

**PLANNING ASSISTANCE TO STATES
PROGRAM**

TARRANT COUNTY DROUGHT SIMULATION

A computer simulation of drought conditions
in a major water supply system

U.S. ARMY CORPS OF ENGINEERS
FORT WORTH DISTRICT
FORT WORTH, TEXAS

June 1996

SYLLABUS

This study has been undertaken as a joint effort between the Fort Worth District of the Corps of Engineers and the Texas Water Development Board in an attempt to determine the applicability of a commercial computer program to model a complex water distribution system and to simulate periods of drought so that the adequacy of existing reserves and operating rules can be evaluated.

The Tarrant County Water Control and Improvement District Number 1 (TCWCID#1) was selected as a test case for using and evaluating the program. TCWCID#1 water system is a fairly large system consisting of seven reservoirs and serving a population of approximately 1.35 million. The reservoirs are connected to each other to varying degrees, and are in turn connected to numerous water treatment plants and power generating stations. The computer program, STELLA-II from High Performance Systems of Hanover, NH, allows for the simulation of all of these connections, as well as for many of the operating rules followed by TCWCID#1. The model also allows adjustment to factors such as population growth and rainfall rates to evaluate the practicality of the existing operating rules. The insights gained as a result of using this model will allow the water district to better estimate when the existing water supply system may need to be expanded.

The study confirmed the feasibility of using the STELLA-II program to effectively model a complex water distribution system. A successful public demonstration on May 31, 1996 confirmed the model was useful in predicting changes in operation based on varied decisions, and provided customers useful information on how their decisions affected the overall system operation and associated costs of supplying water.

This modeling program has a great deal of potential as a tool for evaluating a water supply system. A current drought contingency plan for a system can be tested under a variety of conditions, or numerous different contingency plans can be analyzed to establish which may respond best under the widest range of possibilities. Although most water supply systems are not as complicated and flexible as that of Tarrant County, a fully developed STELLA-II model would be very useful in the policy and decision making operations of any system.

TARRANT COUNTY DROUGHT SIMULATION

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TARRANT COUNTY DROUGHT SIMULATION

CHAPTER 1- INTRODUCTION

This project was undertaken as a joint effort between the Fort Worth District of the Corps of Engineers and the Texas Water Development Board in an attempt to determine the applicability of a commercial computer program to model a complex water distribution system.

STUDY AUTHORITY

This study was conducted under authority of Section 22 of the Planning Assistance to States Program (Public Law 93-251), as amended. This legislation provides authority for cooperating with any state in preparation for the development, utilization, and conservation of the water and related resources of basins located within the boundaries of such state. The State of Texas, through the Texas Water Development Board, is the principal contact for work under this program. However, other entities such as water districts and river authorities are also eligible to participate.

PURPOSE AND SCOPE

The primary purpose of this study was to evaluate the suitability of a commercially available computer program to model a water distribution system. The resulting model could then be used to evaluate scenarios in which various factors that affect water use and supply are altered. The resulting output from these different scenarios can then be used by the water distributor, in concert with the public and other entities, to evaluate the future need for additional resources.

Given the above stated purpose, and under the authority of Section 22 of the Planning Assistance to States Program, the Texas Water Development Board requested the cooperation of the Corps of Engineers in the preparation of a test case model. The water distribution system for the Tarrant County area was chosen as the basis for testing the program's capabilities. This system, controlled by the Tarrant County Water Control and Improvement District Number 1 (TCWCID#1), is fairly complex, but sufficient data and records were available to allow the accurate development of a model. It therefore served as an excellent test case for evaluation of the program.

STUDY PARTICIPANTS

This study was conducted by the Fort Worth District of the U.S. Army Corps of Engineers, under the direction of the Texas Water Development Board, and with information being provided by TCWCID#1 as required. During the development of the computer model, extensive coordination was maintained with TCWCID#1 with regard to proper understanding and interpretation of the Operations Manual and to obtaining necessary records of rainfall events and reservoir levels.

CHAPTER 2 - DESCRIPTION OF STUDY AREA

The majority of the TCWCID#1 system lies within an area referred to as the Upper Trinity River Basin. Figure 2-1 shows the extent of that area and the relationship of the Tarrant County system reservoirs to other reservoirs in the basin.

GENERAL

The Upper Trinity River Basin can generally be defined as that area upstream of the confluence of the Trinity River and the East Fork of the Trinity River. This confluence is on the border of Ellis and Kaufman Counties, southeast of Dallas County.

Contained within the basin area is the Dallas-Fort Worth Metroplex, one of the largest and most populated urban centers in Texas. Current estimates show Dallas and Tarrant Counties to have a 1990 population of approximately 3.6 million residents. The total sixteen county region surrounding Dallas-Fort Worth has a population of over 4 million.

The economy of the region has become quite diversified compared to what once was a primarily oil-related economy. Many large corporations have relocated their operations into the region. Major high-tech, communications, and electronic firms are located throughout the area. Additionally, many military-oriented manufacturing and assembly plants are located in the study area. A major military installation is the Naval Air Station - Fort Worth Joint Reserve Base, in the northwest quadrant of the City of Fort Worth. Total employment in the area is estimated at 2.4 million jobs.

CLIMATOLOGY

The climate in the Upper Trinity watershed is humid subtropical with hot summers and mild winters. Snowfall and subfreezing temperatures are experienced occasionally during the winter season. Generally, the winter temperatures are mild with occasional cold periods of short duration resulting from the rapid movement of cold pressure air masses from the Northwestern polar regions and the continental western highlands. Temperatures at Dallas-Fort Worth Regional Airport have ranged from a high of 113°F in June 1980 to a low of -1°F in December 1989. The average annual temperature over the watershed varies from 64°F at Bridgeport in the northwestern extremity of the watershed to 66°F at Dallas-Fort Worth Metroplex. The mean annual relative humidity for Dallas-Fort Worth Metroplex is 65 percent. The average annual precipitation over the watershed varies from 30 inches at Jacksboro in the northwestern extremity of the watershed to 32 inches in the Metroplex. The extreme annual precipitation amounts since 1887 are a maximum of 53.54 inches occurring in 1991 at Dallas-Fort Worth Regional Airport and a minimum of 17.91 inches occurring in 1921 at Fort Worth. The maximum precipitation in a 24 hour period for Fort Worth was 9.57 inches in September 1932. A large part of the annual precipitation results from thunderstorm activity, with occasional heavy rainfall over brief periods of time. Thunderstorms occur throughout the year, but are most frequent in the spring. The average length of the warm season (freeze-free period) in Dallas-Fort Worth Metroplex is about 249 days. The average last occurrence of 32 degrees or below is mid-March and the average first occurrence of 32 degrees or below is in mid November.

Generally, the major storms experienced in the study area are produced by heavy rainfall from frontal-type storms which occur in the spring and summer months, but major flooding can also be produced by intense rainfall associated with localized thunderstorms. These thunderstorms may occur at any time during the year, but they are more prevalent in spring and summer months.

MAJOR TRIBUTARIES

CLEAR FORK OF THE TRINITY RIVER

This portion of the basin is located within the cities of Fort Worth and Benbrook. The Clear Fork begins at its confluence with the West Fork near downtown Fort Worth and extends to Benbrook Lake Dam with its headwaters in the northern portion of Parker County. In March 2, 1945, Congress approved the Clear Fork and West Fork Floodway, a Federal flood control project. With the improvements and modifications associated with the construction and maintenance of this flood control project, the environmental resources were significantly modified and altered as well.

The construction of the Benbrook Dam in 1952 also altered wildlife habitats downstream of its construction. Clearing of riparian vegetation has eliminated much of the terrestrial habitat; however, this corridor is still used by waterfowl, shorebirds, and mammals such as beaver and nutria. Wildlife species found along the Clear Fork are similar to other segments or streams located within the study area. The impoundment of Benbrook Lake has increased the number of days of zero flow, decreased peak discharges, and increased in-bed deposition of siltation, thus degrading the stream fishery from pre-impoundment conditions. Several pools have been created by low flow dams (most of which were built by the TCWCID#1) using Streams and Valley Committee funds, and have benefitted the fishery and improved access to the stream.

