A MICROCOMPUTER MODEL FOR IRRIGATION SYSTEM EVALUATION

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Abstract

ICEASE (Irrigation Cost Estimator and System Evaluator) is a microcomputer model designed and developed to meet the need for conducting economic evaluation of adjustments to irrigation systems and management techniques to improve the use of irrigated water. ICEASE can calculate the annual operating costs for irrigation systems and has five options that can be used to economically evaluate improvements in the pumping plant or the way the irrigation system is used for crop production.

Key words: irrigation, economics, irrigation system efficiency, irrigation costs, irrigation system management, microcomputing.

Establishment of economical irrigation practices is influenced by the knowledge the irrigator has concerning both the economic and technological aspects of irrigation. It is critical for irrigators to know how to estimate irrigation costs under various operating conditions in order to evaluate alternative irrigation techniques. However, many irrigators have difficulty trying to estimate irrigation costs for alternative operating conditions or do not have the proper tools available to economically evaluate water use strategies. Therefore, many operators have a limited potential for making use of water conservation or economical use techniques, and, thus, the probability for a wrong decision is high.

The objective of this manuscript is to report on a model designed to increase the operator's ability to evaluate irrigation system costs. The microcomputer model, Irrigation Cost Estimator and System Evaluator (ICEASE), can be used to estimate costs under a variety of operating conditions and to evaluate irrigation systems for economical water use. ICEASE is designed to utilize user-supplied data to calculate the operating costs for center pivot and gated pipe irrigation systems that use either natural gas, propane (LP) gas, diesel fuel, or electricity.

ICEASE is unique for several reasons. The program is designed specifically to be used with data collected from a standard well and pumping plant performance test. In addition, it has an algorithm to estimate the impact on operating costs from a falling water table and/or a pump efficiency decline in an aquifer. The Oklahoma State University Irrigation Cost Generator (Kletke et al.), which is often referenced in research publications, and the widely used AGNET program, "PUMP" (Thompson and Fischback), do not have this capability.

MODEL OVERVIEW

ICEASE is designed to calculate operating costs for eight items associated with operating irrigation systems and the total annual operating costs on a per-acre or per-hour basis. The eight costs that are calculated on an annual basis in the program are listed in Table 1. Cost estimates are included for an actual farm irrigation system.

In addition to calculating the annual operating costs, the model has five options that can be used to economically evaluate improvements in the pumping plant or the way the irrigation system is used for crop production. These options are:

1. evaluation of pump repair or replacement,

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2. evaluation of switching power units from one power source to another,
3. estimates of operating cost changes caused by a falling water table and/or a pump efficiency decline,
4. estimates of operating costs for different levels of water application, and
5. estimates of operating costs under selected fuel inflation rates.

The components and steps in the general ICEASE model are illustrated in Figure 1.

ECONOMIC ANALYSIS

The economic model is basically composed of budget generator and present value analysis algorithms. Technical data concerning the use of the irrigation system to be evaluated are entered interactively into ICEASE along with input prices and costs. There are 52 major equations in the model. Many of these equations use the input data along with engineering standards applicable to the specific type of irrigation system and power source to estimate current costs and projected costs under expected future operating conditions or alternative operating conditions.

Annual Costs

The first major component of the computer model estimates eight annual operating costs for the system being evaluated. The eight components and sample output from ICEASE which uses data for an actual flood irrigation system in southwestern Kansas are shown in Table 1. Most of the costs are calculated using standard engineering formulas from per-unit cost and wage rate information supplied by the operator. The exceptions to this are the costs for maintenance and repair of the irrigation system, which are estimated by procedures based on survey data collected by Etzold and Williams. During 1984, irrigators who recently had completed pumping plant performance tests were surveyed in Kansas and Texas. A data base of repair and maintenance costs was established which corresponded to recently measured pumping plant characteristics. Maintenance costs for the power unit are based on costs per hour of operation, and repair costs for the distribution systems are based on costs per acre. Total operating costs for the actual flood irrigation system using a natural gas power source are $60.67/acre.

TABLE 1. COMPUTER OUTPUT FORMAT OF ANNUAL IRRIGATION OPERATING COSTS

These are the cost estimates for your irrigation system:
All costs are based on 160 acres, 1440 estimated pumping hours, and estimated 106.53 water-horsepower.

