TARLETON STATE UNIVERSITY

STEPHENVILLE, TEXAS

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Institute For Applied Research

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FINAL REPORT

North Bosque River Basin

Evaluation of Dairy Best Management Practices

Prepared for:
Texas Water Development Board
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FINAL REPORT FOR TEXAS WATER DEVELOPMENT BOARD

This report presents a summary of work elements completed for the Upper North Bosque project. In addition, it describes the progress made towards institutional solutions to problems and participation of government, industry and local citizenry.

Committee for Constituency Development

As part of the approach to solving problems associated locally with the dairy industry and to building a constituency for proposed solutions, input from affected parties has been solicited. In many cases implementation activities have been defined as technical/scientific solutions that are within the economic capabilities of the dairy farmer. This is a very limited definition which does not necessarily provide a predictable regulatory climate, nor a citizenry that endorses the waste management system utilized by the region's dairy farmer. These two elements are essential for success.

Unfortunately, most efforts toward implementation do not focus on these two elements until the technical/scientific and economic studies are completed. If these elements are the last elements considered, it is "too little, too late". The institutional and public policy questions will be addressed, but the arena in which they are discussed becomes the "state house". In this environment of "political solutions", much of the relevant technical/scientific information is left out of the decision process. This is a very inefficient and wasteful use of program funds.

To ensure implementation, the institutional and public policy elements must be integrated into the initial study design and recognized as components that must be addressed throughout the program effort. The Institute has taken steps to insure that these elements are woven into the very fabric of all program elements related to the nonpoint source pollution problems in the North Bosque River Basin by the use of the Committee for Constituency Development (CFCD). The CFCD includes dairy operators, neighbors of dairies, local government officials, environmental group members, community and industrial leaders, and representatives of other agricultural sectors.

Senator Bob Glasgow created and chairs the CFCD. The CFCD met June 13, 1990, at Tarleton State University. Senator Glasgow presented an overview of the goals and objectives of the grant program for Nonpoint Source Pollution. Ron Jones, Director of the Institute, and Institute staff members presented the work elements of each task for the EPA grant. The meeting was attended by approximately fifty-five people. A second CFCD meeting was held on August 9, 1990. Representatives from the Texas Water Commission (TWC), Texas Air Control Board (TACB), and the Texas State Soil and Water Conservation Board (TSSWCB) presented overviews of the roles of these agencies with regard to the dairy industry.

Appendix I contains minutes from the CFCD meetings and lists of the members of the CFCD.

Board of Advisors

Senator Glasgow also created and chairs a Board of Advisors composed of the Executive Directors of the Texas Water Commission, Texas Department of Health, Texas State Soil and Water Conservation Board, Brazos River Authority, Texas Water Development Board and Texas Air Control Board. The Institute staff met with the Board of Advisors on June 7, 1990 in Austin, Texas at the State Capitol. Senator Glasgow presented an overview of the goals and objectives of the grant program for Nonpoint Source Pollution. Ron Jones, Director of the Institute, discussed the work program on a task by task basis.

Appendix I also contains a list of the members of the Advisory Committee.

Institute Staff

Institute staff who have performed the work elements for the project and their expertise are briefly described below.

Full time staff includes:

- Ron Jones, Director, whose background includes 23 years experience in public policy, business management, and environmentally related issues. He holds a bachelors degree in agronomy and a masters in agricultural economics with an emphasis in natural resources. He has authored publications and lectured at many governmental, educational and civic functions.
- Jack Nelson, Research Associate, whose background includes 21 years experience with developing water resources design criteria, environmental science, hydrology, and agricultural enterprises. He holds a bachelors degree in biology and a masters in environmental science. He has managed civil engineers, environmental engineers, biologists and geologists. As Director of the Environmental Division of the Texas Water Development Board, close liaison was required with the U.S. Army Corps of Engineers, Bureau of Reclamation, Environmental Protection Agency, and Fish and Wildlife Service, as well as other state agencies in Texas.
- Leila Gosselink, Research Associate, whose background includes five years experience in environmental engineering, hydrology, water quality, computer modeling and regulatory compliance. She also holds a bachelors degree in mechanical engineering and a masters in marine sciences (hydrology).
- Melissa Parks, Administrative Assistant, whose background

includes six years experience in banking management and administrative supervision. She also holds a bachelors degree in accounting.

- Nancy Easterling, Research Technician, who holds a bachelors degree in hydrology and whose background includes experience with an environmental consulting firm and work in education.
- Joan Flowers, Research Technician, who is a dairy farmer and holds bachelors degrees in biology and hydrology and has experience with an environmental consulting firm.
- Jan Stephens, Secretary, has a background in computer information systems and previous experience in typesetting.

Part-time Faculty members include:

- Dr. Hugh Jeffus, P.E., Hydrology professor, environmental engineer with 25 years of experience in designing and operating waste treatment systems.
- Charles Maguire, M.B.A., Economics instructor and president of Pecan Valley Nut Company, Inc., with 15 years experience in processing and marketing agricultural products.

Graduate Research Assistants include:

- Bill Dollar, a graduate student with 15 years experience in geology and a strong computer background.
- Lynn Smith, a graduate student in biology.
- Ronnie Moore, a graduate student in the business administration who has operated his own construction business in Austin Texas.
- Patrick Farrell, a graduate student in the business program with a strong computer background.

In addition, Hari Shrestha, a temporary intern from the Tarleton Hydrology program, was hired to complete soil laboratory work under the supervision of Dr. Hugh Jeffus. Also, a student worker, Melinda Erickson was hired to complete miscellaneous office tasks.

DETAILED SCOPE OF WORK

The work of Tarleton Institute for Applied Research has been divided into six tasks. Flowcharts for the task activities have been made and are included as Appendix II.

TASK I

Task Definition:
Define present siting criteria for dairy farms. Implement, educate and demonstrate to farmers in the North Bosque River Basin how to properly site dairy farms. This task was developed to minimize the cost of implementing management practices required to bring dairy

farms into regulatory compliance. Management practices required to prevent adverse environmental impacts in identified sensitive areas are generally more extensive and costly.

CFCD Subcommittee:
A subcommittee from the CFCD was selected to serve as a task force on Task I. The members include:

- Mr. John Moore, Co-chairman, FMC Representative
- Ms. Darlene Bates, Co-chairman, dairy owner
- Mr. Byron Brewer, Sierra Club member
- Mrs. Metta Collier, Stephenville citizen
- Mr. Wade Cowan, business owner in dairy area
- Mr. Don Davis, City Manager of Stephenville
- Mr. Bill Hailey, Erath County Judge
- Mr. Jim Leatherwood, Mayor of Dublin

The subcommittee met July 24, 1990 and August 21, 1990. Presentation of material, including maps and overlays, were made at the first meeting to demonstrate how siting criteria may impact the environment. The subcommittee members indicated that they would like prospective dairy farmers to be made aware of these considerations as soon as possible. They suggested a brochure be produced for distribution through real estate agencies, governmental agencies, and milk producer associations. During the second meeting, which included a tour of a large dairy farm, a draft brochure was handed out for the review of the members. Minutes from these meetings are included as Appendix III.

Task Activities:
Work on Task I has primarily focused on defining the present informal siting criteria and evaluating their effectiveness and current level of implementation. To define the present criteria, Institute staff met with several local dairy farmers who had moved into the area and discussed their methods of site selection. In addition, representatives from AMPI, local banks and the SCS were consulted. A draft list of the present siting criteria and the maps, with a list of parameters to be considered in the siting process, have been prepared. Siting considerations were selected by the subcommittee to be included in the brochure for distribution The draft criteria lists and brochure are included in Appendix IV.

To evaluate the effectiveness of existing criteria with respect to environmental impacts, and to identify environmentally sensitive areas, the Institute staff began evaluating criteria which may provide environmental protection and, therefore, minimize the cost of regulatory compliance. A meeting was held with Margaret Hart, TWC, and Institute staff members in Stephenville on June 20, 1990, to discuss the DRASTIC system, a system for evaluating the potential for groundwater contamination in an area. The DRASTIC information will be used to identify areas with a high potential for groundwater pollution if dairies are located there. In addition, Ms. Hart discussed a geographical information system (GIS), which the Institute could use as a tool for compiling and distributing siting information. The Institute staff has prepared draft maps of areas which may be environmentally sensitive. Sources of information included the DRASTIC maps for Erath county, soils maps and descriptions, floodplain maps, and the Geographic Atlas of Texas.

The draft brochure as recommended by the subcommittee was prepared and distributed for review. The next subcommittee meeting will invite local agency representatives to discuss who should be responsible for distribution of material or for maintaining siting information, so that it is readily available to prospective dairy farmers.

TASK II

Task Definition:
Monitor and evaluate the implementation of water quality management plans as proposed in dairy permit applications submitted to the TWC. Assist dairy farmers in properly managing their dairies to prevent pollution of the surface and groundwaters of Texas. Evaluate the implementation of present management plans in place for dairies in the Upper North Bosque River Basin. Evaluate technical effectiveness along with financial and institutional aspects.

CFCD Subcommittee:
A subcommittee from the CFCD was selected to serve as a task force on Task II. Subcommittee members include:

- Dr. Ken Dorris, Chairman, veterinarian
- Mr. Jerry Clark, AMPI representative
- Mr. Jon Crunk, Texas United representative and dairy farmer
- Mr. Lloyd Easley, Farmers Home Administration
- Mr. W.L. Felts, Chairman, Cross Timbers Concerned Citizens Group
- Mr. Jack Parks, dairy farmer and AMPI National Board member
- Mr. Chaunce Thompson, Texas and South-western Cattle Raisers Association

The first subcommittee meeting was held July 24, 1990 at Tarleton State University to review a draft survey form, to ensure that it is comprehensive and to provide suggestions for standardizing the monitoring procedures. The second subcommittee meeting was held on August 14, 1990 at a large dairy against which heavy fines had been levied. Management practices which had been implemented in order to bring the dairy into compliance were observed. Minutes from these meetings are included as Appendix V.

Task Activities:
A list of specific requirements for permitted dairies in Erath County has been compiled from the Texas Water Commission files of individual dairy permits, permit applications, and management plans. This list will be used in the monitoring of compliance.

To prepare for the monitoring of operational practices of the individual dairies, a draft survey form was prepared. The survey form was prepared through review of regulatory and permit specific requirements, and is included in Appendix VI. In addition, Jerry Clark, an AMPI representative, has agreed to work with the Institute on developing and implementing the monitoring of permitted dairies in the North Bosque River Basin. The cooperation with AMPI will enable the Institute to gain access to dairy sites for monitoring and provide a means of ensuring that information to assist the farmers is distributed and supported.

A meeting was held on August 30, 1990 at the Stephenville AMPI building to explain the proposed monitoring system to dairy farmers with permits or with permits pending. A copy of a letter sent to area dairy farmers subsequent to the meeting is included as Appendix VII.

TASK III

Task Definition:
Best management practices (BMPs) will be selected for implementation on small dairy farms using criteria from evaluation of the effectiveness of BMPs. Effectiveness will be determined through the use of field data from large farm demonstration projects and modeling analyses. Using modeling techniques, it will be demonstrated to farmers how the BMPs, when implemented as recommended in the state's management plan, can be utilized to abate nonpoint source pollution in the watershed. Using these evaluations, the Institute will assist in implementation of appropriate BMPs for small dairies. Updated BMPs may be recommended.

CFCD Subcommittee:
A subcommittee from the CFCD was selected to serve as a task force on Task III. Subcommittee members include:

- Mr. Jim Johnson, Chairman, Appleton Electric
- Mr. Kurt Averhoff, dairy farmer
- Mr. Joe Cordell, Texas Farm Bureau
- Mr. Jon Crunk, Texas United
- Judge Regina Hanson. County of Bosque
- Mr. John Hatchel, City of Waco
- Mr. Fred Lueck, dairy farmer
- Mr. Ralph White, County of McLennan

The first subcommittee meeting is scheduled for September 26,1990.

Task Activities:
The Institute staff has completed the review for selection of a water quality mathematical model to evaluate farm management practices. This review included meetings held at the Blacklands Research Station, on April 12, 1990, with key personnel who developed and support several of the farm-scale models. Blacklands Research Station personnel in attendance included Verel Benson (SCS), Jimmy Williams (Agricultural Research Service), Walter Knisel (ARS), Ray Griggs (Texas A&M University), and Paul Dyre (Texas A&M Extension Service). Specific applications of the EPIC, CREAMS, and GLEAMS farm-scale models were discussed. The Institute draft report, included as Appendix VIII, was sent to TSSWCB, TWC and EPA for review and comment on July 11, 1990.

After incorporating information received in the aforementioned meeting with additional literature review, the EPIC model was considered to be the most applicable farm-scale model for the area of study. On June 5, 1990, Joan Flowers attended an EPIC workshop in Fort Worth, Texas. This seminar gave further information concerning the preparation of data sets for evaluation of best management practices.

To further evaluate its usability, an input data set was constructed by Joan Flowers. The data set was developed for a specific dairy farm in Erath County and was used to perform a sensitivity analysis of the EPIC farm-scale computer model. The sensitivity analysis identified critical data needs and the physical factors most important in controlling nutrient uptake and runoff. It also assessed the relative importance of input parameter accuracy which is required for calibration and verification of the EPIC model. The sensitivity analysis performed by the Institute staff was completed on June 3, 1990 and is included as Appendix IX.

Watershed modeling is scheduled to begin in January 1991, in order to simulate the downstream impact of the dairy industry on the Bosque River Basin and to demonstrate the effectiveness of BMP implementation. Leila Gosselink and Joan Flowers attended a short course, "Water Quality Modeling and Water Quality Modeling with WASP4" on June 11-13, 1990, to evaluate specific watershed models for their capabilities as applied to this region and particular application. Technical assistance in this evaluation was provided by the Dept. of Civil Engineering, University of Texas at Austin, in cooperation with the Center for Exposure Assessment Modeling, USEPA. This review is necessary for the evaluation and selection of a watershed model.

The preparation of a QA/QC plan and sampling program is underway, pending further instructions from the EPA and TSSWCB. Selection of

EPA approved water quality tests for 17 parameters was completed and a list of the chemicals and materials needed for the tests was made. The Institute examined the location of existing SCS structures and accessible stream sampling sites in the North Bosque River basin. Sampling sites were chosen to include areas without dairy influences to be used as control sites as well as areas which are vulnerable to dairy run-off. The selected sites for the water quality monitoring program were identified in conjunction with the TSSWCB and will be included in the QA/QC sampling plan.

TASK IV

Task Definition:
Educate the region's dairy farmers regarding alternative disposal practices for solids. This task includes evaluation of BMPs utilized for solids disposal on dairies larger than 250 milking cows. The evaluations consider the effectiveness in preventing pollution and cost considerations.

CFCD Subcommittee:
A subcommittee of the CFCD, which will serve as a task force in the education program for Task IV, has been established. The task force members include:

- Nicki B. Jones, Chairperson, partner in KMN Garbage (Local Garbage Collection Company)
- Don Davis, City Manager of Stephenville
- Bill Hailey, rancher and Erath County Judge
- James Leatherwood, Mayor of Dublin, local bank president
- Fred Lueck, dairy farmer

An initial analysis of environmental pollution effects and cost effectiveness on alternative composting or disposal methods was completed for presentation to the Task IV subcommittee to get their preliminary input on the scope of work. The first monthly meeting for this task force was held on July 19, 1990. Minutes from this meeting are included as Appendix X.

Task Activities:
Charles Maguire and the Institute staff have investigated the feasibility of a composting facility for the dairy solids. Literature on composting has been compiled and composting operations and equipment suppliers have been identified. The project staff contacted the USDA (SCS) and the Texas A&M Extension Service (TAES) for information on composting in order to identify additional composting operations. The Institute staff surveyed the identified operations in order to ascertain the ones that would represent design alternatives that could be considered by this region's dairy farmers. As these operations were identified, they were contacted by phone and/or by mail to provide additional information on their type of operation.

In addition, three commercial composting operations have contacted the project staff to offer information and to express interest in operating a commercial composting facility in the region. In the evaluation of composting and other operations as possible solids disposal alternatives, the Institute staff used three basic criteria:

1) Environmental soundness - to ensure that additional air or water quality problems are not associated with the alternative.
2) Operational practicality - implementation will not occur if additional work or operational difficulties are seen by the farmer in this area,
3) Economic feasibility - alternatives were evaluated considering additional financial burdens on both the dairy farmer and the local political subdivisions.

As possible design alternatives have been identified by the project staff, and as information from solicited composting operations has been received, the elements affecting capital cost and operating cost have been identified. To the degree possible, actual capital cost and operating cost on a per ton basis is being established for each design alternative. For the purpose of discussing the economic feasibility of the composting alternatives with the dairy farmer, the cost of current disposal techniques being used by the dairies has also been established.

A presentation was made by the project staff at the June 13, 1990 CFCD meeting. Committee members have stimulated local interest as evidenced by frequent contacts with Institute staff members initiated by community members interested in the composting facility. Members of the City and County governments have questioned Institute staff concerning the feasibility of a composting facility that would compost the solid wastes of the region as well as dairy wastes. The project staff are expanding design possibilities to include composting garbage. Ron Jones and Charles Maguire have met with representatives of a company (Agripost) which operates a composting facility in Dade County, Florida. This facility processes about 250 thousand tons of municipal solid waste per year. The management of this company is interested in working with the Institute to establish a composting facility here. They have provided useful operating information and information on bulk application uses for compost.

Because broad based community support is important for the ultimate implementation of a composting operation for the dairy solids, it is important that interest be generated early in the process. Participation in CFCD and subcommittee meetings reflects this interest.

TASK V:

Task Definition:
Implement and evaluate alternative methods of wastewater disposal. Demonstrate to and educate dairy farmers in the use of appropriate methods for the reduction of quantity of wastewater and resulting pollutant loads.

CFCD Subcommittee:
A subcommittee from the CFCD was selected to serve as a task force on Task V. Subcommittee members include:

- Mr. Jesse Haynes, Chairman, dairy farmer and mechanic
- Mr. Kurt Averhoff, dairy farmer
- Mr. Joe Cordell, Texas Farm Bureau
- Mr. Jon Crunk, Texas United
- Dr. Frank Terrell, ophthalmologist

An educational meeting including the subcommittee members and local dairy farmers will be held in September to discuss alternative wastewater treatment strategies.

Task Activities:
The Institute is currently developing best management plan (BMP) design criteria for dairies which milk less than 250 cows. A seminar held on August 27, 1990, with SCS, Corps of Engineers and EPA determined that alternative wastewater control strategies used in other areas should be evaluated for the Erath County dairy farms. A meeting to prepare a proposal for evaluating constructed wetlands, rock reed filters, solids settling basins and tailwater pits is scheduled for September 24, 1990. A wetland has been constructed on one small dairy farm in the watershed. Although it is not yet completely vegetated, it currently provides a 50% reduction in BOD. The results of our initial test are positive and the Institute will contract additional demonstration BMP's to evaluate the effectiveness for small and large dairy farms. The proposed vegetation plan for a wetland wastewater treatment system is included as Appendix XI.

TASK VI:

Task Definition:
Evaluate past and present lagoon lining criteria and their effectiveness and educate dairy farmers and other interest groups regarding any needed changes. The evaluation of current dairy lagoon lining criteria includes the determination of their effectiveness in protection of critical groundwater recharge zones.

CFCD Subcommittee:
A subcommittee from the CFCD was selected to serve as a task force on Task VI. Subcommittee members include:

- Mr. James Watson, Chairman, Bosque Soil and Water Conservation District
- Ms. Darlene Bates, dairy farmer
- Mr. Jack Parks, dairy farmer and AMPI National Board member
- Mr. Donald Dowell, owner Dowell Well Service, Inc.

The first subcommittee meeting will be held September 27, 1990 to review progress on the task and recommended procedures.

Task Activities:
Because many lagoons in Erath County are lined with in-situ material, properties of local soils were examined. It was found that other states, sucn as Mississippi and California, may not require a placed liner. In addition, the sealing properties of manure, which some states allow as a lining material, were examined. The suitability of local soils and the sealing properties of manure were tested in the laboratory.

Soils were evaluated by Institute staff for their engineering properties. The work was coordinated with the local SCS office for type of soil collected and for analysis and tests to be performed. The laboratory tests and procedures were selected to test the soils for the criteria for lagoon liners set forth by the TWC. The laboratory equipment required to perform these tests was obtained and assembled. The SCS Soil Survey of Erath County and the SCS Erath County Dairy Map were studied to determine the most common soils underlying local dairies. Five soils were chosen as representative of soils on which lagoons in Erath County are constructed.

During April 1990, the North Bosque watershed received storm events that exceeded the 25-year, 24-hour rainfall event (7.3 inches) which dairy lagoons are designed to contain. Many lagoons were filled to capacity and one local lagoon failed. This event enabled the Institute staff to evaluate a cross-section of an existing lagoon. From the visual inspection, it appeared that liquid was not penetrating the manure which had formed a seal over the soil. The Institute staff then designed a test to evaluate the effect on permeability of a layer of manure covering the soil. The settled layer of manure simulates actual lagoon conditions.

The engineering properties required by the Texas Water Commission for approved lining materials were identified. The five soil types selected as representative in abundance in Erath County were examined with standard laboratory procedures for grain size and plasticity. The optimum moisture content was ascertained by determining the maximum density possible for various moisture contents. The soils were then subjected to a covering of dairy waste manure for 45 hours and retested for permeability. The red clay with a manure coating met all the required criteria for lining materials. Descriptions of the testing procedures and results of the tests are included in Appendix XII.

APPENDIX I

MEMBERS OF THE
COMMITTEE FOR CONSTITUENCY DEVELOPMENT

1.	Kurt Averhoff	Dairy farmer
2.	Darlene Bates	Dairy farmer
3.	Byron Brewer	Sierra Club member
4.	Jerry Clark	AMPI representative
5.	Metta Collier	Stephenville citizen
6.	Joe Cordell	Texas Farm Bureau
7.	Wade Cowan	Hoka-Hey Art Foundry
8.	Jon Crunk	Texas United (environmental group) and dairy farmer
9.	Don Davis	City Manager of Stephenville
10.	Dr. Ken Dorris	Veterinarian
11.	Donald Dowell	Dairy farmer and well driller
12.	Lloyd Easley	Farmers Home Administration
13.	W.L. Felts	Chairman, Cross Timbers Concerned Citizens Group
14.	Judge Bill Hailey	Erath County judge
15.	Judge Regina Hanson	Bosque County judge
16.	John Hatchel	City of Waco representative
17.	Jesse Haynes	Dairy farmer
18.	Jim Johnson	Appleton Electric
19.	Nicki Jones	Garbage collection company owner
20.	Jim Leatherwood	Mayor of Dublin
21.	Fred Lueck	Dairy farmer
22.	John Moore	FMC Corporation
23.	Jerry Parham	Dairy commodity broker
24.	Jack Parks	Dairy farmer and AMPI National Board member

25.	Frank Terrell	Dairy farmer and opthalmologist
26.	Chaunce Thompson	Texas and Southwestern Cattle Raisers Association
27.	James Watson	Bosque Soil & Water Conservation District
28.	Ralph White	McClennan County Judge's Office

BOARD OF ADVISORS

Mr. Allen P. Beinke
Texas Water Commission

Dr. Robert Bernstein
Texas Department of Health

Mr. Robert Buckley
Texas State Soil and Water Conservation Board

Mr. Carson H. Hoge
Brazos River Authority

Mr. Sonny Kretzschmar
Texas Water Development Board

Mr. Steve Spaw
Texas Air Control Board

MINUTES OF CFCD MEETING

June 13, 1990

The first meeting of the Committee for Constituency Development was held on June 13, 1990 at 10:00 a.m. in the Guadalupe Room on the Tarleton State University campus. Committee members and speakers were introduced by Chairman Senator Bob Glasgow. Sen. Glasgow also briefed the committee on the initial fundings of the Institute, the workings of the committee, and explained that this committee will most likely serve as a model for solving other nonpoint source agricultural pollution problems in Texas and around the country.

Mr. Ron Jones, Executive Director of the Institute, gave a review of "How does this affect me?" to the committee. The issues that are confronting all of us in today's environment were explained. The relation of the dairy farmer and his neighbor were also explained. There are some tough decisions that affect the community and surrounding regions and these must be dealt with for the dairy industry to continue to function and grow in this area.

Mr. James Moore, Engineer for the Texas State Soil and Water Conservation Board and Mr. Clyde Bohmfalk, Director of the Water Division of the Texas Water Commission, each gave presentations of "The State's Role in Nonpoint Source Pollution", and explained the relationships between their organizations and the other governmental agencies.

The group adjourned for lunch to the Robin Room in the Dining Hall. Dr. Barry Thompson, President of TSU, welcomed the committee to Tarleton and thanked them for their interest in the Institute and this proposed work program.

After lunch, Mr. Wes Oneth, State Conservationist, spoke to the committee on water quality/quantity and the effects of agricultural nonpoint source pollution. Mr. Thomas McBryde also explained the geology of the area.

The Institute staff of Jack Nelson, Charles Maguire, and Leila Gosselink, each presented summaries of their Tasks for the EPA 319 proposal.

Dr. John Sweeten explained "On-farm Dairy Waste Management" and what the Texas Agricultural Extension Service has done to this point.

Before leaving, each committee member was asked to sign-up if they would be willing to serve on a sub-committee for one of the Institute Tasks. The next meeting will be held on August 9, 1990.

The meeting was adjourned at 3:30 p.m.

MINUTES OF CFCD MEETING

August 9, 1990

The Committee for Constituency Development (Committee) met on August 9, 1990 at 10:00 a.m. in the Cardinal Room on the Tarleton State University campus. Chairman Senator Bob Glasgow issued an opening welcome to all and thanked them for taking the time to attend.

The Chair then recognized Subcommittee chairpersons for updates on their meetings. Those giving briefings were: Darlene Bates for Task I- Siting, Dr. Ken Dorris for Task II- Compliance, and Nicki Jones for Task IV- Composting.

Congressman Charles Stenholm will be in Stephenville on August 18, 1990 for a town hall meeting. Senator Glasgow highly encouraged the attendance of the Committee members to ask Congressman Stenholm for financial assistance for work by the Committee and the Institute.

The Texas Water Commission (TWC) gave presentations from the permitting, enforcement, and legal divisions. Louis Herrin, III explained the permitting process of the TWC. It currently takes approximately six months to become permitted and the TWC is looking at tightening the permitting requirements. Hank Smith gave an informative overview of the enforcement process. Routine inspections are performed by the TWC with inspections also done after complaints are issued. They currently have twelve district referral coordinators working in the State. He also explained how fines are calculated and the penalty assessment process. Margaret Ligarde interpreted what she feels are the current strengths of the TWC legal process.

Mr. Bob Buckley of the Texas State Soil and Water Conservation Board gave an overview of his agency's role in cooperation with the Committee.

The Texas Air Control Board (TACB), represented by Gary Wallin and Mark Gibbs, presented an overview of their agency and its function. Currently, any confined feeding operation of over 1000 animals must be permitted by the TACB. Their primary concern in reviewing an odor problem focuses on how the odor issue interferes with the normal use of the property. Their offices place a high priority on complaints with penalties issued accordingly.

Mr. Ron Jones gave a brief update on the Institute work program. The Institute is striving to establish a good working relationship with all affected interest groups of Erath county while working on the dairy pollution problem.

Being no further business, the Committee was adjourned.

APPENDIX II

FIGURE 1

Task 1

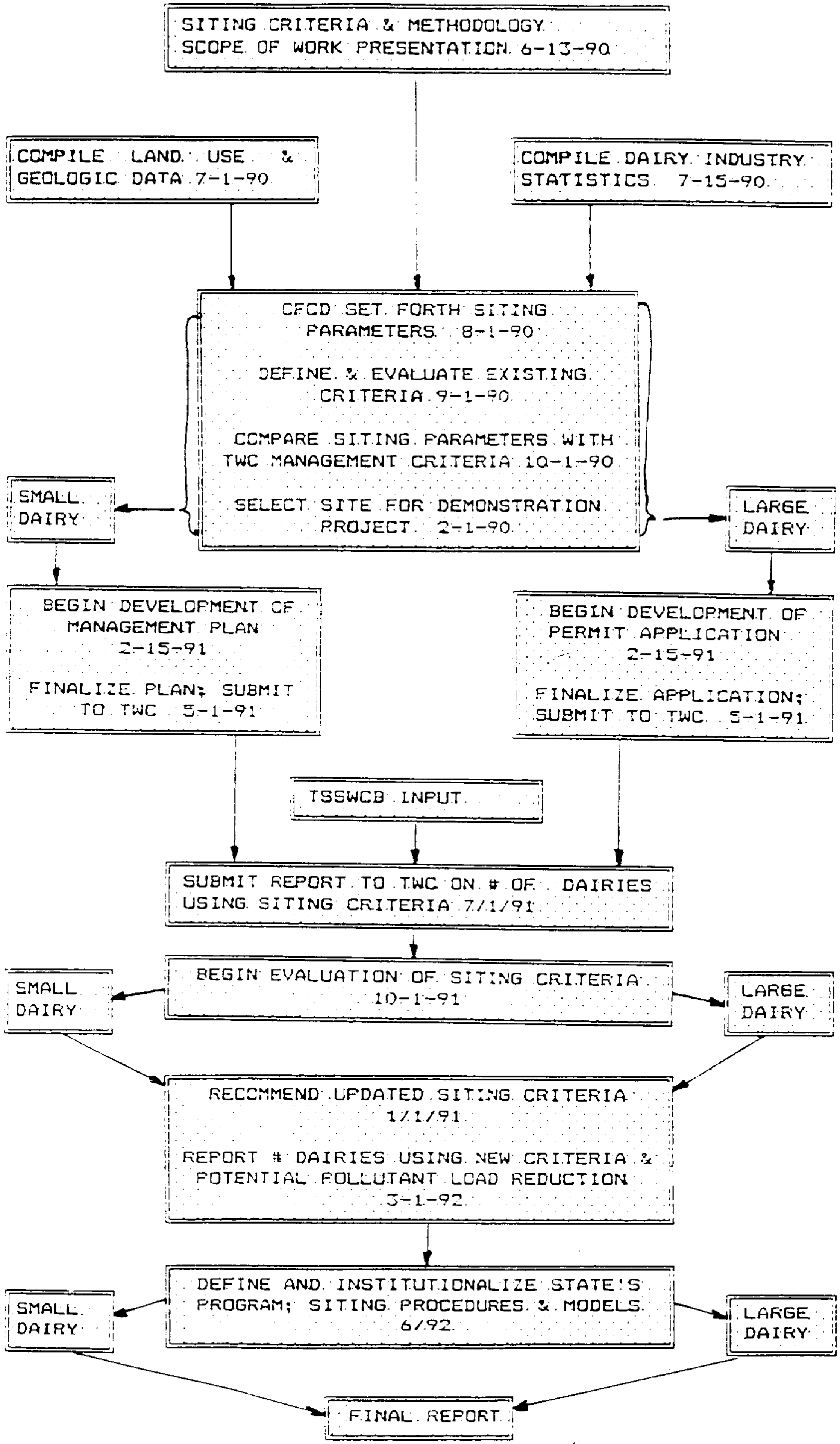


FIGURE 2

TASK 2

MONITORING PERMIT COMPLIANCE
FOR DAIRY FARMS

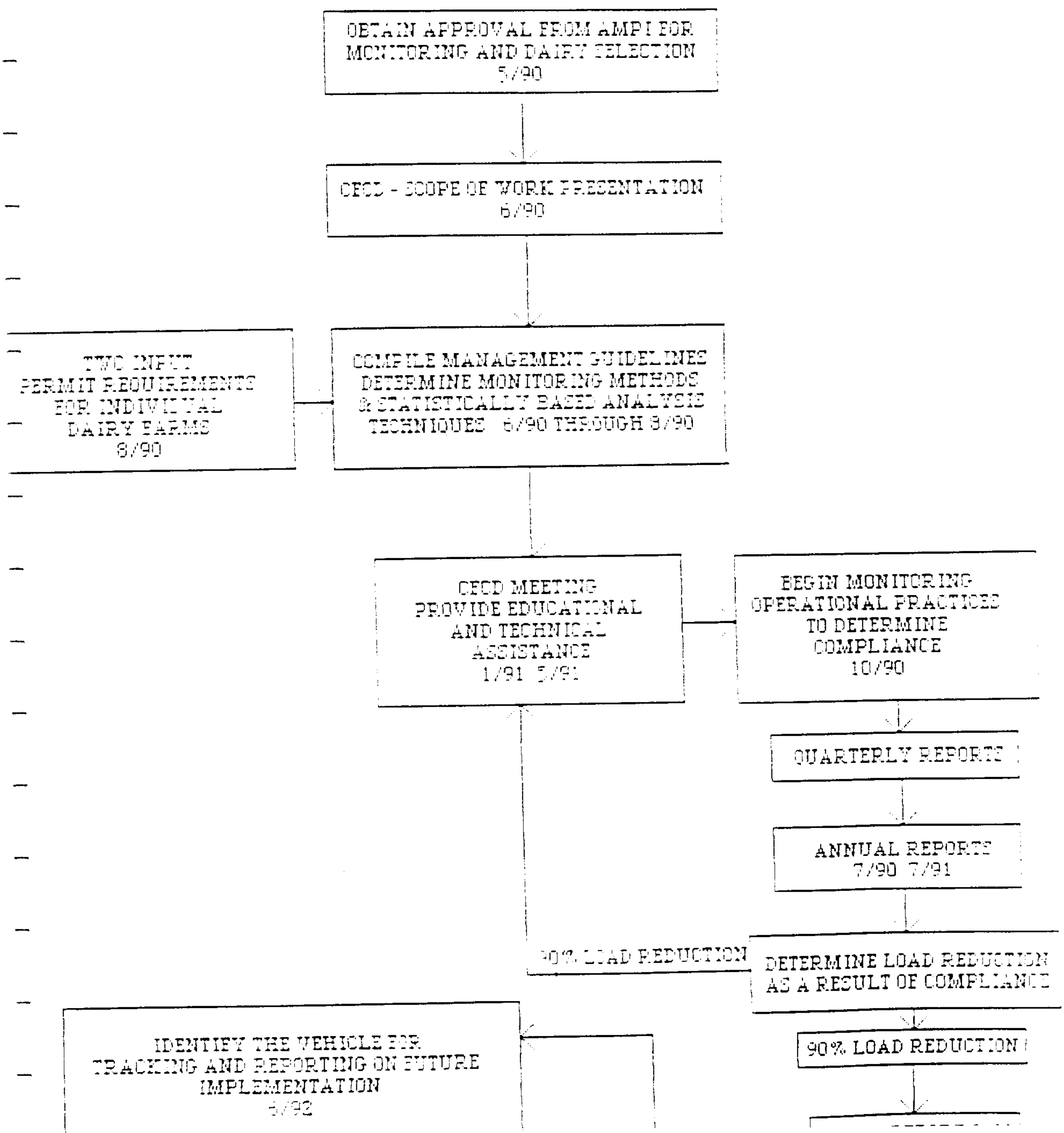
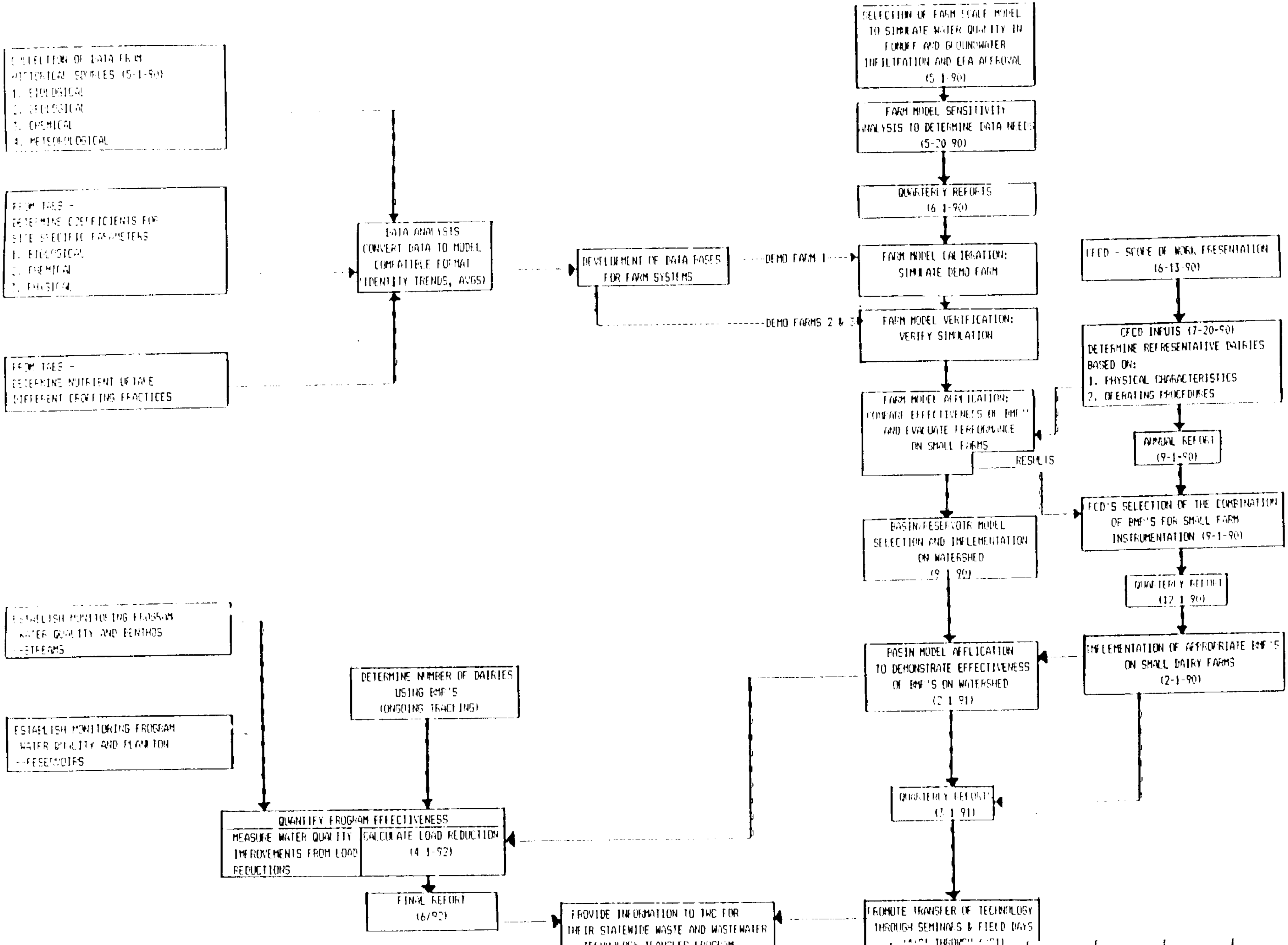


