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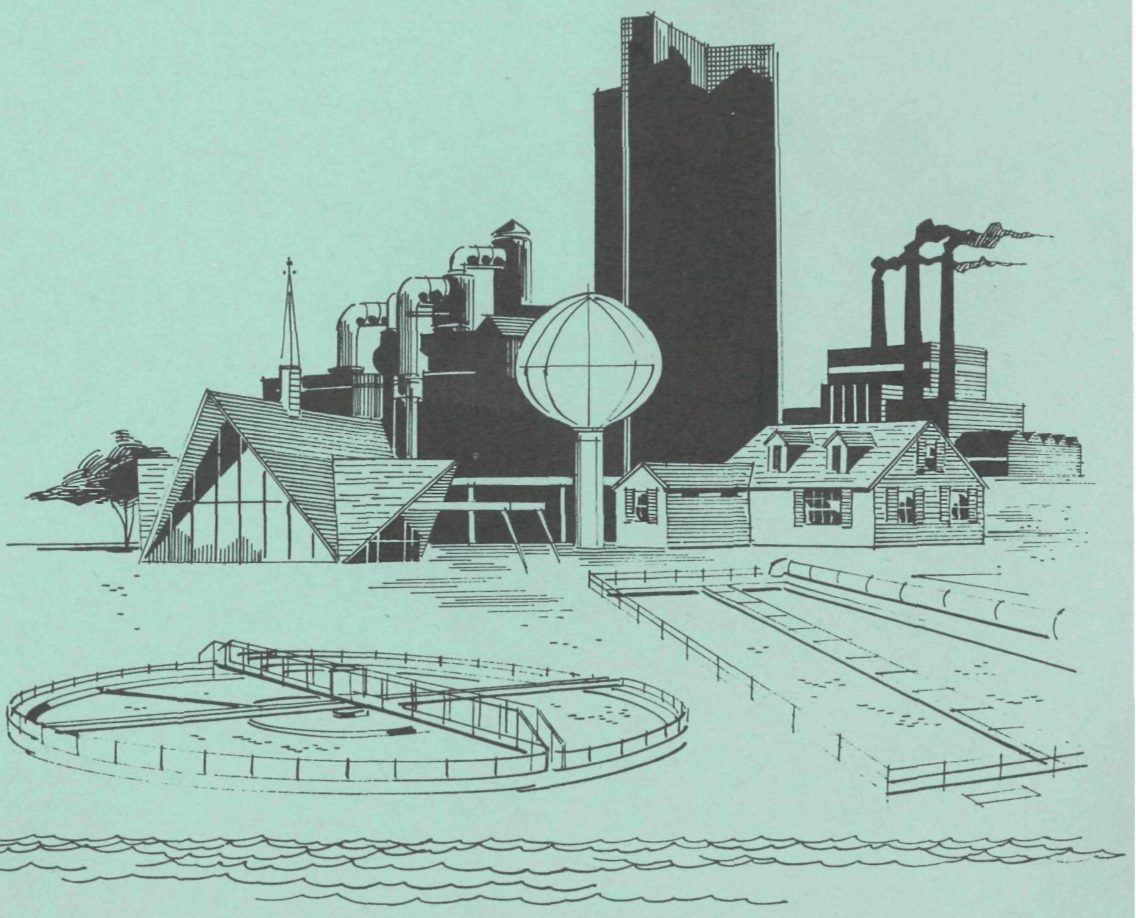
A System for Industrial Waste Treatment RD & D Project Priority Assignment



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A SYSTEM FOR INDUSTRIAL WASTE TREATMENT RD&D PROJECT PRIORITY ASSIGNMENT

by

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for the

ENVIRONMENTAL PROTECTION AGENCY

Project Number 12000 FLX

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ABSTRACT

The Environmental Protection Agency faces the difficult problem of determining priorities for research and development expenditures which will yield maximum overall benefits reflected in water quality improvements at minimum total costs. The computerized management information system described herein rapidly and efficiently determines such RD&D expenditure priorities by maximizing the expected returns on investment.

The modeling system developed as a result of this effort is unique insofar as information management systems are concerned in the degree to which user interaction is allowed. At any point during operation of the system, the user may insert judgmental factors. The system also has been designed to function with readily available data, such as that from the Bureau of the Census. Systems which incorporate theoretically desirable, but virtually unattainable, data have little operational utility. The mathematical and statistical methods employed in the development of the system focused on and supported the structuring, testing, and partial programming of three fixed-X regression modules.

This report is submitted in fulfillment of Contract Number 14-12-840, Program Number 12000 FLX between the Environmental Protection Agency and Synectics Corporation.

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SUMMARY AND CONCLUSIONS

In a dynamic, highly technical society, new products, increasing production rates, larger plants and production units, new processes with attendant obsolescence problems, continuing economic pressures, and changing manpower requirements throughout the society all contribute toward the need for new effluent treatment and control technology. Hence, yesterday's rather simplistic techniques are no longer adequate for today's complex industrial pollution abatement problems. It is a mission of the Environmental Protection Agency to support research and development on techniques which will yield maximum overall benefits reflected in water quality improvements at minimum total cost. In an effort to aid EPA in this task, a computerizable system for determining industrial waste treatment RD&D priorities for PPBS 1200 projects on a national basis has been developed and analyzed.

Model Form

The algorithm which has been formulated to establish priorities for R&D expenditures in the 1200 program series has been built upon five basic data subsets, each of which considers a variety of independent variables, i.e., *variables which are defined outside of immediate EPA policy considerations at the Headquarters level.* Provisions are incorporated in the management model for definition of and alterations in top-level management decisions. The overall result is a model which can be formulated and maintained at a readiness level as an assigned administrative task and can be readily utilized by policy makers as a dynamic management tool.

The five main subsets are listed below and the potential independent variables associated with each are given; the variables are entered in terms of relative rankings rather than as absolute values. See Appendix A for data element sources. Twenty-four information sources are required to update the modeling system's source data files. Table A-1 identifies the source or sources of each data element described in Table A-2.

1. Effluent Constituents

   ✓ Associated industrial effluent volumes.
   ✓ Concentrations in receiving waters permitting all water uses.
   ✓ Concentrations in receiving water permitting all but the "most sensitive" water uses.
   ✓ Frequency of mention in State Water Quality Standards.
   ✓ Economic effects on water uses in receiving waters.
   ✓ EPA Regional Office appraisals of relative pollution severities.
   ✓ Degree of public notice.
   ✓ Target treatment costs as determined by maximum values of recovered materials.

2. Industrial Groups

- √ Size of industry.
- √ Geographical distribution of industry.
- √ Water use practices.
- √ Economic status.
- √ Effluent treatment facilities.
- √ Production parameters.
- √ Effluent constituents.

3. State Dimensions

- √ Industrial effluent volumes.
- √ Population.
- √ Land area.
- √ Value added by manufacture.
- √ Number of manufacturing establishments.
- √ Capital expenditures by manufacturers.
- √ Industrial water use.
- √ Land area in farms and value of farm products.
- √ Population using public water supplies.
- √ Annual precipitation.
- √ Recreational areas and annual use.
- √ Fishing licenses issued.
- √ Metropolitan area population.
- √ Electrical energy production.
- √ Annual water runoff and withdrawals.
- √ Scientific population.

4. Project Descriptions

- √ Industry involved.
- √ Location.
- √ Project dates.
- √ Sources of funds.
- √ Effluent constituents involved.
- √ Type of project.
- √ Project implementation.
- √ Objectives of project.

5. General Statistics

- √ Federal/industry R&D funds by region.
- √ Federal/industry R&D funds by industry group.

The output of the model is a funding "map" which depicts the priorities for future R&D expenditures in terms of type of industry, location, effluent constituent, and level of funding as illustrated in Figures la, lb, lc, 2, and 3.

PPBS	PRIORITY	STATES	% BUDGET	% 1206	EFFLUENT CONSTITUENT	% BUDGET	% 1206
1206	(.3500)	NEW YORK	(8.34)	(23.83)	BOD	(12.80)	(36.60)
		ILLINOIS	(5.92)	(16.94)	SUSPENDED SOLIDS	(11.40)	(32.60)
		IOWA	(4.03)	(11.54)	TOTAL DISSOLVED SOLIDS	(10.78)	(30.80)
		MINNESOTA	(3.92)	(11.22)			
		CALIFORNIA	(3.31)	(9.47)			
		FLORIDA	(2.83)	(8.09)			
		WISCONSIN	(2.65)	(7.59)			
		NEW JERSEY	(1.76)	(5.04)			
		IDAHO	(.68)	(1.96)			
		INDIANA	(.57)	(1.64)			
		COLORADO	(.51)	(1.47)			
		PENNSYLVANIA	(.39)	(1.12)			
		MISSOURI	(.39)	(1.14)			
		NEBRASKA	(.31)	(.89)			

PPBS	PRIORITY	STATES	% BUDGET	% 1204	EFFLUENT CONSTITUENT	% BUDGET	% 1204
1204	(.2566)	NEW YORK	(6.97)	(27.18)	TOTAL DISSOLVED SOLIDS	(16.29)	(63.61)
		WASHINGTON	(3.94)	(15.39)	BOD	(5.16)	(19.99)
		FLORIDA	(3.17)	(14.48)	SUSPENDED SOLIDS	(4.21)	(16.40)
		WISCONSIN	(2.92)	(11.40)			
		GEORGIA	(2.88)	(11.26)			
		MAINE	(1.97)	(7.69)			
		OREGON	(1.67)	(6.53)			
		MICHIGAN	(.79)	(3.08)			
		ALABAMA	(.75)	(2.94)			

PPBS	PRIORITY	STATES	% BUDGET	% 1202	EFFLUENT CONSTITUENT	% BUDGET	% 1202
1202	(.1324)	LOUISIANA	(3.20)	(24.23)	BOD	(6.06)	(45.80)
		TEXAS	(2.53)	(19.10)	COD	(4.70)	(35.50)
		NEW YORK	(2.28)	(17.26)	SUSPENDED SOLIDS	(2.48)	(18.70)
		OHIO	(1.48)	(11.20)			
		NEW JERSEY	(1.19)	(9.00)			
		WEST VIRGINIA	(1.09)	(8.23)			
		TENNESSEE	(.76)	(5.71)			
		MICHIGAN	(.54)	(4.15)			
		PENNSYLVANIA	(.14)	(1.09)			
		VIRGINIA	(.02)	(.12)			

Figure 1a. MAP--General Summary Level I

PPBS	PRIORITY	STATES	% BUDGET	% 1201	EFFLUENT CONSTITUENT	% BUDGET	% 1201
1201	(.0908)	OHIO	(2.83)	(31.18)	SUSPENDED SOLIDS	(7.75)	(85.40)
		NEW YORK	(2.09)	(23.03)	IRON	(.58)	(6.41)
		ILLINOIS	(1.85)	(20.39)	ACIDITY	(.17)	(1.93)
		INDIANA	(.94)	(10.44)	OIL AND GREASE	(.15)	(1.72)
		MICHIGAN	(.72)	(7.94)	AMMONIA	(.08)	(.90)
		PENNSYLVANIA	(.62)	(6.98)	PHENOLS	(.08)	(.90)
					CHROMIUM	(.08)	(.90)
					FLUORIDES	(.08)	(.90)
					CYANIDE	(.08)	(.90)
					TIN	(.08)	(.90)
					ZINC	(.08)	(.90)

PPBS	PRIORITY	STATES	% BUDGET	% 1209	EFFLUENT CONSTITUENT	% BUDGET	% 1209
1209	(.0820)	NORTH CAROLINA	(7.87)	(95.99)	TOTAL DISSOLVED SOLIDS	(3.95)	(48.20)
		TENNESSEE	(.18)	(2.26)	BOD	(2.38)	(29.01)
		MISSOURI	(.06)	(.79)	SUSPENDED SOLIDS	(1.86)	(22.79)
		MASSACHUSETTS	(.05)	(.66)			
		VIRGINIA	(.05)	(.59)			

PPBS	PRIORITY	STATES	% BUDGET	% 1212	EFFLUENT CONSTITUENT	% BUDGET	% 1212
1212	(.0313)	NEW YORK	(2.70)	(86.27)	TOTAL DISSOLVED SOLIDS	(1.57)	(50.26)
		NEW JERSEY	(.41)	(13.03)	SUSPENDED SOLIDS	(1.31)	(36.16)
		CONNECTICUT	(.02)	(.51)	BOD	(.45)	(13.56)
		MASSACHUSETTS	(.01)	(.17)			

PPBS	PRIORITY	STATES	% BUDGET	% 1205	EFFLUENT CONSTITUENT	% BUDGET	% 1205
1205	(.0282)	LOUISIANA	(1.19)	(42.52)	BOD	(2.55)	(90.39)
		NEW JERSEY	(.57)	(20.33)	PHENOLS	(.18)	(6.41)
		ILLINOIS	(.40)	(14.33)	SULFIDES	(.09)	(3.19)
		CALIFORNIA	(.30)	(10.98)			
		TEXAS	(.28)	(9.83)			
		PENNSYLVANIA	(.06)	(1.98)			

Figure 1b. MAP--General Summary Level I

PPBS	PRIORITY	STATES	% BUDGET	% 1207	EFFLUENT CONSTITUENT	% BUDGET	% 1207
1207	(.0167)	NEW YORK	(.68)	(40.61)	OIL	(.84)	(50.10)
		MICHIGAN	(.27)	(16.03)	SUSPENDED SOLIDS	(.43)	(25.78)
		ILLINOIS	(.21)	(12.77)	METALS	(.40)	(24.10)
		NEW JERSEY	(.17)	(10.03)			
		OHIO	(.16)	(9.32)			
		WISCONSIN	(.10)	(5.80)			
		INDIANA	(.04)	(2.49)			
		TEXAS	(.03)	(1.76)			
		PENNSYLVANIA	(.02)	(1.15)			

PPBS	PRIORITY	STATES	% BUDGET	% 1210	EFFLUENT CONSTITUENT	% BUDGET	% 1210
1210	(.0080)	OREGON	(.49)	(61.75)	SUSPENDED SOLIDS	(.38)	(47.10)
		WASHINGTON	(.21)	(26.05)	BOD	(.23)	(28.92)
		CALIFORNIA	(.10)	(12.17)	COLOR	(.19)	(23.96)

PPBS	PRIORITY	STATES	% BUDGET	% 1208	EFFLUENT CONSTITUENT	% BUDGET	% 1208
1208	(.0034)	ILLINOIS	(.13)	(38.74)	SUSPENDED SOLIDS	(.26)	(76.26)
		OHIO	(.06)	(18.61)	FLUORIDES	(.08)	(23.73)
		NEW JERSEY	(.06)	(17.86)			
		CALIFORNIA	(.04)	(11.15)			
		MICHIGAN	(.03)	(9.49)			
		PENNSYLVANIA	(.01)	(4.13)			

PPBS	PRIORITY	STATES	% BUDGET	% 1211	EFFLUENT CONSTITUENT	% BUDGET	% 1211
1211	(.0025)	OHIO	(.17)	(66.08)	BOD	(.16)	(62.86)
		ILLINOIS	(.08)	(33.00)	COD	(.07)	(29.04)
		CONNECTICUT	(.01)	(.59)	SUSPENDED SOLIDS	(.02)	(8.08)
		MASSACHUSETTS	(.01)	(.31)			

Figure 1c. MAP--General Summary Level I

ACTION MATRIX

PPBS 1206 (.3500)

1206	BOD	SS	DS
NEW YORK	1.07	.95	.90
ILLINOIS	.76	.67	.64
IOWA	.52	.46	.43
MINNESOTA	.50	.45	.42
CALIFORNIA	.42	.38	.36
FLORIDA	.36	.32	.31
WISCONSIN	.34	.30	.29
NEW JERSEY	.23	.20	.19
IDAHO	.09	.08	.07
INDIANA	.07	.07	.06
COLORADO	.07	.06	.06
PENNSYLVANIA	.05	.04	.04
MISSOURI	.05	.04	.04
NEBRASKA	.04	.04	.03

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Figure 2. MAP--Action Matrix

SUBACTION	1	INDUSTRY	1206	STATE	NEW YORK	MAJOR EFFLUENT CONSTITUENT	BOD	PRIORITY	.107	% OF BUDGET	1.07
SUBACTION	2	INDUSTRY	1204	STATE	NEW YORK	MAJOR EFFLUENT CONSTITUENT	DISSOLVED SOLIDS	PRIORITY	.097	% OF BUDGET	.97
SUBACTION	3	INDUSTRY	1206	STATE	NEW YORK	MAJOR EFFLUENT CONSTITUENT	SUSPENDED SOLIDS	PRIORITY	.095	% OF BUDGET	.95
SUBACTION	4	INDUSTRY	1206	STATE	NEW YORK	MAJOR EFFLUENT CONSTITUENT	DISSOLVED SOLIDS	PRIORITY	.090	% OF BUDGET	.90
SUBACTION	5	INDUSTRY	1204	STATE	NEW YORK	MAJOR EFFLUENT CONSTITUENT	BOD	PRIORITY	.085	% OF BUDGET	.85
SUBACTION	6	INDUSTRY	1206	STATE	ILLINOIS	MAJOR EFFLUENT CONSTITUENT	BOD	PRIORITY	.076	% OF BUDGET	.76
SUBACTION	7	INDUSTRY	1206	STATE	ILLINOIS	MAJOR EFFLUENT CONSTITUENT	SUSPENDED SOLIDS	PRIORITY	.067	% OF BUDGET	.67
SUBACTION	8	INDUSTRY	1206	STATE	ILLINOIS	MAJOR EFFLUENT CONSTITUENT	DISSOLVED SOLIDS	PRIORITY	.064	% OF BUDGET	.64
SUBACTION	9	INDUSTRY	1204	STATE	WASHINGTON	MAJOR EFFLUENT CONSTITUENT	DISSOLVED SOLIDS	PRIORITY	.058	% OF BUDGET	.58
SUBACTION	10	INDUSTRY	1206	STATE	IOWA	MAJOR EFFLUENT CONSTITUENT	BOD	PRIORITY	.052	% OF BUDGET	.52
SUBACTION	11	INDUSTRY	1206	STATE	MINNESOTA	MAJOR EFFLUENT CONSTITUENT	BOD	PRIORITY	.050	% OF BUDGET	.50
SUBACTION	12	INDUSTRY	1206	STATE	IOWA	MAJOR EFFLUENT CONSTITUENT	SUSPENDED SOLIDS	PRIORITY	.046	% OF BUDGET	.46
SUBACTION	13	INDUSTRY	1206	STATE	MINNESOTA	MAJOR EFFLUENT CONSTITUENT	SUSPENDED SOLIDS	PRIORITY	.045	% OF BUDGET	.45
SUBACTION	14	INDUSTRY	1204	STATE	WASHINGTON	MAJOR EFFLUENT CONSTITUENT	BOD	PRIORITY	.044	% OF BUDGET	.44
	⋮										
SUBACTION	270										

Figure 3. MAP--Subaction Strategy

This study has resulted in the development of a computerizable system for determining priorities for expenditures in industrial effluent treatment and control research, development, and demonstration on a national basis, i.e., for the PPBS 1200 programs. The system takes into account past and current funding of projects, allows policy decisions on the part of EPA management to be superimposed at several levels, and permits analysis of the effects of various policy decisions.

The system has been shown to be practical and workable and can be readily implemented by machine computation. The initial software requirements, software maintenance, and hardware requirements are not excessive and are well within the limits of available resources.

The data requirements of the system are such that maximum use can be made of public industrial data, the various EPA publications including The Cost of Clean Water series and the various industry profiles, current effluent treatment technology information, current compilations of effluent and water quality data, and the readily available data from the Bureau of the Census. The system is such that input data format or availability is not a limiting constraint.

The development of the system has included a means for ranking the severity of pollution by various industrial effluent constituents in varying concentrations. Ranking is such that all significant factors involved in pollution severity for particular constituents can be individually evaluated and readily altered as additional information becomes available or as the relative importance of the several factors change due to hard data acquisition or to policy decisions.

The system has been developed for implementation on the basis of aggregation of data on a state-by-state basis. The nature and detail of the basic data are such that extension to a more detailed geographical basis is not warranted for initial operation. Data have been utilized which are available on a county-by-county basis. However, the system can be readily exercised on the basis of geographical units such as census regions or river basins, if future needs so require. The states as basic geographical units are felt to be optimum at this time.

The system development has additionally produced a means by which past EPA policy can be quantitatively depicted and analyzed in detail. It has also indicated some desirable modifications in the format and content of basic input information, particularly in the "Needs Statements" as inputed to the EPA Technical Information and Management Planning System (TIMPS).

RECOMMENDATIONS

1. Based upon favorable design and practicability results, an RD&D priority and fund allocation model should be implemented for use in 1200 PPBS category management. Owing to the current developmental state of the model, two further steps are necessary to bring the model to operational readiness in a form which generates a funding allocation "map" (MODE I). These are:

   Step 1. To specify operating file structures, finalize report formats, adapt programs for each module (4) and intermodule linkages to the EPA machine configuration, and develop database maintenance and update procedures.

   Step 2. To conduct critical and volume tests on the model to demonstrate satisfactory performance in support of the Industrial Pollution Control Branch technical management staff. (1200 PPBS category "Need Statements" should provide a sufficient data base for this purpose.)

