DAM: A Computer-Implemented Water Resource Teaching Game

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Citation: Titlow, Franklin B., and Robert T. Lackey. 1974. DAM: a computer-implemented water resource teaching game. *Transactions of the American Fisheries Society.* 103(3): 601-609.

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ABSTRACT

Development and use of DAM, a computer-implemented learning exercise designed to illustrate management of a large multiple-use reservoir system, is described. Five management roles are available to students using DAM: (1) a regional planning commissioner; (2) a fisheries manager; (3) a power company executive; (4) a recreation specialist; and (5) a city mayor. We found that allowing students to switch roles emphasized inherent management conflicts and increased total system appreciation. There is no "best" management scheme for DAM. In practice, students manage until they can agree on and defend a particular strategy. The specific goal of DAM is to provide students with an understanding of the principles and problems of managing a multiple-use resource. Response from students indicates this goal was achieved. DAM is currently played by students' keypunching decisions on computer cards and submitting these to the computer center. An improvement would be to place DAM on a permanent file for access by remote typewriter terminal.

Field management experience is a valuable commodity to practicing natural resource managers. A resource manager's decision-making adeptness usually increases with the amount of field management experience that he possesses. Resource agencies employing managers seek those with experience, those who have made many decisions, and those who have had time to receive useful feedback or observe responses to their decisions. Methods of providing the equivalent of management experience are vital to training natural resource management personnel. Because of time and financial constraints placed on management training programs, as well as general public unwillingness to utilize natural resource systems as experimental case studies, efforts to provide long-term field management experience to natural resource management trainees are rare.

Using computer-implemented learning exercises in natural resource education can provide management experience to students in the classroom. Use of learning exercises does not totally substitute for actual field management experience, but does allow students to evaluate response of a natural resource system to *their* management decisions. This contrasts with other teaching methods, such as case studies, during which students can only evaluate management strategies applied by other people.

Computer-implemented learning exercises are models of realistic natural resource management situations. When using a learning exercise, students make management decisions for a particular resource system, analyze the impact of their decisions on the system, and revise their management strategies accordingly. Computer-implementation minimizes the time lag between making decisions and evaluating results, thus allowing management efforts to continue until a satisfactory strategy has been attained.

There are two methods for using computer-implemented learning exercises: direct card deck manipulation and remote terminal operation. Generally, deck manipulation requires some familiarity with computer facilities since each user must keypunch his management decisions on data cards and submit these cards to the computer center. There is a delay of at least several hours before management output is ready. With a remote terminal, each student simply enters numbers representing his management decisions directly into the main computer system.

There are two general classes of computer-implemented learning exercises: large, interactive system exercises and specific subsystem exercises emphasizing management of a par-

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ticular system component while involving relatively few system interactions. Large system exercises stress interrelationships between components, as in management of estuaries, reservoirs, or river drainages, while specific subsystem exercises usually illustrate particular management principles such as the stock-recruitment relationship in salmon fisheries management. Large system exercises are being received with increasing interest. The idea of allowing students to actively manage resource systems in which economic and political factors are considered, as well as biological factors, is especially appealing (Paulik 1969).

There have been extensive applications of simulation modeling and computer-implemented learning exercises in manufacturing, marketing, corporate structure, transportation, communications, medicine, facility planning, artificial intelligence, and in a large variety of military and space fields (Paulik 1969). However, learning exercises have been used sparingly in natural resource education. There is a dearth of published material concerning previously developed learning exercises in natural resources, in part because simulation models are difficult to express in the usual publication format (Garfinkel 1968).

Examples of current learning exercises in natural resources are TROUT, SCRAP, and FARMS. TROUT and SCRAP are specific subsystem exercises. TROUT illustrates the principles of managing a rainbow trout fishery (Titlow and Lackey 1973). Robert H. Giles, Jr. and Charles H. Lobdell formulated SCRAP at Virginia Polytechnic Institute and State University. Students manage for optimum yearly harvest of a deer population when using SCRAP. FARMS is a large system exercise developed to evaluate land use and big game populations in British Columbia. The model incorporates plant production and succession, wildlife habitat and food selection, and dynamics of wildlife herds (Walters and Bunnell 1971).

