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THE ECONOMICS OF IRRIGATING MEDIUM AND FINE TEXTURED SOILS IN MINNESOTA

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I. Introduction

A. Purpose

Previous studies of the profitability of irrigation in the upper midwest have emphasized the coarse textured soils in the glacial outwash areas (e.g., see Eidman (1977); Eidman, et al. (1978)). While relatively little experimental data has been available on the profitability of irrigating finer textured soils, some farmers have installed irrigation systems and have been using them to irrigate fine and medium textured soils in the area.

One purpose of this report is to provide information on the type of irrigation systems being used and the increase in yields achieved by southern Minnesota farmers on fine and medium textured soils. The irrigators in 26 south central and southwestern counties of Minnesota were interviewed to obtain data on the type of irrigation systems, the amount and timing of water applications, fertilizer rates, cultural practices, and the yield obtained. These data provide a description of the irrigation systems being used, the amounts and timing of inputs that are used in the production of field crops, and data on the difference between irrigated and non-irrigated yields obtained by farmers in the area. The survey data are summarized in the second section of this report.

The second purpose of this report is to provide estimates of the potential profitability of irrigating the major field crops on fine to medium textured soils in south central and southwestern Minnesota. The third section of the report defines typical irrigation systems based on the survey data and provides estimates of current investment costs for those systems. Average annual cost and return budgets are included for corn, soybeans and alfalfa to summarize the input data and production costs assumed in the analysis as well as to provide a very tentative indication of the net returns that can be achieved with irrigation. The final part of section three provides a more complete assessment of the profitability of irrigation by water holding capacity of the soil. The after-tax internal rate of return was calculated for a corn/soybean rotation on alternative soils to indicate the effect of available water holding capacity on the potential profitability of an irrigation system.

Before turning to the survey and the economic analysis, it is useful to outline the time, path, and geographic concentration of irrigation development in Minnesota. This provides a perspective to evaluate the feasibility of irrigating medium to fine textured soils.

B. Irrigation in Minnesota

Periodic and detailed data on irrigated acreage in Minnesota is unavailable. These data are not routinely collected because of the minor role irrigated agriculture plays in determining the aggregate productivity and well being of the Minnesota agricultural sector.

Prior to 1970, field crop irrigation in Minnesota was a phenomena primarily restricted to the glacial outwash soils of central Minnesota. With improved technology and an increased understanding of the benefits (not necessarily the costs) of irrigation during the dry years, the irrigated acreage increased five-fold during the period 1970-1976. Machmeier (1977) estimated that there were approximately 250,000 acres of sprinkler irrigated land in 1976, which represented approximately 1.1 percent of the crop land in Minnesota at that time. More recent data of the Crop and Livestock Reporting Service showed that approximately 359,000 acres were irrigated during the 1979 crop year. This represents 1.6 percent of the crop land in Minnesota.

Another means of evaluating irrigation growth is to look at the number of irrigation permits that have been issued by the Minnesota Department of Natural Resources (DNR) in recent years. These figures are presented in Figure 1 for 1950-1980[1/]. Irrigation permit requests increased by 214 percent in 1976 over 1975 and peaked at over 1,500 permits in 1977, a 127 percent increase over the previous year. The overriding reason for these new requests was the drought of 1974-76 which adversely affected Minnesota agricultural production. During these

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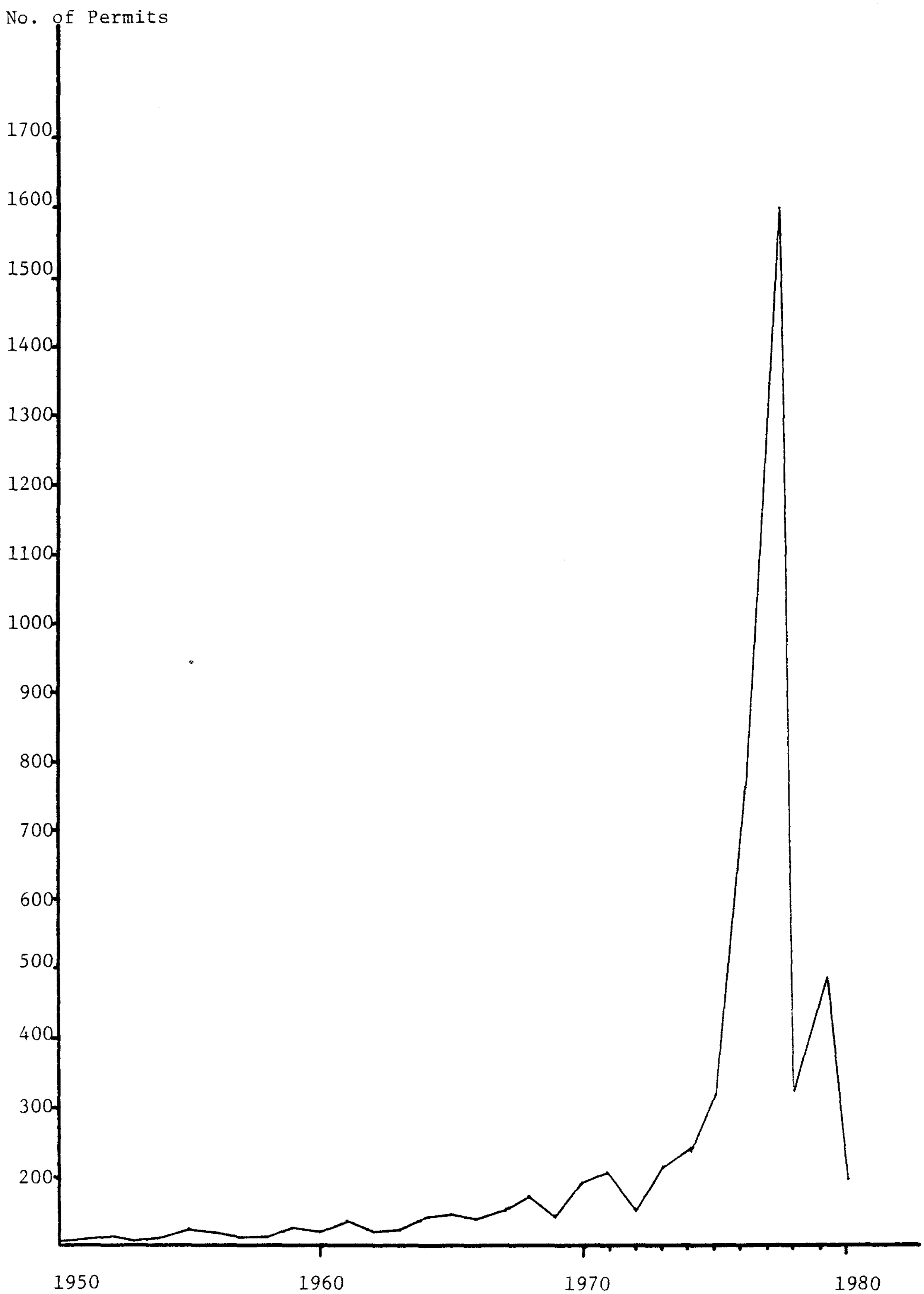
[1/] The state's accounting/fiscal year is July 1 through June 30. Therefore, fiscal year 1980 ended on June 30, 1980.

Figure 1: Number of Agricultural Irrigation Permits Granted by the Minnesota Department of Natural Resources between 1950 and June 30, 1980 (Entire State)



years subsoil moisture was depleted early in the growing season and rainfall data presented in Appendix A for the southwest and south central regions of the state indicate precipitation during the critical growing period (July-August) was only two-thirds of the average rainfall for that two month period.

A variety of water sources were approved for use in the irrigation permits issued by the DNR. This is of interest because the type of water source can have an important effect on the profitability of a particular irrigation system. Wells are expected to be expensive to drill and equip (i.e., casing, pump) while streams and lakes typically require less investment as a water source. The water sources for active agricultural irrigation permits through 1978 for the state are:

Water Source	Number (Percentage)
Well	2596 (72.3)
Lake	195 (5.4)
Stream/River	483 (13.5)
Dug Pit, Ponds	315 (8.8)
	3579 (100.0)

Seventy-two percent of the permits claim a well as their water source, while lakes, streams, rivers and dug pits or ponds account for the remaining 28 percent of all permits. These figures are significant because they reflect the sources of irrigation water for the entire state and, as will be shown later in this report, vary significantly from water sources for agricultural irrigation in subregions of the state, especially regions where fine textured soils predominate.

Machmeier (1977) also estimated the irrigated acreage by crop for 1975. Corn was by far the leading irrigated crop with 100,000 acres or 57 percent of the total irrigated acreage. Potatoes and truck crops (i.e., strawberries, lettuce, radishes, etc.) accounted for 17 percent, and 11 percent of the irrigated acreage respectively. The remaining acreage included alfalfa, small fruit, turf and nurseries and other crops. It is notable that soybeans were not listed as a major irrigated crop in 1975.

As mentioned earlier, the majority of the irrigated acreage in Minnesota can be found in the glacial outwash soils in central Minnesota because of the predominate coarse textured soils found in this area and available water sources. In 1975 the top ten counties in sprinkler irrigated acreage were:

Rank	County	Acreage
1	Sherburne	28,420
2	Pope	18,765
3	Ottertail	18,160
4	Stearns	16,618
5	Dakota	14,801
6	Swift	7,500
7	Wadena	6,221
8	Todd	5,790
9	Hubbard	4,052
10	Benton	3,625

Figure 2 presents a graphic picture of how irrigated acreage was distributed throughout the state in 1975.

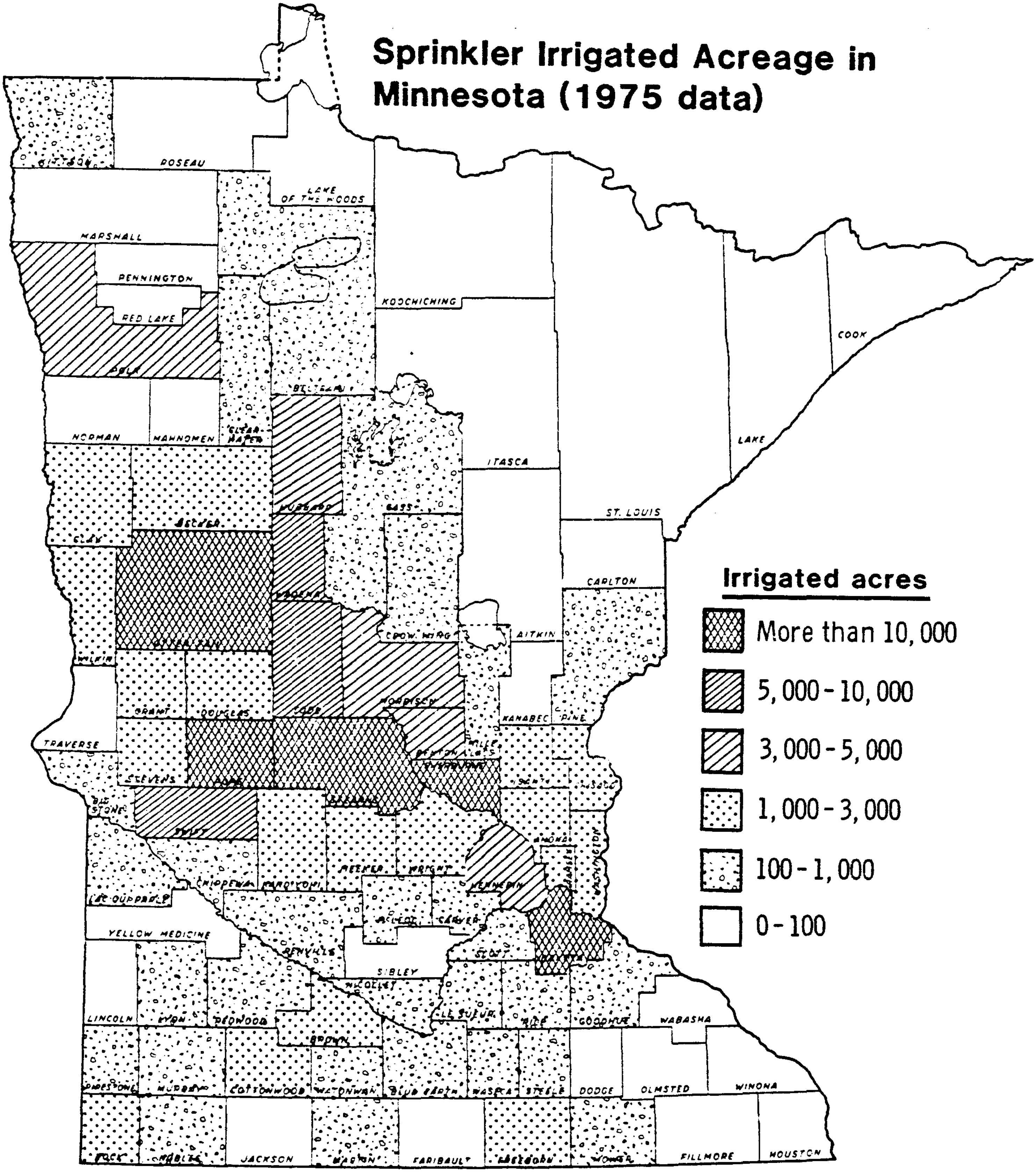
Due to the droughty conditions of 1975-76, farm operators became extremely interested in the possibility of irrigation. This active interest was demonstrated by the increase in irrigation permits granted. Also, the University of Minnesota increased its extension efforts in irrigation. Special emphasis was placed on the publication of four Development of Irrigation and Specialty Crop (DISC) reports which analyzed irrigation in the Minnesota context. The third of these reports is entitled "Water Sources and Irrigation Economics." This report concentrates on providing an economic and financial framework for analyzing the feasibility of irrigating sandy soils. A similar framework is developed in this paper for medium and fine textured soils.

II. A Survey of Irrigators

A. Design

There is little information available on the irrigation of heavy soils in the Upper Midwest in general. Prior to the 1974-76 drought, the high productive capacity of the fine textured soils generally was taken for granted by the farming public and agricultural support personnel (e.g., extension agents, input suppliers). When additional information on irrigating these soils was requested by farmers they found a dearth of valuable data.

Figure 2:



Source: Roger E. Machmeier, "Sprinkler Irrigated Acreage -- Minnesota" for 1970 - 1976. Agricultural Extension Service, University of Minnesota.

As one step to rectify this situation, a survey of farm operators was undertaken in July-August 1979 to gather information on farming and irrigation practices on heavy soils. The southwest and south central regions of the state were selected as the survey region because the predominant soil types in this area are fine textured with high water holding capacities (Figure 3). Typical soil series or associations in this area include Clarion-Nicollet-Webster, Clarion-Storden and Barnes-Aastad-Flom (Arneman, 1963).

Available water capacity (AWC) was chosen as the variable that would be used to differentiate between fine and coarse textured soils. AWC is the moisture held between field capacity and wilting point (Buckman and Brady, 1969). More simply, "the portion of water in a soil that can be absorbed by plant roots" (Soil Science Society of America, 1978). It is the estimated plant available water and AWC are alternative ways of expressing the same concept. AWC will be used throughout the report.

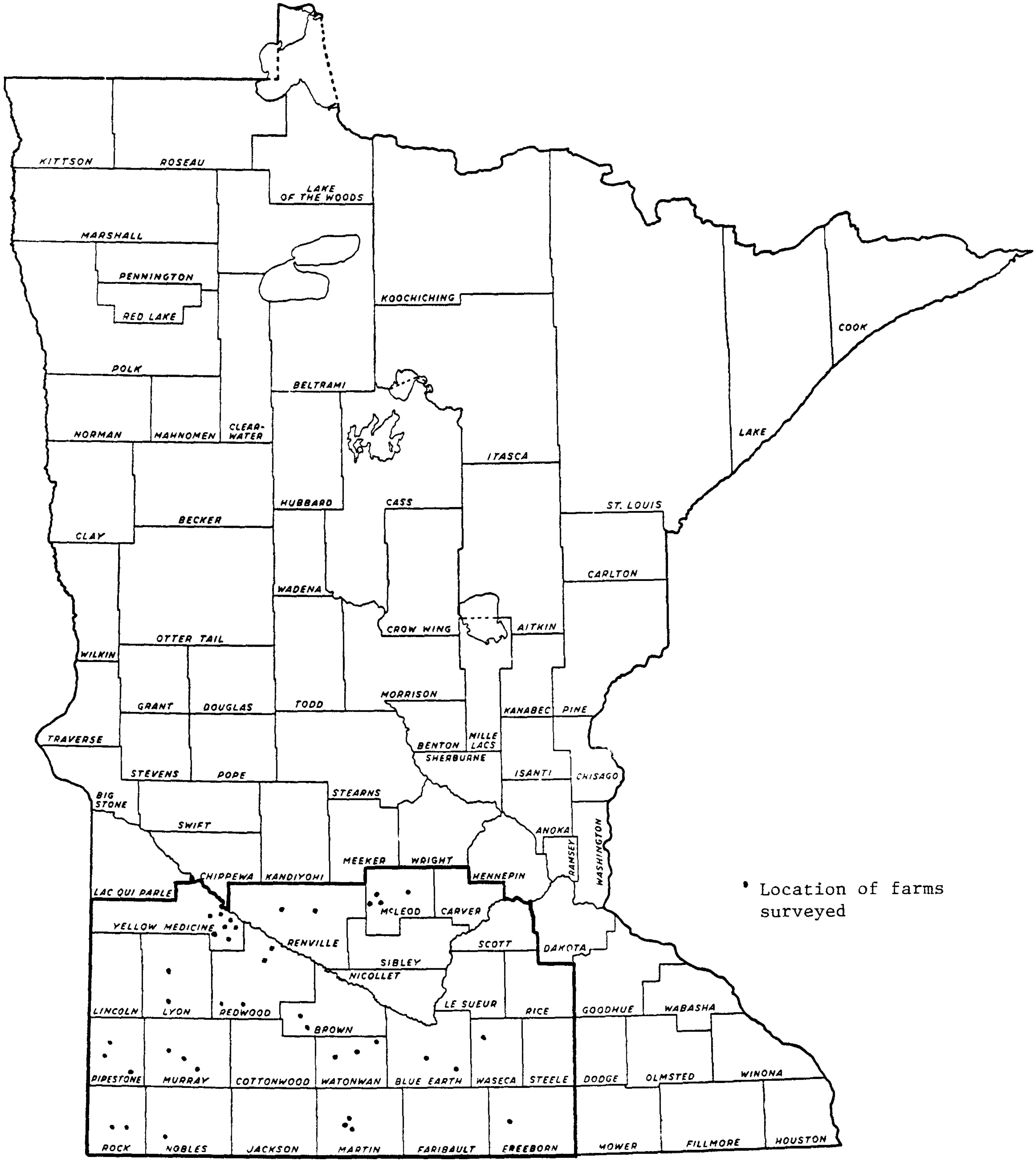
Soil texture, organic matter content and bulk density are the principal variables that determine the AWC of a soil. AWC can be expressed as inches of water per inch of soil profile or inches of water per standard depth of soil profile (i.e. 60"). Throughout this report AWC will represent the inches of water in 60" of soil profile.