The Texas Parks and Wildlife Department (TPWD) and the TCWCID#1 operate a "put and take" trout fishery on the Clear Fork of the Trinity River. Average stocking by TPWD is approximately 7,500 fish per year and these fish range in length from 8 to 12 inches. TCWCID#1 stocks approximately 6,000 fish per year and these fish average about 14 inches in length. One of the main reasons that trout can be stocked in the Clear Fork is because of the good water quality within this stream.

WEST FORK OF THE TRINITY RIVER

The West Fork portion of the basin is located in both Tarrant and Dallas Counties. The West Fork begins at the confluence of the Elm Fork and the mainstem of the Trinity River located in Dallas County, and ends, for the purpose of this description, at the Lake Bridgeport Dam. The tributaries located within this study area include Village Creek from its confluence with the West Fork to the dam at Lake Arlington, and Mountain Creek from its confluence with the West Fork to the dam at Mountain Creek Lake. Urban expansion has resulted in large scale alteration to the natural features of practically all tributaries, and a significant amount of the West Fork. Within the past few years, economic conditions have led municipalities and developers to seek use of the West Fork and its tributary flood plains. The West Fork and tributary flood plains contain some of the last vestiges of natural, high-value resources within the study area. The flood plains are broad, and the river meanders through the many unleveled portions. The cutbanks are steep and at normal low flow the river surface elevation conditions may be 10 to 20 feet below the top of the banks.

CHAPTER 3 - TARRANT COUNTY WATER DISTRIBUTION SYSTEM

The Tarrant County Water Control and Improvement District Number 1 provides raw water for most of the cities in the county, including the large population centers of Fort Worth and Arlington. There are seven reservoirs in the system to provide this service, ranging in size from Lake Arlington at 2,148 acres to Richland Chambers Lake at 44,752 acres.

GENERAL

On the following page, figure 3-1 shows the general size and layout of the water system, including all the reservoirs, facilities and demand points. The figure was prepared by Freese and Nichols Consulting Engineers for an operations manual they recently produced for the District.

Although there is some interconnection between all portions of the system, it is basically two separate parts, the West Fork Reservoirs and the East Texas Pipelines. The West Fork Reservoirs include Lake Bridgeport, Eagle Mountain Lake and Lake Worth, and serve the communities to the north and west of the City of Fort Worth. The East Texas Pipelines connect Cedar Creek Lake and Richland Chambers Lake to Lake Arlington and Lake Benbrook, providing water to the southern and eastern portions of Fort Worth, as well as to Arlington and Mansfield.

RESERVOIRS

As noted in chapter 2, a large portion of the Tarrant County water supply is located within the Upper Trinity River basin. For most municipalities, surface water is the dominant supply source. However, Richland Chambers Lake and Cedar Creek Lake, southeast of the Metroplex, are connected via the East Texas Pipelines to augment the supply for Arlington, Mansfield and parts of Fort Worth. The water supply lakes which have dedicated storage allocated for water supply are as shown in table 3-1 on page 3-3.

Lake Benbrook was designed and built by the U.S. Army Corps of Engineers and, in addition to providing water to TCWCID#1, it also provides storage for flood control. None of the other non-Federal lakes have dedicated flood control storage.

TABLE 3-1
RESERVOIR CAPACITIES AND HISTORY

Reservoir Name	Owner/Controller	Impoundment Date	Capacity (Acre-Feet) @ Conservation Level
Lake Bridgeport	TCWCID#1	1932	374,836 @ 836.0
Eagle Mountain Lake	TCWCID#1	1934	178,422 @ 649.1
Lake Worth	City of Ft. Worth	1957	37,066 @ 594.0
Lake Benbrook	Corps of Engineers	1952	88,248 @ 694.0
Lake Arlington	City of Arlington	1957	39,930 @ 550.0
Cedar Creek Lake	TCWCID#1	1965	679,415 @ 322.0
Richland Chambers Lake	TCWCID#1	1986	1,181,886 @ 315.0

CHAPTER 4 - COMPUTER MODEL OF TARRANT COUNTY WATER SYSTEM

The computer program used to model the Tarrant County water system is named STELLA-II. The program was developed by High Performance Systems of Hanover, New Hampshire and provides a very visual and user-friendly environment in which various scenarios of a modeled system can be tested. The program can be used to model any situation where relationships between separate elements of a situation can be quantified. Water supply and distribution systems are ideal subjects for modeling with this program because the logic and terminology of the program parallels that of a water system. The program uses reservoirs to hold products, pipelines to move products, and clouds to simulate an unlimited source of the product.

GENERAL

The program has three separate, interrelated levels; the highest level contains the relationships between various segments of the model, the middle level contains the detail of the relationships between all the individual components of a segment (and is the primary modeling level), and the lowest level contains all of the mathematical equations and graphs. Also available from the middle modeling level is a block for comments or notes whereby assumptions or modeling techniques can be noted.

TARRANT COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NUMBER 1

The STELLA-II model for the TCWCID#1 consists of, at the uppermost level, seven primary segments which represent each of the reservoirs in the system. Within each of these elements, all inflows and outflows of the lake are represented, including rainfall, evaporation, local usage and TCWCID#1 usage. In addition to these direct influences on the content of the reservoirs, operating rules are also modeled to simulate the effect of operational transfers between lakes.

Within the model, each of the lakes is defined mathematically to relate the volume of the lake to its elevation and surface area. Spillway flow is then based on elevation, and evaporation based on area. Use, both local and by TCWCID#1, is based on projections made in January of 1996. Because the purpose of this study has been to simulate the conditions of a protracted period of drought, the rainfall records from January of 1948 through December of 1957 were used as input data. This time period includes the most severe drought for which records are available, and for the flooding that ended that drought in 1957. Most of the current reservoirs did not exist for that entire period of time, but rainfall data from that time has been combined with actually observed runoff and evaporation rates at today's reservoirs to create realistic estimates of water quantities.

As stated previously, this model was developed in order to evaluate how the TCWCID#1 could respond to drought conditions. With this goal in mind, the Corps of Engineers worked with the engineering department of TCWCID#1 to create a model that would allow for the various users of the water system to participate in a simulated drought scenario and quickly realize the consequences of their individual actions on the entire system. Although any variable or relationship in the model can be modified, it was written so that the factors over which the District's customers have control are easily adjusted through the use of graphic "slide bars". Additional information about the presentation of this simulation to the users of the water system is presented in chapter 5.

The seven pages beginning on page 4-4 present much of the middle level of the model. These Pages 4-4 through 4-10 show each of the seven individual reservoirs and all of the inflows and outflows from those reservoirs. As an example of the terminology and abbreviations used in each of these sub-models, please refer to the table on page 4-3 and to Eagle Mountain Lake on page 4-4. Pages 4-11 through 4-13 show the additional modeling blocks that are necessary to complete the interconnections, rules and demand points of the TCWCID#1.

Data used in the model was provided by TCWCID#1. All data has units of months for time and acre-feet for volume. To use this one month time increment in the model would produce poor results because the proper interactions and responses of the system cannot take place. Therefore, the time step used in the model was set at 1/16th of a month. All calculations divide the monthly input value by 16 and use that value to "step" the model. This results in the minor inaccuracy that the rainfall for a given month occurs equally over that one month period. However, the resulting end of month values and the overall model accuracy are not affected. The 1/16th month time increments also allow for operating rules to govern releases and cut-offs much more realistically than otherwise.

Due to the complexity of system wide operating rules, and the difficulty of representing those rules within the parameters of the program, those factors cannot be easily changed. Also, at this time, the many factors that can influence the public's use of water were not incorporated in the model. Example influences are voluntary conservation, landscape watering rules of varying degree, and the additional use of cooling water by power generating plants (drought is usually accompanied by hotter weather).

Other factors that can effect the overall operation of the TCWCID#1 are based on revenue. Income from recreational fees is directly related to lake levels for many activities, and to stream flow volumes for other activities. Changing user fees for various actions generates different cash flows for operating the system, and may allow changes in operating rules. These factors have not been included in the current model, and probably could not realistically be represented.

