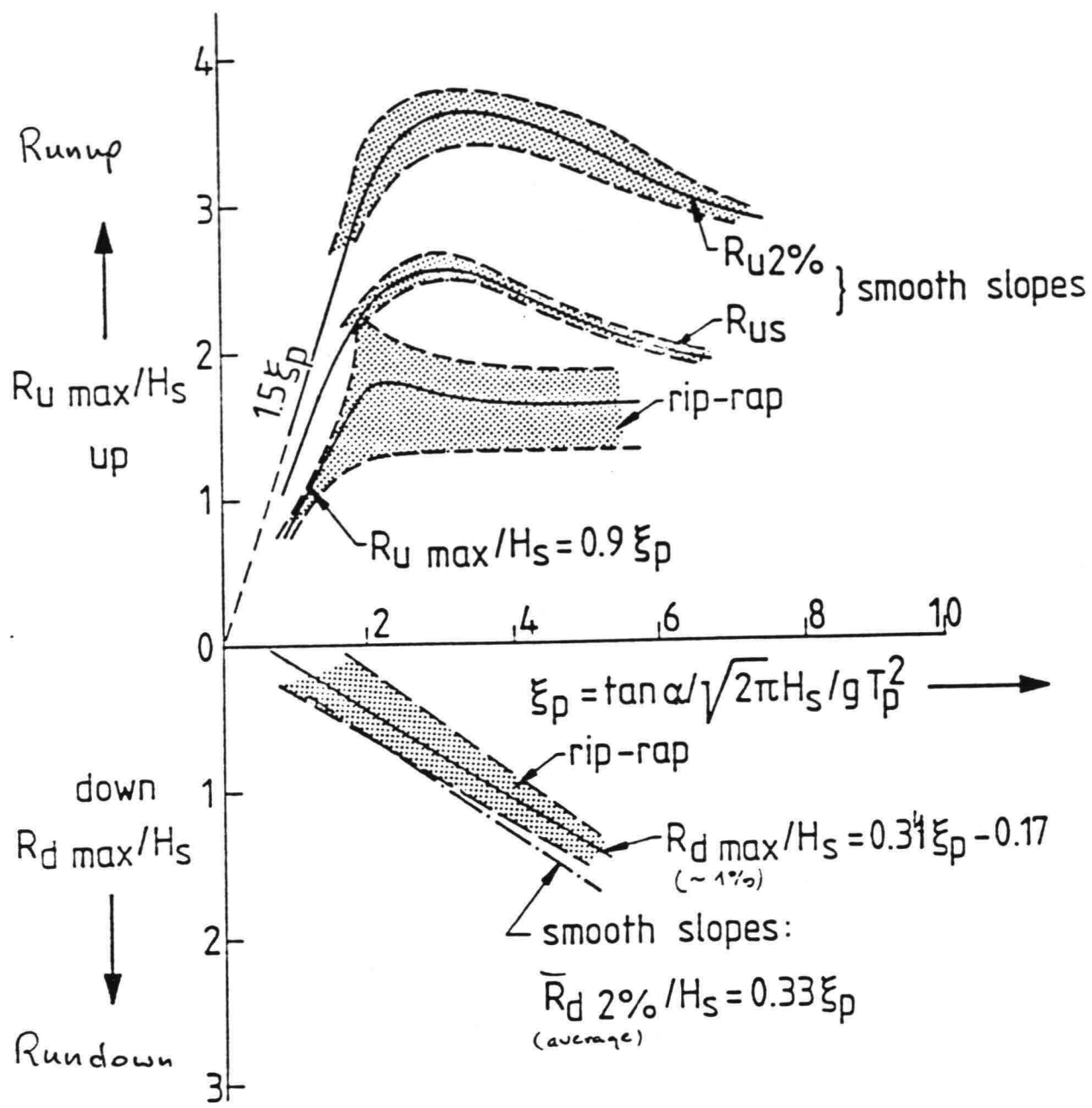


FIG. DETERMINATION OF DIKE HEIGHT



rip-rap: $D_{85}/D_{15} = 2.25$
 $D_{50} = 20 ; 30 ; 40 \text{ mm}$

IRREGULAR WAVES

FIG. RUN-UP AND RUN-DOWN FOR SMOOTH AND RIP-RAP SLOPES

$$R_{2\%} = 1.75 \xi_{top} H_s$$

(safe assumption)

results :

	ctg $\alpha = 3$; $\gamma_b = 1$	ctg $\alpha = 4$; $\gamma_b = 1$	ctg $\alpha = 4$; $\gamma_b = 0.7$
storm surge MSL +	5.00	5.00	5.00
run-up	13.30	10.00	7.00
sea-level rise	0.25	0.25	0.25
seiches / oscillations	0.25	0.25	0.25
settlement	0.50	0.50	0.50
dike crest MSL +	19.30	16.00	13.00

