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Jeffery R. Williams, RichardV. Llewelyn, Dan DeLano, and Ilango Thangavelu*

July, 1996

*Professor, Research Associate, and Research Assistant, Department of Agricultural Economics, and Graduate Student, Industrial Engineering, Kansas State University, Manhattan, KS 66506.

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ABSTRACT

IRRIGATION COST ESTIMATION PROCEDURES USED
IN THE IRRIGATION ECONOMICS EVALUATION SYSTEM (IEES)

Establishment of efficient farm irrigation practices is influenced by the knowledge the irrigator has concerning both the economic and technological aspects of irrigation. The eventual goal of water conservation research is to have water users establish conservation techniques as parts of their continuing operating procedures. However, this will happen only when economic incentives exist. The farm manager requires a basic understanding of the economics of water use in order to evaluate adjustments to the irrigation system or management of water.

IEES (Irrigation Economics Evaluation System), a microcomputer model, has been 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. IEES can calculate the operating costs for seven types of irrigation systems. It also can help compare which type of irrigation system might be most economical for the manager to own and operate. In addition to calculating the annual operating costs, the model 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.

Key words -- irrigation / economics / irrigation system efficiency / irrigation costs / irrigation system management

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INTRODUCTION AND PROBLEM

Establishment of efficient 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 know how to estimate costs of irrigation under various operating conditions in order to evaluate efficient water use-techniques. However, few irrigators have good estimates of their irrigation costs or have the proper tools available to economically evaluate water use strategies. Therefore, the potential for operators to utilize water conservation or efficient use techniques is limited, and the probability for a wrong decision is high.

The eventual goal of water conservation research is to have water users establish conservation techniques as part of their continuing operating procedure. However, this will happen only when an economic incentive exists. This requires a basic understanding of the economics of water use.

The overall objective of this study is to meet this need by constructing an applicable computer model that could be used to estimate costs under a variety of operating conditions and evaluate adjustments of irrigation systems for efficient and economical water use.

The model developed as a result of this project is entitled IEES (Irrigation Economics Evaluation System). IEES has been developed for use on a microcomputer and with data collected from a pumping-plant performance test. Seven types of irrigation systems that use either natural gas, propane (LP) gas, diesel fuel, or electricity can be evaluated. These seven systems are medium-pressure center pivot, low-pressure center pivot, low-drift-nozzle center pivot, low-energy-precision-application (LEPA) center pivot, conventional furrow-flood gated pipe, surge furrow-flood gated pipe, and subsurface drip.

OBJECTIVES

The overall objective of this study is to establish a simple but applicable model that can be used to estimate costs under a variety of operating conditions. The specific objectives are to:

1. Construct a mathematical model to estimate irrigation costs for irrigation systems technically feasible for use in the High Plains region.
2. Develop mathematical subroutines within the model for use with the operating cost estimates to evaluate the economic feasibility of adjustments in the irrigation system or its frequency of use.
3. Construct the model and program the mathematical algorithm for use on a microcomputer system.
4. Develop the computer model so it can be used with technical data collected from pumping-plant performance tests and farm records.

MODEL OVERVIEW

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. These costs are:

1. Fuel cost for operation.
2. Oil cost for an internal combustion engine.
3. Annual electric connect charge.
4. Oil cost for an electric motor.
5. Oil cost for a gear drive.
6. Maintenance costs for pumping plant.
7. Repair and maintenance costs for the distribution system.
8. Labor costs for maintaining the pumping plant.
9. Labor costs for setup and takedown and operating the distribution system.
10. Cost of operating a reuse system for gated pipe systems.
11. 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. The options are:

1. Evaluation of pump repair or replacement.
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.
5. Estimates of operating costs under selected fuel inflation rates.
6. Estimates of changes in operating costs when switching distribution systems and net present value analysis of returns from switching distribution systems.

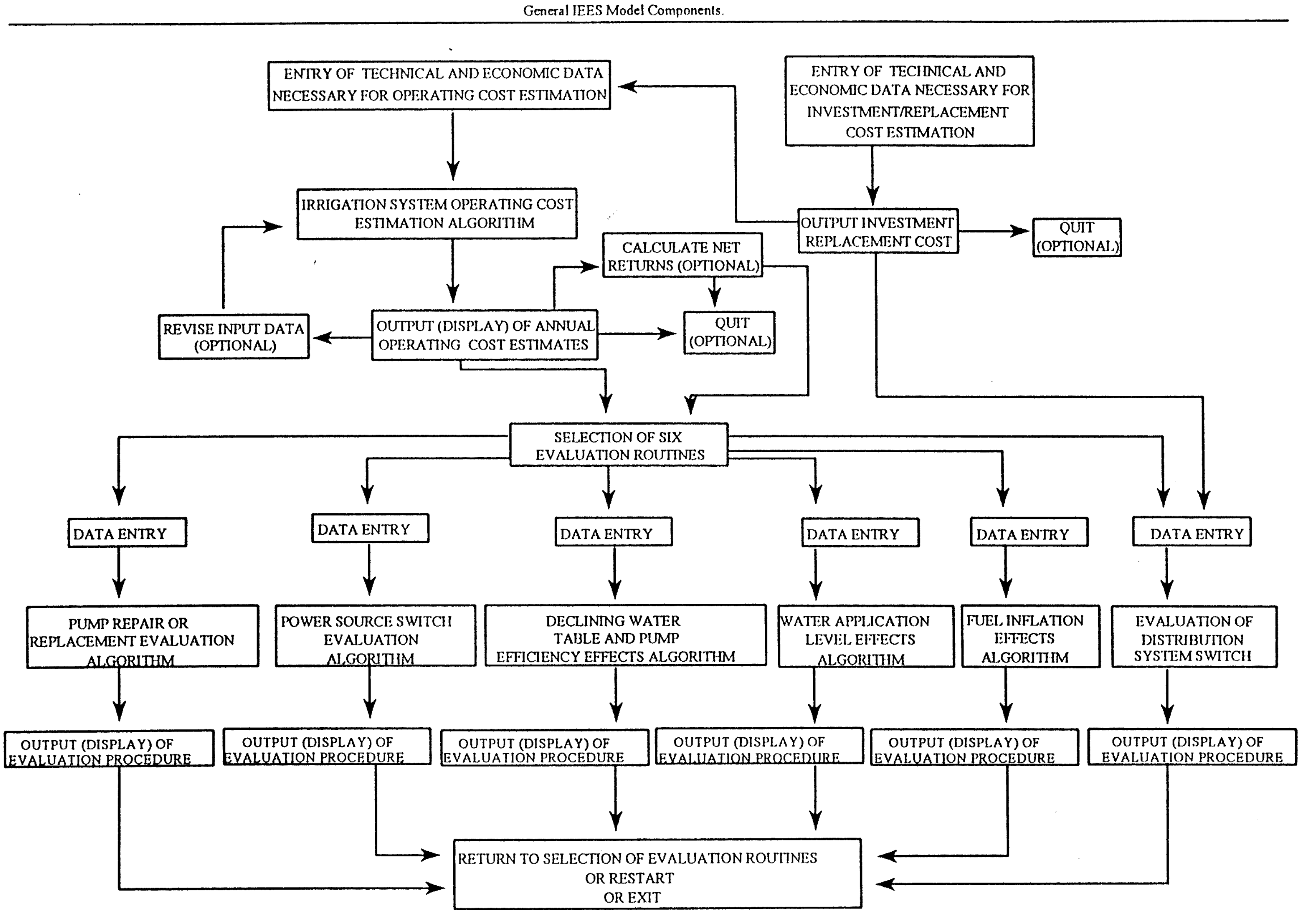
A discussion of how the model estimates costs and conducts the six evaluation options can be found in the Model Development section of this report. Figure 1 illustrates the components and steps in the general IEES model.

The computer program is written in Visual BASIC. IEES is a "user friendly" program. The computer prompts the user with specific questions to which the user must respond. The questions that are asked 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. These ranges are found in Appendix B. If the operator inputs a value for a variable that falls outside of typical specified ranges, the computer will respond with a request that the operator check the input data. Results of the analyses are routed to the computer monitor with the option of also having this information printed or routed to a file for later printing.

DATA NEEDS

Before the IEES model can be used to calculate costs or evaluate irrigation system adjustments, technical and economic data need to be collected that will serve as input to the model. The required input data for each evaluation are listed below.

FIGURE 1. General IEES Model Components.



A. Calculation of Operating Costs of Irrigation

1. Number of acres irrigated.
2. Number of inches of water irrigated per acre per season.
3. System operating pressure (PSI - pounds per square inch).
4. Pumping water level (feet).
5. Flow rate in gallons per minute (GPM)
6. Fuel consumption per hour (MCF - 1,000 cubic feet, gallon, KWH - kilowatt hours) or the efficiency of the pump (%).
7. Fuel or electricity price per unit, (MCF, Gallon, KWH).
8. BTU content of natural gas, if applicable (BTU/MCF).
9. Electric connect charge per rated horsepower, if using an electric motor for a power source ($/rated horsepower).
10. Hourly wage rate for maintenance of the pumping plant power unit ($/hr).
11. Hourly wage rate for setup and takedown and operating the system ($/hr).
12. Engine oil cost ($/gal.).
13. Drip oil cost ($/gal.).
14. Inches of water applied per irrigation cycle (optional).
15. Labor hours per irrigation cycle (optional).
16. Labor hours per irrigation season for setup and takedown (optional).
17. Gear oil cost ($/gal.).
18. Replacement cost of distribution system ($).
19. Annual repair and maintenance costs ($) of distribution system (optional). If unknown, the computer model will make an estimate.
20. Pumping plant annual maintenance cost ($) (optional). If unknown, the computer model will make an estimate.

For Optional Calculation of Net Returns

20. Expected crop price ($/bu,$/ton).
21. Expected yield of the irrigated crop (bu/a, ton/a).
22. Per-acre cash production costs excluding irrigation costs ($/a).
23. Total government deficiency payments received for this acreage ($).