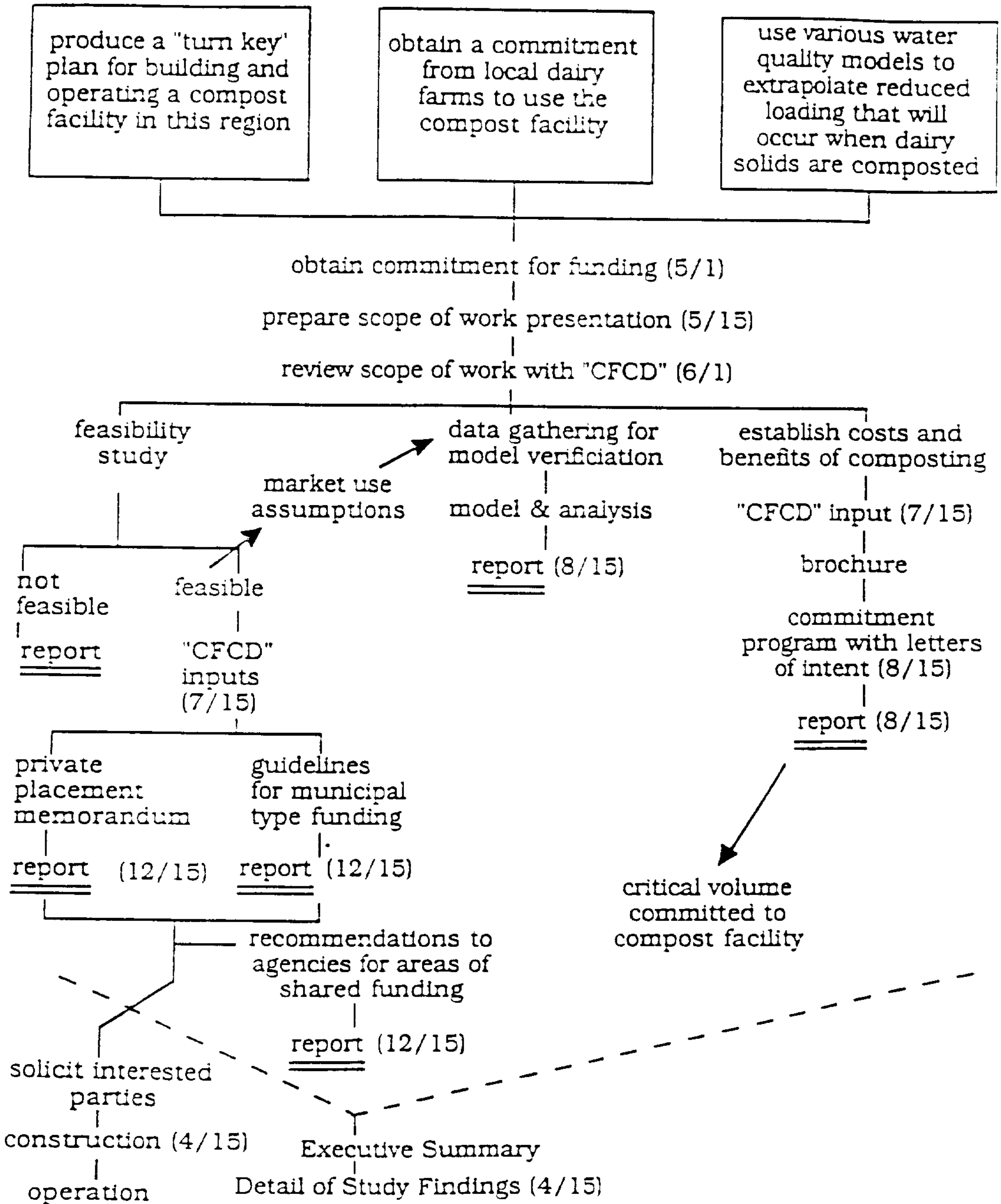
FIGURE 5

EVALUATION OF THE MANAGEMENT PRACTICES USED ON DAIRY FARMS IN THE NBRR



Tarleton Institute for Applied Environmental Research and Public Policy

COMPOSTING DAIRY SOLIDS



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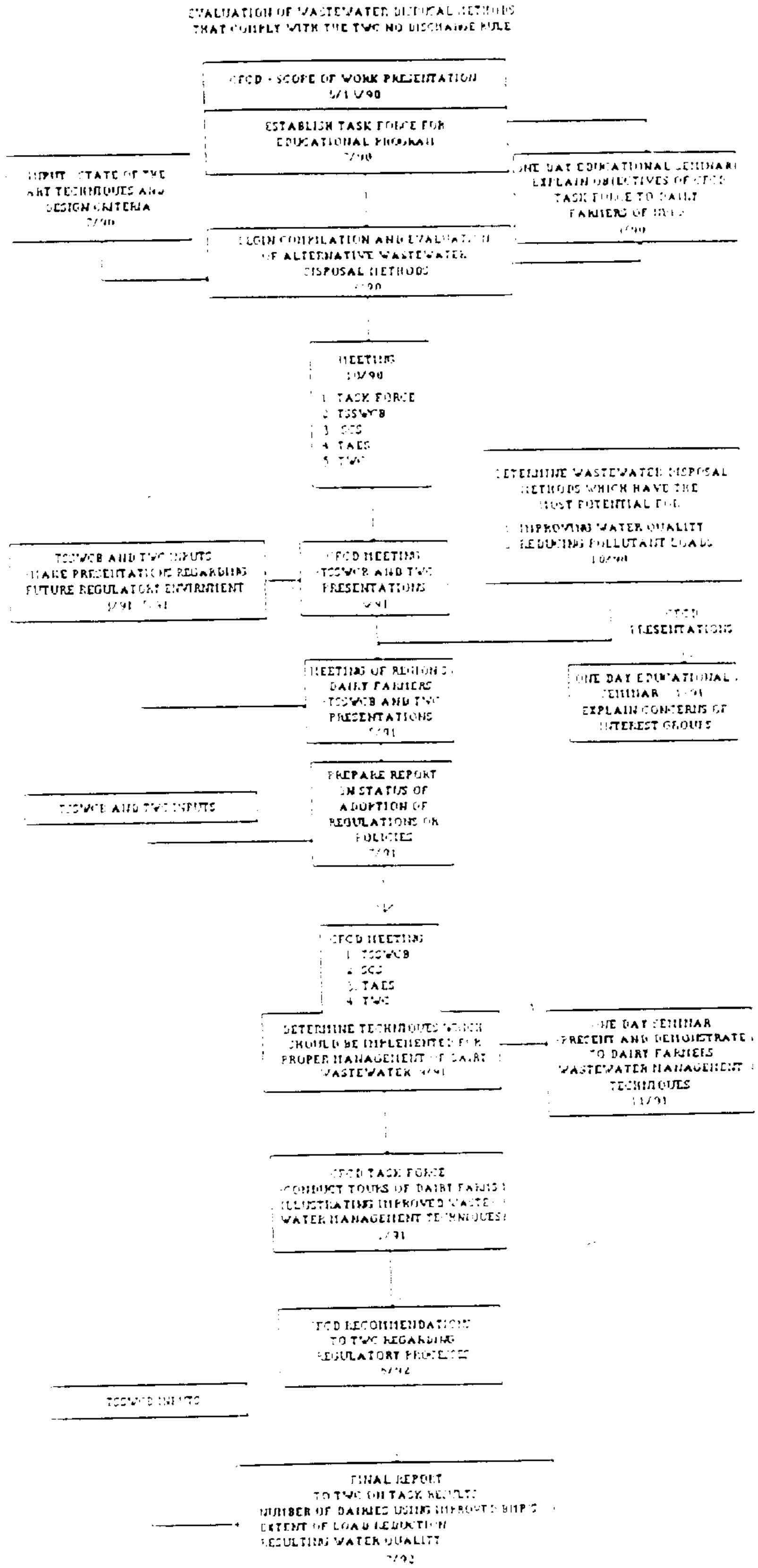
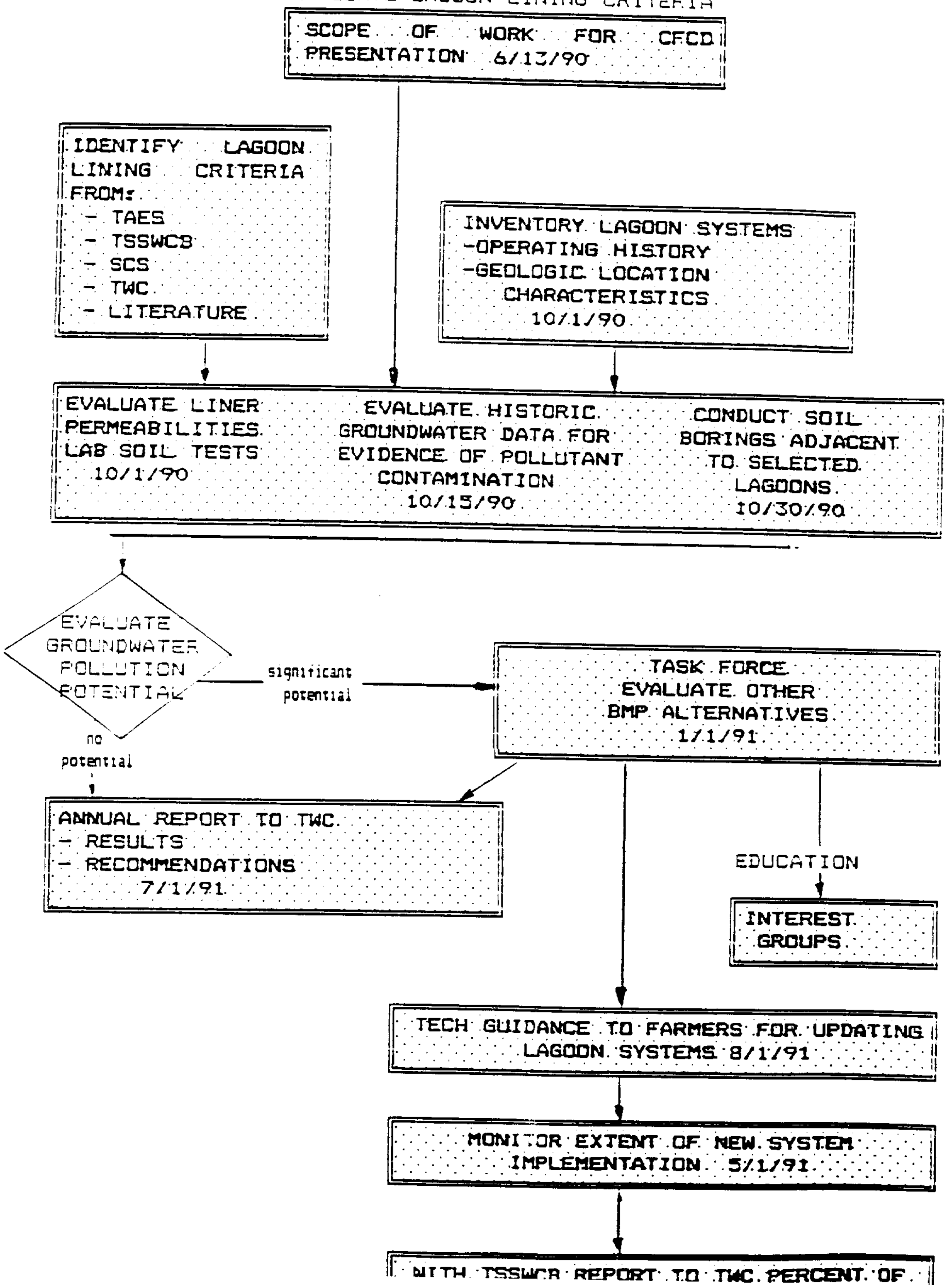

EVALUATION OF WASTEWATER DISPOSAL METHODS
THAT COMPLY WITH THE TWC NO DISCHARGE RULE
ESTABLISH TASK FORCE FOR
EDUCATIONAL PROGRAM
INPUT STATE OF THE
ART TECHNIQUES AND
DESIGN CRITERIA
ONE DAY EDUCATIONAL SEMINAR
EXPLAIN OBJECTIVES OF
TASK FORCE TO DAIRY
FARMERS
BEGIN COMPILATION AND EVALUATION
OF ALTERNATIVE WASTEWATER
DISPOSAL METHODS
MEETING
1. TASK FORCE
2. TSSWCB
3. SCS
4. TAES
5. TWC
DETERMINE WASTEWATER DISPOSAL
METHODS WHICH HAVE THE
MOST POTENTIAL FOR
IMPROVING WATER QUALITY
REDUCING POLLUTANT LOADS
TSSWCB AND TWC INPUTS
MAKE PRESENTATION REGARDING
FUTURE REGULATORY ENVIRONMENT
MEETING
TSSWCB AND TWC
PRESENTATIONS
PRESENTATIONS
MEETING OF REGIONAL
DAIRY FARMERS
TSSWCB AND TWC
PRESENTATIONS
ONE DAY EDUCATIONAL
SEMINAR
EXPLAIN CONCERNS OF
INTEREST GROUPS
PREPARE REPORT
ON STATUS OF
ADOPTION OF
REGULATIONS OR
POLICIES
TSSWCB AND TWC INPUTS
MEETING
1. TSSWCB
2. SCS
3. TAES
4. TWC
DETERMINE TECHNIQUES WHICH
SHOULD BE IMPLEMENTED FOR
PROPER MANAGEMENT OF DAIRY
WASTEWATER
ONE DAY SEMINAR
PRESENT AND DEMONSTRATE
TO DAIRY FARMERS
WASTEWATER MANAGEMENT
TECHNIQUES
11/91
TASK FORCE
CONDUCT TOURS OF DAIRY FARMS
ILLUSTRATING IMPROVED WASTE-
WATER MANAGEMENT TECHNIQUES
RECOMMENDATIONS
TO TWC REGARDING
REGULATORY PROCESSES
TSSWCB INPUTS
FINAL REPORT
TO TWC ON TASK RESULTS
NUMBER OF DAIRIES USING IMPROVED BMPS
EXTENT OF LOAD REDUCTION
RESULTING WATER QUALITY

FIGURE 6

TASK 6

EVALUATE LAGOON LINING CRITERIA



APPENDIX III

MINUTES OF TARLETON INSTITUTE FOR APPLIED RESEARCH
CONSTITUENCY SUBCOMMITTEE FOR TASK I
July 24, 1990

Members in attendance:
John Moore, Darlene Bates, Byron Brewer, Bill Hailey, Jim Leatherwood, Don Davis
T.I.A.R. Members in attendance:
Ron Jones, Leila Gosselink, Jack Nelson, Nancy Easterling, Bill Dollar

Ron Jones opened the meeting by discussing Task I, which enumerates environmental factors to be considered when siting a dairy. Using these siting considerations may help to obtain a permit more easily and also may prevent the potential for pollution of the environment.

Leila Gosselink presented a list of existing siting considerations. Proximity to highways and availability of 3-phase electricity are additional siting considerations commonly used by dairymen.

Environmental siting considerations were then presented. A map of Erath County showing current dairy sites was compared with maps showing flood plains, soil types, outcrop regions, and corridors around heavily populated areas. Additionally, a map showing DRASTIC ratings in Erath County was shown. DRASTIC is a system of evaluating the environmental sensitivity of a site with respect to soil type, topography, hydraulic conductivity, depth to groundwater, location of flood plains, and infiltration.

The environmental criteria were discussed. Stephenville presently has no limit concerning the proximity of dairies to the city, although there are some building codes extending five miles from the city limits. Soil considerations are complicated, with fertile soil underlain by an impermeable layer being favored to allow cropping and prevent movement of pollutants to groundwater. A suggestion was made to incorporate a tracking of rainfall amounts in various parts of the county into the program.

It is estimated that there are presently 50,000-60,000 dairy cattle in Erath County, with a future projection of 85,000 cattle. It was pointed out that contamination can come from cities, home sewage systems, and other agricultural industries as well as from the dairy industry.

A suggestion was made that the Texas Water Commission (TWC) should require permits from all dairies, not just those with at least 250 cows. It was pointed out that a small dairy can pollute just as much as a large dairy.

The method of informing dairy farmers of the environmental siting criteria was discussed. The data could be given to realtors and to AMPI. An outline of considerations could be given out at a meeting of realtors, milk marketers, and others in the dairy industry. A brochure of recommendations could be included in information from the Health Department to dairymen and in the ASCS newsletter. A suggestion was made to include a list of requirements and prohibitions, as well as things to consider.

The subject of legislation and enforceability were discussed. It was mentioned that the Institute could make recommendations, based on its research, to the Legislature on what the standards should be. Task I should serve as a data base for exclusion criteria for choosing a location of a dairy.

The committee will meet at Darlene Bates's dairy for the next meeting.

MINUTES OF TARLETON INSTITUTE FOR APPLIED RESEARCH CONSTITUENCY SUBCOMMITTEE FOR TASK I

August 21, 1990

Members in attendance:
Darlene Bates, Byron Brewer, Meta Collier
T.A.I.R. Members in attendance:
Leila Gosselink, Jack Nelson, Joan Flowers, Nancy Easterling

The meeting was held at Darlene Bates's dairy. Her husband, Mike Schouten, guided a tour of the facilities. He described factors concerning soil type which should be considered in choosing a dairy site. The feeding lanes on their dairy are located on an elevated outcrop with a gentle slope. Rocky, gravelly soil underlain by limestone makes a good base for the cows to walk on, especially during wet weather. The gentle slope allows for good drainage of the confinement area. The soil in their pastures can support coastal Bermuda and in winter the land is overseeded with no-till wheat. This allows the production of 50% to 60% of the feed for their dry cows.

The location and number of neighbors near potential irrigation fields is another siting consideration. Mr. Schouten pointed out that the lagoon is not in sight of the highway. This helps maintain better relationships with neighbors. Buffer zones around the farm is a requirement being considered by the Texas Air Control Board. It is, therefore, important to ascertain whether the lagoon can be located away from property lines at potential sites.

While it is desirable to site a dairy away from heavily populated areas, Mr. Schouten also pointed out that it is advantageous to locate on or near a highway. Availability of three-phase electricity, as well as easy access for milk and hay trucks, makes proximity to roads an important consideration.

Mr. Schouten also described water usage on his dairy. They previously used 70-80 gallons of water per cow per day for washing, drinking, and sanitary cleanup. Now that usage is down to 38-40 gallons. This reduction is due in large part to a recycling system installed in the parlor. Water which is warmed by the milk-cooling and other machines is then used to wash the cows. The wash water is used to flush the parlor. The water is, therefore, used three times before it is sent to the lagoon and subsequently used for irrigation. Mr. Schouten indicated that water reuse was instituted to reduce pumping requirements of the well and irrigation guns, as well as to decrease the amount of water going to their lagoon. Both of these reductions provide economic incentives for water conservation.

The comfort of the cows is a high priority on the Schouten dairy. The cows under the shed are misted with fresh water so that they will eat during hot summer days. This practice leads to higher productivity.

Predator wasps are used on the dairy approximately six months out of the year to reduce the fly population. This is an added expense, but aids the comfort of both the cows and humans.

The Schouten dairy has a double-sided concrete settling basin which collects solids before they enter the lagoon. This greatly extends the life of the lagoon, as well as reduces the odors coming from it. Additionally, they dry-scrape their feeding lanes every other day. When asked if this was a labor intensive procedure, Darlene Bates responded that it does create more work on a continuous basis, but in the long run it reduces the labor and expense of cleaning out the lagoon more often. The risk of damaging the liner is always a possibility when a lagoon is cleaned, so practices that extend the capacity and life of the lagoon are desirable.

Because of the irregular precipitation patterns in Erath County, the Schouten dairy has a secondary lagoon to catch runoff in excess of the 25-year, 24-hour storm. They presently have the capacity of retaining 180% of the required volume of runoff.

The subcommittee then briefly visited the Kurt Averhoff dairy to compare operations at a smaller dairy. The dairy, which has no lagoon, has a concrete pit which catches the runoff from the parlor. When the pit is full, the raw manure is pumped into tanks which spread it onto the fields. Coastal fields serve as buffer zones around the dairy. Any runoff from the containment areas is intercepted by the fields, avoiding discharge from the property.

APPENDIX IV

EXISTING SITING CRITERIA FOR DAIRIES

1) Ground Water Availability of 100 gpm+

2) Foundation soil for barns and lots

3) Cultivated land for applying solid and liquid waste

4) Land sloping from parlor and lots for ease of construction of wastewater handling facilities i.e. serpentine waterway, lagoon etc.

5) Cost of Land = $700.00/acre

6) Access to support industries i.e. marketing center, vets, feed, supplies, commission sale barn, road system for trucking

7) Financing

Note: Concentrations of dairies provide for better service and lower prices from support industries.

ENVIRONMENTAL SITING CONSIDERATIONS

- Location within a floodplain
- Proximity to surface water drainage, including consideration of topography and soil type
- Proximity to populated areas, including consideration of predominant wind direction
- Density of dairy operations in an area
- Underlying aquifer(s)*
  - depth to water
  - water quality
  - aquifer media
- Ground water recharge*
  - precipitation, including intensity and duration
  - irrigation
  - topography
  - evaporation rates
  - vegetation
  - soil types and thicknesses
- Topography (slope of land)*
- Vadose zone*
  - media
  - depth of zone
  - porosity
  - permeability
- Hydraulic conductivity (horizontal)*
  - permeability
  - porosity
  - transmissivity
- Soil types (for groundwater pollution potential)*
  - permeabilities
  - presence of and location of clay layers
  - shrink-swell potential
- Parameters for operational considerations
  - soil type for cropping potential
  - topography for drainage
  - natural drainage for water source
  - impermeable base layers for lot maintenance, and lagoon and tank sites
  - groundwater availability

* Included in DRASTIC index

SITING CONSIDERATIONS	ENVIRONMENTAL	OPERATIONAL	Maps Available
● **Location within a floodplain**	X		FEMA maps
● **Proximity to surface water**	X		SCS Dairy map
● **Proximity to populated areas, including consideration of predominant wind direction**	X		County maps
● **Groundwater:** **Aquifer outcrop area**	X		Geologic Atlas of Texas
Depth to water	X	X	TWDB Rept #298/ County DRASTIC Map
Water quality	X	X	TWDB Rep #298/ County DRASTIC Map
Availability of 100 ppm +		X	
● Soil Type: Cropping Potential		X	ASCS Crop Surveys
Impermeable layer for lagoon and lot construction and maintenance	X	X	SCS Soil Maps
● Topography for drainage	X	X	USGS topos
● Density of dairy operations	X	X	SCS Dairy map
● Access to support industries, i.e., marketing, supplies, vets, etc.		X	
● Access to good road system		X	County Maps
● 3 Phase electricity available		X	
● Cost of land		X	
● Finan			

For further information on these siting criteria and free assistance in evaluating available land being considered for a dairy site, contact the following agencies:

County Extension Agent
Erath County: 1491 S. Loop
Stephenville, TX
817-965 3510

Agricultural Stabilization and Conservation Service (ASCS)
245 S. Virginia
Stephenville, TX
817 965 3715

Soil Conservation Service (SCS)
Area Office
239 E. McNeill
Stephenville, TX
817 965 3213

APPENDIX V

MINUTES OF THE TARLETON INSTITUTE FOR APPLIED RESEARCH CONSTITUENCY SUBCOMMITTEE FOR TASK II

July 24, 1990

Members in attendance:
W.L Felts, Jack Parks, Jerry Clark, Ken Dorris
T.I.A.R. Personnel in attendance:
Ron Jones, Leila Gosselink, Jack Nelson, Nancy Easterling

Ron Jones opened the meeting by discussing Task II, which measures the degree to which dairymen are managing their operations in accord with approved management plans. The Texas Water Commission (TWC) has recommended best management plans in an effort to reduce pollutant loadings in streams. If future monitoring studies indicate no decrease in pollutants, the TWC might conclude that either the management plans are not being followed or that the management plans are not adequate and need to be made more stringent.

Leila Gosselink presented a list of current regulatory requirements for dairies. Additional requirements not on the list include salinity tests for wastes, buffer zones, and notification of TWC before scraping.

Ken Dorris sited the need to establish good public relations with the dairy farmers so that they see the Institute as a helpful organization, rather than as a regulatory agency. A discussion followed concerning the best way to establish good relationships with dairymen. Mail-outs, articles in the AMPI newsletter, one-on-one contacts, and a public meeting were mentioned. Contacts with the TWC to ascertain their intentions on checking permits in Erath County during the study period were deemed necessary to avoid the perception that any TWC monitoring on dairies in the study group is a result of the Institute activities.

Positive aspects of the Task II study for the dairy farmer were discussed. One aspect of Task II is to help discover if the rules are adequate when the dairymen are in compliance. It can also aid them in determining whether the dollars they spend are the best use of their money. The stream sampling program in Task III can be used as a tool, just like the testing of milk for microbes, to give information to the dairyman. The design of the sampling program will help the dairy farmer to determine whether contamination is coming from his operations or from upstream. Since the TWC will be checking stream quality in the future, this will allow for correction of any problems before they are regulated.

Testing of water for disinfectants, such as iodine and chlorine, used by the dairy industry has not been planned. Ken Dorris mentioned that disinfectants might pose a problem in composting. Jerry Clark said that disinfectants have not yet been a problem. The cumulative effect on composting could be looked into.

The role of the Institute in building a data base was discussed. The results of stream sampling need to be correlated to herd size. Because permits do not always have the current herd size, correct data must be obtained in order to evaluate the effect of management practices.

Ron Jones discussed holding a meeting at the Holiday Inn to inform dairy farmers of the efforts of the Institute. He asked if all committee members would sign a sheet encouraging people to come. Jerry Clark added that we should do one-on-one education first. Ron requested that committee members think about what should be done preparatory to such a meeting and what should be said at this meeting.

A draft of a questionnaire was reviewed by the committee. The purpose of the questionnaire is to determine whether the dairy is in compliance with its management practices. Committee members were requested to review the questionnaire before the next meeting to determine if any parts are unclear or if anything needs to be added. Some of the information requested is difficult to determine, and suggestions for improvement were requested. Determination of the amount of freeboard on the lagoons is considered an important feature. The prohibition against irrigation and wastewater/sludge application during a rainfall event was discussed. An observation judging compliance when ponding and puddling have occurred is somewhat arbitrary. Suggestions were made to help make the judgment more objective. The person making the observation should visit the site before a rainfall, should occasionally be double-checked, and should have a dairy background in order to be able to tell the difference between wet dirt and manure. Additionally, a statistician should be consulted about the study. Ken Dorris suggested adding a question about other types of fertilizers used by the dairy. Ron Jones suggested adding a question about irrigating and spreading solids on the same field. Leila would like to receive other suggestions concerning the questionnaire before the next meeting.

Regulation of the number of dairies and their activities in Erath County was discussed with respect to avoiding oversaturation with cattle. It is hoped that something could be done before things get bad and regulation is mandatory.

We should look at the EPA end-of-year budget to se if any money is left. We should make our study applicable to dairies around the country.

The next meeting will be on Tuesday, August 14 at 9:30 a.m. Jack Nelson will set up the location, hopefully at a dairy.

MINUTES OF THE TARLETON INSTITUTE FOR APPLIED RESEARCH CONSTITUENCY SUBCOMMITTEE FOR TASK II

August 14, 1990

Members in attendance:
Ken Dorris, Lloyd Easley, W.L Felts, Jerry Clark
T.I.A.R. Personnel in attendance:
Ron Jones, Leila Gosselink, Jack Nelson, Hugh Jeffus, Nancy Easterling, Joan Flowers
Visitors:
Fred Lueck, Jesse Hain, Bill Veldhuizen, Steward Veldhuizen

The meeting was held at the Aztec Dairy. Fred Lueck, owner of the dairy, explained its basic operations to the subcommittee. A system of five lagoons is in operation on the dairy for management of the wastes. The dairy presently has three times the lagoon storage required by the TWC. A lagoon having only the minimum storage requirements would not have been sufficient to contain the heavy back-to-back rains this spring, according to Mr. Lueck. Mr. Lueck also stated that the TWC can give orders that a dairy come into compliance within a 60 to 90 day period. Weather factors can delay compliance beyond this period, even if adequate plans, money, and materials are available.

A discussion of fines levied by the TWC was held. It was pointed out that fines for non-compliance in municipalities can be applied toward purchasing equipment and services which bring the facility into compliance. This procedure, if applied to the dairy industry, would help dairy operators achieve compliance without excessive economic hardship. Jerry Clark discussed a stipulated fine which is waived if the dairy comes into compliance within a specified time. It was also discussed that the rate structure for assessing fines seems to be the same for dairies as it is for large industrial companies.

The TWC requires that records be kept concerning the location, amount, and type of manure placed on fields. A farmer can be fined for not having current paperwork, which is time-consuming and frequently difficult for the employees. It was suggested that the Institute work with Mr. Leuck on preparing a generic data sheet to be used for keeping all data required by TWC concerning manure application, so that each dairy operator does not have to make up his own form. Additionally, the Institute could request that TWC inform us each time a new requirement is added so that the form could be kept up to date.

It was brought up that dairymen are not interested in polluting their own groundwater. The average dairyman wants to be in compliance. There needs to be a balance between compliance and economics. Ken Dorris noted that management ability and willingness to work are key factors in determining who will make it in the dairy business. Jerry Clark voiced concern about a person who works hard being able to make a good living without being leveraged to death. Ron Jones stated that this committee, working with a consensus, has the clout to influence the agencies and the legislature. The first two CFCD meetings were informational in nature. Ron said that the next meetings should be an arena in which to bring up issues. Working with the various agencies, we should be able to move toward a more predictable regulatory environment. Committee members should not be afraid to bring up issues in the meetings.

The committee also discussed issues related to education, which is important to both dairy operators and the general public. Both need to know the regulations and what they mean so that unnecessary complaints are not made and that imprudent dairy practices are not followed. Wise use of fertilizers (i.e., no more than is necessary) will be beneficial to both the dairy budget and to the local water quality.

The use of solids separators was discussed. They decrease the build-up of solids in the lagoon which lessens the need for cleaning out the lagoon, as well as lessening the chance of overflow during heavy rains.

Education with regard to governmental requirements is also important. Mr. Lueck noted that if he had known all the requirements from all of the agencies when he first set up his dairy, he could have saved a lot of money in coming into compliance. Doing things in a piecemeal fashion, as each new problem arises, can be much more expensive. Because permit requirements are constantly being made more stringent,as explained by a TWC representative last week in the general meeting, it is increasingly important for the operator to keep abreast of the changes.

Jerry Clark suggested that the technology of waste management be investigated. The management of resources is an important part of solving some of the problems. For example, a business could be developed by finding uses for dairy wastes. Organic fertilizer releases nutrients slower and more steadily than commercial products. Additionally, it holds moisture into the soil and blankets the ground in winter. Some potential purchasers of manure may be reluctant to buy it because they think they would have to keep records for TWC. Only the dairy operators, however, are required to keep the records.

Fred Lueck stated that he paid $125.00 for each soil analysis, which is the only way to tell if the soil is being overloaded with nutrients from fertilizer. It was suggested that the Institute look into the feasibility of setting up a soil testing laboratory.

Requirements of the Air Control Board were discussed. The ban on dewatering after dark, in conjunction with the ban on dewatering when the ground is saturated and the need to dewater after heavy rains, makes compliance a difficult task for the operator. In addition, irrigation during the day only means the operator loses up to 25 percent of his irrigation water through evaporation. The need for lagoons to be significantly larger than the minimum requirements in order to hold all runoff during rainy seasons was noted. Fred Lueck said that the placement of concrete settling pits for the flush water was the only current Air Control Board requirement on his dairy. He described a two section pit in which one side can be cleaned while the other side is being used as being superior to the regular single pit.

Evaluating the various aspects of each prospective dairy site is a complex procedure. For example, the advantage of moving far from neighbors to avoid air pollution problems can be offset by the additional cost of having new electrical lines run to the dairy. Working with the real estate industry is considered necessary to avoid having dairy sites being sold which will have great difficulty in complying with all the regulations. This is especially true with regard to people coming in from more crowded, less regulated areas. Realtors should be knowledgeable on regulations and requirements. Having representatives of the real estate industry on some of the Institute committees was discussed.

The complex interactions of dairy growth, milk prices, loan institutions, land prices, market status, and new technologies were discussed with regard to the direction of growth of the dairy industry in Erath County. Dairy operations are part of a competitive industry. We should discuss and evaluate any limits or regulations on the development of the industry so that it develops in a manner beneficial to both the present and the future.

APPENDIX VI

APPENDIX VII

DRAFT SURVEY FORM

IDENTIFICATION NO. ______________________

CURRENT HERD SIZE ______________________ BREED ______________________

SOLIDS DISPOSED OF BY ______________________

LIQUID DISPOSED OF BY ______________________

APPLICATION OF SOLIDS/LIQUIDS TO THE SAME AREA? ( )YES ( )NO

PRESENCE OF TANKS, TERRACES, ETC. IN DISPOSAL AREAS, DESCRIBE ______________________

APPLICATIONS OF COMMERCIAL FERTILIZER ______________ AMOUNT ______________

DISCHARGE WITHIN LAST YEAR ( )YES ( )NO IF YES, EXPLAIN:

REVIEW OF RECORDS

LINING CERTIFICATION PROVIDED? ( )YES ( )NO ( )NA-NOT REQUIRED

WASTE APPLICATION RECORDS MAINTAINED?

( )YES DESCRIPTION:

( )NO ( )NA - EXPLANATION:

SOIL ANALYSES - RECORDS MAINTAINED? ( )YES ( )NO ( )NA

FREQUENCY? ____________ LOCATION AND TYPE? ______________________

LAGOONS

NO. RETENTION BASINS ______ TYPE ____________ LINED WITH ______________

TOTAL DESIGN VOLUME __________ FREEBOARD DURING INSPECTION ______________

EVIDENCE OF EXCESSIVE SOLIDS IN HOLDING PONDS? ( )YES ( ) NO

IS LINER ADEQUATE? ( )YES ( )NO IF NOT, EXPLAIN:

LOTS

ALL RUNOFF CONTAINED? ( )YES ( )NO - EXPLAIN:

WASTE STOCKPILE AREAS: ISOLATED BY ( )DIKES ( )TERRACES

( )DRAINAGE, TERRAIN ( )OTHER - DESCRIBE

FREQUENCY OF SCRAPING ______________________

COMMENTS:

IRRIGATION FIELDS

LOCATION ______________ WASTEWATER VOL. APPLIED ______________

TYPE OF IRRIGATION ______________ AREA __________ CROP ______________

TYPE OF TAILWATER CONTROL/BUFFER ______________________

EVIDENCE OF PONDING/PUDDLING ______________________

COMMENTS:

SOLIDS FIELDS

DISCING/APPLICATION METHOD? ______________________

LOCATION ______________ AREA ______________ CROP ______________

ESTIMATE OF VOLUME APPLIED ______________________

TYPE OF TAILWATER CONTROL/BUFFER ______________________

COMMENTS:

September 10, 1990

Dear Farm Manager:

A seminar was held at the AMPI Building on August 30, 1990. Dairy farmers in Erath County with permits and those with permits pending were invited to the meeting to discuss a compliance monitoring program. The program seemed to be well received and no objections were voiced. It is hoped that operators of dairies having fewer than 250 cows will also become active in this endeavor. This letter explains the proposed compliance monitoring program discussed at the meeting.

The Tarleton Institute for Applied Research and AMPI are working together on a project which will demonstrate that dairy farmers in Erath County can prevent pollution of the surface and ground waters by following the best management practices (BMPs) as listed in their Texas Water Commission permit applications. The dairy industry should be able to comply with the no-discharge rule without the fines and uncertainties previously encountered. The Institute and AMPI think this can be accomplished if a unified effort is made to abate pollution by implementing the required BMPs and managing them properly.

It is vital to the dairy industry, as well as the region as a whole, to have a reliable source of clean water both for the present and the future. The no-discharge rule is already on the books for all dairies, TWC is going to be monitoring the industry more closely, and the permit requirements are becoming more stringent. Following best management practices is, therefore, a given requirement for the future.

In a county populated by dairies, it is easy to blame any pollution problems on the dairies. We hope to show with documented studies that water pollution reduction results from compliance by the dairy industry with their BMPs. If an ongoing monitoring program indicates that the BMPs are still being followed, future pollution sources should not be attributed to the dairy industry.

The Tarleton Institute for Applied Research and AMPI have proposed a compliance monitoring program to establish a history of compliance for dairy farmers in the Upper North Bosque River basin. The program requires that a survey be made of the permitted and cooperating dairies. Each dairy will be given a number which will be used, instead of a name, in any reference made to that dairy. No information on any individual dairies will be released to the public or to the TWC. It is important that farmers understand that this information will not be used by regulatory agencies. It is also important that enough dairies participate to make the study statistically valid for the area.

The survey will include a visual inspection of the farm management practices, as specified in the permits, and of records pertaining to the disposition of solid and liquid wastes. The Institute and AMPI will hire a person for this monitoring effort. The survey form was developed by the Institute in conjunction with AMPI and the Task II subcommittee, which is composed of dairy farmers and other citizens that advise the Institute. Through this system, the dairy farmers will have a self-reporting system for monitoring their own industry.