2. The RD&D priority and fund allocation modeling technique could readily be extended to include the entire PPBS category set. Each category should be examined, however, to determine the optimum form and practicability of model functions for priority determination and fund allocation within the specific category.

3. A most important application of the priority and fund allocation model would be its incorporation into the Technical Information and Management Planning System (TIMPS) as a user accessible subsystem on an interactive basis. Since the key to successful operation of TIMPS is some form of R&D priority list generator, it appears highly desirable to incorporate the modeling subsystem in TIMPS as early as possible. In this connection, a vital consideration should be the optimization of the hard/software (console and query subroutines) which bridges the man-machine interface in order to permit facile and responsive information transfer between manager and data base. As a consequence of incorporating the model within TIMPS, a somewhat modified information flow would result which, in general, should proceed as follows:

   a. A need is generated and an area priority will be assigned.

   b. The need is coded and entered on the need file.

   c. The model is exercised and all existing needs assigned priorities and ranked.

d. The model-generated priority "map" is generated as a function of:

   (1) Priorities at the beginning of the fiscal period.

   (2) Current priorities remaining to be funded.

   (3) Where and how funds have been allocated to date in the fiscal period.

e. The "map" is submitted for executive committee review.

f. A new "map" is generated to reflect the decisions reached in executive review.

g. Priorities are stored for submittal to central data processing.

4. To enhance the ease and precision of requirements entries into the data base (in conjunction with the preceding recommendation), the "Statements of Need" should be modified and restructured to include model significant data. The latter changes should afford those responsible for initiating requests an improved, more incisive means for describing their requirements.

5. The STORET system should be modified so as to incorporate Water Quality Standards and to generate a yearly measure of observed deviations from standards at each location.

6. An effort should be made to develop the present costs of treatment of specific constituents from such EPA programs as the Industrial Waste Inventory, Effluent Criteria Development Projects, and Discharge Permit Program.

INTRODUCTION

As the complexity of manufacturing technology increases force changes in pollution abatement requirements to achieve adequate protection of the Nation's water uses, industrial waste treatment and control requires new, improved methods. That is, new products, increasing production rates, larger plants and production units, new processes with attendant obsolescence problems, continuing economic pressures, and changing manpower requirements throughout industry all contribute toward the need for new effluent treatment and control technology. Hence, the relatively simplistic means of the past are no longer adequate for today's complex industrial pollution abatement problems.

The Environmental Protection Agency faces the difficult problem of determining priorities for research and development fund allocations which will yield maximum overall benefits as reflected in water quality improvements at minimum total cost. Fiscal constraints, existing suitable research and development facilities, and manpower insist that R&D expenditures return the greatest possible benefits. A computer-aided management information system which rapidly and efficiently determines such R&D expenditure priorities on a realistic cost/benefit basis will be of great value. The purpose of this study was to design such a system and to determine its practicability.

R&D expenditures applicable to the industries included in PPBS Subprogram 1200 of the EPA R&D Program were selected as the focus for this study, which made maximum use of current data compilations. Existing data compilations did not properly conform to the above industrial classifications, nor were the costs and benefits of most R&D expenditures strictly assignable within specific industrial groups; additionally, plants and processes, as well as the nature and magnitude of pollution, varied within groups. Such factors, however, did not preclude the use of available data; rather, the data merely required recognition and proper treatment in their use.

The cost side of the economic evaluation generally presents relatively little difficulty in cost/benefit analysis as compared to the benefit side; the cost/benefit analysis of R&D expenditures was no exception. The literature is replete with dissertations on various methods by which benefits, both economic and non-economic, may be determined and few specialists in the field are in complete agreement on methodology or even on some definitions of benefits. However, these problems were reduced in this study, since relative benefits were of primary interest. While absolute dollar-expressible benefits vary with methodologically different approaches, the benefits may still be in relative agreement. For example, the methodologically different analyses of Kneese (1964) and Bramer (1966) reach the same conclusions as to the relative values of the various uses of the surface waters, placing the highest values on recreational uses.

A computerized system for determining priorities in R&D expenditures was known to be technically within the state-of-the-art of systems analysis, mathematical modeling techniques, economic theory, information handling, and machine capabilities. The desirability of such a system as a management information tool for the optimum utilization of R&D resources was also clear. The feasibility and practicability of such a system would be determined by the quality of the system design and the mode chosen for eventual operation. In order to design and determine the practicability of the desired computerized modeling system, consideration was given to the various critical components, i.e., the user requirements, the data base, and the component requirements of the system itself. A practical system must be able to operate within existing resources and constraints, particularly available data; an otherwise optimum system would be of little utility. A practical system must also meet the needs of the users. The system itself must show a cost/benefit advantage to the user over other alternatives for determining R&D expenditure priorities such as manual computations or individual judgments.

The developmental system has two basic operating modes:

Mode I - operates on specific input parameters to generate a funding "map" which describes an optimum procedure for allocating available monies to industrial effluent treatment RD&D as functions of Industry, Location, Effluent Constituent, and Percent of Budget, at three levels of detail.

Mode II - ranks proposed projects or "needs" as a function of specific parameters such as industry, location, etc,, and assigns a priority to each project.

The succeeding sections describe the preliminary design, development, and practicability assessment of the model.

MODEL DEVELOPMENT

As is the case with most mathematical model development, the basic approach was: Identify and define measurable variables, collect and analyze a set of relevant "real-world" data, develop and test hypotheses regarding the nature of apparent relationships, and refine the mathematical statements of relationships by determining their predictive accuracy on fresh "real-world" data. The data drawn from the "real world" was in this case comprised of information on funded projects, described in the FWQA Water Pollution Control Research Series publication DAST·38 entitled "Projects of the Industrial Pollution Control Branch" (1970). Table I gives a list of potential dimensions for describing these projects. This list was re-evaluated with respect to the availability of data and the phenomenon of funding industrial waste treatment and control research, development, and demonstration projects in terms of six possible criterion variables and 83 possible predictor variables. Criterion variables are those dependent variables that best describe or measure the phenomenon which the model developer is trying to predict or model. Predictor variables, on the other hand, are those independent or dependent variables that best "predict" the criterion variables. See Appendix B for the sample data collection From No. 0100. Each of the 126 projects described in "Projects of the Industrial Pollution Control Branch" was coded on Form No. 0100 and entered into the computerized data base. The data base was then subjected to associative statistical analysis and rank ordering, resulting in base level ranks for each variable and the degree of covariance associated with all variable combinations. Based on these results, it was concluded that Federal funds per project showed the most promise as a criterion variable. That is, it was initially felt that Federal funds per project, Federal funds per month per project, total funds per project, total funds per month per project, other funds per project, and other funds per month per project each might prove to be rational criterion variables. However, early correlation analysis showed Federal funds per project to be most closely associated with the 83 predictor variables. Federal funding for all the projects examined was sorted on the basis of each of the following predictor variables:

- ✓ PPBS category
- ✓ State in which project is located
- ✓ Effluent constituents to be removed or reduced
- ✓ Type of project
- ✓ Organization implementing the project
- ✓ Objectives of the project

Rankings of these variables and their respective predictor variables as a function of Federal funding constitute a succinct statement of prior EPA policy in RD&D project funding. The first three variables were shown

Table I

Potential Dimensions for Ranking Industrial Wastewater R&D Projects

I. Industry Involved
   A. Description
      1. PPBS number
      2. 2-digit SIC code
      3. 3-digit SIC code
      4. 4-digit SIC code
   B. Size of Industry
      1. Number of plants
         a. Number of small plants
         b. Number of large plants
      2. Number of employees
      3. Value added by manufacture
      4. Total water use
         a. Intake for process
         b. Intake for cooling
         c. Intake for sanitary and other uses
   C. Geographical distribution
      1. Number of states with plants
      2. Number of plants per state with plants
      3. Water discharged per state with plants
      4. Number of employees per state with plants
      5. Population in states with plants
   D. Water use practices
      1. Rate of water reuse
      2. Water intake per dollar added by manufacture
      3. % purchased water
      4. % ground water
      5. % brackish water
   E. Economic status
      1. Age of average plant
      2. Return on investment
      3. Return on sales
      4. Unemployment rate
      5. Projected growth rate
   F. Wastewater treatment practices
      1. % treatment facility investment of total investment
      2. % treatment facility investment of projected requirements
      3. % wastewater discharged to municipal sewers
   G. Production parameters
      1. Operational days per year
      2. Production as % of capacity
      3. Level of technology
         a. % old technology
         b. % averaged technology
         c. % advanced technology
      4. Average life of process equipment

II. Objectives of R&D Project

A. Reduction of wastewater constituents
   1. Type of constituent
   2. % reduction

B. Wastewater discharge reduction
   1. % reduction
   2. % to municipal treatment facilities

C. Water use reduction
   1. Process water
   2. Cooling water
   3. Sanitary and other uses
   4. % reduction

D. Applicability
   1. Large plants
   2. Small plants
   3. Old technology
   4. Average technology
   5. Advanced technology

E. Applications
   1. Treatment processes
      a. New process
      b. Process improvement
   2. Process equipment
      a. New equipment
      b. Equipment improvement
   3. Cost reductions
      a. Capital costs
      b. Operating costs
   4. Treatment control
      a. Measurement
         i. Methods of analysis
         ii. Methods of sampling
         iii. Instrumentation
      b. Automation
   5. Engineering
      a. Process design methods
         i. conventional
         ii. Mathematical models
         iii. Cost calculations
      b. Treatment plant design methods
         i. Conventional
         ii. Mathematical models
         iii. Cost calculations
      c. Information handling
   6. Production process modifications
   7. By-product recovery
   8. Manpower factors
      a. Training
      b. Requirements determinations
      c. Requirements reductions
         i. Man-hours
         ii. Level of skills

- III. Type of R&D Project
  - A. Research
    - 1. Desk-top study
      - a. Technology
        - i. State-of-the-art report
        - ii. Conceptual study
      - b. Economic study
      - c. Manpower study
    - 2. Hands-on research
      - a. Laboratory
      - b. Bench-scale pilot plant
  - B. Development
    - 1. Special facility
    - 2. Industrial in-plant
  - C. Demonstration
    - 1. Industrial in-plant
    - 2. Joint industrial-municipal
    - 3. Residual pollution abatement
  - D. Contract research
  - E. Grant

- IV. Project Implementation
  - A. Profit-making R&D organization
  - B. Not-for-profit R&D institution
  - C. Manufacturing industry
  - D. Government unit
    - 1. Federal
    - 2. State
    - 3. Regional
    - 4. Local
  - E. Joint effort
  - F. University
  - G. Organizational qualifications
    - 1. Previous performance
      - a. Organization
      - b. Research staff
      - c. EPA projects
      - d. Other federal agency projects
    - 2. Staff qualifications
      - a. Professional staff
      - b. Support staff
    - 3. Facility resources
      - a. Technical resources
      - b. Support resources
    - 4. Financial resources
      - a. Matching funds
      - b. Operating funds
      - c. Accounting procedures

V. Project Initiation
   A. Request for proposal
   B. Unsolicited proposal
   C. Public notice
      1. Local
      2. Regional
      3. National
      4. Public press
      5. Technical literature
      6. Legislative

VI. Spin-Off Benefits of R&D Project
   A. Training
      1. Academic
      2. On-the-job
   B. Stimulation of non-federally funded R&D
   C. Other applications of technology developed
   D. Applications of other technology
      1. Military
      2. Aerospace
      3. Other

VII. EPA Administrative Considerations
   A. R&D budget
      1. Total
      2. Industrial wastewater control
      3. Administrative industrial allocations
         a. Contract research
         b. Grants
         c. Demonstrations
   B. Fiscal year period
   C. Prior year allocations
      1. Industry
      2. Type of R&D
   D. Previous similar projects by others
      1. Technical similarity
      2. Level of funding
   E. Current similar projects by others
      1. Technical similarity
      2. Level of funding
   F. Utilization of prior base R&D
   G. Projected time to implementation of R&D results

to be non-linear and their distributions are given in Figures 4-6; the latter three are considered to be linear in accordance with the distributions shown in Tables II-IV. Note that the entries in these tables are not mutually exclusive; that is, a project can be characterized by more than one "type." *These data may be interesting in themselves insofar as they indicate prior EPA funding policy.*

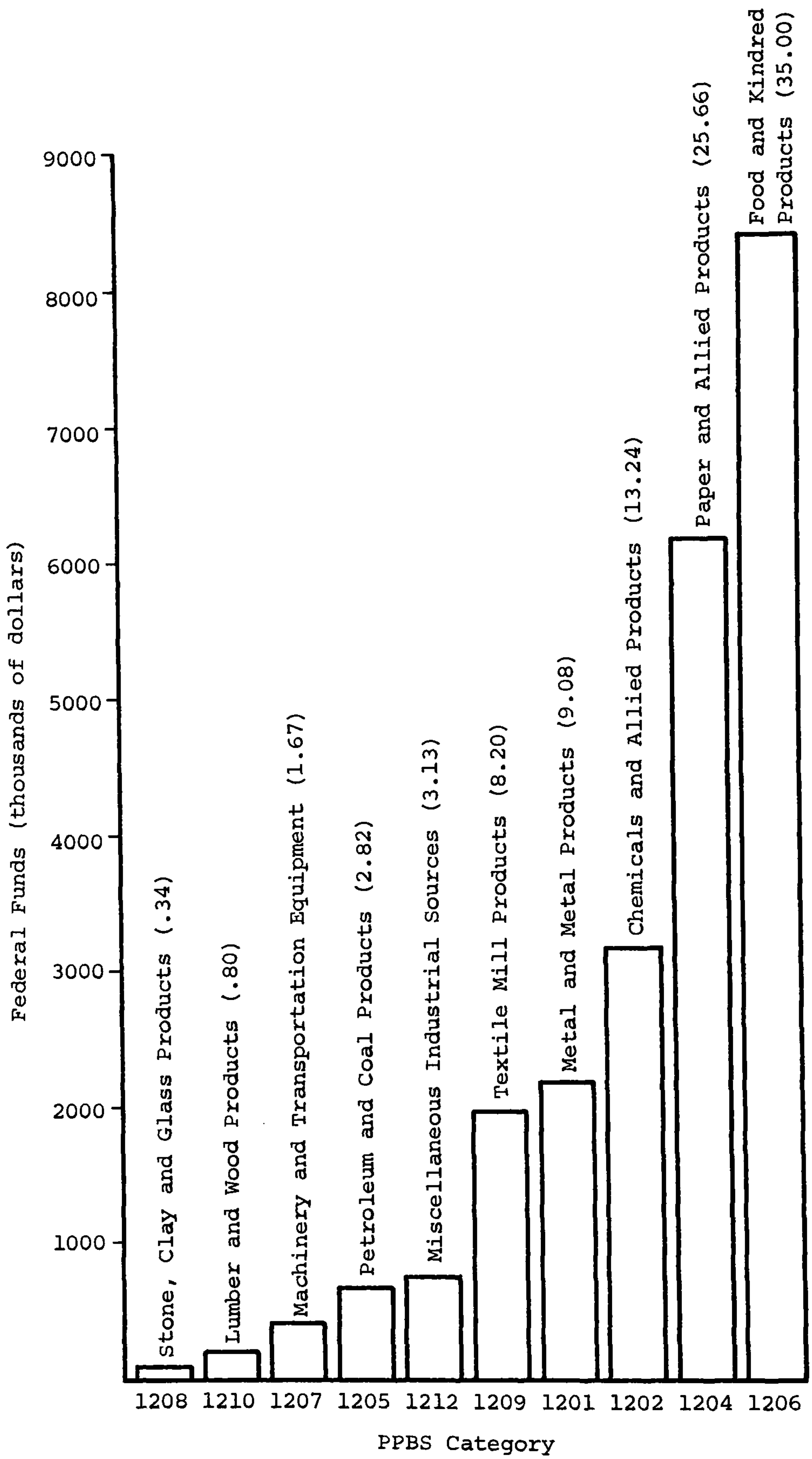


Figure 4. PPBS Categories Ranked According to Federal Funding

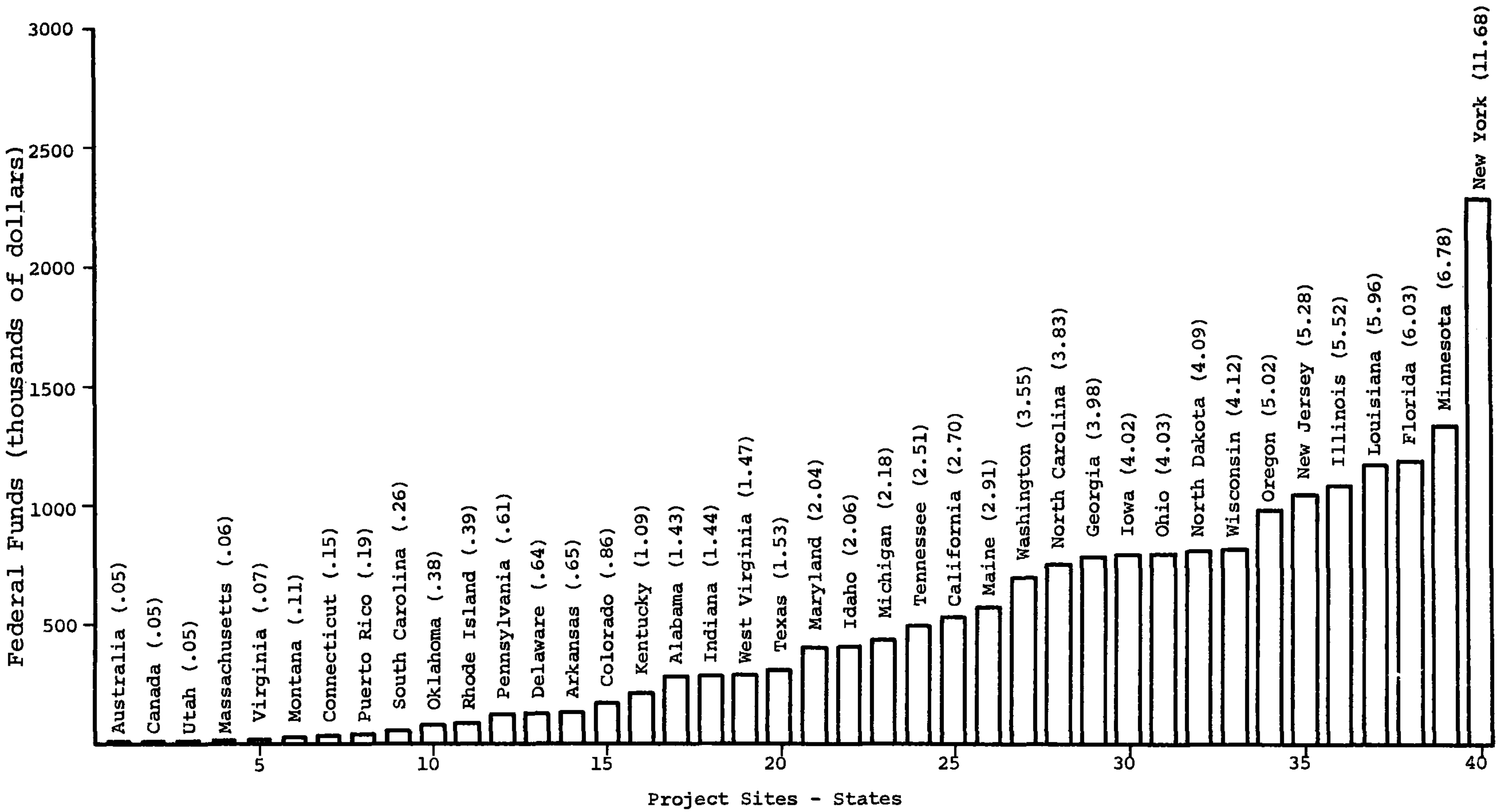


Figure 5. Locations by State of Projects Ranked According to Federal Funding

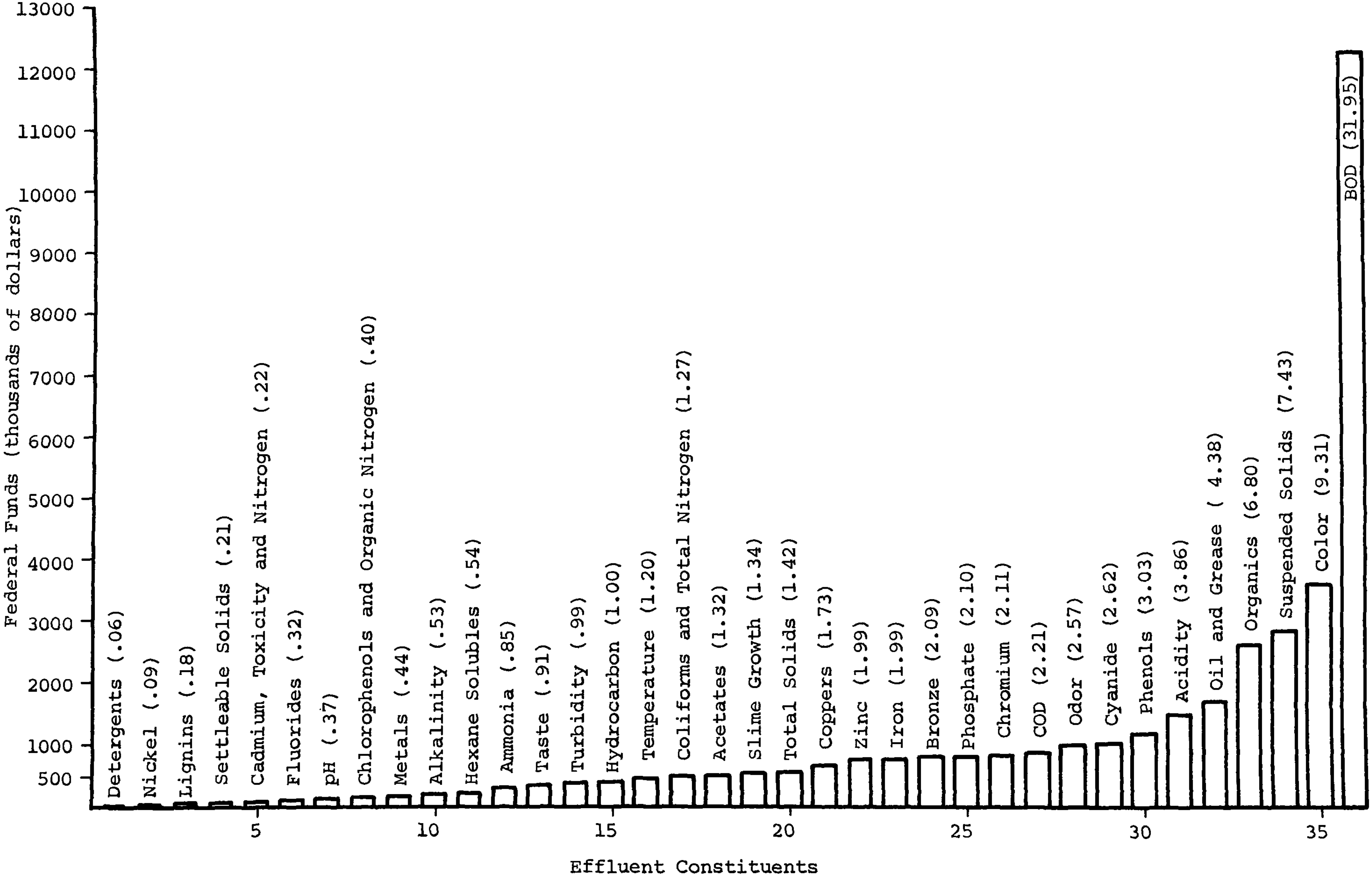


Figure 6. Effluent Constituents Ranked According to Federal Funding

Table II

Types of Projects Ranked According to Federal Funding

Rank	Priority	Type of Project
17	.324	Grant
16	.283	Demonstration
15	.243	Full-scale
14	.614	Industrial in-plant demonstration
13	.066	Pilot plant
12	.041	Research
11	.040	Development
10	.100	Laboratory
9	.088	Hands-on research
8	.079	Industrial in-plant development
7	.042	Bench-scale pilot plant
6	.030	Special facility
5	.014	Joint industrial-municipal treatment (except 1106)
4	.014	State-of-the-art report
3	.012	Desk-top study
2	.002	Conceptual study
1	.001	Contract

