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# Evaluative Methodology for Comprehensive Water Quality Management Planning

H. Lawrence Dyer

July 1, 1973

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# Evaluative Methodology for Comprehensive Water Quality Management Planning*

by

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with contributions from

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Center for Environmental Studies

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## ABSTRACT

Computer-based evaluative methodologies have been developed to provide for the analysis of coupled phenomena associated with natural resource comprehensive planning requirements. Provisions for planner/computer interaction have been included. Each of the simulation models developed is described in terms of its coded procedures. An application of the models for water quality management planning is presented; and the data requirements for each of the models are noted.

## 1. INTRODUCTION

In order to assist the State of Illinois in satisfying the water resource planning objectives required by the 1971 Federal Guidelines and the Amended Federal Water Pollution Control Act of 1972, the Center for Environmental Studies of Argonne National Laboratory has developed a series of computerized techniques. These techniques are considered to represent a codification of the state-of-the-art principles implicit in the comprehensive planning process. Specifically, five computer routines have been developed to serve as a tool for the evaluation of alternative solutions for resource analyses, such as for water quality management studies. This developmental program was sponsored by the Illinois Institute for Environmental Quality under contract number 31-109-38-2656.

A separate computer model has been developed for each task envisioned as part of the planning process: a Socioeconomic/Land Use Model (SELUM) for the projection and allocation of growth activities; a Waste Conversion Model (WCM) (Resource Demand Model) to convert the future levels of growth activities into their appropriate resource demands; and a Facility Cost/Schedule Model (FCSM) to determine the dollar costs and the resource abatement associated with alternative strategies (planning policies) for managing the projected resource demands. For water quality management studies, two models have been developed: a Hydrology Package (HP), which is used to generate and to test alternative scaling procedures for equally probable synthetic or historic flow sequences for a river system; and a Water Quality Model (WQM) for the analysis of resource reaction to alternative strategies for managing the forecast demands (water quality). The first three models have been developed in general terms so that they may be employed for natural resource analyses, and not merely for resource studies. Each of the computerized techniques developed is described in detail in References 1-4.

The following pages present a succinct description of each of the simulation programs developed. A second section presents a discussion of the types of information that may be analyzed by the models. A third section provides a list of the types of data required by the models.

## 2. MATHEMATICAL MODELS

A series of computer-based methodologies has been developed to become an integral part of a natural resource planning process in a comprehensive context. A series approach involving the development of separate, but compatible, models was chosen. Such an approach was adopted to provide for:

a) maximum planner/computer interaction in directing simulations and in analyzing the results of simulations,

b) ease of comprehension of the techniques coded, and

c) maximum utilization of the individual procedures for other natural resource analyses when and where applicable.

### 2.1 Socioeconomic/Land Use Model

A Socioeconomic/Land Use mathematical model (SELUM) has been formulated; it forecasts future levels of demographic, economic, and land use activities. The model is constructed in modular form, in that there is a separate subroutine provided for each activity for which data manipulations particular to a growth entity are to be performed. Also, each computational procedure that is common to the forecasting of all growth activities is contained within a separate subprogram. Separate subprograms are also provided for manipulation of the majority of input data required by the model and of output results generated by it. Figure 1 shows the general structure of the program.

The model recognizes three levels of geographical resolution:* regions, subregions, and sub-subregions. A region is a grouping of subregions, while a subregion is composed of a number of sub-subregions. The relationship between a subregion and the sets comprising it is determined by program input. Separate

*For example, a river basin (region) containing counties (subregions) which contain municipalities (sub-subregions).

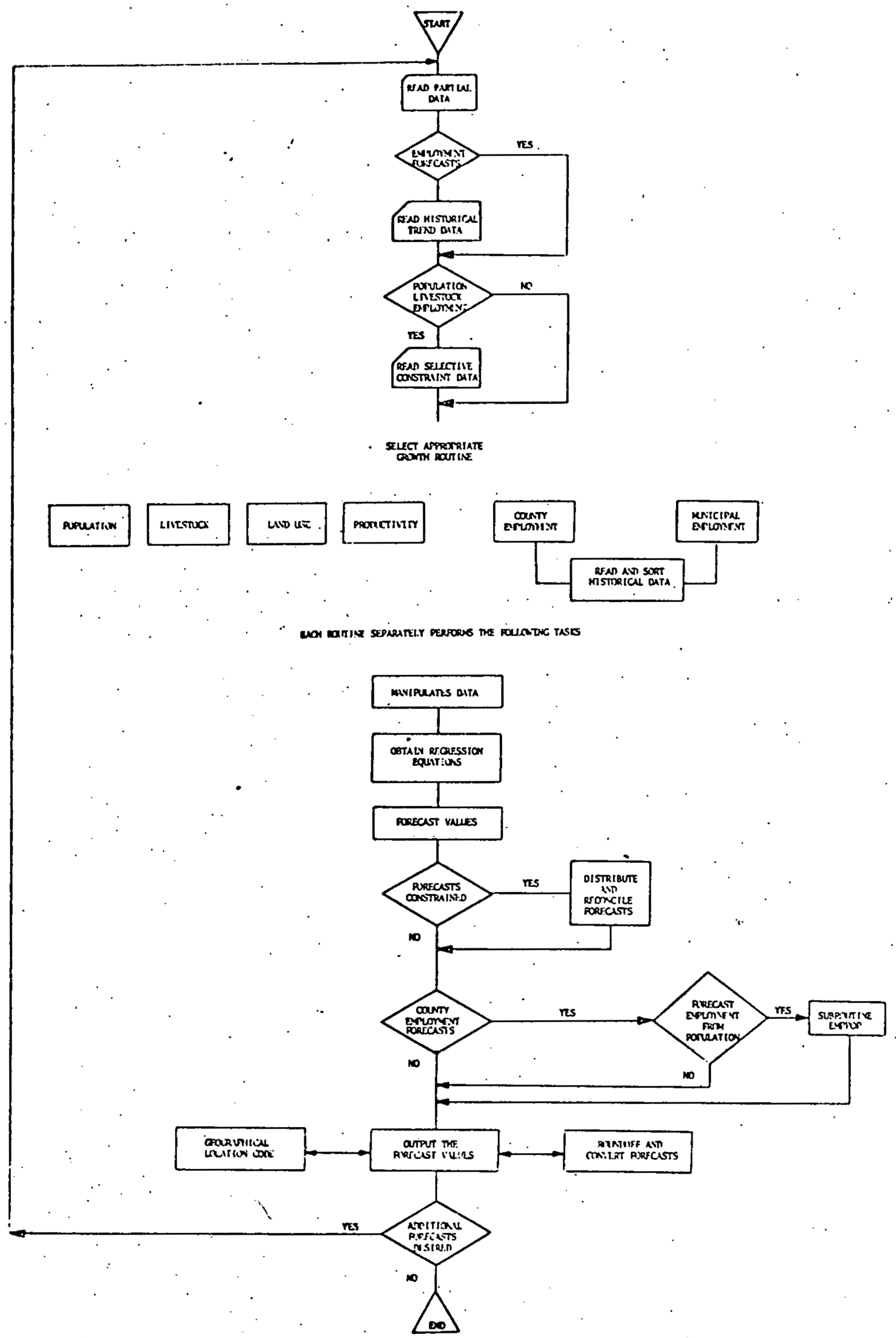


Fig. 1 General Structure of the Socioeconomic/Land Use Model

independent functional forms, for entities to be projected, are obtained for each level of resolution. Growth projections are made from these functional relationships. The projected entities are distributed to the subsets using a proportional shift technique. Reconciliations, based on the assumption that the projections of aggregated data are more realistic than the projections of the individual values thus aggregated are made; that is, projections on a sub-subregional and/or a subregional level are usually reconciled to a regional projection.

