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IRRIGATION LOAD MANAGEMENT OPTIONS IN WISCONSIN

by

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Summary:

The study examined the possibility of shifting irrigation energy demand to off-peak periods with limited impact on growers' irrigation and crop management programs. Opportunities for and barriers to implementing demand side management methods were investigated. Wisconsin irrigators can participate in load control management programs by increasing the irrigation system's capacity from the current range of 3030 to 3785 L/min (850-1000 gpm) to about 5000 L/min (1320 gpm).

Keywords: Electrical energy, load control, irrigation systems

INTRODUCTION

Irrigated land in Wisconsin totaled 330,000 acres in 1992 [USDC, 1994]. Approximately 230,000 acres are irrigated by electrically powered center pivot systems. Pumping plant capacity ranges from 1890 to 4165 L/min (500-1100 gpm). The water deficit (rainfall - ET), rainfall uniformity (timing and amount), and variable water needs of the crop during critical growth stages makes irrigation very economical on droughty (sandy) soils.

Potato, field corn, snap bean, sweet corn and alfalfa are major irrigated crops. Potato, with a very shallow root zone of 30 cm (1 ft), is the most difficult crop to manage because crop quality and value is very sensitive to water stress. The other canning and field crops with deeper root zones are less sensitive to stress, so have fewer irrigation management problems.

Over-irrigation of major crops is estimated to be 10 to 25% of total usage. Wisconsin growers over-irrigate because the "risk-of-being-wrong" is large. Electrical energy is only 5 to 6% of the total potato crop production costs. Stressing the crop could reduce quality, and therefore revenues, by 25 to 30%. Penalties are too great compared to the relatively low cost of irrigation.

Annual use of electricity by all of Wisconsin's agriculture is only 3% of the total, but powering irrigation pumping plants (75-100 kW) is thought to be highly correlated with utility peak demand periods. Of the approximately 3700 irrigation wells in Wisconsin, four utilities each have over 400 irrigation customers; three have between 40 and 120 customers. The summer peaking utilities are most active in demand side management of irrigation customers.

IRRIGATION ENERGY DEMAND MANAGEMENT PRACTICES

Energy conservation and load shifting is encouraged through rebates and pricing incentives. Irrigators appreciate the need for demand side management but are concerned about loss of control over irrigation management decisions.

Rebates For Converting To Low Pressure -

One Wisconsin utility's conservation rebate program pays $200 per kW saved, $10 per kW for installing a high efficiency motor, a first year price reduction of $0.02 per kWh, and up to $300 for a pump test. A lower operating pressure will reduce costs, but farmers must be convinced the low/medium pressure systems will perform satisfactorily with their crops before converting their systems. Growers think irrigation risks are reduced if pumping capacity is increased during the conversion.

The average cost to convert to low pressure with the same or reduced pumping capacity is approximately $6260 in Wisconsin. A new pumping plant to increase capacity (column, shafting, motor and control panel) and convert to low pressure will cost between $12,000 and $14,000.

tion systems based on irrigation system operating pressure and capacity, crop, soil type and climatic factors. The modeled results are used to compare low and high pressure systems, system capacities, impact of load management on farmers' crop management, and on-peak use for different system sizes and irrigation scenarios.

The modeled crops were potato, snap bean, sweet corn and alfalfa. Potato, a very high value crop, is highly sensitive to drought. Snap bean and sweet corn are canning/processing crops grown in rotation with potato. Snap bean is planted early (June 1st) or late (July 1st). Alfalfa is a long season (April-October) crop with 3 to 4 harvests. Effective root depths of potato, snap bean, sweet corn and alfalfa are 30, 61, 76 and 91 cm (12, 24, 30 and 36 in), respectively.

The model components are (Figure 1):

1. Seasonal irrigation use (mm or in) on Plainfield loamy sand using the Wisconsin Irrigation Scheduling Program (WISP). Daily rainfall and ET data for 1987-1992 used in the model were from the Agricultural Research Station near Hancock.
2. Hours needed to apply the irrigations for system capacities of 3030, 3785 and 5110 L/min (800, 1000, 1350 gpm).
3. Total electrical use and load curves for TOD, DLC and no load control scenarios.

