WaPUG

Environmental Design Optimisation for the North of Scotland

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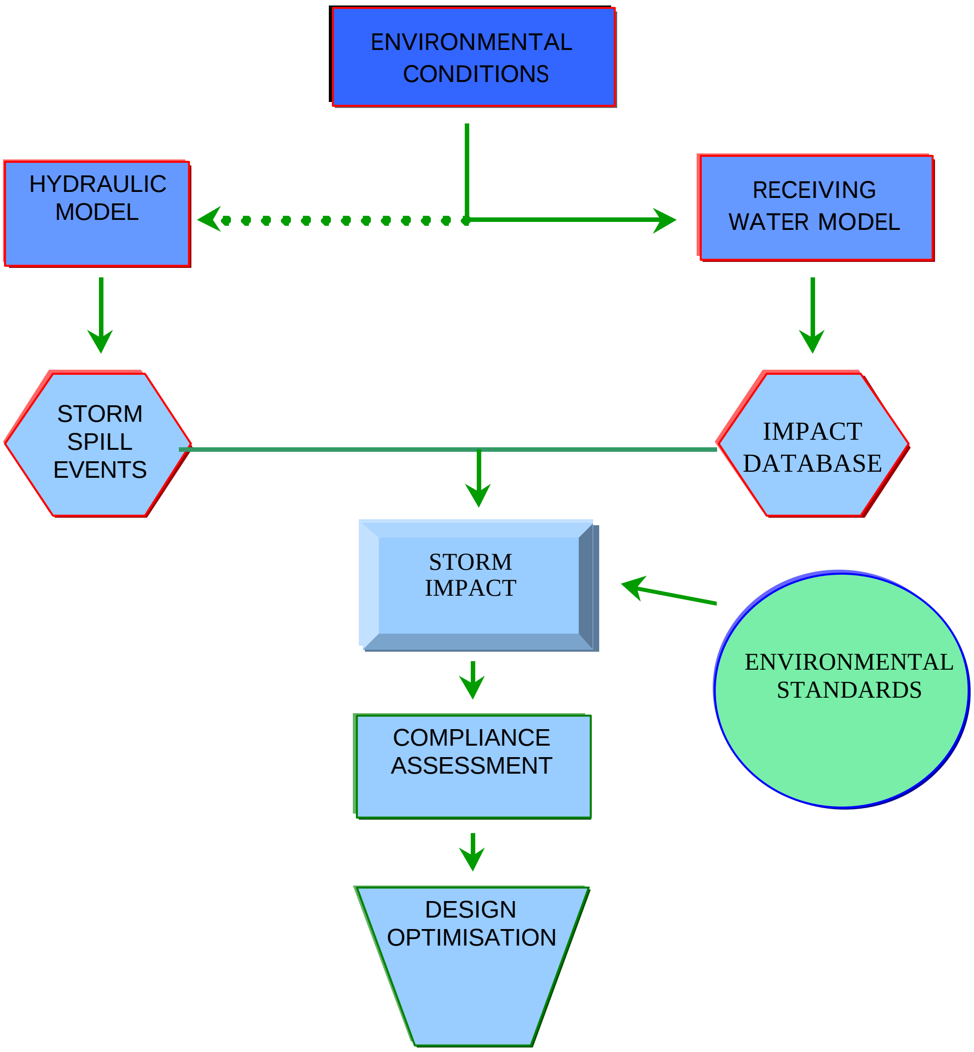
ABSTRACT

Environmental Design Optimisation (EDO) is a process that is used to optimise the environmental design of continuous and intermittent discharges. EDO provides robust solutions, based on delivering both long and short term compliance against EU Directives or any other environmental standards. The process combines a number of tools to provide a solution that is both compliant with standards and minimises the impact on the environment. North of Scotland Water Authority (NoSWA) commissioned Metoc to deliver the Integrated Modelling and Data System (IMDS), which gives model coverage of the whole of the NoSWA coastline. The models have been constructed using Mike-21, available from the Danish Hydraulic Institute. STORM-IMPACT is a solution to the management of discharges from combined sewer overflows, developed by Metoc. STORM-IMPACT can interface with any receiving water model, including the IMDS, and with the results of any network model. Using the IMDS and STORM-IMPACT, the EDO process has delivered substantial cost savings and environmental benefits at a number of sites in the north of Scotland.

