# Operational forecast methodology for submarine outfall management: application to a Portuguese case study

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## Summary

Coastal waters are an integral part of the natural environment. Careful planning and management is needed to protect and conserve them, and to ensure that the water supply is useful for a variety of uses.
Submarine outfalls for effluent disposal are used to ensure that the water quality is maintained and that the environmental values and water uses are protected.
Decision on treatment and disposal is based on objectives set by national and international legislation and on coastal and maritime uses identification.
An operational forecast methodology is proposed for the management of submarine outfalls providing information to deal with the marine environment problems and to satisfy needs at different levels for coastal communities.
From a management perspective the forecast methodology will support decision making by predicting where a discharged plume is likely to be transported over a few days from its last known location.
Short-term forecasts of maritime climate and hydrological conditions along with foreseen effluent characteristics (depending on seasons and population equivalent) of the studied region are used for an accurate estimation of the effluent plume advection and diffusion processes near the coastline.
The operational forecast methodology, continuously evaluating the plume behavior and its relation with the protection perimeter (identified through a coastal usage map), allows the implementation of a precautionary and adjustable management of the submarine outfall. Corrective measures (e.g. increase dilution, increase the number of outlets, increase outflow speed) may avoid possible operational disruptions and minimize potential water quality impacts.
To illustrate the application of the procedure, a submarine outfall case study located in the Portuguese coast is analysed.

## Keywords

*Submarine outfalls, failure modes, operational forecast methodology, management*

### Introduction

Wastewater management is a result of cultural, environmental, political and economic factors, among others. Submarine outfalls, encountered in the final step of the effluent treatment, are one of the most important sanitation infra-structures used nowadays, mostly in countries where the coastline is extensively developed for housing and industry, being almost inevitable that the chosen places for the final effluent disposal will be the sea and the estuaries.
The project of submarine outfalls is a complex problem for solving because equal significance should be given to the environment, economy and social aspect of the problem requiring: i) investment costs and permanent operating costs; ii) sensitive management, since solutions are directly related to the environment and population; iii) long-term resolutions, since implementation of problem solution and expected improvement of environment conditions are slow, while monitoring measures should be carried out constantly [1].
For a variety of reasons, these structures may lose their resistance (loss of safety), structural capacity (loss of serviceability), and/or operational capacity (loss of exploitation). This may occur either suddenly or gradually, temporarily or permanently, partially or totally. One of the main objectives of the project design is to ascertain that the proposed structure will be reliable with regard to safety, functional with regard to serviceability, and operational with regard to use and exploitation. For that reason, values or target levels of reliability, functionality and operationality should be specified beforehand [2]. The construction and maintenance costs of the structure, as well as its use and exploitation, depend on all of these elements during its useful life.
The risk management of the project of submarine outfalls focusing on the design work and predictive studies on effluent discharges [3], which may trigger important failure modes, provides a rational and systematic procedure for automatic and optimal design of submarine outfalls, granting a cost optimization of submarine outfall projects, preventing accidents with these structures and their environmental dramatic consequences.

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The economic, social and environmental repercussions produced when the structure stops functioning or reduces its operational level are specified by means of its operational intrinsic nature [4]. This is evaluated by selecting the mode, from among the principal modes of operational stoppage, which gives the minimum operational level [2][5]. Operational limit states include the stoppage modes that cause loss of use and exploitation without the occurrence of a structural or functional failure.

In order to achieve appropriate discharge management, the authorities and the entities that are developing and managing submarine outfall installations should be provided with appropriate tools to improve discharge efficiency and to increase the effectiveness of effluent dilution into the sea.

**Aim and Scope of the Paper**

The main purpose of this paper is to present the methodology to develop a tool for the operational management of submarine outfalls that provides information in real time about the conditions of the receiving medium using this information to predict the behaviour of the plume near the coastline, which will allow an adaptive management in the operationality of these structures. Additionally, when fully developed can also be used as a powerful alert and information tool for authorities, companies operating the installations, and the pertinent environmental authorities.

First, the **failure modes** related to the operational limit states of these structures are identified and characterized. An **environmental failure effect** is chosen and its compliance with the European and Portuguese **legislative framework** is described. The importance of identifying **coastal and maritime values** is outlined. A procedure is presented to **forecast at daily-bases the plume** behavior of submarine outfalls near the coastline. The developed methodology is illustrated with the submarine outfall of **Vale de Faro**.

