Performance evaluation of irrigation systems in Western Oklahoma

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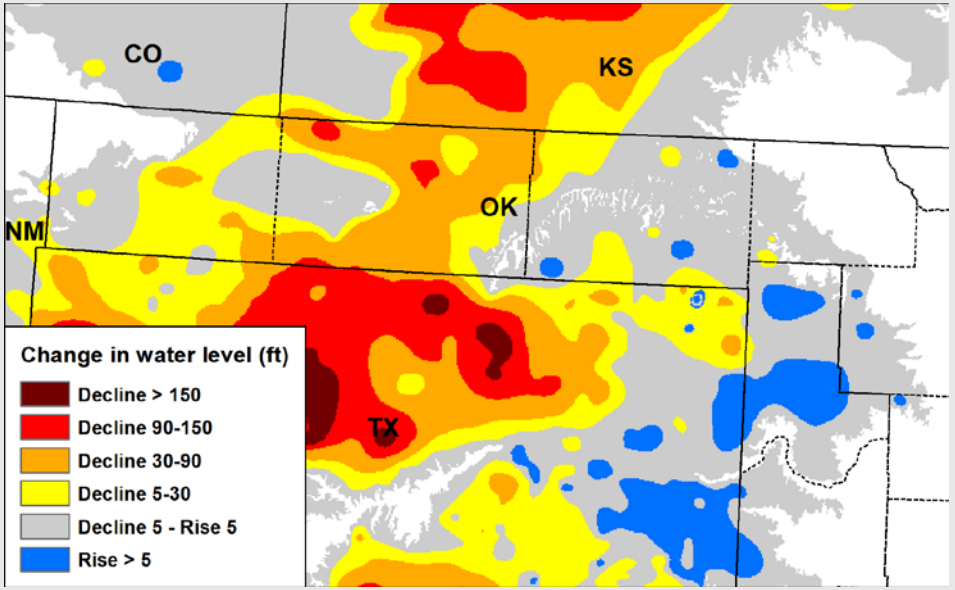
Blessing Masasi; Saleh Taghvaeian; Scott Frazier

Biosystems and Agricultural Engineering Department,

Oklahoma State University

IRRIGATION IN OKLAHOMA

- Crop irrigation constitutes 41% of total water use in OK *(OWRB)*
- 95% sprinkler irrigation systems; 3% gravity systems & 2% drip systems *(Taghvaeian, 2015)*
- 92% irrigation water is from groundwater & 8% surface sources *(FRIS, 2013)*

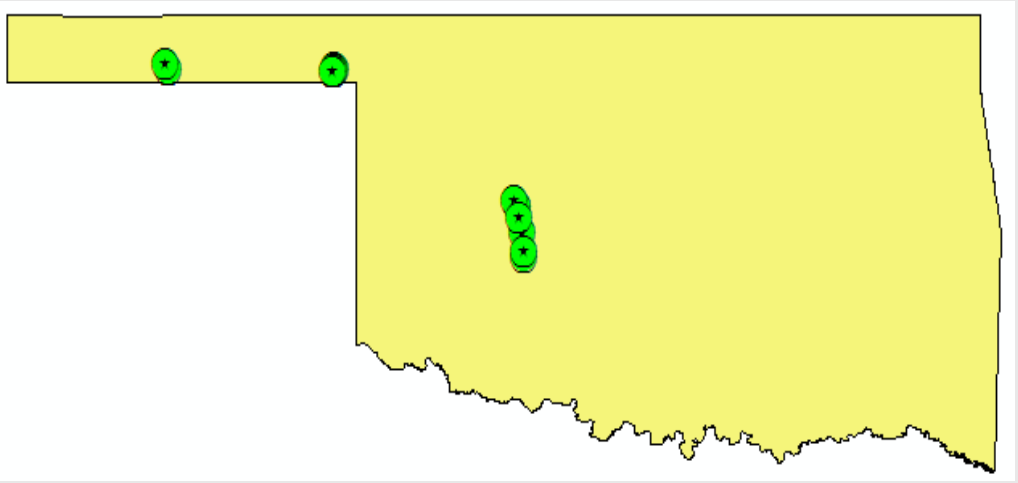


WHY PERFORMANCE EVALUATION?

