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NORWEGIAN INSTITUTE FOR WATER RESEARCH

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BIOLOGICAL AND CHEMICAL INVESTIGATIONS AT
THE ISLAND SOTRA IN HORDALAND COUNTY, NORWAY

Oslo, May 23rd 1977

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PREFACE

Norwegian Institute for Water Research (NIVA) has prepared the present programme on the commission of Den norske stats oljeselskap (Statoil). The directives were stated at a meeting at NIVA March 29th 1977.

The main purpose of the programme is to outline the necessary biological and chemical baseline investigations at sites, expected to be influenced by oil activities, at the island of Sotra.

Oslo, May 23rd 1977

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1. INTRODUCTION

1.1 Presentation of the Institute

The Norwegian Institute for Water Research (Norsk institutt for vannforskning, NIVA) is a semi-governmental independent research institute.

NIVA was founded in 1958 by NTNf, The Royal Norwegian Council for Scientific and Industrial Research and operates as one of 15 such institutes.

According to the statutes the purpose of NIVA's activities are:

The institute's operations deal with all aspects of water quality.

Included are the water supplies for domestic, agricultural and industrial use, the transport, treatment and discharge of polluted water and the water quality of ground waters, rivers, lakes, estuaries, fjords and coastal waters in connection with discharge of pollutants or any other activity which affects water quality.

With this frame the institute's mandate is to:

1. Conduct research, development and investigations. Special attention shall be given to factors that appear important for a purposeful exploitation of Norway's water resources. Research activities should have a long-term perspective and be of interdisciplinary nature.
2. On a contract basis conduct research, investigations and advisory services for central and local governmental authorities, for industry and others.
3. Collect and distribute information to water users, planners, governmental authorities and others such that new results and developments both domestic and foreign can be useful applied in practice to insure management of water resources.
4. Contribute to its employees' development so that they can function within and outside of the institute to the best of their abilities.

The activities of the institute cover all types of fresh waters, estuaries, fjords and nearshore coastal waters. All aspects of water pollution are dealt with at NIVA as well as problems related to treatment, disposal and purification of waste water. In addition to its research activities the institute conducts repayment work sponsored by public agencies.

The institute cooperates closely with the Ministry of the Environment and other governmental bodies, as well as with domestic research institutions and universities.

NIVA cooperates with similar institutes in other countries, directly or through international organisations.

The total staff of NIVA is at present (May 1977) approx. 150, of which approx. 50 are research scientists.

The institute is governed by a board of five members appointed by the NTNF Council, representing municipalities, industry, universities, water authorities and health authorities.

Director of the institute from its foundation till today's date is chem.eng. KJELL BAALSRUD.

The institute includes sections for:

- Freshwater Investigations
- Fjord and Coastal Water Investigations
- Industrial Water Problems
- Water Technology Development
- Ecology
- Chemical and Biological Analysis
- Data Processing and System Analysis

NIVA has an experimental research station at Kjeller, approx. 25 kms N.E. of Oslo, for studies on sewage treatment. A small marine experimental station is some 30 kms south of Oslo. At Hamar, NIVA operates a laboratory and field station for investigations of the problems represented by pollution of lake Mjösa.

For studies of the effects of acid precipitation on forests and freshwater fish, the institute has field stations at several locations in southern Norway.

The operating costs of the Institute are covered in part (approx. 35%) by a general grant from the Ministry of the Environment and the remaining by repayment work on a non-profit basis.

NIVA issues a yearly report in Norwegian on the main research activities, problems and experiences during the preceding year and also a monthly and modest news bulletin in Norwegian. Results of research projects and consultant jobs are presented in written reports. The library, regularly issues lists of publications.

1.2 Aims of the project

The main purposes of the project are as follows:

1. To establish a base-line with respect to water chemistry, sediment geochemistry and marine biological conditions within specified areas at the island Sotra.
2. To observe present day levels of hydrocarbons and other chemical constituents, together with descriptions of the structure of shore and shallow water communities. These informations will serve as reference data in relation to future monitoring of the area.