The Socioeconomic/Land Use Model is a trend model in which the historic patterns of growth phenomena are functionalized and used as a basis for projecting future levels of those growth activities. To perform realistic projections and reconciliations for all growth entities, a method for constructing representative subsets or constraint groups is provided via program input. Figure 2 shows the subset grouping methodology provided. The subsets defined may be combinations of subregions whose growth trends are sufficiently similar that it is desirable to allow them to grow together and to reconcile their future growth together. However, there may be subregions that demonstrate no common growth characteristics; therefore, subregions may also be allowed to grow individually. When arbitrary subsets are used in the computational procedure, forecasts of those growth entities for the overall region are obtained by summation of future values over the subregional values.

Additionally, the model contains an option wherein control totals for future subregional population values may be input to the model and used as a basis for redistributing the forecasted levels. These control values are exogenous to the model. When the option is activated, these totals are preserved for all future years. All forecasts are made by the model as usual. However, the exogenous control values, as opposed to similar values computed by the model, are used as a basis for distributing and reconciling the forecast values.

NGRPS = The number of arbitrary subsets or constraint groups

NCY = The total number of subregions comprising the region

NA,NB = The first and last subregion comprising the subset

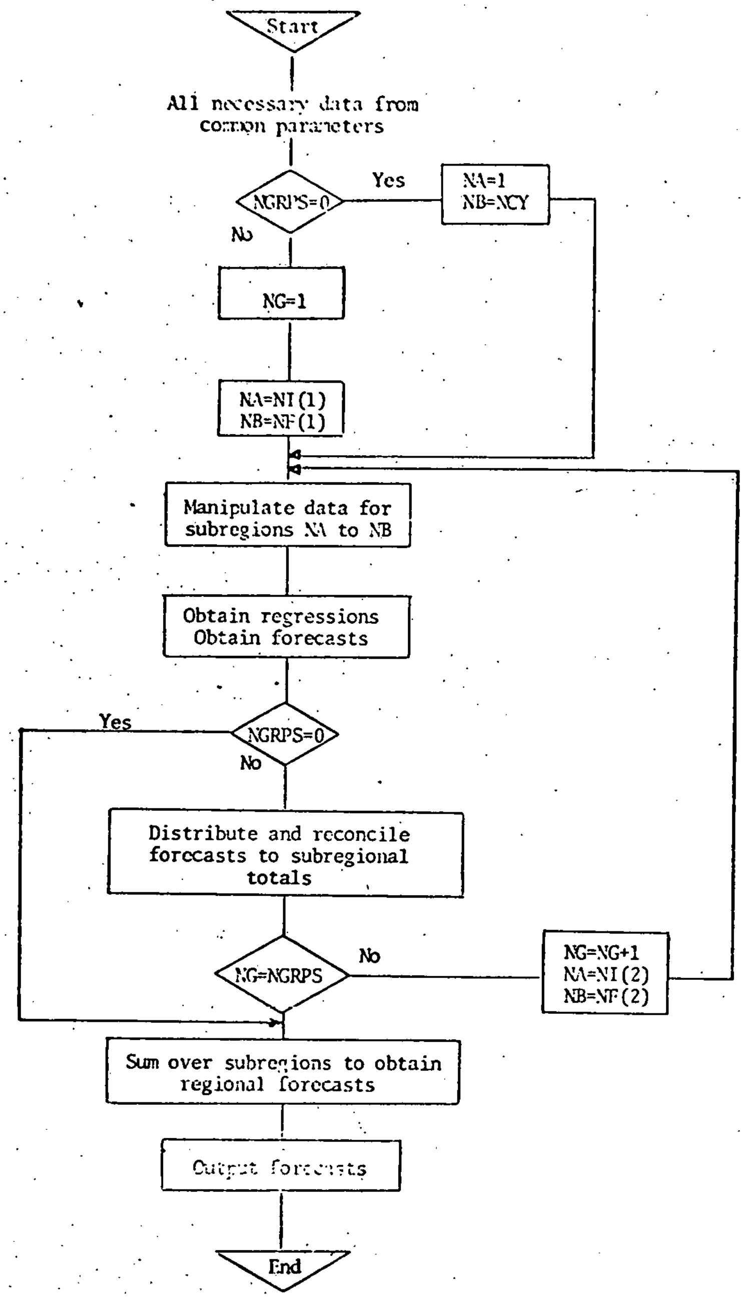


Fig. 2 Constraint Grouping Computational Procedures

Another option within the program provides for the computation of employment by SIC classification within the various political boundaries from the future control total values of subregional population. For this option a ratio of total employment to total population on a subregional scale is functionalized with population as the independent variable. Future levels for this ratio are obtained from the functional relationship and the future control population values. The ratio, in addition to standard employment projections, is then used for distributing the forecasted levels to SIC class at the appropriate level of resolution.

The ability to preserve and to base computations on future values for growth entities, exogenous to the model, increases the sophistication of the model and provides for alternative computational methodologies which may be used as a primary forecasting device or as a means for verifying previously projected values.

## 2.2 Waste Conversion Model

One objective of any program concerning the quality of a natural resource such as air, water, or land is to ascertain the effects of growth on the resource. The types of growth may be industrial, population, agricultural, or others. Therefore, the amount and type of waste generated by each type of growth (pertinent to the resource being considered) must be determined. These waste loads may then be aggregated over the various generating agencies (or treated individually) in order to estimate the burden that will be placed on a resource. Such aggregations may be performed for a present time period, or for future time periods, depending on the type of information required as a study goal.

The Waste Conversion Model (WCM) has been written to convert current and/or projected levels of economic, demographic, and land use related growth into their appropriate waste parameters. The model is general, in that the waste relationships for various growth entities are formulated external of, and are exogenous to, the model. The computational method is structured so that waste loads and concentrations of various pollutants may be determined for such point sources as industrial manufacturing operations and domestic operations, and/or for such nonpoint sources as land runoff. The model is constructed in modular form in that there is a separate subprogram for each type of waste-generating growth agency, as shown in Fig. 3. Thus, if alternative methodologies are developed for the analysis of included growth entities, or additional waste generating agencies are of importance, then they may be easily incorporated into the model.

The model may be used for the estimation of point source and nonpoint source waste loads. The point source loads represent a burden that is normally exerted on some type of waste collection and treatment facility, where the concentrations of various pollutant species are reduced, prior to their imposition onto an assimilative body (e.g., a river system). The composition of these point source waste loads is determined from the projected levels of demographic and/or economic activity, and combined on the basis of exogenous decision variables. Thus an analyst (planner) may investigate alternative policies based on the magnitude of combined waste loads that will require treatment, thereby investigating future waste load allocations and/or alternative construction schedules for waste treatment. The next three models provide the cost and the water quality associated with the combined point source waste loads.

Nonpoint source waste loads are estimated from input levels for future land use allocations and for the forecast levels of growth activities associated with a particular land use category. From additional program input concerning runoff coefficients, which are activity dependent, and annual rainfall, a runoff flow and various pollutant specie concentrations are estimated.

