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The Effect of a Computerized Interactive Water Resource Management Simulator on the Understanding of Water Resource Management Principles and Practices

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THE EFFECT OF A COMPUTERIZED INTERACTIVE WATER RESOURCE MANAGEMENT SIMULATOR ON THE UNDERSTANDING OF WATER RESOURCE MANAGEMENT PRINCIPLES AND PRACTICES

I. Problem

Water is an essential component of agricultural and industrial production, energy conversion, wildlife management, and residential life. Growth in our nation's population and standard of living is placing an increasing demand on this limited and often variable resource while effective management of our water resource is hampered by a lack of public understanding of the major variables and limitations of the resource system. Current water research provides us with new management alternatives, but in many cases technical advances are being made at a more rapid rate than society is able to assimilate the implications of these discoveries. Technical and legislative decisions must be made today which will affect the lives of future generations. Responsible management of our water resources is dependent upon knowledgeable action of an informed public and its elected representatives.

The point of this study was to determine the ability of an interactive computer to transmit technological information. The Water Resources Management Simulator (WRMS) is an interactive computer designed to improve understanding of the major factors involved in intelligent management of our water resources. The computer provides general-level hydrologic information offering participants the opportunity to develop and evaluate water management strategies. Four problem areas are treated: (a) source and quantity of water, (b) use of water, (c) quality of water, and (d) political management of the water resources.

The Water Resources Management Simulator models a region's water supply and demand situation. It is operated by workshop participants, using several small sub-basin control consoles. Water management decisions regarding storage of surface and ground water, rate of water use, sources of water, technology of water use, and disposition of used water are made with controls on these consoles. Five water use categories are provided in the model: (a) irrigation (Figure 1), (b) livestock, (c) municipal and industry, (d) energy, and (e) inter-basic transfer. For each of these uses the water may be drawn from either the ground water or surface water resource.

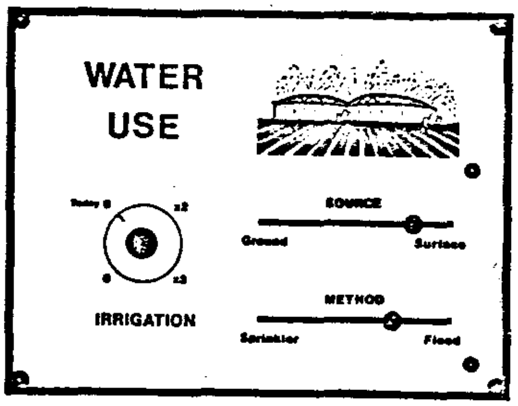


Fig. 1 Sample Irrigation Console

A large panel (Figure 2 on the following page) is placed in view of the audience. The panel simulates the water situation in an entire river basin and in addition receives input from each console. This information, summarized and displayed on the panel, provides the audience with the consequences of the water use by the irrigation, energy, municipal/industrial, and livestock users.

The main simulator panel (Figure 2) includes displays for stream flow above and below the water use area. (Stream flow is based on actual USGS historical data for the basins modeled.) Water quality (silt and total dissolved solid) is indicated by green, amber, and red lamps while a large red lamp

