A Microcomputer Model for Irrigation System Economics Evaluations[1]

Jeffery R. Williams,* Daniel R. DeLano, and Richard V. Llewelyn

ABSTRACT

The Irrigation Economics Evaluation System (IEES) 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. The objective of this paper is to describe the model and the types of analysis for which it can be used. The IEES is designed to utilize user-supplied data to calculate operating costs for four types of center-pivot systems, two types of gated-pipe systems, and a subsurface drip irrigation system. In addition, natural gas, propane (LP) gas, diesel fuel, or electricity can be considered as power sources for the irrigation pumping plant. The model can help determine which type of irrigation system is most economical to own and operate. It can also be used to evaluate several irrigation system changes including pump repair or replacement, switching power units from one power source to another, operating cost changes caused by a falling water table, and/or a pump efficiency decline, operating costs for different levels of water application, operating costs under alternative fuel inflation rates, and estimates of changes in operating costs when modifying or switching distribution systems and net present value analysis of returns from modifying or switching distribution systems. The program is designed specifically to be used with data collected from standard well and pumping performance tests. Input data and results of the analysis can be saved on disk for future modification and analysis.

IRRIGATION management and conservation of water in Ogallala Aquifer, which underlies parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas, is becoming increasingly important. Significant economic growth in the agricultural sector of this region occurred due to irrigation of water from the aquifer. Irrigators in this region are facing declining water availability and increasing pumping costs. They are concerned about conserving water in their crop production decision, but also using water in a profitable manner. An incentive will exist to conserve water if it is profitable to do so.

Establishment of efficient and profitable irrigation practices is influenced by the knowledge the irrigator has concerning both the economic and technological aspects of irrigation. It is of critical importance for irrigators to have irrigation cost estimates under various operating conditions to evaluate efficient and profitable water-use techniques. Few irrigators have the proper tools available to evaluate water use strategies and investments in alternative irrigation technology using standard economic analysis.

Department of Agricultural Economics, 342 Waters Hall, Kansas State Univ., Manhattan, KS 66506-4011. Kansas Agric. Exp. Stn. Contrib. 98-25-J. Received 8 Sept. 1997. *Corresponding author (jwilliam@agecon.ksu.edu).

Published in J. Nat. Resour. Life Sci. Educ. 27:101–106 (1998).
http://www.agronomy.org/journals/jnrlse/1998/

This manuscript describes a model designed to increase the operator's ability to evaluate irrigation system costs. The microcomputer model, Irrigation Economics Evaluation System (IEES), can be used to estimate costs under a variety of operating conditions and evaluate adjustments of irrigation systems for efficient and economical water use. The IEES computer model can be used to estimate irrigation operating costs and net returns of production for seven separate irrigation-distribution systems, including medium-pressure center pivot, low-pressure center pivot, low energy precision application (LEPA) center pivot, low-drift-nozzle center pivot, conventional furrow-flood gated pipe, surge furrow-flood gated pipe, and subsurface drip. Four alternative power sources can be evaluated with these distribution systems: natural gas, propane (LP) gas, diesel, and electricity. Although one of these systems must be specified by the user, the program is flexible and allows a wide range of operating conditions for each system to be modeled.

The IEES is unique for several reasons. The program is designed specifically to be used with data collected from standard well and pumping performance tests. In addition, it can evaluate irrigation costs for dynamic pumping conditions and new investments in irrigation technology. For example, the program can estimate the impact of declining flow rates and increasing pumping water levels along with modifications or changes to an irrigation system.

MODEL OVERVIEW

The IEES is designed to calculate the annual operating costs for 11 items associated with operating irrigation systems and the total annual operating costs on a per acre, per hour, and per acre-inch basis.[1] The items are: fuel cost, oil cost for an internal combustion engine, annual electric connect charge and oil cost for an electric motor, oil cost for a gear drive, maintenance costs for the pumping plant, repair and maintenance costs for the distribution system, labor costs for maintaining the pumping plant, labor costs for setup and takedown and operating the distribution system, cost of operating a reuse system for gated pipe systems, and cost of driving the center pivot for center pivot systems.