The Irrigation Guide for Minnesota, published by the Soil Conservation Service in 1976 classifies soils in terms of their AWC as follows:

Inches of water in 60" depth of soil or to a limiting layer whichever is shallower	Class Name
0 - 3	Very Low
3 - 6	Low
6 - 9	Moderate
9 - 12	High
Greater than 12	Very High

Farm operators were interviewed who irrigated soils in the moderate, high and very high categories with special emphasis placed on the high and very high classes. A detailed description of each soil and its appropriateness for irrigation can be found in the Irrigation Guide for

Figure 3: Survey Region and Individual Farms Surveyed



Minnesota which served as a major source of technical information for this report.

Only farmers irrigating field corn, soybeans and alfalfa were interviewed. This restriction allowed the survey to focus its attention and resources on the irrigation of the major Minnesota crops.

A list of persons with irrigation permits was obtained through the cooperation of the Water Permits Division of the Minnesota Department of Natural Resources. This list was reduced to only those people living in the counties in the sample region. It was assumed that a random sample could be taken from this list but this proved to be impossible once field work began because a significant number (10-30 percent) of the farm operators with permits had failed to install an irrigation system. These farmers reported they intended to hold on to their permits as insurance against another drought.

Since a random sample was impossible, an attempt was made to interview every farmer in the 26-county survey region who irrigates field corn, soybeans and alfalfa on fine textured soils. This effort was successful because of the cooperative efforts of the personnel of Soil Conversation Service and the Cooperative Extension Service in identifying the target group in each county. Forty irrigators were interviewed using the questionnaire in Appendix B.

B. Survey Findings

The following section summarizes the most relevant data gathered in the survey.

1. Profile of an Irrigator

Irrigation of medium and fine textured soils is not limited to large farms. As Table 1 points out, both small and large operators have irrigation systems. However, there is a significant tendency for an irrigator to farm 400 acres or more. Sixty-eight (68) percent of the farm operators interviewed were in this category. Eleven of these irrigators farmed over 1,000 acres.

Table 1. Total Cultivated Acreage by the Irrigator*

Acreage	Frequency	Percent
200 acres or less	5	12.5
201-400	8	20.0
401-600	7	17.5
601-800	7	17.5
801-1,000	2	5.0
1,001 and over	11	27.5

*Includes both owned and rented acreage.

Table 2. Total Annually Irrigated Acreage on Fine Textured Soils

Acreage	Frequency	Percent
100 acres or less	8	20.0
101-150 acres	19	47.5
More than 150 acres	13	32.5

Table 2 shows that the majority (68 percent) of the farmers irrigating heavy soils are irrigating a quarter section or less. Approximately 130 acres is the established coverage for a center pivot on a quarter section. Thirty-two percent of the operators irrigate more than 150 acres, which means that they employ two irrigation distribution systems or have a towable center pivot with more than one pad (see Section III.A).

A conscious effort was made to interview all irrigators on the fine textured (e.g., Webster-Glencoe, Clarion-Nicollet-Webster) soils with high and very high AWC ratings. Farmers on coarser soils (e.g. Estelline, Hanska-Sparta) with moderate AWC ratings were also interviewed.

With the cooperation of Soil Conservation Service (SCS) technicians, individual farms were identified on soil maps and the types and percentage of soils present in the irrigated fields were noted. A weighted average water capacity then was calculated for each respondent and the results are presented in Table 3. The AWC of one farm could not be determined.

Table 3. Average Water Capacity of Surveyed Farms

Inches of Water in 60" of Soil	Frequency	Percent
6 - 9 inches (Moderate)	7	17.5
9 - 12 inches (High)	17	42.5
Greater than 12" (Very High)	15	37.5
Not Determined	1	2.5

Irrigating fine textured soils in Minnesota is a relatively new phenomena (Table 4). Only four of the 40 irrigators interviewed had an irrigation system prior to 1975. The types of systems installed prior to 1975 were booms, stationary guns, and traveling guns. Eighty percent of the irrigation systems now in use were installed in 1976 and 1977.

Two of the farm operators purchased traveling guns prior to making the larger investment for a center pivot system. The traveling gun was used for a single crop year which gave the operators an opportunity to evalute the crop response to supplemental irrigation. Upon favorable completion of the trial period, the operators installed a center pivot and kept the traveling gun for irregular shaped fields.

Less than 10 percent of those interviewed expressed any uncertainty about the profitability of their investment. The general feeling was that the investment in an irrigation system was a wise decision with a medium to long run planning horizon in mind. Only one of the persons interviewed was considering the sale of his irrigation system.

Table 4. The Year the Irrigation System Presently in Use was Installed

Year	Frequency	Percent
Before 1975	4	10
1975	2	5
1976	18	45
1977	14	35
1978	2	5

Most of those interviewed commented on their need to learn more about irrigating fine textured soils. Their major problems were: (1) the timing of water application, (2) fertilizer rates, especially nitrogen, and (3) the optimal plant population or seeding rate. The operator's responses and yield figures substantiated the claim that it takes 3-5 years to obtain economically optimal yields. This time period often is referred to as a learning curve (Eidman, 1978).

When asked why they invested in an irrigation system, the farm operators' responses were varied (Table 5). Some gave two or three reasons for their decision while others limited their reasons to one response. As expected, the drought of 1974-76 was the predominant reason (75 percent) for installing an irrigation system. The farm operators felt that they had too much money tied up in the land and crop to risk a dry growing season or a dry period during July and/or August. Their irrigation systems gave them control over soil moisture which eliminated a large amount of uncertainty in their operation.

Eighteen percent of the farmers mentioned the need for a secure feed supply for their dairy herd or beef cattle as the primary reason for the investment decision. In 1976 these operators had to import poor quality alfalfa from Nebraska at $100 per ton. This unsatisfactory situation provided the stimulus to make the investment in an irrigation system.

Table 5. Reasons Mentioned for Installing an Irrigation System

Irrigator's Response	Frequency	Percent
Drought of '74 - '76	30	75.0
Farm More Intensively	5	12.5
Increase Yields	6	15.0
Improve Timing and Control of Water Application	5	12.5
Soil Type Would Respond to Irrigation	4	10.0
Insure a Supply of Animal Feed	7	17.5
Pollution Control and Animal Waste Disposal	4	10.0
Wanted to Grow Seed Corn	2	5.0

Five farm operators responded that their investment in an irrigation system was the only means by which they could expand their production. Some cited the difficulty of obtaining financing to purchase land valued at $2,000-$3,000 per acre. Others stated that there was no land available for sale in their area. These farmers decided to farm more intensively by purchasing an irrigation system.

The survey found that pollution control and animal waste disposal are an increasingly popular application of irrigation technology. Dairymen, hog producers and cattlemen are all searching for effective and efficient methods to dispose of their animal wastes in a manner which is beneficial to them (increased soil fertility), and society (reduced pollution). Adapting traveling gun and center pivot technology to this growing need was a concern of those interviewed. In addition, the optimal rate of manure application is considered to be a key unanswered question in the minds of these irrigators.

Table 6. Method Used to Finance the Irrigation System

Method	Frequency	Percent
Lease	5	12.5
Cash	15	37.5
Loan/Line of Credit	20	50.0

The purchase of 50 percent of the systems operated by those interviewed was financed by loans or lines of credit (Table 6). Local commercial banks, Production Credit Associations (PCA), Federal Land Bank (FLB) and the Farmers Home Administration (FHA) have financed systems in the survey area. Thirty-eight percent of the operators paid cash for their systems which in some cases cost more than $100,000.

Five operators leased their systems. The major reasons for leasing were: (1) the difficulty in getting financing to purchase the irrigation system, (2) leasing reduced cash flow problems, (3) fear of the rapid technological obsolescence of the present system, and (4) leasing was competitive with loan financing at the time. Only one irrigator has switched from a lease agreement to a purchase agreement.

Corn for grain is the principal irrigated crop for those surveyed (Table 7). In 1979, 62 percent of the irrigated acreage was planted in field corn while soybeans and alfalfa represented 30 percent and 6 percent respectively. There has been a noticeable increase in the irrigated soybean acreage in the past three years. The farmers surveyed attributed this acreage shift to favorable soybean prices and a positive response by soybeans to properly timed and managed supplemental irrigations. Irrigated alfalfa production was for consumption on the same farm by dairy herds or beef cattle.

Table 7. Total Irrigated Crop Acreage by Crop and Year for Those Irrigators Surveyed*

Crop	Acres (1979)	Percent	Acres (1978)	Percent	Acres (1977)	Percent
Field Corn	3,758	62	3,553	62	3,295	68
Soybeans	1,793	30	1,745	30	1,003	21
Alfalfa	352	6	392	7	462	10
Other (Peas, Wheat)	100	2	60	1	60	1
Total	6,003	100	5,750	100	4,820	100

*Percentages have been rounded to simplify presentation.

2. Types of Irrigation Systems

One of the major factors which determine whether an irrigation system will be economically feasible is the availability of water. The Department of Natural Resources divides water sources into the following types: well, stream/river, lake, and other. In most cases, the "other" category refers to a dug pond or pit. Each source requires a specific type of investment in order to make water available to the irrigation distribution system. Wells normally are thought of as being more expensive than dug pits while streams and lakes require a relatively smaller initial investment.

The 40 irrigators interviewed represented all four water sources. Table 8 represents a frequency distribution by source type. Wells represent 50 percent of the water sources while dug ponds/pits, streams and lakes represent 27.5 percent, 12.5 percent and 10 percent, respectively. These figures show that the irrigation sources in southwestern and south central Minnesota are more varied than for the state as a whole. In the survey area there is a greater frequency or percentage of dug pits and lakes as water sources. The use of dug ponds or pits is three times as frequent among the surveyed irrigators as the state average. Favorable relative costs of ponds compared to wells and a desire to use spring runoff water are possible explanations for more dug pits in this area.

Table 8. Source of Irrigation Water for Irrigators Surveyed

Source	Frequency	Percent
Well	20	50.0
Stream/River	5	12.5
Lake	4	10.0
Dug Pond/Pit	11	27.5

Dug pits vary considerably in size, shape and water source throughout the survey region. Approximately 75 percent of the dug pits were fed by shallow aquifers or by underground springs or streams. The remaining pits were filled each April by the spring runoff from the farmer's tilling system. Pit size ranged from 20 foot depth x 30 foot width x 50 foot length to larger pits measuring 30' x 100' x 300'.

The depth of the wells varied. As Table 9 points out, well depths range from 50 feet or less to over 300 feet. Twenty-five (25) percent of the wells were 51-100 feet in depth, 20% were between 151-200 feet while 30% were over 300 feet deep. The depth of a well and the cost of an irrigation system are positively related, i.e. as the well depth increases so does the investment cost of the system.

Table 9. Well Depth and Pumping Lift for the Irrigators With Wells as Sources of Irrigation Water

	Well Depth		Lift During Pumping	
Depth	Frequency	Percent	Frequency	Percent
50 feet or less	2	10.0	13	65.0
51-100 feet	5	25.0	4	20.0
101-150 feet	1	5.0	2	10.0
151-200 feet	4	20.0	1	5.0
201-250 feet	1	5.0	0	0.0
251-300 feet	1	5.0	0	0.0
Greater than 300 feet	6	30.0	0	0.0

Although 60% of the wells were over 151 feet deep, only 1 irrigator was pumping water from a distance of more than 151 feet. Eighty-five percent of the farmer operators were pumping water from less than 100 feet.

Over half of the irrigators used electric motors to pump their water (Table 10). In some cases the 3-phase, 480-volt lines were already on the farm property while in other situations the potential irrigator had to request that the rural electric cooperative or private power supplier extend the line onto their property. The extension of a 480-volt line can represent a significant cost in the installation of an irrigation system. Section III.A discusses this cost in more detail.

Table 10. Power Unit Used to Pump Irrigation Water

Source	Frequency	Percent
Electric Motor	21	52.5
Diesel Engine	10	25.0
Diesel, Tractor PTO	7	17.5
LP Gas Engine	2	5.0

Table 11 presents the total number of distribution systems in use by the persons interviewed. The total number of systems is 49 because some farmers operated more than one system. Center pivot distribution systems are the most popular with units ranging from 4 tower to 13 tower models. Thirty of the 33 center pivot systems were electric driven and the remaining three systems were driven by water pressure. A detailed description of the center pivot, traveling gun and lateral move systems is presented in Section III.A.

Sixty-four (64) percent of these center pivot systems are mobile or towable (Table 12). Only 48 percent of the farmers with towable systems actually tow their center pivots between pads. Examples of farmers towing 4 tower and 10 tower systems were found with total irrigated acreage for one towable system ranging from 80 acres for a 4 tower model to 350 acres for a 10 tower center pivot.

Table 11. Total Number of Irrigation Distribution Systems by Type*

Type	Frequency	Percent
Center Pivot	33	68.0
Traveling Gun	8	16.0
Lateral Move	4	8.0
Boom	2	4.0
Stationary Gun	2	4.0

*Six irrigators had 2 center pivot systems. One irrigator had one pivot and one traveling gun. One irrigator had 2 pivots and a traveling gun.

Table 12. Mobile Features of the Center Pivot System

Feature	Frequency	Percent
Towable: System is moved to other pads where it is connected to a main line and irrigates additional acreage	16	48.5
Non-Towable: Irrigates One Field	12	36.5
Not Towed: System is towable but the irrigator does not move the system	5	15.0

3. Yield Differentials

Crop response to supplemental irrigation is the major factor in determining the profitability of investing in an irrigation system. Yield differentials between non-irrigated and irrigated production are determined by soil type, crop seeding rate, irrigation management, cultural practices (e.g., cultivation), the fertilization program and climate, especially rainfall.

Beer and Wiersma (1970) compiled data on corn yields for 1950-1958 from throughout the Corn Belt and differentiated yields by fertilizer application, timing or irrigation, soil type (sand vs. loam) and plant populations. Two important patterns are observed in their analysis. The first pattern is that the highest irrigated corn yields occur on sandy soils with low plant populations and on loamy soils with high plant populations. Secondly, yield increases due to irrigation on loam soils were in the 35-40 percent range given similar fertilization and seeding practices.

Lucas and Vitosh (1977) studied the response of corn yields to irrigation in Michigan. Soil texture and its effect on yields was one of the major variables analyzed. Yield responses to irrigation are greater (140-300 percent) on sandy soils than on heavy loam soils (40-60 percent). The authors argue that these lower yield differentials do not necessarily mean that irrigation of heavy soils in Michigan in unprofitable. They do advise irrigators of fine textured soils to have their fields well tiled, apply .5-.7 inches of water per irrigation, and keep the available soil moisture in the effective rooting zone at less than 80 percent of capacity.

The Minnesota survey of irrigators of heavy soils gathered yields response data for corn and soybeans (Table 13). Alfalfa yields are not included because the majority of the alfalfa acreage is chopped for silage so the dairymen and cattlemen didn't have accurate estimates of their yields per acre. Their rough yield estimates for irrigated alfalfa ranged from 7-12 tons of hay equivalent per acre. This is a considerably increase over the 3-6 tons they estimated they harvested without irrigation.

Farm operators were asked what their corn and soybean yields were in favorable, average, and poor years. They then were asked to estimate the frequency of a favorable year, an average year, and a poor year occurring in ten years. The modal estimate for the respondents was 5-4-1, that is out of ten years they expected five excellent crops, four crops with average yields and one year where yields were significantly lower than average yields. The respondents' yield data were weighted by these probability estimates to arrive at the non-irrigated yield figures in Table 13.

Table 13. Field Corn and Soybean Yield for Surveyed Farmers (Bushels/Acre (From Years 1977-1978)

	Average Yields					
	Field Corn			Soybeans		
Available Water Capacity*	Non-Irrigated	Irrigated	% Increase	Non-Irrigated	Irrigated	% Increase
Moderate (6-9 in.)	76	141	86%	34	45	32%
High (9-12 in.)	104	150	44%	41.5	52	25%
Very High (over 12 in.)	108	152	41%	40	53	33%

*Inches of water in 60" depth of soil.

The irrigated yield estimates reflect the average corn and soybean yields in 1977 and 1978. Yield estimates are for the same field with and without irrigation. The yield differentials cannot be attributed solely to supplemental irrigation. Increased fertilization, higher seeding rates and, in some cases, improved management practices were also significant. However, farm operator recall for fertilization and seeding rates over a 3-5 year period was limited. As a result, the data on the irrigation and non-irrigation management practices of these individuals is incomplete. The crop production budgets presented in Section III.B. represent the typical or modal management practices of the farmers surveyed.

Field corn yields for moderate soils increased 86 percent when supplemental irrigation was used. Corn yields on soils with high and very high water holding capacities increased 44 percent and 41 percent respectively. The highest irrigated yields for field corn were 175-180 bushels per acre. The largest percentage increase in yield was a 142 percent increase (62 to 150 bushels per acre) on a moderate soil.

Irrigators indicated soybeans did not respond as dramatically as corn to supplemental irrigation. For moderate soils, soybean yields increased 32 percent. Soybean yields on soils with high and very high water holding capacities increased 25 percent and 33 percent respectively. Better management practices for non-irrigated soybeans on high AWC soils explain much of the reason why irrigated yields increased less for these soils relative to the moderate and very high AWC soils. The highest reported yield for irrigated soybeans was 60 bushels per acre on a high AWC soil.

It is appropriate to note here that proper tiling is essential to successfully irrigate fine textured soils. Only one surveyed farm operator did not have his field drained properly. As a result his yields had actually declined after installing the irrigation system.

