Preliminary Evaluation of Impacts of Sand Extraction Near Iles-de-la-Madeleine Archipelago, Québec, Canada

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ABSTRACT


This paper assesses the potential sedimentological impacts of an inner-shelf sand extraction project near the Iles-de-la-Madeleine archipelago, in the central Gulf of St. Lawrence. Commercial extraction of nearshore aggregates is a growing industry around the world, but sound techniques to evaluate its impacts on local physical environment are still scarce.

A review of the potential impacts is first presented, based mainly on European experience. Criteria related to impacts, developed for conditions prevailing in the North Sea or in the Gulf of Gascogne (France), are adapted to meet the more moderate hydrodynamic and sedimentologic conditions of the Gulf of St. Lawrence. It is found that modifications to the wave refraction patterns due to bathymetry changes is the dominant criterion here. Excavations are then designed to limit these modifications in such a way as the resulting littoral drift changes are kept within bound specified after the local sediment budget.

ADDITIONAL INDEX WORDS: Marine aggregates, nearshore extraction, sediment transport, wave hindcast.

INTRODUCTION

The constant increase in the need for aggregate material, combined with a desire to protect local ecosystems, has forced industries to seek other sources of sediment, including sources on the continental shelf. In this specific field, the Japanese are the world leader with over 900 ships extracting between 60 and 70 million tons of aggregate each year (PADAN, 1983), which represents around 20% of their national production. All together, the European countries apply a fleet of 80 ships to the same task, producing around 30 million tons of sediment annually. For example, PRICE et al. (1978) estimate that 11% of England's aggregate supplies (15 million tons yearly) are dredged materials.

In North America, the exploitation of sea deposits is not as generalized as elsewhere. The United States has tended to delay intensive exploitation of its shelves, in order to prevent potential negative impacts (PADAN, 1983). The same situation has prevailed in Canada, except in the Beaufort Sea where in 1982 alone 15 million tons of aggregate was dredged to satisfy the requirements for offshore petroleum exploration activities. But commercial extraction may progress more rapidly since important deposits have recently been identified, especially along the east coast (DRINNAN and BLISS, 1986).

Near-coast dredging operations must be undertaken with caution in order to avoid inducing perturbations to the sedimentological equilibrium of the area. MIGNIOT and VIGUIER (1980) report a shoreline erosion rate of 15 m/a due to intense sand dredging near a French coast. One can easily imagine the economic and social consequences of such mismanagement.

Project Description

The Iles-de-la-Madeleine archipelago (Figure 1) essentially consists of seven bed-rock islands, linked together by sandy barrier beaches. The local sand, originating mainly from the gradual erosion of rocky cliffs and sandy beaches, is transported by wave action, ultimately to one of the two spits: Sandy Hook in the south, and...
Figure 1. Localization of Iles-de-la-Madeleine archipelago. The sandy beaches are shown with a dot pattern and the potential dredging sites with dash lines.
Pointe de l'Est to the northeast where the mean accretion rate is estimated to reach 14 m/a (MERCIER, 1987). A Canadian company owns the right over two potential dredging grounds near these spits, where sand proves to be silica rich.

One of the leading constituents of the archipelago economy is fisheries, especially lobster. Before dredging operations may begin, the company must prove to the government officials that the exploitation will not affect the fragile biota and physical environment of the islands. Only the second part of the impact study is assessed here.

The first dredging site (Figure 1), located between Sandy Hook and Entrée Island, is 16 km² in area, and the second one, located off Pointe de l'Est, extends over 30 km². The company wishes to progressively increase its annual dredging volume from 500,000 tons to 1,000,000 tons, using a trailing suction hopper ship (i.e. working in a non-stationary mode). This technique leaves a continuous 10 cm deep excavation along the ship's path, and so has only a slight impact on local bathymetry. The ship considered for the operation draws 10 m of water, for an overall capacity of 20,000 tons per trip. The silica rich sand would then be unloaded at Gaspé, to be treated for the glass or the cast iron industries.