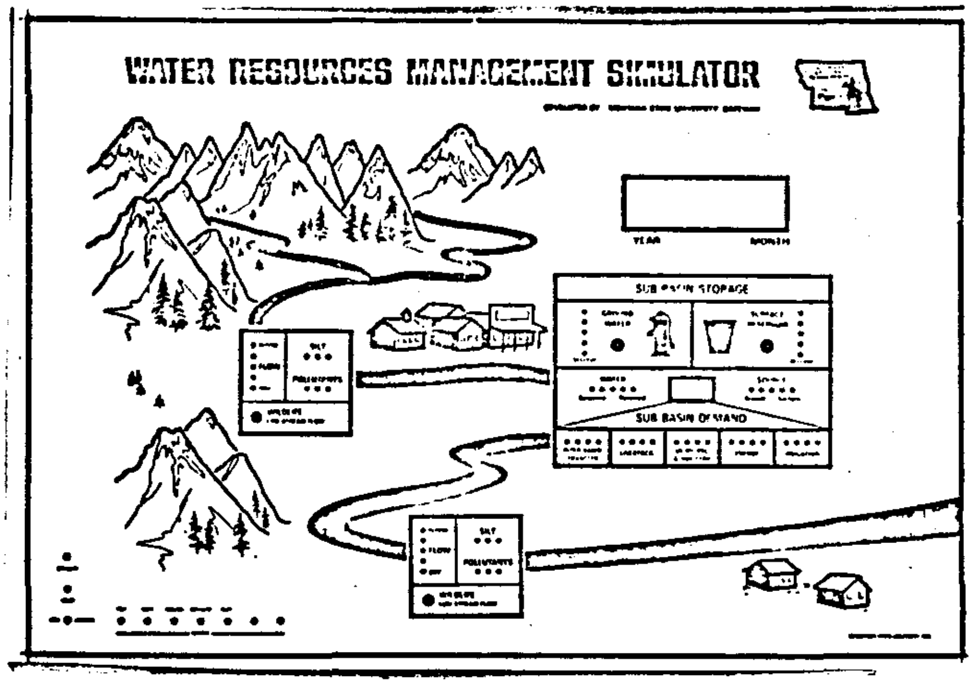


Fig. 2 Main Simulator Panel

glows if the stream flow falls below that level the group reserves for downstream users, wildlife, and navigation. The sub-basin display shows the current ground and surface water reserves and the relative demands by users. Horizontal bar graphs indicate the ratio of ground to surface water used and the ratio of water consumed to water returned to the stream. A clock located in the upper right sector of the main simulator panel indicates time in months and years. The simulator may be programmed for any set of ground and surface water conditions by data statements in the computer memory.

As the simulator operates, important parameters are stored in memory as they are computed. Following a simulation, one can re-construct the conditions and strategies used during any selected portion of the run. This data can be either manually plotted on an overhead projector or graph paper, or can be automatically presented with a color graphics display. Figure 3 on the following page illustrates sample stream flow and water demand hydrographs for an unregulated high mountain stream system. The lack of overlap between high

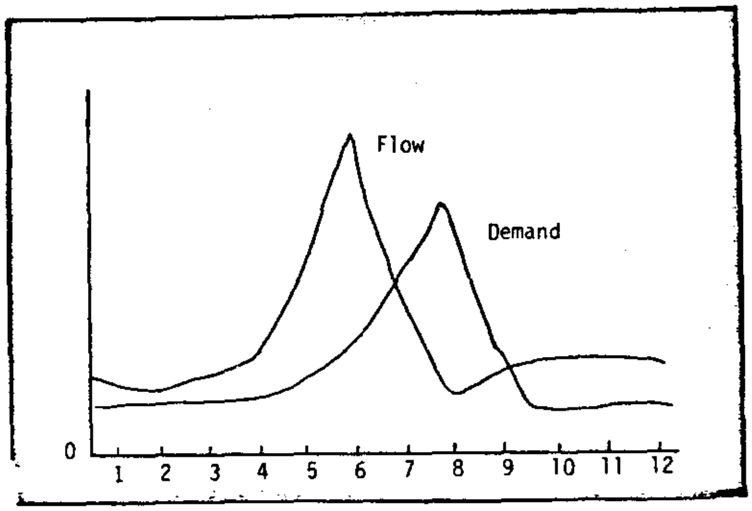


Fig. 3 Stream Flow and Demand

stream flow periods and periods of high water use, caused principally by irrigation, illustrates well one of the major water management problems faced in many parts of our country.

The group conducting the simulation may interact with the model at any time, changing variables to optimize their situation. After observing the result of a given simulation, participants can discuss the strong and weak points of their water management policy, modify their strategy, press the reset button, and try again. A major value of the simulator is its ability to place people in a decision-making situation involving real variables and alternatives, and to project for them the probable consequences of their water management strategies.

This study involved a cooperative effort between the U.S. Department of the Interior, Water and Power Resources Service, Southwest Region, and the Natural Resources and Environmental Education Center, Oklahoma State University, College of Education. The intent is to determine the effectiveness of the interactive computerized Water Resources Management Simulator to increase public awareness and knowledge of water management practices.

II. Objectives

The specific purpose of this study was to:

1. present a series of WRMS interactions where persons interact with the computerized WRMS;

2. assess the amount and type of knowledge the WRMS imparts to target populations;

3. determine which sub-populations might benefit most from WRMS interaction; and

4. identify the basic level of water resource management knowledge of target populations.

III. Methods

Test questions (Appendix A) were developed for each of the theoretical outcomes (Appendix B) of WRMS interaction. A series of demonstration sessions were scheduled with populations in the 13 through adult age range. Thirteen- through 18-year-old subjects were public school students in grades 7-12. Adult subjects were members of the Corps of Engineers, Sierra Club, University courses, League of Women Voters, and state water management agencies.