To perform the economic analysis needed to determine the profitability and feasibility of irrigating heavy soils, a measure of the expected yield differential must be available. This yield differential can than be used in the crop and cash flow budgets to reflect the increased yield and hence, increased revenues due to irrigation. Of course, there are additional costs attributable to the irrigation system and these, too, are considered in the budgets.

It was hypothesized prior to initiating this study that there was a relationship between the available water capacity of the soil and the yield differential the farmer could expect from irrigating his corn crop. Yield differentials were expected to be larger on moderate soils than the differentials found on high and very high AWC soils.

A linear regression model was developed to summarize the relationship between yield differentials for field corn and AWC from the date for 22 of the respondents.[2/] The general model took the following form:

[2/] The soybean data was incomplete so a similar analysis could not be performed.

(1) $Y = B_0 + B_1(AWC) + B_2(RAIN) + e_i$ where:

Y = average corn yield in bushels per acre (Y_I = irrigated; Y_N = non-irrigated,

B_0 = constant,

B_1 = coefficient for AWC,

AWC = inches of average water capacity in top 60" soil profile,

B_2 = coefficient for RAIN,

RAIN = inches of average rainfall during five month growing season (May-September), and

e_i = error term.

The average corn yield data came from the respondents to the survey. The AWC figures for each farm surveyed were developed from the Irrigation Guide for Minnesota with the help of Soil Conservation Service technicians and county soil maps. Rainfall data was obtained from the reporting station closest to the respondent's farm. Appendix C includes the twenty-one year precipitation average for May through September for the reporting stations used in this analysis.

Equation (1) was estimated using the irrigated corn data from the survey. The coefficient on AWC was not significantly greater than zero at the five percent level, indicating AWC was not a significant variable in explaining variability in irrigated corn yields. This result was anticipated because the purpose of irrigation is to reduce the variability of yields due to drought prone soils.

RAIN is a significant variable at the five percent level. The coefficient B_2 had a positive sign which means that as average rainfall during the growing season increases, irrigated yields also increase.

Deleting the insignificant AWC, the equation for irrigated corn was estimated using only RAIN as the independent variable. The result was:

(2) $Y_I = 1.5 + 8.7(RAIN)$

(.05)	(4.85)	(t-value)
(30.22)	(1.78)	(standard error)

$R^2 = .54$

B_0 is not significantly different from zero at the 5% level, but B_2 is significant. The coefficient of determination (R^2) equals .54, meaning that 54 percent of the yield variability is explained by equation (2).

Assuming the potential irrigator knows the value for RAIN for his farm, this figure can be used to roughly approximate the average irrigated corn yield. For example, in the Welcome area of Martin County the 20-year average value for RAIN is 18.23 inches. By substituting this figure into equation (2) a value of 160 bushels per acre is obtained for Y_I (Irrigated Corn Yield).

A similar analysis was performed for non-irrigated corn yields using the same data. AWC and RAIN proved to be significantly different from 0 at the 5 percent level using the general model (Equation 1). The result was:

(3)	Y_N =	-143.4 +	6.2(AWC) +	10.4(RAIN)	
		(-3.32)	(3.06)	(4.63)	(t-value)
		(43.25)	(2.02)	(2.26)	(standard error)

$R^2 = .63$

Equation (3) explains 63 percent of the variability in average non-irrigated corn yields. The negative constant may be of concern, but notice that it results in a prediction of nonpositive yield to be interpreted as a zero yield when there is no rain during the May-September period, no matter how high the water holding capacity of the soil. Some respondents in the southwestern area of the state on moderate soils reported yields of 0-20 bushels per acre in 1976. For example, assume that a farm is located in Murray County on a soil with an AWC of approximately 8 inches. If it rains 10 inches during the growing season (average rainfall during this period is 17.2 inches), equation (3) indicates a farm operator can expect an approximate yield of 10 bushels per acre. This is a reasonable approximation of what many farmers experienced during 1976.

A very high AWC soil withstood the drought of 1976 much better according to equation (3). Assume that a farm is located in Martin County on a soil with an AWC of 12.36 inches (e.g., Webster-Glencoe soil). In 1976 precipition during May-September period was approximately 13 inches (average rainfall during this period is 19 inches). Equation (3) estimates the average non-irrigated yield level was 68 bushels per acre. Corn yields for 1976 for survey respondents in this general region varied from 60-100 bushels per acre. The average yield for Martin County in 1976 was 76 bushels per harvested acre. Seventy-one bushels per acre was the yield per planted acre. These comparisons suggest equation (3) provides a somewhat low yield estimate for high AWC soils under drought stress.

Equations (2) and (3) are summarized for the survey region in Table 14. Irrigated and non-irrigated yield levels are estimated using AWC and May-September precipitation figures as independent variables.

Table 14. Estimated Field Corn Yields for the Survey Region by AWC and Average May-September Precipitation.

Precipitation (Inches)		AWC (Inches in 60" Soil Profile)			
		6"	8"	10"	12"
15	Non-Irrigated	50	62	75	87
	Irrigated	132	132	132	132
16	Non-Irrigated	60	73	85	97
	Irrigated	141	141	141	141
17	Non-Irrigated	71	83	95	108
	Irrigated	149	149	149	149
19	Non-Irrigated	81	93	106	118
	Irrigated	158	158	158	158

The reader is cautioned to accept these relationships as approximations.[3/] AWC and RAIN explain only a portion of the variability in the yield data. The equations are not to be considered production functions. They simply provide a convenient way of summarizing the subjective yield estimates obtained from the farmers interviewed. The relationships indicate that as AWC increases, the corn yield differential due to irrigation will diminish and may reach a point (given low corn prices, or high energy prices) where the investment in an irrigation system may be unprofitable.

III. Economic Analysis

A. Prototype Irrigation Systems

The survey results presented in Section II illustrate the variety of irrigation systems in use in southwestern and south central Minnesota. Criteria for selecting a particular system include availability of labor, field size and shape, initial investment costs, projected operating costs, type of water source, neighboring systems, and the aggressiveness

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3/ The standard error of predicted values is approximately 16 bushels per acre. Therefore, a 95 percent confidence interval for a predicted value would be the value obtained with equation (3) plus or minus 32 bushels per acre.

of local irrigation dealers and salesmen. Only two operators started with a traveling gun system and later purchased a center pivot. Usually the farm operator selected the type of system he wanted realizing it was a long-term investment.

Based on the information gathered in the survey, six prototype or typical irrigation system designs and their respective costs are presented below. These systems represent the most common irrigation designs found in the survey region. Each system is designed for electricity or diesel fuel as the energy source. All horsepower ratings are for continuous duty. The investment costs for each system are based on prevailing prices as of August 31, 1979. These summarized costs are presented in Table 15. More detailed cost calculations are included in Appendix D.

System No. 1: Center Pivot/Well (Figure 4)

A non-towable center pivot irrigation distribution system is a popular model. The system chosen here is a 10-tower model which will cover approximately 130 acres of a quarter section field (160 acres). A small electric motor on each tower provides power to the wheels and moves the system around the field.

A 150 foot well was chosen as the water source with a suction lift of 50 feet and a discharge lift of 12 feet. Two alternative energy sources are considered, electricity and diesel fuel.

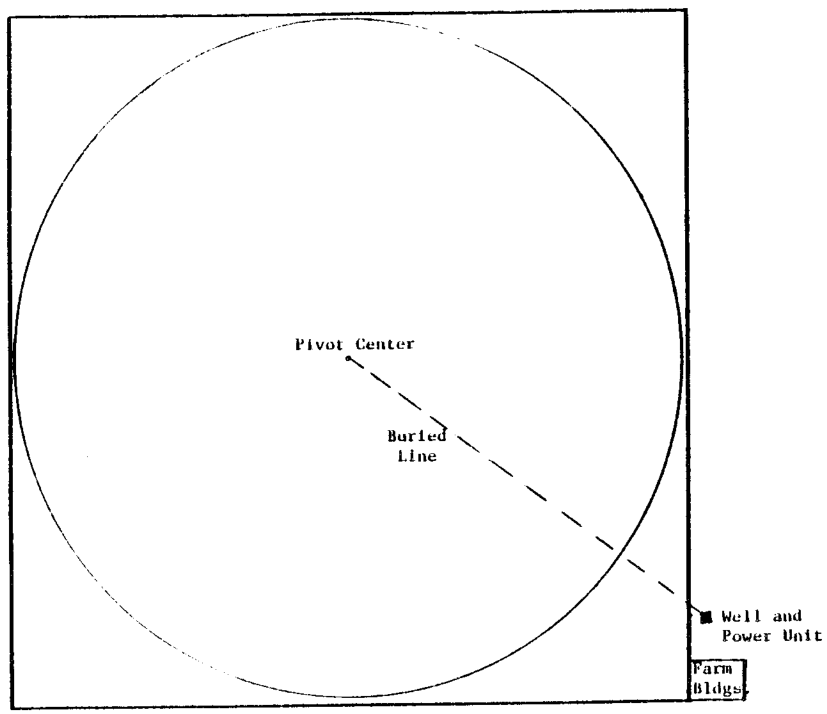
Three phase 480-volt electricity is required to power the electric motor. In the prototype system it is assumed that the farm operator has 3-phase power on his farm building site and the center pivot is located in an adjacent quarter section. This is the predominant arrangement found in the survey. In the event the farmer does not have 3-phase power on his farm, he must ask the local rural electric cooperative or private power company to extend 3-phase power onto his property. The electric utilities typically require the farmer to pay part of the investment cost to build the line. Irrigators surveyed who did not have 3-phase electricity paid from $5,000 to $10,000 to have 3-phase power extended onto their property. This charge varies with the individual situation so no average charge is included here. Nevertheless, the potential irrigator who wants to use electricity as his power source needs to investigate the cost of acquiring

Table 15. Prototype Irrigation Systems Investment Cost by Power Source

Item	System No. 1 Elec.	System No. 1 Diesel	System No. 2 Elec.	System No. 2 Diesel	System No. 3 Elec.	System No. 3 Diesel	System No. 4 Elec.	System No. 4 Diesel	System No. 5 Elec.	System No. 5 Diesel	System No. 6 Elec.	System No. 6 Diesel
Well, Pit Development	11,370.00	11,370.00	3,889.00	3,889.00	11,370.00	11,370.00	11,370.00	11,370.00	--	--	3,889.00	3,889.00
Pump	5,091.00	5,091.00	2,188.00	2,188.00	5,091.00	5,091.00	5,105.00	5,105.00	1,850.00	1,850.00	2,188.00	2,188.00
Motor or Engine including Gear Drive and Generator	4,860.00	10,922.00	4,195.00	9,432.00	4,860.00	10,922.00	4,415.0	10,792.00	4,245.00	7,917.00	3,738.00	7,957.00
Pipe	5,540.00	5,540.00	4,640.00	4,640.00	10,895.00	10,895.00	3,392.00	3,392.00	16,992.00	16,992.00	11,130.00	11,130.00
Valves, Fittings and Wire	2,256.00	3,060.00	2,121.00	2,121.00	6,000.00	6,000.00	3,294.00	3,294.00	1,800.00	1,800.00	2,500.00	3,000.00
Fertilizer Injection	1,803.00	1,803.00	1,803.00	1,803.00	1,803.00	1,803.00	1,803.00	1,803.00	--	--	--	--
Distribution System*	34,424.00	34,424.00	34,424.00	34,424.00	35,419.00	35,419.00	17,315.00	17,315.00	13,146.00	13,146.00	28,379.00	28,379.00
Totals	65,344.00	72,210.00	53,260.00	58,497.00	75,438.00	81,500.00	46,694.00	53,071.00	38,033.00	41,705.00	51,824.00	56,543.00
Cost Per Acre Irrigated	502.64	555.46	409.69	449.98	301.75	326.00	583.68	663.39	292.56	320.81	398.64	434.95

* Discounts on the distribution systems range up to 20% depending on the time of the year the equipment is purchased. A 10% discount has been calcualted for all the distribution systems. A 4 percent sales tax has been incorporated into the total figures.

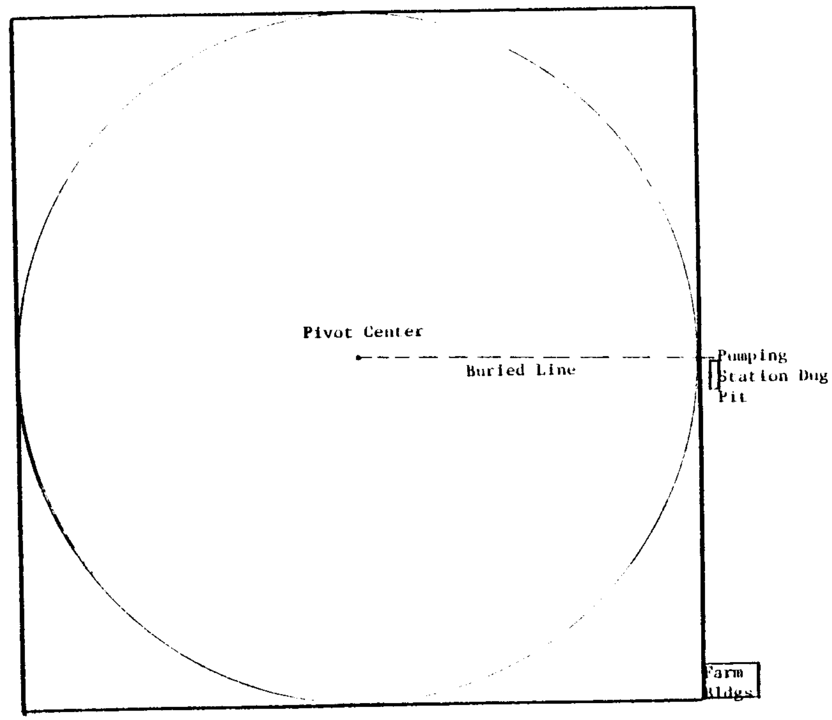
Figure 4: Irrigation System No. 1 (Center Pivot/Well)



Specifications: Scale 1" = Approx. 500 feet

Type: Center Pivot (Non-Towable)
Size: 10 Tower
Acreage Covered: 130 Acres
Drive: Electric
Water Source: Well
Well Depth: 150 Feet
Suction Lift: 50 Feet. Discharge Lift: 12 Feet
Energy Source: 3-phase, 480-volt Electricity: Diesel Fuel
Power Unit: 75 H.P. Electric Motor; 100 H.P. Diesel Engine
Distance from Well to Center Pivot: 1680 Feet (Buried Polyvinyl Chloride (PVC) Pipe)
Pumping Rate - GPM: 800
Operating Pressure in psi at Entrance to Distrubtion System: 75

Figure 5. Irrigation System No. 2 (Center Pivot/Dug Pit)



Specifications of System 2 Scale 1" = Approx. 500 feet.

Type: Center Pivot
Size: 10 Tower (Non-Towable)
Average Covered: 130 Acres
Drive: Electric
Water Source: Dug Pit (Aquifer Fed) 50' x 150' x 20'
Suction Lift: 15 Feet. Discharge Lift: 12 Feet
Energy Source: 75 H.P. Electric Motor - 92 H.P. Diesel Engine
Distance from Pump to Center Pivot: 1380 Feet (Buried PVC Pipe)
Pumping Rate - GPM: 800
Operating Pressure in psi at entrance to distribution system: 75

3-phase electricity if it isn't on his property already.

Installation and delivery charges have been included in the cost calculations. The electric-drive center pivot system must be wired properly. A charge of approximately $1,200 has been included for this service. For System No. 1, pump delivery and installation charges are estimated at $350. Pipe installation is estimated at $1,340 while the delivery and installation costs for the center pivot system are calculated at $3,600.

System No. 2: Center Pivot/Dug Pit (Figure 5)

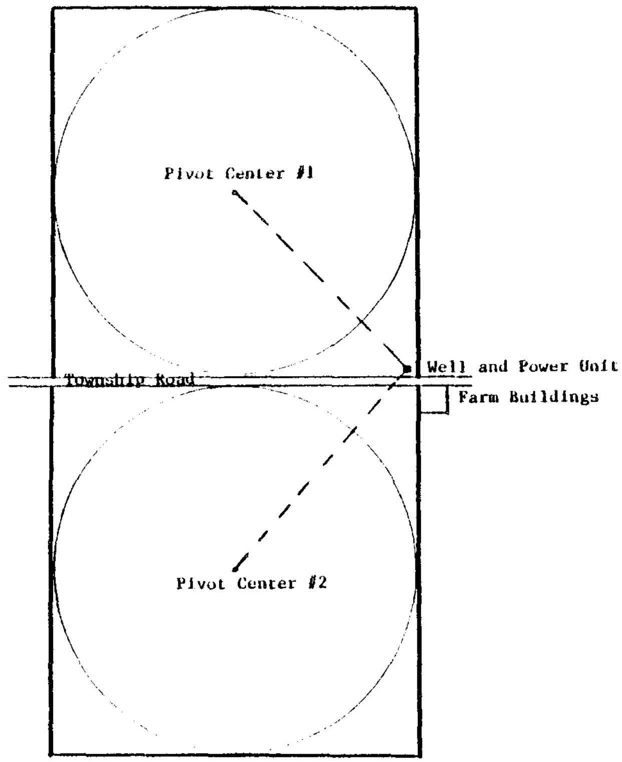
This model is almost identical to System No. 1 except the water source is a dug pit. This pit is fed by an aquifer and has the capacity to supply water to an irrigation system that requires 650-1300 acre inches of water per year. Although horsepower requirements are reduced slightly because the lift is less for pumping out of the pit as opposed to the well, the electric motor size remains at 75 horsepower while the size of the diesel engine decreases by 8 horsepower.

System No. 3: Large Towed Center Pivot/Well (Figure 6).

The survey indicates that 48.5 percent of the center pivots used to irrigate heavy soils are being towed between or within fields. System No. 3 is a model of a towable 10-tower system irrigating two quarter sections (260 acres). Estimates vary for the time it takes to move the pivot. A modal response from the irrigators surveyed with this type of system was that it took three men approximately three hours to move the distribution system.

Two quarter sections was the maximum acreage for one center pivot system. The reasoning is as follows: Assume it takes 72 hours to irrigate one quarter section. If the farmer irrigates three quarter sections, it will take 6½ to 8 days to return to the portion of the first section irrigated on the first day. During a dry period, this time without water may stress the crop and reduce yields. With two quarter sections the first section can be irrigated again in five days.