The hydrodynamics and sedimentological setting of the area are first described, then potential impacts, based mainly on European experience, are reviewed and adapted for the Gulf of St. Lawrence environment. Special attention is given to wave refraction pattern modifications due to bathymetry changes, and its indirect impact on local littoral drift. Excavations are then designed to limit these modifications in such a way as the resulting littoral drift changes are kept within bound specified after the local sediment budget.

HYDRODYNAMICS

The hydrodynamics of the Iles-de-la-Madeleine archipelago is largely dominated by wind-waves resulting from the frequent storms prevalent over the Gulf of St. Lawrence area. Tidal effects do not play an important role near the archipelago, due to the presence of a semi-diurnal amphidromical point some 50 km to the southwest (FORRESTER, 1983). Data collected at the proposed dredging sites (Endeco 110 currentmeter) showed the tidal current to be generally weak, with maximums reaching 40 cm/s. Such currents have some impacts on sediment movements at the bottom and on the settling of the overflowed fine particles from the vessel, but since current speed slows down rapidly near the coast, this parameter has only a small influence on littoral drift.

Wave Hindcasting

The only wave measurements available are three six-month data sets collected in 1974, 1975 and 1976 from a Waverider buoy installed a few kilometers off Pointe de l'Est (MEDS, 1976). Since local wave characteristics cannot be reliably estimated from such scarce information, they are hindcast instead from wind data. The model used here is based on the parametric relations of the SMB method (DESJARDINS and OUELLET, 1984).

In the present project, hindcast estimates were derived from wind data collected at the Cap-aux-Meules Island climatological station, operated by Environment Canada. The instruments were located 500 m inland, near the summit of a 65 m high hill. The land slopes rapidly on each side, leaving excellent exposure to wind from all directions. The highest summit in the area reaches 165 m some 4 km west of the station. The station was closed in February 1983.

The hindcast and measured waves at Pointe de l'Est are in good agreement (Figure 2), suggesting that wind speed corrections are unnecessary. Note that the comparison is less satisfactory for the smaller wave heights, due mainly to the presence of swell which cannot be handled by the model. Wave directionality cannot be verified because the Waverider buoy does not measure the directional component of wave motion. Finally, waves are hindcast for both sites, using all the wind data available (1953 to 1982). Note that the shore of the archipelago is generally packed with ice from December 15 to April 15, so only the eight-month ice-free period is considered here.

Wave Propagation

Wave height and direction may vary considerably from deep water to their breaking point near shore. A second model is used to estimate
these parameters in accordance with local bathymetry. It is based on the radiation theory which considers the combined effects of refraction, shoaling and energy loss due to friction and infiltration (DESJARDINS and OUELLET, 1984). This theory is still one of the simplest ways to consider these phenomena (HEADLAND and CHU, 1984). Its validity is comparable to the much more complex "mild slope equation" if its assumptions are respected, namely a simple bathymetry and negligible reflection and diffraction, such as the case here.
SEDIMENTOLOGICAL SETTING

The Iles-de-la-Madeleine archipelago is surrounded by a gentle slope shelf, composed of numerous sand deposits, of variable depth, and some rocky outcrops. LORING and NOTA (1973) proposed a map which summarizes the area's sand characteristics (Figure 3). Both dredging sites are located in zone 3, dominated with medium to coarse sand from 0.25 to 2.00 mm. This zone extends from the islands' shoreline to about 20 m depth, except in the northern part where it reaches 40 m depth.

The archipelago sediment budget has only two sources: (1) the coast (sandy dunes and rocky cliffs alongshore), and (2) the surrounding shelf. Waves, and to a lesser extent, winds and currents initiate sand movements. When waves progress toward shore, they produce a shearing force which entrains bottom sediments. When they break obliquely nearshore, they generate littoral drift. This activity is not regular, but is concentrated mainly during storms, when cliffs and dunes undergo severe attack. At these times, sediments are also mobilized on the shelf.

