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Northwest Agricultural Irrigation Market Characterization and Baseline Study

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Table of Contents

List of Figures and Tables

Figures:

Tables:

Executive Summary

The Northwest Energy Efficiency Alliance (NEEA) is a non-profit organization working to accelerate energy efficiency to meet our future energy needs. NEEA is supported by and works in partnership with Bonneville Power Administration, Energy Trust of Oregon and more than 100 Northwest utilities for the benefit of more than 12 million energy consumers. NEEA uses the market power of the region to accelerate the innovation and adoption of energy-efficient products, services and practices. Since 1997, NEEA and its partners have saved enough energy to power more than 600,000 homes each year. Energy efficiency can satisfy more than half of our new demand for energy, saving money and keeping the Northwest a healthy and vibrant place to live. For more information, visit neea.org.

NEEA contracted Navigant Consulting, Inc. (Navigant) to estimate the baseline for integrated decision making irrigation systems in Idaho, Oregon, and Washington (the three-state region) at the present (2012) and over the coming 20 years. At NEEA's request, Navigant focused on the use of center pivot irrigation systems and the use of information and decision-support systems in conjunction with center pivot systems. Navigant conducted secondary research to identify current market characteristics and the historic trends leading to current conditions. Navigant also conducted primary research—by interviewing qualified market observers—to understand the context behind historic trends, to estimate trends from 2008 to the present (2012), forecast trends through 2032, and capture qualitative information about the irrigation market in the three-state region. This report presents the results of those research activities.

Market Characterization

Navigant observed several dynamic market conditions driving the market for irrigation technologies in the three-state region. These conditions include:

- **Availability of—and competition for—suitable lands for agriculture purposes:** There is a continual competition for land between agriculture and urban sprawl.
- **Availability of—and competition for—water for agricultural irrigation:** Water scarcity is not currently an issue on farms in the three-state region. However, respondents stated that water is fully allocated in most areas in the region, and that states are not issuing new water rights, which prevents expansion of irrigated agricultural lands.
- **Crop value and demand for crops:** Commodity prices and demand for specific crops tend to be volatile, and any changes in crop type on a given farm may necessitate changes in the type and quantity of irrigation needed.
- **Cost of labor and production:** The component costs of crop production—particularly labor costs—can strongly influence farmers' motivations to adopt labor-saving tools and strategies that shift costs.
- **Crop yield focus and capability of farmers**: A trend towards larger farms means that a farmer's already limited time and efforts must be spread over a larger area. Most farmers in the three-state region use crop yield, rather than profit, as an explicit objective to simplify decision-making. The increased demands on farmers' time and attention are driving farmers towards automated irrigation systems such as center pivots and also

driving the use of information to reduce the amount of hands-on effort required from farmers.

- **Availability and demonstration of technologies and practices**: Farmers typically look to the performance of innovative technologies and strategies on nearby and showcased farms before deciding to adopt these innovations.

Irrigated Acreage of Interest for this Study

NEEA defined the market of interest for this research as irrigated farms with the following characteristics: 1) irrigated or suitable to irrigation by center pivot systems *and* 2) on farms 100 acres or larger. Navigant estimated the share of irrigated acreage in the three-state region[1] meeting these criteria based on United States Department of Agriculture (USDA) Farm and Ranch Irrigation Survey (FRIS) data and interviews with regional and manufacturer respondents.

The three-state region contains approximately 6.9 million acres of irrigated farm land. (United States Department of Agriculture [USDA] 2008b) This amount has not changed significantly in the past two decades, and respondents thought that the amount would decrease slightly in the coming decades due to non-agricultural competition for land and water.

The **use of center pivot irrigation** has increased steadily since 1988, due to a variety of factors including: improved ease of farming; cost reductions in labor, energy, and water; requirements from crop purchasers; and current high commodity prices, which provide farmers with cash for capital expenditures such as new irrigation systems. Currently, center pivots irrigate 50% of irrigated land in the three-state region. Regional respondents thought that all suitable land (approximately 69% of all irrigated acreage) could be converted to center pivots by 2032.

The majority (91%) of irrigated acreage in the three-state region was on **farms 100 acres or larger** in 2008; this share has likely stayed the same or increased slightly in the past four years, and may increase to as much as 95% by 2032 due to a trend toward larger farms.

Navigant estimated the **total acreage meeting NEEA's criteria** by multiplying the total acreage of irrigated farm land in the three-state region, the percentage irrigated by or suitable to irrigation by center pivot systems, and the percentage on farms of 100 acres or more. As shown in Table 1, Navigant estimates that the acreage meeting NEEA's criteria is currently 3,165,260 acres and forecasted to grow to approximately 4,283,072 acres by 2032.

Table 1. Irrigated Acreage Meeting NEEA Criteria

Parameter	**2012**	**2032**
Total irrigated acreage	6,881,000	6,674,570
% using center pivot irrigation	50%	69%
% on 100+ acre farms	92%	93%
Total acreage meeting NEEA's criteria	**3,165,260**	**4,283,072**

[1] Among the 4-state Northwest Region only Oregon, Washington and Idaho were included in this study. Montana was excluded from this study because of its current and forecasted low prevalence of center pivot irrigation.

Navigant also characterized the irrigated acreage in the three-state region by analyzing the distribution of acreage by total dynamic head[2] (TDH). Total dynamic head directly correlates with energy consumption. The median TDH of irrigated acreage meeting NEEA's criteria is 207 feet and the median water energy intensity is 403 kWh/acre-foot[3].

Baseline Adoption of Irrigation Strategies

NEEA's initiative product "is an integrated irrigation decision support solution (IIDS) that will make it easy and compelling for growers to take action to lower their irrigation electrical energy use, and as a result, reduce their operating costs and consequently improve profitability." No single product currently exists in the market that is comparable to NEEA's IIDS, yet some components of IIDS are in use in the three-state region. Navigant asked respondents to estimate current and forecasted levels of use of these components, and to discuss the future use of components not currently in use.
Table 2 summarizes respondents' estimates of the current and forecasted adoption of these components, or irrigation strategies, in the absence of a NEEA initiative.

Table 2. Current and Forecasted Baseline Adoption of Irrigation Strategies

Irrigation Strategy	Current Usage	Forecasted Usage by 2032
Planning (i.e., co-optimizing expected crop yield and water usage)	15-30%	15-30%
Farm- and field-level tools (e.g., scientific irrigation scheduling, evapotranspiration reports, computer simulation)	10-30%	10-60%
Sub-field-level tools (i.e., spatially granular information such as soil type and topography in conjunction with modeling and variable rate irrigation controls)	0-1%	0-10%
All three of the above strategies	0-1%	0-10%
Integrated decision making tools	0%	10-25%
None of these strategies	60-80%	40-80%

None of the respondents thought that any integrated decision making tools (either hardware or software) are currently in use in the three-state region. By 2032, 10-25% of irrigated acreage may be subject to the use of integrated decision making tools. Navigant thinks that much of the performance benefits (water savings, energy savings, improved yields) achieved by IIDS would be achieved by the integrated decision making tools likely to appear in the market in the absence of NEEA's intervention. Navigant therefore recommends that the estimates of current and forecasted adoption of integrated decision making tools (i.e., 0% in 2012 and 10-25% in 2032) be used as the baseline for NEEA's IIDS initiative.

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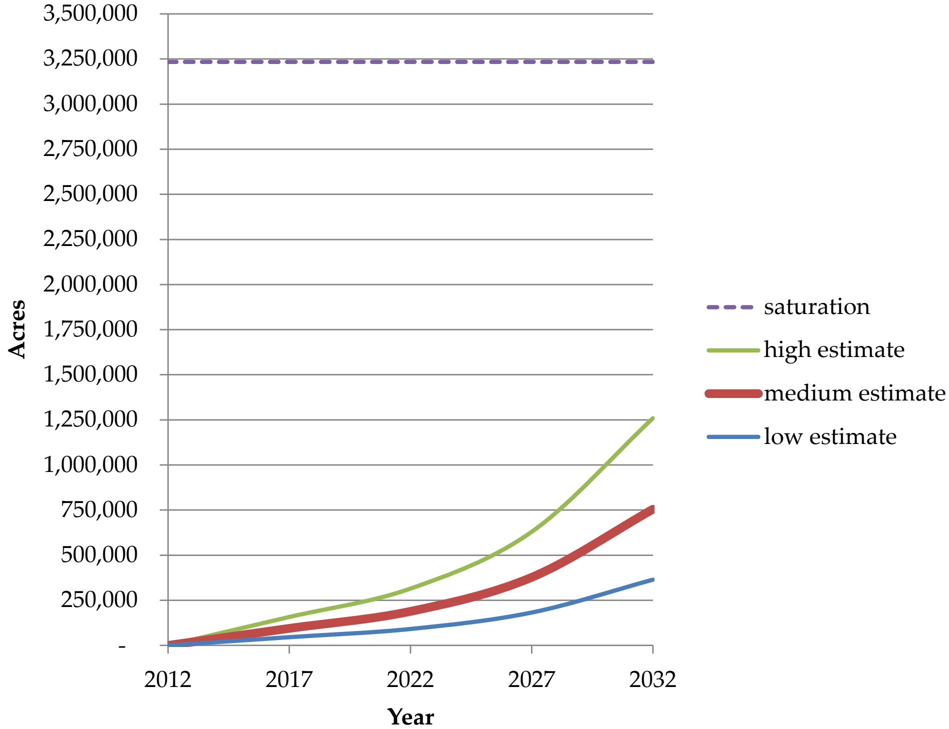
[2] This is the total dynamic head (TDH) which includes pressure required to lift water from well to ground level, to overcome friction in pipes, valves and fittings, and to provide the water at the sprinkler head with the appropriate water pressure for the sprinkler system.

[3] Median TDH by state: Idaho - 222 feet, Oregon – 176 feet, Washington – 148 feet.
Median on-site energy intensity of water consumption by state: Idaho – 434 kWh/acre -foot, Oregon – 343 kWh/acre-foot, Washington – 289 kWh/acre-foot.

Figure 1. Current and Forecasted Baseline of Acreage Subject to Integrated Decision Support and Meeting NEEA's Criteria



Navigant estimates that there are currently 3,165,260 acres of farmland in the three-state region that meet NEEA's criteria, and that there will be 4,283,072 acres in 2032. This increase is primarily due to the expected increase in center pivot adoption over this time period. Navigant estimates that be baseline usage of integrated decision making tools on NEEA criteria acreage in the region in 2032 will be 364,000 to 1,259,000 acres, with an expected value of 755,000 acres[4].

[4] The low end estimate (364,000 acres) is 10% of Navigant's low end estimate of NEEA criteria acreage in 2032 (3,643,000 acres). The high end estimate (1,259,000) is 25% of Navigant's high end estimate of NEEA criteria acreage in 2032 (5,036,000 acres). The expected value is 17.5% of Navigant's medium-case estimate of NEEA criteria acreage (4,312,000 acres).

1. Introduction

The Northwest Energy Efficiency Alliance (NEEA) is in the process of launching an initiative to promote the use of integrated decision making irrigation systems on farms in the Northwest. NEEA requires an estimate of what the market would do in the absence of the initiative (the market baseline) as a first step in estimating the savings potential of the initiative. Future evaluators can compare this baseline to observed market behavior in the presence of NEEA's initiative to estimate the incremental effect of the initiative.

NEEA's initiative will promote the use of an integrated irrigation decision support solution (IIDS) to aid growers in reducing energy consumption related to irrigation and thereby reduce costs and increase profitability. The IIDS will consist of a software architectural platform that integrates data from multiple sources, analyzes different irrigation scenarios, and provides the growers with the data and analysis results in user-friendly formats. The technology is described in more detail in Appendix C.

In May 2012, NEEA contracted Navigant Consulting, Inc. (Navigant) to estimate the baseline for integrated decision making irrigation systems in Idaho, Oregon, and Washington (the three-state region) at the present (2012) and over the coming 20 years. At NEEA's request, Navigant constrained their research to Idaho, Oregon, and Washington (the three-state region) and focused on the use of center pivot irrigation systems and the use of information and decision-support systems in conjunction with center pivot systems. This report summarizes the agricultural irrigation market research conducted by Navigant for NEEA.

Navigant conducted both secondary and primary research for this study. For both of these efforts, Navigant provided NEEA with a memorandum of findings; these memoranda are included as appendices to this report. Navigant worked closely with NEEA staff throughout the project to ensure that Navigant's research efforts aligned with NEEA's information needs.

Navigant has provided findings in this report primarily at the three-state level. However, Navigant has provided some findings at the state level—particularly historical data—in the primary and secondary data memoranda, which are included in this report as Appendix A and Appendix B.

2. Research Objectives

At the onset of this project, Navigant worked with NEEA to refine the research objectives initially presented in the RFP for this project. Navigant provided NEEA with a work plan to document the revised approach. The research objectives used to guide the Navigant team's primary and secondary research are summarized as follows:

- To characterize the market for center-pivot systems on farms 100 acres and larger in the three-state region of Idaho, Oregon, and Washington, including descriptions of the following:
  - Size/trend of agricultural irrigation market in terms of acres irrigated
  - Grower business goals/approaches/business drivers and the relative importance of yield, profit, cost, energy efficiency, and water efficiency
  - Current irrigation practices and forecasted trends, including technologies and strategies in use
  - Barriers to improved irrigation efficiency practices

- To estimate the baseline for the adoption of integrated irrigation decision support solutions (IIDS) in the absence of NEEA's intervention, including:
  - Total acres irrigated within the target market
  - Current usage of irrigation decision making tools, including tools specifically designed to increase energy efficiency, and the associated acreage on which such tools are used
  - Best estimate forecast of changes in these parameters over the next 20 years, in the absence of NEEA's intervention

3. Methodology

Navigant conducted primary and secondary research for the completion of this report. Navigant conducted secondary research to identify current market characteristics and the historic trends leading to current conditions. Navigant conducted primary research—by interviewing qualified market observers—to understand the context behind historic trends, to estimate trends from 2008 (the last FRIS) to the present (2012), forecast trends through 2032, and capture qualitative information about the irrigation market in the three-state region.

NEEA has requested a twenty-year forecast of the irrigation baseline. Given this long-term interest, Navigant has focused its analysis on long-term trends, rather than short term variation such as that caused by commodity price volatility.

3.1 Secondary Data Collection

Navigant used secondary data sources to identify the historic disposition of irrigated agricultural land and regional irrigation practices and trends. Navigant used the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Census of Agriculture Farm and Ranch Irrigation Surveys (FRIS) to determine irrigation market characteristics and trends from 1988 through 2008. The USDA conducts these surveys approximately every five years and includes many of the same questions from survey to survey[5]. These periodic surveys provide an excellent source of time-series data on characteristics of irrigated land and irrigation technologies. Unfortunately, the next survey will likely not be until 2013 and results would not be available until 2014. Therefore, this analysis does not capture non-linear trends such as acceleration of adoptions that may have begun only recently. Navigant filled data gaps such as these through primary data collection efforts.

A significant limitation of the publicly available FRIS data is that the USDA posts tabulations of survey results, rather than the full datasets. Navigant therefore could not cross-tabulate survey results to the most relevant specification of the NEEA project. For example, the FRIS indicates the number of acres irrigated, categorized by farm size (Table 2 in the 2008 Survey), and the number of acres irrigated, categorized by irrigation type (Table 4 in the 2008 Survey), yet the correlation between farm size and irrigation type cannot be determined. While NEEA is specifically interested in center-pivot irrigation on farms larger than 99 acres, this type of conditional query cannot be performed on the available data. The USDA does offer to conduct these types of queries for a fee[6]; The USDA provided Navigant with a query for this analysis related to electricity consumption, but found that there were limitations to the queries due to confidentiality constraints.[7] However, queries could provide NEEA with the characteristics of a more specific target market (for example, farms growing a particular type of crop) than the criteria considered for this study.

[5] Surveys were conducted in 1988, 1994, 1998, 2003, and 2008.
[6] This service is offered on the NASS website: http://www.nass.usda.gov/Data_and_Statistics/Special_Tabulations/index.asp.
[7] Specifically, queries cannot cross-tabulate by too many different parameters (particularly at the more granular geographic level, such as by county) because that would reveal the identity of individual farms.

Navigant used additional secondary sources to understand the factors contributing to observed trends in the FRIS data, to develop estimates of current parameter values, and to begin to inform later forecasting efforts (see Appendix A for more details on secondary research conducted).

3.2 Primary Data Collection

Navigant conducted primary research to address recent trends in the irrigation market not reflected in the USDA FRIS data. Navigant interviewed qualified market observers to discuss current and forecasted trends in the three-state agricultural market. The research also addressed the use of irrigation strategies in the region, which was a knowledge gap identified from the secondary research.

Navigant targeted qualified market observers of agricultural irrigation technologies and practices in Idaho, Oregon, and Washington. Table 3 summarizes the types of qualified market observers that were targeted, and the targeted and completed number of interviews. Navigant has not identified interviewees in this document for purposes of confidentiality.

Table 3. Interview Targets and Completions

Qualified Market Observer Type	Targeted Number of Interviews	Completed Number of Interviews	Comments
Regional representatives of irrigation control equipment manufacturers	3	3	
Irrigation specialists at state agricultural extension services	3	3	
Staff at state agricultural commissions and trade groups	2	2	Contacts deferred to a Ground Water Management Area representative for one of these interviews
Irrigation District and trade association management personnel	1	2	Additional interview completed at the request of NEEA
Northwest Irrigation and Soils Research Lab staff	1	1	
Qualified market observer of another irrigation market	0	1	Additional interview completed at the request of NEEA
Total	**10**	**12**	

The Navigant team developed a detailed interview guide for these telephone interviews, and worked with the NEEA staff to ensure that the guide addressed NEEA's prioritized topics of interest. Prior to the interviews, the Navigant team provided the interviewees with a visual aid from this guide (via email) to reference during the interviews. Appendix B includes the interview guide.

3.3 Baseline Estimation

Navigant defined the baseline for this project as the amount of irrigated acreage meeting NEEA's criteria (irrigated by center pivots, on farms 100 acres or larger) and using integrated decision support irrigation systems.

To determine the current amount of irrigated acreage meeting NEEA's criteria, Navigant analyzed time-series data through 2008 from the FRIS and then asked respondents to estimate changes from 2008 to the present (2012). Navigant also estimated characteristics in 2032 based on interview responses.

To determine the present and forecasted (through 2032) baseline, Navigant scaled their estimates of acreage meeting NEEA's criteria by the estimated portion of acreage using integrated decision support systems.

4. Key Findings

The section summarizes the key findings of Navigant's data collection and analysis efforts for this project. These findings include general characteristics of the three-state agricultural market as well as specific characteristics and forecasted characteristics of the target market for NEEA's IIDS initiative. More detailed findings from the primary and secondary data collection efforts can be found in Appendix A and B of this document.

4.1 Northwest Agriculture Trends and Market Dynamics

Navigant observed several dynamic market conditions driving the market for irrigation technologies in the three-state region. These conditions include the following:

- **Availability of—and competition for—suitable lands for agriculture purposes**: There is a continual competition for land between agriculture and urban sprawl. Developers are continually converting agricultural lands surrounding urban areas into residential lands. The pace of this conversion follows real estate prices: faster during the housing boom of the early 2000's and slower since the housing market collapsed in 2008. This competition shifts some agricultural activity to marginal lands further from urban areas and reduces the overall level of agricultural activity.

- **Availability of—and competition for—water for agricultural irrigation:** Respondents did not think that water scarcity was currently an issue on farms in the three-state region. However, respondents stated that water is fully allocated in most areas in the region, and that states are not issuing new water rights, which prevents expansion of irrigated agricultural lands. At the same time, demand for non-irrigation water uses is increasing, driven by factors including urban sprawl and the support of endangered species. Respondents said that future availability of water will be affected in yet unknown ways by climate change, but did not think that climate change would *increase* the availability of water for agricultural irrigation. Water availability can influence capital decisions such as the purchase of irrigation systems, planning decisions such as what crops to grow, and operating decisions such as when to irrigate.

- **Availability of labor**: The cost of labor can be a determining factor in farm economics. In recent years, some areas of the three-state region have had a shortage of field labor. The cost and availability of labor can strongly influence the investment of labor-saving equipment such as automated irrigation systems.

- **Crop value:** Commodity prices tend to be volatile. Periods of relatively high commodity prices—such as the present—coincide with periods of higher capital investment and slower rates of land loss to urban sprawl.

- **Demand for crops:** Examples of demand for crops in the three-state region include demand for corn and other feed to support the expanded dairy industry, demand for sugar beets driven by federal subsidies for ethanol production, and demand for barley from breweries, and demand for potatoes from large agribusiness. While these are key drivers of the disposition of agricultural land use, it is difficult to predict their magnitude beyond the coming few years.

- **Cost of production**: The component costs of crop production, such as equipment capital, labor, water, energy, fertilizers, and pesticides, influence farmers' motivations to adopt tools and strategies that shift costs. Currently in the three-state region, the cost of labor was the most commonly cited factor influencing adoption of center pivot irrigation. Water and energy are relatively inexpensive and comprise a small portion of total operating costs on farms in the three-state region.[8]

- **Crop yield**: Most farmers in the three-state region use crop yield, rather than profit, as an explicit objective. This choice is made to simplify farmers' decision processes to a level that they have the bandwidth to address, and is justified currently by the relatively high commodity prices.

- **Capability of farmers**: The trend towards larger farms means that a farmer's already limited time and efforts must be spread over a larger area. This is driving farmers towards automated irrigation systems such as center pivots and also driving the use of information (for example, moisture sensors, evapotranspiration reports) to reduce the amount of hands-on effort required from farmers.

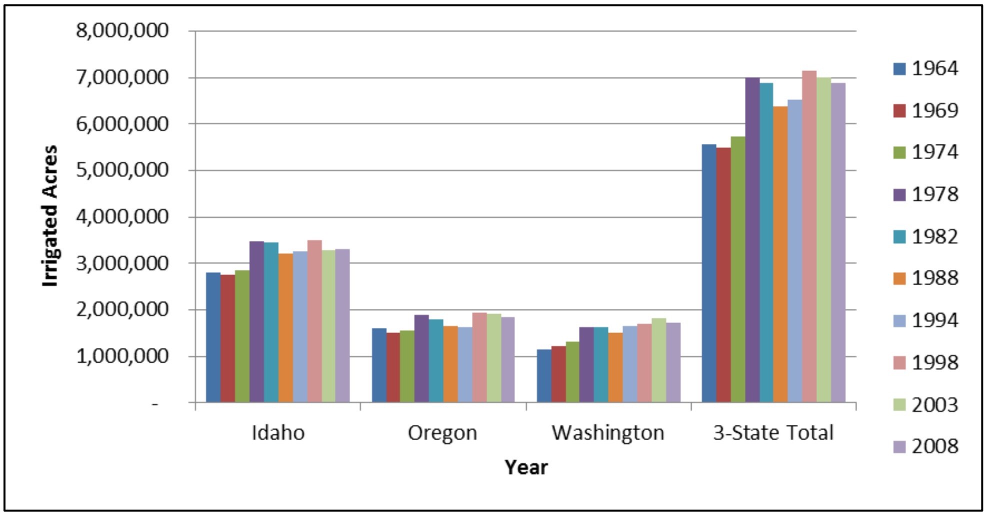
- **Availability and demonstration of technologies and practices**: While the limited bandwidth of farmers suggests a captive market for decision support technologies, most growers are skeptical of relying on a computer to manage their farm and prefer traditional methods of irrigation decision making such as personal judgments on the look and feel of soil and crops. Farmers typically look to the performance of innovative technologies and strategies on nearby and showcased farms before deciding to adopt these innovations.

4.2 Uses for and Disposition of Irrigated Agricultural Land in the Three-State Region

The three-state region contains approximately 7,000,000 acres of irrigated farm land. (United States Department of Agriculture [USDA] 2008b). This amount has not changed significantly in the past two decades, and respondents thought that the amount would decrease slightly in the coming decades due to non-agricultural competition for land and water. Figure 2 shows the amount of irrigated acreage in the three-state region.

[8] As of 2007, utility costs comprise 3.1% of total farm expenses in Oregon, 3.5% in Washington, and 3.8% in Idaho. These percentages are based on the expenses of all farms, not only irrigated farms. (USDA 2007)

Figure 2. Irrigated Acreage in Idaho, Oregon, and Washington, 1964 to 2008



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Farms in the Censuses of Agriculture*. Survey years 1988, 1994, 1998, 2003, and 2008.

Common irrigated crops in the region include corn for fodder, alfalfa, hay, wheat, barley, potatoes, and sugar beets. Table 4 shows the historical and forecasted relative distribution of irrigated acreage, by crop type, in the three-state region. Values from 1988 to 2008 are derived from data in the USDA FRIS. Navigant estimated the values for 2012 and 2032 based on responses from regional respondents. Assuming current conditions remain, regional respondents did not think that the distribution of acreage by crop type would change from the 2012 levels. However, these respondents noted that distributions are governed by unpredictable factors such as commodity prices and government policy as much as by observable trends.

Table 4. Relative Distribution of Irrigated Acreage, by Crop Type, in the Three-State Region

Crop Type	1988	1994	1998	2003	2008	2012*	2032*
Crops for Forage or Fodder (including alfalfa, hay, and others)	22%	24%	27%	32%	32%	35%	35%
Grain (including wheat, barley, and others)	20%	20%	19%	20%	20%	19%	19%
Other Vegetables (including beans, beats, and others)	9%	9%	9%	8%	14%	13%	13%
Pasture	12%	11%	11%	13%	13%	12%	12%
Potatoes	8%	8%	9%	8%	7%	6%	6%
Orchard	4%	3%	4%	4%	3%	3%	3%
Other	26%	24%	22%	14%	12%	12%	12%

Source for 1988 to 2008 estimates: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Estimated Quantity of Water Applied and Primary Method of Distribution by Selected Crops Harvested*. Survey years: 1988, 1994, 1998, 2003, and 2008. **Source for 2012 and 2032 estimates:** Navigant interviews with regional respondents.