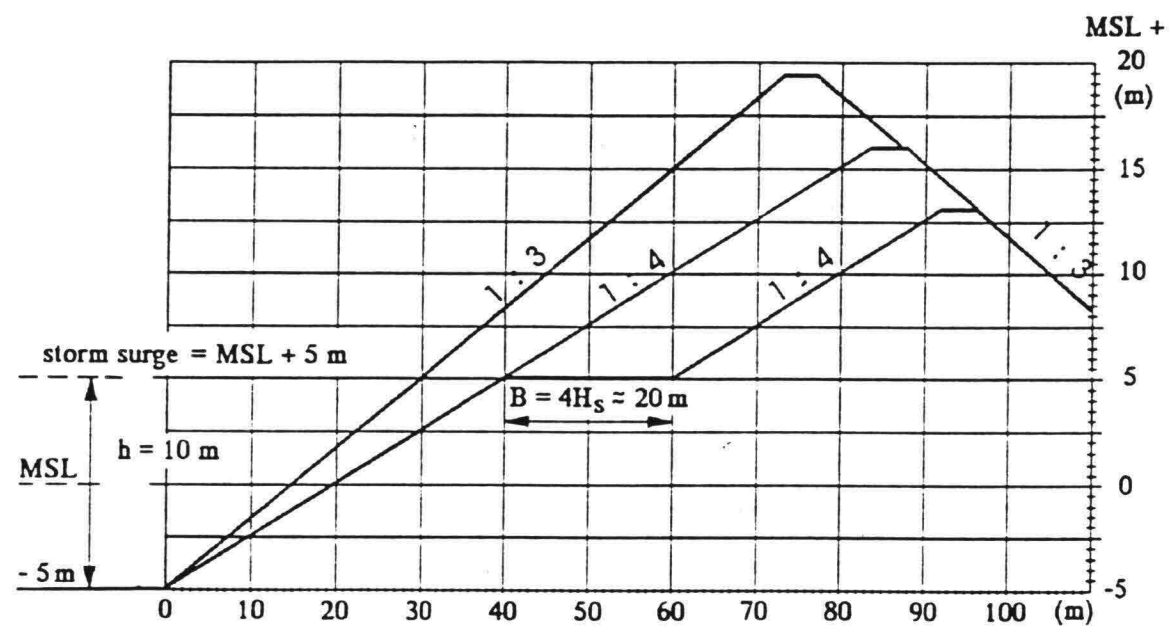


Figure 3 Example of dike calculation (alternatives) ; ($H_s = 4.7$ m, depth limited, $T_p = 8.5$ sec, berm reduction $\gamma_B = 0.7$ for $ctg \alpha = 4$ and $B = 4 H_s$)

Comparison with Russian formula



$$\begin{aligned}\frac{R_{u2\%}}{H_s} &= 1.5 \xi \cdot \gamma_R \cdot \gamma_\beta \\ &= 1.5 \frac{\tan \alpha}{\sqrt{H_s/L_s}} \gamma_R \cdot \gamma_\beta\end{aligned}$$

Wave steepness during a storm $H_s/L_s \approx 0.04$
(0.05 \rightarrow 0.03)
young sea \rightarrow developed sea)

$$\begin{aligned}R_{u2\%} &= 1.5 H_s \tan \alpha \frac{1}{\sqrt{0.04}} \cdot \gamma_R \cdot \gamma_\beta \\ &= 1.5 H_s \tan \alpha \frac{10}{2} \cdot \gamma_R \cdot \gamma_\beta \\ &= 7.5 H_s \tan \alpha \cdot \gamma_R \cdot \gamma_\beta\end{aligned}$$

For riprap $\gamma_R \approx 0.7$ (riprap on thin filter)

