WaPUG

River Modelling Guide

Version W01

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RIVER MODELLING GUIDE

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1. INTRODUCTION

This document is intended as catalogue of good practise rather than a prescriptive approach for river modelling. It is intended to aid the development of river models for use in UPM studies. It has been put together based upon collective experience of North West Water (NWW), Yorkshire Water Services (YWS) and Montgomery Watson (MW) from previous UPM studies. The document is set out as a generic guide to detailed river model although it is based upon detailed river modelling using MIKE 11 and simplified UPM modelling using SIMPOL. Examples where quoted refer to these models but the conclusions are relevant to all river models.

2. PLANNING A MODELLING STUDY

2.1 Types of Model Study

Table 1
The Different Types of River Modelling Studies for UPM Applications

Modelling Approach	Applications
Mass Balance	• Assessment of compliance with derived intermittent standards.
Simplified River Model	• Assessment of compliance with fundamental intermittent standards.
Full 1 D model with default parameters	• Assessment of solutions.
Fully calibrated 1 D model	• Calibration of simplified models or development of site specific standards. • Assessment of solutions to water quality standards. • Develop understanding of river system, focus in on true problem.

2.2 Initial Requirements

2.2.1 Desk Studies

Field data collection is a very expensive exercise, in many cases it can only provide a snap shot or series of snap shots of how a watercourse behaves. It should be regarded as a means of supplementing existing information. It is therefore essential to carry out a desk study to pull together existing information from various sources (Water Services Company (WSC), Environment Agency (EA), Consultants) to define present understanding and deficiencies in knowledge.

The desk study should identify what data are held in archives which will be useful for model construction. For instance, a large number of watercourses, particularly those in urban areas, are subject to flood prevention work. In many cases the agency responsible for this work will hold river cross section and long section information.

Any available hydrological data such as spot gauging or flow statistics must be obtained. Within the scope of UPM studies boundary conditions are required to be presented as statistical distributions. All of the significant inputs to the river system must be identified and flow distributions obtained for them. A short term field data collection exercise will never be comprehensive enough to observe anything near a full range of hydrological conditions within the catchment.

Water Quality Data is very valuable for ascertaining trends in a watercourse and is also a requisite for river impact analysis. Routinely collected spot sampling data are unlikely to be frequent enough to conclusively identify intermittent pollution events but may well be able to demonstrate annual or seasonal trends in a system, Hazelton (1998) discusses some of the limitations of this data. A useful pre-requisite to any modelling exercise would be details of all Environment Agency monitoring locations, frequency of sampling and determinands collected. Access to the data collected at these sites would allow a patchwork picture to be drawn up of the background water quality in the modelled area.

Boundary conditions are required for simulation of impact assessment. These can either be developed from archive data or taken from River Ecosystem (RE) Classifications. If RE values are used, two statistics are required to develop a distribution. RE classifications are versed in terms of 90%ile values so a further value such as a mean or standard deviation for the distribution are required to recreate it. BOD and ammonia data are typically represented as log-normal distributions. Temperature and pH are modelled as normal distributions. Temperature and pH values vary seasonal so it is important that the values chosen reflect summer conditions. Percentile values for in river DO levels will also be required for analysis.

Further background information such as pollution incident databases, invertebrate and fisheries data will provide information about quality problems in the receiving watercourses.

Other features of the watercourses can be picked out of literature, such as changes to the hydraulic operation of the system due to control sluices, moveable weirs or abstractions.

The study should search out records detailing water quality issues such as heavy sediment build up, gassing (gas bubbles given off by anoxic river processes) or hydraulic issues such as stratification of flow.

Table 2

Summary of Data Requirements from Desk Study

Data	**Likely Source**
Plan of river showing all principal inputs	Generate during study

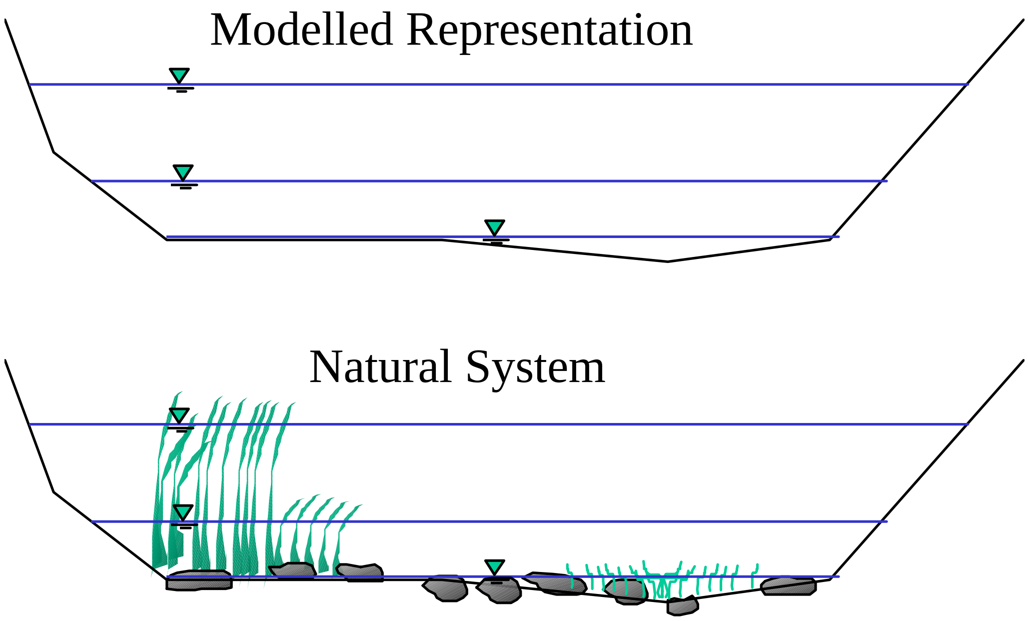
Good quality maps of system preferable in digital format to insert in GIS system or CAD.	Ordnance Survey
River cross sections	EA Flood Defence
Flow distributions Mean and 5%ile flows for all significant tributaries in catchment. Location of all gauging sites in catchment.	EA hydrology section
WQ formal sampling locations frequency of sampling and range of determinands sampled.	EA
WQ formal sampling spot data.	EA
River Ecosystem classifications for watercourse and tributaries.	EA
Pollution incident database. Fisheries and invertebrate data.	EA / WSC
Further data from previous studies, anecdotes.	EA, universities, WSC, staff, watercourse users.

2.2.2 Walking the River

This element of the modelling process is essential as it helps define where model building and data collection are to be pursued. The walk should identify or confirm the key reaches requiring explicit modelling. Spot DO measurements could be taken to investigate oxygen levels at locations of interest to decide if further survey data is required. The walk should also help to confirm potential water quality and flow data collection sites and to identify where key wastewater discharge outfalls are located. Also to identify where to take new cross sections / weir sections.

A numerical model of a river system can only be a general representation of reality. A good quality survey at discrete intervals will give an approximation of the shape of a channel over a river length and therefore will only be able to represent ideal hydraulic conditions. The model is very unlikely to be able to give an adequate representation of a highly variable natural system where cross sections vary continuously and wetted perimeters will change with the number of boulders on the bed, or weed growth. These features are represented by terms such as roughness and dispersion coefficients. Knowledge of the watercourse will give much better understanding of features in observed data sets and justify coefficients if required to achieve fits during calibration.

Figure 1
Why Roughness Changes With Water Depth



Good local knowledge will also aid the calibration of elements of the water quality model. Locations with high re-aeration potential, plant growth, bed slime, sewage fungus or standing pools of water can all have an influence on the choice of parameters.

Useful tools to take on a river walking exercise are a camera, some large scale plans of the watercourse 1:1250 or larger plotted onto A4 paper to enable notes about key features to be made and to link photographs to. A log sheet for recording DO readings, times and locations is also necessary.

In terms of river hydraulics features to note are areas of variable cross section, large changes in gradient, large changes in depth, river beds strewn with boulders, long culvert sections, control structures, areas of high weed growth and ponded sections. Figure 1 illustrates the kind of features that can affect channel conveyance as water levels change.

The dispersion term in the advection dispersion model is principally a surrogate term for differential flow velocities which occur through a river cross section, which result in a variation in travel time across the river. Parts of the watercourse where velocities can vary greatly across the sections, for instance a braided channel, may require a higher diffusion factor than a straight trapezoidal concrete culvert.