Table III

Project Implementation Ranked According to Federal Funding

Rank	Priority	Project Implementation
9	.592	Manufacturing industry (.708)
8	.164	Government unit (.196)
7	.124	Local government
6	.041	University (.049)
5	.026	Profit-making R&D organization (.031)
4	.023	Regional government
3	.015	State government
2	.011	Not-for-profit R&D organization (.013)
1	.001	Federal government

Table IV

Project Objective or Applicability Ranked According to Federal Funding

Rank	Priority	Objective or Application
27	.200	Treatment process study
26	.181	Treatment process improvement
25	.100	Economic feasibility determination
24	.077	Engineering
23	.077	Sludge disposal
22	.072	Process design
21	.042	By-product recovery
20	.040	Water reuse
19	.032	Plant design
18	.019	Treatment control
17	.019	Large plants
16	.018	Effluent characterization
15	.018	New treatment process
14	.016	Measurement methods
13	.010	Manpower factors
12	.009	Manpower requirements
11	.007	Production process modifications
10	.006	Effluent volume reduction
9	.006	Cost reductions
8	.005	Information systems
7	.005	Small plants
6	.004	Conventional engineering techniques
5	.004	Old technology
5	.004	Average technology
5	.003	New technology
4	.002	Effluent effects
3	.001	Process equipment
2	.001	Mathematical models
1	.001	New process equipment
1	.001	Automation
1	.001	Training
1	.001	Manpower reduction

From the viewpoint of developing a computer-aided priority determination system, the nature and derivation of each of the predictor variables is of great importance. The independent predictor variables are dimensionable within themselves and are simple in nature, i.e., they are not functions of other factors. The dependent predictor variables are complex, i.e., they are functions of factors which lie outside of current EPA policy control at the Headquarters level.

The simple variables--those dimensionable within themselves--can, of course, be aggregated as one function, which predicts Federal funding to some low degree. However, it is essential to treat each complex variable as a separate predictor function, thus segregating the influence of each on the criterion variable. Three such variables were identified:

- √ Industry
- √ Severity of pollutant
- √ Location

Furthermore, it was desirable to modularize the model system according to these three variables, since each assumed a different hypothesis regarding the amount of Federal funding per project. That is, each module required a basis for grouping variables in terms of the homogeneity of associated prediction functions, in order to identify and describe a potential rating policy for determining RD&D priorities. The point of departure selected for deriving hypotheses was recent EPA policy. This choice presented an additional problem, however, in that sufficiently precise measures of policy had to be identified to permit quanitative analysis. Although structured interviews with key EPA personnel provided considerable insights into agency goals and policies, it was also necessary to identify an additional measure to augment these results. The method utilized a fixed-X multiple linear regression model to generate mathematical equations defining and quantifying recent policy (Christal, 1968). Simply put, the procedure for each module was as follows:

- √ Criterion variable and all reasonable, possible, predictor variables were defined.

- √ Each variable was then scaled according to the appropriate properties possessed by that variable. Since the policy capturing model relies on fixed-X assumptions, variables need not be normally distributed.

- √ The model was then exercised over the data base and the resultant equation examined for significance.

- √ Where appropriate, additional predictor variables were identified and included in the analysis, terms were altered to approximate curvilinear functions, and insignificant terms were dropped to maintain simplicity. After each alteration, the model was exercised to generate a new function.

To assess the approach used, prior EPA policy as measured by the Federal funding in the various PPBS categories, was compared with announced policy as expressed in the listings "Sources of National Pollution Priorities" and "1200 Program Schedule of Milestones." In Table V, a composite net ranking (policy rank) is shown for the 1200 categories and compared with the ranking based upon prior funding; the differences between these ranks (d) are tabulated.

Comparing these rankings, using Spearman's rank correlation analysis:

$$r_s = 1 - \frac{6\ (\Sigma d^2)}{N\ (N^2 - 1)}$$

$$r_s = 1 - \frac{6\ (54)}{12\ (144 - 1)} = 0.811$$

The rank correlation coefficient is significant at the .01 level and indicates that prior policy as measured by project funding is reliably related to stated policy. Similar procedures were used to enhance the validity of the effluent constituent and location modules until the cost of this incremental increase in accuracy surpassed the value of that increment.

Module I. Location

Although various descriptors of geographic location are available, a state basis proved to be most realistic, since it is a common denominator of the others and is the basis on which most data are readily available. Table VI indicates the relationships associating each state with the following other descriptors:

- √ Cost of Clean Water Series Drainage Regions
- √ Water Resources Council Drainage Areas
- √ Census Bureau Industrial Water Use Regions
- √ Census Bureau Standard Regions and Divisions

Appendix C contains the data collection form for location dimensions. Each state was ranked as a function of Federal funding (Figure 5, page 19). This ranking reflects the relative importance of the location dimensions associated with each state and is referred to as the rank order in Table VII. For example, project location in New York was attributed 1.72 times the significance of location in Minnesota and 166 times the significance of location in Virginia. Associative statistical analysis indicated that the most important predictor variables associated with location of projects by state are:

- √ Industrial effluent volume per state, in bgy, $\sigma = 447.8$, $\beta = -.1156$
- √ Population per state, in thousands, $\sigma = 6507$, $\beta = -.1426$

Table V

PPBS Ranks Based upon Policy Statements and Funding

PPBS Number	Policy Rank	Funding Rank	d
1206	11	11	0
1204	10	10	0
1205	9	5	4
1202	8	9	-1
1201	7	8	-1
1209	6	7	-1
1210	5	3	2
1203	4	1	3
1207	3	4	-1
1211	3	1	2
1212	2	6	-4
1208	1	2	-1

√ Value added by manufacture per state, in millions of dollars, σ = 2418, β = .4173

√ Annual runoff per state, in thousands acre ft/yr, σ = 21830, β = .1974

√ Water area in each state, in square miles, σ = 1517, β = -.3616

√ Population density per state, in square miles, σ = 2079, β = -.1469

√ Industrial water used per state, in bgy, σ = 1581, β = .0800

Table VI

Geographic Parameters

Cost of Clean Water Series Drainage Regions	Water Resources Council Drainage Areas	Census Bureau Industrial Water Use Regions	Census Standard Regions and Divisions	Maine	New Hampshire	Vermont	Massachusetts	Rhode Island	Connecticut	New York	New Jersey	Pennsylvania	Ohio	Indiana	Illinois	Michigan	Wisconsin	Minnesota	Iowa	Missouri	North Dakota	South Dakota	Nebraska	Kansas	Delaware	Maryland	Dis. of Columbia	Virginia	West Virginia	North Carolina	South Carolina	Georgia	Florida	Kentucky	Tennessee	Alabama	Mississippi	Arkansas	Louisiana	Oklahoma	Texas	Montana	Idaho	Wyoming	Colorado	New Mexico	Arizona	Utah	Nevada	Washington	Oregon	California	Alaska	Hawaii
North Atlantic	North Atlantic	New England, Delaware and Hudson, Chesapeake Bay		⊖	⊖	○	⊖	⊖	⊖	○	⊖	●													⊖	⊖	⊖	●	○																									
Ohio	Ohio	Ohio Cumberland				○						○	●	●	○													○	●					⊖	○																			
Western Gulf	Rio Grande Texas-Gulf	Western Gulf																																					○		●				○	●								
Missouri	Souris-Red-Rainy Missouri	Missouri																○	○	●	⊖	⊖	⊖	○																		●		●	○									
Great Lakes	Great Lakes	W. Great Lakes, E. Great Lakes, St. Lawrence								○			○	○		⊖	○	○																																				
Great Basin and Colorado	Upper Colorado, Lower Colorado, Great Basin	Great Basin and Colorado																																										○	○	○	⊖	⊖	⊖		○	○		
Southeast	South Atlantic-Gulf	Southeast																										○		●	⊖	⊖	⊖			●	○																	
Tennessee	Tennessee	Tennessee																										○		○					○	○																		
Upper Mississippi	Upper Mississippi	Upper Mississippi													●		●	●	●	○																																		
Lower Mississippi	Lower Mississippi	Lower Mississippi																		○																	○	○	○															
Arkansas-White-Red	Arkansas-Red-White	Arkansas-Red-White																		○				○														●	○	⊖	○				○	○								
Pacific Northwest	Columbia-North Pacific	Pacific Northwest																																								○	⊖	○						⊖	●		⊖	
California	California	California																																																	○	●		⊖
			Division	New England						Middle Atlantic			East North Central					West North Central							South Atlantic									East South Central				West South Central				Mountain								Pacific				
			Region	Northeast									North Central												South																	West												

⊖ All
○ Little
● Most

Table VII

Location Matrix

State	Rank Number	Rank Order	Industrial Wastewater Volume	Population	Value Added by Manufacture	Annual Runoff	Water Area	Population Density	Industrial Water Use
New York	40	11.68	569	17,894	7,010	58,168	1,707	350.1	1,054
Minnesota	39	6.78	87	3,529	1,166	16,141	4,779	42.7	208
Florida	38	6.03	230	5,654	874	40,600	4,424	91.5	690
Louisiana	37	5.96	843	3,493	1,168	43,995	3,368	72.2	2,141
Illinois	36	5.52	591	10,538	6,465	30,079	523	180.2	1,473
New Jersey	35	5.28	395	6,680	4,731	8,359	304	806.6	814
Oregon	34	5.02	151	1,886	488	67,238	772	18.4	270
Wisconsin	33	4.12	236	4,100	2,853	29,948	1,690	72.2	495
North Dakota	32	4.09	1	650	17	1,886	1,385	9.1	23
Ohio	31	4.03	1,115	10,124	8,821	26,382	204	236.9	1,935
Iowa	30	4.02	103	2,763	1,165	13,809	247	49.2	149
Georgia	29	3.98	213	4,304	1,390	47,101	679	67.8	655
North Carolina	28	3.83	146	4,861	2,072	47,793	3,706	92.9	350
Washington	27	3.55	341	2,971	2,041	76,375	1,529	42.8	996
Maine	26	2.91	163	984	326	44,286	2,282	31.3	393
California	25	2.70	313	18,003	6,879	71,937	2,156	100.4	1,273
Tennessee	24	2.51	287	3,805	1,499	45,061	878	85.4	649
Michigan	23	2.18	739	8,161	8,368	37,258	1,398	137.2	1,299
Idaho	22	2.06	47	687	197	37,877	880	8.1	141
Maryland	21	2.04	401	3,442	1,674	9,025	686	314.0	531
Texas	20	1.53	1,455	10,401	4,196	49,909	4,369	36.4	5,069
West Virginia	19	1.47	670	1,823	1,433	24,503	97	77.3	817
Indiana	18	1.44	830	4,832	5,097	23,226	102	128.9	1,283
Alabama	17	1.43	242	3,431	1,311	57,802	758	64.0	583
Kentucky	16	1.09	117	3,163	1,585	36,626	544	76.2	414
Colorado	15	.86	54	1,941	708	22,798	453	16.9	122
Arkansas	14	.65	42	1,939	373	48,149	929	34.0	451
Delaware	13	.64	164	494	508	1,646	75	225.6	286
Pennsylvania	12	.61	1,475	11,505	6,926	48,356	308	251.5	2,903
Rhode Island	11	.39	16	884	291	1,424	165	812.4	19

(Table VII (Continued)

State	Rank Number	Rank Order	Industrial Wastewater Volume	Population	Value Added by Manufacture	Annual Runoff	Water Area	Population Density	Industrial Water Use
Oklahoma	10	.38	10	2,461	369	19,018	935	33.8	290
South Carolina	9	.26	101	2,528	1,154	24,844	775	78.7	332
Puerto Rico	8		-	2,578	-	-	14	686.8	-
Connecticut	7	.15	118	2,784	2,153	5,877	139	517.5	205
Montana	6	.11	26	703	89	29,823	1,535	4.6	60
Virginia	5	.07	275	4,371	1,741	32,652	976	99.6	459
Massachusetts	4	.06	144	5,287	2,360	10,129	424	654.5	207
Utah	3	.05	27	977	463	8,152	2,535	10.8	176
Canada	2		-	-	-	-	-	-	-
Australia	2		-	-	-	-	-	-	-
Alaska	1		34	256	29	-	19,980	0.4	95
Arizona	1	.001	10	1,549	318	4,250	346	11.5	125
District of Columbia	1		-	795	-	-	6	12523.9	-
Hawaii	1		102	712	117	-	25	98.6	245
Kansas	1	.001	43	2,237	900	12,285	208	26.6	231
Mississippi	1	.001	65	2,304	345	53,442	358	46.1	231
Missouri	1	.001	82	4,471	2,260	40,877	640	62.5	221
Nebraska	1	.001	24	1,471	285	7,414	705	18.4	46
Nevada	1	.001	4	418	50	3,537	651	2.6	11
New Hampshire	1	.001	35	659	158	12,405	271	67.3	79
New Mexico	1	.001	1	1,008	26	3,893	221	7.8	11
South Dakota	1	.001	5	700	67	2,875	1,091	8.9	15
Vermont	1	.001	7	399	88	12,812	335	42.0	9
Wyoming	1	.001	7	338	45	20,366	633	3.4	60
American Somoa	1		-	-	-	-	-	-	-
Canal Zone	1		-	-	-	-	-	-	-
Guam	1		-	-	-	-	-	-	-
U. S. Virgin Islands	1		-	-	-	-	-	-	-
Pacific Island Trust Territories	1		-	-	-	-	-	-	-

β, the standard partial regression coefficient, is a measure of the degree of importance EPA has associated with each predictor variable with respect to past policy and Federal funding. Of course, β coefficients will continue to serve as important measures of policy in the future by constantly keeping EPA management abreast of the relative importance they are placing on predictor variables. β times 100 represents the percentage change that will occur in the criterion variable for a given change in the predictor. For example, value added by manufacture has a β of .4173. This means that when there is a 1 standard deviation change in value added by manufacture, there has been a .42 standard deviation change in EPA funding. Noting that the standard deviation (σ) for value added is 2418 and the standard deviation for rank order is 2.075, given a 2418 increase in value added, we would find a (.4173) (2.075) = .8659 increase in rank order. Thus, we can see that value added was an important variable in the past. On the other hand, industrial effluent volume has had a slight negative effect in the past, that is to say, the higher the industrial effluent volume per state, the less money EPA has allocated to that state. Again, this is a statement of past policy and now that it has been measured, it can be adjusted to meet current thinking through the model discussed herein. Thus, an increase of 447.8 of industrial effluent would produce a rank order reduction of (-.1156) (2.075) = -.2399. Of course, a similar exercise can be carried out for each predictor variable. We are only interested in past policy as a starting point for future modeling, therefore we will not dwell on the subject, but will leave any further exercises up to the reader.

In general, EPA has given higher priorities to states with:

- √ *Lower industrial effluent volumes*
- √ *Lower populations*
- √ *Higher values added by manufacture*
- √ *Higher annual runoffs*
- √ *Higher water areas*
- √ *Lower population densities*
- √ *Any volume of water used*

Table VII shows the matrix of values for the predictor variables with respect to the criterion. In addition, data were obtained from STORET for some 400 stations. Station data were aggregated by state for measurements of temperature, conductivity, dissolved oxygen, and pH. For each station, data were available for these parameters in terms of averages for the period of record which was generally 6-12 months. A tabulation was made of the median, minimum, and maximum observed average values in each state. In Table VIII, the maximum average values of temperature and conductivity and the minimum average values of dissolved oxygen and pH are tabulated. The only data discarded were conductivity values in Maine, Rhode Island, and South Carolina which were obviously measurements in seawater.

Water quality data may be used in a number of ways as indicators of priorities for pollution abatement needs; indeed, such data may well be of prime overall importance. It has been the intent of the present study,

Table VIII. Period-of-Record Average Water Quality Measurements by State

State	Max. Temperature, °C	Max. Conductivity, mhos	Min. D.O., ppm	Min. pH
Alabama	19.3	155	7.2	6.9
Arizona	29.8	6334	8.0	7.0
Arkansas	18.9	803	5.1	7.8
California	21.4	1399	8.9	8.1
Colorado	13.4	6334	7.5	6.8
Connecticut	8.3	109	9.4	7.2
Florida	28.0	669	3.4	6.7
Idaho	16.5	4823	8.7	7.7
Illinois	16.1	562	9.3	7.5
Indiana	12.4	748	9.5	7.5
Iowa	11.0	820	8.6	7.6
Kansas	17.7	2405	7.6	7.6
Kentucky	13.1	407	9.6	6.7
Louisiana	20.6	409	5.1	6.9
Maine	14.6	78 (1)	7.3	6.4
Maryland	16.1	719	8.1	3.4
Massachusetts	13.3	269	8.9	6.9
Michigan	9.9	222	11.9	7.1
Minnesota	12.6	525	8.5	7.9
Mississippi	19.7	7808	3.1	6.2
Missouri	15.6	820	6.5	7.6
Montana	14.7	2022	4.5	7.3
Puerto Rico	30.3	18413	0.8	6.2
Nebraska	17.3	1716	9.6	7.8
Nevada	16.3	5525	9.6	7.8
New Hampshire	15.7	120	7.1	5.0
New Jersey	15.1	5823	4.3	4.9
New Mexico	23.6	13000	0.4	7.4
New York	15.2	729	0.8	6.8
North Carolina	19.1	8940	0.7	6.4
North Dakota	19.3	896	1.8	7.7
Ohio	24.7	748	2.1	6.8
Oklahoma	19.6	2178	5.6	8.1
Pennsylvania	17.9	434	0.2	4.8
Rhode Island	12.7	- (1)	0.1	7.7
South Carolina	17.7	5158 (1)	0.8	6.8
South Dakota	9.8	2680	9.5	7.6
Tennessee	17.0	358	9.5	4.6
Texas	19.0	812	8.2	7.2
Utah	14.0	3553	6.8	7.4
Vermont	9.0	96	10.0	7.1
Virginia	15.1	440	8.2	6.4
Wisconsin	3.4	232	13.4	8.2
Wyoming	10.5	3227	8.5	7.2
Alaska	-	-	-	-
Delaware	-	-	-	-
District of Columbia	-	-	-	-
Georgia	-	-	-	-
Hawaii	-	-	-	-
Washington	-	-	-	-
West Virginia	-	-	-	-

(1) Measurements in seawater discarded.

however, to utilize data that are readily available; little suitable data are presently available in sufficient detail or in a satisfactory form. The data used here to illustrate a method of ranking locations by water quality were those available from the STORET system. It is intended only to illustrate a need; the data were not judged to be of sufficient quality for incorporation into the model. Some states yielded complete data for dozens of locations; others had sparse data for only a few locations. Little basis was indicated for statistical adjustment in terms of confidence levels or otherwise.