**Operational Failure Modes**

Sound design, available protective measures and regular maintenance and monitoring programs contribute to the adequate functioning of submarine outfalls, which present among their principal benefits low operating and maintenance costs, ability to cope with significant seasonal variations in flow and to obtain an effective dilution that is normally enough to prevent negative effects due to the discharge of organic matter and nutrients.

Nevertheless, in some cases submarine outfalls have presented low performances due to maintenance problems, damage by winter storms and sailing and fishing vessels, among others.

The main operative failure effects/modes and causes in submarine outfalls are represented in Table 1, including modes that cause loss of use and exploitation without the occurrence of a structural or functional failure.

This study focus on the environmental failure effects of submarine outfalls related to the inefficient plume dispersion. The environmental values considered are aquatic ecosystem and recreational activities (including aesthetics).

The aquatic ecosystem environmental value relates to the intrinsic value of the aquatic ecosystem, including flora, fauna and habitat. This value is preserved by protecting the water from risks that harm the ability to support and maintain a balanced community of aquatic organisms.

The recreational environmental value relates to the suitability of water for recreation, such as swimming, surfing, diving, water-skiing, wake-boarding, boating and fishing.

Moreover, the location of major recreational coastal zones (i.e. areas with high levels of recreational activities, mostly surrounding highly populated shack areas and campground locations) and sensitive areas in terms of fauna and flora have to be identified for a suitable management of submarine outfalls.

Different environmental values require different types and levels of water quality protection. The current legislative framework provides a context for the establishment of codes of practice to minimize water quality risks, management and control of point and diffusive sources of pollution and water criteria, discharge limits and listed pollutants.

Table 1. Operational failure modes for submarine outfalls.

| FAILURE EFFECTS | FAILURE MODES | CAUSES | ROOT CAUSE |
|---|---|---|---|
| Hydraulic | Pipe Obstruction | Flows that exceed outfall capacity<br>Blockage by marine growth in the upstream pipe.<br>Action by nets and solid objects.<br>Changes in effluent composition: minimum velocities required for self-cleansing not respected.<br>Malfunction of the self-regulating valve.<br>Air intrusion: pipe curvatures, high slopes that influence additional sedimentation and air accumulation. | Improper equipment maintenance<br>Design deficiency<br>Changes in effluent composition<br>Poor control procedures |
| Hydraulic | Diffuser Clogging/ Obstruction | Blockage caused by marine growth or greasy substances around and inside the diffuser reducing partly or totally the flow section.<br>Sea water intrusion. | Improper equipment maintenance<br>Poor control procedures<br>Low flux periods<br>Sea water and effluent density differences |
| Hydraulic | Risers Obstruction | Blockage by marine growth or greasy substances. | Improper equipment maintenance<br>Poor control procedures |
| Environmental | Inefficient Plume Dispersion | Insufficient dilution, insufficient dispersion.<br>Offensive matter in effluent.<br>Effects of currents and wind. | Design deficiency<br>Installation errors<br>Improper equipment maintenance<br>Poor monitoring measures |
| | Exceedance of Legislated Values | Extreme events (e.g. high rainfall).<br>Effects of currents and wind. | Poor monitoring measures<br>Design deficiency<br>Improper equipment maintenance |
| Hydraulic | Manholes Surcharging | Supercritical velocities → hydraulic jumps → pipes flowing full | Design deficiency |
| Hydraulic | Buoyancy due to Liquefaction | When soil liquefies, it behaves like a thick fluid; the pipe embedded in it will be subjected to the buoyant force from below. | Design deficiency |

**Compliance with the Legislative Framework**

Instruments for water resource management have an important role in preventing water-related conflicts, through assessing the resource's spatial and temporal variability on coastal areas. It is therefore important to follow the water policy in order to promote more adequate land use and better protection of water quality and associated ecosystems. In this context, it is also important to relate and integrate water resource management with the prevention of and protection against extreme hydrological conditions. The management of submarine outfalls is tied to:

- **Exceedance of threshold values**: related to the agents of the physical environment (climatic agents);
- **Unacceptable environmental effect or social repercussion**: stoppage modes carried out to avoid damage to people, historical and cultural heritage, and environment;
- **Legal constraints**: stoppage modes carried out to fulfil legal requirements.

Legislation of particular relevance implemented in Portugal is outlined in Table 2.

According to the legislative framework, submarine outfall monitoring focuses on eight critical stressors/constituents: salinity, pathogens, nutrients, turbidity, heavy metals, natural and organic material, hydrocarbons and pesticides. These eight constituents can be evaluated within the context of four different environmental measurement areas: effluent, water column, sea floor environments, and fish and shellfish. Table 3 resumes the stressors considered along with their potential effects on the aquatic system and recreational environmental values.