Features should be identified that affect the water quality calibration of the model, such as:

- Areas of organic silt build up - a possible sediment/BOD source in high flows.
- River gassing - a possible DO sink and source of sediments with a high oxygen demand which will be re-entrained in high flows.
- Plant growth - a DO source in the day time and a sink at night.
- Points where high levels of aeration take place such as riffle sections should be noted as they are unlikely to be clearly identifiable from a river X-section survey.

In conducting a survey all of the parties involved should be aware of other sources of pollution for instance: land fill sites, scrap yards, road drainage and farmyards. These could contribute to a decline in watercourse quality by leakage or direct run off.

Figure 2
Channelled Urban Watercourse

2.3 Data Collection

A brief overview is provided here of key issues in data collection. The methodologies for collection are described in detail in the WaPUG River Data Collection Guide.

2.3.1 Liaison with Survey Contractor

It is important that the modeller is in direct contact with the survey contractor. The location of monitoring sites is likely to be a compromise between where the data is required and where it can be effectively and safely collected.

It would be advisable to undertake a site visit with representatives from the survey company, the Client and the river modeller walking the entire length of the study area so that all parties have a clear understanding of the objectives, site conditions and significant structures. This could take place as part of the river walk described in section 2.2.2.

It is important that the contractor is aware of what the data is to be used for and priorities on the data. So a follow up meeting should then be held to sort out any problems thrown up by the site inspection.

2.3.2 Data Collection Sites

The location of data collection sites should be a collaborative task, between the survey contractor and the modeller, having taken onboard comments from the WSC and the EA. The modeller should be responsible for providing co-ordinates and a description of the sites and the contractor will be responsible for the physical location of the monitors.

2.3.3 Prioritisation of Sites

Within the data collection exercise there will be certain sites that will be critical to the modelling exercises. Without these sites there is little chance of building a satisfactory model. These sites will include river boundaries and principal input locations. They generally provide data that will be fed through to check the fundamental integrity of the model whereas the intermediate sites are used for calibrating against. It is therefore worthwhile to direct more resources at these sites in terms of planning, installation and maintenance visits.

2.3.4 Agreement of Collection Sites

This needs to be done as part of the study area walk or subsequent meeting detailed in section 2.3.1. All interested parties including the modeller must agree the final sites.

2.3.5 Phasing of Data Collection / Provision

The data provision should be in parallel with the modelling process.

Table 3
Proposed phasing of model data provisions

	Phase of Dynamic Model Construction	**Data Requirement**
1	River System Description	Cross Section data Plans of River System
2	Hydraulic Calibration - Dry Weather	Time of travel dye tracer studies. River flows for dye tracer studies. River flows/levels for dry weather sampling.
3	Calibration of Advection Dispersion model.	Time of travel dye tracer studies. River flows for dye tracer studies.
4	Stability testing of the WQ model. Run WQ data set in AD model then rerun in WQ mode. Typical WQ values should be adopted.	EA Routine sample data . Typical flow values.
5	Hydraulic Calibration - Wet Weather	River flows/levels from Storm Studies. CSO / surface water outfall spill

		flow data.
6	Water Quality Calibration - Dry Weather	River flows for dry weather sampling. Water quality data from sampling exercise. DO long section profile. Sediment sample data.
7	Water Quality Calibration - Wet Weather	River flows from Storm Studies. CSO / surface water outfall spill flow and quality data.

3. DATA HANDLING

3.1 Data Requirements

This section details the data needs for different levels of river impact modelling.

3.1.1 Mass Balance Modelling

Table 4

Data requirements for simplified modelling

Data Type	**Requirements**
Asset Data	None
Flow Data	Mean and Standard Deviation of a log-normal distribution of summer flow at all boundaries/tributaries.
Water Quality Data	Mean and Standard Deviation of a log-normal distribution of BOD and Ammonia at all boundaries/tributaries. Summer temperature and pH as normal distributions.

3.1.2 Simplified River Impact Modelling

Table 5
Data Requirements for Simplified River Impact Modelling

Data Type	**Requirements**
Asset Data	Up to 6 sets of: Length (m), Slope of long section (m/m), Bottom Width (m) and Side Slope (m/m).

Flow Data	Mean and Standard Deviation of a log-normal distribution of flow at all boundaries/tributaries.
Water Quality Data	Mean and Standard Deviation of a log-normal distribution of BOD and Ammonia at all boundaries/tributaries. Mean and standard deviation of a normal distribution of DO, pH and Temperature.
Calibrated Simplified Water Quality Model	Hydraulic Radius or Resistance Radius; Manning's n; BOD decay rate (day-1); NH3 decay rate (day-1); Net gain of ammonia from BOD decay (gN/gO2); Ammonia yield factor (gN/gO2); Constant (a) in re-aeration equation; Velocity exponent (b); Depth exponent (c).

This list indicates the range and type of data needed.It is based on the requirements for SimpolV2. The modeller must investigate the exact data requirements of the simplified process model used.**.**

3.1.3 Detailed River Modelling

This section breaks down into comments on Hydraulic, Dye Tracer and water quality data and is summarised in Table 6 at the end of the section.

HYDRAULIC DATA REQUIREMENTS

In order to calibrate a detailed river impact model efficiently the data requirements should be tailored to the future application. So if the model is to examine storms during summer low flow events the data collection exercise should be based around this final goal. Furthermore, models require a minimum amount of data to demonstrate that changes throughout the watercourse are represented but supplementary data collection could be used to enhance the confidence in the modelling. This collection outside the minimum requirements of the modelling will help to fill in gaps of uncertainty.

The asset data collection requirements for the construction of a water quality model is a function of the final application of the model. For UPM purposes the model will not be required to examine high flow conditions in excess of a few years return period. Therefore, flow constraining structures such as bridges and culverts are not required to be added, unless they are seen to have a significant influence on the flow in the watercourse. River cross sections should be taken at all of the significant points in the channel and also at regular intervals down the watercourse if it is homogeneous in nature. As a rule of thumb cross sections should be taken at 100 m intervals. On steep rivers this distance may need to be decreased. On flat canalised rivers of uniform section the intermediate length could be increased to 500 m reduce surveying costs. The second edition of the UPM manual classifies rivers as those with a mean slope less than 1.0m/km as flat and greater than that as steep. Preferably sections should be surveyed at the point of flow and quality monitoring so model nodes are suitable for a direct comparison of modelled and observed data.

The judgement where to take river cross sections should be made by the modeller, after consideration of channel type and accessibility.

Weirs and level control structures can be critically important to the flow and quality modelling and these require careful surveying. A survey of a weir should incorporate a high resolution survey of the weir crest. In many cases weir crests are not level so for large weirs a number of levels have to be taken to characterise them. In addition to the weir crest survey, cross sections are required upstream and downstream of the weir. Weirs should be included in modelling if they have influence on flow in a channel or if they have been identified as making a major contribution towards re-oxygenation. This question should have been resolved from the long section DO profiling exercise (See the WaPUG River Data Collection Guide) undertaken prior to the modelling

The ponded areas behind weirs are frequently identified as critical reaches, so a good model of the hydraulics behind the weir is necessary and therefore sufficient sections must be taken there.

On the downstream side of the weir a single cross section is required to be taken. This section should preferably be 10 or 20 m downstream of the weir. Generally if sections are too close together models suffer from stability problems, so there is no gain in collecting cross sections closer together than this. All models have different characteristics but, for example, in Mike 11 the distance between a weir and the next cross section is represented as a ramp down from the weir crest, rather than an immediate drop. If this ramped section is too long then the model becomes unrealistic and could produce spurious results.

High quality flow data is essential for river impact modelling at all times. The location and concentration of dissolved or water borne substances at any time is dependent on the flow. The most accurate flow measurements are collected from well established flow gauging stations such as those maintained by the EA. Temporary flow gauging stations are extremely difficult to establish in open channels, much greater success can be achieved placing gauges at permanent or temporary weirs.

The temporal resolution of the flow data should be at a frequency to adequately identify changes in the river system. Five to fifteen minute intervals are usually adequate. None of the subsequent modelling exercises can be carried out without good flow data.

Flow and pollutant data is required at all major inputs to a system. Small tributaries that only contribute of few percent of the overall flow may well be disregarded and can be patched in from archived datasets or inferred from difference in flow station measurement.

Intermediate flow and stage measuring stations down a system are important as a cross check on the modelling and the other flow monitoring locations.

