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Design Of A Drought Management Exercise: Simulation Gaming Applied To The Indianapolis Water Supply System

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Exhibit 19

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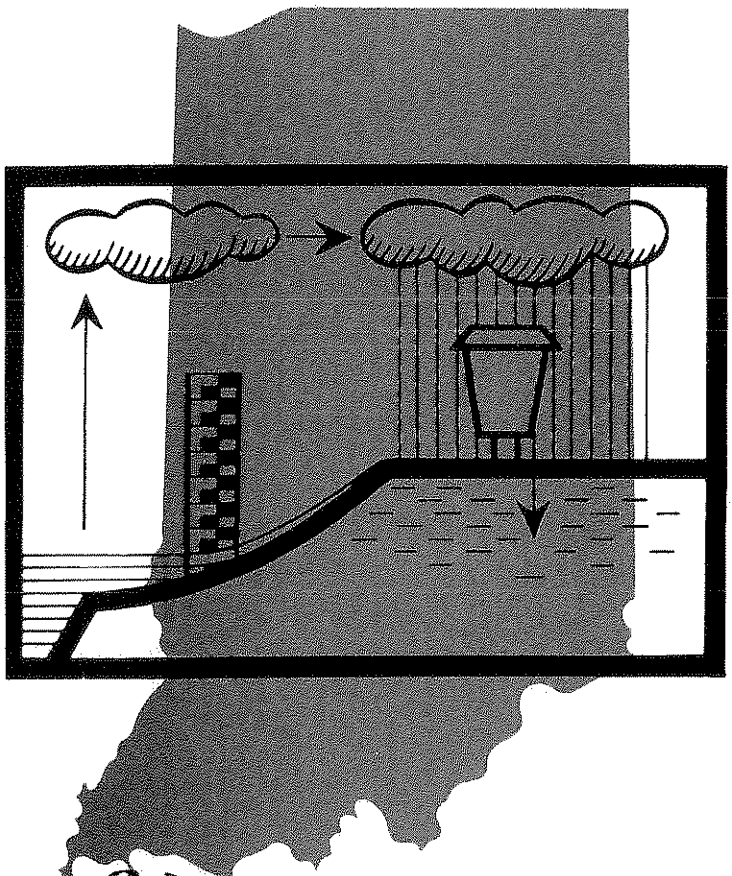

by

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PURDUE UNIVERSITY
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PREFACE AND ACKNOWLEDGEMENTS

Approximately five years ago, a research effort focused on the Indianapolis Water Supply System began at Purdue. During this entire period, the Indianapolis Water Company and especially Messrs. J. Darrell Bakken and Robert Trivers have been very generous in providing data and their time to assist us. We thank them for their invaluable help.

We also thank Dr. J. W. Delleur, who was serving as Acting Director of the Purdue University Water Resources Research Center at the inception of this project, for his assistance. Dr. John Cushman, current Director of the Center, Mrs. Jill Hellmann, Administrative Assistant for the Center, and Ms. Jan Valentine, Secretary Extraordinaire in the School of Civil Engineering, all deserve our thanks.

ABSTRACT

The potential use of simulation gaming to enhance the effectiveness of drought management planning in Indianapolis is described. First, the probability of experiencing a severe drought in Indianapolis is examined using historical streamflow data. The effects of such a drought on the municipal water supply system are then analyzed using a recently developed simulation model of the Indianapolis water system. Consideration is given to the water resource decision making problems which might arise under drought conditions, along with a discussion of the benefits of employing simulation gaming in the analysis of these problems. A basic outline for the design of a drought management simulation exercise is provided. References to relevant literature are included.

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CHAPTER ONE

DROUGHT IN INDIANAPOLIS

During the past century, several regions in the United States have experienced drought conditions and shortages in public water supply. As recently as 1977, much of the western United States was subjected to severe drought conditions. Shortages in water supply were especially intense in California, where mandatory water conservation measures were instituted in an effort to stave off the exhaustion of water supplies. The eastern United States has had its share of water shortages also. Severe droughts occurred during the early 1930's and again during the mid 1960's in the Washington D.C. Metropolitan area, including portions of Maryland, Virginia, Pennsylvania, and West Virginia. Water shortages of smaller magnitude have occurred in many other areas throughout the nation in recent years, and serve to illustrate the fragility of our water supply systems.

There have been few, if any, instances of public water shortage in the Indianapolis metropolitan area in the last century. The water supply system in Indianapolis, as in most areas, is designed to withstand adverse environmental and climatic conditions. Analyses of the projected demands for water around Indianapolis have prompted decision makers to take various measures to ensure an adequate supply of water for the metropolitan area well into the future. To date, the careful management of water resources coupled with favorable climatic conditions have forestalled major water supply problems. *Is it possible that Indianapolis may someday face a water shortage?* If so, when might it occur, and what implications might it have in terms of the public water supply?

To address these issues, it is first necessary to conduct an analysis of water supply records of Indianapolis. Using historical streamflow data as an indicator of water availability, it should be possible to estimate the return period of the 1940-1941 drought, a drought widely regarded in the region as the most severe in recent years. Furthermore, such an analysis will provide estimates of the severity, at least in terms of streamflow, of a 100 year drought, a 200 year drought, and droughts of other return periods. The second phase of the analysis will then employ these estimated drought streamflows in a simulation model of the current water supply system in Indianapolis. The results of such a simulation should provide insight as to the effects of a severe drought on the public water supply system in the Indianapolis metropolitan region.

Frequency Analysis

According to USGS records of streamflow at a monitoring station on the White River near Nora (Table 1), the most severe drought in the Indianapolis region occurred between 1940 and 1941, when the mean annual flow for the 1941 water year (October, 1940 to September, 1941) was 235 cfs (cubic feet per second). Experts generally agree that this drought lasted approximately 600 days, from June 18, 1940, to February 3, 1942. In comparison, the mean annual flow of the White River near Nora in recent years has been greater than 1400 cfs (1978-1980). Only at one other time since 1940 has the streamflow approached the levels of the 1941 drought, when 370 cfs was recorded as the mean annual streamflow for the 1954 water year.

TABLE 1: MEAN ANNUAL STREAMFLOW: WHITE RIVER NEAR NORA, INDIANA

Water Year	Flow (cfs)	Water Year	Flow (cfs)	Water Year	Flow (cfs)
1931	514	1947	1119	1963	751
1932	962	1948	1367	1964	1066
1933	1690	1949	1394	1965	833
1934	345	1950	2052	1966	441
1935	560	1951	1419	1967	1059
1936	522	1952	1343	1968	1167
1937	1585	1953	957	1969	1139
1938	1692	1954	370	1970	1117
1939	1105	1955	825	1971	770
1940	499	1956	1165	----	----
1941	235	1957	1617	1976	1047
1942	865	1958	1683	1977	431
1943	1425	1959	1317	1978	1462
1944	872	1960	845	1979	1476
1945	964	1961	1109	1980	1493
1946	1174	1962	1027		

Several frequency analysis methods were employed to estimate the probability of a drought similar to the 1940-1941 drought beginning in any particular year. The following table (Table 2) illustrates five plotting - position formulas that were used in these estimations.

Define:

P = the probability that streamflow WILL exceed the 1941 water year streamflow in any year.

1-P = the probability that streamflow WILL NOT exceed the 1941 water year streamflow in any year.

T = the return period of a drought of the 1941 water year severity, computed as 1/(P-1).

n = number of years of record (n = 46).

m = rank, from highest to lowest flow, of event of interest (m = 46).

TABLE 2: FREQUENCY ANALYSIS METHODS

Method	Formula	P	1-P	T
Hazen	2(m-1)/(2n)	0.9783	0.0217	46
Weibull	m/(n+1)	0.9787	0.0213	46.9
Chegadayev	m-0.3/(n+0.4)	0.9849	0.0150	66.3
Blom	m-0.375/(n+0.25)	0.9865	0.0135	74
Tukey	3m-1/(3n+1)	0.9856	0.0144	69.4

A Log Pearson III analysis was also performed on the mean annual streamflow data. Although this distribution has been widely adopted as the standard method for flood frequency analysis, it was considered as appropriate as other statistical methods to apply to mean annual streamflows. The results of the Log Pearson III analysis indicate that the return period for a drought (as measured by streamflow) of the 1941 severity is approximately 83 years. This translates to a better than 1% chance that a similar drought may begin in any particular year. This probability is in agreement with estimates by experts familiar with the regional water supply system.

However, due to the inherent uncertainty associated with fitting various distributions to the streamflow data, it would be most appropriate to conclude that there is a range of possible values for the 1941 drought return period, with 46 years and 83 years being included in that range.

The Log Pearson III analysis was also used to develop estimates of the expected severity of droughts other than those similar to the 1940-1941 drought. For example, based on a streamflow of 370 cfs it was determined that the dry period of the 1954 water year has an approximate return period of 22 years. Furthermore, using streamflow as an indicator, it was estimated that the volumes of streamflows corresponding to 100 year and 200 year droughts would be 222 cfs and 182 cfs, respectively.

Simulation Modeling

A study of the Indianapolis water supply and distribution system was recently completed by Randall in a dissertation entitled *Operation of a Metropolitan Water Supply System During Drought* (1984). The author developed a mathematical optimization model of the Indianapolis water system in order to observe supply system behavior and study optimal system operating policy under drought conditions. Incorporated into this model is a linear program that optimizes an objective function subject to constraints that define the capabilities of the water supply and distribution system.

For a given objective, the simulation program determines the best way to operate the supply and distribution system under the most severe drought conditions on record (the 1940-1941 drought) given various projections of the demand for water and other parameters. Because the water supply system in the Indianapolis area is operated by a private utility, one objective function of particular interest is "Maximize Revenue", although other objectives may be of concern. From the perspective of the water resource decision-maker, the model could be used to provide estimates of what might happen to reservoir levels, for instance, if the drought of 1940 - 1941 were to occur today. The model also provides estimates of whether or not the demand for water will be satisfied, and the amount of reduction in environmental flowby (releases made from reservoirs to satisfy downstream low flow requirements) that would be required to meet expected demand.

Results of the study by Randall indicate that if the drought of 1940 -1941 were to occur today, the Indianapolis metropolitan area would not experience significant water shortage, although it appears that one of the major reservoirs might run dry. Decision makers may not be entirely satisfied with this knowledge, however. Aside from the contributions and insight provided by the Randall study, investigation of drought conditions more severe than those of 1940 -1941 may provide insight as to the actual capability of the water supply and distribution system to withstand adverse environmental and climatic conditions. The Randall simulation model will provide a valuable research framework that should facilitate this investigation.

What would be the results of a drought more severe than that drought of 1940 - 1941? Log Pearson III estimates of the 100 year and 200 year mean annual streamflows for the White River near Nora were incorporated into the Randall model to study the behavior of the water system under four separate scenarios:

Scenario 1:

Drought return period: 100 years
Drought duration: 600 days
Average daily demand: 110 mg
Date demand expected: 1986 - 2001

Scenario 2:

Drought return period: 200 years
Drought duration: 600 days
Average daily demand: 100 mg
Date demand expected: Current demand

Scenario 3:

Drought return period: 200 years
Drought duration: 600 days
Average daily demand: 110 mg
Date demand expected: 1986 - 2001

Scenario 4:

Drought return period: 200 years
Drought duration: 600 days
Average daily demand: 120 mg
Date demand expected: 1992 - 2015

The Randall model was modified to simulate the conditions specified in the preceding scenarios. The estimated effects of each scenario on the Indianapolis water supply and distribution system are summarized in Figures 1 - 12. Three parameters were chosen to illustrate these possible effects: (1)

reservoir storage, (2) the extent to which the demand for water in the system could not be satisfied by the supply of water in the system (percent system shortage), and the volumes of flowby released downstream of two major reservoirs, Broad Ripple and Keystone. Each of these parameters would represent a major concern for the water resource decision maker concerned about to providing quality service and maintaining good relations with customers, public agencies, and citizen groups.

Under the first scenario (Figures 1-3), the volume of storage in two of the major reservoirs is estimated to fall below the 50% capacity level throughout much of the drought period. Some districts would experience slight shortages at times during the drought and flowby would have to be reduced temporarily at two of the dams in order to augment existing water supplies.