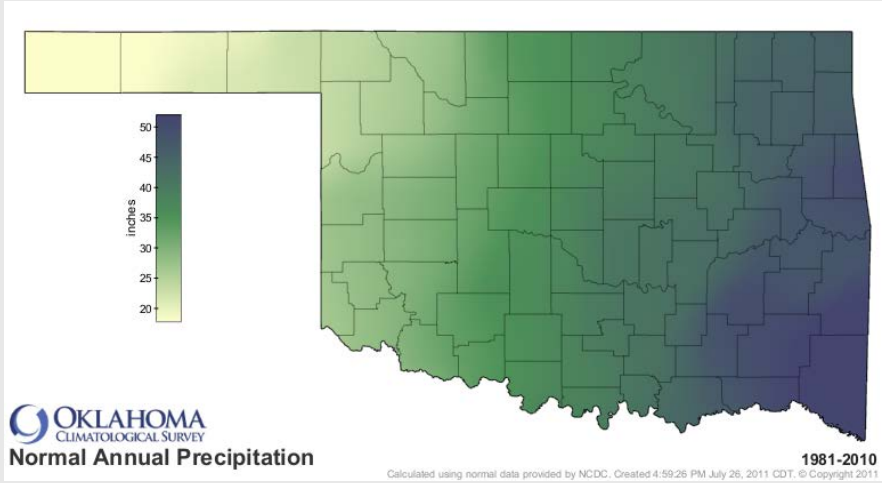
- ❑ Decline in average well pumping capacity:
  - 505 GPM in 2008 to 408 GPM 2013 *(FRIS, 2013)*
- ❑ High cost of pumping
  - $22 Million spent in irrigation energy use in 2013 *(FRIS, 2013)*

STUDY AREA

TEST LOCATIONS



RAINFALL PATTERN



(Oklahoma Climatological Survey)

PROJECT OBJECTIVES

- To estimate water application uniformity and efficiency
- To estimate the Overall Pumping Efficiency (OPE)
- To work with producers to improve the efficiencies
- To carry out a Life Cycle Assessment (LCA)

WATER AUDIT

CATCH CAN TEST

Estimation of water application uniformity (CU_{HH} & DU_{lq})

$$CU_{HH} = 100\% * [1 - \frac{\frac{1}{n}\sum_{i=1}^{n} S_i |V_i - \bar{V}_p|}{\sum_{i=1}^{n} V_i S_i}]$$

(ANSI/ASAE S436.1)

$$DU_{lq} = 100\% * \frac{\bar{V}_{lq}}{\bar{V}}$$

(Merriam and Keller, 1978)

