REPORT OF THE ICES WORKING GROUP ON EFFECTS ON FISHERIES OF MARINE SAND AND GRAVEL EXTRACTION

3rd MEETING OF THE WORKING GROUP

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CONTENTS.

1. Terms of reference
   Working Group Members
2. Present state and future development of marine sand and gravel extraction by ICES member countries.
3. Additional licensing regulations and national codes of practice for the control of dredging activities.
4. Review of current research programmes.
5. Techniques for decreasing the effects on fisheries of marine aggregate dredging.
8. Recommendations.
9. References.

Table I + II.
Figures 1 - 14.
Appendices.
1. TERMS OF REFERENCE.

Resolution C. Res. 1973/ 2 : 9 which was passed at the 61st Statutory Meeting of ICES set up a Working Group to consider the various effects of sand and gravel extraction on fisheries. The Working Group held its first meeting at the Fisheries Laboratory, Lowestoft on 2 - 3 April 1974, with Mr. A.J. Lee as its Chairman and its report was published as ICES Coop. Res. Rep. 46: 1-57.

After considering a proposal from the United Kingdom at the 63rd Statutory Meeting of ICES, it was decided (C. Res. 1975/ 2 : 12) to meet again. The 2nd meeting of the Working Group met at The Netherlands Institute for Fishery Investigations on 9-10 December 1975, with Mr. A.J. Lee as its Chairman and its report was published as ICES Coop. Res. Rep. 64: 1-26.

At the 64th Statutory Meeting of ICES it was decided (C. Res. 1976/ 4 : 14) that the member countries should collect and submit maps etc. for all areas of potential dredging activity showing: (1) the distribution of different types of sediment, bathymetry etc., and (2) relevant fishing grounds, spawning areas, nursery areas etc., Mr. A.J. Lee was invited to be the Coordinator. A further resolution of relevance to the Working Group (C. Res. 1976/ 4 : 15) was adopted as follows:

The Council should, as a matter of urgency, draw the attention of the Governments of member countries and of the North-East Atlantic Fisheries Commission to the potential harm to certain fish stocks from the increasing demand for marine aggregate extraction; to the fact that while fishing in the ICES area is international, decisions to dredge for aggregate on the continental shelf are taken on a national basis; and to the lack of an intergovernmental organization with the necessary authority to harmonize the respective requirements of the fishing industry and the sand and gravel industry. In the meantime, the Council requests its member countries not to proceed with any dredging on herring spawning grounds and other critical fishing areas.

At the 65th Statutory Meeting the collected data in response to C. Res. 1976/ 4 : 14 were reported in Doc. C.M. 1977/E : 68 by A.J. Lee, R.R. Dickson and R.S. Millner. In general the response to the Council's request for information was poor. At the same meeting it was decided (C. Res. 1977/ 4 : 12) that in relation to the report of the Working Group on the Effects on Fisheries of Marine Sand and Gravel Extraction the following actions should be undertaken: (1) each country should complete a representative chart as suggested in Doc. C.M. 1977/E : 68, (2) completed charts should be returned to the ICES Secretariat for assembly, (3) the results should be reported to the Working Group so that the feasibility of an unified system of sea-use mapping could be determined.

Belgium, Finland, Norway, United Kingdom and U.S.A. returned charts and information. These were reported to the 66th Statutory Meeting in Doc. C.M. 1978/E : 12. At this meeting it was decided (C. Res. 1978/ 4 : 9) that "in view of the widespread interest in charts showing different uses of the sea-bed, the Bureau should investigate the practical problems in producing such charts". It was also decided (C. Res. 1978/ 2 : 25) that the Working Group should meet for three days, probably in The Hague, in March 1979 under the chairmanship of Dr. S.J. de Groot.
and that its agenda should include an assessment of recent data and research on aggregate extraction and its effects.

The Working Group met for three days from 21 - 23 March 1979 in Rijswijk (Z.H.), The Netherlands at the Ministry of Public Works and Transport, Rijkswaterstaat, North Sea Directorate.

A field excursion was made on the 22nd of March, during which the participants went on board a trailing suction hopper dredger, involved in maintenance dredging for the Port of Rotterdam (Europort).

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2. PRESENT STATE AND FUTURE DEVELOPMENT OF MARINE SAND AND GRAVEL EXTRACTION BY ICES MEMBER COUNTRIES;

Dredgings for non-calcareous sand and gravel can be considered in the three categories below. The much smaller scale extraction of calcareous material is considered separately.

Sand and gravel:

a. **Licensed_dredging:**

This is dredging for which an extraction licence is required from the appropriate government department or agency. Material is generally used ashore by the building industry but may be used for sea wall defences or beach replenishment. Amounts extracted under licence are reported to the Working Group by ICES member countries and are shown in Table I.

b. **Shipping_channel_maintenance:**

In some localities sand and gravel is produced during shipping channel maintenance. Material of suitable quality may be used in the same way as that from licensed dredging activity. Usually dredging in shipping channels occurs in areas of no fisheries interest. However, as there may be occasions when the dredging and/or the disposal of the dredged material may adversely affect fisheries the Working Group has recommended (see RECOMMENDATION 8.) that in future the quantities of sand and gravel extracted by this method should be reported. For this purpose a new dredgings return form has been prepared (Appendix 1) which will be sent to all ICES member countries for completion and return to the Working Group Chairman by July of each year.

c. **Other_dredging_activities:**

The locations from which aggregates have been dredged have, in some countries, resulted in the omission from the annual returns of substantial quantities of dredged material. For example, extraction of sand for sea wall defences from brackish waters (e.g. Dutch Waddenzee) and where the sea-bed is under private ownership has not been reported in the past. Clearly it is the effects of dredging activity which are of primary importance rather than the ownership or nature of the area dredged or the use to which the aggregate is to be put. Therefore it is recommended (see RECOMMENDATION 8.) that data on all such activities should be obtained and reported.
Calcareous material:

Production of calcareous material is shown in Table II and includes maerl (Lithothamnium) and shell deposits. This also includes the extraction of dead shell in brackish waters (e.g. Dutch Waddenzee).

Figure 1 shows the ICES squares in which the licensed dredging listed in Table I has taken place. Dredgings off the east coast of the U.S.A. are not included in this figure. Details of most dredging areas from the separate ICES countries are included below.

Belgium

Up to 1 March 1979, permits were issued to six companies for sand extraction on the west side of the Belgian Continental Shelf (Oost Dijk and Kwinte Banks) (Figure 2). Dredging activities started in September 1976 and up to 31 December 1978, 1.6 million m³ 1) were extracted. This amount is likely to increase in the future, as permits allow for a total amount of approximately 2 million m³ per year. In the near future, extraction will also start on the Goote Bank, some 13 miles from Ostend.

Denmark

Almost all extraction occurs in the Kattegat and Baltic (Figure 3). No dredging is permitted off the west coast or in the Danish Waddensea without a special licence. However, proposals have been made for large scale extraction to provide material for coastal protection in the Danish Waddensea.

Finland

No information available since ICES C.M. 1977/E : 68 (Figure 4).

France

Annual production of marine sand and gravel in 1977 amounted to approximately 2.8 million m³ with a further 0.7 million m³ obtained from maerl and other calcareous deposits. Dredging is concentrated along the coast of Brittany (Figure 5) on numerous, small deposits. Most of the 60 dredgers employed are less than 200 tonnes (∘150 m³) capacity and are operated by small, localized companies within three miles of the shore in up to 15 m depth. Estimated reserves of over 300 million m³ of sand and gravel are thought to exist in less than 50 m depth within reach of main industrial centres, in the Baie de Seine, off the Loire and the Gironde estuaries and in the Eastern Channel but in spite of the purchase of relative more powerful dredgers of up to 1 000 tonnes capacity, licensed production has not increased as anticipated owing to a general decline in demand. The full exploitation of these reserves is also dependant on the results of environmental impact studies now required by law (see section 3) to assess the likely effects on living resources and fisheries.