The next three scenarios represent increasing degrees of drought/demand severity and, as would be expected, there is an associated increase in adverse consequences. Under the various scenarios, the consequences range from virtually emptying one reservoir temporarily to operating two reservoirs at close to zero storage for an extended period of time. System shortages range from zero to greater than 45% and conditions sometimes necessitate an almost 100% reduction in normal flowby volumes.

Whether or not these consequences represent "critical" conditions is not considered, but the water resource decision maker must be prepared to deal with not only the potential of running the reservoirs dry, but with the discontent that may arise from shortages in the supply districts and groups concerned about the environmental and economic effects of low volume flow downstream of the major dams.

Although the Randall model provides an excellent representation of the Indianapolis water system under most conditions, it should be emphasized that under the extreme environmental and social conditions associated with the severe droughts represented in this paper, the consequences of these droughts as illustrated in Figures 1 - 12 may be significantly understated. Given the conditions represented by the four scenarios, it is possible that assumptions built into the model may not be entirely appropriate, projections of demand and other parameters may be inaccurate, and the variability of climate and streamflow phenomena may lead to significant differences between what is predicted to occur and what might actually happen. Here are some reasons why conditions during an actual drought may be more severe than predicted by the model.

- Evaporation rates for the reservoir during a drought may be greater than those rates assumed in the model due to the unusual environmental conditions associated with a drought. This would imply that less water is available than is indicated by the Randall model.
- Sedimentation in the reservoirs may have reduced their capacities to levels lower than those assumed in the model.
- The arid conditions associated with a drought could increase the demand for water above projected levels. For example, homeowners may begin to water their lawns at more frequent intervals in an attempt to save grass.
- The optimization model is driven by a set of deterministic streamflow data representing the 1940 -1941 drought. The results of the simulations are based on the assumption that the reservoir operators have perfect knowledge of streamflow into the reservoirs for 30 day time intervals. This assumption is clearly invalid, and implies that the actual consequences of the four scenarios could be considerably more adverse than depicted.
- The optimization model determines the best operating policy for the reservoirs for a given set of conditions. The best results can be obtained only if there are perfect controls on the supply and distribution system. If the model indicates that 172.6 mg of water should be released from a particular reservoir during a particular period, then releases of more or less than this amount can only produce suboptimal results. In actuality it may be difficult to achieve such fine degrees of control over the system, with the result being drought consequences more severe than indicated by the Randall model.
- Under a given set of reservoir conditions, the optimization model will always select the best (in terms of a specified objective) method or operating policy to satisfy the demand constraints. If water could be released from one of two reservoirs to meet the demand at a particular district, the model will select that reservoir which will best meet the demand. During an actual drought, there is no guarantee that reservoir operators will be able to make such a determination.
- Seepage losses could decrease effective reservoir capacity.

To date, the careful management of water resources coupled with an adequate supply of water in the Indianapolis area have forestalled major water supply problems. However, analysis of the water supply history and the simulation of the supply and distribution system of Indianapolis indicate the potential for significant water supply problems. Three findings support this conclusion: 1) a major drought, more severe than the 1940 - 1941 drought, has at least a 1% chance of occurring in any given year; 2) simulations of the Indianapolis water supply and distribution system indicate that two reservoirs may nearly run dry, shortages of up to 50% may occur in the system, and flowby may be reduced to unacceptable levels if such a severe drought were to occur; and 3) the actual consequences would most likely be more adverse than those outlined above, given the four scenarios and assumptions of the Randall model.

Water resource decision makers should be prepared to anticipate and handle the challenges and complications that would arise under drought conditions. Careful planning and management of the Indianapolis system have been responsible for the highly reliable water supply of that region. Contingency planning at all levels must continue if this record of reliability is to be maintained under more severe of drought conditions.

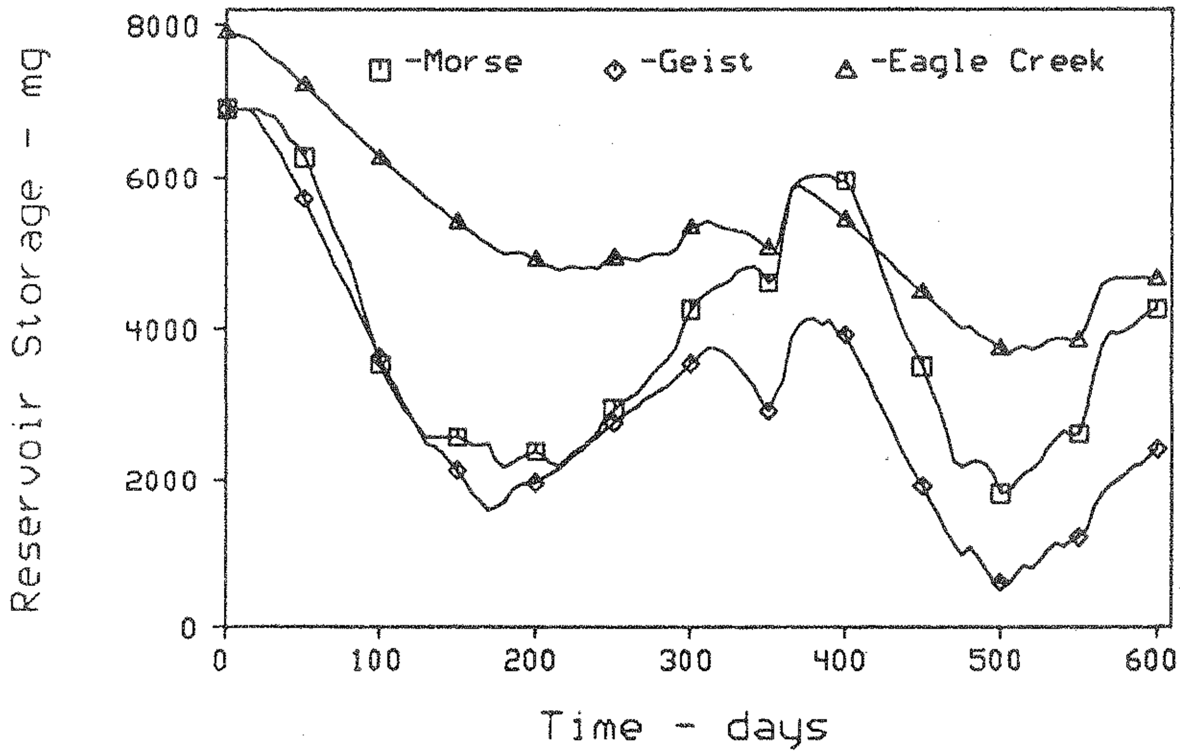


FIGURE 1. RESERVIOR STORAGE: SCENARIO 1

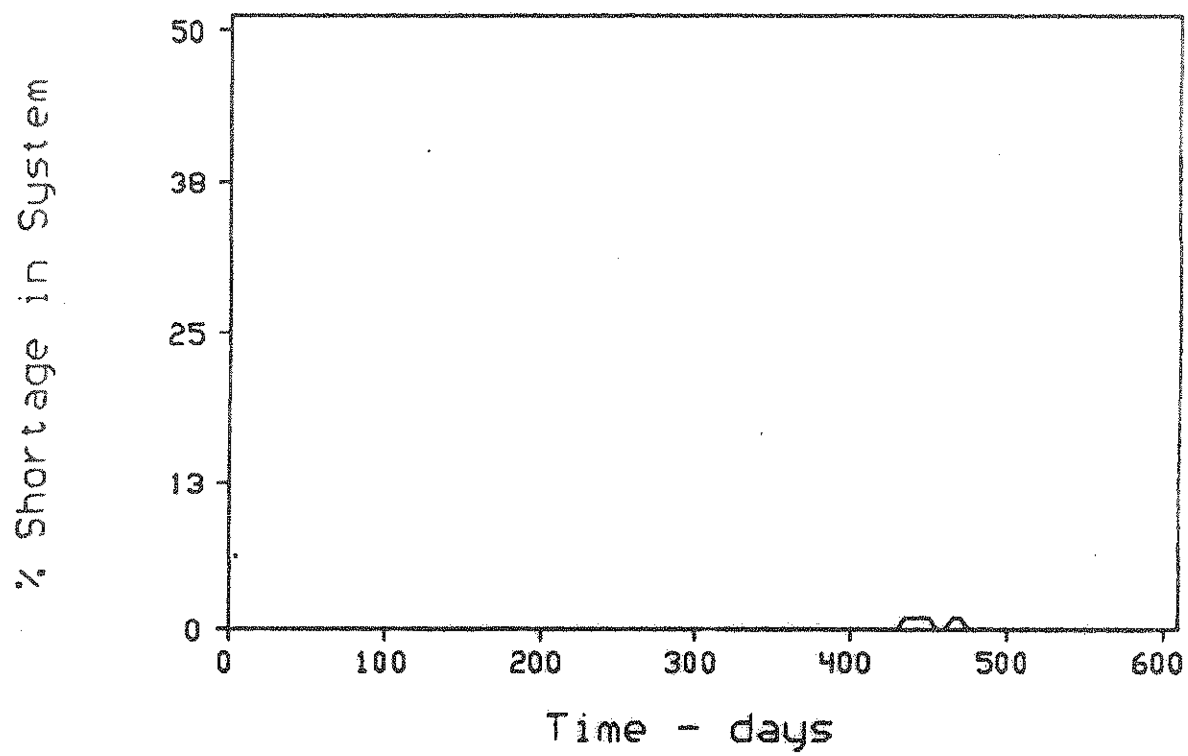


FIGURE 2. SHORTAGE IN SYSTEM: SCENARIO 1
(PERCENTAGE OF UNMET DEMAND, SYSTEM WIDE)