$$R_{u2\%} = \frac{5.25 H_s}{\text{ctg} \alpha} \cdot \gamma_\beta$$

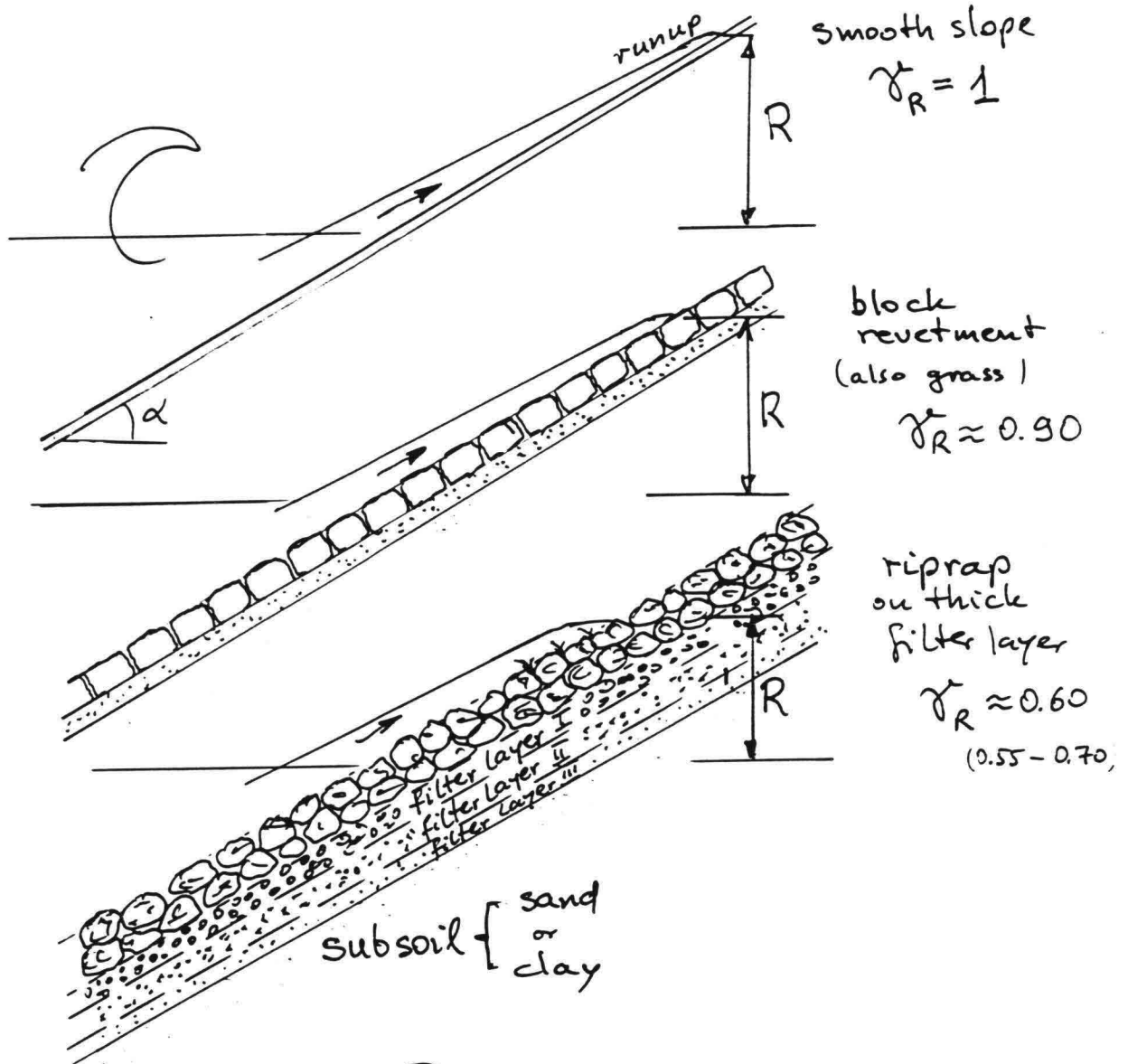
$$R_{us} = \frac{5.25}{1.4} \frac{H_s}{\text{ctg} \alpha} \gamma_\beta = \frac{3.75 H_s}{\text{ctg} \alpha} \cdot \gamma_\beta$$

(sign: 13%)

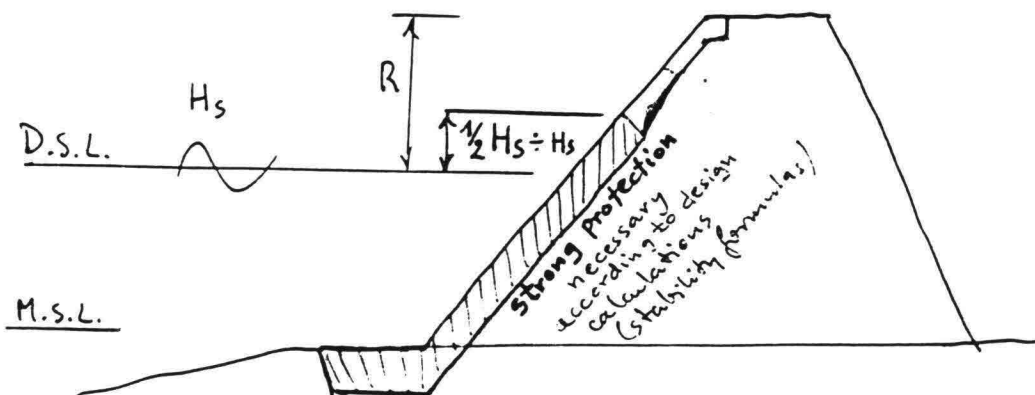
Russian formula

$$R = \frac{3.8 H_s}{\text{ctg} \alpha} (\cos \beta) \gamma_\beta$$

Reduction of wave runup

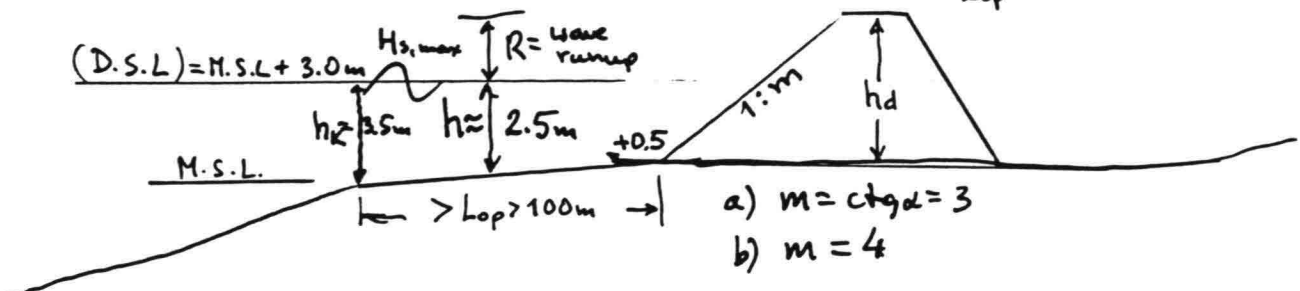


Protection zones



Case study: Foreshore M.S.L. + 0.5m, design waterlevel MSL + 3.0m
 Deepwater waves $H_{0.5} = 5m$, $T_p = 8sec$ (wind 25m/s, fetch 100km)