B. Pump Repair or Replacement Evaluation

1. Combined marginal federal and state tax rates.
2. Allowable tax credit for installing new pump ($).
3. Estimated salvage value of the old pumping unit ($).
4. Estimated salvage value of the new pumping unit 10 years from now.
5. Estimated depreciated book value of the old pumping unit.
6. Current static water level (feet).
7. Estimate of annual fuel inflation (%/yr).

8. Annual interest rate or opportunity rate of interest for financing repair or replacement (%/yr).
9. Original pumping water level (optional).
10. Original flow rate (optional).
11. Original system pressure (optional).
12. Cost to repair pump to peak operating efficiency or replace it ($). This is an optional input, but is needed if item 14 is unknown.
13. Bowl setting depth (feet). This is an optional input, but is needed if item 13 is unknown.

C. Switching Power Units to an Alternative Power Source Evaluation

1. Fuel cost of alternative power source ($/MCF, $/gal, $/KWH).
2. BTU content of natural gas if applicable (BTU/MCF).
3. Electric connect charge if applicable ($/rated horsepower).
4. Estimate of annual fuel inflation for the original power source (%/yr).
5. Estimate of annual fuel inflation for the alternative power source (%/yr).
6. Annual interest rate or opportunity cost rate of interest to finance the purchase of an alternative power unit (%/yr).
7. Estimate of purchase and installation costs of the alternative power unit (optional).
8. Combined marginal federal and state income tax rates (%).
9. Salvage value of old power unit ($).
10. Salvage value of the new power unit 10 years from now ($).
11. Estimated depreciated book value of old power unit ($).
12. Miscellaneous costs to switch power units ($).

D. Evaluation of Water Table and Pump Efficiency Decline

1. Estimated average annual decline in water table (feet/yr).
2. Estimated average annual percentage point decline in pump efficiency (%/yr).
3. Estimate of annual fuel inflation (%/yr).
4. Current static water level (feet).

E. Evaluation of Water Application Levels

1. Minimum number of inches applied (inches/a).

F. Fuel Inflation Analysis

1. Estimate of annual fuel inflation (%/yr).

G. Evaluation of Switching Distribution Systems

1-20. Values for the new distribution for items 1 through 19 listed in Part A.
21. Estimated salvage value of old distribution system.
22. Estimated depreciated book value of the old distribution system.
23. Estimated salvage value of new distribution system 10 years from now.
24. Cost of repair and adjustment to current power unit to operate with new distribution system.
25. Cost of purchasing and installing new power unit to replace old unit.
26. Estimated salvage value of current power unit if installing a new unit.
27. Estimated salvage value of new power unit 10 years from now.
28. Estimated depreciated book value of current power unit.
29. Cost of repairing or replacing current pump.
30. Estimated salvage value of current pump if the pump is replaced.
31. Estimated depreciated book value of current pumping unit.
32. Estimated salvage value of repaired or new pump 10 years from now.
33. Annual interest rate or opportunity cost of financing new equipment or repairing old equipment (%/year).
34. Combined state/federal marginal tax rate (%).
35. Estimated fuel inflation rate over next 10 years for current fuel source (%/year).
36. Estimated fuel inflation rate over next 10 years for fuel source to be used with new distribution system (%/year).
37. Annual average inflation rate for petroleum products over next 10 years (%/year).
38. Wage inflation over next 10 years (%/year).
39. Dollar amount of income tax credit or other tax credit in first year of ownership for new irrigation system ($).
40. Inflation rate for electric connect charge over next 10 years (%/year).
41. Maintenance-cost inflation rate for power unit and pump (current system and new system) (%/year).
42. Maintenance-cost inflation rate for distribution system (current system and new system) (%/year).
43. Per acre cash costs excluding irrigation costs for crop grown with current irrigation system ($/acre).
44. Expected yield for crop grown with current irrigation system (bu/a or tons/a).
45. Per-acre cash costs excluding irrigation costs for crop grown with new irrigation system ($/a).
46. Expected yield for crop grown with new irrigation system (bu/a or tons/a).
47. Total government payments for crop grown with current irrigation system ($).
48. Total government payments for crop grown with new irrigation system ($).
49. Expected price for crop grown with current irrigation system ($/bu or $/ton).
50. Expected price for crop grown with new irrigation system ($/bu or $/ton).
51. Inflation of annual production costs excluding irrigation costs for current crop (%/year).
52. Inflation of annual production costs excluding irrigation costs for crop grown with new distribution system (%/year).

53. Acres of dryland crop grown on the corners or ends of the field when using the current irrigation system.
54. Acres of dryland crop grown on the corners or ends of the field when using the new irrigation system.
55. Gross returns per acre (yield * price) of the dryland crop grown on the corners or ends of the field when using the current irrigation system (bu/a, ton/a, etc.).
56. Gross returns per acre (yield * price) of the dryland crop grown on the corners or ends of the field when using the new irrigation system (bu/a, ton/a, etc.).
57. Cash production costs per acre for the dryland crop grown on the corners or ends of the field when using the current irrigation system ($/a).
58. Cash production costs per acre for the dryland crop grown on the corners or ends of the field when using the new irrigation system ($/a).

GENERAL REQUIREMENTS AND USE

Before using the computer model, a pump test must 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, it is necessary to assume that the power unit is efficient 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.

Data items A3, A4, A5, A6, B6, B7, and D4 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 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 two megabytes of hard disk storage space. To run IEES, four megabytes (4 MB) of random-access memory (RAM) are recommended.

Installation

The IEES software is provided on 3 ½ inch high density diskettes. IEES may be installed in either the Windows 3.1 or the Windows 95 environments. Check the system requirements above to be sure the system meets the criteria listed. To install IEES in the Windows 3.1 environment, insert the setup diskette into the appropriate floppy disk drive (usually A or B). Enter Windows and open the Program Manager window. Click File and Run. In the Command line type A:\(B:\)Setup and click OK. The IEES setup procedure will be initialized and the IEES SETUP window will appear. The user will then be prompted to indicate the directory where IEES is to be installed. The default directory is C:\IEES. If this is the desired directory click on Continue. If another directory or drive is desired, type the new path or directory and click on Continue. The IEES SETUP window will indicate which files are being copied. Once all files have been copied, the installation procedure prompts the user that "IEES Installation is Complete." Click OK and the installation procedure is complete.

To install IEES in the Windows 95 environment, insert the setup diskette into the appropriate floppy disk drive (usually A or B). Click on the Start button. Choose Run and type A:\(B:\) Setup in the command line of the Open window. Click OK to continue. The IEES SETUP window is then initialized. The user will then be prompted to enter the directory where IEES is to be installed. The default directory is C:\IEES. If a different directory is desired, type the new directory in the command line. After the directory is selected, click Continue. The IEES SETUP window will now display the installation of files. When installation is complete, the user will be prompted, "IEES Installation is Complete." Click on OK. IEES is now installed.

Alternative Installation Procedure

The IEES software is provided on a 3 ½ inch high density diskette. Insert the diskette into the appropriate floppy disk drive (A or B usually). A directory for IEES needs to be created on the hard drive, and the files copied to the directory. This may be done either in Windows or in DOS. If in DOS, go to the C:\> prompt and type md IEES and <ENTER>. This creates the IEES directory. Then type cd IEES and <ENTER> to change the directory to the IEES directory. Type copy *x*:*.* and <ENTER> where *x* is the appropriate drive. This copies all files from the floppy diskette to the IEES directory on the hard drive.

To create the IEES directory and copy the files when in the Windows 3.1 environment, enter Windows and open the Program Manager window. Open the File Manager window (usually found in the Main program group). Open a window for the hard drive (usually the C drive). Click C:\ at the top left to be sure you are in the root directory. Click File, Create Directory, and type IEES when prompted for the name of the directory to be created. Then open a window for the B:\ (A:\) drive where the IEES files are stored. When this appears, highlight all of the files on this disk by using the mouse and the Ctrl key or by using the arrow keys on the right side of the keyboard and the Shift key. Click File, Copy, and type C:\IEES when prompted for the place to copy the files.

After the files have been copied, enter Windows 3.1 and open the Program Manager window. From the menu line in Windows, select File, which produces a pull down menu. Select New and select Program Group then click OK. Type IEES in the description box and click OK. Click File, New, and Program Item. Type IEES in the description box. In the Command Line box, type C:\IEES\IEES.EXE. In the Working Directory box, type C:\IEES. Click OK. The installation is now complete for Windows 3.1.

To install the IEES program in the Windows 95 environment, you must create a new Program folder and copy all the IEES files to the new folder. To do this, insert the IEES diskette in the floppy disk drive. Click Start, then Programs. Click the Windows Explorer icon on the Windows 95 desk top to open the Windows Explorer screen. Click File on the Explorer screen's task bar to open a menu. Select New to open a menu. From the menu, click Folder to create a new program folder. A new folder icon with a default name "New Folder" appears on the Explorer screen. Highlight the "New Folder" icon. Click File on the Explorer screen's task bar to open a menu. Select Rename from the menu, and type IEES in the highlighted area to replace the default name.

Next, click on the 3 ½ inch floppy drive icon on the Explorer screen. The contents of the floppy drive will appear in the window on the right. Some of the files may be hidden, depending on the configuration of Windows 95. This is noted at the bottom left of the Explorer screen. Click on the top file listed, then highlight all of the files by holding down the Shift key and pressing the down arrow. After all of the files are highlighted, click with the right mouse, hold the mouse button and drag the mouse to the left side of the Explorer window until the newly created IEES folder is highlighted. Release the mouse button, then click Copy Here. Wait for the files to be copied from the floppy drive to the IEES folder. Then exit Windows Explorer.