The dominant trend affecting irrigated agriculture has been the increase in dairy cows in the region, which has resulted in an increase in corn and other feed for these cows. This increase is particularly apparent in southern Idaho. The increase in forage and fodder crops has been at the expense of a variety of other crops. One respondent suggested that acreage for sugar beets has likely decreased due to improvements in yield per acre of this crop, coupled with a fixed demand for sugar. Any significant changes in crop type can influence the quantity of irrigation required as well as the appropriate irrigation delivery method.

4.3 Irrigated Acreage of Interest for this Study

NEEA has defined the market of interest for this research as irrigated farms with the following characteristics:

- irrigated by or suitable to irrigation by center pivot systems (estimated in Sections 4.3.1 and 4.3.2)
- 100 acres or larger (estimated in Section 4.3.3)

In Section 4.3.4, Navigant estimates the amount of irrigated acreage meeting and forecasted to meet these criteria by using the FRIS data for historical insight and discussing current and forecasted trends with the regional respondents.

Section 4.3.5 provides characterization of the three-state region's irrigated acreage by the amount of total dynamic head[9] (TDH) required for irrigation systems. TDH is directly correlated to the energy consumption per volume of water consumed for irrigation.

4.3.1 Amount of Irrigated Acreage

There are approximately seven million irrigated acres of agricultural land in the three-state region. (USDA 2008b) Regional respondents thought there was little (+/- 3%) if any change from 2008 to 2012 and that the amount of irrigated acreage would remain the same or decrease slightly (up to 6%) between now and 2032. Respondent cited water already being fully allocated in the region, as well as pressures from suburban expansion, as reasons why irrigated farm acreage would not increase, and may decrease, in the coming 20 years.

4.3.2 Acreage Irrigated by Center Pivots

As of 2008, 45% of irrigated acreage in the three-state region was irrigated by center pivots and has been increasing fairly linearly at an average rate of more than 1 percentage point per year since 1988, the first year of Navigant's analysis. (USDA 2008a) Respondents thought that the same linearly increasing trend was present from 2008 to 2012, which implies that center pivots currently irrigate 50% of irrigated land in the three-state region, which is approximately 3.5 million acres.

Reasons that respondents provided for this continuing increase in market share of center pivots included: improved ease of farming; reductions in costs associated with labor, energy, and water;

[9] This is the total dynamic head (TDH) which includes pressure required to lift water from well to ground level, to overcome friction in pipes, valves and fittings, and to provide the water at the sprinkler head with the appropriate water pressure for the sprinkler system. It is expressed as the equivalent lift height that could be provided by the pump system if no surface distribution or pressurization were required. For reference, each foot of TDH is equivalent to approximately 2.3 pounds per square inch (psi) of pressure.

requirements from crop (primarily potatoes) purchasers[10]; and current high commodity prices, which provide farmers with cash for capital expenditures such as new irrigation systems.

Regional respondents thought that all suitable land for center pivots could be converted to center pivots by 2032. Approximately 62-77% of all irrigated land (either pressure or gravity systems) in the three-state region is suitable for center pivots, based on respondents' estimates. Findings from Navigant's discussions with these respondents include:

- Regionally, 70% to 85% of land currently irrigated by pressure systems is suitable for center pivot irrigation. The remaining acreage is not suited to center pivots because of soil types, slope of land, or other topographic issues.
- Approximately 50% to 70% of land irrigated by gravity fed systems is suitable for center pivot irrigation. The remaining acreage is not suited to center pivots for the following reasons:
  - Seed crops and beans are not well suited to center pivots because water on the plants can cause disease.
  - Smaller farms may not be able to afford the capital investment of a center pivot system.
  - Capital investment in center pivot may not be warranted at farms likely to be converted to residential land in the near future.

4.3.3 Irrigated Acreage on Farms 100 Acres or Larger

91% of irrigated acreage in the three-state region was on farms 100 acres and larger in 2008. (USDA 2008b) Regional respondents think that this percentage has either stayed the same or increased slightly from 2008 to 2012, and that this percentage will either stay the same or increase to as much as 95% by 2032, since smaller farms are less profitable and thus more likely to sell their lands to larger commercial farms or residential developers.

4.3.4 Irrigated Acreage Baseline and Forecast Trends

Navigant estimated the amount of irrigated acreage meeting NEEA's criteria as the product of the previous three parameters: total irrigated acreage, percent irrigated by center pivots, and percent on farms 100 acres or larger. This analysis approach assumes that there is no correlation between the prevalence of center pivots and whether or not a farm is larger than 100 acres. This assumption was necessary because the cross-tabulation of FRIS data needed to identify such correlations was not available to Navigant at the time of this analysis. However, Navigant discussed this issue with respondents and concluded that this analysis approach was reasonable.

Table 5 summarizes this analysis. In short, Navigant's best estimate is that 3,165,206 acres in the three-state region meet NEEA's criteria in 2012 (with a range of 3,036,929 to 3,260,218 acres); these estimates are forecasted to increase to 4,283,072 (with a range of 3,649,325 to 5,033,452 acres) by 2032.

[10] Potato purchasers want assurance of the moisture content of the potatoes purchased, resulting in growers paying closer attention to irrigation strategies for those crops.

Table 5. Analysis of Irrigated Acreage Meeting NEEA Criteria

Parameter	2008	Estimate	2012	2032	Saturation	Sources/Notes
Irrigated agricultural land (acres)	6,881,000	High	7,087,430	6,881,000	~7,000,000	*2012:* 3% increase from 2008 for high estimate, 3% decrease for low estimate. *2032:* No change from 2012 medium estimate for high estimate, 6% decrease for low estimate.
		Medium	**6,881,000**	**6,674,570**		
		Low	6,674,570	6,468,140		
Percentage of all irrigated acres that are irrigated by center pivot	45%	High	50%	77%	2032 estimates	*2012:* continuation of linear trend from 2003 to 2008. *2032:* 70-85% of land currently irrigated by sprinklers and 50-70% of land currently irrigated by gravity systems.
		Medium	**50%**	**69%**		
		Low	50%	62%		
Percentage of all irrigated acres that are on 100+ acre farms	91%	High	92%	95%	95%	*2012:* 1% increase from 2008 for high estimate, no change for low estimate. *2032:* 3% increase from 2012 for high estimate, no change for low estimate.
		Medium	**92%**	**93%**		
		Low	91%	91%		
Resulting acreage meeting NEEA's criteria		High	3,260,218	5,033,452		Determined by multiplication of the three parameters above.
		Medium	**3,165,206**	**4,283,072**		
		Low	3,036,929	3,649,325		

Source: Navigant analysis based on primary and secondary research detailed in preceding sections.

4.3.5 Total Dynamic Head Levels Across Irrigated Acreage

Navigant also conducted an analysis to estimate the total dynamic head[11] (TDH) across irrigation systems in the three-state region. TDH is an important parameter for this study because it directly correlates with the on-farm energy consumed for water usage. The energy savings from an incremental change in water consumption (e.g., due to the NEEA initiative) can be estimated from the TDH.

To conduct this analysis, Navigant requested a custom query from the USDA which estimated the electricity cost per acre-foot of water on irrigated farms of 100+ acres, by county[12]. The USDA query presented the results as the number of acres in each county that had electricity costs of $0-$10 per acre-foot, $10-20, $20-30, $30-60, and >$60. Navigant used these results in combination with the electricity rates of the predominant utility in each county to estimate the electricity consumption in terms of kWh/acre-foot. Navigant then estimated TDH from the kWh/acre-foot estimates by assuming an average pump system efficiency of 50%[13].

Table 6 characterizes the NEEA criteria acreage across TDH levels and the corresponding on-farm energy intensity (kWh/acre-foot) levels.

Table 6. System Pressure and Energy Intensity on NEEA Criteria Acreage

Total Dynamic Head	Corresponding Energy Intensity Range (kWh/acre-foot)	3-State Region	Idaho	Oregon	Washington
less than 100 ft.	0 to 195 kWh/acre-foot	16%	13%	20%	36%
100 to < 200 ft.	196 to 390 kWh/acre-foot	27%	21%	61%	30%
200 to < 300 ft.	391 to 586 kWh/acre-foot	19%	22%	1%	18%
300 to < 400 ft.	587 to 781 kWh/acre-foot	19%	21%	11%	2%
400 to < 500 ft.	782 to 976 kWh/acre-foot	3%	3%	0%	10%
500 to < 600 ft.	977 to 1172 kWh/acre-foot	4%	5%	5%	1%
600 to < 700 ft.	1173 to 1367 kWh/acre-foot	10%	12%	0%	2%
700 ft. or greater	1368 kWh/acre-foot and greater	3%	3%	2%	0%

Note: Totals do not add to 100% due to rounding.

4.4 Baseline Adoption of Irrigation Strategies

As described in Section 1, NEEA's initiative product "is an integrated irrigation decision support solution (IIDS) that will make it easy and compelling for growers to take action to lower their

[11] This is the total dynamic head (TDH) which includes pressure required to lift water from well to ground level, to overcome friction in pipes, valves and fittings, and to provide the water at the sprinkler head with the appropriate water pressure for the sprinkler system. It is expressed as the equivalent lift height that could be provided by the pump system if no surface distribution or pressurization were required. For reference, each foot of TDH is equivalent to approximately 2.3 pounds per square inch (psi) of pressure.
[12] Query results were provided by the USDA National Agricultural Statistics Service Datalab to the authors via email on December 10, 2012 and February 22, 2013.
[13] TDH is computed as the energy intensity (kWh/acre-foot) divided by the system efficiency. This is multiplied by a unit conversion factor of 1.0241 to obtain TDH in feet.

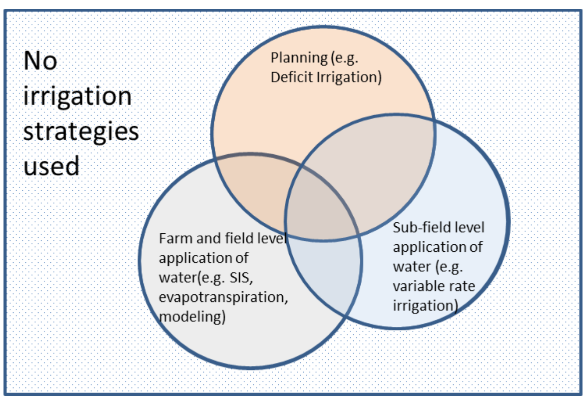
irrigation electrical energy use, and as a result, reduce their operating costs and consequently improve profitability." No single product currently exists in the market that is comparable to NEEA's IIDS, yet some components of IIDS are in use in the three-state region. Navigant asked respondents to estimate current and forecasted levels of use of these components, and to discuss the future use of components not currently in use.

Navigant developed a framework for this discussion with respondents which discussed irrigation decision making in a generalized format. Navigant began by defining *irrigation strategies* as "the use of methods, information, and/or technologies to reduce the amount of water and energy used for irrigation, relative to conventional approaches to water decisions, such as visual or tactile assessments." Navigant then described three types of irrigation strategies:

- **Planning:** the co-optimization of expected crop yield and water usage, by using techniques such as deficit irrigation.
- **Farm and field-level tools**: the use of data and models to determine the amount of water to apply to a farm or field at a given time. Tools include scientific irrigation scheduling, other scheduling services, evapotranspiration reports, and/or computer simulation.
- **Sub-field-level tools**: the use of spatially granular information such as soil type and topography, in conjunction with modeling and variable rate irrigation (VRI) controls, to vary the amount of water applied over portions of a field."

Navigant also provided respondents with a Venn diagram that categorizes farms by their use of irrigation strategies (Figure 3).

Figure 3. Venn Diagram of the Use of Irrigation Strategies



Navigant asked respondents to estimate the percentage of irrigated acreage in the three-state region belonging to each category in the diagram, for example, acreage subject to none of these strategies (the area within the rectangle but outside of the circles), the acreage subject to all three strategies (the intersection of the three circles), or the acreage subject to a specific strategy.

Finally, Navigant asked respondents to estimate the current and forecasted levels of use of tools for data integration and decisions making.

Navigant discussed irrigation strategies with both regional and manufacturer respondents. Navigant asked manufacturer respondents additional questions about their current and planned product offerings in each category of irrigation strategies. The following subsections discuss the regional respondents' perspectives (Section 4.4.1) and the manufacturers' perspectives (Section 4.4.2).

4.4.1 Findings from Interviews with Regional Respondents

Key findings from this portion of the primary data collection task are presented here:

- **General**
  - **The co-optimization of yield and water usage is rare.** No regional respondent explicitly mentioned water efficiency as a driver in decision making. Several respondents noted that water and energy are currently not expensive enough to drive decisions. Additionally, at the current high commodity price levels, farmers value yield more than savings in operating costs.

- **Planning Strategies**
  - *Usage:* Planning strategies are likely used on approximately 20% of irrigated acreage in the three-state region.
  - Planning strategies are used primarily to optimize crop yield and quality.
  - For reference, the 2008 FRIS reported that 6% of farms (not acreage) in the three-state region used a commercial or governmental scheduling service, 14% used a water delivery organization schedule, and 32% used a personal calendar.[14] However, the FRIS report does not indicate how much these categories overlapped.
  - Many of these strategies are concentrated on potato and wheat crops. Nearly all potatoes are grown with an explicit irrigation strategy and one regional respondent estimated that 60% of wheat crops are grown using deficit irrigation. In 2008, potatoes were grown on 7% of all irrigated acreage in the region and wheat was grown on 15%[15].

    Grower Types that Favor this Strategy: The types of growers currently using planning strategies are those using it to solve a specific problem, big commercial growers, and some innovative independent farmers. *Forecasted Changes:* Regional respondents did not foresee a significant rise in the use of planning strategies in the next 20 years.
- **Farm- and Field-level Strategies**
  - *Usage:* There is a broad spectrum of tools within the farm- and field-level tools category, which led to a wide range of estimates of usage. The use of tools in this category is likely in the range of 10% to 30% of irrigated acreage.
  - The use of moisture sensors was the most commonly cited farm- and field-level strategy. One regional respondent indicated that almost all growers in his region use moisture sensors, whereas other regional respondents suggested a 10% to 30% range.
  - The use of more sophisticated technologies such as evapotranspiration reports and computer simulation are far less common, except in the potato industry, where they are very common.

[14] Note that Navigant did not consider personal calendars to be a "planning strategy" in the usage estimate.
[15] It is unclear how much of this wheat is grown in rotation on fields used primarily for potatoes; therefore, the estimates of irrigated acreage for wheat and potatoes should not be summed.

- For reference, the 2008 FRIS reported that 9% of farms (not acreage) in the three-state region used soil moisture sensors, 2% used plant moisture sensors, and 7% used evapotranspiration reports. The use of Scientific Irrigation Scheduling (SIS) is driven primarily by subsidies, which suggests that a review of program activity would be a good indicator of regional prevalence. This is consistent with the findings of Navigant's 2010 evaluation findings for Bonneville Power Administration's SIS program[16].
- *Grower Types that Favor this Strategy:* The types of growers currently using farm- and field-level strategies are those using it to solve a specific problem, trying a new approach (largely driven by subsidies), and large commercial growers.
  Forecasted Changes: There was general uncertainty on the levels of farm- and field-level tool usage in the future. Two regional respondents thought that it would double from existing levels.

- **Sub-Field-Level Strategies**
  - *Usage:* The use of sub-field-level strategies in the three-state region is too rare for regional respondents to quantify. All regional respondents who attempted to quantify the current levels of usage used a "less than X%" structure, with responses ranging from "less than 10%" to "less than 1%," with one regional respondent estimating the level at 0%. No regional respondents indicated any knowledge of variable rate irrigation (VRI) systems in use in the NW aside from experimental or demonstration projects.
  - *Grower Types that Favor this Strategy:* Regional respondents could not describe the types of growers that currently use these tools because it is unclear who, if anyone, is using sub-field-level tools.
    - One regional respondent suggested that large growers might be using these tools.
    - One regional respondent suggested that growers using sub-field-level tools would be growers trying new approaches.
  - *Forecasted Changes:* Most regional respondents did not foresee any increased adoption of sub-field-level strategies in the next 20 years. Reasons for this included the following:
    - Water availability is forecasted not to be an issue.
    - Sub-field-level tools are too complicated and require too much time for most farmers.
    - The majority of untapped water and energy savings can be achieved at the field-level.
  - One regional respondent did foresee sub-field-level tools being used on as much as 45% of irrigated acreage in the three-state region by 2032 *if* several changes to current conditions occur. These changes included:
    - reductions in water availability

[16] Schare, Stuart and Deborah Swarts, "Evaluation of Bonneville Power Administration's Scientific Irrigation Scheduling Program," 2010. Available at http://www.bpa.gov/energy/n/reports/evaluation/pdf/BPA_SIS_evaluation_Final_Report_Dec_2010.pdf.
From the executive summary: "The regional market was found to be dependent upon available incentives in order to continue and expand the use of SIS. This was due to the combined cost of services and implementation exceeding the budget of a typical grower."

    - increases in energy prices
    - availability of tools that manage and deliver information better than current tools, and are user-friendly

- **Tools for Data Integration and Integrated Decision Making**
  - *Usage:* There is currently little to no use of tools to integrate data from multiple sources, or to help farmers make irrigation decisions. Respondents indicated that integration of information is currently done in farmers' heads or "by the seat of their pants".
  - *Forecasted Changes:* Several regional respondents thought that increasing trends in computing power and usage (for example, smart phones, iPads) suggested that such tools would be adopted in the next 20 years, but none indicated that any existing tools in the market were moving in this direction (becoming less expensive, more powerful, and more user-friendly). One regional respondent estimated a penetration of 10% to 20% by 2032 and another estimated a penetration of "optimistically, 20% to 25%."
  - *Saturation:* Regional respondents thought that most users of farm- and field- level tools could benefit from integrated decision making tools. However, these tools would not be suitable for all farms; for example farms on which integrated decision making tools would not be cost effective, or where growers are prefer direct control of decisions.

4.4.2 Findings from Interviews with Manufacturer Respondents

The Navigant team interviewed representatives of the three largest center pivot manufacturers in the U.S., who collectively hold approximately 75% of the U.S. center pivot market. The respondents were all national representatives of their respective companies, but with strong knowledge of the Northwest market.

Significant findings from these interviews include the following:

- **Planning Strategies**
  - *Usage:* Manufacturer respondents perceive the use of planning as an irrigation strategy in the three-state region as currently rare. Two thought that it was minimal and one estimated it as 15 to 20% of irrigated acreage.
  - *Forecasted Changes:* Two thought that the use of planning tools would become widespread within 20 years *if* water became less available for irrigation in the region.
  - *Manufacturer Involvement:* Center pivot manufacturers do not currently market planning tools. It is possible that at least one of the manufacturers will offer a product within the next few years.

- **Field-Level Tools**
  - *Usage:* Manufacturers' perceptions of the use of field-level tools are varied. Responses from the three manufacturer respondent were "very few," "15-20%," and "most." Likely reasons for this discrepancy are:
    - Ambiguity of definition: Is this just the use of moisture sensors, or something more sophisticated that influences irrigation decisions?

        - Diversity of clientele: There may be correlations between the types of customers and their irrigation practices. A manufacturer that primarily markets to large customers may have a skewed perception of the entire regional market.
    - For reference, in the 2008 FRIS, 9% of growers on irrigated farms reported using soil moisture sensors, 2% reported using plant moisture sensors, and 7% reported using evapotranspiration. It is impossible to tell from this dataset *which* growers are using these tools. For example if larger farms are more likely to use these tools (which the Navigant team heard from respondents), thenthe percentage of acreage is larger than the percentage of growers.
    - *Manufacturer Involvement:* All three manufacturers currently offer field-level tools, and new products from at least one manufacturer are likely to enter the market in the next few years.

- **Sub-Field-Level Tools**
    - *Usage:* All three manufacturer respondents thought that the use of sub-field-level tools is currently less than 1% in the three-state region.
    - *Forecasted Changes:* Two of the three manufacturer respondents thought that use of sub-field-level tools would be significant (33% to 50% of acreage) within twenty years and one manufacturer respondent thought that there would be no significant market for these products in the next five years.
        - One manufacturer respondent forecasted that 50% of acreage would be subject to sub-field-level tools, conditional on increased production costs, water scarcity, and lower commodity prices.
        - One manufacturer respondent forecasted that 33% to 50% of acreage would be subject to sub-field-level tools, conditional on water scarcity in the region.

- **Tools for Data Integration and Integrated Decision Making**
    - *Usage:* None of the three manufacturer respondents thought that any hardware or software tools for data integration or integrated decision making were being used in the region. However, one of the three manufacturer respondents did note that consultants provide a service intended to accomplish the same functions as these tools, and estimated that about 20% of irrigated acreage was subject to consultants. He estimated that 80% of sugar beet and potato acreage was subject to consultants, and that corn and hay were starting to be subject to consultants because of their recent high commodity prices.
    - *Forecasted Changes:* The same respondent forecasted that 80% of irrigated acreage would be subject to data integration and integrated decision making in 20 years, and that half of this would be from software and half from consultants.
    - *Manufacturer Involvement:* One manufacturer respondent said that his company offered such products, one manufacturer respondent said that his company was considering developing such a product, and one said that they had no near-term plans to develop such a product.

4.4.3 Conclusions from Interviews

Based on the interview results described in the preceding sections, Navigant made the following estimates (percentage of irrigated acreage) of current, future (2032), and eventual saturation levels of adoption of irrigation strategies:

- **Planning tools**: 15% to 30% in 2012 and not changing through 2032. 75% at saturation.
- **Farm- and field-level tools**: 10% to 30% in 2012. Respondents were uncertain where adoption would be in 2032, ranging from no change to a doubling of current levels; a range of 10% to 60% was assumed for 2032. 90% at saturation.
- **Sub-field level tools**: 0% to 1% in 2012. 0% to 10% in 2032 because tools are available and improving, but the respondents saw little interest in them in the three-state region under current conditions. 50% at saturation.
- **Use of all three strategies**: All farmers using sub-field level tools would use all three strategies. 0% to 1% in 2012, 0% to 10% in 2032. 50% at saturation.
- **Use of integrated decision making tools**: 0% in 2012. 10% to 25% in 2032. Navigant did not include the use of consultants in this estimate, only the use of software and hardware. Tools would primarily be at the farm- and field-level. 75% at saturation.
- **No irrigation strategies used**: Navigant assumed that there would be significant overlap between farms using planning tools and farms using farm- and field-level tools. 60% to 80% in 2012, 40% to 80% in 2032. 10% at saturation.

Table 7 summarizes these estimates.

Table 7. Estimates of Current, Forecasted, and Saturation Levels of Irrigation Strategy Adoption

Parameter	Estimate	2012	2032	Saturation	Sources/Notes
Use of planning tools	High	30%	30%	75%	Primarily deficit irrigation used for potato and wheat crops. No increase in the use of these strategies in 2032.
	Medium	**20%**	**20%**		
	Low	15%	15%		
Use of farm- and field-level tools	High	30%	60%	90%	Change from 2012 to 2032: anywhere from no change to double current levels.
	Medium	**20%**	**30%**		
	Low	10%	10%		
Use of sub-field level tools	High	1%	10%	50%	2012: virtually none in the three-state region. 2032: under current conditions, significant adoption is not expected.
	Medium	**0%**	**5%**		
	Low	0%	0%		
Use of all three strategies combined	High	1%	10%	50%	Limited by the use of sub-field-level tools.
	Medium	**0%**	**5%**		
	Low	0%	0%		
Use of integrated decision making tools	High	0%	25%	75%	Estimate is for hardware and software only, excludes the use of consultants to support decision making. Does not necessarily require the use of sub-field level tools.
	Medium	**0%**	**18%**		
	Low	0%	10%		
No irrigation strategies used	High	80%	80%	10%	
	Medium	**70%**	**65%**		
	Low	60%	40%		

Source: Navigant analysis based on primary and secondary research detailed in preceding sections.

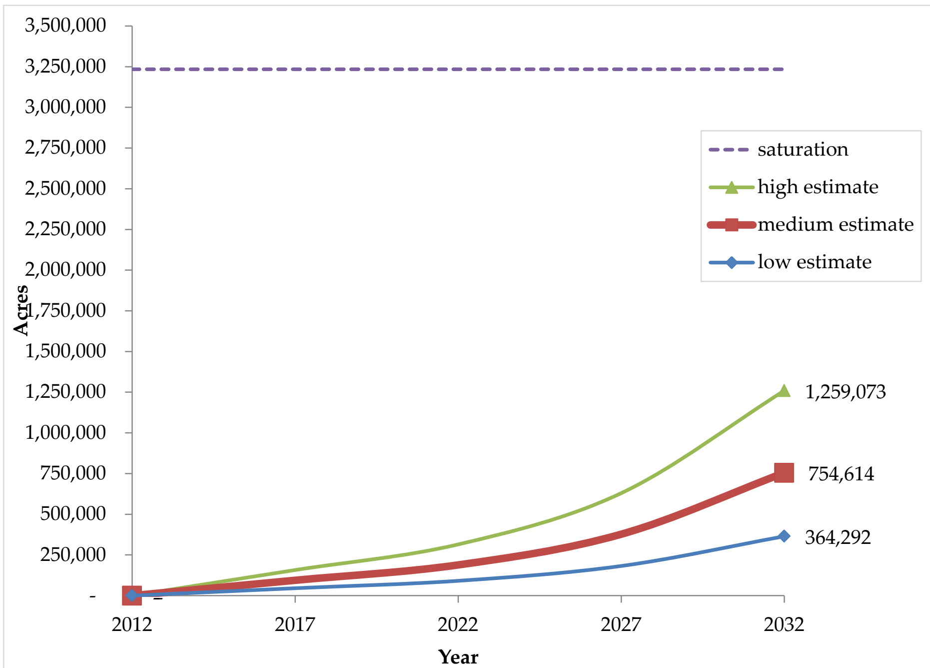
4.4.4 Baseline for Integrated Decision Making Tools

Navigant thinks that much of the performance benefits (water savings, energy savings, improved yields) achievable by IIDS would be achieved by the integrated decision making tools likely to appear in the market in the absence of NEEA's intervention. Navigant therefore recommends that the estimates of current and forecasted adoption of integrated decision making tools be used as the baseline for NEEA's IIDS initiative. As stated in Table 7, this baseline has no adoption in 2012 and 10% to 25% adoption in 2032, with an eventual saturation level of 75%. The limiting factor in this saturation level is the forecasted saturation of the use of planning tools.

