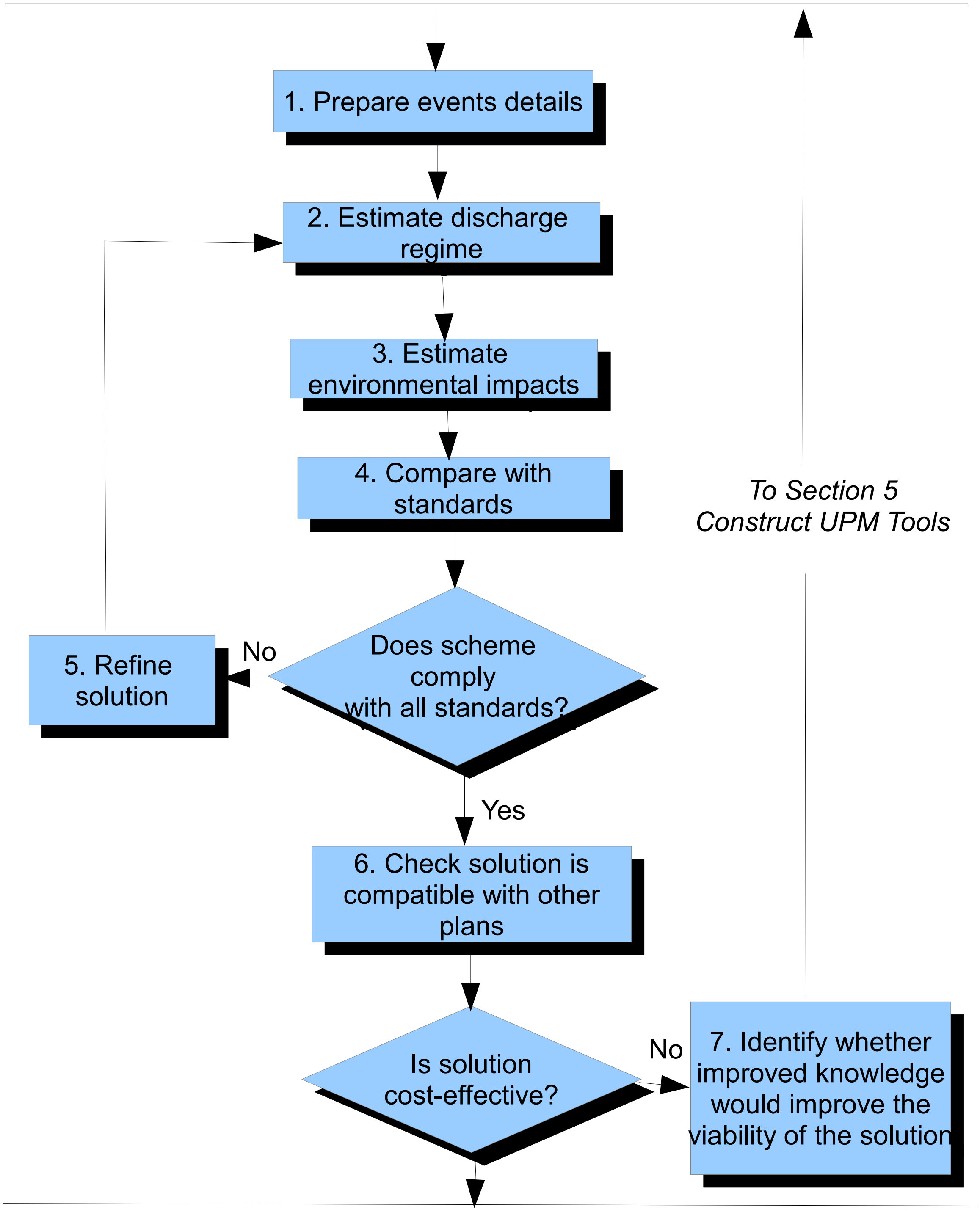
Section 6

Assessing Performance

From Section 5, Construct UPM Tools



To Section 7, Post Planning Study Issues

6. ASSESSING PERFORMANCE

This section of the UPM Procedure is concerned with using the various models from previous sections to assess the performance of the existing system and, if necessary, develop solutions to solve wet weather problems.

This section presents methodologies for using these models to test the performance of existing and revised systems for compliance with the environmental framework which was agreed in section 3. For most UPM applications, this environmental framework will comprise environmental and/or emission standards and the models developed in section 4 will have been chosen with these standards in mind.

