Lessons Learned from Irrigation Pump Monitoring in the Midsouth

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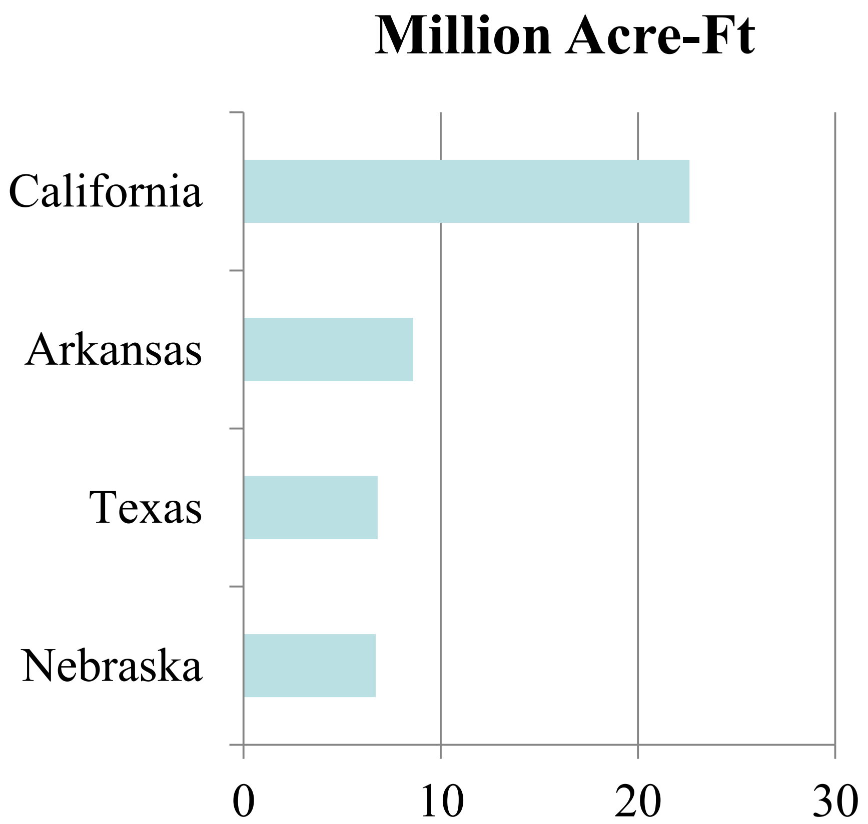
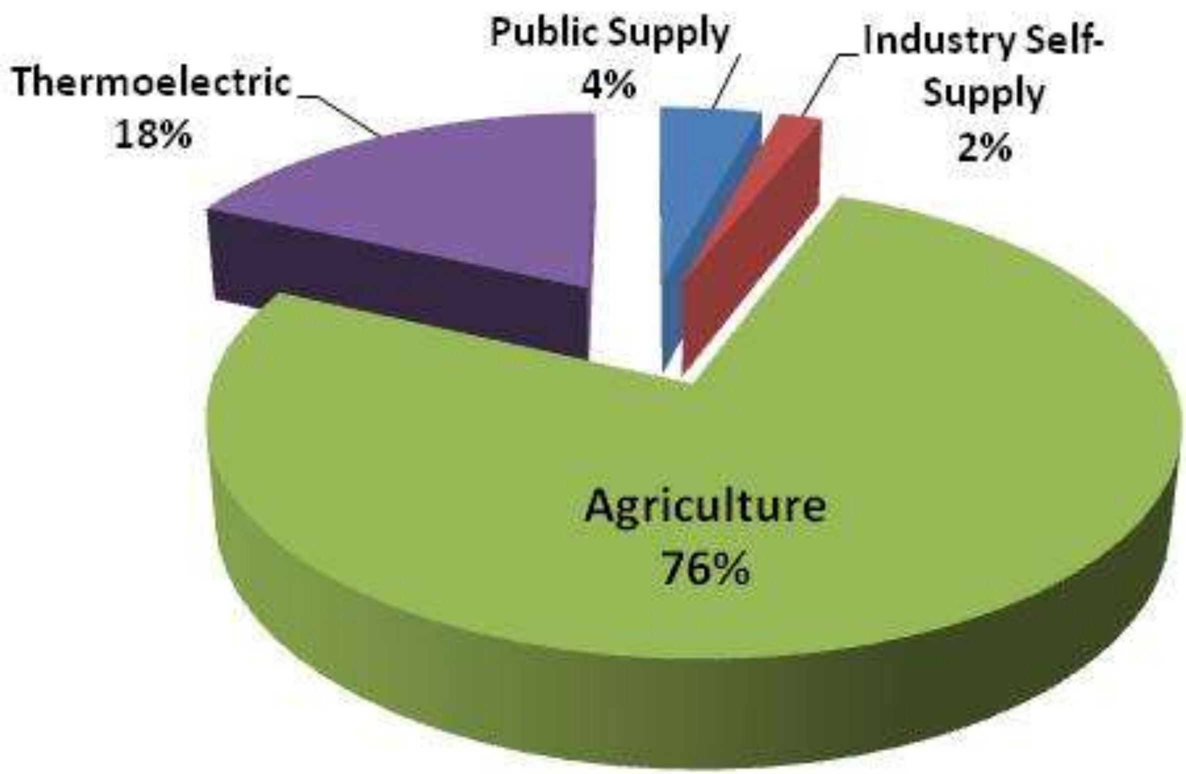
Top 4 States in Quantity of Water Applied for Irrigation (Million ac-ft)