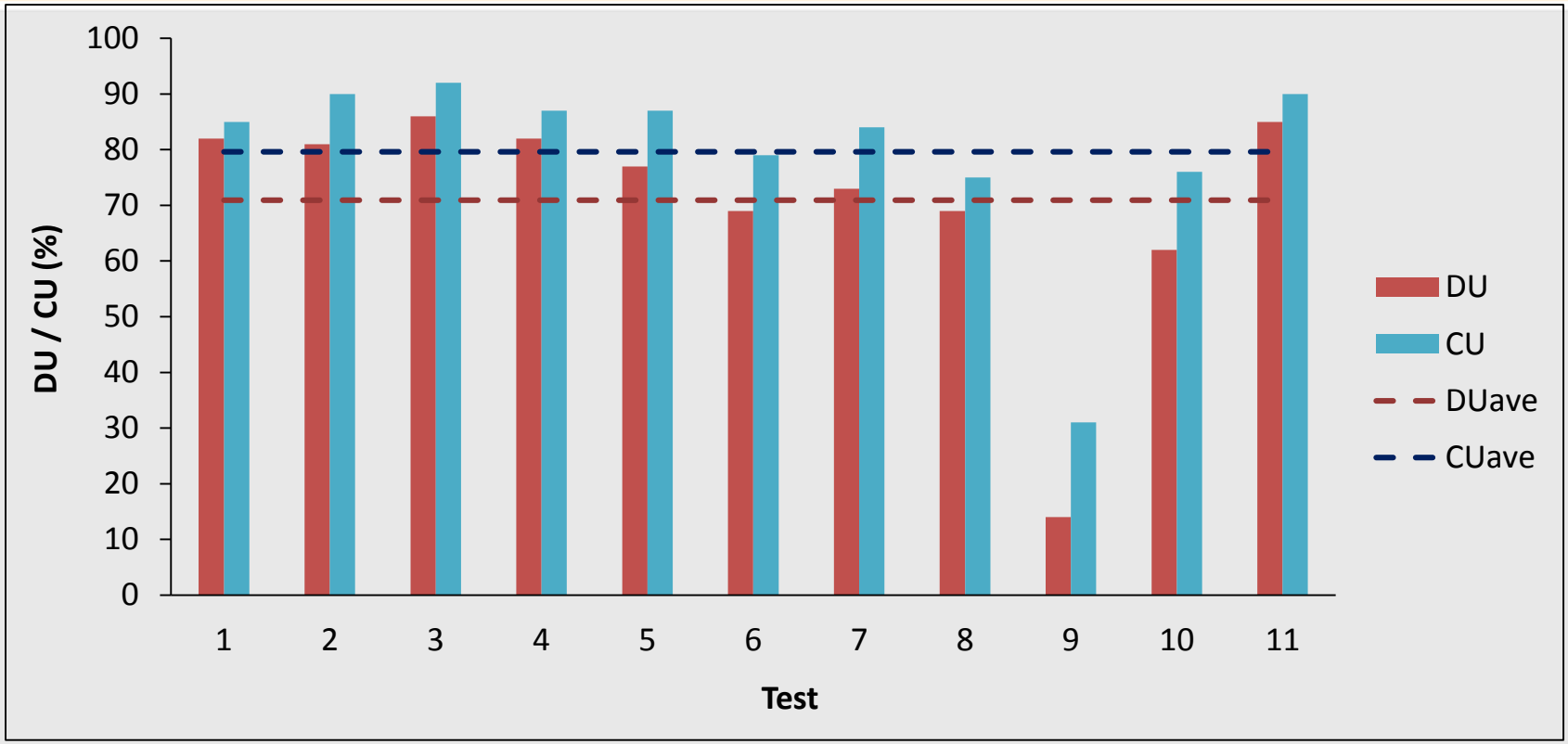
WATER AUDIT

Estimation of Water Application Efficiency (WAE)

$$\text{WAE} = \frac{\text{water delivered to the field} * 100\%}{\text{water supplied by the irrigation source}}$$

(Rogers et al., 1997)