In relatively simple cases, the environmental framework may comprise minimum wastewater system performance requirements only; for example, a minimum retained flow and the improvement of CSOs to ‘good engineering design’. If this is the case, there is no specific work to do in section 6 and the study can move immediately to detailed design.

There are three subsections, the first of which presents a generic UPM methodology, which encompasses all the key steps which should be followed for any application of the UPM Procedure. Subsequent sub-sections describe in more detail the variations of the generic procedure necessary to assess performance against specific forms of standard.

The list of sub-sections comprises.

6.1 Generic UPM methodology.

6.2 Methodology for assessing performance against standards for protecting freshwater aquatic life.

6.3 Methodology for assessing performance against standards for protecting bathing or shellfish waters.

6.1 Generic UPM methodology

The generic UPM methodology is illustrated by a flow chart in Figure 6.1 and each step is described below.

6.1.1 Step 1 - Prepare simulation details

In general, the models will need to be run for a continuous time series of rainfall, typically 10 years (or seasons). Different series may be chosen for testing compliance against the different standards that may be applicable at a given site.

In addition, decisions are also required on the sewer and receiving water conditions at the time of the rainfall events. In the case of marine waters, tide and wind conditions are also important. Combinations which could cause relevant thresholds to be exceeded need to be identified.

Previously, a decision should have been made (see section 4), on the degree of detail to which the receiving water regime is to be represented, as follows:

- CSOs and other discharges represented as a single lumped input in a simple impact model;
- discharges grouped into clusters, each impacting on a different part of the receiving water, as represented by an impact model consisting of a number of individual compartments; and,
- discharges represented individually, with a corresponding fully distributed impact model.