The STORET system itself should be modified to supply the needed data with little manipulation required within the priority-determining model. If the Water Quality Standards were incorporated into the STORET system, the system might compare each recorded water quality measurement with the applicable Standards and report deviations, weighted as to magnitude for each location. The summation of such weighted deviations per year per state might then be used as a relative water quality indicator. In each case, of course, corrections would have to be made for frequency of measurement, numbers of locations measured, proportions of each state's streams monitored, and similar factors which might bias the indicator function.

The most reasonable interpretation of the available water quality data for the present purposes would be to consider them as measures of the quality of the surface waters, making no assumptions as to origins of constituents. We might then conclude that poorer quality is related to higher priorities for pollution abatement, either because pollution loads are greater or because pollution cannot be tolerated due to already poor available water quality.

On this basis, the states are ranked according to each of the four water quality parameters with a rank of 1 equivalent to best quality, i.e., the lowest priority for pollution abatement measures as shown in Table IX.

In Table X, each series of ranks is reduced to a common basis to yield ranking factors which were then summed to yield composite net ranks. On the basis of the data used, these composite net ranks show the relative status of the states insofar as prevailing water quality is concerned, and may be interpreted as discussed above, as one measure of the need for pollution abatement.

The policy capturing model produced the basic structure for equation (1) as a result of analyzing the data in Table VII. However, interviews with potential users suggested that the user should have an opportunity to control the influence of past policy; thus, the policy capturing equation was augmented to provide such an opportunity. Notice that the regression coefficients (constants) in equation (1) are consistent with the previously discussed β coefficients. For example, $-.96V_{1,N}$ accounts for the -.1156 standard deviation change in P_N.

Table IX. Ranks of States According to Average Water Quality Measurements

State	Temperature	Conductivity	Dissolved Oxygen	pH
Alabama	31	5	17	13
Arizona	39	36	12	12
Arkansas	28	20	22	4
California	35	24	6	2
Colorado	13	36	14	14
Connecticut	2	3	4	10
Florida	38	16	25	15
Idaho	23	32	7	5
Illinois	21	15	5	7
Indiana	8	19	3	7
Iowa	7	22	8	6
Kansas	26	28	13	6
Kentucky	11	10	2	15
Louisiana	34	11	22	13
Maine	15	1	16	16
Maryland	21	17	11	22
Massachusetts	12	8	6	13
Michigan	5	6	1	11
Minnesota	9	14	9	3
Mississippi	33	37	26	17
Missouri	19	22	19	6
Montana	16	26	23	9
Puerto Rico	40	40	29	17
Nebraska	25	25	2	4
Nevada	22	34	2	4
New Hampshire	20	4	18	18
New Jersey	17	35	24	19
New Mexico	36	39	31	8
New York	18	18	29	14
North Carolina	30	38	30	16
North Dakota	31	23	28	5
Ohio	37	19	27	14
Oklahoma	32	27	21	2
Pennsylvania	27	12	32	20
Rhode Island	10	20.5	33	5
South Carolina	26	33	29	14
South Dakota	4	29	3	6
Tennessee	24	9	3	21
Texas	29	21	17	10
Utah	14	31	15	8
Vermont	3	2	18	11
Virginia	17	13	20	16
Wisconsin	1	7	10	1
Wyoming	6	30	17	10
Alaska	20.5	20.5	17	11.5
Delaware	20.5	20.5	17	11.5
District of Columbia	20.5	20.5	17	11.5
Georgia	20.5	20.5	17	11.5
Hawaii	20.5	20.5	17	11.5
Washington	20.5	20.5	17	11.5
West Virginia	20.5	20.5	17	11.5

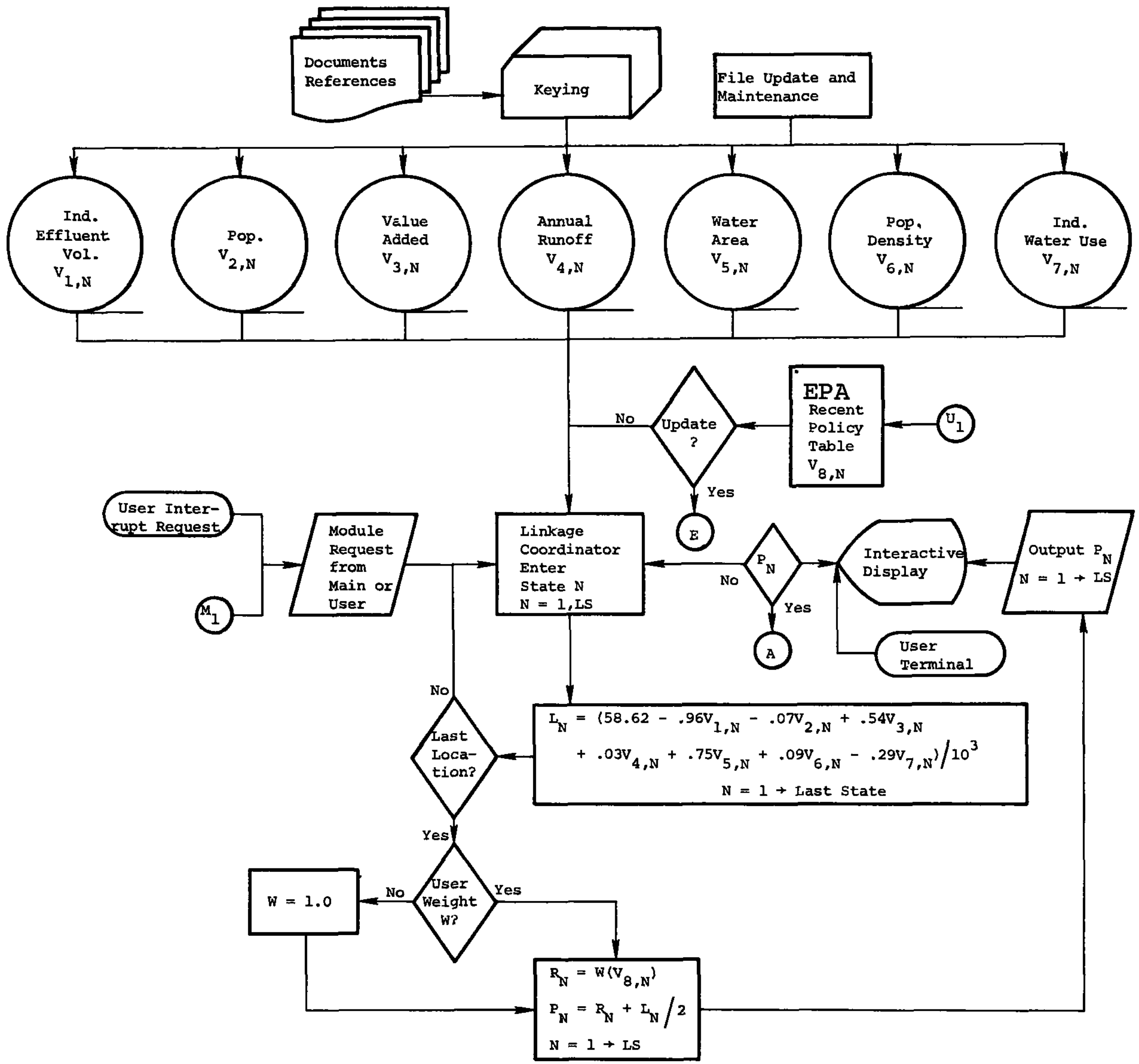
State	Temperature	Conductivity	Dissolved Oxygen	pH	Net Ranking Factor	Composite Net Rank
Alabama	31	5	20	23	79	21
Arizona	39	36	14	21	110	31
Arkansas	28	20	25	6	79	21
California	35	24	7	3	69	14
Colorado	13	36	17	25	91	28
Connecticut	2	3	5	17	27	2
Florida	38	16	30	26	110	31
Idaho	23	32	8	8	71	15
Illinois	21	15	6	12	54	10
Indiana	8	19	3	12	42	5
Iowa	7	22	9	10	48	7
Kansas	26	28	16	10	80	22
Kentucky	11	10	2	26	49	8
Louisiana	34	11	26	23	94	29
Maine	15	1	19	28	63	12
Maryland	21	17	13	39	90	27
Massachusetts	12	8	7	23	50	9
Michigan	5	6	1	19	31	3
Minnesota	9	14	11	5	39	4
Mississippi	33	37	31	30	131	36
Missouri	19	22	23	10	74	17
Montana	16	26	28	16	86	25
Puerto Rico	40	40	35	30	145	38
Nebraska	25	25	2	6	58	11
Nevada	22	34	2	6	64	13
New Hampshire	20	4	22	32	78	19
New Jersey	17	35	29	34	115	33
New Mexico	36	39	37	14	126	35
New York	18	18	35	25	96	30
North Carolina	30	38	36	28	132	37
North Dakota	31	23	34	8	96	30
Ohio	37	19	33	25	114	32
Oklahoma	32	27	25	3	87	26
Pennsylvania	27	12	39	36	114	32
Rhode Island	10	20.5	40	8	78.5	20
South Carolina	26	33	35	25	119	34
South Dakota	4	29	3	10	46	6
Tennessee	24	9	3	37	73	16
Texas	29	21	20	17	87	26
Utah	14	31	18	14	77	18
Vermont	3	2	22	19	46	6
Virginia	17	13	24	28	82	23
Wisconsin	1	7	12	1	21	1
Wyoming	6	30	20	17	73	16
Alaska	20.5	20.5	21	21	83	24
Delaware	20.5	20.5	21	21	83	24
District of Columbia	20.5	20.5	21	21	83	24
Georgia	20.5	20.5	21	21	83	24
Hawaii	20.5	20.5	21	21	83	24
Washington	20.5	20.5	21	21	83	24
West Virginia	20.5	20.5	21	21	83	24

$$P_N = \left\{ \left[(58.62 - .96V_{1,N} - .07V_{2,N} + .54V_{3,N} + .03V_{4,N} + .75V_{5,N} + .09V_{6,N} - .29V_{7,N}) \Big/ 10^3 \right] + W(V_{8,N}) \right\} \Big/ 2 \qquad (1)$$

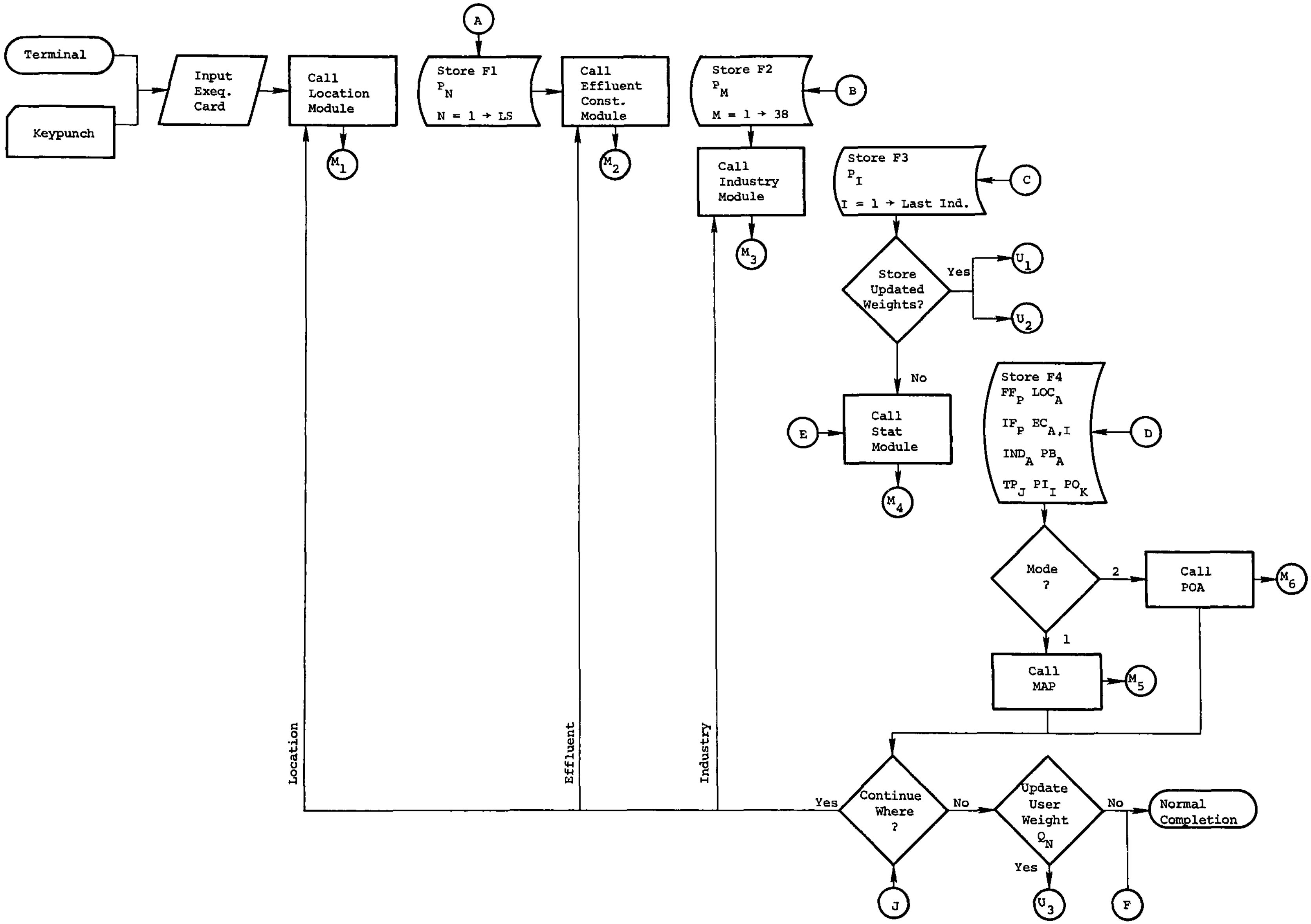
Where $V_{1,N}$ = Industrial effluent volume per state N
$V_{2,N}$ = Population of state N
$V_{3,N}$ = Value added by manufacture in state N
$V_{4,N}$ = Annual runoff for state N
$V_{5,N}$ = Water area in state N
$V_{6,N}$ = Population density of state N
$V_{7,N}$ = Industrial water use in state N
W = User weighted policy influence $0 \leq W \leq 10$
$V_{8,N}$ = Most recent policy priority accorded to state N
P_N = Priority for each state

$V_{8,N}$ represents the most recent policy priority accorded to state N. Table VII refers to this initial policy priority as "rank order." It is anticipated that the model will be exercised as policy changes occur within EPA, thus equation (1) is concerned with the budget allocation percentages (priorities) from the previous period. Further, equation (1) has a "built-in" user-varied damper (W) on periodic policy changes which allows the user to specify the magnitude of importance given to $V_{8,N}$.

Flow Chart 1 represents the functional flow of operations in the location module. Files $V_{1,N}$ through $V_{7,N}$ should be stored on magnetic disk. Although random access capabilities are not necessary for the operation of this module under Mode I, it may prove valuable under Mode II and is clearly advantageous during update and file maintenance procedures. These procedures are primarily concerned with updating the information on file to insure the highest possible degree of file integrity. $V_{8,N}$ represents the most recent EPA policy decisions. Upon acceptance of model results by EPA, the system automatically updates this table. Operationally, if access to this table is for update, control goes to "E"; if it is to fetch, control is returned to the Linkage Coordinator (LC). Of course, the module may be requested either by Mode I and II Module Control Program, Flow Chart 2, or manually from console keyboard. The module is initiated through the Linkage Coordinator. The LC retrieves $V_{1,N}$ through $V_{7,N}$ for state N. L_N is calculated for that state, and if it is not the last state, control is returned to LC. After the last state is processed through L_N a user weight is requested from the console or batch input device. This weight determines the amount of influence accorded to past policy. If a weight is not received, a value of 1.0 will



Flow Chart 1. Location Module



Flow Chart 2. Mode I and II Module Control Program be assigned to W. R_N and P_N are then determined and output to the console for review. If array P_N is approved from the console, control is transferred to "A"; if not, control goes to "LC" which queries the operator to ascertain why array P_N was not approved and where to direct control. This process is continued until array P_N is approved. In both Mode I and Mode II operation, array P_N is stored in working file F1 and control is transferred to the Effluent Module.

Module II. Effluent Constituent

The first step in developing the Effluent Constituent Module was to determine the relative importance attributed to each effluent constituent in terms of the criterion variable. Figure 6, page 20, depicts the result of this analysis where, for example, BOD has an importance of 3.40 times that of color and 532 times that of detergents. Data were collected on Data Form 4100 (Appendix D) and from sources indicated in Table A-1 and submitted to associative statistical analysis for the purpose of identifying possible predictor variables. The most highly correlated predictor variables were:

- √ Effluent Volume, dimensionless, $\sigma = 11.18$, $\beta = .2029$
- √ State Standards, number of times mentioned, $\sigma = 1.281$, $\beta = .2726$
- √ Economic Effects, dimensionless, $\sigma = 1.723$, $\beta = -.1001$
- √ EPA Regional Standards, dimensionless, $\sigma = 13.99$, $\beta = .1691$
- √ Public Notice, dimensionless, $\sigma = .3360$, $\beta = -.1723$
- √ Low Cencentration Limit, dimensionless, $\sigma = 4.197$, $\beta = -.2868$
- √ High Concentration Limit, dimensionless, $\sigma = 3.867$, $\beta = .3213$

Six of the seven interesting predictor variables are ranks and dimensionless; therefore, to preserve consistency effluent volume was transformed into a dimensionless rank. (See Data Form 4100 [Appendix D]). Considerable attention was given to the quantification of public notice inasmuch as it was generally agreed that this variable has much significance as a predictor of priority assignment and fund allocation. It was determined, however, that a separate subsystem in the model is required for inclusion, due to the variety of sources of appropriate raw data, variable confidence of such, and alternative mechanisms for inputting same to the data base. For the purposes of model definition and initial test, source data were entered as dichotomies and held constant. Of course, these β coefficients are interpreted in the same manner as those described on page 29. In brief, they indicate that EPA has put higher priorities on treating effluent constituents with:

- √ *Higher effluent volumes*
- √ *Higher state standards*
- √ *Lower economic effects*
- √ *Higher EPA regional standards*
- √ *Lower public notice*
- √ *Lower low concentration limits*
- √ *Higher high concentration limits*

Table XI describes each effluent constituent in terms of selected predictor variables. In addition to these seven variables, the relative cost per pound removal of each constituent was determined. To incorporate cost considerations into the model, it seemed most logical to assume that the highest priority for research effort would be assigned to potential cost reductions in removing constituents of lowest value, i.e., to those constituents which could support the lowest costs even with complete recovery as salable products. This assumption is supported further by considering the costs involved with no recovery; thus, a high-cost product can more easily bear waste treatment costs as an operating expense. The relative costs of removal for various wastewater constituents presented a difficult case for inclusion in the priority model. Removal cost data are sparse at best, and are not available for most specific wastewater constituents. Bearing in mind that the model is concerned with priorities, i.e., relative instead of absolute measures, and that significant pollution abatement measures in industry include conservation of materials and by-product recovery, the values of the wastewater constituents would seem to be valid measures of the treatment or particularly the conservation or recovery costs which define the upper economic cost limits. This is to say that if the total cost of recovering a material is equal to or less than its value as a product at the plant, such recovery is a no-cost operation and defines the desirable maximum cost.

It would, of course, be desirable if specific costs of present treatment methods for each specific constituent were available. This would, at least in theory, be preferable to the more hypothetical "target" costs as defined by values of materials if recoverable. As has been pointed out previously, the inputs to the present study have been formulated on the basis of readily available data and no suitable data are presently available other than these "target" costs.

The costs of present treatment methods might be made available as a result of EPA's Industrial Waste Inventory, Effluent Criteria Development Projects, and Discharge Permit Program. Unless the development of treatment cost data by specific constituents is built into these programs, such data would be very difficult to extract and beyond what should be considered as reasonable for incorporation as a procedure within the priority-determining model. Industrial treatment costs are typically given in terms of effluent volumes and rarely in terms of constituents removed. Municipal treatment costs can be expressed in pounds of BOD or solids removed only because such effluents are reasonably uniform. The costs of suspended solids removal from steel mill effluents, by contrast, are hardly comparable to, say, removal from the effluents of the glass industry. Within the steel industry the costs of removing suspended solids from basic oxygen furnace gas-washer water and from cold rolling mill soluble oil emulsions are greatly different; the values of the recovered solids per unit weight are, however, very similar.

