MIKE 11 APPLICATION GUIDE

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MIKE 11 APPLICATION GUIDE

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EXECUTIVE SUMMARY

The aim of this study has been to produce an Application Guide for version 3.01 of MIKE 11. MIKE 11 is a dynamic, one dimensional, water quality model, developed by the Danish Hydraulic Institute. It has been recently upgraded to meet specifications defined by the Urban Pollution Management (UPM) Programme for a tool to aid investigation into the impact of combined sewer overflows (CSOs) on receiving waters. The resulting Application Guide will enable new users of the upgraded software to become familiar and confident in such applications. The Application Guide provides advice on how to use MIKE 11 within a framework of NRA policy and standards. This is reinforced through support and self-training by a series of illustrative examples. The Application Guide has been developed as a complementary document to the existing software documentation and forms a supporting document to the forthcoming UPM Manual which will describe the detailed applications procedures for the integrated use of the UPM models.

This report summarises the background requirement for this project. It gives the history of the project and comments on the recent software upgrades. It also briefly describes the contents of the Application Guide which is the major product of the study.

KEY WORDS

1. INTRODUCTION

1.1 Overview

The objective of this project was to produce an Application Guide for the MIKE 11 software, for studies investigating the impact of CSO discharges. It aims to give MIKE 11 users in the NRA greater confidence in applying the software. The Application Guide was the main product of the project and is available in the NRA as R&D Note 190.

MIKE 11 is a dynamic, one dimensional water quality model that simulates river flows, sediment transport, water quality processes and interactions between sediments and any attached pollutants. The software has been developed by the Danish Hydraulic Institute (DHI).

The MIKE 11 software was chosen by the Urban Pollution Management (UPM) Programme in 1990, as being the most appropriate tool available, to investigate the impact of continuous and intermittent sources of pollution on receiving water courses. The UPM Programme was established in 1986. Its aims were to develop methodologies that would be used to help the water industry to improve the management of urban water quality in response to rainfall events. The methodologies that have been developed under the UPM Programme include a number of tools which can be used together, to provide a fully integrated modelling approach to all aspects of waste water disposal. In addition to MIKE 11 these tools include:

- Time series rainfall and stochastic rainfall generator;

- MOSQITO sewer flow quality simulation model;

- STOAT dynamic sewage treatment works model;

- Biological standards for the impact of intermittent discharges.

More recently, MIKE 11 has been recommended in the Guidance Note for Preparation Work Required for AMP2 (NRA 1993), as an appropriate river impact tool to be used for undertaking detailed modelling investigations of intermittent discharges which are of high environmental significance.

1.2 Development of MIKE 11 software under the UPM Programme

Part of the UPM Programme involved an appraisal of the available software that could be used either in its present state or in modified form to model the dynamic impact of intermittent waste water discharges on urban rivers. As a result of this appraisal, MIKE 11 was selected, but with the proviso that modifications were to be made to the software to make it fully compatible with the needs of the UPM Programme, as identified in a Requirement Specification.

The major development requirements in the UPM specification covered three aspects. First, the software should have the capability to model the interactions between river and sewer derived sediments and the effect of attached pollutants. Second, the software should be fully compatible with sewer flow quality models to allow output from one to be used as input to the other. Third, the results must be presented in terms of Event Summary Statistics to enable easy comparison of results with the proposed intermittent river quality standards (NRA 1993). These modifications were made by DHI via a separate contract from WRc with FWR/NRA funds. The resulting software was tested (Becker and Hutchings 1992) under an FWR/NRA funded contract. The testing concluded that the upgraded software met the requirement specification, but there were constraints relating to the application of MIKE 11 to streams that were steep and had very low flows.

The MIKE 11 software can now be used in conjunction with the other tools developed under the Programme. However, current experience within the industry in the use of Version 3.01 of the MIKE 11 software is very limited and advice on the application of MIKE 11 to typical CSO consenting problems is similarly scant. Hence, there was a need within the NRA for MIKE 11 application guidance that would go further than the User Manual (DHI 1992a) and would concentrate more on the practicalities of using MIKE 11 as a tool to aid the management of intermittent discharges.