1. Fuel cost for operation = $6820.13
2. Oil for the engine or annual electric connect charge = $862.90
3. Oil for electric motor or gear drive = $172.58
4. Maintenance cost for pumping plant = $243.36
5. Repair and maintenance cost for distribution system = $395.20
6. Labor costs for maintaining the pumping plant = $230.40
7. Labor cost for setup, takedown, and operating = $816.00
8. Costs of reuse or driving center pivot on annual basis = $166.65

Total Operating Cost = $9707.21.
Cost/Acre = $60.67.
Cost/Hr. = $6.74.

Optional Evaluations

The first optional evaluation involves determining if pump repair or replacement is economically justified. One of the most important parts of this evaluation is predicting the flow rate in gallons per minute (GPM) of the well when the pump is repaired or replaced. To do this, the model uses a procedure developed by Pacific Gas and Electric. Complete documentation of this procedure can be found in Dvorak et al. (1985a).

Once the new flow rate for the repaired pump is estimated, the operating costs of the pumping plant can be calculated using the new predicted flow rate and technical pumping efficiency. The flow rate and technical pump efficiency will be improved, and operating hours and total costs will be reduced, assuming the same amount of water is applied as before the pump was repaired or replaced.

Total annual operating cost for the system is estimated for a 10-year period with and without improvements. The difference between the two is the savings that can be expected. For the example irrigation system, the discounted operating cost savings are positive (Table 2). The data for this example can be found in Table 3. If the total savings of the 10-year period calculated are negative, the model will terminate the evaluation because it is not economically feasible to make improvements to the pumping plant. If the savings are positive in the evaluation of pump repair or replacement, the model will continue the evaluation by asking for an estimate or using a computer-generated estimate of the cost to repair or replace the pump. Repair cost estimates are based on equations developed by Ngo. Annual discounted savings for each year

