Lessons Learned from Irrigation Pump Monitoring in the Midsouth

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Top 4 States in Quantity of Water Applied for Irrigation (Million ac-ft)

- California
- Arkansas
- Texas
- Nebraska
How much ground water does Arkansas use?

7.2 billion gallons/day
Agriculture consumes 90% of consumptive water use
Total water withdraws: 20% surface water, 80% groundwater
Mississippi River Valley Alluvial Aquifer

Wells 50-150 ft deep, 300-2,500 gpm production sand and gravel composition

7,049 MGD withdraw annually Only 42.4% is sustainable
Sparta/Memphis Aquifer

- 100-1,000 feet deep
- 100-500 gpm
- Sand, silt and clay composition

- 187 MGD withdrawn annually
- Only 46.5% is sustainable
Irrigation Pump Monitors

- Industrial automation for agriculture.
- Provides producer with information regarding individual pumping plant operation (1 hour data reported).
- Allows for remote control operation using cell phone modem or wireless 802.11g connectivity through web-based interface.
- Tracks energy and water use over time.
- Product being developed for White River Irrigation District through Diesel Engine Motors Inc (dieselenginemotor.com).
- NRCS cost share available through the Mississippi River Basin Initiative (MRBI).
- Cost is about $7,000 for diesel and $4,000 for electric (but don’t quote me on this).
A variety of Flow meters have been used and tested for flow measurement.
Calibration using propeller meters or portable ultrasonic flow meters
Surface water creates challenges not experienced in groundwater based irrigation systems.
Pressure sensors can be used to monitor system, leaks, set changes, pumping plant performance.
• Uses laser so acquire a distance to the surface of the water from the sensor.
• Allows the producer to have a close estimate of the depth of the reservoir or other irrigation source.
• Uses a programmed benchmark level and a simple mathematical formula to calculate depth and present a value to the monitor box.
Depth Sensors provide ditch elevations for TDH, monitoring water supply, and pumping plant performance for surface water relifts. Can be used to automate pumping. Unfortunately well depth is rarely available for submersibles and vertical turbines.
Precipitation data is provided via specially designed rain gages suitable for the agricultural irrigation environment.
Current meters have been used to measure energy consumption.
Remote Control and operation of pumps is possible through solenoids
A variety of attempts have been made to measure fuel flow to high accuracy. However, this has yet to be accomplished to satisfaction.
Internet Camera provides user with visual image of irrigation progress, pump operation, and crop.
Connectivity

- Cellular modems and wireless 802.11 can be used to push data to web server.
Screen shot of Diesel Engine Motors website, which provides real time data and power up/shut down ability to the farmer. All data collected can be exported to Microsoft Excel directly from the website.
Pumping Plant Monitoring
Alluvial Well, electric, 160 ac
Field 14-18 (NE Arkansas)

Total Water Delivered: 396.7 Acre-Ft.
Total Power Used: 36,240 kWh
Seasonal Delivery Cost: $8.27/Acre-Ft.
Operational Time: 981 hrs.
Maximum Flow: 2,490 GPM (6/9/2011)
Minimum Flow: 1,720 GPM (8/28/2011)
Start of Irrigation: 6/9/2011
End of Irrigation: 8/28/2011
Average Flow: 2,147 GPM
Power Cost: $3,260 ($0.09/kWh)
Flow Decrease: ~30% (18.6 GPM/Operational Day)
Cost Increase: ~41.3% ($0.48/Operational Week)
Pumping Plant Monitoring
Field 14-18 (NE AR)
Alluvial Well, electric

Water Pumped

28% reduction in pump capacity

\[
y = -0.72x + 2563
\]
\[
R^2 = 0.91
\]
Pumping Plant Monitoring
Field 14-18

Delivery Cost

42% increase in cost during growing season
Pumping Plant Monitoring
Sparta Deep Well (Central AR) Multiple crops

Total Water Delivered: 272 Acre-Ft.
Total Power Used: 139,900 kWh
Seasonal Delivery Cost: $47.66/Acre-Ft.
Operational Time: 1,307 hrs.
Maximum Flow: GPM 1,440 (6/6/2011)
Minimum Flow: GPM 910 (8/7/2011)
Start of Irrigation: 6/6/2011
End of Irrigation: 8/9/2011
Average Flow: 1,105 GPM
Power Cost: $12,600 ($0.09/kWh)
Flow Decrease: ~29% (7.6 GPM/Operational Day)
Cost Increase: ~28-37% ($1.81/Operational Week)
Pumping Plant Monitoring
Central, AR

Flow Delivery

\[ y = -0.29x + 1343 \]

\[ R^2 = 0.92 \]
Pumping Plant Monitoring
Central AR

Delivery Cost

28%-37% increase in pumping cost during growing season
Initial Drawdown

• In most cases, flow loss is most rapid at the beginning of an irrigation set and most extreme during the first irrigation set of the season.
• This initial flow decline is a result of the development of a cone of depression within the alluvial aquifer.
• Flow often exhibits exponential decline for the first 24-48 hours of irrigation. This is not always the case, with flow sometimes showing linear decline throughout the season.
• This seasonal trend for many pumping plants (15-30% flow decline) is important to realize for irrigation system design and management.
• Graph above of flow delivery over time exhibits exponential decline in flow rate at the beginning of each set. The slope is most extreme during the first irrigation set as the cone of depression is developed.

