

Approaches to Planning Water Resources

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Abstract

Water resource systems are complex and their management can be confusing for both technical and policy participants. Such confusion can be reduced with the development and application of a planning approach. This paper attempts to summarize and organize various technical approaches to water resources planning. The basic approach of rational planning is presented, followed by brief reviews of Requirements-based, Benefit-Cost-based, Multi-objective, Conflict Resolution, Market-based, and Muddling Through approaches to planning. Each approach has particular advantages and disadvantages for specific situations. Each approach also tends to have somewhat different analytical requirements and policy expectations. These approaches are discussed in terms of practical contributions to solving long-term water problems in contemporary contexts.

Introduction

“The plan is nothing. Planning is everything.” - Dwight Eisenhower

Water resources planning is an ancient problem, dating back to flood control and water supply activities of the earliest civilizations. The success of most civilizations has rested, in part, on their ability to manage water (China, Indus, Europe, South and Central America). The demise of several civilizations has been traced directly to failed regional water management (Peru, Mesopotamia) (Artzy and Hillel 1988; Ortloff et al. 1985). In the United States, water resource planning has evolved historically with changing economic and political circumstances (White 1969; Shad 1979; Kelley 1989; Lund 2006). Quantitative analysis and even economic thinking in water planning date at least to Roman times (Frontinus 97 AD; Leveau 1993) and has been vital to successful water management in modern times, being formalized by early 19th century French engineers (Ekelund and Hébert 1999; Morgan 1951). Lack of planning or poor planning often are blamed for continued controversies, expense, and inefficiencies in water management. The complexity and controversy of water problems should lead water planners and policy makers to seek fundamental principles and approaches for organizing the technical aspects of preparing solutions. This paper attempts to summarize and organize a range of planning approaches often seen or advocated for water planning.

The paper begins with a review of rational planning, the fundamental process aspired to by most planning efforts. This is followed by a review of various technical approaches common or commonly discussed for water resources planning. Practical problems for effectively completing planning processes are then reviewed. In light of these practical problems of water management, some realistic and limited objectives are suggested for water resources plans. Finally, analytical and organizational aspects for each planning approach are compared and some conclusions are suggested for contemporary water resource problems.

Rational Planning

Rational planning is a systematic procedure to making near-term decisions for resolving problems in the future. Many have written about rational planning for water resource problems (Orth and Yoe 1997; Yoe and Orth 1996; US Water Resources Council 1983; White 1966). Rational planning ideas also have been employed in some of history's most innovative water projects (Morgan 1951). These thoughts on planning are closely related to work on other urban, regional, landscape, and environmental planning problems (Meyerson and Banfield 1955; Briassoulis 1989) as well as more general rational or “smart”

decision-making (Simon 1947; Hammond et al. 1999). While there are substantial differences in the methods and approaches suggested by these authors, there is an essential procedural similarity. These “rational” approaches share a largely sequential rational planning thought process.

Table 1: An Outline of Rational Planning (* = most fundamental steps)

Step 1. Statement of Problem: John Dewey said, "A problem well stated is a problem half solved." Early in rational planning, the problem should be firmly defined, stating people's concerns and what motivates the planning exercise.

Step 2. Inventory/Background: What is known about the problem and the problem-setting? What has been learned already? How have earlier attempts to solve similar problems fared?

Step 3. Forecasting: The lifetime of most water problems and solutions is very long, far longer than the careers of individual policy-makers, engineers, and planners. Forecasts of demands and related conditions estimate how the problem and problem setting are likely to change over the life of proposed solutions. Uncertainty and inaccuracy in forecasts is unavoidable.

***Step 4. Statement of Performance Objectives:** What makes a proposed solution "good" or desirable? Performance objectives can be economic, financial, environmental, social, or the reliability of achieving technical standards. Both planners and stakeholder representatives typically define performance objectives.

***Step 5. Identification of Alternative Solutions:** What actions are available to solve the problem (including doing nothing)? Alternatives should be mostly reasonable, represent a wide range of activities for solving the problem, and come from a variety of sources. Past experience with similar problems is helpful, as is more academic and creative thinking. Public participation and preliminary modeling often aid in identifying promising or politically important alternatives.

Step 6. Development of Alternatives: Time and resources prohibit examining “all possible alternatives.” A limited number of promising alternatives are developed in sufficient detail for evaluation on performance objectives (the next step). Discussions with stakeholders and preliminary modeling often help screen, narrow, and refine alternatives.

***Step 7. Evaluation of Alternatives on Stated Objectives:** Each developed alternative is evaluated in terms of expected performance on each stated objective (e.g., economic, financial, environmental, social, risk, technical standards, etc.). This is typically the most analytical step and may include consideration of reliability and uncertainties. Interpretation and sensitivity analysis are desirable aspects of the evaluation.

Step 8. Selection of a "Best" Alternative(s). The "best" alternative is selected based on the evaluation in Step 7 and relevant stakeholder, policy, and public consultations. "The plan" consists of the write-up of steps 1-8, with particular emphasis on presenting the selected alternative(s). Selection often involves multiple objectives and decision-makers.

Step 9. Implementation and Pragmatic Revisions of the Selected Alternative(s). Implementation often requires substantial modification of a selected alternative. Practical considerations arise regarding political and institutional support, financial support, construction, operation, and ultimately closure or replacement over an alternative's lifespan.

Step 10. Periodic Re-Examination: For the next problem, did we learn anything from this experience? How could we have improved our work?

All forms of rational planning take some variant of the rough series of steps summarized in Table 1. These steps are usually, but not always, sequential; steps often are re-visited as a result of technical or stakeholder feedback, new information, or changing events. Nevertheless, the general direction and order of the planning effort remains the same. The special importance of Steps 4, 5, and 7 should be noted.

Statement of Objectives, followed by Identification of Solution Alternatives and Evaluation of Alternatives on Stated Objectives are the core of rational planning. This reduced set of steps parallels more formal and mathematical definitions of rationality and mathematical optimization (Von Neumann and Morgenstern 1944; Tribus 1969; Hillier and Lieberman 1995).