How much ground water does Arkansas use?
7.2 billion gallons/day
USGS

Total Water Use by Sector in Arkansas



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

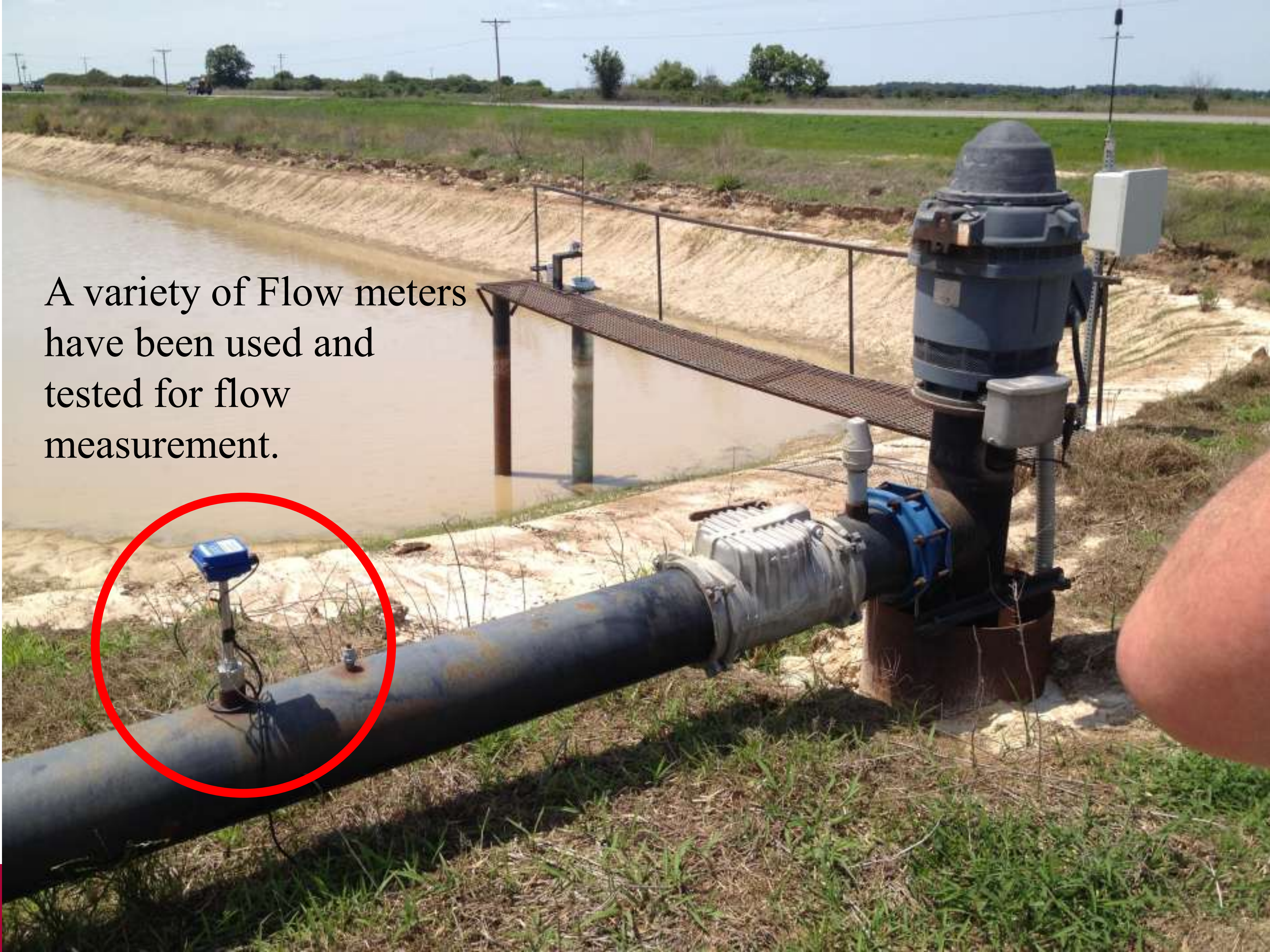
187 MGD withdrawn annually

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).