In addition to calculating the annual operating costs, the model can calculate net returns to crop irrigation for the current system and also has six 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: evaluation of pump repair or replacement, evaluation of switching power units from one power source to another, estimates of operating cost changes

[1] This journal uses SI units, according to the ASA-CSSA-SSSA style. Due to the circumstances of this article, however, English units are used.

Abbreviations: IEES, Irrigation Economics Evaluation System; LEPA, low energy precision application; LP, propane; RAM, random-access memory.

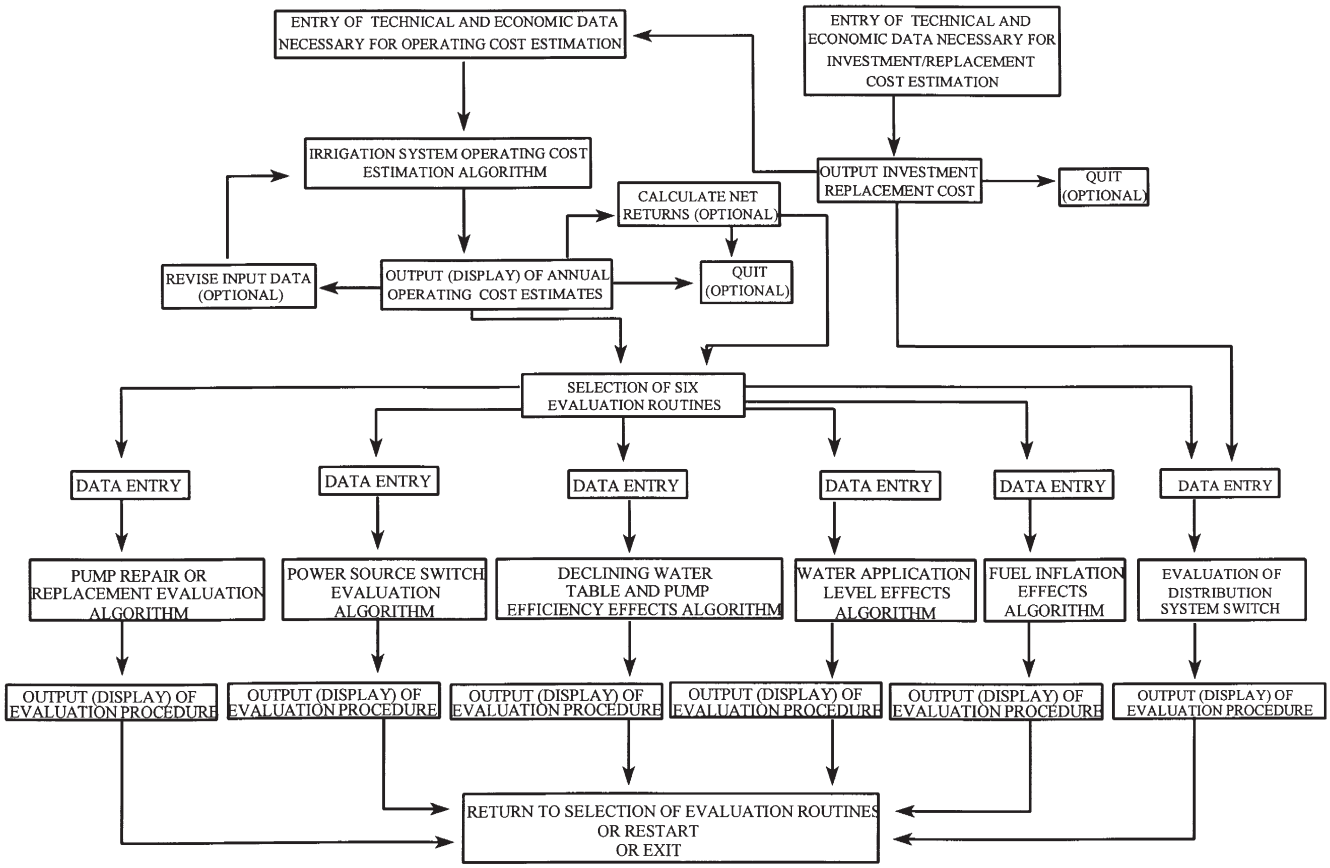

Fig. 1. General IEES model components.

