Environmental management for the Great Belt

Environmental Management for the Great Belt
Gestion de l'environnement pour le projet du Great Belt
Umweltmanagement für den Grossen Belt

Knud Mose POULSEN
Civil Eng.
A/S Storebæltsforbindelsen
Copenhagen, Denmark

Knud Mose Poulsen, born in 1945, received his MSc at the Technical Univ. of Denmark. For 12 years he worked for consulting firms in the fields of pollution and hydraulics. Presently, he is Project Manager for the Environment at A/S Storebæltsforbindelsen.

Jan DIETRICH
MSc, Civil Eng.
Water Consult
Glumsø, Denmark

Jan Dietrich, born 1946, received his civil engineering degree at the Technical Univ. of Denmark. For 13 years he was a research engineer at the Danish Hydraulic Institute. He is now Managing Director for a consulting firm dealing with environmental issues in the Marine Environment.

SUMMARY

The Act of the Danish Parliament for the construction of the fixed link across the Great Belt determines that the link be constructed in sush a way that the water flow through the Belt to the Baltic Sea is unaffected by the presence of the Link. This environmental design requirement is called the "Zero Solution".A conditional hypothetical concept is introduced, meaning that if a hypothesis is confirmed, additional survey is triggered off. The Feedback Programme describes the procedure to be followed when predetermined levels of the impact of the local environment are exceeded. The paper describes the management and organization of the environmental programmes.

Gestion de l'environnement pour le projet du Great Belt

Résumé

L'acte du Parlement danois pour la construction d'une liaison fixe sur le Great Belt précise que la liaison doit être construite de sorte que les courants marins à travers le détroit jusqu'à la Mer Baltique ne soient pas modifiés. Cette condition pour l'environnement est appelée la "solution zéro". Un concept de conditions hypothétiques est introduit, précisant que si une hypothèse est confirmée des études supplémentaires doivent être déclenchées. Un programme itératif nouveau décrit la procédure à suivre lorsque des niveaux prédéterminés de l'influence sur l'environnement local sont dépassés. L'article décrit la gestion et l'organisation de ces programmes d'environnement.

Umweltmanagement für den Grossen Belt

Zusammenfassung

Der dänische Parlamentsbeschluss über den Bau einer festen Verbindung über den Grossen Belt verlangt, dass die Strömungsverhältnisse durch den Belt in die Ostsee durch die Verbindung nicht beeinträchtigt werde. Diese ökologische Entwurfsbedingung wird die "Null-Effekt-Lösung" genannt. Ein Konzept hypothetischer Bedingungen wurde eingeführt, bei dem das Eintreffen einer Modellannahme automatisch weitere Untersuchungen auslöst. Ein Feedback-Programm gibt Handlungsanweisungen für den Fall, dass die Umweltauswirkungen festgelegte Schwellenwerte überschreiten. Der Artikel beschreibt das Management und die Organisation dieser Umweltprogrammme.

1. INTRODUCTION

A Master Plan for the protection of the environment around the Great Belt Link is being implemented.

The Master Plan comprehends all studies and investigations which A/S Storebæltsforbindelsen has already initiated or intends to carry out in order to protect the environment. The Plan was set off with initial studies in 1987-88 of the Zero Solution Concept for the Baltic Sea and the impact on the near field environment on which the approval in October 1988 of the overall design of the fixed link was based. It will be concluded with the final environmental documentation in 1997.

The Master Plan was designed on the basis of two overall environmental criteria and on an overall environmental link optimization made by the Danish Government in 1987/88.

2. OVERALL DESIGN CRITERIA

The overall environmental design criteria set up by the Government was divided into:

- The Zero Solution Concept for the Baltic (far-field).
- Minimization of the impact on the local environment.

The Zero Solution Design Concept is described in § 5 of the Act of Parliament of 26 May 1987 (Law No. 380) concerning the link across the Great Belt, which reads as follows:

> "*The two stages of the work are to be carried out separately in such a way that the water flow through the Great Belt shall remain unchanged after the completion of the work for the sake of the marine environment in the Baltic.*"

3. LINK DESIGN - ENVIRONMENTAL OPTIMIZATION

The preliminary purely economic optimization of the link design resulted in a combined bridge - ramp - tunnel layout as shown in Figure 1.