Table 2. Water and Wastewater Management Legislation for Portugal.

| Legislative Framework | |
|---|---|
| **1987** | **Law 11/87:** 'Environmental Basis Law' |
| **1990** | **CD 90/71:** Pollution protection of waters, beaches and margins |
| **1991** | **CD 91/271/EEC**: urban waste-water treatment<br>**CD 91/676/EEC**: protection of waters against pollution caused by nitrates from agricultural sources<br>**CD 37/91, 18 May**: Cooperation Agreement for the protection of the coasts and waters of the north-east Atlantic against pollution |
| **1993** | **Resolution of the Council of Ministers (RCM) 25/93**, Clean Sea Plan: maritime pollution prevention |
| **1995** | **RCM 38/95**: National Environmental Plan |
| **1997** | Legal transposition (Portugal) **CD 91/271/EEC** and **CD 91/676/EEC**<br>**CD 91/271/EEC**, Article 5: Identification of sensitive waters |
| **1990-1994** | **CD 91/271/EEC**: urban waste-water treatment<br>Art. 11: Regulation of discharge of industrial waste water into urban wastewater systems<br>Art. 13: Regulation of discharges of industrial wastewater into receiving waters |
| **1998** | **CD 91/271/EEC**, Art. 17:<br>Waste water treatment facilities available for agglomerations:<br>Sensitive areas PE > 10 000<br>Normal areas PE > 15 000 |
| **2000** | River Basins Management Plans |
| **2005** | **CD 91/271/EEC**<br>Collecting and treatment systems in agglomerations:<br>Sensitive areas 2 000 < PE < 10 000<br>Normal areas 10 000 < PE < 15 000<br>Secondary treatment for agglomerations: PE > 2000<br>Sensitive areas and their catchments: PE >10 000<br>Water Law (**Law 58/2005**) transposes the **CD 2000/60/EC** into the Portuguese law: a new era in terms of the water resources management policies and practices. |
| **2006** | **CD 2006/7/EC:** Bathing Water Directive to protect public health and the environment from sewage pollution in bathing waters.<br>**CD 76/464/EEC:** for priority substances in the marine environment, was integrated into the Water Framework Directive, CD 2006/1/EC, Dangerous Substances going into inland, coastal and territorial waters.<br>**CD 2006/44/EC**: Freshwater Fish Directive<br>**CD 2006/113/EC**: Shellfish Waters Directive |
| **2008** | Hydrographic Region Administrations, HRAs<br>**CD 2008/56/EC**: Marine Strategy Framework Directive |
| **2009** | **CD 2009/90/EC**: technical specifications for chemical analysis and monitoring of water status<br>Hydrographic Regions Management Plans |

Table 3. Water quality contaminants and their potential effect on environmental values (adapted from [6]).

| STRESSORS | AQUATIC ECOSYSTEM | RECREATIONAL USE |
|---|---|---|
| **Salinity** | Decreases species diversity and health | - |
| **Pathogens** e.g. *E. Coli*, *Giardia*, *Cryptosporidium* | - | Potential health implications |
| **Nutrients** e.g. phosphorus and nitrogen compounds | Contributes to algal growth/blooms; reduced DO levels and fish kills; ammonia is toxic to the biota | Contributes to algal growth/blooms; toxicity, skin irritant, visual clarity of the water |
| **Turbidity** e.g. suspended solids | Changes optical properties, affects photosynthesis, smothers habitats | Changes optical properties, limits visual clarity |
| **Heavy metals** e.g. arsenic, lead, zinc, copper | Potential toxic; may bio-accumulate in some species | Health implications from skin contact at high concentrations |
| **Natural and other biodegradable organic matter** e.g. oils, leaves, hair, dissolved organic carbon | Breakdown leads to reduction in DO which can result in fish kills; release of nutrients and increase in algal growth | Aesthetics at high concentrations |
| **Hydrocarbons** e.g. fuel, diesel | Toxic; affects surface-dwelling organisms | Health implications, aesthetics |
| **Pesticides** e.g. insecticides, fungicides | Toxic; may bio-accumulate | Health implications from skin contact at high concentrations |

Studies have been developed by the Portuguese Hydrographic Institute and the Portuguese Water Institute on quality survey, and characterization and monitor of the main Portuguese estuarine and coastal areas in order to assess the fulfillment of national obligations regarding International Conventions as well as European Directives for water quality management. The Portuguese Water Resources Information System, SNIRH, operated by the Portuguese Water Institute has a General Use Interface developed based on ArcView2 with data on climate, hydrology, ground-water and water uses, originated on over 1200 measurement stations in the country, as well as from the day-to-day management tasks of the Institute.

