DECISION SUPPORT SYSTEMS IN IRELAND'S EASTERN RIVER BASIN DISTRICT

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ABSTRACT

In compliance with the European Union (EU) Water Framework Directive (WFD), CDM is managing the development of a River Basin Management System for the Eastern River Basin District (ERBD) in the Republic of Ireland. Divergent stakeholders with potentially conflicting interests require a role in the planning and management of this project, to begin at project commencement and to continue throughout project duration. There are two critical components in the decision-support process. The first is involvement of key stakeholders in the problem evaluation and solution development. The second is use of a set of analytical tools to facilitate comparative evaluation of options; specifically, the application of a decision support system (DSS). To demonstrate the range of DSS that may be appropriate in the ERBD Project, two *illustrative* methods are discussed: (1) a relatively simple two-dimensional method that we refer to as Multiple Objective Tradeoff Analysis (MOTA), and (2) more complex tools, known collectively as System Representation Models (SRM).

Keywords: consensus building, decision support system, multiple objectives, public participation, river basin management, water quality; watershed management

INTRODUCTION

Ireland's Department of the Environment and Local Government (DoELG) is sponsoring river basin/watershed management projects for all inland and coastal waters throughout Ireland in order to comply with the European Union (EU) Water Framework Directive (WFD) [1]. The WFD is being imp lemented in Ireland on the basis of five designated River Basin Districts (RBDs). In each RBD, the river basin planning process will result in the development of a River Basin Management System, inclusive of programmes of measures, to achieve and maintain, at a minimum, "good" water status for all water bodies.

Of the five RBDs in Ireland, one of the most urbanised is the Eastern River Basin District (ERBD), which includes Greater Dublin and its vicinity. CDM is managing the development of a River Basin Management System for the ERBD under the direction of a Steering Committee of Local Authorities coordinated by the Dublin City Council (DCC).

There are a variety of complex issues and challenges in this urban basin. These include, among many others, nutrient loads from farming operations, toxic components of industrial discharges, potential linkages between surface and ground water, and the continuous attainment of wastewater treatment plant effluent quality. In addition, there are numerous concerned parties with conflicting interests that require a role in the planning and management process.

In this paper, some overall characteristics of decision-support systems relevant to the ERBD planning and management process are identified and discussed. The importance of early stakeholder involvement, including the selection of DSS approaches that reflect the learning and communication styles of stakeholders, is highlighted. When this paper is presented at DiPCON in August, the ERBD planning process will have advanced with the intention that the actual selection of DSS methods can be discussed.

METHODS

I. The Inclusion of Concerned Parties in the Decision-Making Process

The inclusion of concerned parties/stakeholders in the decision-making process is fundamental to comprehensive watershed planning and a requirement of the WFD. Evolution in watershed planning has led to changes in the types of communities (interest groups or stakeholders) involved in the decision-making process. Current watershed planning practice suggests that stakeholders will comprise not only the technical and regulatory communities faced with management of the river basin, but also the general public, who are the direct recipients of the results of a watershed management program and the ultimate source of funding for investment in the solution.

Some general observations related to the categories of stakeholders pertinent to ERBD, and representative of those likely to be involved in any comprehensive watershed management project, are outlined below.

1. The *general public's* level of interest and involvement in a particular watershed planning and management project is difficult to gauge in advance, and thus it is not feasible to make accurate generalisations regarding interest or involvement. However, in most cases, the general public can be presumed to be knowledgeable about the overall issues and conflicts that are pertinent to the river basin in which they live or work, but unacquainted with specific technical details of watershed management. The incorporation of public perspectives in the planning process

therefore demands that clear communication of issues and alternatives is accomplished *at the earliest stage possible in the project, and sustained throughout the project duration*.