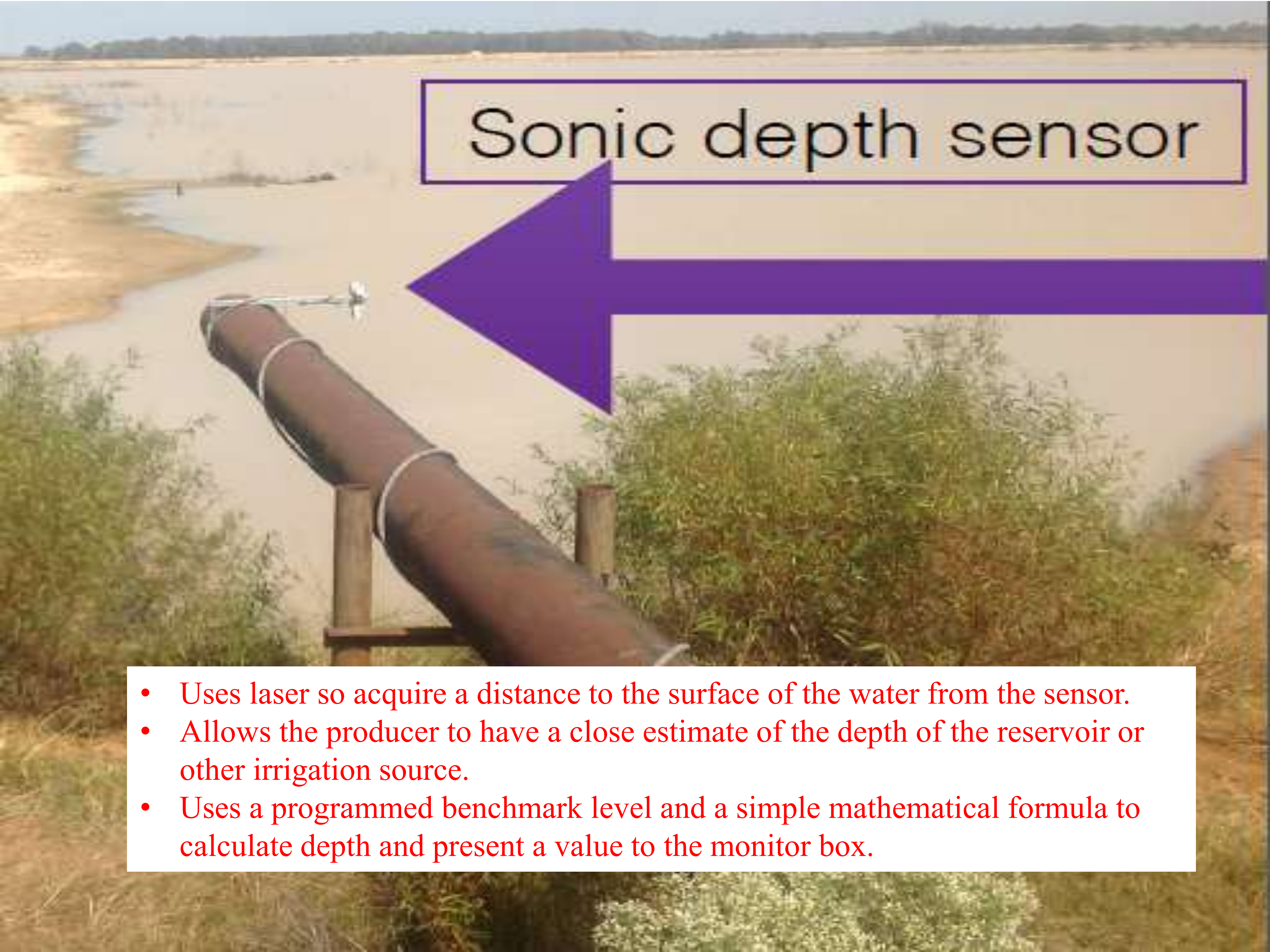

AMC


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



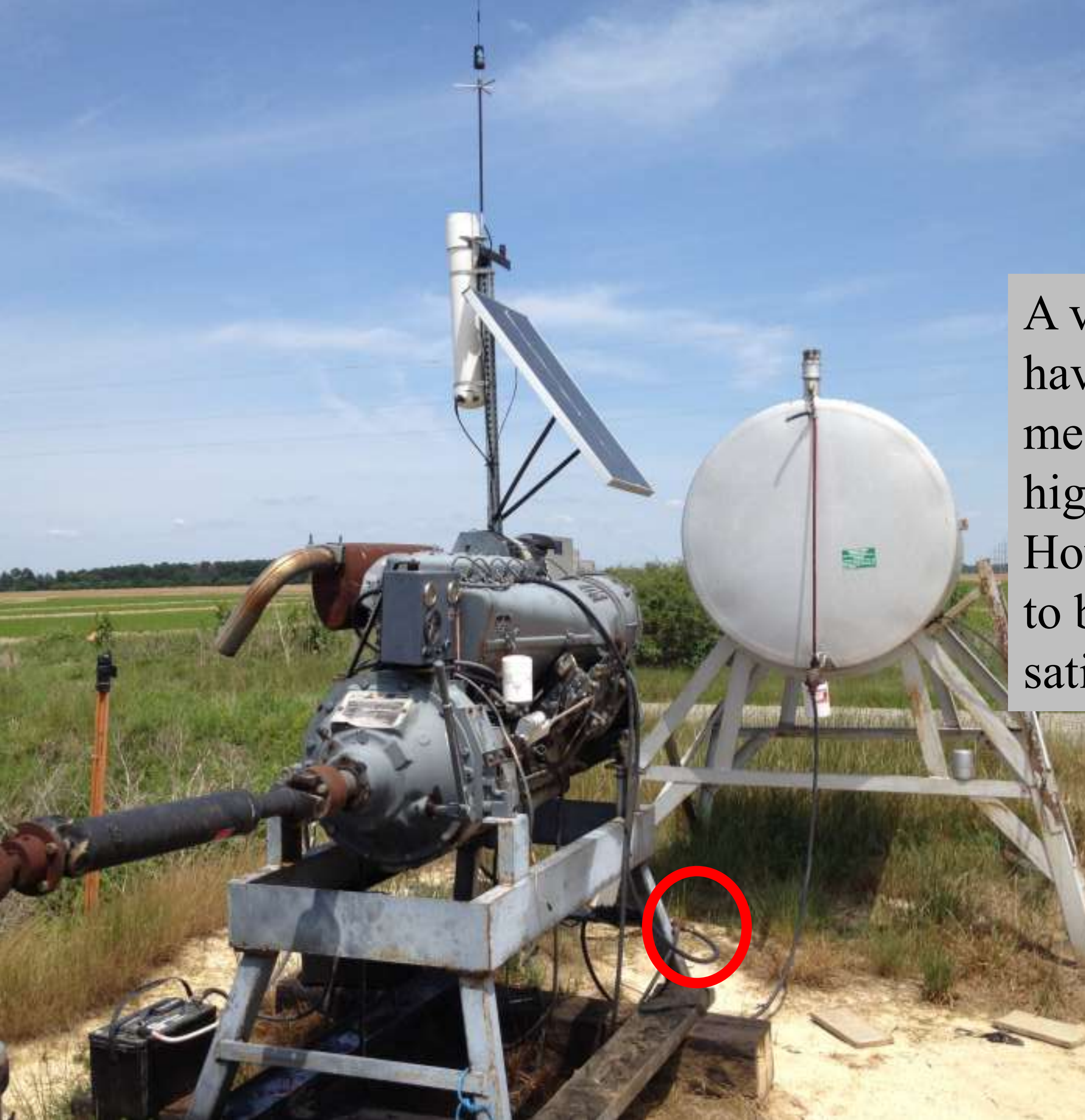
- Uses laser so acquire a distance to the surface of the water from the sensor.
- Allows the producer to have a close estimate of the depth of the reservoir or other irrigation source.
- Uses a programmed benchmark level and a simple mathematical formula to calculate depth and present a value to the 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 provide via specially designed rain gages suitable for the agricultural irrigation environment.

Current meters have been used
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.

Internet Screenshot

Turn On	Turn Off	Location	Pump		Water Flow	Line Pressure	Air Temperature	12V Power Supply	Sensor Voltage	Channel2	Channel4	Channel5	Channel6	Digital2	Digital3	Digital4
		-B5 Reservoir	Off	G	0.00	13.10	0.00	3.50	5.30	0.00	0.00	0.00	0.00	0.00	0.00	0
					Annual Efficiency: 71.47%		**Kwh Used:** 1926.36		**Cost per Acre Ft:** $2.57							

Turn On	Turn Off	Location	Pump		Water Flow	Line Pressure	12V Power Supply	Sensor Voltage	Air Temperature	Channel2	Channel4	Channel5	Channel6	Digital2	Digital3	Digital4
		-B6 Reservoir	Off	G	0.00	99.90	12.10	12.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
					Annual Efficiency: 46.66%		**Kwh Used:** 3691.34		**Cost per Acre Ft:** $3.27							

Turn On	Turn Off	Location	Pump		Water Flow	Line Pressure	Reservoir	Air Temperature	12V Power Supply	Sensor Voltage	Channel2	Channel4	Channel5	Digital2	Digital3	Digital4
		-Bearskin C14 Reservoir	Status Unknown	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
					Annual Efficiency: 63.37%		**Kwh Used:** 765.88		**Cost per Acre Ft:** $8.07							

Turn On	Turn Off	Location	Pump		Water Flow	Line Pressure	12V Power Supply	Sensor Voltage	Channel1	Channel2	Channel4	Channel5	Channel6	Digital2	Digital3	Digital4
		-Bearskin Cole Reservoir IN	Status Unknown	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
					Annual Efficiency: 0.00%		**Kwh Used:** 0.00		**Cost per Acre Ft:** 0							

Turn On	Turn Off	Location	Pump		Water Flow	Line PSI	Air Temp	12V Power Supply	Sensor Voltage	Channel2	Channel4	Channel5	Channel6	Digital2	Digital3	Digital4
		5 Oaks Electric	On (R)	G	10097.00	3.50	0.00	12.10	11.30	0.00	0.00	0.00	0.00	0.00	0.00	0
					Annual Efficiency: 0.00%		**Kwh Used:** 0.00		**Cost per Acre Ft:** 0							

Turn On	Turn Off	Location	Pump		Water GPM	Line Pressure	Rain Fall	12V Power Supply	Sensor Voltage	Channel1	Channel2	Channel4	Channel5	Channel6	Digital2	Digital3
		94 Tyler Bros 11	Status Unknown	G	0.00	0.00	0.550	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
					Annual Efficiency: 23.91%		**Kwh Used:** 9638.87		**Cost per Acre Ft:** $6.04							

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.