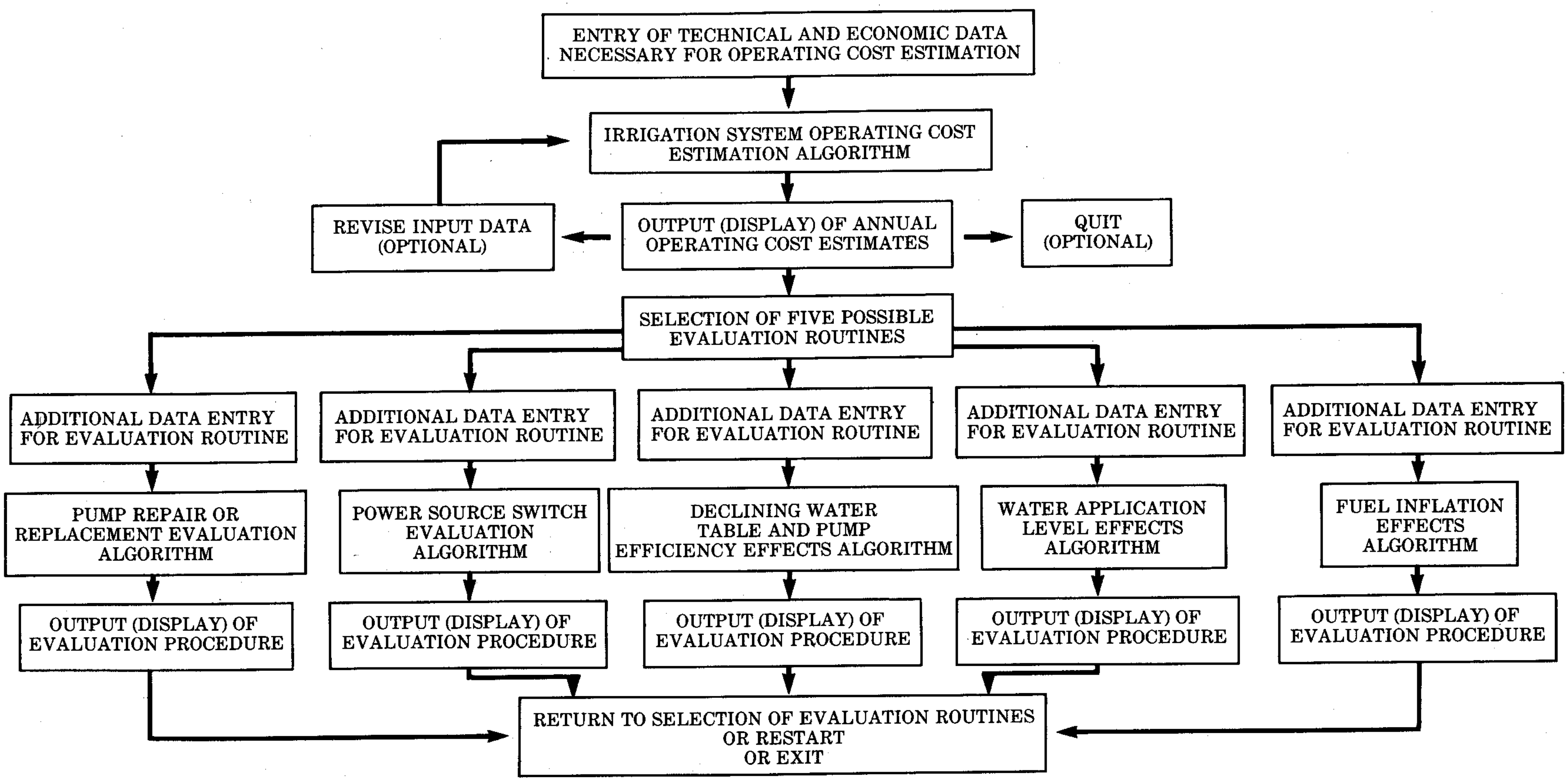

Figure 1. General ICEASE Model Components.

over the 10-year period are summed. If the total discounted savings are less than the estimate to repair or replace the pump, the evaluation is complete. If the discounted savings exceed repair cost, the repair cost is subtracted from the total discounted savings to show the user the net savings that can be expected over a 10-year period. In the example, the net savings from repair are also positive (Table 2). The number of years (payback period) required to pay for the repairs is also estimated.

TABLE 2. COMPUTER OUTPUT FORMAT OF PUMPING PLANT REPAIR EVALUATION

Projected Savings from pumping plant repair are estimated assuming an annual fuel inflation rate of 5%.
Required pumping hours are now 1264.82 to apply 24 inches/acre.

Year	Total Savings	Previous Cost	New Cost
1	$ 884.57	$ 9707.21	$ 8822.64
2	$ 925.61	$ 10048.21	$ 9122.60
3	$ 968.71	$ 10406.27	$ 9437.56
4	$ 1013.97	$ 10782.23	$ 9768.27
5	$ 1061.48	$ 11176.99	$ 10115.51
6	$ 1111.37	$ 11591.48	$ 10480.11
7	$ 1163.76	$ 12026.70	$ 10862.94
8	$ 1218.77	$ 12483.68	$ 11264.92
9	$ 1276.52	$ 12963.51	$ 11686.99
10	$ 1337.17	$ 13467.33	$ 12130.17

The total savings over 10 years is estimated to be $10961.92
The total savings with no fuel inflation included is $8845.65
Present Value Savings Analysis

Estimated costs for pumping plant replacement or refurbishment are $5218.20
Present value of 10 years of savings is $6498.58
The analysis indicates savings exceed costs
Discounted savings minus costs are $1280.38
Number of years to payback repair costs = 8

The second optional evaluation procedure determines if switching to an alternative power source is economically feasible. When switching power sources, operating conditions associated with the pumping plant are assumed to remain the same. The model uses a procedure developed by Dorn to convert the fuel consumption for the current power source to an equivalent amount of fuel for the alternate power source. Once the model estimates the fuel consumption for the alternate power source under consideration, the total annual operating costs are estimated. To evaluate the switching of power units, the model estimates the savings from switching to the alternative power source. If the total savings for a 10-year period are negative, the evaluation is completed and the power unit switch is not economically feasible.

If the total savings from switching power units are positive, the model evaluates the cost of purchasing and installing a new power unit. This is compared to the present value of the total savings from switching power units over a 10-year period. The model prompts the user for an estimate of the cost to install a new power unit and gear head (if needed) or generates an estimate. The power unit, gear head, and any miscellaneous costs are subtracted from the present value of the 10-year total savings and any salvage value is added to arrive at the net savings. If this results in a positive value, the switching of power units is economically feasible and the model will estimate the number of years required to pay back the associated costs. The output format is similar to that of option 1 in Table 2. A complete documentation of the underlying criteria and engineering procedure can be found in Dvorak et al. (1985b).