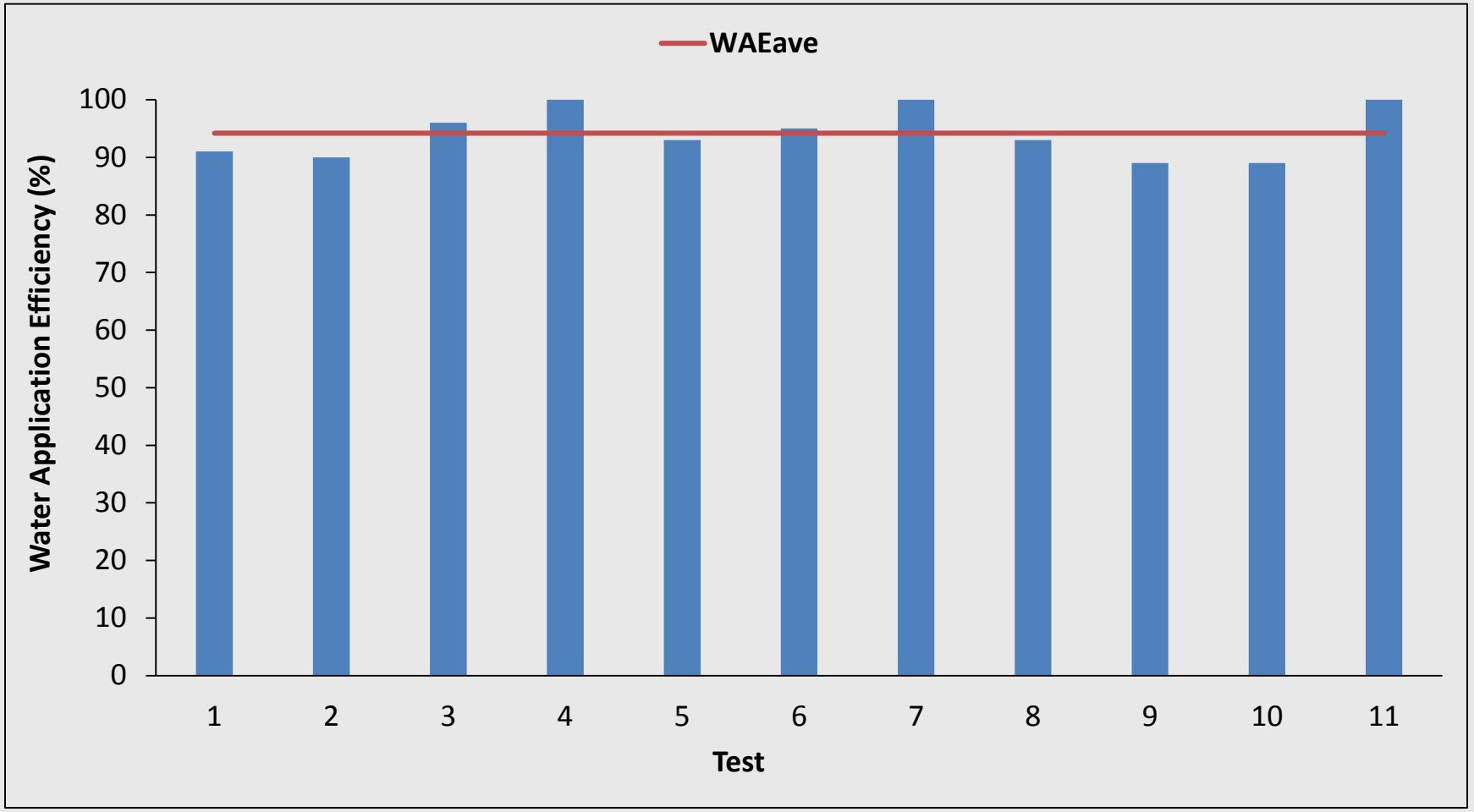
WATER APPLICATION UNIFORMITY



DU Range	Classification	# of systems
>=85%	Excellent	2
80%	Very Good	3
75%	Good	1
70%	Fair	3
<65%	Poor & unacceptable	2

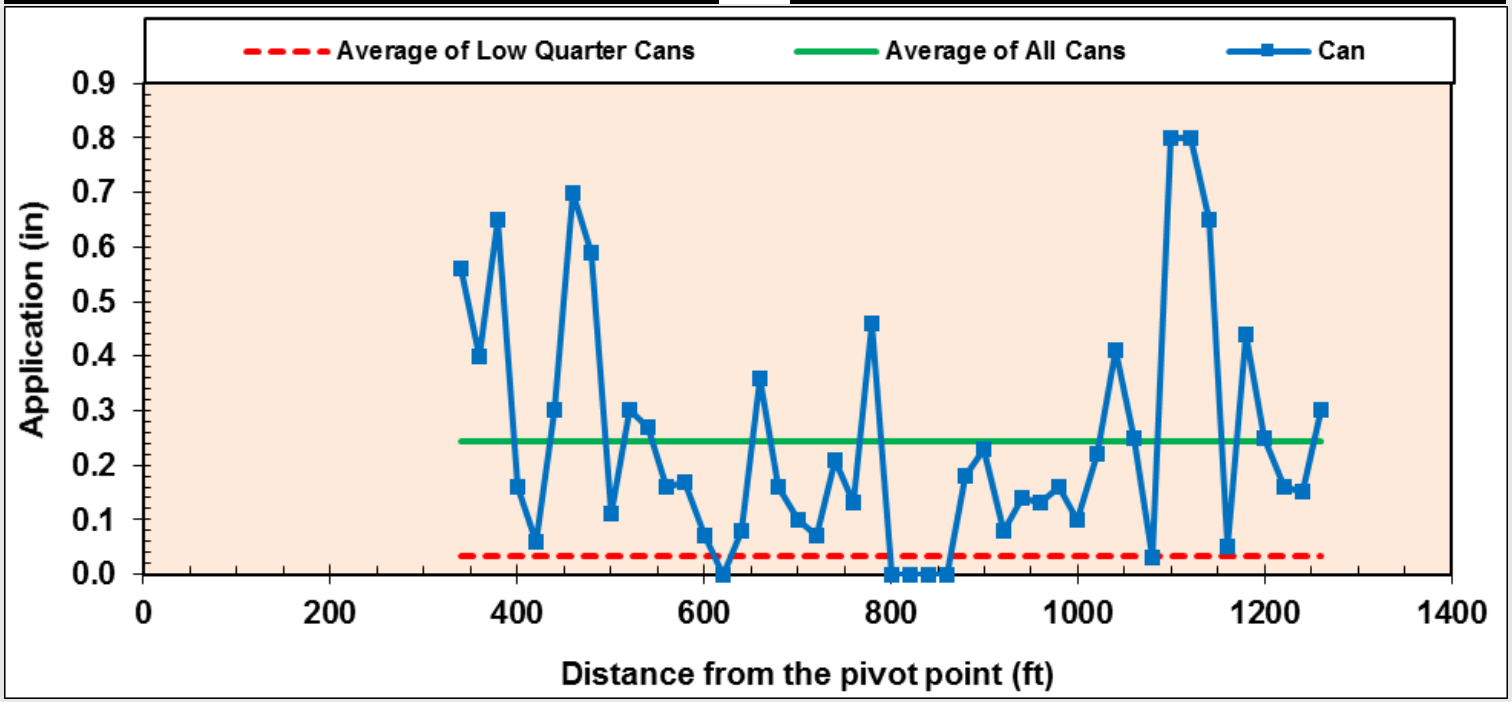
CU Range	Classification	# of systems
90%-95%	Excellent	3
85%-90%	Good	3
80%-85%	Fair	1
<80%	Poor	4