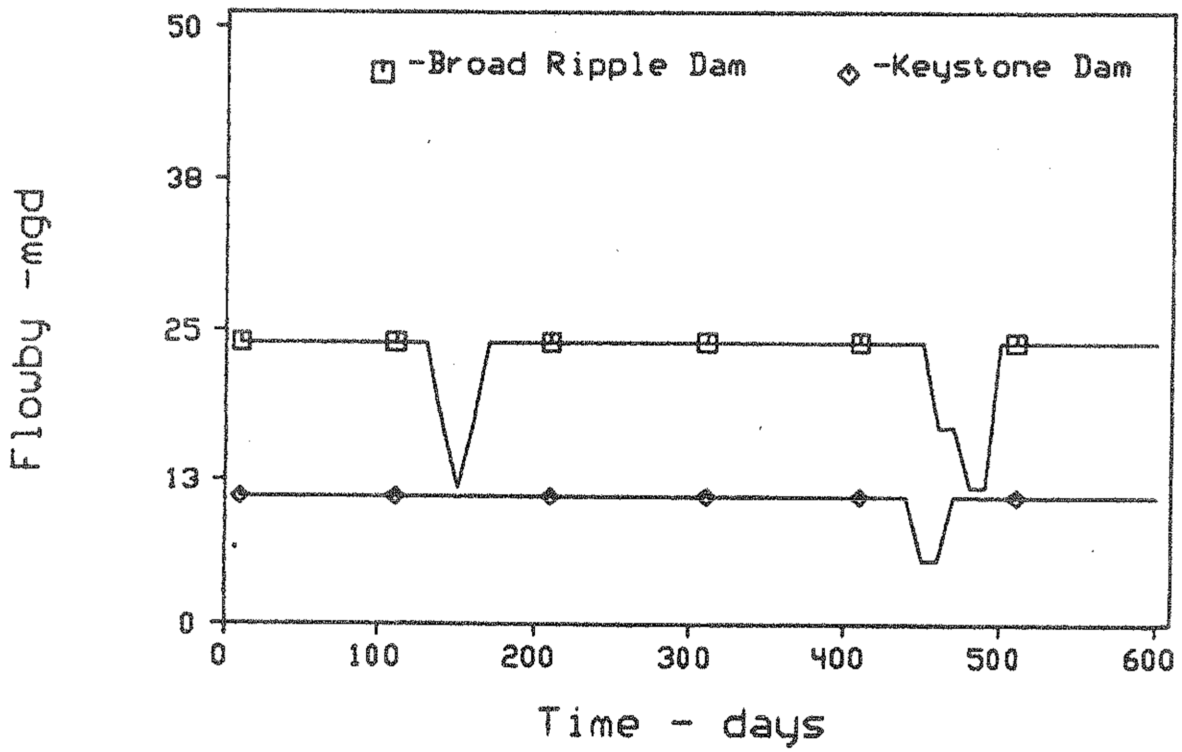


FIGURE 3. ENVIRONMENTAL FLOWBY: SCENARIO 1

TARGET FLOWBY AT BROAD RIPPLE DAM = 24 MGD
TARGET FLOWBY AT KEYSTONE DAM = 11 MGD

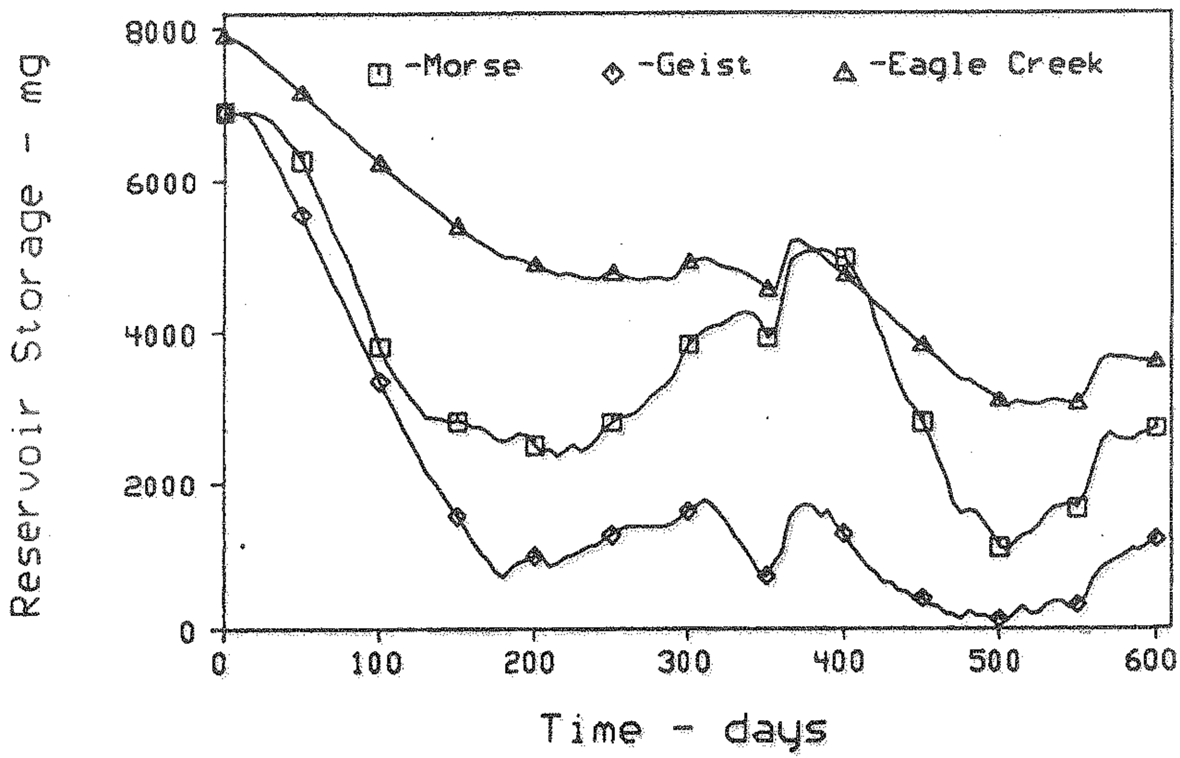


FIGURE 4. RESERVIOR STORAGE: SCENARIO 2

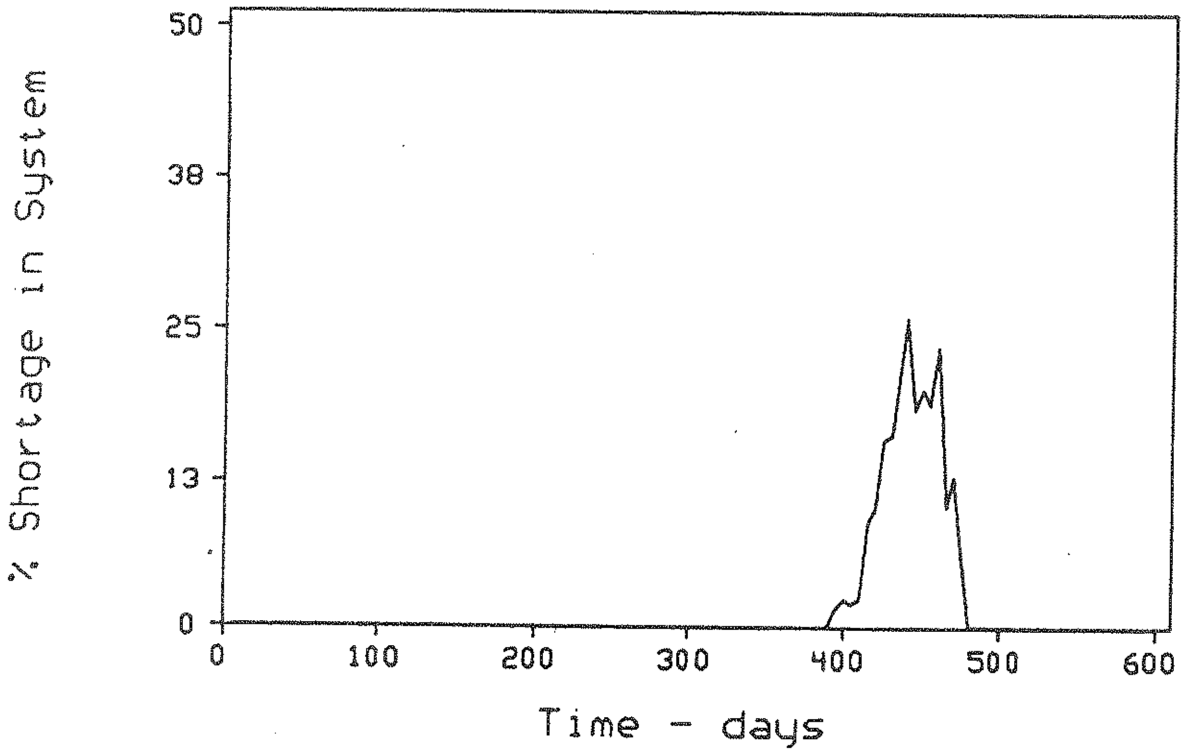


FIGURE 5. SHORTAGE IN SYSTEM: SCENARIO 2
(PERCENTAGE OF UNMET DEMAND, SYSTEM WIDE)