Complex management situations are created by impounding large multiple-use (e.g., hydroelectric power, recreation, and flood control) reservoirs. Due primarily to rapidly increasing demands for electrical energy and flood control, the number of large reservoirs in the United States increases significantly every year. Large reservoir systems are exceedingly difficult to manage because of: (1) speed of development around the reservoir; (2) nature of developmental controls; (3) strength and influence of local governments; (4) amount and allocation of financial assistance; (5) extent of public sewage treatment and water supply facilities; (6) type of secondary road systems; (7) quality of recreational facilities; (8) effects of river pollution; and (9) range of local public services (e.g., police and fire protection, refuse collection) (Burby, Donnelly, and Weiss 1972; Wirth and Associates 1971).

To effectively manage a newly impounded reservoir system, participating management personnel must appreciate the total system. The complexity of interactions between a variety of system demands (e.g., physical, chemical, biological, economic, political, and sociological) makes cooperation and compromise an integral part of successful reservoir system management. A spirit of cooperation and compromise can best be derived by providing multi-discipline orientation during management training programs. Potential values (e.g., economic, recreational, industrial) of newly impounded reservoir systems are too great to entrust to inexperienced decision makers. There exists a need for a method of allowing prospective reservoir management personnel to test their management strategies within the confines of a classroom. The purpose of this paper is to describe development and use of a computer-implemented learning exercise, DAM, designed to illustrate management of a large multiple-use reservoir system.

DAM: DESCRIPTION AND USE

Study Area

Much of DAM is based on information about Smith Mountain Lake, a 8,100-ha (20,000 acre) hydroelectric and flood control reservoir located on the Roanoke River in south-central Virginia. The reservoir is located approximately 80 km from Roanoke, Virginia, and is bounded by four counties, Franklin, Campbell, Pittsylvania, and Bedford. The project was completed in 1965 by Applachian Power Company as a pump-storage facility for annual production of approximately 400,000 kilowatts of electrical power.

Model Conceptualization

The general objective of model conceptualization was to determine basic relationships involved in reservoir management. This objective was accomplished by accumulating information about the Smith Mountain Lake area. Personnel from numerous federal, state, and local agencies were interviewed by telephone and in person. Information from available literature on general reservoir management problems and possible solutions was used extensively.

The initial phase of model conceptualization involved delineation of management units and major decision areas. Five management units were selected: (1) a regional planning commissioner; (2) a fisheries manager; (3) a power company executive; (4) a recreation specialist; and (5) a city mayor. Each major decision area was tentatively assigned to a management unit (Table 1). Also a range of management alternatives was deduced for each major decision area. For example, an antiquated secondary road system is a major problem in the Smith Mountain Lake area. Correspondingly, road construction was designated as a major decision area for DAM. A user of DAM can select the number of kilometers of secondary roads he wants to construct, improve, and maintain.

DAM may be used either by a single student sequentially assuming each management role or by a group of students selectively occupying the five management positions. The choice of several management units for DAM allows role switching during group use of the learning exercise. Members of a management group may either assume different roles (e.g., the regional planning commissioner becomes the power company executive) in successive management years or retain the same roles throughout the management period.

Reservoir system response to application of each management alternative was based on previously accumulated information and verified by contact with appropriate personnel in the Smith Mountain Lake area. For instance, interviews with Virginia Commission of Game and Inland Fisheries and Appalachian Power Company personnel established that a minimum flow regulation of 18.4 m^3/sec [650 cubic feet per second (cfs)] was necessary for protecting the fishery in the river below Smith Mountain Lake. In addition, local Coast Guard Auxiliary personnel stated that permanent navigation of the river below the dam required a guaranteed flow of 170 m^3/sec (6,000 cfs). The Commission recommended that a minimum flow regulation of 18.4 m^3/sec be included in the project license application for Smith Mountain Lake, and Appalachian Power complied. The regulation required for navigation (170 m^3/sec) would be too costly to Appalachian Power Company in terms of loss of generating head. The student manager, assuming the role of power company executive, must decide on a minimum flow regulation when using DAM. Choosing a flow regulation of less than 18.4 m^3/sec will result in lawsuits, whereas one of 170 m^3/sec or greater could cost the power company executive his job. System response to other management alternatives was determined in a similar manner.