The third optional evaluation estimates the effect of a falling water table and/or technical pump efficiency decline on operating costs. The user has to enter the expected annual drop in the water table and percentage estimate of the annual technical pump efficiency decline. The model iteratively recalculates the expected flow rate (GPM) and the pumping water level (PWL) for each successive annual decline in technical pump efficiency and increase in water table depth so the annual operating cost changes can be calculated. The program displays the annual total operating costs for each year over a ten-year period, given the specified scenerio.

The fourth optional evaluation routine calculates and displays the annual operating costs for the irrigation system given alternative levels of water application (inches applied per acre). The fifth optional procedure estimates and displays the annual operating costs for each year in a ten-year period given a user supplied scenario of annual fuel inflation rates. The operating costs for both the fourth and fifth optional evaluations are estimated with the same procedures used to estimate operating costs in the initial section of the model, using two-inch water application increments or any fuel inflation estimate desired.

Further documentation of the computer algorithm, including equations and parameters used, can be found in Williams et al. (1985).

DATA NEEDS

Before the ICEASE model can be used to calculate costs or evaluate irrigation system adjustments, technical and economic data, which will serve as input to the model, need to be collected. A pumping plant and well performance test must be completed for the pumping plant and irrigation system to be evaluated. When a pump test is conducted, it is suggested the power unit should be in top operating condition so the majority of the pumping plant technical inefficiencies may be attributed to the pump. A significant number of pump tests do not differentiate between power unit and pump efficiency. Therefore, it is necessary to assume that the power unit is operating at the Nebraska standard (an engineering standard established by the American Society of Agricultural Engineers) and the pumping plant technical inefficiency is attributed to the pump.

Data items 2, 4, 5, 6, 20, 21, 42, and 43 listed in Table 3 can be obtained from a pumping plant performance test. Other necessary data must be collected from farm records, utility companies, and pump and well equipment dealers. The required input data for each evaluation are listed in Table 3.

TABLE 3. INPUT DATA REQUIREMENTS

Calculation of Operating Costs of Irrigation

160	1. Number of acres irrigated.
5	2. System operating pressure (PSI—Pounds per Square Inch).
24	3. Number of inches of water irrigated per acre per season.
340	4. Pumping water level (feet).
1200	5. Flow rate in gallons per minute (GPM—Gallons per Minute).
1.99	6. Fuel consumption per hour (MCF—1000 Cubic Feet, Gallon, KWH—Kilowatt Hours).
$2.38	7. Fuel or electricity price per unit (MCF, Gallon, KWH).
925	8. BTU content of natural gas per MCF if using a natural gas engine.
—	9. Electric connect charge per horsepower, if using an electric motor for a power source.
$4.50	10. Lubricating oil cost per gallon.
—	11. Pumping plant annual maintenance cost (optional). If unknown, the computer model will estimate the cost.
—	12. Distribution system annual repair and maintenance costs (optional). If unknown, the computer model will estimate the cost.
$4.00	13. Hourly farm wage rate for maintenance of the pumping plant.
$4.00	14. Hourly farm wage rate for setup, takedown, and operation of the system.

(The previous data must be collected to use any of the five options that follow.)

Pump Repair or Replacement Evaluation (Option 1)

205	15. Rated horsepower of power unit.
—	16. Original static water level (optional).
—	17. Original pumping water level (optional).
—	18. Original flow rate (optional).
—	19. Original system pressure (optional).
305	20. Current static water level.
340	21. Current pumping water level.
5%	22. Estimate of fuel inflation percentage per year (optional).
—	23. Cost to repair pump to peak operating efficiency (optional). This information will be needed if 24, 25, and 26 are unknown. The computer can make an estimate using items 24, 25, and 26. However, it is preferable to obtain an estimate from a local pump and well equipment dealer.
4	24. Number of bowl stages (optional). These data are required if 23 is unknown.
360	25. Bowl setting depth in feet (optional). These data are required if 23 is unknown.
12 in	26. Diameter of pump bowl (optional). These data are required if 23 is unknown.
10%	27. Interest rate or opportunity rate of interest for financing repair or replacement of the pump.