A. Pre/Post Testing.

All subjects received instruction with the WRMS. The WRMS knowledge test was administered to 349 subjects prior to instruction and to 497 subjects following instruction. The pretest groups acted as a control and provided data as to basic knowledge levels of current public understanding of water resource management. Where possible, intact groups were split into pre and posttest samples to reduce variables between groups. For example, in any one school, one-half of the classes at a grade level were given the pretest and one-half the posttest. Large adult groups were similarly treated.

B. WRMS Presentation.

Trained presentors, following a detailed outline, presented the WRMS treatment to groups. Each session consisted of a short slide show describing the water-related factors and the components of the WRMS as they relate to these factors. Due to time constraints, the public school population generally received less time with the WRMS than did adult groups.

C. WRMS Knowledge Test.

A total of 25 test items were written to measure the stated objective of the WRMS. The objectives of the WRMS were derived by the WRMS Steering Committee. The Steering Committee is composed of users of the WRMS as well as its designer, Dr. John Amend. In addition, the objectives of the WRMS have been reviewed and revised by various groups, including water resource managers and researchers. Since the test items were written to measure the attainment of these objectives, content validity was assumed to be high.

Test reliability was determined using the Kuder-Richardson formula eight for 839 subjects. The 25-item test had an acceptable reliability of .77. Twenty-five is the highest possible score on the WRMS knowledge test.

Table I

Test Statistics

	Actual	Recommended
Mean	11.33	15.00
Standard Deviation	4.38	3.33+
Reliability	.77	.70+

IV. Results

A. WRMS Presentations.

The list on the following three pages outlines the total number of WRMS presentations conducted between fall, 1980 and summer, 1982.

C

WATER RESOURCES MANAGEMENT SIMULATOR PRESENTATIONS

Date			Population	Location	Time	# of Persons
1980	Sept.	23	Undergrad. Elem. Majors	OSU	1 1/2 hrs.	18
		24	Undergrad. Elem. Majors	OSU	1 1/2 hrs.	18
		25	NSF Inservice Teachers	NSF OSU	2 1/2 hrs.	43
	Oct.	6	Grad. Science Methods	OSU	2 hrs.	9
	Nov.	11	NSF, Inservice Teachers	NEOSU	2 1/2 hrs.	35
			OK Conservation Comm.	State Capital	1 hr.	9
		13	NSF, Inservice Teachers	ECOSU	2 1/2 hrs.	40
	Dec.	12	Faculty & Graduate Stud.	OSU	1 1/2 hrs.	10
		15	Governor's Water Conf.	OKC	20 min.	31
1981	Jan.	9	Staff Bureau of Rec.	Amarillo, TX	2 hrs.	20
		26	Graduate Colloquium	OSU	1 1/2 hrs.	20
		30	Minority Water Awareness Prog.	Phoenix, AZ		
	Feb.	5	Maggie Glover, Americans for Indian Opportunity	OSU	3 hrs.	2
		20-21	Water Resource Management Workshop	Camp Redlands	2 days	15
		27-28	Water Resource Management Workshop	Camp Redlands	2 days	30
	Mar.	3	Americans for Indian Opportunity--Seminar on "Environmental Health"	Sacramento, CA	2 hrs.	100
		4	CIED 4723	OSU	2 hrs.	15
			CIED 5233	OSU	2 hrs.	8
		17	Bur. of Rec. Dam Tenders	Amarillo, TX	2 hrs.	34

Water Resources Management Simulator Schedule (continued)

Date			Population	Location	Time	Persons
1981	April	14-16	Representative of Missouri and Southwest River Basin	OSU	2 1/2 hrs.	32
	May	6	NEEA	Gilbertsville, Kentucky	1 1/4 hrs.	15
		22	Ok. Water Resources Board	OKC	1 1/4 hrs.	15
	June	8-9	New Mexico State University Secondary Teachers	Las Cruces, New Mexico	4 hrs.	15
		12	CELTP	OSU	2 hrs.	23
		17	Water, Inc.	Goodwell, OK	1 hr.	17
	July	15	Water, Inc.	Tahlequah	1 hr.	20
		16	Kiwanis	Sapulpa	20 min. Awareness Level	30
	Aug.	2	CEA	Ashville, NC		
	Sept.	9	KSU Faculty	Manhattan, KS	1 1/2 hrs.	12
		10	Heads of State and Federal Agencies	Topeka, KS	All day Workshop format	15
		17	Mini/Micro Computer Workshop	Edmond, OK	1 hr.	20
	Oct.	7	Sierra Club & Ed. Majors	OSU	2 hrs.	27
		10-11	Kansas Science Teachers	Manhattan, KS	1 day	30
		14	Political Sci. Majors	OSU	2 hrs.	15
		22	Education Majors	OSU	2 hrs.	15
	Nov.	30	Kansas Science Teachers	Manhattan, KS	2 hrs.	26
	Dec.	3	Community Education Public	Bristow	3 hrs.	30