Flow charts were used to clarify interactive system response to simultaneous application of two or more management alternatives (Fig. 1). For example, during use of DAM, the city may give financial assistance to the regional planning commissioner who may use the money to develop the reservoir area. With an $8,000 donation, the regional planning commissioner could hire another deputy sheriff, resulting in a decrease in burglaries and auto accidents in the reservoir area. Also, additional enforcement agents will facilitate establishing water surface zoning regulations and boat licensing ordinances by the fisheries manager.

Finally, the economic aspects of DAM were also considered during model conceptualization. A cost or revenue was affixed to each management alternative. For example, consultation with a county secondary road engineer led to the cost of road construction being set at $28,000/km ($45,000/mi), im-

TABLE 1.—*Areas in which decisions are made by users of DAM. Choices in each area are made each year*

Decision Area	Decision Range	Unit cost (dollars/year)
Regional Planning Commissioner		
Development controls		
None	Yes (Y)–No (N)	—
Option to counties	Y–N	—
Subdivision regulations	Y–N	—
Land use plan	Y–N	150,000
Financing Land Use Plan		
Request county funds	Y–N	—
Apply for federal funds	Y–N	—
Sell bonds	Y–N	—
Sewage treatment		
Inspect septic systems	Y–N	—
Extend water supplies	Y–N	800,000
Construct treatment plant	Y–N	3,000,000
Water supply		
Inspect private wells	Y–N	—
Extend water supplies	Y–N	400,000
Construct water supply facility	Y–N	2,000,000
Financing utility improvements		
Increase utility rates	Y–N	—
Apply for federal funds	Y–N	—
Road construction and maintenance		
Km of construction	0–185	28,000
Km of improvement	0–1,850	9,000
Km maintained	0–1,850	6,000
Number of bridges constructed	0–100	100,000
Public services		
Hire deputy sheriffs	0–100	8,000
Construct fire stations	0–100	20,000
Construct landfills	0–100	20,000
Construct schools	0–100	50,000
Hire agricultural agents	0–100	9,000
Fisheries Manager		
Research		
Effects of water level fluctuation	Y–N	10,000
Monitor water quality	Y–N	5,000
Stocking feasibility study	Y–N	10,000
Population dynamics of largemouth bass	Y–N	10,000
Comprehensive creel census	Y–N	10,000
Gamefish-roughfish ratio	Y–N	5,000
Nutrient limiting factors	Y–N	10,000
Effects of water discharge on plankton	Y–N	10,000
Fishery effects of artificial reefs	Y–N	10,000
Stocking (lbs)		
Largemouth bass (7–10 cm)	0–1,000,000	1.50
Rainbow trout (15–20 cm)	0–1,000,000	2.00
Coho salmon (7–10 cm)	0–1,000,000	1.65
Striped bass (5–7 cm)	0–1,000,000	5.00
Muskellunge (13–15 cm)	0–1,000,000	4.25
Bluegill sunfish (2–5 cm)	0–1,000,000	0.12
Threadfin shad (2–5 cm)	0–1,000,000	0.15
White bass (5–7 cm)	0–1,000,000	3.00
Other management techniques		
Fertilization (number of ha)	0–8,100	250
Chemical eradication of fish (number of ha)	0–8,100	200
Introduce artificial reefs	0–1,000	1,000
Public services		
Recreational land grant (number of ha)	0–40,000	5,000
Install navigational lighting	Y–N	10,000
Hire fish and game wardens	0–100	10,000
Conduct boating safety classes	Y–N	—
Pass licensing ordinance for boaters	Y–N	—
Implement water surface zoning regulations	Y–N	—