A major project involving the removal of approximately 28 million m³ from shipping channels off St. Nazaire has been recently commended, of which 40 % brought ashore and the remainder will be dumped elsewhere. So far only 0.3 million m³ has been extracted. A second similar scheme for the port of Bordeaux has been proposed which would make 7 million m³ of aggregate available to the industry. A detailed environmental impact study has been completed but the results are not yet available.

1) These and subsequent figures are based on the following conversion factors: 1 m³ = 1.8 tonnes mixed aggregate = 1.7 tonnes gravel= 1.9 tonnes sand.
Germany
Licensed dredging is limited to small-scale operations in Kiel Bight but an extensive beach replenishment programme has been carried out at the island of Sylt. In 1972 approximately one million m³ was transported from Rantumer Bucht, a tidal area 8 km east of the replenishment area, and a second stage of the scheme was completed in 1978. There are no immediate proposals for future expansion of licensed dredging.

Iceland
No information available since ICES C.M. 1977/E : 68.

Ireland
No sand or gravel is being extracted on a commercial basis at present, and future development is being very carefully considered with a bias against dredging activity where any risk to the environment might exist. Most industrial interest is likely to be centred on the east coast between Dublin and Wexford.

Only one extraction licence has been issued for Lithothamnium. The terms of this specify the methods of working and include the right of the University College Galway Shellfish Laboratory to monitor progress. Any serious objection could cause the stoppage of extraction or processing until a solution is found. Work has not commenced under this licence to date. It is hoped to use experience gained in this case as a basis for future regulation.

The Netherlands
After a decline in the early 1970's, the demand for supplies of marine aggregates has increased largely due to restrictions on extraction on land. In addition to the 2.4 million m³ of aggregate, derived from licensed dredging in 1978 (Table I), 0.65 million m³ was extracted during shipping channel maintenance and a further 0.2 million m³ dredged specifically for beach replenishment making a total of approximately 3.3 million m³ taken from marine areas (Figure 6). These data do not include large quantities from the Waddensea and the Eastern and Western Scheldt which, although taken from estuarine and brackish situations, may have far reaching effects on North Sea fisheries (e.g. a total of 17 million m³ have been extracted from the Waddensea over the past five years) (Figures 7 & 8).

Norway
No information available since ICES C.M. 1977/E : 68.

Sweden
Since 1975 when 4 million m³ were dredged from Bothnian Bay, extraction has been limited to small quantities from the Øresund. However, applications totalling 2.5 - 3.0 million m³ for the period 1979 - 1989 have been submitted, to be taken from the Øresund.

United Kingdom
The demand for marine aggregates has not shown any significant increase in the last 2 - 3 years, and although some increase is to be expected, it is not likely to approach the level predicted in the Verney Report (DOE, 1975) (i.e. an increase from 8.4 million m³ in 1977 to approximately 13 million m³ in 1985).
Current licensed dredging areas are shown in Figure 9. No completely new areas have been allocated but extraction has been recommended in some areas including North and South Goodwin Sands.

**United States of America**

The production of sand and gravel of the North East coast of the U.S.A. has recently been reviewed (PEARCE, 1979). Most of the current dredging activity is in New York Bight (Figure 10) but major increases in aggregate extraction are projected and possible dredging sites off New Jersey and Delaware are shown in figures 11 & 12.

U.S. Army Corps of Engineers information for amounts of sand and gravel authorized to be mined in 1979 is given below. It should be understood that the amounts of sand and gravel permitted to be mined are authorized figures only. Mining activities might produce less than the authorized amount.

**USA 1979 \(^{1}\) (Total aggregate = m\(^3\)).**

**New England Division, US Army Corps of Engineers (COE) 605,839**

Division Subtotal = 605,839

**New York District COE**

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<td>Lower NY Harbor</td>
<td>364,964</td>
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<td>NY Harbor (Brooklyn)</td>
<td>7,299,270</td>
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<td>NY Harbor (Chapel Hill Channel)</td>
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<td>NY Harbor (east bank of Ambrose Channel)</td>
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<td><strong>District Subtotal</strong></td>
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**Philadelphia District COE**

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<td>Great Egg Harbor, NJ</td>
<td>583,942</td>
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<td>Delaware River</td>
<td>4,233,577</td>
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<td><strong>District Subtotal</strong></td>
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**TOTAL = 39,766,423**

\(^{1}\) Totals currently authorized for removal.
3. ADDITIONAL LICENSING REGULATIONS AND NATIONAL CODES OF PRACTICE FOR THE CONTROL OF DREDGING ACTIVITIES.

Only new or amended legislation on licensing or control which has been introduced since information was supplied to the Working Group in 1977 and reported in ICES C.M. 1977/E: 68 is included.

Belgium

The licensing regulations are now stated in a Royal Degree following the law of 13 June 1969 dealing with the mineral resources of the Belgium shelf. Permits for dredging are issued by the Ministry of Economic Affairs.

Denmark

An amendment to Law 285 has been made in the interest of coastal protection and to safeguard fixed gear e.g. stake nets. Dredging is prohibited within 300 m off the shore. Between 300 and 500 m the depth of sediment that may be removed is limited to 1/50th of the distance from the shore (e.g. at 500 m, sediment can be removed to a depth of 10 m). Further laws may be introduced to protect shellfish beds from dredging activity. The licensing authority is now the Ministry of the Environment.

France

In the past, marine sand and gravel extraction has been subject only to land quarrying regulations. A law of 16 July 1976 received approval from a government commission in February 1978 and should soon become operational. These new regulations, which relate mainly to preventative aspects, will require each new application to be scrutinized by all relevant agencies including the Fisheries Institute (ISTPM), the National Center for the Exploitation of the Ocean (CNEXO) and the Ministry of the Environment. All technical aspects of the proposal may be discussed and any application may be refused. Before commencement, dredging companies will be required to answer a comprehensive "check-list" dealing with the possible effects of extraction on the marine environment (further details of the "check-list" are given in ICES Coop. Res. Rep. 64), and to finance impact studies if so required by the licensing authorities. These studies must be completed within 4 months. After dredging has commenced, operators must make regular returns of quantities extracted, number of dredging days etc. plus bottom sounding recordings and bathymetric charts. In addition, administrative and scientific observers must be permitted to board the dredgers. Finally, a post-dredging benthic study will be carried out at the company's expense.

The French Fisheries Institute is pressing for similar regulations to be applicable to the extraction of shell deposits but state that maeerl deposits (Lithothamnium) should be managed as living resources and consequently come under fishery regulations and have similar protection as shellfish beds.

Germany

There has been no legal changes since ICES Coop. Res. Rep. 46 but a Code of Practice requires that (1) dredging should be restricted by location or season, (2) the total dredged area should not exceed $5 \times 5$ km and (3) no stones $> 30$ cm should be left exposed after dredging. Further means of control are still under discussion including a compensation fund for damage to fishing gear.

Ireland

No dredging laws exist at present in Ireland; future applications will be handled by the Department of Transport and Tourism.
The Netherlands

The Bill of North Sea Soil Materials governs the licensing of dredging. It is framed in general terms and allows the appropriate authorities to add their own regulations depending on requirements. For instance, it is possible to stipulate that dredging in certain areas should be carried out on mobile sand waves in order to minimise effects on the environment. At present extraction is not allowed within about 20 km of the coast but investigations are underway to see whether this limit can be relaxed. A depth contour may be a more appropriate limit and minimum depth of 15 m is being considered. The depth to which sediment can be removed is also regulated and at present is restricted to 2 m.