Water Resources Management Simulator Schedule (continued)

Date			Population	Location	Time	Persons
1981	Dec.	7	High School Students	Perkins	3 hrs.	50
		8	High School Students	Perkins	3 hrs.	50
		9	High School Students	Perkins	3 hrs.	50
1982	Mar.	3	Environmental Problem Analysis	OSU	1 hr.	20
		23	League of Women Voters	Bartlesville	1 hr.	30
		25	Comparative Resource Mgt.	OSU	2 hrs.	8
	April	2	NSTA	Chicago	2 hrs.	15
		8	High School Students	OKC	1 hr.	110
		13	Corps of Engineers	Bartlesville	1 1/2 hrs.	13
		19	High School Students	OKC	1 hr.	110
		23	OSTA	Lake Texoma	2 hrs.	5
	May	4	Water Resource Board	OKC	2 hrs.	20
		12	High School Students	OKC, Area	2 hrs.	115
		13	High School Students	OKC	2 hrs.	125
		24	High School Students	OKC, Area	2 hrs.	110
	June	18	CELTP	OSU	2 hrs.	12
	July	7	Water Conference	Little Rock, ARK	1 day	35
		24-25	Water Awareness Day	Tulsa	2 day (display)	
	Aug.	15	American Scientific Affiliation Conference	Grand Rapids, Mich.	Demonstration	20
		19	League of Women Voters	Bartlesville	2 hrs.	14

Over seventy individual presentations were made to audiences ranging from 7th grade students to professional water resource managers and planners. On the average, a WRMS presentation was given at least once every ten days during a two-year period to a total of 1,735 persons. Fourteen presentations were conducted in ten states other than Oklahoma.

Not all of the 58 presentations in Oklahoma were conducive to administering the pre/posttest due to time or other constraints. Table II below lists groups and numbers of persons given the pre and posttest.

Table II

	Pre	Post	Total
Students			
Grade 7	12	103	115
Grade 8	103	120	223
Grade 9	28	34	62
Grade 10	57	75	132
Grade 11	18	30	48
Grade 12	29	42	71
Adults			
Teachers	95	58	153
Sierra Club	7	--	7
Corps of Engineers	--	13	13
Political Science Students (College)	--	10	10
League of Women Voters	--	13	13
TOTALS	349	498	847

B. Analysis of Pre/Post WRMS Water Resource Knowledge.

The data presented in Table III on the following page compares mean scores of the total control (Pre) and experimental (Post) populations. The mean posttest score was significantly higher than the pretest mean.

Table III

t-Test Comparison of Total Population
Pre/Post WRMS Knowledge Scores

Source	N	$\bar{x}$	SD	Deg. of Freedom	t	P
Total Pop. Pre	349	10.99	3.83	844.0	2.67	0.007
Post	497	11.77	4.57	817.7		

Table IV below shows pre/post comparisons between junior high, senior high, and adults. A significantly high posttest score exists for senior high and adult groups.

Table IV

t-Test Comparison of Pre/Post WRMS Knowledge
Scores for Junior High, Senior High, and Adult Groups

Source		N	$\bar{x}$	SD	Deg. of Freedom	t	P	Range Correct Respon.
7, 8, 9	Pre	141	9.64	3.24	394	0.181	0.85	1-18
	Post	255	9.70	3.14	281			3-18
10,11,12	Pre	103	9.86	3.32	248	4.69	0.0001*	1-18
	Post	147	12.39	5.19	246			2-22
Adult	Pre	102	14.14	3.12	194.0	5.52	0.0001*	4-23
	Post	94	16.46	2.71	193.4			10-24

* Significant Dif.

Analysis of variance between student scores (Table V below) indicates significantly different mean scores for 7th, 10th, and 12th grade students. Seventh grade performance is suspect since the size of the pretest population is small.

Table V

t-Test Comparison of Student
Pre/Post WRMS Knowledge Scores

Source		N	$\bar{x}$	SD	Deg. of Freedom	t	P	Range Correct Respon.
7th	Pre Post	12 103	8.41 10.66	4.14 2.91	113.0 12.3	2.41*	0.01	2-15 3-18
8th	Pre Post	103 120	9.64 9.10	3.28 3.13	221.0 212.4	-1.23	0.21	1-18 3-18
9th	Pre Post	27 34	9.85 8.32	3.14 3.73	59.0 58.8	-1.69	0.09	0-16 0-15
10th	Pre Post	56 75	9.78 11.16	3.08 4.25	129.0 128.9	2.14*	0.03	2-16 2-22
11th	Pre Post	18 30	10.33 9.26	2.85 3.12	46.0 33.4	-1.21	0.23	3-15 5-16
12th	Pre Post	29 42	9.72 16.83	3.94 5.25	69.0 68.5	6.17*	0.0001	1-18 6-22

* Significant Dif.

