Potential Conservation Opportunities from the Use of Low-Pressure Irrigation in the Pacific Northwest Region

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POTENTIAL CONSERVATION
OPPORTUNITIES FROM
THE USE OF LOW-PRESSURE IRRIGATION
IN THE PACIFIC NORTHWEST REGION

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SUMMARY

This report documents research efforts to identify the potential energy savings and the costs per kWh saved from reducing the operating pressures of the sprinkler irrigation systems currently being used in the Pacific Northwest agricultural sector. These efforts are part of an overall project aimed at developing a computer model and data base that will allow for estimation of the potential energy savings and cost effectiveness of a number of conservation technologies that are available for use in irrigated agriculture. The research is being sponsored by the Bonneville Power Administration (BPA), Division of Conservation Planning, and is intended to aid BPA in its overall conservation planning efforts.

A computer model that simulates the energy consumption process of irrigation systems and estimates the levelized costs of undertaking conservation improvements has been developed by Pacific Northwest Laboratory personnel and is the primary analytical tool utilized in this research. The model, which has been given the name "ISEP" (Irrigation Sector Energy Planning), generates energy savings and cost per kWh saved estimates using engineering and economic input parameters for the various conservation measures that could potentially be implemented in irrigated agriculture. The objective of this report is to provide documentation on the input parameters that were provided to the model and the output results that were generated pertaining to the conversion of sprinkler irrigation systems to low pressure.

In this report, four types of low-pressure irrigation system designs are examined. These designs include low-pressure single spray systems, low-pressure spray boom systems, furrow drop-tube systems, and low-pressure impact sprinkler systems. Extensive contacts were made with irrigation equipment dealers, irrigators who currently use low-pressure systems, and other knowledgeable experts in an attempt to identify representative operating pressures for low-pressure irrigation systems. On the basis of these contacts, representative design operating pressures ranging from 14 psi for furrow drop-tube systems to 35 psi for low-pressure impact sprinklers were identified as appropriate inputs for use in the model.

The costs associated with converting to low-pressure irrigation are site specific and include the cost of performing pump modifications, as well as the cost of the low-pressure irrigation equipment itself. However, extensive contacts with knowledgeable field experts were again utilized to obtain the most representative input numbers possible on the costs per acre of converting existing irrigation systems to low-pressure irrigation. Data from BPA's Irrigation Conservation Pilot Program was also incorporated into our information base. The representative costs of low-pressure conversion selected for input to the model ranged from \$15 per acre for low-pressure impact sprinklers on handmove and sideroll systems to \$78 per acre for spray booms on center-pivot systems.

Concerns have often been expressed about the technical feasibility of converting sprinkler systems to low-pressure irrigation, especially on steep slopes and tight soils. Possible technical limitations to the use of the various low-pressure alternatives were researched, and it was concluded that there are generally no technical limitations to the use of some type of low-pressure irrigation system. Estimates of the acreages that may have already been converted to low pressure were developed so that remaining potential conservation would not be overestimated. On the basis of this research, approximately 311,000 acres under center-pivot irrigation and 47,000 acres under handmove and sideroll were subtracted from our baseline acreage estimates.

The operating pressure and cost per acre numbers selected for input to the model were generally in the high range of the available estimates. This would tend to cause the output results on the aggregate potential energy savings and the cost per kWh saved for low-pressure irrigation systems to be conservative. However, even under these conservative assumptions, we estimate that approximately 21 average MW could potentially be saved from the conversion of high-pressure center-pivot sprinkler systems to low-pressure single-spray systems at a cost that would average approximately 10.5 mills per kWh saved. Approximately 39 average MW could potentially be saved from the conversion of high-pressure handmove and sideroll sprinkler systems to low-pressure impact sprinkler systems at a cost that would average less than 18 mills per kWh saved.

CONCLUSIONS AND RECOMMENDATIONS

In this study, four types of low-pressure irrigation technologies were examined in reference to their energy-savings potential and their costs per kWh of savings. Various conversion alternatives were selected for analysis from among the technologies of low-pressure single spray systems, low-pressure spray booms, furrow drop-tubes, and low-pressure impact sprinklers. A summary of the conversion alternatives that were analyzed and the major results for each alternative is presented in Summary Table 1. It should again be emphasized that the energy-savings input parameters selected for use in this analysis were generally in the low range of available estimates and the cost input parameters were generally in the high range of available estimates. Thus, the energy-savings estimates shown in Summary Table 1 should be conservatively low, and the cost per kWh saved estimates should be conservatively high.

SUMMARY TABLE 1. Low-Pressure Conversion Alternatives Selected for Analysis and the Major Results for Each Alternative

<u>Conversion Alternative</u>	<u>Estimated Average Cost Per kWh Saved (Mills)^(c)</u>	<u>Estimated Savings On Existing Acres (MW)</u>	<u>Estimated Savings Potential on New Acres (MW)</u>
HPICP ^(a) to LPSSCP ^(b)	10.5	21.4	6.7
LPSSCP to LPSBCP ^(d)	31.7	5.5	Not Estimated
HPICP to LPSBCP	16.0	26.9	Not Estimated
LPSSCP to FDTCP ^(e)	14.3	10.6 ^(f)	Not Estimated
HPIHS ^(g) to LPIHS ^(h)	17.8	39.0	7.2

(a) HPICP = High Pressure Impact sprinklers on Center Pivots

(b) LPSSCP = Low Pressure Single Spray on Center Pivots

(c) Calculated assuming a 20-year system life and a 3% real cost of capital.

(d) LPSBCP = Low Pressure Spray Boom on Center Pivots

(e) FDTCP = Furrow Drop Tube on Center Pivots

(f) Because of technical questions about furrow drop-tube systems, this number should not be incorporated in conservation planning activities.

(g) HPIHS = High Pressure Impact sprinklers on Handmove and Sideroll systems

(h) LPIHS = Low Pressure Impact sprinklers on Handmove and Sideroll systems

The study results show that a technical potential currently exists for saving approximately 21 average MW in the BPA service area through the conversion of existing center pivots using high-pressure impact sprinklers to low-pressure single spray application heads. These savings could be achieved at a cost that would average approximately 10.5 mills per kWh saved.

The use of spray booms could allow for reductions in irrigation system operating pressures below those of single spray systems. However, our analysis indicates that the potential additional energy savings benefits of spray booms compared to single spray systems would generally be relatively costly. The cost per kWh saved for using spray booms rather than low-pressure single-spray systems would average almost 32 mills per kWh saved, according to our analysis. This does not imply that spray booms should not be considered as a conservation option, because in fields with steep slopes and tight soils, these systems or low-pressure impact sprinklers may be an irrigator's best alternative. We estimate that the conversion of high-pressure impact sprinklers to spray booms on existing center-pivot acreages could potentially result in savings of approximately 27 average MW at an average cost of 16 mills per kWh saved.

Furrow drop-tube systems operate at pressures below those of single spray and spray boom systems, and thus they have the potential to produce even greater energy savings. However, a substantial degree of uncertainty exists concerning the technical and economic feasibility of using these systems in the Pacific Northwest. If it is assumed that the use of furrow drop-tube systems would not increase irrigation system operating and maintenance costs by a significant amount, then the use of furrow drop-tube systems instead of low-pressure single spray systems could result in a savings of approximately 11 average MW on existing center-pivot acreages at an average cost of approximately 14 mills per kWh saved. However, there does not appear to be enough available information to allow for the use of such an assumption, and significant questions remain concerning the technical capabilities of furrow drop-tube systems. These systems do appear to have enough potential for further testing and demonstration activities to be warranted. However, the results of these activities should be known before furrow drop-tube systems are incorporated in estimating conservation potentials.

The technology of using low-pressure impact sprinklers on handmove and sideroll irrigation systems is currently not as well known and widespread as is the conversion of center pivots to low pressure. However, our analysis indicates that about 39 average MW could be saved in the region through the conversion of existing handmove and sideroll systems to low-pressure impact sprinklers. These savings could be achieved for an average cost of about 18 mills per kWh saved, including the additional operating and maintenance costs that would be incurred in using an irrigation management technique known as offsetting to obtain adequate water application uniformity. Despite the potential benefits of conversion to low pressure on handmove and sideroll systems, substantial resistance to the technology exists because of concerns about potential yield reductions. Further field demonstration and testing of the technology is recommended as a means of alleviating these concerns.

Based on cost-effectiveness criteria and current trends in irrigation-equipment sales, it is believed that low-pressure single spray systems are the low-pressure conversion alternative that is most likely to be adopted by irrigators using center pivots. Thus, 21 average MW would appear to be the appropriate estimate to use in conservation planning activities for the potential energy savings that can be achieved through conversions to low pressure of existing center pivots. When added to the 39 average MW that could potentially be obtained from the conversion of handmove and sideroll systems to low pressure, an estimate of approximately 60 average MW for the total potential energy savings from low-pressure conversions on existing sprinkler-irrigated acreages is obtained.

It is also estimated that an additional 6.7 average MW can be saved by 2003 on new center pivots. The costs of the savings on new acres (not shown in Summary Table 1) should generally be zero because no evidence was found that low-pressure systems should cost more than high-pressure systems on new center pivots. The estimated potential savings for low-pressure irrigation on new handmove and sideroll systems are 7.2 average MW. The costs associated with obtaining these savings are estimated to average about 7.5 mills per kWh saved. These costs can be attributed solely to the additional operating and maintenance costs associated with the use of offsetting.

Our analysis used a 20-year life in estimating the cost per kWh saved for conservation planning purposes; and based upon technical considerations alone, this may be a conservative value. However, a problem often arises regarding the time frame over which an irrigator must recoup his investment in energy saving technologies. Many irrigators cannot wait 20 years, or even 5 years, to pay back an investment in energy saving technology. Our analysis illustrates that a 3-year payback requirement will often cause the cost per kWh saved for investments in low-pressure conversion to exceed 50 mills per kWh saved.

RECOMMENDATIONS

On the basis of our research, we recommend the following:

- o further research efforts to accurately characterize and monitor the conservation already achieved through low-pressure conversion;
- o further field testing and demonstration of the use of furrow drop-tubes on center pivots and low-pressure impact sprinklers on handmove and sideroll systems.

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1.0 INTRODUCTION

Conservation was forecast to be the primary source of power for meeting the demands of the Pacific Northwest in a plan recently adopted by the Pacific Northwest Power Planning Council. Conservation in the irrigated agriculture sector was incorporated as an important component of the overall conservation effort in the Council's plan.

The Bonneville Power Administration (BPA) is expected to play a major role in the implementation of conservation programs in the region. In keeping with this role, BPA contracted with Pacific Northwest Laboratory to perform additional research on conservation in the irrigated agriculture sector. This report is the first in a series of four that will address the costs and energy-savings potential of various technologies that could be used to reduce the energy used by irrigators in watering their crops.

This report is intended to provide information on the costs and energy-savings potential of various technologies that are referred to collectively as "low-pressure conversion technologies." Although each of these technologies has characteristics which make it unique, all of the technologies reduce irrigation energy use by reducing the operating pressures of the irrigation application systems. In general, experience with low-pressure conversions has shown that the technologies can be used without adversely affecting the water distribution performance of irrigation systems.

In conjunction with its planning efforts, BPA required that specific information on the energy-savings potential (in average megawatts) and the cost per kilowatt-hour saved be developed for each conservation technology selected for analysis. To aid in this effort, a computer model of the irrigation energy consumption process was developed by PNL personnel. This report provides information on the data on low-pressure conversion technologies that were input to the model and the output results that were obtained.

The report is divided into six chapters. In Chapter 2.0, the technical characteristics of the major types of low-pressure conversion technologies are described. Chapter 3.0 identifies the specific types of low-pressure conversion alternatives that were selected for the analysis and describes the energy savings input parameters that were used in analyzing each alternative.

In Chapter 4.0, the input parameters on the costs per acre for installing and operating low-pressure irrigation systems are described. Chapter 5.0 describes the technical limitations that may hinder the use of low-pressure conversion technologies and also provides information on the amount of conservation that may have already been achieved through the use of low-pressure irrigation technologies. Finally, the report concludes with a description of the potential energy savings estimates and cost per kWh saved estimates that were obtained in the study.

2.0 TECHNOLOGY DESCRIPTION

The concept of producing energy savings through a reduction in the operating pressure of irrigation systems would appear to be a simple one. However, considerable variation exists in the characteristics of the available irrigation systems that fall under the general heading of low-pressure irrigation. In this chapter, a description of some of the various types of low-pressure irrigation systems is presented to facilitate an understanding of the analysis of the costs and energy-savings potential of these systems, described in later sections of this report. A brief description of the primary type of high-pressure irrigation system that is still in use today is also presented.

2.1 HIGH-PRESSURE SPRINKLER IRRIGATION SYSTEMS

A more precise term for high-pressure irrigation is high-pressure sprinkler irrigation, because nearly all high-pressure irrigation is done with sprinklers. The primary water-distribution device used in high-pressure sprinkler irrigation is the high-pressure impact sprinkler head. An illustration of an impact sprinkler head is presented in Figure 2.1.