Limitations of rational planning are evident (Banfield 1959; Simon 1947; Braybrooke and Lindblom 1970). It is often difficult or impossible for policy makers and stakeholders to clearly state their objectives in quantifiable ways, particularly for objectives involving reliability and risks. In its idealized form, the identification and comparison of "all possible alternatives" on all relevant objectives is clearly impossible in practice. Only a limited number of alternatives can ever be identified, much less developed into a form that allows comparison of alternatives. In analysis, evaluations contain uncertain assumptions and unavoidable simplifications. Ultimately, any analysis must serve an institutional or political framework that works, however slowly, to make decisions regarding the "best" solution.

The strengths of rational planning are its relative transparency, logic, and the considerable lack of effective technical alternatives to planning. Many variations for implementing rational planning have arisen to help respond to specific circumstances. Often, planning's greatest contribution to problem-solving is the structure and systematic approach it imposes on information-gathering, deliberation, and decision-making. Without such a structured approach, the complexity of water resource problems often leads to levels of confusion which contribute to controversy and policy paralysis. Both rational planning variations and non-rational alternatives to planning should be compared based on how well they might satisfy policy objectives.

Approaches to Water Planning

This section reviews six major approaches for water planning, most of which are variations on rational planning. Each approach addresses technical aspects of water problems within a decision-making context. The political decision-making context of a water problem can be more important than its technical aspects for determining the success of a particular planning approach. Indeed, as discussed later, many political circumstances will greatly limit the practical potential of any planning effort. These six basic approaches are presented in a rough order of their historical formalization for modern applications:

1. Requirements-based planning,
2. Benefit-Cost-based planning,
3. Multi-objective planning,
4. Conflict resolution planning,
5. Market-based planning, and
6. Muddling through.

For each approach to planning, the following aspects are discussed, a) history, b) methods, analysis, use of models, c) data and computational requirements, d) role of public participation, e) how it helps decision-makers, and f) circumstances when it seems more likely to succeed or fail.

Requirements-based Planning

Sometimes referred to as "project and provide," requirements-based planning is a traditional approach to formulating engineering problems. First, define functional specifications that the system must satisfy, perhaps with appropriate factors of safety. Then, design (plan), build, and operate the system to meet these requirements (or loads) at the lowest cost or with the greatest reliability for a given budget (Suh 1990). An outstanding characteristic of requirements-based planning in the water resources context is that it typically assumes given and fixed demands, and limits planning efforts to "supply-side" options. This is reasonable when demands are outside the control of the planner or of such great importance that the costs of meeting demands are less than the costs of any water shortages or demand reductions.

The history, practicality, and method of requirements-based water resources planning are exemplified by the classical Rippl method (1883) for reservoir sizing. Here, future use of water is estimated from forecasting and is assumed fixed. The size of the supply is then determined by finding the reservoir size or combination of water sources that would always meet this demand with a repeat of the historical streamflow record. The sum of water supplies must always meet or exceed forecast use. This so-called "firm yield" approach to water planning has dominated water planning until very recently, when the costs of providing supply reliability have grown to exceed the costs of reducing water use and the external environmental costs of water supplies have become more highly valued.

Requirements-based planning is very effective and appropriate for many water system components (pump stations, distribution lines, local drainage, etc.). For these components performance expectations are relatively fixed and standardized, and more detailed planning analysis might be too expensive relative to potential resulting improvements. However, for large components and overall system planning, requirements-based approaches often result in controversial and overly expensive solutions and can neglect important external costs of water supplies and demand, such as environmental consequences.

Benefit-Cost-based Planning

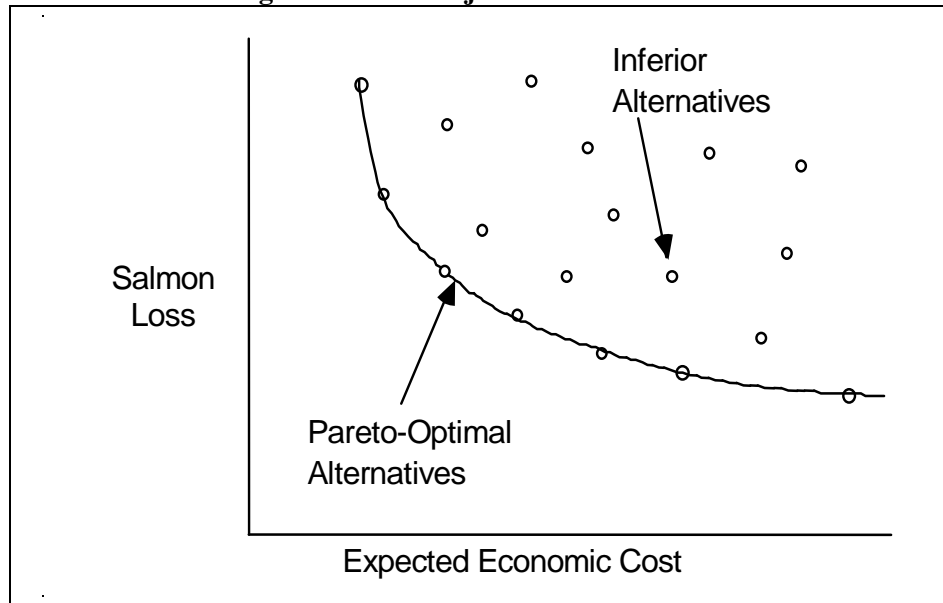
Benefit-cost analysis attempts to consolidate the many supply, demand, and other impacts of each alternative into monetary benefits and costs. The 1936 federal Flood Control Act neatly summarizes the germ of benefit-cost analysis, that a proposed project should have "... benefits to whomsoever they may accrue ... in excess of the estimated costs ...". Since this time, benefit-cost analysis has expanded steadily beyond flood control to include greater varieties of water uses and impacts (Griffin 1998; Russell et al 1970; Howe 1971; James and Lee 1971; Jenkins and Lund 2000; US Water Resources Council 1983; Boardman et al 1996). Flood control, navigation, water supply, hydropower, recreation, and even some environmental water uses have been incorporated into benefit-cost analyses (Loomis 1987). The limitations of benefit-cost analysis are well known, including monetizing all effects of alternatives, selecting discount rates, incorporating social equity, and representing risk preferences. Nevertheless, its application has helped eliminate unworthy projects, justify worthy ones, and raise the quality of discussion for ambiguous cases. Benefit-cost analysis has strong technical aspects, including a broad and potentially rigorous integrating economic perspective with abilities to incorporate variability, reliability, and uncertainty, either as mean economic values or probability distributions of net economic value.