SEASONAL IRRIGATION WATER NEEDED

Seasonal irrigation use was calculated for potato, snap bean, sweet corn and alfalfa. Potato is used to demonstrate the model.

Percent canopy cover input for potato was estimated using a preliminary Russet Burbank potato canopy coverage model under development in the Department of Horticulture, University of Wisconsin-Madison. The potato canopy coverage model relates the growing potential of potato to degree days. The planting date for potatoes is April 20th with emergence on May 10th. The allowable soil water depletion (AD) on Plainfield loamy sand for potato is 18 mm (0.7 in) for a rooting depth of 30 cm (1 ft). The irrigation scheduling scenarios were:

Conservative, but normal grower irrigation schedule
  P1: 13 mm (0.5 in) if AD BAL $\leq$ 5 mm (0.2 in)
Over-irrigation
  P2: 19 mm (0.75 in) if AD BAL $\leq$ 5 mm (0.2 in)
  P3: 13 mm (0.5 in) if AD BAL $\leq$ 7.6 mm (0.3 in)
An extra day to decide (rain?) (actually P3, but wait a day)
  P4: 13 mm (0.5 in) day after AD BAL $\leq$ 7.6 mm (0.3 in)
Maximize effective rainfall
  P5: 5 mm (0.2 in), but keep AD BAL $>$ 5 mm (0.2 in)
Time-of-day operation
  P6: 4 mm (0.15 in) weekdays (Mon.-Thurs.) if AD BAL $\geq$ 13 mm (0.5 in); bring to field capacity during the weekend (Fri. 8 P.M.-Mon. 8 A.M.); no irrigation

ELECTRICITY USE PATTERNS

The impacts of several strategies for irrigation scheduling and demand side management on electrical load and usage were examined. Load curves determine possible barriers to demand side management options. The load curves were determined for a center pivot irrigation system to view the:

1. Total electricity use of high vs. low pressure systems.
2. Electrical usage at different system capacities.
3. Impact of load management on crop management.
4. Portion of on-peak operation for irrigation programs.

The depth (amount) of irrigation water applied (cm or in) is converted to the quantity of electricity (in kWh) needed to make the application. The conversion to energy used (kWh) is based on system operating water pressures (low of 172 kPa, 25 psi, and high of 483 kPa, 70 psi), average lift in the well of 23 m (76 ft), pumping efficiency of 65%, water application efficiency of 85%, and three pumping rates of 3030, 3785 and 5110 L/min (800, 1000 and 1350 gpm). The 3030 L/min (800 gpm) rate is the average pumping capacity of an irrigation well in Wisconsin. The 1000 gpm pumping rate has been the design capacity for 30 years. The 1350 gpm capacity was the desired rate for low pressure systems indicated in the focus group meetings.

The amount of electric power needed to pump is:

$$EP = \frac{0.746 \times Q \times H}{3960 \times 0.65}$$

where: EP = Electric Power, kW
Q = Pumping Rate, gpm
H = Total head, ft

The irrigation water applied (mm or in), as calculated by WISP, is converted into hours needed to irrigate for each pumping capacity on a 53.8 ha (133 ac) field with a center pivot irrigation system. The amount of water irrigated is converted to the amount of hours needed to apply the water. By knowing the electrical power of the system and the number of hours of operation (Table 3), electrical use can be determined. The number of hours to irrigate for the three pumping rates is converted to electrical use or load curves using three electrical or operational scenarios:

- E1: Irrigate only during off-peak hours (12 hr Mon.-Fri. and 24 hr on Sat.-Sun.) for TOD rates;
- E2: Start irrigating at 6 A.M. and continue irrigating until the required amount is applied (general user rate);
- E3: Irrigate up to 18 hours a day (DLC of 6 hr/day).

uling program to changing seasonal and year-to-year climatic conditions.

3. A 3785 L/min (1000 gpm) irrigation system can be operated under a DLC program, but the grower must use a very conservative irrigation scheduling program. In years of extreme drought, the irrigation program will have several failures, defined as days when the system cannot deliver sufficient water to keep the crop from suffering stress which reduces yield and quality.