1 OVERVIEW

Environmental legislation covering the water industry has been developing rapidly in recent years. With this have come tougher standards and regulation. These developments have lead to greater challenges that can only be met by better data, better assessment tools, and better analysis of environmental impacts. In the context of the commercial environment, better must be interpreted as more accurate and more robust, certainly, but also as faster and cheaper.

Environmental Design Optimisation (EDO) is a process developed by Metoc that delivers on these challenges. It has been developed largely through work in the north of Scotland, on behalf of the North of Scotland Water Authority (NoSWA), and is dependent on numerous technological innovations. Central to these are NoSWA's Integrated Modelling and Data System (IMDS), which has a core component based on the Mike-21 software, and Metoc's STORM-IMPACT. These tools have been designed and integrated to allow assessment of discharge impacts in the short term, the long term and for dry and wet weather conditions. All this is achieved at a fraction of the cost and time of traditional methods, while solution robustness is increased by orders of magnitude.



In order to provide accuracy EDO is founded on carefully specified approaches to data collection and models. Flexibility is then introduced through techniques that allow changes in environmental and engineering conditions to be incorporated without having to remodel. Finally, robustness and speed are introduced through statistical methodologies that allow many thousands of impact scenarios to be directly assessed in a matter of days.

2 EDO COMPONENTS

Essentially, Environmental Design Optimisation (EDO) is a process that is used to optimise the environmental design of continuous and intermittent discharges. The solutions are robust and based on delivering both long and short term compliance against EU Directives[12] or any other environmental standards. The EDO process is very flexible and combines a number of tools to provide a solution that is both compliant with standards and minimises the impact on the environment.

2.1 IMDS

2.1.1 System Development

NoSWA's managers identified a need to address current and future legislation throughout the region, thus developing sound and sustainable environmental solutions. To assist in the development of these strategies NoSWA commissioned Metoc to specify and develop the Integrated Modelling and Data System (IMDS). The IMDS provides both a strategic tool that ensures that the impact of discharges on sensitive receivers is considered in an holistic fashion and a tool for managing field and model data.

2.1.2 Approach

The IMDS is made-up of three components:

- a GIS interface that provides access to;
- a modelling system covering the whole of the NoSWA area coastal and;
- a database of field and model data.

The modelling system has been set up such that the whole of the NoSWA coastal area, which has the longest coastal line of any of the British water companies, is covered.

2.1.3 Short term and long term assessments

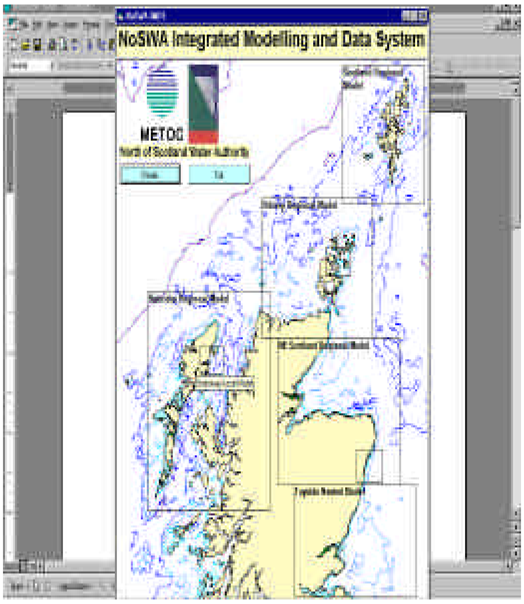
There has been a requirement for both short and long term assessments of the impacts of wastewater discharges on the environment.

Comprehensive Studies for the Urban Wastewater Treatment Directive[3] (UWWTD) are assessments that quantify the long-term environmental impacts of providing primary treatment instead of secondary treatment for discharges to "High Natural Dispersion Areas" (HNDAs). An early version of EDO was used for the Tayside Comprehensive studies in the nineties but a much enhanced process for recent Comprehensive studies at Shetland, Orkney and Lewis, the last remaining HNDAs in the UK. These studies assessed the impacts of discharges on eutrophic status, the concentration of dissolved oxygen and the quality of the benthos, over a period of years. A number of these studies were carried out using the IMDS. Typically, relatively coarse (1000m) grids were used for these studies.