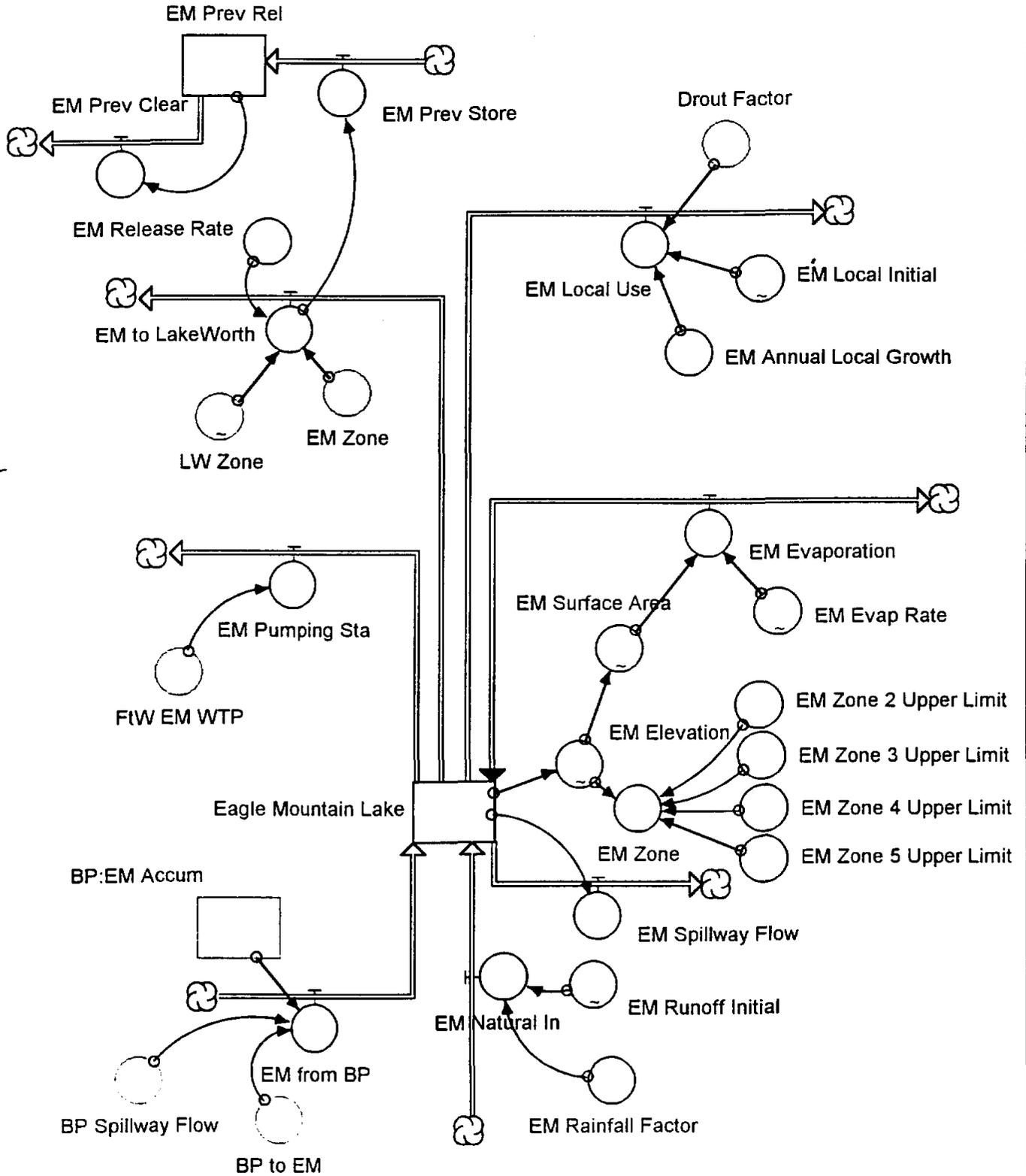
CALIBRATION

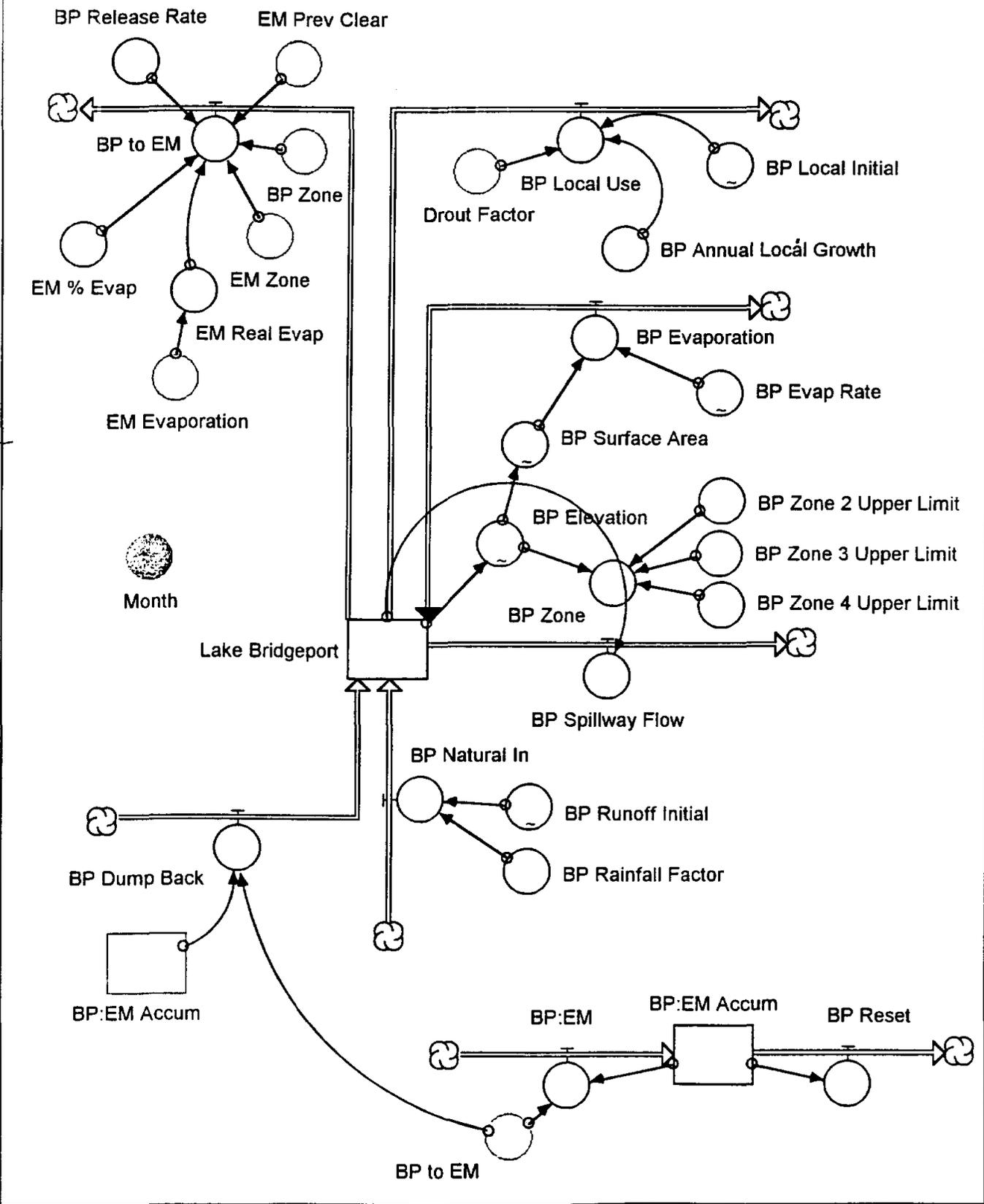
As a means of verifying the Tarrant County system had been properly modeled, a calibration test of the West Fork Reservoirs was conducted. Rainfall and water consumption quantities for the six year period beginning January 1975 were input to the program and the resulting output of lake levels was compared with the records of actual lake levels as maintained by the TCWCID#1. Reference is made to table 4-2 on the last page of this chapter for a listing of the observed versus predicted surface levels for Lake Bridgeport for the 2 year period beginning January 1975. As shown in the last column, for the first 10 months the predictions by the model are very close to the observed lake elevations. (Within 6 inches, often within 1 inch, over a 10 foot range of fluctuation.) However, beginning in November 1975, the model quickly diverges from the observed levels and begins predicting values that are 2 feet and more too high. With TCWCID#1's assistance, investigations were made into this anomaly and it was determined that since the current operating rules were not in place at that time, the operators of the system routinely released water from Bridgeport late in the year. This was done so that sufficient volume would be available in Lake Bridgeport to capture and retain the winter and spring rains to come. As a result of this calibration study, both TCWCID#1 and the Corps of Engineers had a high degree of confidence that the model accurately simulates the actions and reactions of the reservoirs of the water supply system.