An alternative assumption to using forecasted adoption of integrated decision making tools to determine the baseline would be to use the forecasted adoption of sub-field level tools (0% to 10% of acreage in 2032). However, several of the respondents that Navigant interviewed thought that there was greater water and energy savings from field-level tools (for example, deciding when to turn on the irrigation system) than from sub-field level tools. For this reason, Navigant did not think that the baseline should be limited by the use of sub-field level tools, but rather by the use of integrated decision making tools.

In order to determine the baseline of acres subject to integrated decision making tools, Navigant multiplied the irrigated acreage meeting NEEA's criteria (center pivot irrigated, on farms 100 acres or larger, as estimated in Section 4.3.4) by the estimates of baseline use of integrated decision making tools in the absence of NEEA's intervention. This results in a baseline of zero acres at present (2012), increasing to 754,614 acres in 2032 (low estimate 364,292 acres, high estimate 1,259,073 acres). Navigant expects an acceleration of adoption over the 20 years, as is typical of early stages of diffusion of innovations.[17] This baseline is illustrated in Figure 4 and Table 8.

Figure 4. Current and Forecasted Baseline of Acreage Subject to Integrated Decision Support and Meeting NEEA's Criteria



Source: Navigant analysis

[17] Based on discussion with respondents, Navigant assumed that 12.5% of the 2032 level would be achieved by 2017, 25% by 2022, 50% by 2027, and 100% in 2032.

Table 8. Current and Forecasted Baseline of Acreage Subject to Integrated Decision Support and Meeting NEEA's Criteria

Parameter	Estimate	2012	2032	Saturation
NEEA Criteria Acreage (100+ acre farm, with center pivot irrigation)	High	3,248,187	5,036,292.89	4,312,079
	Medium	**3,136,441**	**4,312,079**	
	Low	3,025,723	3,642,917	
Baseline Percentage of Acreage Subject to Integrated Decision Making Tools	High	0%	25%	75%
	Medium	**0%**	**17.5%**	
	Low	0%	10%	
Base Acreage Subject to Integrated Decision Making Tools	High	0	1,259,073	3,234,059
	Medium	**0**	**754,619**	
	Low	0	364,292	

Source: Navigant analysis based on primary and secondary research detailed in preceding sections.

4.5 Use of Irrigation Strategies in More Water Constrained Regions

From their research for this project, Navigant found that there is currently little interest in water and/or energy savings on irrigated farms in the three-state region because the cost of these resources is relatively low. However, as discussed earlier in this report in Section 4.1, water scarcity may become an issue in the three-state region over time due to increased competition for water for non-agricultural uses and/or changes to water supply due to climate change. To understand how the irrigation market in the three-state region might change in response to water scarcity, Navigant interviewed a recent University of Nebraska extension agent to learn more about irrigation practices in this more water constrained region.

The respondent noted that water is often a factor in decision making, particularly in the western part of the state, where water is scarcer. He cited several indications of water considerations in the state:

- A common strategy for farmers of fall harvested crops is to leave soil dry in the fall (allowing the loss of up to four to five inches of soil moisture without replacement), which reduces yield somewhat, and rely on off-season moisture to refill the soil profile.
- The respondent estimated that 60 to 70% of irrigated fields are currently subject to crop consultants.
- Irrigation in Nebraska has been trending away from gravity systems to center pivots, and even to drip irrigation on some farms.

Although water is more of a concern in Nebraska than the three-state region, water saving technologies that rely on information and analysis are not popular in Nebraska because of the amount of work required of the farmer is too great, based on the technologies currently available.[18] Given this, it is likely that the future adoption of integrated decision making tools in water scarce regions would be a predictor of the adoption of such tools in the three-state region if water scarcity became an issue.

[18] For reference, the 2008 FRIS reports that 30% of farms in Nebraska used reports on daily crop-water evapotranspiration, whereas only 7% of farms in the three-state region used such reports.

4.6 Key Areas of Uncertainty

Navigant developed the baseline for this project under significant sources of uncertainty. Some of the most significant sources of uncertainty are briefly discussed here:

- **Definition of "decision support based irrigation"**: Decision support based irrigation is not a standard term in the agricultural industry, and as such interpretations of this term vary. In order to estimate the baseline for decision support based irrigation, Navigant made the assumption that the use of any integrated decision making tools would qualify as decision support based irrigation. However, NEEA's initiative product, IIDS, would likely be more comprehensive and user-friendly than other emerging products in the market. More research would be required to determine the relative effectiveness of decision support products such as NEEA's and those being developed by irrigation manufacturers.

- **Forecasted market conditions**: It is difficult to forecast many of the dynamics in the market discussed in Section 4.1. Because of this difficulty, respondents tended to provide forecasts that assume no change to current market conditions. However, changes in market conditions could affect key factors in this analysis such as the amount of irrigated acreage, the economic desirability of center pivot and decision support technologies, and the disposition of irrigated lands. Given these uncertainties, a static baseline forecast such as that provided for this report can be used to estimate incremental effects for NEEA's initiative planning purposes. However, underlying assumptions in this analysis may change over time, calling into question the use of this baseline for an *ex post* evaluation.

  One approach to this problem is to develop an influence model of irrigation practices, and to use this model to forecast baseline changes in irrigation practices under a variety of scenarios (for example, water scarcity, high energy prices). This model could be calibrated to existing conditions and then be used to examine sensitivities to inputs affected by market intervention. This sensitivity analysis could be conducted both prior to intervention (using scenario analysis) and after intervention (using observed market conditions). Development of an influence model would be an analytic exercise informed by interviews with qualified market observers and calibrated to observed market conditions at regular intervals.

- **Current levels of water efficiency and the potential for water savings**: Determining the baseline consumption of water and energy on irrigated farms was beyond the scope of this project. However, NEEA's initiative is motivated by the pump energy savings associated with the improved irrigation water efficiency that decision support systems. Additional research would be required to determine this baseline of energy and water consumption (or effectiveness, for example in acre-feet per unit of crop).

  Navigant began to address this issue through the use of the irrigation strategies section of their primary data collection interview instrument. From data collected, Navigant was able to estimate the percentage of growers using different types of tools and techniques to make irrigation decisions. Recently, NEEA has provided Navigant with a list of tools that the use of could be correlated to relative irrigation water effectiveness. These tools are:

soil mapping, SIS, weather and evapotranspiration data, yield analysis, and flow meters. Some of the data that Navigant collected could be used to inform estimates of usage of tools on NEEA's list. However, additional research would be required to construct a baseline of these tools' usage.

5. Conclusions

Navigant concludes the following:

- **Multiple dynamic market conditions in the agricultural irrigation market may affect the potential for decision support based irrigation, including:**
    - **Availability of—and competition for—suitable lands for agriculture purposes:** There is a continual competition for land between agriculture and urban sprawl.
    - **Availability of—and competition for—water for agricultural irrigation:** Water scarcity is not currently an issue on farms in the three-state region. However, respondents stated that water is fully allocated in most areas in the region, and that states are not issuing new water rights, which prevents expansion of irrigated agricultural lands.
    - **Crop value and demand for crops:** Commodity prices and demand for specific crops tend to be volatile, and any changes in crop type on a given farm may necessitate changes in the type and quantity of irrigation needed.
    - **Cost of labor and production:** The component costs of crop production—particularly labor costs—can strongly influence farmers' motivations to adopt labor-saving tools and strategies that shift costs.
    - **Crop yield focus and capability of farmers**: A trend towards larger farms means that a farmer's already limited time and efforts must be spread over a larger area. Most farmers in the three-state region use crop yield, rather than profit, as an explicit objective to simplify decision-making. The increased demands on farmers' time and attention are driving farmers towards automated irrigation systems such as center pivots and also driving the use of information to reduce the amount of hands-on effort required from farmers.
    - **Availability and demonstration of technologies and practices**: Farmers typically look to the performance of innovative technologies and strategies on nearby and showcased farms before deciding to adopt these innovations.
- **The total potential market for decision support based irrigation is large, yet untapped.** Navigant estimates that approximately 3.1 million irrigated acres in the three-state region currently meet NEEA's criteria (center pivot irrigated, on farms 100 acres or larger) and this will increase to 4.3 million acres by 2032, primarily because of increased adoption of center pivot irrigation on existing acreage.
- **The current baseline and forecast of future adoption is dependent upon the definition of "decision supported based irrigation".**
    - Navigant has used a loose definition that includes any systems that integrate information from multiple sources and provide irrigation decision support to growers, because such systems would likely capture much of the water and energy savings of the most comprehensive systems such as NEEA's IIDS. This results in a current adoption level of 0% and a forecasted adoption level of 18% of acreage meeting NEEA criteria in 2032 (approximately 0.8 million acres).
    - A stricter definition that includes only systems as comprehensive and user-friendly as the anticipated NEEA IIDS would lead to a much lower baseline over time because Navigant does not anticipate any products like this entering the

market in at least the next few years. Navigant's forecast of adoption of sub-field level tools (0% to 10% of irrigated acreage in 2032) would be a reasonable proxy for this, as the use of tools such as variable rate irrigation would require integration of information and automated irrigation decision support.

- **An influence model of integrated decision support adoption would aid NEEA in estimating the effects of their initiative.** The model could be used for scenario analyses to address uncertainty in market drivers such as water availability and commodity prices. It could also be used during and after the initiative to determine *ex post* program impacts.

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Appendix A. Secondary Data Collection

To: Steve Phoutrides, Geoff Wickes, Lori Rhodig, NEEA

From: Ryan Firestone, Barrett Mooney, Wayne Leonard, Navigant Consulting

Date: July 23, 2012

Re: Northwest Agricultural Irrigation Market Characterization and Baseline Study: Secondary Data Collection and Review

The attached report summarizes Navigant Consulting, Inc.'s (Navigant) secondary research on irrigation technologies in Idaho, Oregon, and Washington in support of Navigant's effort to establish a baseline forecast for irrigation technologies. The focus of this research is on center pivot irrigation systems and the technologies and strategies used to make decisions about watering timing and quantities.

In this report, Navigant identifies areas where additional secondary research is needed, as well as data gaps that Navigant will attempt to fill through interviews with regional experts and market actors.

This is a revised draft of the initial memo submitted on July 6, 2012. It has been revised to reflect comments from Steve Phoutrides and to include more data on the distribution of types of crops in the three-state region.

A.1 Overview of Research Completed and Sources Reviewed

This report summarizes the secondary research conducted by Navigant Consulting, Inc. (Navigant) for the Northwest Energy Efficiency Alliance (NEEA) on the subject of irrigation market characteristics and baseline[19] trends in Idaho, Oregon, and Washington (the three-state region). Navigant used secondary data sources to identify historic regional irrigation practices and trends, and will conduct primary research to determine current conditions and near term trends. This research focuses on center-pivot irrigation systems and the controls and strategies that growers use to determine the amount of water used for irrigation.

As stated in Navigant's work plan for this project, "Relevant data include:

- Size/trend of agricultural irrigation market in terms of acres irrigated;
- Technology and metrics in use or of interest to irrigation efficiency
  - e.g. soil mapping, soil moisture monitoring, plant-stress monitoring
- Types of crops irrigated and current irrigation practices including but not limited to: Scientific Irrigation Scheduling, Infrared Irrigation Scheduling and Deficit Irrigation
- Disaggregation of estimates by variables including crop type, climate region, effective pumping head (e.g., less than 100 feet and greater than 100 feet)."

[19] For this project, "baseline" refers to the market for irrigation technologies and strategies in the absence of intervention from NEEA.

NEEA has requested a twenty-year forecast of the irrigation baseline. Given this long term interest, Navigant has focused its analysis on long-term trends, rather than short term volatility such as that caused by commodity price volatility.

Navigant has developed a workbook of collected secondary data, which they used to develop this memorandum. Navigant will provide this workbook to NEEA and will provide an updated version of the workbook when the primary data collection and analysis has been completed.

Secondary Sources Reviewed

Navigant used the U.S. Department of Agriculture National Agricultural Statistics Service (NASS) Census of Agriculture Farm and Ranch Irrigation Surveys (FRIS) to determine irrigation market characteristics and trends from 1988 through 2008. The USDA conducts these surveys approximately every five years and includes many of the same questions from survey to survey. The collection of periodic surveys provides an excellent source of time series data on characteristics of irrigated land and irrigation technologies.

A significant limitation of the publically available FRIS data is that the USDA posts tabulations of survey results, rather than the full datasets. Navigant therefore could not cross-tabulate survey results to the most relevant specification of the NEEA project. For example, the FRIS indicate the number of acres irrigated, categorized by farm size (Table 2 in the 2008 Survey), and the number of acres irrigated, categorized by irrigation type (Table 4 in the 2008 Survey), yet the correlation between farm size and irrigation type cannot be determined. While NEEA is specifically interested in center-pivot irrigation on farms larger than 99 acres, this type of conditional query cannot be performed on the available data.

Unfortunately, the 2013 Survey results will likely not be available until 2014. Therefore, this analysis does not capture non-linear trends such as acceleration of adoptions that have begun only recently. Navigant intends to fill data gaps such as these through a primary data collection effort consisting of interviews with 10 market actors and experts across the three-state region.

Navigant used additional secondary sources to understand the factors contributing to observed trends in the FRIS data, to develop estimates of current parameter values, and to begin to inform later forecasting efforts.

Section A.13 provides a bibliography of sources used for this research.

A.2 Farm Irrigation in the Three-state Region

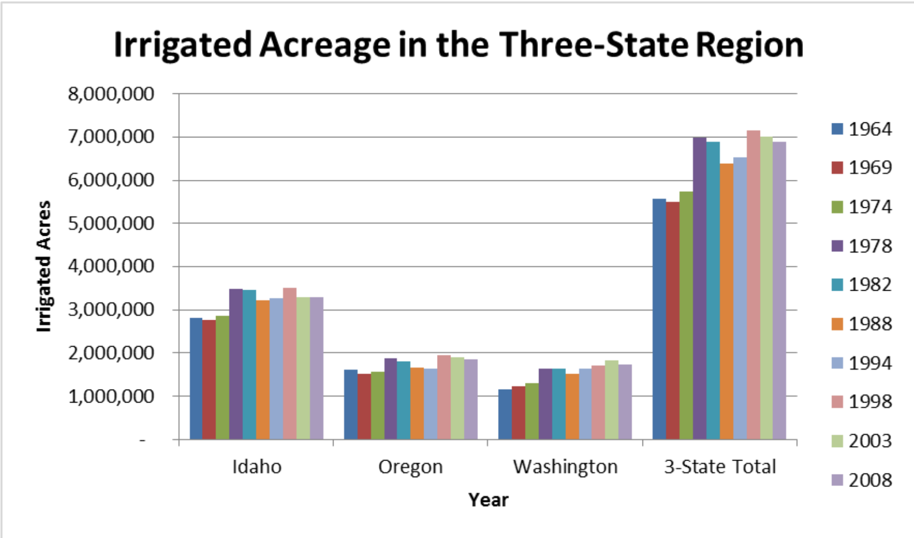
Irrigated Acreage

The amount of irrigated acreage has shown only a slight increasing trend over the past several decades.
Figure 5 illustrates the irrigated acreage in the three-state region from 1964 through 2008. Table 9 lists the average annual growth in acreage and as a percentage of 2008 values for each of the three states. Collectively, the amount of irrigated acreage in three-state region has increased at a

rate of slight.ly less than 0.5 percent per year from 1988 to 2008 and has *decreased* during the period of 1998 to 2008.

Navigant will ask interviewees to estimate current and future changes in irrigated acreage. Navigant will use this data to develop their baseline estimate.

Figure 5. Irrigated Acreage



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Farms in the Censuses of Agriculture*. Survey years 1988, 1994, 1998, 2003, and 2008.

Table 9. Annual Trends in Amount of Irrigated Acreage

	Average Annual Growth (acres per year)		Average Annual Growth (% of 2008 values)	
	1964-1988	1988-2008	1964-1988	1988-2008
Idaho	28,139	3,726	0.85%	0.11%
Oregon	7,897	13,391	0.43%	0.73%
Washington	20,379	12,614	1.17%	0.73%
3-State Total	56,415	29,731	0.82%	0.43%

Source: Navigant analysis of United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Farms in the Censuses of Agriculture*. Survey years 1988, 1994, 1998, 2003, and 2008.

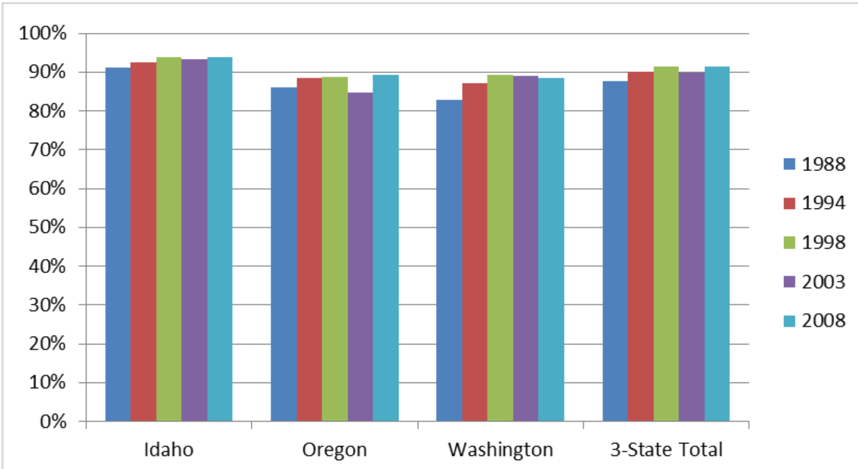
Commodity prices are a primary factor affecting the amount of irrigated acreage in the Northwest. Numerous secondary sources that Navigant reviewed cited commodity price fluctuations as key factors driving short-term trends in irrigated acreage, crop choice, and irrigation methods. During times of relatively low commodity prices, producers tend more towards less irrigation intensive crops. For example, in Oregon, production shifts towards wheat, oilseed, dry beans, and hay [20].

[20] Oregon Department of Agriculture, *State of Oregon Agriculture*, 2010

A.3 Irrigated Acreage by Farm Size

Approximately 90 percent of all irrigated acreage is on farms that are 100 acres or larger. In the three-state region, this percentage has increased only a few points since 1988, from slightly less than 90 percent to slightly greater than 90 percent. Figure 6 illustrates these percentages.

Figure 6. Irrigated Acres on 100 Acre and Larger Farms, as a Percentage of All Irrigated Acres



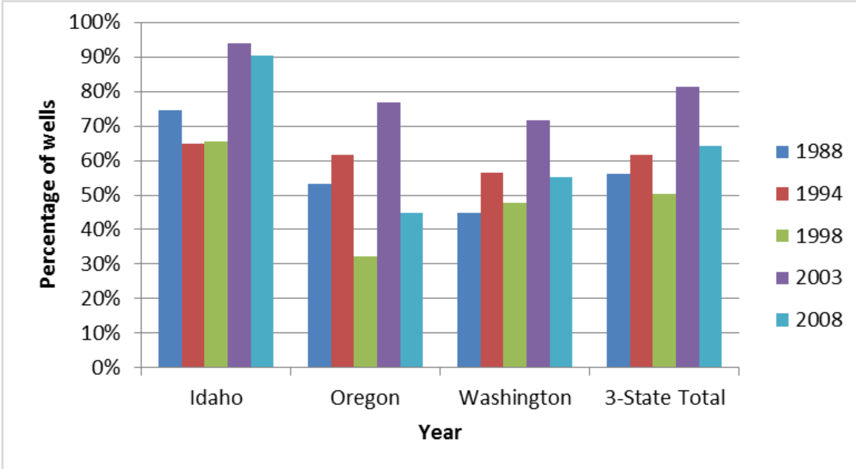
Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Farms by Acres Irrigated*. Survey years 1988, 1994, 1998, 2003, and 2008.

A.4 Irrigated Acreage by Well Depth

Energy savings from water savings on farms are proportional to the pump heights required to provide water on the farm. The FRIS includes information on the count of irrigation wells by depth of pumping height, although the wording and contents of these data tables have varied from survey to survey. Figure 13 illustrates the percentage of wells with a pumping height of 100 feet or greater. Note that there has been significant variation in this percentage from survey to survey, which will make a forecast of future pump height difficult to develop. Generally, though, roughly half of the wells used for irrigation had pump heights of at least 100 feet. In Idaho, 90 percent of the wells had a pump height of at least 100 feet.

In addition to the volatility of this metric over time, it is unclear from the FRIS data how many acres are irrigated by each pump or if there is a correlation between the acres covered and the pump height. Navigant will explore this topic further through additional secondary research and through the interviews.

Figure 7. Percentage of Wells with a Pumping Height of 100 Feet or Greater



Source: Navigant analysis of United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Wells Used on Farms by Pumping Depth*. Survey years 1988, 1994, 1998, 2003, and 2008.

A.5 Irrigated Acreage by Crop Type

The baseline of irrigation technology usage is tied to the types of crops that are being grown. The FRIS includes questions on the topic of the acreage and average water consumption by crop. There is a considerable amount of data for numerous crops across the surveys, including the acreage (disaggregated by non-irrigated, gravity fed, and sprinkler irrigated) and the average amounts of water applied per acre. Navigant has included much of this data in the database accompanying this memorandum. Common irrigated crops in the region include corn for fodder, alfalfa, hay, wheat, barley, potatoes, and sugar beets. Table 4 shows the historical and forecasted relative distribution of irrigated acreage, by crop type, in the three-state region. Values from 1988 to 2008 are derived from data in the USDA FRIS. Navigant estimated the values for 2012 and 2032 based on responses from regional respondents. Assuming current conditions remain, regional respondents did not think that the distribution of acreage by crop type would change from the 2012 levels. However, these respondents noted that distributions are governed by unpredictable factors such as commodity prices and government policy as much as by observable trends.

Table 4 summarizes the relative distribution of irrigated acreage by crop type, and Table 11 summarizes the relative distribution of acreage irrigated by gravity and pressure systems, by crop type.

Table 10. Relative distribution of irrigated acreage, by crop type, in the three-state region

	1988	1994	1998	2003	2008
Alfalfa and alfalfa mixtures for hay or dehydrating	16%	17%	19%	22%	20%
Wheat for grain	13%	14%	13%	14%	15%
Pasture	12%	11%	11%	13%	13%
Other hay, including wild or native hay	6%	7%	8%	10%	12%
Land in vegetables	4%	4%	4%	3%	10%
Irish potatoes	8%	8%	9%	8%	7%
FRIS "Other" Crops	4%	4%	5%	5%	5%
Barley for grain	7%	6%	6%	7%	5%
Land in Orchards	4%	3%	4%	4%	3%
Sugar beets for sugar	2%	3%	4%	4%	2%
Beans, dry edible	3%	2%	1%	1%	1%
Crops not tabulate	22%	20%	17%	9%	7%

Table 11. Percentage of irrigated acreage in the three-state region that is irrigated by pressure systems

	1988	1994	1998	2003	2008
Alfalfa and alfalfa mixtures for hay or dehydrating	71%	74%	76%	78%	86%
Wheat for grain	82%	88%	86%	84%	88%
Pasture	32%	27%	30%	31%	43%
Other hay, including wild or native hay	26%	33%	20%	45%	41%
Land in vegetables	73%	77%	85%	77%	93%
Irish potatoes	96%	96%	96%	94%	98%
FRIS "Other" Crops	67%	74%	76%	76%	89%
Barley for grain	76%	77%	88%	85%	91%
Land in Orchards	90%	95%	90%	94%	100%
Sugar beets for sugar	51%	82%	91%	90%	83%
Beans, dry edible	28%	46%	59%	57%	57%

Source: Navigant analysis of United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Method of Distribution by Selected Crops Harvested*. Survey years 1988, 1994, 1998, 2003, and 2008.

