

Economic Contrast of Independent and Competitive Water Extraction With Limited Water Supply

presented by,

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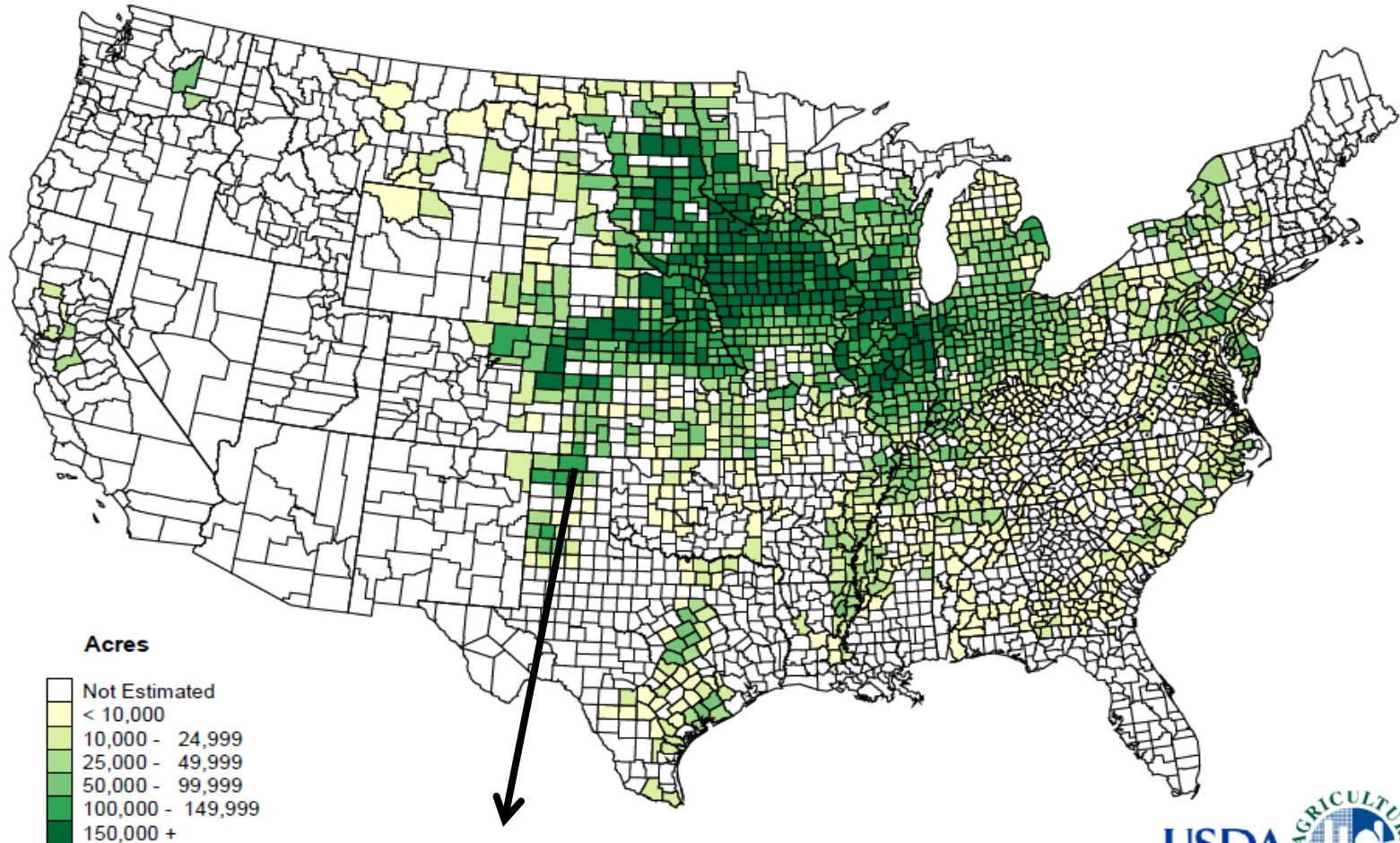
Introduction

- Oklahoma Panhandle agriculture production supplies abundance of grain, livestock feed, domestic ethanol, and bio-products.
- Due to very less recharge, producers are facing significant drop in their water levels.
- The study focusses on deciding the size of cropland, and irrigation system purchase on a finite groundwater resources.