The model, in effect, is a resource demand estimator wherein projected levels of a growth activity are converted into their appropriate natural resource

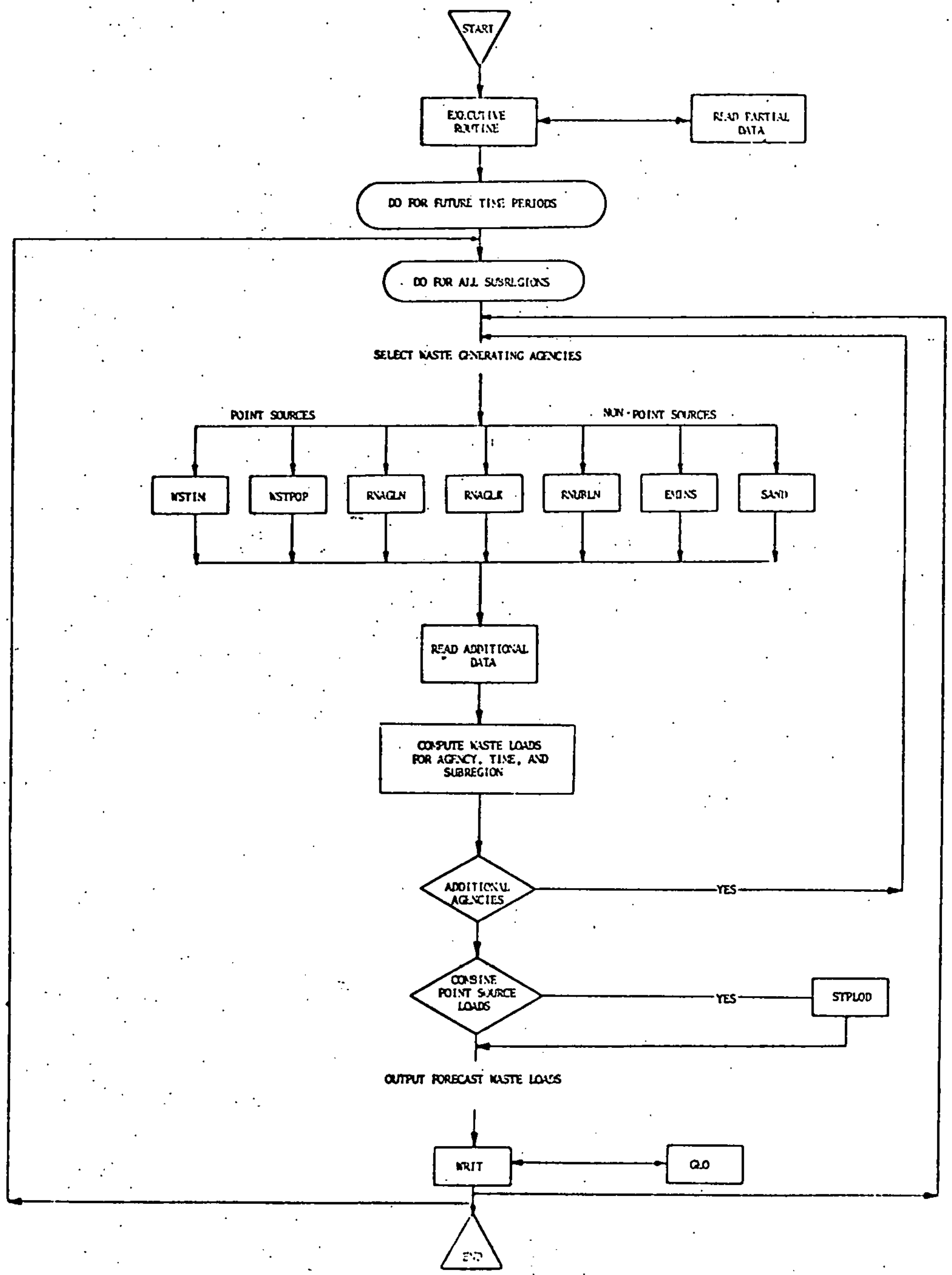


Fig. 3 General Structure of the Waste Conversion Model

each treatment facility location. It may be decided to construct a new wastewater treatment plant, to upgrade an existing plant, to expand an existing plant, to build an interceptor, which will carry the waste loads to some other wastewater treatment plant, or to do nothing. This decision must be described for each location and each time period. If it is decided to build an interceptor to a regional wastewater treatment plant, then information is required regarding the location of the receiving plant, the distance to the receiving plant and the type of grading that will be encountered. If it is decided to do nothing, a program option allows for the automatic expansion of an existing facility whenever the actual flow through a facility is approximately at the design capacity of that facility (determined from input). For instances where existing facilities are operated at excess capacity, the influent flow is divided such that the design flow cycles through the plant where the pollutant specie concentrations are appropriately reduced. The excess flow (actual minus design) is bypassed. The plant effluent is then combined with the bypass flow according to continuity considerations.

The computational structure of the model is shown in Fig. 4. In each time period the program computes a design capacity based on a weighted average (input) of the future wastewater influent flow rates, together with any effects due to interceptor systems. Also, a construction cost inflation index is estimated; to be used in the subsequent cost determinations. The program then executes the appropriate construction strategy. The costs in terms of construction (based on a design flow), operation and maintenance (based on actual flow), amortization, and depreciation are computed for the strategy. Next, the wastewater effluent specie concentration is determined. Similar computations are performed for all locations and for all time periods. At the conclusion of these analyses, a time series of annual accumulative costs, for each location, is constructed (amortization, depreciation, and operation and maintenance). Each of these entries demands. Since the factors that relate growth to demand are exogenous to the model, it may be applied to any natural resource provided the data are available.

## 2.3 Facility Cost/Schedule Model

Strategies with regard to the siting of wastewater treatment facilities, the upgrading of wastewater treatment plants to a higher efficiency of waste removal, the expansion of existing facilities to accommodate larger flows, and/or the consolidation of municipal plants into larger regional systems represent water quality and the associated cost. The objectives of the Facility Cost/Schedule Model are to measure the relevant costs of such policies on a basinwide scale and to determine the effluent concentrations of various species contained in the wastewater influent, which has been processed by an existing, modified, and/or constructed facility. These pollutant concentrations and wastewater effluents may then be employed as partial input into a water quality, or a natural resource simulator.

The computations are input dependent in that parameters are required to describe the program control options, the existing facilities inventory (location dependent), the waste loads to be treated (time and location dependent), and the alternative strategies to be evaluated (time and location dependent). The program control values set the assumed life times for existing and/or constructed facilities, the number of locations to be considered in the analysis, the number and length of time intervals to be considered, the anticipated treatment efficiencies for the various processes, the ratio of sewer costs to treatment costs to be used at each location, and the flow weighting factors to be used to determine the excess capacity that should be designed into each facility constructed.

The input strategy describes the construction alternatives to be evaluated. An analyst may make one of five basic decisions for each time period at