TABLE 1.—*(Continued)*

Decision area	Decision Range	Unit cost (dollars/year)
Recreation Specialist		
Constructing recreational facilities		
Swimming beaches	0–100	60,000
Rental cottages (2.8 ha each)	0–100	15,000
Public access sites (1.6 ha each)	0–100	20,000
Parks (40 ha each)	0–100	300,000
Marinas	0–100	70,000
Floating fishing docks	0–100	20,000
Public services		
Construct scenic road (number of ha)	0–185	22,000
Purchase wildlife management land (number of ha)	0–40,000	5,000
Promotional campaign (number of months)	0–12	10,000
Design and publish up-to-date maps	Y–N	20,000
Power Company Executive		
Operational constraints		
Minimum flow (number of m^3/sec)	0–2,800	2,150
Flood control (number of vertical storage meters)	0–21	80,000
Fluctuation control during spawning periods	Y–N	90,000
Land management		
Sell (number of ha)	0–40,000	—
Buy (number of ha)	0–40,000	5,000
Lease (number of ha)	0–40,000	—
Public services		
Construct a visitor center	Y–N	200,000
Hire public relations personnel	0–100	15,000
Equipment maintenance		
At dam sites (number of dollars)	0–100,000,000	—
City Mayor		
Immediate plans for sewage treatment improvement		
None	Y–N	—
Construct holding pond	Y–N	1,500,000
Install manual chemical feed facilities	Y–N	250,000
Install automatic chemical feed facilities	Y–N	1,000,000
Future plans for sewage treatment improvement		
None	Y–N	—
Expand present plant	Y–N	2,500,000
Construct new plant	Y–N	15,000,000
Financing sewage treatment improvements		
Apply for federal funds	Y–N	—
Increase sewage service charges	Y–N	—
Request county funds	Y–N	—
Financial aid		
To regional planning commission (number of dollars)	0–1,000,000	—

provement at $9,300/km ($15,000/mi), and maintenance at $620/km ($1,000/mi). Analysis of the total budget of the Virginia Department of Outdoor Recreation led to an

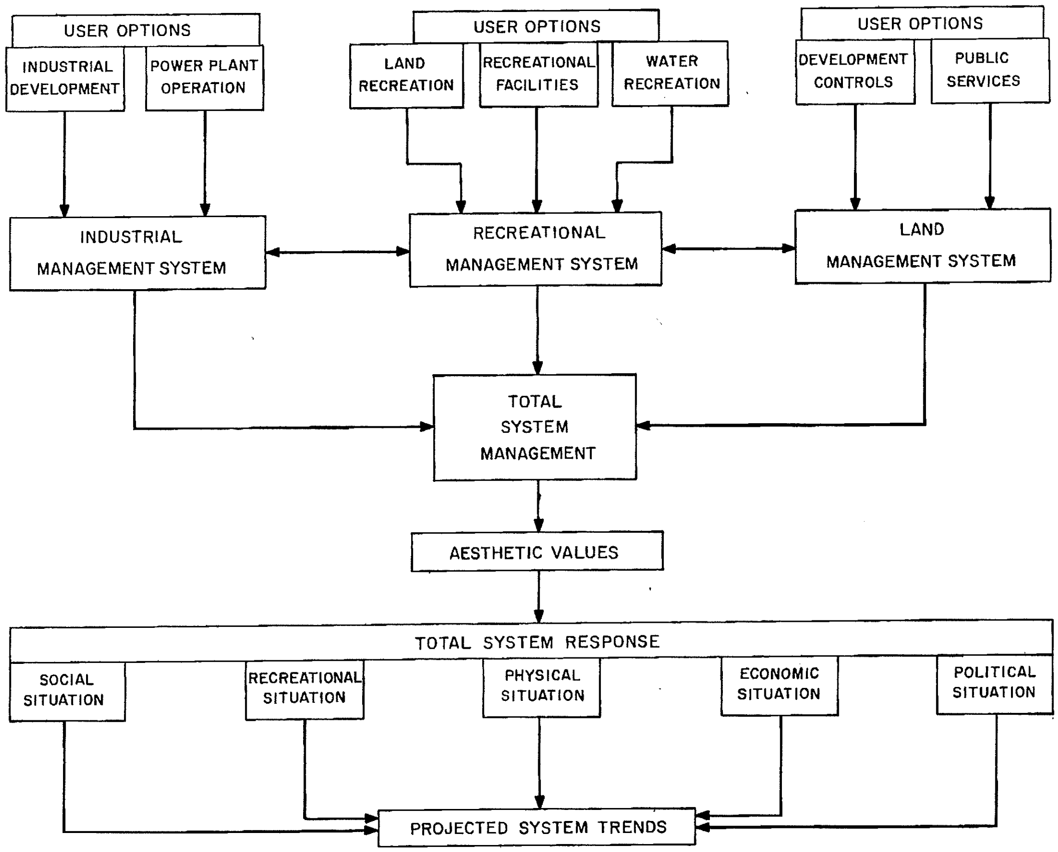

FIGURE 1.—Simplified model of reservoir system used in DAM.

annual budget allocation fluctuating between zero and $500,000 for the recreation specialist of DAM. Contact with several real estate agents in the Smith Mountain area established an average land value of $4,940/ha ($2,000/acre).