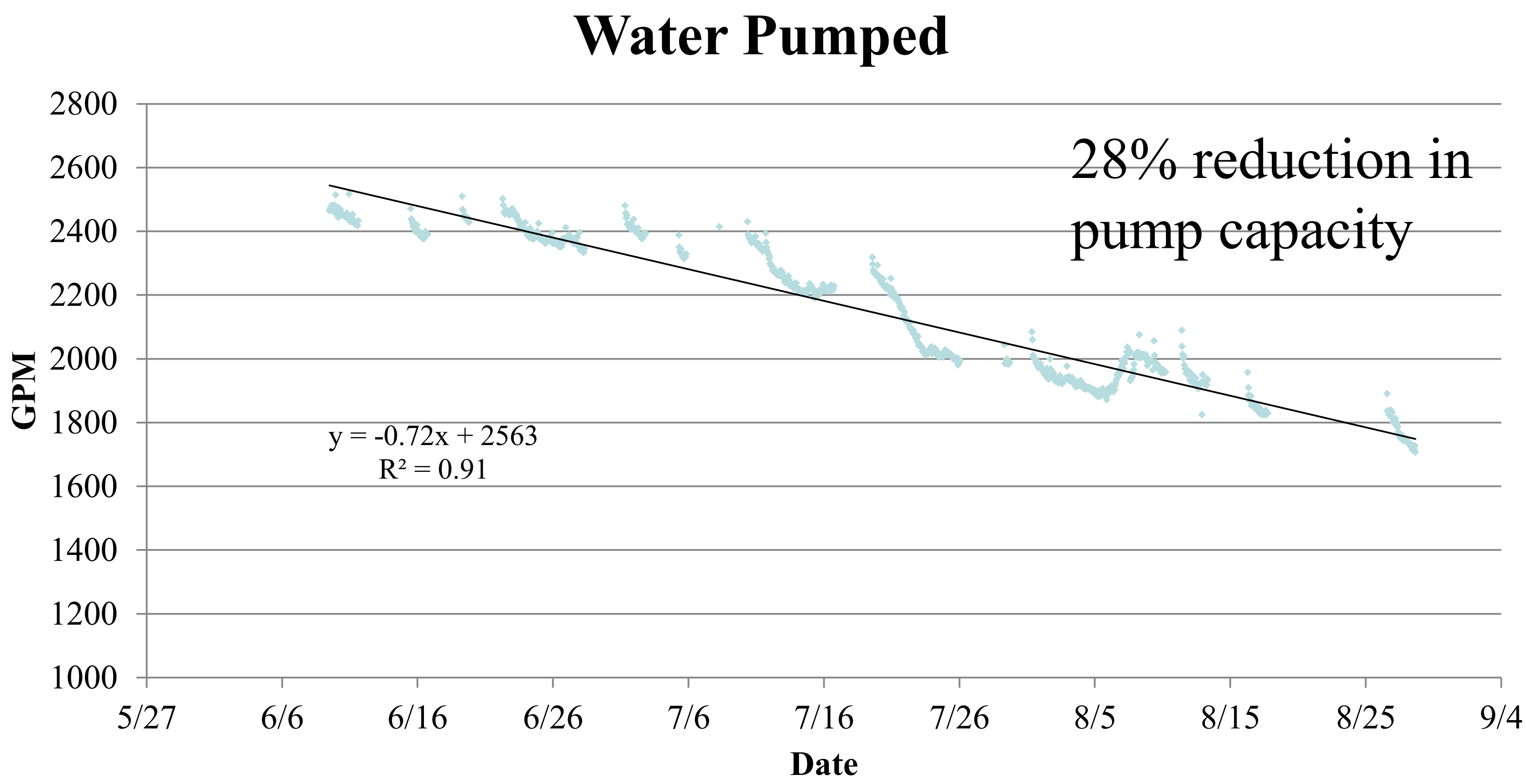
Pumping Plant Monitoring

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)**

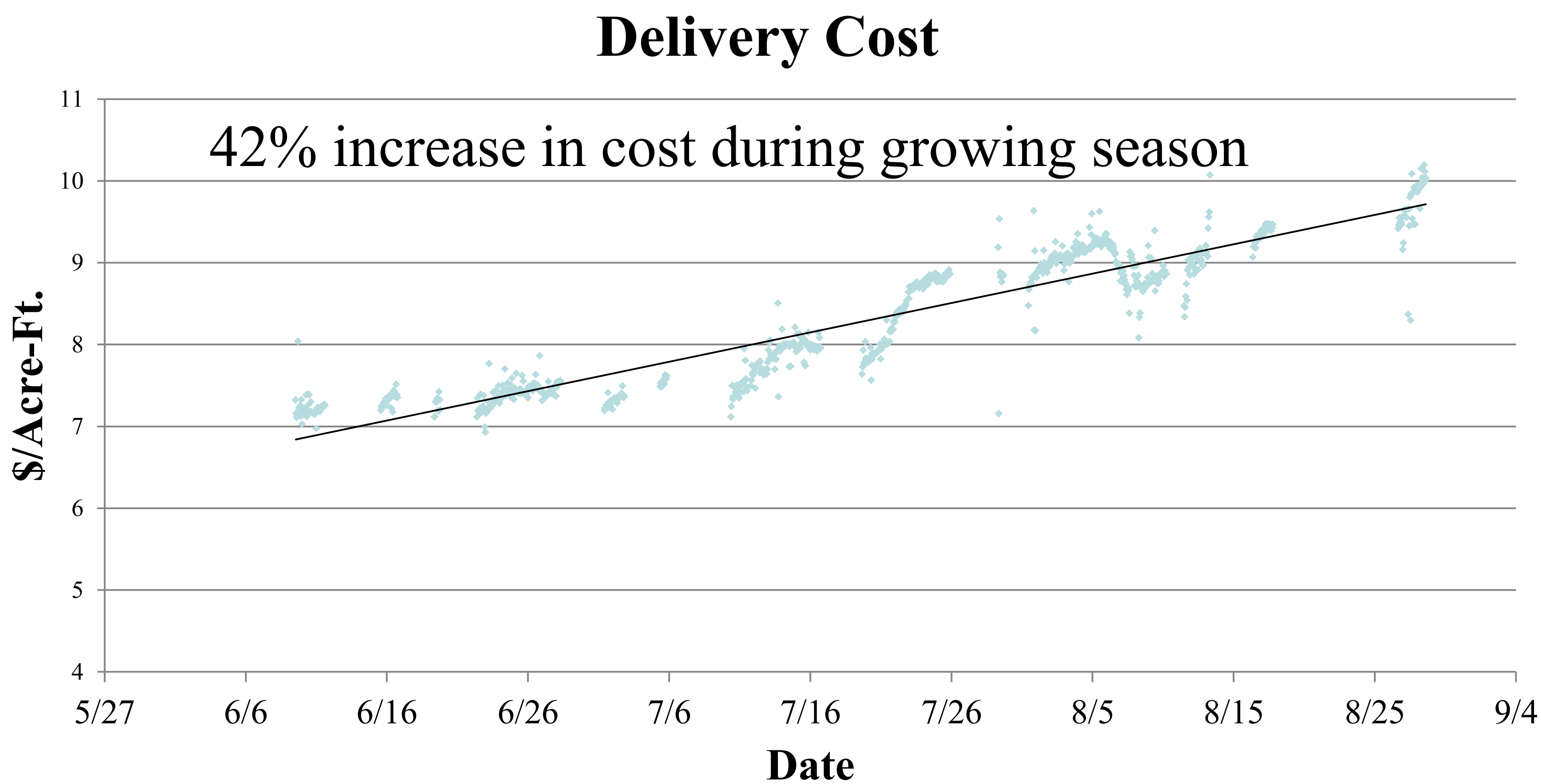
Pumping Plant Monitoring

Field 14-18 (NE AR)
Alluvial Well, electric



Pumping Plant Monitoring

Field 14-18



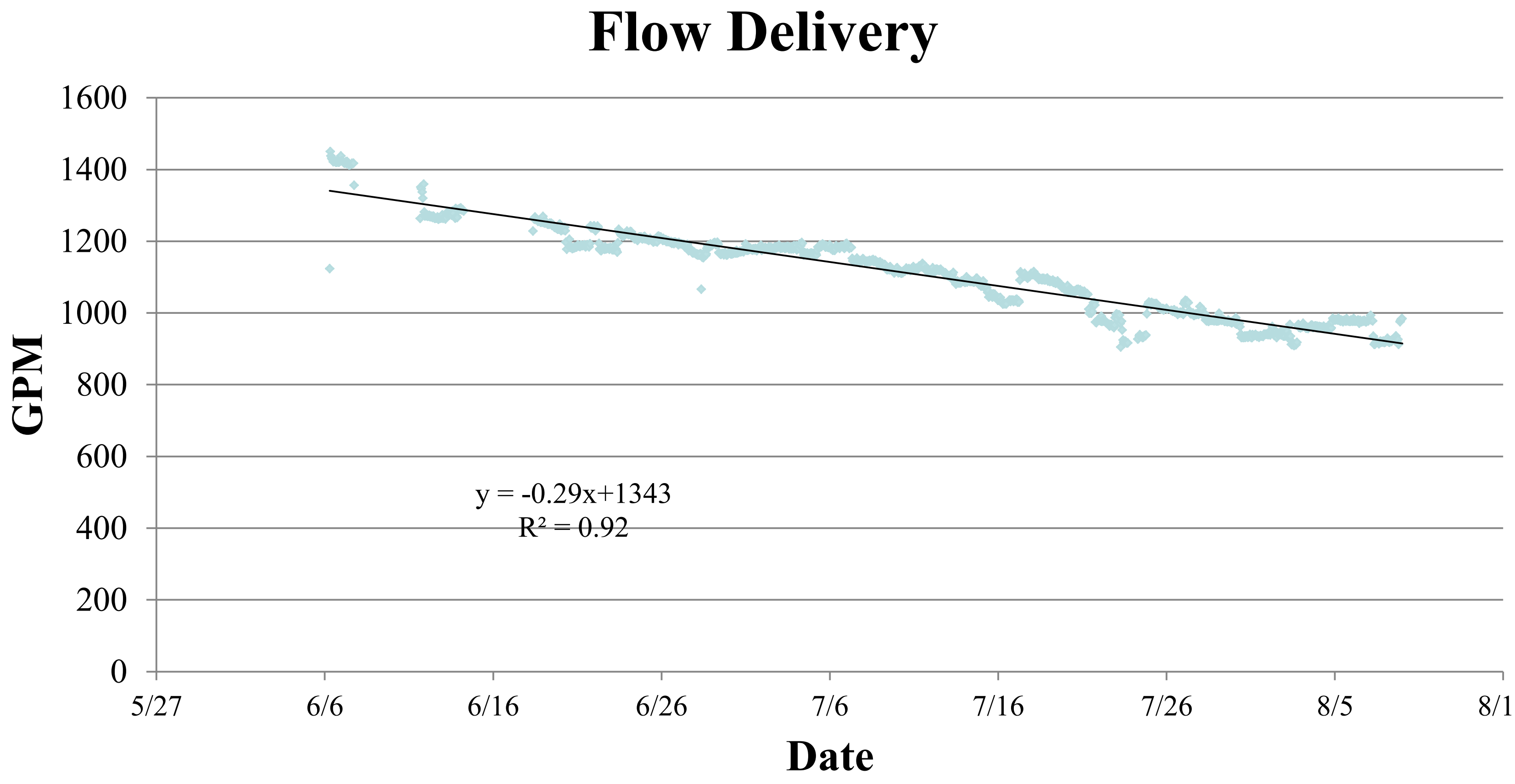
Pumping Plant Monitoring

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)**

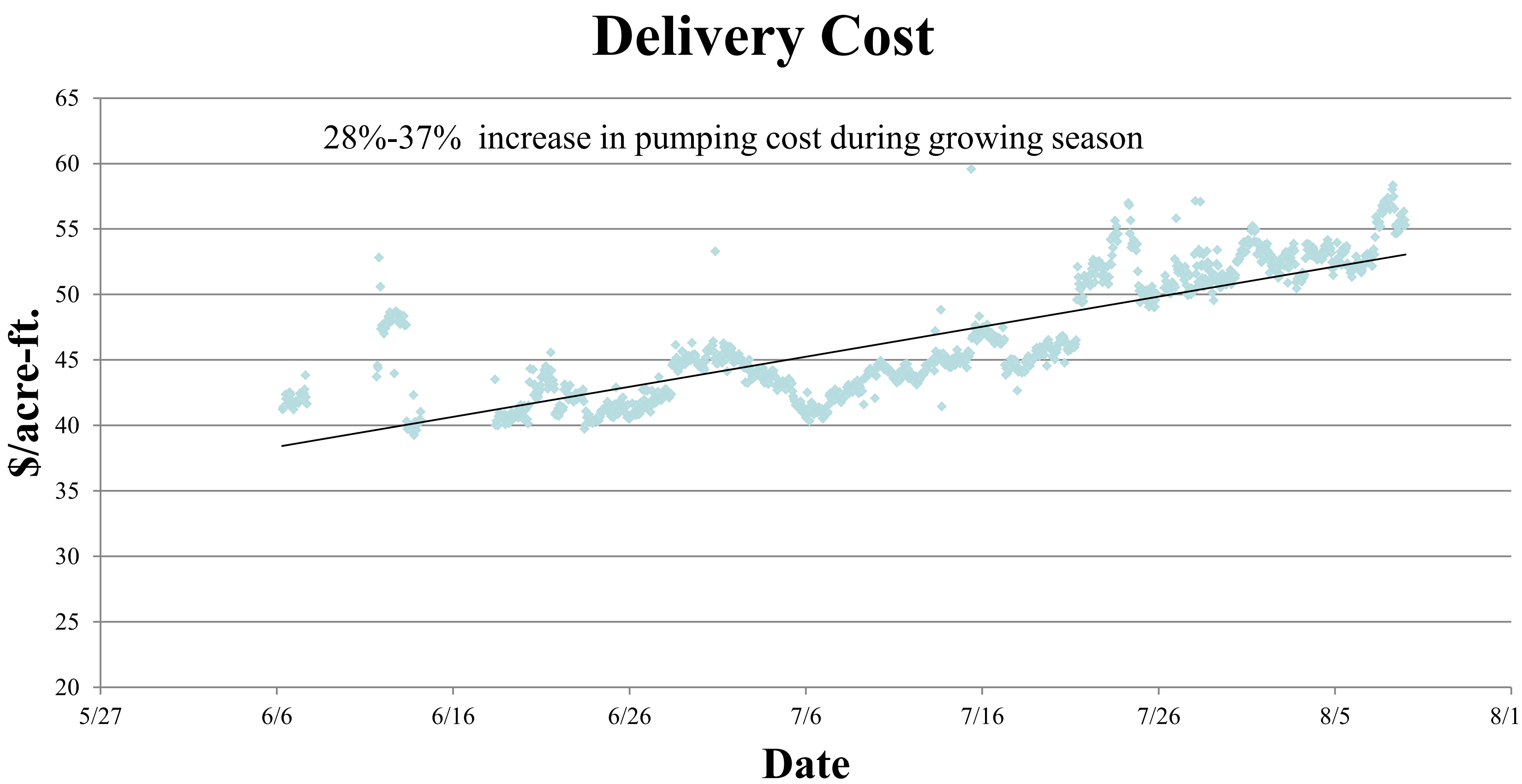
Pumping Plant Monitoring

Central, AR



Pumping Plant Monitoring

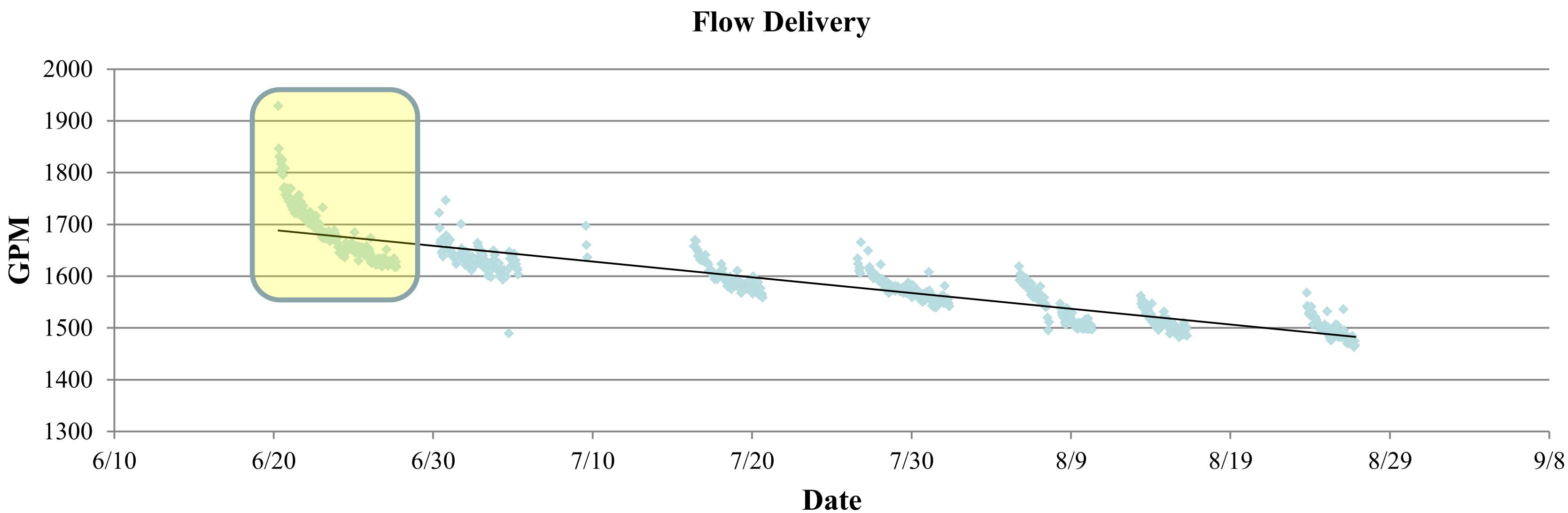
Central AR



Initial Drawdown

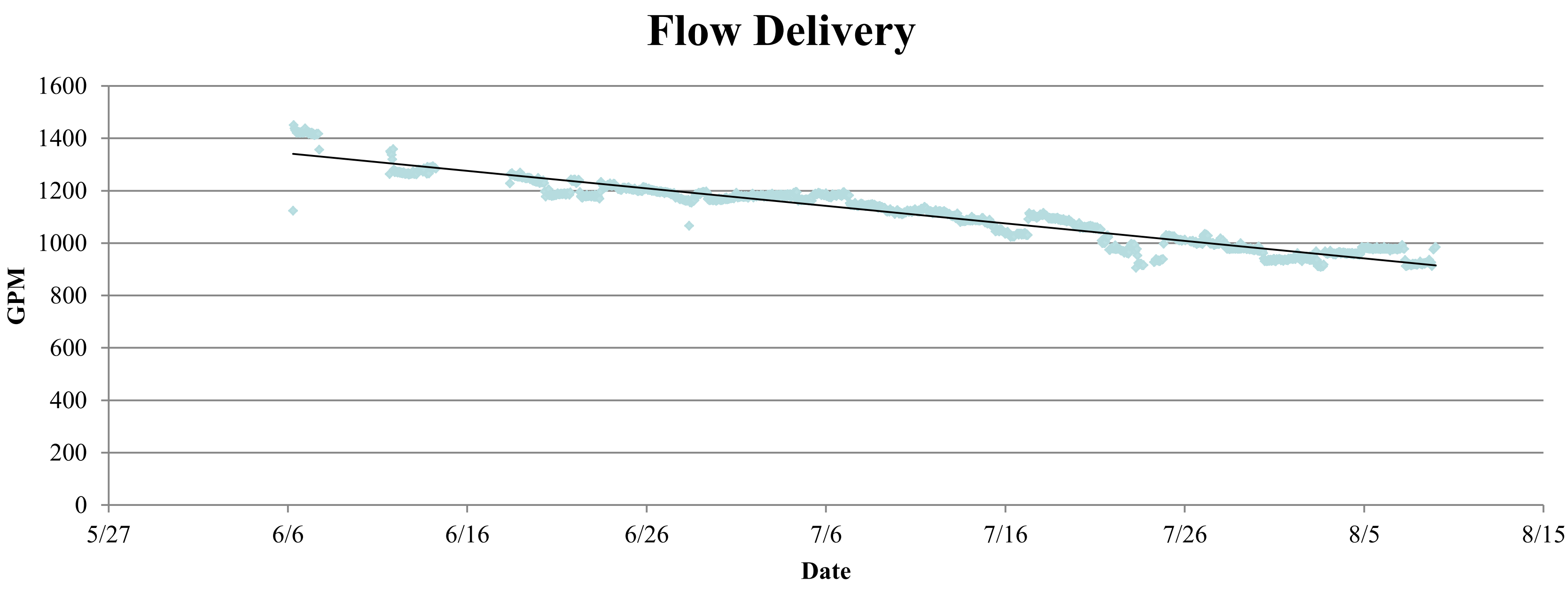
- In most cases, flow loss is most rapid at the beginning of an irrigation set and most extreme during the first irrigation set of the season.
- This initial flow decline is a result of the development of a cone of depression within the alluvial aquifer.
- Flow often exhibits exponential decline for 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.

Initial Drawdown Analysis



- 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