A.6 Center Pivot Irrigation

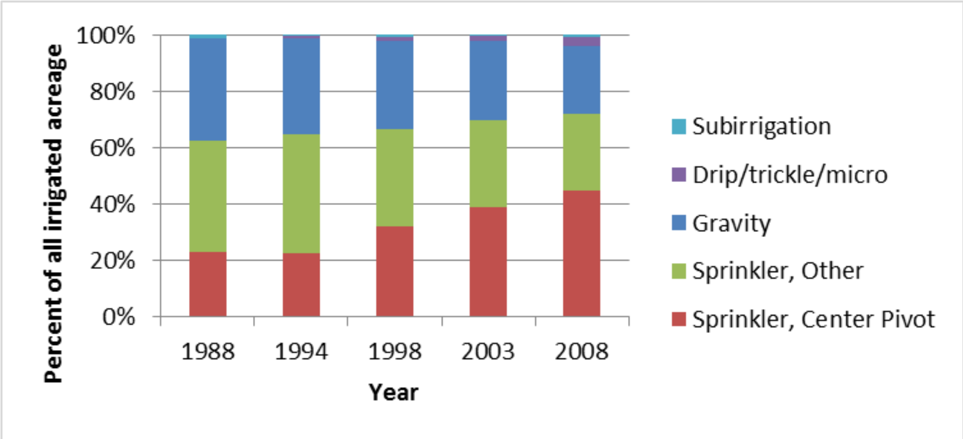
Center pivot technology originated in the U.S. Midwest in the 1950s as an economic method of irrigating large fields. Wide-scale adoption began in the early 1970s and has been ramping up since then. The industry considers center pivot irrigation the flagship for precision and efficient irrigation equipment for large farms with crops in rotation. Center pivot irrigation is becoming a larger portion of the irrigation market; center pivots irrigated 47 percent of irrigated acreage in the three-state region in 2008. This increase in market share has been at the expense of other types of sprinkler irrigation[21] and of gravity fed irrigation systems, as illustrated in Figure 8, and Table 12 illustrate the corresponding increase in center pivot irrigated acreage in the region;

[21] Other types of sprinkler irrigation include other mechanically moved systems such as linear and wheel move systems, hand move systems, and solid set and permanent sprinkler systems.

since 1994, center pivot irrigated acreage has increased at rate of approximately 100,000 acres per year. Increased use of center pivots in Idaho has contributed the most to this trend.

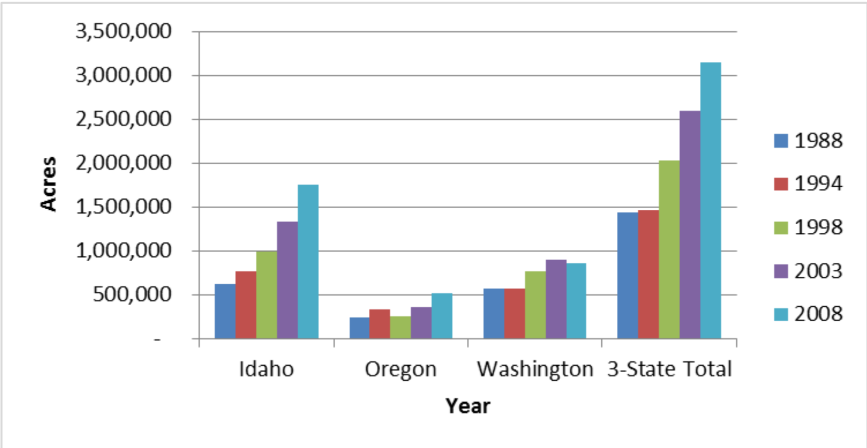
Navigant will ask interviewees about the limits to center pivot irrigation market share, and the expected time frame over which those limits might be reached.

Figure 8. Distribution of Irrigation Types in the Three-State Region



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Land Irrigated by Method of Water Distribution* and *Land Irrigated by Sprinkler Systems*. Survey years 1988, 1994, 1998, 2003, and 2008.

Figure 9. Acres Irrigated by Center Pivots in the Three-State Region



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Land Irrigated by Sprinkler Systems*. Survey years 1988, 1994, 1998, 2003, and 2008.

Table 12. Acres Irrigated by Center Pivots in the Three-State Region

	1988	1994	1998	2003	2008	annual increase (1994 to 2008)
Idaho	625,299	776,081	1,001,607	1,333,589	1,758,277	70,157
Oregon	246,819	337,270	256,678	367,743	525,061	13,414
Washington	573,835	578,414	773,788	905,233	866,116	20,550
3-State Total	1,445,953	1,691,765	2,032,073	2,606,565	3,149,454	104,121

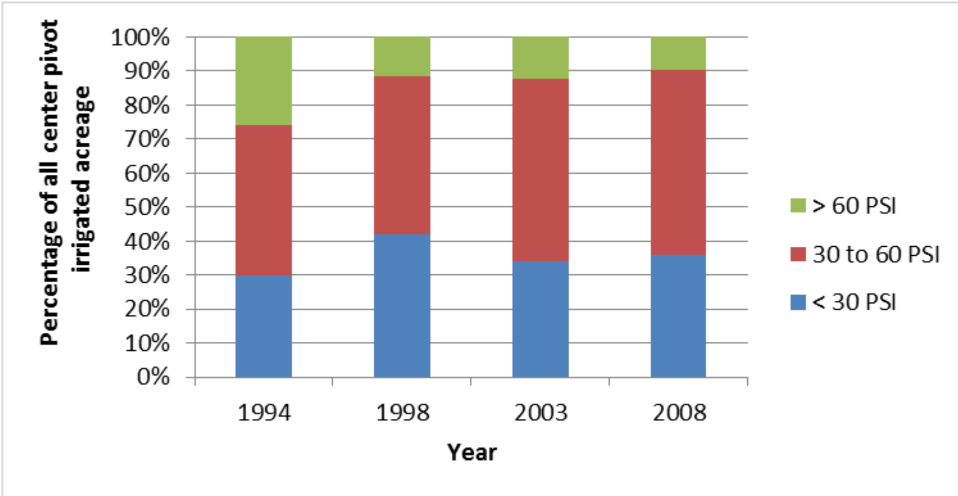
- Continued growth in the center pivot sales is expected. Center pivot technology is growing in popularity for a variety of reasons.
    - Demonstrated performance – Center pivots are now an established technology that have demonstrated cost savings and irrigation precision relative to other irrigation methods
    - New, younger decision makers – Navigant has observed anecdotal evidence that as a younger generation transitions to farm management, their farms become more open to newer technologies such as center pivot irrigation[22]. Navigant will explore this in the interviews.

Navigant will ask interviewees about limits to center pivot's share of the total irrigation market to understand how long the growth in center pivot market share can continue.

Center pivots can be categorized by their pressure levels, which roughly correspond to spray heights. Since 1994, when the FRIS included three pressure levels, the proportion of high pressure systems (> 60 PSI) has declined, the proportion of medium pressure systems (30 to 60 PSI) has increased, and the proportion of low pressure systems (< 30 PSI) has not changed much. This is illustrated in Figure 10.

[22] Irrigation Advances published by Zimmatic in Spring of 2011interviewed a dealer in Paul Idaho. The interview identifies south-central Idaho as a continually growing market for center pivots, especially as a younger generation begins to transition into managing the family farm. The market is growing in Idaho for progressive, capitalized farmers that for labor saving technologies that make their operation more convenient.

Figure 10. Distribution of Center Pivot Irrigated Acreage by Pressure Level in the Three-State Region



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Land Irrigated by Sprinkler Systems*. Survey years 1988, 1994, 1998, 2003, and 2008.

A.7 Farm Expenditures for Irrigation Equipment, Machinery, and Computers

Expenditures for irrigation equipment and machinery were relatively constant over the examination period (1988 to 2008) near $42/acre (in 2011$) until a large increase in 2008 to $67/acre. Navigant will ask their interviewees if 2008 was an anomaly or if there is an increasing trend in irrigation equipment and machinery expenditures. The increase in expenditures in 2008 was driven primarily by a large increase in expenditures in Washington, although expenditures in Idaho and Oregon both increased from approximately $40/acre to $53/acre from 2003 to 2008. Computer expenditures were first recorded in the 1998 Survey, and increased from $8/acre (in 2011$) to $10/acre between 1998 and 2008. The rapid improvements in computer costs and capabilities may have motivated increased computer spending since 2008; Table 13 summarizes this data.

Table 13. Farm Expenditures for Irrigation Equipment, Machinery, and Computers in the Three-State Region

	Expenses per Acrce (nominal $)	Expenses per Acrce (2011$)	% Replacement	% Water Conservation	% New Expansion
Irrigation Equipment and Machinery					
1988	$22	$42	75%	4%	21%
1994	$30	$43	82%	4%	14%
1998	$27	$35	87%	6%	8%
2003	$36	$42	77%	8%	15%
2008	$65	$67	81%	7%	13%
Computers					
1998	$6	$8	*	*	*
2003	$8	$9	27%	22%	51%
2008	$9	$10	37%	54%	9%

** Computer expeditures were first tracked in the 1998 Survey and were not categorized until the 2003 Survey*

Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Expenditures for Irrigation Equipment, Facilities, Land Improvement, and Computer Technology*. Survey years 1988, 1994, 1998, 2003, and 2008.

Given the rapid change in expenditures recently, likely due to the increased prevalence and economy of computing, Navigant decided that an update to this data based on interviews with regional market observers would be unreliable. Similarly, given these changes, Navigant decided that translating dollars spent into irrigation practices would not be feasible.

A.8 Irrigation Water Control

Growers use a variety of tools and strategies to determine the timing and volume of water applied to fields[23]. In many simpler operations decisions on when to irrigate are based on look and feel of the soil or crop and an estimate of crop response to very recent weather events. However, several factors have increased the value of advanced tools and strategies that can provide increased yields and reduced water consumption. These factors include increased farm sizes, higher commodity prices, and higher yield crop species. The move to precision irrigation systems such as center pivot has improved the ability of growers to implement advanced tools and strategies.

Tools for Determining Irrigation Rates

Table 14 summarizes the percentage of farms using each identified type of decision making tool. Note that some farms indicated multiple methods; the sum of the percentages in each column therefore exceeds 100 percent. Also note that the USDA reports results by farm, not by irrigated acres, so that any correlation between farm size and tools (e.g. larger farms using more sophisticated tools) cannot by determined from this dataset. Findings include:

[23] Here, Navigant defines "tools" as technologies that provide information on the condition of crops and soil. Navigant defines "strategies" as decision-making approaches, which are *informed* by the information provided by tools.

- The predominant tools have consistently been an assessment of the condition of the crops (approximately 75 percent of farms use this method) and the feel of the soil (approximately 45 percent of farms use this method).
- Personal calendars have become increasingly popular; in 2008 32 percent of farms reported using this method.
- The use of soil moisture sensors has increased slightly to 9 percent in 2008.
- Technological improvements such as evapotranspiration reports, plant moisture sensors, and computer simulation are relatively new to the industry and are used by relatively few farms.

Table 14. Irrigation Decision Making Tools Used in the Three-State Region

	1987	1994	1998	2003	2008
Any method	96%	96%	100%	100%	100%
Condition of crop	71%	72%	73%	76%	75%
Feel of soil	47%	45%	47%	40%	42%
Soil moisture sensors	6%	8%	6%	4%	9%
Plant moisture sensors	0%	0%	0%	0%	2%
Commercial or govermental scheduling service	2%	3%	3%	6%	6%
Evapotranspiration reports	0%	0%	0%	5%	7%
Scheduled by water delivery organization	13%	23%	11%	14%	14%
Personal calendar	14%	16%	16%	23%	32%
Computer simulations	0%	1%	0%	0%	2%
Neighbors	0%	0%	0%	8%	7%
Media reports	5%	4%	0%	0%	0%
Other	6%	8%	3%	10%	11%

Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Methods Used in Deciding When to Irrigate*. Survey years 1988, 1994, 1998, 2003, and 2008.

Navigant was unable to determine the proportion of farms using *at least* one of the more sophisticated tools because the FRIS question allows for multiple responses per respondent, and the FRIS report only shows the total number of positive responses to each tool. For example, it is not possible – using the FRIS report – to determine the percentage of farmer who use evapotranspiration reports and also use soil moisture sensors.

A.9 Strategies for Determining Irrigation Rates

Determining how much water to apply to crops requires a strategy in addition to the tools used to determine the conditions of crops and soil. Strategies include detailed analysis of collected data from multiple sources to precisely determine water needs and scientific approaches to the timing of watering relative to a plants water needs. Modern irrigation technologies such as center pivots have enabled variable-rate irrigation strategies, which apply non-uniform rates of irrigation across fields to reflect spatial differences in water needs.

Findings from Navigant's secondary research include:

- Several technologies using advanced soil and crop moisture balances have been released since 2007 and continue to gain exposure. Irrigation system vendors package these decision systems with the installation of new irrigation equipment, but the third party vendor market has been retrofitting existing machines. These proprietary systems utilize a soil moisture balance, weather tracking, and estimated evapotranspiration (ET) of the crop to inform the farmer on when to irrigate. These systems offer advanced features utilized by farmers to control the irrigation equipment remotely and analyze water application data via the web and smart-phone notifications.

- In 2010 the American Society of Agricultural and Biological Engineers (ASABE) published a report on integrated decision support for sprinkler irrigation technologies. The decision systems required a variety of onsite and remote measurements to achieve the highest efficiencies. ASABE authors noted much of the industry research has been applied to hardware and controls technologies, neglecting the agronomic details needed to achieve high yields under limited water resource conditions.

- An Othello, Washington farmer publicized in *Irrigation Advances* reports using Zimmatic's FieldNET© system to control 8 center pivots. The farmer retrofitted 1,000 acres previously under flood irrigation to use advanced water pumping technology and center pivot units. The package installed included variable frequency drives at the pumping station, electronic butterfly valves, and a controls package. This system allows the farmer to control and track water application electronically. The estimated 13,000 man hours saved by this system is attracting a lot of attention from neighbors.[24]

Scientific Irrigation Scheduling

In 2010, Navigant evaluated Bonneville Power Administration's (BPA) Scientific Irrigation Scheduling Program (SIS). As described by BPA, "scientific irrigation scheduling provides information on when to irrigate, how much water to apply, and how to apply water to satisfy crop water requirements and avoid plant moisture stress. When used appropriately, irrigation scheduling saves water, energy, labor, and fertilizer, and in many cases improves crop yields and crop quality.[25]" The evaluation of this program serves as a case study for the adoption of other water saving irrigation technologies.

Navigant found that when utilities contacted additional growers in the area to increase participation, 50 percent to 80 percent of the growers were already aware of both the SIS practices and the incentive program provided by their utility. However, there are few growers implementing SIS without participating in a cost sharing program and it is unlikely that participants in BPA's SIS program are continuing or expanding use of SIS without incentives. Although many farmers are aware of the benefits of SIS, many farms rely on short term bank loans to float seasonal expenses and banks are unwilling to cover non-capital investments.

[24] Irrigation Advances, Summer 2009
[25] Bonneville Power Administration website, *Agriculture Sector* page. http://www.bpa.gov/energy/n/agriculture.cfm

Although it is unclear how many farmers would take the initiative to implement SIS without incentives, it does appear that many potatoes growers may be willing to invest in added monitoring due to two factors: 1) the high value of the crop justifies the expense even if it results in relatively small increases in productivity and 2) the irrigation data requirements from potato buyers is already driving those farms to more closely monitor water application. For example, Simplot is a large agribusiness firm that purchases raw foods to create processed meals; they require irrigation records from their contracted potato farmers.

Some wine grape buyers require irrigation records because the amount of water supplied to the grape vines during their growth can alter the quality and flavor of the grapes.

Additional findings from the study include the following:

- Growers who are familiar with SIS practices are more inclined to use them as they readily see the benefits from controlling water usage.
- In addition to the added monthly costs, growers often require two or three seasons to become accustomed to the SIS process. Regional farm service providers (irrigation specialists, fertilizer sales reps, etc.) and annual product expos are an essential link between new technologies and farmers. These groups act as educators and promoters for new technologies.
- Most non-energy benefits are not quantified by service providers but they are verbalized by growers who note the changes in crop quality when properly using SIS. One quantifiable benefit of better water management is the reduced use of fertilizer during the growing season.
- Growers' feedback to the utilities and service providers about their experiences with SIS typically reflects satisfaction with the improved quality of their crops and appreciation for having someone to assist them with the equipment and monitoring procedures.

Deficit Irrigation

Deficit irrigation is a strategy that provides sufficient irrigation at drought-sensitive times in the plant growth cycle yet allows plants to be stressed at other times in the growth cycle. Plant stress has been shown improve the water productivity of irrigation and to increase yields in some cases. Farmer's adoption of other irrigation strategies like deficit irrigation had been met with mixed success. An article published by Washington State University (WSU) extension agents in 2011 suggests water stress reactions differ significantly by crop and cultivar.

Variable Rate Irrigation

Irrigation suppliers also market the energy and water savings benefits of variable rate irrigation. A recognized industry motivator is labor savings, as outlined by University of Georgia scientists in the *Western Farm Press.* This technology can reduce water use in a field by as much as 15 percent annually, but is complicated to program and cost between $5,000 for a modular system and $30,000 for a large full system. [26]

[26] *http://westernfarmpress.com/irrigation/irrigation-pivots-much-improved-variable-rate-upgrades?page=2*

Navigant has not found any evidence in their secondary research of any significant adoption of variable rate irrigation, despite the capabilities of irrigation technologies (including center pivots) to implement these strategies in an automated fashion. Navigant will ask interviewees about the prevalence of variable rate irrigation capabilities and of the usage of these capabilities.

A.10 The Irrigation Technology Market

The irrigation technology market is comprised of buyers and sellers: buyers are growers that can benefit from the water savings, increased crop yields, and reduced labor costs that improved irrigation technologies can achieve. Sellers are the manufactures and vendors of this equipment, computer hardware and software, and information services.

Manufacturers and Vendors

Five manufacturers dominate the center pivot and lateral move irrigation equipment market:

- Lindsay Corporation (Zimmatic © brand),
- Pierce Corporation,
- Reinke Manufacturing Company (Electrogator© brand),
- T-L Irrigation Company, and
- Valmont Industries (Valley © brand).[27]

Valmont sells nearly half of the center pivots in the market, on a unit basis. Each brand offers design assistance and automated control features. Irrigation supply companies market products by advertising in trade magazines, visiting trade shows, educating regional sales staff, and publishing independent newsletters and magazines available in print and online.

The agronomic information industry creates partnerships with the center pivot market to provide decision support systems and automated controls. Companies range from equipment companies, like AgSense to full-service companies, like CropMetrics. Each offer packages for irrigation tools related to weather, yield forecasts, and GPS enabled remote management. CropMetrics and others, like PureSense specialize in advanced yield analysis. They provide web-based software and data processing. These full service agronomic technology companies have been successful in the Midwest, but are not as widely publicized in other parts of the US. CropMetrics has recently partnered with Valley to offer a single package offering to clients interested in precision agriculture in an effort to expand the market using the agronomy services. These industry partners are still growing their presence in the market, but as variable rate irrigation gains in popularity so will the automated decision systems.

Third party irrigation system vendors also influence a large number of sales in precision agriculture equipment. Area retailers have a unique knowledge of their service territory and have established relationships with the local market over many years. Vendors of large farm equipment in many areas now possess the staff necessary to evaluate, design, and install custom irrigation systems. The new vendor outlets derive most income during the growing season from

[27] ASABE, Does Center Pivot Irrigation Have a Future to Continue to Meet the World’s Needs for Efficient and Precise Irrigation?, December 2012

field repairs, and from sales of irrigation equipment and heavy machinery during the offseason. Vendors also provide after-sales support to customers[28].

A.11 Factors Affecting Irrigation Technology Adoption

The adoption of irrigation technologies including center pivot systems, integrated information systems, and variable flow controls is dependent on a variety of factors, including cost-effectiveness, opportunity costs of water usage, perceived risk, availability of capital for investment in upgrades, and the lifetime of existing equipment.

Cost effectiveness

Irrigation technologies are adopted because of the improvements they offer to the economics of operations. Benefits of these systems may include water, energy, and fertilizer savings; energy savings; improved yields; and labor savings. Cost effectiveness is increased when the value of these savings increases.

- Higher costs of water and energy drive the new irrigation technology into the market. Conversely, areas with relatively low energy costs and low marginal costs for water provide less of an incentive to save water.

- High pump lift areas contribute to increased market adoption where energy prices are significant. For example, Oregon State Extension Service conducted an analysis on a region of the Upper Klamath Basin. The study discovered a 27 percent rise in energy costs in the region would make 193,000 acres, out of the 430,000 irrigated acres in the region, unprofitable. The study also suggests the operators of the 193,000 acres would be more likely to adopt sprinkler energy and water saving measures to reduce their pumping costs.[29]

- An article on center pivot technology in the Western Farm Press quoted a farmer as saying, "The cost and the availability of labor is the No. 1 reason we are using center pivots…It costs us 25 percent less in labor to get a stand with the pivot than with hand lines. There is a huge amount of labor in germinating a field of carrots with hand lines…You literally have to have a solid set of sprinkler hand lines to germinate a seeded carrot field.[30]

Perceived risk

Technology adoption generally follows the dissemination of information about the technology. In the case of agricultural technologies, information dissemination can be slower than in other industries. One reason for this is the annual periodicity of agricultural events; a minimum of a

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[28] *http://www.farm-equipment.com/pages/Features---Selling-Precision-Ag-Demands-Focus.php*
[29] Oregon State University Extension Service, Energy Pricing and Irrigated Agriculture in the Upper Klamath Basin, July 2004
[30] *http://westernfarmpress.com/irrigation/center-pivots-gain-favor-west*

year is required to demonstrate the effectiveness of a technology, and typically several years for growers to be convinced of a technology's merits. Additional time is required for high capital costs to be worked into the grower's budget.

In order to forecast the baseline for water saving irrigation technologies, Navigant will need to estimate the pattern of adoption for these technologies. This will be based on typical adoption patterns seen in the agriculture industry for technologies of similar costs. Navigant will include questions on this topic in the interview guide and will also conduct addition secondary research to develop this estimate.

Opportunity Costs and Access to Capital

Where water scarcities have led to the establishment of water rights, growers face opportunity costs to using water. The value of saved water to a grower may not be the cost of the water, but rather the cost of lost productivity from not using the water elsewhere on the farm. Water savings can become particularly valuable in these situations.

Additionally, the limited availability of capital on a farm creates another opportunity cost. Investments in irrigation technologies and upgrades may be at the expense of investments in other machinery and systems on the farm, or at the expense of expanding the farm or the irrigated acreage of the farm. In some cases, there may be insufficient access to capital for any significant improvements.

Equipment Lifetime

Irrigation systems can last many decades. Some older operating center pivot systems are 30 years old. For growers that are hesitant to retire equipment early, the lifetime of existing equipment creates a limit on technology adoption rates.

A.12 Summary

This report summarizes Navigant's secondary research findings to date. The quantitative findings are from the time series of FRIS. Key findings include:

- Acreage irrigated by center pivots in the three-state region has increased rapidly (approximately 100,000 acres/year from 1994 to 2008). Center pivots irrigated nearly half of all irrigated acreage in the three-state region in 2008.
    - The increase center pivot coverage is due primarily to the increased market share of center pivot irrigation. This has been at the expense of other sprinkler systems and gravity fed systems.
- Irrigated acreage in the three-state region has fluctuated slowly.
- In 2008, roughly 90 percent of center pivot systems operated at 60 psi or below. There has been a decreasing trend in higher pressure systems.
- 90 percent of irrigated acreage is on farms that are 100 acres or larger
- In 2008, 2/3 of irrigation wells in the three-state region had a pump height of at least 100 feet. This proportion has fluctuated significantly from survey to survey, though.

- The large majority of farms are not using sophisticated tools such as evapotranspiration, computer simulation, or moisture sensors to determine water needs. None of these tools were used by more than 10 percent of farms as of 2008.

This report also identifies many gaps in the knowledge necessary to forecast baseline irrigation technologies and practices. Navigant will collect much of this information by interviewing regional experts and market actors. Knowledge gaps include:

- Recent trends in metrics tracked through FRIS. The most recent FRIS was 2008.
- Forecasted trends in metrics over the next twenty years.
- Correlations between factors of interest in the FRIS data, such as farm size, pump height, and irrigation characteristics.
- Usage trends for irrigation strategies such SIS, deficit irrigation and variable rate irrigation.
- Manufacturer plans for product development and marketing in the coming years.
- Technology diffusion patterns for comparable agricultural technologies.

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Appendix B. Appendix B. Primary Data Collection

To: **Steve Phoutrides, Geoff Wickes, Lori Rhodig, NEEA**

From: **Ryan Firestone, Barrett Mooney, Robert Russell, Wayne Leonard, Navigant Consulting, Inc.**

Date: **October 1, 2012**

Re: **Northwest Agricultural Irrigation Market Characterization and Baseline Study: Primary Data Collection and Review**

The attached report summarizes Navigant Consulting, Inc.'s (Navigant's) primary research on irrigation technologies in Idaho, Oregon, and Washington in support of Navigant's effort to establish a baseline forecast for irrigation technologies. The focus of this research is on center pivot irrigation systems and the technologies and strategies used to make decisions about watering timing and quantities.

In this report, Navigant summarizes the findings from interviews with eight qualified market observers. This memorandum will be updated to include interviews with three manufacturers and/or vendors of irrigation technologies and one interview with a qualified market observer of the California agriculture market, when these interviews are completed.

This report is a revised version of the one that Navigant originally submitted to NEEA on September 6th, 2012. It has been revised to include the results of interviews with three center pivot manufacturers, which had not been entirely completed until recently.

This report summarizes the primary research conducted by Navigant Consulting, Inc. (Navigant) for the Northwest Energy Efficiency Alliance (NEEA) on the subject of irrigation market characteristics and baseline[31] trends in Idaho, Oregon, and Washington (the three-state region). Navigant previously used secondary data sources to identify historical regional irrigation practices and trends. The primary research described in this memorandum is a series of telephone interviews with qualified market observers to discuss current and forecasted trends in the three-state agricultural market. The research also addressed the use of irrigation strategies in the region, which was a knowledge gap identified from the secondary research.