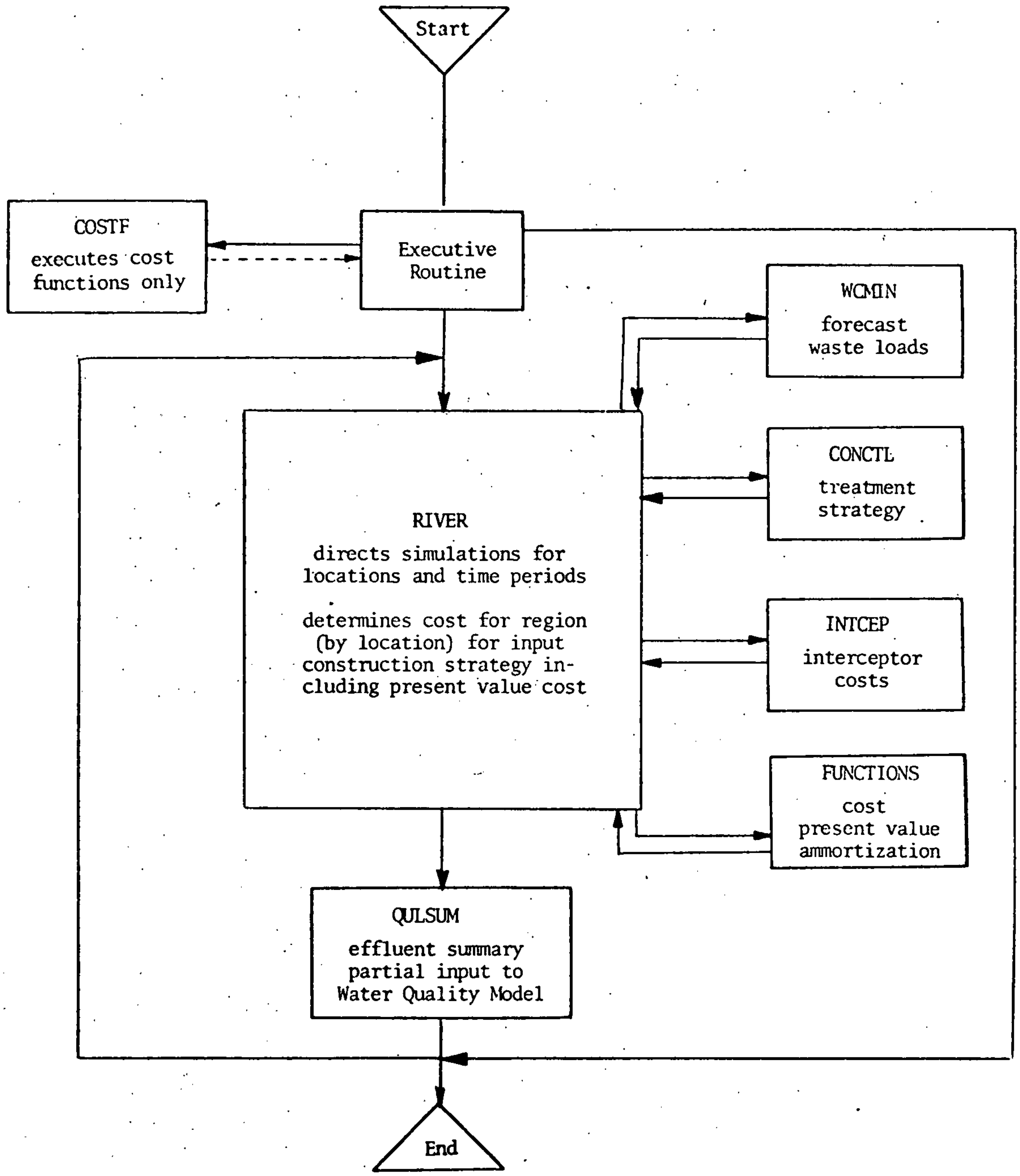


Fig. 4 General Structure of the Facility Cost/Schedule Model

is presented valued back to a base year dollar. These present value entries are then combined (with or without depreciation expenses) to form a total present value cost for each location, over time, and for the specified construction strategy. These present value costs are summed over all locations to provide one, total present value dollar figure representative of the regional burden incurred. This regional burden figure, plus other similar values, may then be used (in addition to a water quality model) for the determination of "cost-effective" wastewater treatment strategies.

## 2.4 Water Quality Model

The water quality simulation package consists of a group of mathematical models (or sub-packages) that are linked together by programmed logic. The purpose of the water quality simulator is to relate waste loads entering the river system (i.e., from the FCSM) to the quantity and to the quality that results at selected points, in terms of chosen water quality indices. Both conservative and nonconservative (degradable) water quality indices may be modeled using the existing package. The concentrations of up to five indices may be determined simultaneously during a single simulation.

The simulation of a river, by the model, is based upon the branched river scheme developed by Pisano.[5] For such an abstraction, a river system is codified into a configuration of node points where a particular node is of some utilitarian or geometric interest. For the existing simulation package, the node points must be classified as either one of five types:

1) A water quality or test point
2) A waste discharge point
3) A channel dam site
4) A junction point: must be limited to the confluence of streams
5) A termination point

Because of the large number of variables included, an abstracted river system may contain up to a maximum of 50 node points per simulation. These nodes must contain an endpoint and may be composed of up to the maximum number of each of the following node types: 15 test points, 25 waste discharge points, 15 dam sites and 10 junction points. In order to circumvent storage limitations, multiple simulations may be performed. For these cases, the computed quantities for the last few nodes processed are retained and are used as initial points for the next simulation.

The computer model is primarily an accounting routine wherein pollutants are routed from point to point in a river system. The general sequence of computational events is shown schematically in Fig. 5. The model consists of a main or executive routine that accesses the main processing routines: these include a simulator and a statistical summary program. The simulator branch accesses input data routines, echo output routines and the auxiliary routines. The logic for the simulation analyses is shown in Fig. 6: for each time frame being simulated, appropriate gage flows, determined external to the program, are adjusted to obtain flows for every point within the system. At each point, the existence of waste inputs, water demands, tributary streams, or channel dams is checked. Depending on the results of this check, waste loads or tributary flows are added and mixed (perfect mixing is assumed) with the upstream flow, water withdrawal quantities are subtracted, and channel dam characteristics are referenced, as appropriate. Once all changes taking place at a point (or node) are considered, the program moves to the next downstream point. During the move downstream, nonconservative constituents are degraded, and, if dissolved oxygen concentrations are being simulated, a check is made to determine if a critical deficit occurs between the two nodes. This process is repeated until the end of the study area is reached, at which time statistical information is extracted from