OWENS (1974) measured sand distribution at various sites along the dunes and barrier beaches of the archipelago. His results show that sediment characteristics are quite similar from place to place. Iles-de-la-Madeleine sediments can be characterized as well-sorted medium sand of about 0.25 to 0.30 mm diameter.

Sediments at both sites are characterized as follow: well-sorted sand of about 0.25 mm, with percentage of finer particles increasing with water depth. Since the glass industry uses well sorted silica rich sand, from 0.5 to 0.1 mm, the deeper parts of the dredging area are of no use, because it contains too many fine particles. These later deposits are, however, acceptable for cast iron industries, which use silica rich particles as fine as about 0.07 mm.

Figure 4 presents the two proposed extraction areas. Since the 20,000 ton trailing suction hopper ship draws 10 m of water, only a portion of the proposed area is, in fact, exploitable. Even then, sediments found in some sub-areas does not meet the standards of the glass or the cast iron industry. Overall, there is only an area of 2.8 km² of valuable sediments for this project at Sandy Hook, from which 2.4 km² is suitable for casting and 0.4 km² for glass industry. The availability of sediments is much larger at Pointe de l'Est, with a corresponding area of 13.0 km², from which 5.1 km² meets the needs for the glass industry and 7.9 km² for the cast iron industry.

Sediment Transport

Accretion and erosion rates along the Iles-de-la-Madeleine coast have been quantified from maps and aerial photographs covering the period 1963 to 1977, and from over 200 beach profiles (DRAPEAU and MERCIER, 1987). In this way, the sediment budget of the archipelago has been established, assuming that the long-term persistence of an island implies a balanced budget; otherwise it would be unstable, either diminishing or increasing in size indefinitely. The overall erosion rate of 300,000 m³/a (dune and barrier beach only) is found to be counterbalanced by an equivalent overall rate of accretion. Cliff erosion is, however, estimated to reach 60,000 m³/a, so the budget is not balanced.
Figure 4. Sedimentological description, (A) Sandy Hook, (B) Pointe de l'Est. Dashed zones represent areas of sand suitable for glass production, and dotted zones for cast iron production.
in perfect equilibrium; the rocky islands erode slowly to the benefit of the shelf.

Note that the cliff erosion rate is based on a 0.10 m/a retreat (DRAPEAU and MERCIER, 1987). An evaluation of this phenomenon, performed from cadastral surveys at Cap-du-Dauphin, revealed a retreat rate of 0.35 m/a. But, since this area is exposed to some of the worst wave conditions of the archipelago, a 0.10 m/a value seems like a reasonable approximation for the islands as a whole.

Near the dredging sites, the results are as follows (DRAPEAU et al., 1987). At Sandy Hook, the littoral drift progresses northeastward (Figure 5a). On the south side of the hook, 111,000 m$^3$/a comes from the west, of which 98,000 m$^3$/a reaches the tip, leaving some 13,000 m$^3$/a along the spit dunes. The other side contributes 37,000 m$^3$/a to the tip, for a grand total of 135,000 m$^3$/a. However, DRAPEAU et al. (1987) consider the exchange between the Baie de Plaisance shelf and shore to represent a loss of 89,000 m$^3$/a for the shelf, thus leaving only 46,000 m$^3$/a of supply to the nearby shelf.

The Pointe de l’Est littoral drift progresses in a clockwise motion (Figure 5a). Some 39,000 m$^3$/a enters the area from the west side (not shown on Figure 5a), to which 108,000 m$^3$/a is added from intensive erosion of the northern part of the spit. On the southern side, considering an overall accretion of 136,000 m$^3$/a and that no sediment can go further down the coast (being blocked by Pointe Old Harry), 11,000 m$^3$/a is supplied to the nearby shelf.

Sandy Bars and Dunes

Bars and dunes protect the coast from severe wave attack by forcing wave breaking, partial wave reflection and energy losses by friction. It is quite obvious that the dredging of such bars and dunes would disable their protective capacity, increasing erosion of the formerly protected shore.