NoSWA together with the Scottish Environment Protection Agency (SEPA), is working towards achieving guideline standard (100 cfu/dl) of the Bathing Water Directive at all designated bathing waters. In addition SEPA has designated recreational and shoreline waters where the mandatory standard (2000 cfu/dl) must be met; bacterial standards have also been set for shellfish waters. As bacteria have a relatively short life span in coastal receiving waters, their impact on sensitive receivers is in general short-term. A large number of these short-term studies have been carried out, using the IMDS, to assess the impact of discharges on bacterial water quality. These studies have typically been carried out using fine grid models.

2.1.4 User Interface

The IMDS has a GIS user interface which give access to both the models and the database. The models and the database are accessed by 'clicking' on the appropriate geographical region.



2.1.5 Hydrodynamic and Water Quality Models

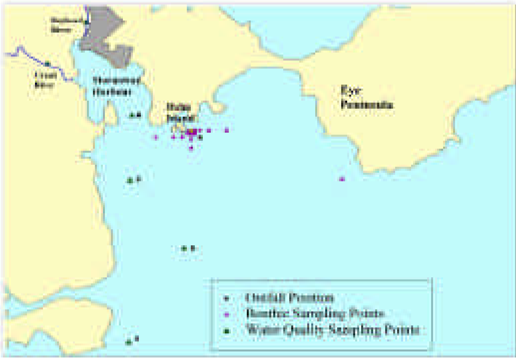
The IMDS has been developed to give model coverage of the whole of the NoSWA coastline. The models have been constructed using Mike-21[4], available from the Danish Hydraulics Institute. There are five regional models covering:

- Tayside;
- North East Scotland;
- Orkney Islands and the North Coast of Scotland;
- Shetland Islands;
- Western Isles and the West Coast of Scotland.

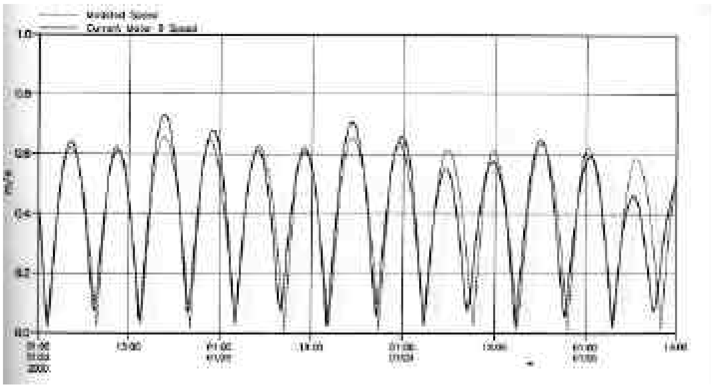
The areas covered by each regional grid are shown above. The grids have been developed such that discharges from all major communities in the north of Scotland can be modelled. These models typically have a grid size of 1000m. The bathymetry data have been derived from digitised contour and depth sounding data taken from appropriate Admiralty charts, and boundary data were typically obtained from the Proudman Oceanographic Laboratory's CS3 fine grid continental shelf model[5]. The model hydrodynamics have been calibrated against tidal elevations predicted from tidal constituents, current speeds and directions obtained from tidal diamond data and field surveys, where available. Dispersion in the water quality models has been calibrated against dye tracing data.

Fine grid models, typically of grid size 200m, have been developed within the regional models. Fine grid models have only been developed where there has been a need for short-term bacterial modelling. These models have been developed at:

- Stornoway;
- Kirkwall;
- Aberdeen and
- Tayside.