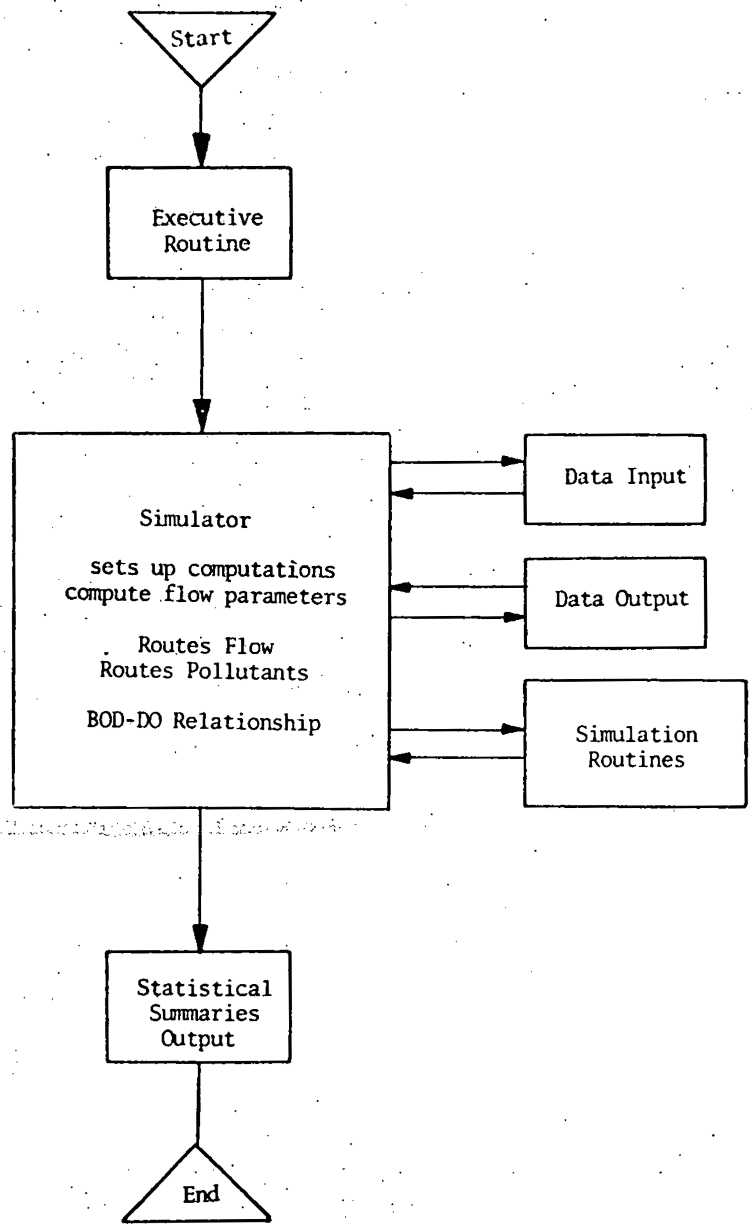


Fig. 5 General Structure of the Water Quality Model

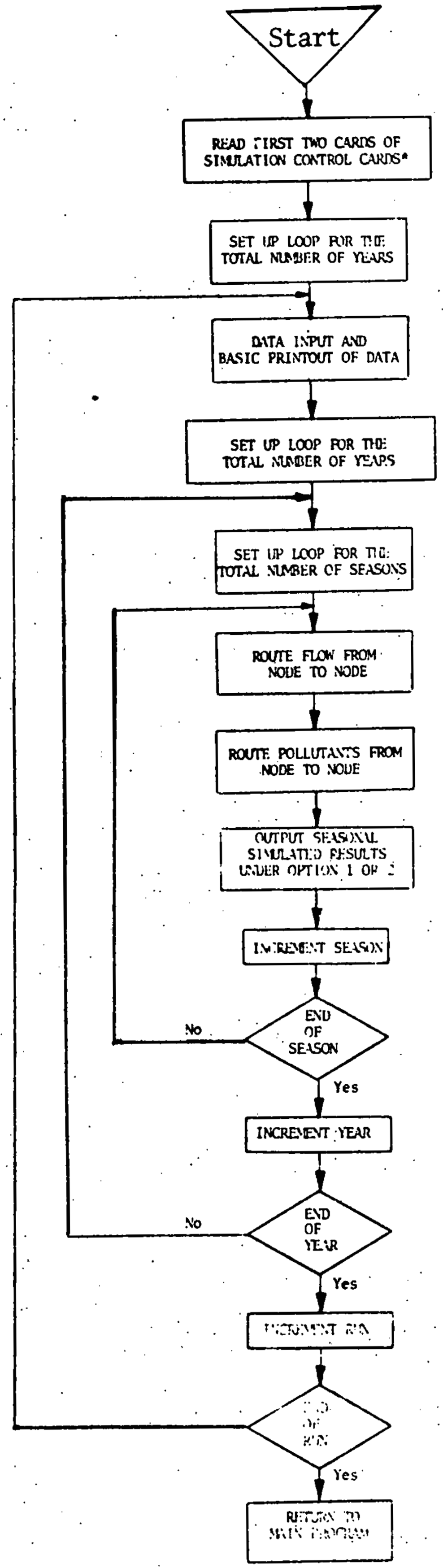


Fig. 6 Logic of Simulation Routine

the simulated results, appropriate output is generated, and the program returns to the starting point for the next time frame. Upon consideration of the last simulation for a given set of conditions, the model generates overall statistical summaries of the simulated water quality.

## 2.5 Hydrology Package

Hydrological considerations are prerequisite to the analysis of water quality indices. Typically, flows at any particular point in a river system vary over a wide range, and flow patterns of different streams, within a river basin, vary considerably. The history of flows at gaging points within a basin may be used for determining the extent of flow variations and may also be used to predict flow sequences to be expected in future years. Since flow sequences observed historically are not likely to be repeated in the future, Monte Carlo techniques are used to generate probable future flow sequences. Such an approach permits an evaluation of alternative pollution abatement policies under a variety of likely future hydrologic conditions, and the calculation of appropriate probabilities to evaluate the degree of risk associated with each policy.

The computation of hydrologic parameters required for water quality analyses is done by the Water Quality Model. The procedure for these calculations is presented in Fig. 7. The Water Quality Model accepts as input flow data for all basis gages in the codified river system. These data may be either historical flows, or synthetic flows generated by the Hydrology Package. The input flow record is extended to all points of interest on the codified river system using scaling procedures based on input drainage areas. The average velocity and the hydraulic depth at each critical point, plus the time of travel for each reach, are computed using exponential relationships. These calculations are based either on actual measured cross sections at the critical points, or on generalized hydraulic geometry equations (for free flowing streams and for channel dam pools) developed by the Illinois State Water Survey.

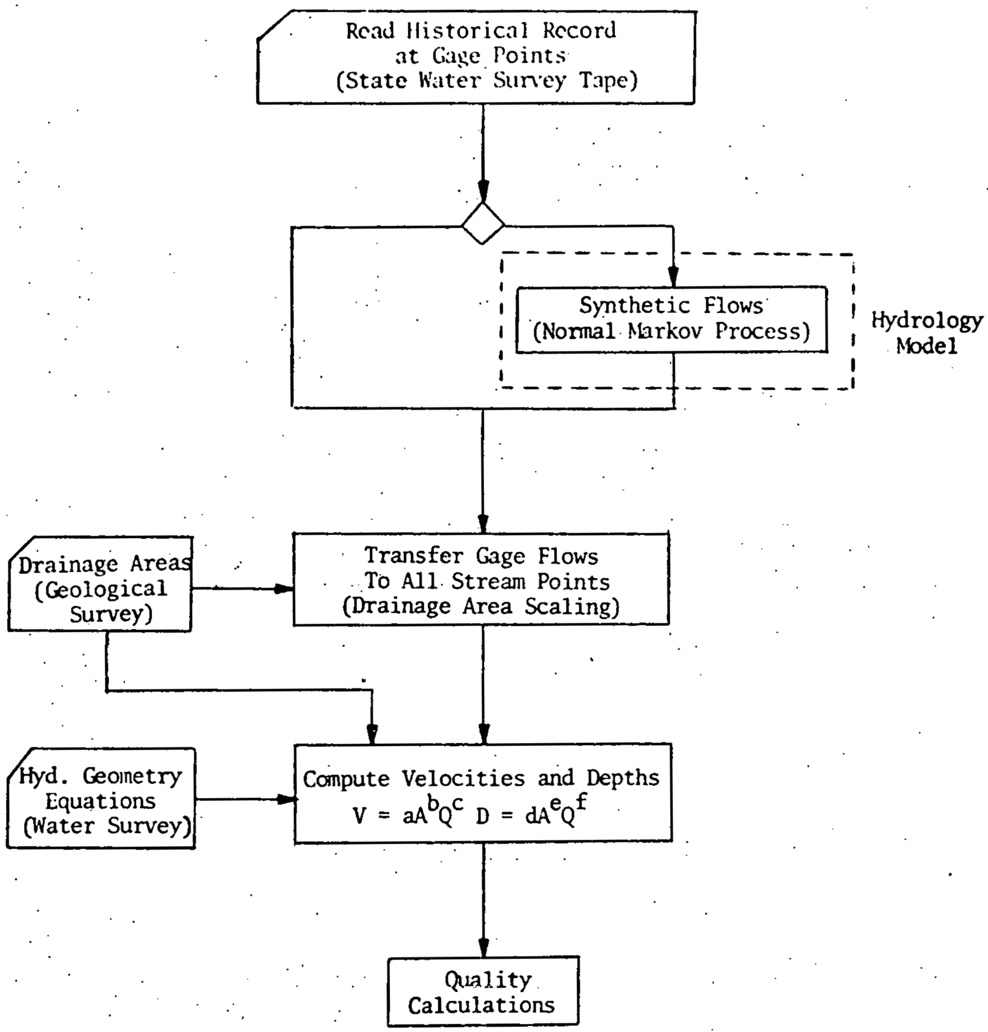


Fig. 7 General Structure for Hydrologic Computations

The Hydrology Package consists of three computer programs. Two of those programs (MEAN and MIN) have been developed for generating and testing synthetic flow sequences. Each program accepts historical flow data, via magnetic tape, for up to 25 gaging stations. Program MEAN is used for the generation of monthly average flows; program MIN is used for the generation of minimum 7-day average flows for each month. A separate program (SCALE) has been developed to test alternative drainage area scaling schemes. Such schemes are required in order to extend existing or synthetically generated flow sequences, at basis gages, to other points of interest (where flow values are required) in a river system. The scaling factors are based on official drainage areas obtained from the USGS.