It is hoped to introduce a "black box" system for dredging surveillance which will monitor the position of the dredge, depth of dredge head, amount dredged, etc.

United Kingdom

There have been no major changes in the licensing procedure which was reported in ICES Coop. Res. Rep. 46, except that fisheries interests are now consulted not only before an extraction licence is issued but also before a prospecting licence is granted.

Informal contact with the dredging companies has been encouraged and there is a possibility that dredging companies will inform local fishing groups if they do not intend to extract aggregate from an area for the following few years. This will allow fishermen to continue using an area without fear of losing their gear, even though a dredging licence has been granted.

United States of America

In his review of sand and gravel production off the north east coast of the U.S.A., Pearce (1979) states:

"During the past several decades the US Army Corps of Engineers (COE) has been involved with a permit process which authorized industry to remove sand and gravels for construction purposes from marine and estuarine habitats. Generally, the COE districts issue permits pursuant to Section 10 of the Rivers and Harbors Act of 3 March 1899, Section 404 of the Federal Water Pollution Control Act (Amendments of 1972), and Section 103 of the Marine Protection Research and Sanctuaries Act of 1972. A specific COE district will usually develop an environmental assessment for a particular sand/gravel mining project proposed within its jurisdiction. If it is deemed necessary, the COE may require that an environmental impact statement (EIS) be developed for a particular project. In any case, public hearings may be held prior to issuance of a permit for a particular mining project. The COE jurisdiction in regard to permits under Section 10 extends from the outer continental shelf into estuaries and as far upstream as past, present, and potential interstate commerce can be conducted on navigable streams.

In the areas of immediate interest to ICES three separate Districts of the Corps of Engineers have had jurisdiction over issuance of permits for mining sand and gravels: the Philadelphia District, Delaware and New Jersey; the New York District, New York; and the New England Division, Connecticut, Rhode Island, Massachusetts, New Hampshire and Maine."
No information regarding new legislation or Codes of Practice have been received.

4. REVIEW OF CURRENT RESEARCH PROGRAMMES.

Belgium
A study of the effects of trailer dredging for sand in an area of high sediment mobility was started in 1977 and will be paid for by the dredging company as a condition of the licence. Biological and physico-chemical monitoring is carried out every two months at twelve positions on and around the sand extraction area.

- Biological survey: qualitative and quantitative assessment of the ichthyofauna, macrobenthic infauna, epibi- and hyperbenthos.

- Physico-chemical monitoring:
  - Water: dissolved oxygen, pH, salinity, redox potential, ammonia, nitrates, nitrites, phosphates, silicates, turbidity, suspended sediment, COD, sulphides.
  - Sediments: carbonates, total organic matter.

Although no adverse effects have been observed, it is too early to draw firm conclusions from this study. A similar study is planned on a second area where dredging has been licensed but has not yet started.

Denmark
An investigation of herring spawning grounds in the Limfjord and off the north coast of Mjen is to start soon. In addition there will be a study of the benthic community in two areas where dredging occurs and has occurred.

France
The effect on the environment of restricting dredging operations to a single deep trench has been examined in the Baie de Seine. Approximately $1.2 \times 10^6$ m$^3$ of aggregate was removed from an area of sand overlying gravel, and a trench 1700 m long by 70-150 m wide and 4-6 m deep was left. The aims and some results from this study have been reported previously (Cressard, 1974; Bouchet et al., 1975; Debyser, 1975). However, apart from some early observations on recolonisation of the benthic fauna, it has not been possible to carry out long term studies on the resettlement of the benthos in the trench because dredging is still continuing.

In view of the need to obtain further information on recolonisation of dredged areas, the Working Group recommended that every effort should be made to allow the biological studies to continue without disturbance from dredging (see RECOMMENDATION 8.).

A major project to extract up to $12 \times 10^6$ m$^3$ of aggregate during the development of a shipping channel into the port of Bordeaux, has resulted in a detailed environment impact assessment. The study was completed in March 1978 and the results have been published (ANON., 1978 e).
In addition to these large scale projects, each new dredging area is studied before a licence is issued. A geological survey of the deposit is undertaken by the geology department of CNEXO and the Research Bureau for Geology and Mining, and an assessment of the possible impact on the living resources, with an emphasis on the fisheries in the area, is undertaken by the ISTPM. Based on the results of these studies, a choice is made of the most suitable method for dredging and the following criteria are among those used in selecting the area:

(a) importance of available fishing resources
(b) fishing effort in the area
(c) importance of the area as a nursery or spawning ground
(d) distance from marine culture grounds (e.g. oysters, mussels, etc.).

In the long term, research is aimed at defining specific areas where priority would be given to the living resources, and all dredging activities would be prohibited. The selection of these areas will be based on scientific studies and will depend particularly on being able to delineate the spawning and nursery grounds of commercial fish species.

Ireland

No research is in progress. However, under the Institute for Industrial Research and Standards, Ocean Services Division, a subcommittee which includes the Department of Fisheries and the Geological Survey, is considering a programme.

The Netherlands

The Dutch Waddensea is at present the major source of marine sand for building activities (roads, dykes, etc.) in the three northern provinces, Noord Holland, Friesland and Groningen and over the last five years a total of $17 \times 10^6$ m$^3$ have been extracted. On the 19 April 1977 the Director General of the Rijkswaterstaat (Ministry of Public Works and Transport) appointed a committee to deal with the effects of sand extraction in the Waddensea. The Steering Committee formed two technical working groups, one of which concentrated on the physical and the engineering aspects of dredging, the other on the biological aspects. The first working group investigated the sand and silt transport and the backfill of former sandpits. They also studied the technical and financial aspects of sand extraction. The second working group studied the origin and regeneration of sediment layers, the flora and fauna of the sediment and the rate of recovery of the benthic ecosystem. Both working groups carried out extensive literature surveys and in additional feasible short term field investigations.

Investigations to determine the source of sand in the Waddensea were not conclusive. One possibility is that sand is transported into the area from the North Sea; another suggestion is that the sand is derived from the erosion of the chain of islands bordering the North Sea margin of the Waddensea.

1. Recovery of bottom fauna in dredged pits

The regeneration of the bottom fauna was studied by comparing the biomass in and outside old marine sand extraction pits (Figure 7). These pits were dredged 2 - 4 years ago. It was established that recovery of the bottom fauna took 2 - 3 years which was similar to the period already described in the literature. Only when sand was extracted in areas where the tidal currents were minimal was full recovery not reached within 4 years. Turbidity caused by the outwash fines of the dredgers was detectable under favourable weather conditions, even in the natur-
ally very turbid waters of the Waddensea. Roughly a doubling in turbidity was detectable about 2 km below the dredger. It is unlikely that the values reached exceed those in the same waters during stormy conditions or even strong winds and it is thought that the bottom fauna of the Waddensea is very well adapted to turbid conditions.

As extensive mussel culture parks occur near the three major sand extraction areas, a brief experiment was undertaken in which bags of mussels were suspended at a range of distance above and below a dredging area and the growth of the mussels was examined. Although further experiments are necessary before firm conclusions can be drawn, the preliminary results showed that mussels close to the dredger grew less than those further away. In addition settlement of encrusting organisms was adversely affected near the dredger.

2. Effects of dredging on the bottom fauna of a gully area.

One method of minimizing the effects of dredging in the Waddensea might be to dredge in gully areas rather than on the tidal flats and a survey of a gully area was undertaken to examine this possibility.