This layout involved large marine earth works for construction of ramps and the execution of the necessary extensive compensatory dredging. As the major impact on the environment originates from the spillage of sediments and nutrients during the handling of earth volumes, the following projects were decided upon during the "environmental optimization", see Figure 1.

- The size of Sprogø island and the length of the ramps were reduced considerably.

- The ramp at Halsskov was removed.
- The bridge piers and anchor blocks were hydraulically shaped.

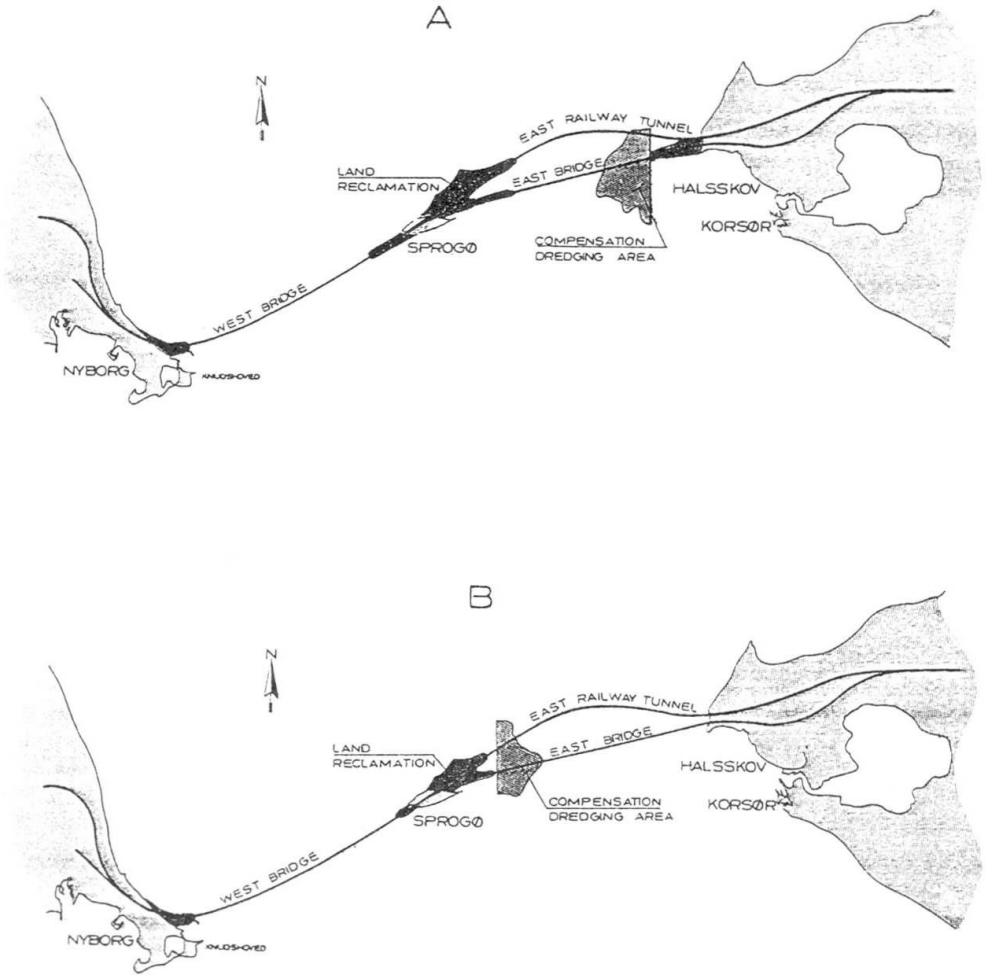


Figure 1 **A: Economically optimized link design**
B: Environmentally optimized link design

It became apparent that this link design had a very small blocking effect against the flow to the Baltic, in the order of .5%.

In order to further reduce the spillage to the Great Belt, it was decided to deposit all excavated marine material, that contained more than 5% organic matter, in special sedimentation basins at Sprogø, see Figure 2.