Pumping plant performance testing

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

Water Delivered: **452.4 Acre-Ft**
(34 ac-in)

Power Used: **53,801 kWh**

Power Cost: **$4,825.00**

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

Current Peak Load Program

Water pumped: **431.6 Acre-Ft.**
(32.3 ac-in)

Estimated Loss: **20.8 Acre-Ft. (5%)**
(1.56 ac-in)

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?

PHAUCET Existing Field Design

File Edit Design Type of Pipe Input Screen Crown Profile Soils and Furrow Rcommendation Editor Help

Total Acres = 40.0

Name:

GPM: 2490

Location

Date: 11-06-2012

Target Head (ft): 2

Enter Rod Readings or Elevations (R or E): E

Acadia Sil

Recommended Furrow Flow = 10 GPM

Average Furrow Flow = 4.7

Gross Applied (in.)	Hours	Days
0.5	3.6	.2
1.0	7.3	.3
1.5	10.9	.5
2.0	14.5	.6
3.0	21.8	.9

Distribution Uniformity = 90.3

Station (Feet)	Hole Dia. (Inches)	Hole Number	Furrow Flow (GPM)	Head (feet)	Flow Ratio	Furrow Length (feet)	Elevation (feet)	Number of Holes per Furrow	Mil	Pipe Diameter	Planted Width Between Watered Furrows