2.   PRODUCTION OF AN APPLICATION GUIDE FOR MIKE 11

2.1   Requirements for the Application Guide

The Application Guide is intended to give advice and guidance on why, when, where and how to use MIKE 11. It is also intended that the Application Guide should be a complementary document to the User Manual and Reference Manual and, therefore, does not cover the detailed mechanics of using the software. Instead, it concentrates on the practical aspects of the application of the model, from building models to calibration, verification and producing the results. It assumes an existing, competent familiarity with the software and provides more detailed advice on the areas where the software has been modified to incorporate the UPM Programme requirements. Details of the full modelling procedure and interpretation of results will be given in the forthcoming UPM Manual.

The style chosen for the Application Guide was the same as that used for the SIMCAT User Guide (Crockett *et al.* 1990). An example of the style used is given in Appendix A. This was selected because it allows ease of use for different types of user, both the inexperienced and the more experienced, and provides a user friendly approach which facilitates cross referencing. Being modular in style, it also allows updates to be made and inserted easily.

2.2   Aims of the Application Guide

The Application Guide has been aimed primarily at the novice user of MIKE 11, but the content of the Application Guide should be useful to both regular and experienced modellers and water quality planners. The Application Guide aims to cover all the aspects of using MIKE 11 as an aid to assessing the impact of, and setting consents for, intermittent wet weather discharges. The areas of advice include: model suitability, data requirements, procedures for model building, calibration, verification and the production and interpretation of results in terms of the proposed intermittent water quality criteria. Current NRA policy regarding the situations for which detailed modelling is necessary and the proposed standards are also included. Recent experience with MIKE 11 has highlighted a number of constraints when applying the software to some catchments. The Application Guide points out these limitations and offers advice on how to minimise their impact.

2.3   MIKE 11 Version 3.01

During the production of the Application Guide, a further release of MIKE 11 was made available. Changes were made to the software to improve the description of the exchange of BOD between bed and suspended sediments, modifications were also made to the erosion and deposition equations for non-cohesive sediments. This latest version (3.01) has since been tested (Becker 1992) and the Application Guide has been significantly revised to incorporate these changes. This has unfortunately led to a delay in the release

of the Application Guide. The Application Guide now refers to version 3.01 of the software and represents the most up to date advice.

2.4   Dissemination

Fifty copies of the Application Guide have been supplied to the NRA and will be published as R&D Note 190. A set of four master tapes containing the data files for the illustrative examples and the training example have also been supplied.

3. CONTENT OF THE APPLICATION GUIDE

The Application Guide is divided into three parts, plus appendices. These describe:

Part 1:   the background to the production of the Application Guide, the need to use MIKE 11 and what MIKE 11 can do;

Part 2:   the basics involved in applying MIKE 11, including the processes of building, calibrating and verifying;

Part 3:   a series of worked examples which illustrate the earlier sections of the Application Guide; and finally

Appendices: a hands-on training example.

Each part of the Application Guide is described in more detail below. A full contents list is given in Appendix B.

3.1   Part 1 - Introduction to MIKE 11

The first part of the Application Guide is split into five chapters which introduce the "whys and wherefores" of using MIKE 11. Chapter 1 is a general introduction to the Application Guide, which states that its purpose is to introduce newcomers to MIKE 11; to the types of study likely to be encountered when setting discharge consents; and that it aims to increase familiarity with the software and confidence in its use. This section emphasises that the Application Guide has been written to be used in conjunction with the User Manual and Reference Manual and that references are made to both documents throughout the Application Guide. Chapter 1 concludes with a brief section on further sources of help both with the software itself and with NRA policy for the use of MIKE 11.

A broad discussion in the first part of Chapter 2 covers why MIKE 11 was selected as a tool to aid CSO consent setting and gives a brief description of the UPM Programme (Clifforde et al. 1990). The functions of MIKE 11 as a river impact modelling tool and a summary of the equations and solution techniques are explained in the next two sections. This is followed by a section from the Guidance Note for Preparation Work for AMP2 on where and when to use MIKE 11 with additional guidelines on the practicalities of applying MIKE 11 to different types of catchment. Details of the proposed Statutory Water Quality Objectives are given in Chapter 3. This includes a description of how the Event Summary Statistics can be used to help interpret the model output and be compared to the proposed intermittent discharge criteria (Milne and Seager 1990, 1991).