DYE TRACER - Advection Dispersion (AD)

Dye tracer time of travel studies are essential for the calibration of roughness and dispersion terms in a model. The studies should incorporate the entire length of the watercourse, for a range of flows from low flow to mean flow. In UPM studies the model's principal application will be to assess CSO spills into watercourses during rainfall events so it is important that dye tracing studies are representative of the flow conditions under which the model will be operated. Dye tracer studies are more difficult to monitor and model in rapidly varying conditions e.g. Flash floods, where in river dye concentrations are affected by the advection of flood waves. However, provided with good quality flow data it should be possible to provide a good fit to the observed data sets for less rapidly varying flows.

A minimum of three studies per reach are required for model calibration, two should be taken at low flows and one at an interim value between low and mean flow during summer conditions.

It is important that measurements of in-river dye concentrations are taken at the same locations or very close to where permanent flow and quality monitoring are to take place. They can then be tied into the same location in the model.

WATER QUALITY

Ideally water quality data are collected from either samplers from which the samples have to be taken to a laboratory to be analysed or from probes that take continuous measurements but which require regular re-calibration.

Ideally water quality data collection studies should reflect the condition under which the model will be operated, i.e. unsteady flow. However, the mechanics of collecting data during storm conditions are very difficult and sufficient rainfall events cannot be guaranteed. To get around this problem a number of dry weather events are collected to get baseline data for the river system and its operation. Preferably dry weather datasets should also embrace a range of flow conditions and be in a stable dry period. The conditions a day after a storm (i.e. urban runoff to watercourse has ceased could be considered as dry weather although as the river will not have had time to stabilise out after the high flows and water levels will still be high, conditions will be similar to wet weather in many cases. It should be noted that rivers with a high sediment oxygen demand will have higher DO levels after a storm than before it because storm flows cleanse the river, flushing away the sediment. In rivers like these sampling soon after a rainfall event would show atypically high oxygen levels.

The survey work should also be undertaken as close as possible to the time of year that the model is to represent in most cases, summer low flow conditions with maximum plant growth. This period is likely to span from May to September.

Sonde probe data is relatively easy to collect and so should be provided for the entire survey period. Although this is insufficient for model calibration purposes without the complementary sampling of the water quality sampler, it may be useful for identifying trends in the river system behaviour.

Further to the permanent monitoring sites other complementary data should be collected. It is possible to get fits at all of the data measurement points in the river system but inaccurately model the effects at intermediate locations. This is particularly an issue for DO which can continuously vary down the river system between the monitor sites. The re-aeration taking place at weirs and riffle sections is generally unknown and should be quantified to aid model building.

SEDIMENT

In-river sediments are also an important component. Sediment sampling is a very difficult task - physical parameters such as size and settling velocities are difficult to obtain and use in models. However chemical analysis of the sediment is beneficial. Appendix B in the WaPUG River Data Collection Guide) details an analysis for river bed sediments. BOD analysis of bed sediments would allow sediment potency to be ascertained. Ammonia analysis of the sediments would indicate decay within the sediment, hence a potential sediment oxygen demand. However, this would have to be used qualitatively rather than quantitatively within the modelling to complement the data obtained from continuous monitoring and sampling.

Different models may deal with sediment loads differently. It is important to understand the schema applied in the model used when deciding how to use sediment data that can be collected. For example in Mike 11 the collection of a large data set would be inappropriate because these values would be forced to be generalised. It is more efficient if the sediment data is used to interpret the in-river measurements, i.e. to use it qualitatively (as stated above).

BOD

One further issue with data collection is the difference between BOD fractions. In an analysis concerned with the oxygen demand of sediments the break down of suspended and Dissolved BOD is critical. The dissolved BOD fraction associated with sediments is provided as either filtered or settled BOD. Filtered BOD is the fraction left over after all of the sample has been passed through a standard filter paper. The settled BOD is the BOD concentrations in the water column after the sample has been left to stand for one hour. Generally, in a well mixed system such as a river the differences between filtered and settled BOD are likely to be negligible. For WwTW and storm tanks where effluent may be left standing for over one hour there may be greater variation between the two measurements. Both settled and filtered BOD require relatively time consuming (expensive) laboratory techniques.

The influence of suspended and dissolved BOD fractions on the overall water quality is important. It is desirable to obtain total BOD and dissolved BOD for all samples collected. Analysis costs can be reduced by only measuring dissolved BOD for a subset of the samples collected whilst obtaining total BOD values for all of the samples. The ratio of dissolved to total BOD values measured in the sample subset can be used to fractionalise the samples for which there are only total BOD values. However, this approach is not recommended for wet weather samples where the fractionalisation will vary throughout the event.

Table 6 itemises the data collection requirements.

Table 6
General Data requirements for Dynamic River Impact Modelling

Data Type	Requirements	Frequency
Asset Data	River Cross sections at select locations; River Structure data, notably weirs Water level data to supplement the survey information.	As deemed appropriate, high resolution data not generally required. (See text above).
Flow/level Data	Flow data plus level data	Five to fifteen minute data to complement the dye tracer studies and all of the water quality events both DWF and Storm.
Advection Dispersion Data	Dye tracer profiling at all monitoring sites in the river. Preferably the dye is input above the most upstream of the river sites.	Minimum of two events along the entire watercourse. Preferably the flows should vary from low to medium flows.
Water Quality Data Sonde	DO; Temperature; pH; (Ammonia);	This data can be collected for the duration of the study. This monitoring should also run for the day following any storm events to identify features such as DO sags due to settled organic sediments.
Water Quality Auto Samplers	BOD (Suspended and dissolved); Suspended Solids; Nitrate; Ammonia;	Three dry weather events and a minimum of two storm events. Time interval for river samplers could be longer than for overflow samplers because short time scale of CSO event leads to longer impact in river. The decision as to frequency will have to be made within the project constraints of number of bottles and cost of sampling.

Data Type	Requirements	Frequency
Complementary data	Qualitative BOD or COD data about in-river sediments at locations where there appears to be considerable amounts of deposition of organic sediments. DO spot measurements to provide a longitudinal profile along the water courses to be dynamically modelled. Particular emphasis should be placed on the weirs and measurements should be taken above and at some distance below the weir (to eliminate the effects of air bubbles or super-saturation of Oxygen).	The sediment data should be collected during a period of dry weather. The DO data should be collected for a period of low oxygen, ideally in the early morning. The sampling will by the nature of the exercise be both spatially and temporally variable

3.1.4 Data Formats

Formalised data collection formats allow standardised tools to be developed. Standardised data formats, provided they are well designed can improve data handling efficiency by increasing the speed of processing and removing errors from transposing data from one format to another.

Cross-Section Data

River cross sections should be provided in digital format in an ASCII file which can be easily inserted into model cross sectional databases. Typically sections are identified by three parameters.

- River Name String;
- Topo ID String. Topographical identification;
- Chainage Real number. km.

Providing that survey data is sufficiently well named that it can be cross referenced with these parameters then it is sufficient to provide survey data in separate delimited ASCII files with columns for x co-ordinates (Chainage across the cross-section m) and level in mAOD. Usually this format can be pasted directly from a spreadsheet into a model database saving time and risk of error in transferring data from file to file.

The provision of the grid reference of the mid point of the cross section data is required so that sections can be tied into background mapping and GIS systems

Time Series Data

Time series data for flows and water quality should be provided in a format that allows it to be handled in as efficient a manner as possible.

All data should be provided to the same time base, typically Greenwich Mean Time, in a date format that can be identified by a spreadsheet. A common format such as day/month/year hour: minute i.e. 24/09/65 23:55 is easily transferable to and from a spreadsheet by cut and paste. Using a common Time series data format will simplify conversion to special formats such as the single determinand ASCII file used in MIKE 11 version 3.

It should be noted that there are arguments for providing data in terms of local time (e.g. BST) and a standard reference time (e.g. GMT). Before data is processed the time base that the original data was collected at should be established.

A consistent time base must be used for all data in the modelling process.

It is both useful to be able to break up time series into short lengths and to be able to extract large series of a particular determinand or produce plots of a range of parameters against one another. The decision as to how raw data is to be requested is a combination of the requirements for pre-modelling quality checks and the formats required for model inputs.

3.1.5 Provision of Data

In order that model construction and data quality control can run in parallel with the data collection, field data should be provided to the modellers in a logical sequence.