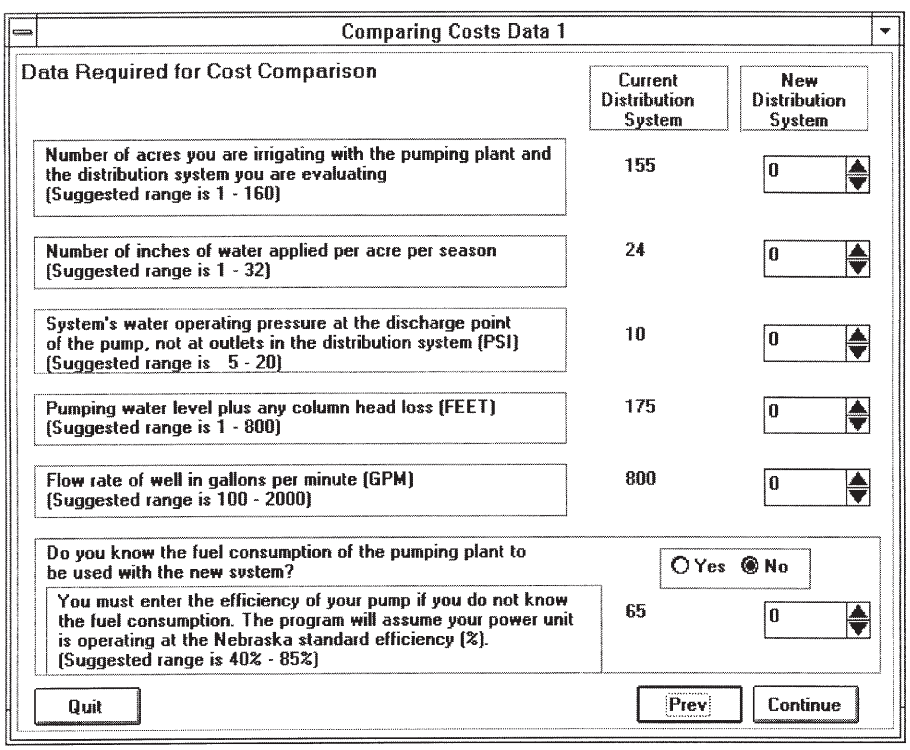

Fig. 2. Typical format of input screen.

caused by a falling water table and/or a pump efficiency decline, estimates of operating costs for different levels of water application, estimates of operating costs under selected fuel inflation rates, and estimates of changes in operating costs when modifying or switching distribution systems and net present value analysis of returns from modifying or switching distribution systems.

The components and steps in the general IEES model are illustrated in Fig. 1.

ECONOMIC ANALYSIS

The economic model is composed basically of a budget generator and present value analysis algorithms. Technical data concerning the use of the irrigation system to be evaluated are entered interactively into IEES along with input prices and costs. Figure 2 illustrates a typical input screen. The model includes 73 major equations, many of which 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.

Current Distribution system: Medium Pressure Center Pivot
Current Power source: Electric Motor
All costs are based on 126 acres, 1701.00 (10.13 weeks) estimated pumping hours and an estimated 70.35 water horsepower, 108.24 brake horsepower and 108.24 rated horsepower for the old system.

New Distribution system: Sub-surface Drip System
New Power source: Electric Motor
All costs are based on 155 acres, 1743.75 (10.38 weeks) estimated pumping hours and an estimated 44.69 water horsepower, 63.84 brake horsepower and 63.84 rated horsepower for the alternative system.