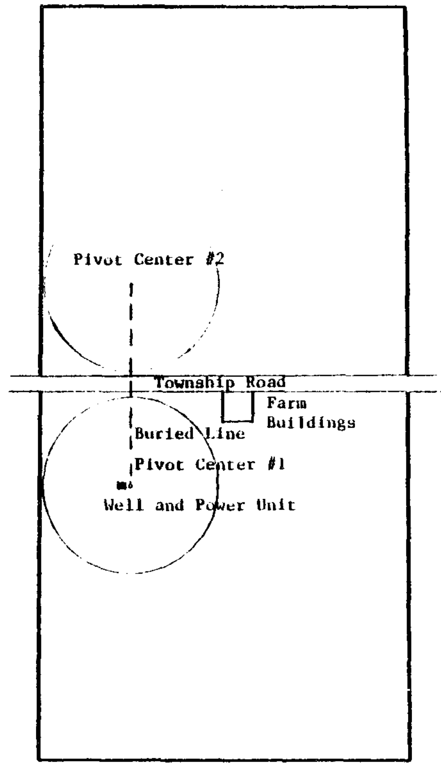
Figure 6. Irrigation System No. 3 (Large Towed Center Pivot/Well)



Specifications of System No. 3 — Scale 1" = Approx. 900 feet

Type: Center Pivot (Towable)
Size: 10 Towers
Acreage Covered: 260 Acres
Drive: Electric
Water Source: Well
Well Depth: 150 Feet
Pumping Lift: 50 Feet
Energy Source: 3-phase, 480 volt Electricity, Diesel.
Power Unit: 75 H.P. Electric Motor, 100 H.P. Diesel Engine.
Distance from Well to Pads: To Pad #1, 1650 ft.; To Pad #2, 1815 ft.
Pumping Rate - GPM - 800
Operating Pressure in psi at Entrance to Distribution System: 75

Figure 7. Irrigation System No. 4 (Small Towed Center Pivot/Well)



Specifications of System #4 — Scale 1" = Approx. 900 feet

Type: Center Pivot (Towable)
Size: 5 Towers
Acreage Covered: 80 Acres
Drive: Electric
Water Source: Well
Well Depth: 150 Feet
Suction Lift: 50 Feet   Discharge Lift: 12 Feet
Energy Source: 3 phase, 480 volt Electricity, Diesel.
Power Unit: 60 H.P. Electric Motor, 92 H.P. Diesel Engine
Distance From Well to Pads: To Pad #1, 0 Feet, to Pad #2, 1560 Feet
Pumping Rate - GPM: 600
Operating Pressure in psi at Entrance to Distribution System: 75

System No. 4: Small Towed Center Pivot/Well (Figure 7)

A second type of towable center pivot system is the fourth prototype. This 5-tower system irrigates approximately 40 acres and then is towed to another field where it covers another 40 acres. This smaller system is particularly appropriate for farmers who do not have access to a labor source other than themselves. This 5-tower system can be moved from one pad to the other by one person in approximately 2.5 hours. Slightly larger systems (7 and 8 tower models) can be moved in a similar amount of time but require at least two individuals.

System No. 5: Traveling Gun/River (Figure 8)

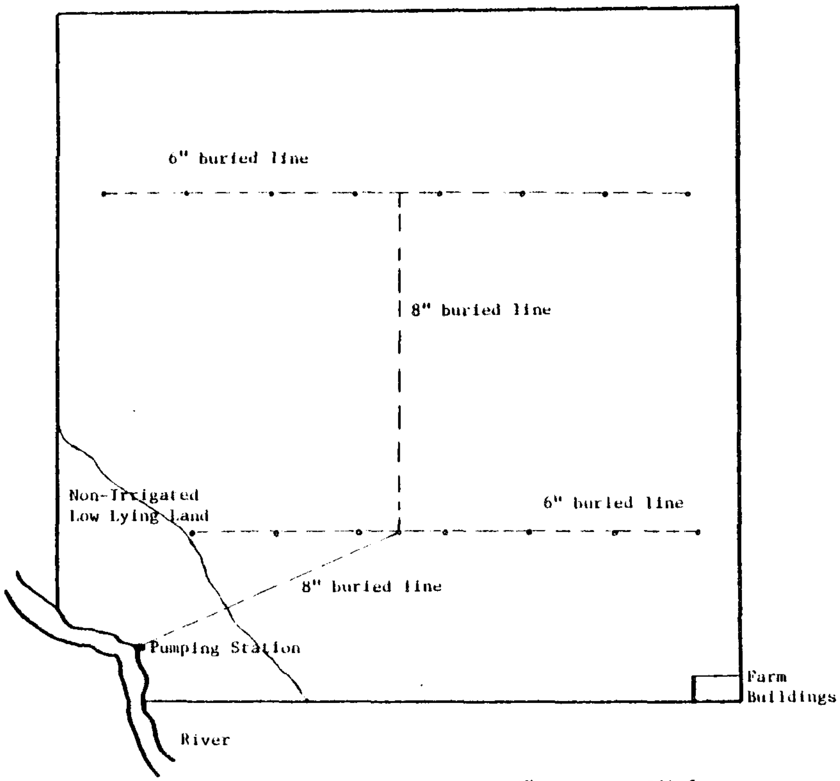
A continuous move volume gun or traveling gun system was used by 16 percent of the irrigators surveyed. A typical design of a traveling gun irrigation system is presented as System No. 5. The water source is a river. Water is pumped through buried 8" polyvinyl chloride (PVC) main lines to 6" buried PVC branch lines. Risers from the buried pipe to the surface provide connection points for the traveling gun. Some traveling gun systems have above-ground aluminum pipe which requires at least half a day for two men to set up. The pump and power unit are mounted on a trailer so they can be moved to a sheltered place during winter and moved during spring flooding.

The traveling gun system, even with the buried lines, requires more labor than the center pivot systems. Farmers reported a moving time of 1 to 2 hours between settings. The number of settings varied with the field layout but a typical number of settings was 14 for 130 acres. Farmers' estimates imply that 14-35 hours can be spent moving the gun system for one complete irrigation.

System No. 6: Lateral Move/Dug Pit (Figure 9)

The final system analyzed is the lateral move distribution system. This is an automated solid-set type system that irrigates up to 11 acres in one setting and is then moved to the next setting. Each setting is typically 150 feet apart. The system is powered by a 16 horsepower gasoline engine and the operator rides the system as it is moved. Half a day was normally spent laying the aluminum pipe. Producers estimated it took them one-half to one hour to shut the system off, drain it, move the system, connect it to the set point and start irrigating again. Respondents stated

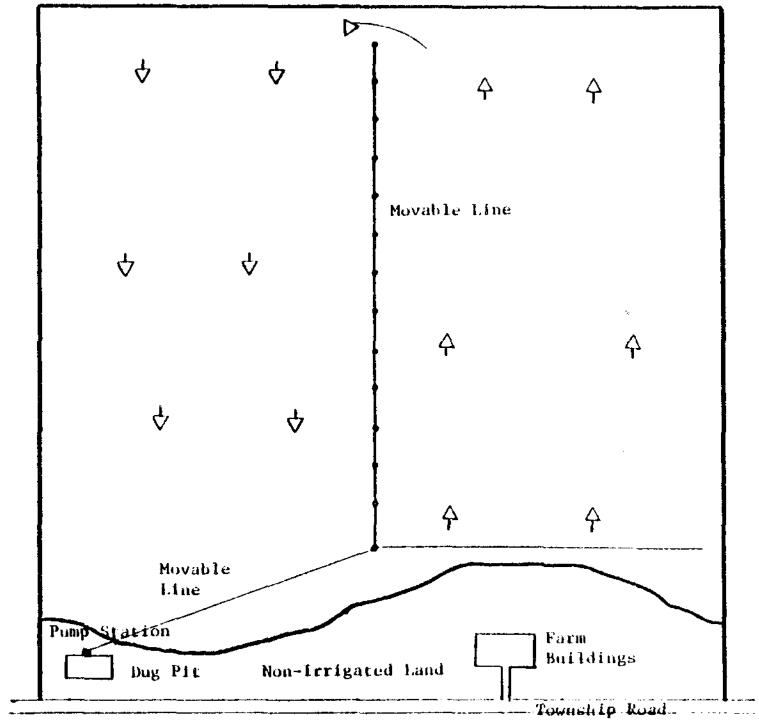
Figure 8. Irrigation System No. 5 (Traveling Gun/River)



Specifications of System No. 5   Scale 1" = Approx. 500 feet

Type: Traveling Gun
Acreage Covered: 130 Acres
Drive: Diesel Auxiliary Engine
Water Source: Stream/River
Suction Lift: 10 Feet Discharge Lift: 15 Feet
Energy Source: 3-phase, 480 volt Electricity, Diesel Fuel
Power Unit: 75 H.P. Electric Motor; 85 H.P. Diesel Engine
Distance From Pumping Station to Farthest Connection: 3,600 Feet
Pumping Rate - GPM: 600
Operating Pressure in psi at the Gun: 90

Figure 9: Irrigation System No. 6 (Lateral Move-Dug Pit)



Specifications of System No. 6   Scale 1" = Approx. 500 feet

Type: Lateral Move
Size: 1320 Feet Long
Acreage Covered: 130 Acres
Drive: Gasoline
Water Source: Dug Pit 50' x 150' x 20'
Suction Lift: 10 Feet, Discharge Lift: 15 Feet
Energy Source: 3-phase 480 volt Electricity, Diesel Fuel
Power Unit: 75 H.P. Electric, 85 H.P. Diesel Engine
Distance From Pit to Farthest Setting: 3180 Feet
Pumping Rate - GPM: 800
Operating Pressure in psi at Entrance to Distribution System: 75

that 5-6 days were necessary to irrigate 130 acres with $1\frac{1}{2}$ inches of water.

B. Crop Production Budgets

This section presents estimates of expected costs and returns per acre for field corn, soybeans, and alfalfa produced on fine-textured soils (Tables 16-23). These enterprise budgets include both (a) irrigated and (b) non-irrigated crop production. Machinery operations, fertilizer application rates, herbicide use, etc., reflect the production methods of the survey respondents. As mentioned in the introduction these net return values represent a tentative measure of profitability. Part D of this section provides a more realistic measure of profit potential.

The crop prices used in these budgets are the five-year planning prices projected by extension agricultural economists at the University of Minnesota (Agricultural Extension Service, 1979). Field corn, soybean and alfalfa yield levels are based on the estimates for a Webster-Glencoe soil with an AWC of 12.36 in south central Minnesota with an average growing period rainfall of 18 inches.

Machinery cost estimates were taken from Minnesota Farm Machinery: Economic Cost Estimates for 1979 (Benson and Hatteberg, 1979). Input prices were determined through discussions with agricultural input suppliers and by analyzing suppliers' price lists. All prices reflect August, 1979 price levels.

The cost and return information for each crop, both irrigated and non-irrigated, is presented in two tables. The first table (A) presents a summary of the costs and returns for the particular enterprise. Gross receipts are calculated by multiplying the estimated yield times the expected price. Operating costs are divided into two parts: preharvest costs, and harvest costs. Preharvest costs include costs associated with land preparation, planting, irrigation, and cultivation. Harvest costs only include those expenses incurred during harvest operations. The machinery expense under these two categories includes fuel, oil, lubrication and repair costs associated with the operation of the machinery.

The farm operator's labor is valued at $6.50 per hour. Although this is not a cash cost, the operator has the opportunity to use his labor in other ways and it is appropriate to include it as part of the production cost. Interest is calculated on cash costs. Therefore, interest is calculated on hired labor, but not on the operator's labor.

Ownership costs include depreciation, interest on the investment, insurance, and housing expense for the machinery and irrigation systems. An estimate of real estate taxes and interest on land is based on land values and rental values in the survey region. Land values range from $1,500-2,000 per acre in the survey zone (Hasbargen and Thomas, 1979). Rental rates in the survey region vary from $75-100 per acre. As benchmarks it is assumed that cash rental rates are approximately 5 percent of the value of the land, that property or real estate taxes account for .7 percent of the rental rates and interest on the land accounts for the remaining 4.3 percent.

The total costs shown should not be interpreted as total production costs. There are certain overhead expenses, such as office space, management time, and accounting costs that have not been allocated to this enterprise. Net returns above costs shown cannot be considered profit for similar reasons. These net returns represent returns to the unallocated overhead expenses of the farm firm.

The second table (B) for each crop provides a calendar of operations, tooling (machinery used) and materials. Each operation is described with the appropriate machinery complement, labor and machinery time to perform the operation, the machinery variable and fixed costs attributed to each operation, and the type and quantity of each material applied during the operation. These figures are used to determine the operating and ownership costs presented in the first table.

For each irrigated crop budget it is assumed that a center pivot system (System No. 1, described in Section III.A), is being used. Six acre-inches of supplemental water is applied to corn, three inches to soybeans, four inches when establishing alfalfa with a companion oat crop, and eight inches to the alfalfa crop in full production. These water levels reflect the irrigation practices of the surveyed farms. The detailed irrigation costs were calculated using the University of Minnesota's IRRCOST computer program which is available to farmers through the Agricultural Extension Service. Appendix E presents a sample computer output from the IRRCOST program for field corn.

Table 16A: Non-irrigated corn for grain, fine-textured (heavy) soils in south central Minnesota, average per acre costs and returns.
Outgoing crop: Field corn.

	Units	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Corn	Bu.	2.50	120.00	300.00
Total				300.00
2. Operating Costs				
Preharvest				
Corn Seed	Bag	45.00	.325	14.62
Nitrogen (N)	Lbs.	.18	30.00	5.40
Anhydrous Ammonia	Lbs. of N	.10	110.00	11.00
Phosphate P_2O_5	Lbs.	.17	100.00	17.00
Potash K_2O	Lbs.	.08	130.00	10.40
Herbicide	Acre	14.72	1.00	14.72
Insecticide	Acre	7.60	1.00	7.60
Crop Insurance	Dol.	.025	300.00	7.50
Machinery	Acre	8.93	1.00	8.93
Labor	Hours	6.50	1.57	10.21
Interest on Operating Capital	Dol.	.11	48.58	5.34
Subtotal, Pre-harvest				112.72
Harvest Costs				
Machinery	Acre	6.91	1.00	6.91
Custom Drying	Bu.	.14	120.00	16.80
Labor	Hour	4.50-6.50	.696	3.64
Interest on Operating Capital	Dol.	.11	12.85	1.41
Subtotal, Harvest				28.76
Total Operating Costs				141.78
3. Income Above Operating Costs				158.62
4. Ownership Costs				
Machinery	Acre	31.34	1.00	31.34
Taxes (Land)	Acre	.007	1,800.00	12.60
Land (Interest)	Acre	.043	1,800.00	77.40
Total Ownership Costs				121.34
5. Total Costs Shown				262.82
6. Net Returns Above Costs Shown				37.18

Table 16B: Calendar of Operations, Tooling, and Materials for Non-Irrigated Field Corn for Grain.

							Materials					
Date	Operation	Times Over	Labor Hours	Machine Hours	Fuel, Oil Lub. Repair Per Acre	Ownership Cost Per Acre	Rate/Acre & Name	Unit	Price of Cost/Unit	Quantity	Cost of Materials	Cost of Operation
Oct.-Nov.	Chop Stalks 12 ft., 75 h.p.	1	.276	.230	1.15	2.65	Nitrogen	Lbs.				5.60
Nov.	Dry Fert. Spread, 40 ft., 75 h.p.	1	.031	.026	.18	.62	Nitrogen	Lbs.	.18	30.00	5.40	
							Phosphate (P_2O_5)	Lbs.	.17	80.00	13.60	29.61
							Potassium (K_2O)	Lbs.	.08	120.00	9.60	
Nov.	Plow 5-16 ft., 120 h.p.	1	.413	.344	3.01	5.24						10.93
Apr.	Anhy. Ammonia Applic., 120 h.p.	1	.134	.112	.87	2.56	Anhydrous Ammonia	Lbs.	.10	110.00	11.00	15.31
Apr.	Disk 20 ft., 120 h.p.	1	.124	.103	.93	1.88	2½ qts. Lasso	Mixture	14.72	1.00	14.72	18.34
							1.6 qts. Atrazine					
May	Springtooth Drag 48 ft., 75 h.p.	1	.040	.033	.19	1.00						1.45
May	Corn Planter, Starter, Fert., Insecticide 80-30", 75 h.p.	1	.157	.131	.95	4.21	Nitrogen	Lbs.	.18	10.00	1.80	
							Phosphate (P_2O_5)	Lbs.	.17	20.00	3.40	
							Potassium (K_2O)	Lbs.	.08	10.00	.80	
							10 Lbs. Furadan	Lbs.	.76	10.00	7.60	
							.423 Bag of Seed Corn	Bag	45.00	.325	14.62	34.41
May	Sprayer 30 ft., 40 h.p.	1	.085	.071	.31	.51	2, 4-D	Pint	.85	1.00	.85	2.23
June	Cultivate 8-30", 75 h.p.	2	.310	.258	1.34	2.56						5.92
Oct.	Combine 8-30 in.	1	.254	.212	4.65	6.85						13.16
Oct.	Hauling (Medium Truck)*	2	.442	.368	2.26	3.26						7.51
Oct.-Nov.	Custom Drying						120 Bu. @ $.14/Bu.					16.80
	Totals		2.266	1.888	15.84	31.34					83.39	161.27

*Unskilled Labor $4.50/hour

Table 17A: Irrigated field corn for grain, fine textured (heavy) soils in south central Minnesota, average per acre costs and returns. Outgoing crop: Field corn.