Background

- In Oklahoma Panhandle,
 - Land in irrigated farm acres has increased from 98,169 in 1964 to 1,066,423 by 2012 (NASS).
 - During the same period the number of irrigation wells increased from 623 to 2,562 (OWRB).
 - Most irrigated acres are overlying the Ogallala aquifer.

**Corn for All Purposes 2014
Planted Acres by County
for Selected States**



TEXAS COUNTY, OKLAHOMA

U.S. Department of Agriculture, National Agricultural Statistics Service



Data Collected

Table 1. Data collected for TEXAS COUNTY (*NASS & OPREC*)

Crop	Irrigated Land Price Received		Yield	
	(acres)	(\$)	(bu/acre)	Revenue (\$)
Corn	80,731	4.48	190 (w/22 inch)	851.2
Sorghum	13,259	4.18	145 (w/10 inch)	606.1
Wheat	45,036	6.34	45	285.3

- Corn is known for high input cost and drought intolerant.
- Grain Sorghum is known low input cost and drought tolerant.

Crop Modeling

- EPIC model was calibrated for 50 years to predict the historical yields using daily weather.
- Crop inputs and water use was extracted from EPIC and used to calculate the total variable costs.
- EPIC (ENVIRONMENTAL POLICY IMPACT CALCULATOR)

CENTER PIVOT RESULTS

	CORN AT STRESS(70%)		CORN AT NO STRESS(10%)	
GPM \ /	Yield	Irrigation (inch)	Yield	Irrigation (inch)
800	159.3	12.4	213.4	9.5 bu/in 22.5
600	156.9	12.4	186.9	21.6
400	148.5	13 bu/in 11.5	164.4	17.6
200	117.5	7.4	122.2	10.3

	SORGHUM AT STRESS(70%)		SORGHUM AT NO STRESS(10%)	
GPM \ /	Yield	Irrigation (inch)	Yield	Irrigation (inch)
800	122.1	8.3	162.8	10.4 bu/in 15.6
600	122.3	8.2	148.4	12.6
400	116.9	15.2 bu/in 7.7	133.8	10.4
200	88.4	2.9	92.0	4.1

Subsurface-drip Results

CORN AT STRESS(70%)

GPM \	Yield	Irrigation (inch)
800	150.9	10.5
600	138.8	8.6
400	124.1	6.5
200	112.9	5.2

CORN AT NO STRESS(10%)

Yield	Irrigation (inch)
214.9	22.6
202.1	20.0
178.7	15.6
144.1	9.9

SORGHUM AT STRESS (70%)

GPM \	Yield	Irrigation (inch)
800	115.6	5.7
600	104.3	4.7
400	89.5	3.6
200	87.1	0.9

SORGHUM AT NO STRESS(10%)

Yield	Irrigation (inch)
166.6	12.7
161.0	11.4
147.0	9.0
96.6	2.9

Net Returns (PIVOT example)

Center Pivot Profits per acre (w/o irrigation cost)

Corn @ \$4.48/bu & Sorghum @ \$4.17/bu

GPM √	At Stress (70%)		At No Stress (10%)	
	Corn	Sorghum	Corn	Sorghum
800	\$ 201.3	\$ 160.4	\$ 373.3	\$ 271.7
700	\$ 198.3	\$ 161.3	\$ 327.2	\$ 252.2
600	\$ 193.7	\$ 160.9	\$ 289.1	\$ 232.2
500	\$ 183.9	\$ 156.1	\$ 251.3	\$ 212.2
400	\$ 166.8	\$ 146.2	\$ 217.5	\$ 192.3
300	\$ 119.7	\$ 113.3	\$ 148.3	\$ 147.1
200	\$ 68.2	\$ 68.4	\$ 83.3	\$ 78.2
100	\$ 2.2	\$ 66.0	\$ 9.5	\$ 68.7

GPM – Gallons Per Minute

Net Returns (SDI example)

Subsurface-Drip Profits per acre (w/o irrigation cost)