1. Asset data - river sections and structures to generate the model.

2. Dye tracer data and associated flow data for checking the calibration of the hydraulic model.

3. Dry weather flow and water quality data to check the hydraulics and begin water quality calibration.

4. Complementary data sets - DO spot measurements.

5. Wet weather flow data from all sources (CSOs, river, WwTW, surface water outfalls) to check flow balances.

6. Water quality data for wet weather flow for all sources.

3.1.6 Discussion

Dry weather WQ data collection is required to provide confidence in the model. For the most part the data are there to supplement data that may be missed during a wet weather data collection exercise and to help understand the river system processes.

Experience has shown that marked changes can occur in a river with changes in flow. In general the average roughness tends to be reduced as flows increase reducing the influence of the rougher river bed. Roughness has been noted to increase with depth for rivers with well defined dry weather channels. Re-aeration equations that produce good fits for low flows can give unrealistic DO values in higher flow regimes.

The response of the biological activity in the watercourse can change in response to storm flows. Bacterial colonies are sloughed from rocks, plants are submerged or obscured by sediment-laden water, and more bacteria are introduced to the watercourse in response to runoff from WwTW washout or CSO spills. These different mechanisms can all significantly influence the water quality parameters chosen to obtain a calibration fit.

For this reason, if sufficient storm events were captured early on in a river flow and quality survey it could be possible to review the continuing need for dry weather calibration events.

3.2 Data Quality Control

The principal question to be answered when provided with field data is "is it fit for purpose ?" Field data collection exercises are complex and can dogged by failures of monitors, samplers and incomplete datasets.

Ultimately the purpose of the exercise is to have a reliable model capable of transporting and decaying pollutant, and assessing this transport and decay with response to CSO inputs. Data sets do not have to be complete but sufficient for the modelling task.

The initial check is on flow data. It is important that flows are accurately measured along the watercourse. To check this measured hydrographs from the different river stations should be plotted over one another to demonstrate flow balance. Providing that there is not considerable abstraction of water or evaporation losses the total area beneath a set of hydrographs should increase as the system is monitored downstream.

Dye tracer data should be examined to look for a diffusion of concentration. The time of arrivals of peaks should be later the more downstream a site is. Initially, only a check by eye can be made. Ultimately the advection dispersion module and flow measurements can be used to further check this data.

Water quality data should be roughly checked. Plots of various determinands at different stations are useful to identify outliers of spurious data. Patterns in datasets of conservative or slow decaying substances such as Ammonia and Nitrogen should be reflected down the river system.

Datasets for boundaries must be substantially complete as these provide inputs to the whole of the model. The boundary data set will be input to the model and as such transported all the way through it. Intermediate sites are used for calibration purposes to compare the transposed boundary data. Failures at some of these points can be tolerated providing there are sufficient sites to check organisation in the rest of the data set.

The following checks on the field data are proposed:-

1) Plot hydrographs at all river modelling sites along the main stretch of river to assess water balance.

2) Plots of dye tracer data (concentration vs. time) along river to assess consistency in measurements.

3) Check quality and flow data is available for all boundary sites and that flows are available at any permanent monitoring sites.

4) Check water quality data is consistent, demonstrated by plotting (concentration vs. time) data series collected from different sampling sites against one another. This is useful for suspended solids, Ammonia and total BOD values.

5) That BOD fractions balance (Dissolved BOD < Total BOD) and that any difference there can be accounted for. In dry weather it is also likely that the ratio of total BOD to dissolved BOD is relatively consistent.

6) Any major changes in SS or BOD are cross checked against each other and other sites to determine whether they look authentic.

Once the data has been checked agreement must be made with the various interested parties that the data will be accepted as fit for modelling purposes.

Ironing out data problems before modelling begins can remove a large amount of wasted effort modelling with defective or unrepresentative data sets.

3.2.1 Data Processing

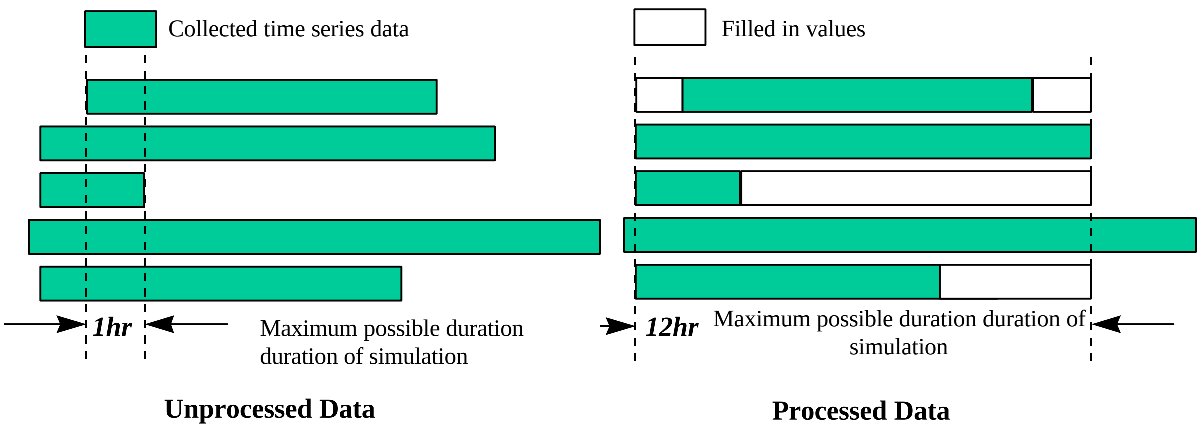
There may also be a requirement to process some of the collected datasets e.g. outliers and unrealistic values can be removed. This is particularly important if these values occur at model boundaries because their effect can be propagated down through the model. It is essential to maintain good records of any changes made to field data sets for audit purposes.

It is also necessary to check that there are no missing timesteps in one part of a calibration data set that may make other parts of the data set redundant.

For example Mike 11 models require simultaneous sets of time series data sets to be run. In the case that a set of field data that had been simultaneously collected at five boundary sites consisting of four twelve hour sets and a single one hour series, there would only be sufficient data for a maximum of a one hour simulation. In this case it may be necessary to supplement the one hour series with assumed values to enable a twelve hour simulation to take place. The assumed values should be justified by reference to the existing data. (see figure 3).

Figure 3

How Simulation Time in MIKE11 is Limited by Available Datasets



Before a hydraulic or more critically a water quality model is run the time series data will need tidying. This is likely to require the addition of data points in order that simulations of a suitable period can be run.

These changes or additions to the collected data sets should be recorded in the model building notes. It is probably expedient to undertake all this data processing in a spreadsheet or database before importing to the model databases. Specialist time series data processing and archiving software could be a more efficient tool for data handling and auditing.

4. MODEL BUILDING

This section of the report details the process of incorporating the physical characteristics of a river system into the dynamic river model.

4.1 Data Management

Section 3.1.4 provides some guidance as to a proposed format for the collection of raw data for River Modelling based upon data requirements for Mike 11. The modeller must be aware that while other models will have similar requirements, all models will differ in detail data specification..

It is important that any cross sections built into a model can be cross checked against drawings but the provision of data in a format ready to be inserted into a model removes the likelihood of errors arising from the transcription of data.

4.2 River Schematisation and Naming Conventions

A watercourse structures is built up out of river cross sections. These sections are grouped together into lengths termed ‘branches’ or ‘reaches’. These are composed of elements of the cross-sectional database which are defined by river name, chainage and Topographic Identification (TOPO-ID). Models built for river impact analysis are unlikely to encounter or need to consider morphological changes so the TOPO-ID is irrelevant. The choice of informative river names and chainages is important. For example the minimum chainage expressed by Mike 11 is 0 km, which is the most upstream section of the model. If there is a likelihood of extensions to the model in the future then it would perhaps be prudent to begin the numbering system at a higher chainage. This would leave room for expansion upstream. Otherwise the river name reference for the future upstream reach will be forced to be different to that used for the down stream river name. This may only seem to be a small point, but well thought out naming conventions from the beginning of a project will remove the scope for confusion, errors and possible misinterpretation of model results.

Paper plans detailing the schematisation of the model plus cross-section naming conventions are required to illustrate the construction of the model. These plans should be updated to incorporate any changes to the model, throughout the course of the project. These plans should show the following:-

1) Boundary locations

2) Cross sections with river names and chainage conventions

3) CSO inputs locations

4) Background mapping if possible

5) Weirs and other important structures

6) Tributaries and lateral inputs

7) Monitoring locations.

All information should be stored electronically to enable easy transfer to modelling software, a GIS or CAD system. In general the modelling systems will be able to hold all the data, but the other systems may be necessary to improve data visibility and presentation.