Direct Shore Erosion

Offshore-onshore sediment transport may play an important part in limiting coastal erosion. During storms, sediment is drawn into deeper water where it tends to form bars or dunes which, in turn, protect the coast from continued erosion. During calmer periods, these particles are pushed back toward shore. If the dredging site is located somewhere within this active region, it will interfere with the process and cause significant shore erosion.

Beach Drawdown

MIGNIOT and VIGUIER (1980) physically modeled the sedimentological evolution of dredged excavations located at depths of 7, 12, 16 and 21 m. Test wave conditions were in similitude with storms regularly prevailing in the Gulf of Gascogne, France, and lightweight particles were scaled down to react as 0.25 mm sand. No particle movement was noted until a critical wave height was reached. The sides of the excavation then began to fall in, the erosion being greater on the shoreward side. Under even larger wave conditions, ripples began to appear and the excavation started to fill, with shoreward erosion always greater than seaward erosion.

MIGNIOT and VIGUIER (1980) conclude that excavations in 6 and 11 m depths can directly lead to beach drawdown. While this phenomenon is less active at the 16 m depth, excavations beyond 21 m depth are recommended.

Shoreward Sediment Movement

CRICKMORE et al. (1972) and MIGNIOT and VIGUIER (1980) present studies, using radioactive tracers, on sediment transport under different hydraulic conditions. Their results can be summarized in two statements: (1) 7 m waves have almost no impact in depth greater
Figure 5. Sediment budget, (A) Sandy Hook, (B) Pointe de l’Est. Arrows indicate drift paths, numbers are in thousand cubic meters per year.
than 30 m and only a small impact at 20 m; and (2) in depth less than 15 m, onshore sediment transport induced by wave action becomes increasingly important.

These results considered only waves perpendicular to the coastline and a regular bottom of gentle slope. Littoral drift effects are therefore not included. Considering those limitations, a dredging limit of 20 m depth seems reasonable. However, DRINNAN and BLISS (1986) report more recent studies that tend to show that these results are conservative.

Wave Refraction Patterns

Littoral drift is a function of the wave height and direction at breaking. Modifying the bathymetry by dredging may have a direct impact on wave parameters, and consequently an indirect impact on the littoral drift and on the sediment dynamics of the coast. MOTYKA and WILLIS (1974) studied this phenomenon with a model combining wave propagation and shoreline evolution. In particular, they investigated the impact of different dredge holes on a straight beach of infinite length, confronted with the prevalent wave conditions in the North Sea. Their results show that the distance from the shoreline (water depth) and, to a lesser extent, the excavation depth are the two parameters governing the sedimentological response of the coast. The length and the width of the dredge hole are not as important. The critical water depth was estimated to be 14 m, but the depth of excavation should be kept to a minimum as it is the source of refraction pattern modifications.

Adaptation of the Criteria

Most of the criteria presented herein are valid for the specific conditions prevalent in the North Sea or in the Gulf of Gasconne. However, wave action at both Iles-de-la-Madeleine dredging sites is less severe. The criteria proposed are therefore too conservative for this project.

The first criterion controls sand bars and dunes extraction. According to BOCZARKARAKIEWICZ et al. (1987), the Iles-de-la-Madeleine coast is surrounded by a sand bar system which extends to a depth of 3 to 5 m. Considering that those bars play a dynamic role in shore processes, it is not advisable to dredge shoredward of this point.

The second criterion can be rephrased this way: the dredging site must not be located in a sedimentologically active zone. This avoids beach drawdown and interference with sediment transport towards the shore. HALLERMEIER (1978; 1981) proposed a limit, based on the wave climate, where the wave shearing forces on bottom sediment are important enough to cause profile fluctuations. For both sites, following Hallermeier, an 11 m depth limit is obtained with the hindcast waves. Dredging beyond that limit should then be performed with particular caution.