0	1/2	1	5.97	3.50	1.27	1320	10.00	1	10	15	2.50
3	1/2	2	5.96	3.49	1.27	1320	10.00	1	10	15	2.50
5	1/2	3	5.95	3.48	1.26	1320	10.00	1	10	15	2.50
8	1/2	4	5.95	3.47	1.26	1320	10.00	1	10	15	2.50
10	1/2	5	5.94	3.46	1.26	1320	10.00	1	10	15	2.50
13	1/2	6	5.93	3.45	1.26	1320	10.00	1	10	15	2.50
15	1/2	7	5.92	3.44	1.26	1320	10.00	1	10	15	2.50
18	1/2	8	5.91	3.43	1.26	1320	10.00	1	10	15	2.50
20	1/2	9	5.90	3.42	1.25	1320	10.00	1	10	15	2.50
23	1/2	10	5.89	3.41	1.25	1320	10.00	1	10	15	2.50
25	1/2	11	5.89	3.40	1.25	1320	10.00	1	10	15	2.50
28	1/2	12	5.88	3.39	1.25	1320	10.00	1	10	15	2.50
30	1/2	13	5.87	3.38	1.25	1320	10.00	1	10	15	2.50
33	1/2	14	5.86	3.37	1.24	1320	10.00	1	10	15	2.50
35	1/2	15	5.85	3.36	1.24	1320	10.00	1	10	15	2.50
38	1/2	16	5.84	3.35	1.24	1320	10.00	1	10	15	2.50
40	1/2	17	5.83	3.34	1.24	1320	10.00	1	10	15	2.50
43	1/2	18	5.83	3.33	1.24	1320	10.00	1	10	15	2.50
45	1/2	19	5.82	3.33	1.24	1320	10.00	1	10	15	2.50
48	1/2	20	5.81	3.32	1.23	1320	10.00	1	10	15	2.50