Multi-objective Planning

In reaction to the narrow economic focus of benefit-cost evaluations, multi-objective approaches to planning attempt to display to decision-makers the trade-offs inherent in selecting alternatives where all objectives cannot be measured in the same units (US Water Resources Council 1983; Cohon 1978; Cohon and Marks 1975). Such a trade-off display appears in Figure 1, separating Pareto-optimal alternatives that represent efficient trade-offs from inferior alternatives. Tables are often used to help sort better from inferior alternatives where there are more than two objectives. Some authors attempt to go beyond the development and display of efficient trade-offs to propose rational bases for making decisions with these trade-offs identifying optimal solutions through multi-dimensional concepts of utility (Keeney and Raiffa 1976; Haimes and Hall 1974).

While the analysis approach of multi-objective planning is technically attractive, it typically lacks a formal institutional mechanism to establish the trade-offs needed to identify a most desirable alternative from a set of "Pareto-optimal" solutions (Figure 1). Thus, in practice for multiple stakeholder problems, multi-objective planning is limited to informing decision-makers or stakeholders on the relevant trade-offs involved in their decisions or to helping identify promising alternatives that satisfy a range of likely objective weights (Brill et al 1982). Difficulties visualizing or communicating trade-offs among more than a few objectives often hamper the practical value of multi-objective methods. Where the water resource problem involves fundamental political conflicts among objectives, multi-objective analysis cannot resolve those conflicts, only make them clearer.

Figure 1: Multi-objective Trade-off Plot



Planning to Resolve Conflicts

"Don't walk in front of me, I may not follow. Don't walk behind me, I may not lead. Walk beside me and be my friend." - Albert Camus

Planning to resolve conflicts differs fundamentally from other planning settings. The objective is to create a process where groups with conflicting objectives can negotiate a common plan or strategy. In most conflict settings, planning occurs in a political environment where parties have alternatives to participating in a formal planning process, posing a constant threat to such processes. Several forms of conflict resolution-based planning have emerged to respond to the common difficulties of planning in many institutional and political situations (Viessman and Smerton 1990; Delli Priscoli 1990). These approaches typically emphasize the need of various parties or stakeholders to communicate, understand, and negotiate as necessary conditions for any solution to be accepted politically (Raiffa 1982). Often considerable emphasis, effort, and time is required to establish broad confidence and communication in both technical and policy-making processes as part of developing and implementing solutions.

Conflict resolution-based planning typically gages its success based on how well a "consensus" solution is achieved, and may be less concerned with the Pareto-optimal rationality of a solution. Any plan agreed upon by the diverse stakeholders is generally thought to be a good plan. While consensus-based conflict-resolution processes appear to be useful, they have been far from universally successful, perhaps because such problems are tremendously messy and difficult (Walters 1997). Conflict resolution is often a long process and consensus is often difficult for a large number of diverse and competing interests having a history of conflict and distrust, within an unstable political context and changes in individual representation. Where decision-making authority is highly decentralized, incentives or threats from outsiders are usually required, such as promises of Federal or state funding or credible threats of regulatory or court action. Even where formally unsuccessful, such processes can serve an important long-term role in improving communications, information, and other conditions needed to work on solutions in the future.

Two broad categories of these still-emerging planning approaches are summarized below.

Adaptive Management and Shared Vision Modeling

Adaptive environmental management was first proposed in the late 1970s by a group of ecologists (Holling 1978; Walters and Holling 1990; Walters 1997; Walters and Green 1997; *Environmental Management* 1996). The objective was to support ongoing environmental management with consideration of uncertainties and incorporating an ability to change management of the system as more was learned of the system's behavior and response to management. A central tenet of this school of thought is that computer modeling has a central role for synthesizing knowledge of environmental problems, integrating new knowledge of the problem, and developing promising management strategies. In adaptive management, the development of computer models is a collaborative exercise among different disciplines and stakeholders. The intent of modeling is to aid development and negotiation of management alternatives, with both management and model-represented understanding adapting to new information over long periods of time, and to use modeling to design management experiments. The approach has had mixed success (Walters 1997; Lee 1999; Richards and Rago 1999).

A similar approach has taken hold recently among water resources engineers, often called "shared vision planning" (USACE 2007; Palmer, et al. 1999; Keyes and Palmer 1995; Werrick and Whipple 1994; Reitsma et al 1996). This approach also uses a group of stakeholders and technical experts to develop a computer model to represent a common understanding of the problem and develop, quantitatively compare, and negotiate potential solutions. Shared vision planning makes a greater effort at placing the modeling within a more traditional rational planning process with extensive facilitated public participation, merging aspects of rational planning and multi-objective analysis with aspects of facilitated conflict resolution processes (Imwiko et al. 2007). The approach is a modern expression of ideas for planning large complex public systems with public transparency and participation (Geddes 1915).

"Watershed" Planning

"Watershed planning" has been widely advocated by federal, state, and local agencies, though with less formal guidance of how it should be done (Kenney 1999; Gelt 1998). This concept differs fundamentally from long-standing ideas of relatively centralized planning for water at a watershed scale (White 1969; Goodman 1984). The most common tenets of current usage of "watershed planning" are that all stakeholders in the watershed should be involved in discussions of its management, all aspects of water quality and quantity in the watershed should be considered, and that the parties should have great flexibility in arriving at a consensus solution. The emphasis is on developing consensus-based water plans, involving all major stakeholders and agencies. As with adaptive management, mutual education among parties and stakeholders is a major aspect of watershed planning, although documentation of understanding is less quantitative. Watershed planning seems to be more successful where there is a balance between expectations and resources/funding, effective leadership and management, interpersonal trust, committed participants, and a flexible and informal structure (Leach and Pelkey 2001). A relatively formalized and comprehensive application of watershed planning principles is the Texas water plan, which was based on watershed plans for 16 regions of Texas (TWDB 2002).