## 3. APPLICATION OF THE SIMULATION MODELS

The computerized techniques presented in the previous section were executed sequentially in order to assess the water quality and the assimilative capacity of the river system in the Illinois portion of the Rock River basin. The entire watershed is located in southeastern Wisconsin and in northwestern Illinois. The Illinois portion of the basin includes approximately 5,300 sq. mi., with approximately 163 miles of the course of the Rock River. The application of the computer models for such a study is shown in Fig. 8.

The Socioeconomic/Land Use Model was used to generate forecast levels of growth activities from historic data and exogenous growth strategies. The growth activities included population, selected industrial manufacturing employment, livestock inventories by specie, and land use categories. The results obtained are presented in Fig. 9. The Waste Conversion Model was used to convert the projected levels of growth activities into their representative point source and nonpoint source waste loads. These computations were based on exogenous emission factors and planning strategies. The computed point source waste loads (determined from curve D of Fig. 9.1, and curve C of Fig. 9.2), for various locations within the basin, were compared with similar reported values from actual treatment plant operations[6] for a comparable time period. The results of those comparisons, in terms of flow, untreated BOD (treatment plant influent), and treated BOD (treatment plant effluent - determined using removal efficiencies contained in the Facility Cost/Schedule Model) are presented in Fig. 10. Those comparisons indicate the "reasonableness" of the methods employed.

From a study of the magnitude of the point source waste loads, it was possible to isolate twenty-six places, primarily located on the main body of the Rock River, that accounted for approximately 95% of the industrial and 60% of the domestic waste loads in the basin. These locations were then employed for an assessment of the assimilative capacity of the Illinois portion of the Rock River.

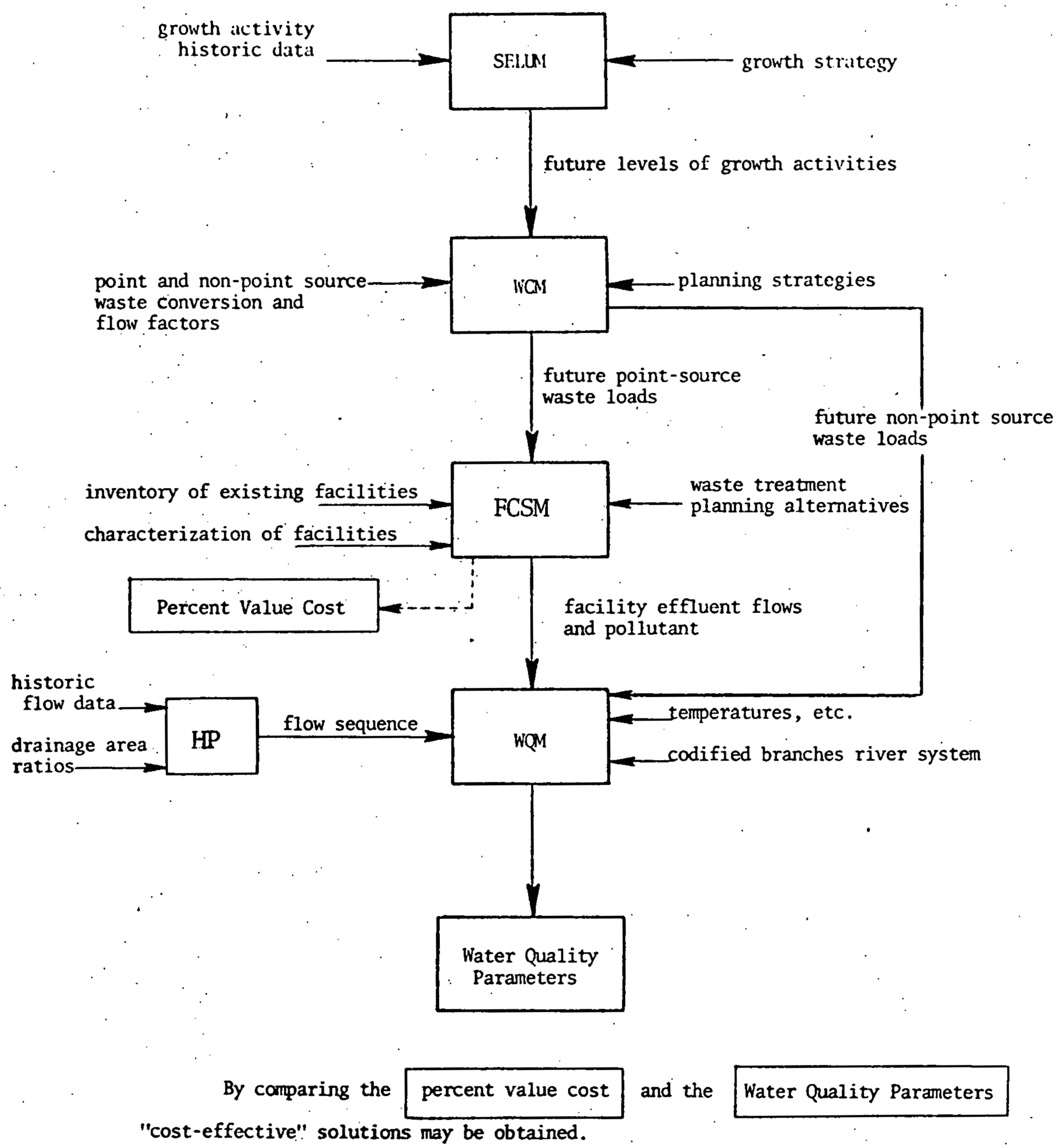


Fig. 8 Schematic Representation of Model Execution Sequence for Water Quality Management Planning Studies