50	1/2	21	5.80	3.31	1.23	1320	10.00	1	10	15	2.50
53	1/2	22	5.79	3.30	1.23	1320	10.00	1	10	15	2.50
55	1/2	23	5.79	3.29	1.23	1320	10.00	1	10	15	2.50
58	1/2	24	5.78	3.28	1.23	1320	10.00	1	10	15	2.50
60	1/2	25	5.77	3.27	1.23	1320	10.00	1	10	15	2.50

Re-Calculate

Complete Design

Highest Head: 3.50

Max Head Station: 0

Lowest Head: 1.77

Low Head Station: 1318

Max. Furrow Flow: 5.97

Min. Furrow Flow: 4.24

Calculated GPM: 2489

Active Design

Stations 0 - 1320

Hole Diameter 1/2

Number of Holes 529

As flow decreases, time to irrigate field increases

PHAUCET Existing Field Design

File | Edit | Design | Type of Pipe | Input Screen | Crown Profile | Soils and Furrow Rcommendation Editor | Help

Total Acres = 40.0

Name:

GPM: 1720

Location

Date: 11-06-2012

Target Head (ft): 2

Enter Rod Readings or Elevations (R or E): E

Acadia Sil

Recommended Furrow Flow = 10 GPM

Average Furrow Flow = 3.3

Distribution Uniformity = 89.8

Gross Applied (in.)	Hours	Days
0.5	5.3	.2
1.0	10.5	.4
1.5	15.8	.7
2.0	21	.9
3.0	31.6	1.3