The area selected was in the western part of the Waddensea (Figure 8) where two major streams, the Texelstroom and Malzwin, meet. One of the criteria was that the area should be representative of an area where sand dredging is licensed and carried out. This would provide an indication of the real significance of the influence of sand dredging on the recovery of the bottom fauna.

Initially dredging was restricted to the removal of 5000 m³ of sand in the period April to July 1978. However, this was considered to be only a minor extraction and a further 50,000 m³ was removed between August and December 1978. The benthos was sampled with a 0.1 m² Van Veen grab and 170 samples were taken for analysis during the first period of dredging followed by 119 samples during the second extraction phase.

The bottom fauna of the gully which consisted almost exclusively of the genus Nephtys, had a biomass of about 0.6 g/m² compared with biomass values of 1.5 - 3.2 g/m² on the flats. It was found that the effect of dredging was to reduce the biomass values by about half. In the deepest pits (about 2.5 m deep) a fine blackish sediment was deposited with no life in it at all several months after dredging. During the period investigated, the pits showed no signs of filling in even though there were strong tidal currents in the area.

3. Proposed study on beach erosion and benthic recolonisation

Dredging off the Dutch coast is usually not permitted within 20 km of the coast for coast protection reasons. In order to find out whether this limit could be relaxed, a new project is being planned which will examine the effects of the removal of at least 5 - 6 x 10⁶ m³ of sand from an area only 5 km from the port of IJmuiden in a water depth of 16 m. The dredging will be very closely supervised and a pit approximately 2700 m long by 700 m wide and 2 - 5 m deep will be excavated. The axis of the pit will lie approximately parallel to the coast. The influence of the pit on wave refraction, coast erosion, sediment transport, etc. will be studied and an extensive grid of stations will be monitored around the pit so that the movement of sand back into the pit can be followed.
Dredging is planned to start in 1980 and will be completed within two years. The natural variation in benthic fauna around the pit will be studied from 1979 onwards. After the pit has been thoroughly dredged to ensure that all benthos have been removed, the rate of recolonisation of the pit will be followed for a further two years.

4. Examination of dredged tracks using side scan/sonar

A survey of a dredged area 20 km off the town of Scheveningen on the Dutch coast was carried out using side scanning sonar as a mapping device (Bakker & Kubik, 1978). Extraction was by trailer suction dredger in a water depth of 19 m and was directed along the tops and steep sides of the sand waves or mega ripples where the coarsest sand (median diameter 350 \( \mu \text{m} \)) was found.

Extensive movement of sand was found to occur along the tops of the banks especially during storms and 6 months after dredging had stopped all the dredge tracks had disappeared. In some places the tracks which were 25 - 30 cm deep had disappeared within a few hours. These results suggest that the environmental effects of dredging can be minimized by dredging in areas of high sediment mobility.

United Kingdom
Southwold experimental area

A study on the effects of trailer dredging off Southwold on the east coast of England has been completed and the results are being analysed. The methods used and some of the preliminary results were reported in ICES C.M. 1977/E : 48.

Physical effects

Change in sediment structure

The dredged sediments can be considered as three generalized fractions. A coarse fraction which is retained by the dredger, the sands, part of which are washed back into the sea and deposit on the sea bed and the silt fraction also washed overboard which remains in suspension and is dispersed over the area. Trailer dredging on a sediment containing a mixture of these fractions can have two main effects. Firstly, by disturbing the bottom topography it will increase the process of tidal scour by which the finest particles are lifted into suspension by tidal currents. Secondly, as dredging proceeds and the gravel fraction is removed, an increasing burden of sand and silt is returned to the sediment surface as outwash from the dredger. Reductions in the gravel component will be restricted to the dredge tracks whereas the effect of the relative increase in sand will be more widespread. Analysis of sediment samples taken from the dredged area and from a control area to the east approximately a year after dredging started and again two years later showed that some of the changes which were predicted had occurred in both areas. Within the dredged area there was a decrease in the proportion of fine sand (90 - 180 \( \mu \text{m} \)) and an overall increase in medium sand (200 - 500 \( \mu \text{m} \)) at most stations. Similar results were found in the control area although the loss of fine sand was less marked.

The absence of any clear difference between the results in the two areas could mean that the effects of dredging were extended to the control area, or that the differences in size composition in both areas were merely a result of natural variability. Analysis of a more detailed set of samples will be undertaken and may help to resolve this problem.
Rate of infill of dredged tracks

Current velocities at the sediment surface were measured using a shear velocity current meter. The velocities were not fast enough to move gravel so that infill can only occur by the transport of sand and silt into the tracks. Initially, there appears to be little infill and tracks were clearly displayed on sector scanning sonar records more than four years after dredging in one area had ceased.

Outwash fines

The discharge of fine sand and silt from the hold of the dredger takes place during dredging operations. The silt is dispersed by tidal currents and although it gives rise to a temporary increase in turbidity, the natural background levels in the Southwold area are high and would tend to mask the effects of dredger induced turbidity. The deposition of sand onto the sediment may cause problems by smothering benthos either side of the dredged track. This problem would be expected to increase in areas on intense dredging activity since as the gravel is removed an increasing load of sand is left at the sediment surface.

Biological effects

Changes in the benthos living in or attached to the sediment

A comparison was made between the abundance of the animals sampled by a 0.1 m² Day grab in the dredged and control areas. Although there was great variability in the samples, a number of general conclusions can be made. Both the numbers of individuals and numbers of species was lower in the dredged area than in the control, although the fauna from both areas was generally sparse with usually less than 25 species per 0.1 m². The variation in abundance or organisms in both areas showed similar trends from year to year with a decline in the numbers of individuals on the dredging ground reflected by a decline in the control area. However, when closer analysis was made of individual species which because they are closely associated with gravel substrates might be expected to show up any effects of dredging, a number of differences between the two grounds emerged. For instance, the calcareous tube building polychaete Pomatoceros triqueter and the chiton Lepidochitona cinerea were two species which usually showed a decrease in abundance on the dredged ground relative to the control area. In contrast the brittle star Ophiura albida which was quite abundant on both grounds showed a greater decline in numbers on the control ground than it did in the dredged area.

Changes in the mobile epibenthos

A survey of the epibenthos was made by beam trawling across the grid of stations in the two areas both before dredging began and for several years after dredging had started. The numbers of both species and of individuals were significantly higher on the control ground than on the dredged area and the annual fluctuation in abundance was clearly different on the two grounds. In both areas the numbers of individuals of the commonest species varied from cruise to cruise but on the dredged ground there was a consistent downward trend in numbers of most of the species. On the control ground numbers again showed great variation but there was no obvious trend and in many cases an increase in numbers occurred. Examination of individual stations on the dredging ground showed a clear relationship between dredging intensity and the decrease in the numbers of epibenthos.
Fish feeding
Examination of the gut content of fish caught in the area of the dredging ground showed that, with the exception of the sea urchin *Psammechinus* and starfish *Asterias*, all the other common species of epibenthos formed part of the diet of commercial fish species.

Effects of dredging on sandeel fisheries
Many sandeel fisheries take place on restricted areas of sea bed which may be vulnerable to the activities of dredgers. Although dredging directly on the fishing ground can be avoided by the refusal of a licence, dredging close to a sandeel fishery could result in the deposition of outwash fines onto the area of sediment in which the fish bury and on which they deposit their eggs. In order to assess the impact of dredging on sandeels, a survey of the Outer Dowsing Shoal, which is an important sandeel spawning ground in the southern North Sea, has been undertaken together with studies on the development of eggs and larvae of sandeels.

Survey of the Outer Dowsing Shoal
Grab samples have been taken across the Shoal in a number of places and have shown that the sediments consist largely of medium and fine sands with a very low silt content. Water samples taken over a tidal cycle at spring tides near the Shoal indicate that the concentration of suspended material both at the surface and near the bottom is low. The presence of large quantities of outwash fines from dredging will contribute substantially to the load of suspended solids in the water column over the Shoal and to the load of fine sediment deposited on the Shoal.