$L_{op} = 1.56 T_p^2 = 100m$



$H_{s,max} \cong 0.6 \cdot h_k = 0.6 \cdot 2.5 = 1.5m$

$L_s = T \sqrt{g h_k} = 8 \sqrt{9.81 \cdot 3.5} = 46.9m$

$S = \frac{H_{max}}{L_s} = \frac{1.5}{46.9} = 0.032$

- $m=3 \quad \xi = \frac{\tan \alpha}{\sqrt{S}} = \frac{1/3}{\sqrt{0.032}} = 1.86$

- $m=4 \quad \xi = \frac{1/4}{\sqrt{0.032}} = 1.40$

$R_{0.2\%} = 1.5 H_{s,max} \xi$ (smooth slope)

- $m=3 \quad R_0 = 1.5 \cdot 1.5 \cdot 1.86 = 4.18m$ (Dike height: smooth slope $h_d = 2.5 + 4.18 = 6.68m$)

- $m=4 \quad R_0 = 1.5 \cdot 1.5 \cdot 1.40 = 3.15m$ ($h_d = 2.5 + 3.15 = 5.65m$)

Runup with revetment $R_{uz\%} = \tau_r \cdot R_0$

- $m=3 \quad R_1 = 0.9 \cdot 4.18 = 3.76m$ (block revetment)

$R_2 = 0.6 \cdot 4.18 = 2.51m$ (riprap)

- $m=4 \quad R_1 = 0.9 \cdot 3.15 = 2.83m$ (block revetment)

$R_2 = 0.6 \cdot 3.15 = 1.89m$ (riprap)

Dike height: $h_d = h + R$

- for $m=3 \quad h_{d1} = 2.5 + 3.76 = 6.26m$ (MSL + 6.26m) / block

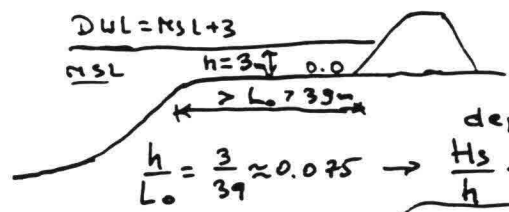
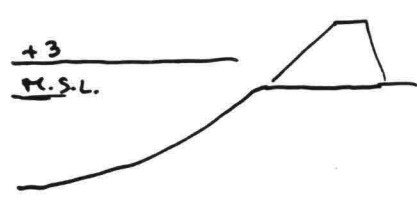
$h_{d2} = 2.5 + 2.51 = 5.01m$ (MSL + 5.51m) / rippap

- for $m=4 \quad h_{d1} = 2.5 + 2.83 = 5.33m$ (MSL + 5.83m) / block

$h_{d2} = 2.5 + 1.89 = 4.39m$ (MSL + 4.89m) / rippap

Fetch 10 km, wind 25 m/s

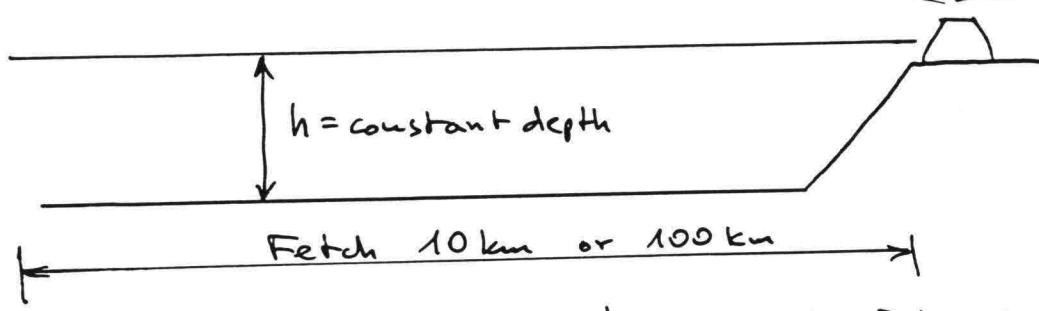
Deepwater conditions: $H_{0s} = 2.0m$, $T_p = 5sec$, $L_0 = 1.56T^2 = 39m$



depth limited

$$\frac{h}{L_0} = \frac{3}{39} \approx 0.075 \rightarrow \frac{H_s}{h} = 0.5$$

$$H_{s,max} = 0.5 \cdot 3 = 1.5m$$



wind $W = 25 m/s$; Fetch 10 km	$W = 25 m/s$; Fetch 100 km
$h = 50m$ $H_s \approx 1.9m$ $T_p \approx 4.9sec$	$h = 50m$ $H_s \approx 4.4m$ $T_p \approx 7.8sec$
20 m 1.7 4.7	20 3.3 6.6
10 m 1.6 4.5	10 2.4 6.4
<u>5 m 1.25 4.2</u>	5 1.4 5.4

x) When, for your given conditions, the local wave height $H_s < H_{s,max}$, use H_s .