As stated in Navigant's work plan for this project, "Relevant data include:

- Size/trend of agricultural irrigation market in terms of acres irrigated
- Technology and metrics in use or of interest to irrigation efficiency
    - e.g., soil mapping, soil moisture monitoring, plant-stress monitoring
- Types of crops irrigated and current irrigation practices including but not limited to: Scientific Irrigation Scheduling, Infrared Irrigation Scheduling, and Deficit Irrigation
- Disaggregation of estimates by variables including crop type, climate region, effective pumping head (e.g., less than 100 feet and greater than 100 feet)."

[31] For this project, "baseline" refers to the market for irrigation technologies and strategies in the absence of intervention from NEEA.

NEEA has requested a twenty-year forecast of the irrigation baseline. Given this long-term interest, Navigant has focused its analysis on long-term trends, rather than short term volatility such as that caused by commodity price volatility.

Navigant has developed a workbook of collected primary data that is provided along with this memorandum. Navigant will combine this primary data with the secondary data in a single workbook to accompany the final report at the end of this project.

In order to encourage candid interviews, Navigant assured all interviewees that their replies would be kept confidential. As such, Navigant has not identified interviewees in this document. However, Navigant received approval from NEEA on the list of interviewees and has discussed the results of individual interviews with NEEA project staff.

B.1 Research Design

For the interviews, Navigant targeted qualified market observers of agricultural irrigation technologies and practices in Idaho, Oregon, and Washington. Table 3 summarizes the types of qualified market observers that were targeted, and the targeted and completed number of interviews.

Table 15. Interview Targets and Completions

Qualified Market Observer Type	Targeted Number of Interviews	Completed Number of Interviews	Comments
Regional representatives of irrigation control equipment and service providers	3	3	
Irrigation specialists at state agricultural extension services	3	3	
Staff at state agricultural commissions and trade groups	2	2	Contacts deferred to a Ground Water Management Area representative for one of these interviews
Irrigation District and trade association management personnel	1	2	Additional interview completed at the request of NEEA
Northwest Irrigation and Soils Research Lab staff	1	1	
Qualified market observer of another irrigation market	1	0	This was an additional request from NEEA in August. Navigant is attempting to schedule this interview.
Total	***11***	***11***	

The Navigant team developed a detailed interview guide for these telephone interviews, and worked with the NEEA staff to ensure that NEEA topics of interest were appropriately addressed in the guide. The Navigant team provided the interviewees with graphics from this guide beforehand (via email) to reference during the interviews. The interview guide is provided as Appendix A to this memorandum.

The Navigant team completed most of these interviews in August 2012. Two additional interviews are expected to be completed in September, in time for inclusion in the final report.

B.2 Summary of Findings

This subsection contains a high-level summary of the Navigant team's findings. A more detailed discussion and interview results are provided in the following sections of this memorandum. Each section includes a table summarizing the responses to the topic of that section. The font size of these tables is relatively small to fit on the pages of this memorandum. These same tables are provided in the accompanying Excel spreadsheet for easier viewing.

A distinction is made between "regional" respondents and "manufacturer" respondents. Regional respondents are those that were interviewed because of their knowledge of irrigation practices and prevalence in the three-state region. Manufacturer respondents are representatives of center pivot manufacturers.

- **Irrigated Acreage** – The amount of irrigated acreage in the region has changed little, if any, from 2008 to the present. It is expected to remain the same or decrease up to 10% over the next 20 years due to anticipated reductions in water availability, competition for water from non-irrigation purposes, and competition for land from urban sprawl.
- **Farms Larger than 100 Acres –** Farms larger than 100 acres represent more than 90% of the irrigated acreage in the three-state region. This percentage is expected to stay the same or increase up to five percentage points in the next 20 years. Several regional respondents indicated that independent farmers typically need several hundred acres to make a living farming.
- **Well Depth** – The large proportional increase in wells with a pump height greater than 100 feet in the 2003 Farm and Ranch Irrigation Survey (FRIS) was likely due to a drought and lowering of water table levels. Regional respondents offered a range of forecasts for how this proportion would trend over the next 20 years, although no regional respondents forecasted a change of more than 10 percentage points from current levels. Uncertainty in this metric translates into uncertainty in NEEA's target market (farms with 100 feet of lift or more and 100 acres or larger.).
- **Crop Distribution** – The dominant trend affecting irrigated agriculture has been the increase in dairy cows in the region, which has resulted in an increase in corn and other feed for these cows. This is particularly apparent in southern Idaho. From 2008 to 2012, this trend has shifted the distribution of acreage several percentage points in favor of feed and fodder crops, and away from other types of crops. However, no additional shifts are expected in the absence of unpredictable events such as changes in policy, commodity prices, or land values.
- **Irrigation System Types** – Nearly 50% of irrigated acreage in the NW is irrigated by center pivot (CP) sprinkler systems. The market share of these systems in increasing at a rate of one to two percentage points per year, at the expense of other pressure systems and of gravity systems. CPs will likely eventually irrigate approximately 80% of irrigated acreage. Benefits of CPs relative to other pressure irrigation systems include improved ease of farming, labor savings, water and energy savings, improved chemigation and

fertigation capabilities, and flexibility in crop selection. Potato purchasers often *require* the use of precision systems such as CPs.

- **CP Appropriateness** – CPs are not appropriate for some of the common crops in the three-state region, including orchard crops, grapes, tomatoes, cucumbers, seed crops, and some beans. Perhaps 10% of irrigated lands in the three-state region are not suited to CPs because of topography or soil types. The capital requirements of CP are a barrier to smaller farms and to land that may be converted to residential land in the near future.
- **Correlation of CP Prevalence to Farm Size and Pump Lift** - In general, larger farms are more likely to have CP. However, above 100 acres, size is not a significant factor in CP prevalence. Regional respondents have conflicting opinions about whether or not CPs are more prevalent where pump heights are greater (several hundred feet of lift) because of the energy savings achieved by water savings.
- **Rarity of Co-Optimizing Yield and Water Usage –** When asked about irrigation strategies, no regional respondent explicitly mentioned water efficiency as a driver in decision making. The current availability of water in the three-state region was generally described favorably. However, several regional respondents did expect water scarcity to be an issue in the future due to foreseen factors such as the drawdown of water tables, climate change, and competition for water from non-irrigation demands such as ecological preservation.
- **Planning Strategies -** Planning strategies are used primarily to optimize crop yield and quality. The use of these strategies is likely in the range of 20%. Much of this is concentrated on potato and wheat crops. Nearly all potatoes are grown with an explicit strategy and one regional respondent estimated that 60% of wheat crops are grown using deficit irrigation. It is unclear how much of this wheat was grown in rotation on fields used primarily for potatoes.
    - Regional respondents did not foresee a significant rise in the use of planning strategies in the next 20 years.
    - The types of growers currently using planning strategies are those using it to solve a specific problem, big commercial growers, and some innovative independent farmers.
    - Manufacturer respondents thought that the use of planning strategies is currently in the range of 0 to 20%.
    - Two of the three manufacturer respondents thought that the use of planning strategies would increase significantly in the next 20 years if water for irrigation becomes scarce in the region
    - Center pivot manufacturers do not currently market planning tools. It is possible that at least one of the manufacturers will offer a product within the next few years

- **Farm- and Field-Level Strategies** – Tools such as moisture sensors and evapotranspiration reports are used to make real-time decisions about irrigation quantities on about 10% to 30% of irrigated land, although this varies significantly by area within the three-state region. The use of farm- and field-level irrigation strategies is most common with potato growers. The use of scientific irrigation scheduling is driven primarily by subsidies.

  - There was general uncertainty on the levels of farm- and field-level tool usage in the future.
  - The types of growers currently using planning strategies are those using it to solve a specific problem, trying a new approach (largely driven by subsidies), and large commercial growers.
  - Manufacturer respondents' perceptions of the use of field-level tools varied from "very few" to "most". For reference, in the 2008 FRIS, 9% of growers on irrigated farms reported using soil moisture sensors, 2% reported using plant moisture sensors, and 7% reported using evapotranspiration. It is impossible to tell from the FRIS report how the use of these tools correlates with the size of farms.
  - All three manufacturers currently offer farm and field-level tools, and new products are likely to enter the market in the next few years.

- **Sub-Field-Level Strategies** - The use of sub-field-level strategies such as variable rate irrigation (VRI) in the three-state region is too rare for regional respondents to quantify. No regional respondents indicated any knowledge of VRI systems in use in the NW aside from experimental or demonstration projects.
  - Most regional respondents did not foresee any increased adoption of sub-field-level strategies in the next 20 years because of the adequacy of water supplies, the complexity of tools, and potential for greater and easier water and energy savings from other strategies (planning and field-level tools).
  - The use of sub-field-level strategies would increase under certain circumstances, such as:
    - reductions in water availability
    - increases in energy prices
    - availability of tools that manage and deliver information better than current tools, and are user-friendly
  - Regional respondents could not describe the types of growers that currently use these tools because it is unclear who, if anyone, is using sub-field-level tools.
  - All three manufacturer respondents thought that the current use of sub-field-level tools is currently less than 1% in the three-state region.
  - Two of the three manufacturer respondents thought that use of sub-field-level tools would be significant (33% to 50% of acreage) within twenty years, one respondent thought that there would be no significant market for these products in the next five years.
  - Manufacture product offerings and plans reflect respondents' forecasts of future adoption levels. The two manufacturer respondents forecasting large adoption rates currently offer VRI products and expect to have new offerings next year or in the next few years. The manufacturer respondent that does not see a market for these tools developing in the next five years does not offer any such tools, nor have plans to develop such tools.

- **Data Integration and Decision-Making Tools** - There is currently little to no use of tools to integrate data from multiple sources, or to help farmers make irrigation decisions. Consultants are hired to provide this service, primarily for potatoes. Several regional respondents thought that increasing trends in computing power and usage (e.g., smart phones, iPads) suggested that such tools would be adopted in the next 20 years, but none indicated that any existing tools in the market were moving in this direction (i.e., becoming less expensive, more powerful, and more user-friendly).

- One regional respondent estimated a penetration of 10% to 20% and another estimated a penetration of "optimistically, 20% to 25%."
- None of the three manufacturer respondents thought that any hardware or software tools for data integration or integrated decision making were being used by growers in the region.
- However, one the three manufacturer respondents did note that consultants provide this service, and estimated that about 20% of irrigated acreage was subject to consultants. He estimated that 80% of sugar beet and potato acreage was subject to consultants, and that corn and hay were starting to be subject to consultants because of their recent high commodity prices.
  - The same respondent forecasted that 80% of irrigated acreage would be subject to data integration and integrated decision making in 20 years, and that half of this would be from software and half from consultants.
  - One manufacturer respondent said that his company offered such products, one said that his company was considering developing such a product, and one said that his company had no near term plans to develop such a product.

- **VRI Capabilities** - Most new CPs and some (perhaps 20%) existing CPs have the capability to do speed control operation. Speed control is not frequently used, even when CPs are capable of it; farmers have not seen the benefits that would warrant the use of something so complicated. Few, if any, CPs have the capability to do zonal control.

B.3 Additional Research Needed to Quantify Market Metrics

The primary research described in this memorandum provides a qualitative characterization of the irrigation market in the three-state region. This characterization will inform NEEA's understanding of the energy savings potential from market intervention, and the likely target audience for such intervention.

However, this research does not provide the precise quantitative benchmark from which NEEA could determine the impacts of their market intervention. Statistically rigorous quantification of current irrigation practices would likely require a survey of farmers in the region. The Navigant team recommends that such a survey be stratified by crop type, state (or other geographic section), and farm size. A less rigorous – but less expensive and quicker – approach would be to use a Delphi panel of qualified market observers, such as those interviewed for this study, to develop estimates of irrigation practices for each of the stratifications listed above.

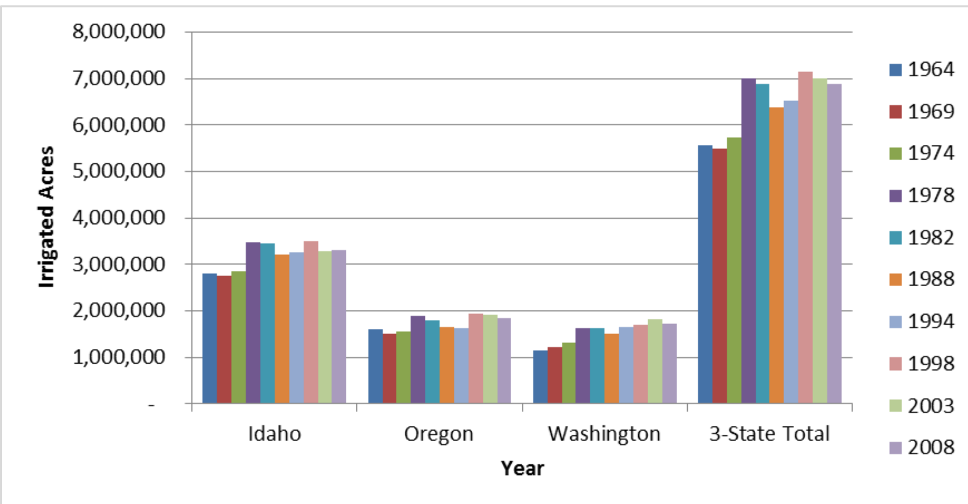
While these methods provide estimates of existing irrigation practices before and after market intervention, they do not provide a forecast of irrigation practices. Estimating future adoption rates of tools that are rare in the market today, under uncertainties in future values of driving factors such as water availability, energy prices, and volatile commodity prices is highly speculative.

One approach to this problem is to develop an influence model of irrigation practices, and to use this model to forecast baseline changes in irrigation practices under a variety of scenarios (e.g., water scarcity, high energy prices). This model can be calibrated to existing conditions and then be used to examine sensitivities to inputs affected by market intervention. This sensitivity analysis can be conducted both prior to intervention (using scenario analysis) and after intervention (using observed market conditions). Development of an influence model would be an analytic exercise informed by interviews with qualified market observers and calibrated to observed market conditions.

B.4 Irrigated Acreage in Idaho, Oregon, and Washington

Regional respondents were shown Figure 2, the historical levels of irrigated acreage in the three-state region, and asked to estimate changes from 2008 to the present (2012). They were also asked to forecast changes to this metric over the next 20 years (through 2032). This topic was not addressed with manufacturers and vendors.

Figure 11. Irrigated Acreage in Idaho, Oregon, and Washington



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Farms in the Censuses of Agriculture*. Survey years 1988, 1994, 1998, 2003, and 2008.

Table 16 summarizes the responses to this set of questions. From these responses, Navigant concludes the following:

- **The amount of irrigated acreage has changed little, if any, from 2008 to the present.**
    - Most regional respondents thought that there had been no change
    - Two (speaking to Washington and Oregon trends only) thought there had been a slight (1% to 3%) increase
    - One (speaking to trends in all three states) thought there had been a slight (1% to 2%) decrease
- **The amount of irrigated acreage is expected to remain the same, or decrease slightly between now and 2032 (relative to 2008 levels).**
    - Three regional respondents could not provide an estimate of the change
    - Three regional respondents thought that there would be no change

    - One regional respondent thought that irrigated acreage in the three-state region would decline by 2% to 3%
    - One regional respondent thought that irrigated acreage in Washington would decrease by 6%
        - This respondent estimated that irrigated acres supported by ground water will decline 10% over the next 20 years, and that 20% to 30% of water used for irrigation in the three-state region is ground water.
- **Conditions favorable to the expansion of irrigated acreage are expected to remain the same or decline in the future.** These conditions include:
    - Water Supply
        - Water is fully allocated in most areas and states are not issuing new water rights.
        - Climate change could reduce the amount stored water in snow pack.
        - Demand for non-irrigation purposes is increasing, and includes the following:
            - Endangered species such as anadromous fish
            - Urban sprawl
    - Land value
        - Urban sprawl converts farmland into residential land. This process happened rapidly during the recent housing boom, during which land in residential areas was more valuable for homes than for farming. Since 2008, however, high agricultural commodity prices have made this land more valuable for farming. Overtime, sprawl is expected to continue, but the rate will be erratic.
    - Irrigation Cost
        - Energy prices are generally expected to increase and could lead farmers to abandon high lift areas. Costs of other inputs may increase, as well. Note that some respondents did not think that energy prices were high enough to drive decisions.
- **None of the regional respondents cited commodity prices as a factor driving the amount of irrigated acreage in the region.**

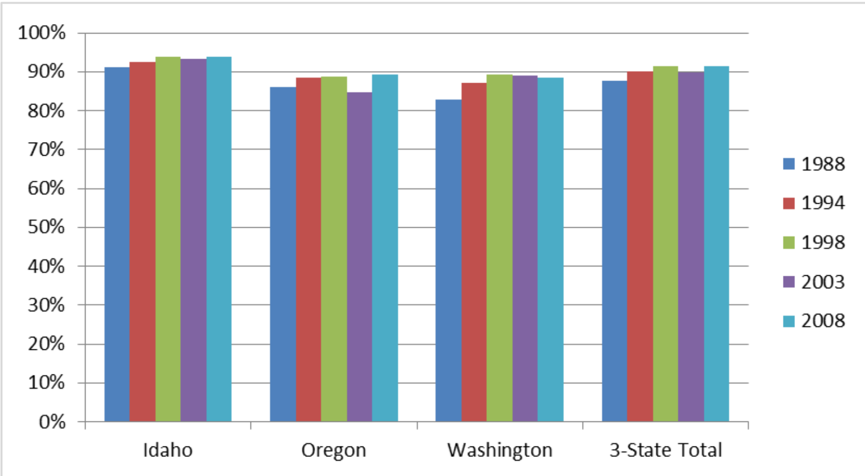
Table 16. Findings on Irrigated Acres

Interviewee	Region of Expertise	Trend (relative to 2008 level)		Comments
		2008 to 2012	2012 to 2032	
#1	ID	0%	0% (+/- 5%)	**2012 to 2032 -** Although the general trend in irrigated acreage has been upward, it is limited by water at this point. The state is not giving out new permits and water sources are fully allocated (even over-allocated), so don't expect much increase. Climate change may decrease water availability if there's less snow pack to store water. However, as energy prices increase, irrigated acreage goes down because growers abandon high lift areas, although some of this abandonment is just a shift to lower lift areas. An increase in the cost of other inputs could also reduce acreage.
#2	ID/WA/OR	decrease by 1 to 2% for all states:	decrease by 2 to 3%	**2008 to 2012 -** Water demand for non-irrigation purposes is greater. Demands include endagered species (e.g. anadromous fish) and conversion of farmland to residential land. **2012 to 2032 -** Competing factors make this pretty stable: 1) conversion of farms to homes and 2) conversion of non-irrigated farms to irrigated farms for increase in yield and decrease in risk. The supply of water is not getting bigger: Surface water in ID is fully allocated and there is a moratorium on well drilling for agriculture. Also, water rights are structured such that you cannot spread your water usage beyond your territory, which alleviates some motivation to save water on some land and spread out to more irrigated acreage.
#3	ID	0%	0%	**2008 to 2012 -** There haven't been any major expansions or declines. There has been some conversion of farmland to homes near Boise, though. **2012 to 2032 -** If current conditions continue, there shouldn't be much change. There will be some decrease from farmland to home conversion. This happened rapidly until 2008, when land was worth more for housing. However, now that commodity prices are high, land is more valuable for farming. Water is an issue. However, water problems are probably more than 20 years away. Idaho has good water resources.
#4	WA and OR	increased slightly	0%	**2012 - 2032 -** This is all based on commodity prices for a grower. They will make decisions as cost changes year to year.
#5	ID/WA/OR	don't know	don't know	**General Comments:** It is too difficult to forecast, it could level out, but it could increase in certain areas. It is very closely tied to biofuels. There is high volatility in the market, and agriculture is very policy driven and regionally focused. The state focuses on the ecological perspective. The American Indian Water Right Settlements relocate water within agriculture. It is getting reassigned for agriculture to native American lease holders. Around 50% of farmers in the west are already using efficient water application systems. USDA hasn't done much about farm water management. However, growing pressures will force agriculture to be more concerned with how water is handled once on the farm.
#6	WA	0%	6% decrease by 2032 3% decrease by 2022 1.5 % drecrease by 2017	**General** - Believes this gragph shows ground water irrigation, not all irrigation [Navigant team reviewed FRIS to confirm that this is all irrigation]. Note, water use for "irrigated acres" is not equal between climate zones. For example, Willamate Valley farmers might only irrigate a handful of times per season while farmers in central WA will irrigate every few days. **2012 to 2032 -** There will be significant losses in irrigated acres due to urban sprawl, and some of that will be made up with new farms. Policy and surface water limitations will keep it from growing. Irrigated acres supported by ground water will decline 10% over the next 20 years. So, given that 20-30% of water sourced in tri-state area is ground water, expect a 3% net decrease from water limitions. And expect an additional 2-3% decrease due to irrigated acres being lost to "alternative use" such as municipal/urban sprawl and industrial uses.
#7	OR	1 - 3% increase	don't know	**General** - Energy cost is not a barrier. However, there are legal barriers to consider. Current legislation over whether more water can be pulled out of the Columbia will play a big role. Policy questions will not be answered in the next few years. The industry might pick up if favorable legislation is passed, but currently it is slow to accelerate.
#8	WA	0%	don't know	**2008 - 2012 -** This has stayed flat because the state (WA) has not issued new water rights. **General -** Some Columbia river projects were charged to find additional water for fish and agriculture. Findings suggest drawing down Lake Roosevelt as the approved method, instead of other projects for aquifer recharge.

B.5 *Irrigated Acreage by Farm Size*

Regional respondents were shown Figure 12, the percentage of irrigated acreage on farms 100 acres and larger as a percentage of all irrigated acres, and asked to estimate changes from 2008 to the present (2012). They were also asked to forecast changes to this metric over the next 20 years (through 2032). This topic was not addressed with manufacturers and vendors.

Figure 12. Irrigated Acres on 100-Acre and Larger Farms, as a Percentage of All Irrigated Acres



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Farms by Acres Irrigated*. Survey years 1988, 1994, 1998, 2003, and 2008.

Table 17 summarizes the responses to this set of questions. From these responses, Navigant concludes the following:

- **The percentage of irrigated acres that are on farms 100 acres or larger has remained the same or increased slightly from 2008 to the present.**
  - Four regional respondents thought that the percentage had increased. Although most could not quantify the increase, they acknowledged that this metric was close to a saturation point.
  - Three regional respondents thought that there had been no change.
  - No regional respondents thought that the percentage had *decreased*.
- **This percentage will stay the same or increase slightly between now and 2032 (relative to 2008 levels), and will stay in the range of 90% of 95%.**
  - Three regional respondents thought that the percentage would increase, and two suggested a saturation point of 92% to 95%.
  - Two regional respondents thought that –absent changes in current conditions – there would be no change.
  - No regional respondents thought that the percentage would *decrease*.
- **Conditions that favor farms larger than 100 acres are expected to remain.** These conditions include:
  - Retirement of small independent farmers and the acquisition of these farms by larger farms

- Independent farmers typically needing at least several hundred acres to make a living
- The increase in very small farms representing a negligible portion of acreage

Table 17. Findings on Percentage of Irrigated Acreage on Farms 100 Acres and Larger

Interviewee	Region of Expertise	Trend (relative to 2008 level)		Comments
		2008 to 2012	2012 to 2032	
#1	ID	increase less than 5 percentage points	will saturate at 95%	**2008 to 2012 -** There has been a consolidation of farms as the older generation (who could make a living on smaller farms) retires and larger farms move in. Smaller farms are primarily comprised of a lot of hobby farms without much acreage. **2012 to 2032 -** The maximum level is about 95%, which is why it won't increase beyond 2012 levels.
#2	ID/WA/OR	increase 1 or 2 percentage points	increase 2 to 3 points witin 5 to 10 years, then stabilize	**General -** Growth has been bimodal - there has been an increase in large farms and increase in small farms, but a decrease in middle-sized farms (the traditional family farm). A lot of these small farms aren't really "farms" - they're just someone with 10 or 20 acres that they rent out.
#3	ID	no change	no change	**General** - There are no real farmers under 100 acres. 500 acres is the lower end for independent farmers. There might be some increase in smaller farms, but the percentage of acreage that this represents is small.
#4	WA and OR	refused	refused	
#5	ID/WA/OR	increase, can't quantify	don't know	
#6	WA	no change	no change unless commodity prices change	**General** - If commodity prices go up, larger farms will break up. If prices do down, there will be more large farms.
#7	OR	increased, can't quantify	don't know	
#8	WA	no change	increase, can't quantify	**General** - Larger farms are growing to improve economies of scale. Smaller farms are being subdivided for housing projects.

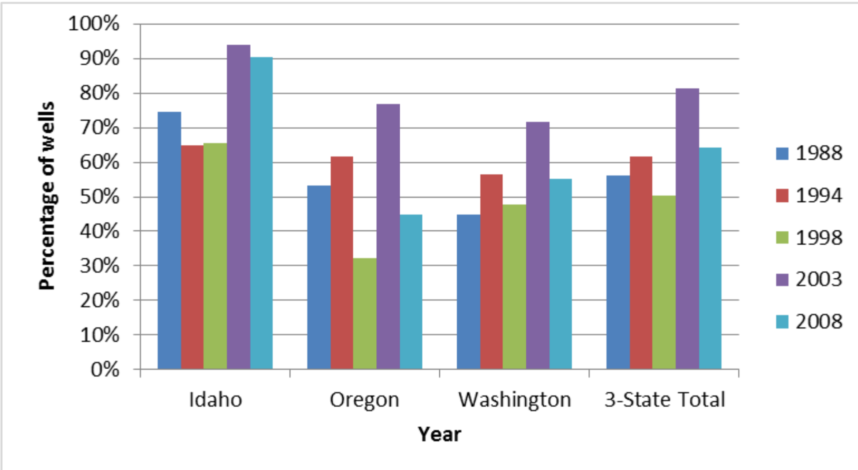
B.6 Irrigated Acreage by Well Depth

Regional respondents were shown Figure 13, the percentage of wells with a pumping height of 100 feet or greater as a percentage of all wells, and asked to do the following:

- explain the volatility in these results
- estimate changes from 2008 to the present (2012)
- forecast changes to this metric over the next 20 years (through 2032)

This topic was not addressed with manufacturers and vendors.