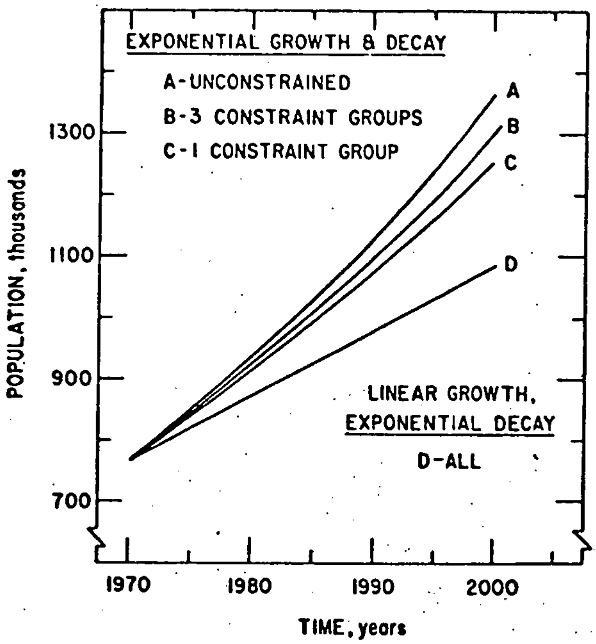


Fig. 9.1 Population

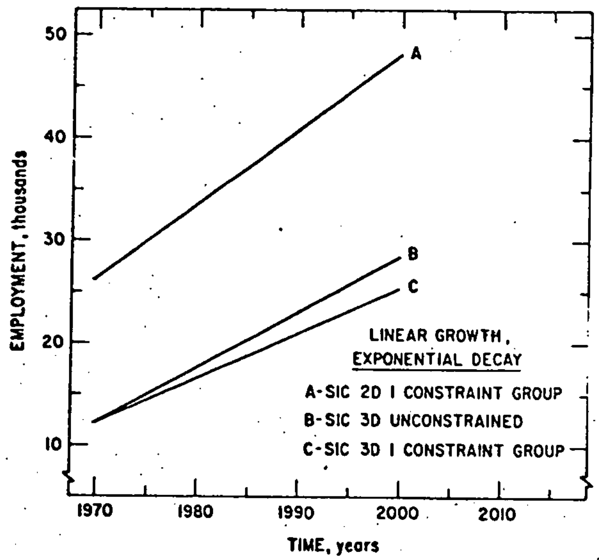


Fig. 9.2 Selected Employment

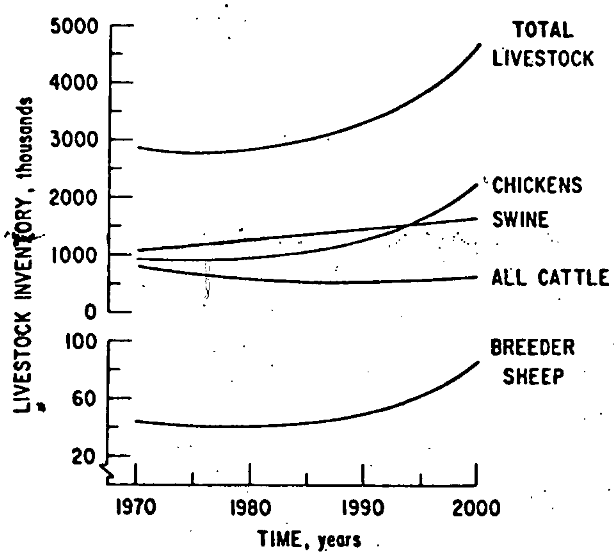


Fig. 9.3 Livestock

| LAND ACTIVITY | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|
| PASTURE | 343,000 | 183,000 | 106,000 | 69,000 |
| CROP | 2,138,000 | 2,124,000 | 2,102,000 | 2,062,000 |
| IDLE | 500,000 | 560,000 | 557,000 | 547,000 |
| TOTAL AGRICULTURE | 2,981,000 | 2,867,000 | 2,765,000 | 2,678,000 |
| URBAN* | 126,600 | 126,500 | 126,600 | 126,600 |
| SAND & GRAVEL* | 10,000 | 10,000 | 10,000 | 10,000 |
| OTHER | 82,400 | 196,300 | 298,400 | 385,400 |
| BASIN TOTAL | 3,200,000 | 3,200,000 | 3,200,000 | 3,200,000 |
| PERCENT OF BASIN TOTAL | | | | |
| PASTURE | 10.7 | 5.7 | 3.3 | 2.2 |
| CROP | 66.8 | 66.4 | 65.6 | 64.4 |
| IDLE | 15.6 | 17.5 | 17.4 | 17.1 |
| TOTAL AGRICULTURE | 93.1 | 89.6 | 86.3 | 83.7 |
| URBAN | 3.9 | 3.9 | 3.9 | 3.9 |
| SAND GRAVEL | 0.3 | 0.3 | 0.3 | 0.3 |
| OTHER | 2.7 | 6.2 | 9.5 | 12.1 |
| BASIN TOTAL | 100.0 | 100.0 | 100.0 | 100.0 |

* ESTIMATED

Fig. 9.4 Land Utilizations (Acres)

Fig. 9 Projections of Growth Activities for the Rock River Basin

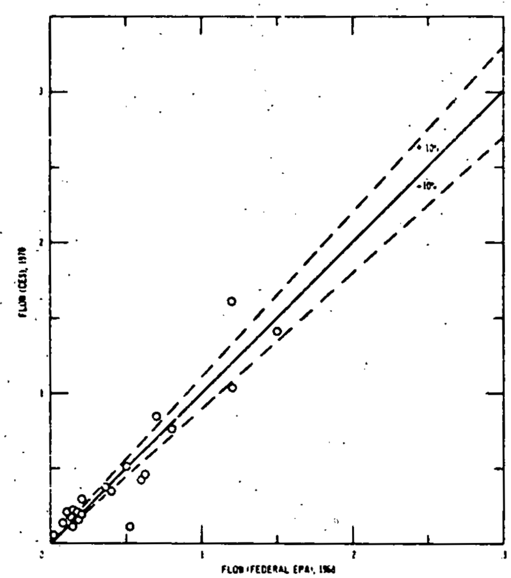

Fig. 10.1 Flow (MGD)

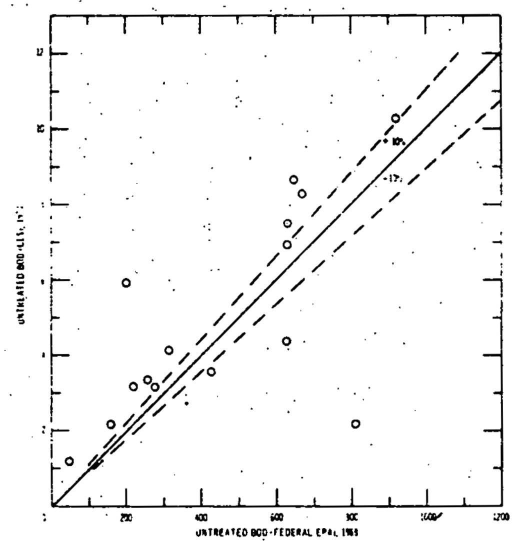

Fig. 10.2 Untreated BOD (mg/ℓ)

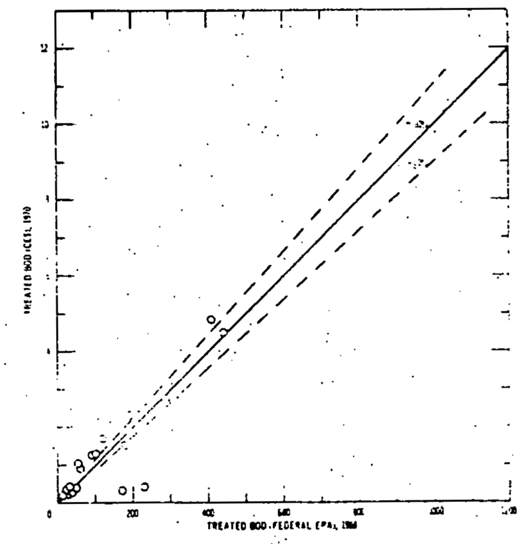

Fig. 10.3 Treated BOD (mg/ℓ)

Fig. 10 Comparison of Computed Parameters with Similar Reported Values[6]

Four alternative wastewater treatment strategies, over a 30-year planning period, were evaluated using the Facilities Cost/Schedule Model. These evaluations were in terms of a present value regional burden (depreciation expenses were not included), and the associated treatment facility effluents. Each of the strategies, as well as the resultant regional burden, is presented in Table 1. Strategy A consisted of operation and maintenance costs associated with the operation of existing facilities. Plants operated at excess capacity were assumed to bypass the excess flow; plant effluent and the bypass flow were combined prior to imposition onto the river. This strategy, therefore, represents a base over which all others may be compared. Strategy B included the upgrading of five primary facilities to secondary plants by 1975. Strategy C included the expansion of fourteen existing facilities (no upgrading of process type) over the forecast period. Strategy D included the upgrading and expansion of all existing facilities to include the addition of microscreens by 1980.

Table 1

Present Value Regional Burden

| Strategy | Present Value Cost (1970) |
|---|---|
| A - no change | $11,000,000.00 |
| B - primary to secondary | $17,150,000.00 |
| C - no change, expansion | $20,400,000.00 |
| D - addition of microscreens | $34,000,000.00 |

The effluent flows and specie concentrations were imposed on the river system and water quality parameters were determined using the Water Quality Model and the Hydrology Package. For these analyses, 50 years of synthetically generated, mean-monthly flow sequences were used at each point of interest on the river system. The results of the simulations, in terms of concentrations of dissolved oxygen along the main branch of the Rock River, for the effluents associated with Strategy A, are shown in Fig. 11. These results show that, even though several facilities were operated at excess capacity, the river was capable of assimilating these wastes, in terms of the flow sequences employed. However, these results are preliminary in that industrial discharges were not included, runoff phenomena were approximated, mean-monthly flow sequences were used, and a nitrogenous oxygen demand was not included.