To clarify the source of variance in adult pre/post scores (Table IV), the pre and post teacher responses are compared in Table VI on the following page.

Table VI

t-Test Comparison of Teacher Pre/Posttest Scores

Source	N	$\overline{x}$	SD	Deg. of Freedom	t	P	Range Correct Respon.
Pre	95	14.13	3.15	149.0	6.00	0.0001	4-23
Post	56	17.12	2.58	133.8			12-24

The mean posttest score (Table IV) for adults was 16.83 compared to 17.12 for teachers alone. Teachers scored significantly higher on the posttest and their mean posttest score was higher than that of the total group which included Corps of Engineers, League of Women Voters, Energy Committee, and political science college students.

C. Analysis of Responses by Test Item.

To determine the type of knowledge imparted during WRMS presentations, x^2 values were determined for students by grade level and the total adult population. The 25 x 7 x^2 table comparing pre/post, correct/incorrect frequencies indicated that correct pretest frequencies were often significantly different, sometimes in favor of the pretest! Table VII on the following page presents a summary of significant frequency distribution tending to favor either the pre or posttest. A total of 17 items had response frequencies in favor of pretest scores by various groups, primarily 8th and 11th grade. A total of 44 items favor posttest frequencies by various groups. Significant posttest frequencies tended to occur in the 12th grade and adult groups. No observable pattern existed favoring the pretest across groups; however, for test items 3, 5, 6, 7, 12, 16, and 19, the frequency of correct responses favored the posttest for all groups, in addition to those items with significant Chi-Square values.

Table VII

Summary Chi-Square Determinations on Test Item
Response Frequencies by Group

Item	Group: 7	8	9	10	11	12	Adult
1			*	*	*	**	
2		**			*		
3+	**	**	**	**		**	**
4						*	**
5+		**				**	**
6+	**					**	**
7+							**
8				**		**	**
9						**	**
10		**					
11						**	
12+	**	**	**	**		**	
13		*				**	
14		*		**			
15	**					**	
16+				**		**	**
17		*	*				
18		*				**	
19+	**					**	**
20		*				**	
21	**	*					
22					**	*	
23			*			**	
24		*				**	
25		*			*		

* Pretest significant at .05 or greater
** Posttest significant at .05 or greater
\+ Frequency of correct response favors posttest for all groups

D. Comparisons of Groups' Pretest Performance.

Table VIII below compares each group's total mean pretest performance on 25 items.

Table VIII

Pretest Mean Scores

Group	N	$\bar{x}$
7th	12	8.41
8th	103	9.64
9th	27	9.85
10th	56	9.78
11th	18	10.33
12th	29	9.72
Total Students	245	9.69
Adult	102	14.14
Total Population	347	10.99

Pretest scores for all subjects excluding adults show that fewer than 50% of the test items were answered correctly. In general, pretest scores indicate a lack of water knowledge associated with the WRMS by 7th-12th grade public school students. Pretest mean scores indicate adults responded correctly to over 50% of the 25 test items. The total mean score for all students, as expected, is lower than that for adults.

The comparison between student and adult performance on the pretest and posttest is shown in Table IX below.

Table IX

t-Test Comparison of Adult and Student Performance on Pre and Posttests

Source		N	$\bar{x}$	SD	Deg. of Freedom	t	P	Range Correct Respon.
Pretest	Adults	102	14.14	3.12	199.3	11.58	.0001	4-23
	Students	247	9.69	3.32	347.0			1-18
Posttest	Adults	94	16.46	2.71	211.2	16.52	.0001	10-24
	Students	403	10.67	4.21	495			2-22

Adults consistently performed significantly better than students on both pre and posttests.

V. Conclusion

The purpose of this study was to determine the information dissemination potential of an interactive computer. It was to determine (1) if the WRMS could teach, (2) for what groups it was best suited, (3) the kind of information obtained by those interacting, and (4) general levels of water resource information possessed by the control group.

Significant increases in mean posttest scores for the experimental group indicate the WRMS is a valuable tool for imparting water resource management information. The overall higher performance of 10th grade through adult populations suggests that the WRMS may be best suited to older as opposed to younger (grades 7-9) audiences.