4. A system with a capacity of 3030 L/min (800 gpm) cannot participate in a load-control program because economic losses are too large. These systems can successfully irrigate less demanding crops, such as sweet corn, snap beans, field corn and alfalfa.

Incentives which encourage growers to increase pumping capacity and reduce pressure will permit an irrigation system to operate off-peak. The larger pumping plant capacity gives growers more irrigation management flexibility and increases their acceptance of load management programs. Increasing a system's capacity from 3785 L/min (1000 gpm) to 5110 L/min (1350 gpm) will increase the demand for a low pressure system by about 15 kW, from 45 to 60 kW. With the increased capacity, irrigation can be totally done during off-peak hours for potato (the most sensitive crop) with a moderately aggressive scheduling program. Use of the weekend off-peak hours can take up the slack during extreme weather conditions (drought). Incentive programs to increase well capacity should have requirements for off-peak energy use.

The cost in dollars per kW for changing the center pivot and pumping plant was investigated (Table 4). The options were:

1. Reduce system operating pressure.
2. Reduce operating pressure and increase pumping capacity in an existing well.
3. Reduce operating pressure and increase pumping capacity by constructing a new well.
4. Increase pumping capacity of a low pressure system in an existing well.

Table 4. Cost per Kw for System Conversion

kW	Increase Capacity	Reduce Pressure	New Well	Cost ($)	$/kW
75 to 45	No	Yes	No	~~13,000~~ 6260	209
75 to 60	Yes	Yes	No	~~6,260~~ 13000	173
75 to 60	Yes	Yes	Yes	22,500	300
45 to 60	Yes	No	No	13,000	289

Reducing the operating pressure of the system while increasing the pumping capacity of an