Egg and larval development
The development of eggs at low dissolved oxygen concentrations both at the sediment surface or when buried under layers of silt has been studied in the laboratory. Conclusions drawn from these experiments suggest that although the eggs can survive and develop at low oxygen concentrations, they will be unable to reach the surface if deposition is particularly heavy. In addition, the rate of development of the eggs will be greatly delayed which could have serious consequences in terms of the food supply of the absence of specific predators of the larvae.

United States of America
Although there have been several recent reports concerned with the effects on fisheries of marine sand and gravel extraction, much of the work in the U.S.A. is related to either deep ocean mining or channel and harbour dredging.

Lane (1978) recently reviewed the various activities that are being carried out within a National Oceanic and Atmospheric Administration (NOAA) program concerned with deep sea bed mining. Ozturgut et al (1978) also discussed the pre-mining environmental conditions that might exist at deep ocean mining sites and reviewed the anticipated effects of deep ocean mining. Some of these effects would probably be common to inshore mining activities as well. A preliminary document has been developed based on possible effects of sand and gravel mining off the United States Virgin Islands. NOAA has agreed to manage and fund environmental studies associated with pilot mining activities and Padan (1977) has edited a final report concerned with the possible effects of mining on resources located in the offshore coastal waters of New England.
In addition to the various activities that are directly concerned with extraction of marine aggregates there has been considerable research activity in the United States in regard to ocean dumping, including dredging spoils and other contaminated and uncontaminated sediments. Recently NOAA (1978b) completed a Report to the Congress of the United States on Ocean Dumping Research.

Whilst this section has summarized some of the more recent research projects which have dealt with the effects of dredging on the environment, there is an extensive bibliography which has not been considered. The Working Group recommended (see RECOMMENDATION 4) that to ensure that research of relevance to dredging was brought to the attention of all members, a summarizing bibliography should be prepared. This would include all reference reported in previous publications by the Working Group together with useful papers produced more recently. The completed bibliography would be submitted to the Marine Environmental Quality Committee at the 1980 statutory meeting of ICES and would be updated annually.

5. TECHNIQUES FOR DECREASING THE EFFECTS ON FISHERIES OF MARINE AGGREGATE DREDGING.

The relative advantages and disadvantages of trailer and anchor dredging were discussed, but no consensus was reached. It was appreciated that the choice is a complex one and is governed by many factors including the type and depth of deposit and also the fisheries implications, both directly by physical means and indirectly by effects on the benthos. Also consideration to other shipping activity should be given.

Most countries, especially those countries with deep, sandy deposits, favoured a policy of containment, using stationary or slow moving dredges with capability of deep dredging, whereas the United Kingdom and The Netherlands favoured trailer dredging on its more superficial deposits.

Information on rates of faunal recolonization on different substrates would be most useful to appreciate the relative effects of trailer dredging and the significance of the removal of benthos during the period of extraction. Increased turbidity is one of the more obvious results of dredging. Recently in Japan anti-turbidity overflow systems for hopper dredgers have been developed (ANON, 1978). It was found that turbidity was greatly increased when excess water fell from the hopper to the overflow trough and passed the overflow chute to be discharged overboard. The numerous air bubbles thus generated and entrained in the overflow water, together with muddy water, where discharged overboard and produced an "air lift" effect inducing solid particles to rise to the surface of the sea and thus increasing the turbidity. The Japanese were able to minimize this turbidity increase by inhibiting the generation of air bubbles and eliminating existing bubbles before the overflow water was discharged overboard, thus enabling the tailings to settle rapidly. The method can be improved by means of a special discharge pipe when the overflow discharges at a greater depth. (ANON., 1976 a, b).

De Groot (1979 a) in a recent discussion on the effects of gravel dredging noted:

"If it is agreed to exploit a certain area for gravel, one should survey this area comparable as described by Van Oostrum (1973) and Oele (1978). One should map the concentrations of gravel, only
the lower concentrations of gravel should be extracted, as removal of the high concentrations of gravel will alter the marine environment too much, it is fully understood that this is against the interests of the industry and perhaps this approach should be confined to those areas as indicated in ICES Coop. Res. Rep. no.61, when a licence is given to extract gravel in such an area. Owing to the newly developed aid of programmed dredging it is possible to reduce the unnecessary disturbances of the sea bed with their benthic ecosystem and spawning sites, especially those for the herring.

There is still a gap in our knowledge of herring behaviour why they are selecting specific areas on a shingle bank to spawn. It is likely that temperature, sound, bottom current velocity, transparency of the water (no siltation) plays an important role. One should investigate what will happen to a known spawning area if part of the sediment is dredged away. Will the herring adapt itself to the change in environment, or not at all. Will we get a repetition of what happened to the former Zuiderzee herring, who were unable to spawn on their traditional spawning grounds, who still were able to spawn, however, all their eggs and larvae were destroyed by wave action and other external factors. It should never be allowed that an area should become completely devoid of gravel. If the type of sediment remains more or less the same this will not lead to abrupt changes of the benthic ecosystems (De Groot, 1979 b). The influence of marine gravel mining will have indirectly also consequences when the stocks of sandeel are affected. Commercial a not too important species, however, for many cod-like species a primary food source. Local populations of cod are feeding on them, lack of food will automatically have its repercussions.

6. SEA BED CHARTS

C. Res 1976/4 : 14 adopted by the Council at its 64th statutory meeting recommended that "The Council takes steps to obtain from member countries and appropriate international scientific bodies for all areas of potential dredging activity, maps, etc, showing:

a. the distribution of different types of sediment, bathymetry, etc.,
b) fishery grounds, spawning areas, nursery areas, etc.

The Council should appoint a coordinator(s) to synthesize the material".

The material gathered in response to this resolution was reported in ICES C.M. 1977:E : 68 and ICES C.M. 1978:E : 12. In both documents, the usefulness of large scale sea bed maps was recognized but the difficulty in obtaining the necessary information had prevented more than a few charts being produced. The Working Group decided that there was a pressing need to chart areas of biological activity but in view of the amount of work involved, this would be considered a long term aim. However, a considerable amount of data on marine sediments was already available or in preparation even though it was not easily accessible. For instance, a detailed chart of the Dutch continental shelf has recently been completed (Figure 13 and Schüttenhelm, 1979). The chart shows the distribution of 9 main sediment types from gravel to boulder clay. Coloured booklets with charts are already available for some parts of the U.S.A. ') showing the

') As an example a list of the atlases prepared for the New York Bight area under the Marine Ecosystems Analysis (MESA) Program is given at the end of the references (section 9).
distribution of a number of oceanographic features and coloured maps are shortly to be produced by France covering the whole of the channel at a scale of 1 : 500 000. This type of information is available for many countries and the Working Group recommended (see RECOMMENDATION 3) that a master chart should be produced which would show all the areas of the sea bed within the boundaries of ICES member countries, for which existing charts of surface sediments had been prepared.

While the main priority of such an exercise was to bring together all existing information on sea bed sediments, it would clearly be helpful if in the future maps were produced at a similar scale and on the same map projection. In addition the Working Group agreed that the standardization of the symbols used to depict sedimentary types and other features would greatly improve the ease with which different charts could be used and compared.