2. In Ireland, there are multiple layers to the stakeholder structure that must be carefully considered. A key issue is the mature and stable structure of *Statutory Authorities* (cities and counties), of which there are 14 within or partly within the ERBD. Because Statutory Authorities' roles are related to development and governance, they may be the means by which lower level stakeholders need to be involved in the project. Resolving this question will be a key early project requirement, as will encouraging key Statutory Authority representatives to play direct roles in the identification and resolution of the many critical issues.

3. Gauging the interest of the *technical community* in a particular project poses challenges as well, since a complex watershed management project comprises diverse technical interests. Stakeholders with relevant technical knowledge of the project will include scientists and engineers, landscape architects, urban planners, economists, and other specialists. Both as communities and individuals, these parties will display varied knowledge and areas of interest. Because of the range of issues involved in this type of project, participants will likely have profound expertise in some aspects of the project, and casual competence in other aspects. The priority that is given to a particular solution can therefore be swayed by the knowledge of a participant. Thus, the project information relayed to the technical community must be *technically complete in all respects,* since experts in a particular project domain are likely to have the ability and desire to exhaustively analyse design alternatives.

4. *Other distinct communities* will also be present in the watershed, and must be part of the decision-making process. Wildlife organisations or other public environmental groups may have vested interest in the project. Major land owners or developers may have interests that distinguish them from the general public. The range and scope of potential participants' interests, however, will not significantly affect the nature of the planning problem, only its details and definition, based on the contextual perspective of the stakeholder.

II. The Need for Decision Support

The process by which people interpret and synthesize information is relevant to watershed planning and management. The method in which information is communicated and preferences assessed will affect the public's consensus, understanding and involvement in the watershed planning process. Overall, CDM's experience suggests that some form of DSS will be required in any river basin management project.

It can be said that there are two basic learning perspectives that affect the population. In general terms, some people are interested in details and facts, while other people conceptualise the world in terms of relationships and patterns [2]. These differences in perspective can lead half a group to feel fully informed after a presentation, and the other half dissatisfied or wary, due to incomprehension caused by the manner in which the information was presented. Bridging these discrepancies is key to finding effective solutions. Communicating in an effective manner with both groups involves the conscious application of techniques that are visual as well as textual, and expression of problems in ways that fully incorporate facts and effectively convey the relationships and patterns that those facts suggest.

Relevant to the learning styles just mentioned are the tools and techniques that watershed planners utilise to facilitate decision-making. In order for stakeholders to be productively involved in the planning process, they must have appropriate and complete project information. The level of sophistication of such information depends on many factors, including:

- How much data collection and synthesis work has been done to date on various topics
- Whether sufficient information is available for:
  - The development of goals
  - The identification of key issues, impacts and stakeholder categories
  - The identification and comparison of options
- What additional information is needed for these purposes
- Stakeholder "savvy" (or comfort level with technical and political information)

Thus, in order to fairly reconcile the divergent perspectives of various stakeholders, complex information, and a wide range of diverse data, *the authors believe that some form of DSS is needed in complex multi-stakeholder planning and management projects* such as the ERBD. Such systems will be used in coordination with public consultation and public participation techniques to permit successive development, screening, assembly and comparative analysis and evaluation of alternatives, to yield a preferred set of programs.

Below, we describe the features and benefits of two illustrative decision support systems that can be applied to a complex watershed management project such as the ERBD. They are:

(1) Multiple Objective Tradeoff Analysis (MOTA): As an *example* of the "simple" class of DSS tools that include various forms of easily understood two-dimensional graphs and matrix-like displays, we discuss one specific

technique that CDM has applied successfully to numerous water resources planning and management projects throughout the world.

(2) Systems Representation Models (SRM). We refer to the more complex class of DSS tools that facilitate the examination (simulation) of the numerous interactive water-related activities that take place within a watershed as SRM.

These two examples are representative of the range of available techniques – from simple to complex. We describe each example method in detail below.