To access IEES in Windows 95, two ways are suggested. First, create a shortcut IEES program icon. Click anywhere on the desktop of Windows 95 with the right mouse button to bring up a menu. Select New, to get a submenu. Select Shortcut from the submenu to open the "Create Shortcut" window. Type C:\IEES\IEES.EXE in the command line slot and click Next. Type the name, IEES, in the "Select Name for the Shortcut" slot and click Finish.

To add IEES to the Programs menu, click Start with the right mouse button, then click Open. Double-click the Programs folder, then from the command line, click File, and New, then Folder. Type IEES, then press <Enter>. Double click on the newly created IEES folder. Click

File on the command line, then Shortcut. Type C:\IEES\IEES.EXE in the command line slot and click Finish. Exit from the windows.

Uninstall Procedure

To uninstall IEES in Windows 3.1, enter the Program Manager window and highlight the IEES (or user named) group. Click on File, Delete, and then Yes to delete the group IEES.

Next, enter the File Manager window (usually found in the Main group) and double-click on the drive where IEES was installed. Click on the IEES (or user named) directory to highlight the directory. Click File and Delete. C:\IEES or the user named directory shows in the Delete line. Click OK to delete. Click Yes To All to delete the directory. Click Yes To All to confirm file deletion.

To uninstall IEES in Windows 95, click Start with the right mouse button. Choose Open from the menu. Double-click the Programs folder and click on the IEES (or user named) folder. From the command line, click File and Delete. Click Yes to remove the folder "IEES" and move all of its contents to the Recycle Bin. Click Yes again to confirm the folder deletion.

Using the IEES Program

To operate IEES in Windows 3.1, double-click on the IEES icon. In Windows 95, either double-click on the IEES icon, or start IEES by clicking Start, then Programs, and click IEES from the menu. This causes the IEES icon to appear to the right of the program name. Click on the icon.

The opening screen of IEES appears. Click Continue. The following screen, the Cost Estimate Selection window, allows the user to select the desired distribution system and power unit to be used in the analysis. Alternatively, if input data files exist, one of these files can be loaded by clicking Load Input Data. Select the appropriate directory where the input files are stored then select the file. Input files in IEES have the file extension IPD.

Once the distribution system and power unit are selected, two options exist. The user may proceed to calculate operating costs for the selected distribution system and power unit or choose to calculate investment and replacement costs of the distribution system that has been selected. If the latter option is selected, a window describing this section appears. Click Continue to advance to the worksheet used for calculating investment costs.

The investment or replacement cost for the distribution system is a necessary input in the initial section. If unknown, the program will automatically send the user to a worksheet to use as a guide for calculating investment costs. The worksheet differs for each distribution system depending upon the necessary components needed in each system. These components are listed by row. Refer to Appendix A for additional detail. The worksheet calculates the total cost for each component, the annual maintenance cost, and the salvage value at the end of 10 years. Annual maintenance cost and salvage value are calculated as percentages of initial cost using default percentages based on engineering standards for these components. These may be changed to reflect differing situations, if desired. Total investment for the entire irrigation system is calculated at the bottom of the worksheet by summing the total price of the individual components. A distribution system subtotal is also calculated. This is the value that is to be entered when prompted for a distribution system replacement cost. When finished, click OK to return to the Cost Estimate Selection window.

To continue, select Calculate Operating Costs for Your Irrigation System and click OK. An Introduction to the Operating Costs Section appears, describing the program options. Click Next, to continue. The next screen is titled Select Analysis. Only one option is available initially, that of Calculating System Operating Costs for the selected distribution system and power unit.

The program proceeds through this section, and after initial system operating costs have been calculated, returns to this menu and allows the use of the other options.

MODEL DEVELOPMENT

Annual Operating Cost Estimate Procedures

The first major component of the computer model estimates the annual operating costs for the system being evaluated using data items A1-A19. The relevant range for each variable is shown. Data can be entered from the keyboard or using the arrows next to each data box to increase or decrease the value. The cursor can be moved from one item to the next using the mouse or the Tab key on the keyboard. When all data are entered on a screen, click OK.

Many of the calculation procedures for this section of the model are drawn from a previous computer model, ICEASE, Irrigation Cost Estimator and System Evaluator, developed by Williams et al. (1985). This model has been revised to improve the method of estimating annual operating costs and expanded to estimate costs for a wider variety of systems. The critical equations used to estimate operating costs in the initial part of the program are listed below.

Annual pumping hours (PH).

$$PH = \frac{A * I}{GPM/450} \qquad [1]$$

where	A	=	acres irrigated
	I	=	inches of water applied per year
	GPM	=	flow rate in gallons per minute

Acres irrigated, inches of water applied, and the flow rate are program inputs.

Water horsepower (WHP).

$$WHP = \frac{((PSI * 2.31) + PWL) * GPM}{3960} \quad [2]$$

where PSI = operating pressure in pounds per square inch at the discharge point of the pump not the gate, sprinkler, or drip tape.

PWL = pumping water level in feet

The operating pressure and pumping water level are program inputs.

1. Calculate fuel costs (FC).

$$FC = PH * F * C \quad [3]$$

where F = fuel price per unit ($/gal, $/kwh, $/mcf)

C = fuel consumption per hour (kwh, gal/hr, mcf/hr)

Fuel price is a program input. C is measured with a pump test for a program input or calculated with equation [4].

$$C = (WHP * .75)/(PC * BTU * .001 * E_p/100) \quad [4]$$

where PC = performance criteria (energy consumption standard) in whp-h/unit of energy

BTU = natural gas BTU content (BTU/MCF)

E_p = pump efficiency (%)

.75 = 75% efficient pump at which the PC is based

The PC values are the Nebraska performance criteria for pumping plants as provided in Dorn (1982). The PC value for natural gas is 66.7 whp-h/mcf. The BTU value and .001 factor are dropped if the fuel is not natural gas. The values for PC are 6.89 whp-h/gallon for LP gas, 12.5 whp-h/gallon for diesel fuel, and

.885 whp-h/kwh for electricity. E_p is a required program input, if C is not known.

2. Calculate engine oil cost (OC).

For engine oil cost

$$OC = \frac{WHP * PH * O}{OCON} \qquad [5]$$

where O = lubrication oil price ($/gal)

OCON = oil consumption (whp-h/gal)

For diesel engines
OCON = 700 whp-h/gal

For natural gas and LP gas engines
OCON = 800 whp-h gal

The lubrication oil price is a program input. The oil consumption (OCON) values are from Thompson and Fischbach (1981).

3. Calculate the annual electric connect charge (AEC).

$$AEC = RHP * EC \qquad [6]$$

where EC = annual connect charge per rated horsepower

RHP = rated horsepower

The annual connect charge per horsepower is a program input. To estimate the brake and rated horsepower requirements, the model goes through the following procedure uses the Nebraska performance criteria (Schroeder, 1982):

a. Determine pumping plant performance (PP).

$$PP = \frac{WHP}{C} \qquad [7]$$

where C = fuel consumption (unit of energy/h)

b. Determine the performance rating (PR).

$$PR = \frac{PP}{PC} * 100 \qquad [8]$$

where PC = performance criteria (whp-h/unit of energy)

The values for PC are 6.89 whp-h/gallon for LP gas, 12.5 whp-h/gal for diesel fuel, and .885 whp-h/kwh for electricity from Dorn (1982).

For natural gas systems:

$$PR = \frac{PP/PC}{BTU * 0.001} * 100 \qquad [9]$$

where PC = performance criteria (whp-h/unit of energy)

The PC value for natural gas is 66.7 whp-h/mcf.

c. Estimate overall pumping plant efficiency (EOE).

$$EOE = PR * SOE \qquad [10]$$

where SOE = standard overall efficiency

The values for SOE are 17 for natural gas, 18 for LP gas, 23 for diesel, and 66 for electricity found in Schroeder (1982).

d. Estimate pump efficiency (E_p), assuming the power unit is efficient.

$$E_p = \frac{EOE}{PUE} \qquad [11]$$

where PUE = power unit efficiency (%)

The values of PUE for efficient power units are 22.67 for natural gas, 24 for LP gas, 30.67 for diesel, and 88 for electricity also from Schroeder (1982).

e. Estimate brake horsepower requirements (BHP).

$$BHP = \frac{WHP}{E_p/100} \qquad [12]$$

f. Estimate rated horsepower requirements (RHP).

$$RHP = \frac{BHP}{1 - derating} \qquad [13]$$

To find the rated horsepower requirements for natural gas, LP gas, and diesel engines, the brake horsepower requirements need to be derated. The derating is estimated using the procedure by Hansen et al. (1962) and Lane and Milliner (1982). The derating for this model is assumed to be as follows:

a. Elevation of 3500 feet	=	0.105
b. Temperature of 100° F	=	0.04
c. Accessories, using heat exchanger	=	0.05
d. Continuous load	=	0.2
e. Drive losses	=	0.025
Total losses (derating)	=	0.42

For electric motors the RHP = BHP.

4. Calculate drip oil cost for electric motor (EMO).

$$EMO = \frac{WHP * PH * DO}{OCONE} \qquad [14]$$

where	DO	=	drip oil price (\$/gal)
	OCONE	=	oil consumption for electric motors (whp-h/gal).

The value of OCONE is 4000 (Thompson and Fischbach, 1981.) Drip oil price is a program input.

5. Calculate gear oil cost for gear drive (GOC).

$$GOC = \frac{WHP * PH * GO}{GCON} \qquad [15]$$

where GO = gear oil price ($/gal)

GCON = gear oil consumption for gear drives (whp-h/gal).

The value of GCON is 4000 (Thompson and Fischbach, 1981). Gear oil price is a program input.

6. Calculate maintenance costs for power unit (PUM) using an operator estimate or equation [16], [17], or [18].

Natural gas or LP gas engines for

PUM = $2.40 * BHP * PH/1000 [16]

For diesel engines

PUM = $3.75 * BHP * PH/1000 [17]

For electric motors

PUM = $0.62 * BHP * PH/1000 [18]

The values used here are based on information provided in Klocke and Clark (1991).