The Texas Water Commission, in their monitoring of dairies, will check wastewater and solid waste disposal compliance with the best management practices defined in the dairy permits. It is necessary, therefore, that each dairy farmer develop a management strategy to show a compliance history. This will require a record-keeping system that will track both solid and liquid wastes. The Institute is currently developing a system that could be used or modified for individual dairy operations so that each farmer does not need to create his own form of documentation.

The Institute and AMPI are also working on the details for developing the survey format and funding for compliance monitoring. We anticipate funding for this in October, 1990. A draft survey form is included for you review and comment.

I am looking forward to working with you.

With best regards,

Ron Jones

RJ:js

Copies to: Commissioner John Birdwell, Texas Water Commission
Mr. Allen Beinke, Texas Water Commission
Dr. Robert Bernstein, Texas Department of Health
Mr. Robert Buckley, Texas State Soil and Water Conservation Board
Mr. Carson Hoge, Brazos River Authority
Mr. Sonny Kretzschmar, Texas Water Development Board
Mr. Steve Spaw, Texas Air Control Board

APPENDIX VIII

RUNOFF MODEL
REVIEW, COMPARISON AND SELECTION
FOR EVALUATION OF FARM MANAGEMENT PRACTICES

Prepared by:
Tarleton State University
Institute for Applied Research

July 11, 1990

Table of Contents

1.0 INTRODUCTION

Analysis of agricultural nonpoint pollution is more difficult than point source control for many reasons, including the following:

(1) the relatively large number of diverse nonpoint sources,

(2) complex interactions that occur in the overland flow and waterways draining agricultural land, and

(3) stochastic storm events and runoff flows.

Measurement of off-site damages, while large, cannot be done explicitly for all nonpoint sources of pollution because of cost. Economists have used modeling to evaluate the off-site effects of cropland erosion for more than 20 years. "Computer technology and extensive research have enabled agricultural scientists to build mathematical models which improve our understanding of the linkages between farming practices and water quality" (Crowder 1987). These simulation models are used to estimate the effects of existing and planned practices, and thus minimize the uncertainty associated with the effects of management practices on runoff and groundwater quality. A great number of management alternatives can be simulated and compared with computer models at minimal cost, a significant advantage for analysis of agricultural best management practices (BMPs).

Before using a hydrologic model for analysis of water quality problems and management alternatives, a number of issues must be resolved. First, of course, the water quality problems must be defined. The pollutants and the media (e.g., surface drainage, streamflow or groundwater) to be considered will determine which models are appropriate. In economic studies, relative comparisons among alternative management practices are more important than the absolute values of the estimates. In addition, the scale of the problem to be addressed is crucial in making a decision on which class of models to use. Evaluation of individual management practices as they affect field losses is best performed by using field-scale models. Time scale is another important consideration. Some models simulate only single storm events, while others simulate up to 50 years of meteorologic data and produce storm event data, along with monthly and annual summaries of water movement and quality.

2.0 MODEL SELECTION

Several models were considered for use on Task 3.0 for the evaluation of BMPs on demonstration farms. The models discussed represent those most commonly used to estimate agricultural nonpoint pollution. The model selection criteria were:

(1) The models allow users to estimate loads or concentrations of nutrients as well as hydrologic flows and sediment.

(2) The models are primarily used for estimating nonpoint pollution from agricultural land, cropland in particular.

(3) The models have been applied and verified, and similar applications can be made in any geographic region with minimal modification to the computer programs.

(4) Sufficient written documentation and/or user support exist to allow application of the model by users at any location and to resolve problems encountered during an application.

The models were selected on the basis of available literature, discussions with water quality modeling professionals, previous or ongoing studies using the models, and published analyses of water quality problems.

The discussion in this paper will focus on the utility of these models for analysis of BMPs on a farm scale. Abatement of agricultural nonpoint pollution requires a focus on farm fields, the scale at which agricultural activities are performed. The models considered are shown in Table 1. The results from the field scale studies will be incorporated into a watershed scale model as a further step in this study. However, if only a broad-scale analysis using a watershed or larger model is performed, it is more difficult to associate changes in pollution with different agricultural management practices and land uses.

2.1 MID-SCALE RUNOFF MODELS

Several of the models discussed may be used for larger scale modeling as well as for farm-scale modeling by incorporating spatial variations or different management practices. These include AGNPS, ACTMO, ARM, and NPS. The ARM model assumes uniform land use and is the least applicable for this study as it requires long-term runs for initialization of its steady state in order to calibrate output (Crowder 1987). Our application is in an arid climate where flow and runoff are storm event driven, and steady state conditions would not be representative. In general, the other models in this group were eliminated from consideration because of our program design for further implementation as a watershed model, which will include spatial variations. Therefore, the simplifications required in these models in order to simulate spatial variations are not necessary.

ACTMO is an older watershed model, developed by ARS. Applications of the model have been limited, and the ARS has effectively replaced it with the CREAMS and SWAM models. The NPS model is related to ARM and estimates only losses of nutrients associated with sediment. Nutrient forms, such as nitrate-nitrogen, ammonia-nitrogen, and phosphate-phosphorus, which are largely dissolved in runoff will not be simulated well. Widely used in many areas, the AGNPS models allows spatial variation, including barnyard and feedlot COD and nutrients, to allow targeting of animal-waste management practices in conjunction with field practices. The primary disadvantage of AGNPS is its limitation to single storm events, which precludes its usefulness in tying it into a continuous simulation watershed model.

Table 1
Water Quality Models Selected for Review

Model	Acronym	Supporting Agency
Agricultural Chemical Transport Model	ACTMO	ARS/USDA
Agricultural Nonpoint Source Pollution Model	AGNPS	Minn. Poll. Control Agency
Agricultural Runoff Management Model	ARM	USEPA
Chemicals, Runoff, and Erosion from Agr. Management Systems	CREAMS	ARS/USDA
Erosion/Productivity Impact Calculator	EPIC	ARS/USDA
Groundwater Loading Effects of Ag. Management Systems	GLEAMS	ARS/USDA
Nonpoint Source Pollutant Loading Model	NPS	USEPA

2.2 FARM-SCALE MODELS

The three farm-scale models considered include CREAMS, GLEAMS, and EPIC. The following section presents a brief overview of each model and a discussion of the considerations involved in the selection process.

2.2.1 CREAMS

The USDA CREAMS model (Chemicals, Runoff, and Erosion from Agricultural Management Systems) was developed as a tool to evaluate effects of management practices on non-point source pollution (Knisel, 1980). CREAMS was developed specifically for simulation of field-size areas and has been used successfully on a large number of field-scale agricultural sites to evaluate alternative practices and conservation measures. Input data required for the CREAMS model include historical rainfall data; parameters describing soils, crops, land slopes, engineering structures such as terraces and waterways; and chemical application amounts, timing, and methods. Model outputs are the expected runoff volumes, sediment yield, sediment composition, and chemicals in the water and sediment. The model can provide continuous simulation for periods up to 20 years. The model consists of three major components: hydrology, erosion/sedimentation, and chemistry.

The hydrology component estimates runoff volume and peak rate, infiltration, evapotranspiration, soil water content, and percolation on a daily basis. Depending on the availability of rainfall data, storm runoff can be estimated by either an adaptation of the SCS curve number method (Williams and LaSeur, 1976) or by an infiltration-based method based on the Green and Ampt equation (Smith and Parlange, 1978). Percolation is determined by a storage routing technique to estimate flow through the root zone. The root zone is divided into seven layers with the top layer representing the active surface layer where interrill erosion occurs. The evapotranspiration element of the hydrology component is estimated using a modified Penman equation which calculates soil and plant evaporation separately (Ritchie, 1972).

The soil erosion component considers the basic processes of soil detachment, transport, and deposition. Soil detachment is described by a modification of the universal soil loss equation for a single storm event (Foster et al., 1977). In addition to calculating the sediment transport fraction for each of five particle classes, the model computes a sediment enrichment ratio.

The chemistry component estimates the transport of both plant nutrients and pesticides. The model computes nitrogen and phosphorus loss with sediment due to soil particle adhesion, soluble nitrogen and phosphorus loss with surface runoff, and soil nitrate loss by leaching, denitrification and plant uptake. The pesticide component estimates concentration of pesticides in runoff (water and sediment) and total mass carried from the field, accommodating multiple annual application of up to ten pesticides simultaneously. Movement of pesticides from the soil surface is a function of runoff, infiltration and pesticide mobility. The CREAMS model simulates nitrate, but not pesticides, leached below the plant root zone.

2.2.2 GLEAMS

The GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) model (Leonard et. al.,1987) was developed as an extension of the existing ARS CREAMS model, incorporating a vertical pesticide flux to evaluate the impact of management practices on potential pesticide leaching below the root zone, as well as surface runoff and sediment losses from field-size areas. GLEAMS retains the daily hydrology/soil-water balance features and the rill-interrill soil erosion/sediment transport features of CREAMS along with the pesticide components for simulating degradation, foliar washoff and partitioning of pesticide between surface runoff and infiltration. The GLEAMS model has the additional capability of routing pesticides within and through the root zone. Several other added features include irrigation options, pesticide metabolite tracking, increased simulation time up to 50 years, and software to facilitate model implementation and output analysis. The model was modified to consider up to 12 computational soil layers instead of the original seven as in CREAMS.

Input requirements include daily rainfall volumes for the period of simulation, crop and management parameters, soil and physical parameters for sediment transport, and pesticide data such as solubility, expected half-life, and adsorptivity. Output data includes surface runoff volumes, percolation volumes, sediment yields, and pesticides in surface runoff, transported sediments and leachates.

The hydrology component uses daily climatic data to calculate the water balance in the root zone. The SCS curve number method (1972) modified by Williams and Nicks (1982) is used to estimate runoff. A seasonally frozen-soil representation (Knisel, et al., 1985) enhances estimates of snowmelt runoff. Water balance computations are the same as those described above for CREAMS which include the percolation and evapotranspiration elements.

The erosion component of GLEAMS is essentially the same as that in the CREAMS model. The only significant change is the calculation of sediment particle characteristics. Foster, et al. (1985) used additional data to better define aggregate sizes and their respective fraction in the detached soil. A modified version of the universal soil loss equation (Wischmeier and Smith, 1978) is used for storm-by-storm estimates of rill and interrill erosion in overland flow areas.

Elements of the CREAMS pesticide component (Leonard and Wauchope, 1980) for surface losses in runoff and in sediment were retained in GLEAMS (Leonard et. al., 1987). The same adsorption characteristics were coupled with the water storage-routing technique to route pesticides within and through the root zone. Plant uptake by transpiration and upward movement of pesticides with soil evaporation were included along with a modification for considering pesticide degradation.

2.2.3 EPIC

EPIC (Erosion/Productivity Impact Calculator) is a comprehensive model developed specifically to determine the relationship between soil erosion and soil productivity (National Soil Erosion-Soil Productivity Research Planning Committee USDA-ARS 1981; Williams, et al.,1985). EPIC continuously simulates the processes associated with erosion, using a daily time step and readily available inputs. Since erosion occurs relatively slowly, EPIC has the capabilities to simulate the process over hundreds of years, if necessary. EPIC is composed of physical components and economic components. The physical components include hydrology, weather simulation, erosion-sedimentation, nutrient cycling, plant growth, tillage and soil temperature. The economic components include cost of erosion, crop yield, profit, and other parameters for determining optimal management strategies.

Runoff volume is estimated by using a modification of the SCS curve number technique (SCS, 1972). Peak runoff rates are based on a modification of the Rational formula. The model offers two options for estimating potential evaporation, the Priestley-Taylor(1972) and the Penman(1948). The model computes evaporation from soils and plants separately by an approach similar to that of Ritchie (1972), which is used in CREAMS and GLEAMS. The EPIC snowmelt component is also similar to that of the CREAMS model.

The weather variables necessary for driving the EPIC model are precipitation, air temperature, solar radiation, wind speed and relative humidity. If daily weather data is available, it may be input directly into EPIC; however, solar radiation, relative humidity and wind data are generally scarce. Thus, EPIC provides options for simulating various combinations of the five weather variables.

The EPIC component for water-induced erosion simulates erosion caused by rainfall, runoff and irrigation. The EPIC erosion component contains three equations, the USLE (Wischmeier and Smith, 1978), the MUSLE (Williams, 1975), and the Onstad-Foster modification of USLE (Onstad and Foster, 1975) which is user specified. Only the specified equation interacts with the other EPIC components.

For wind-induced erosion, the Manhattan, Kansas equation (Woodruff and Siddoway, 1965) was modified by Cole, et al. (1982) for use in the EPIC model.

EPIC simulates nutrient transport in both the soluble phase and the sediment bound phase. It provides a comprehensive nitrogen balance which includes transport (soluble and sediment bound), denitrification, mineralization, immobilization, nitrogen fixation, plant uptake and nitrogen contribution from rainfall. It provides a similar phosphorus balance.

The plant environment control component provides mechanisms for applying irrigation water, fertilizer, lime and pesticides, or for simulating a drainage system. Fertilizer applications can be user specified or automatically applied during the simulation. EPIC also has an option which allows for organic fertilizer applications.

The economic component of EPIC includes crop budgets which are calculated using components from the Enterprise Budget Generator (Kletke,1979). Inputs are divided into fixed and variable costs. The model output includes yield, gross income from the crop and net profit.

2.2.4 Model Validation and Application

The CREAMS and GLEAMS models have been applied and extensively tested in several watersheds in the western and north central United States, including Iowa, Ohio, Michigan, South Dakota, and Montana, which represent diverse climatic and land use conditions. Watershed P-2, a study site in the cooperative ARS/EPA pesticide project (Smith et. al.,1978) in Watkinsville, Georgia, was used in the validation of CREAMS. GLEAMS was validated in several test studies in Tifton, Georgia.

The EPIC model was extensively tested by the SCS before the model was used for the 1985 RCA analysis. Seventeen major land resource areas in the U.S. were selected for the tests. Several deficiencies were discovered and the model was modified to overcome them. The tests were repeated and the model validated. The model was subsequently used for 13,000 RCA simulations (of 50 years each) performed during 1984 and 1985 which covered the entire U.S. Besides this extensive testing and application , the model is being used internationally in research and in management.

2.3 MODEL COMPARISON AND SELECTION

Table 2 lists the major considerations involved in the selection of a farm-scale model. All three models are restricted to small areas due to the assumptions of 1) a single land use, 2) relatively homogeneous soils, 3) spatially uniform rainfall and 4) a single management system. CREAMS and GLEAMS do not have the capabilities for weather simulation, as does EPIC, and require at least 1 year of precipitation data. EPIC can be used to simulate long term effects of more than 100 years whereas CREAMS and GLEAMS are restricted to shorter simulation periods.

TABLE 2

MODEL COMPARISONS

	CREAMS	GLEAMS	EPIC
Simulation duration	20 yr	50 yr	100+ yr
Soil layers	7	12	10
Nutrient Transport	yes	no	yes
Simulation Area	<100 Ac	<100 Ac	<2.47 Ac
Wind Erosion	no	no	yes
Weather Simulation	no	no	yes
Irrigation	no	yes	yes
Fertilizer Appl.	yes	no	yes
Manure Appl.	no	no	yes
Soil Salt Sim.	no	as pesticide	being dev.

GLEAMS can simulate irrigation application, but not manure application nor nutrient transport. Although CREAMS simulates nutrient transport, it lacks the capabilities of irrigation and manure applications. EPIC can simulate all three parameters.

EPIC contains parameter files for soils, crops, tillage, and weather. The crop parameter table contains information needed for simulation of the production of 22 crops. Weather generation parameters are available for 134 locations in the U.S., soil data for over 800 U.S. soil series, and input data for over 50 types of farm equipment. An interactive data entry system, EASE, is available to aid in building EPIC data sets.

Another advantage in the EPIC model for use in examining both runoff and infiltration of nutrients and salts from applicaitons of animal waste and wastewater is the addition of a soil salt component currently being developed by the USDA, Agricultural Research Service, for the simulation of salt accumulation in the soil. This component of the EPIC model, which is anticipated to be released in the near future, includes the effects of salt stress on plant growth for nutrient calculations and crop yield.

The EPIC model was selected as the model for evaluating BMPs for confined animal feeding operations in Task 3.0 based on the simulation capabilities described above, as well as the user convenience features.

3.0 REFERENCES

Cole, G.W., L. Lyles, and L.G. Hagen. 1982. "A Simulation Model of Daily Wind Erosion Soil Loss." ASAE Paper #82-2575.

Crowder, B.M. 1987. Issues in Water quality Modeling of Agricultural Management Practices: An Economic Perspective. Symposium on Monitoring, Modeling, and Mediating Water Quality. Am. Water Resources Assoc. May, 1987.

Foster, G.R., D. L. Meyer and C.A. Onstad. 1977. A runoff erosivity factor and variable slope length exponents for soil loss estimates. Trans. Amer. Soc. Agr. Engineers, v. 20, pp. 683-687.

Foster G.R., R.A. Young. and W.H. Neibling. 1985. Sediment composition for nonpoint source pollution analyses. TRANSACTIONS of the ASAE 28(1):133-139. 146

Kletke, D.D. 1979. Operation of the Enterprise Budget Generator. Oklahoma State Univ., Agric. Exp. Sta. Res. Report p-790.

Knisel. W.G., D.C. Moffitt, and T.A. Dumper. 1985. Representing seasonally frozen soil with the CREAMS model. TRANSACTIONS of the ASAE 23(5):1487-1493.

Knisel, W.G. 1980. CREAMS, A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. USDA Conserv. Res. Report No. 26. 643 pp.

Knisel, W.G., G.R. Foster and R.A. Leonard 1983. CREAMS: A system for evaluating management practices. In Agricultural Management and Water Quality. F.W. Schaller and G.W. Bailey (Eds.), Iowa State University Press, Ames, pp. 178-199.

Leonard, R.A. and R.D. Wauchope. 1980. The pesticide submodel. In: Knisel, W.G. (Ed.). 1980. CREAMS: A field-scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U.S. Department of Agriculture, Science and Education Administration. Conservation Research Report No. 26, pp. 88-112.

Leonard, R.A. and W.G. Knisel. 1989. Groundwater Loadings by Controlled-Release Pesticides: A Gleams Simulation. ASAE Paper No. 88-2624. ASAE. St. Joseph. MI 49085. pp. 1915-1922.

Leonard, R.A. and H.F. Perkins and W.G. Knisel. 1989. Relating Agrichemical Runoff and Leaching to Soil Taxonomy: A Gleams Model Analysis. Proceedings of the 1989 Georgia Water Resources Conference, The University of Georgia, Athens, G.A. May 16-17, 1989.

Leonard, R.A. and W.G. Knisel and D.A. Still. 1987. Gleams: Groundwater Loading Effects of Agricultural Management Systems. ASAE Paper No. 86-2511. ASAE. St. Joseph. MI 49085. pp. 1403-1418.

Leonard, R.A. 1986. Agriculture and Ground Water Quality. Proceedings of the Focus Conference on Southeastern Ground Water Issues. Tampa, Florida. Oct 6-8, 1986. pp. 125-144.

Onstad, C.A. and G.R. Foster. 1975. "Erosion Modeling on a Watershed." Trans. ASAE 18:288-292.

Penman, H.L. 9148. "Natural Evaporation from Open, Bare Soil and Grass." Proc. Royal Soc. (London) A193:120-145.

Priestley, C.H.B. and R.J. Taylor. 1972. On the assessment of surface heat flux and evaporation using large-scale parameters. Mon. Weather Rev. 100:81-92.

Ritchie, J.T. 1972. "A Model for predicting Evaporation from a Row Crop with Incomplete Cover." Water Resources Res. 8:1204-1213.

Smith, R.E. and J.Y. Parlange. 1978. A parameter-efficient hydrologic infiltration model. Water Resources Res., v. 14, pp. 533-538.

Smith. C.N., R.A. Leonard, G.W. Langdale, and G.W. Bailey. 1978. Transport of agricultural chemicals from small upland Piedmont watersheds. U.S. Environmental Protection Agency. Athens. GA. and U.S. Department of Agriculture. Agricultural Research Service, Watkinsville, GA. Final Report on Interagency Agreement No. D6-0381. Publication No. EPA 600/3-78-056.363 pp.

USDA, Soil Conservation Service. 1972. "Hydrology." Chapters 4-10. In National Engineering Handbook. USA Government Printing Office.

Williams, J.R. and K.G. Renard. 1985. Assessments of soil erosion and crop productivity with process models (EPIC). pp. 67-103. In R.F. Follett and B.A. Stewart, eds., Soil Erosion and Crop Productivity. Am. Soc. Agron., Crop Sci. Soc. Am, Soil Sci. Soc. Am, Madison, WI. 533 pp.

Williams, J.R. 1975. "Sediment Yield Prediction with Universal Equation Using Runoff Energy Factor." USDA, ARS-S-40, 244-242.

Williams, J.R. and A.D. Nicks. 1982. "CREAMS Hydrology Model--Option One." In Applied Modeling Catchment Hydrology, Proc. Intl. Symp. Rainfall-Runoff Modeling, V.P. Singh, ed. (Mississippi State, MS, May 18-21, 1981), 69-86.

Williams, J.R. and W.V. Laseur. 1976. Water yield model using SCS curve numbers. J. Amer. Soc. Civil Engineers. Hydraulics Division, v. 102 (HY9), pp. 1241-1253.

Williams, J.R. 1989. EPIC: The Erosion-Productivity Impact Calculator. Proceedings 1989 Summer Conference of Society for Computer Simulation, Austin, TX., July 1989.

Wischmeirer, W.H. and D.D. Smith. 1978. Predicting Rainfall Erosion Losses, A guide to Conservation Planning. USDA Agric. Handb. No. 537. 58 pp.

Woodruff, N.P. and F.H. Siddoway. 1965. "A Wind Erosion Equation." Soil Sci. Soc. Amer. Proc. 29:602-608.71

APPENDIX IX

EPIC SENSITIVITY ANALYSIS

A sensitivity analysis was performed on EPIC (Erosion-Productivity Impact Calculator), a farm-scale model, to determine the quantitative effects each input parameter had on relevant model output. This information will be used to assess the relative importance of input parameter accuracy during the calibration and verification of the EPIC model, and the physical factors most important in controlling nutrient uptake and runoff.

An input data set was constructed for a test site in Erath County. The input data was determined for a 42 acre coastal bermuda field located approximately 16 miles southeast of Stephenville near the Bosque County border. Because wind data is not available for Erath County, wind and weather data for Bosque county were used for the simulation. The coastal field was located on Houston Black Clay with an approximate 2 percent slope, and was fertilized with 300 lbs./acre of 13-13-13 commercial fertilizer in early spring.

METHODOLOGY

A one year simulation was run for the initial data set and the output was used as a control for comparison. Selected input parameters were adjusted to determine their effects on the model output. Each selected parameter was changed to a different value within the recommended range to eliminate erroneous results. The simulation was rerun following each change while all other inputs remained at their control values. Table 1 lists the input data for which the sensitivity was determined. The wind and weather data required for input were assumed to be fairly accurate and are measured in the study area, and the influence of precipitation on runoff is well documented. Therefore, the sensitivity of the model to climatological data was not investigated.

The results of each simulation were compared with the control output. The selected output parameters relevant to our study include average annual values for sediment bound and soluble nutrients (nitrogen and phosphorus), soil parameters, runoff volume, soil erosion and crop data. Appendix B lists the output parameters used for comparison.

The percent change of each input and output parameter was calculated as follows:

$$\% \text{ Change} = \frac{\text{Value(initial)} - \text{Value(after change)}}{\text{Value(initial)}} \times 100$$

This information was used to graph the percent change of the input versus the percent change of the output, these graphs are included in Appendix C. The slope of the line was calculated as follows:

$$\text{Slope} = \frac{\% \text{ change of the output parameter}}{\% \text{ change of the input parameter}}$$

The sensitivity of the model to each input parameter was determined from the slopes and were classified as described below.

SLOPE	SENSITIVITY
>1	Highly Sensitive
.5 - 1	Sensitive
.1 - .499	Slightly Sensitive
<.1	Not Sensitive

Tabulated results of the sensitivity analysis are shown in Appendix D. Only the output parameters which showed a significant change were listed in the results. Any output parameters not listed showed no change or so small a change that the sensitivity was negligible.

RESULTS

SOIL PARAMETERS

Erosion and sediment bound nutrient loss showed the greatest sensitivity. Soil loss due to water erosion is sensitive to the erosion control practice, slope steepness, soil particle size and runoff curve number. Soil loss from wind erosion is slightly sensitive to soil particle size, particularly to the silt concentration of soil layer 1. It is also slightly sensitive to the power of the modified exponential wind speed.

The slope steepness and soil particle size can be accurately measured; however, the other parameters are estimations derived from tables. Due to the sensitivity of the EPIC erosion component, these values should be estimated with great care and adjusted during the calibration process.

The saturated conductivity and lateral conductivity of the soil are sensitive to the initial sand concentration. Soil water is sensitive to initial soil parameters such as field capacity, wilting point and bulk density.

Surface runoff and the inherent soluble nutrient loss were highly sensitive to the bulk density of soil layer 1 and to the runoff curve number. Many output parameters of the EPIC model appear to be very sensitive to the moist bulk density of the soil. Therefore, the bulk density should be measured as accurately as possible for each soil layer.

NUTRIENT PROCESSES

Transpiration is sensitive to the wilting point of the soil and slightly sensitive to the carbon dioxide concentration in the atmosphere. Nitrogen loss by denitrification is highly sensitive to the wilting point of the soil and slightly sensitive to the crop residue. Denitrification is the only parameter sensitive to changes in crop residue input.

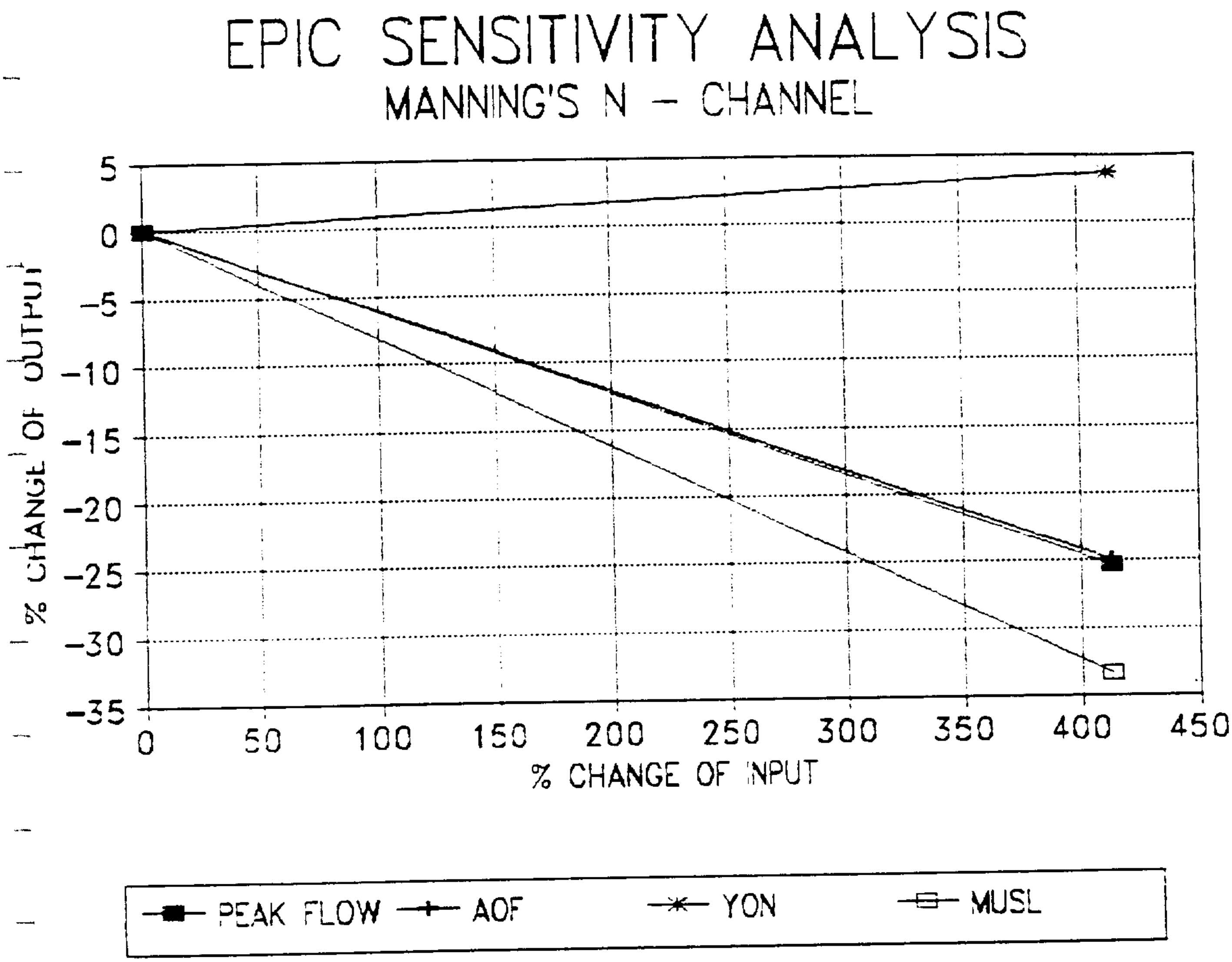
Soil phosphorus concentrations are highly sensitive to the percentage of calcium carbonate in the soil. In the final soil nutrient concentrations, both phosphorus and nitrogen were sensitive to the initial organic nitrogen concentration present in the soil.

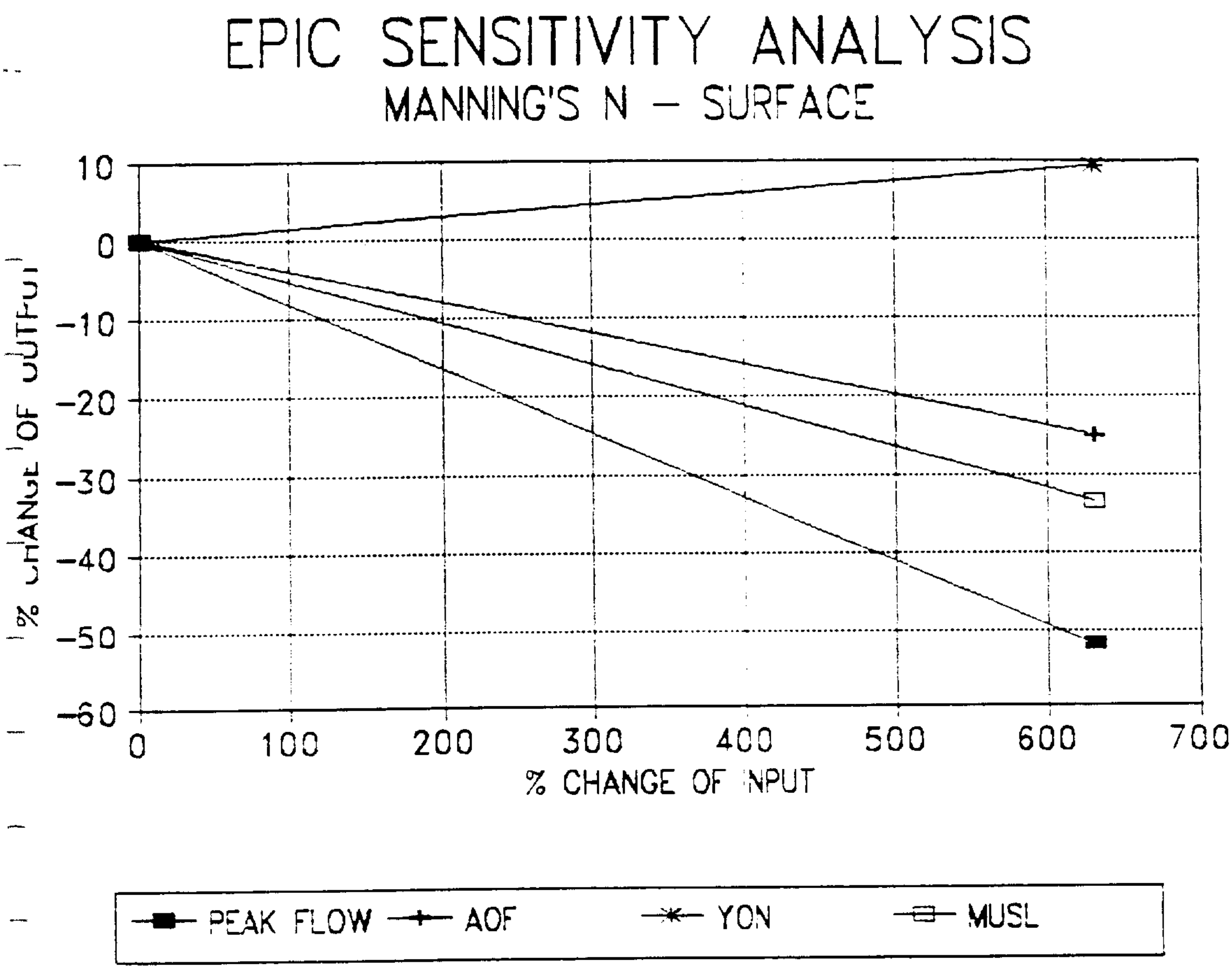
INSENSITIVE PARAMETERS

Several input parameters seemed to have no effect on the output. For instance, the oven dry bulk density of soil layer 1 had no effect on the output, whereas the moist soil bulk density had significant effects on the model output. Other input parameters that showed no effect on the output were soil Ph, sum of the bases, and the cation exchange capacity (CEC). Since only output parameters relevant to the project were compared, these input parameters may affect output which was not examined. Additionally, because EPIC allows for user specified equations for erosion and potential evaporation, these input parameters may be used in equations or subroutines which do affect the output.