	Current	New
Fuel cost for operation:	$7,801.26	$4,716.87
Oil for the engine:	$0.00	$0.00
Annual electric connect charge:	$1,082.36	$0.00
Oil for electric motor:	$70.31	$45.78
Oil for gear drive:	$164.55	$107.14
Pumping plant maintenance cost:	$114.15	$69.14
Repair and maintenance cost for distribution system:	$362.88	$744.00
Pumping plant maintenance labor cost:	$272.16	$279.00
Labor cost for distribution system:	$640.00	$1,069.77
Costs for reuse system on annual basis:	$0.00	$0.00
Costs for driving center pivot on annual basis:	$288.31	$0.00
Total operating cost:	$10,795.97	$7,031.59
Cost per acre:	$85.68	$45.37
Cost per acre-inch:	$3.57	$2.27
Cost per hour:	$6.35	$4.03

	Current System		New System	
Year	Total	Per Acre	Total	Per Acre
1	$10,795.97	$85.68	$7,031.59	$45.37
2	$10,999.09	$87.29	$7,150.82	$46.13
3	$11,206.27	$88.94	$7,272.44	$46.92
4	$11,417.60	$90.62	$7,396.50	$47.72
5	$11,633.15	$92.33	$7,523.03	$48.54
6	$11,853.02	$94.07	$7,652.10	$49.37
7	$12,077.28	$95.85	$7,783.74	$50.22
8	$12,306.02	$97.67	$7,918.02	$51.08
9	$12,539.34	$99.52	$8,054.99	$51.97
10	$12,777.33	$101.4	$8,194.69	$52.87

AFTER TAX NET PRESENT VALUE OF OPERATING COSTS
Current: $56,086.31
New: $36,263.20
Savings: $19,823.11

AFTER TAX NET PRESENT VALUE OF CROP RETURN
Current: $180,603.98
New: $215,780.16
Difference: $ 35,176.18

AFTER TAX NET PRESENT OWNERSHIP COST OF NEW SYSTEM
Cost: ($52,254.12)

AFTER TAX NET PRESENT VALUE OF RETURNS FROM SWITCHING SYSTEM
Value: $2,745.17

SWITCHING DISTRIBUTION SYSTEMS IS ECONOMICALLY FEASIBLE

Fig. 3. Example output from system modification or switching analysis.

Annual Costs

The first major component of the model estimates 11 annual operating costs for the system being evaluated. Most of the costs are calculated using per-unit costs and wage information supplied by the operator. Standard engineering formulas are used to calculate fuel costs and intermediate values such as pumping hours, which are used to calculate costs. Costs for maintenance and repair of the irrigation system are estimated by procedures outlined in Williams et al. (1996). Maintenance costs for the distribution system are based on the number of acre-inches of water applied. The annual operating costs are reported as total $, $ acre^{-1}, $ acre-inch^{-1}, and $ h^{-1}. Figure 3 illustrates the output of the annual cost estimates.

Optional Evaluations

Pump Repair or Replacement

The first optional evaluation determines if pump repair or replacement is economically justified. This analysis accounts for income tax implications of the investment.

The model estimates a new flow rate for the well if the pump is repaired or replaced. The new predicted flow rate and technical pumping efficiency then are used to calculate the new operating costs. Because the flow rate and technical efficiency will be improved, operating hours and operating costs will be reduced, assuming the same amount of water is applied as before the pump was repaired or replaced.

Total operating cost for the system is estimated for a 10-yr period with and without improvements. The model then calculates the present value of the difference or total savings for the 10-yr period. If the calculated savings are negative, the model will end the evaluation because making improvements to the pumping plant is not economically feasible. If the savings are positive, the model continues with the evaluation by asking for an estimate of the cost to repair or replace the pump. If the user does not have that information, the model can estimate the cost based on procedure outlined in Williams et al. (1996). The estimates include pump cost, labor cost, column pipe, tube cost, and pump setting cost based on cost information collected from pump dealers. The cost of repairing or replacing the pump is subtracted from the present value of savings in operating costs to determine the net present value of pump replacement that can be expected.

Power Source Replacement

The second optional evaluation procedure determines if switching to an alternative power source is economically feasible. This analysis also accounts for income tax implications of the investment. 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 (1982) to convert the fuel consumption of the current power source to an equivalent amount of fuel for the alternative power source. Once the model estimates fuel consumption for the alternate power source, it then estimates the present value of energy savings and operating costs from switching to the alternative power source. If total savings are negative, the evaluation is complete because the power unit switch is not economically feasible.