7. Calculate repair and maintenance costs for distribution system (DSRM) using an operator estimate or equation [19].

DSRM = DSRC * DSMCF [19]

where DSRC = distribution system replacement cost ($)

DSMCF = distribution system maintenance cost factor (%).

The values of DSMCF are .05 (5%) for center pivot systems, .013 (1.3%) for gated pipe, .015 (1.5%) for surge gated pipe, and .02 (2%) for subsurface drip. These values were derived using maintenance guidelines derived by Thompson, Spiess, and Krider (1983). The value for DSRC should not include the costs of the pump, well, and power unit.

8. Calculate power unit labor cost (PULC).

$$PULC = PH * LP * WR \qquad [20]$$

where	LP	=	hours of labor required per hour of power unit operation.
	WR	=	wage rate per hour for power unit.

The values of LP are .04 for internal combustion engines (natural gas, LP gas, and diesel) and .02 for electric motors. The values used here are based on information provided in Klocke and Clark (1991).

9. Calculate labor costs for setup and takedown and operating system per season (DSLC).

$$DLSC = DSWR * ((LDE * C/U) + S) \qquad [21]$$

where	DSWR	=	wage rate per hour for the distribution system
	LDE	=	estimated labor hours per irrigation, LDE = (LD/MA)*A
	LD	=	default labor hours per irrigation for the maximum irrigated acres of the system on a quarter section
	MA	=	maximum irrigated acres per quarter section
	A	=	actual acres irrigated

C	=	total inches of water applied per season
U	=	inches of water applied per irrigation
S	=	setup and takedown hours per season

Table 1 shows the factors for each system type. Actual acres irrigated and total inches of water applied per season are program inputs. Labor hours per irrigation cycle for the MPCP and FF systems are from Williams et al. (1985). The value for the SD system is from Bosch et al. (1992). The labor requirement for the SF system is 30% less that the requirement for the FF system because fewer trips to the field are required (Cahoon, 1993). The requirements for the LPCP and LEPA/LDN are based on work by Dale et al. (1988). The number of setup and takedown hours for the center pivot and flood systems per season are from Williams et al. (1985). The number of hours for the SD system is assumed to be equivalent to that for the center pivot system. If inches of water per irrigation cycle, labor hours per irrigation cycle or labor hours for setup and takedown differ from the values used in the program, IEES allows the user to enter new values.

Table 1. Factors for Calculating Labor Costs of Operating a Distribution System.

	System[1]						
Factor[2]	MPCP	LPCP	LDN	LEPA	FF	SF	SD
LD	4	3.6	2.6	2.6	18	12.6	6.0
MA	126	126	126	126	158	158	158
U	1.5	1.25	1	1	4	4	1
S	16	16	16	16	varies[3]	varies[3]	16

[1]MPCP = Medium-Pressure Center Pivot
LPCP = Low-Pressure Center Pivot
LDN = Low-Drift-Nozzle Center Pivot
LEPA = Low Energy Precision Application
FF = Furrow-Flood Gated Pipe
SF = Surge-Flood Gated Pipe
SD = Subsurface Drip

[2]LD = Labor hours per irrigation
MA = Maximum irrigated acres per quarter section
U = Inches of water applied per irrigation
S = Setup and takedown hours of labor

[3] The number of setup and takedown hours of labor depends upon the number of inches irrigated. If inches applied is 4 or fewer, S=32 hrs. If inches applied is greater than 12, S=96 hrs. For all other amounts of water applied, S=64 hrs.

10. Calculate annual cost of reuse system for gated pipe (RS).

$$RS = \frac{3.0 * PH * F}{PC * BTU * 0.001} \quad [22]$$

where PC = fuel consumption is whp-h/unit of fuel

The BTU content value and 0.001 factor are dropped if the fuel is not natural gas. The value 3.0 represents 3 WHP. This value is based upon information received from irrigation equipment dealers.

11. Calculate annual center pivot drive costs (CPD).

$$CPD = \frac{3.0 * PH * F}{PC * BTU * 0.001} \quad [23]$$

The BTU content value and 0.001 factor are dropped if the fuel is not natural gas. The value 3.0 represents 3 WHP. This value is based upon information received from irrigation equipment dealers.

12. Calculate total cost per season (TC).

$$\begin{aligned} TC = {} & FC + OC + AEC + EMO + GOC + PUM \\ & + DSRM + PULC + DSLC + RS + CPD \end{aligned} \quad [24]$$

13. Calculate cost per acre (CA).

$$CA = \frac{TC}{A} \quad [25]$$

14. Calculate cost per acre inch (CI).

$$CI = CA/I \quad [26]$$

15. Calculate cost per hour (CH).

$$CH = \frac{TC}{PH} \qquad [27]$$

Estimates of operating costs are shown for the selected distribution system and power unit based on the data that have been entered and the calculations described above. Each cost item, 1 through 15 above, is reported. Input data for this section may be saved using the option <u>Save Input</u>. Output data may be saved also be clicking <u>Save Output</u>. If changes in the data or additional evaluation of operating costs is desired, click <u>Prev</u> to move back to the previous screens and change data. Output data can be printed directly from the screen using the <u>Print</u> command or saved to a file and printed at a later time. Use <u>Quit</u> to end the program session and click <u>Further Analysis</u> to continue. This returns the program to the Select Analysis screen where each of the six optional evaluations are now available for use.

An optional analysis within the Operating Costs section is to calculate net returns from producing an irrigated crop with this system. This option is available by clicking <u>Net Returns</u> on the Operating Costs Estimates results screen. Four inputs are required: the crop price and yield, the cash production costs excluding irrigation costs, and total deficiency payments received for the irrigated acreage. Gross crop returns (GCR) are calculated using Equation 28.

$$GCR = (P*Y*A) + GP \qquad [28]$$

where P = estimated crop price ($/bu, $/ton)

Y = expected crop yield (bu/a, ton/a)

A = acres irrigated

GP = total government payments received for this acreage ($)

Irrigation costs calculated and reported on the previous screen are reported as well. Total production costs (TC) are calculated using Equation 29.

$$TC = (CC*A) + IC \qquad [29]$$

where CC = cash production costs per acre excluding irrigation costs

A = acres irrigated

IC = irrigation costs

Net returns then are determined by subtracting Total Costs (Equation 29) from Gross Crop Returns (Equation 28) and reported with the results. The user can Print, Save Data, return to the previous screen (Prev), Quit the program session, or continue with Further Analysis.

System Evaluation Procedures

The model is constructed in such a fashion that once the annual operating costs are estimated, optional evaluations of the irrigation system can be conducted.

1. Evaluating Pump Repair or Replacement

The first optional evaluation involves determining if pump repair or replacement is justified economically. One of the most difficult parts of this evaluation is predicting the flow rate (GPM, gallons per minute) of the well, when the pump is repaired or replaced. To predict the flow rate of a repaired or replaced pump, the model uses the procedure (equation 38) developed by Pacific Gas and Electric (1984). To use this procedure for all types of systems, some slight modifications were made to a procedure for calculating the input horsepower requirements of the pumping plant.

To estimate the flow rate of the well, assuming the pump is repaired or replaced, the model uses the following equations.

1. Calculate original input horsepower or estimate input horsepower from the measured fuel consumption from the pump test (HPI).

$$HPI = \frac{EP * (EN + (2.31 * EQ))/3960 * 0.75}{0.6} \qquad [30]$$

where EP = original flow rate (GPM)

EN = original pumping water level (feet)

EQ = original operating pressure at the discharge point of the pump (PSI)

The 0.6 is dropped if the energy source is electricity and replaced with 0.9. The 0.75 is for a 75% efficient pump

If EP, EN, and EQ are unknown, HPI is estimated as follows:

Natural Gas Energy Source;

$$HPI = \frac{(C * BTU/UNIT * 1000)}{2545} \qquad [31]$$

LP Gas Energy Sources;

$$HPI = \frac{(C * 92000)}{2545} \qquad [32]$$

Diesel Fuel Energy Source;

$$HPI = \left(\frac{C * 140000}{2545}\right) \qquad [33]$$

Electric Power Energy Source;

$$HPI = (C * 1.341) \qquad [34]$$

2. Projected work horsepower (PWHP).

$$PWHP = HPI * SOE \qquad [35]$$

where SOE = expected overall pumping plant efficiency (%).

The values for SOE are 17 for natural gas, 18 for L.P. gas, 23 for diesel fuel and 66 for electricity (Schroeder, 1982).

3. Calculate well yield per foot of draw down (YIELD).

$$YIELD = \frac{GPM}{PWL - SWL} \qquad [36]$$

where GPM = current flow rate

PWL = current pumping water level (feet)

SWL = current static water level (feet)

SWL and PWL are program inputs.

4. Calculate discharge pressure head level (DL).

$$DL = PSI * 2.31 \qquad [37]$$

where PSI = current system operating pressure at the discharge point of the pump.

5. Calculate expected pumping water level (EPWL).

$$EPWL = \frac{(SWL - DL) + \sqrt{(SWL - DL)^2 + 4\left[(SWL * DL) + \left(\frac{PWHP}{YIELD} * 3960\right)\right]}}{2} \qquad [38]$$

where SWL = static water level (feet)

DL = discharge level (operating pressure * 2.31)

PWHP = projected work horsepower

YIELD = gpm per foot of draw down

6. Calculate expected flow rate (EGPM).

EGPM = (EPWL - SWL) * YIELD [39]

Once the new flow rate (EGPM) is estimated, the operating costs of the pumping plant can be calculated using the new predicted flow rate. The flow rate will be higher for the new pump in comparison to the old pump, which had a lower pump efficiency. A higher flow rate will reduce operating hours and total costs, assuming the same amount of water is applied as before the pump was repaired or replaced.

The model assumes that some conditions, such as well yield per foot of draw down and operating pressure, will be the same after the pump is repaired or replaced. In addition, the model assumes that the pump will be 75 percent efficient, the power unit will be efficient, and the estimated flow rate will be achieved.