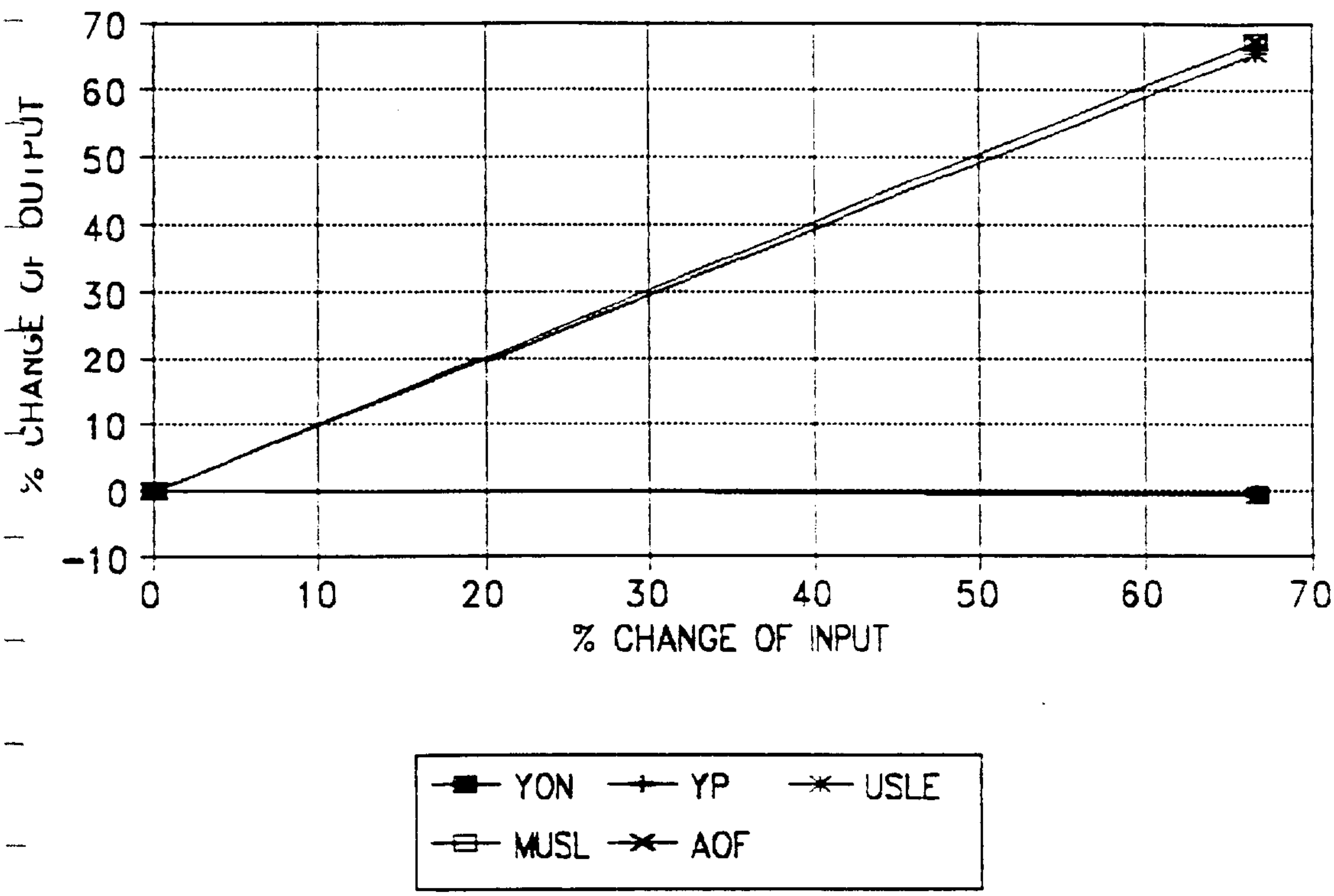
INPUT PARAMETERS FOR EPIC

- Manning's n - channel roughness
- Manning's n - surface roughness
- Soil albedo
- Erosion control practice
- Power of the modified exponential wind speed - for calculation
- Slope steepness
- Calcium carbonate percent - in soil layer 1
- Organic carbon percent - in soil layer 1
- Sum of bases - in soil layer 1
- Soil pH
- Organic nitrogen concentration - soil layer 1
- Silt concentration percent - soil layer 1
- Sand concentration percent - soil layer 1
- Field capacity - soil layer 1
- Wilting point - soil layer 1
- Bulk density - soil layer 1
- Slope length
- Carbon dioxide concentration in atmosphere
- Average concentration of nitrogen in rainfall
- Average channel slope
- Distance from outlet
- Runoff curve number
- Drainage area
- Bulk density - soil layer 1
- Crop residue
- Cation exchange capacity
- Sum of bases - soil layer 1
- Labile phosphorus concentration - soil layer 1
- Nitrate concentration - soil layer 1
- Coarse fragment content


EPIC SENSITIVITY ANALYSIS
MANNING'S N - CHANNEL
% CHANGE OF OUTPUT
5
0
-5
-10
-15
-20
-25
-30
-35
0
50
100
150
200
250
300
350
400
450
% CHANGE OF INPUT
PEAK FLOW
AOF
YON
MUSL

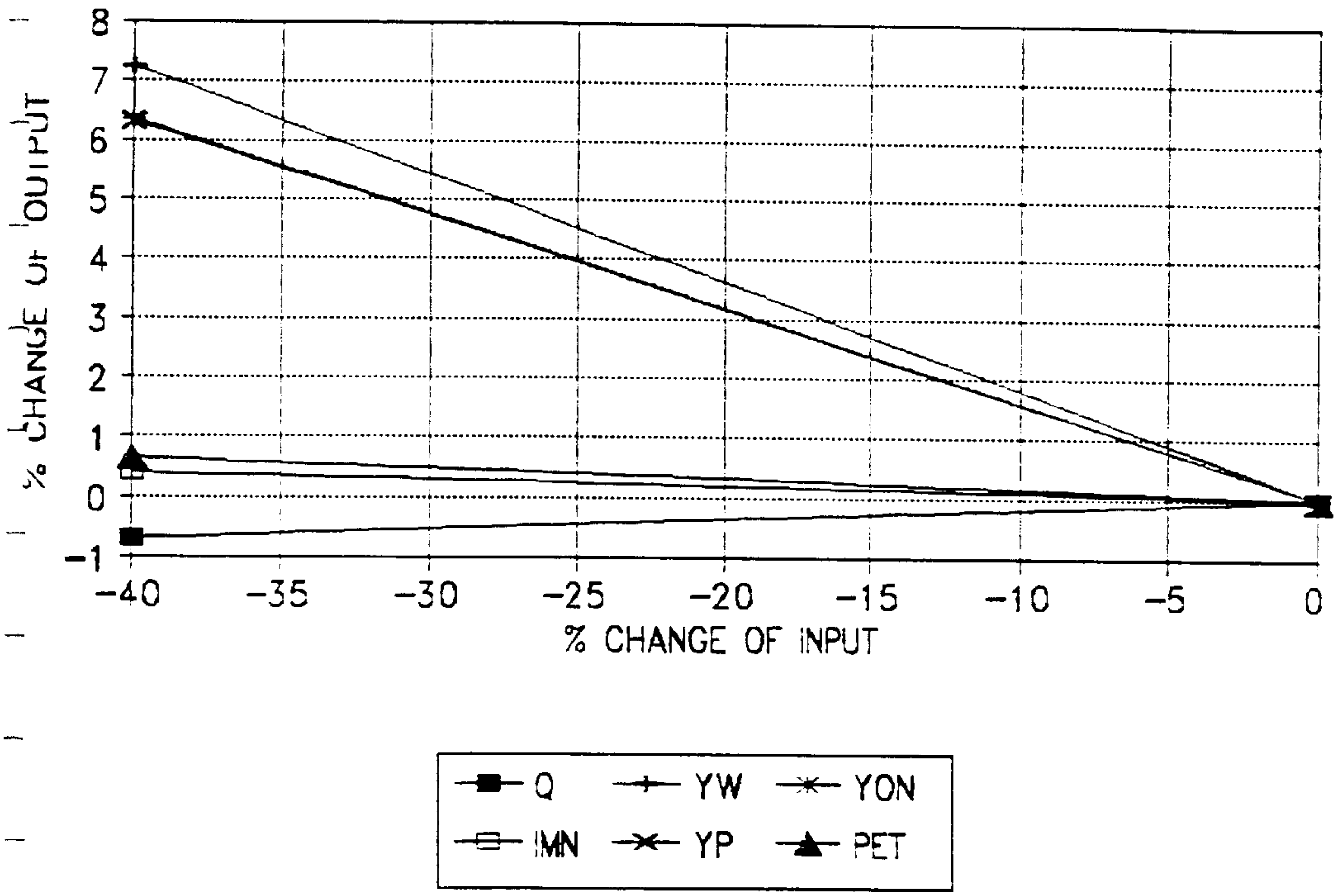

EPIC SENSITIVITY ANALYSIS
MANNING'S N – SURFACE
10
0
-10
-20
-30
-40
-50
-60
% CHANGE OF OUTPUT
0
100
200
300
400
500
600
700
% CHANGE OF INPUT
PEAK FLOW
AOF
YON
MUSL

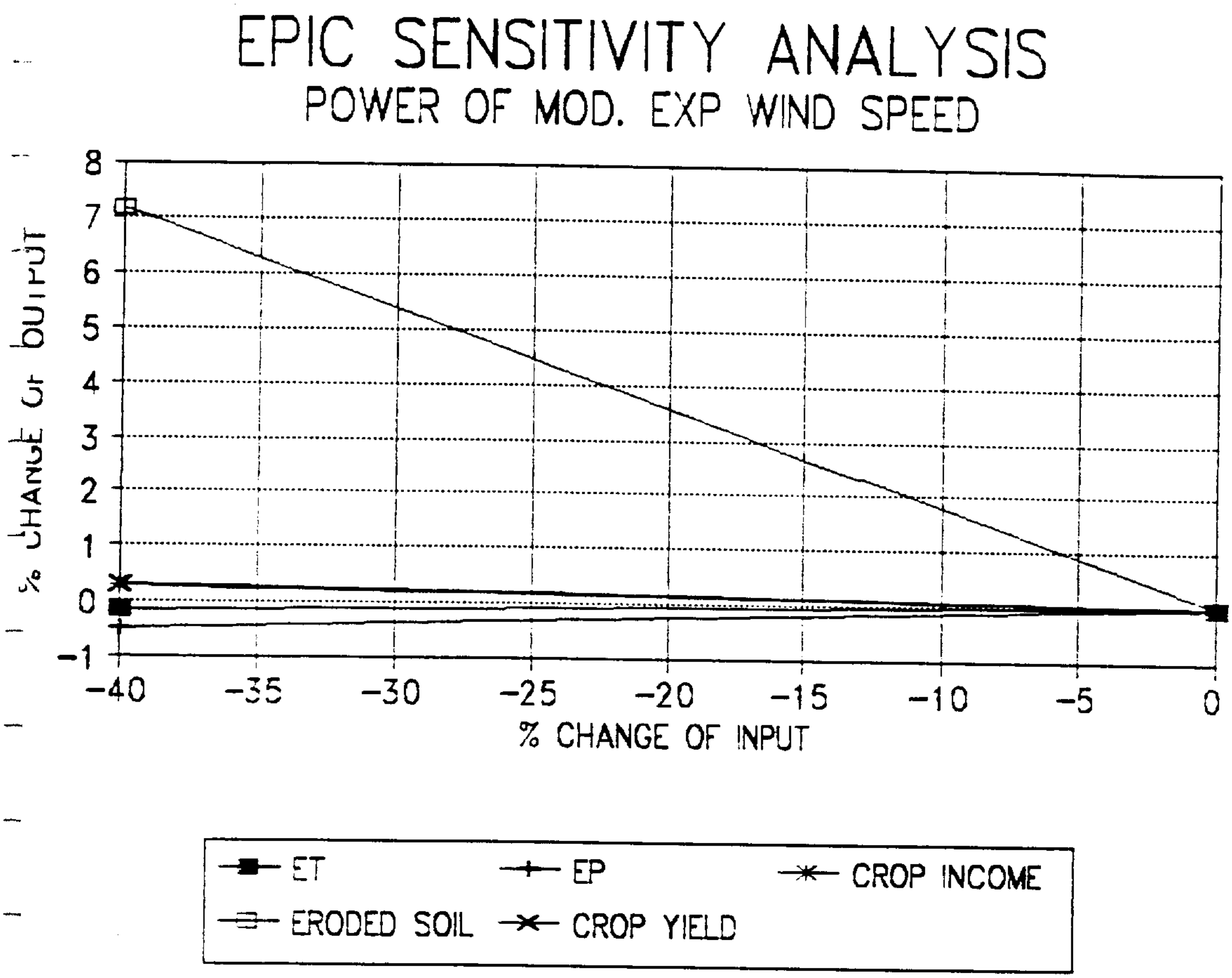
EPIC SENSITIVITY ANALYSIS
EROSION CONTROL PRACTICE



EPIC SENSITIVITY ANALYSIS

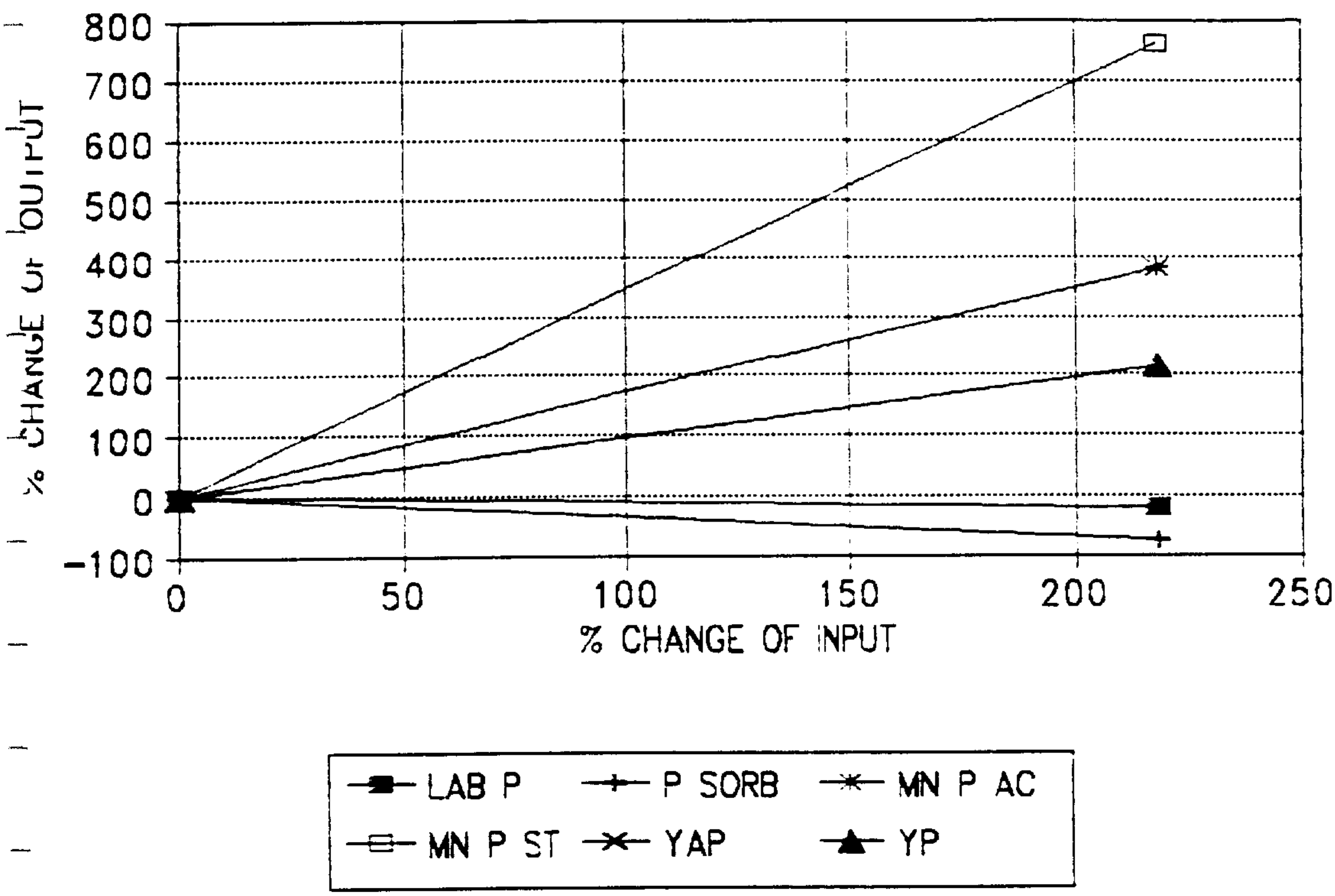
POWER OF MOD. EXP WIND SPEED



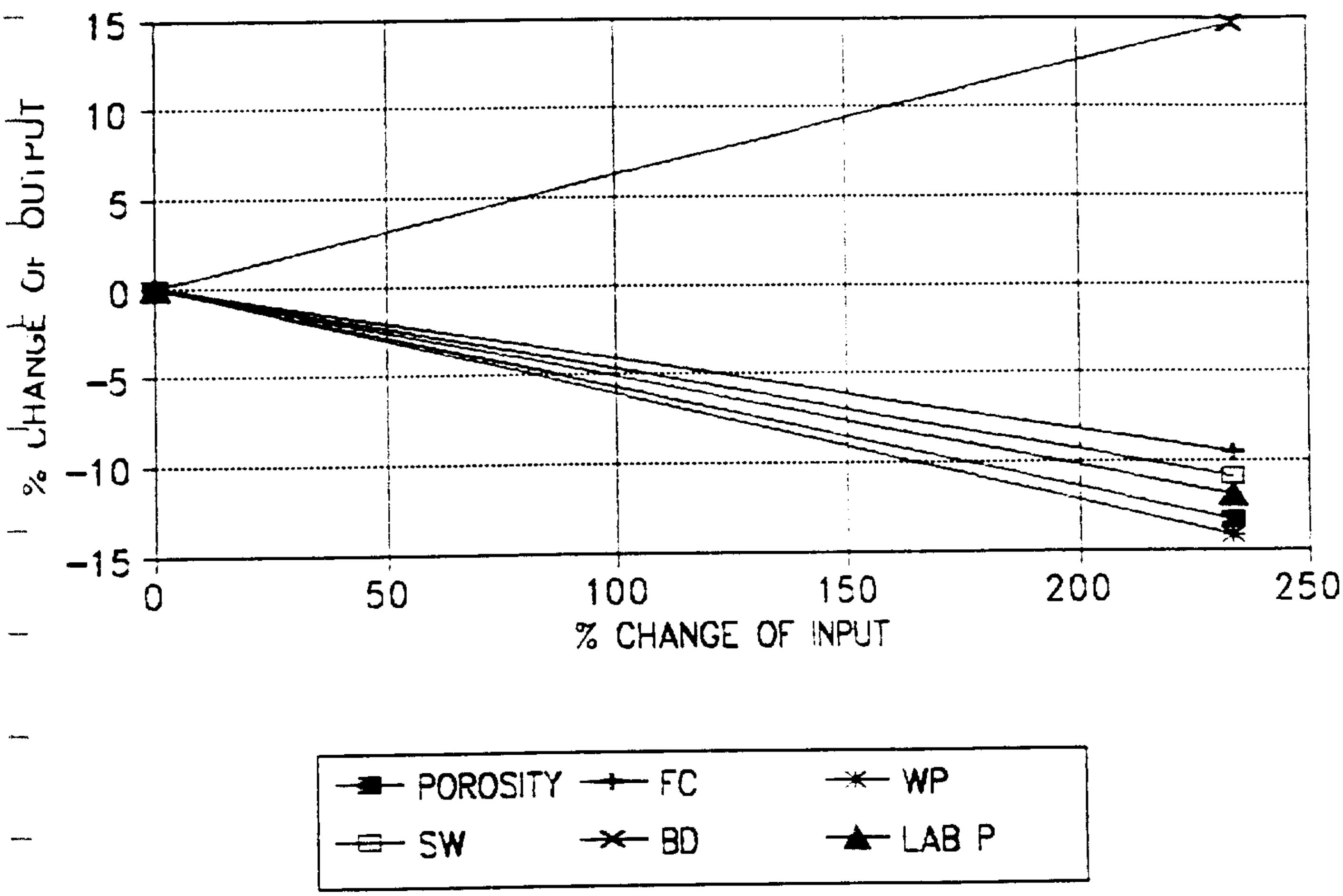


EPIC SENSITIVITY ANALYSIS
POWER OF MOD. EXP WIND SPEED
% CHANGE OF OUTPUT
8
7
6
5
4
3
2
1
0
-1
-40
-35
-30
-25
-20
-15
-10
-5
0
% CHANGE OF INPUT
ET
EP
CROP INCOME
ERODED SOIL
CROP YIELD

EPIC SENSITIVITY ANALYSIS
CALCIUM CARBONATE % IN SOIL LAYER 1

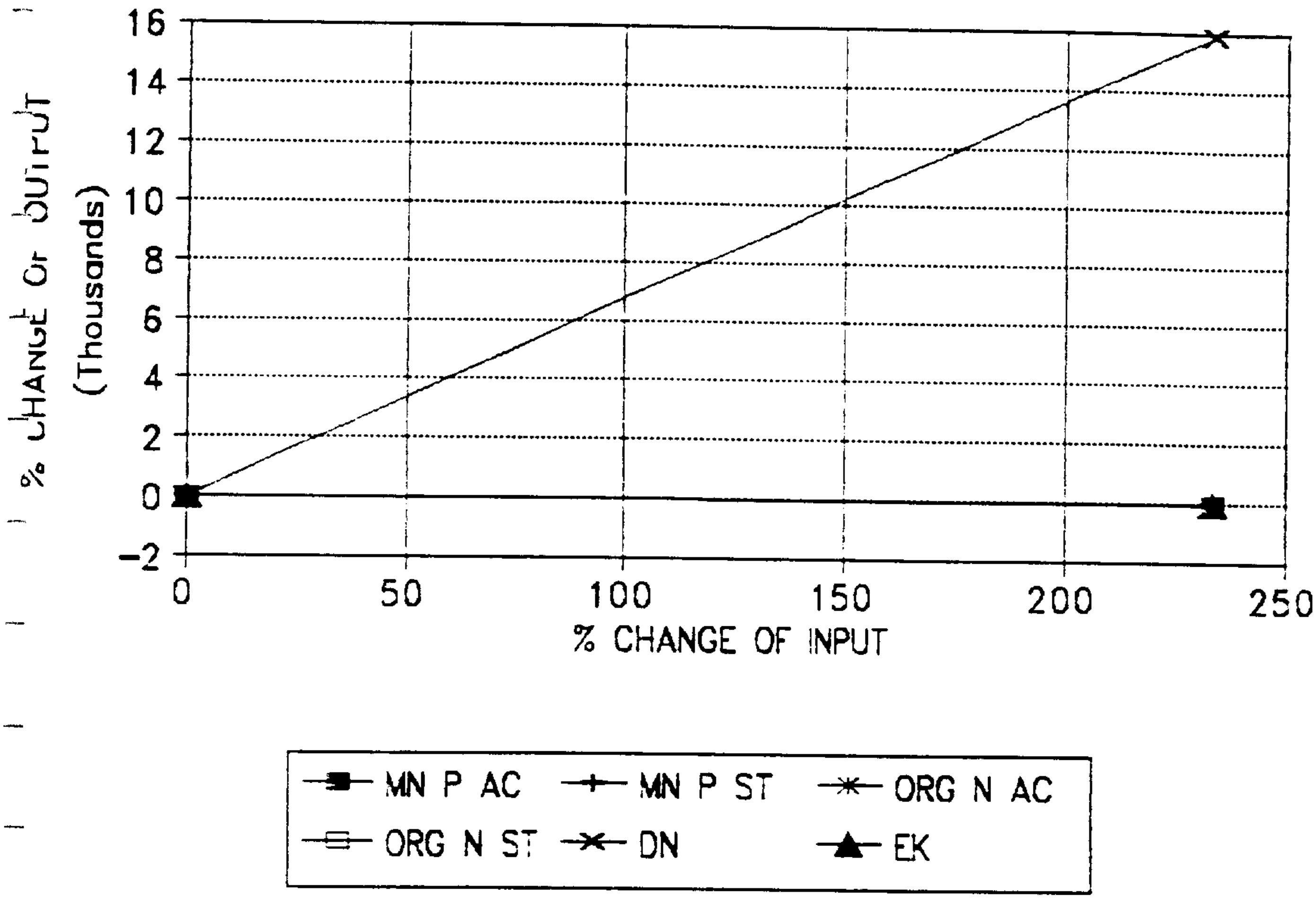


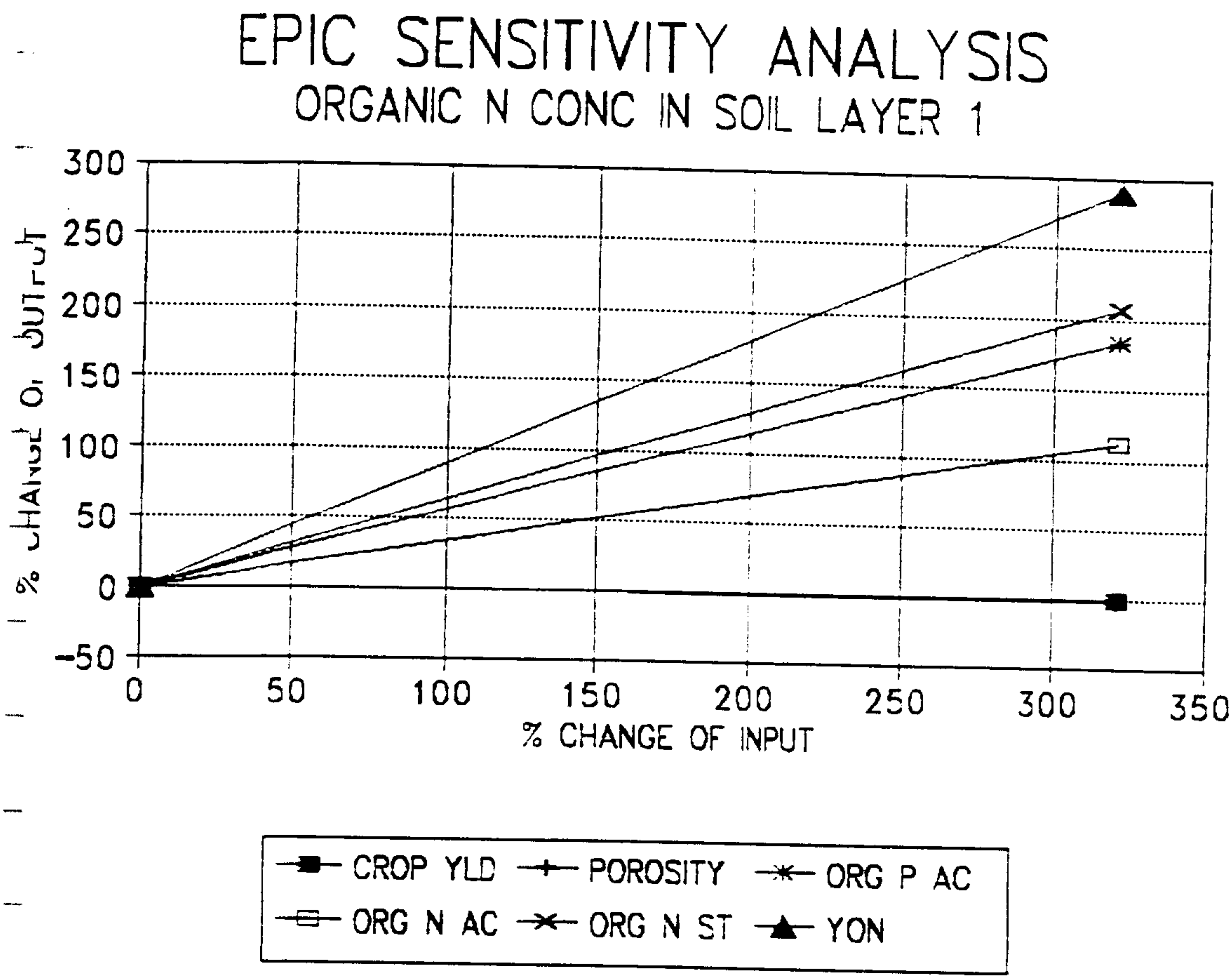
EPIC SENSITIVITY ANALYSIS
ORGANIC CARBON % IN SOIL LAYER 1



EPIC SENSITIVITY ANALYSIS

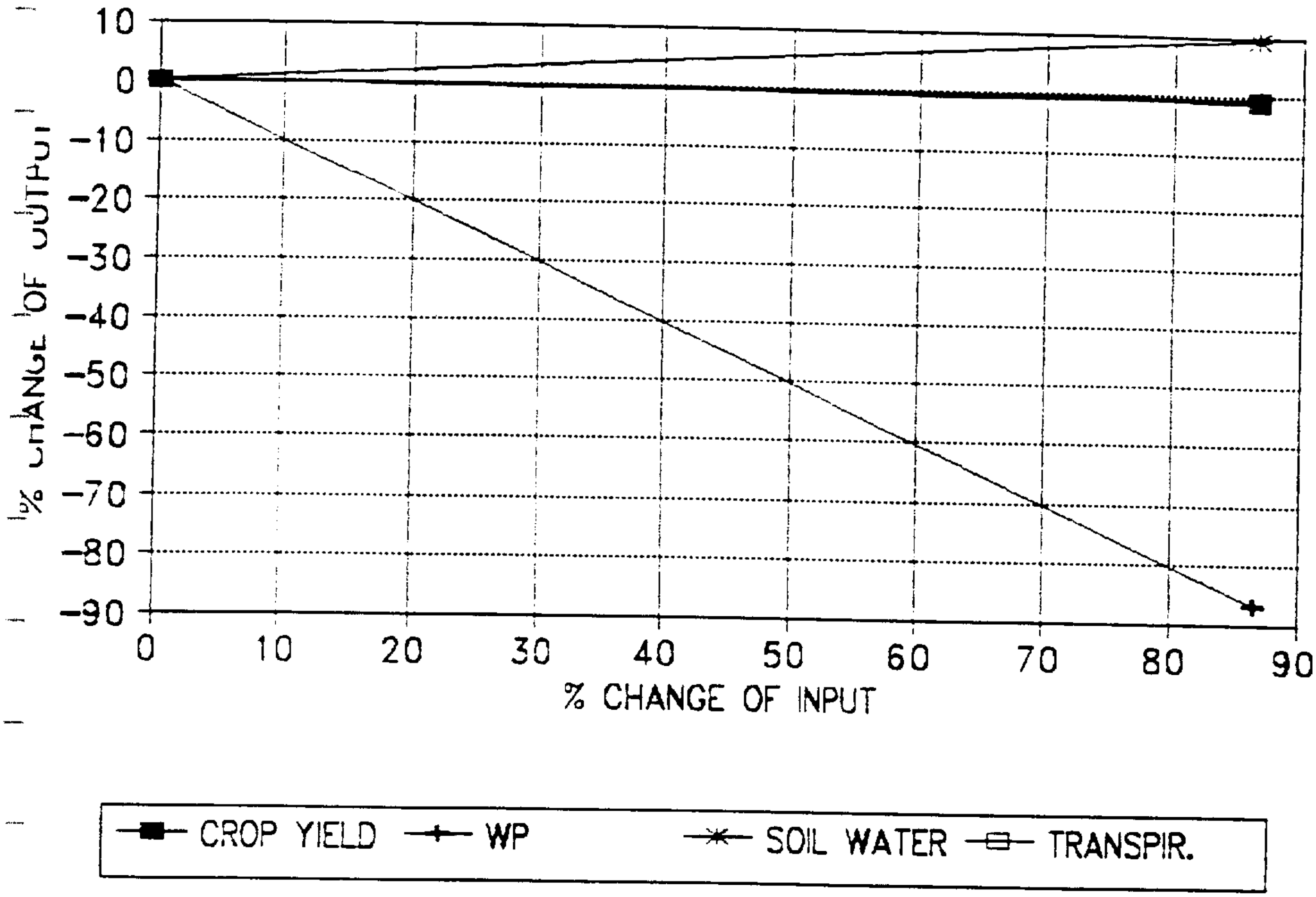
ORGANIC CARBON % IN SOIL LAYER 1




EPIC SENSITIVITY ANALYSIS
ORGANIC N CONC IN SOIL LAYER 1
300
250
200
150
100
50
0
-50
0
50
100
150
200
250
300
350
% CHANGE OF INPUT
CROP YLD
POROSITY
ORG P AC
ORG N AC
ORG N ST
YON