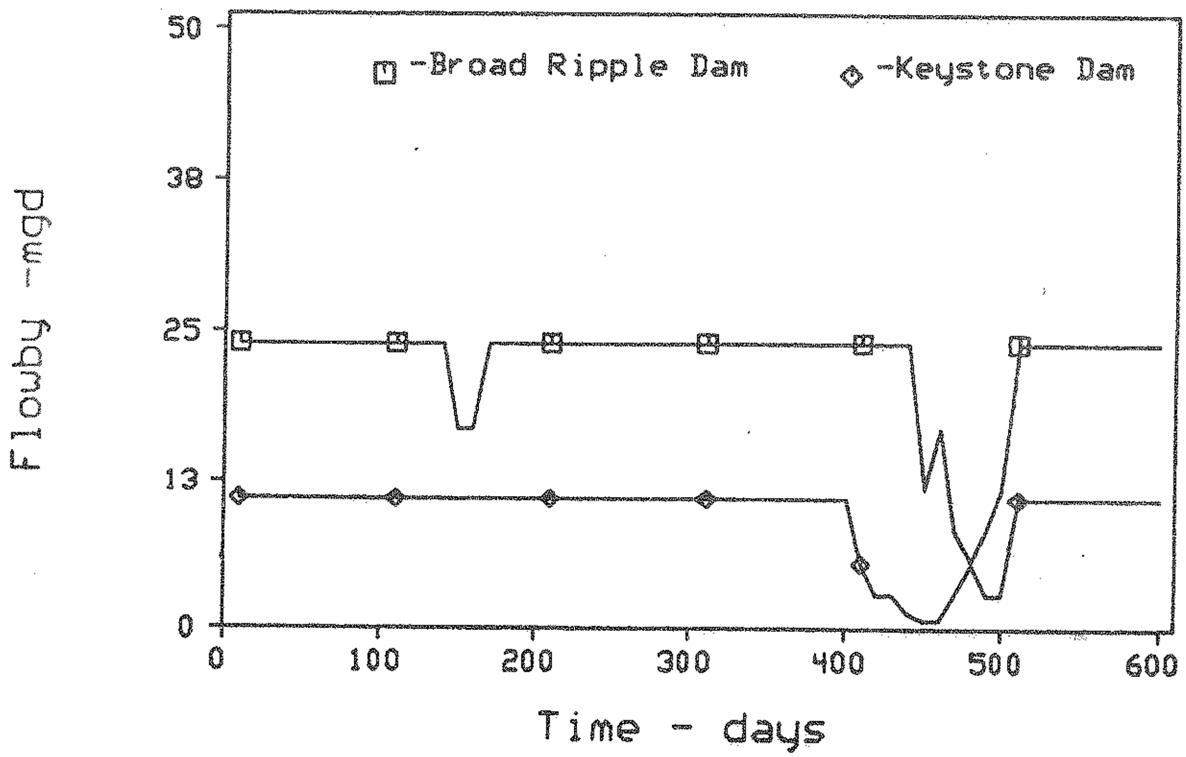


FIGURE 6. ENVIRONMENTAL FLOWBY: SCENARIO 2

TARGET FLOWBY AT BROAD RIPPLE DAM = 24 MGD
TARGET FLOWBY AT KEYSTONE DAM = 11 MGD

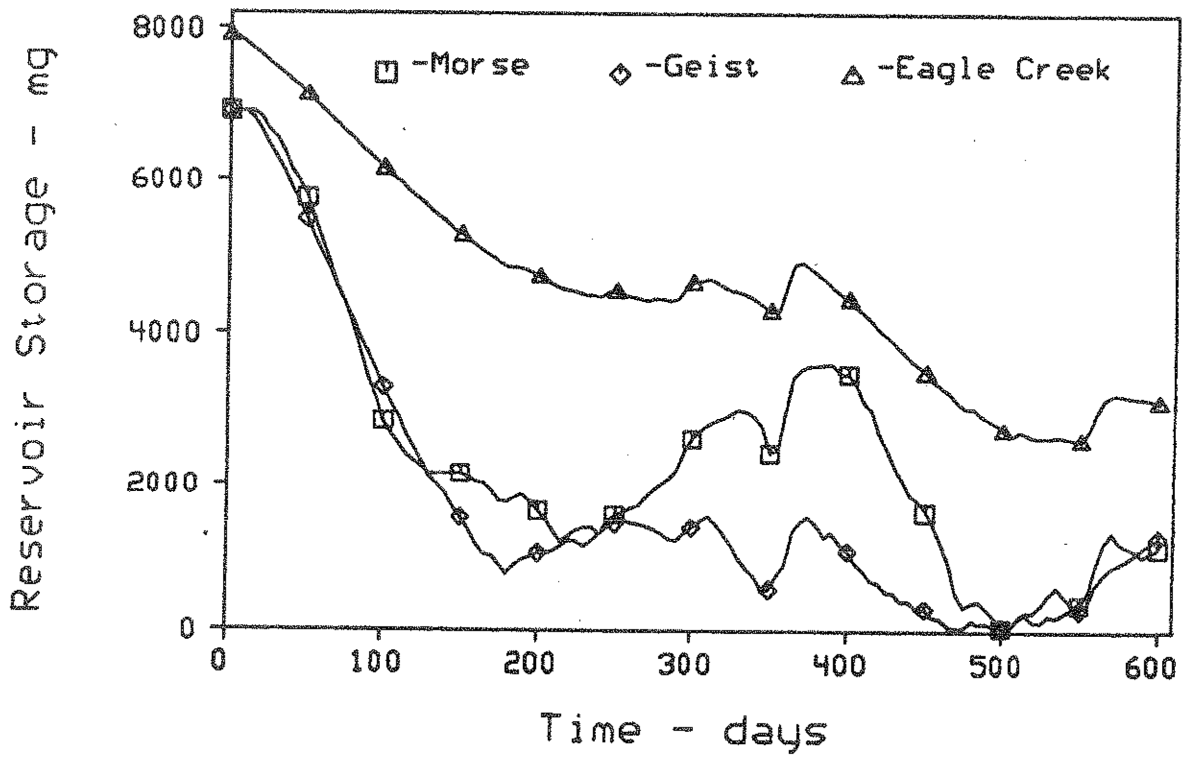


FIGURE 7. RESERVIOR STORAGE: SCENARIO 3

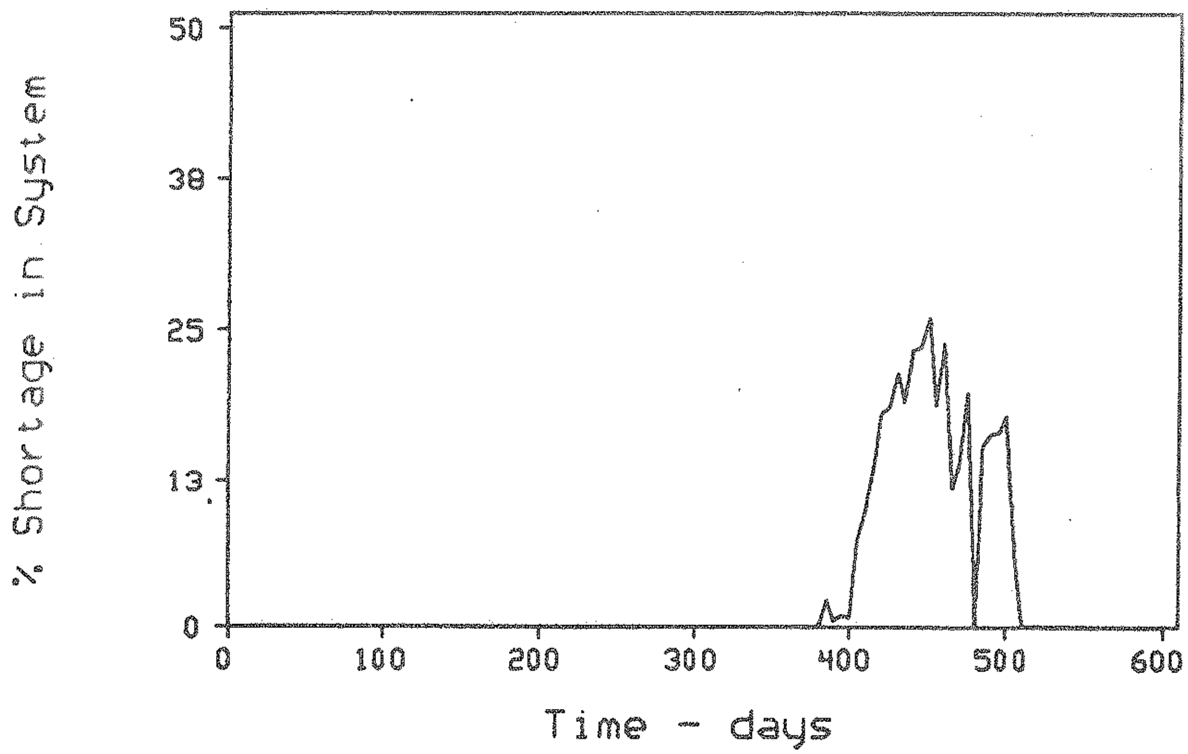


FIGURE 8. SHORTAGE IN SYSTEM: SCENARIO 3
(PERCENTAGE OF UNMET DEMAND, SYSTEM WIDE)

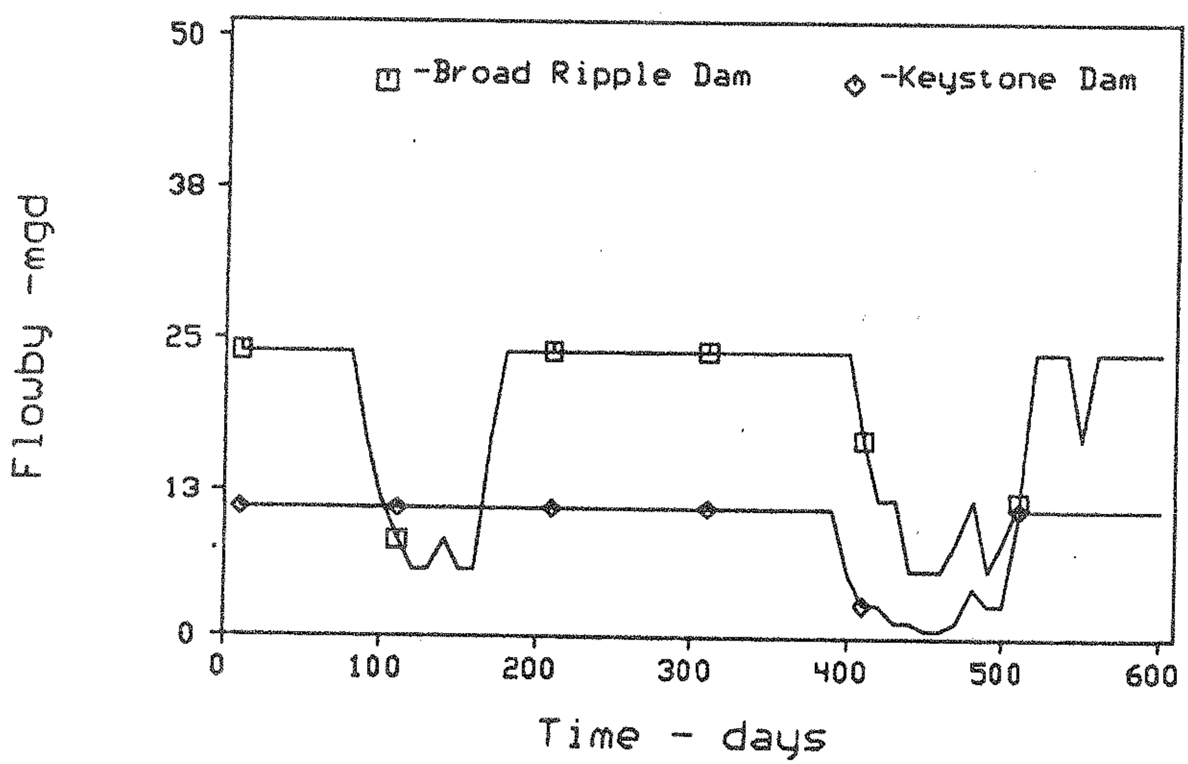


FIGURE 9. ENVIRONMENTAL FLOWBY: SCENARIO 3

TARGET FLOWBY AT BROAD RIPPLE DAM = 24 MGD
TARGET FLOWBY AT KEYSTONE DAM = 11 MGD

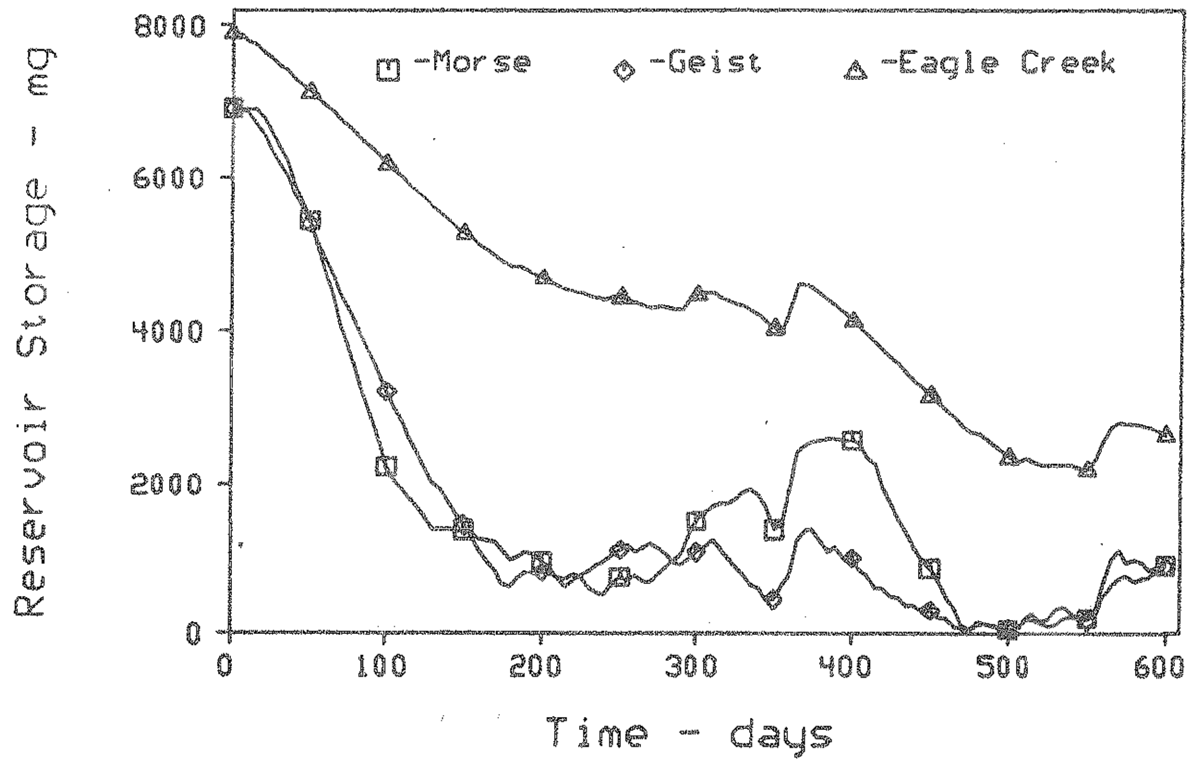


FIGURE 10. RESERVIOR STORAGE: SCENARIO 4

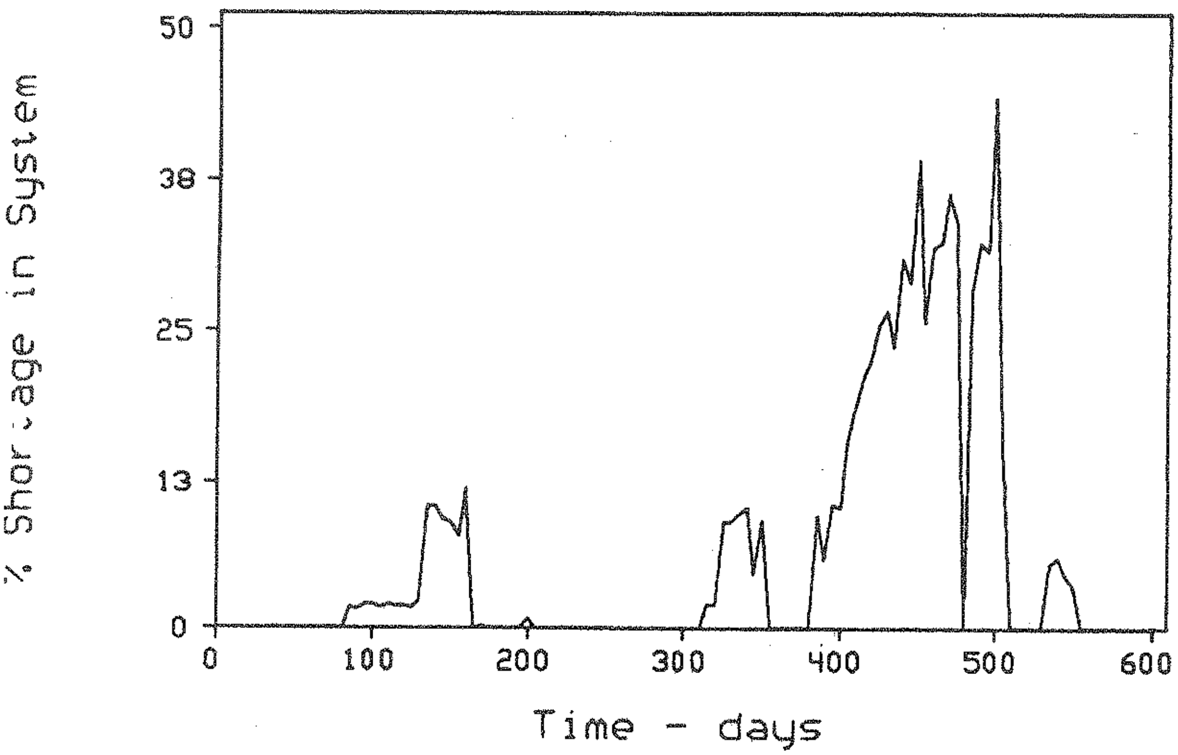


FIGURE 11. SHORTAGE IN SYSTEM: SCENARIO 4
(PERCENTAGE OF UNMET DEMAND, SYSTEM WIDE)