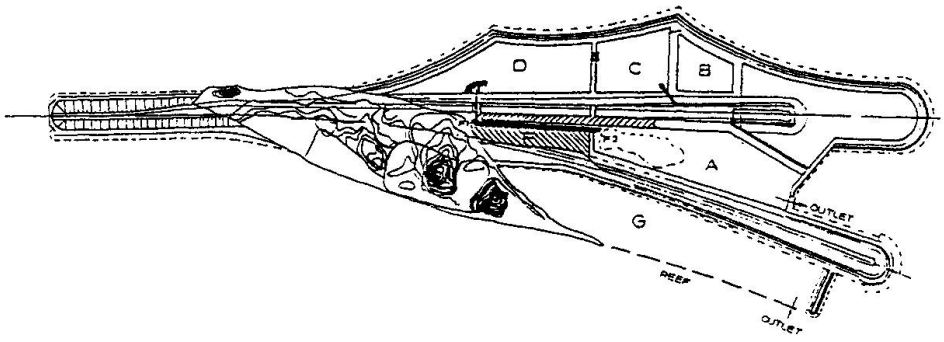


Figure 2 Sedimentation basins at Sprogø

Finally, it was decided that the loss of material from the sedimentation basins and from the reclamation at Sprogø should be less than 3% and at Knudshoved should be less than 5%.

The environmental benefits of the optimization were thus:

- Considerable reduction of the absolute uncertainties on the achievement of the Zero Solution.
- 50% reduction of the total spillage of sediment and nutrient to the Great Belt from the reduced amount of marine earth works and the inclusion of sedimentation basins.
- Particularly, a considerable reduction of the spillage at the reefs of Sprogø and Halsskov.

The costs of the environmental minimization were estimated at: DKK .5 billion for the compensatory dredging, DKK .15 billion for the execution of the environmental Monitoring Programme, and DKK 1 billion for the changes of the overall The total cost of these benefits were thus estimated at DKK 1.65 billion, corresponding to nearly 10% of the total link construction budget.

4. THE ZERO SOLUTION

The legal design requirements were technically interpreted into the following requirements to the link:

- The water flow through the Great Belt must not be changed by the link.
- The salt balance in the Baltic Sea must not be changed by the link.

Hereby the environmental design requirements for the far field were reformulated into a purely hydraulic requirements.

The technical hydraulic requirements to the link involve:

- that the hydraulic flow resistance in the Great Belt be unchanged.

- that the mixing between the surface layer and the bottom layer in the Great Belt be unchanged.
- that the frequency of the supercritical two-layer flow be unchanged.

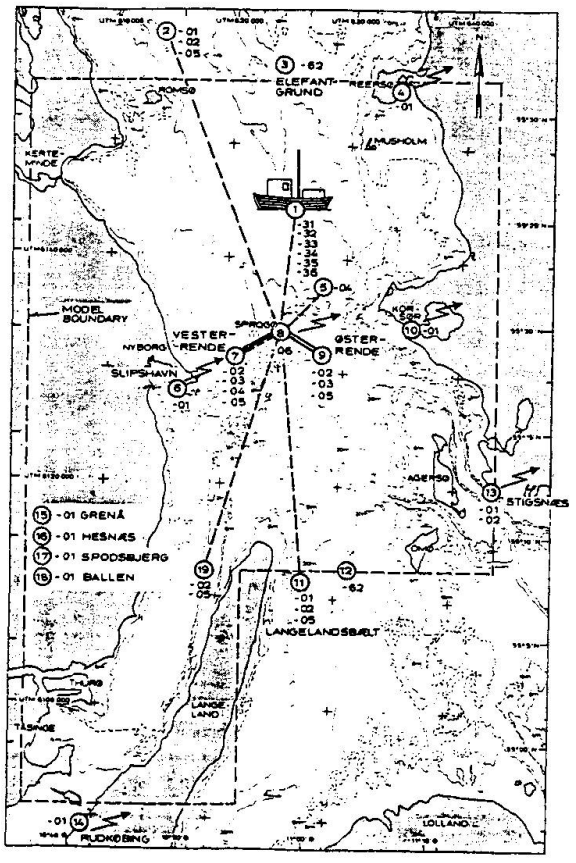
The hydraulic design criteria is met by compensating for the blocking of the flow by the bridge piers and the ramps with a corresponding enlargement of the flow cross section.

The compensatory dredging is carried out at Sprogø East Reef and comprises the excavation of a total amount of 6 - 8 million m^3 sand, stone and moraine clay, see Figure 1.

An advanced, mathematical two-layer hydraulic model was developed for the calculation of the extent and amount of dredging.

A series of physical model tests were performed in order to improve the capability of the model to reproduce the various hydraulic features in the Great Belt and blocking effects of the various link elements.