DSS EXAMPLE #1: MULTIPLE OBJECTIVE TRADEOFF ANALYSIS (SIMPLE)

A straightforward method to provide a visual framework that both communicates well and is tractable borrows from classical *bivariate optimality methods*. In classical methods, an optimum solution given two variables can be achieved provided that a function can be found which defines preference in terms of the two variables. This well-known approach is effective in many aspects of water resources planning and management.

A specific type of the bivariate method is termed here as MOTA. As noted above, this specific technique is representative of the "simple" class of DSS useful in watershed planning and management. MOTA is based on the principle that for every potential management alternative, "total" costs and benefits can be accounted for and displayed in two-dimensional space, as shown in **Figure 1.** The method relies on movement away from the origin as preferable, and thus costs are plotted on a decreasing scale. When costs and benefits are mapped, results form an 'envelope' where perimeter cases are joined. The 'envelope' is the Tradeoff Curve shown in Figure 1.

The salient feature of this method is that alternatives that lie within the space are inherently less preferable to those located on the perimeter, since values within the space have benefits that are less for a given cost than the points located directly on the perimeter. The method provides a visual framework that defends choices of a limited number of alternatives for intense contrast and comparison. Points on the perimeter are retained for further evaluation, and points on the interior are dropped. MOTA provides an effective basis for screening large numbers of alternatives, and paring them to a small number of alternatives. The resultant alternatives can be termed the 'preferred envelope set'.

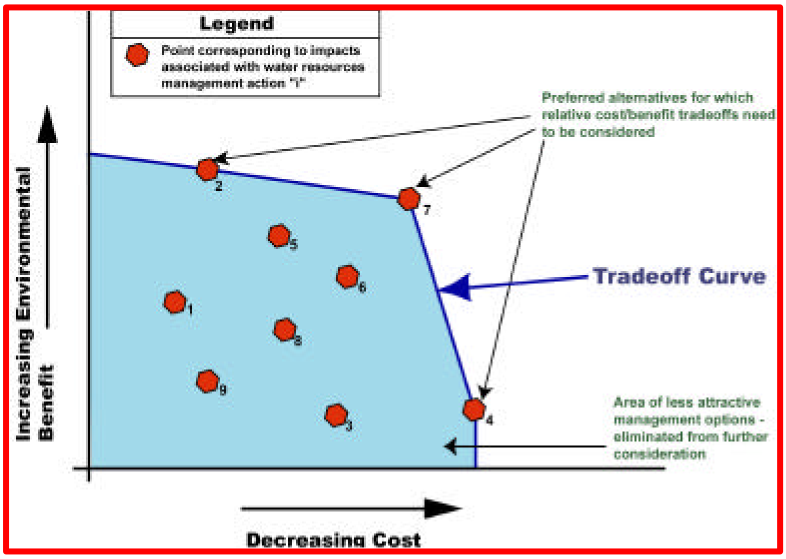

Figure 1: Diagram illustrating the MOTA method

This method communicates well to a wide range of practitioners, while familiar in both format and intention to those accustomed to classical bivariate optimality methods. However, the usefulness of MOTA-type DSS can be somewhat limited, since the perimeter values are in fact discrete and not continuous. If it can be demonstrated that the connecting lines represent continuous potential solutions, then the screening method is fully valid. If not, then it can be argued that some of the values within the space, as entities in a discrete as opposed to continuous space, should not be eliminated.

It is recognized that most watershed planning problems ultimately result in numerous benefits and that the two-dimensional space that is the foundation for MOTA inherently deals with a single benefit variable. However, MOTA can easily accommodate multiple benefit variables using at least two supporting techniques:

- Applying a preference weighting method to combine numerous benefit criteria into a single representative variable. This is commonly accomplished by hosting a facilitated session with stakeholders, and agreeing, through the use of a consensus-building process, on the relative influence of each benefit. By applying weighted aggregation (typically, summation of the product of criterion value and criterion weight), a single representative benefit variable is obtained, and the method proceeds directly.