Finally, the last criterion concerns the possible modifications imposed on the refraction pattern by dredging. This particular point needs to be studied through a model combining wave propagation and littoral drift phenomena, as each site has its own specific bathymetry. The extraction of sand can then be planned in such a way as to prevent major damage to the shore. However, considering that exact sedimentological modeling is still not feasible without a great deal of field data, it is advisable to be extremely cautious when quantifying the impact of commercial dredging on a shoreline, and to plan the exploitation so that it interferes as little as possible with local sediment dynamics.

SEDIMENTOLOGICAL CONSEQUENCES OF EXTRACTION

With a ship drawing 10 m of water, sand bar extraction is not possible. Direct erosion is not a potential problem either because the 11 m limit determined above can barely be reached by the vessel. Refraction pattern modifications due to bathymetry changes induced by the extraction must, however, be controlled.

Modeling Littoral Drift

Many formulations have been proposed to model littoral drift. The approach adopted here is based on the work of INMAN and BAGNOLD (1963) and KOMAR and INMAN (1970) which relates the drift rate to wave energy at breaking (DEJSARDINS and OUELLET, 1984). This method has two shortcomings: the across-shore distribution is not estimated, and the local drift

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rate does not account for sediment availability. In other words, the model needs to be calibrated with field data. Note that the breaking criterion relies on the formulation of WEGGEL (1972), and that a breaking wave is considered sedimentologically active only if it has previously crossed a limit proposed by HALLERMEIER (1978; 1981).

In both locations, the bathymetry has been modified to simulate 20 years of extraction, according to three different schemes. Considering that on-site sand has a bulk density of 1,900 kg/m³, around 0.53 m³ of sediment is needed to yield one ton. With an anticipated capacity progressing gradually from 500,000 to 1,000,000 tons per year over the first 10 years, and constant at 1,000,000 tons for the second decade, the estimated total reaches 17,700,000 tons, or 9,400,000 m³ of on-site sand.

**Scheme 0**

No dredging has yet occurred. Figures 6 and 7 present the calibrated littoral drift values and directions for Sandy Hook and Pointe de l'Est respectively. To facilitate the comparison between the different schemes, two summary values are estimated for each site (Table 1). The net value takes into account the direction of littoral drift, and the gross value represents the overall rate of displaced sediment. The summary values are means of the littoral drift results, presented schematically on Figures 6 and 7. This evaluation is achieved in order to compare with DRAPEAU et al. (1987) results which also represent mean drift along a specified shoreline. In other words, calibration is achieved over the whole region of interest, and not segment by segment.

**Scheme 1**

Bathymetries are modified to take into account 20 years of extraction. For this case, only sediments suitable for the cast iron industry are considered. A 1 m thick layer of sediments is extracted over 2.4 km² at Sandy Hook and over 7.9 km² at Pointe de l'Est, which provides 10,300,000 m³ of sand; even more than needed. Littoral drift rates are presented in Figures 6 and 7, and summary values are provided in Table 1. It appears that the Sandy Hook littoral drift is not significantly affected by the change in bathymetry; however, at Pointe de l'Est, the net drift is increased by 15%, though without much change in the gross values.

**Scheme 2**

Here, the extracted volume is equally partitioned between the two sediment categories. A 2 m thick layer of sand is removed at Sandy Hook over the 2.4 km² area of cast iron sand, and 1 m is dredged in the 5.1 km² area proper for the glass industry, giving a total extraction of 9,900,000 m³. The Sandy Hook littoral drift is increased by 15%, and the Pointe de l'Est drift is more or less the same as scheme 1 (Figures 6 and 7, Table 1).

**Scheme 3**

This scheme only exploits sand suited for the needs of the glass industry. A 2 m thick layer is extracted over the 5.1 km² available at Pointe de l'Est, giving a total volume of 10,200,000 m³. No sediment is dredged at Sandy Hook. The net littoral drift is increased by about 30%, even if the gross value diminishes slightly (Figure 7, Table 1).