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Field Corn	Bu.	2.50	158.	395.00
Total				395.00
2. Operating Costs				
Preharvest				
Corn Seed	Bag	45.00	.350	15.75
Nitrogen (N)	Lbs.	.15-.18	60.00	9.90
Anhydrous Ammonia	Lbs. of N	.10	110.00	11.00
Phosphate	Lbs.	.17	100.00	17.00
Potash	Lbs.	.08	130.00	10.40
Herbicide	Acre	14.72	1.00	14.72
Insecticide	Acre	7.60	1.00	7.60
Crop Insurance	Dol.	.025	395.00	9.88
Machinery	Acre	8.93	1.00	8.93
Irrigation Machinery	Acre	16.56	1.00	16.56
Labor (Tractor + Mach.)	Hours	6.50	1.57	10.21
Labor (Irrigation)	Hours	6.50	.39	2.53
Interest on Operating Capital	Dol.	.11	60.87	6.70
Subtotal, Pre-harvest				141.18
Harvest Costs				
Machinery	Acre	6.91	1.00	6.91
Custom Drying	Bu.	.14	158.00	22.12
Labor	Hour	4.50-6.50	.696	3.64
Interest on Operating Capital	Dol.	.11	15.51	1.71
Subtotal, Harvest				34.38
Total Operating Costs				175.56
3. Income Above Operating Costs				219.44
4. Ownership Costs				
Machinery	Acre	31.34	1.00	31.34
Irrigation Machinery	Acre	70.90	1.00	70.90
Taxes (Land)	Acre	.007	1,800.00	12.60
Land (Interest)	Acre	.043	1,800.00	77.40
Total Ownership Costs				192.24
5. Total Costs Shown				67.80
6. Net Returns Above Costs Shown				27.20

Table 17B: Calendar of Operations, Tooling and Materials Used Per Acre of Field Corn (Irrigated)

Date	Operation	Times Over	Labor Hours	Machine Hours	Fuel, Oil, Lub., Repair Per Acre	Ownership Cost Per Acre	Materials: Rate/Acre & Name	Unit	Price of Cost/Unit	Quantity	Cost of Materials	Cost of Operation
Oct.-Nov.	Chop Stalks, 12 ft., 75 h.p.	1	.276	.230	1.15	2.65						5.60
Nov.	Dry Fert. Spread, 40 ft., 120 h.p.	1	.031	.026	.18	.62	Nitrogen	Lbs.	.18	30.00	5.40	
							Phosphate (P_2O_5)	Lbs.	.17	80.00	13.60	
							Potassium (K_2O)	Lbs.	.08	120.00	9.60	29.61
Nov.	Plow, 5-16', 120 h.p.	1	.413	.344	3.01	5.24						10.93
April	Anhyd. Ammonia Applic., 120 h.p.	1	.134	.112	.87	2.56	Anhydrous Ammonia	Lbs.	.10	110.00	11.00	15.31
April	Disk, 20 ft., 120 h.p.	1	.124	.103	.93	1.88	2½ qts. Lasso 1.6 qts. Atrazine	Mix.	14.72	1.00	14.72	18.34
May	Springtooth Drag, 48 ft., 75 h.p.	1	.040	.033	.19	1.00						1.45
May	Corn Planter, Starter Fertilizer, Insecticide, 8-30", 75 h.p.	1	.157	.131	.95	4.21	.350 bag of seed corn	Bag	45.00	.350	15.75	
							Nitrogen	Lbs.	.18	10.00	1.80	
							Phosphate (P_2O_5)	Lbs.	.17	20.00	3.40	
							Potassium (K_2O)	Lbs.	.08	10.00	.80	
							10 lbs. Furadan	Lbs.	.76	10.00	7.60	35.54
May	Sprayer, 30 ft., 40 h.p.	1	.085	.071	.31	.51	2, 4-D	Pint	.85	1.00	.85	2.23
June	Cultivate 8-30", 75 h.p.	2	.310	.258	1.34	2.56						5.92
July Aug.	Irrigate	4	.390	3.394	16.56	70.90	28% solution liquid N	Lbs.	.15	30.00	4.50	94.50
Oct.	Combine 8-30"	1	.254	.212	4.65	6.85						13.16
Oct.	Hauling (Medium Truck)*	2	.442	.368	2.26	3.26						7.51
Oct. Nov.	Custom Drying						158 Bu. at $.14/Bu.					22.12
	Totals		2.656	5.282	32.40	102.24					89.02	261.80

*Unskilled Labor $4.50/hr.

Table 18A: Non-irrigated soybeans, fine textured (heavy) soils in south central Minnesota, average per acre costs and returns. Outgoing crop: Field corn.

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Soybeans	Bu.	6.50	40.00	260.00
Total				260.00
2. Operating Costs				
Preharvest				
Soybean Seed	Bu.	9.50	1.00	9.50
Herbicide	Qt.	6.88	1.00	6.88
Crop Insurance	Dol.	.025	260.00	6.50
Machinery	Acre	6.68	1.00	6.68
Labor	Hours	Varies	2.15	8.60
Interest on Operating Capital	Dol.	.11	15.78	1.74
Subtotal, Pre-harvest				39.90
Harvest Costs				
Machinery	Acre	4.66	1.00	4.66
Labor	Hour	Varies	.47	2.57
Interest on Operating Capital	Dol.	.11	2.83	.32
Subtotal, Harvest				7.55
Total Operating Cost				47.45
3. Income Above Operating Costs				212.55
4. Ownership Costs				
Machinery	Acre	22.32	1.00	22.32
Taxes (Land)	Acre	.007	1,800.00	12.60
Land (Interest)	Acre	.043	1,800.00	77.40
Total Ownership Costs				112.32
5. Total Costs Shown				159.77
6. Net Returns Above Costs Shown				100.23

Table 18B: Calendar of Operations, Tooling and Materials Used for Non-Irrigated Soybeans.

Date	Operation	Times Over	Labor Hours	Machine Hours	Fuel, Oil, Lub. Repair Per Acre	Ownership Cost per Acre	Materials					Cost of Operation
							Rate/Acre and Name	Unit	Price of Cost/Unit	Quantity	Cost of Materials	
Nov.	Disk, 20 feet, 120 h.p.	1	.124	.103	.93	1.88						3.62
Nov.	Plow, 5-16', 120 h.p.	1	.413	.344	3.01	5.24						10.93
April-May	Disk, 20 feet, 120 h.p.	1	.124	.103	.93	1.88	1 qt. Treflan	Quart	6.88	1.00	6.88	10.50
May	Springtooth Drag, 48', 75 h.p.	1	.040	.033	.19	1.00						1.45
May	Bean Planter, 8-30", 75 h.p.	1	.157	.131	.95	4.21	1 Bu. Soybean Seed	Bu.	9.50	1.00	9.50	15.68
June	Cultivator, 8-30", 75 h.p.	1	.155	.129	.67	1.28						2.96
July	Walk Beans	1	.670	.670	0.00	.14	Wage Rate $3.00/hr					2.01
Sept.	Combine, 8-30"	1	.242	.202	3.53	5.06						10.17
Sept.	Hauling (Medium Truck)*	1	.221	.184	1.13	1.63	Unskilled Wage Rate $4.50/hour					3.76
	Totals		2.146	1.899	11.34	22.32					[illegible]	61.00

*Unskilled Labor $4.50/hour

Table 19A: Irrigated soybeans, fine textured heavy soils in south central Minnesota, average per acre costs and returns. Outgoing crop: Field corn.

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Soybeans	Bu.	6.50	50.00	325.00
Total				325.00
2. Operating Costs				
Preharvest				
Soybean Seed	Bu.	9.50	1.00	9.50
Herbicide	Qt.	6.88	1.00	6.88
Crop Insurance	Dol.	.025	325.00	8.12
Machinery	Acre	6.68	1.00	6.68
Irrigation mach.	Acre	10.14	1.00	10.14
Labor (mach.)	Hours	Varies	2.15	8.60
Labor (irrigation)	Hours	6.50	.193	1.27
Interest on Operating Capital	Dol.	.11	21.66	2.38
Subtotal, Pre-harvest				53.57
Harvest Costs				
Machinery	Acre	4.66	1.00	4.66
Labor (Tractor & Mach.)	Hour	Varies	.47	2.57
Interest on Operating Capital	Dol.	.11	2.83	.32
Subtotal, Harvest				7.55
Total Operating Cost				61.12
3. Income Above Operating Costs				263.88
4. Ownership Costs				
Machinery	Acre	22.32	1.00	22.32
Irrigation Mach.	Acre	70.90	1.00	70.90
Taxes (Land)	Acre	.007	1,800.00	12.60
Land (Interest)	Acre	.043	1,800.00	77.40
Total Ownership Costs				183.22
5. Total Costs Shown				244.34
6. Net Returns Above Costs Shown				80.66

Table 19B: Calendar of Operations, Tooling and Materials Used Per Acre of Irrigated Soybeans

Date	Operation	Times Over	Labor Hours	Machine Hours	Fuel, Oil, Lub. Repair Per Acre	Ownership Cost per Acres	Materials: Rate/Acre and Name	Unit	Price of Cost/Unit	Quantity	Cost of Materials	Cost of Operation
Nov.	Disk, 20 ft., 120 H.P.	1	.124	.103	.93	1.88						3.62
Nov.	Plow, 15-16', 120 H.P.	1	.413	.344	3.01	5.24						10.93
Apr.-May	Disk, 20 ft., 120 H.P.	1	.124	.103	.93	1.88	Treflan	Quart	6.88	1.00	6.88	10.50
May	Springtooth Drag, 48', 75 H.P.	1	.040	.033	.19	1.00						1.45
May	Bean Planter, 8-30", 75 H.P.	1	.157	.131	.95	4.21	Soybean Seed	Bushel	9.50	1.00	9.50	15.68
June	Cultivator, 8-30", 75 H.P.	1	.155	.129	.62	1.28						2.96
July	Walk Beans	1	.670	.670	0.00	.14	Wage Rate $3.00/hr	Hour				2.01
July-Aug.	Irrigate	3	.195	1.662	10.14	70.90						83.41
Sept.	Combine, 8-30"	1	.242	.202	.353	5.06						10.17
Sept.	Hauling (Medium Truck)*		.221	.184	1.13	1.63	Unskilled wage rate $4.50	Hour				3.76
	Totals		2.341	3.451	21.48	93.22					16.38	144.49

*Unskilled labor $4.50/hr.

Table 20A: Non-Irrigated alfalfa hay establishment with companion crop oats, fine textured (heavy) soils in south central Minnesota, average per acre costs and returns. Outgoing crop: Field corn.

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Oats	Bu.	1.30	65.00	84.50
Oat Straw	Ton	35.00	2.00	70.00
Total				154.50
2. Operating Costs				
Preharvest				
Herbicide	Lbs.	.85	.25	.22
Phosphorus P_2O_5	Lbs.	.17	80.00	13.60
Potassium K_2O	Lbs.	.08	180.00	14.40
Alfalfa Seed	Lbs.	2.35	12.00	28.20
Oat Seed	Lbs.	2.75	2.00	5.00
Crop Insurance	Dol.	.025	154.50	3.86
Machinery	Acre	6.61	1.00	6.61
Labor	Hours	.967	6.50	6.29
Interest on Operating Capital	Dol.	.11	36.94	4.06
Subtotal, Pre-harvest				82.24
Harvest Costs				
Twine (Bale)	Bale	15.00	.20	3.00
Machinery	Acre	7.95	1.00	7.95
Labor	Hours	4.50-6.50	1.61	8.64
Interest on Operating Capital	Dol.	.11	7.48	.83
Subtotal, Harvest				20.42
Total Operating Cost				102.66
3. Income Above Operating Costs				51.84
4. Ownership Costs				
Machinery	Acre	31.70	1.00	31.70
Taxes (Land)	Acre	.043	1,800.00	77.40
Land (Interest)	Acre	.007	1,800.00	12.60
Total Ownership Costs				121.70
5. Total Costs Shown				224.36
6. Net Returns Above Costs Shown				-69.86

Table 20B: Calendar of Operations, Tooling and Materials Used Per Acre of Non-Irrigated Alfalfa Establishment with Companion Crop Oats

Date	Operation	Times Over	Labor Hours	Machine Hours	Fuel, Oil, Lub. Repair Per Acre	Ownership Cost per Acre	Materials: Rate/Acre and Name	Unit	Price of Cost/Unit	Quantity	Cost of Materials	Cost of Operation
Oct.	Plow, 5-16', 120 h.p.	1	.413	.344	3.01	5.24						10.94
Oct.	Disk, 20 feet, 120 h.p.	1	.124	.103	.93	1.88						3.62
April	Dry Fert. Spread, 40', 75 h.p.	1	.031	.026	.18	.62	Phosphorus (P_2O_5) Potassium (K_2O)	Lbs.	.17 .08	80.00 180.00	13.60 14.40	29.01
April	Disk, 20 feet, 120 h.p.	1	.124	.103	.93	1.88						3.62
April	Springtooth Drag, 48', 75 h.p.	1	.040	.033	.19	1.00						1.45
April	Grain Drill, 20 feet, 75 h.p.	1	.150	.125	1.06	3.86	Oat Seed Alfalfa Seed	Bu. Lbs.	2.75 2.35	2.00 12.00	5.00 28.20	39.10
April	Spray, 30 feet, 40 h.p.	1	.085	.071	.31	.51	2, 4-D mine	Lbs.	.85	.25	.22	1.60
July	Swather, 18 feet	1	.138	.115	.67	2.77						4.34
July	Combine, Sm. Grain Med.	1	.255	.212	3.50	5.59						10.75
July	Medium Truck*	1	.255	.212	1.31	1.87						4.33
July	Baler PTO Twine 75 h.p.	1	.318	.265	1.72	2.72	.200 Twine	Bale	15.00	.20	3.00	9.51
July	Wagon*	2	.636	.530	.75	2.98						5.68
	Totals		2.569	2.139	14.56	30.92					64.42	123.95

*Unskilled labor $4.50/hour.

Table 21A: Irrigated alfalfa hay establishment with companion crop oats, fine textured (heavy) soils in south central Minnesota, average per acre costs and returns. Outgoing crop: Field corn.

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Oats	Bu.	1.30	75.00	97.50
Oat Straw	Ton	35.00	2.25	78.75
Alfalfa	Ton	45.00	1.50	67.50
Total				243.75
2. Operating Costs				
Preharvest				
Phosphorus P_2O_5	Lbs.	.17	80.00	13.60
Potassium K_2O	Lbs.	.08	180.00	14.40
Alfalfa Seed	Lbs.	2.35	12.00	28.20
Oat Seed	Lbs.	2.75	2.00	5.00
Herbicide	Lbs.	.85	.25	.22
Crop Insurance	Dol.	.025	243.75	6.10
Machinery	Acre	5.68	1.00	5.68
Irrigation Mach.	Acre	13.02	1.00	13.02
Labor (Mach.)	Hours	6.50	.843	5.48
Labor (Irrigation)	Hours	6.50	.260	1.69
Interest on Operating Capital	Dol.	.11	43.11	4.74
Subtotal, Pre-harvest				98.13
Harvest Costs				
Twine (Bale)	Bale	15.00	.225	3.38
Machinery	Acre	13.43	1.00	13.43
Labor (Mach.)	Hours	4.50-6.50	3.245	18.04
Interest on Operating Capital	Dol.	.11	11.85	1.31
Subtotal, Harvest				36.16
Total Operating Cost				134.29
3. Income Above Operating Costs				109.46
4. Ownership Costs				
Machinery	Acre	41.79	1.00	41.79
Irrigation Machinery	Acre	70.90	1.00	70.90
Taxes (Land)	Acre	.043	1,800.00	77.40
Land (Interest)	Acre	.007	1,800.00	12.60
Total Ownership Costs				202.69
5. Total Costs Shown				336.98
6. Net Returns Above Costs Shown				-93.23

Table 21B: Calendar of Operations, Tooling and Materials Used Per Acre of Irrigated Alfalfa Establishment with Companion Crop Oats.

Date	Operation	Times Over	Labor Hours	Machine Hours	Fuel, Oil, Lub. Repair Per Acre	Ownership Cost per Acre	Materials: Rate/Acre and Name	Unit	Price of Cost/Unit	Quantity	Cost of Materials	Cost of Operation
Oct.	Plow, 5-16', 120 h.p.	1	.413	.344	3.01	5.24						10.94
Oct.	Disk, 20 feet, 120 h.p.	1	.124	.103	.93	1.88						3.62
April	Spray, 30 feet, 40 h.p.	1	.085	.071	.31	.51	2, 4-D amine	Lbs.	.85	.25	.22	1.60
April	Dry Fert. Spread, 40', 75 h.p.	1	.031	.026	.18	.62	Phosphorus (P_2O_5) Potassium (K_2O)	Lbs. Lbs.	.17 .08	80.00 180.00	13.60 14.40	28.80
April	Disk, 20 feet, 120 h.p.	1	.124	.103	.93	1.88						3.62
April	Springtooth Drag, 48', 75 h.p.	1	.040	.033	.19	1.00						1.45
April	Grain Drill, 20 feet, 75 h.p.	1	.150	.125	1.06	3.86	Oat Seed Alfalfa Seed	Bu. Lbs.	2.75 2.35	2.00 12.00	5.00 28.20	39.10
July	Swather, 18 feet	1	.138	.115	.67	2.77						4.34
July	Combine, SM Grain Med.	1	.255	.212	3.50	5.59						10.75
July	Baler PTO Twine, 75 h.p.	1	.318	.265	1.72	2.72	.225 Twine	Bale	15.00	.225	3.38	9.89
July	Medium Truck*	1	.255	.212	1.31	1.87						4.33
July	Wagon*	2	.636	.530	.75	2.98						5.68
Aug.	Swather-Cond., 12 feet	1	.220	.183	1.03	3.91						6.37
Aug.	Rake (HYD), 40 h.p.	1	.345	.287	1.05	1.26						4.56
Aug.	Baler PTO Twine, 75 h.p.	1	.318	.265	1.72	2.72	.20 Twine	Bale	15.00	.200	3.00	9.51
Aug.	Wagon*	2	.636	.530	.75	2.98						5.68
June-Aug.	Irrigate	4	.260	2.263	13.02	70.90						85.61
	Totals		4.348	5.667	32.13	112.69					67.80	235.85

*Unskilled labor $4.50. Second Wagon is attached to a 40 h.p. tractor.

Table 22A: Non-irrigated alfalfa hay, full production, fine textured (heavy) soils in south central Minnesota, average per acre costs and returns. Outgoing crop: Field corn.