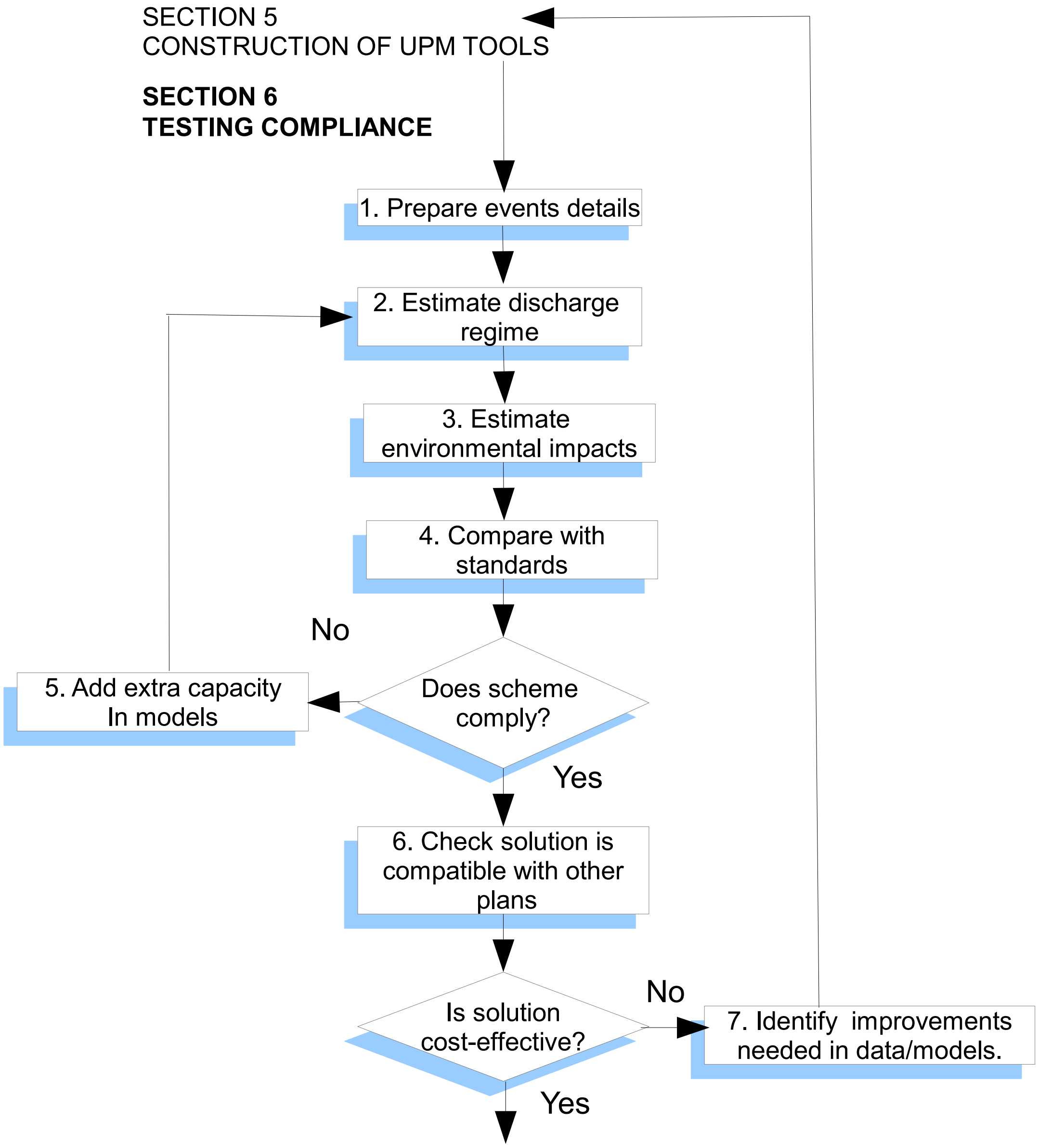


Figure 6.1 Generic flowchart for section 6 – Assessing performance

6.1.2 Step 2 – Estimate the discharge regime

Section 4 covered calibration of models to assess the current, actual system performance. Depending on the complexity of the problem being investigated, and the associated modelling approach, part of the output from Section 4 should be to identify whether the current performance meets the defined standards and, if not, the key reasons for that failure.

Where current performance is not acceptable, a structured approach to selecting and evaluating potential improvements should then be taken. In evaluating improvements, they should typically include any upgrading likely to be required for:

- eliminating unwanted throttles in the sewer system;
- the rationalisation of CSOs, e.g. to eliminate unwanted, obsolete or redundant overflows;
- meeting flooding or structural upgrading requirements; and,
- other planned allowances, e.g. for new development.

When evaluating future system performance, it is importance that any future changes that need to be evaluated as part of the agreed environmental planning framework (Section 3) should be incorporated, particularly in relation to growth/decline and climate change.

6.1.3 Step 3 - Estimate environmental impacts

This is the environmental modelling step and is required where environmental standards have been defined. The river (or estuary or marine) model (Sections 4.5, 4.6 and 4.7) is run with the discharges using the associated rainfall sequence to provide the resultant water quality impact information for step 4. Runs may be repeated for a range of different environmental conditions as identified in Step 1.

6.1.4 Step 4 - Compare with standards

A statistical analysis of the results from Step 3 (and/or Step 2 where emission standards are defined) will confirm the performance of the system against the agreed environmental standards. Checks against any minimum performance requirements should also be made at this stage.

As part of this and the following step, it is prudent to test out the robustness of the performance evaluation, by identifying any areas of the work that are not well defined, and evaluating the degree of uncertainty this leads to, in either the assessment or any associated solution.

6.1.5 Step 5 - Optioneering

This step is the start of an iterative process to find a solution which complies with the standards. In this context, options to appraise could include:

- rationalisation of overflows;
- increasing pass forward flows;
- extra detention tank storage;

- outfall resiting, to a location where there is extra ‘environmental capacity’ to absorb the discharges without compromising the standards;
- limitation of trade effluent loads;
- source control;
- reduction in inflow / infiltration;
- RTC to maximise the use of existing and new capacity; and,
- extra treatment, either at CSOs or at the STWs.

In the optioneering phase, the models are adjusted to represent potential upgrading measures and the process returns to Step 2. It is important that when a solution is identified that is compliant with all the standards its performance is finally checked using a full sewerage model along with a full set of input conditions. The checking should include features that are material to the actual performance of the system, such as the drain down of tanks, or the functioning of CSOs being impeded by high river levels.

6.1.6 Step 6 - Check solution is compatible with other plans

This requirement has already been referred to in Step 2. It is important that it is reassessed at this stage to ensure that a solution is obtained that is fully integrated with the requirements for all wastewater system problems.

6.1.7 Step 7 - Identify whether refinements in data/tools would be beneficial

Having identified a scheme that is compliant with the applicable standards, this is the stage when that solution is reviewed for cost-effectiveness. If the solution turns out to be very costly this may be because simplifying assumptions have been made to avoid detailed investigation and modelling.

The question which must be asked is whether the solution is cost-effective, or if additional effort spent in getting better data or building more realistic models could allow significant savings to be made while still meeting the environmental standards. To help answer this question, sensitivity testing can be used to examine which assumptions have the greatest influence upon the result.