Figure 13. Percentage of Wells with a Pumping Height of 100 Feet or Greater



Source: Navigant analysis of United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Wells Used on Farms by Pumping Depth*. Survey years 1988, 1994, 1998, 2003, and 2008.

Table 18 summarizes the responses to this set of questions. From these responses, Navigant concludes the following:

- **The large increase in the portion of wells greater than 100 feet in the 2003 survey was likely due to drought and a lowering of water table levels.**
- **There is uncertainty in which direction this percentage has moved from 2008 to the present, although it is likely within a few percentage points of the 2008 levels.**
    - Two regional respondents thought that it had increased and two thought that it had decreased. One thought that it had not changed.
- **There is similar uncertainty in what this percentage will be going forward (to 2032), although the change is expected to be within 10 percentage points of the 2008 levels.**
    - One regional respondent estimated a 10 percentage point decrease and two regional respondents estimated decreases, but could not quantify their magnitude.
    - One regional respondent estimated a 7 percentage point increase and one regional respondent estimated a 1 to 3 percentage point increase.
- **Several factors were identified that would contribute to a constant or increasing percentage of deeper wells:**
    - Water tables are dropping in most regions. They are also dynamic and can drop several hundred feet over the course of the growing season in some regions.

    - As farm locations shift in response to urban sprawl, new farm lands tend to be marginal, and require deeper wells.
    - Although energy prices do affect the economics of wells, at current energy prices, energy cost is not a factor for lifts of less than several hundred feet.
- **There was less justification for a *reduction* in the percentage of deeper wells:**
    - One regional respondent thought that high energy prices would reduce the percentage of wells with a pump height greater than 100 feet.
    - One regional respondent thought that improvements in water efficiency would lead to rising water tables, and therefore, lower pumping heights.

Table 18. Findings on the Percent of Wells with a Pumping Height of 100 Feet or Greater

Interviewee	Region of Expertise	Trend (relative to 2008 level)		Comments on Graph
		2008 to 2012	2012 to 2032	
#1	ID	decrease 0 to 1%	decrease 10% in 20 years, linear trend	**Historical** - There was a increase in 2003 because of drought - people dug supplemental wells. Also, newly developed areas tend to be marginal areas with deeper pumping depths. **Since 2008** - This should decrease somewhat as energy costs increase, which makes irrigation not cost effective at very large (>500 ft) pump lifts.
#2	ID/WA/OR	don't know	don't know	**Historical** - Not sure why the variation. Ask the ID department of resources. They might have a clearer view of this. Part of the jump in ID might have been due to a drop in ground water levels. Ground water levels have lowered because of over pumping and a lack of recharge (due to more efficient irrigation technologies). But there's a limit to the increase because electricity costs prevent very high lift wells.
#3	ID	Can't speak to this topic	Can't speak to this topic	Can't speak to this topic
#4	WA and OR	stayed the same	don't know	**Histroical** - A lot of that depends on water coming straight from the Columbia. The water table started dropping and they put in more wells.
#5	ID/WA/OR	decrease, can't quantify	maybe dropping, but can't quantify	**2008 - 2012** - Irrigated acreas are declinine and water application systems are becoming more efficienct, so aquifer levels could rise.
#6	WA	increased about 4 percentage points to 90% (note this assumes a different level in 2008 than on the graph)	2017 - 2.5 percentage point increase (to 92.5%) 2022 - up to 97% 2032 - stays flat at 97%	**General** - The collection of static water level is dramatically variable because of compartmentalization between water pockets. "Statisticians don't understand dynamic water level and generally only take their measurements in January and February when aquifers are freshly recharged." The correct metric to use is "average dynamic water level" as collected in July or, better, throughout the growing season. Over the previous 20 years, the average dynamic water level has been dropping 10'-15' per year. The average well depth in in our region is 600' for deep wells, and more than 400' for all wells. The annual dynamic shift (drop) is approaching 300 feet over the course of a growing season. In the tri-state region, the water level is dropping 3-5 feet per year. No more than 10% - maybe as few as 5% - have a static dynamic water level of less than 100'. Assumes that ID and WA would be the same.
#7	OR	increase, can't quantify	1 to 3% increase in some areas, but flat in others	**General** - Sometimes, increasing the number of wells on a farm is the only way to access more water. Once established, these wells are in service for a long time. Some areas have a moratorium on additional wells, such as north/central OR in isolated areas on the WA border. They had put in large wells as well as part of a bunch of cherry orchards and they are studying what is underground. They are drilling more wells in southeastern OR.
#8	WA	no change	decrease, can't quantify	**General** - Most of WA is irrigated on surface water, in the areas forced to use wells the water tables are dropping. The Odessa aquifer is definitely dropping. The push has been to move farmers away from deep pumping and more toward using surface water. There will be a shift to increase surface water irrigation, because it is more energy efficient.

B.7 Irrigated Acreage by Crop Type

Regional respondents were shown Common irrigated crops in the region include corn for fodder, alfalfa, hay, wheat, barley, potatoes, and sugar beets. Table 4 shows the historical and forecasted relative distribution of irrigated acreage, by crop type, in the three-state region. Values from 1988 to 2008 are derived from data in the USDA FRIS. Navigant estimated the values for 2012 and 2032 based on responses from regional respondents. Assuming current conditions remain, regional respondents did not think that the distribution of acreage by crop type would change from the 2012 levels. However, these respondents noted that distributions are governed by unpredictable factors such as commodity prices and government policy as much as by observable trends.

Table 4, the relative distribution of irrigated acreage, by crop type, in the three-state region, and asked to estimate changes from 2008 to the present (2012) and to forecast changes to this metric over the next 20 years (through 2032). This topic was not addressed with manufacturers and vendors.

Table 19. Relative Distribution of Irrigated Acreage, by Crop Type, in the Three-State Region

	1988	1994	1998	2003	2008
Crops for Forage or Fodder (Alfalfa, Hay, etc.)	22%	24%	27%	32%	32%
Grain (Wheat, Barley, etc.)	20%	20%	19%	20%	20%
Other Vegetables (including beans, beets and other vegetables)	9%	9%	9%	8%	14%
Pasture	12%	11%	11%	13%	13%
Potatoes	8%	8%	9%	8%	7%
Orchard	4%	3%	4%	4%	3%
Other	26%	24%	22%	14%	12%
Total	100%	100%	100%	100%	100%

Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Estimated Quantity of Water Applied and Primary Method of Distribution by Selected Crops Harvested*. Survey years: 1988, 1994, 1998, 2003, and 2008.

Table 20 summarizes the responses to this set of questions. From these responses, Navigant concludes the following:

- **The dominant trend affecting irrigated agriculture has been the increase in dairy cows in the region, which has resulted in an increase in corn and other feed for these cows. This is particularly apparent in southern Idaho.**
    - Four regional respondents identified this trend, including two speaking to Idaho conditions, one to Washington conditions, and one to the three-state region as a whole.
    - The increase in corn (and hay, to a lesser extent) has likely shifted the percentage of acreage for forage and fodder from 32% in 2008 to 35% in 2012.
    - In Oregon, there has been a one or two percentage point increase in alfalfa.
    - Acreage for sugar beets has likely decreased due to improvements in yield per acre of this crop, coupled with a fixed demand for sugar.

  - The increase in forage and fodder crops has been at the expense of a variety of other crops.
- **Assuming current conditions remain, regional respondents did not think that the distribution of acreage by crop type would change from the 2012 levels.**
  - Distributions are governed by unpredictable factors such as commodity prices and policy, rather than observable trends.

Table 20. Findings on the Relative Distribution of Crops Grown

Interviewee	Region of Expertise	Trend (relative to 2008 level)		Comments
		2008 to 2012	2012 to 2032	
#1	ID	increase in forage/fodder to 35% at the expense of grains. Sugar beets decreased too.	no change	**2008 to 2012** - The increase in forage/fodder is corn for the increasing amount of dairy cows. Sugare beets have decreased because demand is flat but yield per acre has improved.
#2	ID/WA/OR	2 percentage point reduction in wheat - 60% of this land has gone to corn and 40% to hay.	no change	**2008 to 2012** - The trend in ID has been a increase in forage to support the expanding dairy industry (largely a move from CA to ID). This increases demand for corn (60% of increase) and hay (40% of increase). This has been at the expense of wheat. Barley production has stayed constand because the demand from breweries has been constant. Unpredictable events can affect this distribution: for example, changes to the federal sugar beet policy.
#3	ID	increase in corn (forage/fodder) at exense of all other crops. Can't quantify. Additioanally, vegetable crops back down to 9%.	no change	It is very hard to forecast this.
#4	WA and OR	refused	refused	
#5	ID/WA/OR	refused	refused	
#6	WA	5 percentage point increase in forage/fodder, 5 percentage point decrease in pasture.	refused	
#7	OR	1-2 point increase in alfalfa, didn't what that would be at the expense of	additional increase in alfalfa, can't quantify	the shift in OR has been towards high quality alfalfa
#8	WA	slow shift from hay to wheat or grapes	slow shift from hay to wheat or grapes	

B.8 Types of Irrigation Systems

Regional respondents were shown Figure 14 through Figure 17, the relative distribution of irrigation types in the three-state region and in each individual state, and asked to:

- discuss the factors driving the transition to CP systems
- estimate changes from 2008 to the present (2012)
- forecast changes to this metric over the next 20 years (through 2032)
- estimate maximum levels of CP penetration

This topic was not addressed with manufacturers and vendors.

Figure 14. Distribution of Irrigation Types in the Three-State Region

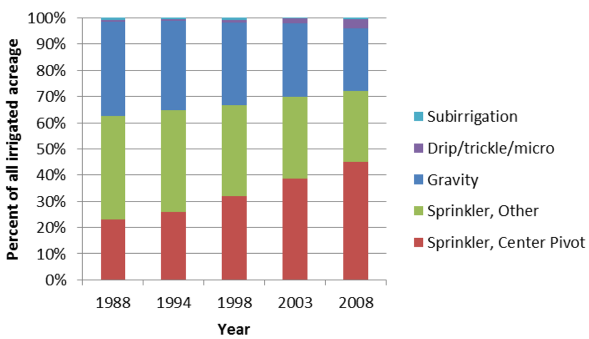


Figure 15. Distribution of Irrigation Types in Idaho

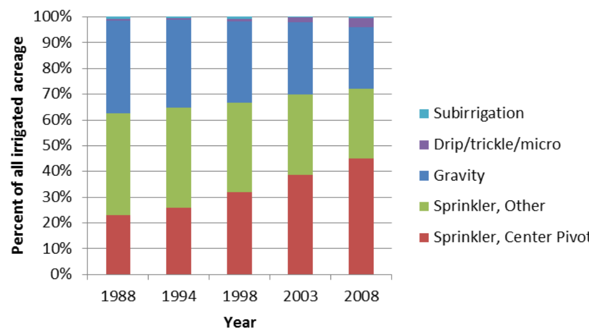


Figure 16. Distribution of Irrigation Types in Oregon

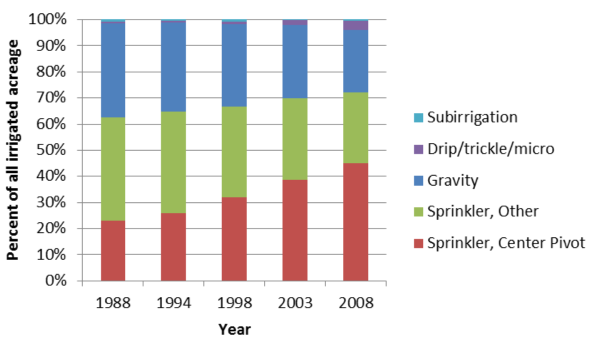
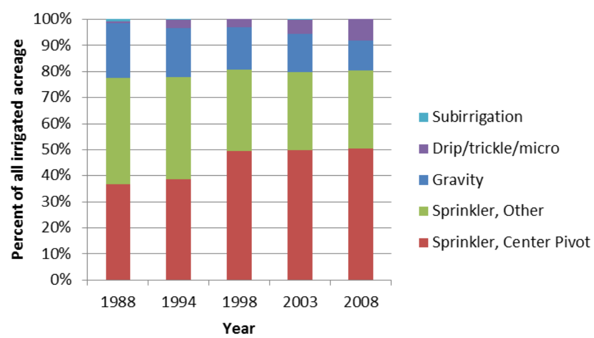


Figure 17. Distribution of Irrigation Types in Washington



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Land Irrigated by Method of Water Distribution* and *Land Irrigated by Sprinkler Systems*. Survey years 1988, 1994, 1998, 2003, and 2008.

Table 21 summarizes the responses to this set of questions. From these responses, Navigant concludes the following:

- **Labor savings have been the primary driver in the shift to CPs.**
- **Many additional benefits of CPs were identified.** These include:
    - improved ease of farming
    - water savings
    - improved ability to do chemigation and fertigation

    - energy savings from water savings
    - wide variety of crops that can be grown with the systems
    - improved yields
    - purchaser requirements for some crops (primarily potatoes) to be irrigated by precision systems such as CPs
    - improved rentability of land
    - **CPs likely increased in prevalence from 2008 to 2012 at the same rate they had been increasing before 2008. This increase was likely at the expense of gravity systems and some other types of sprinkler systems.**In recent years, high commodity prices have enabled investment in new technologies and systems.
- **CPs irrigate approximately half of the irrigated farmland in the three-state region.**
- **In some regions, CPs are even more prevalent than this.**
    - One regional respondent in Washington said that in his region, 90% of irrigated land is irrigated by CPs and the remainder by gravity systems. He expects half of the gravity irrigated land to convert to CPs over time.
- **CPs will continue to gain market share in the near future, until they reach a saturation point.**
- **Regionally, 70% to 85% of land currently irrigated by pressure systems is suitable for CP irrigation.**
    - Some fields are not suited to CP because of soil types, slope of land, or other topographic issues.
- **Approximately 50% to 70% of land irrigated by gravity fed systems is suitable for CP irrigation.**
    - Seed crops, including beans, are not well suited to CP because water on the plants can cause disease.
    - Smaller farms may not be able to afford the capital investment of a CP system.
    - Capital investment in CP may not be warranted at farms likely to be converted to residential land in the near future.

Table 21. Findings on the Distribution of Irrigation System Types

Interviewee	Region of Expertise	Drivers for shift to CPs	Trend (relative to 2008 level) 2008 to 2012	Trend (relative to 2008 level) 2012 to 2032	Maximum portion CP for currently irrigated land	Maximum portion CP for currently gravity fed land	Comments
#1	ID	labor, water, and energy savings	increase in CP and increase in total irrigated (at expense of gravity) - a continuation of the linear trends in the graph	continuation of linear trends, until saturation	85% - some soils too tight or otherwise not suited to CP	90% technically. However, prevalance of seed crops limits this to 50%, practically.	high commodity prices are driving these shifts seed crops are not suited to CP because water on plants and seeds can cause disease. These crops are gravity irrigated.
#2	ID/WA/OR	labor savings (labor has become more expensive and less available) water savings improved ability to do chemigation and fertigation improved yield of some high-value crops	continued linear trend in increase of CPs, at the equal expense of other pressure systems and of gravity systems	continuation of current linear trends.	80 to 85% - still some preferences for wheel lines (where land is too expensive to "waste" the corners) and geographic limitations.	70% - some applications, like seed crops, can't use sprinklers because they will ruin the crop	
#3	ID	Labor at first. CPs make farming easier and faster, and they provide better control of water. There is still the issue of what to do with the corners, though.	commodity prices are currently high, which is fueling adoption. in ID no increase in drip.	continuation of linear trends, until saturation (about 10% of land will remain surface irrigated. Within sprinkler, the percentage that is "other" will remain constrant.	70 or 80%. Some areas aren't good for CP because of steep slopes or other conditions.	50%. Some farms are too small. And if land is expected to be developed residentially in the near future, it may not be worth the capital investment.	
#4	WA and OR	Labor and ease of use. To a lesser extent, water and energy savings, plus fertilizer and pesticide savings.	couldn't quantify	couldn't quantify	at current commodity and CP prices, we're close to saturation	refused	
#5	ID/WA/OR	energy prices combined with larger pump heights drive water savings	continued shift to CP from gravity. Couldn't quantify	refused	refused	couldn't quantify	
#6	WA	more efficient application and improved "rentability" of the land as farms get larger, farmers don't want to deal with multiple types of systems allows a wider range of crop type options	"other" pressure systems are gone in his region. In 2008 - 15% gravity, 85% CP. In 2012 - 10% gravity and 90% CP. For WA in total, gravity is 5 percentage points higher. Less than 5% drip in his region (half of onions and half of orchards are on drip)	2012 to 2017 - little to no change 2017 and beyond - refused	100% (this is what it is in his region)	most - ultimately, maybe 5% of land won't be CP - because it will soon be removed from farming due to urban sprawl.	
#7	OR	water conservation and labor savings. also improved control. Drip systems save water, but they are crop specific.	don't know	2012 to 2017 - 1-3% increase in CP 2017 to 2022 - 3-5% increase in CP 2022 and beyond - refused [answers in percentage points relative to 2012]	refused	don't know. Doesn't have customers with gravity systems	
#8	WA	More effective and efficient, supported by higher valued crops.	USDA NRCS cost share for move to CP. This has accelerated adoption. Couldn't quantify	increase, but at slower rate than historically because the the remaining acreage is not as easy to convert, or not feasible because it's rented land or because of tribal policies. Newly farmed land will get CPs, but there's not much of this on the horizon.		very little	

B.9 Correlations between Variables

A weakness of using FRIS data for this research has been that the collected data is not available, as there are only a limited set of compiled reports. These reports do not cross-tabulate across variables of interest; therefore, the Navigant team cannot consider the conditional estimates from the data. For example, the Navigant team cannot consider the percentage of acreage irrigated by CP systems of only those farms with pump lifts of 100 feet or greater.

The Navigant team asked regional respondents to discuss correlations between crop type and CP prevalence, farm size and CP prevalence, pump height and CP prevalence.

Table 22 summarizes the responses to this set of questions. From these responses, Navigant concludes the following:

- **CP irrigation is appropriate for most types of crops popular in the three-state area.**
    - Regional respondents indicated that CP was appropriate for at least some crops in all of the crop categories in the survey except orchards.
    - Buyers of potatoes often *require* that the potatoes are irrigated by precision systems such as CPs to control the moisture content of the potatoes.
    - It is not appropriate for orchard crops, vine crops, seed crops, some vegetables, and is only sometimes appropriate for hay and beans.
    - Carrot seeds, tomatoes, and cucumbers are being irrigated by drip systems.
- **In general, larger farms are more likely to have CP. However, above 100 acres, size is not a significant factor in CP prevalence.**
- **Regional respondents have conflicting opinions about whether or not CPs are more prevalent where pump heights are greater (several hundred feet of lift) because of the energy savings achieved by water savings.**

Table 22. Findings on Correlations between Variables

Interviewee	Region of Expertise	Crops that CP is appropriate for [excluding orchard]	Comments	Stronger correlation to CP: farm size or pump height	Comments
#1	ID	all	potatoes *have* to be irrigated by sprinklers	pump height for all crops	The greater the height, the greater the energy benefit of saving water.
#2	ID/WA/OR	all, but less so for pasture		don't know - both are important	bigger farms are more likely to have CP higher pump height means more incentive (energy savings) to conserve water
#3	ID	all categories, but only some within "other vegetables"	sprinklers are not common for seed crop because of disease	neither	above 100 acres, size isn't an issue there is no correlation with lift height either: once you're lifting, you'll put on the extra pressure needed for CP.
#4	WA and OR	all		neither	cost and the shape of the field are the important factors
#5	ID/WA/OR	refused		neither	
#6	WA	all categories	not for seed crops	neither	CP not applicable for farms under 20 acres, but above 20 acres, size is not an issue. Pump height is irrelevant to CP applicability.
#7	OR	all	In the "other vegetables" category, farmers are moving towards drip irrigation for carrot seeds in central OR	neither	Field shape is one of the biggest contributing factors. Pivots can run at much lower pressures so that contributes in energy and water savings. The grower is mostly concerned with whether or not they can financially afford the asset. Pump height, and farm size are not really indicators in my experience. Growers care about labor and ease of operation, they don't always see the economics behind technologies (e.g. soil, SIS)
#8	WA	all	not tomatoes and cucumbers (these have mostly been converted to drip)	neither	Irrigation system selection depends on field shape, topography, tillage, water source (single well will make it easier to make it a pivot). It is economics that drives most of the pivot market, and quality of life for the growers. Much easier with labor savings and time spent per hour.

B.10 Irrigation Strategies

The Navigant team asked regional respondents about the use of irrigation strategies, using the following description:

"For the purposes of this interview, we have defined irrigation strategies as 'the use of methods, information, and/or technologies to reduce the amount of water and energy used for irrigation, relative to conventional approaches to water decisions, such as visual or tactile assessments.'

Specifically, we are interested in three types of irrigation strategies:

- Planning – is the co-optimization of expected crop yield and water usage, by using techniques such as deficit irrigation.*
- Farm and field-level tools – is the use of data and models to determine the amount of water to apply to a farm or field at a given time. Tools include scientific irrigation scheduling*, other scheduling services, evapotranspiration reports, and/or computer simulation.
- Sub-field-level tools – is the use of spatially granular information such as soil type and topography, in conjunction with modeling and variable rate irrigation controls*, to vary the amount of water applied over portions of a field."

Definitions of deficit irrigation, scientific irrigation scheduling, and variable rate irrigation controls were provided if asked.

Regional respondents were then asked to review Figure 3, which illustrates a categorization of irrigated lands by the types of strategies used on the land. A series of questions were then asked to:

- quantify the sizes of each of the eight categories in the diagram at the present time (2012)
- quantify these sizes in the future
- describe the types of farmers using these strategies

Several additional questions were asked in this section of the interview to:

- characterize the under-utilization of existing VRI strategies
- quantify the use of data integration and decision-making tools

Figure 18. Venn Diagram of the Use of Irrigation Strategies

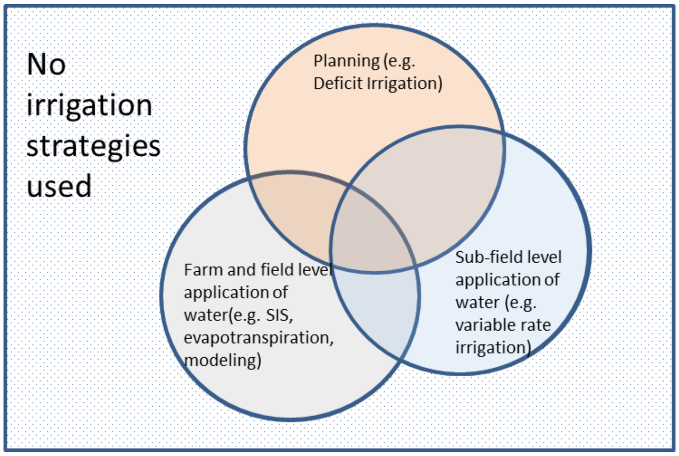


Table 23 through Table 26 summarize the responses to this set of questions. From these responses, Navigant concludes the following:

- **The co-optimization of yield and water usage is rare.**
    - No regional respondent explicitly mentioned water efficiency as a driver in decision making.

Planning Strategies:

- **Planning strategies are used primarily to optimize crop yield and quality. The use of these strategies is likely in the range of 20%.**
    - Many of these strategies are concentrated on potato and wheat crops. Nearly all potatoes are grown with an explicit strategy and one regional respondent estimated that 60% of wheat crops are grown using deficit irrigation. In 2008, potatoes were grown on 7% of all irrigated acreage in the region and wheat was grown on 15%.
        - It is unclear how much of this wheat was grown in rotation on fields used primarily for potatoes.
    - For reference, the 2008 FRIS reported that 6% of farms in the three-state region used a commercial or governmental scheduling service, 14% used a water delivery organization schedule, and 32% used a personal calendar. However, the FRIS report does not indicate how much these categories overlapped.
- **Regional respondents did not foresee a significant rise in the use of planning strategies in the next 20 years.**
- **The types of growers currently using planning strategies are those using it to solve a specific problem, big commercial growers, and some innovative independent farmers.**

Farm- and Field-level Strategies:

- **There is a broad spectrum of tools within the farm- and field-level tools category, which led to a wide range of estimates of usage. The use of tools in this category is likely in the 10% to 30% range.**
    - The use of moisture sensors is common in some areas, but not overall.
        - One regional respondent indicated that almost all growers in his region use moisture sensors, whereas other regional respondents suggested a 10% to 30% range.
            - For reference, the 2008 FRIS reported that 9% of farms in the three-state region used soil moisture sensors, 2% used plant moisture sensors, and 7% used evapotranspiration reports.
    - The use of more sophisticated technologies such as evapotranspiration reports and computer simulation are far less common, except in the potato industry, where they are very common.
    - The use of Scientific Irrigation Scheduling (SIS) is driven primarily by subsidies, which suggests that a review of program activity would be a good indicator of regional prevalence.
        - This is consistent with the findings of Navigant's 2010 evaluation findings for Bonneville Power Administration's SIS program[32].
- **There was general uncertainty on the levels of farm- and field-level tool usage in the future.**
    - Two regional respondents thought that it would double from existing levels.
- **The types of growers currently using farm- and field-level strategies are those using it to solve a specific problem, trying a new approach (largely driven by subsidies), and large commercial growers.**

Sub-Field-Level Strategies:

- **The use of sub-field-level strategies in the three-state region is too rare for regional respondents to quantify.**
    - All regional respondents who attempted to quantify the current levels of usage used a "less than X%" structure, with responses ranging from "less than 10%" to "less than 1%," with one regional respondent estimating the level at 0%.
    - No regional respondents indicated any knowledge of VRI systems in use in the NW aside from experimental or demonstration projects.
- **Most regional respondents did not foresee any increased adoption of sub-field-level strategies in the next 20 years.** Reasons for this included the following:
    - Water availability is forecasted not to be an issue.