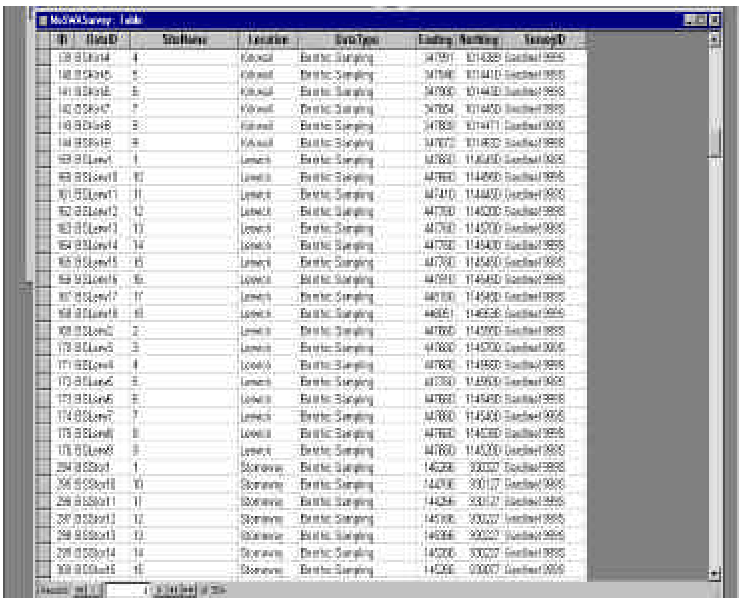


The bathymetry for these models has, similarly, been derived from digitised contour and depth sounding data, while the boundary conditions have been obtained from the appropriate regional model. Each fine grid model has been calibrated and verified against tidal elevations derived from tidal constituents, tidal diamond data, field-recorded elevations and current speeds, and drogue tracks and dye tracing, where appropriate.



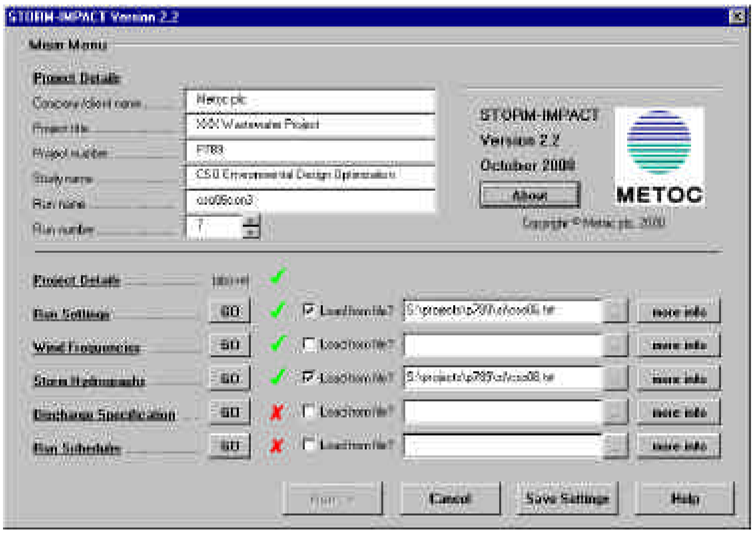
2.1.6 Data Management System

The data management system catalogues all of the survey data relating to each of the models. Oceanographic, water quality, benthic and other data are catalogued.