If for any reason co-ordinate data is not available for cross sections then schematic drawings should be produced.

4.3 Asset Data

Asset data is the term used to describe the cross section data and all of the hydraulic controls in a watercourse.

4.3.1 Data Input

CROSS-SECTIONS

Where existing survey data is available, the cross sections to be included in the model need to be selected carefully. Too many cross sections, too close together can cause stability problems and will reduce model run times.

There is more leeway to use fewer sections in a water quality model than a flood defence model because precise knowledge of water levels is not so critical. It is satisfactory to have enough sections to generally represent the overall shape of a channel.

WEIRS

Models handle weirs in two ways.

The first method is to feed weir width versus level into the model. This is used in the broad crested weir equation to develop a flow / head relationship.

The second approach is to use the "special weir" representation to provide a stage discharge relationship. For example in Mike 11 Version 3 these values are entered through the Mike 11 interface, whereas in Version 4 the data can be directly pasted in from a spreadsheet.

To develop a broad crested weir model, data are required in two columns the first containing level information and the second weir width at that level. In cases where the weir is wider than the upstream and downstream cross sections the software is unable to generate a stage discharge relationship. In these cases the special weir approach is required or the weir will need to be narrowed and weir coefficients altered to satisfy the requirements of the model. Narrowing a weir and reducing the headloss factor will have a similar net effect which should be checked against 'manual' hydraulic calculations.

CULVERTS

Culverts that significantly limit flow down channels at the flow ranges required for UPM modelling should be incorporated. Culverts are represented by their physical characteristics and a variety of shapes can be incorporated including irregular culverts defined by depth or level to width relationships. Data has to be input manually so values will have to be taken from drawings or sketches of the structure. For more complex channel, sections of tables of level and width values may reduce the amount of typing required if Mike 11 Version 4 is used whilst achieving sufficient representation of the structure.

REPRESENTING POINT INPUTS FROM MINOR UNMODELLED TRIBUTARIES

Inputs that don't require explicit representation should have been identified at the planning stage. These can be represented as point inputs if required.

Models can manage point inputs in two different ways. The inputs can be at the head of a branch/reach, or lateral to a channel. These different approaches do not greatly influence hydraulic models but can affect the data processing for water quality models.

If the tributary is modelled as a branch/reach inflow, time series are fed into the model for the hydraulic simulation. Water quality time series can then be fed into the channel at the water quality modelling stage. This approach has the computational overhead of extra nodes in the model for the dummy branch.

However, if a tributary is modelled as a lateral inflow then a time series flow has to be input to the hydraulic simulation. For the water quality simulation a time series consisting of the input hydrographs and pollutant concentrations have to be added to generate correct mass inputs. This approach can have high data processing overheads if the inputs at this location are to vary in response to testing a number of scenarios.

4.4 Stability Tests

Once a model has been constructed a number of tests must be undertaken to verify that the completed model runs in a stable manner. The tests have to consider the range of flow conditions that the model is to simulate from low flow to maximum likely flow. Problems that do not occur at high flows can occur at much lower flows.

The following tests should be undertaken:-

1) Run the model for likely minimum flow and check to see if there are any instability problems. Secondly check the velocities, mass errors, accumulated mass errors for the simulation from model output summaries. This simulation must also be checked to see if extremely high velocities are generated which may affect future water quality calibration.

2) As for test 1 but for maximum flows.

3) Run the model with, a spike of conservative substance which should be routed down the watercourse in steady flow conditions. The overall mass balance of this concentration spike should be checked. The total area underneath the “pollutograph” should remain constant.

4) As for test 3 but for the results from the high flow simulation.

5) Create a set of typical water quality boundary values, and run the model in AD mode. The rerun the model in WQ mode to confirm the model will run.

4.5 Method for Resolving Problems with Hydraulic Model

If a hydraulic model is unstable then there are a number of fixes that can be applied.

These methods work with the Mike 11 hydrodynamic module. They may not apply to other models, but similar techniques, the exact nature of which will depend upon the structure of the model process, will apply.

If the river is very wide and is carrying a low flow then this will cause the model problems. In reality there will not be uniform shallow layer of water over the whole channel bed even if it is completely level, but a rivulet will form down the bed. Computational models are not able to simulate this so a very slow moving very shallow depth of water is calculated across the channel width. This will often give the model stability problems. To overcome this it is suggested that a groove is put into the channel bed of approximately 100 mm depth and a few tens of mm.s width. This allows the channel to have a reasonable depth of water at low flows thus removing the stability problems. The volume of the groove is relatively small so it will not greatly affect the calibrated levels.

Sometimes the hydraulic module is unable to make water levels stay above bed level. This problem occurs when the solution at a particular node is unable to reconcile the numerical hydraulic solution with the levels at the upstream and downstream node. However it is possible to place a broad crested weir (h-point) into the model instead of the standard cross section. This will enhance stability and allow the model to be run at a greater timestep.

A third method for maintaining stability is in model initialisation. Steep watercourses can give problems initialising the hydraulic run for low flows. In this case a stable hydraulic hot-start file can be developed by running a very high flow through the channel. This is then ramped down until a steady flow of the required lower flow value is maintained. Providing the model is stable for this lower flow the results of this simulation should be saved to create a hot-start file for future hydraulic simulations.

4.6 Optimising Model for Speed

The run time of a model is dependent on the number of computational nodes and the timestep that the model is run at and the numerical solution scheme adopted.

Minimising the number of cross sections in the model will allow the computational grid to be coarser. Running at larger timestep will reduce simulation times. For some models, for example Mike 11, the hydraulic solution can be run at large timesteps. However the stability of the water quality solution usually requires that much smaller timesteps are used.

This particular problem is enhanced during storm flow simulations where there are lots of short duration impulsive inputs from CSOs discharging to the main watercourses.

In order to speed up model run times as coarse a computational network as possible may be adopted with the model incorporating as large a water quality timestep as possible. The dictates of the water quality and sediment transport models are likely to require timesteps of one minute or less.

4.7 Quality Control

A number of changes are likely to be necessary in order to get a model running correctly. For example: changes may be required in the cross sectional database or the network data file.

For audit purposes it will be necessary to produce a list of all river sections in the model and any changes that have occurred to them. The list must be flexible enough for the addition or removal of sections and details of what changes have taken place.

The various versions of the network data file should be numbered sequentially in order that the latest version of the model is easy to determine. Notes should be made of all the alterations made to the model during its construction.

5. CALIBRATION

Process models should be provided with default parameters which have been found to be generally applicable to typical rivers. However there will be cases where default parameters need to be changed to suit clearly defined alternative types of rivers. Note should always be taken of the process model suppliers recommendations and defaults adjusted to suit.

For example it is suggested that for Mike 11 calibration should start from the model default parameters. However the values in the water quality default file are not all the same as the recommended values in the Mike 11 Manual so some care should be taken to compare recommended constants with those provided in the water quality default file. This is discussed further in Section 5.4.

5.1 Hydraulic Dry Weather Flow

The first check to undertake is that a reasonable flow balance is obtained down through the river system. This is most easily done in a spreadsheet. Providing all the quality control checks have been made on the input data and the data is processed correctly there is little that can be done with dry weather flow as there are no features that can be identified in a reasonable steady data set. In rivers with a diurnal DWF profile, model fits to varying flows can be made.

Ideally all of the flow monitoring sites will be located at weirs so water level calibration will be governed by the stage discharge model of the weir. General water levels are not of great interest, providing depths are not significantly outside the values observed the fit should be deemed acceptable.

If water level predictions vary significantly from observed levels, it is likely that this will be due to problems with the model structure, the input datasets or offsets on the level data recording sites; these should be checked.

5.2 Hydraulic - Storms

The first check to undertake with storm hydraulic data is that a reasonable flow balance is obtained down through the river system. The model itself is likely to be the best way of managing the large number of set of data series, derived from urban drainage systems.

The initial check is that simulated volumes match measured volumes downstream through the system. This may be a difficult task because of the contribution of spill volumes from CSOs, the accurate prediction of which is limited by network modelling constraints. Acceptable volume balance needs to be agreed by all parties.

Once the majority of flow has been accounted for calibration should consider the timing and attenuation of flow peaks. It is likely that the average channel roughness will reduce as a result of higher water levels as illustrated in Figure 1. Calibration will involve adjustment of the average roughness values or, if sufficient data is available, the ‘resistance factor’ that can be used to model the change of channel roughness with depth.