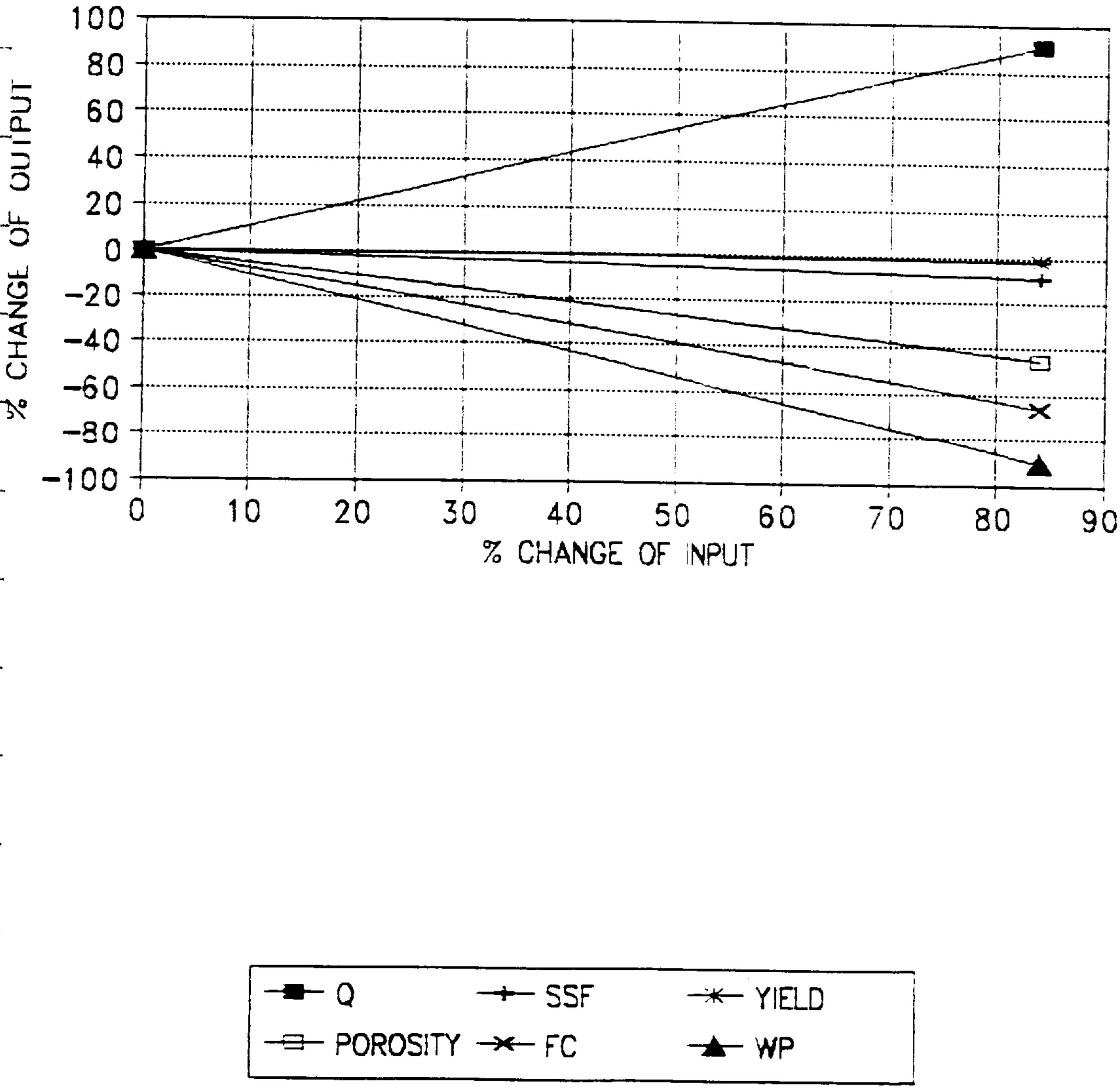
EPIC SENSITIVITY ANALYSIS

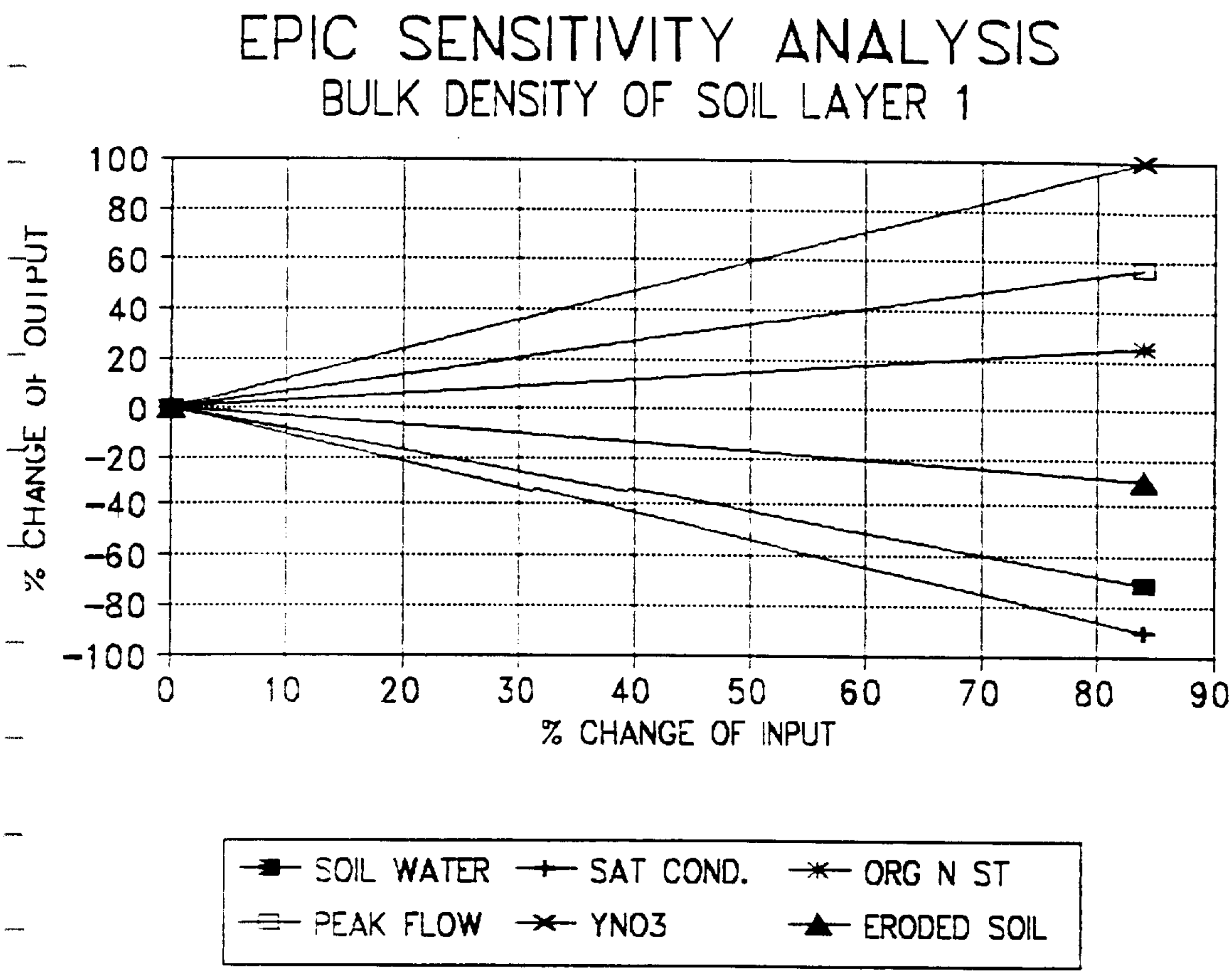
FIELD CAPACITY OF SOIL LAYER 1



EPIC SENSITIVITY ANALYSIS

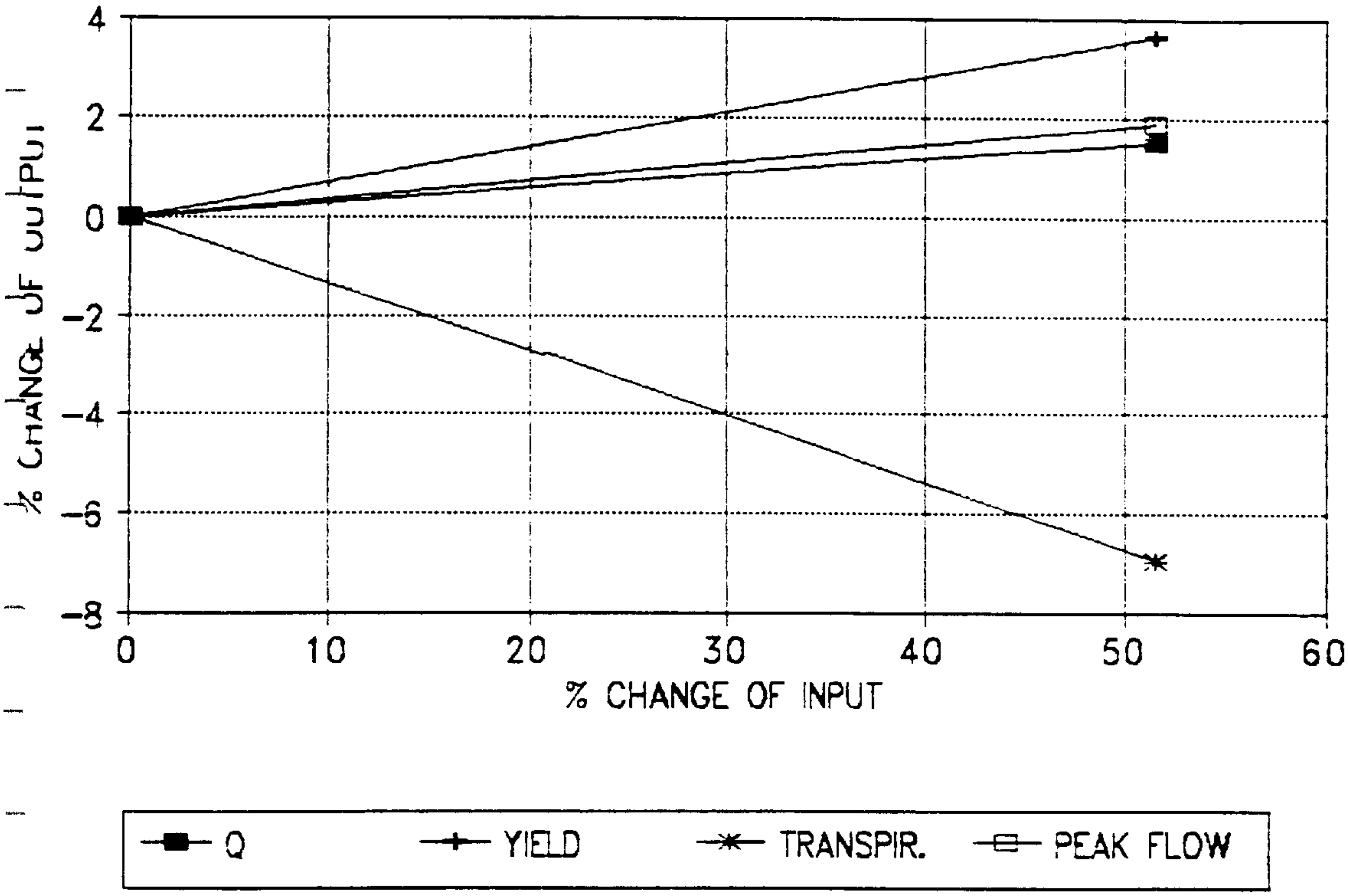
BULK DENSITY OF SOIL LAYER 1

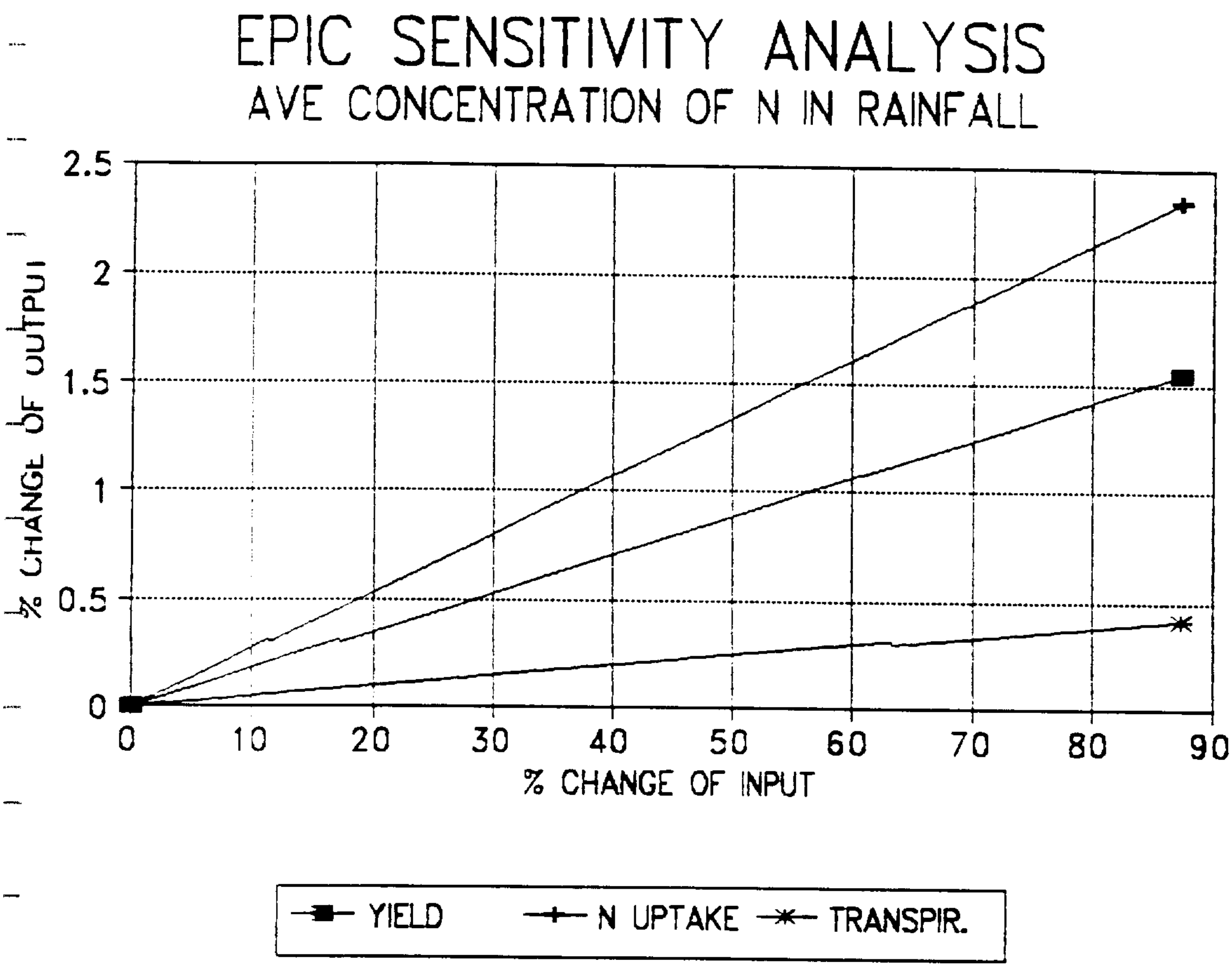




EPIC SENSITIVITY ANALYSIS
BULK DENSITY OF SOIL LAYER 1
% CHANGE OF OUTPUT
% CHANGE OF INPUT
100
80
60
40
20
0
-20
-40
-60
-80
-100
0
10
20
30
40
50
60
70
80
90
SOIL WATER
SAT COND.
ORG N ST
PEAK FLOW
YNO3
ERODED SOIL

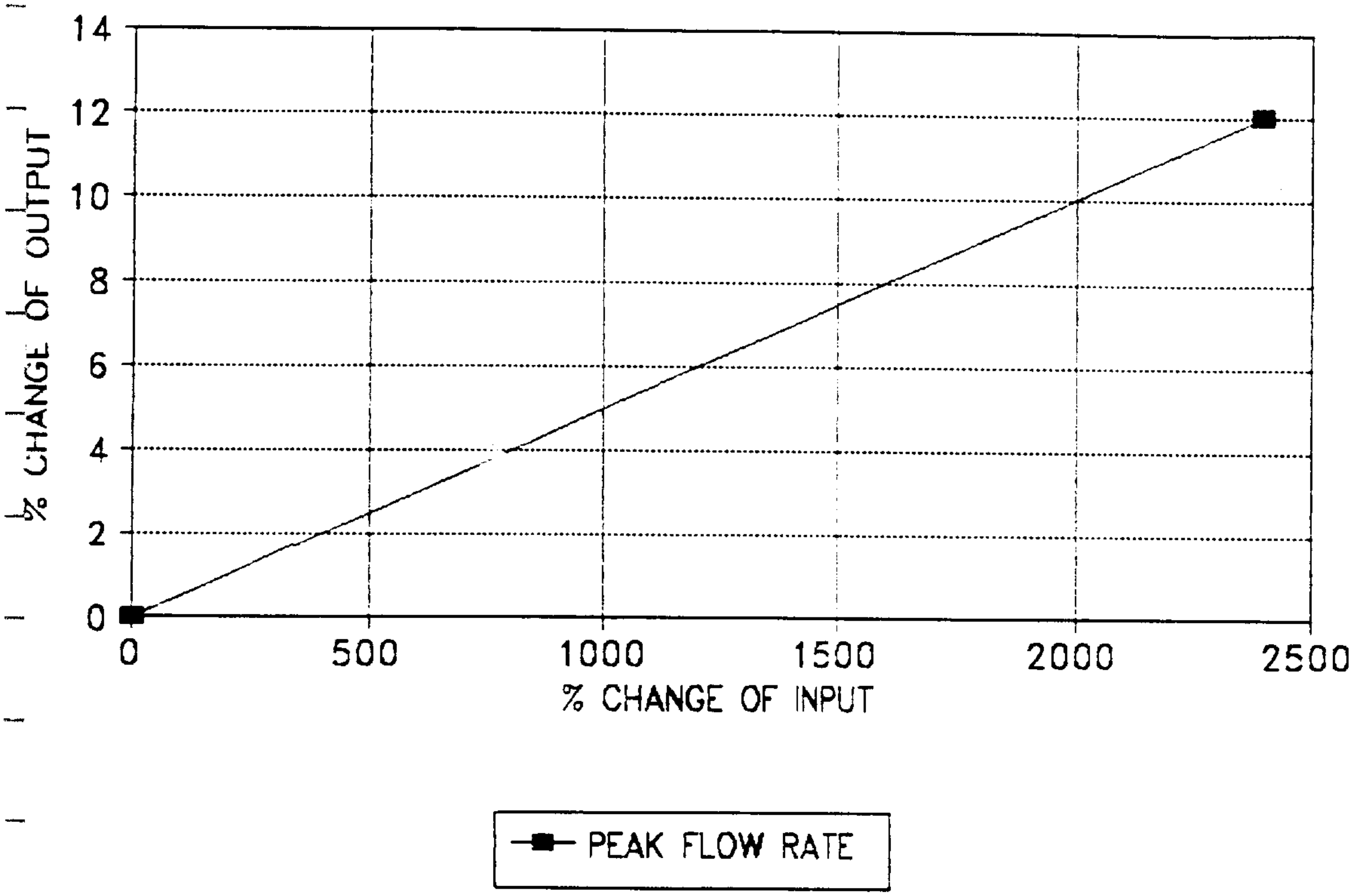
EPIC SENSITIVITY ANALYSIS
CO2 CONC IN ATMOSPHERE

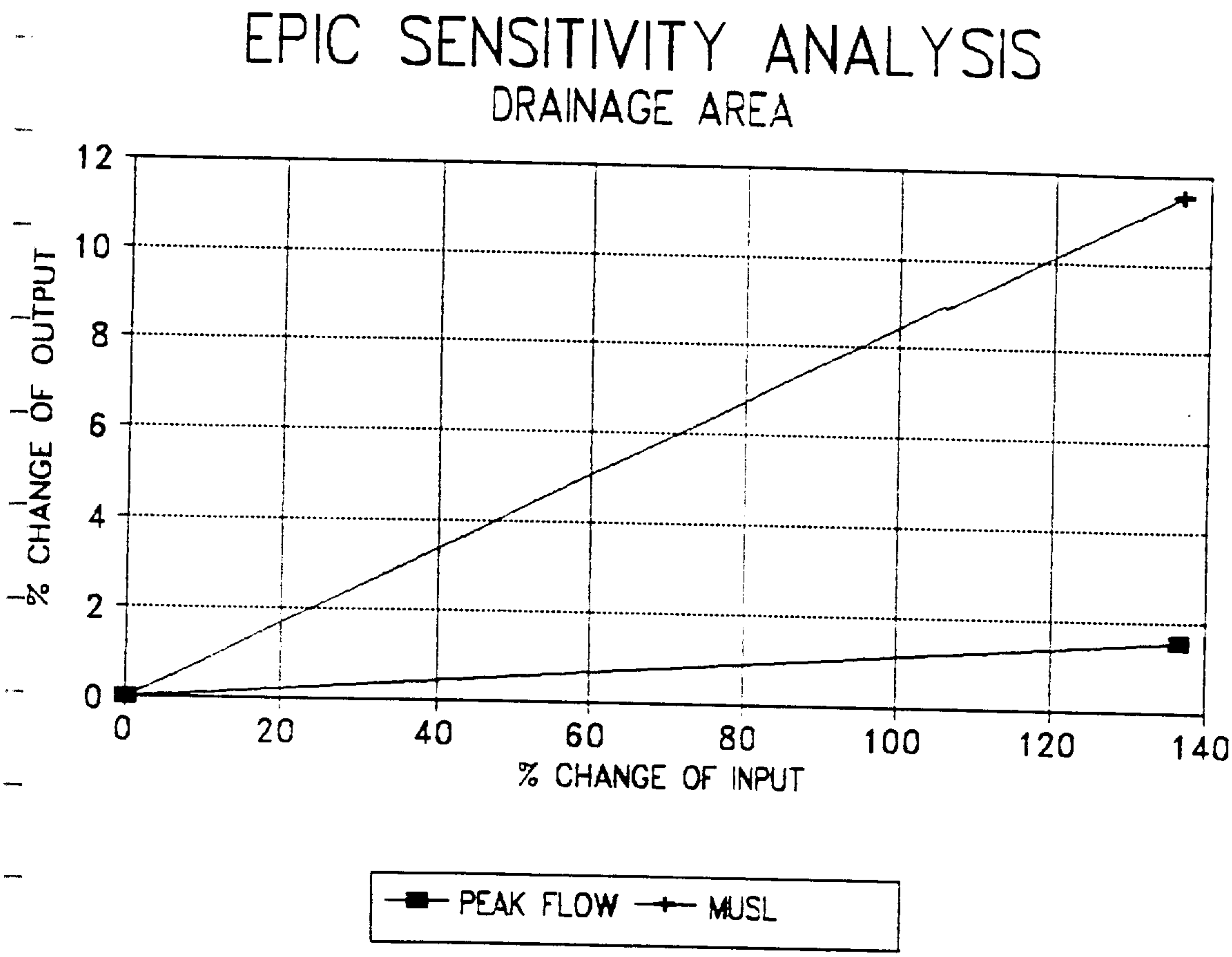



EPIC SENSITIVITY ANALYSIS
AVE CONCENTRATION OF N IN RAINFALL
% CHANGE OF OUTPUT
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
80
90
% CHANGE OF INPUT
YIELD
N UPTAKE
TRANSPIR.

EPIC SENSITIVITY ANALYSIS

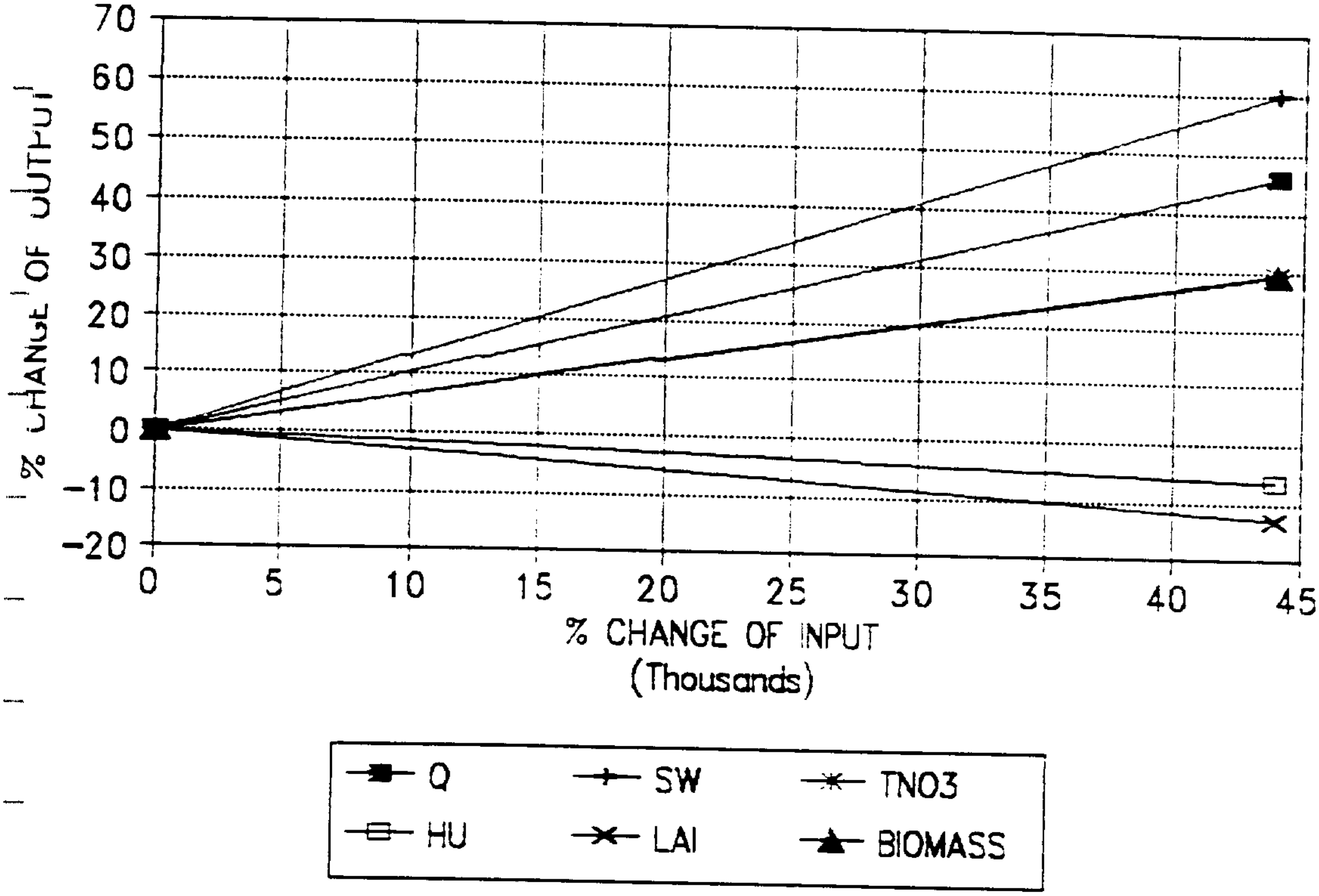
AVERAGE CHANNEL SLOPE

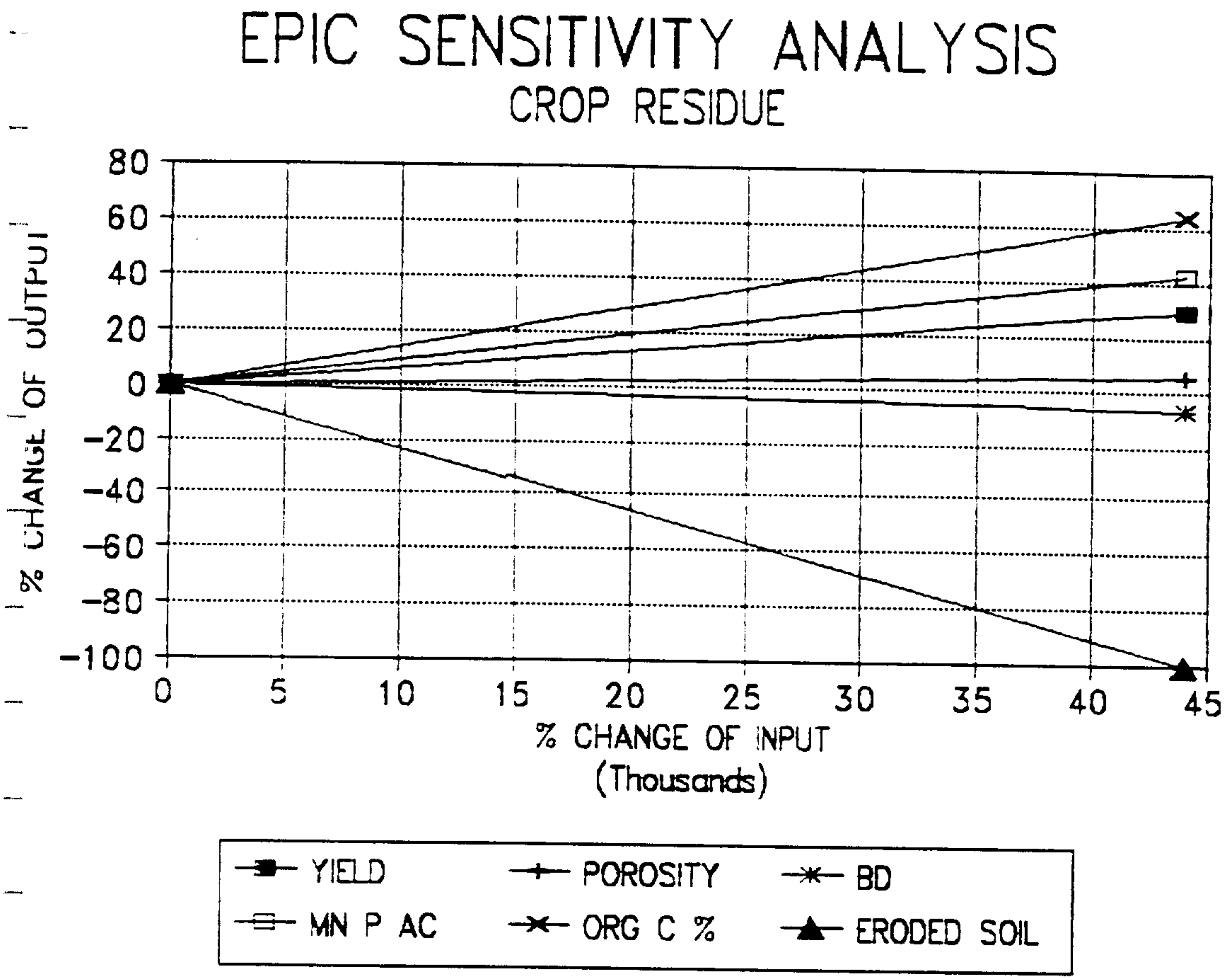



EPIC SENSITIVITY ANALYSIS
DRAINAGE AREA
% CHANGE OF OUTPUT
0
2
4
6
8
10
12
0
20
40
60
80
100
120
140
% CHANGE OF INPUT
PEAK FLOW
MUSL

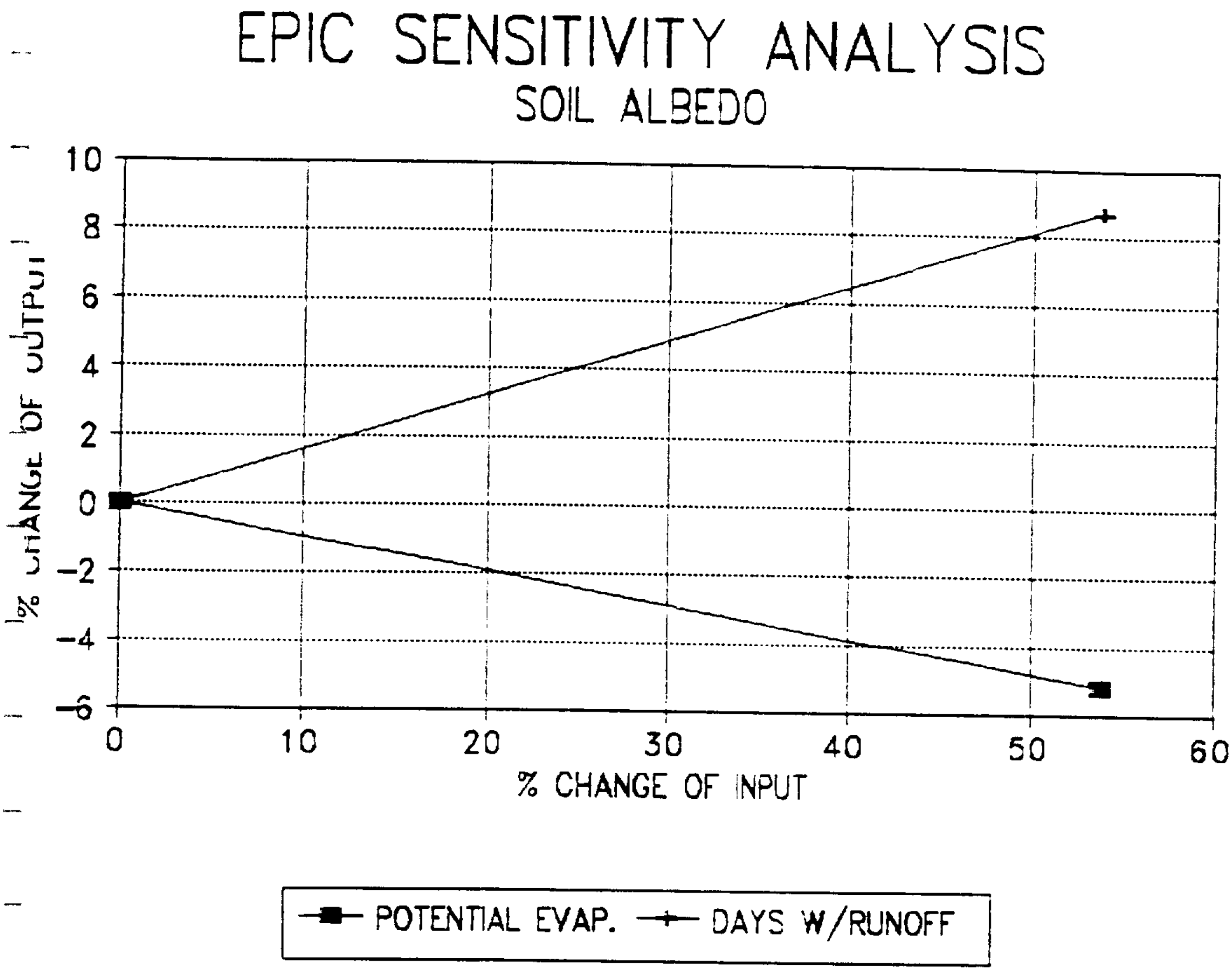
EPIC SENSITIVITY ANALYSIS

CROP RESIDUE





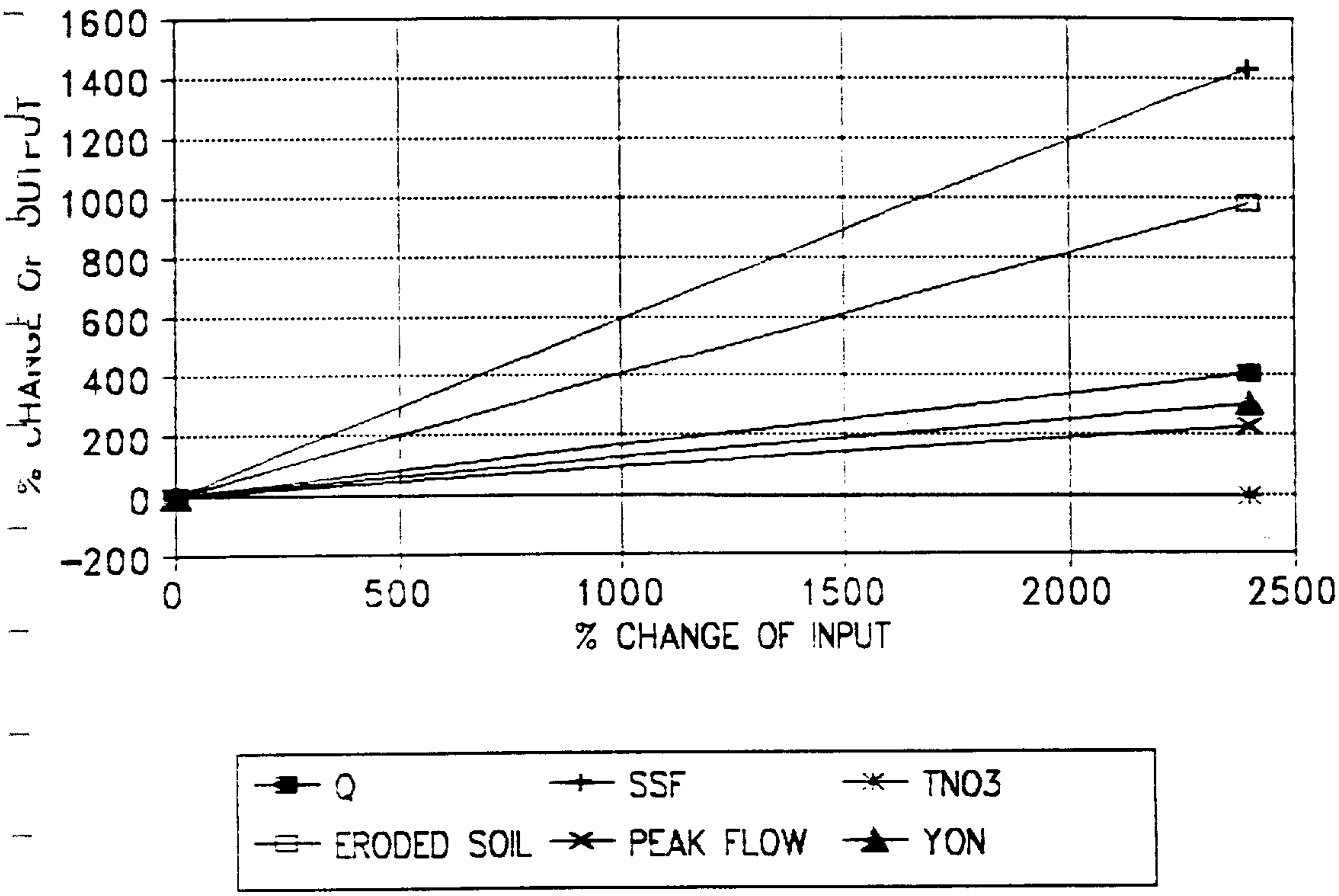
EPIC SENSITIVITY ANALYSIS
CROP RESIDUE
80
60
40
20
0
-20
-40
-60
-80
-100
% CHANGE OF OUTPUT
0
5
10
15
20
25
30
35
40
45
% CHANGE OF INPUT
(Thousands)
YIELD
POROSITY
BD
MN P AC
ORG C %
ERODED SOIL

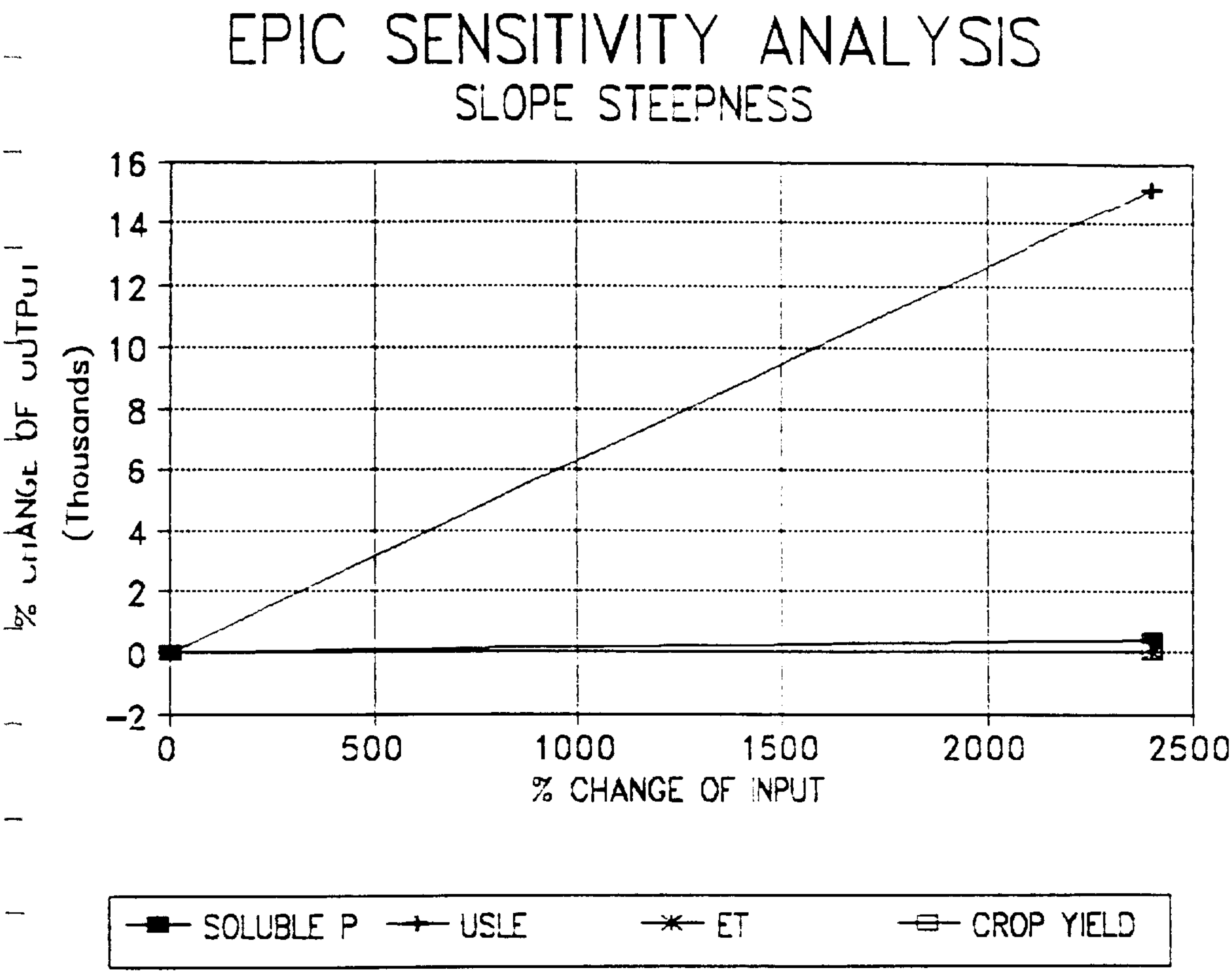


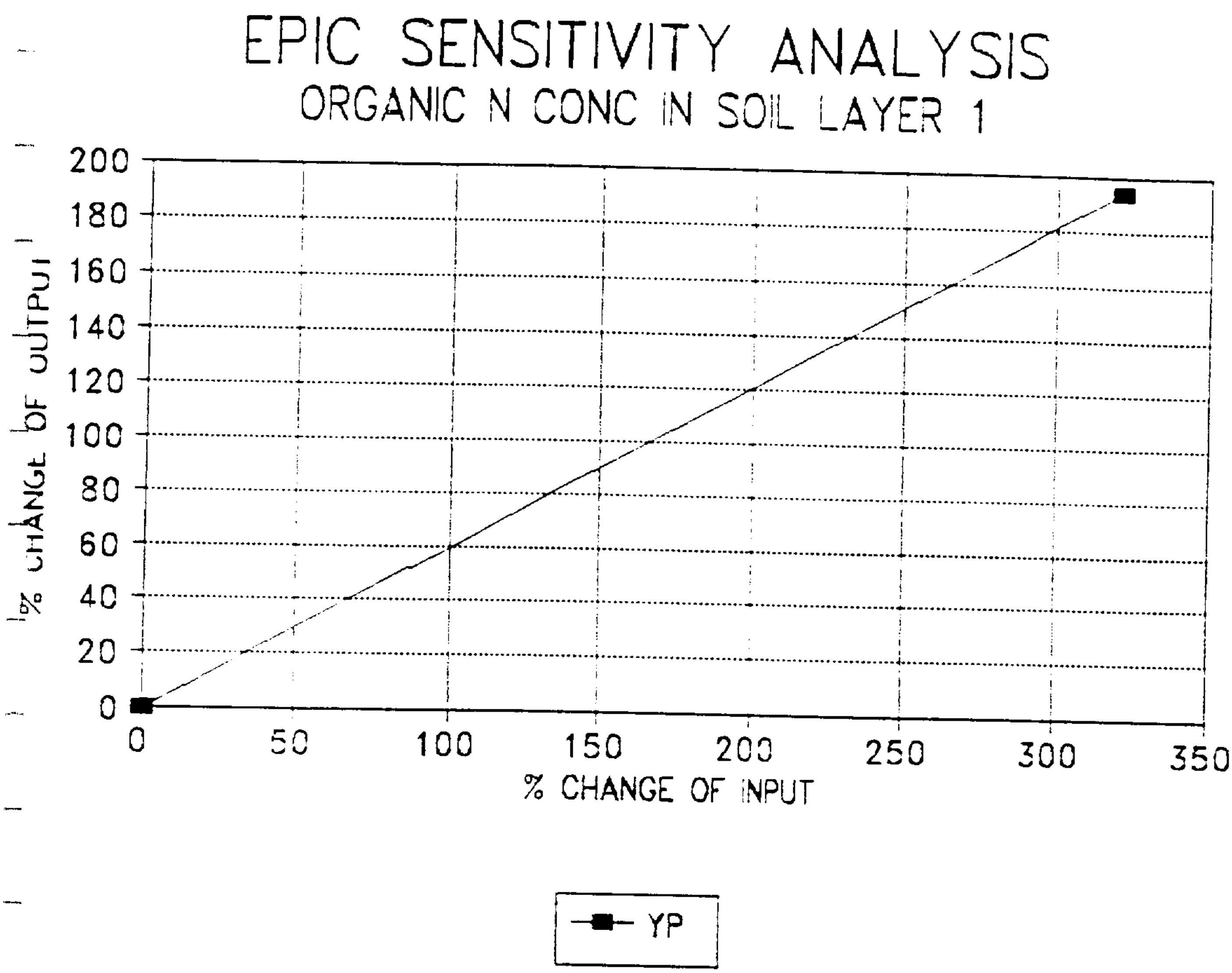
EPIC SENSITIVITY ANALYSIS
SOIL ALBEDO
% CHANGE OF OUTPUT
10
8
6
4
2
0
-2
-4
-6
0
10
20
30
40
50
60
% CHANGE OF INPUT
POTENTIAL EVAP.
DAYS W/RUNOFF