1.3 Further investigations

To ensure that the results of the biological monitoring are representative and to establish reliable baseline data, it is recommended that the investigations are carried out for two consecutive years. This is to neutralize the natural variations from year to year and to avoid the risk of meeting with exceptional conditions (see Syratt and Cowell 1975).

In case of withdrawal of one or more of the landing site alternatives before end of the field work, the number of stations can be reduced accordingly.

2. INVESTIGATION PROGRAMME

2.1 Preliminary work and planning

The institute has general experience of biological and chemical monitoring. To resolve specific problems related to oil transference and oil terminals, it should be valuable to consult international specialists.

Hence, the proposition is made to visit an well established oil-terminal like Milford Haven in South Wales and a terminal under construction in

Sullom Voe, Shetland, to have discussions with the researchers as well as the authorities. These visits will be supported by studies of relevant literature. The study-trip is suggested to September or October this year.

Monitoring of the communities of the rocky shores by the transect method has been carried out for several years in the vicinity of the Rafinor refinery at Mongstad by an English research group.

This year the observations were conducted between 29th April and 10th May. As part of the planning of the Sotra investigation we took the opportunity to contact the group and participated in its fieldwork on the way to Sotra to check on shoreline conditions.

Included in the preliminary work is a registration of already existing discharge of waste in the investigation area.

2.2 Water chemistry

The prime objective of the water chemistry programme is to establish background levels of hydrocarbons in the water, i.e. naturally occurring hydrocarbons (lipids) and the existing contamination level. In addition to quantification of total hydrocarbon content it is important to characterize the various components.

It is assumed that the impact of the oil activities on the waters surrounding Sotra will be mainly local. Particular attention is paid to the water quality in the immediate vicinity of the tanker-terminal at Vindenes. It should be pointed out that the Vindenes Poll is especially vulnerable due to a shallow threshold and restricted water circulation.

The area of investigation includes the terminal at Vindenes and four alternative landing sites for the pipelines along the west coast of Sotra (fig.1). At each landing site two waterstations are planned, one on each side of the site where the pipeline emerges. It is assumed that any oil spillage here would be in a small scale. Hence, the water stations are

located only 1 km apart. At the terminal site 10 water stations are desirable; 3 stations in the Vindenes poll, 2 at Misjeosen and 5 between Vindeneskvarven and Kalvaneset lighthouse, including a profile towards Hanøy, see fig. 1.

Water is sampled in the upper few cms of the surface layer and near a possible density-boundary. The sampling must be repeated a minimum of four times during one year, to investigate the natural fluctuations of the content of hydrocarbons related to biological production, freshwater runoff etc.

The water samples will be analysed for hydrocarbons (including characterisation), total organic carbon and salinity, temperature and oxygen. Water samples in the Vindenes poll will also be analysed for nutrients.

2.3 Sediment chemistry

The sediments play an important role in the aquatic environment for two main reasons:

1. The sediment acts as a substrate for bottom living organisms.
2. The sediment may be a reservoir for pollutants.

Certain fractions of the hydrocarbons accumulate in the sediments, where a further degradation may take place. The composition of the sediments will indicate environmental changes during a certain period of time, which makes sediment studies suitable in monitoring work.

To register the overall effect by the civilizatoric impact on the waters surrounding Sotra it may be advisable to analyse the sediment samples for heavy metals as well as hydrocarbons. The metals concerned are particularly lead, copper, mercury, cadmium and nickel.

It is recommended that sediments are sampled at the same sites as the water is collected, using gravity corer. At each of the alternative landing sites one sediment core is sampled (only surface samples, 0-2 cm).

At the terminal site five sediment stations are recommended. Two of these cores (one from the Vindenes Poll and one outside) are analysed from deeper sections of the core, allowing a complete characterization of the hydrocarbons present in the sediments. All the sediment samples will be analysed for total organic carbon.