Comparison of the regional burden (such as those values presented in Table 1) with the associated water quality indices (such as those presented in Fig. 11), shows that cost-effective planning policies may be isolated. Additionally, the codified procedures may be used to identify those problem areas of a river system (perhaps tributaries) that will require further, more detailed analyses. For example, Effluent Limited Segments and Water Quality Limited Segments may be defined. Also, in relation to Water Quality Limited Segments, the techniques may be used for defining the types of data required, and the locations where these data should be gathered by a segment monitoring program. Such programs will be necessary in order to determine future waste load allocations on certain segments. Furthermore, should a national land use policy be adopted, the methods presented herein could be used for relating those policies to growth parameters, waste loads, and water quality.

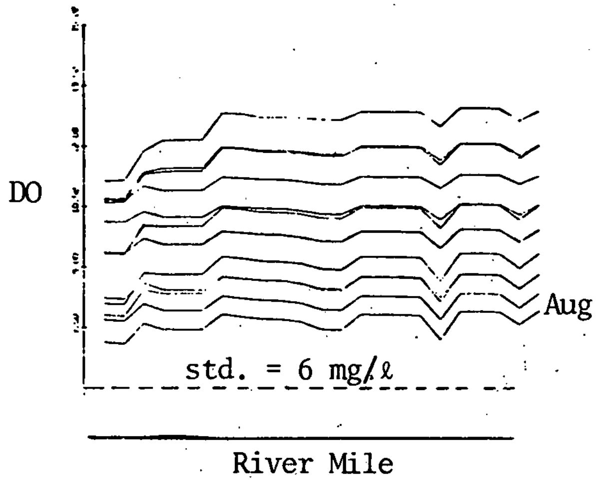


Fig. 11.1 1970 AD

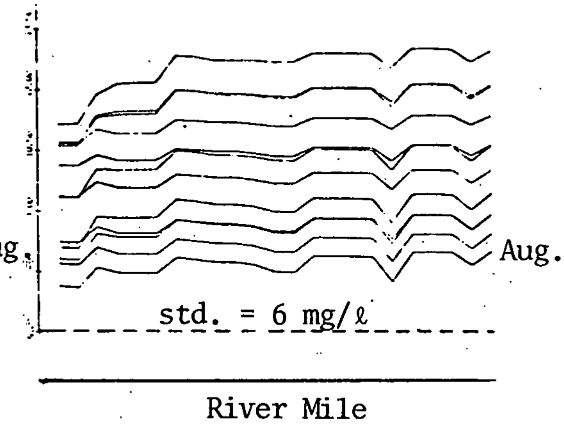


Fig. 11.2 1980 AD

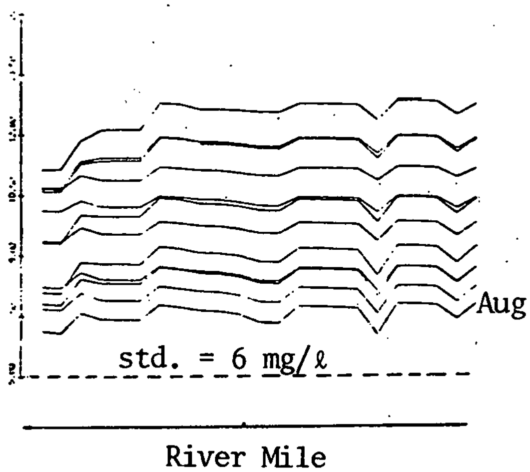


Fig. 11.3 1990 AD

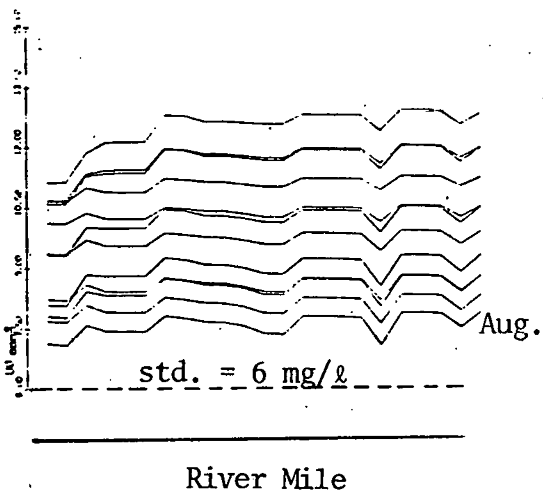


**Fig. 11.4 2000 AD**

Fig. 11 Monthly Dissolved Oxygen Concentrations (mg/ℓ) as a function of River Mile for the main body of the Rock River, obtained using the effluents associated with Strategy A.

## 4. DATA REQUIREMENTS

This section is included in order to convey the magnitude and types of data required to execute the simulation models. The included information is brief; more detailed discussions, as well as the indication of sources of data, are presented in References 1-4.

Socioeconomic/Land Use Model

- Identification of the subregions and the sub-subregions within the boundaries of interest
- Historical trend data on
  - population - by sub-subregion and subregion
  - employment by SIC and sub-subregion
  - livestock by specie and subregion
  - land utilizations - agricultural, urban, etc.
  - industrial productivity by SIC and location
- Growth strategies

Waste Conversion Model

- Emission factors for domestic and industrial processes
  - water use and pollutant concentrations by location
  - industrial operations by SIC and location
  - sewage treatment facilities by place and the population served, the industrial wastes treated (amounts)
  - for nonpoint sources, the average annual rainfall
- Planning decision variables for combining point source waste loads

Facilities Cost/Scheduling Model

- Sewage treatment plant inventory
  - location, design flow and type of facility
- Cost functions for construction and operation and maintenance by location and type of plant optional - these functions are contained in the

model but may be changed if desired

- Wastewater collection and treatment strategy - planning variables
- Point-source waste loads (flows and specie concentrations) - may be supplied by the Waste Conversion Model

Water Quality Model (including hydrology)

- Define node points on the river system
  - water quality station locations
  - stream gage locations
  - channel dam locations
  - identify diversions
- 7 day-10 year low flow map
- River miles for node system
- Drainage areas
- Flow data
  - flow tape (historic)
- Hydraulic geometry
  - channel dam characteristics
  - cross sections (or generalized hydraulic geometry expressions)
- Stream data (node dependent)
  - deoxygenation coefficients, $K_1$
  - constants in the generalized velocity and depth expressions
  - backround concentration of BOD in nonpoint inflow
  - backround concentration tape* (optional method for generating backround concentrations)
  - existing or desired water quality standards
  - stream temperatures

*The model is capable of generating a synthetic record of location-dependent background pollutant concentrations from ample historical data in the same manner as synthetic flow sequences are produced. These location-dependent values are correlated with flow in order to extend the record to other desired locations.

- Waste discharge data
    - flow rates and pollutant concentrations may be supplied by the Facilities Cost/Scheduling Model

## 5. REFERENCES

Documents 1 to 4 are documented in FIRST DRAFT form only, final versions of them will be available in the near future.


1. The Illinois River Basin Pilot Project, Appendix A, the Hydrologic Simulation Model.
2. The Illinois River Basin Pilot Project, Appendix B, the Water Quality Model.
3. The Illinois River Basin Pilot Project, Appendix C, the Socioeconomic/Land Use Model, the Waste Conversion Model.
4. The Illinois River Basin Pilot Project, Appendix D, the Facilities Cost/Scheduling Model.
5. Pisano, W. C., "River Basin Simulation Program," Federal Water Quality Administration, AD No. Ad673564, August, 1968.
6. "1968 Inventory Municipal Waste Facilities - Region V, A Cooperative State Report," Environmental Protection Agency, Office of Media Programs, Water Programs, No. OWP-1 - Volume 5, USGPO, 1971.