Table XI

Effluent Constituent Matrix

Constituent	Policy Funding	Wastewater Volumes	State Standards	Economic Effects	EPA Region Appraisals	Public Notice	Concentration Limits Low	Concentration Limits High
BOD	31.95	38.0	4	6	53.0	1	8.0	10.0
Color	9.31	26.0	4	5	19.0	1	6.0	5.0
Suspended Solids	7.43	38.0	3	9	33.0	1	3.0	5.0
Organics	6.80	18.5	1	5	36.0	1	11.0	13.0
Coliforms	6.80	18.5	4	2	57.0	1	14.0	17.0
Oil and Grease	4.38	37.0	4	6	40.0	2	6.0	7.0
CCE	4.38	18.5	1	5	13.0	1	11.0	13.0
Acidity	3.86	30.0	1	4	32.0	2	3.0	4.0
Sulfate	3.86	24.0	2	8	50.0	1	2.0	1.0
Thiosulfate	3.86	7.0	1	5	28.5	1	5.0	5.0
Phenols	3.03	29.0	2	5	44.0	1	14.0	17.0
Cyanide	2.62	25.0	2	7	22.0	1	14.0	14.0
Thiocyanate	2.62	13.0	1	5	28.5	1	8.0	8.0
Sulfide	2.57	32.0	1	5	31.0	1	14.0	14.0
Odor	2.57	17.0	4	5	15.0	1	14.0	8.5
Sulfur	2.57	16.0	1	5	25.0	1	8.0	8.0
Sulfite	2.25	3.0	1	5	23.0	1	12.0	13.0
COD	2.21	28.0	4	6	43.0	1	8.0	10.0
Chromium	2.11	11.0	2	7	51.0	1	12.0	9.0
Phosphate	2.10	18.0	2	5	55.0	1	8.0	8.0
Detergents	2.10	20.0	1	5	7.0	2	14.0	13.0
Phosphorous	2.10	6.0	1	5	28.5	1	12.0	13.0
Lead	2.00	8.0	2	7	27.0	2	12.0	14.0
Mercury	2.00	1.0	1	7	51.0	2	13.0	16.0
Arsenic	2.00	18.5	2	7	11.0	1	12.5	13.0
Silver	2.00	18.5	2	5	28.5	1	12.5	15.5
Heavy Metals	2.00	18.5	1	7	51.0	1	14.0	13.0
Iron	1.99	27.0	1	1	14.0	1	12.0	13.0
Aluminum	1.99	5.0	1	5	28.5	1	12.0	13.0
Zinc	1.99	10.0	1	5	26.0	1	7.0	9.0
Copper	1.73	10.0	2	7	24.0	1	11.0	13.0
Chlorides	1.42	36.0	2	3	38.0	1	2.0	2.0
Total Solids	1.42	33.0	3	3	43.0	1	1.0	1.0
Conductance	1.42	33.0	1	3	18.0	1	1.0	1.0

Table XI (Continued)

Constituent	Policy Funding	Wastewater Volumes	State Standards	Economic Effects	EPA Region Appraisals	Public Notice	Concentration Limits Low	Concentration Limits High
Corrosiveness	1.42	39.0	1	2	47.0	1	14.0	8.5
Calcium	1.27	21.0	1	8	28.5	1	2.0	3.0
Silica	1.27	9.0	1	5	28.5	1	4.0	6.0
Magnesium	1.27	2.0	1	5	28.5	1	5.0	4.0
Hardness	1.27	18.5	1	8	28.5	1	1.0	1.0
Temperature	1.20	31.0	4	4	56.0	2	14.0	8.5
Hydrocarbon	1.00	18.5	1	5	42.0	1	11.0	13.0
Turbidity	0.99	14.0	4	9	35.0	1	5.0	5.0
Ammonia	0.85	34.0	1	5	1.0	1	14.0	13.0
Total Organic C	0.85	18.5	1	5	45.0	1	11.0	13.0
Alkalinity	0.53	35.0	1	4	29.0	1	2.0	2.0
Organic N	0.40	23.0	1	5	36.0	1	8.0	8.0
Total N	0.40	19.0	1	5	54.0	1	7.0	8.0
pH	0.37	39.0	4	4	47.0	1	14.0	8.5
Fluorides	0.32	28.0	2	5	4.0	1	10.0	11.0
Sodium	0.22	22.0	1	5	6.0	1	5.0	6.0
Potassium	0.22	21.0	1	5	6.0	1	5.0	6.0
Manganese	0.22	15.0	1	1	11.0	1	12.0	13.0
Toxicity	0.22	12.0	4	7	51.0	2	14.0	13.0
Cadium	0.22	8.0	2	5	28.5	1	12.0	8.0
Nitrates	0.22	7.0	2	5	49.0	1	9.0	8.0
Nitrites	0.22	7.0	1	5	37.0	1	12.0	12.0
Radioactivity	0.22	18.5	3	7	46.0	2	14.0	17.0
Barium	0.22	18.5	2	7	28.5	1	8.0	9.0
Selenium	0.22	18.5	2	7	51.0	1	14.0	13.0
Boron	0.22	18.5	1	7	5.0	1	10.0	1.0
Settleable Solids	0.21	38.0	4	9	39.0	1	3.0	5.0
Mercaptans	0.20	21.0	1	5	31.0	1	14.0	15.0
Polysacchrid	0.20	16.0	1	6	28.5	1	8.0	9.0
Tannin	0.18	4.0	1	5	36.0	1	8.0	8.0
Lignins	0.18	3.0	1	5	36.0	1	8.0	8.0
Pesticides	0.15	18.5	1	7	52.0	2	14.0	17.0
Nickels	0.09	8.0	1	5	28.5	1	12.0	13.0

If possible, present costs of the treatment of specific constituents should be acquired from the EPA ongoing programs mentioned above. Until other data are available, the "target" costs as defined herein should be used since they represent at least consistent and available measures of a much-needed criterion in the model.

In Table XII, the wastewater constituents are listed with the costs per pound (1959-60 cost index = 1.0) of the specific constituents or of industrial chemicals which are likely sources of the specific constituents. The wastewater constituents are then ranked on the basis of decreasing values with the rank of one equal to the highest cost. The ranks of Table XII were entered into the model as measures of total cost considerations ($V_{8,M}$) with the highest numerical rank equivalent to the highest priority for research and development where treatment costs are concerned.

In the same manner as we did for equation (1), the data in Table XI were subjected to fixed-X regression analysis which produced the basic structure for equation (2). However, in this instance the user may override the system by replacing the most recent regression coefficient with his own relative weights (Q_N).

$$P_M = -1.59 + 1.15V_{1,M}/\max V_{1,M} + 2.50V_{2,M}/\max V_{2,M} + .75V_{3,M}/\max V_{3,M} + 1.10V_{4,M}/\max V_{4,M} + 1.00V_{5,M}/\max V_{5,M} + .50V_{6,M}/\max V_{6,M} + 1.90V_{7,M}/\max V_{7,M} + 1.00V_{8,M}/\max V_{8,M} + 2.00V_{9,M}/\max V_{9,M} \quad (2)$$

For $M = 1 \rightarrow$ Last Effluent Constituent

where

P_M = Priority ranking for constituent M

$V_{1,M}$ = Effluent volume for constituent M

$V_{2,M}$ = State standard for constituent M

$V_{3,M}$ = Economic effects for constituent M

$V_{4,M}$ = EPA regional standard for constituent M

$V_{5,M}$ = Public notice of constituent M

$V_{6,M}$ = Low concentration limit of constituent M

$V_{7,M}$ = High concentration limit of constituent M

$V_{8,M}$ = Relative cost of removal of constituent M

Table XII. Values of Wastewater Constituents and Related Chemicals

Constituent	Equivalent Chemical	$/lb.	Cost Rank
pH	Calcium Carbonate	0.06	30
BOD	Molasses	0.01	43
Suspended Solids	Bentonite	0.007	44
Oil and Grease	#6 Fuel Oil	0.01	43
Chlorides	Rock Salt	0.01	43
Alkalinity	Lime	0.01	43
Ammonia	Ammonia	0.0425	33
Total Solids	Rock Salt	0.01	43
Sulfides	Sodium Sulfide	0.0525	31
Temperature	Steam	0.0003	46
Acidity	Sulfuric Acid	0.01	43
Phenols	Phenol	0.14	22
COD	Miscellaneous Chemicals (6)	0.13	23
Fluorides	Sodium Fluoride	0.11	25
Iron	Iron	0.10	26
Color	Benzenoid Dyes (3)	1.48	7
Cyanide	Sodium Cyanide	0.17	21
Sulfate	Sodium Sulfate	0.0235	40
Organic N	Nitrophenol	0.50	15
Sodium	Rock Salt	0.01	43
Mercaptons	Ethyl Mercapton	0.70	12
Potassium	Potassium Chloride	0.0135	41
Calcium	Calcium Chloride	0.0135	41
Detergents	Surface Active Agents (2)	0.18	20
Total N	Average of all N Compounds(8)	0.032	38
Phosphate	Calcium Phosphate	0.0375	35
Odor	Phenol	0.14	22
Polysacchrides	Saccharin	1.60	6
Sulfur	Sulfur	0.0133	42
Manganese	Manganese	0.30	17
Turbidity	Bentonite	0.007	44
Thiocyanate	Sodium Thiocyanate	0.71	11
Toxicity	Average of Toxic Compounds	1.388	8
Chromium	Chromium	1.18	9
Copper	Copper	0.30	17
Zinc	Zinc	0.11	25
Silica	Silica	0.115	24
Lead	Lead	0.14	22
Nickel	Nickel	0.60	14
Cadmium	Cadmium	1.70	5
Nitrites	Sodium Nitrite	0.0775	28
Nitrates	Sodium Nitrate	0.025	39
Thiosulfate	Sodium Thiosulfate	0.04	34
Phosphorous	Sodium Phosphate	0.085	27
Aluminum	Aluminum	0.20	19
Tannin	Lignin	0.05	32
Sulfite	Sodium Sulfite	0.0725	29

Table XII (continued)

Constituent	Equivalent Chemical	$/lb.	Cost Rank
Lignins	Lignin	0.05	32
Magnesium	Magneisum	0.27	18
Mercury	Mercury	3.00	4
Radioactivity	Highest Cost	-	1
Arsenic	Arsenic	0.60	14
Borium	Borium Bromide	0.49	16
Selenium	Selenium	5.00	3
Silver	Silver Chloride	12.48	2
Conductance	Rock Salt	0.01	43
CCE	Cyclic Intermediates (4)	0.11	25
Pesticides	Pesticides & Organic Ag. Chem. (1)	0.62	13
Boron	Borax	0.035	36
Hardness	Calcium Carbonate	0.06	30
Organics	Cyclic Intermediates (4)	0.11	25
Corrosiveness	Sulfuric Acid	0.01	43
Settleable Solids	Iron Ore	0.0045	45
Coliforms	Lowest Cost	-	47
Heavy Metals	Average of all	0.83	10
Hydrocarbons	Aliphatic Hydrocarbons (5)	0.034	37
Total Organic C	Crude Products from Petroleum and Gas (7)	0.035	36

(1) Chemical Statistics Handbook, 1966, p. 27 (1964 data)
(2) Ibid, p. 30 (1964 data)
(3) Ibid, p. 50 (1964 data)
(4) Ibid, p. 71 (1964 data)
(5) Ibid, p. 14 (1964 data)
(6) Ibid, p. 78 (1964 data)
(7) Ibid, p. 90 (1959 data)
(8) Ibid, p.285 (1959 data)

$V_{9,M}$ = EPA policy regarding constituent M, or fraction of EPA industrial budget spent on effluent constituent M during last fiscal period

Q_N = Relative weight associated with $V_{N,M}$

max $V_{N,M}$ = Maximum value of $V_{N,M}$

The constants Q_N are set equal to the correlation coefficient or user weights which depict most recent policy. Provision has been made for the user to enter new Q_N values if he should not agree with those most recently used. This process is illustrated below.

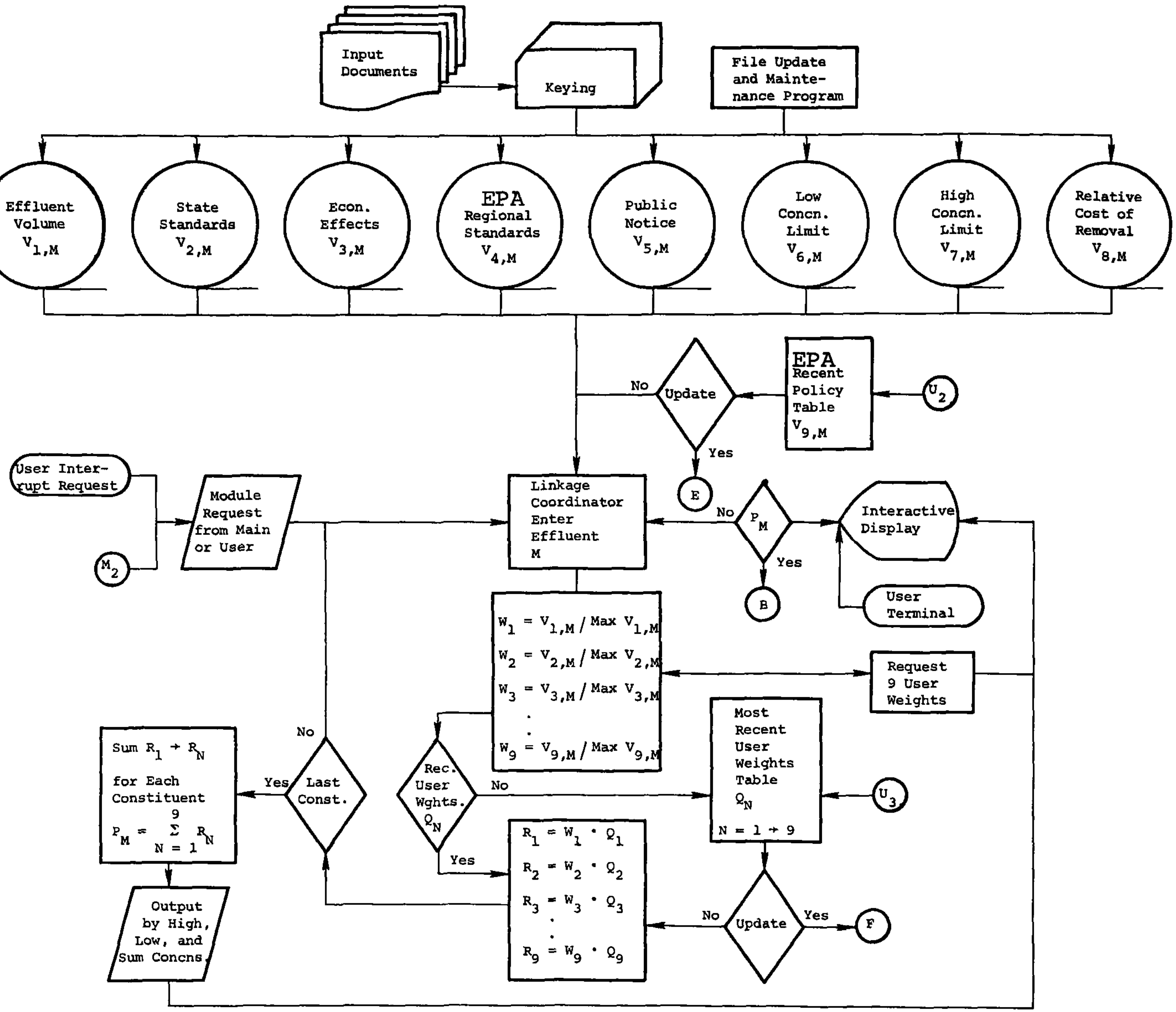
Flow Chart 3 represents the logical and mathematical operations of this Effluent Constituent Module. File integrity is insured through the file update and maintenance program which includes the dynamic Public Notice subsystem. Again, the module may be accessed through a terminal by an operator or through Modes I and II Module Control Program, Flow Chart 2. Upon initiation, control goes to the LC. LC requests user weights Q_N and determines the maximum values of $V_{1,M} \rightarrow V_{9,M}$. $V_{N,M}$ are then retrieved and W_N determined and weighted by Q_N, where W_N is simply $V_{N,M}$/max $V_{N,M}$. Control returns to LC and the process continues until the last constituent is processed. After the last constituent is processed R_N, N = 1,9 are summed by high concentration only, low concentration only, and both. These priorities are then displayed on the console for approval and directions as to which of the three lists to use. Upon receiving approval and direction, control is transferred to "B" in the Module Control Program. If approval is not received, the user is queried relative to reason for rejection and where to restart. Upon approval, P_M are stored in file F2 and the Industry Module is called.

Module III. Industry

This module was developed in a manner similar to those previously described. The complex variable was ranked by describing each PPB category as a function of the prior Federal funding in that category. See Figure 4, page 18. This ranking reflects the relative importance attributed to each category. For example, from Figure 4 it is clear that 1206 (Food and Kindred Products) was attributed 1.36 times the importance of 1204 (Paper and Allied Products) and 103 times the importance of 1208 (Stone, Clay and Glass Products).

The predictor variables, from those included on Form 2100, Appendix E, indicated to be significant from preliminary analysis were:

- ✓ Industrial Effluent Volume, in bgy, σ = 1512, β = -.4233
- ✓ Water Use, in bgy, σ = 3140, β = .4105
- ✓ Value Added by Manufacture, in million dollars, σ = 10150, β = -.3620
- ✓ Employment, in thousands, σ = 725.3, β = .0745



Flow Chart 3. Effluent Constituent Module

✓ Number of States with Plants, $\sigma = 9.921$, $\beta = .3584$
✓ Total Number of Plants, $\sigma = 8993$, $\beta = .2357$
✓ Number of Plants Using more than 20 mgy, $\sigma = 684.2$, $\beta = .0440$

See Table XIII for the matrix depicting these quantities on a national basis. Each of the 126 projects in the data base was ranked according to Table XIII and then subjected to analysis by the Policy Capturing Model which produced the basic structure of the following equation:

$$P_I = (-1230. - .43V_{1,I} \cdot W_1 + .21V_{2,I} \cdot W_2 - .12V_{3,I} \cdot W_3 + .35V_{4,I} \cdot W_4 + 101.96V_{5,I} \cdot W_5 + .07V_{6,I} \cdot W_6 + .20V_{7,I} \cdot W_7)/10^3 \tag{3}$$

where

P_I = Priority associated with the Ith industry
$V_{1,I}$ = Industrial effluent volume associated with the Ith industry
$V_{2,I}$ = Water use associated with the Ith industry
$V_{3,I}$ = Value added by manufacture to the Ith industry
$V_{4,I}$ = Employment for the Ith industry
$V_{5,I}$ = Number of states with plants for the Ith industry
$V_{6,I}$ = Total plants in the Ith industry
$V_{7,I}$ = Plants using > 20 mgy in Ith industry
W_K = User weight for each variable $V_{K,I}$ K = 1,7

Interviews with potential users suggested that the system should allow the user to dampen or increase the influence of any of the variables in the basic equation by entering user weights W_K. Thus, the system was altered to allow such entries.

The nature of P_I allowed measurement of prediction reliability by two independent means. The regression analysis which produced the above equation indicated a coefficient of determination (R^2) equal to 0.84, thus accounting for 84% of the variance in P_I. Availability of the "Needs Statements" for PPB 1200 categories additionally permitted comparison of priorities indicated by past funding with those indicated by the collective judgments of EPA personnel as to needed future research.