A common problem with consensus-based planning conflict-resolution planning, especially its adaptive management forms, is the need for extended studies, funding, and attention from parties involved. While the exchange of ideas in these processes can produce valuable results, the long time frame often causes many good efforts to lapse due to budgetary variability, management and personnel transitions, and short attention spans at funding, managerial, and political levels. However, for controversial systems with decentralized decision authority, conflict resolution approaches are sometimes the only approaches that political authorities can support. Any positive results of a conflict resolution process are likely to be welcomed by agency and political leaders seeking to make an improvement with minimal controversy.

Market-Based Planning

Markets are a decentralized form of planning, which can accomplish planning objectives very effectively in some circumstances (von Hayek 1945). Markets, negotiated contracts, and exchanges have long been important components of water planning, providing flexibility at local scales to adapt to short-term hydrologic, economic, and water demand variability. In recent years, the use of markets and other

negotiated transfers in water planning and management has received increased interest and application to provide short and long-term flexibility in water allocation and operations (Lund and Israel 1995). Market-based planning often includes water contracts, markets for spot, dry-year, or permanent water transfers, transferable discharge permits, or privatization of facilities or operations. Often water markets are exclusively among public agencies or districts. In addition to providing a means for efficient and flexible operations, markets also provide financial incentives to adapt management policies to hydrologic and economic conditions. In California, water markets have provided incentives for local agencies in diverse parts of the state to sponsor conjunctive use and water conservation programs which would not have occurred without the financial incentives of water markets (Pulido, et al. 2004).

There are obvious limits and disadvantages of market-based solutions to public resource problems. The assignment and accounting of rights and real water, third-party and externality effects, and other classical market imperfections all pose problems. Nevertheless, markets are often effective and efficient components of water and environmental management (Anon. 1995; Howe, et al. 1986; Eheart and Lyon 1983; Lund et al. 1992).

"Muddling Through"

Political and economic circumstances often do not support long-term planning, particularly plans that recommend major changes to the current situation. When the political situation is unstable and not supportive of long-term planning, it is often more effective for planning efforts to seek small short-term improvements in a desirable long term direction. This approach is sometimes called disjoint incrementalism or "muddling through" (Lindblom 1959, 1979; Braybrooke and Lindblom 1970). Often, plans developed with the intent of following other planning approaches end up merely contributing to "muddling through." Numerous advantages have been ascribed to incremental actions and alternative evaluations in a pluralistic political environment (Braybrooke and Lindblom 1970), including improved responsiveness to perceived problems, ability to identify important consequences, and diffusion of decision and evaluation responsibilities. In this situation, incremental decisions can be more effective than more formal plans based on formal decision-making calculations (such as elaborate benefit-cost analysis).

Comparison of Approaches

While exposition requires making distinctions among major approaches to planning, actual planning often reflects several approaches. Real planning situations often require an artful mix of approaches tailored to achieve practical political, technical, and legal objectives through practical political and technical means. Table 2 is a summary comparison of water planning approaches in terms of the three most fundamental steps of rational planning. Each of the approaches reviewed employs rational planning core ideas in different ways. Requirements-based, benefit-cost, and multi-objective approaches apply rational planning methods most directly for settings with a more centralized and formal decision process. However, where centralized processes are unavailable politically, conflict resolution, market, and muddling through approaches each seek to accomplish similar rational planning objectives through very different means.

Table 2: Rational Aspects of Common Water Planning Approaches

Planning Approach	Performance Objectives	Alternative Identification	Performance Evaluation
1. Requirements-based	Cost and simple technical performance standards	Alternatives suggested by experts, stakeholders, or technical studies	Cost-effectiveness
2. Benefit-Cost-based	Net economic or financial benefits for owner, region, or nation	Alternatives suggested by experts, stakeholders, or technical studies	Benefit-cost analysis, perhaps including uncertainty & variability

3. Multi-objective	Quantifiable objectives specified by decision-makers or stakeholders	Alternatives suggested by experts, stakeholders, or technical studies	Reduce alternatives to the Pareto-optimal set
4a. Conflict Resolution: Adaptive Management	Mostly quantifiable objectives specified by decision-makers or stakeholders	Alternatives suggested by experts, stakeholders, or technical studies	Reduce alternatives to Pareto-optimal set, with long-term efforts to adapt, monitor, and narrow uncertainties
4b. Conflict Resolution: "Watershed Planning"	Objectives stated by decision-makers or stakeholders	Alternatives suggested by stakeholders and sometimes by experts	Little or no formal evaluation
5. Market-based	Each party has its own objective(s), not necessarily revealed	Alternatives identified by parties to the market individually	Each party evaluates alternatives individually and privately; unsuitable alternatives rejected in market
6. Muddling Through	Only limited objectives and expectations	Only easily implemented alternatives considered	Only simple and expedient evaluation of alternatives

Practical Problems

“Planning is an unnatural process; it is much more fun to do something. The nicest thing about not planning is that failure comes as a complete surprise, rather than being preceded by a period of worry and depression.” - Sir John Harvey-Jones

The problems of planning are not restricted to water resource systems, but are common for urban and other infrastructure system (Wildavsky 1973) as well as other problems, even robot control systems (Agre and Chapman 1990). The practical problems of planning often govern which approaches can or should be taken for a particular situation. Some major practical problems are discussed below.

Conflicting Water Uses and Objectives

Conflict among uses and users of water is the dominant characteristic of contemporary water planning. Agricultural water supply, environmental water uses, urban water supply, flood control, hydropower, recreation and other uses all compete in economic, legal, and political forums over the management of water, at local, regional, state, and federal levels. Even within each common water use, individual users or user groups often disagree on allocation of water, financial costs, and environmental impacts. Table 3 compares how each planning approach addresses conflicts over water use objectives. Where conflicts are least intense, requirements-based, benefit-cost, and multi-objective approaches are suitable, as they allow for a very direct and technical analysis of more focused problems. With greater levels of conflict, conflict resolution, market, and incremental approaches are more likely to be successful.