**Identification of Coastal and Maritime Values**

Effluent management requires wastewater treatment to a level, which will prevent further deterioration, secure protection and enhance the status of aquatic ecosystems, minimise risk of human disease, and protect environmental uses/values of the waters.

To specify the probabilities of a failure or operational stoppage of the outfall within acceptable limits as defined in terms of the possible consequences of the failure or operational stoppage:

(a) the characteristics of the waste must be known (flow, type and content of pollutant);

(b) the waste is to be discharged into the sea in an area encompassing well-defined sensitive zones to be protected against pollution;

(c) these areas are covered by standards of maximum levels of concentration for one or more of the pollutants contained in the waste.

The problem then is to define the particular features of the outfall system in such a way as to satisfy the conditions already established, i.e. to comply with the standards in force in the areas to be protected.

By taking into consideration both the quantities of the waste to be discharged and the geographical and meteorological local conditions, one can select a method which would give a solution with a smaller or greater degree of accuracy in calculating pollutant concentrations at various distances around the point of discharge.

GIS software is used for this study as a vital tool for cataloguing and displaying coastal and maritime uses (e.g. recreational use, ports and shipyards, seaweed resources, fisheries, shellfish and other marine resources). Figure 1 shows an example of usages in the coastal stretch of Algarve.

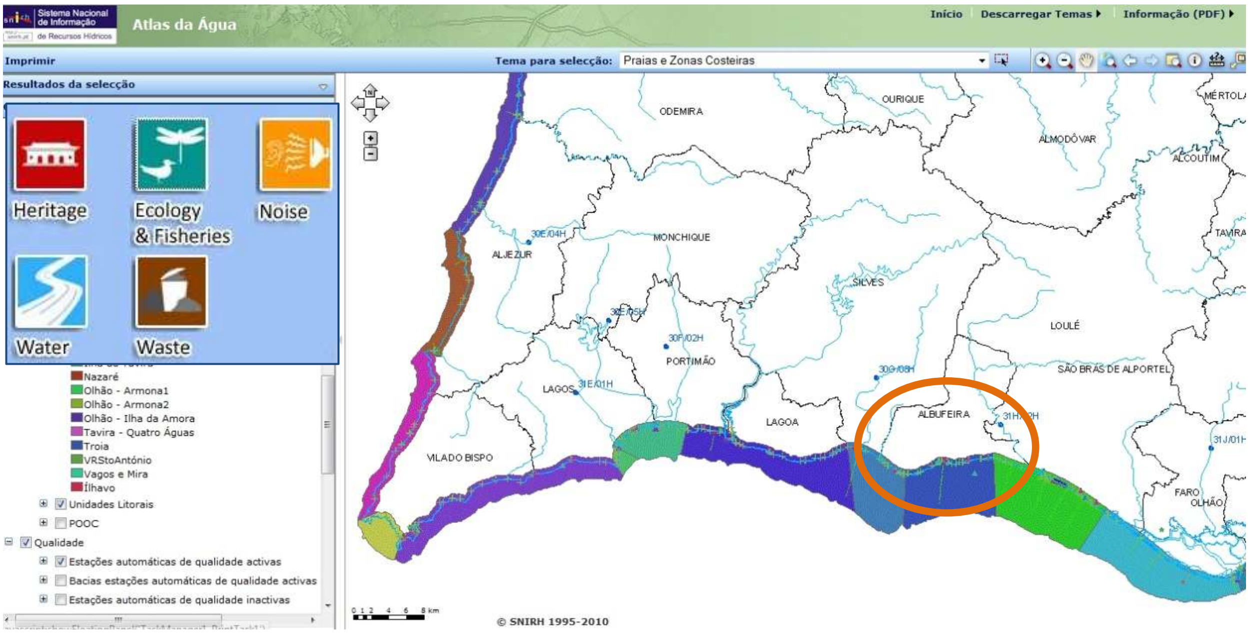

Figure 1. Coastal usages example for Algarve coastline, Portugal (source: www.snirh.pt).

**Operational Forecast Methodology**

The hydrodynamic processes in the coastal zone are governed by two primary phenomena, namely wind and tide. The winds are directly responsible for the generation of waves, currents and water level fluctuations and as a result, for the plume transport onshore and on the beach, while the tides express themselves in a periodic rising and falling of the water and in tidal currents. To understand the problem of submarine outfall management and to find proper control measures one must understand the hydrodynamic processes involved.