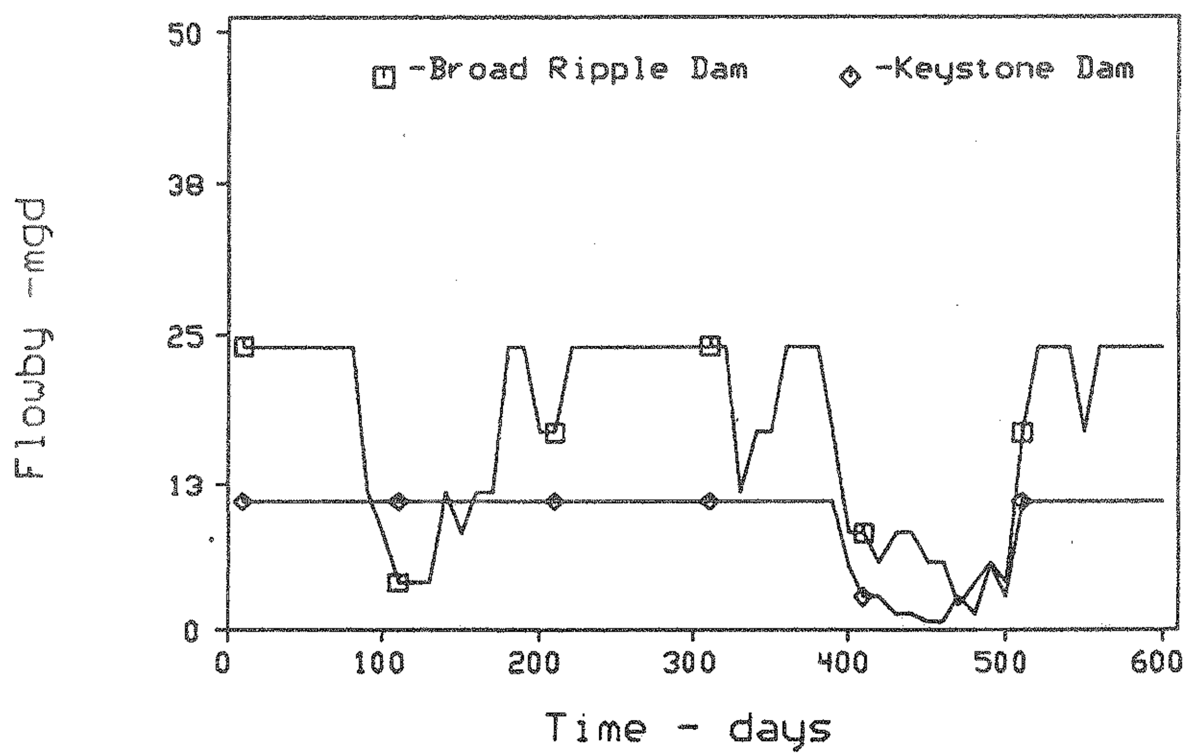


FIGURE 12. ENVIRONMENTAL FLOWBY: SCENARIO 4

TARGET FLOWBY AT BROAD RIPPLE DAM = 24 MGD
TARGET FLOWBY AT KEYSTONE DAM = 11 MGD

CHAPTER TWO

DROUGHT MANAGEMENT AND SIMULATION GAMING

Problems Facing the Decision Maker

What is a drought? How is it defined? As Rosenberg (1980) has pointed out: "There have been many - perhaps hundreds - of definitions of drought". Unlike floods, hurricanes, and other natural disasters which strike suddenly and unequivocally, the onset of a drought is often a slow and imperceptible process. A typical problem facing the decision maker is how to answer the question: "*When does a dry spell become a drought?*"

Drought severity is measured in terms of precipitation statistics, crop yields, streamflow levels and other indices. Different observers use different indices, and there may be little agreement between them as to when a drought exists. Water supply managers must frequently assume the responsibility of forecasting water supply, but because of the uncertainty associated with long range weather forecasts and the different indicators used to measure drought, there is often no consensus as to when to acknowledge or declare the existence of drought conditions. This lack of consensus may lead to a hesitancy in responding to the drought until it is well under way. The longer the delay, the more limited becomes the range of possible responses to the drought. Instead of asking for voluntary water consumption cutbacks, it may become necessary to impose mandatory restrictions on such practices as car washing or lawn watering.

As seen by the drought of Yakima in 1977, the dangers of hesitant response to a drought may be counterbalanced by the dangers of overreacting to it (Glantz,1982). In that excellent case study, forecasts of low water supply exposed decision makers to intense public criticism, if not legal action. Actions taken by citizens, farmers, and businesses in response to a drought forecast often involve economic sacrifice. The decision maker involved with these forecasts assumes considerable responsibility. If the forecasts later prove to be erroneous, many of these groups may seek to recover their costs and take legal proceedings against those responsible for the forecast. At a minimum, the decision maker may suffer a loss of credibility among those groups affected by the forecast. This is particularly important for private utilities interested in maintaining good relations with their customers.

Though it is difficult to define when a drought exists, it is often more difficult to determine what constitutes an appropriate response to the drought. The scarcity of water is not simply a natural resource problem, it is a political problem. Water supply decision makers make decisions in a sociopolitical environment. This fact is never more evident than when the decision makers must allocate a scarce resource among many different, often competing groups that may have different perceptions of where those resources should go. When water is plentiful, it seems that everyone is happy. When water becomes scarce and someone must make the distinction between "the haves" and "the have-nots", the decision maker is placed in an uncomfortable position. Almost every decision will raise questions or create opposition from at least one interest group. If the water supply managers are not adequately prepared to respond to these pressures, they may make decisions which further aggravate the situation and may increase the region's vulnerability to drought.

Determining the appropriate response to a drought involves many levels of decision making. Local, state, and federal government as well as private business may have some degree of authority in the planning and decision making process. There are frequently complex interrelationships between these levels of authority, and communication channels may not be well defined. Each level of authority will most likely have its own perception of the appropriate response to a drought. A response plan adopted by one agency may have multiple objectives which may not only conflict with each other, but might conflict with the objectives of other levels of authority. Some of these objectives may be well defined (reduce residential demand for water by 35%), while others may be non-quantitative and less well defined (impose rationing in an "equitable" fashion). Unless channels of communication and information flow are clearly established and understood by everyone involved in the decision process, poor coordination among various levels of authority may lead to drought programs being implemented too late to have an effect in mitigating drought damage.

Compounding the problem of how best to respond to drought is that there may be little or no prior experience with managing drought in the region. This is particularly true in Indianapolis, where the last major drought occurred almost 50 years ago. Most of the personnel who managed operations during that drought are no longer there. This suggests that those responsible for determining an appropriate drought response may be doing so for the first time. In such cases, there may be a tendency to underestimate the likelihood of experiencing a severe drought and the consequences associated with it. "Because water systems are engineered to withstand the worst drought on record, the adequacy of each system gradually becomes taken for granted and many policymakers assume that because the system hasn't failed, it won't fail." (Hoffman et al.,1979).

However, even if decision makers were experienced veterans of drought management, the fact that every drought occurs under different social, political and economic conditions implies that the response to drought will vary over time. The complex relationships between the various levels of authority may not lend themselves to the flexibility required to develop an appropriate response.

With little prior experience with drought, it is important that decision makers be prepared to depart from the "business as usual" attitude. Drought affects not only the physical supply of water in a region, but the social, political and economic structure of that region as well. It would be naive to assume that water supply decisions can be made in a political vacuum, and to believe that the physical water supply system can be manipulated to conserve water with no consideration of who will receive water and who will not.

Traditional water resource planning has relied primarily on models of a physical and economic systems of the region. Simulation and optimization techniques are tools frequently employed in the water resources planning community. Though standard quantitative approaches such as these have been enormously successful for identifying and selecting among the many alternatives available to the decision maker, such analyses frequently do not incorporate many of the social and political considerations which surround most water resource issues. As a result, many decisions are made without regard to the conflicts which may arise as the result of such decisions. This does not imply that decision makers are unaware of the consequences of their decisions, or that they are unwilling to account for them. Rather, given the complexity of most water resource issues, it is extremely difficult, if not impossible, to anticipate many of the potential consequences of a decision.

How will the public react to voluntary water cutbacks? To mandatory cutbacks? These questions cannot be answered properly without encouraging and incorporating some degree of public participation in the planning process. It is essential that the planning process incorporate as many social, political and economic concerns as possible, and not rely solely on physical models of the water system as determinants of appropriate policy. As Dregne (1980) describes it: "Preparation for responses to future droughts requires some idea about the form a future drought will take and the social context within which it will have its impact..." One methodology particularly suited to this type of planning is simulation gaming.

An Overview of Simulation Gaming

Simulation gaming is described by Wood (1973): "As a form of simulation model, gaming is similar to other simulations where the major purpose is to understand dynamic processes. While the approach emphasizes process, it attempts to comprehend human activities as the products of indeterministic forces which can lead to any one of a possible range of outcomes, and is in essence a probabilistic approach. Where gaming simulation differs from other methods is that it attempts to provide experience of a "real world" decision making situation, where goals have to be formulated, problems evaluated and judgement (sic) exercised".

Because of the complexity of human nature, it is difficult to describe the social and political system in terms of ordinary equations. Simulation gaming is designed to overcome this difficulty. As its name implies, simulation gaming comprises two basic components: gaming, involving interaction between human "players", and simulation, involving interactive computer facilities.

A drought simulation exercise might take the following form: The physical water system, climate and economy of a region would be simulated with the help of computer, while the social and political systems of that region would be represented by people assuming the roles of decision makers, special interest groups, and other "real life" positions. These people would be considered "players" in a game in which each player (or group of players) interacts with each other and with the computer, making decisions and evaluating those decisions on the basis of computer feedback and the reactions of other players.

The computer might be programmed to simulate the conditions of the water system under a variety of weather conditions. If it appeared that there was an impending drought, the group acting as water supply managers might try to institute a particular water conservation plan. By interacting with the computer and other players in the game, these officials would be able to see not only the physical results of implementing their policy, but the reactions of environmentalists, businesspersons, homeowners, and a variety of other special interest groups. Conflicts could be resolved by bargaining, lobbying and delegating authority. In this way, simulation gaming provides a mechanism to incorporate political and social considerations into the modeling process.

The Benefits of Simulation Gaming

Simulation gaming has two distinct advantages over traditional approaches to water resource planning and analysis. By actively involving decision makers and other groups into the planning process, simulation gaming approximates the "real world" conditions under which most decisions are made. This provides decision makers with a feel for the needs and reactions of the public and other parties. Simulation gaming is able to incorporate many of the non-quantitative, intangible elements of the decision environment into the planning process. Societal norms and values must be considered explicitly during the lobbying and bargaining process. Thus, simulation gaming has the potential to deal with complex societal issues in a more effective and enlightened manner than other analytical approaches.

Secondly, simulation gaming may provide enhanced communication between the parties involved in a water resource issue. Communication between groups, especially those in opposition, is essential if a drought contingency plan is to be effective. Though it tends to be more organized and well defined, communication within a group, for example, is just as important. The lobbying and bargaining phase of a drought simulation game is designed to illuminate key issues and areas of conflict, and to identify possible resolutions to these conflicts. This interaction between participants also encourages the exchange of ideas and information vital to any policy formulation process. The exchange process may identify or more clearly define both formal and informal channels of communication that could be used under actual drought conditions. Identifying and establishing channels of communication during the gaming exercise may promote the development of more effective drought management strategies.