[32] Schare, Stuart and Deborah Swarts, "Evaluation of Bonneville Power Administration's Scientific Irrigation Scheduling Program," 2010. Available at
http://www.bpa.gov/energy/n/reports/evaluation/pdf/BPA_SIS_evaluation_Final_Report_Dec_2010.pdf
From the executive summary: "The regional market was found to be dependent upon available incentives in order to continue and expand the use of SIS. This was due to the combined cost of services and implementation exceeding the budget of a typical grower."

  - Sub-field-level tools are too complicated and require too much time for most farmers.
  - The majority of untapped water and energy savings can be achieved at the field-level.
- **One regional respondent did foresee sub-field-level tools being used on as much as 45% of irrigated acreage in the three-state region by 2032, assuming several changes to current conditions.** These included:
  - reductions in water availability
  - increases in energy prices
  - availability of tools that manage and deliver information better than current tools, and are user-friendly
- **Regional respondents could not describe the types of growers that currently use these tools because it is unclear who, if anyone, is using sub-field-level tools.**
  - One regional respondent suggested that large growers might be using these tools
  - One regional respondent suggested that growers using sub-field-level tools would be growers trying new approaches

Tools for Data Integration and Integrated Decision Making:

- **There is currently little to no use of tools to integrate data from multiple sources, or to help farmers make irrigation decisions.**
- **Several regional respondents thought that increasing trends in computing power and usage (e.g., smart phones, iPads) suggested that such tools would be adopted in the next 20 years, but none indicated that any existing tools in the market were moving in this direction (i.e., becoming less expensive, more powerful, and more user-friendly).**
  - One regional respondent estimated a penetration of 10% to 20% and another estimated a penetration of "optimistically, 20% to 25%."

VRI Capabilities:

- **Speed control is not frequently used, even though CPs are capable of it, because farmers have not seen the benefits that would warrant the use of something so complicated.**
  - Most new CPs and some (perhaps 20%) existing CPs have the capability to do speed control operation.
- **Few, if any, CPs have the capability to do zonal control.**

Table 23. Findings on Irrigation Strategies, Venn Diagram, part 1

Interviewee	Region of Expertise	Estimate for Year	Strategy: None	Strategy: Planning	Strategy: Farm and Field-level Tools	Strategy: Sub-field Level Tools	Strategy: All Three Strategies	Strategy: Overlap Between the Two	Comments
#1	ID	**2012**	10% or less	60 to 70%	90%	less than 5%	Any one using sub-field level tools is using all three	most growers using planing are also using farm and field-level tools	CPs are all running at full bore from mid-June until demand drops before harvest. It's the shoulder periods when irrigation strategies can be used to minimize water usage or optimize application of limited water supplies. Deficit irrigation works well for grains, and about 60% of growers are doing this. The increase in sub-field level tools will be driven by water availability limits and increases in energy prices. But this is dependent on the availability of better tools: better sensors, better ways to deliver and manage information, and user-friendly tools. Growers don't have time to use sophisticated tools.
		2032			90 to 95%	maybe 45%			
#2	ID/WA/OR	**2012**	don't know						Not my area of experstise.
		2032							
#3	ID	**2012**	80%	5%	10-20% (sensors)	less than 1%	0%		Farmers can use the selection of crops as planning strategy: if water is short, they can grow grains, which only need water in the early summer. However, most people here have plenty of water. If there was competition for water, planning would increase. All potato farmers use some strategy, and they have a consultant to help them. Technology for sub-field level controls exist but they're not adopted because they're not plug and plan and the benefits of these controls have not been demonstrated.
		2032		maybe up to 10%	15 to 30%	less than 1%			
#4	WA and OR	**2012**	less then 5%	don't know					Not my area of experstise.
		2032							

Table 24. Findings on Irrigation Strategies, Venn Diagram, part 2

Interviewee	Region of Expertise	Estimate for Year	Strategy: None	Strategy: Planning	Strategy: Farm and Field-level Tools	Strategy: Sub-field Level Tools	Strategy: All Three Strategies	Strategy: Overlap Between the Two	Comments
#5	ID/WA/OR	2012	don't know						Not my area of experstise.
		2032							
#6	WA	2012	50%	20%	30%	0%	0%	5 to 10 percentage points of planning and field-level overlap	Planning will decline and level off at 5%. It might increase in ID because of water policy, though. Farm and field-level tools will increase to 100% with sufficient subsidies, but will stay around 25% without subsidies. SIS (planning) is growing because of policy and PUD incentives.
		2032	35%	5%	60%	0%	0%		
#7	OR	2012	90%	less than 10%	less than 10%	less than 10%			NEEA is pushing VRI, but there are other things they could do that would be effective. For example, analysis to size pumps properly, and VFDs on pumping systems. All of the systems I see are run at higher pressures than needed. Education would also be effective - many irrigators that I interact with irrigate the same in May as in August, even though crop requirements are completely different.
		2032	don't know						I hope it will increase, but we need to change the way we are going about getting increased efficiency. We don't have anything that works well. We need more intense water management with weather tracking components. Our best success has been using a third party to monitor soil moisture and provide data to farms. NRCS will pay for the first three years for a grower.
#8	WA	2012	70 to 80%	20 to 30%, combined					Growers tend toward the strategy that requires the least amount of time. I think the most effective approach would be to offer user-friendly tools to help farmers decide when to irrigate. The biggest savings are from leaving the pump off when water is not needed, not from variable rates of irrigation. This is about a 10 to 15% water and energy savings. Tools must be user-friendly to allow growers to make decisions on their phones, in bed, or on their computers. Manufacturers offer these products, but they're too expensive. I think that people are too exact with soil samples and testing. They just need to be in the ballpark to get get good results.
		2032	don't know						

Table 25. Findings on Irrigation Strategies, Use of Integration and Decision-Making Tools

Interviewee	Region of Expertise	Year	Integration tools	decision making tools	Comments
#1	ID	2012	5%		There's an opportunity for user-friendly tools to be developed and used. I don't see this being used or developed currently, which suggests that the increase in usage that I noted would happen more in the later year. Increases in computing power will facilitate this, but the challenge is to take advantage of this power.
		2032	optimistically 20 to 25%		
#2	ID/WA/OR	2012	don't know		
		2032			
#3	ID	2012	0%		Extensions are making tools. Farmers are getting more comfortable with technology (e.g, smart phones, iPads). I could imagine lenders requiring the use of tools that take more information and help make decisions.
		2032	10 to 20%		
#4	WA and OR	2012	don't know		The growers must be able to make decisions at the machine (e.g., smart phone decision making tools).
		2032			
#5	ID/WA/OR	2012	don't know		
		2032			
#6	WA	2012	very little		There are packages available that integrate data from probes, but they are very limitted and have short life expectancies. They get pulled out and abandoned after a few years.
		2032	don't know		
#7	OR	2012	very little		This is not very wide spread. There are some specific tools available, but it is primarily only commercial growers taking advantage of them. There's not much going on in this area.
		2032	don't know		
#8	WA	2012	don't know		
		2032			

Table 26. Findings on Irrigation Strategies, Characterization of Growers and VRI Utilization

Interviewee	Region of Expertise	Description of growers…			How is integration of information done?	comments	% of systems with VRI		why isn't the capability used?	adoption levels on smaller farms
		… using planning	… using farm and field-level	… sub-field level tools			speed control	zonal/site-specific control		
#1	ID	solve a specific problem	solve a specific problem	trying new approaches	in their head	Not a very formal process – growers use their years of experience and mentally take a variety of inputs – soil look, crop look, forecasts – and make decisions. Often while driving past their crops.	majority of new systems, and about 20% of existing	less than 5%	There is a steep learning curve that requires extensive data collection and analysis. A consultant is required for this.	It's hard to say. Some smaller farms have innovative, well-educated growers and others don't.
#2	ID/WA/OR	refused			typically "gut feel"	Farmers have seen some significant technology failures and have a healthy degree of skepticism until they see something that works.	don't know	don't know	don't know	don't know
#3	ID	solve a specific problem	trying new approaches	I don't know anyone using these tools	by the seat of their pants.	In general, water is plentiful and energy is not that expensive, so there's not much need for this. When commodity prices were lower, this was not the case.	not sure, but most new systems have this capability	1% or less. Not aware of any beyond research settings. Valley is selling them, but I'm not sure that anyone in the NW is buying them.	Farmers haven't seen the benefit of them. If someone demonstrates the economic or yield improvements, farmers will use them.	Not sure. Sub-field level tools would be minor.
#4	WA and OR	very few are doing anything (none of the above)	farmers use for a few years because of incentives. Then abandon.	no one is using these	refuse		systems are capable, but no one is using them	none	Farmers will not "bet the farm" on a new technology. They work with incremental change.	
#5	ID/WA/OR	refused	big growers [didn't indicate which category they would fall into]	refused	refused	refused	refused	refused	refused	refused
#6	WA	solve a specific problem	with subsidy - trying new approaches without subsidy - solve a specific problem	no one is using these	in their head. Decisions are based on the priorities of the moment…There is no standard format. They take SIS with a grain of salt.		Less than 10% of current CPs have computer control panels. Older CPs needed a $3,500 panel replacement for controls. Of the systems that have VRI capabilities, no are using the capabilities.	0% - this is too complicated for "real world" use by typical farmers	This is too complicated for "real world" use by typical farmers.	These are most likely specialty farms with unique or custom approaches.
#7	OR	Most are innovators and tend to stick with it. The traditional guys aren't there yet. If the grower understands the benefit and the value they will continue using it.			There is vendor software, "AGRIMET", and [their organization] provides this service for orchards. It would be better to move to a one-stop shop, but that isn't out there yet.		all	none	refused	Funding can be more of an issue for smaller farms.
#8	WA	none of the above - big commercial growers, with specialized staff. Some naturally curious and progressive growers are changing too, but to a much smaller degree.	refused			Investing in the integration of information is a great place to start as long as it is cost effective.	all	none	refused	refused

B.11 Manufacturer Interviews

The Navigant team interviewed representatives of the three largest center pivot manufacturers in the U.S., who collectively hold approximately 75% of the U.S. center pivot market. The respondents were all national representatives of their respective companies, but with strong knowledge of the Northwest market.

These three companies are distinct enough that the Navigant team could not provide the responses of individual manufacturers – even anonymously – and ensure confidentiality. Therefore, no tables of responses are provided from the manufacturer interviews.

Significant findings from these interviews include the following:

General view of irrigation in the three-state region

- **Manufacturer representatives held views about irrigated acreage and the growth of center pivot market share that were consistent with the other study respondents.** Views included the following:
    - The number of irrigated acres in the three-state region is not likely to change by more than a few percent in the near future.
    - Forecasts of irrigated acreage and crop-type distribution further into the future are difficult to make because they are tied to commodity prices, but will not change significantly if commodity prices remain the same.

Planning Strategies

- **Manufacturer respondents' perception of the use of planning as an irrigation strategy in the three-state region as rare currently.**
    - Two thought that it was minimal and one estimated it as 15 to 20% of irrigated acreage.
    - Two thought that the use of planning tools would become widespread within 20 years *if* water became less available for irrigation in the region.
- **Center pivot manufacturers do not currently market planning tools. It is possible that at least one of the manufacturers will offer a product within the next few years.**
    - One manufacturer respondent said that they were not developing any planning tools.
    - One manufacturer respondent said that they were *considering* developing a product in one to two years.
    - One manufacturer respondent said that it was against their corporate policy to discuss future plans. That respondent referred the Navigant team to the manufacturer's corporate website to view their existing products; no irrigation planning tools were on offer.

Field-Level Tools

- **Manufacturers' perceptions of the use of field-level tools are varied.**

    - Responses from the three manufacturer respondent were “very few”, “15-20%”, and “most”. Likely reasons for this discrepancy are
        - Ambiguity of definition – Is this just the use of moisture sensors, or something more sophisticated that influences irrigation decisions?
        - Diversity of clientele – There are potentially correlations between the types of customers and their irrigation practices. A manufacturer that primarily markets to large customers may have a skewed perception of the entire regional market.
    - For reference, in the 2008 FRIS, 9% of growers on irrigated farms reported using soil moisture sensors, 2% reported using plant moisture sensors, and 7% reported using evapotranspiration. It is impossible to tell from this dataset which growers are using these tools. For example if larger farms are more likely to use these tools (which the Navigant team heard from respondents), than the percentage of acreage is larger than the percentage of growers.
- **All three manufacturers currently offer field-level tools.**
- **New products are likely to enter the market in the next few years.**
    - One manufacturer plans on offering a new product next year, one manufacturer is considering developing a new product but has no immediate plans, and one manufacturer declined to comment.

Sub-Field-Level Tools

- **All three manufacturer respondents thought that the use of sub-field-level tools is currently less than 1% in the three-state region.**
- **Two of the three manufacturer respondents thought that use of sub-field-level tools would be significant (33% to 50% of acreage) within twenty years and one manufacturer respondent thought that there would be no significant market for these products in the next five years.**
    - One manufacturer respondent forecasted that 50% of acreage would be subject to sub-field-level tools, conditional on increased production costs, water scarcity, and lower commodity prices.
    - One manufacturer respondent forecasted that 33% to 50% of acreage would be subject to sub-field-level tools, conditional on water scarcity in the region.
- **Manufacturer product offerings and plans reflect respondents’ forecasts of future adoption levels.**
    - The two manufacturer respondents forecasting large adoption rates currently offer VRI products and expect to have new offerings next year or in the next few years.
    - The manufacturer respondent that does not see a market for these tools developing in the next five years does not offer any such tools, nor have plans to develop such tools.

Tools for Data Integration and Integrated Decision Making

- **None of the three manufacturer respondents thought that any hardware or software tools for data integration or integrated decision making were being used in the region.**

    - However, one of the three manufacturer respondent did note that consultants provide this service, and estimated that about 20% of irrigated acreage was subject to consultants. He estimated that 80% of sugar beet and potato acreage was subject to consultants, and that corn and hay were starting to be subject to consultants because of their recent high commodity prices.
    - The same respondent forecasted that 80% of irrigated acreage would be subject to data integration and integrated decision making in 20 years, and that half of this would be from software and half from consultants.
- **One manufacturer respondent said that his company offered such products, one manufacturer respondent said that his company was considering developing such a product, and one said that they had no near term plans to develop such a product.**

B.12 Irrigation Practices in Other Regions

The Navigant team will also be interviewing one qualified market observer of irrigation practices in another region of the U.S. to gauge what can be learned from another region. This section of the primary data collection report will be written upon completion of this interview.

B.13 Appendix A: Interview Guide

Northwest Energy Efficiency Alliance (NEEA)
Interview Guide for Irrigation Technologies and Strategies Market Characterization and Baseline Study
DRAFT – July 31, 2012

Target audience: Qualified market observers of agricultural irrigation technologies and practices in Idaho, Oregon, and Washington. The following types of qualified market observers [and quantities] are targeted:

- Regional representatives of irrigation control equipment and service providers [3]
- Irrigation specialists at state agricultural extension services [3]
- Staff at state agricultural commissions and trade groups (e.g., State Potato Commissions) [2]
- Irrigation District and trade association management personnel [1]
- Northwest Irrigation and Soils Research Lab staff [1]

Interviewers: Barrett Mooney, Wayne Leonard, and Ryan Firestone, Navigant Consulting
Interview Timeframe: 7/31/2012 to 8/10/2012
Interview Format: Telephone interview with graphical prompts provided in advance, via email.

Company Name:	
Company Address:	
Contact Name:	
Contact Phone:	
Contact Email:	
Interview Date & Time:	
Interviewer:	
Notes:	

INTRODUCTION

Hello, my name is [INSERT NAME]. I'm with Navigant Consulting calling on behalf of the region's electric utilities. I received your name from Steve Phoetrides at the Northwest Energy Efficiency Alliance. [REPLACE WITH CONTACT PERSON AS APPROPRIATE] He suggested you might be able to help us with a study we're conducting for them on irrigation technology in the Northwest. We would like to ask you some questions about your experience in the industry and your perception of advanced irrigation equipment and control strategies.

All information that you share will remain confidential. Your response will help efforts to provide growers and service providers with energy efficiency programming. The questions should take about 30 minutes or so. Is this a good time to speak, or would you rather schedule an appointment?

[IF SCHEDULING AN APPOINTMENT, RECORD ALL RELEVANT CONTACT INFORMATION IN THE TABLE ON PRIOR PAGE AND SEND A FOLLOW-UP

REMINDER ONE DAY IN ADVANCE OF APPOINTMENT. ALSO MENTION THAT YOU WILL SEND AN EMAIL WITH GRAPHICS TO REFERENCE DURING THE INTERVIEW.]

RESPONDENT BACKGROUND

1. What are the primary services that your company provides?

2. What is your current job title?

3. How long have you been with [organization name]?

4. In which of the following states does [organization name] operate? [circle all that apply]:
    a. Idaho
    b. Oregon
    c. Washington

5. In which of these states to you personally do the most work?

6. Do you work in any other states?
    a. [IF YES] In which other states to you work?

7. Yes or No – Do you spend at least half of your time focused within ID, OR, and WA combined? [IF YES, CONTINUE. IF NO, TERMINATE INTERVIEW]

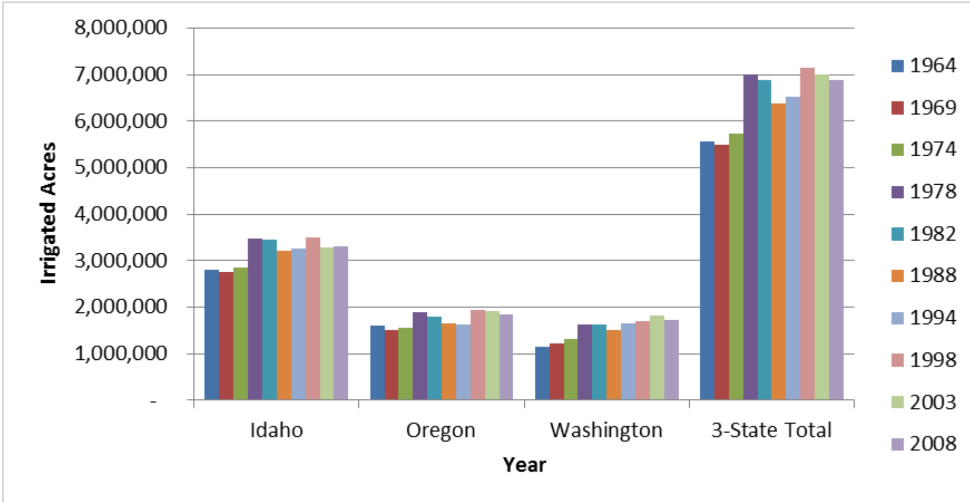
8. What types of growers do you work with? [PROBE FOR TYPES OF CROPS, CORPORATE STRUCTURE, FARM SIZE, TYPES OF IRRIGATION, OTHER]

9. Please describe your typical involvement with growers. [PROBE FOR SERVICES PROVIDED TO, INFORMATION COLLECTED FROM, AMOUNT OF TIME SPENT WITH, ETC.]

IRRIGATION TRENDS OBSERVED IN THE FARM AND RANCH IRRIGATION SURVEY

This set of questions references data compiled from the USDA's Farm and Ranch Irrigation Surveys. Did you receive the email with the graphics? Do you have it handy now? [IF NOT, OFFER TO EMAIL THE FILE DURING THE CALL]

Figure 19. Irrigated Acreage in Idaho, Oregon and Washington



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Farms in the Censuses of Agriculture*. Survey years 1988, 1994, 1998, 2003, and 2008.

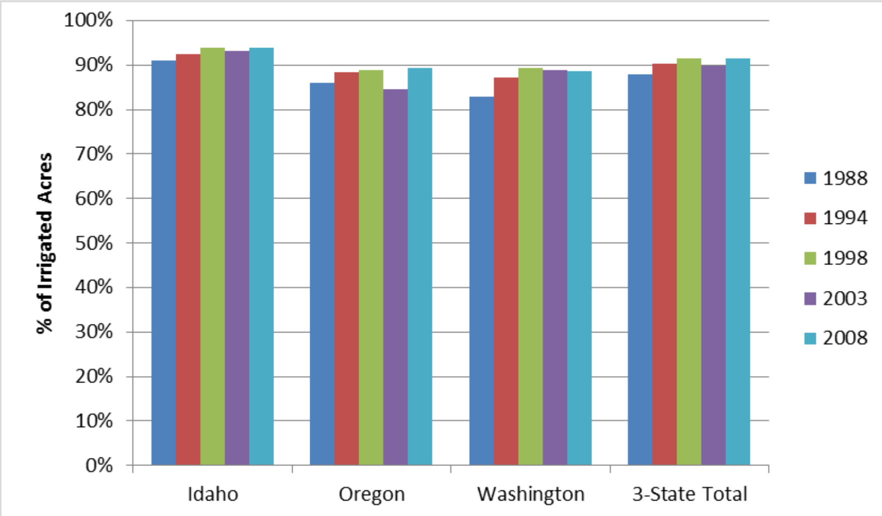
Figure 2 illustrates the total number of irrigated acres in Idaho, Oregon, and Washington from 1964 through the most recent survey in 2008.

10. Do you think this graph accurately reflects what you see based on your experience and current work? [ADJUST TO AUDIENCE: AMONG YOUR CONSTITUENTS; WITH YOUR GROWERS; IN YOUR RESEARCH; ETC.] [IF NOT, ASK WHAT THEY THINK IS MORE APPROPRIATE]

11. From 2008 to 2012, do you think that the amount of irrigated acreage in the three state region has done which of the following: [IF RESPONDENT CAN ONLY SPEAK TO A PART OF THE THREE-STATE REGION, NOTE WHICH PART]
    a. Increased
    b. Decreased
    c. Stayed the same
    d. Don’t know
    e. Refused
12. [IF A OR B] By what percent do you think the total irrigated acreage in the three state region has changed? [IF THEY GIVE THE ANSWER IN ACRES, NOTE IT AND MOVE ON. CONVERT TO PERCENT LATER.]

13. I’m going to ask about what you think will happen over the next few years and beyond. By what percent do you expect that amount of irrigated acreage to change (relative to 2008 levels) in the next
    a. 20 years?
    b. 10 years?
    c. 5 years?

Figure 20. Irrigated Acres on 100 Acre and Larger Farms, as a Percentage of All Irrigated Acres



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Farms by Acres Irrigated*. Survey years 1988, 1994, 1998, 2003, and 2008.

Figure 20 illustrates the percentage of irrigated acreage that is on farms that are 100 acres or larger, from 1988 through 2008. Note that this is shown in terms of acres, *not* the number of farms.

14. Do you think this graph accurately reflects what you see based on your experience and current work? [ADJUST TO AUDIENCE: AMONG YOUR CONSTITUENTS; WITH YOUR GROWERS; IN YOUR RESEARCH; ETC.] [IF NOT, ASK WHAT THEY THINK IS MORE APPROPRIATE]

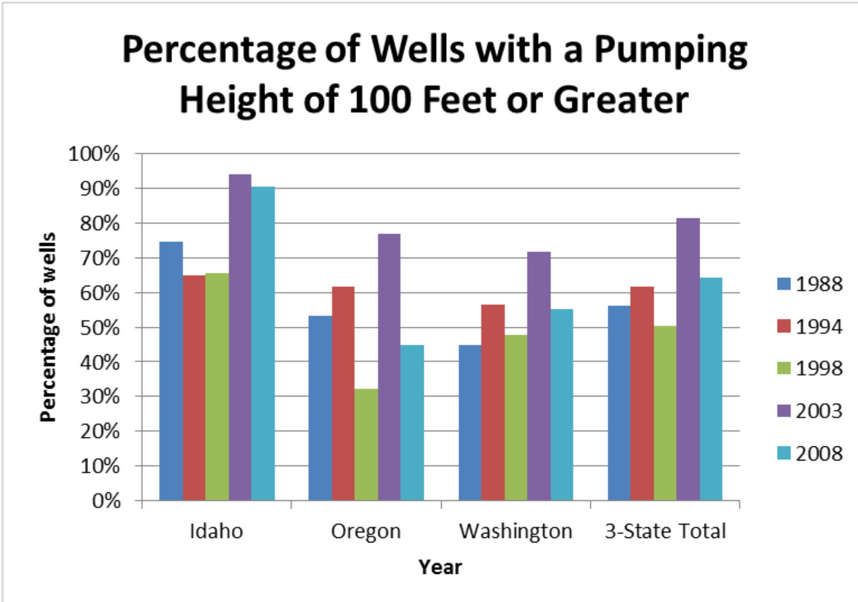
15. Since 2008, do you think that the percentage of irrigated acreage on farms over 100 acres has… [IF RESPONDENT CAN ONLY SPEAK TO A PART OF THE THREE-STATE REGION, NOTE WHICH PART]
    a. Increased
    b. Decreased
    c. Stayed the same
    d. Don't know
    e. Refused

16. [IF A OR B] By what percent do you think the portion of total irrigated acreage on farms of 100 acres or more has changed? [IF THEY GIVE THE ANSWER IN ACRES, NOTE IT AND MOVE ON. CONVERT TO % LATER.]