A good knowledge of wind, wave and tidal conditions along the route of the outfall is required for a variety of reasons that go from: i) the *design stage*, where wave climate data is necessary to assess the expected rate trench infill, stability of the pipe during installation, and choice of plant and downtime; ii) during *installation*, where wave climate data may be augmented by real-time wave forecasting to assist in operations planning; and iii) during *operation*, where real time forecasting permits operational planning using weather windows, assessment of 'unforeseen condition' claims, maintenance operations and in situations where the plume reaches the shore with high concentrations of nocive substances, measures to prevent its consequences and implementation of potential corrective measures.

This study aims to create a methodology to adapt and improve the management of submarine outfall discharges in the marine environment, during its operative phase.

The high variability of marine conditions means that sustainable and efficient management of the outfall must be available for these conditions. At present, there are few options that offer control and adaptation tools in the ordinary management of submarine outfalls into the marine environment [7]. Therefore, the main objective is to develop a methodology that provides this capacity in the following ways:

• **Improve operation control**: Supervise the correct operation of the submarine outfall discharge, corroborate compliance with the EU Legislation and unacceptable environmental effects and social repercussion. Have a real-time monitoring system that enables awareness of the behaviour of the discharge.

• **Adaptation**: Avoid rigid discharge management by adapting to the conditions of the receiving environment. A sustainable management strategy would be based on maximizing the dilution of the waste in the most unfavourable conditions and minimizing it when the conditions allow, given its lesser impact on the environment (maximum turbulence conditions).

A real-time analysis of ocean-meteorological data from the marine environment and from the effluent can optimize the marine environment forecast of the mixing capacity maximizing the efficiency of the outfall system.

Daily forecasts offer short-term predictions of contemporary conditions, one or a few days ahead, with a level of detail designed to be supportive of en route planning and interpretation of plume behaviour.

The main steps of the methodology, described in Figure 2, are:

1. Forecast data: 7-days forecast data - wind, wave height, wave direction, wave period, tide;
2. Numerical modelling: i) Hydrodynamic model with 7-days forecast data; ii) Particle tracking model using the hydrodynamic model results;
3. Operational management: potential corrective activities and management measures.

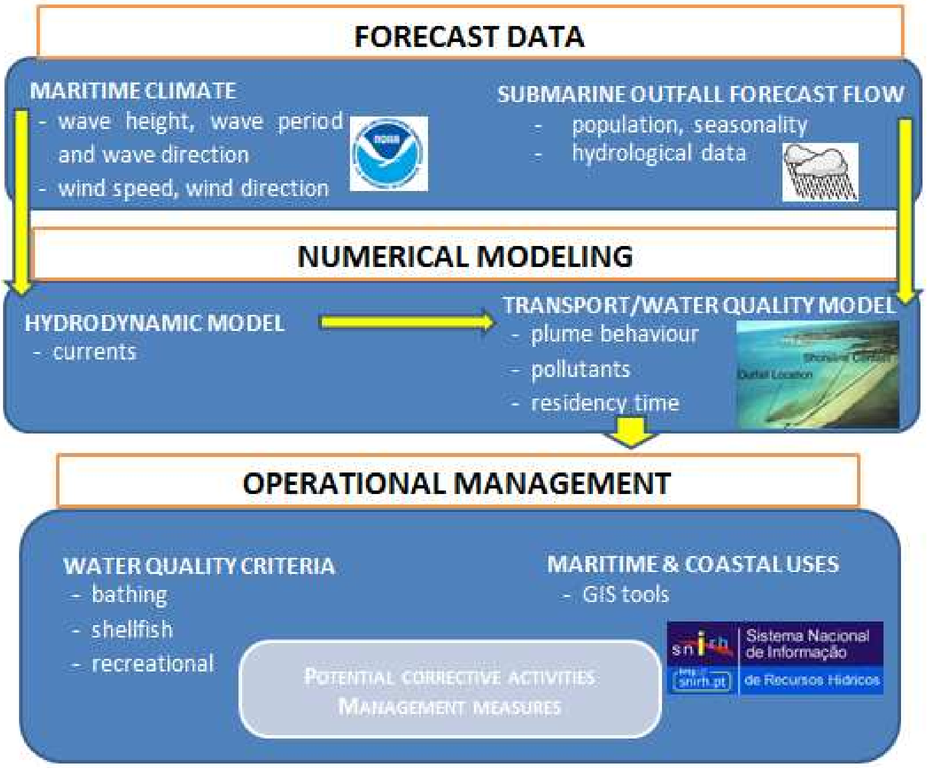


Figure 2. Operational forecast methodology scheme for submarine outfalls.