- Applying the MOTA method several times, once for each benefit variable, and evaluating the resulting preference 'envelope sets' to determine if a pattern emerges. For example, if there is an alternative that emerges in all or many of the preference envelope sets, a global preferred solution may have been found. If not, it may be appropriate to consider the relative significance of each of the benefit variables and evaluate the various preference 'envelope sets' from that perspective.

DSS EXAMPLE #2: SYSTEMS REPRESENTATION MODELS (COMPLEX)

While MOTA-type display techniques have many advantages and uses, when used alone, they are not always sufficient for all aspects of watershed decision-making. This is particularly the case where management options are not discrete.

Some decision variables, such as the number of highway crossings allowed through a natural area, only meaningfully exist in integer quantities, and are readily treated as discrete values. Other variables, such as the minimum water flow rate in a river, do not have physical meaning as a limited number of discrete values, but exist rather as a continuous field of options. In the instance that these kinds of variables are crucial to a given watershed planning project, MOTA-like tools alone are probably inadequate. When the watershed planning process does not lend itself to discrete alternatives, the authors believe System Representation Models (SRM) may then be required.

An SRM can be conceived in many ways, but for present purposes it is defined as a tool that represents elements of the physical watershed system as units, enabling the user to represent movement of quantities of interest between those units in arbitrary ways.

As an example, **Figure 2** illustrates a framework that includes ten units, each representing a factor that generates or moves water flows in a system, where the groundwater component is affected directly or indirectly by the other nine units. One of the units (rainfall) is uncontrollable. Several may or may not be controllable, but directly affect other factors. For example, in the absence of a conservation program, water demand is a direct function of population. Other factors may represent decision factors. For example, population (1), groundwater recharge from treated wastewater (WW) (2) and vegetation (3) might be design choices, affecting groundwater volume (4) and runoff rate (5). Vegetation may be a discrete or continuous variable, as may a recharge facility. Dependent variables may include availability of groundwater, cost of facilities, and riparian flow in the runoff system. *With a model of this type, representations of the system and the consequences of decisions can be realised to greater or lesser levels of sophistication (or following affirmation of available data, interest and understanding).*

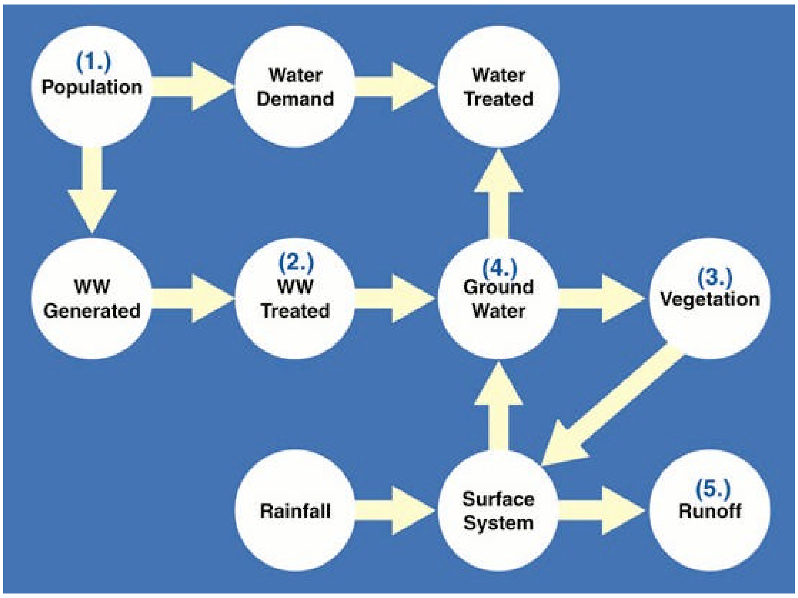

Figure 2: Diagram illustrating a System Representation Model (SRM) of a simplified water flow/movement system

With suitable tools, the SRM can convey the patterns and interactions of the system, and may be used to navigate to any desired level of supporting detail. The units represented can be communicated and visualised as a simple icon and label, but the complexity contained in the algorithms that describe the functional properties of the unit can be developed to any desired degree of complexity.