The final two Chapters in Part 1 cover the hardware requirements, the cost of the software and details of the MIKE 11 User Group. Data requirements for a typical CSO river impact study are discussed in Chapter 5. These are divided into three categories covering data necessary for model building, calibration and verification. Section 5.4 is devoted to the parameters in MIKE 11 that can be used for adjusting the water quality process models. Comments and recommendations are made here on the choice of default values and their

suitability for use in river impact studies. Advice is also given on the amount of data required. There are comments on the practical aspects of data collection for MIKE 11 applications.

3.2 Part 2 - Applying MIKE 11

Part 2 begins by describing the stages involved in building a MIKE 11 model. These are; conceptualisation, defining the channel, setting boundary conditions, importing data from other sources, (such as output from MOSQITO and STOAT) and checking the stability of the model. The methodology of model building is discussed in detail in this chapter and cross reference is made to the User Manual for more detailed information on the different processes of entering data and building models.

Chapter 7 describes the stages required to ensure that the model performs reliably. It starts by discussing the need for calibration and describes the steps that should be followed. These are, checking the channel hydraulics first, then the dispersion and finally the water quality processes. Then the reasons for verification are discussed and comments are made on verification techniques for the hydraulic and water quality components. This chapter concludes with a brief comment on the model results and how they are dependent on the reliability of the calibration and verification.

Part 2 concludes with a brief example of a fully verified MIKE 11 model. This example demonstrates an application of the model to a real stretch of river which receives a continuous discharge from a STW and an intermittent discharge from a CSO. The hydrodynamic and water quality models are described and the results are presented and described in the form of the Event Summary Statistics.

3.3 Part 3 - Examples of MIKE 11 applications

In Part 3 of the Application Guide, four examples illustrate the special features of the upgraded software incorporating the requirements from the UPM Programme. The four examples build up, consecutively, to increase the complexity of the models. The first example describes how MIKE 11 might be applied to a simple river system. It introduces the basic model building techniques to link all the necessary data, including modelling sediments, and describes two flow regimes, one for steady state dry weather flow, the other for dynamic storm flows. The second example builds on from the first by introducing water quality modelling in full by the inclusion of a continuous discharge from a STW and a diffuse pollution source upstream.

Modelling CSOs is illustrated in the third example. The different methods that can be used by MIKE 11 to incorporate data from CSOs are described and demonstrated via the use of the MOSQITO interface (Becker and Hutchings 1992) which is introduced for the first time, as is the inclusion of CSO data as lateral inputs. Sediments are also included and effects of a flood wave are shown. This example is based on a steep catchment and identifies some of the problems likely to be encountered on such catchments.

The final example represents a complex catchment built up from components of the previous examples. It demonstrates the level of modelling effort required for a large system. The model includes STWs, CSOs modelled via the MOSQITO interface, and also as lateral inputs, a weir and an abstraction. Results for various locations in the catchment are presented and discussed.

3.4 Appendices

Appendix 1 of the Application Guide contains a training example to give hands-on experience of model building, calibration and verification for novice users. The user is taken through the stages necessary to produce a fully verified model from the data supplied and then to evaluate results from model runs. The training example runs on a SUN Sparc Workstation or equivalent and it is intended that (following initial MIKE 11 training) it should take about 1-2 days effort to complete excluding computational time, which is dependent on the hardware available and the number of calibration and verification runs made. The training example is held on the distribution tape, which also contains the files for the other illustrative examples.

Appendices 2 and 3 of the Application Guide contain log sheets of the model runs used in the illustrative examples and a set of data templates to aid data organisation in model building, calibration and verification. Appendix 4 contains a list of all the files on the distribution tape.

4. CONCLUSIONS AND RECOMMENDATIONS

A MIKE 11 Application Guide is the main product of this research project. The Application Guide is aimed primarily at inexperienced users of MIKE 11. However, it is also envisaged that it will be used by both modellers and water quality planners as a consultative and planning document to aid the assessment of the impact of waste water on receiving water courses and setting consents for intermittent discharges.