The same procedure used in the basic operating cost component of the model is used to estimate the new annual operating costs with the exception of the energy expenditure. The new energy expense is calculated in a different manner. Standard fuel consumption figures for an efficient pumping plant are used to calculate the new energy costs with one of the following equations.

For all power sources except natural gas

$$FC = PH * F * C \quad [40]$$

where FC = new annual fuel cost ($)

PH = new pumping hours
(acres * inches)/(EGPM/450) [41]

F = fuel price per unit ($/MCF, $/gallon, $/KWH)

$$C = (WHP * .75)/(PC * BTU * 0.001 * E_p/100) \quad [42]$$

WHP = new water horsepower

$$\frac{(((PSI * 2.31) + EPWL) * EGPM)}{3960} \quad [43]$$

PSI = operating pressure in pounds per square inch at the discharge point of the pump

PC = performance criteria (whp-h/unit of energy)

BTU = natural gas BTU content (BTU/MCF)

E_p = pump efficiency % (E_p is 75 when repaired or replaced)

.75 = 75% efficiency at which PC is based.

The values for PC are 66.7 whp-h/mcf for natural gas, 6.89 whp-h/gallon for LP gas, 12.5 whp-h/gallon for diesel fuel, and .88 whp-h/kwh for electricity. The BTU and .001 are dropped, if the fuel is not natural gas.

Once the new annual operating costs are calculated, the model then estimates the savings that can be expected. The model uses an estimate of the annual fuel inflation rate expected over the next 10 years before estimating the savings. This can be considered optional, because a zero percent increase can be entered.

To calculate the annual fuel cost with fuel inflation for a 10-year period, the model uses the following equations. The first equation calculates the fuel cost, including inflation, on an annual basis for the system before any changes are made. The second equation calculates the annual fuel cost, including inflation, assuming improvements have been made to the pumping plant.

$$FC_x = FC_{X-1} * (1 + FI) \quad [44]$$

$$NFC_X = NFC_{X-1} * (1 + FI) \quad [45]$$

where FC_X = fuel cost before improvements ($/year), year (X)

NFC_X = fuel cost after improvements ($/year), year (X)

FI = fuel inflation rate (%/year), a program input

X = year 2 through year 10

To calculate the energy savings with fuel inflation, the model uses the following equation:

$$ES_X = FC_X - NFC_X \quad [46]$$

where ES_X = energy savings ($/year), year X

FC_X = fuel cost before improvements ($/year), year X

NFC_X = fuel cost after improvements ($/year), year X

X = year 1 through year 10

The total operating cost for the system is estimated annually for a 10-year period before any improvements are made and also after improvements have been made using the newly estimated GPM and pumping hours. The model estimates the annual total costs using one of the following equations:

$$OTC_X = TC + FC_X - FC_1 \quad [47]$$

$$NTC_X = ITC + NFC_X - NFC_1 \quad [48]$$

where OTC_X = total annual cost before improvements ($/year), for year X

TC = total annual costs before improvements ($/year), for first year

FC_X = fuel cost before improvements ($/year), year X

FC_1 = fuel cost before improvements ($/year), for first year

NTC_X	=	total annual cost after improvements (\$/year), for year X
ITC	=	total annual cost after improvements (\$/year), for first year
NFC_X	=	fuel cost after improvements (\$/year), year X
NFC_1	=	fuel cost after improvements (\$/year), for first year
X	=	year 1 through year 10

Once the annual total costs are calculated, the total savings can be found using the following equation:

$$TS_X = NTC_X - OTC_X \qquad [49]$$

where TS_X = total savings (\$/year), for year X

The model calculates the total savings for a 10-year period by adding the annual savings over the 10 years together. If the savings calculated are negative, the model will stop the evaluation, because it is not economically feasible to make improvements to the pumping plant.

If the savings are positive, the model will continue the evaluation by asking for an estimate of the cost to repair or replace the pump. If the user doesn't have an estimate, the model can estimate the cost to repair or replace the pump using equation 50. The estimates from this equation include pump cost, labor cost, column pipe, tube cost, and pump setting cost. The equation assumes that the pump will be replaced. To use this equation, the user must know the bowl setting depth (feet).

$$RRC = 1942.38 + (65.89 * BSD) \qquad [50]$$

$(R^2 = 0.95)$

where: RRC = costs of replacing the pump (\$)

BSD = bowl setting depth (feet)

Equation (50) is a regression analysis based on 1995 costs provided by seven well equipment dealers for wells ranging from 85 to 640 feet and the number of bowls stages installed ranging from 2 to 7.

If the required information on bowl setting depth for the above equation is known or the user of the model has an estimate of the cost to repair or replace the pump, the evaluation will continue with an after-tax net present value analysis, where discounted after-tax costs are subtracted from discounted after-tax savings for the 10 year period. Additional data required for the procedures are the combined <u>marginal</u> federal and state income tax rates, the annual interest rate, salvage value and depreciated book value of the old pump, and the salvage value in 10 years for the new pump. The depreciated book value is the value of the pump for tax purposes. If the pump has been depreciated entirely for tax purposes, then the book value is zero. If the age of the pump is more than 7 years, the book value is likely zero. The book value of the new pump in 10 years (BV^N in Equation 51) is assumed to be zero and is not included in this model, because these items are depreciated on a 7-year schedule under MACRS, the Modified Accelerated Cost Recovery System. The net cost of replacing the pump is calculated using equation 51:

$$NCP = CRP - SV^{o} + [(SV^{o} - BV^{o}) * t]/(1+IR) - SV^{N}/(1+IR)^{10} - (ITC)/(1+IR) - t * [\sum_{x=1}^{10} D_x/(1+IR)^x] + [(SV^{N} - BV^{N}) * t]/(1+IR)^{11} \quad [51]$$

where:

	NCP	=	net ownership cost of replacing or repairing the pump ($)
	CRP	=	cost of repair or replacement of pump ($)
	t	=	marginal combined federal and state income tax rates (%)
	SV^{o}	=	salvage value of old pump ($)
	BV^{o}	=	depreciated book value of old pump ($)

SV^N = salvage value of new pump in 10 years ($)

BV^N = depreciated book value of new pump in 10 years ($)

IR = after-tax interest rate or opportunity cost to finance power unit switch (%)

D_x = depreciation of new or repaired pump in year X ($/year)

ITC = income tax credit allowed for replacing the pump

The present value of the total savings is calculated using the interest rate to finance pump replacement. To calculate the present value on an annual basis, the model uses equation 52.

$$PV_X = \frac{TS_X}{(1+IR)^{x-1}} \qquad [52]$$

where PV_x = present value of savings ($/year), in year (X)

TS_x = total savings from improvements ($/year), in year (X)

IR = interest rate of finance improvements (%)

X = year 1 through year 10

To find the total discounted savings, the annual discounted savings for each year over a 10-year period are summed in Equation 53. The net cost of repairing or replacing the pump (NCP) is subtracted from the total discounted savings to show the user the savings or net present value of pump replacement (NPVPR) that can be expected over a 10-year period. These calculations are completed using Equation 53.

$$NPVPR = \sum_{x=1}^{10} PV_x - NCP \qquad [53]$$

This value is negative, if the total discounted savings are less than the estimate to repair or replace the pump. The number of years (payback period) required to pay for the repairs also is estimated, if net savings are positive.

The user has the option of saving output data by clicking Save Output. If changes in the analysis of pump repair and replacement are desired, Prev may be used to move back to the data entry tables. The user can Print output data from the screen as well. The program session can be ended using Quit. Clicking Further Analysis returns the program to the Select Analysis window to choose another option.

2. Evaluation of Switching Power Units

The evaluation procedure that determines if switching to an alternative power source is economically feasible uses many of the procedures previously discussed. 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. These values are in the table below:

Table 2: Energy Equivalency Table.

	Original Fuel			
Alternative Fuel	Natural Gas	LP	Diesel	Electric
Natural Gas	1.000	0.112	0.203	0.01435
LP	8.955	1.000	1.814	0.128
Diesel	4.936	0.551	1.000	0.071
Electric	69.718	7.785	14.124	1.000

Once the fuel consumption is estimated for the alternate power source, the annual operating costs are estimated using the same procedure used to estimate operating costs in the beginning of the model. To evaluate the switching of power units, the model estimates the energy savings from switching to the alternative power source. The energy savings are estimated for a 10-year period. This evaluation uses the same procedure that was used in the evaluation of pump repair or replacement. Equation 46 is used to estimate the energy savings. Total savings also are estimated for a 10-year period. Equation 49 is used to estimate the total savings expected from switching power units. If total savings 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 proceeds to evaluate if purchasing and installing a new power unit are economically feasible. The model prompts the user for an estimate of the cost to install a new power unit and gear head (if needed). If the user doesn't have an estimate, the model will estimate the cost. When switching to natural gas or propane (LP), the user has the option of choosing a standard-duty engine or a heavy-duty (industrial) engine. The model assumes that a gear head is needed when switching from an electric motor to an internal combustion engine. Otherwise, the gear head cost is not estimated.

Regression equations were estimated and incorporated into the model to estimate power unit and gear head costs using 1994 prices. The prices used to estimate the cost of diesel engines are based on data for Caterpillar, Cummins, and John Deere power units. For natural gas and propane power units, the price data used were for Caterpillar, Chevy, Cummins, Ford, International Harvester, and John Deere engines. The Caterpillar, Cummins, and John Deere natural gas engine prices were use to estimate the regression equations for the heavy-duty type engine. Chevy, International Harvester, and Ford prices were used to estimate the regression equation for the standard-duty engines. Electric motor costs were based on price data from U.S. Motors. The prices used to estimate the motor cost were for 3-phase super-standard holoshaft motors, which are commonly used for irrigation.