PPB 1200 categories were ranked on the basis of the number of "needs" reported per industry and compared with those ranks indicated by the module equation. The degree of correlation was then determined by Spearman's r_s as follows:

Table XIII

Industry Matrix

PPB	SIC	Rank	Billion Gal/Yr Effluent Volume	Billion Gal/Yr Water Use	Million $ Value Added	Thousands Em-ployment	No. of States with Plants	Total Plants	Plants Using 20 mgy
1206	20	35.00	690	1280	10073	626	37	21555	2405
1204	26	25.66	1900	6026	3856	249	25	4393	634
1202	28	13.24	3700	7577	12590	480	30	7511	1062
1201	33,34	9.08	4300	6901	14707	1072	24	21658	1270
1209	22	8.20	140	311	2649	353	17	5160	603
1212	39	3.13	12	22	529	43	4	6865	76
1205	29	2.82	1300	6161	3066	119	15	1390	268
1207	35,36,37	1.67	481	1216	34976	2537	24	28836	1287
1210	24	.80	123	217	574	69	6	10584	186
1208	32	.34	218	389	3180	218	17	8415	555
1211	30	.05	160	336	2667	210	13	3312	280

Needs Rank	Module Rank	d^2
1206 = 9	10	1
1204 = 7	9	4
1202 = 10	8	4
1201 = 6	7	1
1209 = 4	6	4
1212 = 4	5	1
1205 = 8	4	16
1207 = 1	3	4
1210 = 5	2	9
1208 = 2	1	1

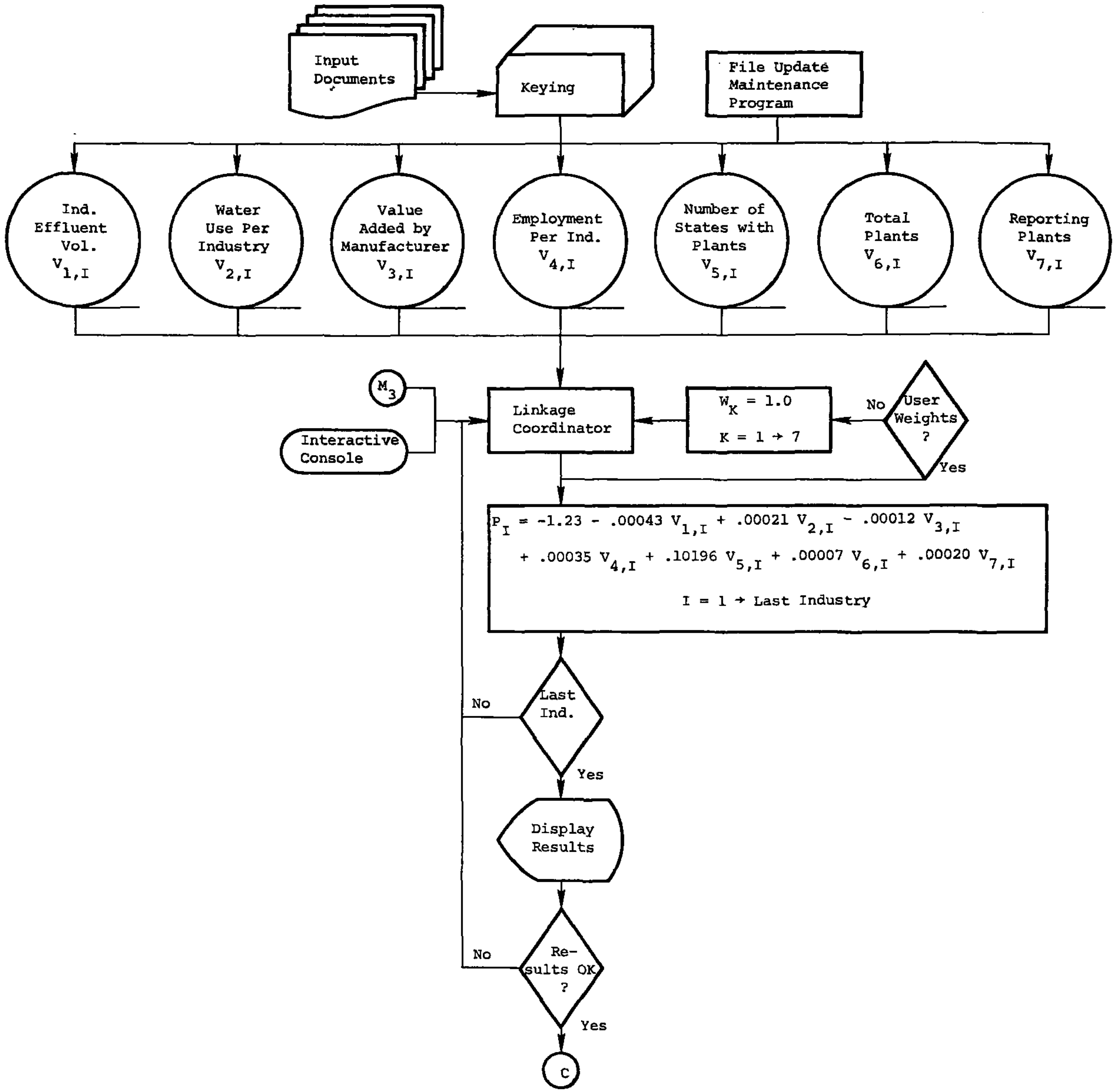
$$r_s = 1 - \frac{6\Sigma d^2}{N(N^2 - 1)} = .73$$

The correlation coefficient is significant at the .01 level which indicates that the module rank is reliably related to the needs rank. Furthermore, equation (3) suggests that previously EPA has given high priorities to industries with:

√ *Low industrial effluent volumes*
√ *High water use*
√ *Low value added by manufacture*
√ *High employment*
√ *High number of states with plants*
√ *High number of total plants*
√ *High number of large water-using plants*

The Industry Module is logically and mathematically straightforward, as can be seen from Flow Chart 4. Similar to the other modules, it has a file update and maintenance program to insure file integrity; however, this module requires a much less sophisticated linkage coordinator. Essentially, a request enters either from the Module Control Program or a user console. User weights W_K are requested; if none are given, unity is assumed and $W_K = 1.0$ for all K. LC retrieves $V_{K,I}$, weights it, and determines P_I for each industry. The priorities are displayed on the console for user approval. Further, they are updated as needed to reflect most recent policy decisions. If approval is received, control goes to "C" where P_I are stored in file F3. If approval is not received, the user is queried for cause of rejection and where to continue. Upon completion, control is transferred to the Statistical Module.

Although PPB number was chosen as the basic unit of classification for this module, two- or four-digit SIC numbers will also suffice. Table XIV cross references PPBs, SICs (two and four digits) and information sources.



Flow Chart 4. Industry Module III

Table XIV

Industrial Classification Cross Reference

CITY AND COUNTY DATA BOOK INDUSTRIAL GROUPS SUMMARY DATA		EPA "COST OF CLEAN WATER" INDUSTRIAL GROUPS SUMMARY DATA		EPA INDUSTRIAL WASTE PROFILES (and/or Industrial Waste Guides)		EPA R&D PROGRAM STRUCTURE DESIGNATIONS		
Industrial Group	SIC	Industrial Group	SIC	Publication Title	SIC	PPBS	Technology Group	SIC
Primary and Intermediate Metal Products	33,34					1201	Metal and Metal Products	33,34
		Primary Metals	33					
		✓ Blast Furnaces/Steel Mills	3312	Blast Furnaces/Steel Mills	3312			
		✓ All Other						
Chemicals, Rubber, Petroleum and Plastics Products	28,29,30							
		Chemicals and Allied Products	28			1202	Chemicals and Allied Products	28
		✓ Organic Chemicals Ind.	2815,-18, -13,-79, -71	Organic Chemicals Industry	2815,-18, -13,-79, -71			
		✓ Inorganic Chemicals Ind.	2812,-13, -16,-19, -51,-71, -79,-92	Inorganic Chemicals Industry	2812,-13, -16,-19 -51,-71 -79,-92			
		Petroleum and Coal Products	29	Plastics Materials and Resins	2821	1205	Petroleum and Coal Products	29
				Petroleum Refining	2911			
		Rubber and Plastics	30			1211	Rubber and Plastics	30
Food and Tobacco Products	20,21							
		Food and Kindred Products	20			1206	Food and Kindred Products	20
		✓ Meat Products	201	Meat Products	201			
		✓ Dairy Products	202	Dairies	202			
		✓ Canned and Frozen Food	203	Canned/Frozen Fruits and Vegetables	2033 2037			
		✓ Sugar Refining	206					
		✓ All Other						
Paper and Printing	26,27							
		Paper and Allied Products	26			1204	Paper and Allied Products	26
				Paper Mills Except Building	2621			
						1203	Power Production	
				Thermal Pollution (Industrial Waste Guide)				
Electrical and Non-Electrical Machinery Transportation and Ordnance	35,36 37,19							
						1207	Machinery and Transportation Equipment	35,36,37
		Machinery Except Electrical	35					
		Electrical Machinery	36					
		Transportation Equipment	37					
				Motor Vehicles and Parts	3717			
Stone, Clay and Glass Products	32					1208	Stone, Clay and Glass Products	32
Textile, Apparel and Leather Products	22,23,31							
		Textile Mill Products	22	Textile Mill Products	22	1209	Textile Mill Products	22
				Leather Tanning and Finishing	3111			
Lumber, Wood Products and Furniture	24,25							
						1210	Lumber and Wood Products	24

Module IV. Statistical

The statistical module retrieves priorities associated with type of project, project organization, and project implementation. See Tables II through IV. As previously stated, these variables are dimensionable within themselves and are largely dependent only upon current EPA policy. Because of their arbitrary nature and the fact that they are quite volatile, the module makes no decisions dependent upon past policy with respect to these variables; instead, that policy is described to the user, thereby supplying him the information he needs to support his judgment. In addition, this module tallies Federal and industrial RD&D expenditures by region and industry using Form No. 8100, Appendix F. The four update and maintenance programs are most important subsystems in this module. UD_1, UD_2, and UD_3 support routine updating to their respective tables with change in EPA policy while UD_4 is charged with the responsibility of accounting for all "actions" taken by EPA during the period of interest. Thus, when a project is funded, the amount of Federal funds, the amount of industrial funds, and the "action description" are stored on disk file. When the "map" is next generated, these data are used as a baseline for action generation. Flow Chart 5 illustrates the sequence of retrieval operations.

The variables, in order of retrieval, are:

FF_P = Federal funding per project P

IF_P = Industrial funding per project P

IND_A = Industry for action A

LOC_A = Location of action A

$EC_{A,I}$ = Effluent constituents associated with action A

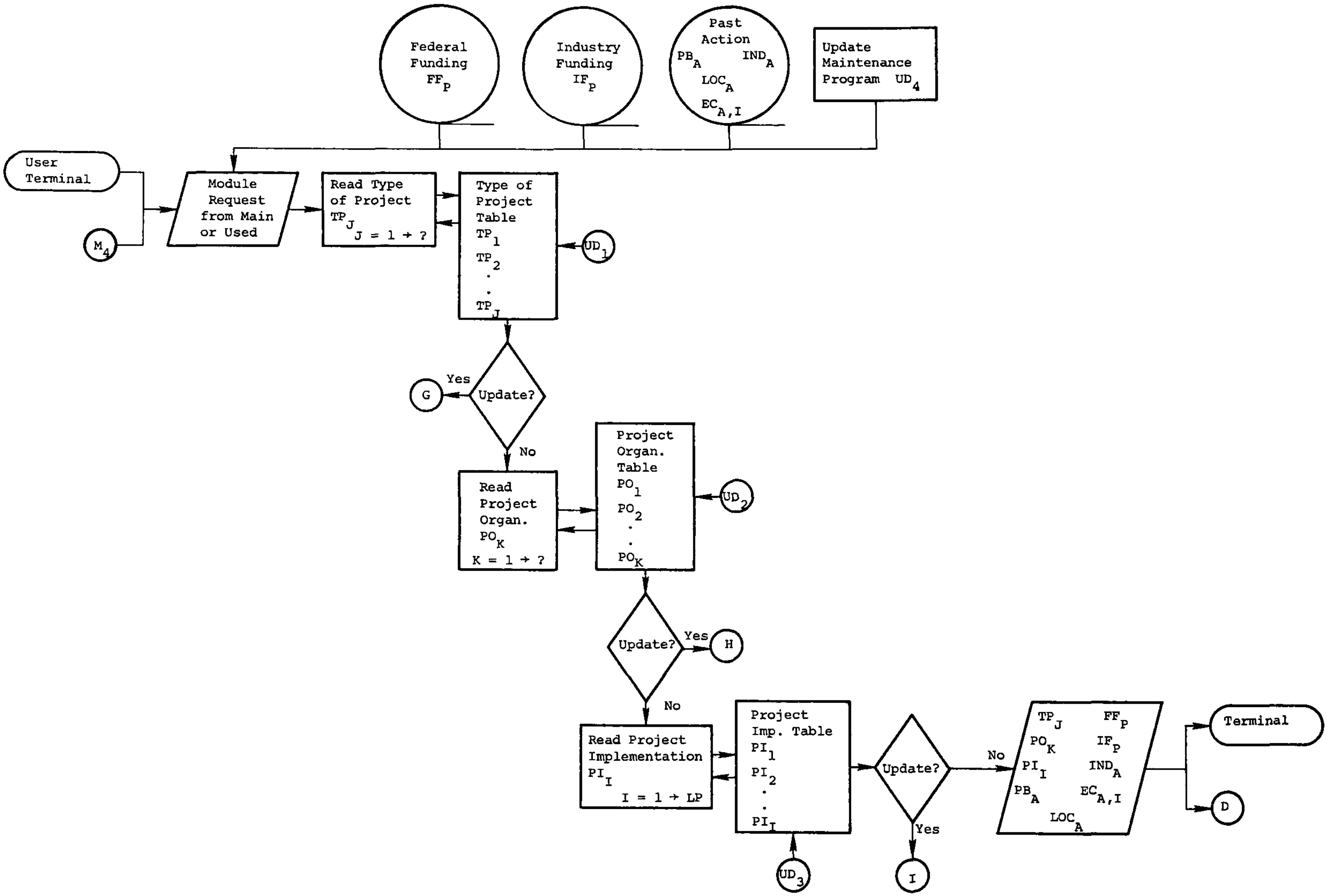
PB_A = Percent of budget spent on A

TP_J = Type of project ranking for J types

PI_I = Project implementation for I types

PO_K = Project organization for K types

After retreival, control is transferred to "D" in the Module Control Program where the variables are stored on file F4.



Flow Chart 5. Statistical Module

MODEL OPERATION

There are two modes of model operation. Mode I "maps" national priorities for industrial effluent treatment and control research, development, and demonstration. It supplies EPA with a number of specific "actions" that should be taken, as well as an appraisal of the relative importance of each action. (See Figure 1.) The MAP may be used as a guide to project development and funding. Mode II reverses the role of the model. In this mode, the model reviews and assigns priorities to project descriptions such as "Statements of Need," provides suggestions as to how one might improve the priority of specific projects, and suggests how similar or complementary "Needs" may be combined. Although the current effort was concerned basically with Mode I, the ultimate utility of Mode II justified considerable attention to its preliminary design. The success or failure of TIMPS is highly dependent upon a sound means for generating an RD&D priority list. The two subsections that follow discuss each mode of operation separately.

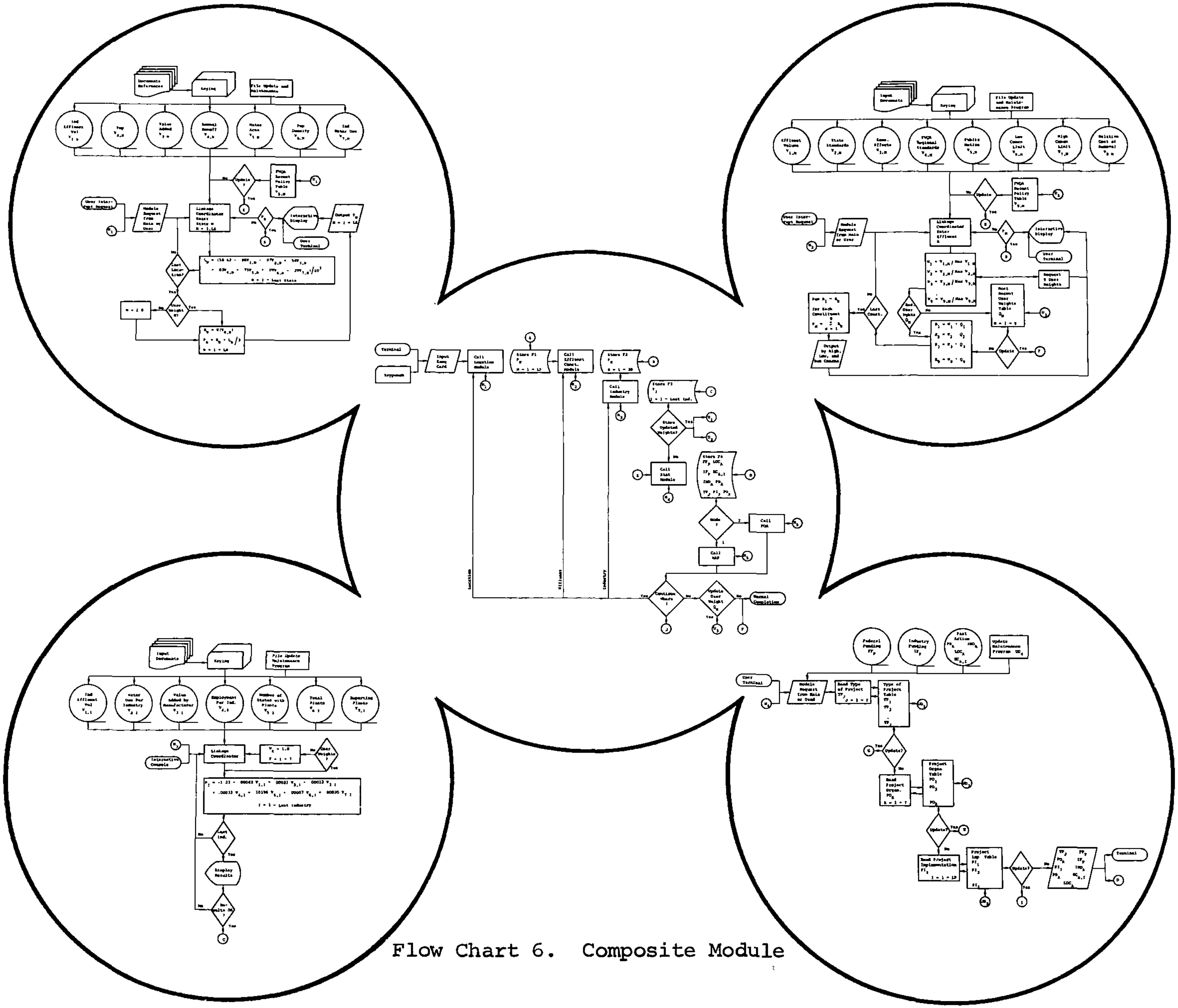
Flow Chart 6 indicates the ties between the four modules and the Module Control Program, Mode I, and Mode II. Note that the only logical difference between Mode I and Mode II is that control goes to MAP in the former and to Project Organization Algorithm (POA) in the latter.

Mode I. MAP

The Multiple Allocation Program (MAP) is based on a multi-dimensional resource allocation routine. Basically, the problem is to allocate a fixed budget "K" over three variably dimensional parameters. The question is how resources can best be allocated with respect to project objectives in order to maximize the return on investment considering all three parameters at any point in time. In order to respond to this question, the model must combine the individual priorities on *a priori* logical ground, not merely according to mathematical optimization techniques.

The "MAP" is generated at three levels of specificity:

> Level I - general summary of the priority associated with each PPB category, the percent of total budget and of PPB budget allocated to each state associated with that PPB category, and the percent of total budget and PPB budget allocated to each primary effluent constituent. Figure 1, pages 3 through 5, illustrates this level of "MAP." The values used in Figure 1 are based on past policy and should only be used as an example of possible output from the model. Since the model requires rather complex manipulations, adequate test results and experience from applications must await the decision to complete and fully implement the modeling system at least for the 1200 PPBS category.



Flow Chart 6. Composite Module

Level II - describes the priorities associated with all "Actions" for each PPB category. Due to the time required to calculate these manually, only the "Action" Matrix for PPB 1206 has been determined for Figure 2. Each entry in the matrix describes the percent of total budget to be allocated to the location/effluent constituent combination. For example, BOD in New York receives 1.07% of budget.

Level III - provides a detailed description of each "subaction" prescribed by the model. Subactions are described by industry, location, effluent constituent, priority, and percent of budget. Figure 3 shows the first 14 subactions prescribed by the model.

Of course, depending upon the size of the RD&D budget, the subactions can be combined into larger projects, or broken into small projects; in short, 270 subactions do not necessarily dictate 270 projects.

Consider the example in Figure 1. Inputs to MAP from the four modules are calculated as described below and illustrated in Flow Chart 7.