Table 3: Planning approaches and conflict, authority, and integration

Planning Approach	Conflicting Uses, Users and Objectives	Limited Authority to Implement Plans	Integrating Local, Regional, & State Plans
1. Requirements-based	Requirements must be established first	Requires consensus on "requirements"	Requires larger framework
2. Benefit-Cost-based	Economic valuation mediates conflicts	Requires consensus on economic evaluation	Explicit
3. Multi-objective	Conflicts presented as trade-offs	Authority absent to select final plan	Difficult

4. Conflict Resolution	Negotiation is the planning process	Negotiation among authorities	Difficult
5. Market-based	Market mediates conflicts	Market forces overcome limited authorities	Implicit, relatively easy
6. Muddling Through	Conflicts avoided whenever possible	Only plan within limited authority	Usually not attempted

Limited Authority to Implement Options

Regional water planners have very limited ability to directly affect the vast majority of water management decisions because most water management decisions are made locally. The effectiveness of regional water plans would be greater if they could be integrated with local water management efforts and activities. In the past, State and Federal governments often intervened in water problems to facilitate regional solutions. In recent times, State and Federal ability and willingness to fund regional options is now greatly reduced, particularly in the face of controversy. Each approach's treatment of limited planning authority is summarized in Table 3.

The need for centralized authority in water management has long been debated, and is central to political theories of water management. Wittfogel (1957) argued that the historical origin of centralized government and political authority arose from the need for a central authority to develop and manage irrigation and flood control in early Mesopotamia (so-called “hydraulic civilizations”). More recent studies also point to the importance of centralized planning authority for water management (Kelley 1989; Worster 1985). However, others point to greater effectiveness and efficiency in many highly decentralized water management systems, in studies of Puget Sound (Bish 1982) and Southern California groundwater management (Blomquist 1992). Decentralized management can better utilize local knowledge, maintain local accountability and performance objectives, widen the range of options considered, and ensure widespread review and comment on intermediate and final policy and planning products. Effective decentralized management requires informal or formal coordinating mechanisms, such as coordinating committees, agreements and contracts, a regional agency of local agency members, regulations, markets, or the courts. A water plan for a region with decentralized water management is likely to be more educational and define a framework or direction for common activity, and less likely to define a direct plan of action.

Integrating Local, Regional, State, and National Plans and Policies

Most water management decisions are local. For every State or Federal water planner, there are dozens of local water utility planners. And for each local water planner, there are thousands of agricultural, residential, commercial, and industrial water users, each making long and short-term water management decisions. Integrating these local and user decisions with regional and state water management decisions is both difficult and essential for effective regional water management. Some summary thoughts on how each approach pursues this function appear in Table 3.

Water planning can rarely be undertaken with the precision and comprehensiveness of an industrial or military enterprise. More commonly, regional water planning must consider policies and plans already existing at local, regional, state, and federal scales. Thus, plans sometimes resemble to the “exquisite corpse” of early 20th century surrealist art circles, as illustrated by the quote below from an early housing study.

“The process by which a housing program for Chicago was formulated resembled somewhat the parlor game in which each player adds a word to a sentence which is passed around the circle of players: the player acts as if the words that are handed to him express some intention (i.e., as if the sentence that comes to him were planned) and he does his part to sustain the illusion. In playing this game the staff of the Authority was bound by the previous moves. The sentence was already largely formed when it was handed to it; Congress had written the first words, the Public Housing Administration had written the next several, and then the Illinois Legislature, the State Housing Board, the Mayor and City Council, and the CHA Board of

Commissioners had each in turn written a few. It was up to the staff to finish the sentence in a way that would seem to be rational, but this may have been an impossibility.” Meyerson and Banfield (1955), p. 269.

A larger framework is needed to integrate requirements-based plans, establishing compatible requirement specifications; this is difficult, though it is commonly done with water quality standards. Benefit-cost analysis provides a consistent economic criterion across all levels of decisions, although decision makers at different levels are unlikely to agree to such a common criterion, as realized (albeit often futilely) in multi-objective approaches. Conflict resolution approaches provide a forum where conflicts among different decision-makers and decision scales can be worked out. Whereas market and muddling-through approaches provide means to plan where explicit collaboration is difficult or impossible.

Data, Time, and Resources for Analysis

Most planning analysis is limited by the quantity and quality of data available, as well as the political circumstances of planning. Moreover, much important data, such as long-term water demands, regulations, and climate change, become reliable only after their quantities are no longer relevant for planning. Large amounts of data do not necessarily contain useful information. Poorly or unsystematically collected or estimated data often contain less useful planning information than simple more transparent estimations. Data often must be digested and reconciled to be useful analytically or conceptually, with understood limitations.

Data problems are compounded when scientific controversy exists over how empirical data should be assembled or interpreted. This is common with biological problems with significant variability in field data and fundamental questions regarding how particular biological and ecological systems work. The lack of data, or useful data, tends to encourage some forms of planning relative to others. These are summarized in Table 4. Small amounts of data tend to encourage market, muddling-through, and requirements-based planning. Conflict resolution planning is the most flexible regarding data availability. The cost and time required for collection, digestion, and use of data will always place technical limits on planning.

Few planners complain of having too much time, funding, or expertise. The lack of time is often imposed by statutory limitations or the attention period of governing political bodies and reduces the level of analysis undertaken, with implications for the approach taken to planning. Nevertheless, the time and resources allocated for plan or study completion often extends beyond the likely time of political attention or importance for a subject. Long-term in-depth plans often have difficulty gaining attention from political leadership.