2.2 STORM-IMPACT

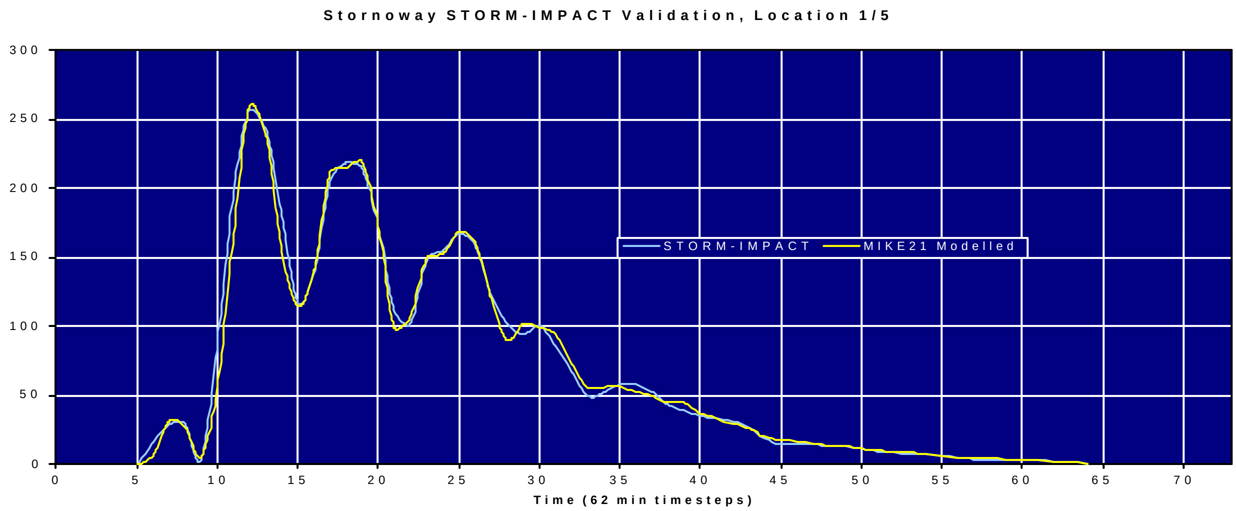
2.2.1 Scientific background



STORM-IMPACT, developed by Metoc, is a solution to the management of discharges from combined sewer overflows. STORM-IMPACT uses a modelling approach that combines network modelling with receiving water modelling, and provides a prediction of compliance with standards and directives at sensitive receivers. The process is able to separate the impact of different discharges such that storage and other interventions can be properly targeted, thus optimising the changes needed to achieve compliance with environmental standards.

A database of responses to CSO discharges is built up using an environmental model (coastal or river), which means that receiving water simulations do not need to be carried out for each storm. This means that changes to the sewerage network can normally be modelled for different scenarios without the need to carry out further coastal modelling.

This system has aproved to be very reliable in reproducing environmental impacts resulting from spill events. A comparison of the response of STORM-IMPACT to a particular storm with the results of modelling that storm directly in a receiving water model is given below.



2.2.2 Interfacing with IMDS and Network Models

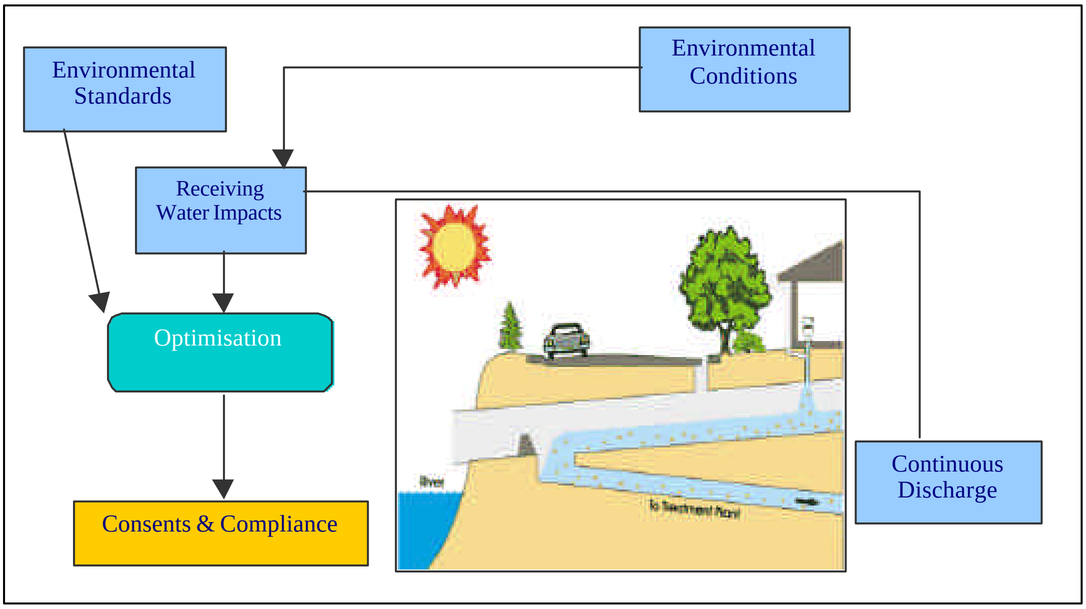
STORM-IMPACT can interface with any receiving water model and with the results of any network model. In the north of Scotland, the receiving water model used in STORM-IMPACT is the appropriate model within the IMDS. Particle tracking simulations are carried out for a range of tidal and wind conditions to build up a database of responses for use in STORM-IMPACT. As far as possible, an holistic approach is taken and thus all discharges to the study area are considered, including continuous discharges, intermittent discharges and, where appropriate rivers.

In these studies, the network model used has typically been Infoworks, although SIMPOL results have been used occasionally. Rainfall events over a number of years are simulated in the network model and storm hydrographs are produced for a large number of storm events.

STORM-IMPACT calculates the predicted compliance with the appropriate environmental standard over the range of modelled tidal and meteorological conditions, using these storm hydrographs.