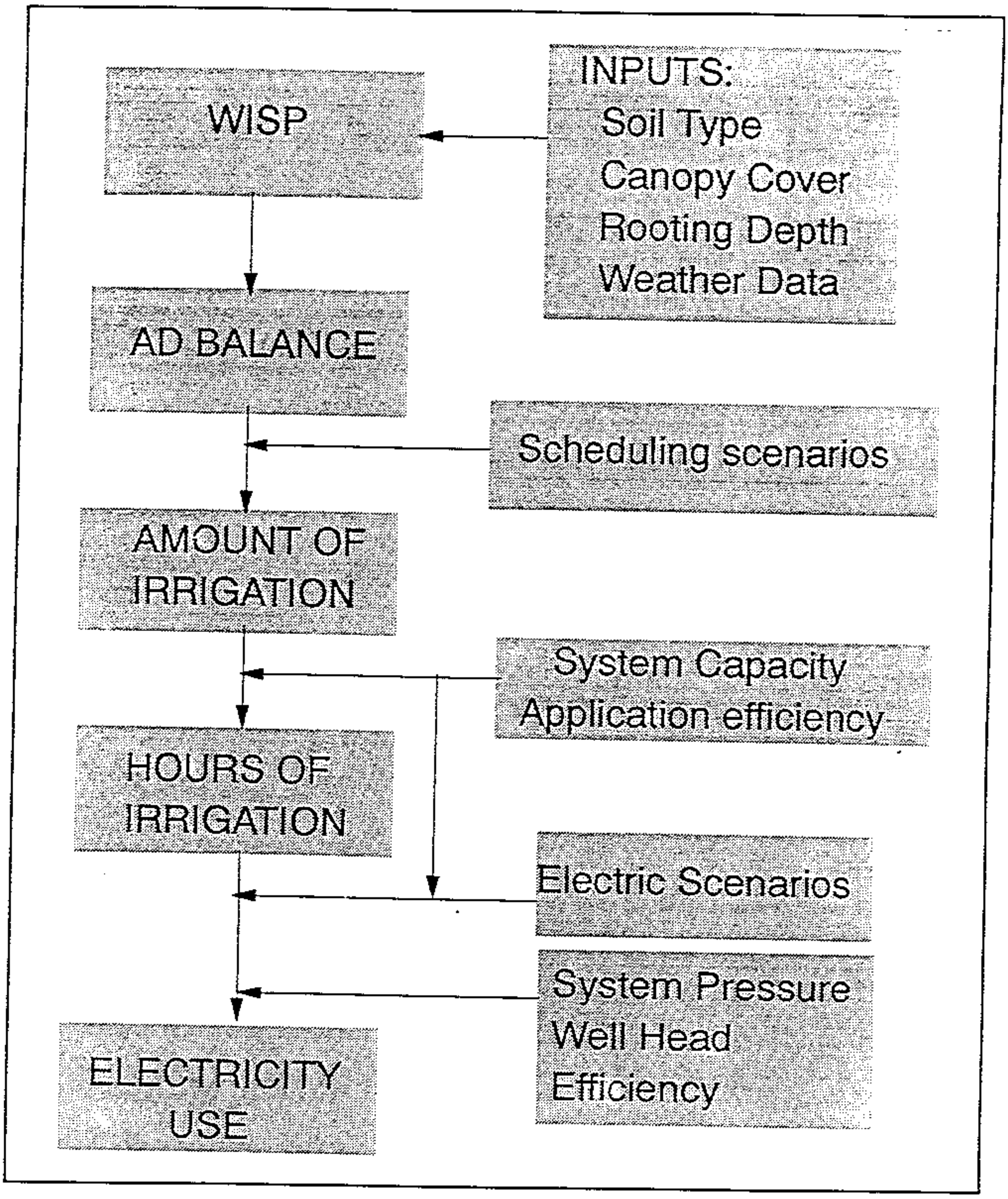

Fig. 1. Diagram of the irrigation modeling.