Example: Fetch 10 km, $W = 25 m/s$, depth 5m $\Rightarrow H_s = 1.25m, T_p = 4.2sec$



$$L = 1.56T^2 = 20.4m, \xi = \frac{1/3}{\sqrt{1.25/20.4}} = 1.35$$

$$R_0 = 1.5 \cdot 1.25 \cdot 1.35 = 2.53m \text{ (on smooth slope)}$$

$$R_1 = 0.9 \cdot 2.53 = 2.28m \text{ (on block revetment)}$$

$$R_2 = 0.6 \cdot 2.53 = 1.52m \text{ (on riprap)}$$

Design waterlevel MSL+3 m, Foreshore on MSL+0.0.

Dike crest = 3.0 + 2.53 \rightarrow MSL + 5.53 m (smooth slope)

3.0 + 2.28 \rightarrow MSL + 5.28 (block revetment)

3.0 + 1.52 \rightarrow MSL + 4.52 (riprap)

Appendix H: Results case study on calculation of stability of revetments

Stability of armour units (top layer)

Hudson:

$$W_{50} = \frac{1}{K_D} \frac{\rho_s \cdot g H^3}{\Delta^3 \text{ctg} \alpha} = \frac{\gamma_s H^3}{K_D \Delta^3 \text{ctg} \alpha}$$



$$H = H_{10\%}$$

$$K_D = 3.5$$

$$\Delta = \frac{\rho_s - \rho_w}{\rho_w}$$

In linear dimensions, if $D_{n50} = \sqrt[3]{\frac{W_{50}}{\rho_s}} = \sqrt[3]{\frac{M_{50}}{\rho_s}}$

$$\frac{H}{\Delta D_{n50}} = (K_D \text{ctg} \alpha)^{1/3}$$

Van der Meer formula

$$\frac{H_s}{\Delta D_{n50}} = 6.2 P^{0.18} \left(\frac{S_d}{\sqrt{N}}\right)^{0.2} \xi^{-0.5} \quad \text{for plunging waves} \quad \xi \leq 2.5 \text{ to } 3$$

$$\frac{H_s}{\Delta D_{n50}} = 1.0 P^{-0.13} \left(\frac{S_d}{\sqrt{N}}\right)^{0.2} \sqrt{\text{ctg} \alpha} \xi^P \quad \text{for surging waves } (\xi \geq 3)$$

$P = 0.1$ to 0.2 for revetments (riprap on filter layer and practically impermeable subsoil; sand, clay)

$P = 0.4 \rightarrow$ rubble structure with fine coarser core

$P = 0.6 \rightarrow$ rubble structure with homogeneous stone incl. core

$S_d = 2$ to 2.5 for $\text{ctg} \alpha \leq 2$ ($S_d = 4 =$ acceptable damage)

$S_d = 3$ for $\text{ctg} \alpha \geq 3$ ($S_d = 8 =$ acceptable damage)

Riprap and block revetments (formula by Pilarczyk):

$$\frac{H_s}{\Delta D} = \Psi_u \Phi \frac{\cos \alpha}{\xi^b} \quad \xi < 3$$

for $\xi > 3$ use values as calculated for $\xi = 3$

$b = 0.5$ for riprap $\Phi = 2.25$ for rock (as reference)

$b = 2/3$ for block revetments $\Psi_u =$ upgrading factor for other revetments

(for $\text{ctg} \alpha \geq 3 \rightarrow \cos \alpha \approx 1$)

Stability calculations of block revetments

Formula: $\frac{H_s}{\Delta D} = \frac{\varphi}{\xi^{2/3}}$ or $D = \frac{H_s}{\varphi \cdot \Delta} \cdot \xi^{2/3}$; $\xi = \frac{\tan \alpha}{\sqrt{H_s/L_s}} < 3$

D = thickness of block, $\Delta = \frac{\rho_s - \rho_w}{\rho_w} \approx 1.3$ (concrete), φ = stability factor:

$\varphi = 3$ for pitched natural stone, $\varphi = 4 \div 4.5$ for placed blocks,

$\varphi = 5$ for placed blocks on geotextile and good (smooth surface) clay,

$\varphi = 6$ pitched columns (i.e. Basalton) washed in by coarse material / or interlock blocks

$\varphi = 8$ interlocked blocks on properly designed sublayers and subsoil.