17. Using the same time increments as before, I'm going to ask about what you think will happen over the next 20 years. By what percent do you expect the amount of irrigated acreage on farms of 100 acres or more to change (relative to 2008 levels) in the next
    a. 20 years?

b. 10 years?
c. 5 years?

Figure 21. Percentage of Wells with a Pumping Height of 100 Feet or Greater



Source: Navigant analysis of United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Irrigated Wells Used on Farms by Pumping Depth*. Survey years 1988, 1994, 1998, 2003, and 2008.

Figure 21 illustrates the percentage of wells with a pump height of 100 feet or greater in the three-state region from 1988 through 2008.

18. Do you think this graph accurately reflects what you see in your experience? [ADJUST TO AUDIENCE: AMONG YOUR CONSTITUATES; WITH YOUR GROWERS; IN YOUR RESEARCH; ETC.] [IF NOT, ASK WHAT THEY THINK IS MORE APPROPRIATE]

19. This graphic illustrates a significant amount of variation. We suspect that some of this is a result of survey design, including survey variation between survey cycles. Do you think that there are other factors that might have driven this variation? [IF NEEDED, SUGGEST CHANGES IN MARKET CONDITIONS, TECHNOLOGY, CLIMATE, WATER ACCESS]
    a. Please discuss these factors.

20. Since 2008, do you think that the percentage of irrigated farms with pumping heights of 100 feet or more has… [IF RESPONDENT CAN ONLY SPEAK TO A PART OF THE THREE-STATE REGION, NOTE WHICH PART]
    a. Increased
    b. Decreased
    c. Stayed the same
    d. Don’t know
    e. Refused

21. [IF A OR B] By what percent do you think the number of wells with pumping heights of 100 feet or more has changed? [IF THEY GIVE THE ANSWER IN ACRES, NOTE IT AND MOVE ON. CONVERT TO % LATER.]

22. Using the same time increments as before, I'm going to ask about what you think will happen over the next 20 years. By what percent do you expect the amount of acreage irrigated using pumping heights of 100 feet or more to change (relative to 2008 levels) in the next
    a. 20 years?
    b. 10 years?
    c. 5 years?

Table 27. Irrigated acreage by crop type, as a percentage of all irrigated acreage

	1988	1994	1998	2003	2008
Crops for Forage or Fodder (Alfalfa, Hay, etc.)	22%	24%	27%	32%	32%
Grain (Wheat, Barley, etc.)	20%	20%	19%	20%	20%
Other Vegetables (including beans, beets and other vegetables)	9%	9%	9%	8%	14%
Pasture	12%	11%	11%	13%	13%
Potatoes	8%	8%	9%	8%	7%
Orchard	4%	3%	4%	4%	3%
Other	26%	24%	22%	14%	12%
Total	100%	100%	100%	100%	100%

Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Estimated Quantity of Water Applied and Primary Method of Distribution by Selected Crops Harvested*. Survey years: 1988, 1994, 1998, 2003, and 2008.

Table 27 illustrates the distribution of irrigated acreage used for the most common crops from 1988 through 2008.

23. Do you think this table accurately reflects what you see ... [ADJUST TO AUDIENCE: AMONG YOUR CONSTITUENTS; WITH YOUR GROWERS; IN YOUR RESEARCH; ETC.] [IF NOT, ASK WHAT THEY THINK IS MORE APPROPRIATE]

24. I'm going to ask you about the crops shown in Table 27 one at a time. Please indicate if you think that the portion of irrigated acres for that crop has increased, decreased or stayed the same since 2008. [IF RESPONDENT CAN ONLY SPEAK TO A PART OF THE THREE-STATE REGION, NOTE WHICH PART]
    a. Increased
    b. Decreased
    c. Stayed the same
    d. Don't know
    e. Refused

25. [IF A OR B] By what percent do you think the total irrigated acreage in the three state region has changed from 2008 to the present? [IF THEY GIVE THE ANSWER IN ACRES, NOTE IT AND MOVE ON. CONVERT TO % LATER.]

CROP TYPE	Increase/Decrease/Same	% Change Since 2008
Crops for Forage or Fodder (Alfalfa, Hay, etc.)		
Grain (Wheat, Barley, etc.)		
Other Vegetables (including beans, beets and other vegetables)		
Pasture		
Potatoes		
Orchard		
Other		

26. Again covering the next 20 years, by what percent do you expect that amount of irrigated acreage to change for each of these crop types (relative to 2008 levels) in the next

a. 20 years?

CROP TYPE	Increase/Decrease/Same	% Change Since 2008
Crops for Forage or Fodder (Alfalfa, Hay, etc.)		
Grain (Wheat, Barley, etc.)		
Other Vegetables (including beans, beets and other vegetables)		
Pasture		
Potatoes		
Orchard		
Other		

b. 10 years?

CROP TYPE	Increase/Decrease/Same	% Change Since 2008
Crops for Forage or Fodder (Alfalfa, Hay, etc.)		
Grain (Wheat, Barley, etc.)		
Other Vegetables (including beans, beets and other vegetables)		
Pasture		
Potatoes		
Orchard		
Other		

c. 5 years?

CROP TYPE	Increase/Decrease/Same	% Change Since 2008
Crops for Forage or Fodder (Alfalfa, Hay, etc.)		
Grain (Wheat, Barley, etc.)		
Other Vegetables (including beans, beets and other vegetables)		
Pasture		
Potatoes		
Orchard		
Other		

Figure 22. Distribution of Irrigation Types in the Three-State Region

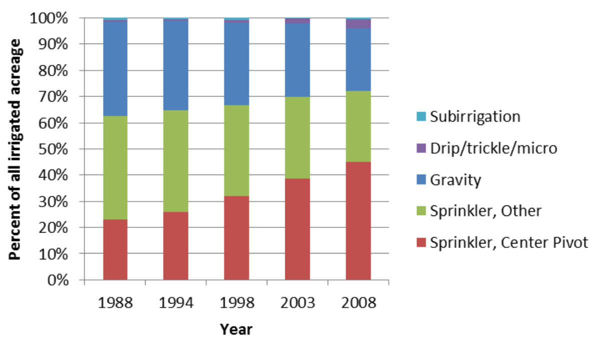


Figure 23. Distribution of Irrigation Types in Idaho

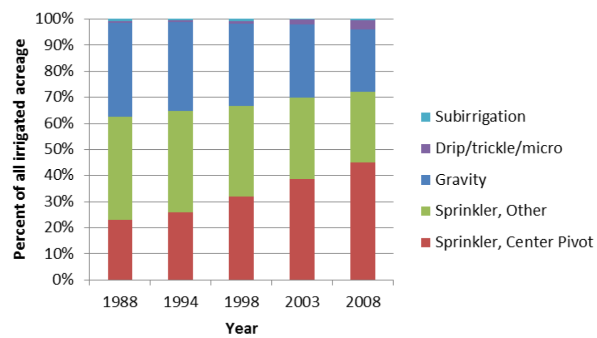


Figure 24. Distribution of Irrigation Types in Oregon

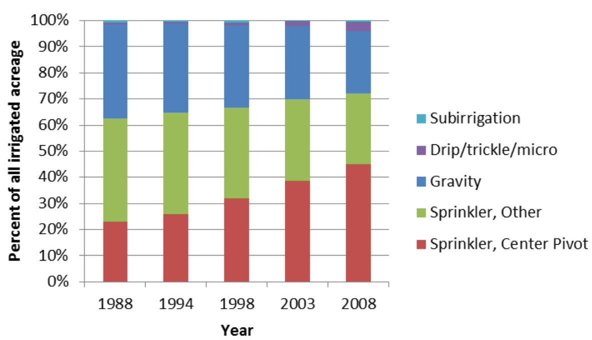
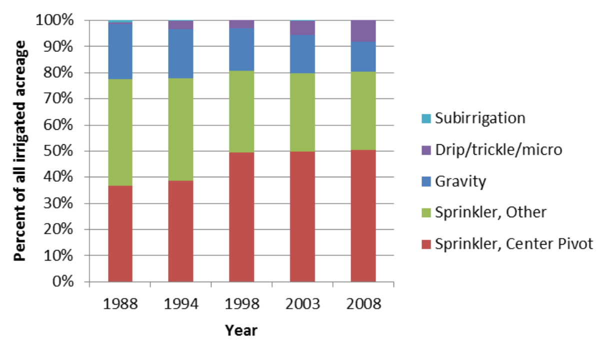


Figure 25. Distribution of Irrigation Types in Washington



Source: United States Department of Agriculture, Farm and Ranch Irrigation Surveys. *Land Irrigated by Method of Water Distribution* and *Land Irrigated by Sprinkler Systems*. Survey years 1988, 1994, 1998, 2003, and 2008.

Figure 14 through Figure 17 illustrate the distribution of irrigated acreage by type of irrigation from 1988 through 2008.

27. Do you think this graph accurately reflects what you see ... [ADJUST TO AUDIENCE: AMONG YOUR CONSTITUENTS; WITH YOUR GROWERS; IN YOUR RESEARCH; ETC.] [IF NOT, ASK WHAT THEY THINK IS MORE APPROPRIATE]

28. [IF GRAPH IS ACCURATE…]We noticed that center pivot irrigation systems have increased in market share, seemingly at the expense of other types of sprinkler systems and of gravity systems. What do you think has driven this shift?

29. How has this distribution changed from 2008 to the present? [IF RESPONDENT CAN ONLY SPEAK TO A PART OF THE THREE-STATE REGION, NOTE WHICH PART].
    a. Have any irrigation types become more prevalent? Less prevalent?
    b. What do you think is driving the market [toward or away from] those technologies?

30. I'm going to ask about what you think will happen in the future. By what percent do you expect the amount of irrigated acreage to change (relative to 2008 levels) in the next
    a. 20 years?
    b. 10 years?
    c. 5 years?

31. What do you think is the maximum portion of acreage currently watered using pressurized irrigation that center pivot systems would be appropriate for?

    a. What do you think are the reasons for this?

32. What do you think is the maximum portion of acreage currently watered using gravity fed systems that center pivot systems would be appropriate for?
    a. What do you think are the reasons for this?

We are primarily interested land irrigated by center pivots, on farms of at least 100 acres and with pumping heights of 100 feet or greater. However, the Farm and Ranch Irrigation Survey reports do not allow us to look at specific cross sections of farms, like the one I just described. The following questions will help us understand correlations between factors.

33. With a yes or no, please indicate if you think a center pivot is generally appropriate for the following crops?

	Yes	No	DK	Refused
Crops for Forage or Fodder (Alfalfa, Hay, etc.)				
Grain (Wheat, Barley, etc.)				
Orchard				
Pasture				
Potatoes				
Other Vegetables (including beans, beets and other vegetables)				
Other				

34. Between farm size and pump height, which is most important to determining applicability of center pivots for the given crop type? [SKIP CROP IF CENTER PIVOT WAS MARKED AS INAPPROPRIATE IN PREVIOUS QUESTION]

	Farm Size	Pump Height	DK	Refused
Crops for Forage or Fodder (Alfalfa, Hay, etc.)				
Grain (Wheat, Barley, etc.)				
Orchard				
Pasture				
Potatoes				
Other Vegetables (including beans, beets and other vegetables)				
Other				

IRRIGATION STRATEGIES

The next set of questions address the use of irrigation strategies in the three-state region.

For the purposes of this interview, we have defined irrigation strategies as “the use of methods, information, and/or technologies to reduce the amount of water and energy used for irrigation, relative to conventional approaches to water decisions, such as visual or tactile assessments.”

Specifically, we are interested in three types of irrigation strategies:

- Planning – is the co-optimization of expected crop yield and water usage, by using techniques such as deficit irrigation.*
- Farm and field-level tools – is the use of data and models to determine the amount of water to apply to a farm or field at a given time. Tools include scientific irrigation scheduling*, other scheduling services, evapotranspiration reports, and/or computer simulation.

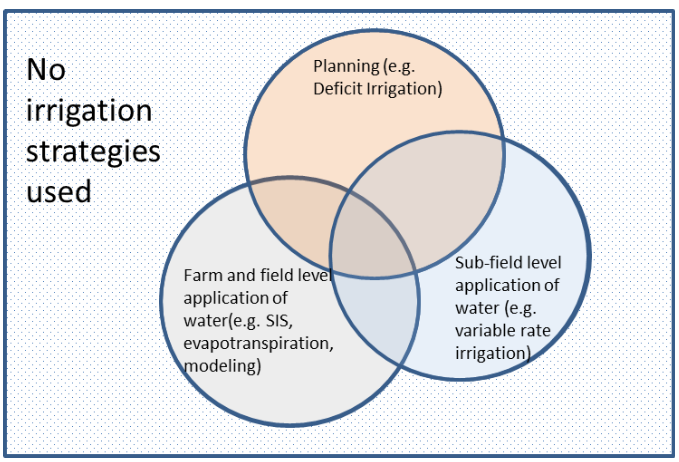
- Sub-field-level tools – is the use of spatially granular information such as soil type and topography, in conjunction with modeling and variable rate irrigation controls*, to vary the amount of water applied over portions of a field.

[*PROVIDE DEFINITIONS IF ASKED:

- Deficit irrigation is a strategy that provides sufficient irrigation at drought-sensitive times in the plant growth cycle, yet allows plants to be stressed at other times in the growth cycle.
- Scientific irrigation scheduling (SIS) provides information on when to irrigate, how much water to apply, and how to apply water to satisfy crop water requirements and avoid plant moisture stress. SIS systems usually include soil moisture sensors in the ground and data loggers that collect the information and display for grower decision-making.
- Variable rate irrigation (VRI) is the use of different amounts of irrigation in different locations within a field, typically facilitated by the mapping of soil features and drainage characteristics. There are two types; VRI "speed" controls the actual speed of the center pivot and VRI "zonal" or "site specific" couples "speed" with automated controls on the center pivot to regulate the water flow down to as few as two sprinklers. **]**

Figure 3 illustrates a categorization of center pivot irrigated acreage, based on the types of irrigation strategies that are used. The following questions refer to the relative sizes of these categories.

Figure 26. Venn diagram of the use of irrigation strategies



35. Are you aware of any other irrigation strategies that are undertaken by Northwest growers? If so, what are they? [IF RESPONSES SUGGEST THAT RESPONDENT IS USING A DIFFERENT DEFINITION OF "IRRIGATION STRATEGIES", REPEAT THE DEFINTION]

36. I'd like you to estimate the percentage of Northwest irrigated acreage on farms 100 or more acres that fall into several of these categories, both currently and at several points in the

future: [CLARIFY WITH RESPONDENT WHETHER THEY'RE ESTIMATING FOR THE THREE-STATE REGION OR JUST THEIR REGION]

	2012	**2032 (in 20 years)**	**2022 (in 10 years)**	**2017 (in 5 years)**	**What is the saturation level?**
Estimate the % of all irrigated acreage on which					
No strategies used					
Planning (e.g. deficit irrigation)					
Farm and field-level tools (e.g. SIS, evapotranspiration reports)					
Sub-field-level tools (e.g. variable rate irrigation)					
All three strategies					
Of acreage using two of the three strategies…					
Which is most common?					
Which is least common?					

37. What is your reasoning behind your estimates in the previous question?

38. Which of the following best describes the growers who have adopted planning strategies:
    a. They regularly try new approaches to farming but rarely settle on one technique for very long
    b. They are using planning strategies to solve a specific problem
    c. They represent the majority of growers and are using planning strategies because it is "main stream"
    d. None of the above; (other description)
    e. Don't know
    f. Refuse

39. Which of the following best describes the growers who have adopted farm and field-level tools:
    a. They regularly try new approaches to farming but rarely settle on one technique for very long
    b. They are using farm and field-level tools to solve a specific problem
    c. They represent the majority of growers and are using farm and field-level tools because they are “main stream”
    d. None of the above; (other description)
    e. Don’t know
    f. Refuse

40. Which of the following best describes the growers who have adopted sub-field-level tools:
    a. They regularly try new approaches to farming but rarely settle on one technique for very long
    b. They are using sub-field-level tools to solve a specific problem
    c. They represent the majority of growers and are using sub-field-level tools because they are “main stream”
    d. None of the above; (other description)
    e. Don’t know
    f. Refuse

41. [IF OTHER STRATEGIES, ASK FOR EACH] Which of the following best describes the growers who have adopted [THE OTHER STRATEGIES]:
    a. They regularly try new approaches to farming but rarely settle on one technique for very long
    b. They are using [OTHER STRATEGY] to solve a specific problem
    c. They represent the majority of growers and are using [OTHER STRATEGY] because it is “main stream”
    d. None of the above; (other description)
    e. Don’t know
    f. Refuse

42. How do growers using more than one irrigation strategy integrate information and decision making for these strategies? [PROBE FOR TOOLS USED TO INTEGRATE INFORMATION AND DECISION MAKING, JUST DOING IT “IN THEIR HEAD”]

43. What percent of center pivot systems are currently capable of

    a. speed controlled variable rate irrigation ?

    b. zonal or site-specific variable rate irrigation ?

44. [COMPARE THIS TO ESTIMATES OF PRESENT SUB-FIELD-LEVEL STRATEGY ADOPTION IN QUESTION 36– IF THERE IS A SIGNIFICANT DIFFERENCE, THEN ASK] Why do you think that this capability is not being utilized?

45. I've been asking you about farms larger than 100 acres. How do current and forecasted adoption levels differ for smaller farms?

46. There are two additional irrigation strategy tools that I'd like to ask you about. As you did previously, can you estimate the current and anticipated levels of usage of the following two tools:

    a. Integration Tools - Tools that integrate more than one of the strategies described above

    b. Decision-making Tools - Tools that improve the ease of decision-making

	2012	2032 (in 20 years)	2022 (in 10 years)	2017 (in 5 years)	What is the saturation level?
Estimate the % of all irrigated acreage on which					
Integration tools					
Decision-making tools					

MANUFACTURER PLANS

[ONLY FOR REGIONAL REPRESENTATIVES OF IRRIGATION CONTROL EQUIPMENT AND SERVICE PROVIDERS]

I'm now going to ask you a series of questions about products that you are currently marketing and products that you plan to market in the near future. If possible, answer these questions with respect to the Northwest only. If this is not possible, please let me know what region you can speak to. [LIKELY RESPONSE IS "THE WHOLE U.S."]

47. Regarding planning strategies such as deficit irrigation:
    a. What products are you currently marketing that provide guidance on planning strategies? Please describe.

    b. What percentage of irrigated acreage in the region uses this technology and/or service? [if percentage of acreage not known, ask about percent of growers]
        1) [IF PREVIOUS RESPONSE WAS IN TERMS OF % OF GROWERS, FOLLOW UP WITH] ARE THESE GROWERS TYPICALLY ON FARMS OF:
            1. LESS THAN 100 ACRES
            2. 100 TO 250 ACRES

3. MORE THAN 250 ACRES

c. To what extent do you expect this percent to change in the next five years?

d. What leads you to that conclusion? [PROMPT FOR…]
   1) Formal market research
   2) "Gut feeling"
   3) Informal technology review

e. What new products are you developing that provide guidance on planning strategies?

f. When do you expect these new products to be commercially available?

48. Regarding <u>farm and field-level tools</u> such as SIS and evapotranspiration reports:

a. What products are you currently marketing that provide guidance on farm and field-level control? Please describe.

b. What percentage of irrigated acreage in the region uses this technology and/or service? [if percentage of acreage not known, ask about percent of growers]
   1) [IF PREVIOUS RESPONSE WAS IN TERMS OF % OF GROWERS, FOLLOW UP WITH] ARE THESE GROWERS TYPICALLY ON FARMS OF:
      1. LESS THAN 100 ACRES
      2. 100 TO 250 ACRES
      3. MORE THAN 250 ACRES

c. To what extent do you expect this percent to change in the next five years?

d. What leads you to that conclusion? [PROMPT FOR…]
   1) Formal market research
   2) "Gut feeling"
   3) Informal technology review

e. What new products are you developing that provide guidance on farm and field-level control?

f. When do you expect these new products to be commercially available?

49. Regarding sub-field level tools such as variable rate irrigation

a. What products are you currently marketing that facilitate sub-field-level control? Please describe.

b. What percentage of irrigated acreage in the region uses this technology and/or service? [if percentage of acreage not know, ask about percent of growers]
   1) [IF PREVIOUS RESPONSE WAS IN TERMS OF % OF GROWERS, FOLLOW UP WITH] ARE THESE GROWERS TYPICALLY ON FARMS OF:
      1. LESS THAN 100 ACRES
      2. 100 TO 250 ACRES
      3. MORE THAN 250 ACRES

c. How do you expect this percent to change in the next five years?

d. What leads you to that conclusion? [PROMPT FOR…]
   1) Formal market research
   2) "Gut feeling"
   3) Informal technology review

e. What new products are you developing that facilitate sub-field-level control?

f. When do you expect these new products to be commercially available?

50. Regarding tools that <u>improve the ease of decision-making</u>

a. What products are you currently marketing that improve the ease of decision-making? Please describe.

b. What percentage of irrigated acreage in the region uses this technology and/or service? [if percentage of acreage not know, ask about percent of growers]
    1) [IF PREVIOUS RESPONSE WAS IN TERMS OF % OF GROWERS, FOLLOW UP WITH] ARE THESE GROWERS TYPICALLY ON FARMS OF:
        1. LESS THAN 100 ACRES
        2. 100 TO 250 ACRES
        3. MORE THAN 250 ACRES

c. How do you expect this percent to change in the next five years?

d. What leads you to that conclusion? [PROMPT FOR…]
    1) Formal market research
    2) "Gut feeling"
    3) Informal technology review

e. What new products are you developing that improve the ease of decision-making?

f. When do you expect these new products to be commercially available?

51. Regarding tools that integrate information and decision-making

a. What products are you currently marketing that integrate information and decision-making? Please describe.

b. What percentage of irrigated acreage in the region uses this technology and/or service? [if percentage of acreage not know, ask about percent of growers]
    1) [IF PREVIOUS RESPONSE WAS IN TERMS OF % OF GROWERS, FOLLOW UP WITH] ARE THESE GROWERS TYPICALLY ON FARMS OF:
        1. LESS THAN 100 ACRES
        2. 100 TO 250 ACRES
        3. MORE THAN 250 ACRES

c. How do you expect this percent to change in the next five years?

d. What leads you to that conclusion? [PROMPT FOR…]
    1) Formal market research
    2) “Gut feeling”
    3) Informal technology review

e. What new products are you developing that integrate information and decision-making?

f. When do you expect these new products to be commercially available?

52. Regarding other tools that facilitate irrigation strategies

a. What products are you currently marketing that facilitate irrigation strategies? Please describe.

b. What percentage of irrigated acreage in the region uses this technology and/or service? [if percentage of acreage not know, ask about percent of growers]
   1) [IF PREVIOUS RESPONSE WAS IN TERMS OF % OF GROWERS, FOLLOW UP WITH] ARE THESE GROWERS TYPICALLY ON FARMS OF:
      1. LESS THAN 100 ACRES
      2. 100 TO 250 ACRES
      3. MORE THAN 250 ACRES

c. How do you expect this percent to change in the next five years?

d. What leads you to that conclusion? [PROMPT FOR…]
   1) Formal market research
   2) "Gut feeling"
   3) Informal technology review

e. What new products are you developing that these irrigation strategies?

f. When do you expect these new products to be commercially available?

CLOSING

53. If I have any additional questions as I'm reviewing my notes, would it be OK if I contacted you again for clarification? Would you prefer phone or email?
    [Get appropriate phone number and/or email address, if not already provided:]
    Phone: ______________________________
    Email: ______________________________

54. Is there anyone else you would recommend I speak with about this topic?

Name: _______________________________________
Organization: ________________________________
Phone: ______________________________________
Email: _______________________________________

Name: _______________________________________
Organization: _________________________________
Phone: _______________________________________
Email: _______________________________________

55. Is there anything else that you would like to add?

[INTERVIEWER: REMIND PARTICIPANT THAT YOUR CONTACT INFORMATION IS IN THE EMAIL SIGNATURE WHERE FILE WAS SENT IF THEY'D LIKE TO CONTACT YOU AT ANY POINT IN THE FUTURE.]

Appendix C. Description of NEEA's Integrated Irrigation Decision Support Solution

As described in their RFP for this project, NEEA's initiative product:

> …is an integrated irrigation decision support solution (IIDS) that will make it easy and compelling for growers to take action to lower their irrigation electrical energy use, and as a result, reduce their operating costs and consequently improve profitability.
>
> The IIDS product solution consists of a common software architectural platform with:
>
> 1. Pre-planting soil mapping survey capability
> 2. A common application programming interface (API) that:
>   a. receives soil moisture data
>   b. receives current and near-future weather conditions
> 3. A database to store and retrieve the above data and integrate irrigation management methods to assist in the irrigation decision process.
> 4. A data analysis engine to calculate the optimum amount of irrigation for the maximum amount of profit, given the crop, soil and weather conditions; these form the basis of the business model. The tool will accept real time updates and provide up-to-the-day recommendations on irrigation management.
> 5. A simulation or integration program (integration of soil mapping, environmental impacts, variable rate applications to maximize profits) that allows users to enter different use case scenarios (for example, variables in crops, soil conditions, weather, market pricing, and other variables)
> 6. Ability to send reports and recommended actions for optimum irrigation
> 7. Provide update information and control direct to a "smart phone" or other portable devices. (NEEA 2012)