If improved data or models are required to develop a more cost-effective solution, the planning procedure moves back to Section 4 to carry out these enhancements. Otherwise, the procedure moves on to Section 7.

6.2 Methodology for testing compliance with standards for protecting freshwater aquatic life

This section describes a specific methodology to be used when standards for protecting aquatic life in the receiving water body have been specified. This will most commonly apply to rivers and the methodology is written in the context of rivers. In principle, the methodology also applies in lakes and estuaries (Section 2.3). Hence, lake or estuary models (Section 4.6) may be needed to estimate concentration exceedance periods for comparison with standards.

The sections below use the steps set out in the generic flow chart, with comments where the specific application is different.

6.2.1 Step 1 - Prepare simulation details

It is now common practice to use a continuous rainfall sequence covering a long time span, along with associated soil moisture deficit (SMD) information, to drive the flow response of both the sewer system and the river system. The quality for the sewer system is normally explicitly modelled in a sewer model, which can use either default or measured values. For river quality generally, this is represented by establishing flow-quality relationships for the river being investigated, although river quality can also be modelled explicitly.

Dependent on the standards being tested, and on when actual failures in the receiving environment are being observed, a decision will be needed on whether the system needs to be simulated for all year, or part of a year, typically summer.

a) Rainfall

The rainfall sequence (along with SMD) should be a representative period of typically ten years. The rainfall sequence should not only capture the rainfall itself, but also the inter event dry periods.

The rainfall information can come either from a statistical rainfall generator, or a long historic sequence. In either case, tests should be made to confirm that the rainfall is typical of the location it is representing.

- **Summer rainfall sequence**
  This is typically a sequence of 10 years of summers. It is restricted to the summer period on the assumption that any breaches of the intermittent river quality standards are only likely to occur in the summer when flows are low and temperatures high. The five month period, May to September, is the most common summer sequence to be used.

- **Annual rainfall sequence**
  This is a continuous sequence of rainfall and intervening dry periods, typically covering 10 years.

b) Sewer system conditions

The two main factors that affect loads discharged from sewers are the foul flow and the amount of sediment built up in the sewer system at the start of any rainfall.

c) Upstream river flow and quality boundary

It is prudent to build a river model that represents the response of the receiving water to rainfall to provide the upstream river flow and quality boundary for the impact model. This is particularly the case for small urban watercourses, where the response time of the river to rainfall can be similar to the response time of the sewer system.

For river quality generally, this is represented by establishing flow-quality relationships for the river being investigated, although river quality can also be explicitly modelled.

It is recommended that surface water sewers are explicitly included within the sewer models If river flows are strongly influenced by urban run-off from surface water sewers.

It is important when modelling upstream boundaries to be clear if the boundary already contains information relating to the performance of upstream assets, or whether this has to be included separately. This is sometimes referred to as ‘clean’ or ‘dirty’ boundaries and is of relevance when evaluating both existing performance and optioneering improvements.

6.2.2 Step 2 - Estimate discharge regime

In this step, the sewer model (representing the existing system or a proposed upgrading solution) is run with the rainfall and SMD to evaluate the flows and loads discharged to the environment. This should include the flows and loads from all intermittent discharges (i.e. discharges from CSOs, SWOs and storm tanks) which are likely to affect the reaches of watercourse under investigation.

If the receiving water is impacted by a STW, the discharges should also include estimates of effluent flow and quality as appropriate for the storm event. These effluent discharges can be estimated either by random selection from known frequency distributions or by detailed sewage treatment quality modelling (Section 4.4).

6.2.3 Step 3 - Estimate concentrations in river

Estimating river concentrations involves two main stages - an initial mass balance and then (if required) downstream river impact modelling to estimate DO impacts.

- **Initial mass balance**

  This stage involves a mass balance calculation in which the CSO/SWO/STW discharges are mixed with the river water to give an estimate of the river concentrations over each event period. This will need to be done separately for each discharge or cluster of discharges represented in the impact model.

  Generally, the response of both the sewer system and river system have been modelled using the same rainfall sequence. Therefore an inherent correlation between the flows in the natural and built environment will have been established.

  Unless upstream river quality has been explicitly related to river quality through a river quality model, the relationship between boundary flow and quality will either be random, or be governed by a correlation. In either of the latter cases, this will require a statistical process to select the most appropriate quality for the associated river flow.