One method of obtaining information on the activities of fishing and other vessels is by plotting their movements from low flying aircraft. A similar exercise has been undertaken by the Dutch to avoid interference between the fisheries and the offshore oil industry, the proposed route of an oil pipeline through the Norwegian Trench off Soltra was surveyed by air and Figure 14 summarizes the movements of ships over a two year period. The speed, direction and activity of the vessel is noted (e.g. whether fishing or steaming) and by analysing clusters of vessels over a period of time, it is possible to locate important areas such as the main seasonal fishing grounds. The increased knowledge provided by this type of charting could help to minimize the conflict between different uses of the sea bed.

7. REPLY BY THE SAND AND GRAVEL DREDGING INDUSTRY (SAGA) TO THE FIRST WORKING GROUP REPORT (ICES COOPERATIVE RESEARCH REPORT NO. 46).

A detailed report from the sand and gravel dredging industry in the U.K. commenting on ICES Coop. Res. Rep. 46 had been sent to members for discussion (ANON., 1979). Copies of the report had not been received in time before the meeting for members to be able to comment in detail on its contents. It was therefore agreed that members would consider the document more thoroughly and consult with their respective dredging industries. It was recommended that comments on the report should be sent to the Working Group Chairman by the 1st of May 1979, who would forward them to the MEQ Committee (see RECOMMENDATION 9).

8. RECOMMENDATIONS.

1. That consideration should be given to developing more direct methods of delineating herring spawning grounds than those employed by Postuma, Saville and Wood (ICES Coop. Res. Rep. 61 : 1-16, 1977) in order to harmonize the interests of the dredging and fishing industries.

2. That before the issue of dredging licences, information on the nature and distribution of deposits should be made available and updated at intervals during the dredging operations.
3. That a master chart should be produced showing the areas of sea bed covered by all existing charts of surface sediments within the ICES area and that such information should be sent to and coordinated by the Working Group Chairman who should also be informed by the Bureau of future developments regarding sea bed charting.

4. That a summarizing bibliography should be prepared by members on all relevant topics related to dredging (including documents by the Working Group) and be sent to the Working Group Chairman for submission as a draft to the MEQ Committee at the 68th Statutory Meeting and that additional information should be submitted annually to the MEQ Committee under a separate heading.

5. That papers published by the member's institutes, relating to the Working Group's terms of reference, should be circulated to all the members.

6. That the MEQ Committee should consider whether the Working Group's terms of reference should be expanded to include (1) the biological effects of the dumping of solid wastes, e.g. harbour dredging, sewage sludge, (2) the use of sand and gravel for offshore construction activities, e.g. the covering of unprotected pipelines, and (3) the storage and capping of polluted fine waste materials in deep dredged or natural pits.

7. That all possible effort should be made to continue the recently terminated Baie de Seine Project in order to ensure that important information be obtained from this major study on the effects of gravel dredging in view of its relevance to the study of the faunal recolonization of dredged areas.

8. That the provision of data on dredging activities should include all types of sand and gravel material removed from marine and brackish waters and that the information be returned to the Working Group Chairman by July on a standard form to be prepared for this purpose.

9. That members of the Working Group should take steps to discuss with the dredging industry problems arising from both dredging and fishing activities and that a summary of their findings should be prepared for submission to the MEQ Committee and the General Secretary.

10. That a further meeting of the Working Group should be held in April or May 1980 for three days.

9. REFERENCES.

A comprehensive bibliography is being prepared by members of the Working Group and the references given below include only those papers cited in the text or submitted at the Working Group meeting, or mailed to the members of the Working Group during the drafting period of this report.

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Geologie en Mijnbouw, 57(1) : 45-54.

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Postuma, K.H., A. Saville, & R.J. Wood, 1977
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Swartz, R.C., 1978


A series of atlases published for the New York Bight area which may be of considerable interest to members of the Working Group is given below. The atlases are produced under the Marine Ecosystems Analysis (MESA) Program by the New York Sea Grant Institute, Albany, New York.

MESA NEW YORK BIGHT ATLAS MONOGRAPH SERIES.

1. Hydrographic Properties
   Malcolm J. Bowman, with cartographic assistance by Lewis D. Wunderlich, Marine Sciences Research Center, SUNY.

2. Chemical Properties.
   James and Elizabeth Alexander, Institute of Oceanography, SUS, Florida.

   Donald Hansen, Atlantic Oceanographic and Meteorological Laboratories.

4. Tides.
   R.L. Swanson, MESA New York Bight Project.

5. Wave Conditions.
   Willard J. Pierson, University Institute of Oceanography, CUNY.


7. Marine Climatology.
   Bernhard Lettau, National Science Foundations, William A. Brower, Jr. and Robert G. Quayle, National Climatic Center.

8. Regional Geology.
   John E. Sanders, Columbia University.

9. Gravity; Magnetics and Seismicity.
   James R. Cochran and Manik Talwani, Lamont-Doherty Geological Observatory.

10. Surficial Sediments.
    George Freeland and Donald J.P. Swift, Atlantic Oceanographic and Meteorological Laboratories.

11. Beach Forms and Coastal Processes.
12. Plankton Production.
   Charles S. Yentsch, Bigelow Laboratory for Ocean Sciences.

   Thomas C. Malone, City University of New York.

    John B. Pearce and David Radosh, National Marine Fisheries Service.

15. Fish Distribution.

16. Fisheries.
    J.L. McHugh, Marine Sciences Research Center, SUNY, and Jay J.C. Ginter, NY Sea Grant Institute.

17. Aquaculture.
    Orville W. Terry, Marine Sciences Research Center, SUNY.

18. Artificial Fishing Reefs.
    Albert C. Jensen, NYS Department of Environmental Conservation.

    E. Glenn Carls, University of Waterloo, Ontario.

20. Port Facilities and Commerce.
    Alfred Hammon, The Port Authority of New York and New Jersey.

    John S. Schlee, U.S. Geological Survey, with a section by Peter T. Sanko, NY Sea Grant Advisory Service.

22. Jurisdictional Zones and Governmental Responsibilities.
    Paul Marr, SUNY at Albany.

23. Demographic Patterns.
    Charles Koebel and Donald Krueckeberg, Rutgers University.

24. Transportation.
    Richard K. Brail and James W. Hughes, Rutgers University.

25. Electricity Generation and Oil Refining.
    H.G. Mike Jones, Harold Bronheim, and Philip F. Palmedo, Brookhaven National Laboratory.

    M. Grant Gross, Chesapeake Bay Institute, Johns Hopkins University.

27. Water Quality.
    Donald J. O'Connor, Robert V. Thomman, and Henry J. Salas, Hydro-science, Inc.

28. Air Quality.
    Volker A. Mohnen, Atmospheric Sciences Research Center, SUNY.

29. The Lower Bay Complex.
    Iver Duedall, Harold O'Connors, and Robert Wilson, Marine Sciences Research Center, SUNY.

30. Industrial Wastes.
    James A. Mueller and Andrew R. Anderson, Manhattan College.

31. Marine and Coastal Birds.

32. Environmental Health.
    Joseph M. O'Connor, Chun Chi Lee, and Merril Eisenbud, Institute of Environmental Medicine, NYU Medical Center.
TABLE I - Total licensed production of marine sand and gravel within the ICES-member countries 1975-1978.