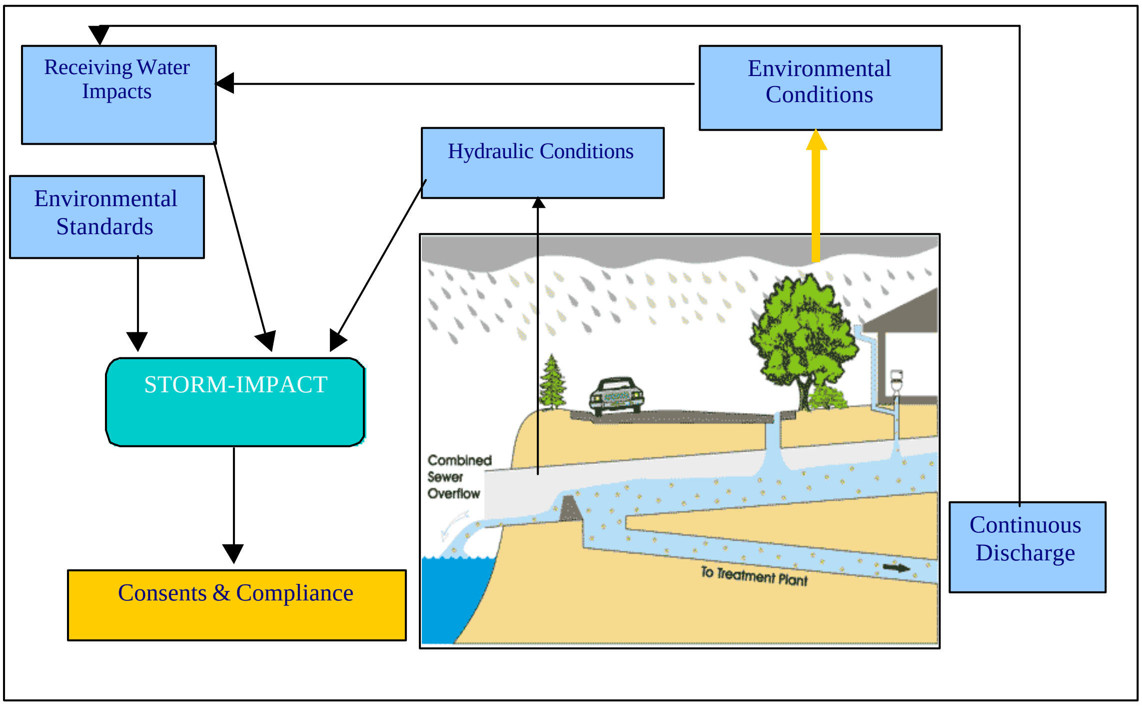
2.2.3 Dry Weather

STORM-IMPACT considers both wet and dry weather impacts in its assessment. Under dry weather conditions, continuous discharge and river impacts on sensitive receivers are assessed and the percentage compliance is calculated.



2.2.4 Wet Weather

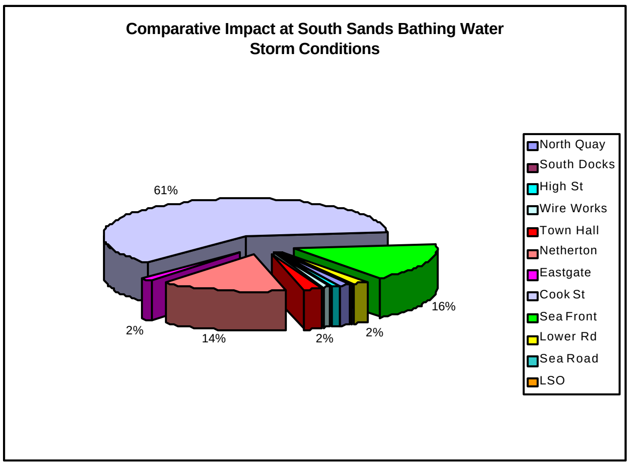
Wet weather compliance is calculated using the results of the network modelling. The impacts of both continuous and intermittent discharges are considered and the compliance figure is calculated.