**Forecast data**

The first step of the proposed methodology is to gather information on wave climate in the study area. For this project 7-days forecast data are used through the National Oceanic and Atmospheric Administration (NOAA).

The operational ocean wave predictions uses the NOAA WAVEWATCH III® operational wave model that consists of a set of five wave models, based on version 2.22 of WAVEWATCH III® [8].

The model is run four times a day: 00Z, 06Z, 12Z, and 18Z. Each run starts with 9-, 6- and 3-hour hindcasts and produces forecasts of every 3 hours from the initial time out to 180 hours. Wave heights (Hs), peak wave periods (Tp), wind speed (U10) and wind direction are available. Figures 3 and 4 show some examples of NOAA forecast for the Portuguese coast (Buoyweather.com – Global WAVEWATCHIII) in terms of waves and wind characteristics, respectively.

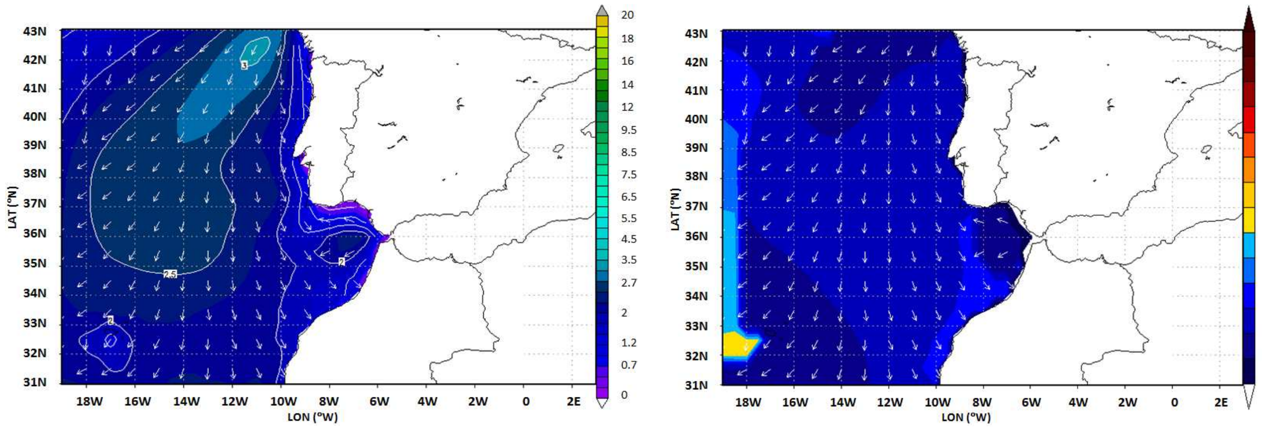


Figure 3. Examples of NOAA forecast for the Portuguese coast (Buoyweather.com – Global WAVEWATCHIII): a) significant wave height (m), b) primary wave period (s). Direction vector 00Z01Sep2012.