The MIKE 11 Application Guide will become a supporting document to the UPM Manual, which is scheduled for publication in 1994. The UPM Manual will propose procedures for the use of MIKE 11 within an integrated UPM approach for controlling wet weather discharges in conjunction with other UPM models, such as MOSQITO and STOAT. The UPM Applications Methodology research project (Crabtree *et al*. 1993), aimed to evaluate such modelling tools; develop a practical approach for their integrated use; and evaluate this approach against other planning techniques. The project concluded that the use of these detailed modelling tools would give adequate results. A design procedure has been developed to allow the models to be used to develop simplified relationships. These were shown to be more cost effective than alternative methods using minimum data and simpler models.

During the study a number of areas were identified in which the MIKE 11 software could be improved. These include: use of the software on small streams or rivers which have both steep gradient and very low flows; modelling of in-river structures; and modelling of non-cohesive sediments.

REFERENCES

Becker, M. and Hutchings, C.J. (1992) Testing of MIKE 11 software. FWR Report No. FR 0242.

Becker, M. (1992) Supplementary testing of MIKE 11 software - Version 3.0. FWR Report No. FR 0341.

Clifforde, I.T., Fiddes, D. and Tyson, J.M. (1990) Urban Pollution Control in the United Kingdom, *Water Science and Technology* **22**, No.10/11.

Crabtree, R.W., Dempsey, P., Becker, M., Gent, R., Simpson, K., and Bryan, D. (1993) UPM Applications Methodology. FWR Report No. FR 0384.

Crockett, C.P., Warn, A.E. and Crabtree, R.W.(1990) SIMCAT User Guide. WRc Report No. PRS 2386-SW.

Danish Hydraulic Institute (1992a) MIKE 11 User Manual, DHI.

Danish Hydraulic Institute (1992b) MIKE 11 Reference Manual, DHI.

Milne, I. and Seager, J. (1990) Proposed Water Quality Criteria for the Protection of Aquatic life from Intermittent Pollution: Dissolved Oxygen. WRc Medmenham Report No. PRS 2498-M.

Milne, I. and Seager, J. (1991) Proposed Water Quality Criteria for the Protection of Aquatic life from Intermittent Pollution: Ammonia. WRc Medmenham Report No. PRS 2682.

National Rivers Authority (1993) Guidance Note for Preparation Work for AMP(2). AMP(2)/Effluent Quality. NRA.

Stimson, K. (1992) Dynamic Sewage Treatment Works Modelling. WRc Report No. UM 1287.

APPENDIX A

AN EXAMPLE OF THE LAYOUT AND STYLE OF THE APPLICATION GUIDE

2.1   **Background to the UPM development work, the catchment approach and methodology**

Overview

This section answers the question "Why should I use MIKE 11?". It aims to give you an understanding of the rationale behind using this type of tool within the context of catchment planning. Within this area, the work of the Urban Pollution Management (UPM) Programme is highlighted.

UPM history

The UPM Programme was initiated in 1985 to develop methodologies to enable the Water Industry to improve the management of urban water quality under wet weather conditions. The programme undertook an appraisal of the modelling tools available and selected those which it considered most appropriate to be incorporated, with or without further development, in these methodologies.

UPM methodology

The UPM programme has approached the problem of improving urban water quality by considering the three major elements of urban wastewater disposal; the sewerage system, the sewage treatment works and the receiving water, together. By examining the global effect of design improvements and capital works on various parts of this disposal system, investment can be made more effectively and improvements can be recommended which are tailored to individual catchments. This methodology, therefore, needs to employ tools which allows detailed investigation of each aspect of the urban wastewater disposal route.

Catchment approach

The essence of the UPM approach is integrated consideration of all problems at an urban catchment scale. Taking this holistic approach to solving problems of rainfall driven discharges from all sources in the urban wastewater collection/treatment facility, allows a more thorough appreciation of the problem and ultimately the most appropriate solution.

Modelling tools

A number of modelling tools were identified as necessary to implement a truly catchment wide study. These tools had to cover each aspect of the urban water pollution problem and, therefore, included: rainfall models, sewer flow and quality models, sewage treatment works models and river impact models. These models would be used together as a "suite" of tools that would be compatible, allowing outputs from one to be included as inputs to another.

APPENDIX B

MIKE 11 APPLICATION GUIDE: CONTENTS LIST

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PART 2 - APPLYING MIKE 11

PART 3 - EXAMPLES OF MIKE 11 APPLICATIONS

APPENDICES