FIGURE 2.1. Illustration of an Impact Sprinkler Head

The majority of high-pressure impact sprinklers used in irrigation are designed to operate in a pressure range of 50 to 65 psi. When these systems were first conceived, the main concerns of irrigators were to reduce the labor costs and the water-application inefficiencies associated with gravity flow irrigation. In addition, the sprinkler systems allowed for the irrigation of fields with steep slopes and sandy soils that had previously been inaccessible to irrigation. In the original design, little thought was given to the energy use of the irrigation system.

All of the low-pressure systems described in this document are alternatives to the high-pressure impact sprinkler. The alternative irrigation systems retain the labor-saving and water-distribution advantages of high-pressure sprinkler systems, while reducing the energy consumed in irrigation.

2.2 LOW-PRESSURE IMPACT SPRINKLER SYSTEMS

Low-pressure impact sprinkler systems have sprinkler heads similar to the one illustrated in Figure 2.1 but operate at low pressure. The 30- to 45-psi pressures at which low-pressure impact sprinklers operate cause them to have a slightly shorter throw diameter than high-pressure impact sprinklers. In addition, the droplet size of the irrigation water is increased. To reduce the droplet size of low-pressure impact sprinkler heads, diffuser nozzles have been developed. These diffuser nozzles use a rubber membrane to break up the water stream of an impact sprinkler, so that possible soil and crop damage from large droplet size is avoided.

Low-pressure impact sprinkler heads with diffuser nozzles may be used on any type of sprinkler system, including center pivots, siderolls, handlines, and solid sets. However, in cases in which discontinuous move systems such as siderolls have been designed for 60-foot spacing between irrigation sets, some

concern has been expressed by farmers and others^{1,2} about whether the smaller throw diameter of low-pressure impact sprinkler systems will result in dry spots in the field from insufficient water coverage.

A technique known as "offsetting" has been studied as a possible method of dealing with the shorter throw diameter of low-pressure impact sprinkler heads on discontinuous move irrigation systems. An irrigator using offsetting will begin his irrigation sets at a different location every other irrigation. For example, on the first irrigation of the field he may place his irrigation laterals perpendicular to the risers on the mainline. On the second irrigation, he may begin his irrigation sets 20 to 30 feet behind the risers of his mainline and use a swing pipe to connect his lateral to his risers. The offsetting technique for a field requiring three irrigation sets is illustrated in Figure 2.2, with the Xs indicating lateral locations on the first irrigation of the field and the Os indicating lateral locations on the second irrigation of the field.

FIGURE 2.2. An Illustration of Offsetting

Field studies have shown that the use of offsetting over repeated irrigations will allow for an acceptable level of water distribution uniformity to be achieved using low-pressure impact sprinklers on discontinuous move irrigation

¹ Personal communication with Dale Kellingsworth, Valley Irrigation dealer in Madras, Oregon, December 30, 1983.

² Personal communication with Thom McVeigh, sales manager at Valmont Northwest in Pasco, Washington, December 14 and 16, 1983.

systems (Wright 1982 and Kincaid 1982).³ In these studies, no significant differences in water distribution uniformity were noted between irrigations performed using high-pressure application methods and low-pressure application methods when 40- and 50-ft spacings between irrigation sets were utilized. However, when 60-ft spacings were used, offsetting of irrigation sets was required to produce an acceptable level of distribution uniformity with low-pressure methods.

Water distribution uniformity at 60-ft spacings without offsets may not differ significantly from that of high-pressure impact sprinklers with some types of low-pressure nozzles.⁴ Some dealers in Idaho and Oregon have installed low-pressure application packages on discontinuous irrigation systems.^{5,6,7} Despite this, and despite the fact that field tests have shown that low-pressure impact sprinklers operating at 30 to 35 psi can produce acceptable levels of water distribution uniformity on such systems, it appears that there is considerable resistance to the concept in many locations.^{8,9} More successful demonstrations of low-pressure methods on discontinuous irrigation systems will be necessary before the use of such methods will be adopted on a widespread basis.

³ Also, personal communication with Dennis Kincaid, agricultural engineer at Snake River Conservation Center, Kimberly, Idaho, December, 1983.

⁴ Personal communication with Jeff Raleigh, dealer at Warrington Irrigation in Malheur County, Oreg, January 3, 1984.

⁵ Personal communication with Jeff Sherbourne, dealer at Silver Creek Irrigation Company, Jerome, Idaho, December 29, 1983.

⁶ Personal communication with Mr. Neal, Falls Irrigation Company dealer, Falls, Idaho, December 28, 1983.

⁷ Personal communication with Bruce Hurtado, Ladd irrigation dealer in Moses Lake, Washington, December 30, 1983.

⁸ Personal communication with Dale Betty, irrigation dealer of Irrigation Rental Company in Toppenish, Washington, December 30, 1983.

⁹ Personal communication with Martin Zimmerman, Jefferson County, Oregon, extension agent, December 22, 1983.

2.3 LOW-PRESSURE SPRAY SYSTEMS

Spray systems provide an alternative to the use of impact sprinkler heads for irrigation on continuous move irrigation systems, such as center pivots. Spray application heads are specifically designed to operate at pressures of 10 to 35 psi. A popular type of spray application head is illustrated in Figure 2.3.

FIGURE 2.3. Illustration of a Spray Application Head

As Figure 2.3 illustrates, in a spray system, a jet of water is deflected off a spray plate and the water is distributed over the crop. Various types of designs for spray plates are available to produce the desired type of water pattern. For example, the plates may be concave so that a downward deflection

of water is produced, or they may be convex so that an upward deflection results. Grooved plates are also available to produce yet another type of water pattern. The pattern illustrated in Figure 2.3 is a flat spray pattern obtained from a flat spray plate.

Spray application heads can be mounted directly on a center-pivot mainline or be extended below the mainline using a drop-tube arrangement. A spray application head attached to a drop tube is illustrated in Figure 2.4. The drop-tube arrangement has been developed to reduce the wind drift and evaporation of the water droplets emitted from spray application heads. The more efficient use of water associated with the drop-tube arrangement could result in savings of both water and energy in irrigation. However, the initial costs of the drop-tube arrangement are higher than for a directly mounted arrangement. In addition, slightly greater operating pressures may be necessary to reduce the possibility of water runoff when a drop-tube arrangement is used rather than a directly mounted arrangement.¹⁰

FIGURE 2.4. Illustration of a Spray Application Head Mounted on a Drop-Tube

¹⁰ Personal communication with Mike Monaghan of Nelson Irrigation in Walla Walla, Washington, December 13, 1983.

From the beginning of the development of low-pressure spray systems, considerable concern was expressed about the potential for increased water runoff from the systems. Individual spray heads disperse water over a smaller area than do high-pressure impact sprinklers. Thus, at a given flow rate, the water application rate of spray systems is higher. In general, experience to date has demonstrated that the use of single-spray application heads operating at 25 to 30 psi does not result in significant runoff problems in the relatively sandy soils of the Pacific Northwest irrigation regions.^{11,12,13} However, to reduce the actual and perceived runoff problems associated with low-pressure spray application heads, irrigation-system manufacturers have developed alternatives to single application head designs. These alternatives are described below.

2.3.1 Spray Booms

One type of spray-boom arrangement is illustrated in Figure 2.5. This is not the only type of spray boom; spray booms with as many as seven, and as few as two, heads per boom are available.

The intent behind the development of spray booms was to spread the water application of low-pressure spray irrigation systems over a wider area. The distribution of water through a number of interconnected spray application heads rather than a single head on the mainline would provide a lower instantaneous water application rate. This lower application rate would increase water penetration and reduce runoff.

¹¹ Personal communication with Wayne Larson, a farmer in the Pasco, Washington, area, December 1983.

¹² Personal communication with Chester Prior, a farmer in the Echo, Oregon, area, December 1983.

¹³ Personal communication with Merlin Jensen, a farmer in the Ritzville, Washington, area, December 1983.

FIGURE 2.5. Illustration of a Spray Boom System

Spray booms were specifically designed for sloping fields and tight soils, where the use of single-spray systems could cause runoff problems. In addition, the potential to lower spray head operating pressures below the 20- to 30-psi level of single-spray systems was enhanced by the use of spray booms because the runoff problems associated with lower pressures are reduced. Theoretically, spray booms should allow for the use of spray application heads with operating pressures in the range of 10 to 20 psi by preventing any significant runoff problems from occurring.

Despite the advantages of spray-boom systems, they have generally not been popular with Pacific Northwest irrigators. Boom systems have substantially higher initial purchase and installation costs when compared to either low-pressure impact or single-spray systems. It appears that many irrigators in the Pacific Northwest who might like to irrigate at lower pressures with spray

booms are discouraged by high initial purchase costs.¹⁴ In addition, the adjustment of the height of certain types of spray booms for the irrigation of field corn is difficult and costly.¹⁵

The use of booms may be required for low-pressure irrigation in tight soils, steeply sloped fields, and situations in which pressures at or below 20 psi are desired.^{16,17} A type of boom system which has proven to be popular with some Pacific Northwest irrigators^{18,19} is illustrated in Figure 2.6. According to those who have used this type of boom,¹⁸ this arrangement reduces the disadvantages of boom systems because it has lower initial purchase costs than other boom systems and because it can easily be adjusted for use in irrigating corn.

¹⁴ Personal communication with Thom McVeigh, December, 1983

¹⁵ Personal communication with Mike Monaghan, December 1983

¹⁶ Personal communication with Thom McVeigh, December 1983.

¹⁷ Personal communication with S-K Farms Irrigation Manager, Hermiston, Oregon, December 1983.

¹⁸ Personal communication with Melvin Campbell, Irrigation Manager, U and I, Inc., Kennewick, Washington, December 1983.

¹⁹ Personal communication with S-K Farms' Irrigation Manager, Hermiston, Oregon, December 1983

FIGURE 2.6. Illustration of a Spray Boom Design Where the Height of the Booms Can Be Adjusted

2.4 FURROW DROP-TUBE SYSTEMS

Furrow drop tubes are similar in design to low-pressure sprays configured in a drop-tube arrangement (Figure 2.4). However, furrow drop tubes are normally designed to operate at pressures of 5 to 15 psi. An illustration of a furrow drop-tube emitter is presented in Figure 2.7. These systems use the force of gravity along with a small amount of operating pressure to distribute water by deflecting it off a splash plate.

FIGURE 2.7. Illustration of a Furrow Drop-Tube System and Its Emitter

One of the earliest types of furrow drop-tube systems was given the name Low Energy Precision Application system, or LEPA. This particular type of furrow drop-tube system has emitters that are designed to operate in the range of 5 to 10 psi. They also are designed to operate very close to the crop root zone, thus reducing wind drift and water evaporation. The system was developed in Texas, and its developer reports that it has been used to successfully irrigate soybeans, cotton, sugar beets, alfalfa, grain sorghum, and corn in the

three years of its existence.²⁰ The developer also reports that several farmers in Texas have converted their entire irrigation systems to LEPA.

The very low operating pressures and water-saving characteristics of furrow drop-tube systems such as LEPA should cause these systems to be attractive to irrigators. However, it appears that the current usage of furrow drop-tube irrigation systems in the Pacific Northwest is close to zero.²¹ It seems that resistance to furrow drop-tube systems by Pacific Northwest irrigators is based on considerations of risk and applicability.

It is generally believed by irrigators and dealers that furrow drop-tube systems are inappropriate for use in the sloped fields of the Pacific Northwest.²² In addition, the feasibility of using furrow drop-tube systems to irrigate crops that are not planted in distinct rows is questioned. Finally, and perhaps most importantly, it is questioned whether the additional benefits of the slightly lower operating pressures of furrow drop tubes compared to low-pressure sprays outweigh the actual and perceived costs of a higher initial purchase cost, increased runoff potential, and a loss of crop rotation flexibility.²³

2.5 ADDITIONAL CONSIDERATIONS IN LOW-PRESSURE ADOPTION

The adoption of low-pressure irrigation methods will require that modifications be made in other parts of an irrigation system besides the application head. These modifications include changes in the irrigation system pumping plant, the addition of pressure regulators to the system, and the possible addition of an end-gun to a center pivot system.

²⁰ Personal communication with William Lyle, Associate Professor in the Texas Agricultural Experiment Station, Halfway, Texas.

²¹ Personal communication with Mike Monaghan, December 13, 1983.

²² Personal communication with Dorrell Larsen, Extension Agent, Parma, Idaho, November 2, 1983.

²³ Personal communication with Mike Monaghan, December 13, 1983.

2.5.1 Pumping-Plant Modifications

In most situations where low-pressure conversion is undertaken, some modification of the current pumping plant will be necessary to realize any energy savings from conversion. The basic principle behind pumping plant modifications is that a smaller amount of pumping horsepower is required by low-pressure irrigation systems and that, unless the horsepower of the pumping plant is reduced, energy savings resulting from low-pressure conversion will not be realized.

The specific type of pumping plant modification undertaken by an irrigator adopting low pressure will vary significantly from one pump to another. Probably the most common modification is trimming of pump impellers and removal of pump bowls. However, farmers may elect to replace their old pumps with smaller, new pumps at the time of conversion. In some cases, pump replacement may be required because the existing pump's impeller cannot be trimmed far enough to conform to the head requirements of low-pressure irrigation.

Often, a major cost involved in performing pump modifications is gaining access to the pump so that modifications can be undertaken. The cost of pulling a pump can be one of the largest cost components of performing necessary pump modifications on deep-well turbine pumps.