Switching Power Units to an Alternative Power Source Evaluation (Option 2)

28. Rated horsepower of power unit.
29. Fuel cost of the alternative power source ($/MCF, $/Gal., $/KWH).
30. BTU content of natural gas per MCF, if applicable.
31. Electric connect charge per rated horsepower of the electric motor, if evaluating a switch to electricity.
32. Estimate of fuel inflation percentage per year for the original power source (optional).
33. Estimate of fuel inflation percentage per year for the alternative power source (optional).
34. Estimate of purchase and installation cost of alternative power unit (optional). This will be used if there are operation cost savings from making the switch. The computer model will estimate the power unit cost, if it is unknown. The user is given a choice of an industrial or automotive engine, if natural gas or LP gas are selected as fuel source. In some cases for small power units, the computer cannot make an estimate of power unit costs. The user is then required to provide purchase and installation costs of the power unit switch from a local equipment dealer.
35. Interest rate or opportunity cost rate of interest to finance the purchase of an alternative power unit.
36. Salvage value of old power unit.
37. Miscellaneous costs to switch units.

Evaluation of Water Table and Pump Efficiency Decline (Option 3)

38. Rated horsepower of power unit.
39. Estimated average annual decline in water table (feet).
40. Estimated average annual percentage point decline in pump efficiency.
41. Estimate of fuel inflation percentage per year (optional).
42. Current static water level.
43. Current pumping level.

Evaluation of Water Application Levels (Option 4)

44. Minimum number of inches that could be applied.

Fuel Inflation Analysis (Option 5)

45. Estimate of fuel inflation percentage per year.

IMPLICATIONS FOR EXTENSION, TEACHING, PRODUCER, AND RESEARCH USES

The model is not only helpful in calculating costs and making irrigation system adjustments, but also in teaching producers and extension personnel the fundamentals of irrigation engineering and economics related to the pumping of water. After using the model, irrigators and educators will have a better understanding of the technical factors that impact irrigation costs as well as economic variables such as energy price and wage rates.

Many states currently are offering free pumping plant performance tests. Often a team of Soil Conservation Service (SCS) engineers or agricultural extension service engineers conduct these tests. Usually when the test is completed, questions arise concerning economic analysis of changes to the system. In most cases, the producer has been referred to his or her pumping plant equipment dealer or an extension economist. Many times there is no follow-up, and the irrigator is left with little economic evaluation of the technical data to make any decisions. This model specifically is designed to handle data collected in a standard pumping plant performance test so that a more complete evaluation of the system can be conducted, providing economic information that the irrigator can use for decision making.

The model may be used for research purposes as well. To date, it has been used to generate irrigation cost parameters for the objective function in whole-farm linear and non-linear programming analyses. These parameters are important for selecting optimum irrigation schedules and cropping systems for a variety of irrigation scenarios. The iterative capabitilites of this program are useful particularly when cost estimates are required for multi-year analysis of irrigation scheduling and cropping system transition under conditions with constrained water availability.

RELEVANCE TO SOUTHERN IRRIGATION PRACTICES

The program can analyze irrigation systems designed to pump water from groundwater sources using a turbine pump and either a center pivot or gated pipe distribution system which are typical of the Ogallala Aquifer region. Sloggett (1982) points out that in 1980 the southern region irrigated 37 percent of the irrigated land in the U.S. Within three of four southern regions, at least 60 percent of the water source is groundwater. The range in feet of lift for extraction of water from groundwater sources for these regions easily can be accommodated by the program. The program is also designed to handle cost estimates for center pivot and gated pipe (surface) distribution systems. In three of four southern regions, center pivot and surface distribution systems account for 58 percent to 94 percent of the system types. In addition, of the 11 states which have major groundwater decline areas, four of them are in the southern region (Sloggett, 1981). Included are areas in the Ogallala region that have groundwater decline of ½ foot to 6 feet. One of the unique features of the program is that it can calculate irrigation costs associated with the dynamic conditions in an area of major groundwater decline.