Table 4: Planning Approaches and Data, Variability, and Assessment

Planning Approach	Data Requirements	Variability and Uncertainty	Assessing Performance on Each Use Objective
1. Requirements-based	Very limited	Reliability standards	Simple. Costs and required specifications
2. Benefit-Cost-based	Great	Can be explicit	Economic estimates often controversial or difficult
3. Multi-objective	Moderate to Great	Difficult to present	Often difficult
4. Conflict Resolution	Minimal to Great	Difficult	Done by relevant stakeholders; may conflict
5. Market-based	Minimal	Implicit, left to buyers and sellers	Implicit. Performed by parties in market
6. Muddling Through	Modest	Usually not attempted	Only limited attempt made

Variability and Uncertainty

Many aspects of real water problems are highly uncertain or variable, particularly over planning time frames. Many fundamental uncertainties exist regarding how water management affects specific environmental resources. Hydrologic uncertainty, from "usual" variations between drought and flood to prospects for climate change; water demand uncertainty, from changes in population and wealth, changes in water use efficiency, and changes in weather; and changes in water quality and demands for water quality all are central to regional water planning and must be treated carefully in planning analysis (Lund 1991). Unavoidable uncertainties exist for long-term prediction in most of these areas.

The formal understanding and analysis of uncertainties involves the use of probabilities. Probabilities are a very powerful and rigorous analysis tool for such problems. However, the use and results of studies using probabilities are difficult to explain to decision-makers, the public, and even most technical people. The treatment of variability and uncertainty for each planning approach is compared in Table 4. Some planning approaches seek to avoid variability and uncertainty (muddling through), while others (benefit-cost analysis) can rigorously incorporate them; however, no approach can handle variability and uncertainty without difficulty.

Limited Range of Alternatives

Consider a water system with only 20 water management options, including various water supply and demand actions to be combined into alternatives for evaluation. Each combination of options is a possible alternative. Mathematically, if each option can either be included or excluded from an alternative, there are $2^{20} = 1,048,576$ possible alternatives. Real water management systems have many thousands of possible decision options and many many more possible alternatives. It is impossible to explicitly enumerate and evaluate all possible alternatives.

It is possible to develop, refine, and evaluate only a limited number of alternatives. Practically, each new alternative, particularly creative or novel alternatives, requires considerable effort for development and education of stakeholders. It is often difficult to develop promising alternatives in an atmosphere of controversy and political maneuvering. Stakeholders often perceive an interest in limiting the range of alternatives to be considered.

Assessing Performance for Each Objective

In planning we would like to quantitatively evaluate proposed alternatives on each performance objective. Several common difficulties commonly arise: 1) Stakeholders often find it difficult to specify their performance objectives, sometimes for political reasons, but also because it is a difficult intellectual and technical problem. 2) Given reasonable verbal statements of performance objectives, it is often difficult to derive quantitative mathematical analogs. 3) Fundamental uncertainties often exist in knowing how a particular performance objective (such as salmon populations) will be affected by specific water management decisions.

Performance assessment is made more difficult by the variability in hydrologic conditions and operations. How well can a particular water use tolerate or benefit from variability in flows? How should various probability distributions of water availability for specific uses be compared? Table 4 summarizes performance assessment problems for each planning approach. Much of the selection of a planning approach should be driven by the types of evaluation results which the political planning process can absorb. Thus, the most fragmented planning processes are most likely to accept market or muddling-through types of analysis. More organized or centralized political planning approaches can employ other approaches.

Transparency: Can We Understand and Communicate It All?

Regional water systems are complex, so reasonable transparent representations also will be complex. Even among experienced water managers, few individuals have both broad and detailed knowledge of

any large regional water system. One career usually cannot encompass complete and up-to-date detailed knowledge of a system and deep thinking about how to improve the system over the long term. No one can understand it all. This problem is compounded by the employment transience at technical, managerial, and political levels; in any planning meeting, many people must be “brought up to speed.”

With the diverse audiences and objectives of regional water planning, can we ever make our thinking and analysis understood? Given the real limitations and realistic expectations of planning, a simplified analysis that more clearly communicates water management guidance might more effectively improve a region's water management than presentation of sophisticated methods and results (Geoffrion 1976). However, more sophisticated and detailed analyses are likely to be needed to develop and detail much of a regional plan. A plan or analysis that cannot be understood is unlikely to attract the confidence or readership needed for implementation.

Some Realistic Objectives for Regional Water Planning

We all have ideas of what a water plan should accomplish. Popularly, water plans lead directly to the solution for water problems. Alas, this is often not the case. In reality, water plans serve a variety of related and important functions, only some of which lead directly to resolving water problems. Other plan functions are useful informational steps for long-term water management.

1. Education. Local, regional and statewide water plans educate the public, political leadership, and water policy professional staff and leadership about water problems and options. Water plans are a regularly updated practical and authoritative overview of a region's water problems, with some directions for improvement. Each individual party concerned with a region's water problems will have a narrower view of the subject, and so cannot provide the integrated perspective of a regional plan. The public education role of the plan is rarely direct; a tiny proportion of the population reads plans. But an authoritative water plan document can provide a reasoned, informed, and readable perspective on regional water problems for the media and "opinion leaders" to improve policy decisions and the accuracy of public perceptions.

The political leadership of general and water-related governments is tremendously distracted by many issues and their own political dynamics. Even the best political leaders can devote little time to technical aspects of decisions. Political leaders must rely on advice from others and authoritative accounts of the problem. Water plans can inform decision-makers and their advisers on relevant aspects of water problems and provide some assurance to statewide, regional, and local stakeholders and water managers that their problems and alternative solutions have been fairly presented for consideration.

New water professionals often use local, regional, and statewide water plans to orient themselves in the practice and context of their work. For these people, regional and local plans provide an authoritative view of the context of their activities as well as perspectives on the overall direction of water management activities and examples of accepted planning methods and options.

2. A reference document. Regional water plans are central reference documents for statewide, regional, and local water management and planning activities and decisions. In one location, a regional plan provides authoritative estimates of water demands and forecasts (dissaggregated by use type), information on storage, conveyance, and water supply availability, an inventory of water distribution systems and their organization, an authoritative inventory of water problems, and a wealth of other information, including where additional information can be found. Plan estimates, data, and discussions have everyday uses for local, regional, statewide, and private water management and user activities. An organized authoritative source of such information provides a common benefit.