2.5.2 Pressure Regulators

Variations in pressure from changes in field elevation along the mainline or lateral of an irrigation system will have a greater impact upon the water discharge rate of a low-pressure irrigation system than for a high-pressure irrigation system. To mitigate the problems associated with varying pressures and discharge rates, pressure regulating devices have been developed for use on low-pressure irrigation systems.

On impact sprinklers, the problem of pressure variations can be dealt with simply by installing relatively inexpensive flow control nozzles on the impact sprinkler heads. These nozzles use a rubber membrane to maintain a constant flow rate from each impact head despite variations in pressure.

The pressure regulation device developed for use on spray and drop-tube systems is slightly more complicated and expensive. It is mounted between the water source pipe and the spray head, and utilizes a spring-loaded chamber to maintain a constant discharge rate on the application head. Unless a field is extremely flat, the use of these pressure regulators will be required in conjunction with low-pressure spray systems if adequate uniformity in water distribution is to be maintained.

2.5.3 End-Guns

It has always been necessary to provide greater water discharge capability at the end of a center pivot than in other sections of the pivot if adequate water application amounts at the end of the pivot are to be achieved. However, the difficulty of achieving adequate water coverage at the end of the pivot is increased by the adoption of low-pressure irrigation.

When a center pivot was pressurized at 60 psi, higher application rates could be obtained by simply adding some extra standard sized impact heads at the end of the line or by installing a larger than normal impact head. The high pressure of the system would allow for a throw diameter on the impact heads that was large enough to shoot beyond the end of the line. Low-pressure application heads do not have as large a throw diameter and, consequently, some system modifications are required if water coverage is to be achieved beyond the end of the pivot.

Probably the most common method of providing water coverage at the end of a low-pressure center pivot is to install end guns. These guns discharge a relatively large stream of water out beyond the end of a center-pivot line. A small booster pump installed at the end of the line is normally required to provide enough pressure to operate an end gun on a low-pressure system.

The use of end guns is not universal. Many farmers, especially those whose fields were originally designed around center pivots, decide that the costs of installing and operating end guns exceed the benefits of irrigating additional land at the end of their pivots. The losses in crop production that will occur from foregoing the use of an end gun will depend on the shape of the field and, thus, will vary substantially from one field to another.

3.0 ALTERNATIVES CHOSEN FOR ANALYSIS AND ENERGY SAVINGS ASSUMPTIONS OF EACH ALTERNATIVE

As the information presented in the previous chapter demonstrates, the alternatives available for the adoption of low-pressure irrigation are varied. To narrow the scope of the analysis, it is necessary to select specific low-pressure conversion alternatives for further analysis. This chapter defines the alternatives chosen for analysis and describes the input assumptions that will be used in estimating the potential energy savings of each alternative.

3.1 SELECTED ALTERNATIVES

The low-pressure conversion alternatives selected for analysis in this study are identified in Table 3.1. Except for furrow drop-tube systems, all of the conversion alternatives were selected because they appear to represent those conversions that are most likely to be adopted by irrigators in the Pacific Northwest.

Note from Table 3.1 that furrow drop-tube systems are among the alternatives selected for analysis. However, in more than 30 separate conversations with equipment manufacturers, equipment dealers, and farmers, no example of a furrow drop-tube system currently being used in the Pacific Northwest was discovered. In addition, all knowledgeable experts questioned about furrow drop-tube systems were skeptical about the systems' potential for use in the Pacific Northwest. Even if furrow drop-tube systems are a practical conservation alternative for Pacific Northwest irrigators, it appears that a number of successful demonstrations of the use of the systems will be necessary before they are adopted in the region. In particular, it will be necessary to extensively demonstrate the successful use of furrow drop-tube systems on non-row crops.

Because of the problems associated with furrow drop-tube systems, the analysis of this alternative be limited to estimation of a cost per kWh saved value. The energy-savings potential of these systems will not be analyzed, because currently there appears to be no evidence that this potential is significantly greater than zero.

TABLE 3.1. Conservation Options Selected for Analysis

Type of Conventional System	Conservation Option Selected
High-Pressure Impact Sprinklers on Center Pivot	Low-Pressure Single-Spray
	Low-Pressure Spray with Adjustable Booms (a)
	Furrow Drop Tube (b)
High-Pressure Impact Sprinklers on Other Sprinkler Systems (c)	Low-Pressure Impact Sprinklers with Flow Control Diffuser Nozzle on Other Sprinkler Systems
Low-Pressure Single-Spray	Low-Pressure Spray with Adjustable Booms
	Furrow Drop Tube (b)

(a) Adjustable booms similar to those illustrated in Figure 2.6.

(b) Analysis to be conducted of the furrow drop-tube system will be limited to estimating a cost per kWh saved only.

(c) Non-center pivot includes sideroll wheel lines and handmove systems.

The conservation alternative of using low-pressure spray systems with adjustable booms was chosen for full analysis as a conservation alternative because this alternative has been successfully used in a large commercial irrigated farming operation in the Pacific Northwest,¹ and it appears to have potential for further expansion in use.² However, caution should be used in applying the results of the energy-savings estimates for these systems. Although all of the parts necessary for the installation of spray boom systems like the one illustrated in Figure 2.6 are commercially available, the boom system as a whole is currently not commercially available. The farming operation that uses the system assembled the various system components in their own shop.³ However, it is believed that if sufficient demand is generated by irrigators for this type of system in the future, the system as a whole could be made commercially available in a short time.

An additional cautionary note with regard to the alternative of adjustable spray booms is that not all farming operations will require booms to achieve good results at design pressures below 20 pounds. On flat land with sandy soils, good irrigation results have been achieved using single-spray systems at design pressures as low as 10 psi.^{4,5,6} To be conservative in the analysis of conservation potential, this analysis assumes that booms would be necessary for the widespread use of systems operating below the most common 25 to 30 psi range of low-pressure single-spray systems. However, about the only thing definite that can be stated about spray booms is that they have higher

¹ Personal communication with Melvin Campbell, December, 1983.

² Personal communication with S-K Farms Irrigation Manager, December, 1983.

³ Personal communication with Jim Meeks, December, 1983.

⁴ Personal communication with Bruce Hurtado, Ladd Irrigation dealer in Moses Lake, Washington, December 30, 1983.

⁵ Personal communication with Thom McVeigh, sales manager at Valmont Northwest in Pasco, Washington, December 14 and 16, 1983.

⁶ Personal communication with Arnold Omlin, a farmer in the Quincy, Washington, area, December 1983.

initial purchase and installation costs than single-spray systems and that they allow for a small additional pressure drop to be accomplished even on sloped fields with relatively tight soils. In addition, it is necessary that the height of the booms be easily adjustable, if they are to be adopted on a widespread basis.

Based on our conversations with irrigation equipment manufacturers and dealers, it appears that the most common conservation alternative adopted to date by irrigators using center pivots is the single-spray system. This does not imply that low-pressure impact heads will not be adopted by some center-pivot users. However, because low-pressure sprays are the most likely alternative, they were selected for analysis.

Low-pressure impact sprinklers appear to be the only practical low-pressure alternative for sideroll wheel line and handline irrigation systems. In an earlier study, it was assumed that sideroll wheel lines could be converted to low-pressure center pivots (Harrer 1982). However, it is now believed that the use of low-pressure impact sprinklers (with offsets where necessary) provides a more practical alternative for achieving energy savings on discontinuous sprinkler irrigation systems. This belief is based on the following considerations:

- 1) Field size and shape limitations will limit the ability to convert sideroll wheel line and handline irrigated fields to center-pivot irrigation.
- 2) The decision to convert sideroll wheel lines and handlines to center-pivot irrigation will be based primarily on labor saving considerations rather than energy saving considerations.
- 3) Differences in operating pressures between spray heads on center-pivot and low-pressure impact sprinklers on sideroll wheel lines and handlines are relatively small.
- 4) The initial capital outlay required for converting a sideroll wheel line or handline system to a low-pressure center-pivot system is large.

Note finally that the options of using low-pressure spray systems with booms and using furrow drop-tubes are included as alternatives to low-pressure single-spray systems. This analysis will provide information on whether the additional energy savings resulting from installing booms and drop-tubes rather than single-spray systems would justify the additional investment costs.

3.2 ENERGY SAVINGS ASSUMPTIONS

Based upon a number of contacts made with irrigators and equipment dealers, 54 psi operating pressure and 170 feet of total application head were chosen to be representative of conventional high-pressure center pivots currently operating in the field. An operating pressure of 50 psi and 150 feet of total application head were selected to be representative of conventional high-pressure handmove and sideroll systems. The rationale behind these assumptions are explained in detail in another document (Harrer 1984b) that was prepared as part of this study. It is assumed that adopting low-pressure irrigation methods would not affect elevation head losses or system frictional losses significantly. Thus, the energy savings benefits resulting from low-pressure conversion will result primarily from a reduction in design operating pressures.

The design operating pressures for low-pressure irrigation systems estimated by various knowledgeable experts are presented in Table 3.2. Based upon the estimates shown in Table 3.2 and other information, representative estimates of design operating pressures for each of the selected conservation options were developed. These estimates are shown in Table 3.3. Estimates of the total application heads corresponding to the selected design operating pressures were also calculated.

Note that the design pressure and application head estimates after system conversion presented in Table 3.3 are generally at the high end of the range of the estimates presented in Table 3.2. The higher-range estimates were selected mainly because in many large integrated pumping systems, it is not possible to realize energy savings on all center pivots by conversion to low pressure. An integrated pumping system supplying water to several center pivots requires a certain amount of head to supply adequate pressure for the operation of the

TABLE 3.2. Estimates of Design Operating Pressures
for Low-Pressure Irrigation Systems

<u>Type of System</u>	<u>Source of Estimate</u>	<u>Estimated Design Operating Pressure (psi)</u>	<u>Estimated Operating Head at Pivot Pad (Feet)</u>
Low-Pressure Single Spray	Mike Monaghan Nelson Irrigation Co.	20 to 25	90 to 115
	Gayle Gering Columbia Basin Farmer	27	90
	Merlin Jensen Columbia Basin Farmer	25 to 30	90 to 125
	S-K Farms Boardman, Oregon	25	---
	Chester Prior Hermiston, Oregon Farmer	---	115 to 125
	Bruce Hurtado Ladd Irrigation Co.	25	90 to 160
Low-Pressure Spray Boom	Mike Monaghan Nelson Irrigation Co.	15 to 20	80 to 105
	Melvin Campbell U and I Farms Irrigation Manager	20	---
Furrow Drop Tube	Mike Monaghan Nelson Irrigation Co.	15	---
	Bill Lyle Texas Ag. Experiment Station	5 to 10	---
Low-Pressure Impact Sprinklers	Dennis Kincaid Kimberly Ag. Research Center	35	---
	Carl Bronson Frutiland Growers Supply	35	---

TABLE 3.3. Conservation Options Selected for Analysis and Estimated Operating Pressures and Heads for Each Option

Type of Conventional System	Conservation Option	Operating Pressure (psi) of Design Sprinklers Before Conversion	Operating Pressure (psi) of Design Sprinklers After Conversion	Total Application Head (ft) Before Conversion ^(a)	Total Application Head (ft) After Conversion
High-Pressure Impact Sprinklers on Center Pivot	Low-Pressure Single-Spray	54	28	170	110
	Low-Pressure Spray with Adjustable Booms ^(b)	54	20	170	91
	Furrow Drop Tube ^(c)	54	14	170	77
High-Pressure Impact Sprinklers on Other Sprinkler Systems ^(d)	Low-Pressure Impact Sprinklers with Flow Control Diffuser Nozzles on Other Sprinkler Systems	50	35	150	115
Low-Pressure Spray without Adjustable Booms	Low-Pressure Spray with Adjustable Booms	28	20	110	91
	Furrow Drop Tube ^(c)	28	14	110	77

(a) Total operating head figures are obtained by multiplying estimated operating pressure at the design sprinklers by a conversion factor of 2.31 feet per psi, adding 35 and 25 feet of head for system friction losses on center-pivot and other sprinkler systems, respectively, and adding 10 feet of head for elevation losses on the two types of systems.

(b) Adjustable booms similar to those illustrated in Figure 2.6.

(c) Analysis to be conducted of the furrow drop-tube system will be limited to estimating a cost per kWh saved only.

(d) Other sprinkler systems include sideroll wheel lines and handmoves.

center pivots with the highest elevations located at the most distant points from the water supply source (i.e., the design center pivots). Thus, in many cases, conversion to low pressure of the pivots closest to the water supply source will not result in any significant energy savings, and such conversion may result in system operation problems such as blown-pressure regulators.⁷ To reflect this consideration, and to be conservative in developing estimates of conservation potential, relatively high psi levels after conversion to low pressure were chosen for this analysis.

In comparing the pressure numbers presented in Tables 3.2 and 3.3, it can be seen that the psi numbers selected for use in this analysis are in the range of the available estimates. However, it should be emphasized that the selected numbers are only representative and will not apply in all situations.

⁷ Personal communication with Mike Monaghan, December, 1983.