Slope $m = \text{ctg} \alpha = 3$

$\text{ctg} \alpha = 4$

1° $H_s = 1.5 \text{ m}$, $T_p = 6.5 \text{ sec}$, $L_p = 1.56 T_p^2 = 66 \text{ m}$

$\xi = \frac{\tan \alpha}{\sqrt{L_p/H_s}} = \frac{1/3}{\sqrt{1.5/66}} = 2.2$

$\xi^{2/3} = 1.69$

+ filter 40 cm (min.)	$\varphi = 3$	D = 0.63 m
	4	0.47
	4.5	0.42
	5	0.38
	6	0.345
	8	0.24

Riprap $D_{n50} = 0.51 \text{ m}$ (min. 0.42 m); 190 ÷ 350 kg

2° $H_s = 1 \text{ m}$, $T_p = 5.8 \text{ sec}$, $L_p = 53.2 \text{ m}$

$\xi = 2.43$

$\xi^{2/3} = 1.81$

+ filter 10 cm (min.)	$\varphi = 3$	D = 0.45 m
	4	0.34 m
	4.5	0.30 m
	5	0.27 m
	6	0.225 m
	8	0.17 m

Riprap $D_{n50} = 0.35 \text{ m}$ (min. 0.30 m)
65 ÷ 120 kg

Select heavier stones for zone up to $MSL + \frac{1}{2} H_s = MSL + 0.5$ and lower

$\xi = \frac{1/4}{\sqrt{1.5/66}} = 1.66$

$\xi^{2/3} = 1.40$

+ filter 30 cm (min.)	$\varphi = 3$	D = 0.525 m	pitched natural stone
	4	0.39	} placed blocks
	4.5	0.35	
	5	0.31	} blocks on clay/ge.
	6	0.26	
8	0.20		

Riprap $D_{n50} = 0.44 \text{ m}$ (min. 0.36 m)
120 ÷ 220 kg

$\xi = 1.82$

$\xi^{2/3} = 1.49$

+ filter 5 cm (min.) (ev. no filter if geotextile) and proper compaction	$\varphi = 3$	D = 0.37 m	pitched natural stone
	4	0.28 m	placed blocks
	4.5	0.25 m	placed blocks proper design sub.
	5	0.22 m	block on geotex. and good clay
	6	0.185 m	washed in prisms interlocked block
	8	0.14 m	interlocked block proper filter/foundation

Riprap $D_{n50} = 0.30 \text{ m}$ (min. 0.25)
40 - 80 kg



Required total thickness of revetment
 = Toplayer + filter-layer

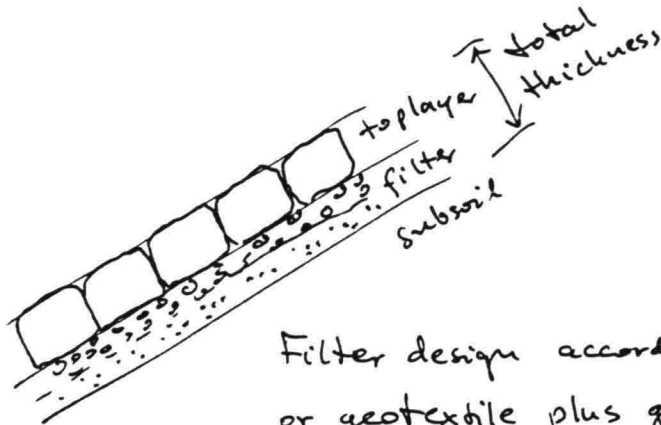
to avoid migration of sandy subsoil

Blocks on sand

ctgd = 3	$H_s = 1.8m$	1.5m	1.25m	1.0m
	1.2m	0.9m	0.65	0.40
ctgd = 4	1.0m	0.7m	0.40	0.20

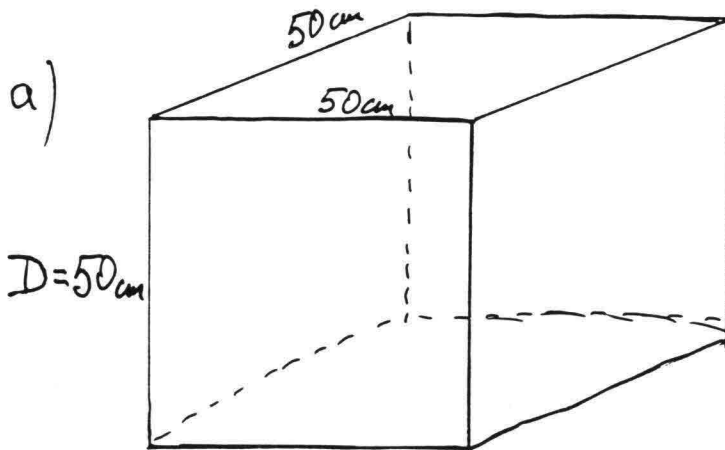
Blocks/interlock blocks on clay

ctgd = 3	0.65m	0.55	0.45	0.35
ctgd = 4	0.55m	0.45	0.35	0.30



Filter design according to filter rules
 or geotextile plus granular layer

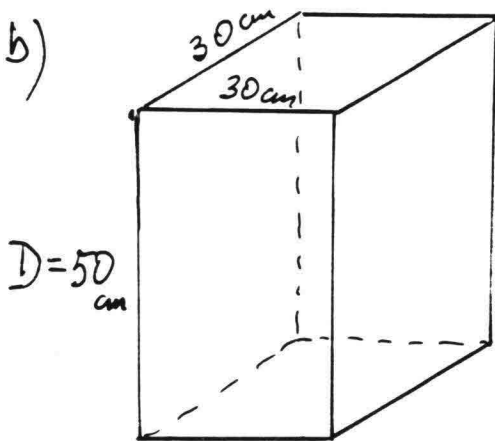
a)