**IMPACTS**

The economic viability of the project is founded on the exploitation of both sediment categories. Thus, because of economics, only the second scheme has a high chance of occurring. However, schemes 1 and 3 are presented in order to consider the extreme cases. Sedimentologic impacts are either nil or negative. No positive impact is found for this specific project. Negative impacts are further subdivided into minor, medium or major, depending on the repercussion of the modified littoral drift rates on the local sediment budget.

**Sandy Hook**

The results presented in Table 1 lead to the following conclusions, if they are compared and integrated in the sediment budget of Figure 5a. Remember that 13,000 m³/a, of the 111,000 m³/a eastbound littoral drift, is left along the dunes, and that 98,000 m³/a reaches the end of the spit. If the Sandy Hook littoral drift is increased, more sand will be pushed to the tip,
Figure 6. Net littoral drift at Sandy Hook.
Figure 7. Net littoral drift at Pointe de l'Est.

Table 1. Mean littoral drift values (m$^3$/a).

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<thead>
<tr>
<th>Scheme</th>
<th>Sandy Hook</th>
<th>Pointe de l'Est</th>
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<td>109,000</td>
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<td>3</td>
<td>97,000</td>
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to the detriment of the actual 13,000 m$^3$/a accretion rate along the spit length.

The first scheme presents no significant variation of the littoral drift (Figure 6), so one can conclude that a 1 m deep excavation will cause negligible or minor impact. On the other hand, the second scheme produces a net drift increase equal to the actual accretion rate along the spit length. Considering that extraction would take
place over a 20 year period, sufficient time is provided for adjustment toward a new coastal equilibrium. Consequently, it is felt that a 2 m deep excavation will imply a medium negative impact. However, any excavation deeper than 2 m would produce erosion along the spit length—a major negative impact. This statement remains to be verified more thoroughly.

Pointe de l’Est

The excavation near Pointe de l’Est only affects the sediment transport of the southern part of the spit. Remember that this region is actually experiencing major accretion (Figure 5b) and that the shoreline near the tip is estimated to progress 14 m offshore per year (MERCIER, 1987). A modification of the actual west-bound drift would only affect the distribution of the accreting sediment along the spit, as no sand crosses Pointe Old Harry at the southern end of the area.

Schemes 1 and 2 can be treated simultaneously because they yield essentially the same results: a 15% net drift increase (Figure 7). This increase, concentrating mainly near the tip of the spit, will simply transport a part of the accreting sediments a little further west before settling. Thus a 1 m deep excavation at either sub-area near Pointe de l’Est will imply a minor negative impact. On the other hand, the third scheme generates a 30% drift increase, with a local increase of 100% near the end of the spit. The impact of the last scheme is more difficult to establish because the increase is such that the present budget may be affected considerably. So a 2 m deep excavation in the “glass” area will cause a major negative impact, even if the period of 20 years should leave time for coastal adjustment.

CONCLUSION

The three schemes analyzed here do not represent all the possible options, but were designed to better understand the impacts of different excavations and to point towards an overall solution which would cause the least impact to the local sediment budget. Simple and uniform excavations were used because one should not overestimate the reliability of littoral drift results. Many uncertainties persist in such determinations and doubts may be raised as to the precision of the parameters used (bathymetries and waves).

A 20 year time frame was preferred to, say, a 1 or 5 year time frame, so the changes in the littoral drift results may be clearly identified. It is understood, though, that such a leap induces some errors which are acceptable from an engineering point of view.

The present project considers the extraction of about 17,700,000 tons (9,400,000 m³) of sand over 20 years, partitioned between the glass and cast iron industries’ needs. From the results of the three studied schemes, a fourth one is elaborated in such a way to limit the negative impacts to the minor category. The glass industry needs can be filled with a maximum 1 m extraction over the specified area near Pointe de l’Est, which was found to cause a minor impact. Cast iron sediments can be extracted from two different sites: a maximum 1 m deep extraction near Sandy Hook, rounded off with sediment taken in the area near Pointe de l’Est. These excavations will also show only minor negative impacts to the local sediment budget.