If the present value of savings from switching power units is positive, the model estimates the cost of purchasing and installing a new power unit. The model prompts the user for an estimate of the cost to install a new power unit and gearhead (if needed) or generates an estimate based on the operating requirements specified by the user and procedures outlined in Williams et al. (1996). The costs are based on the required power unit horsepower, and power unit and gear head prices obtained from engine dealers. These investment costs are compared with the present value of total savings from switching power units over a 10-yr period. The ownership cost of the new power unit is subtracted from the present value of the 10-yr total of the annual savings to arrive at a net present value for the investment. If this results in a positive value, switching power units is economically feasible. The model also will estimate the number of years to pay back the investment costs using present value calculations. A complete documentation of the underlying engineering criteria and procedures can be found in Dvorak (1985).

Impacts of Water Table and Pump Efficiency

A third evaluation routine estimates the effect of a falling water table or decline in technical pump efficiency on operating costs. The user is prompted to enter the expected annual drop in the water table and a percentage estimate of the annual decline in pump efficiency. The model iteratively recalculates the expected flow rate and the pumping water level for each successive annual decline in technical pump efficiency and increase in water table depth or pumping lift, so the annual operating cost changes can be calculated. The program displays the total operating costs for each year over a 10-yr period.

Water Application Levels and Fuel Inflation Rates

The fourth evaluation routine in the model calculates the annual operating costs for the irrigation system under alternative levels of water application (inches applied per acre). The fifth optional procedure estimates the annual operating costs for each year in a 10-yr period, given a user-supplied scenario of annual fuel inflation rates. The operating costs for both of these evaluations are estimated by the same procedures used to estimate operating costs in the initial section of the model, using 2-inch water application increments or any fuel inflation estimate desired.

Modifying or Switching Distribution Systems

A sixth routine allows evaluation of switching from a current distribution system to a different system. For example, modifying a high-pressure center-pivot system to a low-drift-nozzle center pivot or switching from a gated-pipe system to a center-pivot system. The program conducts a net present value analysis, which determines the difference in operating costs, ownership costs, and crop returns of each system. A brief explanation of the estimation of these differences including crop returns follows. The overall net present value of returns for switching or modifying the system also is reported.

The initial part of this analysis requires that the user provide basic inputs that are used to calculate operating costs for both systems (Fig. 2). Once the inputs that influence operating costs are entered, the program requests information that affects the future operating costs, ownership costs, and crop returns of the systems. The present value of operating the current and modified or new system and the crop returns from each system are calculated for a 10-yr period. Ownership costs of the systems also are calculated. The user enters the salvage value and depreciated book value of the old distribution system and the expected salvage value of the new distribution system in 10 yr. Following this, the costs of changing power units, if applicable, or the costs of repairing or adjusting the power unit for use with the new distribution system are entered, if the old power unit is replaced. A salvage value and a depreciated book value for the old power unit are entered. A salvage value for the new power unit in 10 yr also is requested. The user is prompted next to enter the costs of repairing or replacing the pumping unit, including salvage and depreciated book values for the old pump and the expected salvage value in 10 yr for the new pump. The net present value analysis in the model is on an after-tax basis, so the marginal income-tax rate and the after-tax interest or opportunity costs to finance the purchase of new equipment or to repair old equipment are required inputs. Expected inflation rates over the 10-yr planning horizon can be entered for fuel prices, lubrication oils, electric connect charges, maintenance costs, and wages.