<table>
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<th>Country</th>
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<td>78</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>75</td>
<td>1.3</td>
<td>0.4</td>
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<td>76</td>
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<tr>
<td>78</td>
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<td>*</td>
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</tr>
<tr>
<td>Germany (FRG)</td>
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<tr>
<td>75</td>
<td>0</td>
<td>0.98</td>
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<td>Iceland</td>
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<tr>
<td>75</td>
<td>0.08</td>
<td>0.19</td>
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<td>77</td>
<td>0.18</td>
<td>0.42</td>
<td>0.60</td>
</tr>
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</tr>
<tr>
<td>Ireland</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>75 - 78</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Netherlands</td>
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<td></td>
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<td>0.79</td>
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<td>75 - 78</td>
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<td>*</td>
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<tr>
<td>Sweden</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>75</td>
<td>4.0</td>
<td>≠</td>
<td>4.0</td>
</tr>
<tr>
<td>76</td>
<td>0.10 ≠</td>
<td>≠</td>
<td>0.10</td>
</tr>
<tr>
<td>77</td>
<td>0.06 ≠</td>
<td>≠</td>
<td>0.06</td>
</tr>
<tr>
<td>78</td>
<td>0.06 ≠</td>
<td>≠</td>
<td>0.06</td>
</tr>
<tr>
<td>U.K.</td>
<td></td>
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</tr>
<tr>
<td>75</td>
<td>9.59</td>
<td>≠</td>
<td>9.59</td>
</tr>
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<td>76</td>
<td>8.91</td>
<td>≠</td>
<td>8.91</td>
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<td>8.22</td>
<td>≠</td>
<td>8.22</td>
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<td>*</td>
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<tr>
<td>U.S.A.</td>
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</tr>
<tr>
<td>75</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<td>*</td>
</tr>
<tr>
<td>77</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

* = no record available
≠ = sand and gravel combined
= = includes 1.8, 2.3 and 1.8/$10^6$ m$^3$ pebbles (> 6.4 cm) in 75, 76 and 77 respectively.

Between 1968-76 permits and contracts were given in COE District New York to extract 84 x $10^6$/yd$^3$ sand and gravel in total.
TABLE II - Total marine production of calcareous shell by ICES member countries: 1975-1978.

<table>
<thead>
<tr>
<th>Country</th>
<th>Production $10^6$ m$^3$</th>
<th>Type of material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>75 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>76 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>77 0.13</td>
<td>Oyster shell</td>
</tr>
<tr>
<td></td>
<td>78 0.14</td>
<td>Oyster shell</td>
</tr>
<tr>
<td>France</td>
<td>75 *</td>
<td></td>
</tr>
<tr>
<td></td>
<td>76 0.50</td>
<td>Maerl and shell</td>
</tr>
<tr>
<td></td>
<td>77 0.70</td>
<td>Maerl and shell</td>
</tr>
<tr>
<td></td>
<td>78 *</td>
<td></td>
</tr>
<tr>
<td>Iceland</td>
<td>75 0.11</td>
<td>Maerl</td>
</tr>
<tr>
<td></td>
<td>76 0.07</td>
<td>Maerl</td>
</tr>
<tr>
<td></td>
<td>77 0.09</td>
<td>Maerl</td>
</tr>
<tr>
<td></td>
<td>78 *</td>
<td></td>
</tr>
<tr>
<td>U.K.</td>
<td>75 0</td>
<td>Maerl</td>
</tr>
<tr>
<td></td>
<td>76 0</td>
<td>Maerl</td>
</tr>
<tr>
<td></td>
<td>77 0.0005</td>
<td>Maerl</td>
</tr>
<tr>
<td></td>
<td>78 0.003</td>
<td>Maerl</td>
</tr>
</tbody>
</table>

* No record available

Note: No known production in other ICES countries.
Figure 1 — Rectangles within which dredging reported by ICES-member countries takes place. It should be noted that within any one rectangle the actual area dredged may be very small.
Figure 2. Prohibited dredging zones off the coast of Belgium.
Figure 3 — Dredging areas off the coast of Denmark.
Figure 4 - Location of sand deposits and dredging grounds off the coast of Finland.
Figure 5 – Dredging areas off the coast of France.

EXPLOITATION DES SEDIMENTS EN MER
SITUATION AU DEBUT DE 1979

* EXTRACTION D'AMENDEMENTS CALCAIRES
EXTRACTION DE GRANULATS
* EXTRACTION EN COURS
O DEMANDE ACTUELLE
O DEMANDE A MOYEN TERME
ZONES D'INTERET HALIEUTIQUE A PRESERVER
EN PRIORITE (NURSERIES LITTORALES)
Figure 6 — Sand extraction areas off the southern coast of the Netherlands.
Figure 7 - Sand extraction areas within the Dutch Waddensea

1. Marine sand extraction area Wierbalg
2. Marine sand extraction area Blauwe Slenk
3. Marine sand extraction area Dantzigergat
Figure 8  Sand extraction areas south of Texel, The Netherlands.
Figure 9 — Location of licensed dredging areas off the coast of England and Wales.
Figure 10 — The location of important sand and gravel mining operations in New York metropolitan estuaries and coastal waters. Roman numerals indicate sites where beach replenishment materials are obtained. The letter A indicates potential site for sand and gravel operations. Since 1973 only sites 4, 6, 9 and 1 have been used (From Pearce, 1979).

Figure 11 — Potential sites where construction aggregates may be mined off the New Jersey coast in future. These sites have been shown to have potential for mining operations (From Pearce, 1979).

Figure 12 — Possible borrow areas off the Delaware coastline. Surveys suggest that these sites indicated in solid black, may contain considerable construction aggregate material (From Pearce, 1979).
Figure 13 — The superficial geology of the Dutch sector of the North Sea (From Schüttenhelm, 1979)
Figure 14  — Shipping movements off the Dutch coast 1975 - '77
Appendix 1

Report on marine dredged material for year.  

Issuing Authority  

Reporting Period (if different from above)  

<table>
<thead>
<tr>
<th>Type of dredged material</th>
<th>Total production</th>
<th>Source of dredged material</th>
<th>Method of dredging</th>
<th>Encluse of material</th>
<th>Localities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10^6 m^3$</td>
<td>Harbour</td>
<td>Shipping channel</td>
<td>Other</td>
<td>Trailing</td>
</tr>
<tr>
<td>Sand</td>
<td>0.063 - 2.0 mm</td>
<td></td>
<td></td>
<td></td>
<td>Anchor</td>
</tr>
<tr>
<td>Gravel</td>
<td>2.0 - 6.4 cm</td>
<td></td>
<td></td>
<td></td>
<td>Seadefence</td>
</tr>
<tr>
<td>Mixed aggregate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Beachfill</td>
</tr>
<tr>
<td>Maërl (Litho Hiamnium)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Other</td>
</tr>
<tr>
<td>Other calcareous shell</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Give names and Position of area. Indicate on chart (P.T.O.)
Appendix 2

Sand and Gravel Mining

1. Need

In Western Europe, sand and gravel are required in large quantities for various purposes, such as:

- construction of embankments and seawalls
- landfill for raising or levelling of: residential zones, industrial zones, roads, etc.
- aggregates for concrete, glass, etc. (industrial sand)

Elsewhere in the world (Australia, Africa) sand is mined because it contains traces of valuable elements such as zircon etc.

In the Netherlands the annual demand is as follows:

<table>
<thead>
<tr>
<th>Industrial sand in 10^6 ton</th>
<th>1978</th>
<th>1980</th>
<th>1982</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic production</td>
<td>17</td>
<td>10.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Import from Germany</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Total</td>
<td>22.5</td>
<td>16.0</td>
<td>10.5</td>
</tr>
<tr>
<td>Export to Belgium</td>
<td>6.5</td>
<td>3.0</td>
<td></td>
</tr>
</tbody>
</table>

Available 16.0 13.0 10.5
Demand 16.0 17.0 18.0
Deficit - 4.0 7.5
**Industrial Gravel**

<table>
<thead>
<tr>
<th></th>
<th>1978</th>
<th>1980</th>
<th>1985/86</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic production</td>
<td>9.6</td>
<td>9.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Import from Belgium</td>
<td>2.1</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>Import from Germany</td>
<td>4.7</td>
<td>4.8</td>
<td>5.0</td>
</tr>
<tr>
<td>North Sea</td>
<td>1.1</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td>Available</td>
<td>17.5</td>
<td>16.7</td>
<td>6.6</td>
</tr>
<tr>
<td>Demand</td>
<td>17.5</td>
<td>18.5</td>
<td>20.0</td>
</tr>
<tr>
<td>Deficit</td>
<td>-</td>
<td>1.8</td>
<td>13.4</td>
</tr>
</tbody>
</table>

The domestic production is reduced because of the growing opposition against the strip mining techniques.