Model Quantification and Implementation

The objective of model quantification was to summarize the reservoir system in preparation for computer-implementation. Funding probabilities and expectations for occurrence of stochastic events included in DAM were verified by personal contacts. To exemplify, discussion with Office of Economic Opportunity personnel established a probability of 0.20 for obtaining federal funds to finance and implementation of a Land Use Plan in the Smith Mountain Lake area. Contact with Appalachian Power Company and U.S. Army Corps of Engineers personnel established the probability of a serious flood in the Smith Mountain drainage basin of the Roanoke River.

Quantification of DAM is based on use of two types of numerical accumulators, economic and quantity, and a random number generating function. The budget accumulator of the recreation specialist is an example of an economic accumulator. Suppose that the recreation specialist is advised that he had a budget allocation of $250,000 for management during a year. He decides to construct two public swimming beaches ($60,000 each), four public access sites ($20,000 each), and two marinas ($70,000 each). The budget accumulator would total $340,000 at the end of the year and the recreation specialist would be fired for exceeding his budget allocation by $90,000.

The quantity accumulator is used in determining management results based on total value. For example, the fisheries manager may stock striped bass each year and by so doing, increase the value of the striped bass quantity accumulator. Suppose that the fisheries manager chooses to stock 40,000 striped bass during the first year of management, 20,000 during the second year, and 40,000 during the third year. Depending on other factors (e.g., whether or not the power company executive controls water level fluctuation during spawning periods), successive high stocking rates of striped bass will increase the accumulator past a critical number. The fisheries manager will then be advised that stocking has resulted in establishment of a striped bass fishery in the reservoir. The number of striped bass which the fisheries manager can stock is, of course, controlled by budget limitations.

The random number generating function in DAM has several uses. Budget allocations for management units vary in accordance with the current value of the random number generating function. Several managers have the option to apply for financial assistance when using DAM. The value of the random number generating function is the criterion for determining whether an application for funding is approved or declined. An example of this involves the option of the regional planning commissioner to implement a Land Use Plan with federal funds. Each year he has 2 chances out of 10 of having his application accepted.

The occurrence of stochastic events during use of DAM is also controlled by the random number generating function. These events include: (1) flooding of the river valley below the dam; (2) explosion of a generator at the dam; (3) fish kills; (4) serious boating accidents with resultant loss of life; (5) contamination of the underground water supply as a result of septic system seepage; and (6) plankton blooms. Depending on flood control regulations established by the power company executive, the yearly probability of a serious flood during use of DAM ranges from 0.01 to 0.20. A probability range governing occurrence of each stochastic event is similarly included in DAM.

DAM was programmed in basic Fortran IV on an IBM System 370. Program listing and instructions are available in bulletin form from the authors. Each of the five management units of DAM is represented by a separate subroutine. Calculations, with the exception of those involving the random number generating function, are confined to subroutines. Subroutines are called in sequence which enables the value of all variables to be established before processing yearly management results in the main program. Subroutines also list as output decisions made by the unit managers each year. Output results for each year of management follow decision lists.

A DO loop is used to maintain management carry-over from one year to the next. Each group of student managers sets the value of the DO loop in accordance with the number of years they want to manage DAM. A management duration of 5 yr is suggested at which time the "typical" reservoir system would be highly developed and management alternatives would be limited.

Model Refinement

Model refinement involved detection of simulation flaws and was accomplished by exercising the model over a wide range of management alternatives. For example, interviews with recreationists in the Smith Mountain Lake area indicated a definite need for more public access sites. The general opinion was that one public access site is needed for every 64 km of reservoir shoreline. Since Smith Mountain Lake has a total shoreline of 640 km, a minimum of 10 access sites would be required to satisfy the recreation-seeking public. However, too many access sites would be considered as an invasion of privacy by reservoir property owners. Exercising the option of the recreation specialist to develop public access sites over a wide range of values verified that the response of DAM was in accord with the above information. If the recreation specialist constructs too few access sites (< 10), he is advised that recreationists are complaining about the lack of public access sites. If he constructs too many (> 20), he receives a statement that private land owners in the area are upset over the increasing number of public access sites.

As a final refinement step, DAM was tested in a senior level fisheries management class. Evaluation of student response to DAM led to modifications in decision ranges, output, and instructions for use.