4.0 COST INPUT ASSUMPTIONS

A number of costs are associated with conversion to low pressure. These costs will vary depending upon the specific type of low-pressure conversion alternative that is adopted, the type of pumping plant being used, and a number of other factors. Every dealer contacted, including those whose estimates are cited in this chapter, emphasized the unique and site-specific nature of the design, and consequently the cost, of each low-pressure conversion.^{1,2,3} However, for purposes of this analysis, it is necessary to select representative cost numbers from the range of available cost numbers. In this chapter, the representative cost inputs chosen to analyze each of the selected conservation alternatives are described.

4.1 CENTER-PIVOT COSTS

To estimate the representative costs of purchasing and installing low-pressure equipment on a center pivot, a number of irrigation equipment manufacturers, equipment dealers, and farmers were contacted. Some of the responses from these contacts are presented in Table 4.1.

All of the cost numbers presented in Table 4.1 are for modifying an existing system. No evidence was found in our information gathering that indicated that installing a single-spray, low-pressure, center-pivot irrigation system on new acreages would cost more than installing a high-pressure impact, center-pivot system on new acreages. Thus, for analyzing new systems, the only capital costs that will be included are the additional costs of installing spray booms or furrow drop tubes rather than single-spray heads.

¹ Personal communication with Jeff Raleigh, dealer at Warrington Irrigation in Malheur County, Oregon, January 3, 1984.

² Personal communication with Jeff Sherbourne, dealer at Silver Creek Irrigation Company, Jerome, Idaho, December 29, 1983.

³ Personal communication with Carl Bronson, Fruitland Growers Supply, Payette County, Idaho, December 1983.

TABLE 4.1. Center-Pivot Application Head
and Frame Modification Costs

<u>Type of Modification</u>	<u>Source</u>	<u>Cost per Acre^(a)(\$)</u>
Single-Spray Heads	Bruce Hurtado Ladd Irrigation	11.54-13.08
	Dale Kellingsworth Valley Irrigation Madras, Oregon	13.60-14.40
	Jeff Sherbourne Silver Creek Irrigation	11.54
	Mike Monaghan Nelson Irrigation	11.15
Spray Booms	Jim Meeks U and I Farms	45.00
	Jeff Sherbourne Silver Creek Irrigation	42.31
	Mike Monaghan Nelson Irrigation	57.69
Furrow Drop Tube	Bill Lyle Texas Ag. Experiment Station	50.00
	Mike Monaghan Nelson Irrigation	38.46

(a) All costs per acre include the costs of installing all necessary application heads and the costs of installing pressure regulators. Costs are subject to variations that depend on specific design considerations. All costs were computed by estimating cost per system and then dividing by the number of acres covered by a system. The cost of end-gun purchase and installation is not included here.

None of the farmers contacted in our investigation stated that the use of low-pressure irrigation methods rather than high-pressure irrigation methods changed the operation and maintenance costs of center-pivot irrigation by any significant amount.^{4,5} One irrigation manager stated that any increase in labor costs was more than offset by reduced renozzling costs on low-pressure systems.⁶ It seems probable that operation and maintenance costs would increase slightly when a furrow drop-tube system is used. However, the lack of experience with these systems by Pacific Northwest farmers precluded obtaining field information on their incremental operation and maintenance costs. A rough estimate of \$4 per acre incremental operation and maintenance cost for a furrow drop-tube system was estimated in a previous study (Harrer 1982) and, for lack of better information, was also incorporated in this study.

The cost of purchasing and installing an end gun was not included in the estimates presented in Table 4.1. A representative of a large manufacturer of irrigation equipment stated that end guns and their booster pumps generally cost approximately \$2000 per center-pivot system.⁷ However, as was stated before, not all irrigators will install end guns as part of low-pressure conversion. In this analysis, it was assumed that 50 percent of the low-pressure conversions would include end-gun installation. Using this assumption, a cost of \$1000 per 130-acre center-pivot system, or \$7.69 per acre, was calculated to be representative of the cost of end-gun purchase and installation.

⁴ Personal communication with Gail Gering, farmer in the Pasco, Washington, area, December 1983.

⁵ Personal communication with Chester Prior, farmer in the Echo, Oregon, area, December 1983.

⁶ Personal communication with Melvin Campbell, Irrigation Manager for U and I Farms, Kennewick, Washington, December 1983.

⁷ Personal communication with Mike Monaghan, Nelson Irrigation, December, 1983.

4.2 HANDMOVE AND SIDEROLL WHEEL LINE COSTS

Estimates of the costs per acre for purchasing and installing new nozzles on impact sprinklers so that handmove and sideroll systems can be converted to low pressure are presented in Table 4.2. From the table it can be seen that the initial renozzling costs associated with conversion of handmove and sideroll systems are relatively small.

TABLE 4.2. Handmove and Sideroll Wheel Line Renozzling Costs

<u>Source</u>	<u>Renozzling Cost per Acre (\$)</u>
Jeff Raleigh Warrington Irrigation Maheur County, Idaho	2.40 to 2.65
Carl Bronson Fruitland Growers Supply Payette County, Idaho	3.25 to 3.50
Jeff Sherbourne Silver Creek Irrigation Jerome, Idaho	4.80 to 5.00

The cost numbers presented in Table 4.2 assume that either the current handmove or sideroll system utilizes 40- or 50-foot lateral spacings or that offsetting is used in conjunction with 60-foot lateral spacings. All irrigation dealers contacted felt that the costs of converting from 60-foot spacing to 50-foot spacing would be prohibitive if the sole purpose of such conversion was to facilitate the use of low pressure. These costs would be nearly the same as the costs of installing a new system, which can be as high as \$300 an acre.

In our analysis, we assume that offsetting would be necessary when a system designed for 60-foot lateral spacing is converted to low pressure. Those who have tested the use of offsetting stated that the additional piping

and labor costs associated with offsetting would not be large.^{8,9} However, it is believed that the labor costs from using offsetting should not be assumed to be zero. If an additional five minutes per irrigation set is required for moving and connecting the offset pipes, the additional labor costs could range as high as \$2 an acre per year. In our analysis, we assume that an additional \$1 an acre per year of operation and maintenance cost would be required for offsetting a low-pressure handmove or sideroll system.

4.3 PUMPING PLANT MODIFICATION COSTS

The costs associated with modifying an irrigation pumping plant as part of a conversion to low-pressure irrigation are often as large or larger than the costs of actually purchasing and installing the low-pressure equipment itself. Pumping plant modification costs also vary widely from one pump to another and will depend on such factors as the condition of the existing pumping plant, the type of pump being modified, and the underground depth from which the pump is drawing water. Although the specific actions associated with modifying a pumping plant for low-pressure irrigation will vary, common actions include impeller trimming or replacement, bowl modification (on turbine pumps), and pump flow rate adjustment.

Estimates of the costs of modifying pumping plants for low-pressure irrigation were solicited from various irrigation dealers that participate in converting irrigation systems to low pressure. These estimates are shown in Table 4.3.

Note that it was necessary to solicit information on the representative pump size for sprinkler irrigation systems in order to derive representative costs for pump modifications. Most experts contacted stated that the cost of modifying a large pump was not significantly different than the cost of

⁸ Personal communication with Marvin Shearer, Professor Emeritus, Agricultural Engineering Department, Oregon State University, December 1983.

⁹ Personal communication with Dennis Kincaid, agricultural engineering at Snake River Conservation Center, Kimberly, Washington.

TABLE 4.3. Pumping Plant Modification Costs^(a)

Source	Representative Size of Pump (Horsepower)	Cost per Pump Using Surface Water (\$)	Cost per Pump Using Groundwater (\$)	Estimated Acreage Irrigated by Pump
Jeff Raleigh Warrington Irrigation	50 to 75	200	---	N/A
Bruce Hurtado Ladd Irrigation	50 to 60	300 to 400	---	130
Dale Kellingsworth Valley Irrigation Madras, OR	50 to 60	500	---	130
Tom McVeigh Valmont NW Pasco, WA	---	300	5000 to 6000	---
Mr. Neal Falls Irrigation Co. Falls, ID	60 to 75	280	2000	130
Jimmy Brock Layne Pump Co. Pasco, WA	60 to 75	500	1200	130

(a) Costs cited are estimated on the basis of specific field considerations that might be found in dealer's location. Modification costs include expense of pulling pump in order to gain access to it and costs incurred in modifying pump to operate at lower horsepower. Necessary modifications could include removing, trimming or replacing some impellers in a bowl assembly, knocking a stage off a turbine pump, and possible pumping panel changes. The above estimates do not include costs of an end-gun booster pump.

modifying a smaller pump. However, a large pump can supply water for a greater number of acres than can a smaller pump. Thus, the cost per acre for pump modification on a smaller pump is higher than for a larger pump.

The costs for modification of groundwater turbine pumps are substantially higher than for surface water pumps primarily because of the necessity to undertake expensive pump pulling operations in order to gain access to groundwater pumps. In addition, the costs of modifying pump bowls contribute to higher groundwater pump modification costs.

In many cases the impeller of centrifugal irrigation pumps (which are normally used to pump surface water) cannot be trimmed far enough to conform with the head requirements of low-pressure irrigation. In such cases, replacement of the original centrifugal pumps with smaller pumps is required in order to convert to low-pressure irrigation. Estimates of representative costs for purchasing centrifugal irrigation pumps conforming to the head requirements of low-pressure irrigation are shown in Table 4.4.

Analysis of existing BPA irrigation system audit data revealed that centrifugal pump replacement is required to convert to low pressure on approximately 42 percent of the systems that use such pumps. Using a representative cost per pump of approximately \$2630 for a 130-acre field, the estimated average cost per field for centrifugal pump replacement assumed in this study is \$1105 ($.42 \times \2630), or \$8.50 an acre. This cost is assumed to apply strictly to surface water acreages where centrifugal pumps are normally used.

4.4 BPA PILOT PROGRAM COSTS

As the data previously presented in this chapter indicate, a wide variation exists in the estimated levels of the various costs that may be involved in converting to low-pressure irrigation. In an effort to identify cost levels for the various factors that are as representative as possible, data from the BPA Irrigation Conservation Pilot Program were obtained and analyzed.¹⁰ These data are shown in Table 4.5.

¹⁰ Unpublished data obtained from Steve Levy, conservation analyst, Bonneville Power Administration, December 1983.

TABLE 4.4. Centrifugal Pump Replacement Costs^(a)

Source of Estimate	Cost per Pump	Estimated Acres Irrigated by Pump
Byron Wood Hansen Irrigation Idaho Falls, ID	\$2000 - 3000	130
Dick Skreen/Gary Spencer Cornell Pump Co. Portland, OR	\$2800	130
Jerry Stucki Aurora Pump Co. Idaho Falls, ID	\$2250	130

(a) Costs include purchase of pump only and do not include installation. All pumps conform to flow rates of approximately 1100 gpm against a total dynamic head of approximately 110 feet.

TABLE 4.5. Direct and Indirect Costs^(a) Expended in
Converting to Low Pressure Under the BPA Pilot Program^(b)

Study Farm No.	Cost per Acre for Center-Pivot Head and Frame Modification (\$)	Cost per Acre for Pump Modification (\$)	Total Direct Cost per Acre for Low- Pressure Conversion (\$)	Total Direct and Indirect Cost per Acre for Low-Pressure Conversion (\$)
1	1.24	34.43	35.67	66.28
2	7.29	2.47	9.76	15.95
3	10.04	3.05	13.09	46.75
4	21.99	6.98	28.97	71.89
5	NA ^(c)	NA	28.39	59.33
6	NA	NA	26.92	59.20
7	NA	NA	20.62	25.99
8	NA	NA	25.00	78.39
Median	8.67	5.02	25.96	59.27
Mean	10.14	11.73	26.80	60.38

(a) Direct costs are those costs deemed to be directly connected to low-pressure conversion by BPA program officials and, thus, are reimbursable under pilot-program terms. Indirect costs are those costs that were incurred at the time of low-pressure conversion but were not deemed to be directly connected to low-pressure conversion. An example of such an indirect cost would be complete pump replacement.

(b) Source: Unpublished BPA records on the pilot program obtained from Steve Levy.

(c) Specific breakdown of costs was not available from data source.

From the information presented in Table 4.5, it can be seen that substantial differences exist in the costs per acre for the Pilot Program farms. It can also be seen that the program participants undertook substantial investments at the time of low-pressure conversion that were not deemed to be directly related to low-pressure conversion. Typically, the costs determined to be directly connected with low-pressure conversion were less than half of the total costs incurred at the time of conversion.

It appears that the direct costs of conversion are the ones that are appropriate for incorporating into our analysis, because a determination of whether the direct costs were computed correctly is beyond the scope of this study. Single-spray nozzles were installed in the majority of the conversions shown in Table 4.5. Thus, the representative cost per acre for conversion to single spray systems would appear to be from \$25 to \$30 per acre.

4.5 COST INPUTS SELECTED FOR ANALYSIS

Mean estimates for the various costs that may be incurred in converting to low-pressure irrigation and the representative cost input levels that were selected for use in our analysis are presented in Table 4.6. Cost input numbers from a previous study (Harrer 1982) are presented for reference purposes only and were not used in the selection of cost inputs for this analysis.