The regression equations used in the model are as follows:

Diesel = 1692.81 + (RHP * 58.58) [54]

(R-squared = 0.91)

Industrial Natural Gas = -2,053.89 + (RHP * 103.43) [55]

(R-squared = 0.71)

Industrial LP Gas -1,921.99 + (RHP * 103.49) [56]

(R-squared = 0.71)

Standard-Duty Natural Gas = 223.0 + (RHP * 41.54) [57]

(R-squared = 0.75)

Standard-Duty L.P. Gas = 512.18 + (RHP * 39.54) [58]

(R-squared = 0.72)

Electric motor = 470.38 + (RHP * 52.74) [59]

(R-squared = 0.95)

Gear head = 91.44 + (RHP * 16.06) [60]

(R-squared = 0.85)

where RHP = rated horsepower

The data used to estimate these equations were collected from equipment dealers in Kansas in 1994.

After the power unit and gear head costs are estimated, the model prompts the user for the following information:

1. Interest or opportunity cost rate to finance power unit switch.
2. Combined marginal federal and state income tax rates.

3. Salvage value of old power unit.

4. Depreciated book value of the old power unit.

5. Salvage value of the new power unit in 10 years.

6. Miscellaneous cost of switching power units.

With the interest rate, the model will calculate the present value of the total savings expected over a 10-year period using Equation 52.

Because of the variability of the costs associated with switching power units, the power unit and gear head costs are the only items estimated by the model. Any other costs associated with switching power units must be entered as miscellaneous costs by the user, if they are to be considered. If any components of the pumping plant are discarded during the power unit switch, the salvage value of these components must be entered by the user for it to be considered in the evaluation.

The depreciated book value of these components also must be entered, if greater than zero. The salvage values and book value are used with the power unit cost to determine the net ownership cost of switching the power unit as shown in Equation 61:

$$NCPU = -SV^{o} + [(SV^{o} - BV^{o})*t]/(1+IR) + CRPU + MC - SV^{N}/(1+IR)^{10} - (ITC)/(1-IR) \\ -t*(\sum_{x=1}^{10} D_x/(1+IR)^x) + [(SV^{N} - BV^{N})*t]/(1+IR)^{11} \qquad [61]$$

where:	NCPU	=	net ownership cost of replacing the power unit ($)
	CRPU	=	cost of replacement of power unit ($)
	t	=	marginal combined federal and state income tax rate (%)
	SV^{o}	=	salvage value of old power unit in year 0 ($)

BV^o	=	depreciated book value of old power unit in year 0 ($)
SV^N	=	salvage value of new power unit in 10 years ($)
BV^N	=	depreciated book value of new power unit in 10 ($) years
MC	=	miscellaneous costs ($)
IR	=	after-tax interest rate or opportunity cost to finance power unit switch (%)
D_x	=	depreciation of new power unit in year X ($/year)
ITC	=	income tax credit allowed for switching power units

The net ownership cost of replacing the power unit (NCPU) is subtracted from the present value of the 10-year total of the annual savings from Equation 52, as shown in Equation 62.

$$NPVPU = \sum_{x=1}^{10} PV_x - NCPU \qquad [62]$$

This result (NPVPU) is the net present value of a power unit switch. If this value is positive, the switching of power units is economically feasible. If the NPVPU value (net savings) is negative, the procedure is complete and the switching of power units is not economically feasible. As before, the user has the option of saving output data, returning to previous screens, quitting the program session, or continuing with further analysis.

3. Evaluation of Water Table and Pump Efficiency Decline on Operating Costs

This evaluation estimates the effect of a falling water table and/or pump efficiency decline on operating costs. The user has to enter the expected annual drop in the water table and a percentage estimate of the annual pump efficiency decline, as well as estimated annual fuel inflation and the current static water level.

This evaluation uses the same procedures that were used in the sections that estimated annual operating costs (Equations 1-24) and pump repair or replacement costs (Equations 35-43). These procedures are used for a 10-year period, so that the changes in annual operating costs because of the falling water table and pump efficiency decline.

The model assumes that the original amount of water will be pumped, so pumping hours will increase as the water table falls and the pump efficiency declines. This will increase the total pumping costs. The model starts out with the current pump efficiency as estimated or entered in the beginning of the model and assumes that the power unit will be maintained at the standard power unit efficiency for the 10-year period. The model iteratively recalculates the expected flow rate (EGPM) using Equation 39 and the pumping water level (EPWL) using Equation 38 for each successive annual decline in pump efficiency and flow rate.

In Equation 63, the expected overall pumping plant efficiency changes annually as pump efficiency declines. For estimating the expected overall efficiency, the power unit efficiency is assumed to remain at the Nebraska standard. The expected overall efficiency used in the procedure is calculated using Equation 63.

$$EE = E_p * PUE \quad [63]$$

where	EE	=	expected overall pumping plant efficiency (%)
	E_p	=	pump efficiency (%)
	PUE	=	power unit efficiency (%)

The current or first year pump efficiency (E_p) is estimated using Equation 11 or was entered directly by the user in the initial operating costs section. If a positive value for pump efficiency decline is entered by the user, E_p declines in each succeeding year, as shown in Equation

64:

$$E_p^x = E_p^{x-1} - D \quad [64]$$

where E_p^x = pump efficiency in year X (%)

D = pump efficiency decline per year (% point)

Water table decline is accounted for when using Equation 38 to estimate the new pumping water level. The static water level, entered by the user, is increased every time the model calculates the next year's pumping water level. The amount of the increase is entered by the user of the model. The yield or GPM/ft of drawdown used in Equation 38 is assumed to remain constant through the 10-year period.

Having an estimate of the flow rate using Equation 39 and the pumping water level from Equation 38, the model can calculate the pumping hours and water horsepower required to apply the same amount of water every year for 10 years. Equations 41 and 43 are used to calculate new pumping hours and new water horsepower. The new annual operating costs are estimated using the same procedures used to estimate the annual operating costs in the beginning of the model, once the new pumping hours and water horsepower required are estimated. In this case, changes occur not only in fuel costs but also in costs of engine oil, drip oil, and gear oil as well as maintenance and labor costs for the power unit and costs for reuse systems and center pivot drives. This is because of the change in pumping hours that takes place. Fuel costs are estimated using Equation 40. Engine, drip, and gear oil costs are estimated using Equations 5, 14, and 15, respectively, with the appropriate new calculated values for water horsepower and pumping hours. New power-unit maintenance costs are calculated using Equations 16-18 and the new pumping hours. Power unit labor costs are determined with Equation 20, again using the new pumping hours. Equations 22 and 23, with the new pumping hours inserted, are used to calculate the new costs for reuse system or center pivot drive. New total costs are summed as before using Equation 24 for the 10-year planning horizon. New annual fuel costs and new total operating costs are shown, and the annual change in each also is displayed. Output data can be saved to a file or printed, and changes can be made in the data using Prev. Clicking Further Analysis takes the user back to the Select Analysis screen.

4. Estimates of Operating Costs for Alternative Levels of Water Application

The fourth evaluation routine in the model calculates operating costs for the irrigation system under alternative levels of water application. The operating costs are estimated using the same procedures used to estimate annual operating costs in the initial section of the model. The only entered input is the minimum number of inches applied. Values from the initial section of the model are used in calculating total operating costs using Equations 1-24. Variable I (inches applied) in Equation 1 is the only change, as shown in Equation 65. This equation iteratively determines the number of inches of water applied for cost estimation in 2-inch intervals.

$$INCH_X = INCH_{X-1} + 2 \qquad [65]$$

where $INCH_{X-1}$ = minimum number of inches considered for application

Operating costs are calculated for a total of 10 separate water levels. Total operating costs, total cost per acre, and energy costs are displayed for each water level. Total cost per acre is calculated using Equation 25. Fuel costs are determined using Equation 3, where pumping hours from Equation 1 change for each level of water applied.

5. Estimates of Operating Costs under Selected Fuel Inflation Rates

Annual energy costs are estimated using an annual percentage factor for fuel inflation selected by the operator for a 10-year period. The following equation is used to iteratively increase energy costs.

$$ENGC_X = ENGC_{X-1} * (1 + FI) \qquad [66]$$

where $ENGC_X$ = fuel expenditure in year (X) ($)

FI = annual inflation rate for fuel costs (%)

Energy costs are estimated for the first year using Equation 3 and associated equations with the variables that were entered by the user in the initial section of the analysis. Energy costs for succeeding years are inflated by the rate of expected fuel inflation entered by the user using Equation 66, where the previous year's energy costs are multiplied by 1 plus the inflation rate. Annual energy costs for each year as well as energy cost per acre are displayed.

6. Evaluation of Switching Distribution System

The final option involves switching from the current distribution system to a different system. The user is prompted to select the desired new distribution system and then has the option of selecting a different power source or using the current power unit. The user then must input data items A1 to A19 for the new distribution system. The values for the old system are shown for comparison. With these inputs, fuel costs and total operating costs for the new system are calculated using Equation 1 through Equation 24 for a 10-year period and compared with the fuel costs and total operating costs for the original system.

In addition, the program conducts a net present value analysis, which compares the overall discounted costs and returns for the old distribution system with those of the new system. The user first enters the salvage value and depreciated book value of the old distribution system and the salvage value of the new distribution system in 10 years. 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. Salvage value and depreciated book value are entered for the old power unit and also the salvage value for the new power unit in 10 years, if the old one is replaced. The user is next prompted to enter the costs of repairing or replacing the pumping unit, including salvage value and depreciated book value for the old pump and the salvage value in 10 years for the new pump.