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Alfalfa Hay	Ton	45.00	4.5	202.50
Total				202.50
2. Operating Costs				
Preharvest				
Phosphorous P_2O_5	Lbs.	.17	60.00	10.20
Potassium K_2O	Lbs.	.08	90.00	7.20
Crop Insurance	Dol.	.025	202.50	5.07
Machinery	Acre	.18	1.00	.18
Labor	Acre	.21	1.00	.21
Interest on Operating Capital	Dol.	.11	11.33	1.25
Subtotal, Pre-harvest				24.11
Harvest Costs				
Twine (Bale)	Bale	15.00	.45	6.75
Machinery	Acre	12.60	1.00	12.60
Labor	Hours	4.50-6.50	4.212	23.57
Interest on Operating Capital	Dol.	.11	13.97	1.54
Subtotal, Harvest				44.46
Total Operating Costs				68.57
3. Income Above Operating Costs				133.93
4. Ownership Costs				
Machinery	Acre	24.58	1.00	24.58
Taxes (Land)	Acre	.007	1,800.00	12.60
Land (Interest)	Acre	.043	1,800.00	77.40
Total Ownership Costs				114.58
5. Total Costs Shown				183.15
6. Net Returns Above Costs Shown				19.35

Table 22B: Calendar of Operations, Tooling and Materials Used Per Acre of Non-Irrigated Alfalfa Full Production

Date	Operation	Times Over	Labor Hours	Machine Hours	Fuel, Oil, Lub. Repair Per Acre	Ownership Cost Per Acre	Materials: Rate/Acre & Name	Unit	Price of Cost/Unit	Quantity	Cost of Materials	Cost of Operation
Sept.	Dry Fert. Spreader, 40', 75 h.p.	1	.031	.026	.026	.62	Phosphorus (P_2O_5)	Lbs.	.17	60.00	10.20	18.41
							Potassium (K_2O)	Lbs.	.08	90.00	7.20	
June, July Aug.	Swather Cond., 12 ft.	3	.660	.549	3.09	11.73						19.11
June, July, Aug.	Rake (HYD) 40 h.p.	2	.690	.574	2.10	2.58						9.17
June, July Aug.	Baler PTO Twine, 75 h.p.	3	.954	.795	5.16	8.16	Twine	Bale	15.00	.450	6.75	26.28
June, July Aug.	Wagon*	6	1.908	1.902	2.25	1.49						12.33
	Totals		4.243	3.846	12.78	24.58					24.15	85.30

*2 Wagons are used with one being attached to 40 h.p. tractor.

† Unskilled Laborer at $4.50/hour

Table 23A: Irrigated alfalfa hay full production, fine textured (heavy) soils in south central Minnesota, average per acre costs and returns. Outgoing crop: Field corn.

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Alfalfa Hay	Ton	45.00	7.5	337.50
Total				337.50
2. Operating Costs				
Preharvest				
Phosphorus P_2O_5	Lbs.	.17	60.00	10.20
Potassium K_2O	Lbs.	.08	90.00	7.20
Crop Insurance	Dol.	.025	337.50	8.44
Machinery	Acre	.18	1.00	.18
Irrigation Mach.	Acre	20.10	1.00	20.10
Labor	Acre	.21	1.00	.21
Irrigation Labor	Hours	6.50	.52	3.38
Interest on Operating Capital	Dol.	.11	23.06	2.54
Subtotal, Pre-harvest				52.25
Harvest Costs				
Twine	Bale	15.00	.75	11.25
Machinery	Dol.	18.11	1.00	18.11
Labor	Hours	4.50-6.50	5.767	32.40
Interest on Operating Capital	Dol.	.11	20.41	2.25
Subtotal, Harvest				64.01
Total Operating Costs				116.26
3. Income Above Operating Costs				221.24
4. Ownership Costs				
Machinery	Acre	35.01	1.00	35.01
Irrigation Machinery	Acre	70.90	1.00	70.90
Taxes (Land)	Acre	.007	1,800.00	12.60
Land (Interest)	Acre	.043	1,800.00	77.40
Total Ownership Costs				195.91
5. Total Costs Shown				312.17
6. Net Returns Above Costs Shown				25.33

Table 23B. Calendar of Operations, Tooling and Materials Used Per Acre of Irrigated Alfalfa Full Production

Date	Operation	Times Over	Labor Hours	Machine Hours	Fuel, Oil, Lub. Repair Per Acre	Ownership Cost per Acre	Materials: Rate/Acre and Name	Unit	Price of Cost/Unit	Quantity	Cost of Materials	Cost of Operation
Sept.	Dry Fert. Spread.. 40', 75 h.p.	1	.031	.026	.18	.62	Phosphorus (P_2O_5) Potassium (K_2O)	Lbs. Lbs.	.17 .08	60.00 90.00	10.20 7.20	18.41
May, June, July, Aug.	Swather-Cond. 12 feet	4	.880	.732	4.12	15.64						25.48
May, June Aug.	Rake (HYD) 40 h.p.	3	1.040	.861	4.11	5.88						16.75
May, June, July, Aug.	Baler PTO Twine	4	1.272	1.060	6.88	10.88	.75 Twine	Bale	15.00	.75	11.25	37.28
May June, July, Aug.	Wagon*	8	2.544	2.536	3.00	1.99						16.44
May, June, July, Aug.	Irrigate	8	.520	4.525	20.10	70.90						94.39
	Totals		6.287	9.740	38.39	105.91					28.65	208.75

*Two wagons are used with one being attached to a 40 h.p. tractor. 1 Unskilled laborer at $4.50.

Fertilization rates, yields, and prices may vary with the individual firm. Farm operators should modify these enterprise budgets, if necessary, to better reflect their farming operation. The producer can substitute his price, quantity and yield figures for the figures presented and re-calculate his costs and returns. If an irrigation system other than System No. 1 is used, irrigation costs should be calculated for that system and substituted for the System No. 1 costs.

A comparison of the various crops shows that for all non-irrigated and irrigated crops, gross receipts exceed total operating costs. This implies that all of these enterprises contribute to covering the overhead or fixed costs of the business.

Product price and yield per acre are two of the most critical variables for determining the profitability of a particular non-irrigated or irrigated crop enterprise. In calculating the profitability of the proposed irrigation investment, the farmer should vary expected prices and yields to determine how sensitive profitability is to changes in these variables. This type of sensitivity analysis is illustrated in the following section.

C. Sensitivity Analysis

The profitability of investing in an irrigation system is dependent upon a number of factors including crop prices, increased yield resulting from irrigation, the investment cost of the irrigation system, the price of energy, interest rates and many other items. In general, the two most important factors are the price of the crop and the amount of additional yield that can be produced with irrigation. This section analyzes the effect of alternative yield and price levels on the net return above costs shown in the enterprise budgets. Irrigation System No. 1 is used in the sensitivity analysis.

The effect of alternative yield and price levels on the net returns above costs shown (in Table 16A) is presented in Table 24. This sensitivity table assumes corn is planted on land that produced soybeans the year before so the value of the insecticide in Table 16A has been subtracted from the other crop costs. The analysis recognizes that some costs are proportional to the yield produced whereas others are essentially constant if the crop is planted. The costs treated as proportional are nitrogen fertilizer, drying costs, interest cost and crop insurance. They total $61.31 or $.38

Table 24. Per Acre Net Returns Above Costs for Irrigated Field Corn at Alternative Yield and Price Levels (Dollars). Outgoing Crop: Soybeans.

Yield Bu.Ac.	Price Per Bushel 1.75	2.00	2.25	2.50	2.75	3.00
130	-120.79	-88.29	-55.79	-23.29	9.21	41.71
140	-107.09	-72.09	-37.09	- 2.09	32.91	67.91
150	- 93.39	-55.89	-18.39	19.11	56.61	94.11
160	- 79.69	-39.69	.31	40.31	80.31	120.31
170	- 65.99	-23.49	19.01	61.51	104.01	146.51
180	- 52.29	- 7.29	37.71	82.71	127.71	172.71

per bushel. The remaining costs are treated as constant. The costs per acre can be expressed as:

Cost Per Acre = \$289.89 + \$.38 (yield/acre)

Subtracting the cost per acre from gross returns for the specified yield and price results in the entries shown in Table 24.

The entries indicate the net returns above costs shown are very sensitive to the yield and price level. Prices of \$2.00 per bushel and less result in negative net returns, even at a yield of 180 bushels per acre. However, with a price of \$2.75 per bushel net returns are \$9.21 per acre with a yield of 130 bushels per acre.

Throughout our analysis this report has assumed that the soybean crop follows an outgoing crop of field corn. This was the typical cropping pattern found during the irrigation survey. Keeping this in mind, Table 25 shows the per acre net returns for irrigated soybeans for different

Table 25. Per Acre Net Returns Above Costs for Irrigated Soybeans at Alternative Yield and Price Levels. Outgoing Crop: Field Corn.

Yield Bu.Ac.	Price Per Bushel 5.50	5.75	6.00	6.25	6.50
40	-21.92	-11.92	- 1.92	8.08	18.08
45	4.53	15.78	27.03	38.28	49.53
50	30.98	43.48	55.98	68.48	80.98
55	57.43	71.18	84.93	98.68	112.43

yield and price levels. The costs per acre were calculated using the same methods described for corn. Crop insurance and interest on operating capital are assumed to vary with yields so the following equation was used to estimate total costs:

Cost Per Acre = \$233.52 + \$.21 (yield/acre)

For most price and yield levels the net returns are positive.

Table 26 compares per acre net returns for irrigated alfalfa in full production. Fertilizer usage, insurance costs and interest costs

Table 26. Per Acre Net Returns Above Costs for Irrigated Alfalfa (Full Production) at Alternative Yield and Price Levels

Yield Ton/Ac.	Price Per Ton \$30	\$40	\$50	\$60
6.0	-145.96	-85.96	- 25.96	34.04
7.0	-120.04	-50.04	19.96	89.96
8.0	- 94.12	-14.12	65.88	145.88
9.0	- 68.20	21.80	111.80	201.80

vary with yield level and all other costs are assumed to be constant. The equation for costs per acre is:

Total Costs Per Acre = \$301.48 + \$4.08 (tons/acre)

Net returns are negative for a yield of 6 tons per acre when the alfalfa price is less than approximately \$55 per ton. With a price of less than \$35 per ton, net returns are negative at all yield levels considered.

D. Cash Flow Analysis

To more accurately measure profitability, a producer considering the investment in an irrigation system should analyze the effect the investment will have on the firm's cash flow position over time. This analysis involves calculating the estimated cash inflows and outflows attributable to the investment over a chosen planning period. By comparing the cash inflows and outflows for each year, the farm operator can determine if the investment will generate enough additional revenue to cover the incremental operating costs, interest, and principal payments. This projection of net cash inflow or income also provides the basis for calculating the net present value (NPV) and the internal rate of return (IRR) of the investment. If the NPV is greater than 0, then the investment has a rate of return greater than the minimum return desired by the producer. A negative NPV implies the investment has a rate of return below the desired rate and is, therefore, unprofitable for the farm operator. The IRR is that rate of interest that "equates the net present value of the cash flow stream to zero," (Hopkin, et. al. 1973). This rate can be compared to the decision maker's opportunity cost of capital. If the IRR is larger (smaller) than the opportunity cost then the investment is profitable (unprofitable).

The potential irrigator should be cautioned above concluding the irrigation investment is profitable and feasible if the NPV is positive and the IRR is greater than the opportunity cost of capital or desired rate of return. A large investment may be profitable over a 15-year planning period but large negative after-tax and payment cash flows may cause liquidity problems for the operator during part of the planning period. Unless cash is readily available from other farm enterprises, through short-term borrowing or owner savings, the investment may not be feasible although it could be profitable.

A detailed example analyzing the feasibility and profitability of a typical irrigation investment follows. It is assumed that the individual plans to use a center-pivot system identical to System No. 1 to irrigate corn and soybeans in south central Minnesota. A corn-soybean rotation is used with corn planted in the odd numbered years and soybeans in the even numbered years. The corn crop is fertilized heavily and the soybean crop uses the phosphate and potassium carry-over. The other major assumptions for this analysis are:

<u>Assumptions</u>	
AWC of soil	12.36 inches
Total cost of irrigation system	$65,344
Precipitation during the growing period (May-September)	18 inches
Total borrowed (commercial loan) 10 years, 12% interest	$65,344
Individual's tax bracket (federal & state)	40%
Rate of return desired after taxes	12%

Gross inches of water pumped per acre of corn	6
Gross inches of water pumped per acre of soybeans	3

Prices: Corn $2.50/bushel
Soybeans $6.00/bushel

Yields:[4/]

	Corn	Soybeans
Non-Irrigated	120	40
Irrigated	158	50

Length of planning period	15 years
Estimated salvage value	$8,471

Crop production costs are those presented earlier for field corn and soybeans. It is assumed that all prices remain constant relative to one another over the planning period. The yield differential between non-irrigated and irrigated production remains constant.

The initial incremental cash flows are calculated in the following manner:

Corn Year

Incremental cash inflow

Irrigated corn	
130 acres x 158 bushels x $2.50/bushel	$51,350
Non-irrigated corn	
1320 acres x 120 bushels x $2.50/bushel	39,000
	$12,350

Incremental cash outflow

Irrigated corn	
130 acres x $179.29	$23,308
Non-irrigated corn	
130 acres x $140.57	18,274
	$ 5,034

Soybean Year

Incremental cash inflow

Irrigated soybeans	
130 acres x 50 bushels x $6.00/bushel	$39,000
Non-irrigated soybeans	
130 acres x 40 bushels x $6.00/bushel	31,200
	$ 7,800

4/ It is assumed that the operator has previous irrigation experience and obtains the potential yields the first crop year.

Incremental cash outflow

Irrigated soybeans	
130 acres x $64.28	$ 8,356
Non-irrigated soybeans	
130 acres x $51.88	6,744
	$ 1,612

The net cash income before taxes and payments is derived by subtracting the incremental cash outflow from the incremental cash inflow for the year in question. These calculations are presented in Table 27.

The next step is to calculate the effect the investment will have on the tax position of the investor. We've assumed a marginal tax rate (including both federal and state) of 40 percent. The change in taxes is estimated by using the following formula:

ΔT = MTR(NCF-D-I) - IC

where:

ΔT = Change in taxes

MTR = Marginal tax rate

NCF = Net cash flow before taxes and payments

D = Annual Depreciation

I = Annual Interest Paid

IC = Investment credit taken on equipment

In order to calculate the change in taxes, the annual depreciation and interest charges must be calculated. For this example, the useful life of the investment components are:

Well	- 25 years
Pumps	- 15 years
Pipe, Valves and Wire	- 20 years
Electric Motor and Controls	- 25 years
Center Pivot	- 15 years

Assuming that straight-line depreciation is taken, the annual depreciation charge is $3,794.

The investment in our example is financed totally by borrowed capital from a commercial source. The terms of the loan are a 10 year repayment period and an annual rate of interest of 12 percent. Ten equal loan

Table 27. Calculating Net Cash Income Before Taxes and Payments by Years

Year	Crop	Incremental Cash Inflow	Incremental Cash Outflow	Net Cash Income Before Taxes and Payments
1	Corn	$12,350	$5,034	$7,316
2	Soybeans	7,800	1,612	6,188
3	Corn	12,350	5,034	7,316
4	Soybeans	7,800	1,612	6,188
5	Corn	12,350	5,034	7,316
6	Soybeans	7,800	1,612	6,188
7	Corn	12,350	5,034	7,316
8	Soybeans	7,800	1,612	6,188
9	Corn	12,350	5,034	7,316
10	Soybeans	7,800	1,612	6,188
11	Corn	12,350	5,034	7,316
12	Soybeans	7,800	1,612	6,188
13	Corn	12,350	5,034	7,316
14	Soybeans	7,800	1,612	6,188
15	Corn	12,350	5,034	7,316

payments of $11,565 are made at the end of each year. The investment credit allowance is equal to 10 percent of the total investment cost.

The negative values for the change in taxes (Table 28) for the first four years of the planning period imply that the investment reduces the producer's tax liability for that year by the noted amount.

Table 29 shows the estimates for the net cash income after taxes and payments and the net present value (NPV) of the irrigation investment. The estimated NPV is negative ($-6,982) indicating the returns are not sufficient to yield the 12 percent rate of return on the capital investment the operator specified he can earn elsewhere. An IRR of 2 percent reinforces this observation because this rate is much lower than the desired rate of return of 12 percent.

We also can observe the negative net cash income figures for years 2-10. This implies that the investment is not generating sufficient additional revenue to cover loan payments. The irrigator must use cash generated by other enterprises on the farm to pay for the irrigation system.

Throughout this analysis we have assumed that the producer obtains optimal yield increases the first year of irrigation. This may be true for the individual who has previous experience irrigating corn and soybeans. For example, the above analysis could apply to a farm operator who wants to add another center pivot system to his operation after using a center pivot for several years.

But as noted in the results of the irrigation survey, optimal or potential yield increases are not obtained in the first year by the inexperienced irrigator. There exists a learning period of 3-5 years before potential or optimal irrigated yields are reached. Reasons for the learning period include improved knowledge over time in regard to timing of irrigation, fertilization and other agronomic practices.

Table 28. Changes in Taxes Resulting from the Irrigation System Using Straight-Line Depreciation

Year	Net Cash Income Before Taxes and Payments	Depreciation	Interest	Investment Credit	Change in Taxes
1	$7,316	$3,794	$7,841	$6,534	-8,262
2	6,188	3,794	7,394	0	-2,000
3	7,316	3,794	6,894	0	-1,349
4	6,188	3,794	6,333	0	-1,576
5	7,316	3,794	5,706	0	-874
6	6,188	3,794	5,002	0	-1,043
7	7,316	3,794	4,215	0	-277
8	6,188	3,794	3,333	0	-376
9	7,316	3,794	2,345	0	471
10	6,188	3,794	1,239	0	462
11	7,316	3,794	0	0	1,409
12	6,188	3,794	0	0	958
13	7,316	3,794	0	0	1,409
14	6,188	3,794	0	0	958
15	7,316	3,794	0	0	1,409

Table 29. Estimating Net Present Value After Taxes and Payments.

Year	Net Cash Income Before Taxes and Payments	Change in Taxes	Loan Payments	Net Cash Income After Taxes and Payments	Present Value Factor (12%)	Annual Present Value of Net Cash Income
1	$7,316	-8,262	$11,565	$4,013	.893	$3,584
2	6,188	-2,000	11,565	-3,377	.792	-2,675
3	7,316	-1,349	11,565	-2,900	.712	-2,065
4	6,188	-1,576	11,565	-3,801	.636	-2,417
5	7,316	-874	11,565	-3,375	.567	-1,914
6	6,188	-1,043	11,565	-4,334	.507	-2,197
7	7,316	-277	11,565	-3,972	.452	-1,795
8	6,188	-376	11,565	-5,001	.404	-2,020
9	7,316	471	11,565	-4,720	.361	-1,704
10	6,188	462	11,565	-5,839	.322	-1,880
11	7,316	1,409	0	5,907	.288	1,701
12	6,188	958	0	5,230	.257	1,344
13	7,316	1,409	0	5,907	.229	1,353
14	6,188	958	0	5,230	.205	1,072
15	15,787*	1,409	0	14,378	.183	2,631
				Total Net Present Value (NPV)		$ -6,982
				Internal Rate of Return (IRR)		2%

*Includes the estimated salvage value of $8,471 included at the end of the planning period.