The sampling will only be necessary at one occasion prior to the operation of the oil terminal at Sotra. The sampling should be repeated every fifth year.

2.4 Biological investigations

The aims of the biological monitoring are:

1. Prior to petroleum activities at Sotra.

To establish the structure of the biological communities, their composition and condition.

To describe the extent of ecological fluctuations due to natural factors.

To analyse various organisms for hydrocarbons and phenols.

All together these data will constitute a baseline for further monitoring.

2. After starting of the oil-terminal operations.

Detect possible ecological effects from oil-terminal activities.

If detrimental effects are observed, an assessment of the area influence should be made.

To state if the area of influence is increasing, decreasing or remaining static.

2.4.1 Monitoring of the biological communities of the rocky shore

The biology of the area is characterized by rocky shore communities with a marked littoral zonation of organism.

The extreme spring tidal range of approximately 1.8 m is critical in relation to the transportation and deposition of any oily wastes from effluents or from spillage during tanker loading operations. Some parts of the Sotra shoreline are exposed to quite heavy wave action at certain times of the year. For this reason the "splash zone" is frequently extended vertically several meter above extreme high water springs. Hence, it is necessary to extend the monitoring to top of this zone, which may be the upper limit of oil and effluent influences that could occur during heavy wave conditions.

Shore surveys (transects studies), recording the vertical distribution and abundance of 30-40 common littoral species, will be carried out at about 15 stations. The same stations will be visited once a year during the whole monitoring period. It is therefore important to select the stations in sites which are not destroyed or disturbed during the construction period.

Reference stations will be established in sheltered and wave exposed localities some distance away from Vindenes and on the west coast of Sotra. These reference stations are important for the assessment of any changes occurring as the result of extreme weather conditions (i.e. severe winters, hot summers, heavy storms or any other natural phenomena).

At each station a belt transect will be investigated from extreme low water spring to the top of the "splash-zone". The transect will be divided into strips separated vertically by approximately one tenth of the tidal range, modified after Moyse and Nelson-Smith (1963), Crapp (1971) and Syrratt and Cowell (1975).

The best working period for this type of monitoring is the period having the longest consecutive run of low tides approaching chart datum and coinciding with the commencement of the active growing season (Syrratt and Cowell 1975). This usually occurs in May in the Bergen district. It is therefore recommended that the baseline transect work is conducted in May

1977 and 1978. In 1977 it is recommended to start this part of the programme 30th May.

To establish further reference data 20 samples of organisms at different biological stations will be analysed three times a year for petroleum hydrocarbons (total and characterized) and phenols.

2.4.2 Remote sensing of the benthic algal vegetation

Remote sensing will give information on occurrence and distribution of dominant species and communities of the benthic algal vegetation. This is to be used as background material in the event of future pollution of the waters surrounding the island which may cause a change in the biota.

Remote sensing gives the possibility of surveying large areas synoptically at relatively low costs. The use of infra-red false-colour film (IR-film) makes it possible, when combined with ground truths, to identify and classify dominant algal species. The film records are filed for future reference following a brief analysis to compare the signatures on the film with ground truths.

The area of study is approximately 19 km long and 4-5 km in width. Stereo records of this area will be made in 1:20 000 and 1:5 000 scale.

2.4.3 Examination of hard-bottom biological communities by stereo-photography

One purpose of this part of the work is to obtain data on the sublittoral communities of sessile organisms down to 30-35 m depth at several localities in order to assess the quality and vulnerability of the different areas from the biological point of view.

A second purpose is to establish reference data as a basis for documentation of possible future damage to the biological communities.

The stereo-photographic method is mainly used for obtaining records of fixed test areas. In this way well defined areas can be photographed at intervals without interfering with the organisms. The method is thus especially suitable for observing long term changes. A description of the method is given by Lundälv (1971), see Appendix.