The net present value analysis in this part of the model is on an after-tax basis, so the combined marginal federal and state income-tax rates are required inputs as well as the annual interest rate or opportunity cost to finance the purchase of new equipment or to repair old equipment. Expected inflation rates over the 10-year planning horizon can be entered for fuel prices, lubrication oil, drip oil, gear oil, electric connect charges, maintenance costs, and wage inflation. These can be considered optional, because a zero value can be entered. These inflation rates are used to inflate the respective operating costs using Equation 67:

$$Cost_{i,x} = Cost_{i,x-1} * (1 + INF_i) \qquad [67]$$

where:

	$Cost_{i,x}$	=	the *i*th operating cost in year *X* ($)
	$Cost_{i,x-1}$	=	the *i*th operating cost in year *X-1* ($)
	INF	=	inflation rate for operating cost *i* (%)

The dollar amount of all tax credits allowed in the first year of ownership for installing new irrigation equipment is entered, as well as per-acre cash costs for producing the crop grown with the current irrigation system and per-acre cash costs for the crop that will be grown with the new irrigation system. Expected inflation in production costs also can be entered. Expected yields and prices also are entered for the crop grown with the current system and the crop that will be grown with the new system. These yields and prices are assumed to be constant over the

10-year planning horizon. The same crop can be grown under both systems or different crops can be produced. Total deficiency payments expected to be received for both the crop grown under the current irrigation system and the crop that will be grown with the new system are entered.

Different irrigation systems are able to irrigate different acreages. In some cases, dryland crops are grown on the corners or ends of the field. A common practice in the Great Plains is for fallow wheat or another dryland crop to be grown on the corners of center pivot systems, which cannot be irrigated. The model allows the user to include any dryland crop acreage on the corners or ends of the field. This allows for a direct economic comparison of systems with differing irrigated acreage. Dryland crop acres (A^D), expected dryland crop yield per acre (YLD^D), expected price per unit of yield (PR^D), per acre cash production costs (CPC^D), and total government payments (GP^D) for the dryland crop are entered for both irrigation systems. These inputs are used in Equation 70 to calculate total net crop returns for each system.

Operating costs for the current and new irrigation systems are reported first, including total costs, costs per acre, costs per acre-inch of water applied, and costs per hour of pumping. Total costs for each system then are projected over a 10-year period and reported on the following output screen. In each case, the user can save the input data, save the output data, move back to previous screens to change the input data, quit the program session, or move to the next output screen.

The final output screen reports the after-tax net present value of returns for the current and new systems and the net after-tax discounted savings that occur in operating costs when systems are switched. The operating costs are discounted for each year using Equation 68:

$$PVOC_{i,x} = [(1-t)*TC_{i,x}]/(1+IR)^x \qquad [68]$$

where:	$PVOC_{i,x}$	=	Present value of operating costs for system *i* ($) in year *X* where i = 1 to 2
	$TC_{i,x}$	=	Total operating costs for system *i* ($) in year *X* (from Equation 24)
	t	=	Marginal federal and state income tax rate (%)
	IR	=	Interest rate or opportunity cost (%)

The present value of operating costs are summed for the 10-year planning horizon for each system in Equation 69. The present value of operating cost savings (PVSAV) are calculated by subtracting the present value of operating costs for the new system ($PVOC_{2,x}$) from the present value of operating costs of the old system ($PVOC_{1,x}$) as shown in Equation 69.

$$PVSAV = \sum_{x=1}^{10} (PVOC_{1,x} - PVOC_{2,x}) \qquad [69]$$

A positive value for PVSAV indicates that cost savings take place, whereas a negative number indicates that operating costs are lower with the old irrigation system.

The after-tax net present value of crop returns for each system is calculated using expected yields, prices, deficiency payments, and cash production costs that were entered previously. Equation 70 calculates the net crop returns for each system. The difference in crop returns for the two systems is calculated in Equation 71 by subtracting the net returns for the old system from the net returns for 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.

$$\begin{aligned} NPVCR_{i,x} = {} & (1-t)*[(((YLD_{i,x}^{I}*PR_{i,x}^{I}-CPC_{i,x}^{I})*A_{i,x}^{I})+GP_{i,x}^{I})/(I+IR)^{x}] \\ & +(1-t)*[(((YLD_{x}^{D}*PR_{x}^{D}-CPC_{x}^{D})*A_{x}^{D})+GP_{x}^{0}/(1+IR)^{x}] \end{aligned} \qquad [70]$$

where: $NPVCR_{i,x}$ = net present value of crop returns for irrigation system *i* in year *X* ($)

t = marginal combined federal and state income tax rate (%)

$YLD^I_{i,x}$ = per acre irrigated crop yield using system *i* in year *X* (bu/a, ton/a, cwt/a)

$PR^I_{i,x}$ = crop price for the irrigated crop using system *i* in year *X* ($/bu, $/ton, $/cwt)

$CPC^I_{i,x}$ = per acre cash production costs for the irrigated crop for system *i* in year *X* ($/a)

$A^I_{i,x}$ = total irrigated acres using irrigation system *i* in year *X*

$GP^I_{i,x}$ = total government payments for the irrigated crop using system *i* in year *X* ($)

IR = after tax interest rate or opportunity cost (%)

YLD^D_x = yield of dryland crop in year *X* (bu/a, ton/a, cwt/a)

PR^D_x = price of dryland crop in year *X* ($/bu, $/ton, $/cwt)

CPC^D_x = cash production cost per acre for the dryland crop in year *X* ($/a)

A^D_x = total number of dryland acres in year *X*

GP^D_x = total government payments received for the dryland crop in year *X* ($)

The model allows for dryland cropping to occur on the corners or ends of the field in order to better make comparisons between systems. If no dryland crops are produced, then zero can be entered for dryland acres, prices, and yields, and the calculations do not include dryland production. The present value of crop returns are summed for the 10-year planning horizon for each system in Equation 71. The present value of the difference (PVDIFCR) is calculated by subtracting the net present value of crop returns for the new system ($NPVCR_{2,x}$) from the net present value of the old system ($NPVCR_{1,x}$) as shown in equation 71.

$$PVDIFCR = \sum_{x=1}^{10} (NPVCR_{1,x} - NPVCR_{2,x}) \quad [71]$$

where PVDIFCR = net present value of difference in crop returns ($)

$NPVCR_{1,x}$ = net present value of crop returns for the current system in year X ($)

$NPVCR_{2,x}$ = net present value of crop returns of crop returns for the new system in year X ($)

The after-tax net present value of the ownership cost of the new system is calculated using Equation 72.

$$\begin{aligned} NPVO = & -CO \\ & + SVDS + SVPMP + SVPU \\ & -t*[(SVDS-BVDS)+(SVPMP-BVPMP)+(SVPU-BVPU)]/(1+IR) \\ & +(ITC)/(1+IR) \\ & +t*[\sum_{X=1}^{10} (D_x / (1+IR)^x)] \\ & +[(SVDSAT + SVPMPAT + SVPUAT)]/ (1+IR)^{10} \\ & - t * [(SVDSAT - BVDSAT) + (SVPMPAT - BVPMPAT) \\ & + (SVPUAT - BVPUAT)]/(1+IR)^{11} \end{aligned} \quad [72]$$

where: NPVO = net present value of ownership cost of the new system ($)

CO = initial acquisition cost of the new system ($)

SVDS = salvage value of the old distribution system ($)

SVPMP	=	salvage value of the old pump ($)
SVPU	=	salvage value of the old power unit ($)
BVDS	=	depreciated book value of the old distribution system ($)
BVPMP	=	depreciated book value of the old pump ($)
BVPU	=	depreciated book value of the old power unit ($)
t	=	marginal federal and state income tax rate (%)
IR	=	after tax interest rate or opportunity cost (%)
ITC	=	income tax credit allowed in the first year for installing a new system ($)
D_x	=	depreciation deduction for tax purposes allowed in year *X* ($/year)
SVDSAT	=	salvage value of new distribution system after 10 years ($)
SVPMPAT	=	salvage value of new pump after 10 years ($)
SVPUAT	=	salvage value of new power unit after 10 years ($)
BVDSAT	=	book value of new distribution system after 10 years ($)
BVPMPAT	=	book value of new pump after 10 years ($)
BVPUAT	=	book value of new power unit after 10 years ($)

Irrigation system components are depreciated over 7 years using MACRS, the Modified Accelerated Cost Recovery System. The 1995 annual depreciation percentages allowable under MACRS are shown in Table 3. Because irrigation equipment is depreciated fully by the end of the 8 years and the analysis is for 10 years, the book values are assumed to be zero at the end of the tenth year. These values are not entered in the IEES program.

Table 3. Allowable Depreciation Percentages Using MACRS

Year	Percentage
1	10.71%
2	19.13%
3	15.03%
4	12.25%
5	12.25%
6	12.25%
7	12.25%
8	6.13%

One final calculation that is made using Equation 73 is the after-tax net present value of returns from switching distribution systems (NPVSS). It is determined by summing the present value of savings in operating costs (PVSAV from Equation 69); the difference in net present values of crop returns between the two systems (PVDIFCR from Equation 71); and the present value of ownership cost of the new system (NPVO in Equation 72), which will be a negative value. A positive net present value indicates that switching distribution systems in economically feasible where as a negative net present value indicates that a change is not feasible, given the values that are entered in the program. At this point in the program, input and output data again can be saved or printed or the user can quit the program session, return to previous screens to change parameters, or click on Further Analysis to return to the Select Analysis screen for other options.

$$NPVSS = PVSAV + PVDIFCR + NPVO \qquad [73]$$

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 inaccurate, the potential for operators to properly apply water conserving or efficient technologies is limited.

This study develops a computer model that 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. The computer model is entitled IEES (Irrigation Economics Evaluation System) and is a user friendly program designed for use on an IBM or compatible computer operating in the Windows environment.

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 production can be done 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 from inflation, and 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. Suggested ranges in the values of the variables and error

checking are included in the program. A pump test must be completed prior to evaluation to obtain necessary data. Other data from farm records, utility companies, and pump and well equipment dealers also are utilized. The model uses algorithms documented in this study 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 useful to producers who wish to evaluate smaller irrigation systems that might be used for specialty crops. It also can be useful for research regarding the economic viability of various irrigation systems, because it provides a systematic way to determine the operating costs of irrigation associated with the various systems.