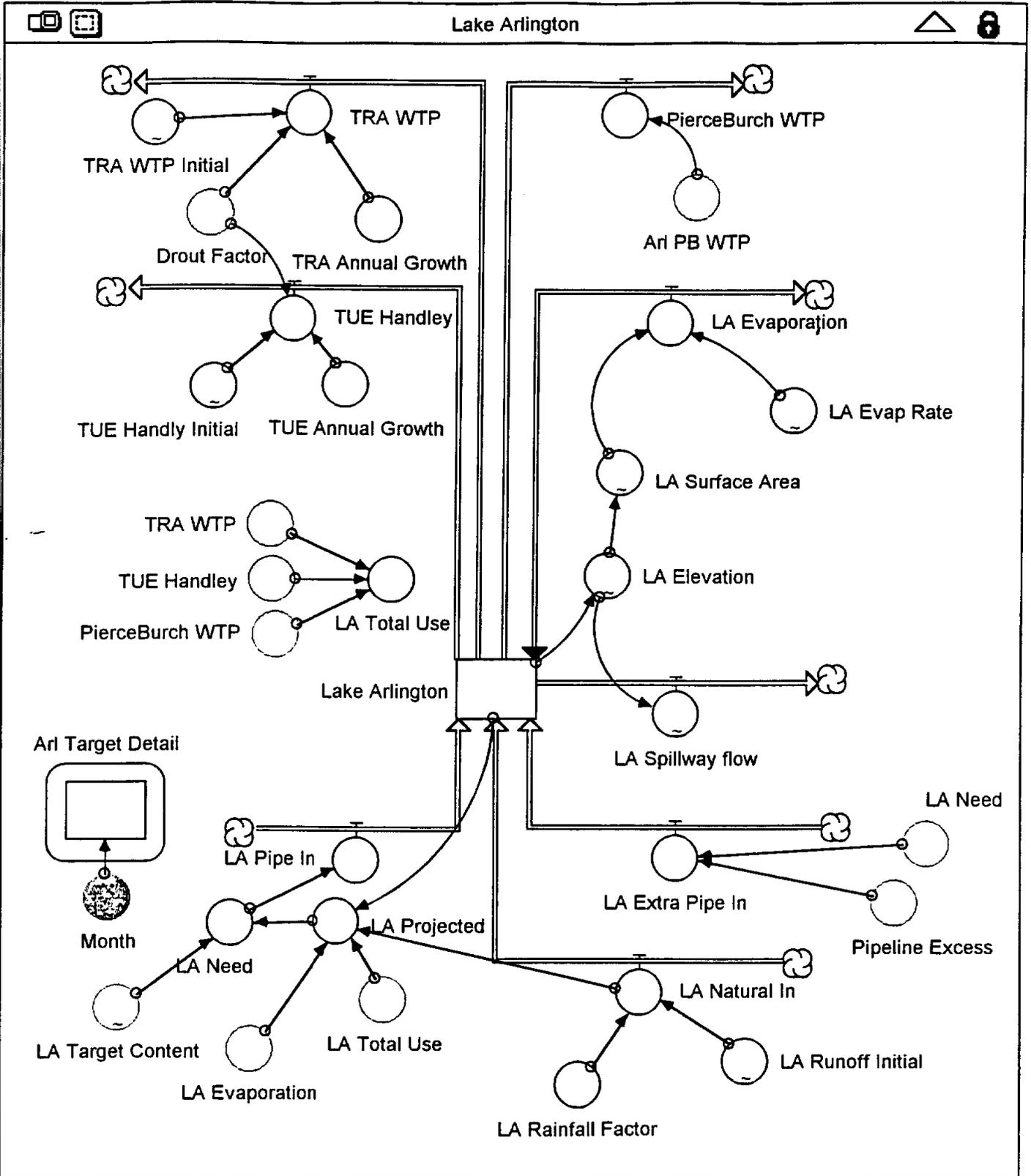
TABLE 4-1

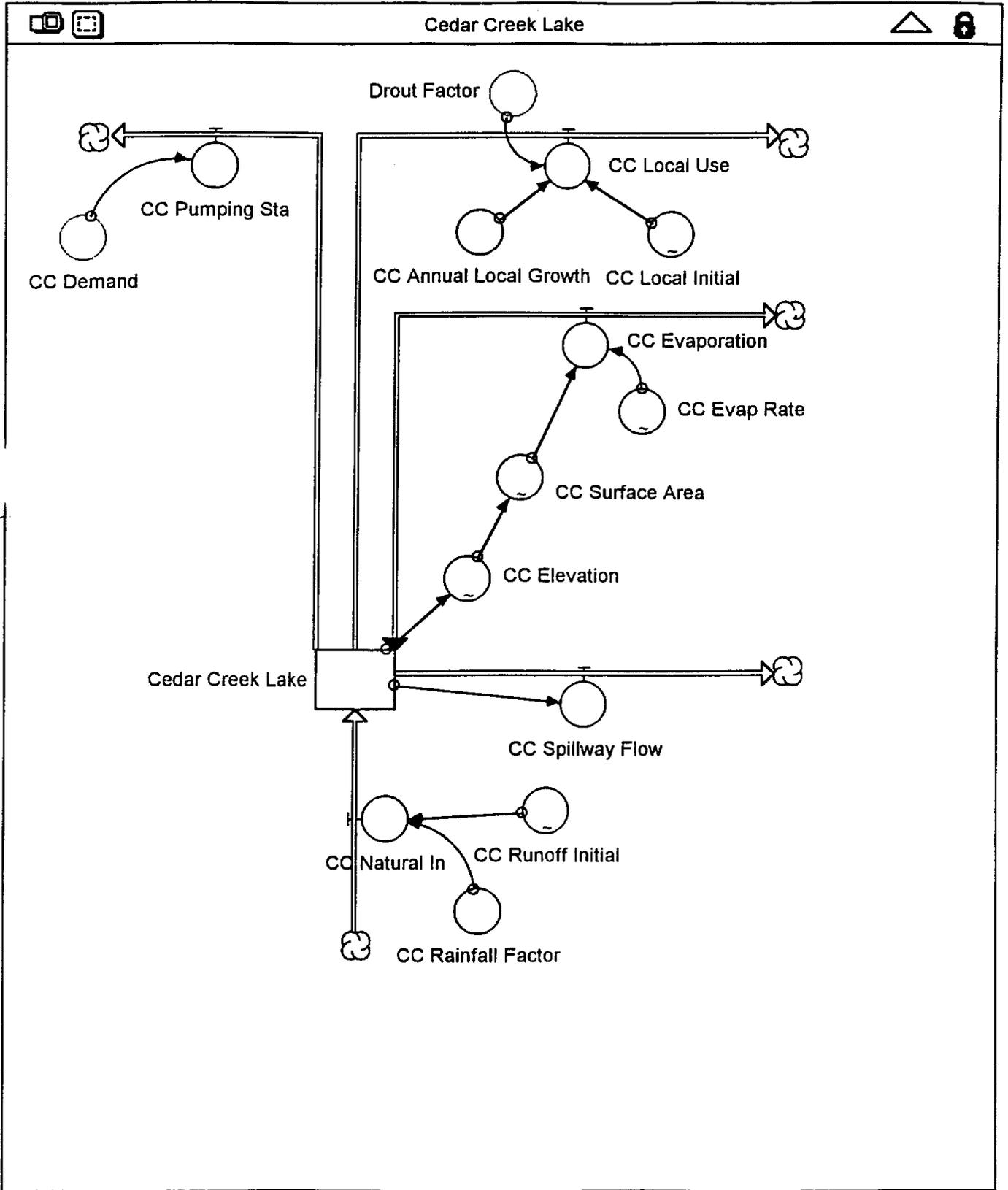
**TYPICAL ABBREVIATIONS USED
THROUGHOUT MODEL**

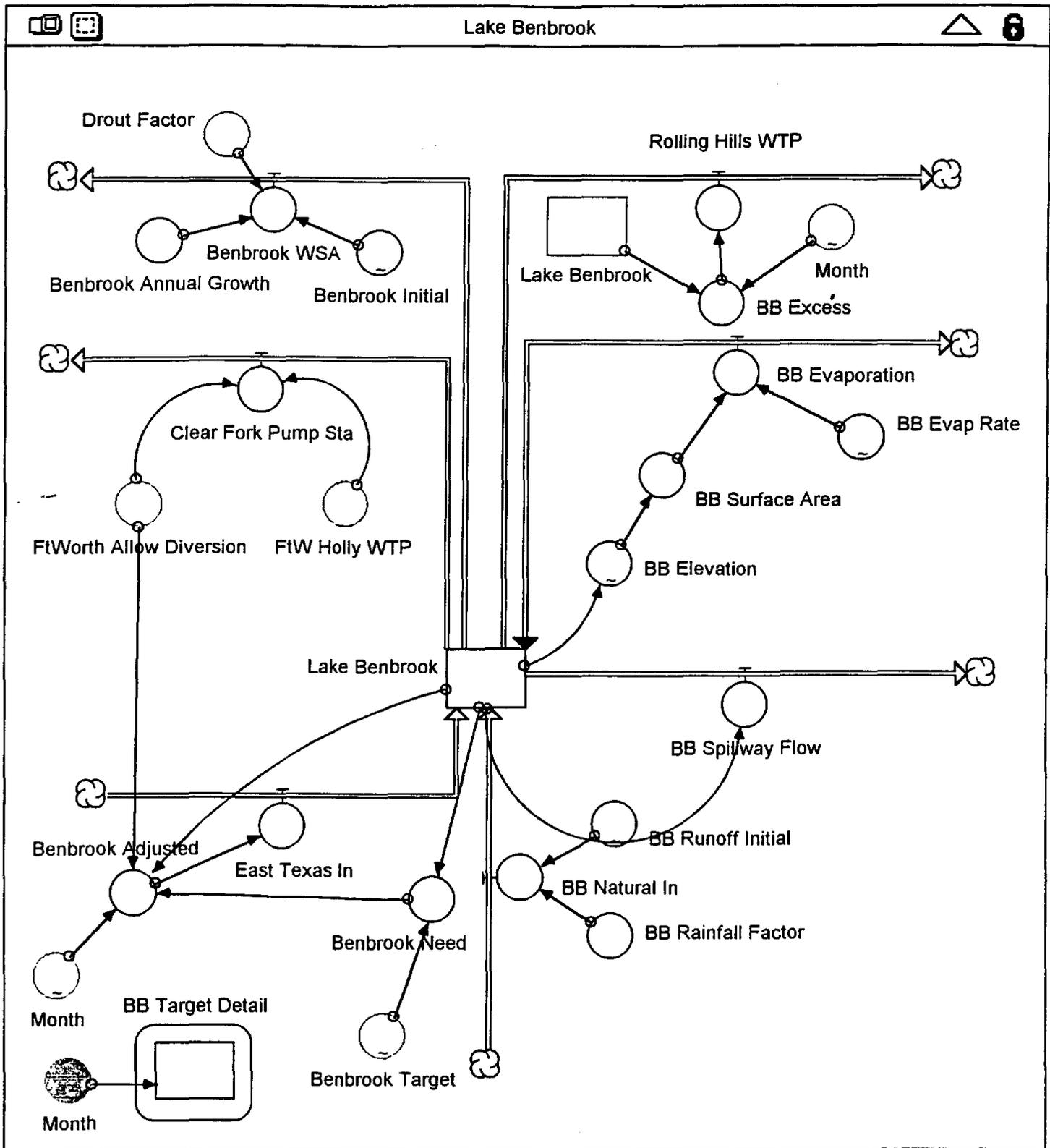
Model Name	Description
Eagle Mountain Lake	Content of reservoir in acre-feet of water.
EM from BP	Controlled water flow from Bridgeport to Eagle Mountain based on operating rules. Direct pass-through of "BP to EM" generated in Bridgeport model.
EM Natural In	Total volume of rainfall and runoff into Eagle Mountain. Combination of "EM Runoff Initial" (past rainfall records) and "EM Rainfall Factor" (easily adjustable percentage increase / decrease applied to EM Runoff Initial).
EM Spillway Flow	Volume of water above spillway level eliminated from reservoir.
EM Evaporation	Volume of water lost to evaporation and based on reservoir surface area, "EM Surface Area", (calculated from elevation of lake, "EM Elevation") and evaporation rate, "EM Evap Rate" obtained from TCWCID#1.
EM Zone __ Upper Limit	User accessible variable to define the limits of the lake level zones for use by the operating rules of the District.
EM Zone	Value of 1, 2, 3, or 4, based on operating rules, for use in controlling transfers between reservoirs.
EM Pumping Sta	Volume of water pumped from reservoir to the Eagle Mountain Water Treatment Plant. Direct pass through of "FtW EM WTP" generated in Ft. Worth Demand calculator.
EM Local Use	Volume of water removed for local use. Combination of "EM Local Initial" (from past records) and "EM Annual Local Growth" (easily adjustable percentage increase / decrease applied to EM Local Initial).
EM to LakeWorth	Volume of water released from Eagle Mountain to Lake Worth under the operating rules. Controlled by the zone values of LW and EM , and the release gate setting at Eagle Mountain "EM Release Rate".
EM Prev Rel	An accumulator of the volume of water removed from Bridgeport. Used to insure operation limits are not exceeded.