For example, during the gaming exercise, decision makers must carefully define what conditions constitute a drought. By simulating hydrologic processes such as streamflow or precipitation over a given "dry" period, decision makers would be forced to make a distinction between what they may believe to be a dry spell or what may be a long term water shortage. Because consultation with other participants in the game is required, mutual agreement on such issues would be facilitated. Costly delays in implementing drought measures could be avoided if and when an actual drought occurs.

During a drought simulation gaming exercise, decision makers might be forced to allocate limited supplies of water among competing users. As representatives of various interest groups, some participants might be satisfied with the allocation process while others might not be satisfied. In a gaming environment, these participants would have the ability to express their concern or satisfaction with any action taken. On the basis of this feedback, the decision makers would be able to evaluate the societal effects of pursuing a particular policy. To insure cooperation and compliance with regulatory policies, it would be in the best interest of these decision makers to adopt policies which best address the concerns of the public. Through simulation gaming, decision makers should develop a better understanding of the needs of the community, the issues of potential conflict, and other areas which would require further attention if drought contingency plans are to be implemented in the most effective manner.

For decision makers who have not had much experience with drought management, simulation gaming would provide the opportunity to become familiar with the issues that they might expect to encounter under actual drought conditions. In Indianapolis, such an exercise would be one form of preparation for contending with a major drought.

By incorporating political and social concerns into the decision making process, simulation gaming provides a unique opportunity to explore the various social, as well as physical system consequences of pursuing a particular drought mitigation strategy. In this manner, the risk of adopting a strategy that would be impractical or inappropriate under actual drought conditions could be minimized.

The Benefits of Interactive Computer Simulation

A vital component of a drought simulation gaming exercise would be interactive simulation modeling. The computer would be one medium through which decision makers and other groups could analyze policies, store data, gather and exchange information. To facilitate efficient use of the computer, most of the simulation and other routines should have interactive capabilities. Interactive computer routines have several advantages over batch simulation processes.

1. The response time of the interactive system allows the decision maker to view the results of his management decision immediately, providing

instant feedback. By obtaining immediate feedback from an interactive simulation routine, drought managers can evaluate the results of a decision and propose modifications to a policy more effectively than with batch simulation processes (Palmer et al.,1979).

2. The decision maker can assume an active role not only in modifying management decisions based on this feedback, but in modifying and suggesting improvements for the computer model itself. Any model, being an abstraction of reality, is based on a set of simplifying assumptions. During the development of the simulation gaming exercise, various assumptions will be made in order to keep the exercise within manageable resource limits. Many of these assumptions become apparent when the decision maker is working interactively with a particular simulation routine. If the decision maker disagrees with any of these assumptions or the structure of the model, the interactive features allow for easy modification of the model.

3. Interactive features promote decision maker confidence in the basic structure of the model. Many of the physical and economic components of a water supply system can be modeled mathematically. When integrated into a computerized simulation routine, these models can identify how a water system might respond to a particular operating policy. However, unless the decision maker is familiar with the techniques employed in the simulation routine, she may not place much faith in the results. There may be assumptions built into the model of which the decision maker is unaware. If at any point the simulation yields results different from what was expected, the decision maker may discount all further information provided by the computer models. By interacting directly with the simulation routine, the structure of the model and the assumptions upon which it is based become more evident, and the decision maker is likely to develop greater confidence in both the results of the simulation and his comprehension of the technical aspects of the model (Palmer et al.,1979).

Review of Simulation Gaming Literature

Although still somewhat of a novel concept, simulation gaming is becoming accepted as a tool in the analysis of water resource systems, especially when decisions are likely to involve conflict. Wright and Howell (1975) described a simulation gaming analysis of a water resource development issue in New South Wales. The exercise, which employed a computer to simulate the physical system and human players as decision makers, was considered successful in identifying issues of conflict and their possible resolution. Furthermore, the simulation gaming approach was described as having the ability to "improve the skill of any protagonist in the real life conflict".

Wright (1978) discusses some of the factors which must be considered when designing and implementing a simulation gaming exercise. Foster (1980) discusses the role of simulation gaming in disaster planning, while Johnson and Whitehed (1973) elaborate on the value of simulation gaming in increasing the awareness of planners involved in water resource issues. One of the foremost authorities on gaming, Duke (1972) contends that gaming is an excellent medium for communicating ideas and information effectively.

Simulation gaming has long been applied successfully in the analysis of energy issues. Pennington et al. (1972) describe ERG, the Energy Resources Game. Unlike many of the earlier simulation games which did not utilize computers, ERG was developed as a technically sophisticated computer based game.

Numerous examples of games and their application to urban planning, disaster preparation and water resource issues are given in Volume 2, Number 2 of the Simulation Council's Proceedings Series (1976). One of the games discussed in the area of water resources is WALRUS I (Water And Land Resource Utilization Simulation). WALRUS I was developed at the Environmental Simulation Laboratory at the University of Michigan under a grant from the National Oceanic and Atmospheric Administration. Although WALRUS I was not used in conjunction with computer based simulation, the primary objective of the game was to facilitate communication between researchers involved with the University's Sea Grant program and the lay public.

One of the most recent and successful applications of water resource gaming occurred in 1982, when a one-day gaming exercise was conducted in Washington D.C.. The focus of the exercise was on reservoir operating policy in the Potomac River Basin. The water supply situation in and around the Washington D.C. area has been the source of considerable controversy for many years. Three agencies are responsible for supplying water, primarily from the Potomac river, to the 2.5 million residents of the region. Complicated relationships have evolved between these agencies as to how water should be allocated during periods of low flow in the Potomac. Traditionally, however, there have been many disputes and little cooperation between the agencies. As a result, what should have been an adequate supply of water to the region during dry periods has been allocated inefficiently, and the reliability of the regional water distribution scheme was questioned.

A group of researchers at The Johns Hopkins University began investigating the problem in 1977. This investigation included an extensive analysis of regional reservoir operation using mathematical programming models. The results of this research indicated that the yield of the regional water system could be improved by coordinating operations at various reservoirs located in the Potomac Basin. To achieve such cooperation, however, the various agencies responsible for the distribution system would have to cooperate with one another.

A second phase of the Hopkins study concentrated on the development of an interactive simulation model of the Potomac basin water system. This model, known as PRISM (Potomac River Interactive Simulation Model), was to be used as a research and learning tool for those groups involved in the water supply planning in the region. Though PRISM was extremely valuable as an aid in identifying alternative management strategies and enlightening many decision makers by itself, it was even more effective when incorporated into a simulation gaming exercise. The exercise brought together many of the key decision makers from each agency and other groups involved with water supply management. Interacting with PRISM and among each other, these groups gained insight into many of the conflicts involved in the water supply issue. As a result of the research at Hopkins, many of the obstacles which previously prevented efficient regional water management have been removed. The investigation approach was so successful that the project was considered for the 1983 Outstanding Engineering Achievement Award. The results are described in the three volume report published by the Water Resources Research Center at the University of Maryland (Palmer et al.,1979).

CHAPTER THREE

THE DESIGN OF A DROUGHT SIMULATION GAME

The success of a simulation gaming exercise depends on how well it is designed and implemented. Gathering and coordinating the data, manpower, equipment and facilities necessary to run an exercise requires extensive planning and preparation. Many details must be considered by the design group if the exercise is to proceed smoothly and produce meaningful results. If the game has not been well planned, the participants may downplay the importance of their roles and the decisions they make. The net result would be a decision making environment unlike the realistic conditions the exercise is supposed to simulate.

Though detailed planning of the gaming exercise is vital to its success, designers must be careful not to "*overplan*". Some degree of spontaneity and freedom is desirable, because it is more representative of real-world conditions, and may stimulate creative approaches toward problem solving. The ideal gaming model should be structured enough to insure that an exercise would proceed smoothly and toward a certain objective, but flexible enough to prevent it from becoming dull, predictable, and unrewarding. It is difficult to achieve this proper balance.

As with any game, there are tradeoffs between playability and realism. It would not be possible or practical to incorporate every feature of the real-world decision making environment into the game. However, the designer cannot simplify the game for the sake of playability to the extent that the exercise is no longer a good representation of reality.

Building the gaming exercise requires an understanding of the environment it seeks to simulate. The designers must be aware of the complex relationships between the systems and groups involved. They must have a good grasp of the issues. They must know what assumptions can be made and which variables should be included and which should not. In fact, there is so much involved with designing a good gaming exercise that it may prove just as valuable as playing it.

Like the gaming exercise itself, the design process of a game should not be rigidly structured, but should be a dynamic process which stimulates creativity and encourages innovative thinking. Without some framework for design, however, it may be difficult to determine how to coordinate the efforts of the design team. The following discussion should provide some guidelines concerning the general design process. Details are not provided, because each exercise represents an attempt to analyze a unique problem, and has varying design requirements.

The design process has been represented in the form of a critical path network . This network graphically depicts the relationships between one phase of the design process and another. Figure 13 illustrates the major steps of the design process, while Figure 14, and Table 3 illustrate the process in detail. The steps outlined in Table 3 are described in the following pages.

FIGURE 13

SIMULATION GAMING EXERCISE

BASIC DESIGN CONSIDERATIONS

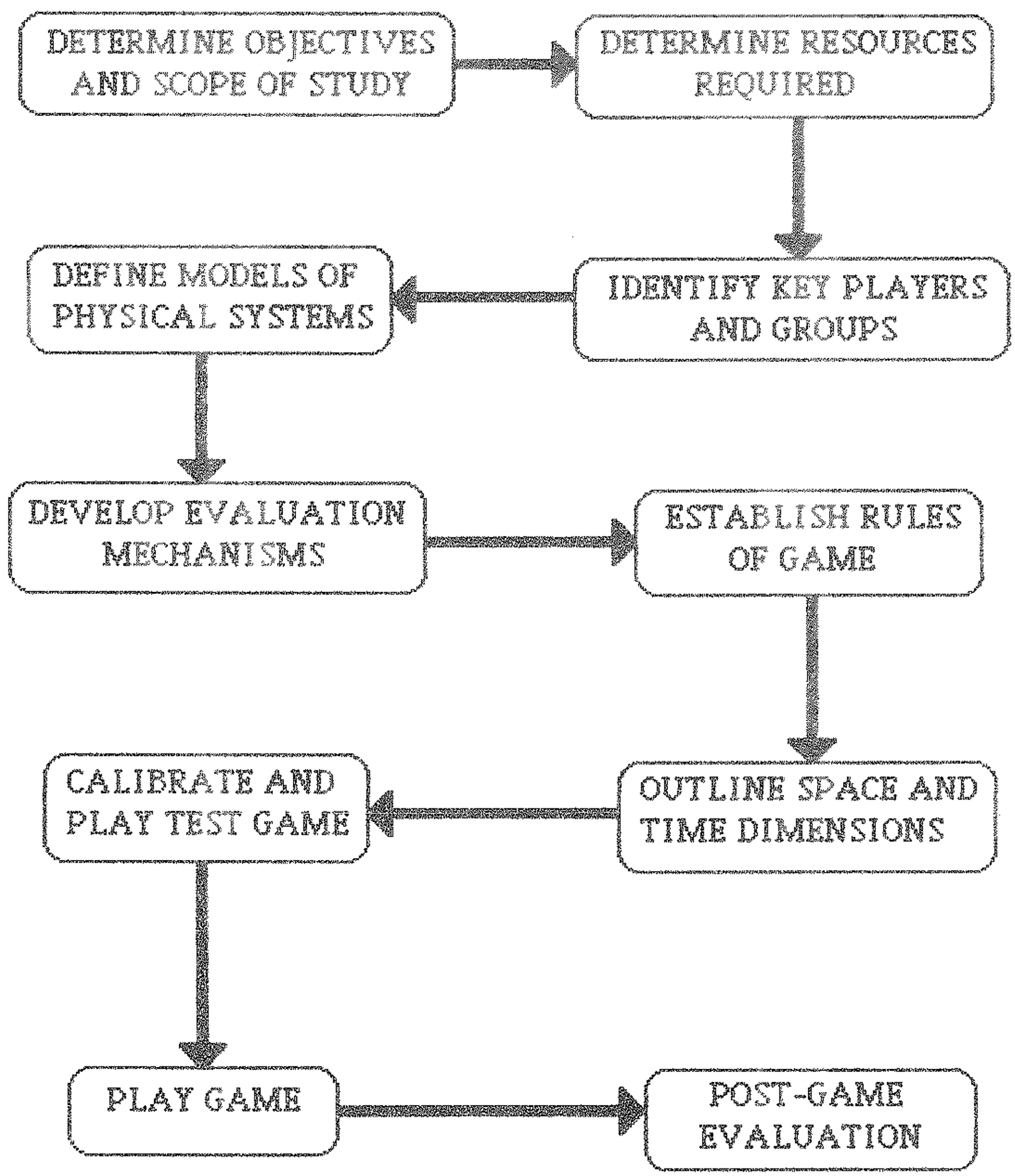


TABLE 3: STEPS IN THE DESIGN PROCESS

Definition Phase

1. Define issues and objectives
2. Define geographical boundaries
3. Define duration of actual game
4. Define duration of event to be modeled
5. Define basic game structure
6. Estimate money, manpower, equipment, time
7. Identify key players and groups
8. Make initial proposals to groups
9. Obtain feedback from groups
10. Modify proposed game structure