Priorities associated with industry ranked from high to low
P_I $I = 1 \rightarrow$ LAST INDUSTRY

Priorities associated with location ranked from high to low
P_N $N = 1 \rightarrow$ LAST STATE

Priorities associated with effluent constituent ranked from high to low P_M $M = 1 \rightarrow$ LAST CONSTITUENT

Past actions during that period
PB_A, $IND_{A,I}$, $LOC_{A,N}$, $EC_{A,I}$ $A = 1 \rightarrow$ LAST ACTION

In the interest of clarity, past actions will not be considered in this example. However, in general, the following three equations illustrate how past actions are discounted from the system:

$$P_I = P_{I_1} - IND_{A,I} \qquad (4)$$

where

P_{I_1} = the priority associated with industry I at time t = A

$IND_{A,I}$ = the percent of budget spent on industry I at time t = A

P_I = industrial priority at t = A + 1 for industry I

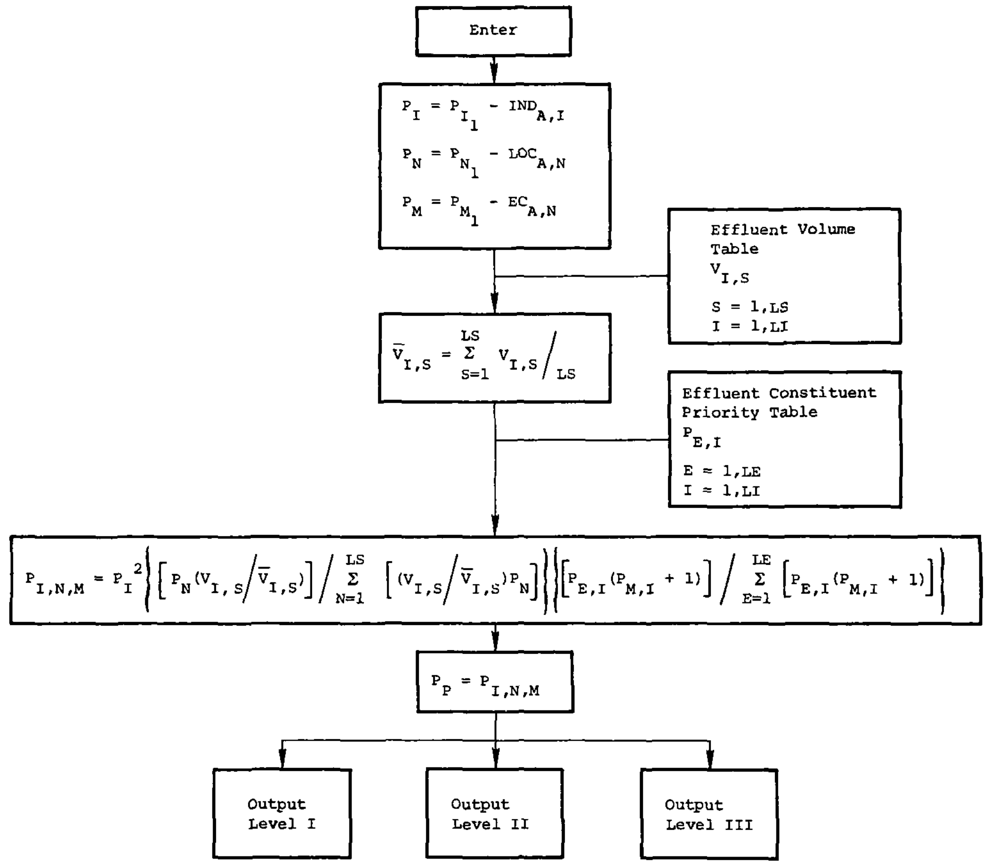
$$P_N = P_{N_1} - LOC_{A,N} \qquad (5)$$

where

P_{N_1} = the priority associated with location N at time t = A

$LOC_{A,N}$ = the percent of budget spent in location N at time t = A

P_N = geographical priority at t = A + 1 for location N



Flow Chart 7. Subroutine MAP

$$P_M = P_{M_1} - EC_{A,M} \qquad (6)$$

where

P_{M_1} = the priority associated with effluent constituent M at time t = A

$EC_{A,M}$ = the percent of budget spent on effluent M at time t = A

P_M = effluent constituent priority at t = A + 1 for constituent M

After P_I, P_N, and P_M have been adjusted by equations (4), (5), and (6), MAP evaluates all rational combinations of industry, location, and effluent constituent in the following equation to determine subaction priorities, Figure 1.

$$P_P = P_{I,N,M} = P_I^{\,2} \quad P_N\,(V_{I,S}/\overline{V}_{I,S}) \quad \sum_{N=1}^{LS} \quad P_N\,(V_{I,S}/\overline{V}_{I,S})$$

$$P_{E,I}\,(P_{M,I} + 1) \quad \sum_{E=1}^{LE} \quad P_{E,I}\,(P_{M,I} + 1) \qquad (7)$$

where

P_P = Priority of project P

$P_{I,N,M}$ = Priority of project in industry I, location N, and primary effluent constituent M

P_I = Priority from industrial module for industry I

P_N = Priority from location module for location N

$V_{I,S}$ = Volume of effluent in state S from industry I in bgy

$\overline{V}_{I,S} = \sum_{S=1}^{LS} V_{I,S}/LS$; mean $V_{I,S}$

$P_{E,I}$ = Priority of effluent constituent E in industry I

LS = Last State

LE = Last Effluent Constituent

$P_{M,I}$ = Priority P_M from effluent constituent module for industry I

Matrix $P_{I,N,M}$ is then sorted from high to low, placed into array P_P, and output to MAP, Level III, as illustrated in Figure 3.

Equation (7) maximizes benefit/cost ratios by determining the combined importance of a volume of an effluent constituent within an industry within a state. The principle of optimization is simple. Returns to scale are maximized by funding projects that deal with large volumes of high priority effluent constituents in high priority industries in high priority states, and further, the relative amount of funding will be described by the relative magnitude of those priorities.

The system first makes logical comparisons of all combinations of industry, location, and effluent constituents to determine which combinations are rational. It then looks up $V_{I,S}$, the volume of effluent under consideration in state "s" from industry I in order to optimize returns to scale. Notice that effluent volume is not being used in the same manner as it was in calculating P_I and P_N, the difference being that in equation (7) <u>effluent volume per state per industry</u> is being used in determining the relative weight $\overline{V}_{I,S}$ which reflects the combined importance of P_I and P_N. In P_I and P_N we were using effluent volume per industry and per state respectively. Notice that P_P will equal zero only if the combination of industry, state, and effluent constituent is irrational, otherwise P_P will only approximate zero for very low priority jobs. The system determines the absolute value of such projects as a function of the budget size and disregards projects whose value falls below a pre-set minimum.

<u>Mode II. POA</u>

The Project Organization Algorithm serves three major purposes:

1. Determines priorities based on structural project descriptions.
2. Illustrates how similar or complementary projects may be combined under one set of objectives.
3. Determines how priorities on a given project may be increased, e.g., a project may be enhanced, if done in a state other than the one proposed, and the reason.

In general, POA is a special organization of the MAP algorithm; that is, it is mathematically the same, but logically reorganized. Upon receiving control from Module Control, P_I, P_N, and P_M are adjusted for past funding as in MAP; however, under POA, the system is provided values for industry "I," location "N," and effluent constituents "M." Based on these values, P_I, P_N, P_M, $V_{I,S}$, and $P_{E,I}$ are retrieved. $P_{I,N,M}$ is then determined as a function of these values. Once the last project description is evaluated, matrix $P_{I,N,M}$ is sorted in descending order into array P_P and displayed. The system then compares all combinations of projects; where like or complementary projects are found, it suggests they be combined and reports the new priority. Based primarily on past funding, the system maximizes each priority by substituting higher priority locations and effluent constituents for, or in addition to, those proposed. It is anticipated that model output to POA will be similar to Level III, MAP, Figure 3.

DETERMINATION OF MODEL PRACTICABILITY

Demonstrable practicability was an overriding consideration in the design and development of a suitable RD&D priority and fund allocation model. In general, this meant that any model design chosen for development must not only be technically sound and potentially responsive to management user needs, but amenable to implementation within established EPA resources and constraints. Specifically, the practicability of the model design was scrutinized from two separate, though related, stand-points: (1) Functional integrity and fidelity to user requirements, and (2) operational feasibility and suitability implications. These areas are discussed, in turn, below.

Functional Integrity and Fidelity

The functional design of the four modules which comprise the priority and fund allocation model in its present developmental form has been described in detail in preceding sections and needs not be repeated here. Based on those descriptions, however, points bearing on the model's integral nature should be apparent.

1. With the exception of the Statistical Support Module, module design was configured on a single, largely compatible framework. Only those differences which were essential to account for unique predictor variable substrata were retained. In fact, the basic form of the policy capturing algorithm applies equally well across the three primary modules.

2. Although, as noted above, this contract was intended only for initial design, sufficient preliminary programming of module subroutines was accomplished to enable the modules to be operated in sequence under operator control. Without a determination of PPBS category scope or the desired machine configuration, further programming at this stage would, of course, have been potentially wasteful and inefficient.

3. Each module has been provided with a comparable elemental maintenance and update subroutine sufficient for entry into the next developmental step.

4. While not a required portion of the effort, a second mode of model operation has been developed which permits "Statement of Need" evaluation on an integral basis with priority determinations.

A major effort was made to assure that the model design and anticipated implementation form would be responsive to critical user information requirements. Accordingly, a number of important provisions serve this end. Chief among these are:

1. User access to all variables and primary operations has been retained in order that final judgment can be exercised by the user at any and all levels. Thus, the user is able to interact with the priority determination and fund allocation process at all times, which ensures that the rationale for any given set of model outcomes is entirely explicit.

2. A wide range of user requests can be dealt with by the model design. Generally, such requests may be grouped in three very broad classes:

   √ Assessment of prior policy effects.
   √ Comparison of immediate alternative policy strategies to support current allocation demands.
   √ Comparisons among and between longer range contingency plans.

3. The model design, owing to its modular form, permits a large degree of manual execution. Limitations on this capability are due primarily to the facility with which the model accepts a large number of variables for consideration, not the complexity of operations. This latter capability is enhanced by the provisions for collapsing a given module (sloughing variables) at the user's discretion.

4. Provisions were made to support a large set of alternatives for establishing the procedures by which final priority and fund allocations will be determined, since both ready-file access and iterative refinement procedures are simple and well defined.

5. Depending upon a final determination of user requirements with respect to precision and degree of confidence, the "Public Notice" variable is accommodated within the model. Options for public notice source data include at least the following:

   √ Congressional Record.
   √ Complaints (number and type) received at regional/state regulatory and enforcement agencies.
   √ Media coverage (frequency, time, space allocated).

Operational Feasibility and Suitability

The implications of the model design can be soundly inferred from present design characteristics and preliminary tests of model behavior. Thus, assuming a typical International Business Machine System 360 model 50 machine configuration, the following essential operating parameters can be specified:

Average Maximum Run Time

Disk IO (2311): approximately 75103 secs/run (assumes 75 millisecond/access and that files 1-4 are either held in main frame core [lower figure] or stored on disk [higher figure]).

Central Processor: approximately 85 secs/run.

IO: variable dependent upon device (e.g., printer or console), device software and extent of output resultant from user request.

Core Requirements (Assumes segmented, modularized instruction set)

Average resident core required during execution: 400 words, assuming data-base matrices (or arrays) associated with given execution available in core.

Resident core storage: 2700 words.

Total core required: 3100 words.

Program

Approximately 2000 Fortran IV instructions, where an average 300 are in resident core at any given time.

Data Reduction Manpower

Input data reduction manpower for module file data base update is estimated at .5 mandays/month for the 1200 PPBS category. This minimal requirement owes to the reliance upon readily available data, much of which are already collected and reduced to machine manipulable form by EPA on a regular basis.

It can be concluded that the entire model places a trivial demand upon machine and personnel resources and is well within existing EPA constraints.

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APPENDIX A

DATA ELEMENT SOURCES

Table A-1

Data Elements and Information Sources

Data Element	Source of Information Code																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Effluent Constituents																								
Associated industrial effluent volumes			X	X	X				X	X	X	X												
Concentrations in receiving waters permitting all water uses																X					X			
Concentrations in receiving water permitting all but the "most sensitive" water uses																X					X			
Frequency of mention in State Water Quality Standards																X				X				
Economic effects on water uses in receiving waters											X						X				X			
EPA Regional Office appraisals of relative pollution severities																			X					
Degree of public notice																		X						
Target treatment costs as determined by maximum values of recovered materials																		X				X		X
Industrial Groups																								
Size of industry	X	X	X	X	X		X								X							X		
Geographical distribution of industry	X	X	X	X	X				X	X							X							
Water use practices									X	X	X	X					X							
Economic status	X						X																	
Wastewater treatment facilities			X	X	X					X														
Production parameters	X	X					X								X							X		
Wastewater constituents			X	X	X																			
State Dimensions																								
Industrial wastewater volumes			X	X	X					X		X												
Population	X													X										
Land area	X												X	X										
Value added by manufacture	X	X					X					X			X									
Number of manufacturing establishments	X	X					X					X			X									
Capital expenditures by manufacturers	X	X													X									
Industrial water use									X		X	X					X							
Land area in farms and value of farm products	X																							
Population using public water supplies	X											X												
Annual precipitation	X																							
Recreational areas and annual use	X																							
Fishing licenses issued	X																							
Metropolitan area population	X													X										
Electrical energy production	X																							
Annual water runoff and withdrawals												X	X											
Scientific population	X																							
Funded Project Descriptions																								
Industry involved						X		X															X	
Location						X		X															X	
Project dates						X		X																
Sources of funds						X		X															X	
Wastewater constituents involved						X		X																
Type of project						X		X															X	
Project implementation						X		X																
Objectives of project						X		X															X	
General Statistics																								
Federal/industry R&D funds by region						X		X																
Federal/industry R&D funds by industry group						X		X																

Table A-2

Sources of Information

1. United States Department of Commerce, Bureau of the Census. Statistical abstract of the United States. (91st ed.) Washington, D. C.: Author, 1970.

2. United States Department of Commerce, Bureau of the Census. 1967 census of manufactures. Washington, D. C.: Author, 1971. (Publication Number MC67(2), Series includes 80 reports):

19 Ordnance and accessories

20 Food and kindred products
- 20A Meat products
- 20B Dairy products
- 20C Canned, cured, and frozen foods
- 20D Grain mill products
- 20E Bakery products
- 20F Sugar and confectionery products
- 20G Beverages
- 20H Fats and oils
- 20I Miscellaneous foods and kindred products

21 Tobacco products

22 Textile mill products
- 22A Weaving mills
- 22B Knitting mills
- 22C Dyeing and finishing textiles, except wool fabrics and knit goods
- 22D Floor covering mills
- 22E Yarn and thread mills
- 22F Miscellaneous textile goods

23 Apparel and other textile products
- 23A Men's and boy's apparel
- 23B Women's and misses' apparel
- 23C Women's and children's underwear; headwear; children outerwear
- 23D Miscellaneous apparel and accessories
- 23E Miscellaneous fabricated textile products

24 Lumber and wood products
- 24A Logging camps, sawmills, and planing mills
- 24B Millwork, plywood, and prefabricated structural wood products
- 24C Wooden containers and miscellaneous wood products

25 Furniture and fixtures
- 25A Household furniture
- 25B Office, public building, and miscellaneous furniture; office and store fixtures

26 Pulp, paper, and board mills
- 26A Pulp, paper, and board mills
- 26B Converted paper and paperboard products, except containers and boxes
- 26C Paperboard containers and boxes

27 Printing and publishing
- 27A Newspapers, periodicals, books, and miscellaneous publishing
- 27B Commercial printing and manifold business forms
- 27C Greeting cards, bookbinding, and printing trade services

28 Chemicals and allied products
- 28A Industrial chemicals
- 28B Plastic materials, synthetic rubber, and manmade fibers
- 28C Drugs
- 28D Soap, cleaners, and toilet goods
- 28E Paints and allied products; gum and wood chemicals
- 28F Agricultural chemicals
- 28G Miscellaneous chemical products

29 Petroleum and coal products

30 Rubber and plastics products, N.E.C.

31 Leather and leather products
- 31A Tanning; industrial leather goods; and shoes
- 31B Leather gloves; and miscellaneous leather goods

32 Stone, clay and glass products
- 32A Glass products
- 32B Cement and structural clay products
- 32C Pottery and related products
- 32D Concrete, plaster, and cut stone products
- 32E Abrasive, asbestos, and miscellaneous nonmetallic mineral products

33 Primary metals industries
- 33A Blast furnaces, steel works, and rolling and finishing mills
- 33B Iron and steel foundries
- 33C Smelting and refining of nonferrous metals and alloys
- 33D Nonferrous metal mill and foundry products
- 33E Forging and miscellaneous primary metal products

34 Fabricated metal products
- 34A Metal cans, cutlery, handtools, and general hardware
- 34B Heating apparatus (except electric and plumbing fixtures)
- 34C Fabricated structural metal products
- 34D Screw machine products, fasteners and washers; metal stampings; and metal services
- 34E Miscellaneous metal products

35 Machinery, except electrical
- 35A Engines and turbines and farm machinery and equipment
- 35B Construction, mining, and materials handling machinery and equipment

35C Metalworking machinery and equipment
35D Special industry machinery, except metalworking machinery
35E General industrial machinery and equipment
35F Office, computing and accounting machines
35G Service industry machines and machines shops

36 Electrical equipment and supplies
36A Electrical measurement and distribution equipment
36B Household appliances
36C Electric lighting and wiring equipment
36D Communication equipment, including radio and TV and electronic components and supplies

37 Transportation equipment
37A Motor vehicles and equipment
37B Aircraft and parts
37C Ship and boat building, railroad and miscellaneous transportation equipment

38 Instruments and related products
38A Instruments; surgical, dental, and ophthalmic equipment and supplies
38B Photographic equipment; clocks, watches, and watchcases

39 Miscellaneous manufacturing industries
39A Jewelry, silverware, and plated ware
39B Musical instruments and parts; toys and sporting goods
39C Office supplies, costume jewelry, and notions
39D Miscellaneous manufactures

3. United States Department of the Interior, Federal Water Pollution Control Administration. The cost of clean water. Washington, D. C.: Author, 1968. (Series includes the following reports:)

Volume 1. Summary report
Volume 2. Detailed analyses
Volume 3. Industrial waste profiles

Number 1. Blast furnaces and steel mills
Number 2. Motor vehicles and parts
Number 3. Paper mills except building
Number 4. Textile mill products
Number 5. Petroleum refining
Number 6. Canned and frozen fruits and vegetables
Number 7. Leather tanning and finishing
Number 8. Meat products
Number 9. Dairies
Number 10. Plastics materials and resins

Volume 4. State and major river basin municipal tables

4. United States Department of the Interior, Federal Water Pollution Control Administration. The cost of clean water and its economic impact. Washington, D. C.: Author, 1969. (Series includes the following reports:)

Volume Number 1. The report
Volume Number 2. Appendix
Volume Number 3. Sewerage charges
Volume Number 4. Projected wastewater treatment costs in the organic chemicals industry.

5. United States Department of the Interior, Federal Water Pollution Control Administration. The economics of clean water. Washington, D. C.: Author, 1970. (Series includes the following reports:)

Volume Number 1. Detailed analysis
Volume Number 2. Animal waste profile
Volume Number 3. Inorganic chemicals industry profile

6. United States Department of the Interior, Federal Water Pollution Control Administration. Projects of the industrial pollution control branch. Washington, D. C.: Author, 1970. (Publication DAST-38 of the Water Pollution Control Research Series)

7. United States Department of Commerce, Business and Defense Services Administration. United States industrial outlook--1970.

8. United States Department of the Interior, Federal Water Pollution Control Administration. Research, development, and demonstration projects. Washington, D. C.: Division of Applied Science and Technology, 1970.

9. Lawson, B. R. Atlas of industrial water use. Ithaca, New York: Cornell University Water Resources Center, 1967. (Publication 18)

10. Manufacturing Chemists Association. Toward a clean environment, 1967.

11. National Association of Manufacturers and Chamber of Commerce of the United States. Water in industry, 1965.

12. United States Department of Commerce, Bureau of the Census. Water use in manufacturing. Washington, D. C.: Author, 1963. (Publication Number MC63(1)-10)

13. Ackerman, E. A., & Lof, G. O. G. Technology in American water development. Resources for the Future Inc., 1959.

14. United States Department of Commerce, Bureau of the Census. County and city data book 1967. Washington, D. C.: Author, 1967.

15. United States Department of Commerce, Business and Defense Services Administration. Industry profiles 1958-1967, 1969

16. Resources Agency of California, State Water Quality Control Board. Water quality criteria, 1963. (Publication Number 3-A)

17. United States Department of the Interior, Office of Water Resources Research. The economic value of water in industrial uses. Washington, D. C.: Author, 1969.

18. Public notice, originating from sources such as newspapers, radio, television, periodicals, congressional record, conservation groups, local government, etc.

19. Reports originating within the framework of the Federal Water Quality Administration.

20. McDermott, J. H., & Sayers, W. T. The role of water quality monitoring in water pollution control. National Meeting of the American Chemical Society, New York, 1969.

21. Bramer, H. C. Economically significant physicochemical parameters of water quality for various uses. American Society of Testing Materials Symposium on Water Quality, Philadelphia, 1966.

22. Manufacturing Chemists Association, Inc. Chemical statistics handbook. (6th ed.), 1966.

23. United States Department of the Interior, Office of Water Resources Research. Water resources research catalog: Volume 5. Washington, D. C.: Author, 1969.