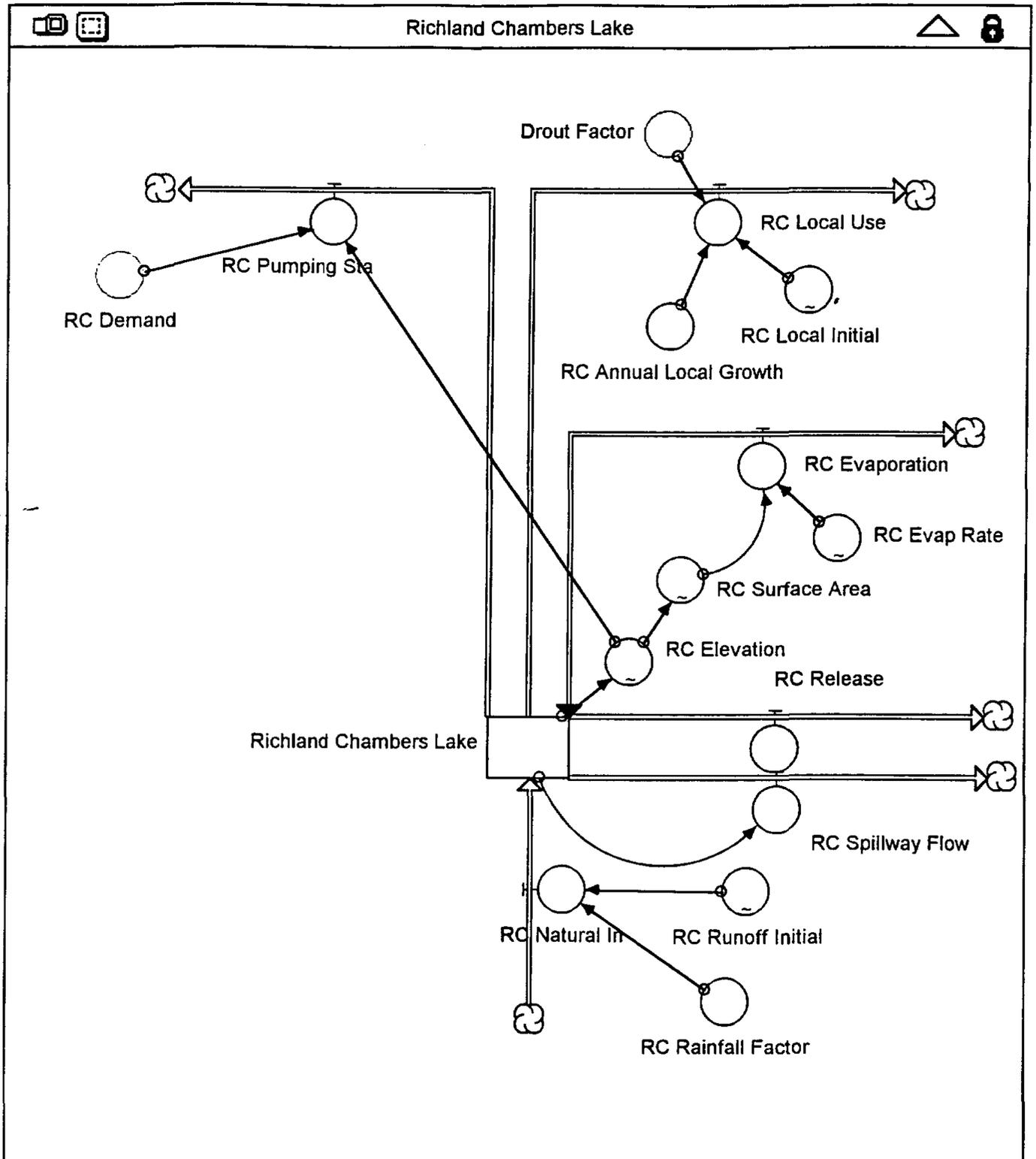


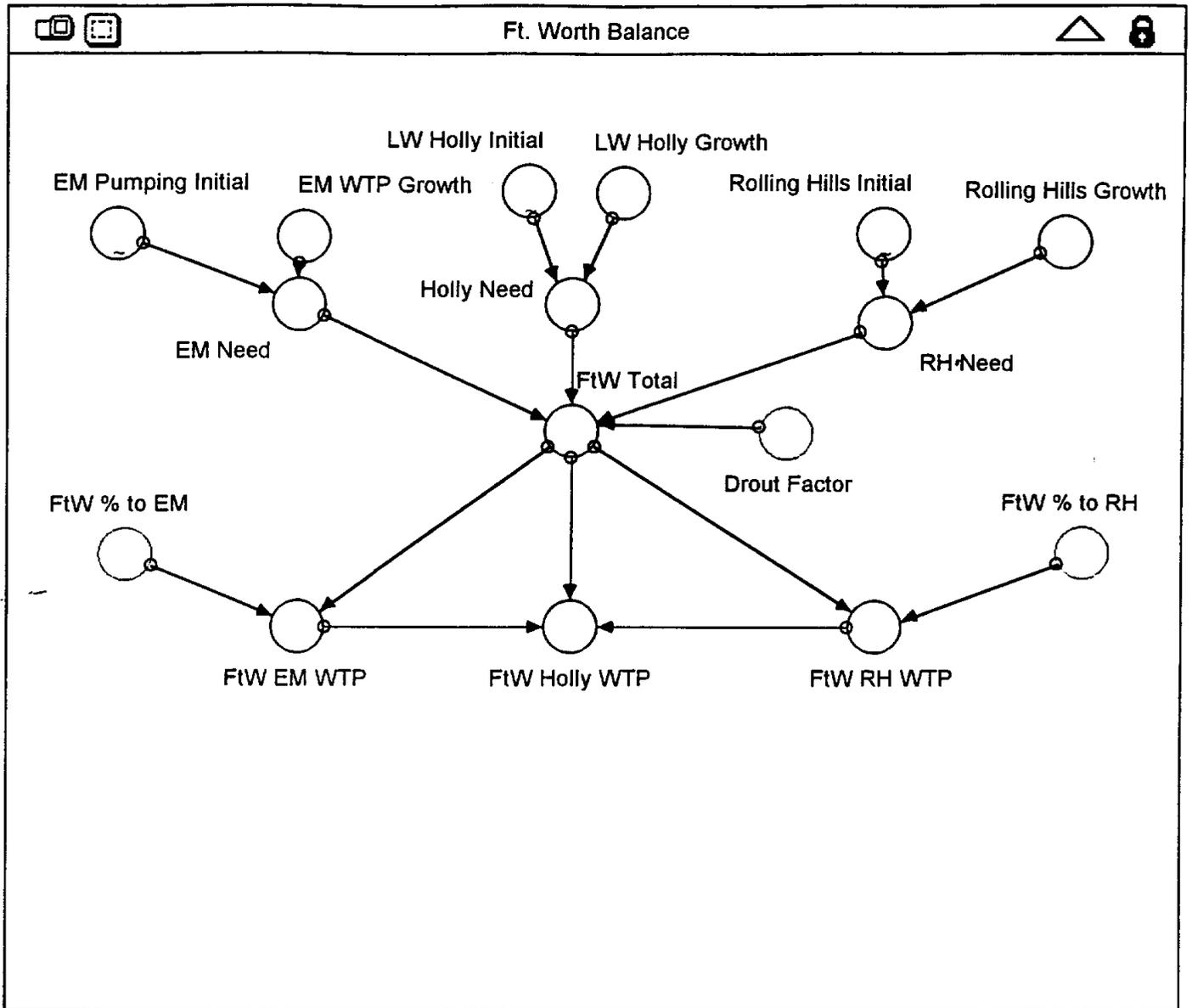




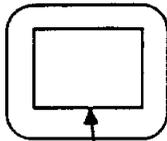