EPIC SENSITIVITY ANALYSIS

SLOPE STEEPNESS

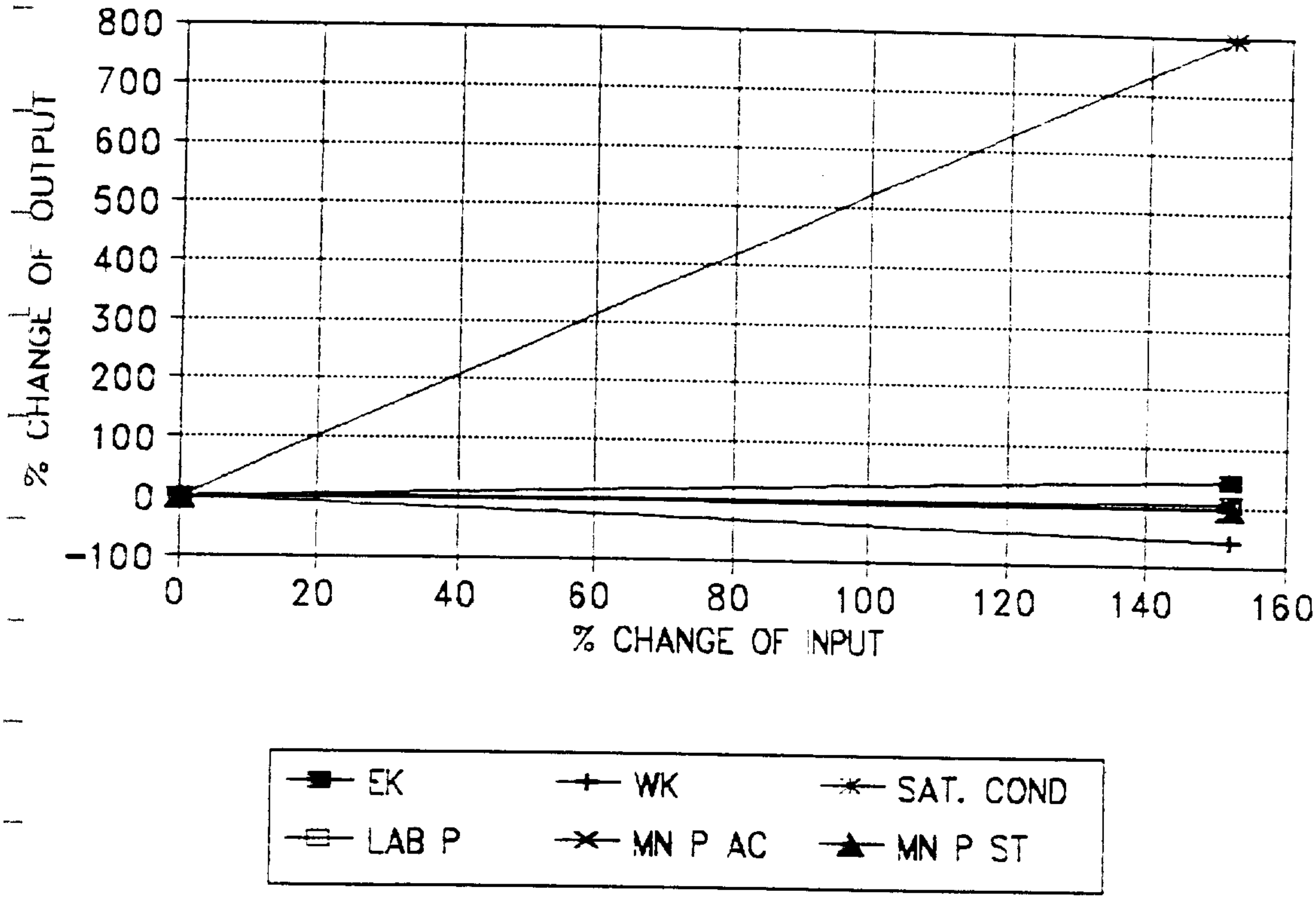



EPIC SENSITIVITY ANALYSIS
SLOPE STEEPNESS
% CHANGE OF OUTPUT
(Thousands)
16
14
12
10
8
6
4
2
0
-2
0
500
1000
1500
2000
2500
% CHANGE OF INPUT
SOLUBLE P
USLE
ET
CROP YIELD


EPIC SENSITIVITY ANALYSIS
ORGANIC N CONC IN SOIL LAYER 1
% CHANGE OF OUTPUT
% CHANGE OF INPUT
0
20
40
60
80
100
120
140
160
180
200
0
50
100
150
200
250
300
350
YP

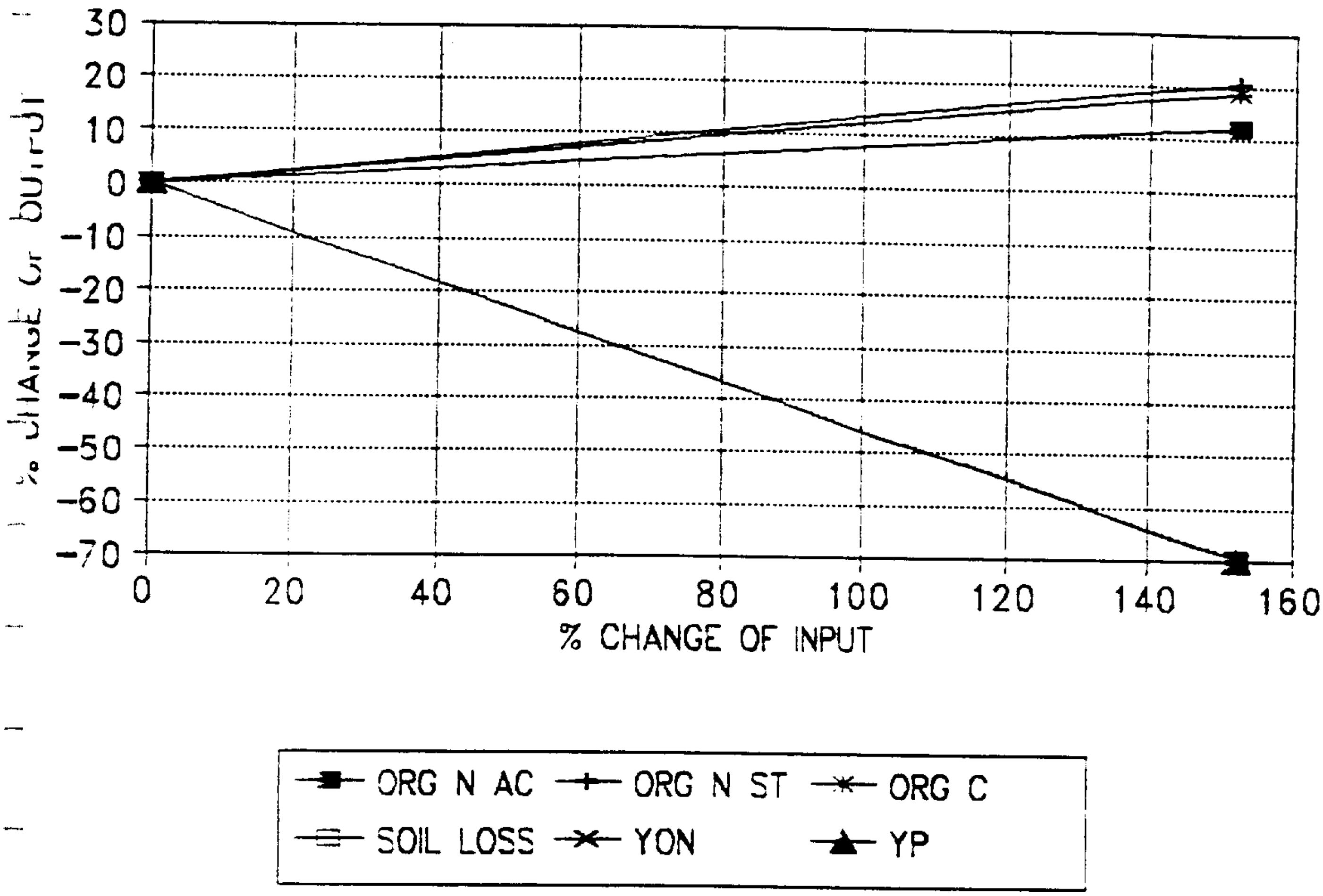
EPIC SENSITIVITY ANALYSIS

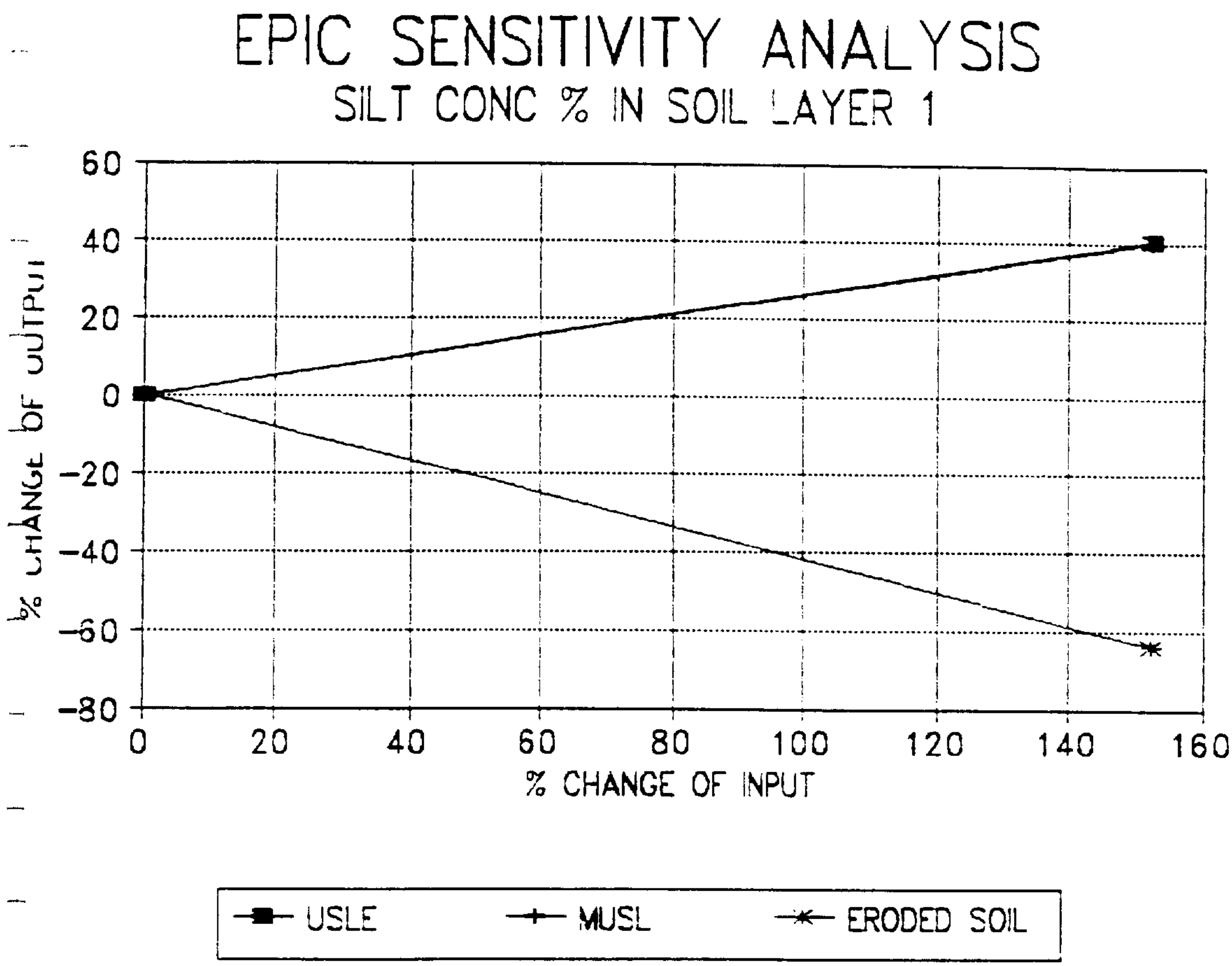
SILT CONC % IN SOIL LAYER 1

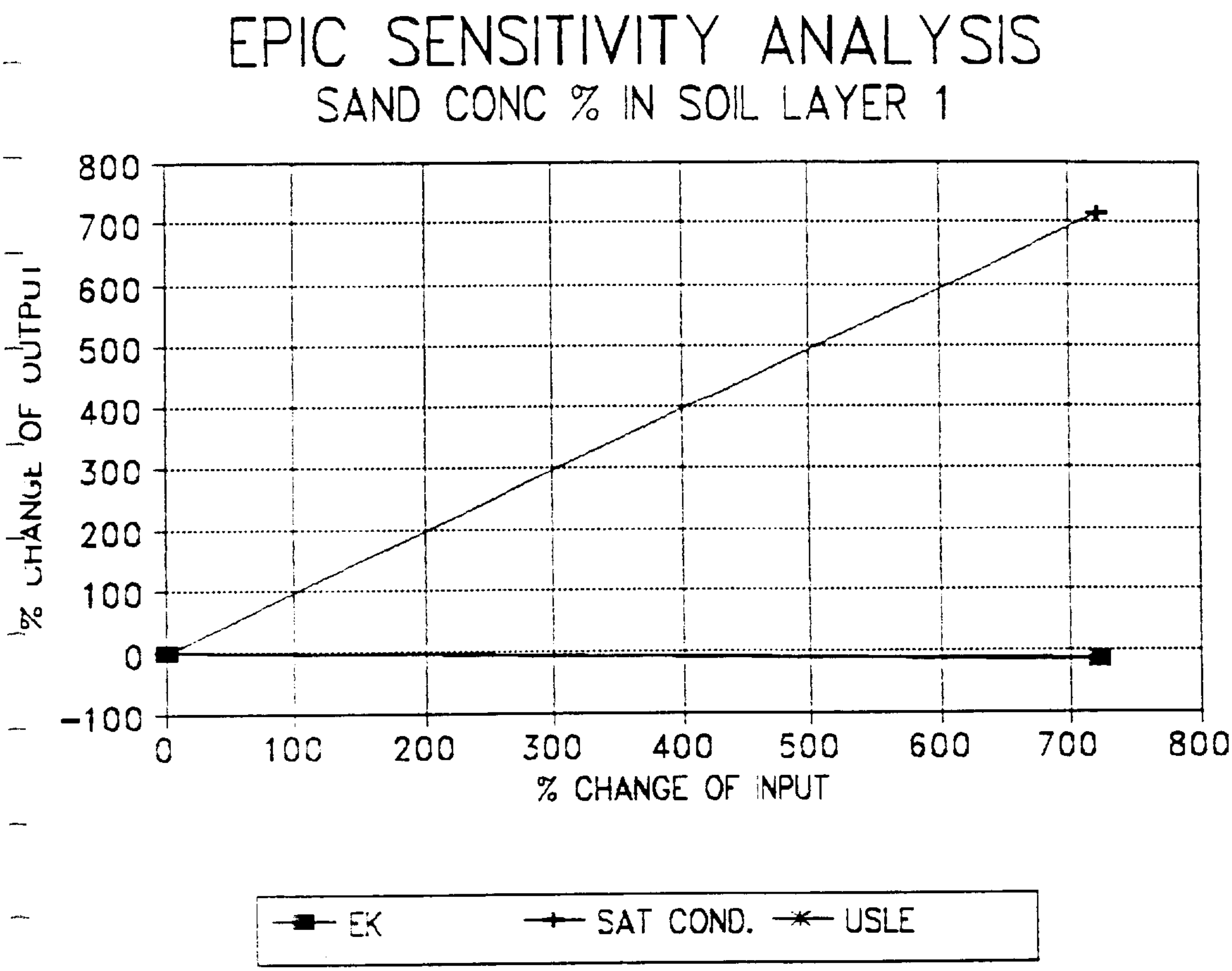


EPIC SENSITIVITY ANALYSIS

SILT CONC % IN SOIL LAYER 1

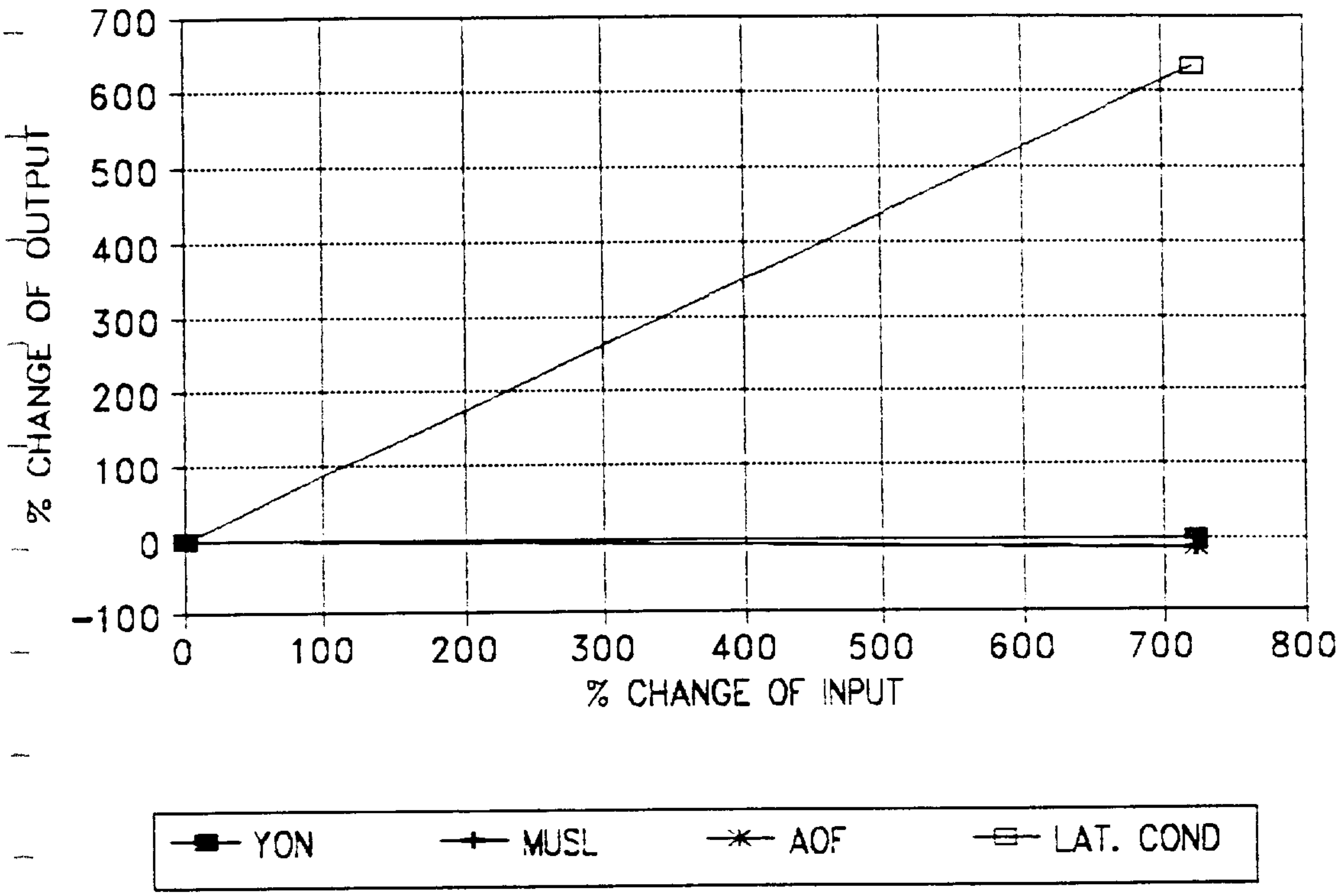


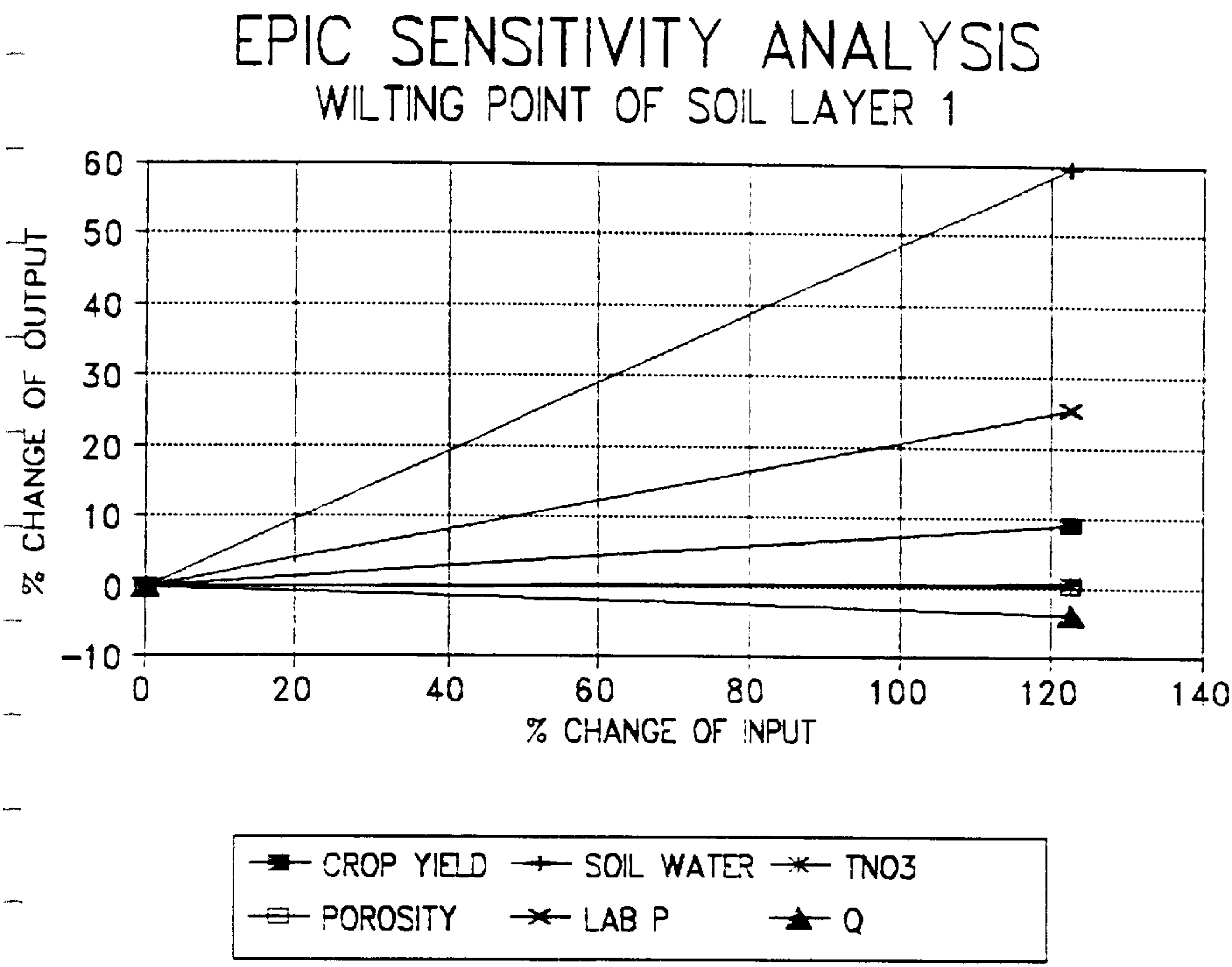

EPIC SENSITIVITY ANALYSIS
SILT CONC % IN SOIL LAYER 1
% CHANGE OF OUTPUT
60
40
20
0
-20
-40
-60
-80
0
20
40
60
80
100
120
140
160
% CHANGE OF INPUT
USLE
MUSL
ERODED SOIL

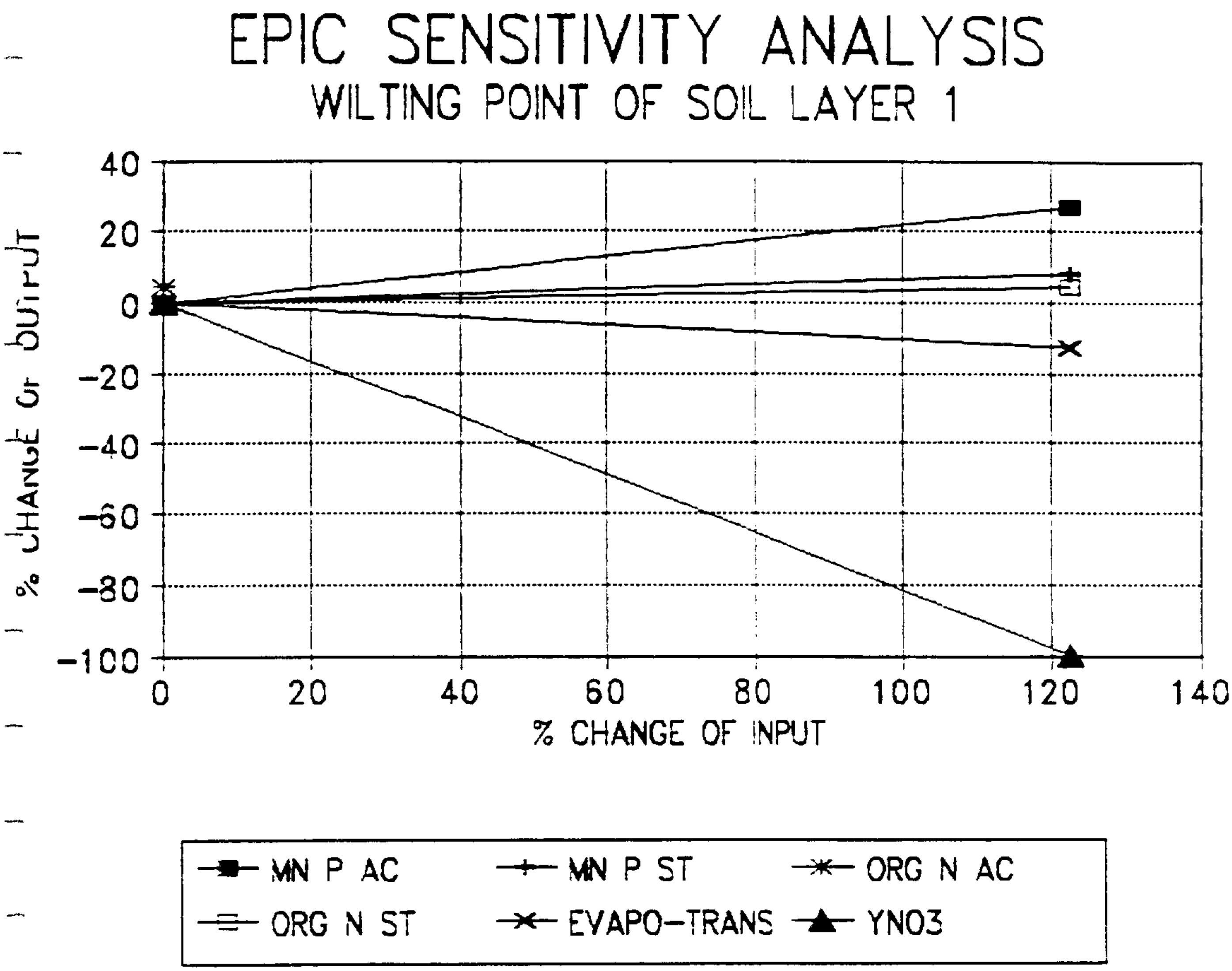

EPIC SENSITIVITY ANALYSIS
SAND CONC % IN SOIL LAYER 1
% CHANGE OF OUTPUT
800
700
600
500
400
300
200
100
0
-100
0
100
200
300
400
500
600
700
800
% CHANGE OF INPUT
EK
SAT COND.
USLE

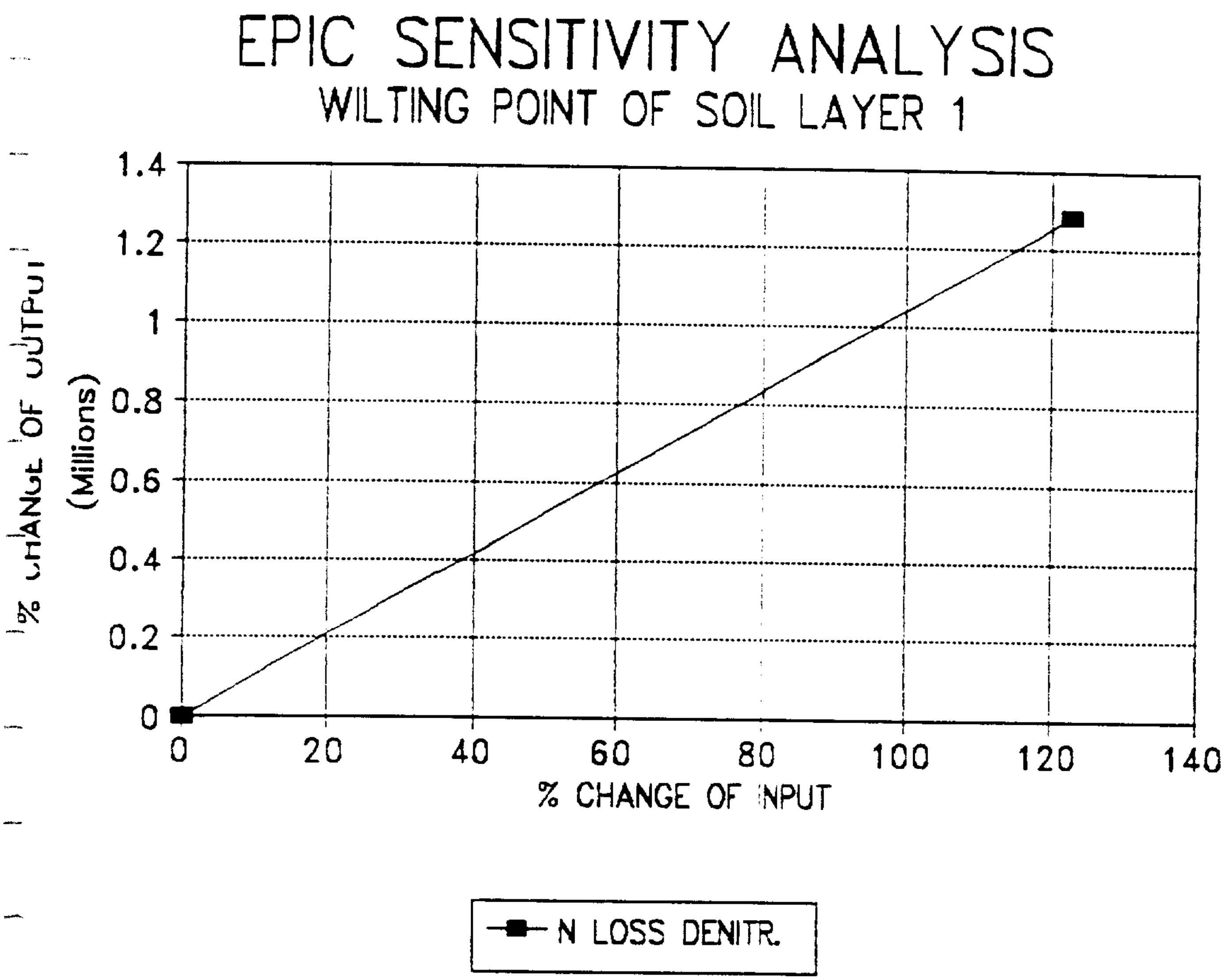
EPIC SENSITIVITY ANALYSIS

SAND CONTENT OF SOIL LAYER 1

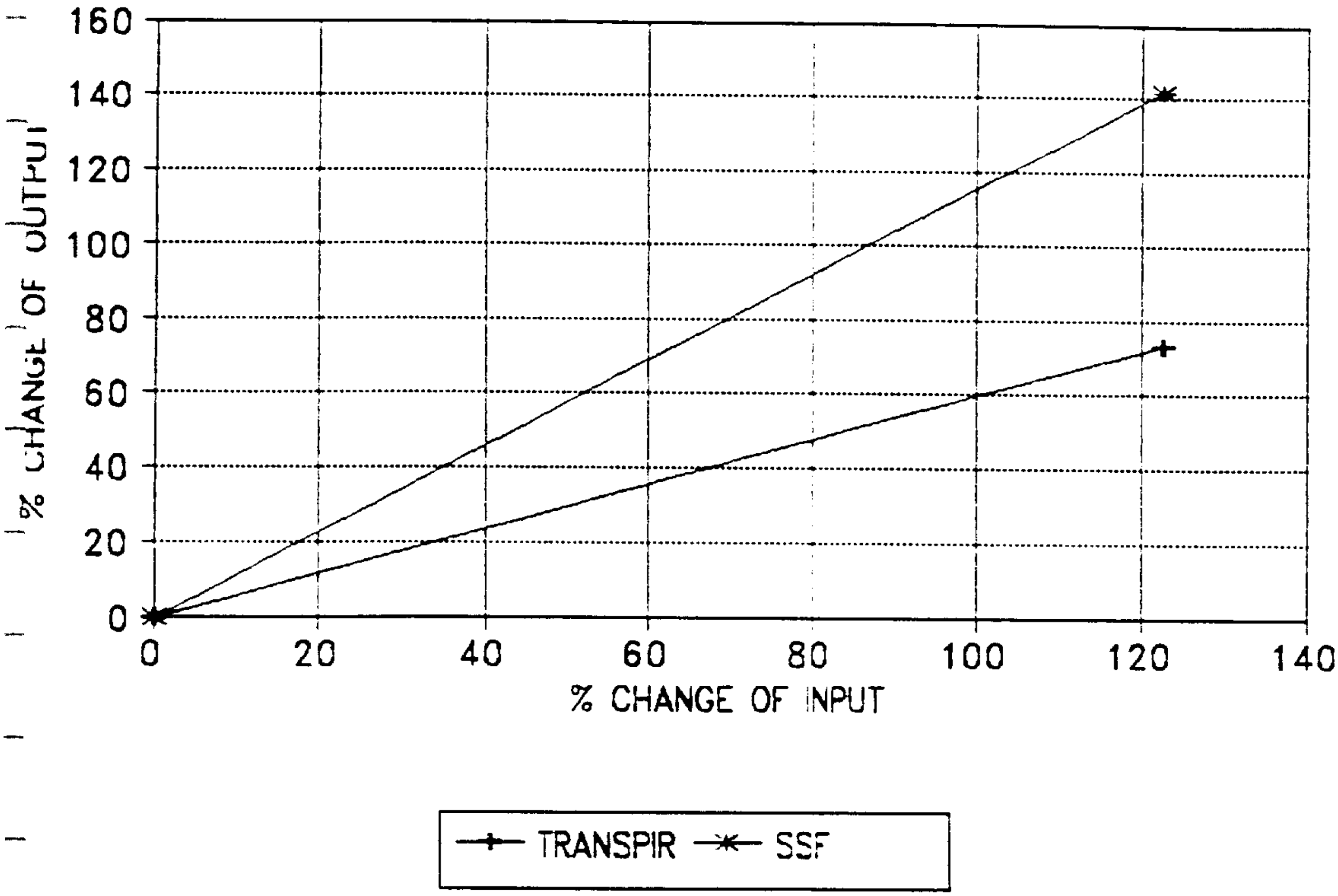


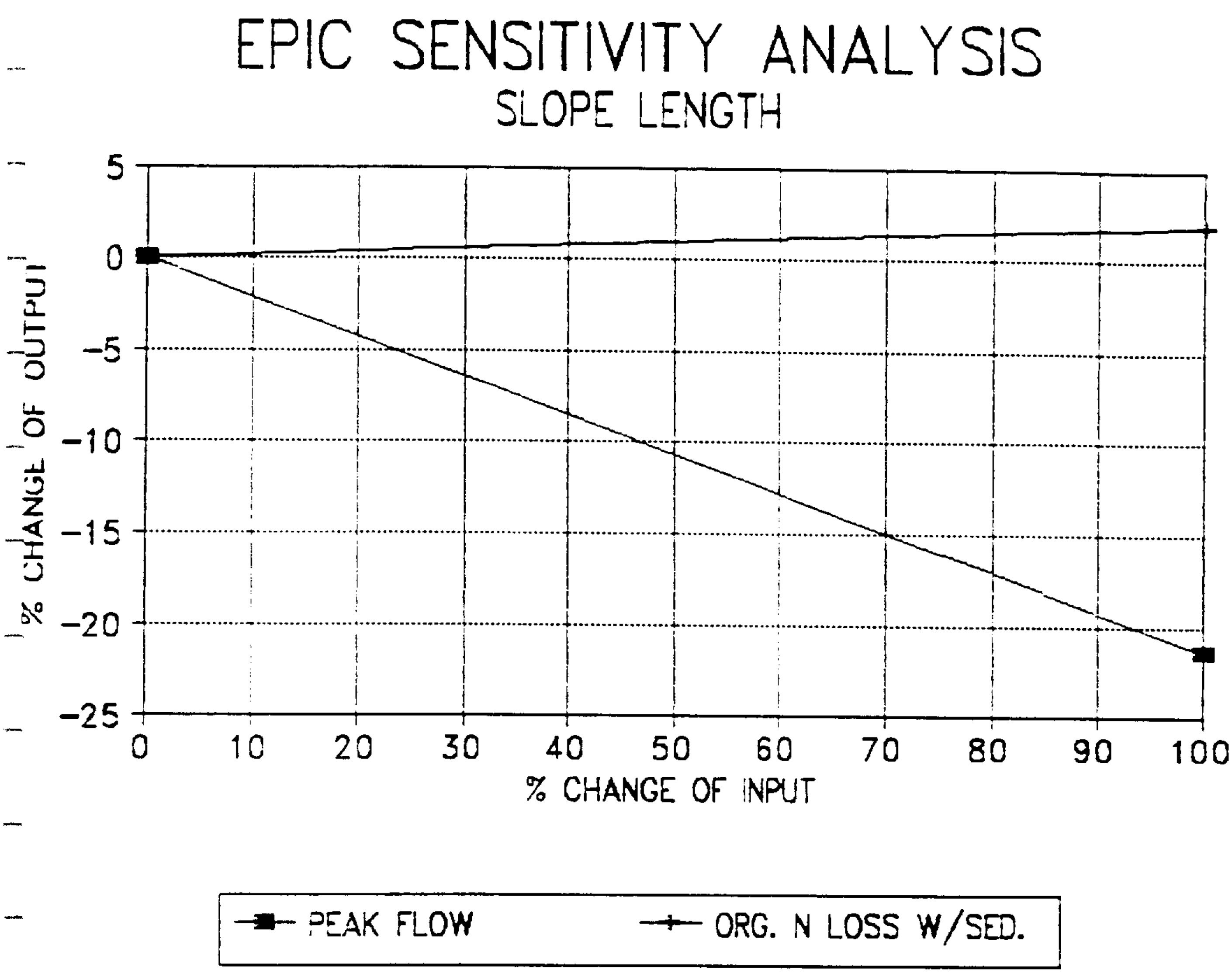

EPIC SENSITIVITY ANALYSIS
WILTING POINT OF SOIL LAYER 1
% CHANGE OF OUTPUT
60
50
40
30
20
10
0
-10
0
20
40
60
80
100
120
140
% CHANGE OF INPUT
CROP YIELD
SOIL WATER
TNO3
POROSITY
LAB P
Q


EPIC SENSITIVITY ANALYSIS
WILTING POINT OF SOIL LAYER 1
% CHANGE OF OUTPUT
40
20
0
-20
-40
-60
-80
-100
0
20
40
60
80
100
120
140
% CHANGE OF INPUT
MN P AC
MN P ST
ORG N AC
ORG N ST
EVAPO-TRANS
YNO3

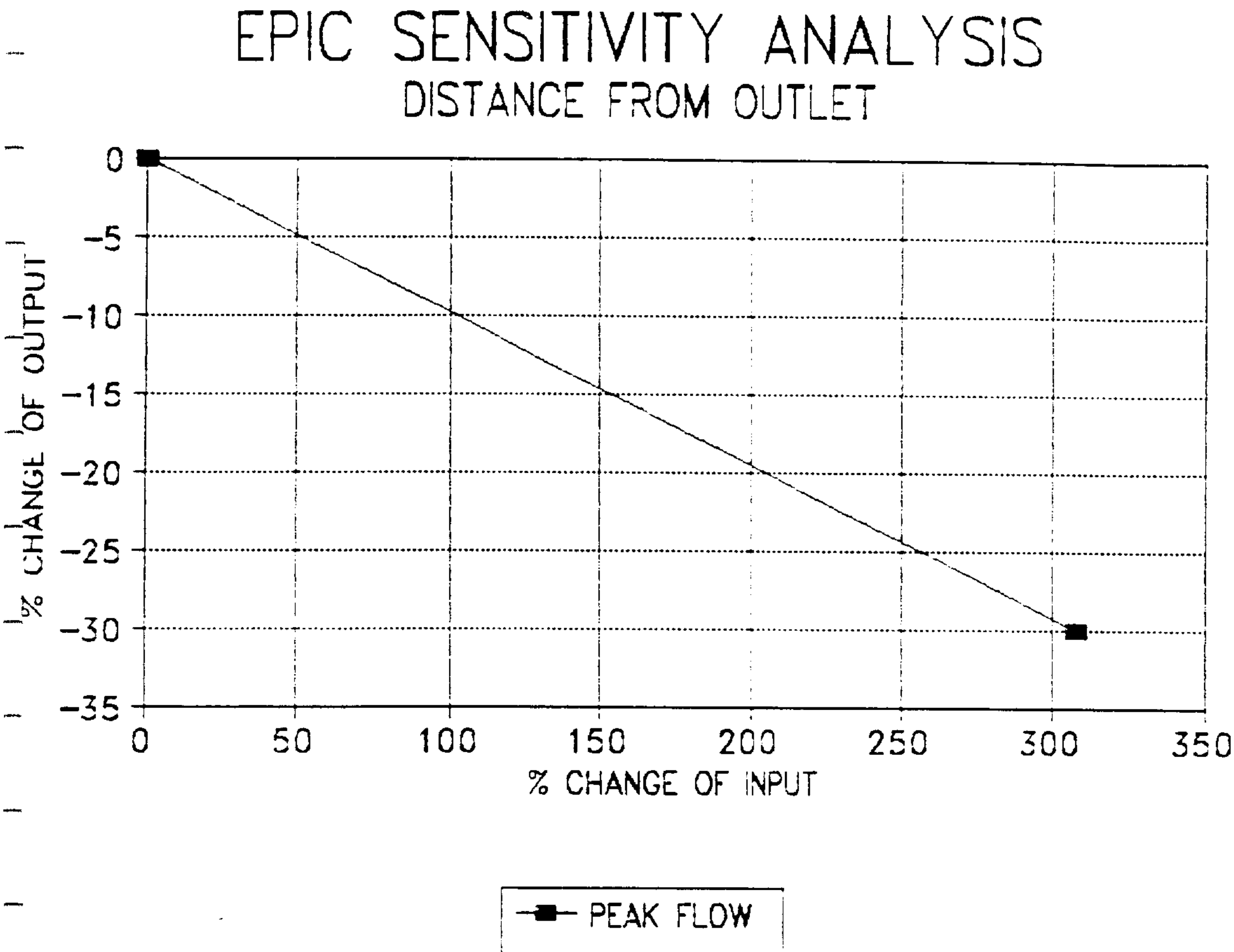

EPIC SENSITIVITY ANALYSIS
WILTING POINT OF SOIL LAYER 1
% CHANGE OF OUTPUT
(Millions)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
% CHANGE OF INPUT
N LOSS DENITR.