Corn @ \$4.48/bu & Sorghum @ \$4.17/bu

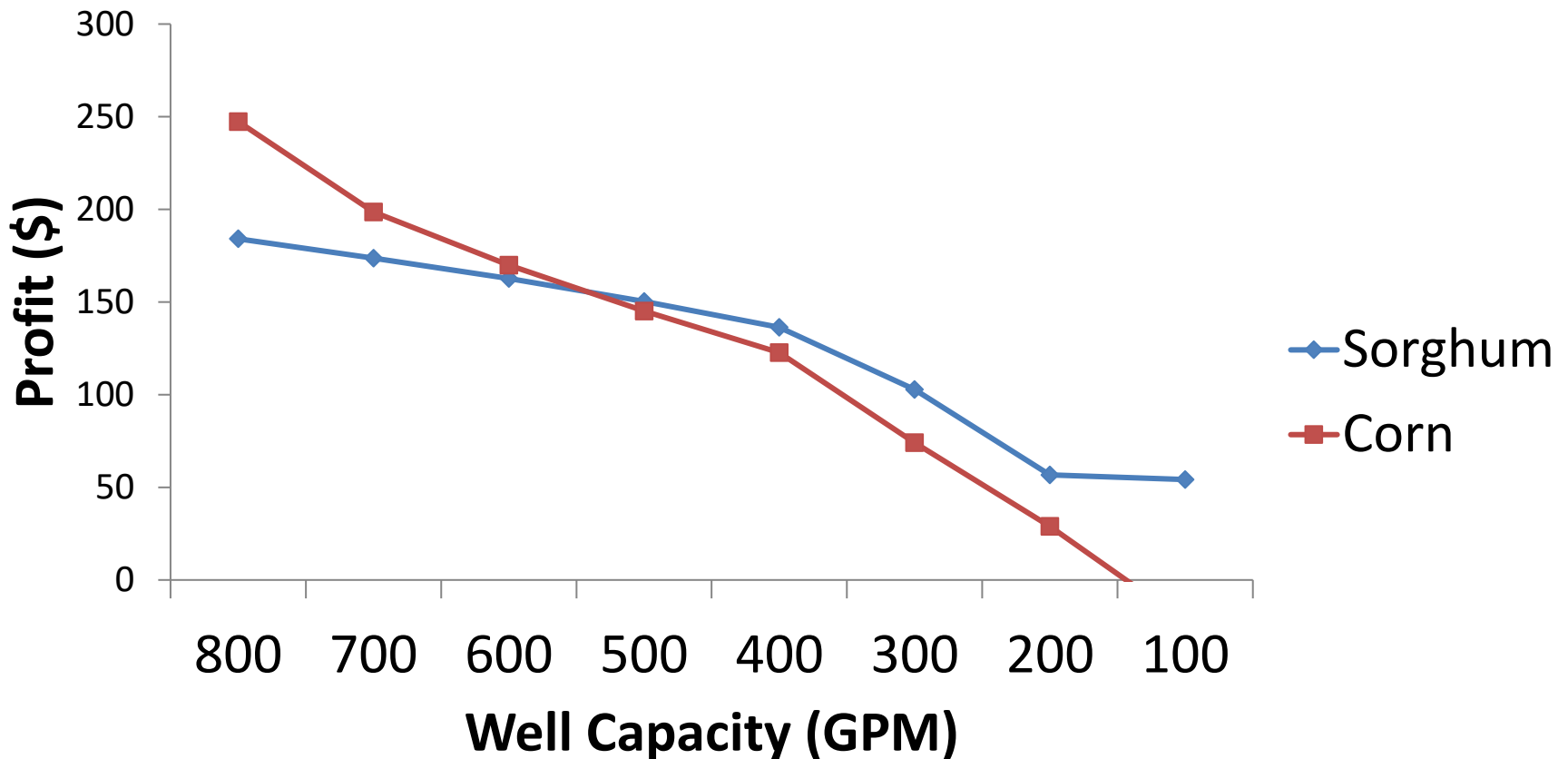
GPM √	At Stress(70%)		At No Stress(10%)	
	Corn	Sorghum	Corn	Sorghum
800	171.4	142.8	374.1	281.9
700	154.6	128.0	357.9	276.2
600	133.4	111.7	333.6	266.6
500	110.1	91.1	295.3	261.0
400	86.7	71.5	259.5	228.5
300	66.1	54.7	209.6	196.8
200	51.4	64.8	150.0	90.8
100	27.6	62.8	80.7	81.1