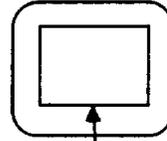


EM Percentage

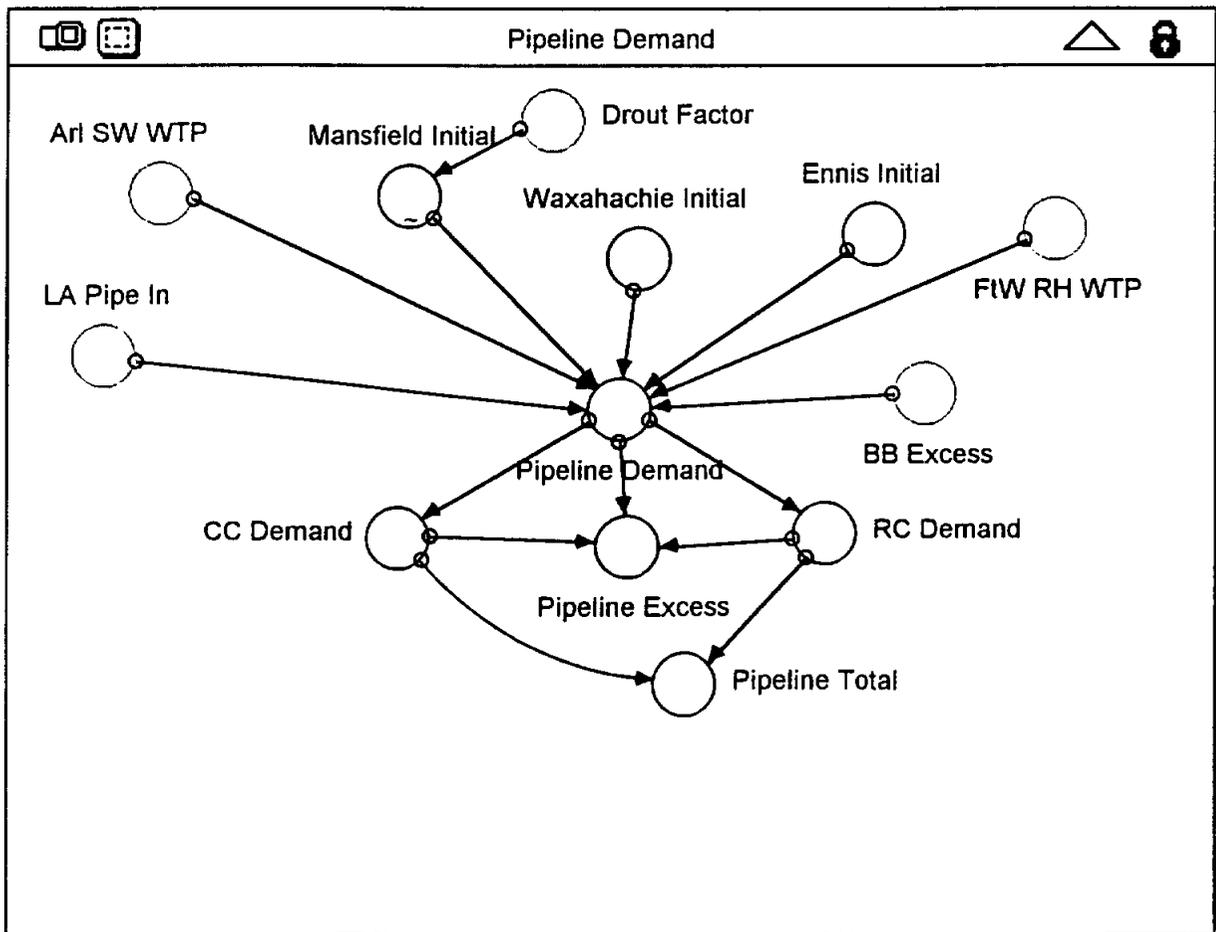
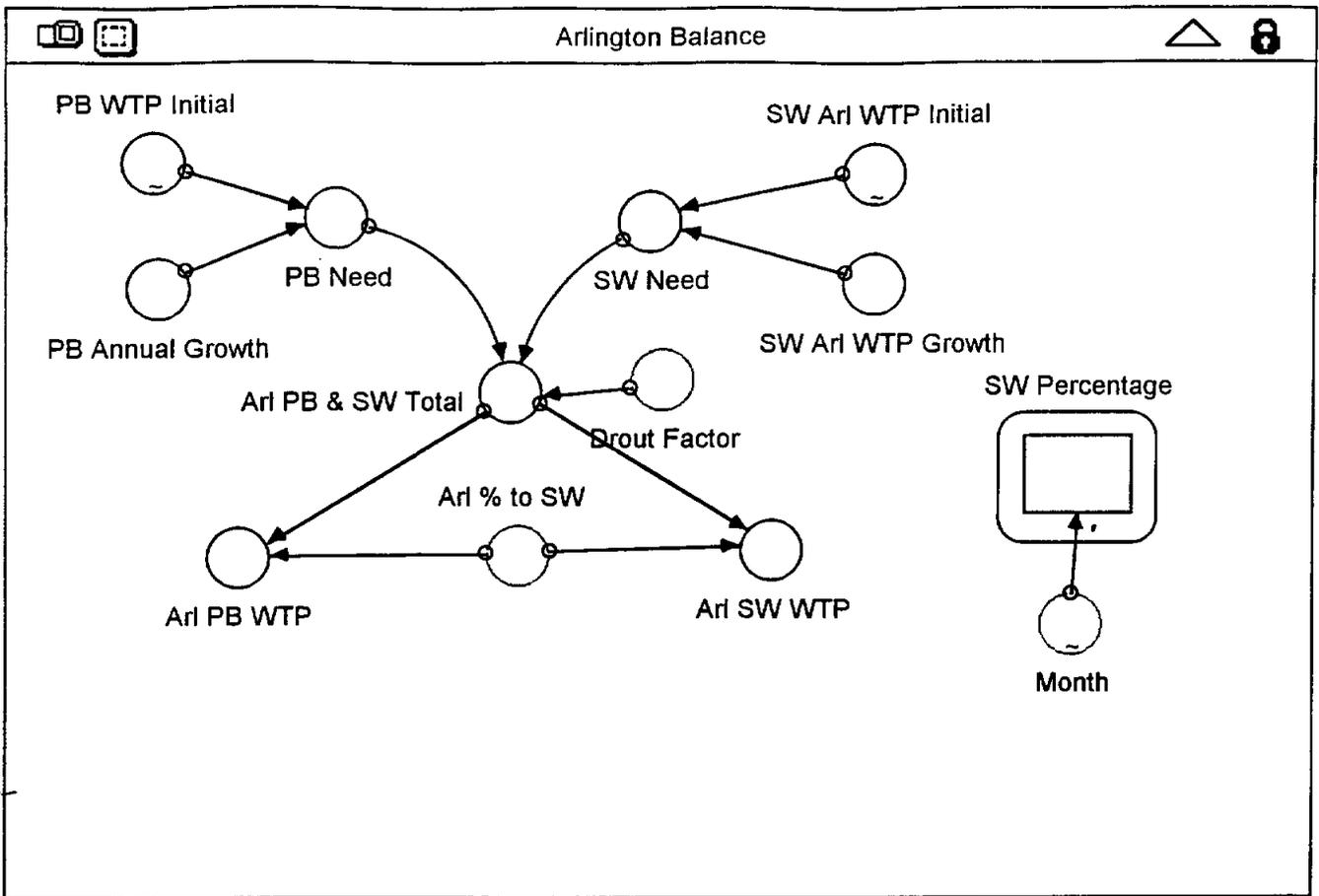