The mean cost estimates for single-spray systems developed from the responses of irrigation equipment dealers and farmers are 36 to 45 percent higher than the estimates developed from BPA Pilot Program records. These differences can be explained by a number of factors, including the method of determining direct costs in the Pilot Program, failure to incorporate end-gun installation costs in the Pilot Program, and the small number of observations contained in the Pilot Program records. To be conservative in estimating the costs per kwh saved, the higher of the cost estimates were selected for use. This conservative approach to cost estimation is consistent with the conservative overall approach that BPA requested be used in this study.

It should be emphasized that the numbers shown in Table 4.6 are only representative averages and should be interpreted as such. In individual situations, the cost levels could vary substantially from those shown in Table 4.6.

TABLE 4.6. Cost Input Estimates Selected for Use in This Study

Type of Conversion	Mean Response ^(a) of Irrigation Dealers and Farmers (\$ per Acre)	Mean Results ^(b) of BPA Pilot Program (\$ per Acre)	Number Used ^(c) in Power Council Study (\$ per Acre)	Number Selected for Use in This Study (\$ per Acre)
High-Pressure Center Pivot To Low-Pressure Single Spray Using Surface Water	31.17	17.27	42	31.00
High-Pressure Center Pivot To Low-Pressure Single Spray Using Groundwater	42.25	27.10	84	42.00
High-Pressure Center Pivot To Low-Pressure Spray Booms Using Surface Water	67.25	NA	NA	67.50
High-Pressure Center Pivot To Low-Pressure Spray Booms Using Groundwater	78.33	NA	NA	78.00
High-Pressure Center Pivot To Low-Pressure Furrow-Drop Tubes Using Surface Water	63.15	NA	65	63.00
High-Pressure Center Pivot To Low-Pressure Furrow-Drop Tubes Using Groundwater	76.64	NA	107	76.50

TABLE 4.6. (cont.)

Type of Conversion	Mean Response ^(a) of Irrigation Dealers and Farmers (\$ per Acre)	Mean Results ^(b) of BPA Pilot Program (\$ per Acre)	Number Used ^(c) in Power Council Study (\$ per Acre)	Number Selected for Use in This Study (\$ per Acre)
High-Pressure Handmove and Sideroll to Low- Pressure Impact Using Surface Water	14.87	NA	NA	15.00
High-Pressure Handmove and Sideroll to Low- Pressure Impact Using Groundwater	25.95	NA	NA	26.00
Low-Pressure Single Spray to Low-Pressure Spray Boom Using Surface Water Or Groundwater	36.08	NA	NA	36.00

(a) Calculated by averaging the data contained in Table 4.1 and adding an average pump modification cost of \$2.41 per acre for surface water and \$19.23 per acre for groundwater. These pump modification costs are averages of the data contained in Table 4.3. An additional cost of \$7.69 per acre was also included to represent the cost of purchasing and installing an end-gun on low-pressure center pivots. A final additional cost is \$8.50 per acre for centrifugal pump replacement on surface water systems.

(b) Surface-water costs are an average of Study Farms 2, 3, and 4 direct costs reported in Table 4.4, while groundwater costs are an average of the other five farms' direct costs reported in Table 4.4.

(c) Harrer, B.J. "Assessment of Electric Power Conservation and Supply Resources in the Pacific Northwest, Volume IV, Irrigated Agricultural Conservation," June 1982.

4.6 OTHER SELECTED ECONOMIC PARAMETERS

Two additional parameters that are required to estimate the cost per kwh saved for low-pressure conversion are the real discount rate required to levelize the initial costs of low-pressure conversion and the assumed measure life for low-pressure equipment. In accordance with current BPA practices, a real discount rate of 3 percent will be used throughout the analysis.

In reference to the assumed measure life for low-pressure equipment, there appears to be no basis for arguing that the measure life of low-pressure equipment would be any shorter than that of high-pressure equipment.^{11,12} In fact, some farmers and dealers felt that conversion to low pressure would actually extend the life of their irrigation systems by reducing the wear from pressurized water running through the systems' components.^{13,14} Thus, for low-pressure conversion alternatives, a value of 20 years will be used as an assumed measure life in our analysis.

¹¹ Personal communication with Bruce Hurtado, Ladd Irrigation, Moses Lake, Washington, December 30, 1984.

¹² Personal communication with Dale Kellingsworth, Valley Irrigation, Madras, Oregon, December 1983.

¹³ Personal communication with Tom McVeigh, Valmont Northwest, Pasco, Washington, December 1983.

¹⁴ Personal communication with Leonard Isaacs, irrigation dealer, Walla Walla, Washington, December 1983.

5.0 TECHNICAL LIMITS ON MEASURE APPLICATION AND CONSERVATION ALREADY ACHIEVED

Concern has frequently been expressed about the technical feasibility of using low-pressure irrigation methods in all situations in which high-pressure irrigation is currently used. In addition, it appears that a substantial number of irrigated acres have already been converted to low-pressure irrigation methods. Conversion that has already taken place must be accounted for in the analysis of conservation potential, or this potential will be overestimated. In this chapter, potential technical limits to the use of low-pressure irrigation and conservation already achieved through low-pressure conversion are described in relation to their possible impacts upon our analysis.

5.1 TECHNICAL LIMITS

Technical limits should not be applied uniformly to all types of low-pressure irrigation systems. For example, furrow drop-tube systems could have significantly different limitations than low-pressure spray systems. Thus, potential technical limitations will be discussed for each specific low-pressure conversion alternative.

5.1.1 Technical Limits On Low-Pressure Single Spray Systems

Three types of limitations are frequently mentioned in reference to the use of low-pressure single spray systems. These limitations are as follows:

- 1) Use of low-pressure single spray systems on steeply sloped fields may not be feasible because of potential water runoff problems.
- 2) Use of low-pressure single spray systems on tight, non-sandy soils may not be feasible because of potential water runoff problems.
- 3) Use of low-pressure single spray systems may not be feasible where prolonged windy conditions occur because wind is believed to have a greater impact upon water distribution uniformity when low-pressure irrigation methods are used.

In general, it appears that the limitations that could potentially be imposed by field slope and soil type on the use of low-pressure single spray systems are not as severe as is often believed. The generally sandy soils of the irrigated fields of the Pacific Northwest cause the runoff problems associated with use of single spray systems to be small in most cases. Most of the irrigators we contacted who were using low-pressure irrigation felt that excessive runoff problems from tight soils and steep slopes are a problem in only a few of their fields.¹ In addition, irrigators questioned whether the few runoff problems that they were experiencing from using low pressure on steeply sloped ground would not also have occurred if high pressure were used.²

One expert questioned did state that single spray systems should generally not be used on fields with greater than a 25% slope.³ This source did not imply, however, that the use of any low-pressure irrigation method on such steeply sloped fields would be inappropriate. On those fields with greater than a 25 percent slope, it was recommended that low-pressure impact sprinklers operating at approximately 35 psi be used rather than single spray systems.

The severity of runoff problems associated with low-pressure irrigation were examined in a field study of 100 low-pressure irrigation systems currently operating in the Snake River Plain of southern Idaho (Longley 1983). The field runoff measurements taken in this study indicate that most of the low-pressure systems in eastern Idaho are operating without excessive runoff problems. However, on relatively steep slopes and heavy silt loam soils, some runoff problems were noted. In such situations, the study recommends that spray booms or basin tillage techniques be used to reduce runoff problems.

¹ Personal communication with Chestor Prior, a farmer in the area of Echo, Oregon, December 1983.

² Personal communication with Arnold Omlin, a farmer in the area of Quincy, Washington, December 1983.

³ Personal communication with Mike Monaghan, Nelson Irrigation, Walla Walla, Washington, December 1983.

Although the use of single spray systems operating at pressures below 30 psi may not be possible on some fields, there appear to be feasible alternatives, such as spray booms or low-pressure impact sprinklers that would allow for the use of some type of low-pressure irrigation method in such situations. In addition, experience has shown that some fields are able to utilize single spray systems at design pressures below 20 psi without incurring significant runoff problems.⁴ Such fields will tend to counteract the impacts on energy-savings potential of fields where the use of low-pressure spray systems is not feasible and allow the 28-psi design pressure used in our analysis of single spray systems to be a representative average.

The problems caused by prolonged wind conditions have been acknowledged by irrigation-equipment manufacturers in the design of their low-pressure equipment. One of the primary reasons for installing drop tubes in conjunction with single spray application heads is to increase the wind-fighting ability of the irrigation system (Valmont Industries 1983). In addition, a convex or flat design of the spray plate on the application head can be used to increase wind-fighting ability (Valmont Industries 1983). None of the farmers contacted who had converted to low-pressure irrigation felt that the water distribution problems associated with windy conditions were significantly greater over an entire irrigation season than those associated with using high-pressure irrigation. One farm manager stated that misconceptions about the water distribution uniformity of low-pressure systems arise primarily because visual observations indicate that after a single irrigation, the dry spots from windy conditions or plugged sprinklers on low-pressure systems appear to be more pronounced, although over the entire irrigation season no difference between high-pressure and low-pressure irrigation systems should be expected.⁵

In summary, the results of our analysis provide no justification for the application of technical limits to the use of low-pressure spray application

⁴ Personal communication with Arnold Omlin, a farmer in the area of Quincy, Washington, December 1983.

⁵ Personal communication with Melvin Campbell, irrigation manager, U and I, Inc., Kennewick, Washington, December 1983.

systems. In some cases, achieving the 28-psi design pressure level assumed in our analysis may not be feasible without using spray booms or basin tillage techniques. However, in other cases pressure levels below 28 psi are possible. If a low-pressure irrigation system is properly designed, it can be used in any situation in which a high-pressure irrigation system can be used.⁶

5.1.2 Technical Limits On Spray Boom Systems

Theoretically, technical limitations on the use of spray boom systems should be less severe than any that could potentially be imposed on single spray systems, because the runoff and water distribution uniformity problems of boom systems should be less severe. The primary reasons that boom systems were developed were to reduce water runoff and to increase water distribution uniformity by spreading water application over a wider area. Thus, in general, no field elevation or soil type constraints should not be expected to limit the use of spray booms.

However, a constraint that could be associated with the use of spray boom systems is that the heights of some types of booms are difficult and expensive to adjust. This almost prohibits the use of such systems for irrigating corn.⁷ One farmer stated that by adopting this type of spray boom system, a farmer was essentially deciding that he would never grow corn on his field.⁸ Given the growing popularity of raising corn under irrigation, it seems unlikely that many farmers would accept this constraint on their operations.

The spray boom system illustrated in Figure 2.6 was designed specifically for use in irrigating corn grown in rotation with potatoes. It has been

⁶ Personal communication with Melvin Campbell, irrigation manager, U and I, Inc., Kennewick, Washington, December 1983.

⁷ Personal communication with Mike Monaghan, Nelson Irrigation, Walla Walla, WA, 12/83.

⁸ Personal communication with Henry Tessitore, a farmer in the Ritzville, WA area, December 1983.

successfully used in irrigating corn and potatoes on over 35 center pivots on one large farming operation.⁹ The height of these booms can be easily adjusted. Other equipment manufacturers stated that the height of their spray booms could be adjusted without great difficulty.¹⁰ Thus, despite the fact that the use of spray booms has not been widely accepted, there appears to be no basis for imposing technical constraints on the use of all types of these systems for crop rotation flexibility reasons.

5.1.3 Technical Limits On Furrow Drop-Tube Systems

As was described previously, the technical feasibility of using furrow drop-tube systems in the Pacific Northwest is questioned by many irrigation experts. However, enough information does not appear to be available to come to a final conclusion on the subject. It is true that the successful use of a furrow drop-tube system in the Pacific Northwest has not been demonstrated. However, it is also true that no one in the Pacific Northwest has actually attempted to use a furrow drop-tube system in a commercial irrigation application. Successful performance of such a system has been demonstrated over a number of field tests in Texas (Lyle 1981 and 1983).

It is possible that the energy- and water-saving benefits of furrow drop-tube systems will provide sufficient potential economic benefits to warrant further research on their technical feasibility. A field test of a furrow drop-tube system on a commercial farming operation in the Pacific Northwest is tentatively planned in the near future.¹¹ This and other tests should provide the ability to come to a definite conclusion regarding the technical feasibility of these systems.

⁹ Personal communication with Melvin Campbell, irrigation manager, U and I Inc., Kennewick, WA, 12/83.

¹⁰ Personal communication with Bruce Hurtado, Ladd Irrigation, Moses Lake, WA, 12/30/83.

¹¹ Personal communication with Melvin Campbell, irrigation manager, U and I Inc., Kennewick, WA, 1/84.

5.1.4 Technical Limits On Low-Pressure Impact Sprinklers In Handmove And Sideroll Systems

The technical feasibility of using low-pressure impact sprinklers on hand-move and side-roll irrigation systems in the Pacific Northwest has not been widely demonstrated. However, the field studies cited previously (Kincaid 1982 and Wright 1982) provide evidence that this conservation option is feasible, even with 60-foot lateral spacings (as long as offsetting is used). No field data was found that indicated the use of low-pressure impact sprinklers would cause significant reductions in crop yields.

Commercial farmers in Southern Idaho are already using low-pressure impact sprinklers in their irrigation operations, and some of the applications utilize 60-foot lateral spacings.^{12,13} This provides further evidence that the use of low-pressure impact sprinklers on handmove and sideroll systems is technically feasible.