The situation in other countries is comparable. Since a number of years there is a growing interest in extraction of sand and gravel from the sea.

In Britain the concrete industry is depending for 100% on sea gravel, in the Netherlands sea gravel was until now mainly used as foundation material in large structures (Europaort breakwaters; Oosterschelde closure).

The same tendencies are visible for sand used in landfill.

**Fill Material**

In 1966, the situation for the coming decade was as follows:

- Estimated demand per year: $63 \times 10^6 \text{ m}^3$
- Estimated production from land: $24 \times 10^6 \text{ m}^3$
- Estimated production from estuaries: $4 \times 10^6 \text{ m}^3$
- Estimated production from sea: $6 \times 10^6 \text{ m}^3$
- Deficit: $29 \times 10^6 \text{ m}^3$
In reality, the shortage did not occur as foreseen for the following reasons:

1. The slacking down of the economic growth decreased the demand for industrial sites, roads, etc.
2. The restrictions to dredging sand from land based borrow pits were not as strong as foreseen.

As a result of these developments, major contractors constructed plants for processing (desalinizing) sea sand. Examples: 'Agulda' by Bos Kalis Westminster and 'Geomaris' by Adriaan Volker. Both installations have been abandoned since there was no shortage anymore in the early 1970's.

In the meantime, one can notice at present again a demand for sand from sea. This demand is due to:
1. conservative licensing policy on land
2. fear for higher cost of inland transport
3. need for major shore protection works

2. Quality Requirements

The qualitative requirements for sand and gravel depend largely on the designation of the material. The bulk of the industrial sand and gravel is used for the production of reinforced and prestressed concrete. Here, the quality requirements are very strict and are connected with:
- grain size distribution (no fines)
- chemical composition of the gravel
- contamination by shells, silt and chlorides
The quality requirements for landfill material are less pronounced, but again, a high silt content is considered a disadvantage in connection with the dewatering process, and salt content of the material is closely controlled to prevent contamination of fresh water.

In view of the quality requirements, the raw material is processed. Because of the high cost of transport it is attempted to sort the material at the mining location. Sorting is done by mechanical and hydraulic sieving processes. The tailings, consisting of clay, silt and fine sand are dumped behind the mining equipment.

3. Outlook to the future

Although in the Netherlands still large quantities of sand and gravel can be obtained from land-based sources, a shortage is foreseen in the near future. This shortage is caused by the reluctance of the provincial authorities to issue licenses for strip mining. The reluctance is also connected with the opposition by action groups against licensing. The zoning legislation provides these groups with ample opportunity to postpone the licensing for many years.

It is obvious that alternative solutions have to be found. In the first place, one wonders whether it is possible to replace concrete as construction material. In this respect it is interesting to show the relative cost level of other construction materials.
### Materials and Their Costs

<table>
<thead>
<tr>
<th>Material</th>
<th>Dfl. per kg</th>
<th>Dfl. per unit of structural strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced concrete</td>
<td>1,--</td>
<td>1</td>
</tr>
<tr>
<td>Brick</td>
<td>2,20</td>
<td>8</td>
</tr>
<tr>
<td>Steel</td>
<td>15,80</td>
<td>2</td>
</tr>
<tr>
<td>Aluminium</td>
<td>40,80</td>
<td>6</td>
</tr>
<tr>
<td>Polyester</td>
<td>66,70</td>
<td>9</td>
</tr>
</tbody>
</table>

It is very unlikely that these figures will change significantly, considering the energy content per m³ of product:

- Concrete (non reinforced): 60
- Concrete (reinforced): 211
- Brick masonry: 245
- Steel: 7,900
- Aluminium: 14,000
- Polyester: 2,000

A second possibility, which is not yet explored in great detail, is the use of recycled construction material as aggregates. Research in this field is initiated by the Netherlands Concrete Society. It is doubtful however, if such materials can ever be used in primary construction elements.

A third possibility is the use of the sea sand and sea gravel in greater quantities than is done at present. It is an interesting exercise to investigate whether or not marine mining is more acceptable from an environmental point of view than mining from land, and if a clear conclusion can be drawn whether or not the public will accept it.
4. **Mining of sand and gravel from the sea.**

The large quantities of sand and gravel can be dredged in principle in two different ways:

a) By dredging a relatively thin superficial layer of material from a large area.

b) By dredging material in thick layers from concentrated areas.

Method a) is followed nowadays for sand and gravel mining at sea. Here, trailing suction hopper dredgers are used because of their good seaworthyness. These dredgers are basically seagoing vessels that trail one or two suction pipes over the bottom. The thickness of the layer removed is 0.1 to 0.3 m. The tracks of the dragheads can be controlled to a reasonable degree, but the horizontal accuracy in the high seas will not be much better than 10 m, unless special measures are taken. The maximum dredging depth is 25 to 30 m.

The quality of the material pumped on board is controlled by acoustic methods.

A consequence of the use of trailing hopper dredgers is the disruption of biological life in a vast area. On the other hand, the dredging will not be 100% effective over the whole area, so that nuclei of biological life remain intact, from where dissemination can follow when the natural conditions are not disturbed to much by the tailings.

Method b) is followed at present by dredging sand from inland lakes and estuaries. It is effectuated by a stationary suction dredger. For reasons of economy, the dredging depths are in general very deep.
Especially the introduction of the underwater pump has allowed dredging depths between 70 and 100 m. Obviously the conditions at the bottom of such deep pits differ considerably from the original conditions. The effects, however, are limited to a relatively small area, since the depth is so great. With the modern techniques it is possible to adapt the stationary suction dredger for work in the North Sea.

5. Reducing the environmental effects

A) Rehabilitation of borrow pits

On land, there is a tendency to issue strip mining licenses only if the borrow pits are rehabilitated after use. This rehabilitation can either consist of refilling the pits with inferior material, or to landscape them. To my knowledge similar techniques are not yet foreseen for marine mining. Still, the possibilities are available. As fill material one can consider to make a productive use of the huge masses of mud that are dredged (and dumped) to maintain the major harbours. To give an impression of quantities involved: from Rotterdam Harbour, including Europoort, annually approximately $20 \times 10^6$ m$^3$ of material is dredged.
B) **Technical measures**

One of the best visible results of the dredging operations is the increased turbidity. Although it is not clear beforehand that a temporarily increased turbidity is harmful, technical measures have been proposed to solve this problem.

Two methods have been proposed recently:

1. Design of overflow weirs in such a way that no air is entrained. In this way the tailings will settle rapidly as a density current.

2. Extension of the overflow to greater depths by means of a special discharge pipe.

6. **Conclusion**

The dredging industry is prepared to follow environmental recommendations by institutes like ICES and others. In many cases however, there are no clear recommendations or they point in different directions. In those conditions, it is very difficult for the dredging contractor to decide what to do.

Because of the fierce competition he will often be forced to select the cheapest solution.

The industry in general, however, and certainly the larger companies, is prepared to develope and introduce working methods that keep damage to the environment within reasonable limits. It is even in the interest of the ecology-conscious companies that clear and uniform regulations are introduced to prevent unfair competition at the expense of the environment.

Rotterdam, 5th March 1979

Ir K. d'Angremond.