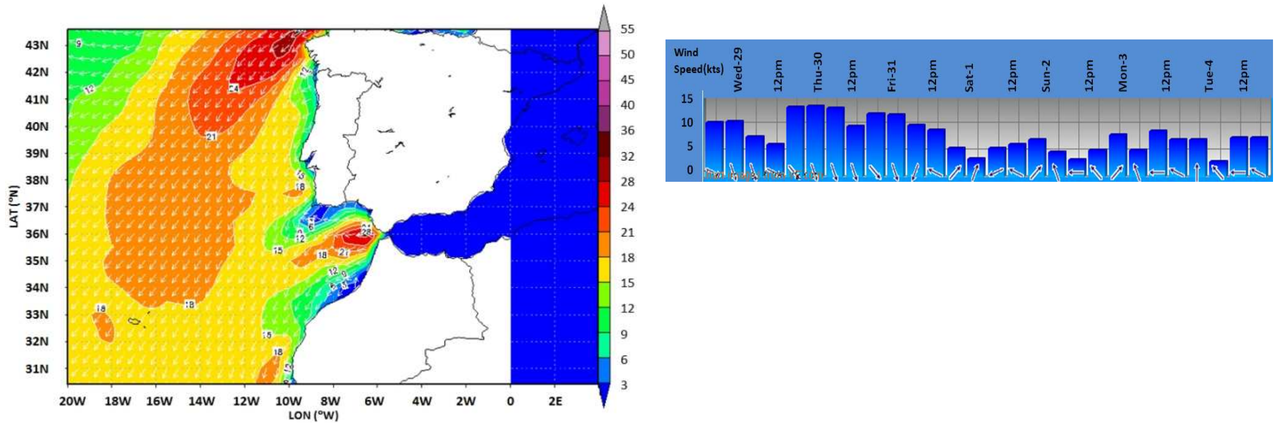


Figure 4. Examples of NOAA forecast for the Portuguese coast (Buoyweather.com NWW3 - Nearshore Wind): a) 10m wind speed (kts) 00Z01Sep2012, b) wind speed and wind direction.

The Portuguese National Meteorological Service has descriptive weather forecasts for Faro district up to 3 days ahead and 10 days weather forecasts with daily values of temperature and precipitation probability.

**Numerical modeling: hydrodynamic model and particle tracking model**

A wide variety and complexity of hydrodynamic and Lagrangean models is available and many factors are involved in the selection of an appropriate model that meets user capabilities and study objectives.

In a first stage CMS-Flow [9], a component of the Coastal Modeling System was applied. CMS-Flow, developed by the United States Army Corps of Engineers, is a finite-volume numerical engine which includes the capabilities to compute both hydrodynamics (water levels and current flow values under any combination of tide, wind, surge, waves and river flow) sediment transport as bed load, suspended load, and total load, and morphology change.

At this first stage the Particle Tracking Model (PTM) [10] [Demirbilek et al., 2008], a Lagrangean model, was also applied for the simulation of particle transport processes. PTM, also developed by the United States Army Corps of Engineers, applies to dredging and coastal projects including dredged material dispersion and fate, sediment pathway and fate, and constituent transport. The model contains algorithms that appropriately represent transport, settling, deposition, mixing, and resuspension processes in nearshore wave/current conditions. It uses waves and currents developed through CMS-Flow and input directly to PTM as forcing functions.

Limitations on PTM results, related to the incapacity of representing the concentration of pollutants over time, lead to the subsequent application of TELEMAC model [11] [Galland et al., 1991], developed by EDF-DRD and distributed by SOGREAH.

**Operational management**

Before identifying the submarine outfall mitigation measures and emergency discharge scenarios for the operation phase, review of the pipe system design, historical emergency discharge records, and precautionary design measures to control emergency discharge have to be conducted gathering information on the structure.

The system should focus on three fundamental management scenarios:

1. The first of these is to **detect stressors** (e.g. coliform concentration values) in the near-field that could be potentially transported to the protection perimeter identified in the coastal usages map (Figure 1). The forecast tool continuously evaluates the coliform/stressors values in the near-field, and the conditions at the edge of the marine protection perimeters.

When necessary alternative management of the outfall is adopted to avoid possible disruptions (e.g. increase the planned dilution, increase the number of outlets, or increase the outflow speed).

2. The second is linked with the **maritime climate**, which implies changes in the energy state of the sea and, therefore, in the dilution efficiency of the plume in both near-field and far-field. A very useful management protocol might be to link the outfall management and progress over time. This would not only prevent possible disruptions caused by low energy, but it would also make use of greater turbulence scenarios, which allows plume dilution.

3. The third is linked with the **total forecasted flow** for the submarine outfall; flow depends on population seasonality and hydrological events. E.g. the forecast of extreme events enables suitable application of early measures for the submarine outfall management.

If there is a potential of polluting the beach water, agencies should be immediately informed with a joint investigation to assess the impact to the environment. If the incident generates an environmental nuisance other than polluting beach water mitigation measures should be worked out to reduce environmental impact. Three levels of alert can be defined:

- **Level 1**- no significant risk to health and the incident can be contained or controlled;
- **Level 2**- potential risk to public health and/or environment and the root cause cannot be immediately contained and will last approximately 24 hours. Emergency procedures have to be initiated;
- **Level 3**- the impact of the incident is severe and the root cause is not easily contained or controlled. The impact of the incident has significant consequences and will last longer than 24 hours. Emergency procedures have been initiated.

A Response Action should be prepared to avoid, if not possible, to minimize environmental impact to the surrounding area and water.

The competent Portuguese authority for dealing with marine pollution is the Direcção-Geral da Autoridade Marítima (DGAM), under the auspices of the National Maritime Authority (Navy) and the Ministry of Defence. DGAM coordinates, at national level, the response to marine pollution at sea and on shore. A national contingency plan 'Clean Sea Plan' was approved in April 1993. This includes regional and local emergency plans.