The public school teacher population was shown to profit significantly.

The WRMS has great potential as an instructional tool in teacher preparation institutions.

An analysis of response frequencies for each item by group identified the tendency for significant increases in correct responses for items 3, 5, 6, 7, 12, 16, and 19 (Appendix A). These items represent 28% of the 25-item test and deal with:

3. the Ogallala aquifer in Oklahoma
5. consumptive use of water in energy production
6. tertiary sewage treatment
7. consumptive use of water for irrigation
12. identifying silt as a serious water pollutant in Oklahoma
16. recognizing that there is no substitute for water
19. understanding that the earth's water supply is finite, and its availability often beyond our control

The significant increases in the number of correct responses to questions dealing with these concepts and facts indicate a wide range of learning. Knowledge dealing with ground water uses in energy and agriculture, municipal sewage treatment, and pollution were imparted to all groups. General ideas such as recognizing our dependence on water and the limits of the water reserve are important basic concepts necessary for wise decision making. Anecdotal data indicated that the experimental group was often surprised to learn that water resource management was not a simple matter. In general the total population did not exhibit extensive water resource management knowledge ($\bar{x}$ = 10.99).

This study substantiates the assumption that the WRMS simulator is a valuable tool in teaching basic concepts of water resource management. Additional study needs to be done with younger audiences to clarify inconsistencies in the responses of some groups to some items.

References

(1) Amend, John, Simulator Handbook, MSU, 1981.

Appendix A

Assessment Test

Water Resource Management Knowledge Test

1. Water users can be divided into municipal, industrial, livestock and energy. Which of the following uses the most water?

   a. municipal/industrial
   b. industrial
   c. livestock
   d. irrigation
   e. not sure

2. Water in Oklahoma's rivers generally flows toward the

   a. Northeast
   b. Northwest
   c. Southeast
   d. Southwest
   e. not sure

3. A major aquifer in Oklahoma is the

   a. Perrniam
   b. Ogallala
   c. Nubian
   d. Hennesey Shale
   e. not sure

4. Water is used to cool coal and nuclear electrical energy generating plants. Which procedure uses the least amount of water?

   a. flow through in closed pipes
   b. evaporative cooling
   c. non-consumptive
   d. condensation cooling
   e. not sure

5. Water is used to cool coal and nuclear electrical energy generating plants. Which procedure returns the least water back to the surface reserve?

   a. flow through in closed pipes
   b. evaporative cooling
   c. consumptive
   d. condensation cooling
   e. not sure

6. Which of the following sewage treatment procedures returns the least polluted water back into the surface reserve?

   a. secondary
   b. floculation
   c. primary
   d. tertiary
   e. not sure

7. Which of the following irrigation methods requires the least amount of water?

   a. sprinkler method
   b. percolation method
   c. flood method
   d. hydrologic
   e. not sure

8. Which of the following irrigation methods returns the most water back into the surface reserve?

   a. sprinkler
   b. percolation
   c. flood
   d. hydrologic
   e. not sure

9. Which would you consider the most feasible solution to Oklahoma's water problems?

   a. new sources of water
   b. new reservoirs and dams
   c. conservation
   d. drill more wells
   e. not sure

10. What percent of all water used in Oklahoma is used for irrigation purposes?

   a. 20%
   b. 50%
   c. 75%
   d. 90%
   e. not sure

11. "Dilution is the solution to pollution" means:

   a. dilution reduces the amount of pollutant present
   b. adding "clean" water reduces the concentration of pollutants
   c. removal of pollutants from surface water
   d. greater stream flow reduces the amount of pollutants
   e. not sure

12. The greatest water pollutant in Oklahoma is:

   a. salt
   b. PCB's
   c. silt
   d. DDT
   e. not sure

13. The most harmful consequence of little winter snowfall in the mountains is

    a. snow mobiles are restricted to certain areas
    b. it makes for poor skiing
    c. wild game animals do not move from higher elevations to the lower elevations
    d. spring snow melt and runoff will be insufficient
    e. not sure

14. During which month of the year does irrigation in the Southwest demand the greater amount of water?

    a. September
    b. May
    c. December
    d. February
    e. not sure

15. Most of the earth's water is stored in

    a. precipitation and clouds
    b. rivers and lakes
    c. ground water and lakes
    d. oceans and snowpack
    e. not sure

TRUE OR FALSE (mark A for true, and B for false)