24. Schnell Publishing Company. Oil, paint, and drug reporter. New York: Author, weekly edition.

APPENDIX B

FUNDED PROJECT DESCRIPTION FOR 1200 PROGRAM R&D EXPENDITURES PRIORITIES

Data Collection Form 0100

FUNDED PROJECT DESCRIPTION FOR 1200 PROGRAM R&D EXPENDITURES PRIORITIES

1. INDUSTRY INVOLVED ______________________

a. PPBS number(s) [ ][ ][ ][ ] 1 2 3 4 [ ][ ][ ][ ] 5 6 7 8 [ ][ ][ ][ ] 9 10 11 12 [ ][ ][ ][ ] 13 14 15 16

b. SIC code(s) [ ][ ][ ][ ] 17 18 19 20 [ ][ ][ ][ ] 21 22 23 24 [ ][ ][ ][ ] 25 26 27 28 [ ][ ][ ][ ] 29 30 31 32

2. LOCATION

a. Grantee address (state) ______________________ [ ][ ] 33 34

b. Project site(s) (state) ______________________ [ ][ ] 35 36 [ ][ ] 37 38

3. DATES

a. Date awarded: month [ ][ ] 39 40 year [ ][ ] 41 42

b. Duration (months) [ ][ ] 43 44

4. FUNDING

a. Total project cost: amount (thousands) $ [ ][ ][ ][ ] 45 46 47 48 for [ ][ ] 49 50 months

b. Federal funds: amount (thousands) $ [ ][ ][ ][ ] 51 52 53 54 for [ ][ ] 55 56 months

5. WASTEWATER CONSTITUENTS TO BE REDUCED

Constituent	Rank No.	Constituent	Rank No.
______	[ ][ ] 57 58	______	[ ][ ] 59 60
______	[ ][ ] 61 62	______	[ ][ ] 63 64
______	[ ][ ] 65 66	______	[ ][ ] 67 68

6. TYPE OF PROJECT

a. Research [ ] 69

Desk-top study [ ] 70

Hands-on research [ ] 71

Laboratory [ ] 72

Bench-scale pilot [ ] 73

Conceptual study [ ] 74

State-of-the-art report [ ] 75

Form No. [0][1][0][0] 76 77 78 79

Card No. [1] 80

b. Development ☐ 1   Special Facility ☐ 2   Industrial in-plant ☐ 3

c. Demonstration ☐ 4   Industrial in-plant ☐ 5   Joint industrial-municipal ☐ 6

d. Grant ☐ 7   e. Contract ☐ 8   f. Full-scale ☐ 9   g. Pilot plant ☐ 10

7. PROJECT IMPLEMENTATION

a. Manufacturing Industry ☐ 11   b. University, or related group ☐ 12

c. Not-for-profit R&D Institution ☐ 13   d. Profit-making R&D organization ☐ 14

e. Governmental unit ☐ 15   Federal ☐ 16   Regional ☐ 17   State ☐ 18   Local ☐ 19

8. OBJECTIVES OF PROJECT

a. Wastewater volume reduction ☐ 20   b. Water reuse ☐ 21

c. Treatment process ☐ 22   New ☐ 23   Improvement ☐ 24

d. Process equipment ☐ 25   New ☐ 26   Improvement ☐ 27

e. Cost Reductions ☐ 28   f. Economic feasibility determination ☐ 29

g. Treatment control ☐ 30   Measurement ☐ 31   Automation ☐ 32

h. Engineering ☐ 33   Conventional ☐ 34   Mathematical Models ☐ 35

Process design ☐ 36   Plant design ☐ 37   Information systems ☐ 38

i. Production process modifications ☐ 39   j. By-product recovery ☐ 40

k. Manpower factors ☐ 41   training ☐ 42   requirement ☐ 43   reduction ☐ 44

l. Applicability: Small plants ☐ 45   Large plants ☐ 46

Old technology ☐ 47   Average technology ☐ 48   New technology ☐ 49

m. Wastewater characterization ☐ 50   n. Wastewater effects ☐ 51

o. Sludge disposal methods ☐ 52   Form No. [0 1 0 0] 76 77 78 79   Card No. [2] 80

Project No.

APPENDIX C

STATE DIMENSIONS FOR 1200 PROGRAM R&D EXPENDITURES PRIORITIES

Data Collection Form 6100

STATE DIMENSIONS FOR 1200 PROGRAM R&D EXPENDITURES PRIORITIES

1. STATE ______________________________ Code [ ][ ] *1 2*

2. CENSUS BUREAU REGION ____ Code [ ][ ] *3 4*   3. CENSUS BUREAU DIVISION ____ Code [ ][ ] *5 6*

4. EPA (COST OF CLEAN WATER) DRAINAGE REGION(s):

a. Region ____________ Code [ ][ ] *7 8*   Number of Counties ____________ [ ][ ] *9 10*

b. Region ____________ Code [ ][ ] *11 12*   Number of Counties ____________ [ ][ ] *13 14*

c. Region ____________ Code [ ][ ] *15 16*   Number of Counties ____________ [ ][ ] *17 18*

d. Region ____________ Code [ ][ ] *19 20*   Number of Counties ____________ [ ][ ] *21 22*

5. WATER RESOURCES COUNCIL DRAINAGE AREA(s):

a. Area ____________ Code [ ][ ] *23 24*   Number of Counties ____________ [ ][ ] *25 26*

b. Area ____________ Code [ ][ ] *27 28*   Number of Counties ____________ [ ][ ] *29 30*

c. Area ____________ Code [ ][ ] *31 32*   Number of Counties ____________ [ ][ ] *33 34*

d. Area ____________ Code [ ][ ] *35 36*   Number of Counties ____________ [ ][ ] *37 38*

6. CENSUS BUREAU INDUSTRIAL WATER USE REGION(s):

a. Region ____________ Code [ ][ ] *39 40*   Number of Counties ____________ [ ][ ] *41 42*

b. Region ____________ Code [ ][ ] *43 44*   Number of Counties ____________ [ ][ ] *45 46*

c. Region ____________ Code [ ][ ] *47 48*   Number of Counties ____________ [ ][ ] *49 50*

d. Region ____________ Code [ ][ ] *51 52*   Number of Counties ____________ [ ][ ] *53 54*

7. INDUSTRIAL WASTEWATER VOLUME ________________ (billion gallons) [ ][ ][ ][ ] *55 56 57 58*

Data Valid for the Year ______________________________ 19[ ][ ] *59 60*

Form No. [6][1][0][0] *76 77 78 79*   Card No. [1] *80*

1. POPULATION ______ (1000) [| | | |] 1 2 3 4 5

2. LAND AREA ______ (sq. mi.) [| | | | |] 6 7 8 9 10 11

3. VALUE ADDED BY MANUFACTURE ______ ($ million) [| | | |] 12 13 14 15 16

4. TOTAL NUMBER OF MANUFACTURING ESTABLISHMENTS ______ [| | | |] 17 18 19 20 21

5. NUMBER OF MANUFACTURING ESTABLISHMENTS WITH MORE THAN 20 EMPLOYEES [| | | |] 22 23 24 25 26

   a. Food and Tobacco Products ______ [| | |] 27 28 29 30

   b. Textile, Apparel, and Leather Goods ______ [| | |] 31 32 33 34

   c. Paper and Printing ______ [| | |] 35 36 37 38

   d. Chemicals, Petroleum, Rubber, and Plastics ______ [| | |] 39 40 41 42

   e. Lumber, Wood Products, and Furniture ______ [| | |] 43 44 45 46

   f. Stone, Clay, and Glass Products ______ [| | |] 47 48 49 50

   g. Primary and Intermediate Metal Products ______ [| | |] 51 52 53 54

   h. Electrical and Non-Electrical Machinery ______ [| | |] 55 56 57 58

   i. Transportation and Ordnance ______ [| | |] 59 60 61 62

   j. Instruments and Miscellaneous Products ______ [| | |] 63 64 65 66

6. CAPITAL EXPENDITURES BY MANUFACTURERS ______ ($ million) [| | |] . [ ] 67 68 69 70 71

7. INDUSTRIAL WATER USE, ANNUAL ______ (billion gallons) [| | |] 72 73 74 75

Form No. [6|1|0|0] 76 77 78 79 Card No. [2] 80

1. LAND IN FARMS ______________________ (1000 acres) [| | | | |] 1 2 3 4 5 6

2. VALUE OF FARM PRODUCTS SOLD ______________________ ($ million) [| | |] 7 8 9 10

3. WATER AREA ______________________ (sq. mi.) [| | |] 11 12 13 14

4. POPULATION USING PUBLIC WATER SUPPLIES ______________________ (%) [|] . [ ] 15 16 17

5. ANNUAL PRECIPITATION ______________________ (inches) [|] . [|] 18 19 20 21

6. STATE PARK AND RECREATIONAL AREAS ______________________ (1000 acres) [| | |] 22 23 24 25

7. STATE PARK AND RECREATIONAL AREAS ______________________ (1000 visits) [| | | |] 26 27 28 29 30

8. STATE FISHING LICENSES ISSUED ______________________ (1000) [| | |] 31 32 33 34

9. METROPOLITAN AREA POPULATION ______________________ (1000) [| | | |] 35 36 37 38 39

10. ELECTRICAL ENERGY PRODUCTION ______________________ (10^6 kw.-hr.) [| | | | |] 40 41 42 43 44 45

11. ANNUAL WATER RUNOFF ______________________ (1000 acre-feet) [| | | |] 46 47 48 49 50

12. ANNUAL WATER WITHDRAWALS ______________________ (1000 acre-feet) [| | | |] 51 52 53 54 55

13. AGRICULTURAL AND BIOLOGICAL SCIENTISTS ______________________ [| | | |] 56 57 58 59 60

14. PSYCHOLOGISTS, ECONOMISTS, AND OTHER SOCIAL SCIENTISTS ______________________ [| | | |] 61 62 63 64 65

15. ATMOSPHERIC AND EARTH SCIENTISTS ______________________ [| | | |] 66 67 68 69 70

16. ALL OTHER SCIENTISTS ______________________ [| | | |] 71 72 73 74 75

Form No. [6 | 1 | 0 | 0] 76 77 78 79   Card No. [3] 80

APPENDIX D

POLLUTION SEVERITY OF WASTEWATER CONSTITUENT FOR 1200 PROGRAM

R&D EXPENDITURES PRIORITIES

Data Collection Form 4100

POLLUTION SEVERITY OF WASTEWATER CONSTITUENT FOR 1200 PROGRAM
R&D EXPENDITURES PRIORITIES

1. WASTEWATER CONSTITUENT ______________________ Code [| |] 1 2 3

2. FREQUENCY OF MENTION IN STATE WATER QUALITY STANDARDS __________ (%) [| |] 4 5 6

3. INDUSTRIES PRODUCING WASTEWATER CONSTITUENT (SIC numbers):

a. Industry ______________________ [| | |] 7 8 9 10

b. Industry ______________________ [| | |] 11 12 13 14

c. Industry ______________________ [| | |] 15 16 17 18

d. Industry ______________________ [| | |] 19 20 21 22

e. Industry ______________________ [| | |] 23 24 25 26

4. CONSTITUENT RANKED [|] 27 28 on basis of economic effect: highest rank [|] 29 30

5. CONSTITUENT RANKED [|] 31 32 on basis of regional appraisals: highest rank [|] 33 34

6. CONCENTRATIONS OF CONSTITUENT IN mg. PER LITER TO PERMIT:

a. "All" water uses [| |] 35 36 37 . [| |] 38 39 40 b. "Most" water uses [| |] 41 42 43 . [| |] 44 45 46

7. CONSTITUENT RANKED [|] 47 48 on basis of "All" water uses: highest rank [|] 49 50

8. CONSTITUENT RANKED [|] 51 52 on basis of "Most" water uses: highest rank [|] 53 54

9. FREQUENCY OF PUBLIC MENTION RANKED [|] 55 56 on basis of highest rank of [|] 57 58

10. IN THE ABSENCE OF SPECIFIC INFORMATION, RANK THIS WASTEWATER CONSTITUENT

the same as ______________________ Code [| |] 59 60 61

Data Valid for the Year ______________________ 19 [|] 73 74

Form No. [4|1|0|0] 75 76 77 78 No. of Cards [1] 79 End of Card [1] 80

APPENDIX E

INDUSTRY DIMENSIONS FOR 1200 PROGRAM R&D EXPENDITURES PRIORITIES

Data Collection Form 2100

INDUSTRY DIMENSIONS FOR 1200 PROGRAM R&D EXPENDITURES PRIORITIES

1. INDUSTRY DESCRIPTION ______________________________

   a. PPBS number(s) ____________________ [1 2 3 4] [5 6 7 8]

   b. SIC code(s) ______________ [9 10 11 12] [13 14 15 16] [17 18 19 20]

2. SIZE OF INDUSTRY (Plants using more than 20mgy, except for item 2a)

   a. Number of Small Plants (< 20mgy intake) [21 22 23 24 25]   b. Number of Large Plants (> 20mgy intake) [26 27 28 29]

   c. Number of Employees ______________________ (1000) [30 31 32 33]

   d. Value Added by Manufacture ____________ ($ million) [34 35 36 37 38 39]

   e. Added Water Use __________________ (billion gallons) [40 41 42 43]

   f. Annual Water Intake ________________ (billion gallons) [44 45 46 47]

   g. Annual Water Intake for Process __________ (billion gallons) [48 49 50 51]

3. GEOGRAPHICAL DISTRIBUTION OF INDUSTRY (Plants using more than 20mgy)

   a. Number of State with Plants __________________________ [52 53]

   b. Number of Plants per State in States with Plants __________ [54 55 56 57]

   c. Water Discharged per State in States with Plants (billion gallons) [58 59 60 61]

   d. Number of Employees per State in States with Plants ______ (1000) [62 63 64]

   e. Population of States with Plants ____________ (1000) [65 66 67 68 69 70]

Data Valid for the Year ______________________________ 19 [71 72]

Form No. [2 | 1 | 0 | 0] (76 77 78 79)   Card No. [1] (80)

4. WATER USE PRACTICES IN INDUSTRY (Plants using more than 20mgy)

a. Purchased Water Intake ________ (billion gallons) [ ][ ][ ][ ] 1 2 3 4

b. Ground Water Intake ________ (billion gallons) [ ][ ][ ][ ] 5 6 7 8

c. Brackish and/or Salt Water Intake ________ (billion gallons) [ ][ ][ ][ ] 9 10 11 12

5. ECONOMIC STATUS OF INDUSTRY

a. Depreciation Period for Major Equipment ________ (years) [ ][ ] 13 14

b. Return on Invested Capital ________ (%) [ ][ ].[ ] 15 16 17

c. Return on Sales ________ (%) [ ][ ].[ ] 18 19 20

d. Projected Growth Rate (%) [ ][ ][ ] 21 22 23 Increase [ ] 24 Decrease [ ] 25

on the basis of ________ [ ][ ] 26 27

for the period (years) [ ][ ] 28 29 from ________ [ ][ ] 30 31

e. Value of Shipments ________ ($ million) [ ][ ][ ][ ][ ] 32 33 34 35 36

6. WASTEWATER TREATMENT FACILITIES

a. Investment Provided by Industry ________ ($ million) [ ][ ][ ][ ] 37 38 39 40

b. Investment Provided by Muncipalities ________ ($ million) [ ][ ][ ] 41 42 43

c. Treatment Facility Investment of that Required ________ (%) [ ][ ] 44 45

d. Wastewater Discharged to Municipal Sewers ________ (%) [ ][ ] 46 47

e. Annual Operating and Maintenance Costs ________ ($ million) [ ][ ][ ] 48 49 50

7. PRODUCTION PARAMETERS

a. Operational Days per year [ ][ ][ ] 51 52 53 b. Production as % Capacity [ ][ ][ ] 54 55 56

c. Level of Technology (%): old [ ][ ] 57 58 average [ ][ ] 59 60 advanced [ ][ ] 61 62

Form No. [2][1][0][0] 76 77 78 79 Card No. [2] 80

8. WASTEWATER CONSTITUENTS ASSOCIATED WITH INDUSTRIAL PROCESSES

Biochemical Oxygen Demand	☐ 1	Color	☐ 2	Suspended Solids	☐ 3
Organics	☐ 4	Oil and Grease	☐ 5	Acidity	☐ 6
Phenols	☐ 7	Cyanide	☐ 8	Odor	☐ 9
Chemical Oxygen Demand	☐ 10	Chromium	☐ 11	Phosphate	☐ 12
Brines	☐ 13	Iron	☐ 14	Zinc	☐ 15
Copper	☐ 16	Total Solids	☐ 17	Slime Growths	☐ 18
Acetates	☐ 19	Total Nitrogen	☐ 20	Coliforms	☐ 21
Temperature	☐ 22	Hydrocarbons	☐ 23	Turbidity	☐ 24
Taste	☐ 25	Ammonia	☐ 26	Hexane Solubles	☐ 27
Alkanlinity	☐ 28	Metals	☐ 29	Organic Nitrogen	☐ 30
Chlorophenols	☐ 31	pH	☐ 32	Fluorides	☐ 33
Cadmium	☐ 34	Toxicity	☐ 35	Nitrogen	☐ 36
Lignins	☐ 37	Settleable Solids	☐ 38	Nickel	☐ 39
Detergents	☐ 40	Mercury	☐ 41	Arsenic	☐ 42
Lead	☐ 43	Hardness	☐ 44	Radioactivity	☐ 45

Other Constituents	Codes	Other Constituents	Codes
________	☐☐☐ 46 47 48	________	☐☐☐ 49 50 51
________	☐☐☐ 52 53 54	________	☐☐☐ 55 56 57
________	☐☐☐ 58 59 60	________	☐☐☐ 61 62 63

Form No. | 2 | 1 | 0 | 0 | (76 77 78 79) Card No. | 3 | (80)

STATES WITH PLANTS OF THE INDUSTRY USING MORE THAN 20mgy:

Maine	☐ 1	New Hampshire	☐ 2	Vermont	☐ 3
Massachusetts	☐ 4	Rhode Island	☐ 5	Connecticut	☐ 6
New York	☐ 7	New Jersey	☐ 8	Pennsylvania	☐ 9
Ohio	☐ 10	Indiana	☐ 11	Illinois	☐ 12
Michigan	☐ 13	Wisconsin	☐ 14	Minnesota	☐ 15
Iowa	☐ 16	Missouri	☐ 17	North Dakota	☐ 18
South Dakota	☐ 19	Nebraska	☐ 20	Kansas	☐ 21
Delaware	☐ 22	Maryland	☐ 23	District of Columbia	☐ 24
Virginia	☐ 25	West Virginia	☐ 26	North Carolina	☐ 27
South Carolina	☐ 28	Georgia	☐ 29	Florida	☐ 30
Kentucky	☐ 31	Tennessee	☐ 32	Alabama	☐ 33
Mississippi	☐ 34	Arkansas	☐ 35	Louisiana	☐ 36
Oklahoma	☐ 37	Texas	☐ 38	Montana	☐ 39
Idaho	☐ 40	Wyoming	☐ 41	Colorado	☐ 42
New Mexico	☐ 43	Arizona	☐ 44	Utah	☐ 45
Nevada	☐ 46	Washington	☐ 47	Oregon	☐ 48
California	☐ 49	Alaska	☐ 50	Hawaii	☐ 51

Form No. | 2 | 1 | 0 | 0 | (76 77 78 79) Card No. | 4 | (80)

APPENDIX F

GENERAL STATISTICS FOR 1200 PROGRAM R&D EXPENDITURES PRIORITIES

Data Collection Form 8100

GENERAL STATISTICS FOR 1200 PROGRAM R&D EXPENDITURES PRIORITIES

CENSUS BUREAU REGION	INDUSTRIAL R&D FUNDS ($ MILLION) FEDERAL	INDUSTRIAL R&D FUNDS ($ MILLION) INDUSTRY
New England	1 2 3 4	5 6 7 8
Middle Atlantic	9 10 11 12	13 14 15 16
East North Central	17 18 19 20	21 22 23 24
West North Central	25 26 27 28	29 30 31 32
South Atlantic	33 34 35 36	37 38 39 40
East South Central	41 42 43 44	45 46 47 48
West South Central	49 50 51 52	53 54 55 56
Mountain	57 58 59 60	61 62 63 64
Pacific	65 66 67 68	69 70 71 72

Data Valid for the Year ______________________ 19 [ ][ ] (73 74)

Form No. [8][1][0][0] (76 77 78 79) Card No. [1] (80)

INDUSTRIAL CATEGORY	INDUSTRIAL R&D FUNDS ($ MILLION) FEDERAL	INDUSTRIAL R&D FUNDS ($ MILLION) INDUSTRY
Food and Kindred Products	1 2 3	4 5 6
Textiles and Apparel	7 8	9 10
Lumber, Wood Products, and Furniture	11 12	13 14
Paper and Allied Products	15 16 17	18 19 20
Chemicals and Allied Products	21 22 23	24 25 26 27
Petroleum Refining and Extraction	28 29 30	31 32 33
Rubber Products	34 35 36	37 38 39
Stone, Clay, and Glass Products	40 41	42 43 44
Primary Metals and Fabricated Products	45 46 47	48 49 50
Machinery and Transportation Equipment	51 52 53	54 55 56 57
All Other Industries	58 59 60 61 62	63 64 65 67 68

Data Valid for the Year ______________________ 19 __ __ (74 75)

Form No. | 8 | 1 | 0 | 0 | (76 77 78 79)   Card No. | 2 | (80)

1 Accession Number	2 Subject Field & Group	
	06A,05D	**SELECTED WATER RESOURCES ABSTRACTS** INPUT TRANSACTION FORM

5 *Organization*

Synectics Corporation
4790 Wm. Flynn Highway, Allison Park, Pennsylvania 15101

6 *Title*

A System for Industrial Waste Treatment RD&D Project Priority Assessment.

10 *Author(s)*

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21 *Note*

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23 *Descriptors (Starred First)*

*Priorities, *Resource Allocation, *Research and Development, Industrial Waste, Cost Allocation, Federal Budgets, Expenditures, Economic Prediction, Systems Analysis, Statistical Models, Mathematical Models, Computer Models, Information Retrieval, Water Pollution Source

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*Management Information System

27 *Abstract*

The Environmental Protection Agency faces the difficult problem of determining priorities for research and development expenditures which will yield maximum overall benefits reflected in water quality improvements at minimum total costs. The computerized management information system described herein rapidly and efficiently determines such RD&D expenditure priorities by maximizing the expected returns on investment.

The modeling system developed as a result of this effort is unique insofar as information management systems are concerned in the degree to which user interaction is allowed. At any point during operation of the system, the user may insert judgmental factors. The system also has been designed to function with readily available data, such as that from the Bureau of the Census. Systems which incorporate theoretically desirable, but virtually unattainable, data have little operational utility. The mathematical and statistical methods employed in the development of the system focused on and supported the structuring, testing, and partial programming of three fixed-X regression modules.

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