DGAM operates a Marine Pollution Response Service, a central service with technical expertise in pollution prevention and combat.

**Corrective measures**, temporary sewage bypass and emergency discharge scenarios which may arise from climate agents (e.g. heavy rainfall, wind currents) during the operation phase of the project should be identified and planned to minimize the potential water quality impacts. These measures are case sensitive and should be established for each submarine outfall project. Some examples are described:

- ❖ Reduce/increase the flow rate or flow quantity being discharged
  - Offsite disposal or alternative treatment facility;
  - Onsite irrigation through emergency pumping;
  - Temporary storage;
  - In the case of ocean-meteorological conditions that favour dilution, the system could help to optimize the operational cost by acting on the pumping capacity of the dilution water or reducing the pressure in the discharge diffusers;
- ❖ Parallel contingency options
  - Provide partial treatment of effluent being discharged; enhance pollution prevention efforts; improve or change disinfection process; enhance solids removal during treatment; primary effluent screening;
  - Decrease the volume of effluent requiring discharge;
  - Reuse subject to strict regulations: urban reuse (e.g. the irrigation of public parks, school grounds, highway medians, and golf courses) agricultural reuse (irrigation for non-food crops), recreational impoundments (e.g.

ponds or lakes), environmental reuse (e.g. the creation of artificial wetlands or enhancement of natural ones) or industrial reuse (e.g. process or makeup water) [12];

- ❖ Emergency discharge
  - o Bypass, located either in the inlet chamber or in the outfall chamber, to allow discharge of sewage to the seashore under emergency conditions;
  - o Manually cleaned screens at the overflow bypass to prevent the discharge of floating solids into the receiving water;
- ❖ Close the concerned beach for public use.

**Case study: Vale de Faro**

To illustrate the application of the steps of the procedure a case study of submarine outfalls located in the Portuguese coast is analysed. The structure was selected to represent a common type of submarine outfall in Portugal, based on the type of effluent (urban) and importance to the region in terms of tourism and municipal serviceability, Figure 5.

The submarine outfall of Vale de Faro, is situated in Praia do Inatel, Albufeira, an important touristic area, in the south of Portugal, with a floating population of 14 000 habitants in summer. The submarine outfall, installed in 1986, became under designed due to increasing number of tourists in the summer season and a new structure was proposed and constructed in 2002. These structures have been monitored and supervised: regarding wastewater and environmental characteristics (e.g. topography and bathymetry, bottom materials and morphology) and the description of important and minor failures that have occurred. The system supplies sanitation to about 130 000 I.E., disposing an urban effluent with secondary treatment, plus disinfection in summer. The marine outfall pipe, in HDPE, is 1020 m long with a 1000 mm diameter and discharging at around 11 m depth (datum level). The diffuser has 32 ports and is 160 m long.


Figure 5. a) Case study location (Albufeira), b) Example of the wastewater treatment system in Algarve region (source: www.aguasdoalgarve.pt)

A preliminary result of the submarine outfall plume behaviour is represented in Figure 6: the hydrodynamic model was run with 3-days forecast data of tide and wind for the period of 28th August to 1st September 2012.

The results from the Lagrangean model are analysed through monitoring 'traps' defined in sensitive areas as bathing areas, fishing areas, coastal and estuarine aquaculture units. For every 'trap' the model computes the concentration of stressors (e.g. faecal coliforms).

Figure 6. Vale de Faro submarine outfall: effluent transport near the coastline.

The results of these processes are related to submarine outfall compliance of the water quality criteria and coastal uses: series of particle locations over time and attributes of those particles at each time, particle paths, identification of the percentage of time that limit threshold concentrations of pollutants are surpassed and identification of the affected areas.

**Conclusions**

An operational forecast methodology is being constructed to compile and validate the data, as well as to produce corrective management measures required within the European and national framework.

The application of forecast systems will provide the outfall management with the necessary flexibility to adapt to the favorable conditions of the marine environment, maximizing dilution and minimizing effluent impact.

Daily forecasts of maritime and hydrological data will provide 72h-ahead estimates of plume location and structure for planning purposes and for near real-time interpretation of observations.

The analysis of physical variability in the estuary and plume under evolving climate and water regulation enables scenario simulations offering an opportunity to contrast modern submarine outfall conditions with reconstructed historical scenarios and future scenarios of change (e.g., associate with climate change or with conditions post a major hydrological event).

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