  As it is not normal to model pH or temperature in discharges, this then requires pH and temperature conditions to be assigned to the mixed body of water below the discharge in order to calculate un-ionised ammonia values. This is best done by random selection from frequency distributions which are judged to be most representative of in-river conditions following storm events. If river pH is known to change significantly at some distance downstream from the point of initial mass balance, it may be appropriate to use those pH conditions for calculating un-ionised ammonia concentrations.

  For a single CSO, this step is relatively straightforward and can be carried out on a spreadsheet. For multiple CSOs discharging at different locations within a branching river network, the process can become quite complex. A detailed river model can be used to account for travel times and river quality processes, thereby, generating time series of mixed river quality at any point in the system. However, this result will be unique to the upstream river flow conditions used and for the (usual) assumption that the rainfall occurs at the same time throughout the sewer catchment. Variations in these conditions will affect the profile of mixed river quality.

- **Downstream river impact**
  In general, the initial mass balance will give the most critical conditions for BOD, ammonia and un-ionised ammonia and, if the relevant standards are framed in these terms, no further work is required.

  If assessment against DO standards is required (or if allowable un-ionised ammonia thresholds may need correction for low DO), an extra step in the river impact modelling is needed.

  First, the initial mass balance should calculate the mixed DO in the river immediately downstream of the discharge(s). This will require an estimate of the DO in the storm discharges, either from field data, local knowledge or results from other studies.

  The mixed plug produced by each event must then be routed down the river to determine the effect on DO. Each event can be simulated in a dynamic river model to locate and quantify the worst DO profile and to estimate the un-ionised ammonia conditions at this location.

6.2.4 Step 4 - Compare with standards

a) Fundamental Intermittent standards for un-ionised ammonia

The worst conditions for un-ionised ammonia normally occur at the point of mixing before any dispersion or decay of the ammonia can occur. The results from the initial mass balance need to be processed to identify the number of events for which different un-ionised ammonia thresholds are breached and for how long on each occasion. These results allow return periods to be calculated and checked directly against the intermittent standards (Table 2.3).

If DO is predicted to fall below 5 mg/l some distance downstream of the point of initial mixing, it is possible that further checks will be required because of the correction factor (see Table 2.3) which must be applied to the un-ionised ammonia thresholds, under low DO conditions.

b) Fundamental Intermittent standards for DO

Similarly, the breaches of the DO standards need to be checked against those intermittent thresholds (Table 2.2) corrected, if necessary, for high un-ionised ammonia conditions, to see how often each threshold is breached. From this analysis, return periods can be calculated and overall compliance with the intermittent standards judged.

c) Percentile standards for BOD and ammonia

The process of checking against high percentile standards (such as 99%ile standards) for BOD and ammonia involves processing the results from the initial mass balance. For each event, the period of time for which the relevant threshold is exceeded is noted. These times are then summed for all the events and divided by the number of years represented by the events. The result of this calculation is then checked against the allowable failure period.

For example, if the quoted standard is a 99%ile standard and the result of the analysis is less than 88 hours/year (= 1% of 1 year) on average, it can be assessed that the scheme is compliant.

it is important for this analysis to include all 'events' that could cause a breach of the threshold being investigated. This is particularly important where STW discharges are a dominant factor affecting BOD and ammonia levels in a river. In this case, high BOD and ammonia levels could be created by non-storm events which may not be included in the previous analysis. This must be taken into account when judging compliance.

d) Other standards

As well as checking compliance with EQSs, checks would also be made at this step with any emission or minimum performance standards that form part of the environmental framework agreed in Section 3.

6.2.5 Step 5 - Optioneering

This step is the start of an iterative process to find a solution which complies with all the standards. In this context, 'extra capacity' can mean:

- extra detention tank storage;
- increased pass forward flow capacity (though this can have knock-on effects upon the loads discharged at downstream CSOs, storm tanks and STWs);
- extra treatment, either at CSOs or at the STWs; and,
- moving the outfalls to a location where there is extra 'environmental capacity' to absorb the discharges without compromising the standards.

The models are adjusted to represent these potential changes and the process returns to Step 2.

6.3 Methodology for testing compliance with standards for protecting bathing and shellfish waters

This section describes a specific methodology to be used for developing solutions when bathing water standards have been specified in the receiving water body. This will most commonly apply to coastal waters and this is the focus for the methodology.

As discussed in Section 2.4, standards for protecting bathing and shellfish waters are likely to be expressed either as simple emission standards (e.g. a limiting spill frequency) or as a bacterial percentile standard in the bathing water itself. The procedure needs to allow for consideration of performance in both such terms.