$$G = \frac{1}{8} \text{ m}^3 \cdot 24 \text{ T/m}^3$$

$$= \underline{\underline{300 \text{ kG}}}$$

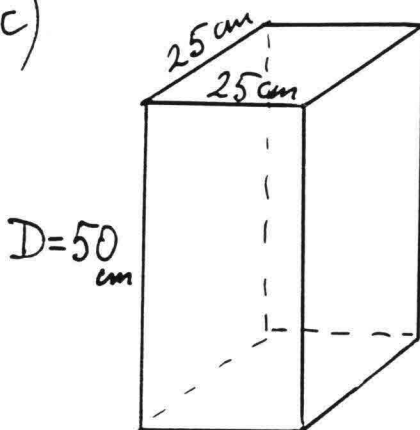
b)



$$0.3 \cdot 0.3 \cdot 0.5 \cdot 2400 =$$

$$0.045 \cdot 2400 = \underline{\underline{108 \text{ kG}}}$$

c)



$$0.25 \cdot 0.25 \cdot 0.50 \cdot 2400 =$$

$$0.03125 \cdot 2400 = \underline{\underline{75 \text{ kG}}}$$

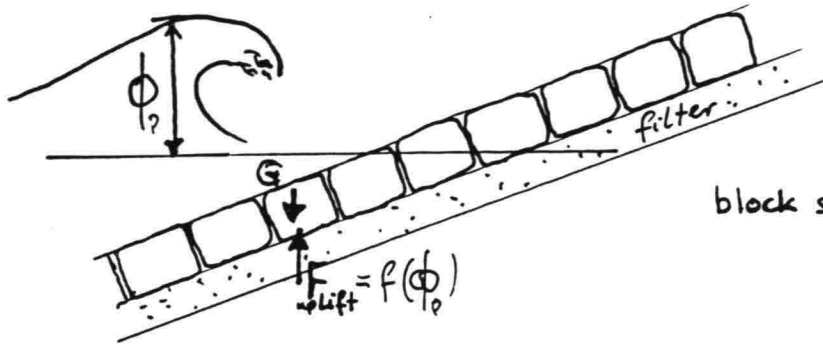
a), b), c) = equal stability
(100%)

$$0.25 \cdot 0.25 \cdot \overset{D}{0.40} \cdot 2400 = 60 \text{ kG} \quad (80\%)$$

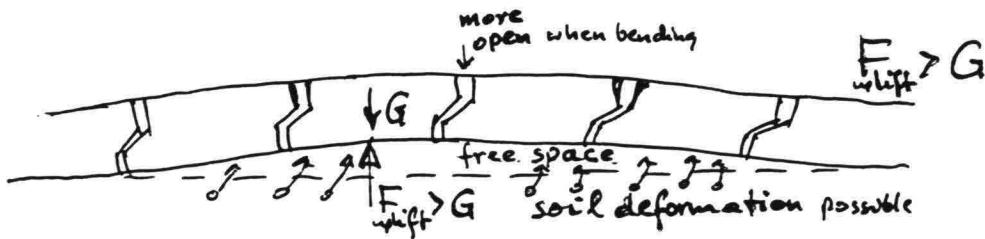
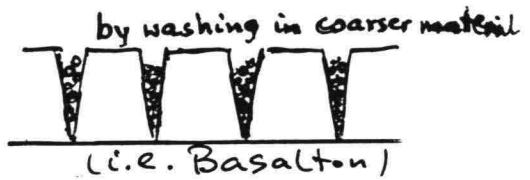
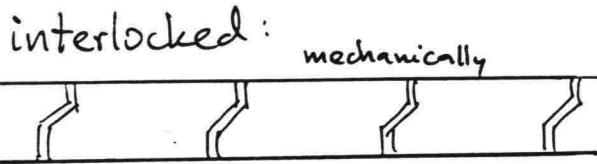
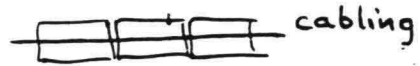
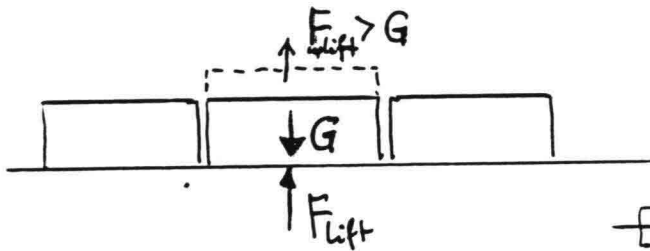
$$0.25 \cdot 0.25 \cdot \underline{0.30} \cdot 2400 = 45 \text{ kG} \quad (60\%)$$