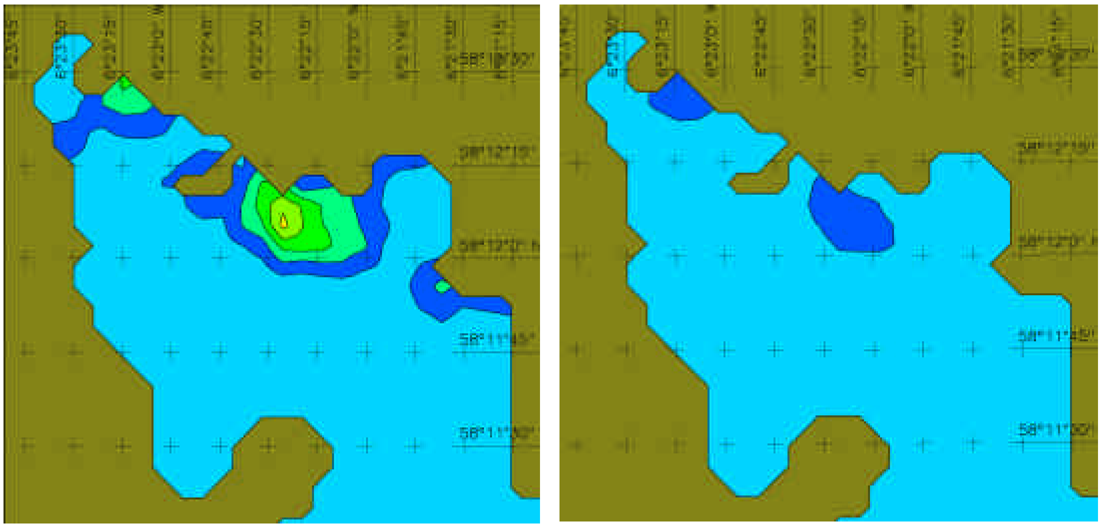
2.2.5 Output and Compliance

One of STORM-IMPACT’s major advantages is that it is able to separate the impact of each individual discharge. This means that engineering solutions to storm overflows can be individually targeted and an optimum solution found. STORM-IMPACT can model the effects of simple engineering interventions, so that checks can be made on solutions before they are verified through the network model. An example of the relative contributions of a number of CSOs to bacterial impacts at a sensitive receiver is given below.

Metoc has developed the concept of Compliance Zone Modelling, as part of the EDO process. The impact of dry weather and storm discharges on bathing, recreational and shoreline waters and on shellfish waters and production areas can be assessed across the whole sensitive area, within the EDO process. The level of compliance can be shown graphically.



Engineering solutions are often based on limiting the number of spills in each bathing season, over all CSOs within a catchment. These solutions often result in very large storage requirements, which in turn lead to considerable land-based environmental impacts. The EDO approach is able to separate the contribution from each discharge, which allows engineering solutions to be carefully targeted. This approach minimises land-based disruption and engineering costs, while ensuring that all environmental targets are met. The plots below show compliance with the mandatory bathing water standard before and after EDO at Stornoway.



3 EDO APPLICATIONS IN THE NORTH OF SCOTLAND

3.1 Nutrients, Oxygen, Eutrophication and Benthic communities

North of Scotland Water Authority required Comprehensive Studies for Shetland, Orkney and Lewis, as laid down under the Urban Waste Water Treatment Directive[6] (UWWTD), Article 6. The purpose of the studies was to identify whether a secondary treated discharge would provide any significant environmental benefit over a primary treated discharge. In the event that it did not, primary treatment would be deemed suitable. The implications to Island communities of installing secondary treatment were significant in terms of charges o be levied.

In phase I, field data were collected at each of the sites and catalogued through the IMDS data management system. Where appropriate these data were used in the calibration and verification of regional and local IMDS model grids.

In phase II, IMDS water quality predictions were made of seasonal nutrients, chlorophyll and oxygen for primary and secondary treatment scenarios and for numerous sets of environmental conditions (e.g. oceanography, meteorology). The methodology used, and the assessment of results, were carried out in accordance with the requirements of the Comprehensive Studies guidelines[3]. IMDS hydrodynamic predictions were also used in the assessment of the impacts on the local benthic communities.

In conclusion, the Comprehensive Studies demonstrated no need for secondary treatment at the island sites, in accordance with the guidelines.

3.2 Bacterial Impacts

EDO of schemes based on bacterial impact modelling has been undertaken at many sites throughout the north of Scotland. The principal legislation driving improvements has been the Bathing Waters Directive[1] and Shellfish Waters Directive[2], coupled with Scottish Environment Protection Agency policy[7]. Impacts have been assessed at bathing waters, shellfish waters, recreational waters and shoreline waters. In each case background sources have been included in the assessment.