5.3 Advection and Dispersion

Advection dispersion calibration has a two fold role - to correct the velocity of flow and to adjust the dispersion of substances in the watercourse.

For each event, the following checks should be carried out

1. that there is a good flow balance in the hydraulic data set.
2. roughneses should be adjusted until predicted peak concentrations of the dye tracer studies coincide with observed peak values.
3. if necessary the dispersion terms need adjusting until the spread of the predicted concentrations match the observed data set. This is not always necessary because the numerical scheme used to calculate the advection dispersion solution creates some natural diffusion.

Providing the base flow data is accurate good fits of the simulated to the observed datasets can be achieved. Once a calibration is achieved the parameter values should be tabulated. The table should include the flow range of the calibration, roughness and dispersion values chosen for each section where a section is defined as the stretch of watercourse between two monitoring sites. The date of the observed data against which the model was calibrated should also be noted. The table will allow the pattern of changes in the watercourse to be observed and will help to develop conclusions as to which parameter values should be used for the final impact model.

5.4 Water Quality

Water quality modelling for rivers is extremely complex with dozens of parameters. It includes simulation of at least the state variables DO, Temperature, Ammonia, Nitrate, Suspended BOD, Dissolved BOD and Sediment BOD. As an example the MIKE 11 model uses 17 different processes to achieve the full analysis, but the model can also be run at five lower levels of complexity where data is either not available or not needed..

Usually the more complex levels of complexity will be needed in order to interact with the sewerage quality model interface for CSO inputs. However lower level models can be used if required if the CSOs are modelled as lateral inputs of tributaries.

Typical parameters which define these processes are listed in Appendix A together with recommended defaults taken from the MIKE 11 manual. Note that available data is limited. Many parameters will not be required to be changed during calibration.

Calibration must be approached in a structured manner breaking the calibration into small units until a final fit is achieved.

Rivers are dynamic systems, calibration parameters will change in response to the amount of sunlight, river flow, bacteria in the watercourse and the time of year. Though the water quality model is complex it is insufficiently detailed to involve all of these changes so calibration parameters are assumed to vary. For these reasons a series of calibration exercises are very unlikely to develop the same set of parameters for each field event captured.

5.4.1 Order of Calibration

The water quality model is constructed of some parameters which are acted on in different ways. Some are only decayed, e.g. dissolved BOD others some such as Ammonia and Nitrate decay and can be produced from other determinands but generally do not change greatly. Sediment BOD is sourced from suspended BOD and is a term that cannot be quantified as part of the data collection exercise. Temperature is a relatively insensitive parameter, particularly over the timescales of the modelling exercise but essential to kinetic rates for the rest of the model. Dissolved oxygen (DO) is the determinand that has the most varied sources and sinks and requires the greatest effort to calibrate. For these reasons the following order of calibration is proposed.

5.4.1.1 Temperature

Temperature calibration should take place first. Temperature is relatively insensitive to its calibration parameters. Temperature is a very important input parameter for all of the kinetic equations. The parameters may need some adjustment to differentiate between a sunny day and an overcast one.

5.4.1.2 Decay Rates of Key Determinands

The first order decay rate for dissolved BOD should be adjusted next. The suspended solids data must then be observed to see if there is a relationship between suspended BOD and suspended solids. This allows a judgement to be made about whether suspended BOD removal is due to settlement or decay. Once BOD decay rates have been determined, fits should be attempted for Ammonia and Nitrate.

5.4.1.3 Sediment

Sediments are divided into different fractions. These may be described by particle size or in more general terms such as cohesivity.

It is extremely difficult to obtain quantitative data about the coefficients describing these sediment fractions. The values for the model have to be selected from the in-river datasets and adjusted until a reasonable fit is achieved. Any supplementary sediment survey information will allow values for the available sediment bed load and potency to be estimated.

The UPM release of Mike 11 contains two sediment fractions, cohesive and non-cohesive, for potential use if the suspension and deposition of sediments is to be modelled as is necessary if the model is to be interfaced with Hydroworks. The cohesive sediment model is easier to use as it is more empirical and with less parameters that the non-cohesive model. CSO inputs from the sewerage quality model interface contain cohesive sediments.

In reality there is unlikely to be sufficiently good data to reliably model one sediment fraction let alone two. Hence it may be sufficient to ignore the non-cohesive sediment fraction, setting its potency and concentrations to zero.

5.4.1.4 Photosynthesis / Respiration

It should also be noted that the amounts of oxygen production from photosynthesis will vary from one day to the next due to the amount of sunlight. Respiration should remain relatively steady from day to day. Both terms will vary seasonally as the number of plants and the rate of growth in the watercourse change. The aim of this exercise is to establish a good representation of observed diurnal variations in DO.

All process model will treat photosynthesis differently. Recommendations of the process model must be carefully considered. The Mike 11 User Manual (Version 3.11) details a method for estimating photosynthesis and respiration values. This method is a useful first step towards calibration. The technique’s limitations are also documented in the manual.

5.4.1.5 Re-aeration

Once representative values have been assigned to the other parameters in the model the re-aeration coefficient needs to be determined. This coefficient describes the aeration that occurs from diffusion with the atmosphere in quiescent waters, and from mixing with the atmosphere in riffle areas and at weirs. The major factors affecting the re-aeration constants are the current velocity, river slope, water depth and temperature.

As for Photosynthesis an understanding of the process built into to the model must be gained in order to achieve a realistic result. For example Mike 11 has three expressions for determining K_2 the re-aeration coefficient. These have been shown to be only suitable for certain watercourses and the applicability is also stated in the original papers. These equations are all of the form K2=D^a*V^b*I^c (where D is water depth, V is velocity of flow and I is river slope). It is likely that a user defined expression will be required, although the adoption of a model provided from literature or the Mike 11 defaults would reduce the modeller's workload. When developing the re-aeration equation the range of flow velocities and depths that the model is to run at must be taken into account. The DO profiling recommended in the data collection exercise will provide a check on the calibration and DO profile between the fixed monitoring locations. It is likely that different re-aeration parameters will be required for weirs than for river channels. The DO profiling exercise will help to determine the amount of re-aeration at intermediate structures.

The development of user defined re-aeration equations is difficult and should only be attempted when all other models are found to be inappropriate.

Whereas water quality calibration parameters may vary from event to event the terms used to develop the re-aeration coefficient K_2 should be universal to both the wet and dry weather events because this is only based on physical characteristics. However two models may be required if providing a universal equation satisfactory for all flow conditions proves too difficult.

5.5 Sensitivity Analysis

It is likely that the calibration exercise will have yielded a number of coefficients for different parameters in the water quality model. The variation in values can be attributable to e.g. weather conditions, flow differences and variations in substrate. It is advisable to determine how these ranges of values affect the river impact model in order that an appropriate set of values can be chosen for use in the final design river impact model.

In order to determine the influence of a parameter a matrix should be drawn up showing the calibration parameter chosen for each event. The mean or the mode parameter value should be taken as the initial parameter value for the baseline model. Then maximum and minimum parameter values should be taken from the parameter matrix.

A typical river impact simulation should be undertaken using the baseline parameter set. This should be repeated a number of times changing each parameter in turn from the maximum range to the minimum of the range whilst all of the other parameters are set to the baseline values.

Before the sensitivity analysis a dry weather initialisation period should be run through the model to create a hot start file so that all of the sensitivity runs can be initialised with the same baseline conditions.

A further point to note is that the sensitivity runs should have a duration greater than the period of the standard. If there are plans to look at the effect of parameters on the 24 hour intermittent standard the model has to be run for at least 24 hours, preferably 24 hours plus the maximum time of travel in the watercourse.

A means of comparison is required to compare the influence of the different parameters on the various sensitivity runs. A recommended value is to plot the 1, 12 or even 24 hour maximum continuous period (Section 8.2) of low DO concentrations and peak ammonia concentrations for each sensitivity event. This final plot will allow the implications of the parameter changes to be assessed in terms of final DO and Ammonia concentrations. The final set of design parameters can be selected from the matrix of values, with the sensitivity plots to demonstrate the range of values these parameters influence.

6. VERIFICATION DATA

Calibration and verification are not separate exercises. All of the events (DWF and WWF) are put together to determine optimum parameter values. The final set of model 'design parameters' should be developed from the model calibration and sensitivity analysis.

Because natural river systems are so dynamic, it is not appropriate to verify the model by comparing the parameters derived from the calibration exercise with a set of field data. It is very likely that the fit will not be optimum due to some change in environmental conditions.