Program Use

The computer program version of DAM requires about 1,300 cards and 200K of core storage. A period of at least 2 wk is required for effective utilization of DAM by means of the card deck manipulation method. Introduction of the learning exercise requires from 15 to 30 min. First, the instructor should briefly familiarize the class with learning exercises (e.g., what are they? what is their value?). Next, members of the class form management groups (1–5 class members per group). Each group member is then given a handout which describes the reservoir system and a set of instructions specific to the management role (roles) he is to assume. Sufficient time should be taken to answer any questions class members may have concerning instruction sheets.

To begin exercise use, each group makes decisions for their first year of management. Thirty to forty-five minutes should be allowed for initial management decision-making. Computer processing of each year's management decisions usually requires several hours. Each management group should arrange meeting times and places for analysis of management strategies. The time required for analysis and revision varies from 30 to 60 min. Each group should manage DAM for a minimum of two 5-yr periods. General class discussion of final management summaries for DAM requires about 60 min.

Response of fisheries management students to DAM was ascertained to further refine the exercise. Many members of the class at first seemed skeptical about computer-implemented learning exercises. Several students voiced displeasure at the volume of information provided for decision-making and at their inability to make correct decisions. Difficulty in obtaining financial assistance was the source for many of these complaints. Most students soon exhibited enthusiasm for the use of DAM, especially during analysis of management output. Each group demonstrated a progressive increase in understanding of the principles involved in the management of DAM. Management cooperation among group members became more apparent with each strategy revision. Final management summaries indicated most students enjoyed trying to cope with the challenging management situation that DAM presents.

DISCUSSION

Among the documented attributes of learning exercises are: (1) students become actively engaged in the learning process instead of passively listening to a lecture; (2) students are aware of good or bad decisions as quickly as the computer can process their management plans; (3) there is a great deal of competition between student groups or individual students during exercise use; (4) students working in groups learn to cooperate with each other which is a necessity for a career in natural resource management; and (5) simulation of natural resource management gives students insight into the interrelationships among system components (Downey 1971).

Among the negative features associated with learning exercises are: (1) they are expensive to utilize properly; (2) extensive development time is usually required; (3) a danger exists of teaching incorrect relationships and concepts; (4) interpersonal rivalries may develop due to intensive involvement; (5) a relatively high level of abstractness exists; (6) there is a tendency to emphasize quantitative factors over qualitative factors; and (7) students may incorrectly transfer exercise results to specific real life situations (Bare 1971).

Dam is an unusual learning exercise in natural resource education because several viewpoints—biological, chemical, physical, political, economic, and sociological—must be considered simultaneously during management activities. Most natural resource learning exercises concentrate on a specific component of a system. For instance, a student's primary concern when using TROUT is maximizing sustained yield of rainbow trout (Titlow and Lackey 1973). FARMS is also based on the premise that computer simulation models can be used as management games to bring together resource decision makers (Walters and Bunnell 1971). In their game, a simple intervention scheme allows users to control harvest rates of game and trees, stocking rates of cattle, range-burning practices, and grazing intensities. Aspects of learning exercises common to FARMS and DAM include: (1) involvement with multiple-use management; (2) inclusion of a variety of management roles; (3) a wide range of management alternatives associated with each management role; (4) use of submodels in the programming technique; (5) application to teaching general management principles; (6) simulation of real management situations in order to provide insight into interrelationships among system components; (7) demonstration of interdisciplinary conflicts attendant with and the degree of cooperation necessary for multiple-resource management; and (8) potential for utilization by students in a variety of fields (e.g., economics, regional planning, and natural resources).

The specific purpose of DAM is to provide students with an understanding of the principles of managing a large multiple-use reservoir. An important part of the learning process involves various external pressures exerted much like those in real management situations. Each unit manager is given specific objectives which he must strive to attain or risk losing his job. A manager cannot make decisions which totally satisfy everyone. For example, if the city mayor decides to assume financial responsibility for sewage treatment plant expansion, the city populace becomes disgruntled because they believe residents of surrounding counties are responsible for overloading the present sewage treatment plant. If the mayor shuns this responsibility, the Water Control Board will place a moratorium on all sewer connections in the city. The lack of clear-cut answers may be unsettling for students who are oriented toward obtaining a "correct" answer.