Table 30 presents the cash flow analysis for the beginning irrigator. All of the earlier assumptions remain the same in this example except that the corn and soybean yields are lower during years one and two. The learning period reduces the net present value of the investment from $-6,982 to $-11,493. As one would expect, the irrigation investment is less profitable with the learning period. The IRR has declined from 2 to -1 percent.

Table 30. Estimating Net Present Value with a Learning Period.

Year	Crop	Yield	Net Cash Income Before Taxes and Payments	Net Cash Income After Taxes and Payments	Annual Present Value of Net Cash Income
1	Corn	140	2,356	1,037	926
2	Soybeans	45	2,288	-5,717	-4,528
3-15	------------------------same as previous example ---------------				

Total Net Present Value (NPV) $-11,493

Internal Rate of Return (IRR) -1%

The preceding analysis implies that irrigating a corn-soybean rotation on Webster-Glencoe soil (AWC of 12.36) is unprofitable if the farmer requires a 12 percent return on his investment. Since this is a specific illustration, a more general treatment of alternative soil types is necessary to provide a better benchmark for potential irrigator to evaluate irrigation investments.

Four typical soil types were selected from both the southwest and south central areas of the survey region. Yield differentials due to irrigation were calculated using the equations presented in Section II.B., and net cash flows after taxes and payments were calculated for each of the eight cases using the same assumptions discussed above, including the learning period. Soybean yields for the moderate AWC soils were assumed to be 35 bushels (non-irrigated) and 45 bushels (irrigated) while for the high and very high AWC soils soybean yields were calculated at 40 bushels (non-irrigated) and 50 bushels (irrigated).

The calculations for these eight soil types are summarized in Table 31. The internal rates of return are shown in the right-hand column. It appears that given the assumptions made, irrigation on moderate soils (AWC 6-9 inches) is profitable.[5/] Rates of return vary from 12 to 26 percent

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5/ Assuming the irrigator has an opportunity cost of capital or a required rate of return of 12 percent.

Table 31. Internal Rates of Return for Various Soil Types

Number	Soil Type*	AWC (inches)	Corn Yield Differential (Bushels)	IRR
	South Central (SC)			
SC1	Hanska-Sparta	6.32	75	26%
SC2	Minnetonka	9.48	56	8%
SC3	Clarion-Nicollet -Webster	11.40	44	2%
SC4	Webster-Glencoe	12.36	38	-1%
	Southwest (SW)			
SW1	Clarion-Estherville	7.62	71	17%
SW2	Estelline	8.40	66	12%
SW 3	Svea-Barnes	11.40	47	2%
SW4	Moody-Primgar-Canisteo	12.36	41	0%

* From the irrigator survey these were found to be typical soil groups/associations being irrigated.

for these soils. The heavier soils with higher AWC values do not produce a favorable return. As already indicated, Webster-Glencoe soil shows a negative IRR. The other heavy soils produce yield differentials which generate rates of return from 0 to 5 percent.

A graphical representation of these values is presented in Figure 10. The exponential shape of the IRR curve occurs because increasing yield differentials add more to cash inflows than to additional cash outflows of the firm. As a result, a 1 percent increase in the corn yield differential causes more than a 1 percent increase in the internal rate of return.

Readers should be cautioned about accepting the relationship presented in Figure 10 as representative of rates of return to all irrigation on heavy soils. The results presented here reflect only one type of irrigation system. Different values for the cost of developing the water source, the discount given on the purchase of the irrigation system, the yield differentials, the crop production costs and other factors will shift the IRR curve upwards or downwards. It is hypothesized that the shape of the IRR curve will not be significantly altered.

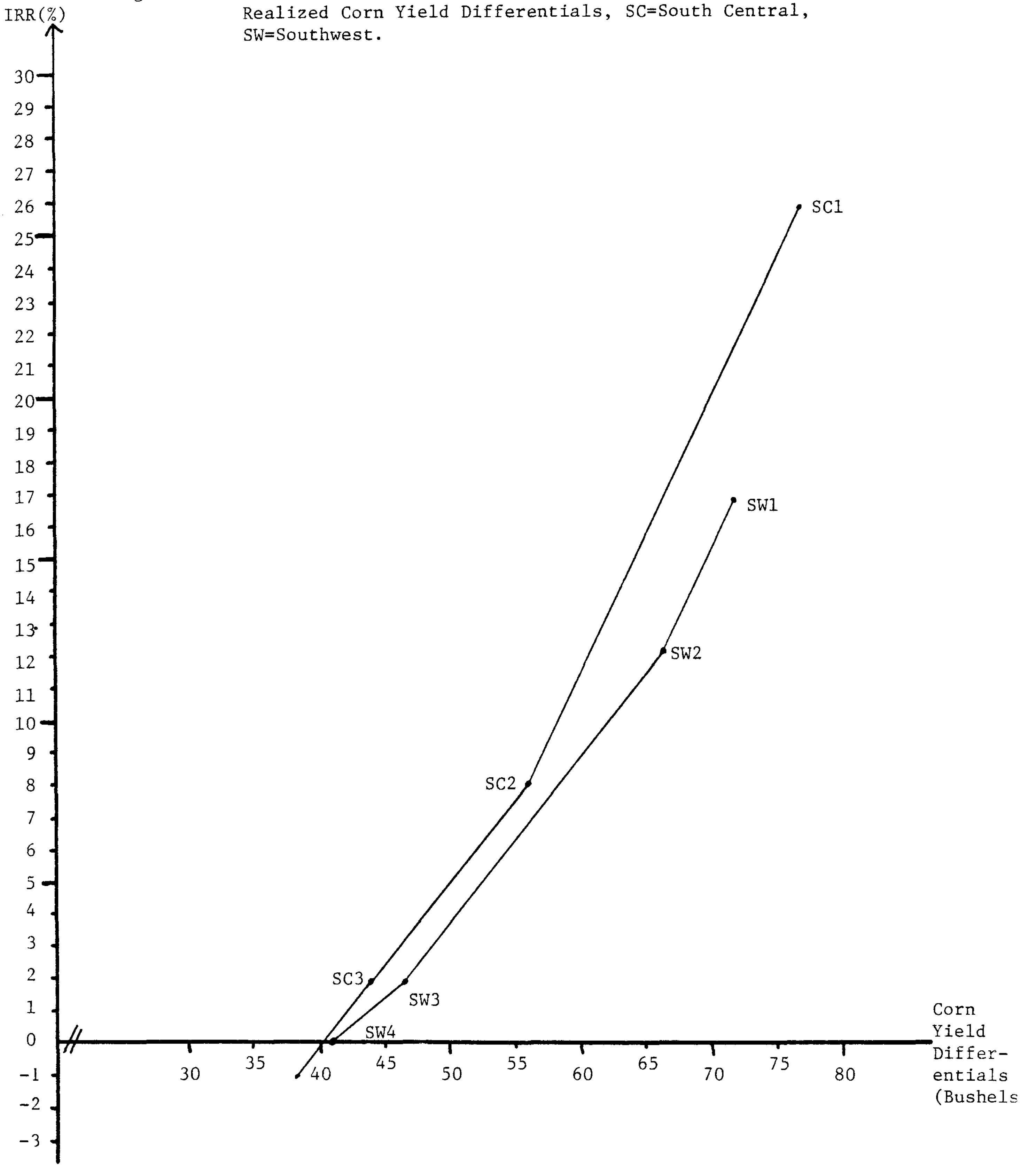
The individual farmer should use these results as a starting place for evaluating his irrigation investment. If the producer expects less than a 60 bushel yield differential due to irrigation he should question the profitability of the investment if the proposed irrigation system is similar to the one presented here. In all cases, the potential irrigator should "push the pencil" to obtain a profitability measure for the investment.

Finally, all the calculations of net cash flows after taxes and payments show some negative cash flow values during the loan repayment period. The number of negative cash flow years vary from five for a Hanska-Sparta soil to nine for a Webster-Glencoe soil. This implies that a potential irrigator of heavy soils, as defined in this report, must be prepared to cover these negative cash flows by drawing from cash reserves (i.e., savings) or from the positive cash flows of other farm enterprises. Without another source of cash, the investment may be profitable but not financially feasible.

IV. Summary and Conclusions

Irrigating cash grain crops on fine textured soil in Minnesota is a recent activity which was stimulated by the drought conditions in the state

Figure 10: Internal Rate of Return (IRR) of Irrigation Investment for Realized Corn Yield Differentials, SC=South Central, SW=Southwest.



during the 1974-1976 period. The majority of the irrigation systems installed on these soils during this period were purchased by farm operators owning and leasing more than 400 acres of crop land. Most of these systems were installed without the farmer determining the feasibility and profitability of the investment on his particular soil. Very little information was available through public and private institutions to assist the farmer in his analysis.

The predominate type of irrigation system installed was the center pivot. Traveling guns and lateral move systems were also purchased. Field corn is the principal irrigated crop. Irrigated soybean acreage increased between 1977 and 1979. All farmers but one reported yield increases as a result of installing the irrigation system.

The profitability of an irrigation investment was analyzed assuming the farmer desires a rate of return on his investment of 12 percent, that a center pivot irrigation system is installed on a quarter section with a well as the water source, and that a corn-soybean crop rotation is used over a 15 year planning period. The economic analysis shows that the irrigation is profitable on moderate soils with an available water capacity (AWC) of 6-9 inches in the top 60 inches of the soil profile. High and very high AWC soils (9-12+ inches) do.not generate a rate of return greater than 12 percent.

Under the given assumptions, each soil type when irrigated, generated negative cash flow for the enterprise during the loan repayment period. To cover these cash deficits, the irrigator must have cash reserves or positive cash flows from other farm or off-farm enterprises.

The results of this analysis will change due to changes in yield differentials, commodity prices, input prices and the initial cost of an irrigation system. Each potential irrigator is encouraged to use the preceding analysis as a guide to evaluate his investment using the prices, costs, and yields that are appropriate for the particular operation. Without making the appropriate calculations, the potential irrigator of fine-textured soils may make the decision to irrigate which may prove later to be unprofitable and infeasible.

REFERENCES

Agricultural Extension Service. Cultural and Chemical Weed Control in Field Crops. Extension Bulletin 400, University of Minnesota, 1979.

Agricultural Extension Service. Farm Planning Prices. University of Minnesota, 1979.

Arneman, H. F. Soils of Minnesota, Extension Bulletin 278, Agricultural Extension Service, University of Minnesota, June 1963.

Beer, C. E., and D. Wiersma. Irrigated Corn Yields in the North Central Region of the U.S., Extension Special Report 65, Iowa State University, 1970.

Benson, Fred and Bruce Hatteberg. Minnesota Farm Machinery Economic Cost Estimates for 1979, FM609, Agricultural Extension Service, University of Minnesota, 1979.

Buckman, Harry O. and Nyle C. Brady. The Nature and Properties of Soils, New York: The Macmillan Company, 1969.

Eidman, Vernon R., F. G. Bergsrud, et. al. Water Sources and Irrigation Miscellaneous Report 150, Agricultural Experiment Station, University of Minnesota, 1978.

Eidman, Vernon R. "Irrigation in Minnesota," Minnesota Agricultural Economist, No. 592, Agricultural Extension Service, University of Minnesota, August-September, 1977.

Fenster, William E., et. al. Guide to Computer Programmed Soil Test Recommendations in Minnesota, Special Report 1, Agricultural Extension Service, University of Minnesota, 1976.

Hasbargen, Paul R. and Kenneth H. Thomas. Cash Rent: How Much in 1979? Crop Share Rent: Is Our Lease Fair? FM661, Agricultural Extension Service, University of Minnesota, March, 1979.

Hopkin, John A., Peter J. Barry and C. B. Baker. Financial Management in Agriculture, Interstate Printers and Publishers, Inc., 1973.

Lucas, R. and M. Vitosh. High Corn Yields With Irrigation, Cooperative Extension Bulletin E-857, Michigan State University, July, 1977.

Machmeier, Roger E. Sprinkler Irrigated Acreage - Minnesota for 1970-1976, Agricultural Extension Service, University of Minnesota, 1977.

Soil Conservation Service. Irrigation Guide for Minnesota, U.S. Department of Agriculture, St. Paul, Minnesota, 1976.

Soil Science Society of America, Glossary of Soil Science Terms, Madison, Wisconsin, January, 1978.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data and Information Service. Climatological Data, Annual Summary, Minnesota, Various Years. National Climatic Center, Asheville, N.C.

APPENDIX A

Table 1 : Rainfall Patterns In Survey Region

Year	Southwest Region Precipitation (Inches) October-September	July-August
1958	19.67	5.39
1959	22.47	7.03
1960	32.23	7.96
1961	20.38	7.71
1962	30.66	8.97
1963	26.31	10.74
1964	25.09	6.99
1965	29.81	3.75
1966	22.41	6.55
1967	21.43	3.64
1968	29.51	8.67
1969	31.47	6.42
1970	25.77	6.74
1971	25.62	3.43
1972	29.82	7.2
1973	23.24	4.44
1974	20.90	5.01
1975	21.93	3.95
1976	17.07	3.95
1977	29.91	7.75
1978	27.89	7.48
Average	25.41	6.37
Standard Deviation	4.43	2.02

APPENDIX A (con't)

Table 2 : Rainfall Patterns In Survey Region

South Central Region

Precipitation (Inches)

Year	October-September	July-August
1958	21.12	6.02
1959	28.13	7.8
1960	32.43	6.7
1961	26.79	9.81
1962	31.46	11.68
1963	25.47	8.84
1964	30.10	8.49
1965	35.17	7.6
1966	24.22	6.98
1967	29.01	7.06
1968	34.34	12.14
1969	28.83	5.54
1970	28.77	6.05
1971	29.69	3.69
1972	31.11	7.68
1973	32.12	7.18
1974	26.24	5.96
1975	27.42	3.49
1976	22.09	4.93
1977	30.22	6.89
1978	30.77	7.50
Average	28.83	7.24
Standard Deviation	3.64	2.18

Source:

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data and Information Service. Climatological Data, Annual Summary, Minnesota. Various years. National Climatic Center, Asheville, N.C.

APPENDIX B

Permit No.__________

Sample No.__________

Irrigation Questionnaire

I. GENERAL INFORMATION

A. Name of Owner/Irrigator______________________________

B. Address and Directions to Farm______________________________

____

____

____

C. Telephone No.____________________

D. Legal Description of Property______________________________

E. Total Acreage Farmed ____________ Owned____________ Leased____________

F. Soil Classification

Soil Atlas__________ SCS__________ Farmer__________ AWC__________

G. How many years experience do you have irrigating____________________

H. When did you begin irrigating with the present system(s)?____________________

____

____

I. Why did you start to irrigate?______________________________

____

____

II. IRRIGATED CROP

A. Total irrigated acreage______________________________

Is this acreage (tile) drained____________ Spacing of tiles____________

B. Cropping Pattern

Crop	Acres (1979)	Acres (1978)	Acres (1977)
1. Field Corn	________	________	________
2. Soybeans	________	________	________
3. Alfalfa	________	________	________
4. Other______	________	________	________
____________	________	________	________
____________	________	________	________

C. Yields

1. Average non/irrigated yields on soils comparable to those irrigated:

Crop	Average Yield		
	Favorable	Average	Poor
a. Field Corn (Bu/Ac)	______	______	______
b. Alfalfa (Ton/Ac)	______	______	______
c. Soybeans (Bu/Ac)	______	______	______

2. Average irrigated yield

Crop	Yield (1978)	Yield (1977)
a. Field Corn (Bu/Ac)	______	______
b. Alfalfa (Ton/Ac)	______	______
c. Soybeans (Bu/Ac)	______	______

III. OPERATIONS

A. Water Application

1. How much water applied per year?______________________Ac/In.

2. Average timing of irrigation

	May	June	July	August	September
No. of Irrigations	____	____	____	____	____
System Time/Complete Rev.	____	____	____	____	____
Ac/In. Per Irrigation	____	____	____	____	____

B. Irrigation System

1. Water Source

a. Well_____ Depth______ Gravel Packed______ Rock Hole______ Natural Development_______

b. Stream _____

c. Lake _____

d. Other (dug pit, etc.) ______

2. Pumping:

   a. Type of Pump

      (1) Turbine__________ (2) Centrifugal__________

   b. Type of Fuel (Energy) ______________________________

   c. Size and Type of Power Unit______________________________

   d. Well Size__________ No. of Stages_____ Dia.of Column_____ Dia.of Bowls_____

   e. GPM ______________

   f. Pumping Depth (Lift): During Pumping__________ Static Level__________

   g. Operating Pressure: Pump__________ Nozzle__________ Dist.System__________

   h. Difference in Elevation Between Pump Discharge and Entrance to the Distribution System______________________________

3. Distribution System

   a. Type

      (1) Center Pivot: Brand__________ Tow vs. Non-Tow__________

      No. of Towers______________________________

      Drive (a) Electric__________

      (b) Water__________

      (c) Hydraulic__________

      (2) Traveling Gun: Brand______________

      Drive (a) Water__________

      (b) Auxiliary Engine__________

      (3) Other______________________________

      ____

      ____

   b. Acres covered by the system(s)______________________________

   c. Type of Pipe

      (1) Aluminum ______________ ft. Diameter______________

      (2) PVC______________ ft. Diameter______________

IV. OPERATIONAL COSTS

A. Do you own or lease your system? ____________________

B. If lease: From whom? ____________________ Term ____________

Payments ____________ Options at end of lease ____________

____

Why did you choose to lease? ____________________

C. If own: Financing Arrangements: Cash ______ Loan ______ Interest Rate ______

Term ______

D. Initial costs were:

	Year	$
1. Well/Pit Development	______	______
2. Pump	______	______
3. Power Unit	______	______
4. Pipe	______	______
5. Hose	______	______
6. Distribution System, New___ Used___	______	______
Total		______

E. Other Costs

1. Insurance ____________________

2. Types of Maintenance and Repairs (Cost?)

   a. Pump ____________________

   ____

   b. Well ____________________

   ____

   c. Dist. System ____________________

   ____

   d. Dug Pit ____________________

3. Labor Cost/Hour ____________________

   Labor Time/Irrigation ____________________

APPENDIX B (con't)

4. Cost of Initial Electrical Hookup ________________________________

5. Annual Standby Charge ________________________________

6. $/KWH ________________________________

7. Cost of Fuel Tank ________________________________

V. FIELD LAYOUT

VI. REVIEW ENTERPRISE BUDGETS WITH INTERVIEWEE

Concentrate on:

1. Seeding Rate
2. Fertilizer Usage
3. Tillage
4. Pesticide Use

APPENDIX C

Average May - September Total Precipitation for Various Reporting Stations in the Survey Area.
(Calculated using 21 years of data)

Reporting Station			
City	County	Average Precipitation 1958 - 1978 (Inches)	Standard Deviation
Pipestone	Pipestone	16.29	4.18
Slayton/ Lake Wilson*	Murray	17.20	4.46
Fairmont	Martin	18.23	3.80
St. James	Watonwan	17.76	4.44
Luverne	Rock	17.39	4.61
Tracy	Lyon	15.46	4.32
Lamberton	Redwood	15.36	4.53
Marshall	Lyon	15.39	4.39
Redwood Falls	Redwood	15.30	4.03
Springfield	Brown	16.26	4.55
Wells	Faribault	18.97	4.86
Bird Island	Renville	16.10	3.35
Albert Lea	Freeborn	19.74	5.63
Waseca	Waseca	19.46	4.61
Stewart	McLeod	16.45	4.37
Young America	Carver	18.47	5.55

* Station moved from Slayton to Lake Wilson in 1972.