The model was calibrated and verified against a comprehensive hydraulic monitoring programme, see Figure 3.



STATIONS

SBF-01 Vessel
SBF-02 Romsø Tue Fyr
SBF-03 Elefantgrund N
SBF-04 Reersø
SBF-05 Sprogø NE
SBF-06 Slipshavn
SBF-07 Vesterrenden
SBF-08 Sprogø
SBF-09 Østerrenden
SBF-10 Korsør
SBF-11 Langelandsbælt N
SBF-12 Omø NSW
SBF-13 Stigsnæs
SBF-14 Rudkøbing
FRV-15 Grenå
FRV-16 Hesnæs
FRV-17 Spodsbjerg
FRV-18 Ballen
SBF-19 Langelandssund

INSTRUMENTS

Stationary:

-01 WLR, water level
-02 AIR, interface level
-03 ADCP, current profile
-04 WR, waves
-05 TC, temp., cond., O_2 turb.
-06 MET, meteorology
-62 AIR, interface, recording

Vessel:

-31 ADCP, current profile
-32 AIR, interface level
-33 CTD, stratification
-34 ES, echo sounder
-35 SYLEDIS, position
-36 EMCP, current profiler
-37 VARIOSENS, flourometer

COMMUNICATION

Cable link
Radio link
Public tele link

Figure 3 Hydraulic Monitoring Programme

The design of the compensatory dredging takes place during the execution of the actual dredging operations. The predicted hydraulic effects of the excavation are verified against field data from the area. If required, the model will be adjusted and the dredging amounts consequently revised. This process will be repeated immediately before completion of the entire dredging operation and final design will be performed.

5. NEAR FIELD

It appears that the Zero Solution Design Concept only deals with the far field. The environmental effects cannot be completely avoided during construction and by the permanent link. In the near field the bridge abutments, tunnel construction works, causeway and artificial island will create certain disturbances in the environment compared to the situation today.

In order to meet the design criteria of "minimizing" the impact on the near field, a comprehensive monitoring of a series of physical and biological variables are performed throughout the entire construction period.

Four concepts were developed and formed the basis for the outline of the Monitoring Programme:

- Conditional Hypothetical Concept
- Feed Back Concept
- Contingency Concept
- Sediment Source and Spreading Concept

Conditional Hypothetical Concept

The key biological variables which are included in this concept were selected on the basis that they are significant ecological components of the Great Belt marine ecosystems and that the effects of the construction activities can be quantified reliably.

The key biological variables are:

- Eelgrass: north of Sprogø, at Vresen and at Halsskov
- Kelp: south of Sprogø and north of Sprogø
- Mussels: around Sprogø, at Vresen, and at Halsskov
- Soft bottom fauna.

A number of hypotheses was formulated on the basis of expected responses. Some of these are conditional, and will only be investigated if a significant effect is found in the first hypothesis.

Hypothesis 1: That due to increased sedimentation (and thereby reduced light) reductions in growth of eelgrass (Zostera marina) and kelp (Laminaria spp.) will occur.

Hypothesis 2: (conditional)	That reduced growth may lead to reduced areas of eelgrass and kelp beds.
Hypothesis 3:	That increased sedimentation will lead to reduced growth rates of mussels (Mytilus edulis).
Hypothesis 4: (conditional)	That reductions in growth rate lead to reduced areas of mussel beds around Sprogø.
Hypothesis 5:	That due to increased sedimentation and/or reduced oxygen concentration, changes in species composition of the soft bottom communities will occur.
Hypothesis 6: (conditional)	That due to increased nutrient discharge there will be an increased growth of epiphytes on eelgrass (Zostera marina).

A large-scale monitoring of the involved variables was designed with the objective of confirming or rejecting the established hypotheses.

If the hyphoteses are confirmed, the Monitoring Programme is to be extended and construction methods more favourable to the environment should be adopted.

Feed Back Concept

Biological monitoring with feed back possibilities is a totally new concept. The basic idea is that unacceptable changes in the environment caused by construction activities can be defined in terms of biological variables, and that exceeding of the prefixed limit should lead to changes in the construction activities which mitigate the adverse effect.