EDO for dry weather continuous discharges focused on identifying outfall routing, discharge siting, diffuser design and treatment identification.

EDO for wet weather continuous and intermittent discharges focussed on storm water attenuation strategies (e.g. identification of storm water storage volumes for environmental compliance).

Depending on the number of scheme discharges (e.g. the number of combined sewer overflows (CSOs)) and environmental sensitivities, the number of impact permutations could be greater than 100,000. Ordinarily such an assessment would take years to complete. However, these timescales have been reduced to a matter of weeks through EDO. The EDO process was designed specifically to handle this sort of volume. Through statistical assessment it was possible to identify the optimum solution for each individual continuous discharge or CSO, with the nature of the optimum being driven by environmental, engineering and cost constraints. For example, it may have been preferable to increase storage at one CSO rather than another because of differences in unit storage costs.

In order to compare the benefits offered by differing approaches, a simple evaluation was carried out to identify the size and cost of CSO storage to deliver three spills per bathing season This solution could be considered as "*engineering only*", since it is not supported by assessment of water quality impacts but is in accordance with industry standards. The engineering only solution costs were then compared with the EDO solutions to see if EDO offered any financial benefit. It was found that EDO provided significant benefits as outlined in the following table.

Scheme	No.CSOs	Saving (£'000)	
Aberdeen	1	-£	512
Fraserburgh	1	-£	346
Stornoway	2	-£	556
Tayside	15	-£	10,000
Moray West	3	-£	843
Moray East	11	-£	697
Banff-Macduff	8	-£	3,120
Stonehaven	1	-£	109
Peterhead	1	-£	71
TOTAL SAVING		-£	16,254

Although many of the EDO schemes are still under construction, evidence to date shows major improvements in environmental performance leading to an optimistic outlook for compliance with water quality objectives.

3.3 Aquaculture

EDO has also been used to assess impacts upon fish farms and impacts from fish processing waste. Results have been similar to investigations of waste water impacts and have lead to identification of significant long term improvement strategies.

4 CONCLUSIONS

Environmental Design Optimisation has been developed specifically to tackle the issues and sensitivities relating to coastal discharges in a timely and cost-efficient manner, while delivering a detailed and robust technical solution. The approach has been used extensively throughout the north of Scotland so as to optimise NoSWA's environmental and engineering solutions.

EDO has been used to gain compliance with a number of legislative issues, including the Urban Waste Water Treatment Directive[6], the Bathing Waters Directive[1], the Shellfish Waters Directive[2] and the Shellfish Harvesting Directive[8].

Aspects of NoSWA's discharges that have been optimised include:

- treatment levels;
- storage requirements;
- outfall positioning;
- diffuser arrays.

EDO has led to a number of environmental, engineering and resourcing benefits, including meeting regulatory and environmental requirements, achieving compliance, addressing engineering constraints, targetting investment, decreasing capital and operating costs and supporting consent applications.

For NoSWA area alone, the Environmental Design Optimisation approach has allowed significant environmental improvements coupled with predicted cost savings of over £16,000,000 compared to the engineering-only solution.

REFERENCES

[1] EEC (1976) Council Directive concerning the quality of bathing waters (76/160/EEC).

[2] EEC (1991) Council Directive concerning the quality required of shellfish waters (79/923/EEC)

[3] CSTT, (1994). Comprehensive Studies for the purposes of Article 6 of DIR 91/271 EEC. The Urban Wastewater Treatment Directive. Marine Pollution Monitoring Management Group.

[4] Danish Hydraulic Institute (1996). User Guide and Reference Manual . Coastal Hydraulics and Oceanography. Release 2.6.

[5] Smith, J. A (1994). The Operational Storm Surge Model Data Archive. Proudman Oceanographic Laboratory, Report No. 34.

[6] EEC (1991) Council Directive on Urban Wastewater Treatment (91/271/EEC)

[7] SEPA (1998). Policy No. 27. Microbiological standards in marine waters (excluding shellfish waters) in relation to design criteria for discharges.

[8] EEC (1991) Council Directive on health conditions for the production and placing on the market of live bivalve molluscs. (91/492/EEC)