However, it may be worthwhile to re-run the storm events used for water quality calibration just to demonstrate that the design set of parameters are generally giving a realistic fit to the observed data set.

7. MODEL APPLICATION TO UPM ISSUES

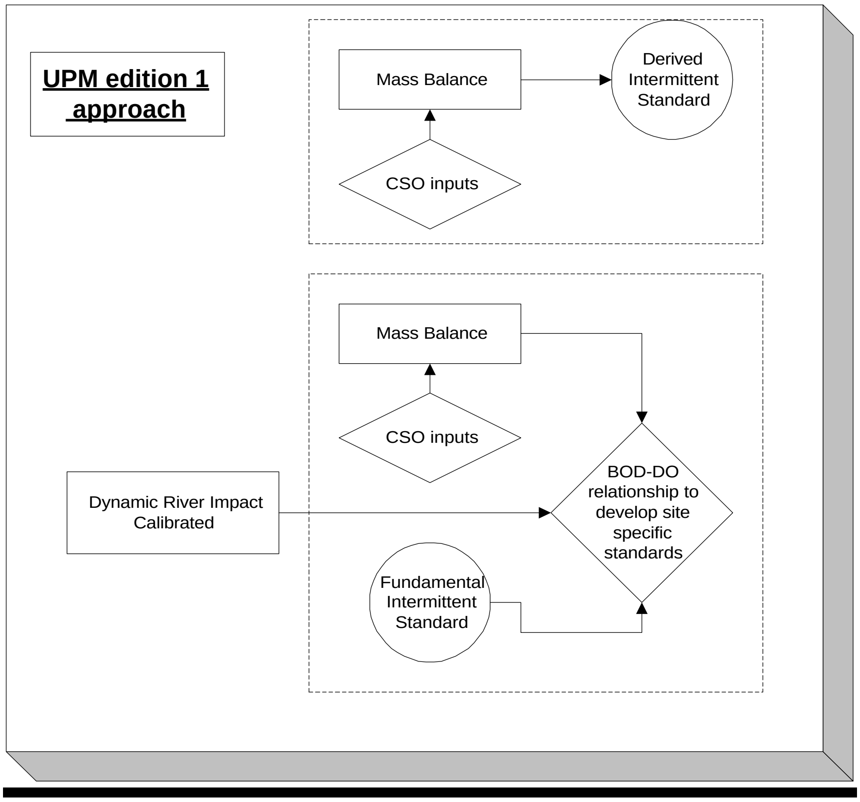
7.1 Applications

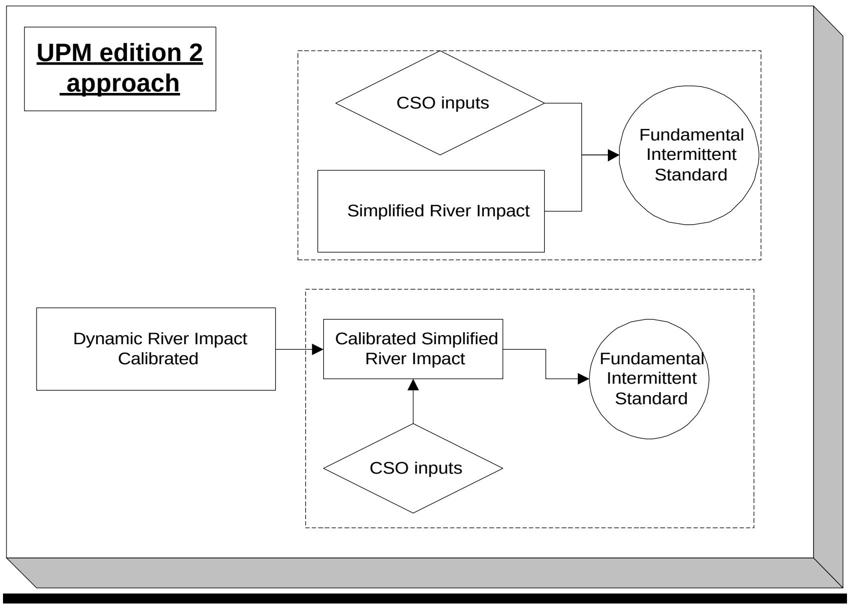
7.1.1 General

The different river modelling approaches available for UPM studies have varying data requirements and applications. Figure 4 shows a breakdown of the different applications for models in the context of the UPM manual edition 1 and 2. The model application can be divided into two approaches:

- The mass-balance and simplified models are used to determine river impacts within a statistical framework with multiple runs.
- The dynamic models are used to develop site specific standards, calibrate the simplified impact models or assess design solutions.

Figure 4 River Model Applications in UPM studies





7.1.2 Specialist- Peak River Levels

The dynamic model is generally not intended to be used for purely hydraulic purposes. However one hydraulic application has been identified, to determine river water levels for CSO design purposes. The approximate water levels generated at the CSO location can be determined from a design flow. Providing the flow for the required return period is not too far from calibration flows this approach though uncalibrated for the specific flow value should provide reasonable design information.

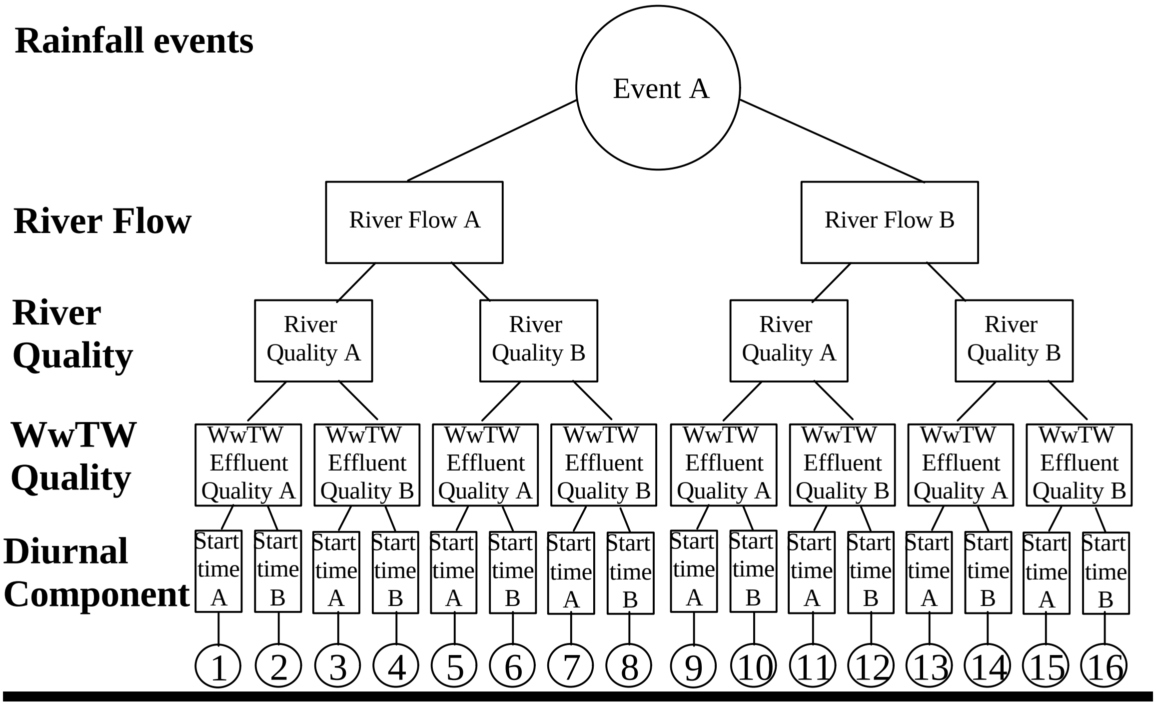
7.2 Scenarios

The scenarios used for the simplified impact procedure calibration have to be developed in order to represent a good spread of river conditions and CSO loadings with which to calibrate the simplified model or develop site specific standards. The calibration events should be set up to provide as much information as possible from as few simulation runs as possible, because of the time and data processing overheads associated with full dynamic modelling. Figure 5 illustrates the number of possible scenarios that can be very quickly determined, for a catchment with both WwTW and CSO inputs.

It would be advisable to determine the number of events that are required to calibrate to simplified procedure and then work backwards to decide on the range of flow conditions to be used. It is suggested that a minimum of eight to ten calibration events are run.

A minimum of two flow scenarios should be used, these should be amongst the lower flows in the distribution because they will demonstrate a more significant river impact. For this reason it is suggested to use 5%ile and 50%ile summer flow values for the boundaries.