Station (Feet)	Hole Dia. (Inches)	Hole Number	Furrow Flow (GPM)	Head (feet)	Flow Ratio	Furrow Length (feet)	Elevation (feet)	Number of Holes per Furrow	Mil	Pipe Diameter	Planted Width Between Watered Furrows
0	1/2	1	4.17	1.71	1.28	1320	10.00	1	10	15	2.50
3	1/2	2	4.16	1.70	1.28	1320	10.00	1	10	15	2.50
5	1/2	3	4.15	1.70	1.28	1320	10.00	1	10	15	2.50
8	1/2	4	4.15	1.69	1.28	1320	10.00	1	10	15	2.50
10	1/2	5	4.14	1.69	1.27	1320	10.00	1	10	15	2.50
13	1/2	6	4.14	1.68	1.27	1320	10.00	1	10	15	2.50
15	1/2	7	4.13	1.68	1.27	1320	10.00	1	10	15	2.50
18	1/2	8	4.12	1.67	1.27	1320	10.00	1	10	15	2.50
20	1/2	9	4.12	1.67	1.27	1320	10.00	1	10	15	2.50
23	1/2	10	4.11	1.66	1.26	1320	10.00	1	10	15	2.50
25	1/2	11	4.10	1.66	1.26	1320	10.00	1	10	15	2.50
28	1/2	12	4.10	1.65	1.26	1320	10.00	1	10	15	2.50
30	1/2	13	4.09	1.65	1.26	1320	10.00	1	10	15	2.50
33	1/2	14	4.09	1.64	1.26	1320	10.00	1	10	15	2.50
35	1/2	15	4.08	1.64	1.25	1320	10.00	1	10	15	2.50
38	1/2	16	4.07	1.63	1.25	1320	10.00	1	10	15	2.50
40	1/2	17	4.07	1.63	1.25	1320	10.00	1	10	15	2.50
43	1/2	18	4.06	1.62	1.25	1320	10.00	1	10	15	2.50
45	1/2	19	4.06	1.62	1.25	1320	10.00	1	10	15	2.50
48	1/2	20	4.05	1.61	1.25	1320	10.00	1	10	15	2.50
50	1/2	21	4.04	1.61	1.24	1320	10.00	1	10	15	2.50
53	1/2	22	4.04	1.60	1.24	1320	10.00	1	10	15	2.50
55	1/2	23	4.03	1.60	1.24	1320	10.00	1	10	15	2.50
58	1/2	24	4.03	1.59	1.24	1320	10.00	1	10	15	2.50
60	1/2	25	4.02	1.59	1.24	1320	10.00	1	10	15	2.50

Re-Calculate

Complete Design

Highest Head	1.71
Max Head Station	0
Lowest Head	.83
Low Head Station	1320
Max. Furrow Flow	4.17
Min. Furrow Flow	2.91
Calculated GPM	1720

Active Design

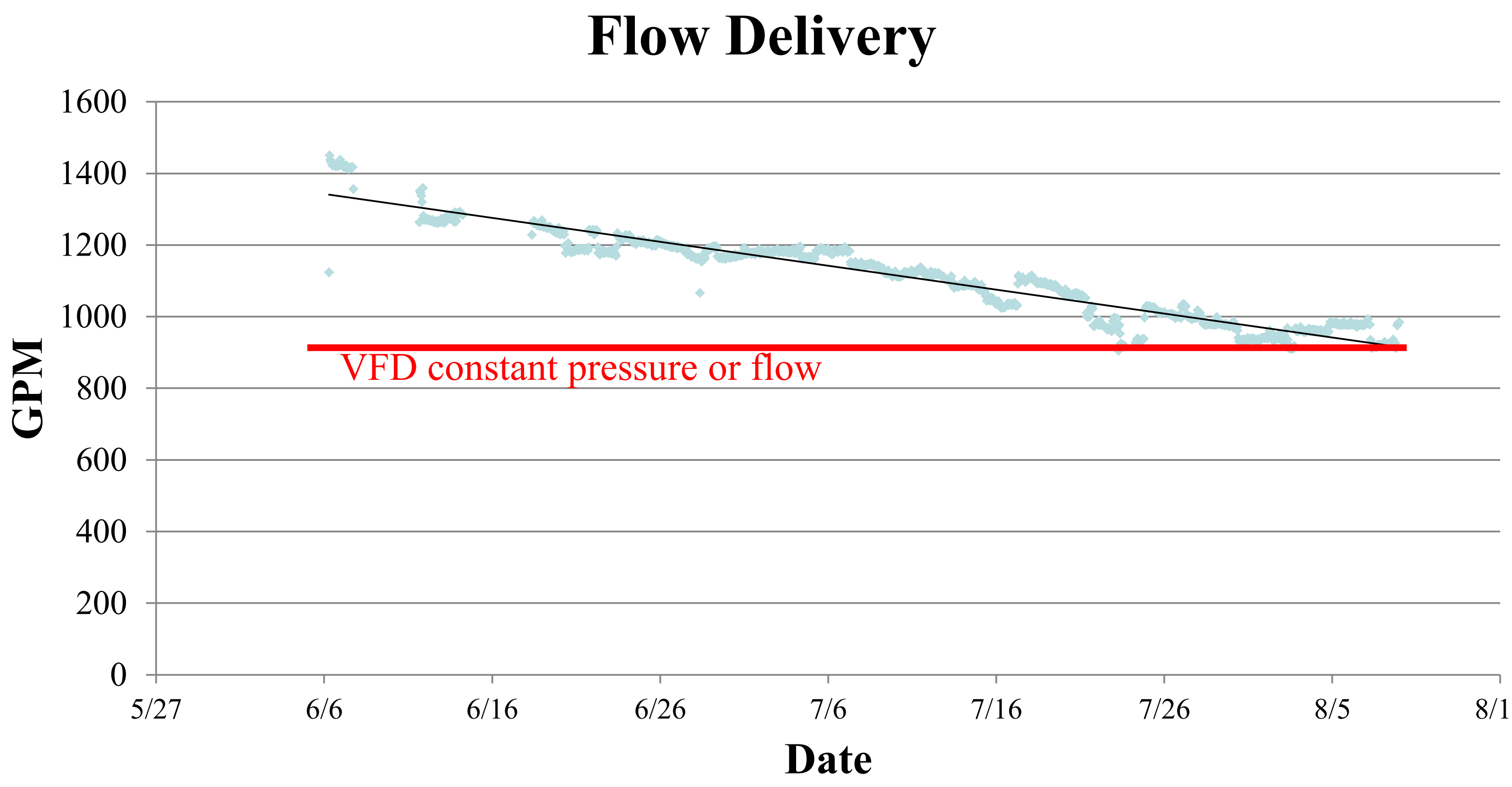
Stations	Hole Diameter	Number of Holes
0 - 1320	1/2	529

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
GPM
1600
1400
1200
1000
800
600
400
200
0
VFD constant pressure or flow
5/27
6/6
6/16
6/26
7/6
7/16
7/26
8/5
8/15
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.

This work was funded by the Arkansas Soybean Promotion Board