The overall methodology involves Steps 1 to 5 of the generic UPM methodology (Figure 6.1).

6.3.1 Step 1 - Prepare event details

A wet weather event, to be run with the models developed in Phase B, is defined not only by the rainfall but also by the conditions in the sewer system and receiving water at the time of the rainfall. It is the combination of these conditions - rainfall, sewer system, receiving water - which defines the event. At this step, information is assembled on the statistical distributions of these individual conditions and any correlations between them. This information is essential both for making sensible choices on events to use and also for interpreting the model results for compliance with standards.

a) Rainfall

The rainfall file defines the rainfall sequence which will be run with the sewer/STW models. The results will be used to test compliance with the standards. It is assumed here that long rainfall time series are being used and that a rainfall sequence representative of, say, ten years has already been established.

- **Summer file**
  Where bathing water standards are defined as a summer season, a rainfall sequence representative of a ten year series of summer seasons is required.

b) Sewer system conditions

The two main factors relating to sewer conditions that can vary from one rainfall event to another are the foul flow (which has a diurnal, and possibly seasonal, pattern) and the amount of sediment in the sewer system at the start of the rainfall.

By running a long rainfall sequence, including intervening dry periods, the sediment stores can be represented correctly. It is useful to run the model in a “warm up” mode before running the actual rainfall sequence to ensure that all sediment stores are correctly initialised.

c) Other environmental conditions

If environmental quality is being investigated, then, besides rainfall details, the other factors which are likely to have an important bearing on bathing water quality during an event are (see Sections 4.6 and 4.7):

- the timing of the rainfall relative to the tidal cycle;
- the type of tide (e.g. neaps or springs);
- the direction and strength of the wind; and,
- a variety of factors which can affect bacterial mortality, such as temperature and sunlight.

The relative importance of these factors needs to be considered and decisions taken about how they will be included in the analysis.

6.3.2 Step 2 - Estimate discharge regime

In this step, the sewer model (representing the existing system or an upgrading solution) is run with the rainfall sequence to estimate the discharges to the environment.

If a spill frequency standard has been specified, then spill volumes (and possibly spill profiles) are all the information required.

If bacterial impact in the bathing and/or shellfish water is to be investigated, then the bacterial load profiles associated with each intermittent discharge are required. These may be estimated directly by the sewer quality models used, or it may be necessary to apply an average event concentration to each predicted spill volume. The bacterial load profiles associated with any other discharges (e.g. treated effluent discharges, local rivers, SWOs) that could have a significant effect upon bacterial levels in the bathing and/or shellfish water will also need to be estimated.

6.3.3 Step 3 - Estimate bathing and shellfish water concentrations

This step is only required if a percentile concentration exceedance standard has been specified for the bathing water. In principle, this work involves running the marine model (Section 4.8) with the inputs produced from Step 2, having regard to the full range of tide and wind conditions specified for each event. The periods of time for which the bacterial levels exceed the allowable threshold in each part of the bathing water are noted.

This step is clearly quite demanding as potentially many events need to be considered with varying tidal and wind conditions. The most common approach to this is to use the marine model (in a single pre-processing exercise) to create a large database of concentrations for each part of the bathing water, for unit discharges from each outfall under a wide range of conditions. The process of running an event is then one of drawing the relevant information from the database, scaling and aggregating. In this way, many thousands of events can be rapidly simulated with no loss of accuracy.

6.3.4 Step 4 - Compare with standards

If a spill frequency standard has been specified, this step is a relatively simple matter of comparing the results from Step 2 with the standard (bearing in mind how ‘a spill’ is defined).

The results from Step 3 are used if a percentile standard for bathing water quality has been specified. The periods of time for which bacterial levels exceed the allowable threshold in each part of the bathing water for each simulated event are noted. These periods are then summed over the entire sequence and divided by the number of bathing seasons represented. The result of this calculation is then checked against the allowable failure period.

Checks should also be made for compliance with any minimum performance requirements which form part of the environmental framework agreed in Phase A.

6.3.5 Step 5 - Optioneering

This step is the start of an iterative process to find performance improvements that achieve the required standards. In this context, optioneering can include:

- extra detention tank storage;
- increased pass forward capacity (though this can have knock-on effects upon the loads discharged at downstream CSOs, storm tanks and STWs);
- extra treatment, e.g. disinfection of CSO discharges; and,

- moving the outfalls to a location where there is extra ‘environmental capacity’ to absorb the discharges without compromising the standards.

The models are adjusted to represent these potential upgrading measures and the process returns to Step 2.