Month

RH Percentage



Month



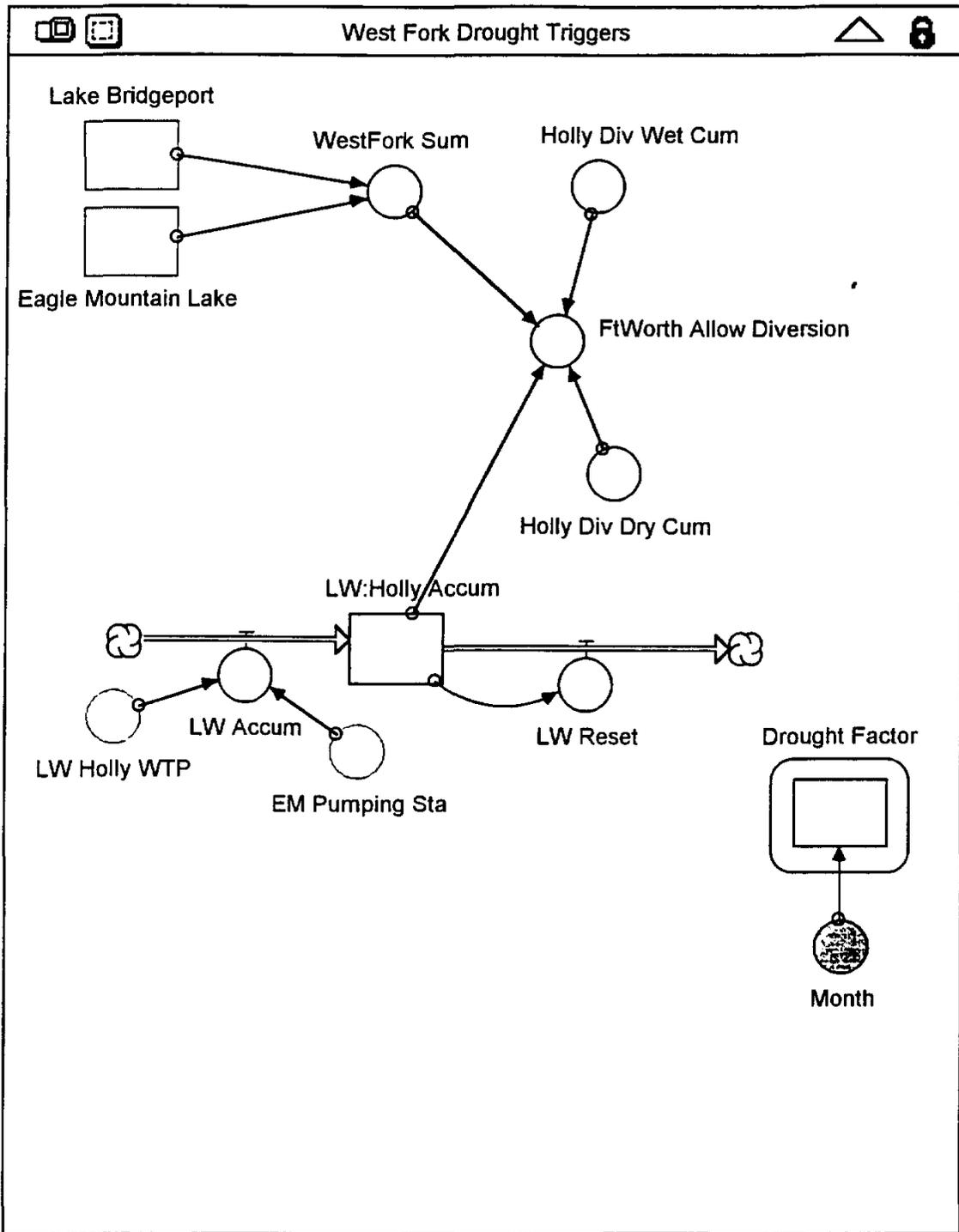


TABLE 4-2**CALIBRATION RESULTS FOR LAKE BRIDGEPORT**

Date	Observed Elevation of Lake Bridgeport	Model Prediction of Elevation of Lake Bridgeport	Elevation Difference in feet
1/1/75	821.19	821.19	0
1/31/75	821.41	821.46	-0.05
2/28/75	824.27	824.35	-0.08
3/31/75	825.19	825.20	-0.01
4/30/75	826.25	826.26	-0.01
5/31/75	831.08	831.09	-0.01
6/30/75	835.88	836.38	-0.5
7/31/75	836.15	836.12	0.03
8/31/75	836.09	836.02	0.07
9/30/75	835.62	835.55	0.07
10/31/75	833.46	835.39	-1.93
11/30/75	832.72	835.40	-2.68
12/31/75	832.32	835.69	-3.37
1/31/76	831.76	835.89	-4.13
2/29/76	831.09	836.02	-4.93
3/31/76	830.28	836.03	-5.75
4/30/76	831.63	836.11	-4.48
5/31/76	832.48	836.03	-3.55
6/30/76	832.83	836.02	-3.19
7/31/76	832.91	835.95	-3.04
8/31/76	830.57	835.53	-4.96
9/30/76	832.38	836.11	-3.73
10/31/76	832.65	836.04	-3.39
11/30/76	833.16	836.03	-2.87
12/31/76	833.18	836.01	-2.83

CHAPTER 5 - PUBLIC INVOLVEMENT

On May 31, 1996, this model was used by the Tarrant County Water Control and Improvement District Number 1 and the Fort Worth District of the U.S. Army Corps of Engineers to conduct a workshop with the local water users. This workshop was held in a meeting room at the Fort Worth Botanical Gardens and involved the organizations listed at the end of this chapter. The model was used in conjunction with spreadsheets developed by TCWCID#1 to educate the District's customers of the importance of their communication and cooperation.

FORT WORTH PRESENTATION

The program began with a short presentation by the TCWCID#1 regarding the systems' overall size, its capacities and physical layout. It continued with a description of the program and model and introduced each of the participants to the roles that they would play, the decisions they would make and the results they would be receiving. The primary participants were divided into four separate groups; the Western Division, the City of Fort Worth, the City of Arlington, and the Eastern Division. Each of the roles were as follows:

The Western Division was responsible for Lakes Bridgeport, Eagle Mountain and Worth and were accountable to the residents living around these lakes regarding lake levels. Its decision making involved defining each of the lake level zone limits, thereby affecting the circumstances under which water is moved from one reservoir to another.

The City of Fort Worth was responsible for distributing its water demand between three water treatment plants; Rolling Hills, Holly and Eagle Mountain. Because Fort Worth is the largest user of the system, this distribution greatly affects the quantity of water pumped through the pipeline and therefore the cost of operations.

As with Fort Worth, the City of Arlington was responsible for distributing its demand between two treatment plants; Pierce-Burch and Southwest. Although Arlington is a smaller user than Fort Worth, almost all of its supply is met by pipeline pumping and it is therefore an important decision maker in the system.

The Eastern Division was responsible for Lakes Arlington, Benbrook, Cedar Creek and Richland-Chambers. The latter two are not subject to operational rules, but Eastern Division establishes target elevations for Arlington and Benbrook and the pipeline operates as necessary to meet those targets. As with the cities of Fort Worth and Arlington, the pumping required to meet lake elevation targets has a great effect on expenses.

To begin the technical portion of the workshop, the most current "real-world" settings for projected usage, lake zone definitions, target elevations, and treatment plant usage were used for a one year analysis. Although the model is flexible enough that it can be operated on a month-to-month basis, with adjustments being made after each 30 day period, this process was deemed to be much too time consuming for a one-day workshop. The model used the rainfall and runoff data previously mentioned (1948 through 1957), combined with these current demands to determine resulting lake levels at each of the reservoirs. These results were then presented to each of the four participant groups so that they could define the settings they wanted to use for the items for which they were responsible. During analysis of the previous year results, and subsequent determination of upcoming year settings, the Engineering Manager for TCWCID#1 issued a long range weather "forecast" to help the groups anticipate rainfall and demand.

This process of running the model, reviewing and discussing the results and adjusting the settings for the next year was repeated for eight cycles. The final year of rainfall data (1957) was then run with the same settings as had been used for the previous year.

The participants in the event were very impressed with the model, its capabilities, and the workshop in general. Several individuals expressed their pleasure at having gained a better insight into the extent of the system and how each user interacted with others users. One of the results of each of the cycles of the model was the annual cost and any associated penalties of the pipeline pumping. Everyone involved realized that those costs, often several million dollars, would have to be passed on to their individual customers. Both the participants and TCWCID#1 recognized the possibility of using the model on a continual basis by updating climatic and demand data and making various projections regarding the future. This would give the TCWCID#1 more quantifiable evidence of the most efficient way to operate the system.

MODEL DEVELOPMENT PARTICIPANTS

Texas Water Development Board
U.S. Army Corps of Engineers, Fort Worth District
Tarrant County Water Control and Improvement District Number 1

WORKSHOP PARTICIPANTS

Texas Water Development Board
U.S. Army Corps of Engineers, Fort Worth District
Tarrant County Water Control and Improvement District Number 1
Arlington Water Utilities
Fort Worth Water Department
Mansfield Water Department
Trinity River Authority
HDR Engineering, Inc.
Camp Dresser & McKee, Inc.

CHAPTER 6 - DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

DISCUSSIONS

The STELLA-II program is very useful in developing a computer model of a water supply system. For a reasonable expense, an experienced program user can model all of the major components of a system and their interconnections and operating rules. This model can then serve the user by allowing both short term and long term investigation of various scenarios of rainfall and population growth to determine potential problem areas. Should such an analysis indicate a short term problem regarding operational expenses or a long term problem regarding potential shortfall in water supply, efforts can then be expended to study the problem in greater detail.

CONCLUSIONS

This modeling program has a great deal of potential as a tool for evaluating a water supply system. A current drought contingency plan for a system can be tested under a variety of conditions, or numerous different contingency plans can be analyzed to establish which may respond best under the widest range of possibilities. Although most water supply systems are not as complicated and flexible as that of Tarrant County, a fully developed STELLA-II model would be very useful in the policy and decision making operations of any system.

RECOMMENDATIONS

Based on the favorable results of the modeling of the Tarrant County system, it is recommended this model be used elsewhere in the state to evaluate water supply systems.