APPENDIX D

Detailed Investment Cost Calculations for Six Prototype Irrigation Systems

System #1 Calculations

Pumping Head

Suction lift in feet during pumping		50
Mainline, pipe, fittings and hose friction		24.92
Difference in elevation between pump discharge and entrance to distribution system		12
Operating pressure in psi at entrance to distribution system	75 x 2.31	173.25
Total Dynamic Head (Feet)		260.17

Water Horsepower

$$\text{w.h.p.} = \frac{\text{Total head (feet) x GPM}}{3960} = \frac{260.17 \times 800}{3960} = 52.56$$

Calculations for Electric Motor

Brake Horsepower

$$\text{b.h.p.} = \frac{\text{w.h.p.}}{\text{pump efficiency \% x efficiency drive \%}} = \frac{52.56}{.70 \times 1.00} = 75.08$$

Calculations for Diesel Engine

Brake Horsepower

$$\text{b.h.p.} = \frac{52.56}{.70 \times .95} = 79.04$$

$$\text{Engine size needed} = \frac{\text{b.h.p.}}{\text{1 - engine derating factors}} = \frac{79.04}{1 - .11} + \text{15 HP (Generator)}$$

$$= 103.80 \text{ HP}$$

System #1 Costs (Electricity)

	Cost
Well Development (for 150 Foot Well)	
Test Drilling (2 holes with Auger at $2.50/ft)	$ 750.00
Drilling, Casing	8,250.00
Screen (20 feet @ $110/ft.)	220.00
Screen Fittings	250.00
Move In, Move Out and Test Pumping	1,150.00
Air Development	750.00
Subtotal	$11,370.00
Pump	
Four Stage Pump with 12" Bowls	$ 2,250.00
Eight-inch Column with 1-1/4" Shaft	1,371.00
Eight-inch Discharge Head	1,120.00
Delivery and Installation Charge	350.00
Subtotal	$ 5,091.00
Electric Motor	
75 H.P, 3-Phase	$ 2,480.00
Cross Line Starter	1,180.00
Electrical Hook-up (3-Phase Already Available)	1,200.00
Subtotal	$4,860.00
Pipe	
1680 Feet of 8" PVC Pipe at $2.50/foot	$ 4,200.00
Pipe Installation	1,340.00
Subtotal	$ 5,540.00
Valves, Fittings and Wire	$ 2,256.00

APPENDIX D (con't)

System #1 Costs (Electricity) (Cont'd)

Fertilizer Injection

Pump	$ 1,028.00
Fertilizer Tank (1800 Gallons)	775.00
Subtotal	$ 1,803.00

Distribution Systems

10 Tower Electric Drive Center Pivot (Non-Tow)	$30,100.00
Accessories (e.g. Auto Stop, End Gun, etc.)	611.00
Pivot Pad	329.00
Installation	2,820.00
Freight/Delivery	564.00
Subtotal	$34,424.00
	$65,344.00

APPENDIX D (con't)

System #1 Costs (Diesel)

		Cost
Well Development		$11,370
Pump		5,091
Diesel Engine		
100 H.P. Engine	$7,200	
100 H.P. Right Angle Gear Drive	1,530	
Drive Shaft	115	
Hubs (2)	42	
Trailer for Engine	360	
Fuel Tank (500 gals.)	200	9,447
Generator		1,475
Pipe		5,540
Valves, Fittings and Wire		3,060
Fertilizer Injection		1,803
Distribution System		34,424
	Total	72,210

APPENDIX D (con't)

Valves and Fittings for System #1

	8"
1-1/4 Gate Valve	$ 60
Check Valve	245
8" Gate Valve	360
P V C Flange	42.09
Pressure Gauge	6.00
6 or 8 x 3 PVC Tee	143.97
Tri-Action Pressure Relief Valve (2)	194
PVC Elbow	100.75
PVC Elbow	100.75
PVC Flange	42.09
Steel Flange	60
Steel Pipe	50
Total	$1,404.65

System #2 Calculations

Pumping Head

Suction lift in feet during pumping	15
Mainline pipe and hose friction	22.13
Difference in elevation between pump discharge and entrance to distribution system	12
Operating pressure in psi at entrance to distribution system — 75 psi x 2.31	173.25
Total Dynamic Head (Feet)	222.38

Water Horsepower

$$\text{w.h.p.} = \frac{\text{Total head (feet) x GPM}}{3960} = \frac{222.38 \times 800}{3960} = 44.92$$

Calculations for Electric Motor

Brake Horsepower

$$\text{b.h.p.} = \frac{\text{w.h.p.}}{\text{pump efficiency \% x efficiency drive \%}} = \frac{44.92}{.65 \times 1.00} = 69.11$$

Calculations for Diesel Engine

Brake Horsepower

$$\text{b.h.p.} = \frac{44.92}{.65 \times 1.00} = 69.11$$

$$\text{Engine size needed} = \frac{\text{b.h.p.}}{\text{1 - engine derating factors}} = \frac{69.11}{.89} + \text{15 HP (Generator)}$$

$$= 92.65$$

System #2 Costs (Electricity)

Pit Development 5,556 cubic yards @ $0.70/yard		3,889.00
Pump		
Centrifugal PUmp		1,288.00
Accessories (e.g. Suction pipe, primer, suction drainer)		900.00
		2,188.00
Electric Motor		
75 HP 3-phase Electric Motor	1,415	
Cross Line Starter	1,180	
Electrical Hook-up	1,200	
Enclosure	400	4,195.
Pipe		
1380 ft. of 8" PVC pipe at $2.50	3,450	
Installation	1,190	4,640
Valves, Fittings and Wire		2,121
Fertilizer Injection		
Pump	1,028.00	
Fertilizer Tank (1,800 gallons)	775.00	1,803.00
Distribution System		34,434.00
	Total	53,260.00

System #2 Costs (Diesel)

Pit Development		3,889.00
Pump and Accessories		2,188.00
Diesel Engine		
Engine (92 H.P.)	7,200	
Drive Shaft	115	
Hubs	42	
Fuel Tank	200	
Enclosure	400	7,957.00
Pipe		4,640.00
Generator		1,475.00
Valves, Fittings and Wire		2,121.00
Fertilizer Injection		1,803.00
Distribution System		34,424.00
	TOTAL	58,497.00

APPENDIX D (con't)

Accessories for Centrifugal Pump

Discharge Priming Valve	$106.00
Primer	82.00
Suction Line	85.00
Foot Valve	175.21
Woods Coupler (Electric); Spicer Shafts, Flanges (Diesel)	
Suction Eccentric	68.30
Suction Elbow	117.20
Discharge Adapter	50.45
Installation	200.00
TOTAL	$884.16

System #3 Calculations

Pumping Head

Suction lift in feet during pumping	50
Mainline, pipe, fittings and hose friction	26.18
Difference in elevation between pump discharge and entrance to distribution system	12
Operating pressure in psi at entrance to distribution system 75 psi x 2.31 =	173.25
Total Dynamic Head (Feet)	261.43

Water Horsepower

$$\text{w.h.p.} = \frac{\text{Total head (feet) x GPM}}{3960} = \frac{261.43 \times 800}{3960} = 52.81$$

Calculations for Electric Motor

Brake Horsepower

$$\text{b.h.p.} = \frac{\text{w.h.p.}}{\text{pump efficiency \% x efficiency drive \%}} = \frac{52.81}{.70 \times 1.00} = 75.44$$

Calculations for Diesel Engine

Brake Horsepower

$$\text{b.h.p.} = \frac{52.81}{.70 \times .95} = 79.41$$

$$\text{Engine size needed} = \frac{\text{b.h.p.}}{1 - \text{engine derating factors}} = \frac{79.41}{1 - .11} + 15 \text{ HP (Generator)}$$

$$= 104.22$$

System 3 Costs (Electric)

Well Development (Same as 1)		11,370
Pump and Accessories		5,091
Electric Motor		4,860
Pipe		
3,465 feet of 8" PVC pipe at $2.50/foot	8,662.50	
Pipe Installation	2,232.50	10,895.00
Valves, Fittings and Wire		6,000.00
Fertilizer Injection		1,803.00
Distribution System		
10 Tower Electric Drive Center Pivot (Towable)	30,766,00	
Accessories (e.g. Auto stop, End gun, etc.	611.00	
2 Pivot Pads	658.00	
Installation	2,820.00	
Freight/Delivery	564.00	35,419.00
Total		$75,438.00

System 3 Costs (Diesel)

Well Development	11,370.00
Pump	5,091.00
Diesel Engine, Right Angle Gear Drive-Accessories (Same as System #1)	9,447.00
Generator	1,475.00
Pipe	10,895.00
Valves, Fittings and Wire	6,000.00
Fertilizer Injection	1,803.00
Distribution System	35,419.00
Total	81,500.00

System #4 Calculations

Pumping Head

Lift in feet during pumping	50
Mainline pipe friction	52.23
Difference in elevation between pump discharge and entrance to distribution system	12
Operating pressure in psi at entrance to distribution system 75 x 2.31 =	173.25
Total Dynamic Head (Feet)	287.48

Water Horsepower

$$\text{w.h.p.} = \frac{\text{Total head (feet) x GPM}}{3960} = \frac{287.48 \times 600}{3960} = 43.58$$

Calculations for Electric Motor

Brake Horsepower

$$\text{b.h.p.} = \frac{\text{w.h.p.}}{\text{pump efficiency \% x efficiency drive \%}} = \frac{43.58}{.70 \times 100} = 62.26$$

Calculations for Diesel Engine

Brake Horsepower

$$\text{b.h.p.} = \frac{43.58}{.70 \times .95} = 65.53$$

$$\text{Engine size needed} = \frac{\text{b.h.p.}}{\text{1 - engine derating factors}} = \frac{65.53}{.89} + \text{15 HP (Generator)}$$

$$= 88.63$$

System #4 Costs (Electric)

Well Development		11,370
Pump		
7 stage pump with 10" bowls	2,500	
6" Column with 1-1/4" Shaft	1,155	
6 inch Discharge Head	1,100	
Installation	350	5,105
Electric Motor		
60 HP Electric Motor	2,035	
Cross-line Starter	1,180	
Electrical Hook-up	1,200	4,415
Pipe		
1260 feet of 6" PVC pipe at $1.45/foot	1,827	
Pipe Installation	1,130	2,957
Valves, Fittings and Wire		3,294
Fertilizer Injection		
Pump	1,028	
Fertilizer Tank (1800 Gallons)	775	1,803
Distribution System		
5 Tower Electric Drive Center Pivot (Towable)	14,119	
Accessories	611	
2 Pivot Pads	658	
Installation	1,363	
Freight/Delivery	564	17,315
Total		46,259

System #4 Costs (Diesel)

Well Development		11,370
Pump		5,105
Diesel Engine		
92 HP	7,200	
Gear Drive	1,400	
Drive Shaft	115	
Hubs (2)	42	
Trailer	360	
Fuel Tank	200	9,317
Generator		1,475
Pipe		2,957
Valves, Fittings and Wire		3,294
Fertilizer Injection		1,803
Distribution System		17,315
	Total	52,636

System #5 Calculations

Pumping Head

Lift in feet during pumping	10
Mainline, pipe fittings and hose friction	98.99
Difference in elevation between pump discharge and entrance to distribution system	15
Operating pressure in psi at entrance to distribution system 90 x 2.31 =	207.90
Total Dynamic Head (Feet)	331.89

Water Horsepower

$$\text{w.h.p.} = \frac{\text{Total head (feet)} \times \text{GMP}}{3960} = \frac{331.89 \times 600}{3960} = 50.29$$

Calculations for Electric Motor

Brake Horsepower

$$\text{b.h.p.} = \frac{\text{w.h.p.}}{\text{pump efficiency \% x efficiency drive \%}} = \frac{50.29}{.65 \times 1.00} = 77.36$$

Calculations for Diesel Engine

$$\text{Engine size needed} = \frac{\text{b.h.p.}}{1 - \text{engine derating factors}} = \frac{77.36}{1 - .11} = 86.92$$

System #5 Costs (Electric)

Pump		
Centrifugal pump	950	
Accessories (e.g., Suction Pipe, Primer, Suction Strainer)	1,000	1,950
Electric Motor		
75 H.P. 3-phase Electric Motor	1,415	
Cross Line Starter	1,270	
Electrical Hook-up	1,200	
Trailer	360	4,245
Pipe		
2,400 feet of 8' PVC at $2.50	6,000	
4,440 feet of 6' PVC Pipe at $1.45	6,438	
Installation (6,840 feet)	4,554	16,992
Valves and Fittings		1,800
Distribution System		13,146
	TOTAL	38,133

System #5 Costs (Diesel)

Pump and Accessories		1,950
Diesel Engine		
85 H.P.	7,200	
Drive Shaft	115	
Hubs	42	
Trailer	360	
Fuel Tank	200	7,917
Pipe		16,992
Valves and Fittings		1,800
Distribution System		13,146
TOTAL		41,805

System #6 Calculations

Pumping Head

Lift in feet during pumping	10
Mainline, pipe fittings and hose friction	54.14
Difference in elevation between pump discharge and entrance to distribution system	15
Operating pressure in psi at entrance to distribution system 75 x 2.31 =	173.25
Total Operating Head (Feet)	252.39

Water Horsepower

$$\text{w.h.p.} = \frac{\text{Total head (feet) x GMP}}{3960} = \frac{252.39 \times 800}{3960} = 50.99$$

Calculations for Electric Motor

Brake Horsepower

$$\text{b.h.p.} = \frac{\text{w.h.p.}}{\text{pump efficiency \% x efficiency drive \%}} = \frac{50.99}{.65 \times 1.00} = 78.44 \text{ (Electric)}$$

Calculations for Diesel Engine

$$\text{Engine size needed} = \frac{\text{b.h.p.}}{1 - \text{engine derating factors}} = \frac{78.44}{1 - .11} = 88.14$$

System 6 Costs (Electric)

Pit Development (5,556 cubic yards at $0.70/Yd)		3,889
Pump		
Centrifugal Pump	1,288	
Accessories (e.g. Suction Pipes, Primer, etc.)	900	2,188
Electric Motor		
75 H.P. Motor	1,258	
Cross Line Starter	1,280	
Electrical Hookup	800	
Enclosure	400	3,738
Pipe		
3180 feet of 8" Aluminum Pipe at $3.50		11,130
Valves and Fittings		2,500
Distribution System		
Lateral Move System	25,850	
Transportation	978	
Installation	1,551	28,379
	TOTAL	51,824

System #6 Costs (Diesel)

Pit Development	(5,556 cubic yards at $0.70/cu. yd)		3,889
Pump			2,188
Diesel Engine			
85 H.P. Engine		7,200	
Drive Shaft		115	
Hubs		42	
Fuel Tank		200	
Enclosure		400	7,957
Pipe			11,130
Valves and Fittings			3,000
Distribution System			28,379
		TOTAL	56,543

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Appendix E: Sample Computer Output for Field Corn

TYPE IRRIGATION SYSTEM: 800 GPM ELECTRIC CP

FUEL TYPE--------------------ELECTRICITY

ENGINE (OR MOTOR) SIZE------- 75.00

FUEL PRICE------------------$ .05

PUMP TYPE--------------------TURBINE

PUMPING RATE (GPM)----------------800.00

TOTAL LIFT------------------------250.92

TYPE DISTRIBUTION SYSTEM: CENTER PIVOT W/ELECTRIC DRIVE

ACRES IRRIGATED-------------------------130.00

INCHES APPLIED PER ACRE------------------6.00

NUMBER IRRIGATION ANNUALLY------------------6

TOTAL ACRE INCHES PUMPED ANNUALLY-------780.00

HOURS ANNUAL OPERATION------------------441.22

WAGE RATE-----------------------------$ 6.50

TOTAL INITIAL INVESTMENT-------------$65344.00

SUMMARY OF COSTS IGNORING TAX AND FINANCING CONSIDERATIONS

	ANNUAL TOTAL	COST PER ACRE IRRIGATED	COST/ACRE-INCH OF WATER PUMPED
OWNERSHIP COSTS-$	9217.48	70.90	11.82
CAPITAL RECOVERY$	8728.65	67.14	11.19
INSURANCE-------$	488.83	3.76	.63
OPERATING COSTS-$	2153.03	16.56	2.76
FUEL-----------$	1354.70	10.42	1.74
LUBE-----------$	12.78	.10	.02
PUMP,MOTOR REPAIRS--------$	138.03	1.06	.18
DIST. SYS. OPER. COSTS----$	647.52	4.98	.83
LABOR 50.70 HOURS$	329.55	2.53	.42
TOTAL-----------$	11700.06	90.00	15.00

THE COST OF PUMPING AN ADDITIONAL ACRE INCH OF WATER-$3.18