• In this example, the flow declines 12% from the original reading (1929 GPM) over the first 48 hours of irrigation.
Initial Drawdown Analysis

- Drawdown is not as significant as other wells.
- Electric pump – well Central AR
Hitting the “sweet spot” on the pump curve may be a moving target.
Could a Pump Monitor Optimize Performance during the season?

YES!
General Trends from the Data

• Surface Water Re-lifts
  – $5-$8/ac-ft

• Shallow alluvial wells
  – $10-$15/ac-ft in NE AR
  – $20-$25/ac-ft in Central AR
  – 20-30% flow reductions over growing season

• Deep Wells
  – $40-$45/ac-ft
  – 5% -30% flow reductions
Load Management Programs

- Program uses automated switch system to perform pumping plant shutdowns (said to be 3 hours) in order to cut power use during peak use periods.
- Producer receives approximately 30% discount on energy bill in return for allowing utility to shut down pumps on demand.
Load Management Case Study

• 160 ac field
• Electric Pump, shallow well (35’ depth)
• Utility promises shutdowns are not more than 3 hours.
• 30% discount
• $0.09/kWh power cost
• What is the impact on annual water use?
• How much downtime does the pump really have?
• Pump monitored was on load management, compared to scenario where pump was not on load management (assumed pump ran during shutdown periods with filled-in data).
# Load Management Case Study

## Assuming No Shutdowns

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<tr>
<th>Water Delivered:</th>
<th>452.4 Acre-Ft</th>
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<tbody>
<tr>
<td></td>
<td>(34 ac-in)</td>
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</table>

| Power Used:     | 53,801 kWh    |
|                 |               |

| Power Cost:     | $4,825.00     |
|                 |               |

| Operational Time: | 1,284 hrs. |
|                   |            |

## Current Peak Load Program

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<th>Water Pumped:</th>
<th>431.6 Acre-Ft.</th>
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<table>
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<th>Estimated Loss:</th>
<th>20.8 Acre-Ft. (5%)</th>
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<td>(1.56 ac-in)</td>
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| Power Used:     | 51,490 kWh         |
|                 |                    |

| Power Cost:     | $4,634.00          |
|                 |                    |

| Estimated Savings: | $1,581 (30% or $10/ac) |
|                   |                        |

| Total Expenditure: | $3,244.00           |
|                   |                     |

| Operational Time: | 1,219 hrs.         |
|                   |                     |

| Total Shutdown Time: | 65 hrs.            |
|                     |                     |

| Number of Shutdowns: | 21                  |
|                     |                     |

| Average Shutdown Duration: | 3.1 hrs. |
|                            |          |

| Max Shutdown Duration:     | 3.9 hrs. (twice) |
|                            |                  |

On shutdown days there is an application difference of 0.07 in/dy
How does this flow dynamic during the season impact poly pipe?
As flow decreases, time to irrigate field increases.

**Distribution Uniformity = 90.3**

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<th>Station (Feet)</th>
<th>Hole Dia. (Inches)</th>
<th>Hole Number</th>
<th>Furrow Flow (GPM)</th>
<th>Head (feet)</th>
<th>Flow Ratio</th>
<th>Furrow Length (feet)</th>
<th>Elevation (feet)</th>
<th>Number of Holes per Furrow</th>
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**Gross Applied (in.)**

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<th>Days</th>
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**Recommended Furrow Flow = 10 GPM**

**Average Furrow Flow = 4.7**

**Highest Head = 3.50**

**Max Head Station = 1318**

**Lowest Head = 1.77**

**Low Head Station = 0**

**Max. Furrow Flow = 5.97**

**Min. Furrow Flow = 4.24**

**Calculated GPM = 2489**
Designing for lower flow results in longer application times or less application depth.

Ever feel like you just can’t keep up at the end of the season?
A possible solution is to use a Variable Frequency Drive to provide constant flow.
• Constant pressure and vary pump flow rates
• Full motor torque across all speed ranges
• > 10 hp motors on single phase power
• More energy efficient
• Soft start and reduces demand charges
Flow Delivery

VFD constant pressure or flow

GPM vs. Date
Why use a Pump Monitor?

- There are many commercial products available with a wide range of prices and capabilities.
- May be able to reduce trips to the field checking irrigation equipment through remote control capability.
- Monitoring pump performance could lead to an indication of pump/bowl maintenance needs.
- To reduce water consumption, must first know how much is being used. Benefit of conservation measures.
- Water use data is very valuable for reservoir sizing.
- Advance sensors and soil moisture sensors can be integrated to assist and possibly automate irrigation decisions.
- LA and TX have pumping plant evaluation programs.
Take Home Message

- Pump monitors will likely be a valuable tool for growers to improve irrigation efficiency and management of water resources.
- In-season flow reduction and increased irrigation cost is significant. How can we use this information to improve water conservation and profitability?
- Initial drawdown on some wells could be significant especially if flow measurement for irrigation systems design or performance is being used.
- Energy savings from load management are substantial for growers, yet participation is low.

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