16. There are alternative forms of energy and water that we can develop to meet our needs.

17. The amount of ground and surface water available for use varies by geographic region.

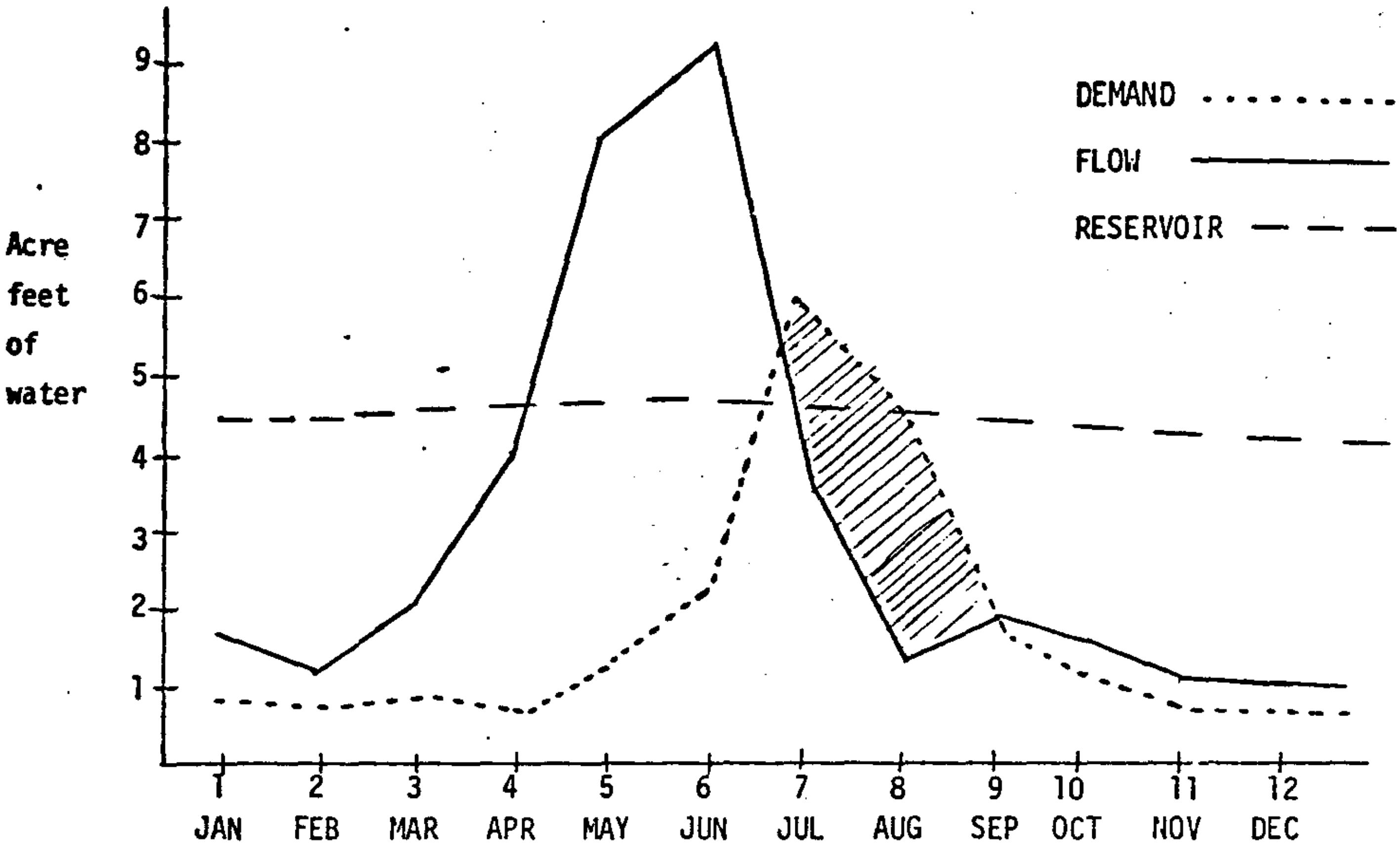
18. Where both ground and surface water are available to a community the decision as to which will be used is made by the Oklahoma Water Resource Board.

19. We have little control over the amount of water available to us.

20. The demand for water by municipal, industrial, agricultural and energy users usually peaks at the same time stream flow peaks.

21. The "life span" of a reservoir is related to the silt load carried in streams and rivers carrying water to the reservoir.