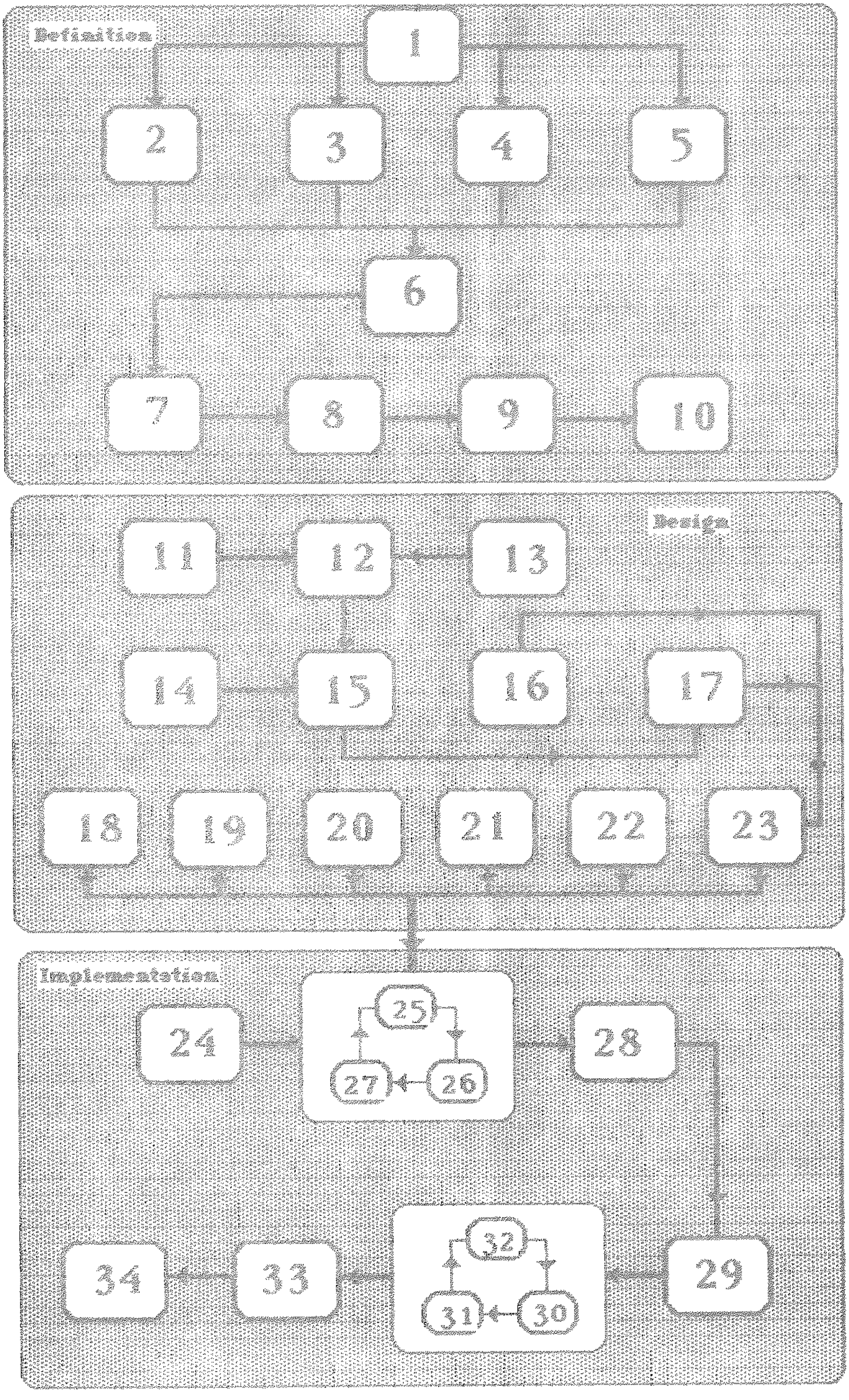
Design Phase

11. Identify physical systems to be modeled on computer
12. Determine hardware and software specifications
13. Determine input and output requirements
14. Collect data for models
15. Develop and code models
16. Design interactive computer components
17. Validate physical system models
18. Identify external constraints on actions of roles
19. Develop means of evaluating game effectiveness
20. Establish performance criteria for evaluating achievement
21. Define sequence of events during game
22. Determine rules under which game is to be played
23. Validate integrated computer package

Implementation Phase

24\. Determine date, time, location for game
25 - 27. Play test game
25\. Plan, bargain, identify alternatives ...
26\. Select alternatives
27\. Evaluate outcome(s)
28\. Obtain feedback from participants
29\. Make modifications to game design
30 - 32. Play actual game (steps 25 - 27)
33\. Perform post-game evaluation
34\. Compile results of exercise

FIGURE 14. CRITICAL PATH NETWORK FOR GAMING



1. Define Issues and Objectives

This is perhaps the most important phase of the design process. Why is the simulation being conducted? Unless the objectives and rationale for conducting a gaming exercise are clearly defined, proceeding beyond the initial step would be fruitless. In the case of drought management, should the exercise be used as a training program intended to develop and refine certain skills? Or should the game be used as medium for exploring issues and developing better relationships and communication channels between interested parties? Should it be a public relations tool, designed to acquaint people with the complexities of the water resource decision making environment? Or should it be a research tool, designed to investigate the effects of alternative drought management policies. Should the exercise be oriented toward problem solving, or should it emphasize competition. For example, should there be a distinct "winner" at the conclusion of the exercise, or should the ultimate objective be mutual cooperation between all parties, with everyone a winner?

Though these questions are "fuzzy", and do not address mutually exclusive objectives, it is important that the gaming exercise have a well defined purpose. Well defined objectives provide a strong focus for the development of other stages of the exercise.

2. Define the Geographical Boundaries

It is necessary to define the region being investigated so that the exercise is conducted on a scale commensurate with available time and resources. Usually these boundaries are determined by political considerations as well as practical limitations. It would not make sense, for instance, for the city of Indianapolis to conduct a drought management exercise which encompassed the state of Indiana. Should it be concentrated at the county level? At the city level? The watershed, or perhaps the communities or districts served by a water utility, may be well-defined. However the boundaries are distinguished, the region should be large enough to ensure a comprehensive analysis of the problem, but small enough to provide a focus on the details of an issue.

3. Define Duration of Actual Game

Because many of the people who would participate in the drought management gaming would be either public officials, or key decision makers, they might be unable or unwilling to devote much time to the exercise. Not only would people be unwilling to participate in a lengthy game, but player appreciation and enthusiasm for it may begin to wane after several days. If a game is to be played in rounds, approximately how long should each round be? If the game is to take more than one day, should it be played on consecutive days, or should it be played one day per week (or month) for several weeks? Depending upon the complexity of the game and the type of issues involved, most of the objectives of a game can be achieved within a short time frame, and the only reasons for continuing beyond that period may be to satisfy enthusiastic participants.

4. Define Duration of Event to be Modeled

In any simulation gaming exercise, events and decisions which would take place over a long period of time are compressed into a very short time frame. Indeed, one of the advantages of the simulation gaming approach is the ability to view the results of a decision almost immediately. The game must be designed to cover a period of real-world time which would be long enough to show the effects of decisions, and yet short enough to ensure the game environment still represents known or anticipated real world conditions. It would be just as senseless to design a game which covered two days of real-world time as it would be to design a game which covered 1000 years.

In a drought management exercise, it would be most realistic if the exact duration of a drought was an unknown, random variable. It would be desirable, however, to define a range of possible durations for the drought. The game may cover several months or several years, but it should represent realistic ranges. Such ranges can be determined from an analysis of historical water supply data in a region.

5. Define Basic Game Structure

Game designers must have a rough layout of the basic game structure at the outset of the design process. Typical questions which should receive initial consideration at this stage include the following:

How many participants should be involved?
What role should computers play?
How will participants be allowed to communicate with one another?
Will the game take place in one central location?
Who will be the game director?

What support material should be provided during the game?
What will be the approximate order of events in the game?
Should there be fictional elements in the game?
Should participants exchange roles during the game?

These questions do not have to be answered in great detail at this stage. They are intended only to provide designers with a feel for the overall structure of the exercise.

6. Estimate Money, Manpower, Equipment, Time

Because simulation gaming is a unique, flexible, and realistic problem solving approach, simulation gaming can be very resource intensive. Once the design group has decided upon the basic objectives and format of the game, they should prepare a preliminary estimate of the resources required to conduct such an exercise. This includes all resources required to support the design phase of the gaming exercise as well as its implementation and operation. It depends not only on the cost of employing designers and on the cost of operating computers, but on the cost of employing "players", public officials and others who might take time off from their official duties to participate in the game. Such estimates should be conducted or revised as necessary throughout the duration of the project.

7. Identify Key Participants and Groups

The primary objective of a drought management gaming exercise would be to improve real-world decision making under crisis conditions. The degree to which simulation gaming approximates real-world conditions is dependent upon the participants involved and the roles they assume. All interest groups, government agencies, public and private officials and other parties which have some stake or interest in the issue of drought management should be identified by the design group. These would be the groups who would assume a role in the simulation gaming identical to that which they assume in the real world. A variety of interests are necessary to provide the interaction between groups that is the driving force behind any simulation gaming. In Indianapolis, for example, environmental groups or the Fish and Wildlife Service might express concern over reductions in environmental flowby (releases made from reservoirs to satisfy downstream low flow requirements). The water company might try to convince these groups that such a reduction would be in everyone's best interest. It is important not to overlook many groups. Some groups may have a stake in the drought issue that may not be obvious at first.

8. Make Initial Proposals to Groups

Once the groups have been identified, effort should be directed at contacting them and informing them of the proposed exercise. A leaflet describing the idea might be useful as a "marketing" device. Special emphasis should be placed on the value of using a simulation gaming approach in the analysis of complex societal issues such as drought management. Representatives of as many groups as can be accommodated in the exercise should be encouraged to participate and become directly involved in both the design phase and actual exercise.

9. Obtain Feedback from Groups
10. Modify Proposed Game Structure

If simulation gaming is to be successful, the participants must believe that it is a legitimate and worthwhile use of their time. For this reason, feedback from the groups that might participate in the exercise is a valuable resource. Each group will have its own perception of the problem, and each will likely have suggestions to improve what they see as design flaws or oversights. By compiling feedback from all the groups regarding the proposed exercise, game designers should be able to evaluate weaknesses in the original game proposal and, presumably, modify the basic structure of the exercise to account for the concerns of the various groups. This should be a dynamic process which continues to take place throughout the development of the simulation gaming project.