Allowing students to switch roles emphasizes inherent management conflicts and increases total system appreciation. In role switching, the fisheries manager may realize some of the fundamental problems facing the regional planning commissioner while the regional planning commissioner learns to appreciate the basic management objectives of the power company executive. An element of cooperation among managers is usually derived from such management interactions.

There is no "best" management scheme for DAM. In practice, each group of users continues managing DAM until they can agree on a final management plan which includes: (1) an outline of their final management strategy; (2) an analysis of the final management decisions of each manager; and (3) an explanation and defense of the recommended strategy. Management summaries are compared and analyzed in a class discussion.

Further research efforts could lead to improvements in the use of DAM and enhance its educational value. Because of its size and complexity, DAM is difficult to use with the card deck manipulation method. Thirty data cards must be keypunched and submitted with the deck for each year of management. Understanding the written instructions requires some prior knowledge of computer center facilities. Slow processing of submitted decks and delayed output cause some interest loss in exercise use. Because of this time lag, a few students cannot readily relate management decisions to management output and, consequently, do not develop the desired degree of understanding of system response necessary for effective management. Remote terminal implementation of DAM would eliminate these problems. Groups of users could apply several 5-yr management plans and arrive at a final magement strategy during a single session.

The most commonly suggested improvement of DAM involves the reversibility of certain management decisions. For example, many students thought that they should have the option to release as well as hire employees. It was also suggested that the need for public services be graduated according to the year of management. For example, the number of sanitary landfills needed to serve the reservoir area should increase each year in accordance with increase in population density.

Changes in DAM should be carefully considered. Providing more information on which to base management decisions or incorporating artificial statements of management success into the programming structure could be detrimental. One must analyze the real management situation before modifying DAM. How much information does a fisheries manager in charge of a 8,100-ha (20,000 acre) reservoir have about the fish populations present? Is an executive of a power company likely to be congratulated for adhering to minimum flow constraints? Although there will probably be some favorable comment, it is virtually impossible to make management decisions to the complete satisfaction of everyone involved in a large scale management situation. Realistically, complaints will outnumber compliments regardless of the capabilities of management personnel.

Large-system learning exercises, such as DAM, have great potential in natural resource education. Management personnel must be cognizant of one another's objectives and problems to ensure cooperation in management activities. Use of large-system exercises may prove to be the best method of providing essential multidiscipline orientation in training prospective management personnel.

DAM is a useful tool for teaching the principles of managing a large multiple-use reservoir system. The potential value of DAM to educational programs in many fields (e.g., natural resources, regional planning, engineering, industry, and government) is considerable. Possibilities for modification and expansion of DAM by other researchers are also numerous.

ACKNOWLEDGMENTS

Financial support for this project was provided by the United States Department of the Interior, Office of Water Resources Research, administered by the Virginia Water Resources Research Center as Project A-049-VA.

LITERATURE CITED

BARE, B. B. 1971. Computerized forest resource management games: an overview and assessment. Working Paper No. 30. Center for Quantitative Study in Forestry, Fisheries, and Wildlife, Univ. Wash., Seattle, Wash. (mimeo).

BURBY, R. J., T. G. DONNELLY, AND S. F. WEISS. 1972. Lake Norman developmental impact study. Center for Urban and Regional Studies, Univ. N. C., Chapel Hill, N. C. 121 p.

DOWNEY, W. D. 1971. The use of computer simulations in teaching management. *In* Electronic Data Processing: Conference for USDA—Land Grant College Committee on Computer Applications in Agriculture, Purdue Univ., Lafeyette, Ind.

GARFINKEL, D. 1968. The role of computer simulation in biochemistry. Computers Biomed. Res. 2: 1–11.

PAULIK, G. J. 1969. Computer simulation models for fisheries research, management, and teaching. Trans. Amer. Fish. Soc. 98(3): 551–559.

TITLOW, F. B., AND R. T. LACKEY. 1973. Computer assisted instruction in natural resource management. Proc. Southeast Ass. Game Fish Comm. 26: 500–505.

WALTERS, C. J., AND F. BUNNELL. 1971. A computer management game of land use in British Columbia. J. Wildl. Manage. 35(4): 664–657.

WIRTH, T. J., AND ASSOCIATES. 1971. A land use plan for North Anna Reservoir, Virginia. *Prepared for* Virginia Commission of Outdoor Recreation, Richmond, Va. 59 p.