Pumping

- What limits well capacity?
 - REMAINING SATURATED THICKNESS
- How REMAINING SATURATED THICKNESS is calculated?
 - $\text{STATIC WATER LEVEL} + \text{DRAWDOWN}$
- Drawdown is a cone of depression at the center of the well.
- Estimating Drawdown gives the irrigation cost for each possible activity.

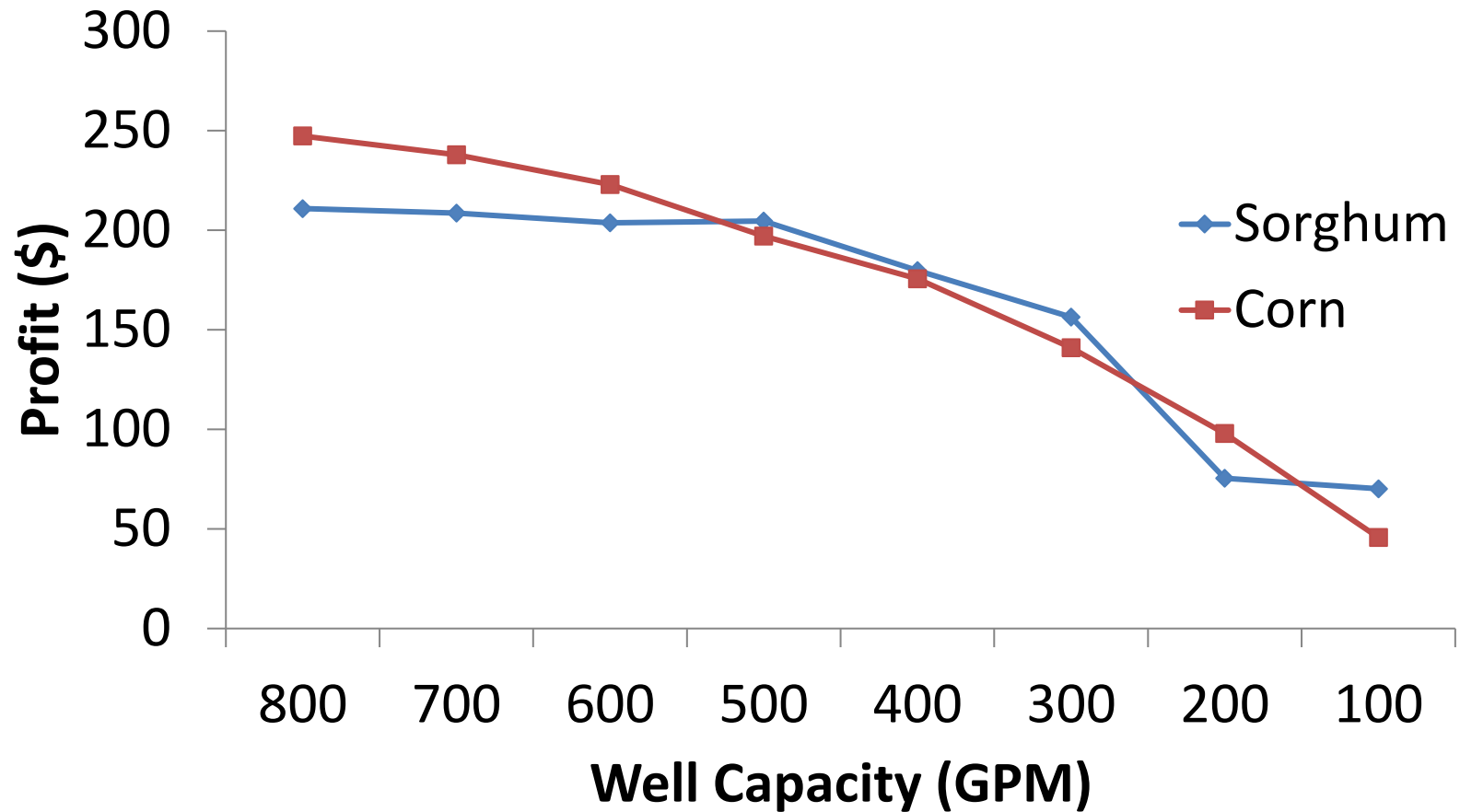
Static Net Returns

PIVOT Net Returns with Pumping Cost @ 10% stress



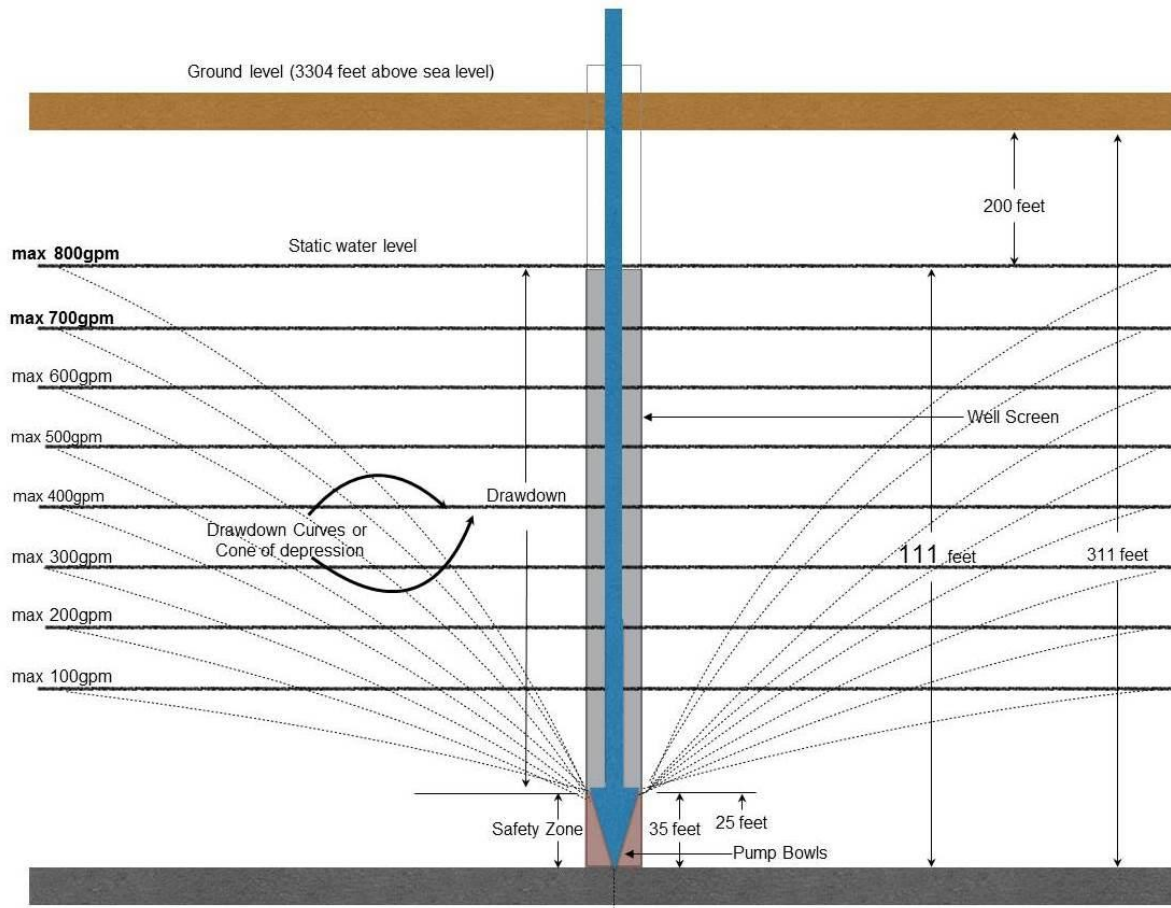
Static Net Returns

SDI Net Returns with Pumping Cost @ 10% stress



Independent Extraction

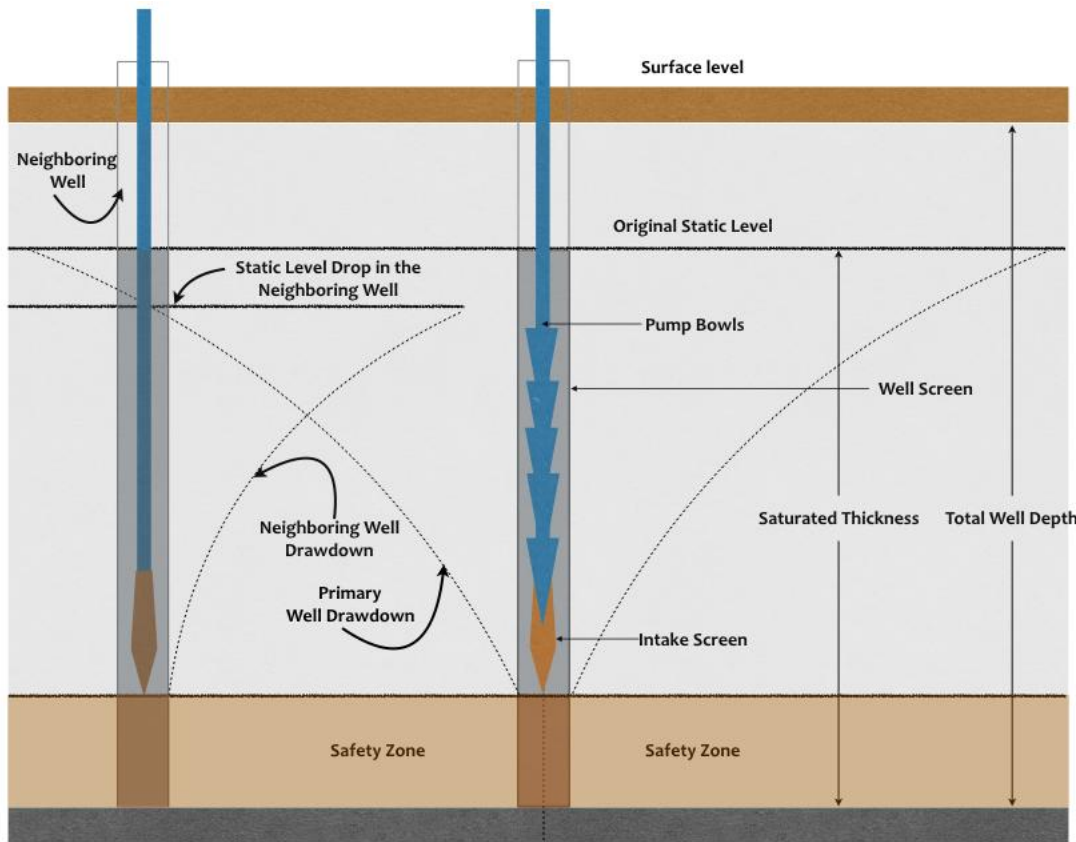
- In this case, it is assumed own drawdown of each well limits the well capacity.



“Drawdowns”
are calculated
using
Cooper-Jacob
Approximation

Competitive Extraction

- In this case, surrounding well drawdown interference limits the well capacity.



“Drawdowns”
are calculated
using
Cooper-Jacob
Approximation

Mathematical Model

- For each objective, a Linear Programming is been set up to maximize the net benefits taking all the possible activities and constraints.
- Saturated thickness limits available water supply at each level for a 640-acre field.

Mixed-Integer Programming

- To decide irrigation purchase activity the model was modified as a Linear Mixed Integer Programming.
- Where irrigation purchases takes integer values (“0” or “1”).
- Non irrigated land are covered with dryland grain sorghum.

Expected Results and Conclusion

- Corn is more profitable per acre at higher well capacities, but not necessarily profitable per unit of water at lower capacities.
- Therefore, sorghum irrigated with subsurface are expected to give maximum net benefits from the remaining groundwater supply.

Research in Progress...

Thank you