11. Identify Physical Systems to be Modeled on a Computer

As described in Chapter Two, computer models are usually restricted to those systems which can be quantified and which have well defined relationships between variables. As a result, computer models have been restricted to the description of physical and economic systems. The political and social aspects have been frequently ignored in traditional water resource modeling approaches, except of course, in simulation gaming. However, the computer in simulation gaming is still devoted primarily to the simulation of physical and economic systems. It is necessary, therefore, to identify, in detail, the physical and economic systems which should be incorporated into a computer model. In drought simulation, this includes, at a minimum, mathematical models of the physical water supply and distribution system of a region, and perhaps a synthetic streamflow generator which would be capable of simulating realistic hydrologic drought conditions. These models should be developed with the capability of allowing an individual assuming the role of a reservoir operator to observe the system-wide effects of releasing a volume of water from a reservoir at any particular moment in time. Additional models of appropriate physical or economic systems should be developed as required by the objectives and scope of the drought management exercise.

12. Determine Hardware and Software Specifications

Once the design group has made an assessment of the computer models that are required for the gaming exercise, they should select appropriate computer hardware and software to meet these requirements. Should a microcomputer be used? How much memory will be needed? How many disk drives? What kind of operating system is appropriate? What programming language is required? Is application software available which could be integrated into the models? Are printing facilities necessary? Should remote terminals be used? These are just a few of the questions which might be addressed when considering hardware and software. The computer will play a major role in the simulation game, and the extent to which it enhances or detracts from the exercise will depend upon the proper selection of these components.

13. Determine Input and Output Requirements

The game designers must consider what type of information will be required as input to the simulation routines, and what information should be stored within the program. For example, should the computer simulation offer the choice of selecting limits on both the duration and severity of a drought? Or should such information be fixed and "built into" the routine. The answers to such questions depend upon the specific objectives of the simulation game. If the exercise is to be used repetitiously, as in a learning exercise, then it may be desirable to allow many of the simulation parameters to be reset at the outset of each game. If the exercise is intended for a one-time demonstration, such a capability may be unnecessary as well as undesirable.

Similarly, consideration must be given to the type of information which should be provided in the output from simulation programs and other routines. Within a drought management exercise, it may be preferable to provide a concise summary of the state of the water system at points in time, rather than present "raw" statistics and data for review. The designers may wish to allow for a choice of the desired output format. Should output be provided at specified intervals, only upon request, or both? The form of the summary is important also. Tables allow for the rapid review of output, but graphs might communicate certain information more effectively.

14. Collect Data for Models
15. Develop and Code Models

To describe the physical water system in a computer model, information must be gathered pertaining to the capacities of water supply lines, reservoir, well, and pump capacities, consumption and demand statistics. Data collection should be as thorough as possible, because the simulation model will only be as accurate as the data from which it is constructed. Once the necessary information has been gathered, the raw data can be transformed into mathematical models of the real-world system. These models will represent the behavior of the physical water system as it responds to the various operating policies formulated and implemented during the course of a gaming exercise.

16. Design Interactive Computer Features

One of the main features of the simulation gaming approach is the ability of the participants to interact directly with the simulation models. The advantages of interactive simulation are discussed in Chapter Two. The design group must determine the format through which the computer will interact with the human users. This will depend upon the intended use of the computer in the simulation exercise. If the computer will be used throughout the exercise by a group familiar with its operation, then it will not be necessary to employ extensive on-line help facilities. However, if many people will be using the computer who are unfamiliar with its operation, then it is important that the simulation routine be "user friendly", and not require so much education in its use that it detracts from the rest of the gaming exercise.

17. Validate System Models

Once the simulation models representing the physical systems have been developed and implemented on the computer, it is important to verify that these models are an adequate and accurate representation of the real-world system. A set of test conditions and inputs which yield a known outcome should be used to ensure that the model produces the results which are expected. Testing should be extensive, because the credibility of the entire exercise could be damaged if a flaw is discovered in the model during the course of an actual simulation game.

18. Identify External Constraints on Actions and Roles

To maintain realism in the simulation game, it is necessary to identify and incorporate into the exercise most of the legal relationships, lines of authority, and decision making powers within and between groups that exist in the real-world. In other words, it is necessary to duplicate the political and institutional structure of the real-world system. This procedure is necessary to ensure that the various participants in the exercise make their decisions in a real-world framework. For example, a reservoir operator would not have the authority to impose restrictions on residential water use. Likewise, elected officials would not dictate how much water should be released from the reservoir, not because they lack the authority, but because they are typically not involved in such decisions. Not only do such constraints maintain realism, but they facilitate understanding of the game structure because participants will be assuming roles and responsibilities with which they are familiar.

The process of identifying external constraints is challenging and represents what might be the most difficult phase of the design process. Sorting through the political and institutional relationships is an enormous task because of the many levels of government and private sector groups that would be involved in the drought issue. Because it would be impractical to incorporate all of these constraints, a subset must be chosen which would best represent the major elements of the political and institutional infrastructure.

It should be emphasized that although replicating the political and institutional framework is important at the beginning of the game, it may be desirable to relax some of these constraints later in the game to allow for experimentation with innovative approaches to problem solving.

19. Develop Means of Evaluating Game Effectiveness

The most valuable aspect of using a simulation gaming approach to drought management is its potential for improving the decision making environment. The structure of the exercise encourages the development of cooperative working relationships between participants, and the exploration of new planning and management alternatives. Many of these benefits will be intangible and hard to define, while others may be distinct and easily measured. Nonetheless, unless some evaluation mechanism is developed to measure the effectiveness of gaming in improving decision making, it will be difficult to describe the value of such an approach to those who did not participate in the exercise. Furthermore, such an evaluation mechanism will provide a basis for comparison if the exercise is later modified or used under different conditions. Developing such a mechanism, however, is difficult at best.

How does one define the quality of a decision? Should it be based on the results of the decision? If so, is it possible to evaluate subsequent decisions using the same metric? Inevitably, definitions of the quality of a decision rely on relative, subjective judgments. What one group considers an improvement in the decision making process, another group make consider a step backward.

Although every participant may agree as to the value of a simulation game, it is hard to quantify these "feelings". Nonetheless, some attempt should be made at measuring the value of an exercise. This may involve developing pre-game and post-game questionnaires designed to elicit the participants' view of the state of the decision making environment before and after the game. Distribution of the questionnaire after the game should be timed to allow any real-world benefits of the game to become apparent and established.

20. Establish Performance Criteria for Evaluating Achievement

As distinguished from evaluating the effectiveness of the *game* in improving decision making, it is important to provide some means of measuring the effectiveness of making a particular decision within the context of the game. If the format of the simulation game emphasizes competition between participants, then some criteria must be established to distinguish between the winners and the losers. If the format of the exercise emphasizes cooperation between groups, with no winner or loser, then some criteria must be developed to measure the degree of cooperation achieved at the conclusion of the exercise.

How should a public interest group register their level of satisfaction or dissatisfaction with a particular decision? Should an exchange mechanism, such as "happiness chips" (Mar and Wright,1978) or "popularity tokens" be considered an effective medium of expressing the overall level of satisfaction with a given state of affairs within the community? Feedback must be provided so that a participant can get an idea of how a particular decision influences other participants. The mechanism must allow for participants to measure the success of different strategies.

21. Define Sequence of Events During Game

To maintain order and facilitate play, a simulation game is usually divided into several distinct stages. For example, there may be a bargaining phase where participants attempt to reconcile disagreements, introduce new ideas or gain influence and power. Likewise, there might be a review stage during which the results of decisions are evaluated, a planning stage in which new drought policies are formulated, and an implementation phase during which decisions are enacted and their effects recorded.

Once the phases necessary to conduct an exercise have been identified and defined, the sequence in which events should occur during the game may become apparent. A review period would logically follow an implementation stage. A bargaining period might precede the implementation phase, or follow the planning period. Whatever sequence is adopted, it should facilitate the smooth operation of the game and reinforce the learning experience of the participants.

22. Determine the Rules Under Which the Game is to be Played.

As distinguished from the rules or constraints under which the real world operates, the rules of a game are required to ensure that the exercise proceeds in an orderly fashion and also maintains realism. If the entire simulation game must be completed within a certain time frame, for example, it would be desirable to enforce time limits on the duration of each phase of the exercise. If participants become engrossed in fervent lobbying and negotiations with each other, there may be little time left for other stages of the game. Furthermore, time limits may force decision makers to act spontaneously when confronted with a crisis situation, much as they would be forced to do under real-world conditions. Various other rules can be adopted as required. If contracts between parties to an agreement would be required in the real world, then contracts could be required as evidence of such an agreement in the game.

23. Validate Integrated Computer Package

Once the models of the physical system have been validated and the interactive components of the simulation have been developed, it is necessary to combine the two packages into an integrated computer package. The interface between the input routines and the analytical models should be tested extensively to ensure that the information transfer is accurate and meets the requirements of the exercise. Error checking routines should be incorporated into the interactive portion of the simulation package. The entire computer based segment of the exercise should be evaluated by the design team to determine if further refinements are required.

24. Determine Date, Time, Location for Game

Depending upon the structure of the simulation game, it will be necessary to find a date, time and location for the exercise which will be suitable to all groups who will participate. Reaching a mutually agreeable arrangement between all of the parties involved may be difficult.

25 - 27. Play Test Game
28. Obtain Feedback from Participants
29. Modify Game Design

If time permits, it would be instructive to play a test game. Such a test would allow game developers to evaluate the strengths and weaknesses of the original game design. The participants (not necessarily those who will be involved with the actual exercise) should also evaluate the game experience. The two groups should decide upon necessary modifications and play subsequent test games, if possible, before the simulation game is presented in final form on the date of the actual exercise.

30 - 32. Play the Game

With proper planning and development, the gaming exercise should be ready for implementation at this stage. Wright and Howell (1975) provide a "feel" for the events involved in an actual simulation game in their description of WRAG, the Water Resource Allocation Game, which was developed in the late 1970's to analyze water resource issues in Hunter Valley, a coastal basin region of New South Wales. The reader is referred to the authors' paper for a thorough description of the actual exercise.

33. Perform Post-Game Evaluation
34. Compile Results of Exercise

As described earlier, some form of evaluation mechanism should be established to measure the effectiveness of the game in achieving the various objectives for which it was designed. Five specific areas which should be evaluated are (modified from Pennington et al. (1972)):

- Knowledge of facts, especially technical facts related to drought management, systems design, costs, locational considerations and environmental impacts.
- Comprehension of social, political, economic and technical processes and interactions.
- The ability to formulate effective strategies that might be used to resolve drought issues and problems.
- The ability to react quickly and effectively in crisis situations.
- Attitudes of participants with respect to , for example, perception of other "roles" in society and concern for environmental issues.

The results of the exercise should be compiled in a post-game report which could be used as a reference for future developments in the application of simulation gaming to drought management.

CHAPTER FOUR

SUMMARY

Although the Indianapolis metropolitan area has not experienced a shortage in public water supply in recent years, analyses of regional streamflow records indicate that there is a better than 1% chance that a drought as severe as the drought of 1940 - 1941 could begin in any given year. Simulation studies of the water supply system indicate that such a drought, or one of greater severity, could significantly decrease reservoir levels and lead to water shortages throughout the region. In particular, if the average daily demand for water was 120 MGD and the 200 year drought were to occur, it is possible that system-wide shortages could be as high as 50%, even though environmental flowby at two of the dams would be drastically reduced.

To date, the careful management of water resources coupled with an adequate supply of water in the Indianapolis area have forestalled major water supply problems. If a severe drought were to occur in the future, however, local water supply decision makers would have to deal with problems and issues with which they may have little experience. Unless these decision makers are adequately prepared to anticipate and respond to these problems, inappropriate policies and management of the water system could exacerbate the drought situation.

Simulation gaming is one method which could be used to prepare decision makers for a drought. Because not only the physical water system, but also the political and institutional systems which are involved with water resource issues are incorporated in a simulation gaming exercise, it is a valuable tool for exploring the societal implications of pursuing a particular drought mitigation strategy. Through simulation gaming, decision makers should develop a better understanding of the needs of the community, the issues of potential conflict, and other areas which would require further attention if drought contingency plans are to be implemented in the most effective manner.

In order for a simulation game to be an effective tool in drought management planning, the exercise must be carefully designed. Though a particular exercise will have unique requirements, there are several fundamental steps in the design process which should be common to the development of any drought simulation game. Some of the considerations involved with these steps in the design process are given in Chapter Three.

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