Figure 5
The Matrix of Possible Modelling Scenarios



7.3 Boundary Conditions

Different approaches to boundary conditions should be taken for the dynamic and simplified models. Tables 3.2 and 3.3 (see Section 3) outline the data requirements for the different approaches.

7.3.1 Hydraulic Boundary Conditions

For UPM analysis it is likely that summer conditions are when the most significant CSO impacts on receiving waters occur. Distributions chosen for river impact analysis or model calibration must reflect this so a subset of the annual flow statistics must be obtained. These summer distributions should be developed from analysis of historical data or by applying an agreed factor to the statistical parameters for the annual flows.

It is recommended that steady flow boundaries are used for hydraulic inputs to the dynamic model, for model calibration purposes. Developing time varying inputs to the model is fraught with problems such as time to peak, magnitude of peak and base flow values the reliable representation of which are all open to debate. The second edition of the UPM manual requires steady flows for calibration events as simplified catchment modelling to provide inputs (i.e. SimpolV2) does not give dynamic flows.

7.3.2 Water Quality Boundary Conditions

Steady water quality concentrations are recommended for all boundaries for calibration and river impact modelling. The mass balance approach and simplified river impact model require inputs for BOD, Ammonia, Temperature and pH with DO also required for the simplified Impact model. The calibration model requires the full range of input parameters if the model is to be run with the sewerage quality model interface. This would require a total of eleven input time series to be fed in at every model boundary including the downstream boundary. Values are required for DO, Temperature, Ammonia, Nitrate, suspended BOD, Dissolved BOD, BOD sediment, Cohesive sediment, Cohesive BOD, Non Cohesive sediment and Non Cohesive BOD. However for Mike 11 the suspended BOD value is dummy because it is the sum of the cohesive and non cohesive BOD.

Care must be taken at this point that the sediment potency factors at upstream boundaries are appropriately set because extra BOD can be added to boundary conditions by the re-suspension of sediment at the boundary. It may be appropriate to set all of the values for non cohesive sediment and its BOD to zero and local sediment potency factors close to the boundary also to zero.

A subset of water quality concentrations have to be selected from the quality distribution for each parameter in order to set up the runs. The data should be selected from the worst water quality conditions to increase the likelihood of significant events to calibrate the simplified procedure against.

Table 0.1
Typical Data Requirements for a River Impact Model Simulation

Items	Requirements	Data Required
Tributary Flows	Steady Flows	Time series flows for all tributaries for each flow scenario.
Tributary Water Quality	Steady WQ values representative of each boundary.	11 time series for each tributary plus 1 dummy series for the downstream boundary for each water quality scenario.
Hot Start Files	Results of a dry weather flow simulation for the time of travel of the model plus 24 hours	One Hot-start file per combination of flow and quality scenarios
WwTW flows	Steady or time varying flows	Time series flows for all WwTW for each WwTW flow scenario
WwTW quality	Steady or time varying qualities	11 time series for each tributary for each WwTW quality scenario.
CSOs	CSO flow and quality output from sewer quality model	Five sewer quality model format files per sewer model output input (maximum of 10 gauge points per file)
Surface Water System	CSO flow and quality output from sewer quality model	Five sewer quality model format files per sewer model output input (maximum of 10 gauge points per file)

7.3.3 CSO Inputs

A list must be developed relating the location of each CSO in relation to the river in terms of chainage. If the river process model has a designated interface for taking the CSO output data it is usually appropriate to reformatted outputs to the required node numbering and file naming conventions. Although this is time consuming it is easier than modelling them as lateral inputs creating time series inputs at each CSO location

7.3.4 Surface Water Inputs

As for CSO inputs.

7.4 Initialisation

No initialisation is required for simplified models.

Initialisation is an important issue with the dynamic river impact model. Any model run is going to be a function of the boundary data, plus the data already in the model. Two approaches to initialisation are automatic, which assumes that the concentration at the boundaries are extended all the way down the model, and to use a hot-start file generated from a previous run. The first approach is a reasonable assumption for rivers with short retention times but it is unrealistic for rivers with long retention times where it is not reasonable to assume that they will have the same chemistry as at the upstream boundary. This will be a particular problem in water courses with lots of plant growth or re-aerating structures. Mike 11 has provision for both methods, as will most other process models.

In order to run the simplified impact procedure calibration events it is worthwhile to set up a hot start file for a 24 hour dry weather flow run. This file can be used as initialisation for further water quality runs, setting the conditions down the river system to typical values prior to a storm. Depending on the retention time in the watercourse the hot start file should be run for the retention time plus 24 hours. The run for the retention time allows the boundary conditions to propagate through the model. The final 24 hour period is used to extract the correct boundary condition for any future model start times. A number of initialisation hot start files will be necessary if a range of flows are used in the calibration runs. The different flow scenarios affect retention time so the water quality and the initial dry weather flow qualities will change with flow rate.

7.5 Calibration of Simplified Models

Simplified river models can be applied in two ways as an uncalibrated tool using default/typical parameters; or as a calibrated tool calibrated against the results of a fully dynamic river impact model.

Calibration of the simplified river model is relevant to the river impact procedure proscribed in the second edition of the UPM manual. The manual states that calibration is achieved by running the simplified river model (e.g.SimpolV2) with the same events as the design version of a deterministic river model (e.g. Mike 11), until the predictions of minimum DO agree with the detailed model results.

In order to verify that the calibration is successful plots will have to be provided of the deterministic model results and the data sheets from the Simplified model. The Simplified model data sheets detail the lowest DO values at the end of each subreach for a simulation of a particular impact duration. This can be compared with the event summary statistic, for the same duration from the deterministic model for the same simulation event. The fits should be assessed by comparing the values predicted by the simplified model by those produced by the dynamic model.

The number of events used for calibration purposes are not prescribed in the UPM manual. However the derivation of how scenarios should be approached is described in section 7.2 of this report.

The development of the simplified model will require reporting and calibration reports will be require depending upon the approach used to develop the model.

8. RESULT PROCESSING

8.1 Data Handling

Mike 11 Version 3 has tolerable data handling facilities in terms of graphing and time series output. The labelling of the times and dates and lines is inadequate, so further annotation can be undertaken by hand or by producing Windows Metafiles of the plots and editing them in a drawing application.

Data output has been upgraded in the Mike View Module used with version 4 of Mike 11. This upgrade permits better quality plots to be formatted and drawn with greater ease.

Generally most data handling requirements are available in Mike 11. Time Series plots and long section animations are all available.

8.1.1 Critical Reach

Critical reach locations can be determined by plotting a time series animation of DO or Ammonia. If the line redraw facility in the long section plot function in version 3 of Mike 11 is turned off then an envelope of values can be produced. The envelope will show all of the values from the entire simulation down the system allowing the minimum or maximum points to be clearly identified.

8.1.2 Sensitivity Analysis

The data produced by dynamic models is variable in both space and time. In order to compare data set from different simulations a common value for comparison needs to be defined. A useful approach is to transform the time series data along the river model using the event summary statistics tool in Mike 11 (Section 8.2). This will pick out the total time or continuous period that the determinand of interest is above a certain level. This approach produces a single comparative value along the water course. Such values can be output from Mike 11 (version 3) into a text file which can be loaded into a spreadsheet. The determinands of interest and the period of concentrations depend upon the specific issues that the model is being used to address.

A recommended approach is to plot the 1 hour or 6 hour maximum continuous period of low DO concentrations and peak ammonia concentrations for each sensitivity event.

8.2 Event Summary Statistics

Mike 11 version 3 has a statistics processing tool which enables the water quality data to be processed to determine event summary statistics. There are a number of statistics offered :

- Cumulative time (CT) above or below a user specified threshold.
- Maximum continuous period (MCP) above or below a specified threshold .
- Maximum continuous period taking into account a recovery period (MCPR) above or below a specified threshold.

Printouts can be obtained for 1, 12 and 24 hour excedance for all three methods plus excedance for user defined periods.

This data can be produced as graphical plots or as ASCII files which can be read into spreadsheets for further analysis.

9. REPORTING REQUIREMENTS

The following requirements for reporting have been outlined.

9.1 Reporting for dynamic model application.

- Interim reports and presentations of modelling progress.
- Final report detailing all aspects of modelling.
- Sensitivity Report
- Model Simplification report

9.2 Reporting for uncalibrated simplified model application

- Simplified model build report.

10. REFERENCES

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