However, it appears that substantial resistance to the concept of using low pressure on handmove and sideroll systems exists among farmers and irrigation dealers.^{14,15} Converting to low pressure (35 psi) on such systems results in a smaller amount of head reduction than for center-pivot systems, and thus, the potential energy savings are lower. A large number of demonstrations of the successful performance of both low pressure and offsetting on a variety of crops will be necessary before farmers will believe that the relatively modest energy savings resulting from low-pressure conversion on handmove and sideroll systems will not result in yield losses.

¹² Personal communication with Richard Malcolm, MG Industries, Sanger, CA, 1/16/84.

¹³ Personal communication with Marvin Shearer, Professor Emeritus, Agricultural Engineering Department, Oregon State University, 12/83.

¹⁴ Personal communication with Dale Betty, Irrigation Rental Co., Toppenish, WA, 12/30/83.

¹⁵ Personal communication with Bruce Hurtado, Ladd Irrigation, Moses Lake, WA, 12/30/83.

All of this suggests that additional testing of this conservation measure is necessary before it is adopted into widespread use.

5.1.5 Additional Technical Limitation Issues

Nothing definite can be stated with regard to potential deterioration in the technical performance of low-pressure conservation technologies over time. None of the farmers or dealers contacted mentioned this as a particular problem. However, most of these systems had been installed for less than two years, which is too short a time period to determine if performance deterioration is a problem.

Some farmers have reported that the energy savings from low-pressure conversion are greater in later years than in the first year, because they become more familiar with their systems.¹⁶ However, the farmers that make this claim generally operate very complex pumping systems. It is believed that the larger savings reported for later years result primarily from increased expertise in optimizing coordination within a complex pumping system rather than any "slow start" phenomena within the technology of low-pressure irrigation itself.

5.2 CONSERVATION ALREADY ACHIEVED

Although a considerable number of center-pivot acres in the Pacific Northwest have been converted to low pressure in the last two or three years, developing a representative estimate of this number is difficult, unless substantial resources are committed to the task. However, it is believed that using a rough estimate of the number of center-pivot acres that have already been converted is preferable for conservation planning purposes to assuming that no conversion has taken place. More confidence can be placed in our estimate of the number of handmove and sideroll irrigated acres that have already been converted to low pressure because, as our findings will show, the use and knowledge of this conservation option is limited.

¹⁶ Personal communication with Marvin Clarkson, irrigation manager, Eastern Oregon Farms, Irrigon, OR, 1/83.

The most accurate method of deriving estimates of conservation already achieved through low-pressure conversion would be to develop a statistically valid farm-level sample of the number of acres that have been converted. Farmers would be polled as to whether they had or had not converted, and representative estimates would be derived from their responses. Despite the advantages of this approach, the level of effort required to develop and analyze a statistically valid sample of irrigation farmers would be substantial.

Project resources required that our analysis be limited to secondary data sources. Thus, development of a statistically valid sample using primary data was not possible. However, a large number of irrigation dealers and farmers were polled as to their "best guess" of the number of low-pressure conversions that had already taken place in their area. A listing of the persons polled in this effort is presented in Appendix Table A.1.

The persons listed in Table A.1 were asked their opinions concerning both the number of acres that had been converted to low pressure and the percentage of total eligible irrigated acreage that this number represented. In many cases, the persons contacted were not able to provide answers to these questions and records on the amount of low-pressure conversion that had been performed by irrigation-equipment dealers were not kept. The specific responses that were received from those questioned were generally too variable to be of use in estimating conservation already achieved. For example, one farmer estimated that the amount of center-pivot conversion that had taken place in his part of the Big Bend utility service area was as high as 60% of eligible acreages,¹⁷ while another farmer located in a different part of the same service area estimated that the conversion that had taken place was less than 20%.¹⁸

¹⁷ Personal communication with Wayne Larson, a farmer in the Pasco, WA area, 12/83.

¹⁸ Personal communication with Gayle Gering, a farmer in the Ritzville, WA area, 12/83.

Some general observations were obtained from the results of the polling process that are useful to our estimation procedure. These observations are the following:

- o Conversion to low pressure on center-pivot acreages has generally been most widespread on large corporate farms located in the intensively irrigated areas of the Columbia Basin, Eastern Oregon, and Southern Idaho. Estimates of the percentage conversion that had already taken place generally ranged in the neighborhood of 50 to 60% of the total center-pivot acres on larger farms in these regions.
- o Conversion to low pressure on the center-pivot acres of small farms has been less common, with estimates ranging in the neighborhood of 20 to 30% of eligible acres.
- o Conversion to low pressure on center-pivot acres for either large or small farms in areas other than the Columbia Basin, Southern Idaho and Eastern Oregon has not been widespread.
- o Conversion to low pressure on handmove and sideroll acres is limited almost exclusively to areas in Southern Idaho. All persons contacted from other regions stated that conversion of handmove and sideroll acres to low pressure was near zero.

To reflect these general observations, arbitrarily specified percentages for the total center-pivot acres on large farms and the total center-pivot acres on small farms were used in developing estimates of conservation already achieved. Farms greater than 2000 acres were arbitrarily categorized as large farms, while all other farms were categorized as small farms. Information on the number of irrigated acres contained in farms greater than 2000 acres in size and less than 2000 acres in size was compiled by our 11 subregions using the 1978 Census of Agriculture as the basic reference source. This information is shown in Table 5.1.

TABLE 5.1. Irrigated Cropland, in Acres, of Small and Large Farms in Regions of Idaho, Oregon, and Washington (a)

Sub-region	Total Irrigated Acres	Irrigated Acres on Farms Less Than 2000 Acres	Irrigated Acres on Farms 2000 Acres or more	% Irrigated Acres in Large Farms
1	85,160	70,615	14,545	17.1%
2	452,577	399,847	52,730	11.7%
3	968,309	657,261	311,048	32.1%
4	114,575	58,848	55,727	48.6%
5	354,410	314,449	39,961	11.3%
6	267,642	117,178	150,464	56.2%
7	600,835	265,330	335,505	55.8%
8	657,946	316,150	341,796	52.0%
9	388,949	258,579	130,370	33.5%
10	3,086,443	2,434,484	651,959	21.1%
11(b)	---	---	---	33.5%

(a) Source: 1978 Census of Agriculture

(b) Data for Subregion 9 also assumed to be representative of Western Montana.

The last column of Table 5.1 was used in estimating conservation achieved. The estimation procedure was performed using the following equation:

$$CF = (\% LF)(\% CLF)(\% CP) + (\% SF)(\% CSF)(\% CP)$$

where CF = conversion factor for deriving estimates of conservation already achieved on center-pivot acreages using groundwater and surface water in each subregion

% LF = percentage of irrigated acreage comprised by farms greater than 2000 acres in each subregion from Table 5.1

% CLF = percentage of center-pivot acreages on large farms assumed to be converted to low pressure in each subregion

% CP = percentage of total sprinkler-irrigated acres by crop and water source that use center-pivot irrigation systems in each subregion

% SF = percentage of irrigated acres comprised by farms less than 2000 acres in size in each subregion (1 - % LF)

% CSF = percentage of center-pivot acres on small farms assumed to be converted to low pressure in each subregion

The percentage of center-pivot acres on large farms (% CLF) which had been converted to low pressure was assumed to be 30% in Subregions 2, 4, 7, 8, 9, and 11, and 60% in all other subregions. The percentage of center-pivot acres on small farms (% CSF) which had been converted to low pressure was assumed to be 20% in all subregions except Subregion 10 (Southern Idaho), where it was assumed to be 30%.

When the conversion factor (CF) was multiplied by existing sprinkler-irrigated acres estimates developed by Northwest Economic Associates (NEA 1984), the estimates shown in Tables 5.2 and 5.3 were obtained. These estimates represent "educated guesses" concerning the number of center-pivot acres on which conservation has already been achieved through low-pressure conversion.

As stated previously, conversions of handmove and sideroll sprinkler acres appear to be limited almost exclusively to Southern Idaho. Thus, it was assumed in our analysis that 20% of all eligible handmove and sideroll acres in Subregion 10 had already been converted to low pressure, while the percentage of eligible acres that had been converted in other subregions were assumed to be zero. Estimates of the number of handmove and sideroll acres that have been converted to low pressure were calculated using these assumptions.

Estimates of conservation already achieved are important inputs in estimating conservation potential because conservation that has already been achieved should not be included in conservation potential. The estimates of acreages on which conservation has been achieved through low-pressure conversion described in this chapter were subtracted from estimates of total

TABLE 5.2. Estimates of Center-Pivot Acres Using Groundwater on Which Conservation Has Been Achieved Using Low-Pressure Irrigation

Sub- region	Crop					
	Wheat	Alfalfa	Potatoes	Corn	Orchard	Other
1	0	0	0	0	0	0
2	1,009	879	44	735	0	324
3	21,476	14,517	8,411	7,165	0	1,471
4	1,694	708	0	0	0	0
5	0	172	0	80	0	0
6	3,824	3,139	2,931	483	0	0
7	1,075	6,030	80	0	0	0
8	1,205	6,540	301	18	0	0
9	0	0	0	0	0	0
10	19,856	19,207	7,831	1,520	0	11,889
11	83	383	2	0	0	2

TABLE 5.3. Estimates of Center-Pivot Acres Using Surface Water on Which Conservation Has Been Achieved Using Low-Pressure Irrigation

Sub- region	Crop					
	Wheat	Alfalfa	Potatoes	Corn	Orchard	Other
1	0	0	0	0	0	0
2	3,155	985	240	4,002	0	755
3	25,384	18,463	17,945	17,281	0	10,880
4	3,615	1,287	0	0	0	0
5	114	286	21	457	0	0
6	15,446	7,365	8,352	1,841	0	0
7	611	2,020	281	0	0	0
8	452	1,888	454	0	0	0
9	0	0	0	0	0	0
10	6,333	4,714	2,302	399	0	858
11	1,338	6,205	27	0	0	39

irrigated acres developed by Northwest Economic Associates¹⁹ to obtain more representative estimates of the baseline acreages from which conservation potential is derived. However, additional research is necessary if reliable estimates of conservation achieved are to be obtained.

¹⁹ Unpublished data supplied by David Ricks, Research analyst with Northwest Economics Associates, Vancouver, WA.

6.0 ESTIMATION OF RESULTS

As stated in the introduction of this report, the primary objective of this study is to develop cost and energy savings information on low-pressure irrigation that BPA can use in its conservation program planning efforts. In this chapter, a brief description of the methodology used in the ISEP model is presented. Following this description, the results derived using the model are presented.

6.1 STUDY METHODOLOGY

To facilitate understanding of the results of this study, a brief discussion of the methodology employed in the ISEP model is presented. Those wishing further detail on the computer model used in the estimation procedure should refer to other documents (Harrer 1984a and 1984b) prepared during this study.

In general, the kWh electrical energy use of an irrigation system can be estimated using the following equation:

$$E = \frac{V \times H \times 1.024}{PPE}$$

where E = annual electrical energy use per acre in kWh for an irrigation system

V = volume of water applied annually through the irrigation system in acre feet

H = total dynamic head of the irrigation system in feet

PPE = efficiency of the pumping plant in converting energy input into energy output

The way in which low-pressure conversions reduce irrigation system energy use is by reducing the head required for pressurizing water for application to the crop. Thus, the total dynamic head of the irrigation system is reduced. Differences in energy use between the various low-pressure conversion alternatives are calculated by the following:

$$\Delta E = \frac{V \times H_0 \times 1.024}{PPE} - \frac{V \times H_1 \times 1.024}{PPE}$$

where ΔE = difference in annual energy use per acre in kWh between an irrigation system and its low-pressure conversion alternative

H_0 = total dynamic head of an irrigation system before low-pressure conversion

H_1 = total dynamic head of an irrigation system after low-pressure conversion

To determine a cost per kWh saved using annual energy savings as the denominator, all costs must be converted to an annual equivalent or levelized cost basis. The equation used in this study for estimating the differences between the levelized costs of the various low-pressure conversion alternatives was the following:

$$\begin{aligned} \Delta LEV &= LEV_1 - LEV_0 \\ &= \left[\left(I_1 - \frac{SV_1}{(1+d)^n} \right) \left(\frac{d(1+d)^n}{(1+d)^n - 1} \right) - \left(I_0 - \frac{SV_0}{(1+d)^m} \right) \left(\frac{d(1+d)^m}{(1+d)^m - 1} \right) \right] \\ &\quad + \left[\left(PVOM_1 \frac{d(1+d)^n}{(1+d)^n - 1} \right) - \left(PVOM_0 \frac{d(1+d)^m}{(1+d)^m - 1} \right) \right] \end{aligned}$$

where ΔLEV = difference in the annual equivalent or levelized cost between an irrigation system and its low-pressure conversion alternative

I_1 = initial capital cost of investing in a low-pressure conversion alternative

SV_1 = salvage value for equipment installed as part of low-pressure conversion

d = discount rate used for converting present initial capital costs to annual equivalent (levelized) costs

n = system life (in years) for low-pressure conversion alternative

I_0 = initial capital cost of an irrigation system
 SV_0 = salvage value for equipment of an irrigation system before conversion
 m = system life for an irrigation system before conversion
 $PVOM_1$ = present value of total annual operation and maintenance costs for a low-pressure conversion alternative
 $PVOM_0$ = present value of total annual operation and maintenance costs for an irrigation system before conversion over its remaining system life

Often, some of the parameters in the above equation are zero. For example, the initial capital costs for high-pressure center pivots on existing acreages are sunk costs and, thus, would be zero at the time a low-pressure conversion alternative is being considered.