22. Water quality is subject to available technology but the choice of technologies is made through public policy.



23. How is downstream water quality affected in the dry months of July, August, and September?

    a. remains the same
    b. lower concentration of pollutants
    c. higher concentration of pollutants
    d. less pollutants in August than in July
    e. not sure

24. The increased demand in July is probably due to

    a. industrial users
    b. municipal users
    c. irrigation users
    d. not sure

25. What action would you take to end the supply/demand problem July through September?

    a. build a dam
    b. initiate conservation practices
    c. find new water supply sources
    d. not sure

Appendix B

Water Resource Management Simulator
Technical and Policy Objectives

WATER RESOURCE MANAGEMENT SIMULATOR

Technical and Policy ___ Objectives

Recognizing that policy is to implement solutions to real technical and social problems and that water policy must be based on sound hydrologic principles, water policy education programs might include learning objectives that increase understanding of the following basic concepts.

A. Basic concepts relating to the source of water:

1) Solar energy moves water through a hydrologic cycle, in which most of the water is stored either in oceans or snowpack. Water is transported by evaporation, cloud movement, precipitation, and stream flow.

2) Water for human, agricultural, and industrial use is drawn from both surface (stream and lake) reserves, and from underground aquifers. The relative amounts of ground and surface water available for use vary by geographic region.

3) Public policy may influence our choice of the source of water.

B. Basic concepts relating to the amount of water:

1) The availability of surface water and consequent stream flow varies considerably by season. Peak flow in stream basins fed by snowmelt is strongly influenced by the elevation, latitude, and weather pattern of the watershed.

2) Significant variations in stream flow occur from wet to dry years.

3) The availability of ground water in a region is dependent both on the geologic structure and size of the aquifer, and upon the rate at which the aquifer is recharged by infiltration of surface and snowmelt.

4) We have little control over the amount of water available but policy may dictate storage or flow.

C. Basic concepts relating to the distribution and use of water:

1) The hydrograph describing the demand for water for municipal, industrial, agricultural, and energy uses rarely peaks at the same time the stream hydrograph peaks. Sufficient water is usually available, but often at the wrong time.

2) Most water uses result in consumption or loss of only part of the water withdrawn, the remainder being returned to the surface water reserve. Although the percent of water consumptively used in municipal, industrial, and livestock applications may be relatively difficult to change, technologies available for irrigation (sprinkler and flood irrigation) and energy (pass-through or evaporative cooling) differ considerably both in the amount of water required to accomplish a given task, and the efficiency with which this water is used.
3) Distribution and use is directly influenced by policy (preferences, water rights, transfers, etc.).
4) Competition for water requires water policy development and education.
5) Geographic characteristics and distribution of population cause large regional variations in the precentage of water used to meet municipal, industrial, agricultural, and energy demands.

D. Basic concepts related to the management of water:
1) The amount of water available in streams may in some regions be quite accurately predicted by measurement of the winter's accumulation of snowpack.
2) For management purposes, surface reservoirs may be divided into zones of dead storage, for silt accumulation; working storage, for irrigation, recreation and other uses; and flood storage, to catch sudden run-off which would endanger downstream land or property.
3) Surface reservoirs can be considered as having a "life span".

Reservoirs must be managed to provide:
a) An adequate year-round supply of water for agricultural, municipal, industrial, and energy (cooling and/or hydro-electric generation).
b) An adequate reservoir level for recreational purposes during at least part of the year.

c) An adequate downstream flow to support wildlife and, in many cases, navigation.

d) Sufficient reserve storage to catch and hold sudden upstream floods

In many cases these goals of reservoir management will result in conflict of reasonable priorities.

3) Minimum stream flow levels for protection of wildlife, downstream users, and navigation may be set by law. Conditions sometimes occur in which natural stream flow is insufficient to meet the minimum legal flow requirements.

4) In many situations, water is transferred from water-rich to water-poor regions through man-made waterways. In some cases transfer occurs from one drainage to another.

5) Management is a blend of competitive demands for "best use" based on technical abilities, economics, environmental impact, and social criteria.

E. Basic concepts relating to the quality of water:

1) A definite relationship exists between the velocity of a stream and its silt content. Rapidly moving streams scour their stream bed, and can carry a larger silt load than slow moving streams. Accumulation of silt dropped in reservoirs is a serious problem in reservoir design and management.

2) Some water users (municipal, industrial, and livestock) have the potential of introducing dissolved contaminants through their return flow to the surface water reserve. In most cases these pollutants can be controlled by treatment of the water prior to return to the natural system. In some cases simple dilution by the stream will bring the pollutant concentration within safe limits. Dilution is often not an effective management strategy during low flow periods.

3) Water used for pass-through cooling of energy plants may be heated enough to cause local aquatic changes when returned to the stream. Evaporative cooling provides an alternative which uses less water

and does not thermally contaminate local streams. This method, however, returns little water to the surface reserve.

4) Quality is subject to available technology but the choice of technologies is made by public policy.