Environmental Risk Assessment: Application to a Proposed Beach Nourishment, Malta

By

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ABSTRACT

An Environmental Risk Assessment software package (ERA) was applied to the findings of an Environmental Impact Statement carried out for a proposed beach nourishment at St George's Bay located on the central Mediterranean Island of Malta. Data produced by typical Environmental Impact Assessment (EIA) studies are particularly suitable for running this type of risk-assessment tool. In addition, the ERA module was identified as an appropriate mechanism that incorporates scientifically acceptable criteria to confirm or otherwise, by semi-quantitative means, the general conclusions reached by the EIA study. The model acts on estimated probability values derived from Bayesian Theory. Two different sized sediments, fine grained (median diameter 0.17 mm) and coarse grained (2.0 mm) involving potential volumes of 13,000 m^3 and 6,500 m^3, were investigated for positive and negative performance during both construction and post-construction project phases. Findings showed a high probability (0.95) of a mild impact during the post-construction phase with fine-grained sediment as against a high probability (0.86) of a negligible impact with coarse-grained sediment. Evaluations with this model can provide greater clarity and consistency in environmental decision making processes.

Keywords: risk assessment, beach nourishment, environmental impact, decision-making tool, probability, St. George Bay, Malta

INTRODUCTION

St. George's Bay (Bajja ta' San Gorg) is located at the heart of one of Malta's largest tourist areas, being surrounded by a large number of hotels, restaurants, and recreation-related facilities (Figure 1). Because of the high level of physical development of this area, ecological considerations are generally limited to the marine environment. St. George's Bay is a small rectangular embayment, approximately 600 m long by 200 m wide, located on the north-eastern coast of Malta, which is the largest of the islands forming the Maltese archipelago (Figure 2). An aerial view of the bay (Figure 3) shows the presence of two sand beach remnants located at the north-west and south-east corners of the beach-head. A narrow and poorly elevated road runs along the back of the entire length of the bay (Figure 4).

Two sediment types (fine- and coarse-grained sand) were evaluated for the proposed beach nourishment. The fine-grained type was natural foreign sand, and the coarse grained sediment comprised crushed quarry material. H.R. Wallingford (2000) described the wave climatology. In essence, visual ship observation (VOS) data and predictions of profile change by H.R. Wallingford's COSMOS-2D model served to identify beach stability with respect to the Maltese wave climate. COS-

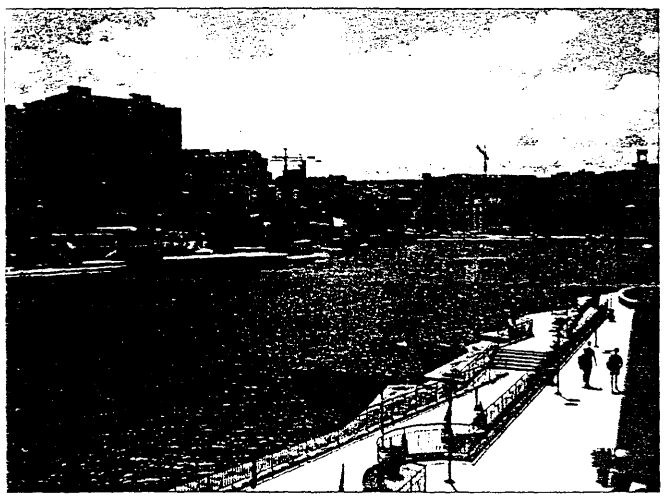

Figure 1. View of St George's Bay, Malta, showing the concentration of hotels and recreation related facilities in the area.

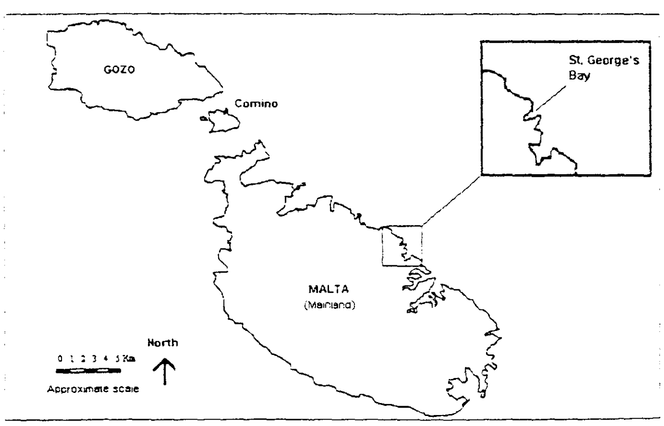

Figure 2. Map of the Maltese archipelago showing location of St George's Bay in the Maltese Islands.