EPIC SENSITIVITY ANALYSIS
WILTING POINT OF SOIL LAYER 1

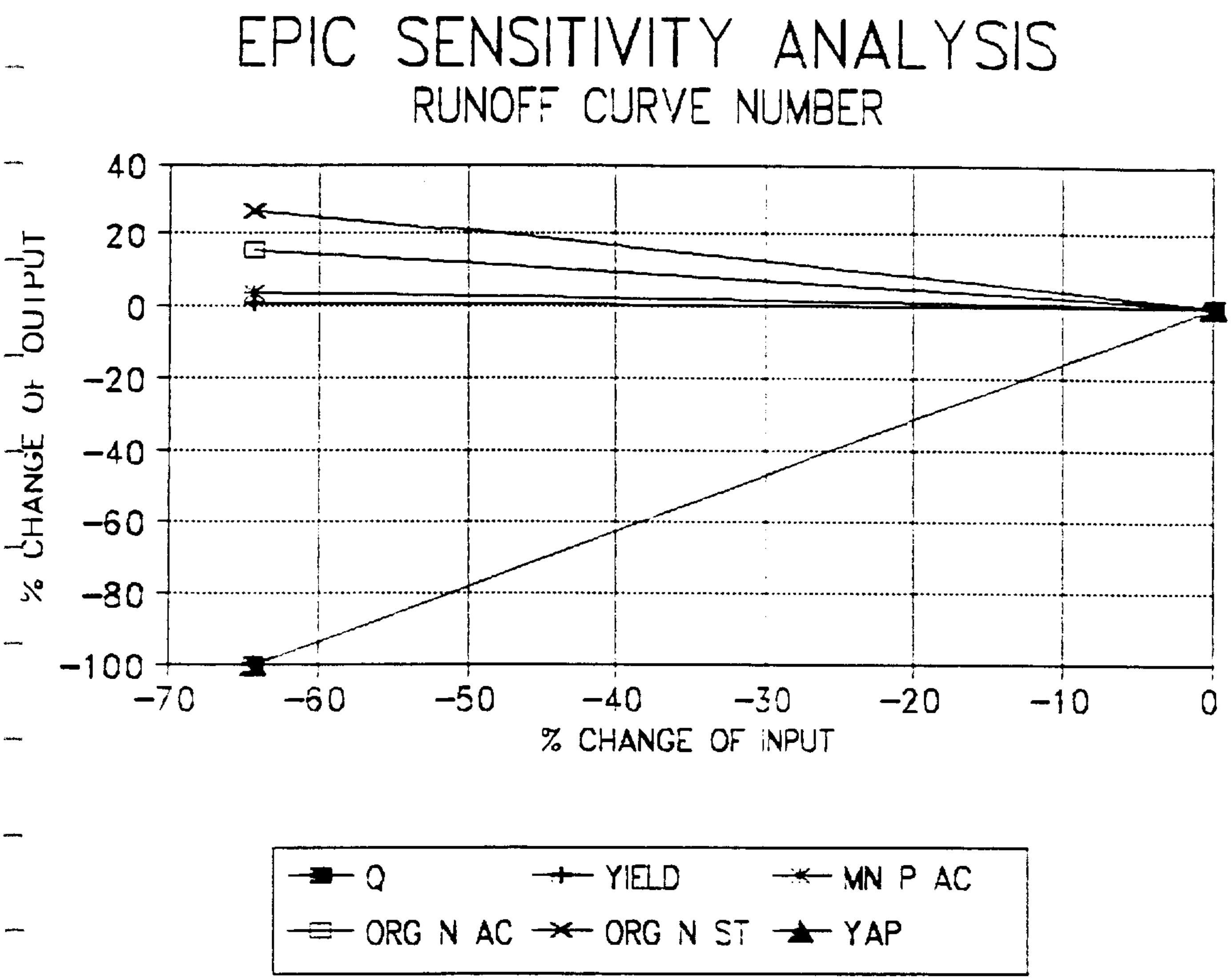




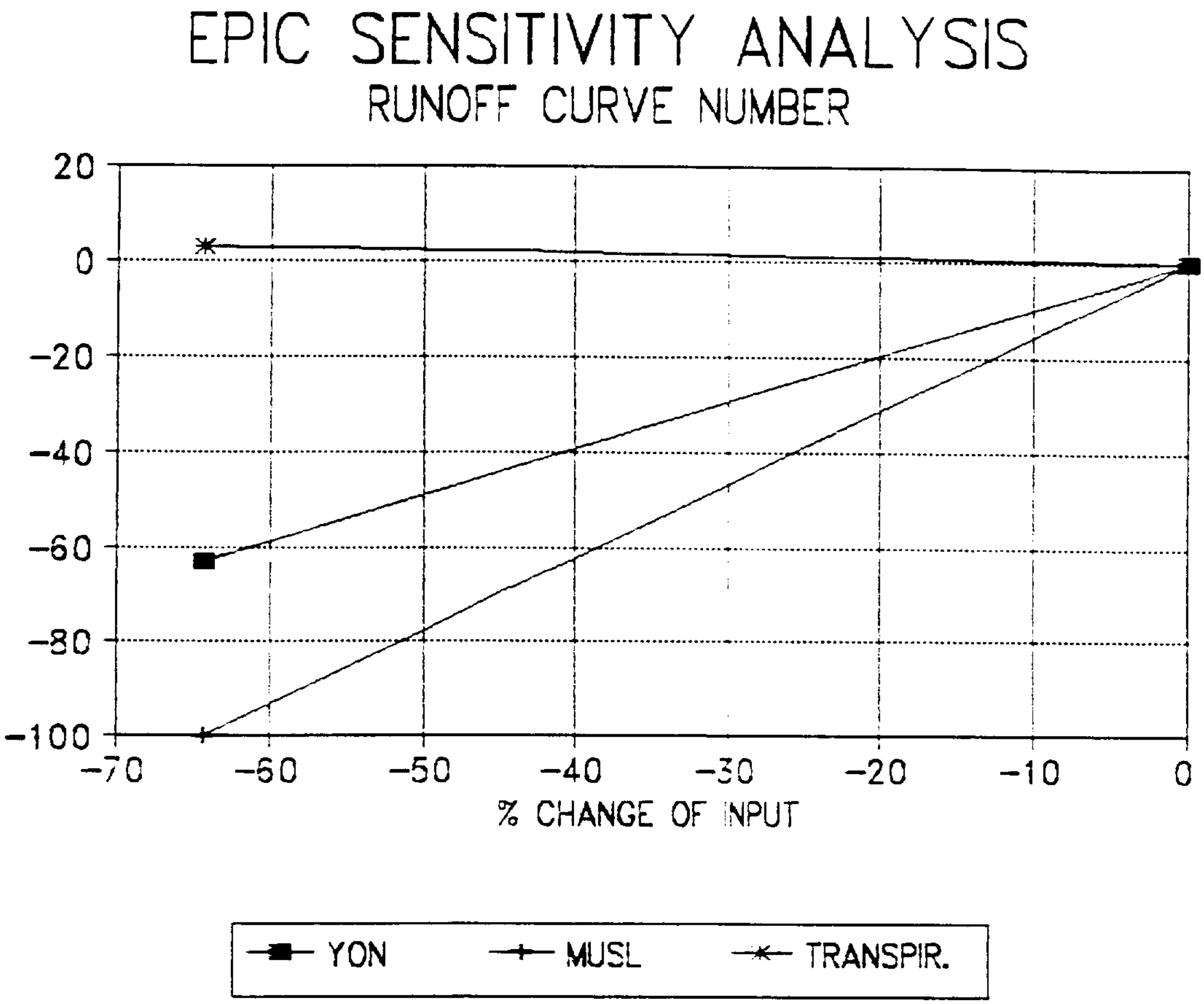
EPIC SENSITIVITY ANALYSIS
SLOPE LENGTH
5
0
-5
-10
-15
-20
-25
% CHANGE OF OUTPUT
0
10
20
30
40
50
60
70
80
90
100
% CHANGE OF INPUT
PEAK FLOW
ORG. N LOSS W/SED.



EPIC SENSITIVITY ANALYSIS
DISTANCE FROM OUTLET
0
-5
-10
-15
-20
-25
-30
-35
% CHANGE OF OUTPUT
0
50
100
150
200
250
300
350
% CHANGE OF INPUT
PEAK FLOW



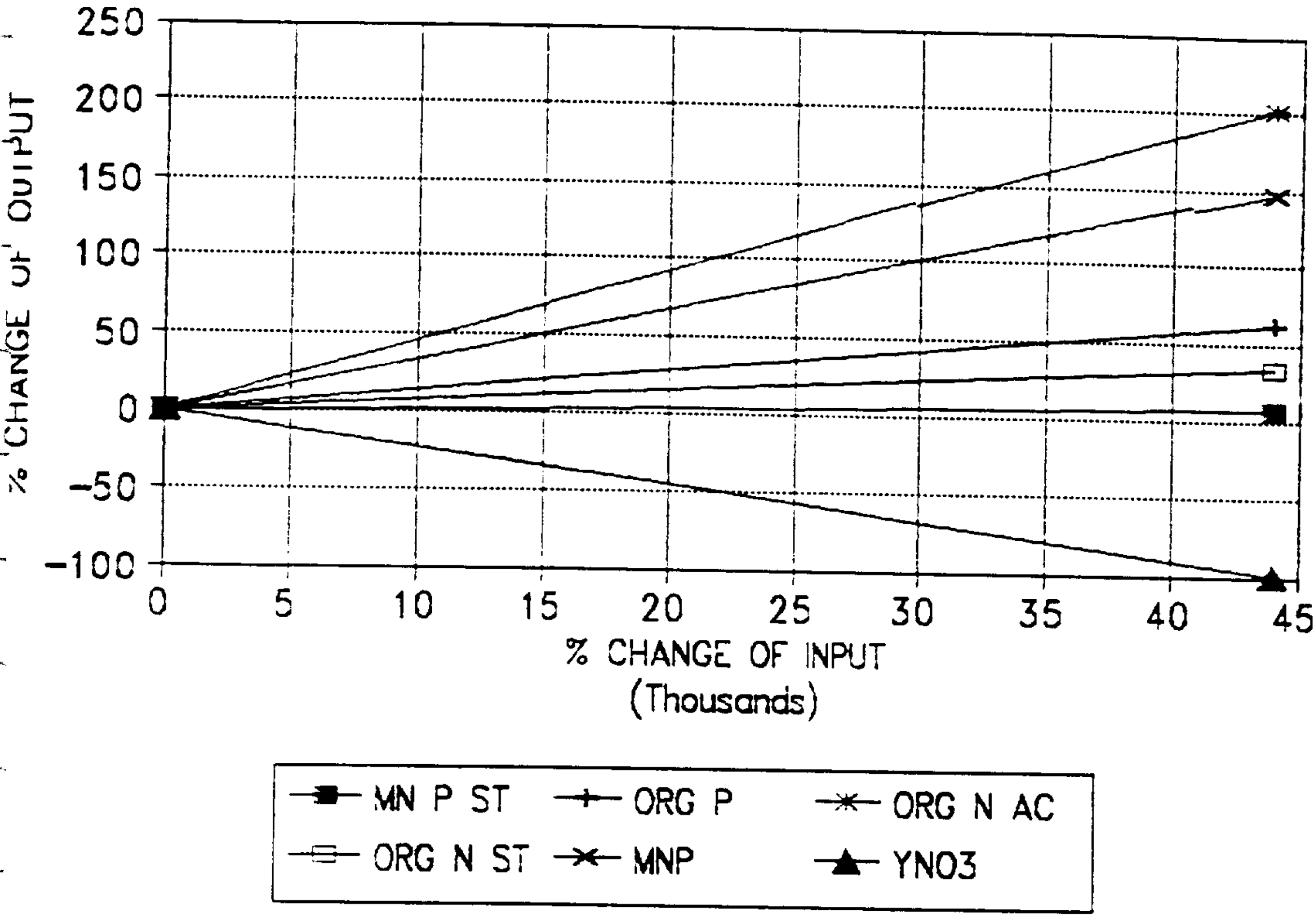
EPIC SENSITIVITY ANALYSIS
RUNOFF CURVE NUMBER
40
20
0
-20
-40
-60
-80
-100
-70
-60
-50
-40
-30
-20
-10
0
% CHANGE OF OUTPUT
% CHANGE OF INPUT
Q
YIELD
MN P AC
ORG N AC
ORG N ST
YAP

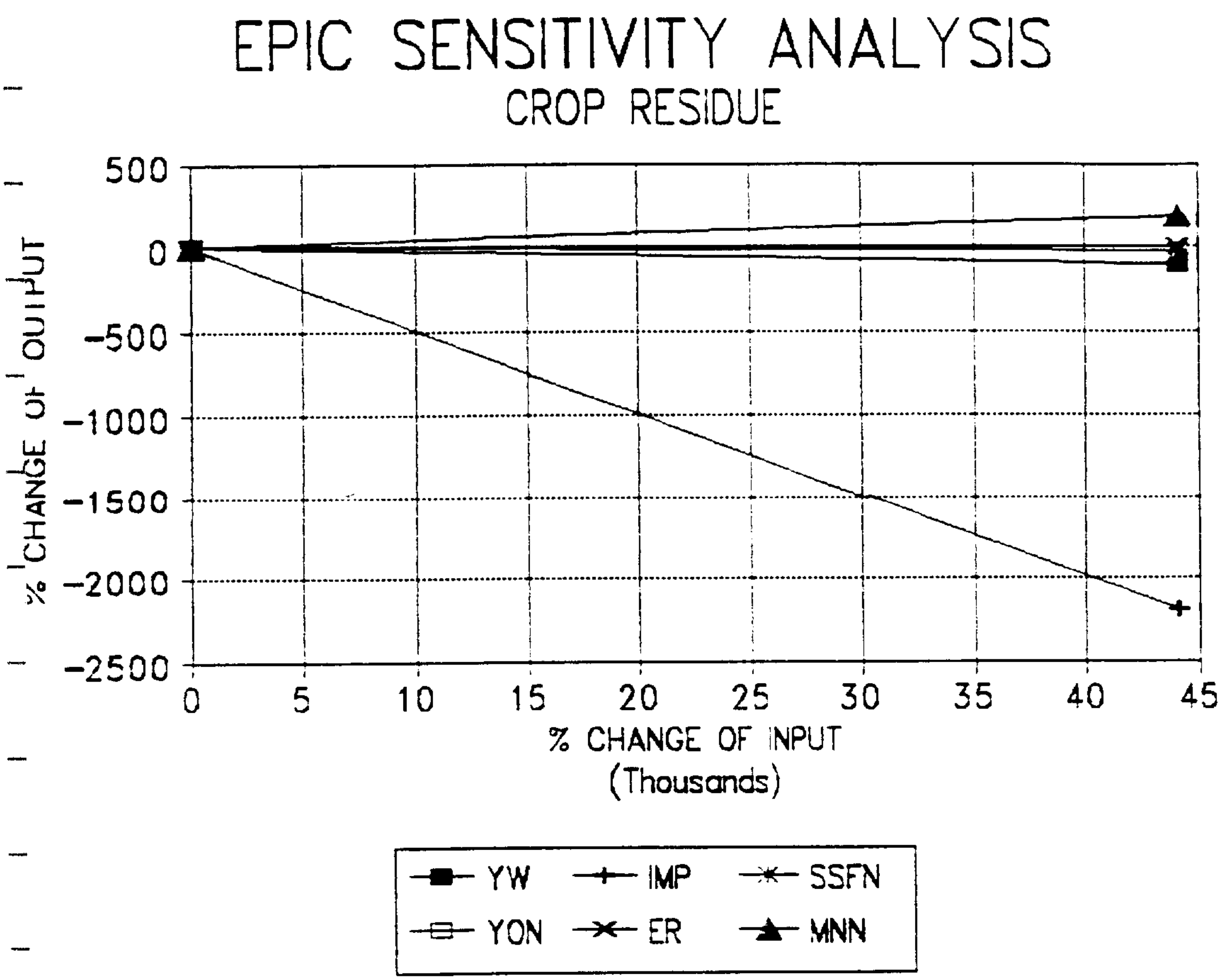


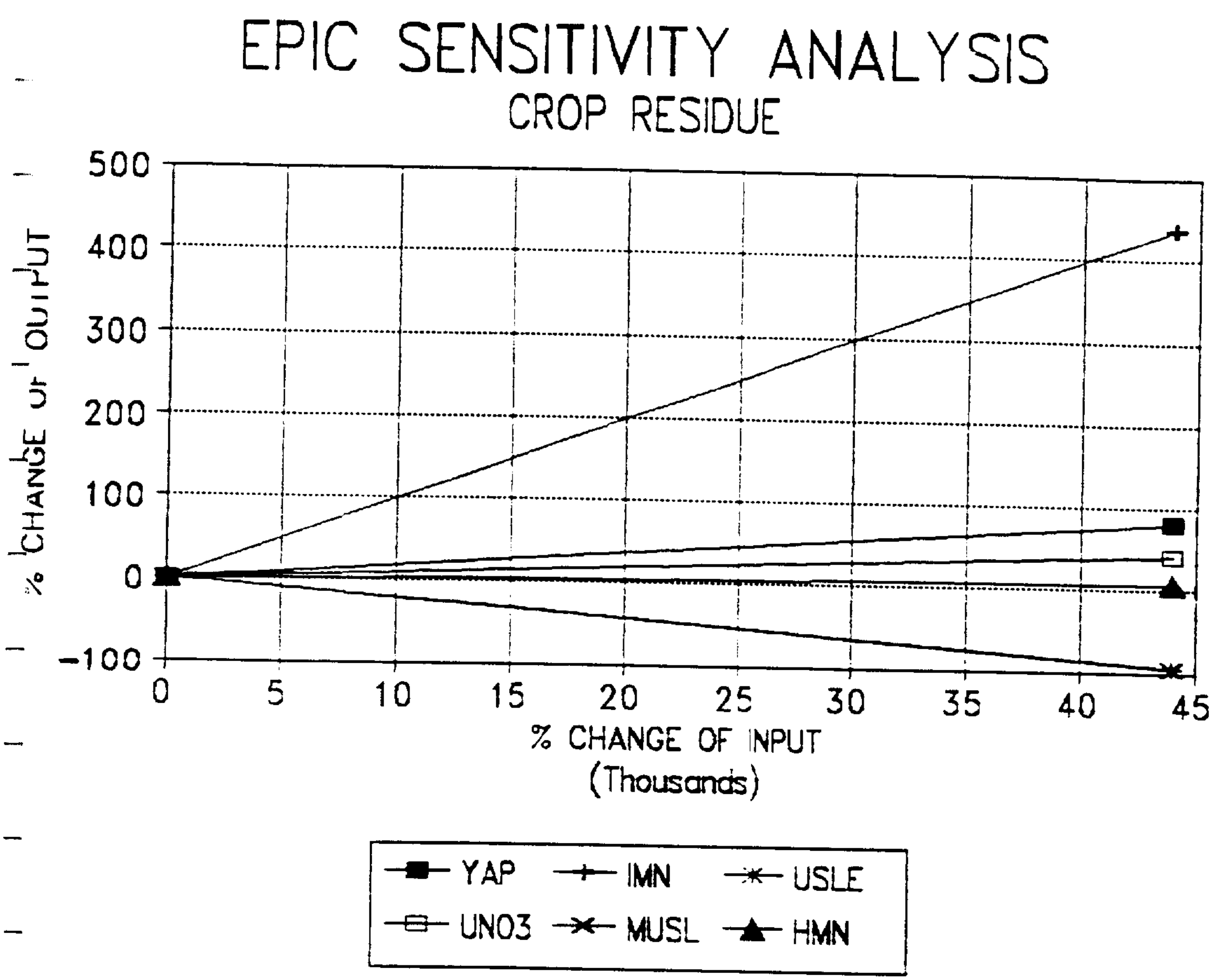
EPIC SENSITIVITY ANALYSIS
RUNOFF CURVE NUMBER
20
0
-20
-40
-60
-80
-100
% CHANGE OF OUTPUT
-70
-60
-50
-40
-30
-20
-10
0
% CHANGE OF INPUT
YON
MUSL
TRANSPIR.

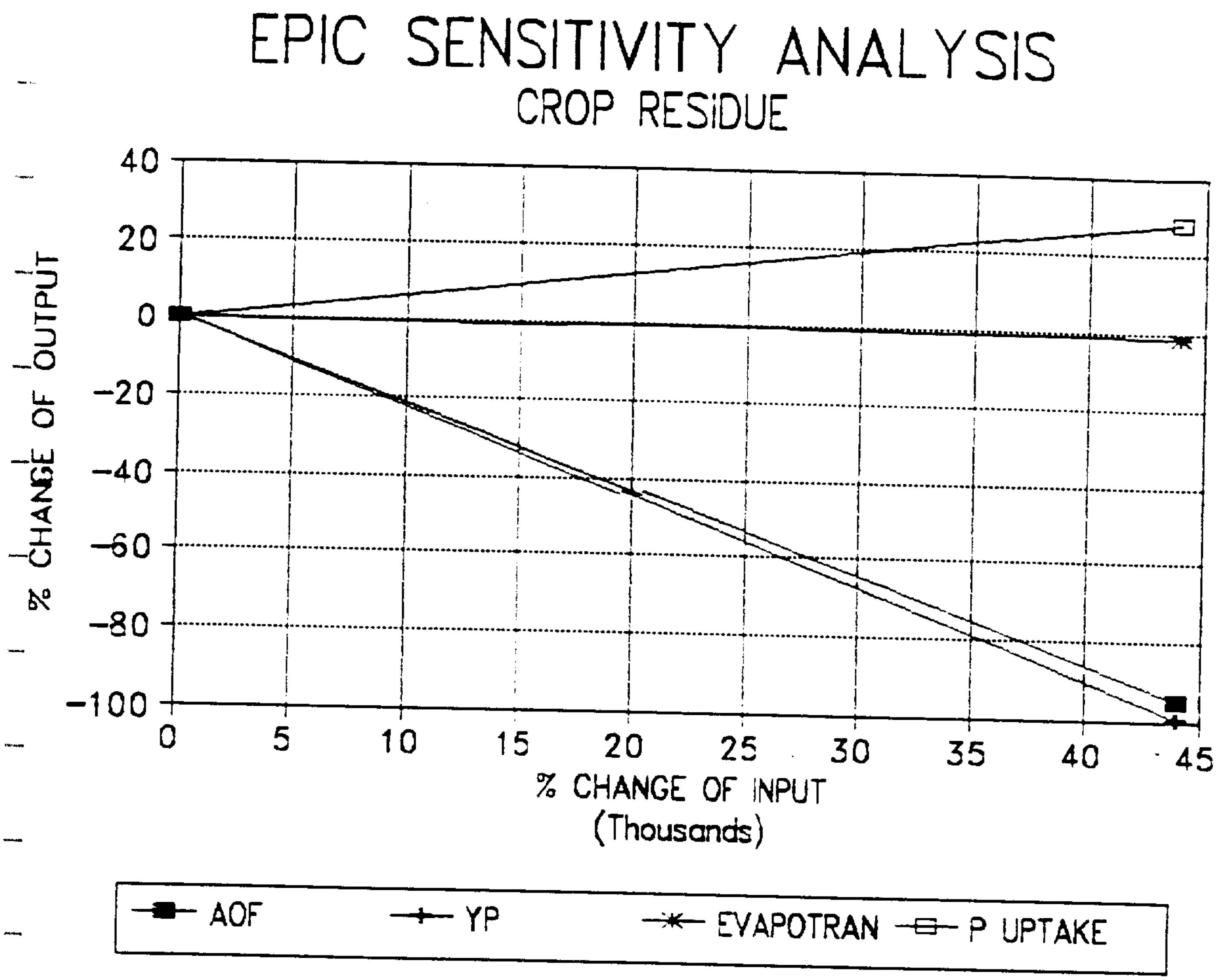
EPIC SENSITIVITY ANALYSIS

CROP RESIDUE

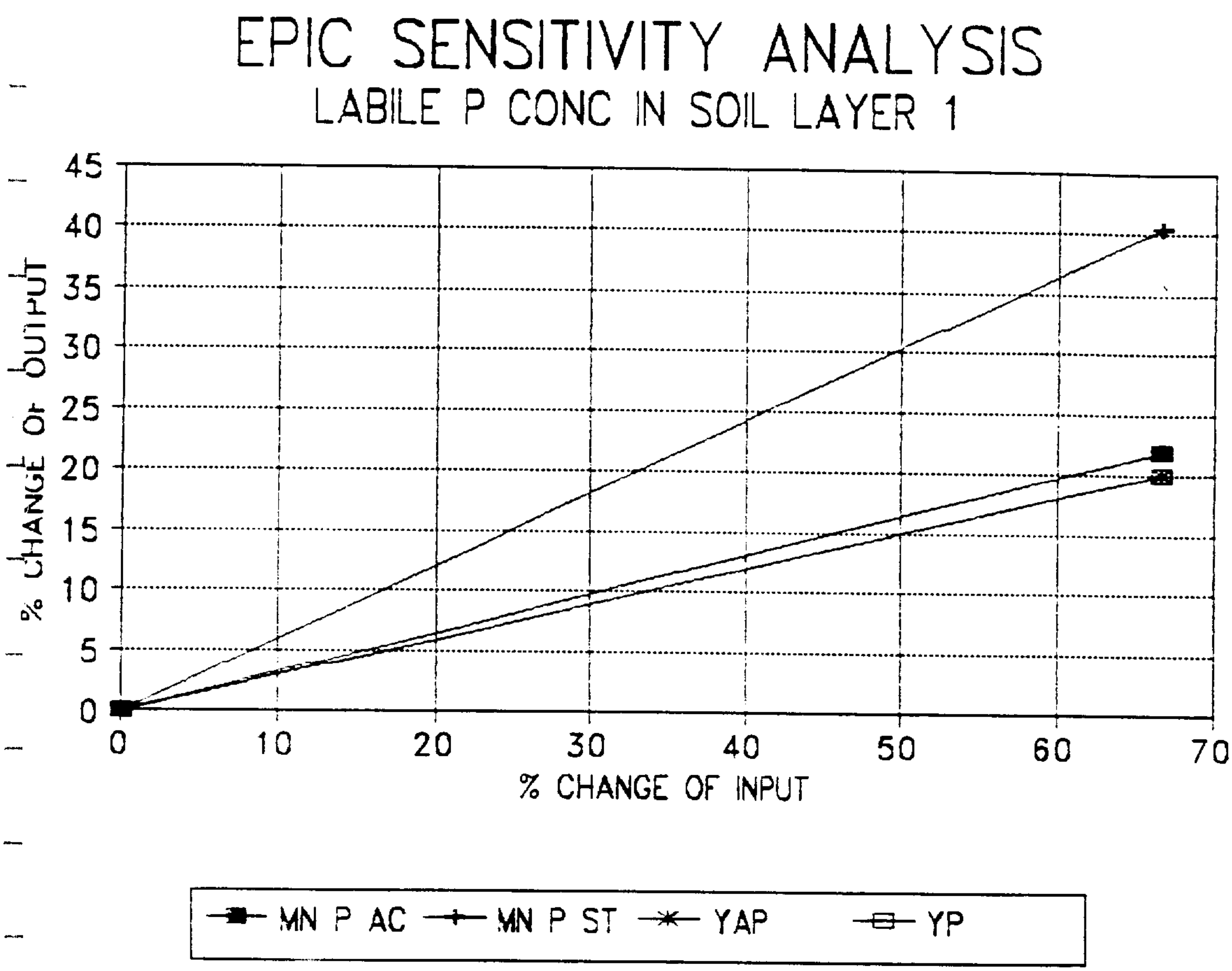



EPIC SENSITIVITY ANALYSIS
CROP RESIDUE
500
0
-500
-1000
-1500
-2000
-2500
% CHANGE OF OUTPUT
0
5
10
15
20
25
30
35
40
45
% CHANGE OF INPUT
(Thousands)
YW
IMP
SSFN
YON
ER
MNN

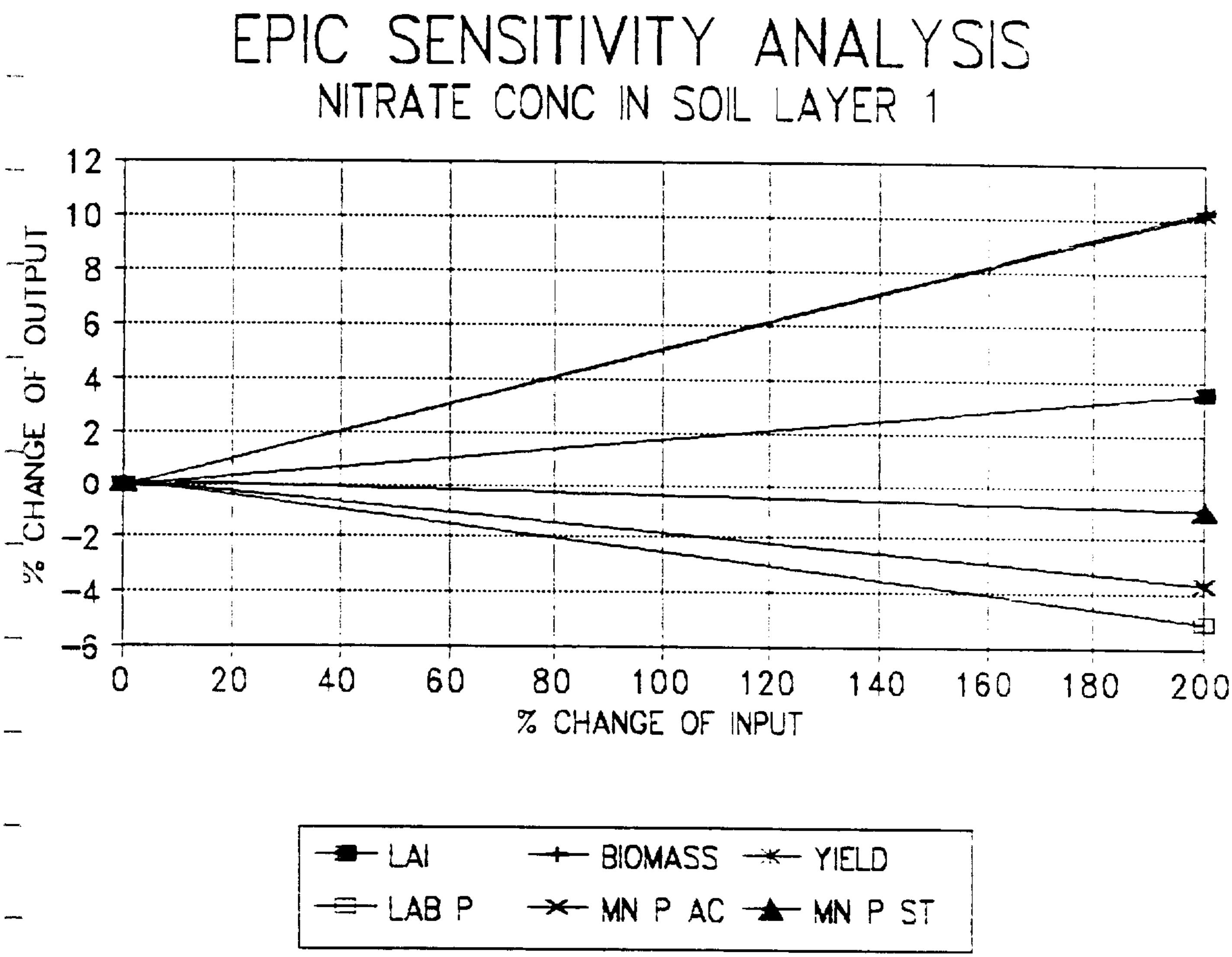

EPIC SENSITIVITY ANALYSIS
CROP RESIDUE
500
400
300
200
100
0
-100
% CHANGE OF OUTPUT
0
5
10
15
20
25
30
35
40
45
% CHANGE OF INPUT
(Thousands)
YAP
IMN
USLE
UNO3
MUSL
HMN