BIBLIOGRAPHY

ASAE. 1977. "Remaining Farm Value, Wear-out Life and Repairs," American Society of Agricultural Engineers Yearbook. St. Joseph, Michigan.

Bosch, D.J., N.L. Powell, and F.S. Wright. 1992. "An Economic Comparison of Subsurface Microirrigation with Center-Pivot Sprinkler Irrigation." Journal of Production Agriculture 5: 431-437.

Cahoon, J. 1993. "Management Considerations in Surged Flow Irrigation." Proceedings of the 1993 Central Plains Shortcourse and Equipment Exposition. Kansas Cooperative Extension Service, Manhattan, KS. 16-23.

Dale, J.F., D.J. Bernardo, M.A. Kizer, and J.R. Nelson. 1988. "Capital and Operating Costs for Alternative Systems in the Oklahoma High Plains with Implications for the Central Ogallala Region." Oklahoma Agricultural Experiment Station.

Research Report No. P-902, Oklahoma Agricultural Experiment Station, Oklahoma State University, Stillwater, OK.

Dorn, T.W. 1982. "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, Lincoln, NE.

Dorn, T.W., P.E. Fischbach, D.E. Eisenhauer, J.R. Gilley, and L.E. Stetson. 1982. "It Pays to Test Your Pumping Plant." Irrigation Pumping Plant Performance Handbook. Agricultural Engineering Department, Cooperative Extension Service, Institute of Agriculture and Natural Resources. University of Nebraska-Lincoln, Lincoln, Nebraska.

Dvorak, G.J. 1985a. "Economic Analysis of Irrigation Pumping Plants," Unpublished Agricultural Mechanization Master's Report, Department of Agricultural Engineering, Kansas State University, Manhattan, KS.

Dvorak, G.J. 1985b. Power Unit Selection for Irrigation Pumping Plants," Department of Agricultural Engineering, Kansas State University, Manhattan, KS.

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

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

Hansen, V.E., O.W. Israelsen, and G.E. Stringham. 1962. Irrigation Principles and Practices. John Wiley and Sons, Inc. New York, NY.

Klocke, N.C. and R.T. Clark. 1991. "Irrigation Pumping Plant Alternative." Proceedings of the 1991 Central Plain Shortcourse and Equipment Exposition. Kansas Coop Ext. Serv., Manhattan, KS. Feb., p. 121-126.

Lane, D.E. and H.R. Milliner. 1982. "Engineering the Irrigation Pumping Plant," Irrigation Pumping Plant Performance Handbook. Agricultural Engineering Department, Cooperative Extension Service, Institute of Agriculture and Natural Resources. University of Nebraska-Lincoln, Lincoln, NE.

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

Pacific Gas and Electric Company. 1984. "Pumping Plant Comparison Studies," (Private Communication).

Schroeder, M.A. 1982. "Using the Nebraska Pumping Plant Performance Criteria," Irrigation Pumping Plant Performance Handbook. Agricultural Engineering Department, Cooperative Extension Service, Institute of Agriculture and Natural Resources. University of Nebraska-Lincoln, Lincoln, NE.

Thompson, T.L. and P.E. Fischbach. 1981. "AGNET "Pump" Computer Program Cost Analysis," Irrigation Pumping Plant Performance Handbook. Agricultural Engineering Department, Cooperative Extension Service, Institute of Agricultural and Natural Resources. University of Nebraska-Lincoln, Lincoln, NE.

Thompson, G.T., L.B. Spiess and J.N. Krider. "Farm Resources and System Selection." Design and Operation of Farm Irrigation Systems. M.E. Jensen, Editor. ASAE. St. Joseph, MI. (1983): 45-73.

Williams, J.R., H.L. Manges, O.H. Buller, G.J. Dvorak, and P.E. Etzold. 1985. "A Study of Managerial Irrigation Cost Estimation Procedures." Kansas Water Resources Research Institute Report No. 247, Kansas State University, Manhattan, KS.

Appendix A: System Components

1) **Medium-Pressure Center Pivot:**
- Center Pivot
- Medium-Pressure Sprinkler Package
- Power Unit
- Underground 8-inch PVC Installed
- Electric Line Installed
- Chemigation Check Valve
- Chemigation Unit
- Water Meter
- Turbine Pump
  - Pump Test
  - Pull Pump
  - Incidentals
  - Overhaul Bowls
  - Add Bowls
- Miscellaneous Costs

2) **Low-Pressure Center Pivot:**
- Center Pivot
- Low-Pressure Sprinkler Package
- Power Unit
- Underground 8-inch PVC Installed
- Electric Line Installed
- Chemigation Check Valve
- Chemigation Unit
- Water Meter
- Turbine Pump
  - Pump Test
  - Pull Pump
  - Incidentals
  - Overhaul Bowls
  - Add Bowls
- Miscellaneous Costs

3) **Low-Drift-Nozzle Center Pivot:**
- Center Pivot
- Low-Drift-Nozzle Package
- Power Unit
- Underground 8-inch PVC Installed
- Electric Line Installed
- Chemigation Check Valve
- Chemigation Unit
- Water Meter
- Turbine Pump
  - Pump Test
  - Pull Pump
  - Incidentals
  - Overhaul Bowls
  - Add Bowls
- Miscellaneous Costs

4) **Low-Energy-Precision-Application Center Pivot**:

- Center Pivot
- LEPA-Nozzle Package
- Power Unit
- Underground 8-inch PVC Installed
- Electric Line Installed
- Chemigation Check Valve
- Chemigation Unit
- Water Meter
- Turbine Pump
  - Pump Test
  - Pull Pump
  - Incidentals
  - Overhaul Bowls
  - Add Bowls
- Miscellaneous Costs

5) **Furrow Flood**:

- New 8-inch Gated PVC
- Socks
- Sock Clips
- 8-inch PVC Gate Valve
- 8-inch PVC (Underground Installed)
- 8-inch PVC Elbows (Underground)
- 8x8 inch Tee (Above Ground)
- 8x8 inch Tee (Underground)
- Check Valve
- Power Unit
- Water Meter
- Land Leveling
- Turbine Pump
  - Pump Test
  - Pull Pump
  - Incidentals
  - Overhaul Bowls
- Miscellaneous Costs

6) **Surge Flood**:

- New 8-inch Gated PVC
- Socks
- Sock Clips
- 8-inch PVC Gate Valve
- 8-inch PVC (Underground Installed)
- 8-inch PVC Elbows (Underground)
- 8x8 inch Tee (Above Ground)
- 8x8 inch Tee (Underground)
- 8-inch Surge Valve
- 8-inch PVC (For Surge)
- 8-inch PVC Elbows (For Surge)
- Check Valve
- Power Unit
- Water Meter
- Land Leveling

Turbine Pump
- Pump Test
- Pull Pump
- Incidentals
- Overhaul Bowls

Miscellaneous Costs

7) **Subsurface Drip:**

Mainline 8-inch 50 psi PVC
Submain 8-inch 50 psi PVC
Submain 6-inch 50 psi PVC
Submain 4-inch 100 psi PVC
Flushline 4-inch 100 psi PVC
8-inch PVC Elbows
8-inch PIP Crosses
8-inch PVC Tees
8- to 6-inch PVC Reducers
6- to 4-inch PVC Reducers
4-inch PVC Elbow, 3-foot Riser, Valve
PVC Glue & Solvent
8-inch PVC Gate Valves
Filter
Chemigation Check Valve and Chemigation Unit
Pressure gages--Glycerine Filled
Driptape
0.40-inch Connecting Pipe
0.40-inch Loc Sleeve
Bondable Saddle
Plastic Manhole
Water Meter
Power Unit
Turbine Pump
- Pump Test
- Pull Pump
- Incidentals
- Overhaul Bowls
- Add Bowls

Miscellaneous Costs

Appendix B: Suggested Ranges in IEES

Variable		Range
1.	Acres irrigated:	1 to 160 acres
2.	Inches of irrigation water applied:	1 to 32 inches
3.	System operating pressure (PSI):	65 to 85 PSI for MPCP
		25 to 65 PSI for LPCP
		15 to 25 PSI for LEPA
		15 to 25 PSI for LDN
		1 to 15 PSI for FF
		1 to 15 PSI for SFF
		5 to 20 PSI for SSD
4.	Pumping water level:	1 to 800 feet
5.	Flow rate (GPM):	100 to 2000 GPM
6.	Pump efficiency:	40% to 85%
7.	Fuel prices	
	Natural gas price:	$2.00 to $6.00 per 1000 cubic feet
	LP price:	$0.60 to $1.20 per gallon
	Diesel price:	$0.80 to $1.50 per gallon
	Electricity price:	$0.05 to $0.15 per kilowatt hour (KWH)
8.	BTU content for natural gas:	800 to 1000 BTU per 1000 cubic feet
9.	Electric connect charge:	$0.00 to $40.00 per rated horsepower (RHP)
10.	Wage rate for maintenance of pumping plant power unit:	$4.00 to $50.00 per hour
11.	Wage rate for set-up/takedown and operating the system:	$4.00 to $20.00 per hour
12.	Engine oil price:	$3.50 to $10.00 per gallon
13.	Drip oil price:	$2.00 to $10.00 per gallon
14.	Gear oil price:	$3.50 to $10.00 per gallon
15.	Static water level:	1 to 800 feet
16.	Annual fuel inflation:	0% to 25%
17.	Annual interest rate or opportunity cost:	0% to 25%
18.	Combined marginal federal/state income tax rate:	0% to 100%
19.	Annual decline in water table:	0 to 5 feet per year
20.	Annual decline in pump efficiency:	0% to 3%
21.	Inflation rates for lubrication oil, drip oil, gear oil, electric connect charge, maintenance cost, and wages:	0% to 25%
22.	Per acre cash costs of producing irrigated crops:	$50 to $999 per acre
23.	Production cost inflation:	0% to 100%

KSU
KANSAS STATE UNIVERSITY

Agricultural Experiment Station, Kansas State University, Manhattan, 66506–4008

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