Figure 3. Aerial view of St George's Bay, Malta, showing the presence of two sand beach remnants in the northwest and southeast corners of the beach-head. (Photograph taken by Project SEAWATCH, under ICoD's Remote Sensing Programmed)

MOS-2D is a computational model of wave propagation, breaking, and cross-shore sediment transport between the shoreline and the limit of wave influence. It calculates the response of the beach profile to storms as a function of time, as well as indicates whether there will be an offshore loss of beach material. Findings were:

a. Fine sediment (0.17 mm). Replenishment volume is estimated at 13,000 m^3. The beach face slope would have to be 1:25 or steeper to intercept the existing seabed without extending the renourishment for 250 m, which would require excessively large amounts of sand. In this alternative, regular replenishment of the beach would be required because of beach drawdown during storms.

b. Coarse sediment (2.0 mm). Estimated replenishment volume is 6,500 m^3. This could be placed with a slope of 1:10 which would be dynamically stable and even in extreme storm conditions, limited amounts of beach material would be drawn down to no deeper than 2.5 m below MSL.

The Malta Ministry for Tourism identified the locality as a suitable site for potential replenishment of the existing sand beach remnants. This position was subsequently formalised by the Planning Authority of Malta through the inclusion of Policy NHCV08 of the North Harbours Local Plan, first presented as a Public Consultation Draft published in April 2000 (Planning Authority, Malta 2000). In Malta, a permit for such beach replenishment is subject to the submission of a satisfactory EIA (Environmental Impact Assessment). The Euro-Mediterranean Centre on Insular Coastal Dynamics (ICoD) was subsequently engaged to carry out an EIA of this project proposal based on DoE (1995) documentation. The general aim was to weigh the

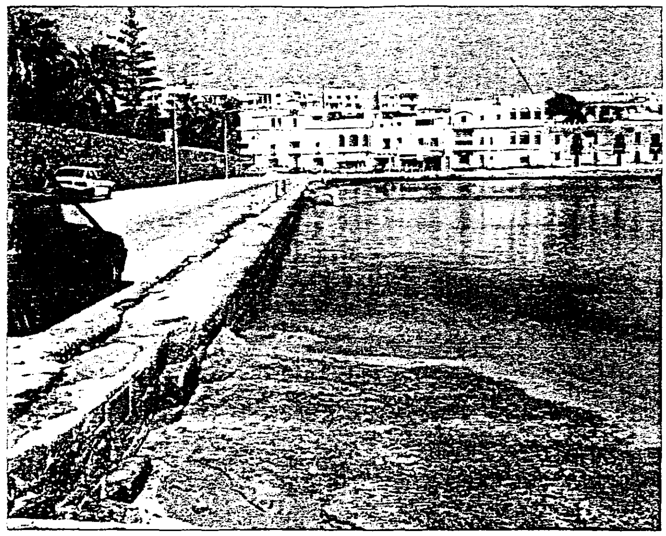

Figure 4. A narrow and poorly elevated roadway runs along the back of the entire width of the bay.

benefits accruing from creation of a more attractive and recreationally viable environment for locals and overseas tourists against any impacts on the natural environment arising from the project implementation. The long-term financial implications of such a project were also considered to be an important aspect.

Consequently, the Environmental Impact Statement (ICoD 2000) was required to consider seven main components, namely:

- A project justification and economic feasibility.
- A description of existing site.
- A project description.
- A beach modelling study.
- Identification of anticipated project Impacts.
- Development of appropriate mitigation measures.
- Development of a post-nourishment monitoring programme.

The aim of the ERA model is to formalise and document the assessment process for any proposed development, allowing judgements to be made on a case-by-case basis (ABP 1997). This process also aims to quantify the impacts as much as possible and to provide a basis on which decisions can be made in the determination of the significant effects of a project. To this end, the ERA model was applied in the proposed beach nourishment study in Malta to analyse potential impacts (positive and negative) during construction (short-term) and post-con-

Table 1. Impacts considered

Negative as arising from construction phase (fine & coarse sediment options)	Positive as arising from post-construction phase (fine & coarse sediment options)	Negative as during post-construction phase (fine & coarse sediment options)
On flora & fauna arising from sand deposition	Introduction of foreign sediment	Impact on flora & fauna
Arising from introduction of foreign sediment source	Visual impacts	Introduction of foreign sediments
Arising from pollution	Impact on local economy	Pollution
Negative visual impacts	Impacts of changes in hydrodynamics	Noise
Smoke / odors produced by engineering works	Coastal defence	Odour
Arising from excessive noise	Sewage system improvements	Increased local traffic Increased human presence
Of inadequate sewerage system	Development of new bathing facilities	Beach stability
Need to upgrade and extend existing storm water culverts	Increased beach-user satisfaction	–

Table 2. Example of ERA report for impacts considered by introduction of foreign sediment.