The technique developed at NIVA is a modification of the Lundälv method, the main difference being a synchronized double camera instead of a single one. This allows use of the system independently of fixed positions, which is preferable in the initial survey of an area. In phase 1 the "free" survey technique will be used. In phase 2 permanently marked positions on hard bottoms will be photographed.

Phase 1: Hard bottoms down to 30-35 m depth should be examined at 2 stations near each of the 4 proposed landing sites on the west coast of Sotra. In the area surrounding the location of the terminal at Vindenes, investigations should be made by survey of 4 stations.

Phase 2: This phase includes establishment of reference data on hard-bottom communities at 7 fixed stations (3 on the west coast of Sotra and 4 in the Vindenes area). Permanently marked strips of 0.5x3 m at 5, 10, 15, 20 and 30 m depth will be photographed twice during one year preceding the start of the petroleum activities.

3. COOPERATION WITH OTHER LABORATORIES

Petroleum hydrocarbons analysis will be carried out at the Central Institute for Industrial Research (SI) in Oslo. The methods used are described below.

Petroleum hydrocarbons consist of several types of chemical substances that are often difficult to separate analytically. Presently, selected aliphatic and aromatic constituents are most frequently encountered in environmental studies, and, in the present proposal, these types of hydrocarbons have

been included. More precisely, the alkane pattern will be determined by high resolution gas liquid chromatography (GLC), and the content of aromatic hydrocarbons will be analysed by either GLC, coupled gas liquid chromatography-mass spectrometry (GLC-MS), high performance liquid chromatography (HPLC) or fluorescence spectrophotometry. Before the actual quantification by an appropriate instrumental method, one or more steps of isolation, purification or separation is usually necessary.

The samples are extracted and the content of hydrocarbons are determined according to methods mentioned above. Some samples are characterized for aliphatic as well as aromatic individual constituents (method 1), while the rest of the samples are analysed for the content of individual aliphatics by GLC and the sum of aromatics by either HPLC or fluorescence spectrophotometry (method 2).

Cost per analysis are for water, sediment and organism samples respectively: N. kr. 600,- (method 2), and N. kr. 1 000,- (method 1), 1 000,- and 1 500,- 2 000,- and 3 000,-. Total cost for all samples amounts to N. kr. 216 000,-.

4. TIME-SCHEDULE

It is always difficult to give an exact time-schedule, due to the dependance on weather and hydrographical conditions during the field-work. With these reservations the following programme is proposed.

Water for chemical analysis is sampled in June, September/October, December/January and April 1977/78.

The sampling of sediments will be carried out during the water sampling cruise in April 1978.

Monitoring of the biological communities of the rocky shore have to be conducted in May 1977 and May 1978, due to tide conditions. Sampling of various organisms for chemical analysis will be carried out in connection with the biological monitoring in May 1977 and 1978. In addition a third

series of samples will be collected during a stereophotography cruise in October/November 1977.

Remote sensing by aircraft will be carried out during the monitoring of the biological communities of the rocky shore in May 1978.

Examinations of the hard bottom biological communities by stereophotography are separated into two phases. Phase one, the introductory field observations, can be terminated by 15th September 1977. In phase two, two cruises are programmed. The first one will take place during November 1977, the second will end prior to June 1st 1978.

Brief reports will be forwarded to state the progress of the field programme.

The report including the whole investigation (May 1977 - June 1978) will be finished during September 1978.

The institute reserves the right to make small changes of a technical nature in the above programme without notice. Any deviations implying change of information gained or delays, must be subject to the approval of the sponsoring authorities (project sponsors).

5. LITERATURE

CRAPP, G. B., 1971: Monitoring the rocky shore in "*The Ecological effects of oil pollution on littoral communities*" (ed. E. B. Cowell). Institute of Petroleum, London pp. 102-113.

LUNDÄLV, T., 1971: Quantitative studies on rocky-bottom biocoenoses by underwater photogrammetry. A methodological study. *Thalassia Jugoslavica*, 7: 201-208.