Once the differences in annual kWh usage and annual levelized cost per acre are calculated, the cost per kWh saved is calculated by the following:

$$\text{Cost per kWh saved} = \frac{\Delta LEV}{\Delta E}$$

The aggregate potential energy savings in average MW for a conversion option is estimated by the following:

$$\text{Potential savings in average MW} = \Delta E \times (ACEL - ACCA) / 1000 / 8760$$

where $ACEL$ = acreage eligible to utilize a low-pressure conversion alternative (i.e., not limited by technical considerations)

$ACCA$ = acreage eligible to use a low-pressure conversion alternative which have already been converted to low pressure

1000, 8760 = factors for converting kWh savings to average MW of savings

6.2 COST PER KWH SAVED AND ENERGY SAVINGS POTENTIAL FOR LOW-PRESSURE SINGLE SPRAY SYSTEMS

Estimates of the average cost per kWh saved by subregion for converting to low-pressure spray systems and the potential energy savings that could be achieved from such conversion on existing center-pivot acreages are presented in Table 6.1. Note from Table 6.1 that the largest potential for energy savings is estimated to be in Subregion 3 (the Columbia Basin Region of Washington). This occurs despite our assumption that approximately 143,000 acres of existing center-pivot acreages in this subregion have already been converted to low pressure. Other relatively large energy-savings potential are estimated for Subregion 6 (Eastern Oregon along the Columbia River) and Subregion 10 (Southern Idaho). The total technical potential for energy savings in the BPA service area from the conversion of high-pressure center pivots to low-pressure single-spray systems is estimated to be approximately 21 average MW. This compares to an estimate of approximately 29 average MW developed in an earlier study for the Northwest Power Planning Council (Harrer 1982). The lower estimate for the current study can be attributed primarily to the fact that conservation already achieved was not accounted for in the earlier Power Council study. At the time the earlier study was performed, the amount of conservation that had been achieved was probably small, because most low-pressure center-pivot conversions have been performed in the last two years.

The cost per kWh saved over a 20-year system life for converting high-pressure center pivots to low-pressure single-spray systems using surface water is estimated to be less than 11 mills for every subregion except Subregion 5 (Oregon Coast). The cost per kWh saved for low-pressure conversions when groundwater is used is estimated to be less than 15 mills per kWh saved for every subregion except Subregion 5. The higher cost for groundwater conversions can be attributed directly to the higher capital expenditures necessary to gain access to a groundwater pump so that it can be modified to pump water at lower pressures.

The last set of information on existing acreages in Table 6.1 is presented to illustrate the situation that some farmers face in obtaining funds to convert to low pressure. If farmers do not have sufficient funds to finance low-pressure conversions out of their own cash flows, they must borrow the

TABLE 6.1. Energy Savings Potential in Average MW and Cost per kWh Saved in Mills for Converting High-Pressure (54 psi) Impact Sprinkler Systems to Low-Pressure (28 psi) Single Spray Systems on Existing and New Center-Pivot Acreages

	Water Source	Subregion											BPA Service Area
		1	2	3	4	5	6	7	8	9	10	11	
Energy Savings (Average MW) on Existing Acreages	Surface Water	NCP	0.75	4.84	0.25	0.04	1.05	0.23	0.33	NCP	2.46	0.41	10.36
	Groundwater	NCP	0.92	4.59	0.14	0.01	0.63	0.57	0.43	NCP	3.74	NCP	11.03
	Total	NCP	1.67	9.43	0.39	0.05	1.68	0.80	0.76	NCP	6.20	0.41	21.38
Cost Per kWh Saved (Mills) 20-Year Life on Existing Acreages	Surface Water	NCP	10.66	7.99	10.62	17.37	8.37	9.38	10.07	NCP	9.62	10.88	8.92
	Groundwater	NCP	13.81	10.91	13.92	17.00	10.72	12.09	13.17	NCP	12.65	NCP	11.93
	Average	NCP	12.39	9.41	11.78	17.28	9.25	11.31	11.82	NCP	11.45	10.88	10.47
Cost Per kWh Saved (Mills) 3-Year Life on Existing Acreages	Surface Water	NCP	54.29	40.77	54.29	99.57	42.73	47.93	51.40	NCP	49.03	55.42	45.54
	Groundwater	NCP	70.69	55.66	71.03	82.40	54.83	61.89	67.38	NCP	64.66	NCP	60.92
	Average	NCP	63.32	48.02	60.30	96.14	47.27	57.88	60.44	NCP	58.46	55.42	53.50
Energy Savings on New Acreages in 2003 (Ave. MW)	Surface Water	NCP	NCP	4.23	0.12	NCP	0.16	NCP	NCP	NCP	0.40	NCP	4.91
	Groundwater	NCP	0.06	NCP	0.02	0.01	0.47	0.12	0.27	NCP	0.72	0.08	1.75
	Total	NCP	0.06	4.23	0.14	0.01	0.63	0.12	0.27	NCP	1.12	0.08	6.66
Cost Per kWh Saved on New Acreages (1984 Mills)	Surface Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Groundwater	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(a) NCP = No Center-Pivot acreages.

money. Often, farm lending institutions require that the investments on which they lend money have a payback period of less than three years.¹ The information presented in Table 6.1 illustrates that the discounted cash flows resulting from energy savings would generally not return the costs of low-pressure conversion over three years unless the cost of power was in the range of 40 to 55 mills per kWh for surface water pumping plants and 50 to 70 mills for groundwater pumping plants. It should be emphasized that the cost and energy savings parameters selected for use in this study are conservative and, thus, the cost per kWh saved estimates for a 3-year life are higher than would be found in many situations.

Also shown in Table 6.1 are the estimated energy savings and cost per kWh saved estimates for low-pressure single-spray systems on new center-pivot acres. Almost 65 percent of the total energy savings for this conservation measure are expected to be obtained in Subregion 3 and approximately 80 percent of the total savings are forecast to be obtained for Subregions 3 and 10 together. The cost per kWh saved estimates are zero because no evidence was found that low-pressure irrigation would cost more than high-pressure irrigation on new center-point acres.

The estimated energy savings in 5-mill increments for the conversion of high-pressure impact sprinklers to low-pressure single-spray application heads on existing center-pivot acres are shown in Table 6.2. All of the estimated energy savings for this conservation measure can be obtained for 20 mills per kWh saved or less and 95 percent of the savings can be obtained for 15 mills or less. Shown in Table 6.3 are the estimated energy savings in 5-mill increments for low-pressure single-spray systems on new center-pivot acres. The estimated savings are equal across all 5-mill categories because no additional cost was specified for low-pressure single-spray irrigation on new center pivot acres.

¹ Personal communication with Henry Tessitore, a farmer in the Ritzville, Washington area, December, 1983.

TABLE 6.2. Estimated Cumulative Energy Savings (Average MW) and Estimated Cumulative Acreages Impacted in 5-Mill Increments of Cost per kWh Saved for Converting High-Pressure (54 psi) Impact Sprinklers to Low-Pressure (28 psi) Single Spray on Existing Center-Pivot Acreages

<u>Water Source</u>	<u>Type of Estimate</u>	<u>Cost per kWh Saved</u>									
		5	10	15	20	25	30	35	40	45	50
Surface Water	Energy Savings (Ave. MW)	0.00	6.98	10.34	10.36	10.36	10.36	10.36	10.36	10.36	10.36
Groundwater	Energy Savings (Ave. MW)	0.00	2.76	9.89	11.02	11.02	11.02	11.02	11.02	11.02	11.02
Total	Energy Savings (Ave. MW)	0.00	9.74	20.23	21.38	21.38	21.38	21.38	21.38	21.38	21.38

TABLE 6.3. Estimated Cumulative Energy Savings Potential (Ave. MW)
In 5-Mill Increments of Cost per kWh Saved for Converting
High-Pressure (54 psi) Impact Sprinklers to Low-Pressure
(28 psi) Single Spray on New Center-Pivot Acreages

Year	Cost per kWh Saved										
	0	5	10	15	20	25	30	35	40	45	50
1985	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
1986	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
1987	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
1988	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
1989	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77
1990	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10
1991	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41	2.41
1992	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69
1993	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
1994	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33	3.33
1995	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66
1996	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02
1997	4.35	4.35	4.35	4.35	4.35	4.35	4.35	4.35	4.35	4.35	4.35
1998	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70	4.70
1999	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08	5.08
2000	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
2001	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89
2002	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26	6.26
2003	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66

6.3 COST PER KWH SAVED AND ENERGY SAVINGS POTENTIAL FOR LOW-PRESSURE SPRAY BOOM SYSTEMS

The addition of spray booms will generally allow for a small reduction in operating pressure compared to single-spray systems. In this study, it was assumed that this reduction was 8 psi. The results presented in Table 6.4 illustrate that the energy savings benefits of an 8-psi reduction for spray booms would generally cost from 30 to 35 mills per kWh saved. These costs should be approximately the same on both existing and new acres.

Even if the energy savings benefits of spray booms are insufficient to justify their costs, the use of booms may be appropriate for other reasons. On steeply sloped fields with tight soils, using spray booms may be the only method of realizing the benefits of low-pressure irrigation. When very large amounts of water are applied, the energy cost reductions achievable with spray booms may compensate for the increased initial costs of the systems. Finally, some farm managers report that the better water distribution characteristics of spray boom systems can lead to increased crop yields.²

Potential energy savings and cost per kWh saved estimates for spray boom systems compared to high-pressure center-pivot systems are presented in Table 6.5. These estimates demonstrate that when a 20-year system life is used, energy savings from spray boom systems can be obtained for a cost that is generally from 15 to 20 mills per kWh saved.

6.4 COST PER KWH SAVED FOR LOW-PRESSURE FURROW DROP-TUBE SYSTEMS

Because of questions concerning the technical feasibility of furrow drop-tube systems, the analysis of these systems was limited to estimating the cost per kWh saved. The results of this estimation are shown in Table 6.6. Note from Table 6.6 that when the assumption is used that the operating and maintenance costs of a furrow drop-tube system are four dollars per acre higher than those of low-pressure spray systems, furrow drop-tube systems are not economically competitive with low-pressure single spray systems unless the cost of power is above 40 mills. However, with the assumption that the operating and

² Personal communication with Melvin Campbell, Irrigation Manager, U and I Inc., Kennewick, Washington, December 1983.

TABLE 6.4. Energy Savings Potential in Average MW and Cost per kWh Saved in Mills for Converting Low-Pressure (28 psi) Single Spray Systems to Low-Pressure (20 psi) Spray Boom Systems on Existing and New Center-Pivot Acreages

	Water Source	Subregion											BPA Service Area
		1	2	3	4	5	6	7	8	9	10	11	
Energy Savings (Average MW)	Surface Water	NCP	0.24	1.75	0.09	0.01	0.41	0.07	0.06	NCP	0.20	0.12	2.95
	Groundwater	NCP	0.08	1.03	0.05	0.01	0.14	0.18	0.19	NCP	0.84	0.01	2.53
	Total	NCP	0.32	2.78	0.13	0.02	0.54	0.25	0.25	NCP	1.04	0.13	5.48
Cost Per kWh Saved (Mills) 20-Year Life	Surface Water	NCP	39.13	28.85	38.03	62.52	30.14	33.78	36.27	NCP	35.66	29.15	31.35
	Groundwater	NCP	37.36	29.14	34.74	51.29	28.50	32.13	34.76	NCP	34.59	38.49	32.04
	Average	NCP	38.69	28.96	38.30	56.91	30.27	32.59	35.12	NCP	34.80	39.10	31.67

(a) NCP = No Center-Pivot acreages

TABLE 6.5. Energy Savings Potential in Average MW and Cost per kWh Saved in Mills for Converting High-Pressure (54 psi) Impact Sprinkler Systems to Low-Pressure (20 psi) Spray Boom Systems on Existing Center-Pivot Acreages

		Subregion											BPA Service Area
Water Source		1	2	3	4	5	6	7	8	9	10	11	
Energy Savings (Average MW)	Surface Water	NCP	0.98	6.09	0.33	0.05	1.26	0.30	0.43	NCP	3.10	0.43	12.97
	Groundwater	NCP	1.20	5.87	0.18	0.01	0.75	0.75	0.55	NCP	4.66	NCP	13.97
	Total	NCP	2.18	11.96	0.51	0.06	2.01	1.05	0.98	NCP	7.76	0.43	26.94
Cost Per kWh Saved (Mills) 20-Year Life	Surface Water	NCP	17.85	13.38	17.80	29.09	14.03	15.72	16.87	NCP	16.12	18.22	14.94
	Groundwater	NCP	19.73	15.59	19.88	24.29	15.32	17.27	18.82	NCP	18.07	NCP	17.04
	Average	NCP	18.89	14.46	18.53	28.01	14.51	16.83	17.97	NCP	17.30	18.22	16.02

TABLE 6.6. Cost per kWh Saved in Mills for Converting to a Furrow Drop-Tube (14 psi) System on Existing Center-Pivot Acreages