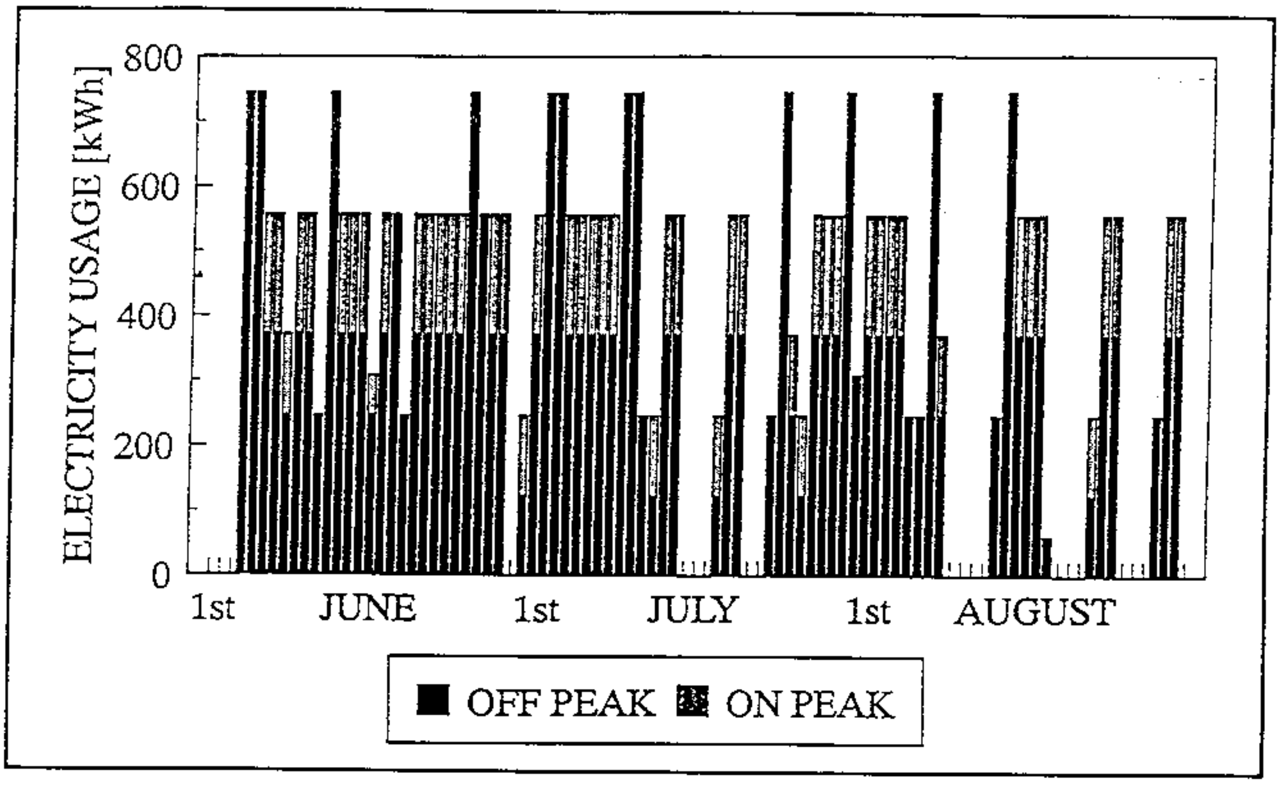

Fig. 4. Load curve: P1-E3-Low-800 gpm, 1988.

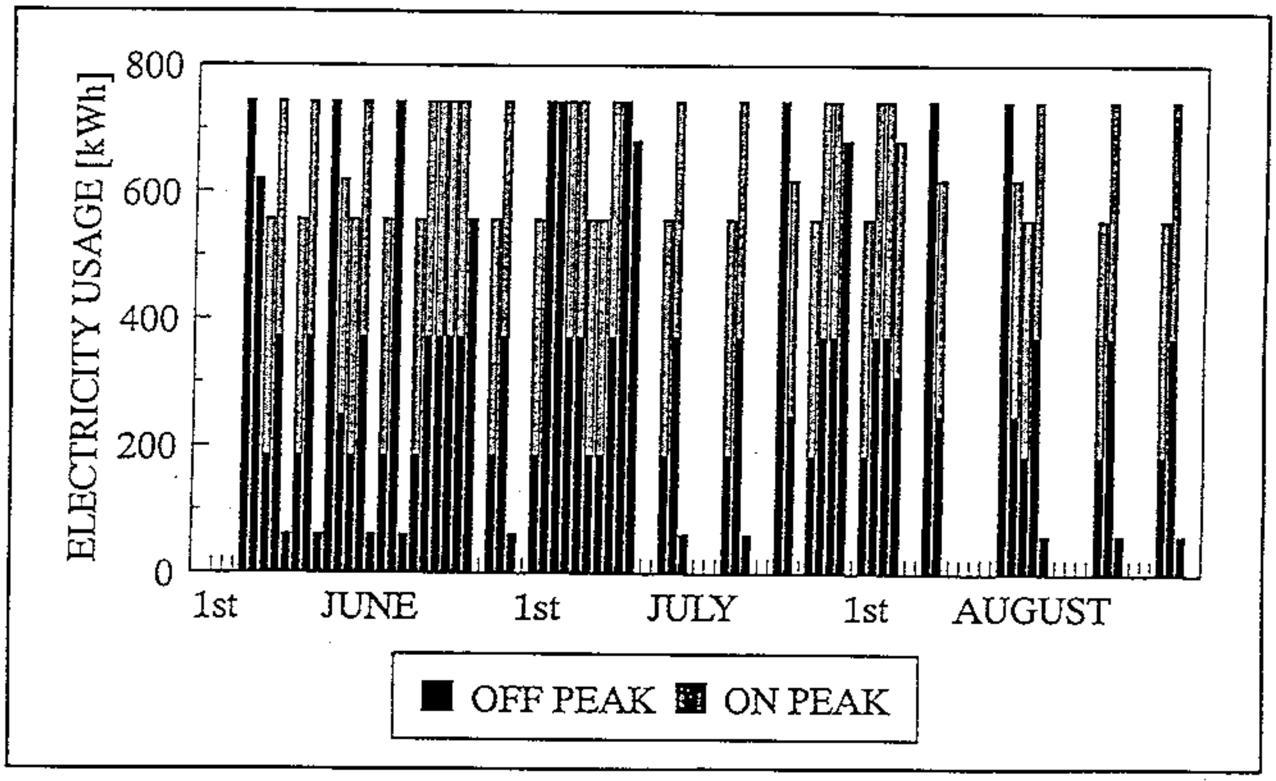

Fig. 5. Load curve: P1-E2-Low-800 gpm, 1988.