Impact No. 2: Introduction of foreign sediment

Impact explanation: Import of foreign sediment is necessary as there is no suitable source of sediment locally.

Consequence No. 1: Contamination by changing granulometry

Magnitude	High
Probability	High
Relevance	Yes
Risk	High

Estimated probability values for each magnitude

Severe	High	Mild	Negligible
0.20	0.55	0.20	0.05

Consequence No. 2: Palaeolontological contamination

Magnitude	Negligible
Probability	High
Relevance	Yes
Risk	Near zero

Estimated probability values for each magnitude

Severe	High	Mild	Negligible
0.10	0.20	0.40	0.30

struction (longer-term) phase.

The ABP Research ERA package is an on-line system that provides a framework for the assessment of the consequences of environmental impacts of a given project (ABP 1997). It was first developed for application in specially protected conservation areas. The ERA process aims to quantify the impacts as much as possible and to provide a basis on which decisions can be made in the determination of the significant effects of a project. This is achieved through a semi-qualitative and statistical weighting of probabilities to provide a consistent qualitative assessment of impact effects. Information regarding the proposed development and the assessment of the project's impacts and consequences is entered by the project supervisors and assessors.

METHODOLOGY

The ERA software provides a structured framework for data entry and assessment of impacts and consequences of proposed development projects; a database facility for storing project descriptions and assessments; semi-qualitative and statistical weighting of probabilities to provide a consistent qualitative assessment of impact effects; and a standard reporting format for the above results. An ERA involves an eight-step approach to risk assessment for the development project:

1. Description of Project or Plan

The description of project requires the provision of information under the following headings:

- the situation prior to development (environmental characteristics, social setting, location of sites, etc.).
- proposed development, its aims, and objectives.
- operations and activities required to carry out development.
- likely changes to operations and activities as a result of development.

2. Identification of Possible Impacts

Each feature of the development that may cause an environmental alteration is listed in the impact record (Table 1). These may be changes to physical processes and to water, soil and air quality, changes affecting an ecosystem function, potential for accidental incidents, and long term effects on the environment.

3. Identification of Consequences

For each of the impacts defined, the consequences which are likely to occur are entered (Table 2). Consequences arising from an impact may be very wide ranging, affecting the living and non-living environment directly or indirectly over the short or long term.

4. Estimation of Magnitude of Consequences (Table 2)

When estimating the magnitude of each consequence, magnitude is defined as severe, high, mild or negligible. An explanation should be given by the assessor for the reasoning behind the estimated magnitude of the consequence. In some cases, in addition to the magnitude of the consequence, a monetary value could be assigned to quantify the consequence. The magnitude is assigned to living environment as well as non-living environment.

5. Estimation of Probability of Consequences (Table 2)

For each consequence, an estimation is made for the probability of an effect that is being-realised. The aim here is to quantify as much as possibility so that the need for judgement is reduced.

6. Relevance of Consequences (Table 2)

A decision has to be made on whether a consequence affects, directly or indirectly, the habitats or species, for which the site was classified or designated.

Table 3. Matrices considering negative impacts of coarse-grained sediment during the construction stage a) all possible consequences, b) only relevant consequences.

a) Count matrix for all consequences
Based on consequence magnitude and probability ratings.

Consequence Probability	Severe	High	Mild	Negligible
High	4	3	1	0
Medium	0	1	1	0
Low	0	3	0	0
Negligible	0	1	0	0

b) Count Matrix for relevant consequences only
Based on consequence magnitude and probability ratings.

Consequence Probability	Severe	High	Mild	Negligible
High	4	3	1	0
Medium	0	1	1	0
Low	0	1	0	0
Negligible	0	1	0	0

Probability of a relevant consequence magnitude occurring
Based on estimated probability values using Bayes Theory.

Severe 0.00 High 0.85 Mild 0.15 Negligible 0.00

Table 4. Estimation of risk from consideration of magnitude of consequences and probabilities.