Three biological events have been chosen as important elements for the feed back monitoring:

- Wintering eider ducks
- Spring spawning herring
- Phytoplankton blooms

These variables were chosen for the reason that they may be affected by the construction activities at distances beyond the near field area.

The prefixed limits and the possible feed back actions were discussed with the authorities and the monitoring programme outlined for each of the variables.

If the prefixed limits are exceeded, alternative construction methods should be analyzed with respect to:

- reducing the spillage
- reducing the disturbances of the environment
- reducing impact during the sensitive seasons of the environment

Contingency Concept

Particular attention was put on the development of oxygen depletion and the development of a sudden algae bloom from the activities in the Great Belt.

A special Contingency Programme has been set up to follow the risk of occurrence of such events.

A weekly routine profiling of the oxygen contents and the flourescens were performed in the Eastern Channel in the period 01 May - 31 September 1990. If the oxygen content fell below 4 mg/l or the content of flourescens exceeded 10 mg/l, the Programme would be extended to cover a larger area and to include a number of water samples.

The authorities were to be notified if the oxygen content came below 4 mg/l or if a toxic algae bloom developed in the Great Belt.

If the oxygen depletion and the algae bloom were caused by the activities of the Great Belt company, steps should be taken to reduce spillage from on-going operations.

Sediment Source and Spreading Concept

As previously mentioned, the major impact on the local environment originates from the spillage of sediments and nutrients during the execution of the compensatory dredging, the sand winning in the Great Belt, and the reclamation works.

The objective of this concept is to evaluate the actual physical and chemical conditions affecting the flora and fauna.

This concept comprehends the follow main variables:

- Source Emission Monitoring
- Plume Emission Monitoring
- Plume Modelling
- Data base for all earth volumes handled during the construction phase

The spillage is measured for all marine earth work operations contributing significantly to the total spill budget in the Great Belt.

The major plumes are traced with respect to:

- Sediment content
- Nutrients
- Oxygen
- Phytoplankton

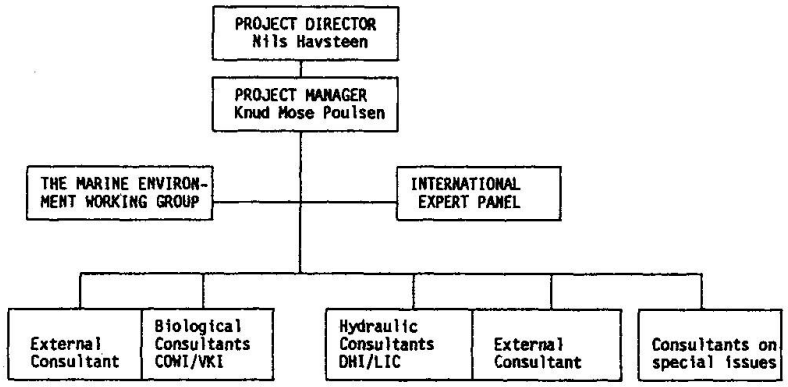
The plume model is calibrated on the basis of the plume tracing.

The results of the modelling are used for the interpretation of the results of the monitoring of the biological variables and the subsequent assessment of the impact on the local environment.

The plume modelling also contributes to the detailed planning of the monitoring of the biological variables.

6. MANAGEMENT

The organization set up for the implementation of the Environmental Master Plan is as follows:



COWI/VKI: COWIconsult and Water Quality Institute Joint Venture
DHI/LIC: Danish Hydraulic Institute and LIC Engineering Joint Venture

The open door policy is the guideline for the organization and management of the Environmental Master Plan.

The contact with the environmental authorities is coordinated through a working group "The Marine Environment". All relevant local and central authorities are represented in the working group.

The planning, execution and results of all the environmental studies and investigations are discussed in the working group on a current basis.

In order to ensure a high technical and scientific level of the Master Plan, an International Expert Panel composed of ten internationally esteemed scientists was appointed. The expert panel follows the implementation of the Master Plan and reviews the results of all the main activities of the plan at an annual review session.

The implementation of the Master Plan is carried out by two consultant groups, COWI/VKI Joint Venture and DHI/LIC Joint Venture.

The consultant groups carry out the biological and hydraulic investigations with the assistance of two internationally esteemed experts (External Consultants) Professor Flemming Bo Pedersen, The Technical University of Denmark, and Professor John S. Gray, Oslo University.

Leere Seite
Blank page
Page vide