The after-tax net present value of crop returns for each system is calculated using expected yields, prices, government payments, and cash production costs for each system under consideration. The user must provide their own estimates of yields, commodity prices, government payments, and production costs for each system they evaluate. Yields are not simulated or estimated by the model. Different irrigation systems are able to irrigate different acreages. Center pivots typically do not irrigate field corners. In some cases, dryland crops are grown on the corners or ends of the field. The model allows the user to include dryland crop acreage to account for the nonirrigated corners when a center pivot is used or ends of the field in the case of gated-pipe furrow systems. This allows for a direct economic comparison of systems with differing irrigated acreages. The present values of crop returns are summed for the 10-yr planning horizon for each system. The present value of the difference is calculated by subtracting the present value of crop returns for the old system from the present value of the new system. A positive value indicates a higher net present value of crop returns from using the new system, whereas a negative value indicates that the net present value of crop returns is higher for the old system.

The final calculation is the after-tax net present value of returns from switching distribution systems. It is determined by summing the present value of savings in operating costs, the difference in present values of crop returns between the two systems, and the present value of net ownership cost of the new system. A positive net present value indicates that switching distribution systems is economically feasible. Figure 3 illustrates the output of this evaluation.

At the end of the annual cost calculation routine or any of the optional evaluation routines described previously, input data and output information can be saved or printed, or the user can exit the program session. Further documentation of the program, including equations and parameters used, can be found in Williams et al. (1996) and Llewelyn et al. (1997).

DATA NEEDS

Before the IEES model can be used to calculate costs or evaluate irrigation system adjustments, technical and economic data that serve as inputs to the model must be collected. Before using the computer model, a pump test should be completed for the pumping plant and irrigation system to be evaluated. Before a pump test is conducted, the power unit should be in top operating condition so that the majority of the pumping plant inefficiencies can be attributed to the pump. A significant number of pump tests do not differentiate between power unit and pump efficiency. Therefore, the assumption that the power unit is efficient is necessary to calculate pump efficiency when power unit efficiency is not measured. The program assumes that the power unit is operating at the Nebraska standard and that the pumping plant inefficiency is attributed to the pump. The required input data for each evaluation are listed in Llewelyn et al. (1997).

SOFTWARE SPECIFICATIONS

The IEES software is written in Visual BASIC for use in the Windows environment. Microsoft Windows version 3.1 or higher is required. The program is designed to run on IBM and fully compatible computers and requires at least 2 megabytes (MB) of hard disk storage space. To run IEES, 4 MB of random-access memory (RAM) are recommended. The program 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 also are included in the program. If the user enters a value for a variable that falls outside the typical specified ranges, the program will request that the user check the input data. Input data and results of the analysis can be saved on disk or routed to a printer. A user's guide is also available with examples showing actual data for each option and results of all optional evaluations.

The IEES software package is available for purchase through the Kansas Cooperative Extension Service, Kansas State University, Manhattan, KS 66506; telephone 785-532-5830; fax 785-532-7938. The package includes a floppy disk (3.5-inch) containing the IEES software (executable file, documentation text, and example data files) and a user's guide.

IMPLICATIONS FOR EXTENSION, TEACHING, PRODUCER, AND RESEARCH USES

The model can calculate costs to evaluate irrigation system adjustments, and also be used to teach producers and extension personnel the fundamentals of irrigation engineering and economics related to the pumping of irrigation water. After using the model, irrigators and educators may have a better understanding of the technical factors that impact irrigation costs as well as economic variables such as energy price and wage rates. Any of the inputs can be varied to determine the impact on the costs and returns of the irrigation system being evaluated.

Often when pumping plant performance tests are completed, questions arise concerning economic impacts of changes to the system. In most cases, the producer has been referred to a pumping plant equipment dealer. Often, no follow-up occurs, and the irrigator is left with little economic evaluation of the technical data to help make 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 can be used in classroom or extension education programs and for research purposes as well. It has been used in the classroom to demonstrate economic analysis concepts and applied investment decisions for new technology. In research, it has been used to generate irrigation cost parameters for the objective function in whole-farm linear and nonlinear programming analyses. These parameters are important for selecting optimum irrigation schedules and cropping systems for a variety of irrigation scenarios. The model also has been used to generate operating costs for irrigated crop cost-return projections and economic analyses of investments in modifications to existing systems and replacement of systems.