	Probability of relevant consequence magnitude occurring				
	Severe	High	Mild	Negligible	Sediment type
Construction Phase – NEGATIVE IMPACTS	0.0	0.99	0.01	0.0	Fine
	0.0	0.85	0.15	0.0	Coarse
Post-Construction Phase – POSITIVE IMPACTS	0.0	0.77	0.23	0.0	Fine
	0.0	0.57	0.43	0.01	Coarse
Post-Construction Phase – NEGATIVE IMPACTS	0.0	0.05	0.95	0.0	Fine
	0.0	0.0	0.14	0.86	Coarse

7. Assessment of Risk (Table 2)

For each consequence, combination of its magnitude and probability produces an estimation of the environmental risk. Estimation of risk can also be considered in more detail by assigning numerical values.

8. Overall Assessment

When the ERA technique is applied, two matrices are normally produced. The first one summarises the estimated magnitude and probability of all possible consequences, and the second matrix deals specifically with the sub-set of consequences relevant to the particular site. In comparing different project scenario options, the relevance of each impact was decided with respect to the sediment size (fine vs. coarse) under consideration. The first matrix therefore accounts for all possible consequences, and the second matrix accounts only for those consequences relevant to the particular sediment size of re-nourishment material being considered in that scenario. This was done for both construction and post-construction scenarios. An example is given in Table 3.

In applying the package, the following points were found important for assessment of impacts and consequences of a proposed development: First, at every stage, assumptions were made explicit and recorded. The intrinsic characteristics of the situation before and after the proposed development were described. In the estimation of probabilities, the event under consideration was carefully defined. Second, information regarding the proposed beach nourishment project and assessment of the project's impacts and consequences was entered by the project team based on information provided by the various sections of the Environmental Impact Statement (ICoD 2000).

To compare risks associated with the different phases of the project, and taking into account the two different sized re-nourishment materials modelled (Wallingford 2000), the ERA package was run for the following different alternatives: (1) Negative impacts of construction phase only (Table 1), using: (1a) fine (0.17 mm diameter) sediment for re-nourishment, and (1b) coarse (2mm) sediment type. (2) Positive impacts of post-construction phase (Table 1), using: (2a) fine (0.17 mm diameter) sediment for re-nourishment, and (2b) coarse (2 mm) sediment type. (3) Negative impacts of post-construction phase (Table 1), using: (3a) fine (0.17 mm diameter) sediment for re-nourishment, and (3b) coarse (2 mm) sediment type

An example of impact-consequence consideration is given in Table 2. No positive impacts could be identified during the construction phase.

RESULTS AND DISCUSSION

Few studies have as yet utilized this methodology. It has been applied in the UK by ABP (1997) to investigate potential dredging in a conservation area and by Williams et al. (2000a) who looked at a breakwater construction in a different conservation area. Summarized results of the analyses for St George's Bay are described in a probability table (Table 4).

Considering the values obtained for the probability of negative impacts during the construction phase (Table 3), the probability of a high negative impact arising from the use of the coarse sediment was found to be less than that associated with use of the finer grained sediment (Table 4). This can be attributed to higher turbidity levels and to the possible risk of palaeontological contamination associated with placement of the fine-grained sediment as replenishment material.

For the post-construction phase, the probabilities of positive and negative impacts were considered in separate analyses. The likelihood of a high positive impact was reduced for the coarse sediment option compared to the fine-grained sand (Table 4). Beach user preferences for finer beach sands from an amenity point of view may be one of the major parameters influencing this outcome. This has been shown to be the case in many coastal research studies (e.g., Micallef et al. 1999; Williams et al. 2000b; Morgan et al. 1996).

A significant decrease in the probability of a negative impact occurred if coarse sediment was substituted for the fine material (Table 4). The shift was from a high probability (0.95) of a mild impact with fine sediment, to a high probability (0.86) of a negligible impact if the coarse sediment was used. The negative impact for the fine sediment is largely related to the environmental impacts resulting from smothering of a large area of benthic habitats and the economic aspects associated with severe sediment losses predicted for storm events.

CONCLUSIONS

The ERA findings reported in this paper supported the findings of the Environmental Impact Statement (ICoD 2000) and indicated that the mitigation of the proposed project's main impacts may be successfully achieved through the choice of a coarse grained sediment as replenishment material. The main findings were:

The ERA model was identified as a particularly suitable risk assessment tool for application to EIA studies. There was a high probability (0.95) during the post-construction phase of a mild negative impact by utilisation of fine-grained sediment. A high probability (0.86) during the post-construction phase of a negligible negative impact occurred if coarse-grained sediment was placed. Placement of coarse rather than a fine sediment fill material increased the probability of positive impacts from 0.57 to 0.77 during the post-construction phase. This model can provide greater clarity and consistency into environmental decision-making processes.

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