Conversion Option	Water Source	Subregion											BPA Service Area
		1	2	3	4	5	6	7	8	9	10	11	
High-Pressure (54 psi) Center-Pivot to Furrow Drop-Tube Assuming \$4 per Acre Additional O & M Cost	Surface Water	NCP	27.45	20.59	27.37	44.76	21.57	24.20	25.97	NCP	24.81	28.02	22.99
	Groundwater	NCP	29.22	23.06	29.42	35.10	22.66	25.56	27.84	NCP	26.76	NCP	25.21
	Average	NCP	28.31	21.79	28.09	42.35	21.98	25.17	26.79	NCP	25.99	28.02	24.13
High-Pressure (54 psi) Center-Pivot versus Furrow Drop-Tube Assuming No Additional O & M Cost	Surface Water	NCP	14.12	10.59	14.08	23.02	11.10	12.44	13.35	NCP	12.76	14.41	11.82
	Groundwater	NCP	16.44	12.98	16.56	20.23	12.76	14.39	15.68	NCP	15.06	NCP	14.19
	Average	NCP	15.40	11.76	14.95	22.39	11.72	13.83	14.67	NCP	14.14	14.41	13.05
Low-Pressure (28 psi) Single Spray to Furrow Drop-Tube Assuming \$4 per Acre Additional O&M Cost ^(b)	Surface Water	NCP	50.95	37.56	46.90	81.40	39.26	43.99	47.22	NCP	46.43	50.97	40.85
	Groundwater	NCP	48.64	37.93	45.34	66.78	37.10	41.83	45.25	NCP	45.03	50.12	41.67
	Average	NCP	50.36	37.70	46.38	77.63	38.71	42.42	45.74	NCP	45.30	50.92	41.23
Low-Pressure (28 psi) Single Spray to Furrow Drop-Tube Assuming No Addition O&M Cost ^(b)	Surface Water	NCP	17.61	12.98	16.21	28.14	13.57	15.20	16.32	NCP	16.05	17.62	14.12
	Groundwater	NCP	16.81	13.11	15.67	23.08	12.82	14.46	15.64	NCP	15.57	17.32	14.40
	Average	NCP	17.41	13.03	16.02	26.83	13.38	14.66	15.81	NCP	15.66	17.60	14.25

(a) NCP = No Center-Pivot acreages.

(b) Cost per kWh saved estimates for comparisons of single-spray to furrow drop-tube systems are applicable to new as well as existing acreages.

maintenance costs of furrow drop-tube systems are equal to those of low-pressure spray systems, then the incremental costs of a furrow drop-tube system compared to a single spray system average less than 20 mills per kWh saved.

It is unclear at this point what the appropriate level of incremental operating and maintenance costs for low-pressure furrow drop-tube systems should be. The four dollars per acre charge developed in a previous study (Harrer 1982) was a very crude estimate based upon the assumption that the maintenance costs would equal 5% of the original purchase price of the furrow drop-tube system.

If the operating and maintenance costs for furrow drop-tube systems are not significantly different from those of low-pressure spray systems, our analysis estimates that approximately 11 average MW could be saved by using these systems rather than single-spray systems on existing center-pivot acreages at a cost generally less than 20 mills per kWh saved. These results suggest that a limited field research and demonstration program on the technical and economic feasibility of using furrow drop-tube systems in the Pacific Northwest may be warranted.

6.5 COST PER KWH SAVED AND ENERGY SAVINGS POTENTIAL FOR LOW-PRESSURE IMPACT SPRINKLERS ON HAND-MOVE AND SIDE-ROLL IRRIGATION SYSTEMS

Estimates of the potential energy savings and the costs per kWh saved for converting existing handmove and sideroll irrigation systems from high-pressure impact sprinklers operating at 50 psi to low-pressure impact sprinklers operating at 35 psi are presented in Table 6.7. Note that the largest potential energy savings from such conversions can be achieved in Subregion 10 (Southern Idaho) and that relatively large savings can also be achieved in Subregion 3 (the Columbia Basin Region of Washington) and Subregion 11 (Western Montana).

The energy savings from conversion of high-pressure handmove and side roll systems using surface water to low pressure can generally be achieved for a cost of less than 20 mills per kWh saved. The costs of gaining access to the pump for modification causes the costs for conversions of systems that use groundwater to be slightly higher than for systems that use surface water. On

TABLE 6.7. Energy Savings Potential in Average MW and Cost per kWh Saved in 1984 Mills for Converting High-Pressure (50 psi) Impact Sprinkler Systems to Low-Pressure (35 psi) Impact Sprinkler Systems on Existing and New Handmove and Sideroll Acreages

		Subregion											BPA Service Area
Water Source		1	2	3	4	5	6	7	8	9	10	11	
Energy Savings (Average MW)	Surface Water	0.25	1.43	4.72	0.57	1.75	1.29	1.85	2.50	0.94	5.77	3.67	27.74
	Groundwater	0.23	0.53	1.77	0.93	0.58	0.38	0.47	0.40	0.29	8.59	0.05	14.22
	Total	0.48	1.96	6.49	1.50	2.33	1.67	2.32	2.90	1.23	14.36	3.72	38.96
Cost per kWh Saved (Mills) 20-Year Life	Surface Water	36.41	14.88	12.70	13.91	25.15	11.42	14.34	15.45	16.80	15.64	17.22	15.82
	Groundwater	48.91	19.57	15.92	19.52	33.97	15.62	19.97	20.89	22.60	21.10	23.16	21.13
	Average	42.51	16.16	13.58	17.40	27.34	12.37	15.49	16.20	18.17	18.91	17.29	17.76
Cost per kWh Saved (Mills) 3-Year Life	Surface Water	99.82	40.67	34.75	38.13	68.63	31.19	39.21	42.23	45.75	42.89	46.92	43.25
	Groundwater	165.54	66.21	53.58	65.74	114.14	52.67	67.17	70.23	75.98	71.31	77.90	71.27
	Average	131.31	47.58	39.89	55.25	79.96	36.08	44.87	46.09	52.88	59.89	47.34	53.49
Energy Savings on New Acreages in 2003 (Average MW)	Surface Water	NOS ^a	NOS	2.66	0.19	NOS	0.10	NOS	NOS	NOS	0.91	NOS	3.86
	Groundwater	NOS	0.03	NOS	0.11	0.52	0.19	0.07	0.17	0.22	1.50	0.50	3.31
	Total	NOS	0.03	2.66	0.30	0.52	0.29	0.07	0.17	0.22	2.41	0.50	7.17
Cost per kWh Saved on New Acreages (1984 Mills)	Surface Water	NOS	NOS	6.32	6.93	NOS	5.69	NOS	NOS	NOS	7.79	NOS	6.68
	Groundwater	NOS	7.12	NOS	7.11	12.36	5.69	7.27	7.60	8.23	7.60	8.23	8.42
	Average	NOS	7.12	6.32	6.99	12.36	5.69	7.27	7.60	8.23	7.72	8.23	7.48

(a) NOS = No Other Sprinkler acreages.

new handmove and sideroll acres, the potential energy savings for low-pressure impact sprinkler systems are estimated to exceed seven average MW. The costs of obtaining these savings average approximately 7.5 mills per kWh saved.

The estimates of system conversion costs, assuming that a 3-year payback is required, illustrate that the costs of converting to low pressure on groundwater acreages under such a requirement would generally be prohibitive. For surface water acreages, the 3-year cost per kWh saved would normally range from 35 to 45 mills per kWh saved.

Estimates of the potential energy savings and impacted acreages for 5-mill cost per kWh saved increments are shown in Table 6.8. These results indicate that approximately 78 percent of the total estimated potential energy savings for this conservation measure on existing acres can be obtained for 20 mills per kWh saved or less. Results shown in Table 6.9 indicate that all of the potential energy savings on new acres can be realized for 15 mills per kWh saved or less and 91 percent of the savings can be obtained for 10 mills or less.

All of the cost estimates pertaining to the conversion of sideroll and handmove systems to low pressure assume that such conversion would not decrease crop yields. This assumption is supported by available field research results (Kincaid 1982). However, many farmers will need to be convinced that low-pressure conversions will not impact their yields before they will undertake such conversions. Thus, further testing and demonstration of the successful use of low-pressure impact sprinklers on handmove and sideroll systems is recommended. A relatively slow rate of market penetration and acceptance for this technology should also be assumed.

TABLE 6.8. Estimated Cumulative Energy Savings (Average MW) and Estimated Cumulative Acreages Impacted in 5-Mill Increments of Cost per kWh Saved for Converting High-Pressure (50 psi) Impact Sprinklers to Low-Pressure (35 psi) Impact Sprinklers on Existing Center-Pivot Acreages

Water Source	Type of Estimate	<u>Cost per kWh Saved</u>									
		5	10	15	20	25	30	35	40	45	50
Surface Water	Energy Savings (Ave. MW)	0	0.00	11.76	22.01	23.38	24.44	24.44	24.75	24.75	24.75
Ground-water	Energy Savings (Ave. MW)	0	0.00	0.80	6.53	12.99	13.62	13.87	13.88	13.98	14.19
Total Energy Savings (Ave. MW)		0	0.00	12.56	28.54	36.37	38.06	38.31	38.63	38.73	38.94

TABLE 6.9. Estimated Cumulative Energy Savings Potential (Ave. MW)
In 5-Mill Increments of Cost per kWh Saved for Low-Pressure
Irrigation on All New Handmove and Sidroll Acreages

Year	Cost per kWh Saved										
	0	5	10	15	20	25	30	35	40	45	50
1985	0.00	0.00	0.51	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
1986	0.00	0.00	0.92	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
1987	0.00	0.00	1.35	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44
1988	0.00	0.00	1.80	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
1989	0.00	0.00	2.25	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
1990	0.00	0.00	2.61	2.78	2.78	2.78	2.78	2.78	2.78	2.78	2.78
1991	0.00	0.00	2.86	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05
1992	0.00	0.00	3.08	3.30	3.31	3.31	3.31	3.31	3.31	3.31	3.31
1993	0.00	0.00	3.34	3.59	3.59	3.59	3.59	3.59	3.59	3.59	3.59
1994	0.00	0.00	3.63	3.91	3.91	3.91	3.91	3.91	3.91	3.91	3.91
1995	0.00	0.00	3.90	4.21	4.22	4.22	4.22	4.22	4.22	4.22	4.22
1996	0.00	0.00	4.22	4.56	4.57	4.57	4.57	4.57	4.57	4.57	4.57
1997	0.00	0.00	4.58	4.96	4.96	4.96	4.96	4.96	4.96	4.96	4.96
1998	0.00	0.00	4.81	5.23	5.23	5.23	5.23	5.23	5.23	5.23	5.23
1999	0.00	0.00	5.16	5.62	5.62	5.62	5.62	5.62	5.62	5.62	5.62
2000	0.00	0.00	5.52	6.01	6.01	6.01	6.01	6.01	6.01	6.01	6.01
2001	0.00	0.00	5.86	6.40	6.40	6.40	6.40	6.40	6.40	6.40	6.40
2002	0.00	0.00	6.20	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78
2003	0.00	0.00	6.54	7.17	7.17	7.17	7.17	7.17	7.17	7.17	7.17

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APPENDIX A

TABLE A.1. Persons Contacted Concerning Conservation
Already Achieved from Low-Pressure Irrigation
and Subregion in which Contact Works

<u>Name</u>	<u>Address and Affiliation</u>	<u>Subregion</u>
Bruce Hurtado	Ladd Irrigation, Moses Lake, WA 765-8864 Valley	3
Dale Kellingsworth	Valley, Madras, OR 475-6776	7
Dale Betty	Irrigation Rental Co., Yakima Toppenish, WA 865-2206	2
Al Presson	Ackland Irrigation, Yakima	2
Jeff Sherbourne	Silver Creek Irrigation Co. Gerome, ID 324-8185	10
Chad Gibbæll	Rain For Rent, Idaho Falls 522-4500	10
Alan Blize	Ag-Sales Co. Missoula, MT (406) 721-2640	11
Thom McVeigh et al.	Valmont Northwest Pasco, WA 547-1623	3
Mr. Neal	Falls Irrigation Co., ID 734-3130	10
Carl Bronson	Grower's Supply, Fruitland (Payette County) 452-4561	10
Leonard Isaacs	Isaacs & Son Irrigation, Walla Walla 529-2286	3
Max Gardner	USDA Extension, Payette, ID 642-9397 (no info)	10
Chad Gibson	USDA Extension, Owyhee, ID 896-4104 (no info)	10
	USDA Extension, Hood River, OR 386-3343 (no info)	6
John Crabtree	Gilliam County, OR (503) 384-2271 USDA	6
Dave Curtis	Bannock, Idaho, SCS (USDA)	10
George Gardner	Bannock, Idaho, Extension (USDA)	10

TABLE A.1. (cont.)

Chris Everts	USDA Extension, Twin Falls, ID 734-9590	10
Martin Zimmerman	Jefferson County Extension, OR 475-3808	7
Rod McCoy	Blain County Extension, ID 788-3451	9
Melvin Campbell	U and I Group Inc. Kennewick, WA	3
Chester Prior	Private farmer Hermiston, OR	6
Wayne Larson	Private farmer Pasco, WA	3

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