SUMMARY

Reliable and accurate information regarding the economic and technological aspects of irrigation is important in making decisions about the use of the various irrigation technologies available to producers. When information is not available or is inaccurate, the potential for operators to properly apply water-conserving or efficient technologies is limited.

The IEES computer model can be used to estimate irrigation operating costs and net returns of production for seven separate irrigation-distribution systems, including medium-pressure center pivot, low-pressure center pivot, LEPA center pivot, low-drift-nozzle center pivot, conventional furrow-flood gated pipe, surge furrow-flood gated pipe, and subsurface drip. Four alternative power sources can be evaluated with these distribution systems: natural gas, LP gas, diesel, and electricity. The computer model is an interactive program designed for use on an IBM or compatible computer operating in each of the available Windows environments.

The model estimates 11 operating costs associated with irrigation and calculates total operating costs and costs per acre, per hour, and per inch of water applied. An optional calculation of net returns from crop production can be performed as well. The model has six options that can be used to evaluate the effects of changes in the irrigation system. These include evaluation of replacing or repairing the pumping plant, switching the power unit, a decline in the water table and/or pump efficiency, changes in the level of water applied or in fuel costs due to inflation, and modifying or switching distribution systems. A separate optional routine allows the user to calculate the investment costs associated with installing or replacing an irrigation system.

Data are entered by the user. A pump test must be completed before evaluation to obtain necessary data. Other data from farm records, utility companies, and pump and well equipment dealers also are utilized. Suggested ranges in the values of the variables and error checking are included in the program. The model uses algorithms documented in Williams et al. (1996) to calculate fuel costs, total operating costs, net returns, and the net present value of making changes to the irrigation system. Results are reported and can be printed from the screen or saved to a file. Input data also can be saved for future use, so that the data need not be entered repetitively.

Potential weaknesses in the model include the fact that a pump test is necessary to obtain needed data for entry into the program. Some producers may opt to forego this test and guess at these values, which decreases the reliability of the estimates produced by the program. Also, the program assumes that the power unit is operating efficiently and that any inefficiencies in the pumping plant are attributable to the pump. The results are less reliable if this is not the case.

The program is suitable for on-farm use by producers who are considering changes in their current irrigation system or who wish to evaluate the feasibility of switching to a more water-efficient system. The program is not specific to a particular crop, soil, or climate. It can be used to evaluate any size irrigation system, making it valuable to producers who wish to evaluate irrigation systems for small acreages that might be used for specialty crops. It also can be useful for research regarding the economic profitability of various irrigation systems, because it provides a systematic way to determine the operating costs of and returns associated with the various irrigation systems.

ACKNOWLEDGMENTS

We appreciate the cooperation of Orlan Buller, Gary Clark, Kevin Dhuyvetter, Terry Kastens, Freddie Lamm, Harry Manges, Dan O'Brien, Matt Reed, Danny Rogers, James Sartwelle, Loyd Stone, and others who provided information for the software development. We thank graduate student programers Sharmila Sekaran, Ilango Thangavelu, Karthik Vaidyanathan, and Ravinder Vaddepally.

REFERENCES

Dorn, T.W. 1982. Selecting the most economical energy source for irrigation pumping. p. 181–201. *In* Irrigation pumping plant performance handbook. Agric. Eng. Dep., Coop. Ext. Ser., Inst. of Agric. and Natural Resources, Univ. of Nebraska, Lincoln, NE.

Dvorak, G.J. 1985. Economic analysis of irrigation pumping plants. M.S. report. Dep. of Agric. Eng., Kansas State Univ., Manhattan, KS.

Llewelyn, R.V., J.R. Williams, I. Thangavelu, and D. DeLano. 1997. User's guide to the irrigation economics evaluation system (IEES). S-97. Kansas Coop. Ext. Serv., Kansas State Univ., Manhattan, KS.

Williams, J.R., R.V. Llewelyn, D.R. DeLano, and I. Thangavelu. 1996. Irrigation cost estimation procedures used in the irrigation economics evaluation system (IEES). Res. Rep. 23. Dep. of Agric. Econ., Kansas State Univ., Manhattan, KS.◆