SYSTEM REQUIREMENTS, MODEL TESTING, AND DISTRIBUTION

The program is available in compiled BASIC for microcomputers with an MS-DOS operating system. It requires 84K of RAM. A printer is not required but would be useful. The computer prompts the user with specific questions that require technical and economic data relevant to the irrigation system being evaluated. Suggested ranges in the values of variables and error checking are also included in the program. If the user enters a value for a variable that falls outside of typical specified ranges, the computer will respond with a request that the user check the input data. Results of the analysis are routed to the computer terminal with the option of also having the information routed to a printer. A user's manual (Williams et al., 1986) is also available with an example showing actual data for each option and results of all optional evaluations.

The model was reviewed and tested using actual pumping plant performance data by an SCS engineer who was independent from the project. The model was also tested against results calculated by hand from several case situations, which were based on actual farm system data. The user's manual was also reviewed and the model was tested by agricultural economics department personnel not associated directly with the project.

Discussions concerning distribution are currently taking place with the SCS and other agency personnel conducting well and pumping plant performance tests in the Ogallala

Aquifer region. A private firm is also negotiating an agreement for wider distribution to individual farm operators. The program is currently free to personnel from all land grant universities.

SUMMARY

Proper use of the model ICEASE will provide an irrigator with estimated costs to operate a specific irrigation system. The model also provides estimates of the costs associated with possible changes to the pumping plant and the amount the system is used. With this information, an irrigator should be able to decide if it is economically feasible to make changes or improvements in the pumping plant to reduce irrigation costs.

ICEASE is unique. The program is specifically designed to be used with data collected from a standard well and pumping plant performance test. It also has an algorithm to iteratively estimate the economic impact on irrigation costs from a falling water table and/or technical pump efficiency due to a decline in an aquifer.

REFERENCES

Dorn, T. W. "Selecting the Most Economical Energy Source for Irrigation Pumping." *Irrigation Pumping Plant Performance Handbook.* Agricultural Engineering Department, Cooperative Extension Service, Institute of Agriculture and Natural Resources. University of Nebraska-Lincoln, 1982.

Dvorak, G. J., H. L. Manges, and J. R. Williams. "Criteria for Repairing or Replacing An Irrigation Pump." ASAE Paper No. MCR 85-129, 1985a.

Dvorak, G. J., H. L. Manges, M. D. Schrock, and J. R. Williams. "Determining an Economic Fuel Source for Irrigation." ASAE Paper No. 85-5549, 1985b.

Etzold, P. E., and J. R. Williams. 1984 Irrigation Repair and Maintenance Survey Results. Department of Agricultural Economics, Kansas State University, 1985.

Kletke, D. D., T. R. Harris, and H. P. Mapp, Jr. "Irrigation Cost Program User's Reference Manual." Agricultural Experiment Station, Research Report P-770, Oklahoma State University, 1978.

Ngo, V. T. "Repair Cost Study: Agricultural Pumps." Pacific Gas and Electric Company. Private communication, San Francisco, CA, 1983.

Pacific Gas and Electric Company. "Pumping Plant Comparison Studies." Private communication, San Francisco, CA, 1984.

Sloggett, G. "Energy and U.S. Agriculture: Irrigation Pumping, 1974–80." Nat. Res. Econ. Div., Econ. Res. Serv. Rep. No. 495. U.S. Department of Agriculture, Washington, DC, 1982.

Sloggett, G. "Prospects for Groundwater Irrigation: Declining Levels and Rising Energy Costs." Nat. Res. Econ. Div., Econ. Res. Serv. No. 478. U.S. Department of Agriculture, Washington, DC, 1981.

Thompson, T. L., and P. E. Fischback. "AGNET 'Pump' Computer Program Cost Analysis." *Irrigation Pumping Plant Performance Handbook.* Agricultural Engineering Department, Cooperative Extension Service, Institute of Agriculture and Natural Resources. University of Nebraska-Lincoln, 1981.

Williams, J. R., H. L. Manges, O. H. Buller, G. J. Dvorak, and P. E. Etzold. "A Study of Managerial Irrigation Cost Estimation Procedures." Consultants' Report to the Kansas Water Resources Research Institute and U.S. Geological Survey, Kansas Water Resources Research Institute, Kansas State University, 1985.

Williams, J. R., H. L. Manges, and L. K. Gross. "ICEASE: Irrigation Cost Estimator and System Evaluator User's Manual." Department of Agricultural Economics Staff Paper No. 86-1, Kansas State University, 1986.