MOYSE, J. and NELSON-SMITH, A., 1963: Zonation of animals and plants on rocky shores around Dale, Pembrokeshire. *Field Studies*, 1: 1-31.

SYRATT, W. J. and COWELL, E. B., 1975: The littoral ecology of the area around Mongstad Refinery, Fensfjorden. Report. Rafinor A/S and Co. Mongstad (mimeographed, 28pp. + tabl., figs. and appendixes).

6. BUDGET

This budget is calculated on the basis of 1977 prices and an expected increase of 15% in 1978. In case of extra work caused by bad weather, the cost must be paid by the project sponsor. The same applies to extra work imposed by the sponsoring authority, which may lead to a budget increase. This is a budget estimate, the actual cost will be based on spent time and direct expenses.

Preliminary work and planning

Introductory visits to Mongstad/Sotra

| | | |
|--------------------|----------------|----------|
| 1 person in 3 days | kr 5 300 | |
| Travel, allowances | <u>" 1 700</u> | kr 7 000 |

Visits to United Kingdom

| | | |
|---------------------|----------------|----------|
| 2 persons in 5 days | kr 13 000 | |
| Travel, allowances | <u>" 8 000</u> | " 21 000 |

Literature studies

" 25 000

Registration of existing discharges of
waste at Sotra

" 15 000

Administration and meetings

" 25 000

Water and sediment chemistry

Field work: 2 persons in 2 days

| | | |
|----------------------------------|-----------|--|
| ã 4 times, included preparations | kr 34 000 | |
|----------------------------------|-----------|--|

| | | |
|--------------------|---------|--|
| Travel, allowances | " 9 000 | |
|--------------------|---------|--|

| | | |
|-----------|---------|--|
| Boat hire | " 6 000 | |
|-----------|---------|--|

| | | |
|----------------|----------|--|
| Water analysis | " 64 000 | |
|----------------|----------|--|

| | | |
|-------------------|----------|--|
| Sediment analysis | " 30 000 | |
|-------------------|----------|--|

| | | |
|-------------------------|-----------------|-----------|
| Data processing, report | <u>" 68 000</u> | " 211 000 |
|-------------------------|-----------------|-----------|

Monitoring of the biological communities on the rocky shore

1977

| | | |
|---|-----------------|-----------|
| Field work: 2 persons in 7 days, included preparations | kr 31 000 | |
| Travel, allowances | " 6 000 | |
| Biological analysis | " 16 000 | |
| Chemical analysis | " 85 000 | |
| Data processing, preliminary reports | <u>" 25 000</u> | " 163 000 |

1978

| | | |
|---|-----------------|-----------|
| Field work: 2 persons in 7 days, included preparations | kr 35 500 | |
| Travel, allowances | " 7 000 | |
| Biological analysis | " 18 500 | |
| Chemical analysis | " 45 000 | |
| Data processing, report | <u>" 60 000</u> | " 166 000 |

Remote sensing of the benthic algal vegetation

| | | |
|--|-----------------|----------|
| Stereo records of the area of investigation | kr 34 000 | |
| Preliminary short analysis of the films | <u>" 10 000</u> | " 44 000 |

Examination of hard bottom communities by stereophotography

Phase 1

| | | |
|---|-----------------|----------|
| Field work: 2 persons in 7 days, included preparations | kr 35 000 | |
| Travel, allowances | " 6 000 | |
| Boat hire, diving | " 8 000 | |
| Picture analysis | <u>" 22 000</u> | " 71 000 |

Phase 2

| | | |
|--|-----------|-----------------------------|
| Field work: 2 persons in 22 days, included preparations | kr 92 000 | |
| Travel, allowances | " 17 000 | |
| Boat hire, diving | " 28 000 | |
| Picture analysis | " 35 000 | |
| Data processing, report | " 30 000 | " 202 000 |
| | | <u> </u> |
| TOTAL | | kr 950 000 |
| | | <u> </u> |