Ensuring overall simplicity and underlying complexity through the use of the SRM is important, for two main reasons. First, the ability to mesh broad patterns of relationships with supporting details in a compelling and convincing way provides users of all types with access to descriptions of the problem that are congruent with their personal communication preferences, as discussed previously. Second, because stakeholders can clearly observe where full details of their area of expertise are represented in the system, they may observe how specific details mesh with the problem as a whole.

Notably, there are two main types of SRM. In some watershed management projects, extensive modelling of system components (such as the physical water system, water quality and environmental aspects or costs) has been conducted previously. If this is the case, it is sometimes more appropriate to incorporate such models, or their outputs, into an overall system representation to show the effects of input changes to specific variables.

In other cases, an SRM can be prepared on the basis of relatively limited existing data and used to identify linkages between inputs (such as daily loads due to emissions in sub-basins), and resultant outputs (such as water user impacts and sensitivity of water quality impacts to changes in daily loads of emitted substances). This type of preliminary system representation modelling can be used to guide:

- Early primary data collection;
- Development of conceptual goal-setting options for review in conjunction with stakeholders, and in parallel with further data collection;
- Comparative evaluation of control options (preliminary screening), after model enhancement and loading of appropriate data; and,
- Understanding by all parties of cause-and-effect relationships (and relative magnitudes of likely effects) throughout the watershed system.

RESULTS AND DISCUSSION

At this preliminary stage in CDM's conduct of the ERBD project, we do not precisely know which stakeholders will be included and active in the planning process, to what degree they will be represented, or which decision support tools and methods will be chosen. However, based on our current understanding of the extant conditions in ERBD, our expectation is that an SRM-type DSS will likely be created.

In coordination with the DCC, other Local Authorities in the ERBD, and the DoELG, CDM plans to:

1. Perform preliminary sub-basin data collection and evaluate the availability of existing data;
2. Facilitate a workshop to review methodological options, in which we will:
   - Identify the types of linkages to be simulated
   - Identify the sources of input information
   - Identify the types of benefits to be evaluated and compared
   - Identify the desired levels of user control and flexibility
   - Demonstrate the types of system representation models we may apply to the project
3. Develop an appropriate systems representation model, train users and identify existing data to be compiled for the purpose of using the model effectively to improve data collection;
4. Collect, compile and enter the data; and,
5. In close consultation with DCC staff and other key technical experts, prepare a preliminary display of impacts due to a limited number of preliminary scenarios and control options; and
6. Conduct a workshop (including representative officials and unofficial stakeholders) to review the graphical system model, adjust stakeholder preferences in order to conduct interactive tradeoff studies, consider the preliminary conclusions, and agree on next steps.

As demonstrated by the above-listed items, CDM anticipates the need for a highly interactive, technically-based approach towards decision support in the ERBD that will provide a basis for comparing the costs, benefits and other effects of various control options, taking into account both quantifiable and non-quantifiable effects, with the direct and sustained involvement of stakeholders.

CONCLUSIONS

CDM's experience indicates that two issues are key to successful watershed planning and management:

- Stakeholder involvement must be early, inclusive and sustained over the life of a project, and must take divergent stakeholder perspectives into consideration; and,
- Tools and techniques for decision support must be used in order to reconcile the divergent perspectives of stakeholders, and can range from simple two-dimensional display techniques to systems representation (simulation) at various levels of sophistication.

CDM's approach towards decision support in the ERBD will take both of the above issues into consideration; providing a basis for comparing the costs, benefits and other effects of various control options, and considering both quantifiable and non-quantifiable effects, with the direct and sustained involvement of stakeholders.

When this paper is presented in August, the authors will report on our success attracting and maintaining stakeholder participation, and on our selection and development of a DSS system.

REFERENCES

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