Calculate thickness D and not weight G! ▽

Interlocked systems (increase stability by factor 1.5 to 2 when properly designed)

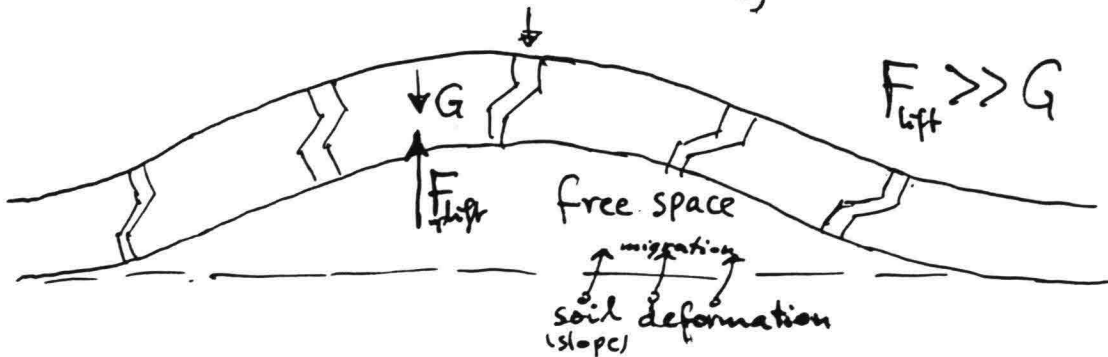


block stable $G > F_{lift}$



when high bending

no interlocking



N.B. small scale investigation → no reproduction of influence of subsoil

Appendix I: Pictures



Picture I.1 Start of W.F.P. project Nr. 5325 in Quang Ninh Province



Picture I.2 Sacral and historical values



Picture I.3 Excavation close to the inner toe of the dike



Picture I.4 *Damage of concrete grouted stones revetment in Hai Hau District*



Picture I.5 *Damage on stone revetment in Hai Hau District*



Picture I.6 Dike with low crest height in Hai Phong Province



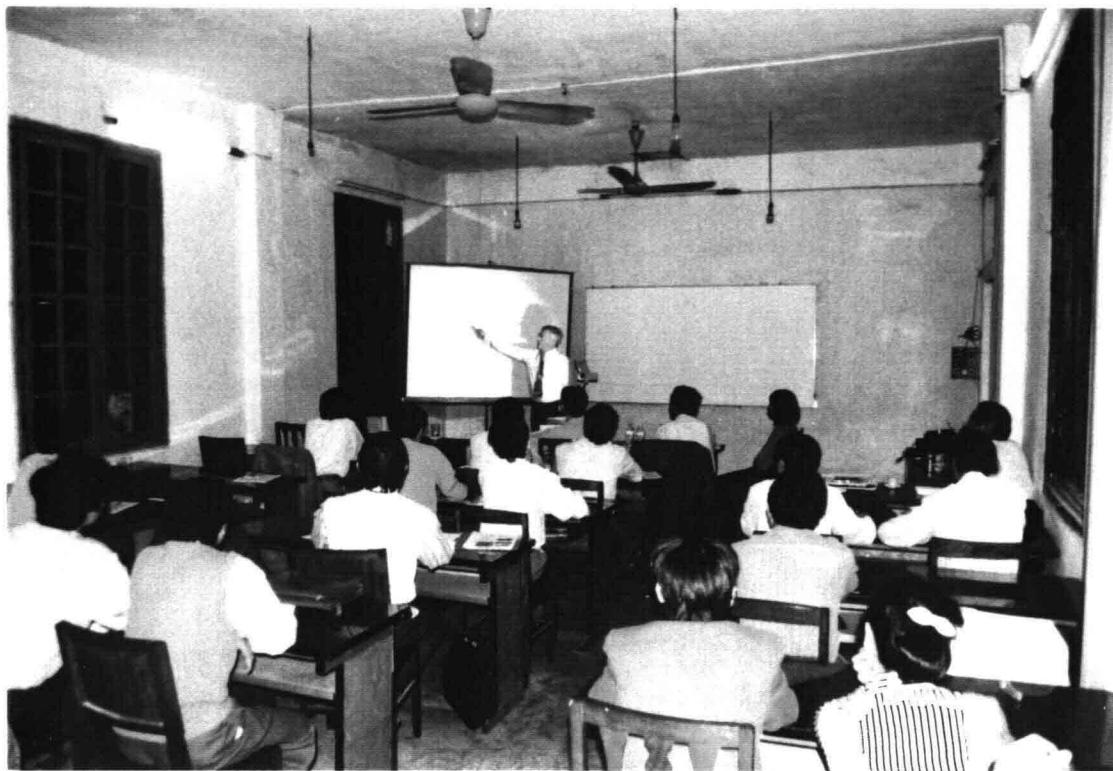
Picture I.7 Damage of concrete grouted stones revetment in Hai Phong Province



Picture I.8 Mangroves in front of the dike



Picture I.9 Dike under construction in Yen Hung District



Picture I.10 Seminar by the Dutch mission



Picture I.11 Hand over of design guidelines

Appendix J: Names and addresses

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