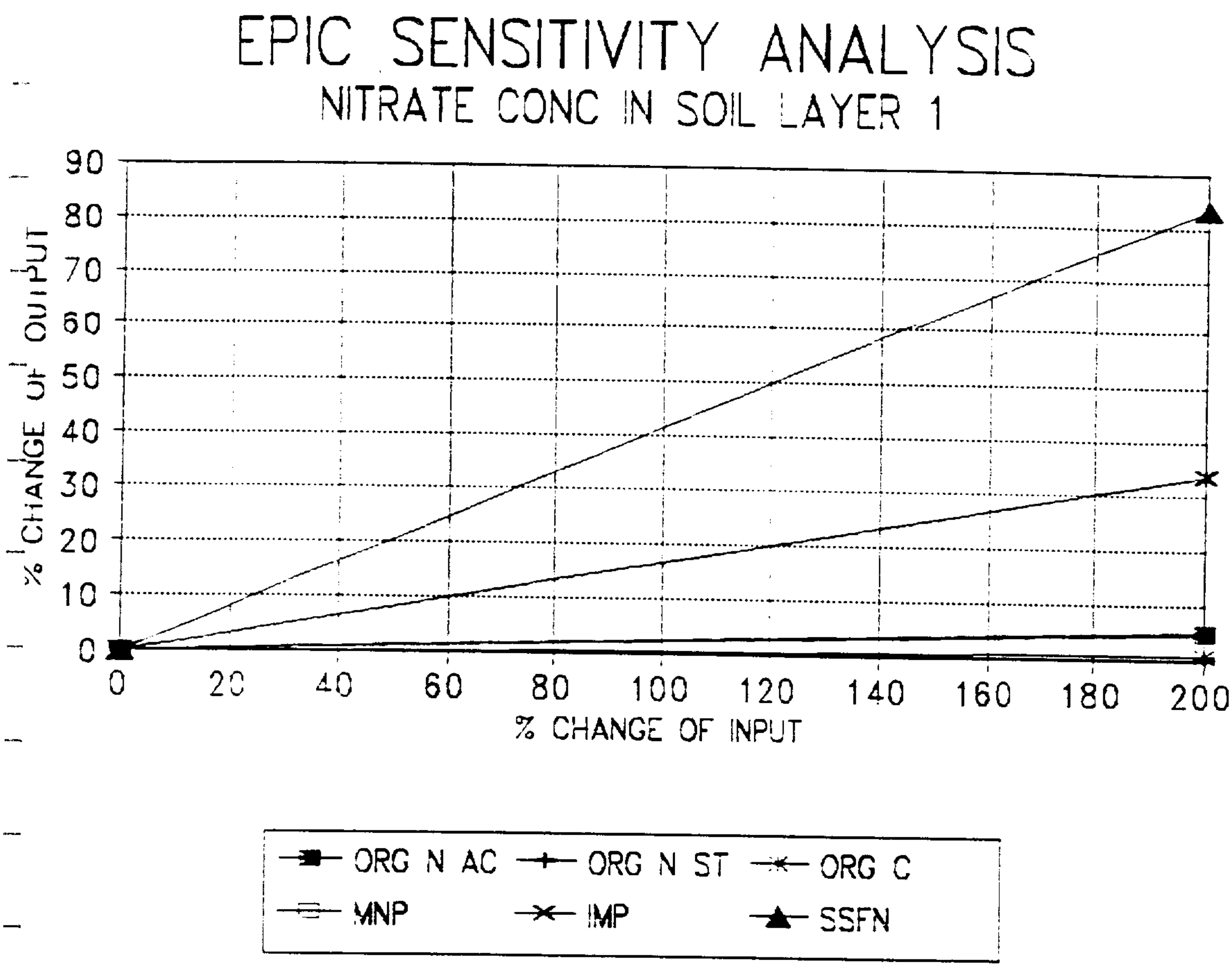


EPIC SENSITIVITY ANALYSIS
CROP RESIDUE
% CHANGE OF OUTPUT
40
20
0
-20
-40
-60
-80
-100
0
5
10
15
20
25
30
35
40
45
% CHANGE OF INPUT
(Thousands)
AOF
YP
EVAPOTRAN
P UPTAKE

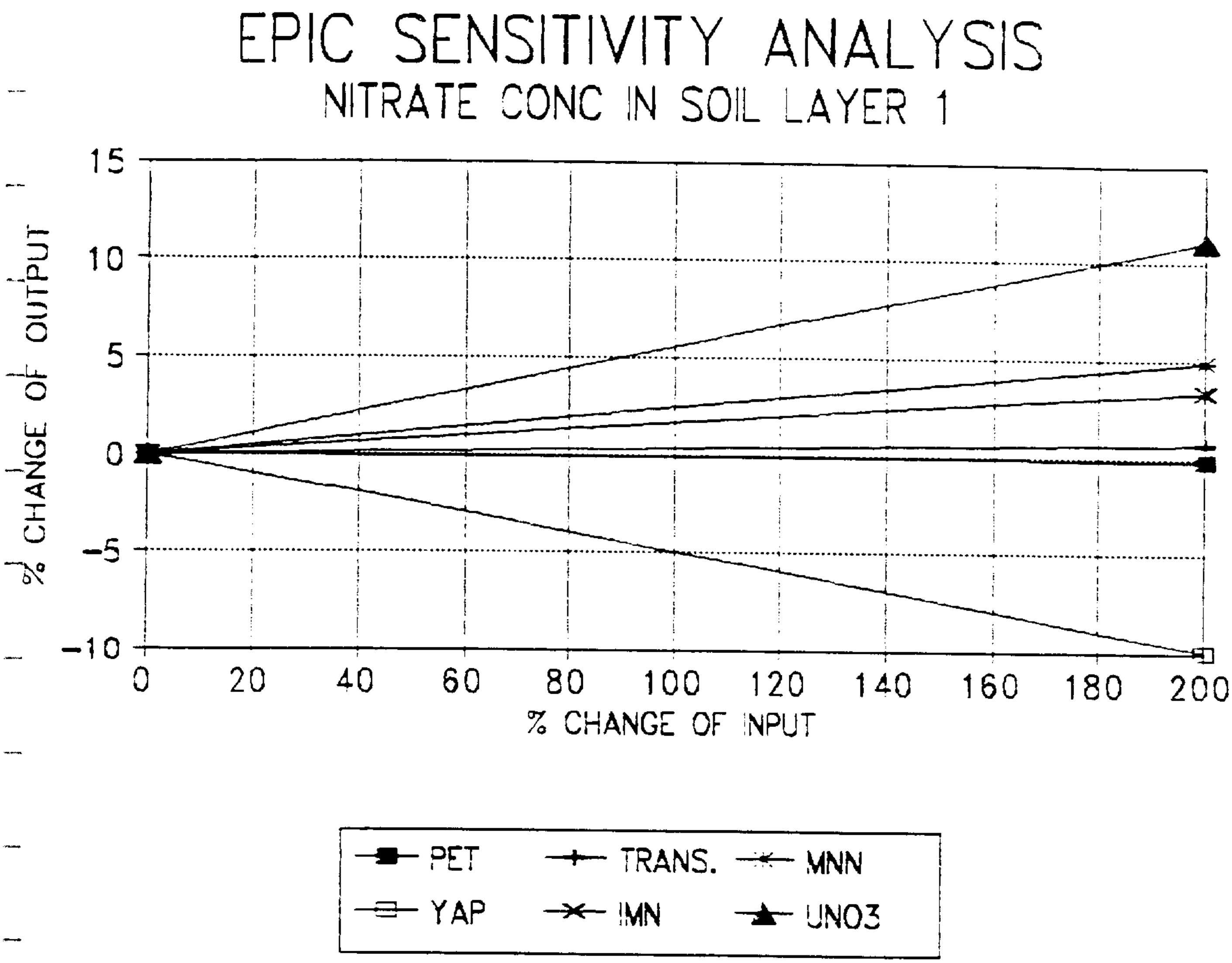


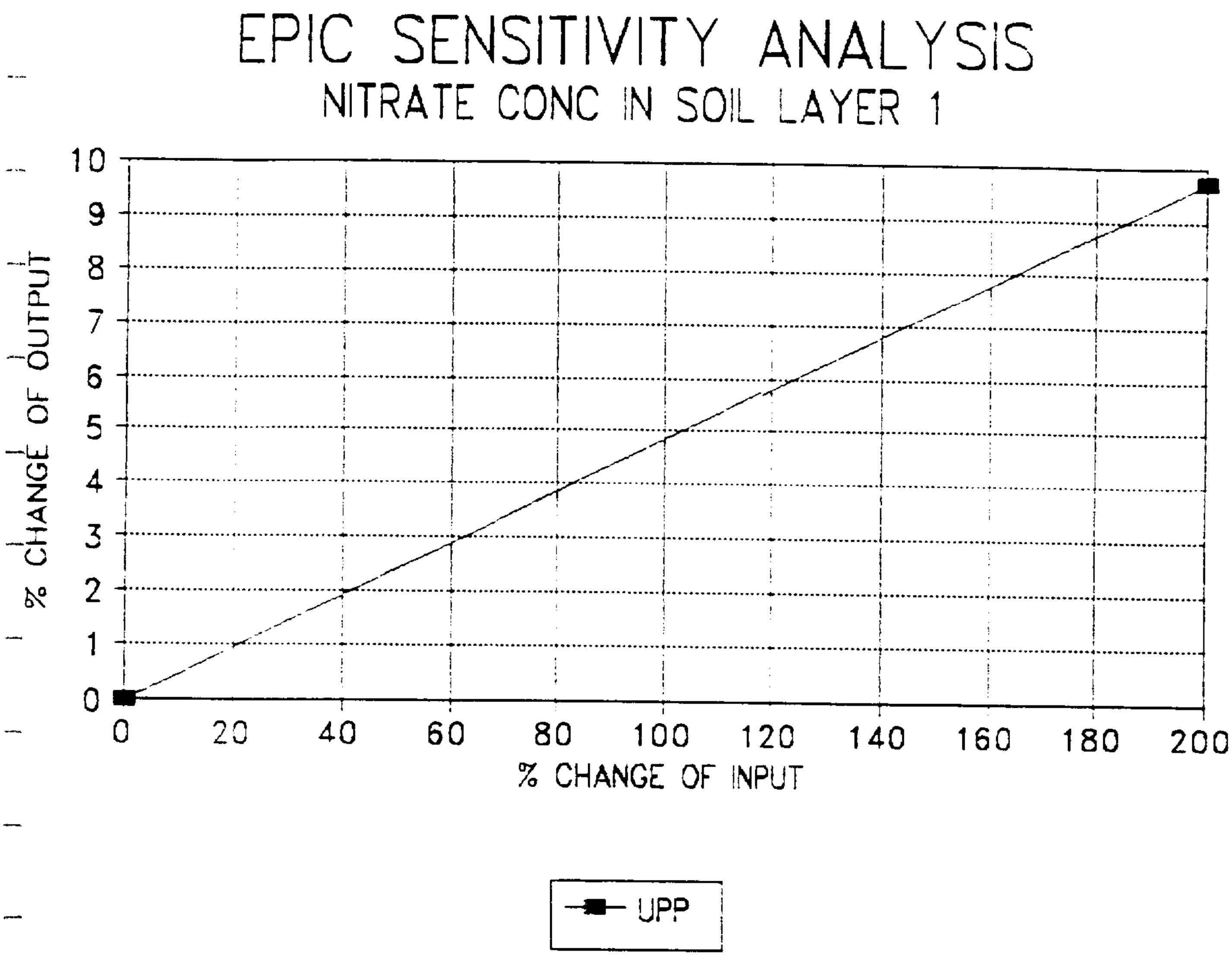
EPIC SENSITIVITY ANALYSIS
LABILE P CONC IN SOIL LAYER 1
% CHANGE OF OUTPUT
% CHANGE OF INPUT
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70
MN P AC
MN P ST
YAP
YP

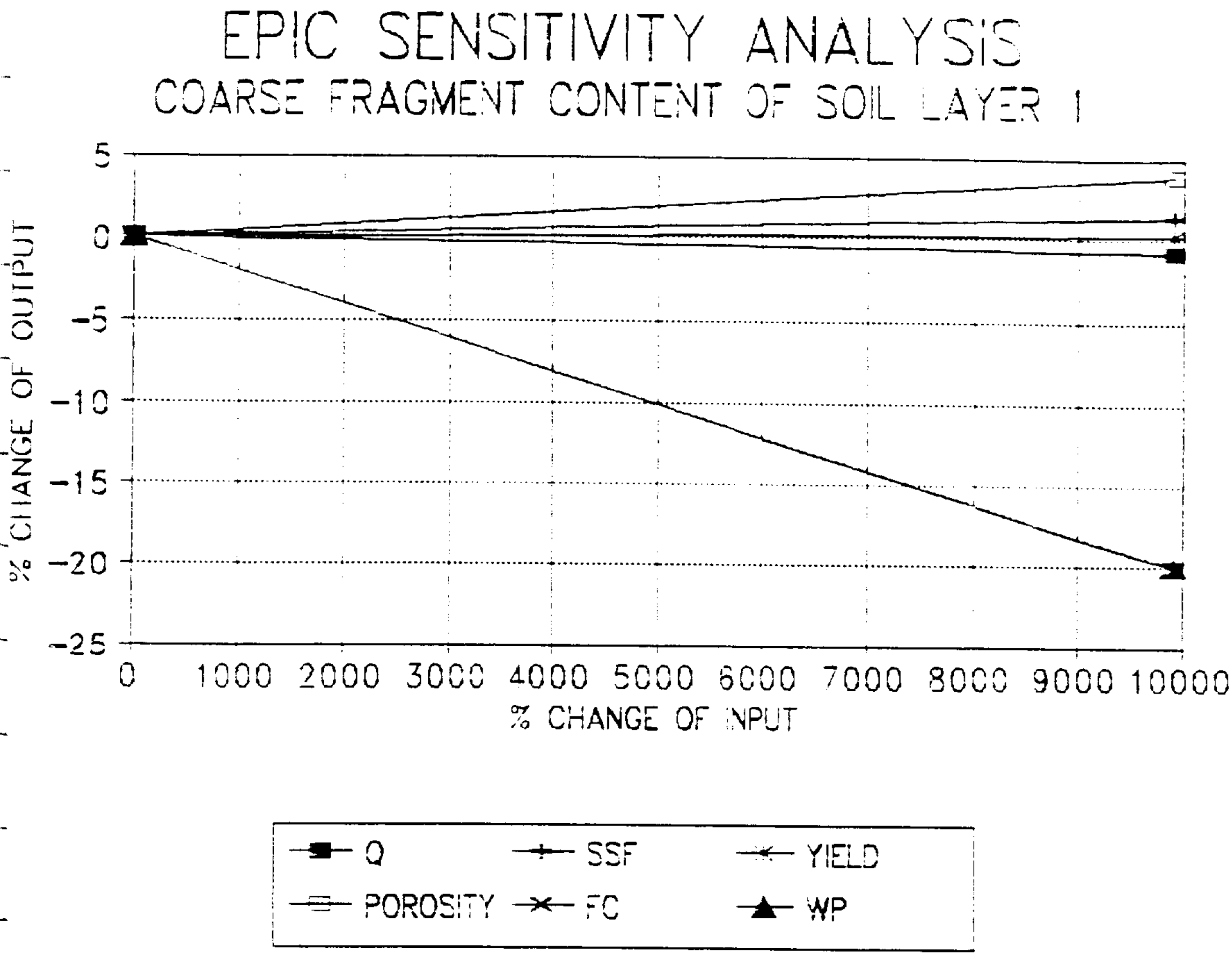

EPIC SENSITIVITY ANALYSIS
NITRATE CONC IN SOIL LAYER 1
% CHANGE OF OUTPUT
12
10
8
6
4
2
0
-2
-4
-6
0
20
40
60
80
100
120
140
160
180
200
% CHANGE OF INPUT
LAI
BIOMASS
YIELD
LAB P
MN P AC
MN P ST



EPIC SENSITIVITY ANALYSIS
NITRATE CONC IN SOIL LAYER 1
% CHANGE OF OUTPUT
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
% CHANGE OF INPUT
ORG N AC
ORG N ST
ORG C
MNP
IMP
SSFN


EPIC SENSITIVITY ANALYSIS
NITRATE CONC IN SOIL LAYER 1
15
10
5
0
-5
-10
% CHANGE OF OUTPUT
0
20
40
60
80
100
120
140
160
180
200
% CHANGE OF INPUT
PET
TRANS.
MNN
YAP
IMN
UNO3

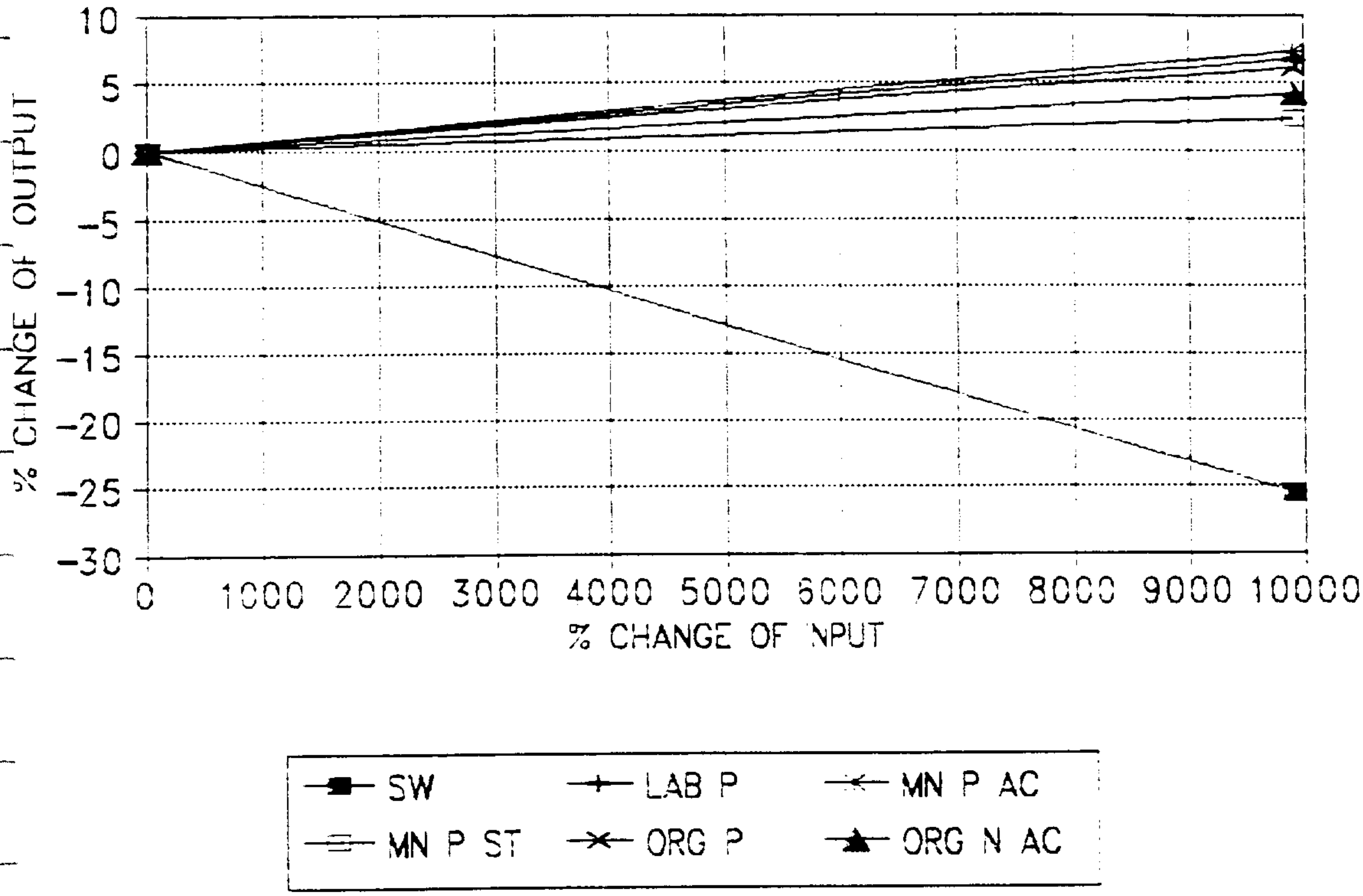

EPIC SENSITIVITY ANALYSIS
NITRATE CONC IN SOIL LAYER 1
% CHANGE OF OUTPUT
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100
120
140
160
180
200
% CHANGE OF INPUT
UPP



EPIC SENSITIVITY ANALYSIS
COARSE FRAGMENT CONTENT OF SOIL LAYER 1
% CHANGE OF OUTPUT
5
0
-5
-10
-15
-20
-25
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
% CHANGE OF INPUT
Q
SSF
YIELD
POROSITY
FC
WP

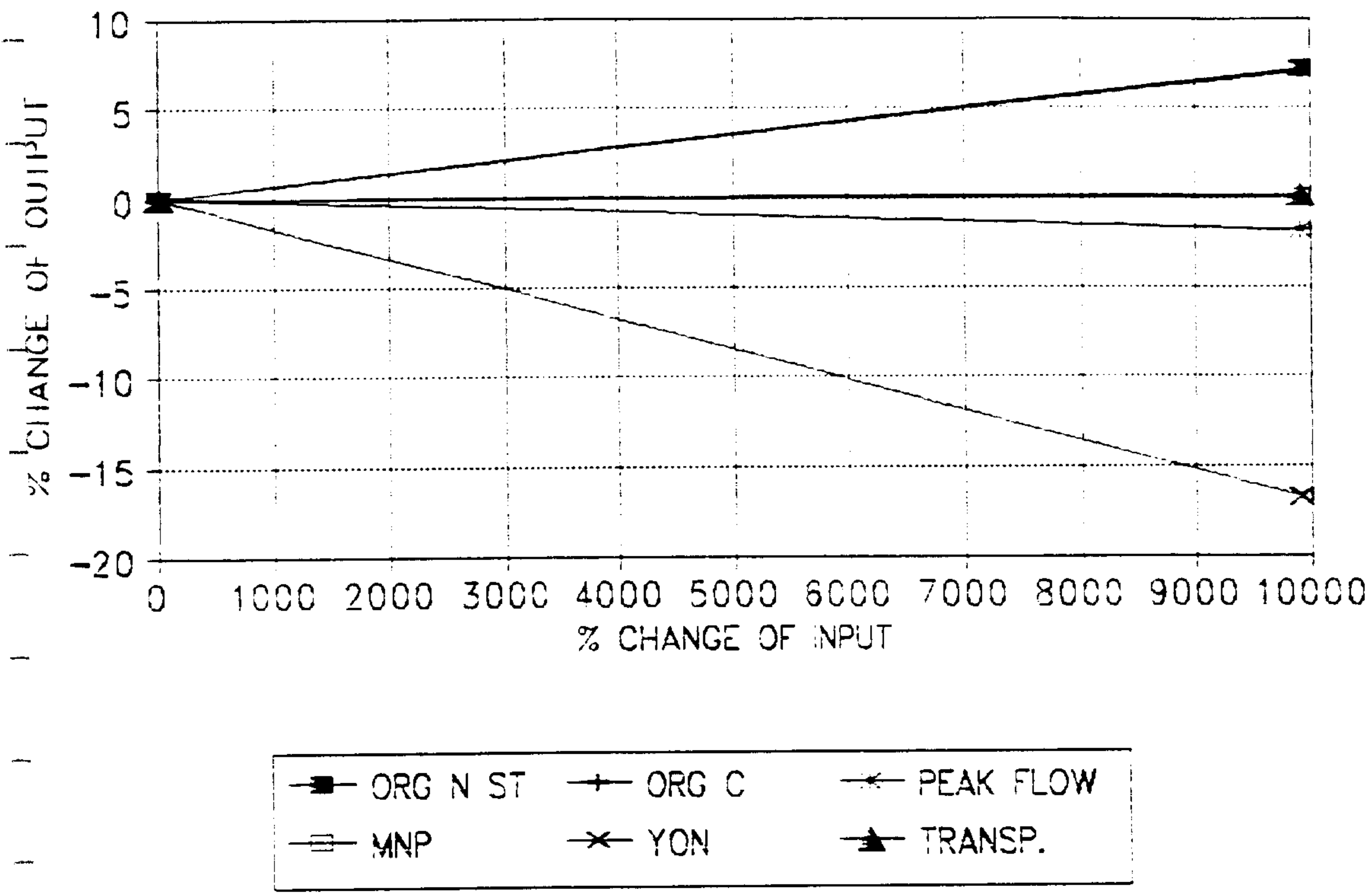
EPIC SENSITIVITY ANALYSIS

COARSE FRAGMENT CONTENT OF SOIL LAYER 1



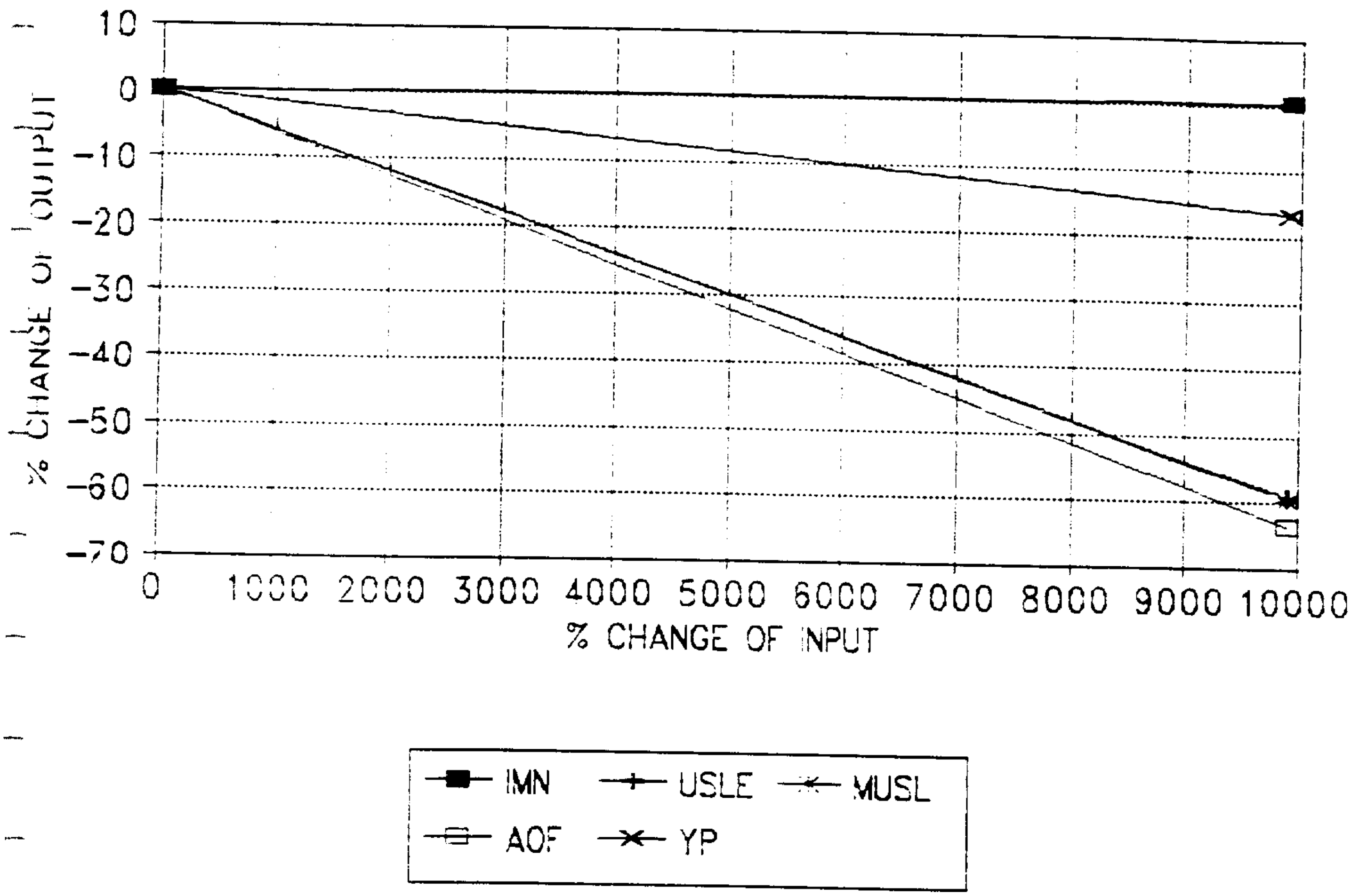
EPIC SENSITIVITY ANALYSIS

COARSE FRAGMENT CONTENT OF SOIL LAYER 1



EPIC SENSITIVITY ANALYSIS

COARSE FRAGMENT CONTENT OF SOIL LAYER 1



APPENDIX X

TASK IV
SUBCOMMITTEE MEETING
JULY 19, 1990

SUMMARY

MEMBERS PRESENT:

Nicki Jones
Don Davis
Bill Hailey
Jim Leatherwood
Jerry Parham

MEMBERS ABSENT:

Fred Lueck

EVALUATION OF THE FEASIBILITY OF COMPOSTING:

1. $6.50 per ton to haul manure to Cresson is below rate set by the Railroad Commission. Hauling alone should be $8.50 per ton. A loader would cost $1.25 more per ton. This makes total cost $9.75 per ton. Presently the Railroad Commission is not involved because Bill Christian is hauling manure on the basis that it is his. If hauling for himself, Railroad Commission rates don't apply.

- Feasibility must be considered with the prospect that on a large scale the Railroad Commission might get involved.
- This is definitely an area where government can help by making environmentally sensitive products exempt.

2. At $6.50 per ton the present practice is about $0.75 cheaper. Presently the dairy farmers are unwilling to pay the additional cost involved in composting at Cresson.

- Perhaps this cost ($0.75) could be paid by the composting facility.
- Perhaps a central location in this area would reduce transportation costs.
- As regulatory pressures increase the present practice may become too dangerous and the composting option may start to look better even if more expensive.

There is one major obstacle in the mind of the Committee regarding the feasibility of composting. The Committee is concerned about the lack of dairy input or interest in our discussions. It is unlikely that the dairies will move to composting until there is a sense of need on their part. In the discussion of this problem there are two unknowns. First, what is going to be the regulatory enforcement position of the Texas Water Commission? Current observations lead to the conclusion that permit conditions and management plans are not being followed. So far the Texas Water Commission doesn't seem to be enforcing those conditions and plans. Second, what will be the response of the dairies to this enforcement? The Committee feels that if there was more certainty about the enforcement intentions of the Texas Water Commission that the dairies would become more interested in the use

APPENDIX XII

PERMEABILITY TESTS ON SOIL SAMPLES FROM ERATH COUNTY

The purpose of this experiment is to find local soil types which may be suitable as lining material in the lagoons of dairy farms in Erath County. For this purpose, five different soil samples were collected from different locations in Erath County. The types of soil collected were Houston Black clay, Blanket clay, Red Windthorst clay, Purves-Dugout complex, and Selden fine sand.

Lagoon liners must be either compacted clay or a membrane lining which meets the Texas Water Commission (TWC) specifications listed below.

a) In-situ or placed and compacted clay soils meeting the following requirements:
   1) More than 30% passing a No. 200 mesh sieve
   2) Liquid limit greater than 30%
   3) Plasticity index greater than 15
   4) A minimum thickness of 12 inches
   5) Permeability equal to or less than 1×10^{-7} cm./sec.
   6) Soil compaction will be 95% standard proctor at optimum moisture content.

b) Membrane lining with a minimum thickness of 20 mils, and an underdrain leak detection system.

The permeability of a soil refers to the degree of ease with which a fluid passes through the soil and depends primarily on the type of fluid, the void ratio, the size and shape of soil grains, and the degree of saturation.

To determine the coefficient of permeability of soils, the falling head method was used. The first two tests were run on uncompacted Red Windthorst clay and Purves-Dugout complex. The results of these two tests indicated that the permeability of these soils is much higher than the TWC maximum limits for uncompacted lining materials. Therefore, on other samples, permeability tests were run with the soil compacted at its optimum moisture content (OMC). Test data is summarized in Table I.

PROCEDURE:

Determination of the OMC of a soil: A soil sample, approximately 2000 grams, was broken into small lumps, and dried in an oven for 18 to 24 hours. The dried soil was pulverized with a hammer until all the soil passed through the U.S. Standard Sieve Number 4. Assuming that the soil gained about 2% moisture from air while it was being pulverized, water (8% by weight) was then added to the soil and mixed thoroughly. The Standard Proctor Test (compaction test) was run on the soil to determine its compactibility at that particular moisture content. In the Proctor Test, soil is compacted in a Standard Compaction Mold (944 c.c.), in three equal layers, with 25 blows per layer, using a 24.5 N compaction hammer. After compaction, the compacted soil is weighed, and its density is determined. The true moisture content of the soil is determined by drying a small sample of the compacted soil.

The same procedure was repeated with different moisture contents in order to get a relationship between moisture content and soil density. After obtaining the true moisture content of each compaction test, the OMC was determined by plotting the dry density of the soil (which is calculated) versus its moisture content. More compaction tests were run after plotting the graph of dry density versus moisture content, in order to get a smooth curve. The peak of each graph indicates the OMC of that soil. The OMC is the amount of moisture in a soil that would facilitate maximum compaction of the soil.

Determination of the permeability of a soil: Once the OMC for a particular soil was determined, the soil sample was dried again, pulverized to make it pass through the Number 4 Sieve, and mixed thoroughly with the amount of water that would facilitate maximum compaction. The soil was then compacted in a Standard Permeability Device, with three equal layers, using a 24.5 N compaction hammer. The compacted soil was saturated with water by immersing the permeability device containing the soil in water, so that the water level was about 5 cm above the opening of the permeability device. Permeability tests were run on the compacted soil after the soil was saturated, using the falling head method. The procedure described in Engineering Properties of Soil and their Measurement (Bowles 1986) was followed, step by step, to run the falling head method of permeability test.

To control evaporation of water from the water tube, a marble was placed on the upper opening of the tube. No vacuum was created by placing the marble on the tube, because of a groove on the base that supported the upper end of the tube.

After running the permeability test on the compacted soil, cow manure, collected about 500 yards below a lagoon of a dairy farm, was introduced to the same soil, with about 60 cm. head, using a small tube attached to the opening of the permeability device. Cow manure was poured into the tube, and was refilled if the level of manure went down more than 15 cm. from the top of the tube. Permeability tests were run again on the soil after continuously supplying manure for 45 hours.

RESULTS:

The results of these tests showed that

(a) none of the soil samples tested meet the TWC's permeability standard (1 x 10^{-7} cm/sec), for use as a lining material, with compaction alone (see Table I for summary of test data),

(b) introduction of cow manure reduces the permeability of a soil,

(c) the reductions in permeability of three types of soils tested, due to the introduction of cow manure, were significant enough to make them meet the TWC's permeability standards. These soils included the Houston Black clay, Windthorst Red clay and Blanket clay.

Prior to permeability testing, other TWC criteria were examined for the five soils. Of the three soils, only the Houston Black and Windthorst had liquid limits greater than 30% (44.5 and 37% respectively). All criteria for the these two soils were then determined, and were acceptable as shown below.

	% Passing No. 200 Sieve	Liquid Limit (%)	Plasticity Index
Houston Black Clay	31	44.5	16.2
Windthorst Red Clay	39.1	37	15

Cow manure in waste water from a dairy farm can be expected to reduce the permeability in actual field conditions. Houston Black clay and Red Windthorst clay may be suitable as lining materials for dairy lagoons in Erath County.

TABLE 1
SUMMARY OF PERMEABILITY TESTS DATA
ON DIFFERENT SOILS FROM ERATH COUNTY

SOIL TYPE	CONDITION OF SOIL	PERMEABILITY (CM/SEC)	TIME TO INFILTRATE 1 FT. OF LINING
HOUSTON BLACK CLAY	A. NATURAL STATE*	$< 4.2 \times 10^{-5}$	> 8.4 DAYS
	B. WITH STANDARD COMPACTION	2.0×10^{-6}	176 DAYS
	C. WITH COMPACTION & MANURE	3.8×10^{-9}	254 YRS
RED WINDTHORST CLAY	A. NATURAL STATE*	2.8×10^{-4}	1.25 DAYS
	B. WITHOUT COMPACTION	2.3×10^{-3}	3.68 HRS
	C. WITH STANDARD COMPACTION	6.4×10^{-6}	55 DAYS
	D. WITH COMPACTION & MANURE	3.0×10^{-8}	32 YRS
BLANKET CLAY	A. NATURAL STATE*	2.8×10^{-4}	1.25 DAYS
	B. WITH STANDARD COMPACTION	3.7×10^{-7}	2.6 YRS
	C. WITH COMPACTION & MANURE	7.3×10^{-8}	13.2 YRS
PURVES-DUGOUT	A. NATURAL STATE*	2.8×10^{-4}	1.25 DAYS
	B. WITHOUT COMPACTION	3.0×10^{-4}	1.17 DAYS
	C. WITH STANDARD COMPACTION	3.7×10^{-5}	9.5 DAYS
	D. WITH COMPACTION & MANURE	2.8×10^{-7}	3.45 YRS
SELDEN (PEANUT SAND)	A. NATURAL STATE*	2.8×10^{-4}	1.25 DAYS
	B. WITH VIBRATION	3.3×10^{-3}	2.56 HRS
	C. WITH VIBRATION & MANURE	4.8×10^{-4}	17.6 HRS

* THE PERMEABLITY DATA FOR SOIL IN ITS NATURAL STATE IS TAKEN FROM THE SOIL SURVEY OF ERATH COUNTY, TEXAS (SCS, 1973).

Note: The TWC Standard for permeability of lining materials is $< 1 \times 10^{-7}$ cm/sec.

SUMMARY OF COMPACTION TESTS DATA ON SOIL SAMPLES FROM ERATH COUNTY

SOIL TYPE	OMC (%)	MWD kN/m^3	MDD kN/m^3	METHOD
HOUSTON BLACK CLAY	20.0	18.62	15.4	PROCTOR
RED WINDTHORST CLAY	12.66	21.77	19.33	MODIFIED PROCTOR
BLANKET CLAY	13.5	21.01	18.51	PROCTOR
PURVES-DUGOUT	9.5	24.66	21.22	MODIFIED PROCTOR

SUMMARY OF ATTERBERG LIMITS TESTS DATA ON SOIL SAMPLES FROM ERATH COUNTY

SOIL TYPE	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX
HOUSTON BLACK CLAY	44.5	28.3	16.2
RED WINDTHORST CLAY	35.0	20.0	15.0
BLANKET CLAY	26.0	**	**
PURVES-DUGOUT	24.0	**	**

** PLASTIC LIMIT IS NOT RUN ON SOILS WITH LIQUID LIMIT LESS THAN 30%.