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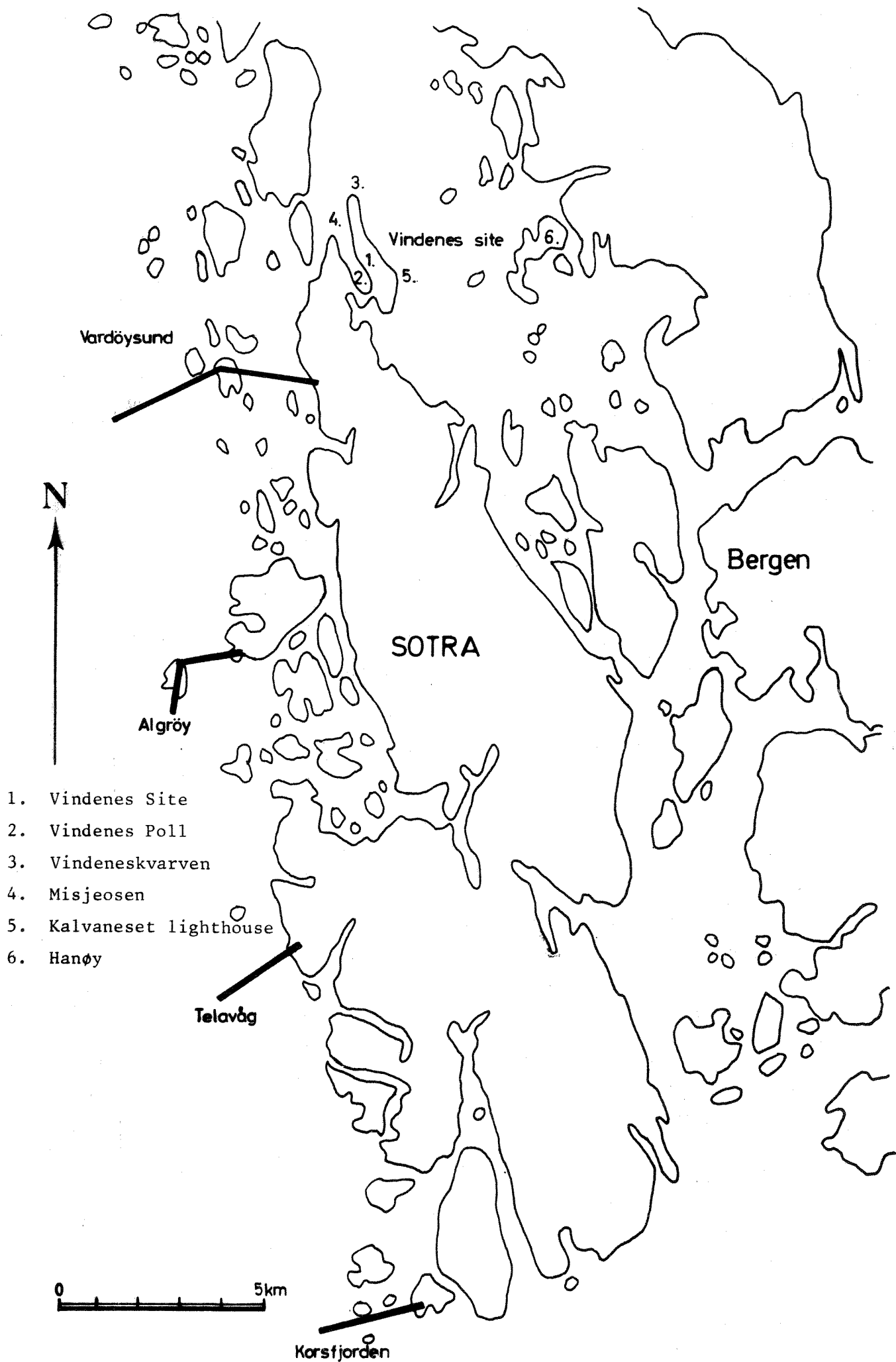


Fig. 1. Location of the investigation area