3. Leadership in water management. Although most regional water plans are conducted by entities with very limited financial and jurisdictional powers for water management, such plans can provide

significant "leadership" for the many water management decisions in a region. The options and objectives considered and the methods used in a plan set an example for other local and regional planning efforts. At regional and statewide scales, and for federal agencies, planning practices set precedence and expectations for other levels of government that are more active and have more resources and jurisdiction to implement water management options. This leadership in content and method has great potential to help integrate and improve the planning efforts of lower units of government, increasing the number of promising alternatives examined and solidifying their evaluations of alternatives. Such leadership must be responsible. Its leadership rests on neither lagging too far behind the advanced state of practice, nor being so far ahead of advanced practice as to risk being misunderstood or ignored.

4. Planning fosters discussion and negotiations. While plans might or might not lead directly to the solution of water problems, any planning process provides long-term opportunities to discuss and negotiate water problems as well as opportunities for public input, feedback, and support. These opportunities can help in long-term development of solutions and understandings of stakeholder concerns, even when plan recommendations are ignored.

5. Specific recommended actions and their implementation. We normally think of water plans as recommending particular thought-through actions for improving a region's water management. However, practically, this is often not the functional case. The specifics of a water plan usually are most relevant at local levels, where agencies tend to have more financial resources and independent implementation authority. For higher regional authorities, including state authority, the financial, jurisdictional, and political wherewithal to implement plan specifics often diminishes. Historically, State and Federal agencies have dominated water development only for short periods. In California, for example, Federal water projects dominated regional water development from the 1940s until 1982 and State projects from 1967-1982. This occurred despite Federal and State planning studies dating from 1873 (Pisani 1984). Before and since these periods, almost all major water supply projects in California have been instigated, financed, owned, and operated locally or sometimes regionally. Now and for the foreseeable future, regional water plans are likely to be effective only where they help integrate activities across jurisdictions and users. This will be a difficult and prolonged process.

6. Following the Law. Planning processes often exist to meet relevant state or federal legislation, such as the federal National Environmental Policy Act (NEPA) or state acts such as the California Environmental Quality Act (CEQA). Such legislation requires various procedures for involving different units of government and the public, specification of objectives and identification and evaluation of alternatives. Such legislation helps standardize planning across many types of planning problems. For example, NEPA requires that federal agencies develop and consider alternative courses of action and evaluate them in terms of environmental impacts. Implementing regulations for NEPA further specify how these and other planning activities are to be accomplished. In addition, more specific legislation exists for particular water problems, such as the federal Clean Water Act or Endangered Species Act and their state variants. Any water management or development proposal or project will be expected to comply with relevant legal requirements. These legal requirements often explicitly or implicitly require a planning process.

Given the increasingly public nature of planning and the decentralized nature of water management, the educational, leadership, and procedural roles of plans and planning processes can have great long-term significance, even where their short-term effects are limited. In terms of rational decision-making, the purpose of a plan is to convince a broad audience of decision-makers and publics that:

- 1) the problem is relatively well considered, including the implications of uncertainties,
- 2) a wide range of potentially promising alternatives has been identified with reasonable thoroughness,
- 3) unreasonable alternatives have been reasonably eliminated,
- 4) remaining alternatives have been developed to provide desirable performance, and
- 5) the final plan was judged the "best" of these well-performing alternatives.

For long term water problems, plan contributions to any of these aspects can be valuable.

Technical Analysis in Planning

Water planning is a complex business involving moving and storing millions of tons of liquid every day with substantial economic impacts and financial costs. So most regional water planning and management activities have a heavily technical component. Lund and Palmer (1997) present a more detailed overview of the roles of computer modeling in planning and conflict resolution in water resources.

The role of technical planning expertise can vary greatly between planning approaches. For requirements and benefit-cost based approaches, engineers and planners are largely isolated technicians, toiling in response to a problem defined by others and offering specific recommendations. Multi-objective planning requires engineers to interact more with stakeholders or their representatives to define and clarify plan objectives and communicate performance estimates to decision-makers. Conflict resolution and muddling through forms of planning place engineers and planners in a far more demanding (and interesting) situation near the center of political decision-making. Here, technical study management must interact directly and interactively with opposing stakeholders, often for prolonged periods. As technical mediators and staff, engineers and planners are often aided by professional facilitators overseeing the conflict resolution discourse, and must become familiar with stakeholder objectives to better represent them, as well as to identify promising consensus solutions. In market-based planning, the engineer often retires somewhat from the public fray, but still must understand market actors and conditions so as to advise in the negotiation of purchases, sales, and exchanges, as well as related legal and regulatory activities.

The purpose of analysis is usually not numbers, but insight (Geoffrion 1976). Under practical conditions and political limitations, it is often difficult to develop policy analysis from technical studies. Often, strategic analytical insight are more readily developed by more independent analysis by internal agency “skunk works”, universities, or others with diminished political accountability.

When to Plan How

Considerable public and professional controversy exists regarding how water planning should be done. Each planning approach presented has been successfully applied in some situations, and has failed in others. No planning approach succeeds in all circumstances. In developing regional and statewide plans, often it will be necessary to integrate plans developed under different planning philosophies.

For discussion, three broad sets of planning circumstances are used to illustrate the likely suitability of different planning approaches. The first circumstance is where only rapid and inexpensive studies are possible. There may be few resources for conducting the study, the pace of political events may limit the time available for planning, or the problem might not merit much attention. The second set of circumstances is where planning resources are greater and a single formal decision-making process exists to adopt and implement a plan. Planning details for most engineered water facilities traditionally fall into these first two categories and represent most day-to-day engineering planning. The third set of circumstances, multi-party decision-making can occur in the midst of considerable controversy and conflict. Table 5 presents some hypothetical ideas on the suitability of each approach for each set of circumstances.

In an era when federal and state governments lack the funding and will to impose or persuade formal planning outcomes on stakeholders, conflict resolution, marketing, and muddling through approaches are all that remain for stakeholders wishing to solve regional water problems. However, even within this less formalized and more pluralistic setting, requirements-based, benefit-cost-based, and multi-objective planning and techniques can be informative and useful.