Further limitations of coastal impact can be achieved by regulating the extraction operation. Bathymetric modifications should be as gradual as possible, to allow ample time for the system to adjust. As the trailing suction hopper ship leaves an excavation ditch of only 10 cm, the annual operations should be planned in order to prevent multiple dredging at the same site. It is also known that coastal impact increases inversely with water depth. Dredging operation should, thus, occur in as deep water as possible.

ACKNOWLEDGMENT

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LITERATURE CITED

RESUME

Une estimation des impacts sédimentologiques d'un projet d'extraction près des côtes de l'archipel des Îles-de-la-Madeleine, situé au cœur du golfe du Saint-Laurent. L'extraction commerciale d'agregats au large des côtes est une industrie de l'état des connaissances sur les impacts potentiels de tels projets est d'abord basée sur l'expertise européenne. Des critères d'évaluation, développés à partir des conditions hydrauliques prévalant en mer du Nord et dans le golfe de Gascogne (France), sont ici adaptés pour le golfe du Saint-Laurent. Il semble que les modifications des diagrammes de réfraction, dues aux changements apportés à la bathymétrie, soit ici le critère dominant. Le dragage est donc planifié afin de limiter ces modifications, et ainsi garder les variations du transport littoral à l'extérieur de limites établies à partir du budget sédimentaire de chaque région.

ZUSAMMENFASSUNG

Dieser Beitrag behandelt die potentiellen sedimentologischen Einflüsse eines Sandentnahme-Projektes auf dem Schelf bei der Inselgruppe Îles-de-la-Madeleine im zentralen St.-Lawrence-Golf. Kommerzieller Abbau küstennaher Ablagerungen ist ein weltweit wachsender Industriezweig, aber Techniken, um deren Folgen auf die natürliche Umgebung abzuschätzen, sind erst selten entwickelt. Zunächst wird ein BERicht über die potentiellen Einflüsse gegeben, vornehmlich auf europäischen Erfahrungen basierend. Dabei werden die Kriterien, welche für die Nordsee oder den Golf von Gascogne (Frankreich) gelten, den gemäßigtären hydrodynamisch-sedimentologischen Bedingungen des St.-Lawrence-Golfes angepaßt. Es wurde festgestellt, daß Abhängigkeiten von der Wellenrefraktion, die wiederum auf wechselnde Wassertiefe zurückgeht, hier die dominierende Einflußgröße ist. Entnahmen sollten daher darauf Rücksicht nehmen, daß die natürlichen Vorgänge des küstennahen Materialtransportes nicht zu stark beeinflußt werden.—Dieter Kelletal, Essen/FRG.
RESUMEN

Este artículo evalúa el potencial impacto sedimentológico del proyecto de extracción de arenas en la plataforma interior cerca del archipiélago de Iles-de-la-Madeleine, en el centro del Golfo de St. Lawrence.

La extracción comercial en la zona próxima a la costa es una industria en crecimiento en todo el mundo, pero las técnicas para evaluar su impacto en un entorno físico localizado son todavía escasas.

Primero, se presenta una revisión de los potenciales impactos, basada principalmente en la experiencia europea. Se adoptó criterios relativos a impactos desarrollados para las condiciones que prevalecen en el Mar del Norte o en el Golfo de Gascogne (Francia), para ajustar las condiciones hidrodinámicas y sedimentológicas del Golfo de St. Lawrence. Se encontró que las modificaciones en los modelos de refracción debido a los cambios de la batimetría son aquí el criterio dominante. Las excavaciones estarán entonces diseñadas para limitar estas modificaciones de modo que los cambios resultantes en el litoral permanezcan dentro de las condiciones especificadas después de la extracción local de sedimentos.—Department of Water Sciences, University of Cantabria, Santander, Spain.