Table 5: Hypothetically Good Conditions for Different Planning Approaches

Planning Approach	Only Rapid and Inexpensive Studies Possible	Single Formal Decision-making Process	Controversial Multi-Party Decision-making
1. Requirements-based	Especially effective for non-controversial and small problems	May overly limit alternatives and evaluation	Usually unsuccessful
2. Benefit-Cost-based	Only limited analysis possible	Good, but usually requires interpretation	Informative, but politically insufficient
3. Multi-objective	Only limited analysis possible	Good, but requires interpretation and final judgment	Informative, but politically insufficient
4. Conflict Resolution	Usually inadequate time or resources	Not needed	Promising, but often politically futile
5. Market-based	Potentially good, if properly arranged	Sometimes good	Promising, if properly arranged
6. Muddling Through	Often best for large problems	Probably not good	Often the only possible approach; success limited and incremental

Figure 2 attempts to place the theories discussed along two commonly relevant dimensions, the problem’s specificity and the political leadership available to implement any plan. Other dimensions could have been used, and the placements or each approach are inexact, but the figure serves to illustrate how muddling through, doubtless the most common approach to planning in practice, can often result from a collapse of conditions suitable for more formal planning methods. Even in the worst cases, attempts at more formal planning can generate insights, alternatives, coalitions, and information useful for muddling through more effectively.

The rational selection of a planning approach should be based on the likely success of alternative approaches in achieving practical objectives for a planning effort. This selection process itself illustrates many practical problems in water resources planning.

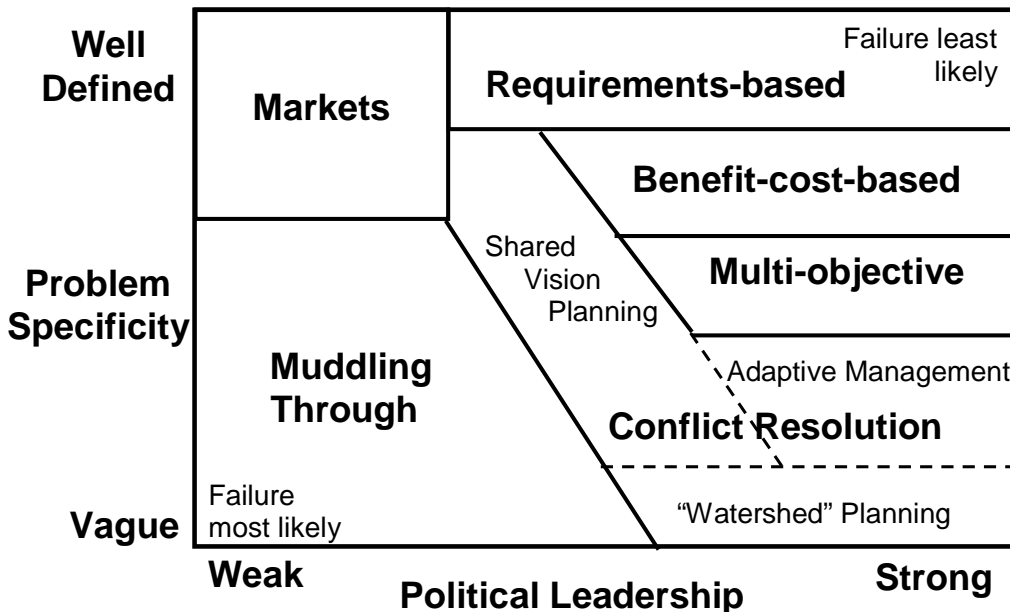


Figure 2: Approaches to Planning in Political and Problem Contexts

Conclusions

Water problems are often complex and controversial. Confusion, controversy, expense, and delay can be magnified if the approach to planning for these problems is unclear or ineffective. A clearly structured approach to planning for water resources problems is often necessary, or at least valuable.

A variety of planning approaches are available for different types and contexts of planning problems. While the general concepts of rational planning reflect fundamentals of rational decision-making and are of broad utility, no specific planning approach is suitable for every planning problem and context. Planning problems vary greatly, with each one being arguably unique. The specifics of planning for a particular problem should attempt to reflect problem peculiarities.

Local and intra-agency water plans with well-defined problems and significant political and financial wherewithal are most likely to apply traditional planning notions. Larger-scale regional water plans usually have more tenuous political support and less well-defined problems, usually will require newer forms of planning, and are less likely to lead directly to implemented solutions. Regional water plans typically serve longer-term educational functions for regional water management. For planning to fulfill most educational, leadership, policy, and project development roles, it must be transparent and comprehensible, "rational", and not require unavailable time and financial resources.

The selection of an appropriate planning approach or mixture of approaches should reflect the objectives and context of addressing the particular planning problem.

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Integrated Water Resource Management is a holistic approach involving technical, economic, financial, and institutional aspects, and where a participatory approach facilitates the best decision-making. Born in the 1990s, the concept has evolved toward a more practical framework during the last 30 years. Furthermore, GIS provides an integrating data and modelling environment for planning and design in water resources engineering (Johnson, 2009). A GIS provides a means to collect and archive data on the environment. Measurements of location, distance and flow by GNSSs are typically handled in digital format and quickly integrated into a spatial database. This approach will help to expedite cooperative, integrated water resource planning, and successful implementation of needed management, thereby facilitating the restoration of water quality. For example, watershed plans that incorporate a full range of other resource management activities, such as source water protection for drinking water, forest or rangeland management planning, agricultural resource management. Why Watershed Plans Fail. The Center for Watershed Protection conducted a broad assessment of the value of planning documents, systems, and parkland or greenspace management will Water allocation planning involves consideration of the total water resources available within a basin. This can include surface and groundwater supplies, as well as water from interbasin transfers. The amount of water available for allocation will be a function of this total volume, less Approaches to defining water entitlements have included: mean annual or monthly diversions such approaches require a mechanism for converting the average volume into an actual volume that may be used, based on the seasonal conditions. minimum guaranteed volume a volume of water that will be supplied in all conditions, and ahead of other competing users.