WATER APPLICATION EFFICIENCY (WAE)



POOR PERFORMANCE

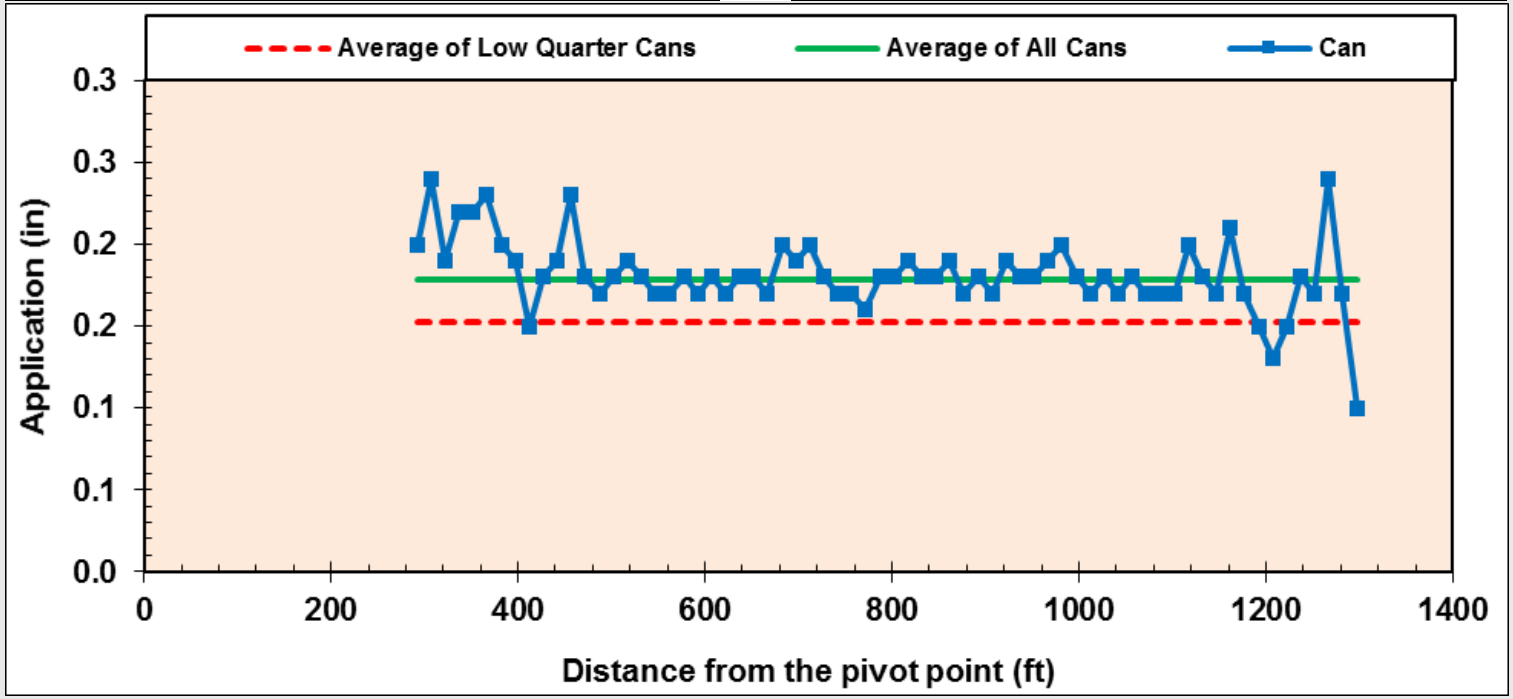
Average catch (in)	0.24	CU	31%
DU	14%	WAE	89%



CAUSES…

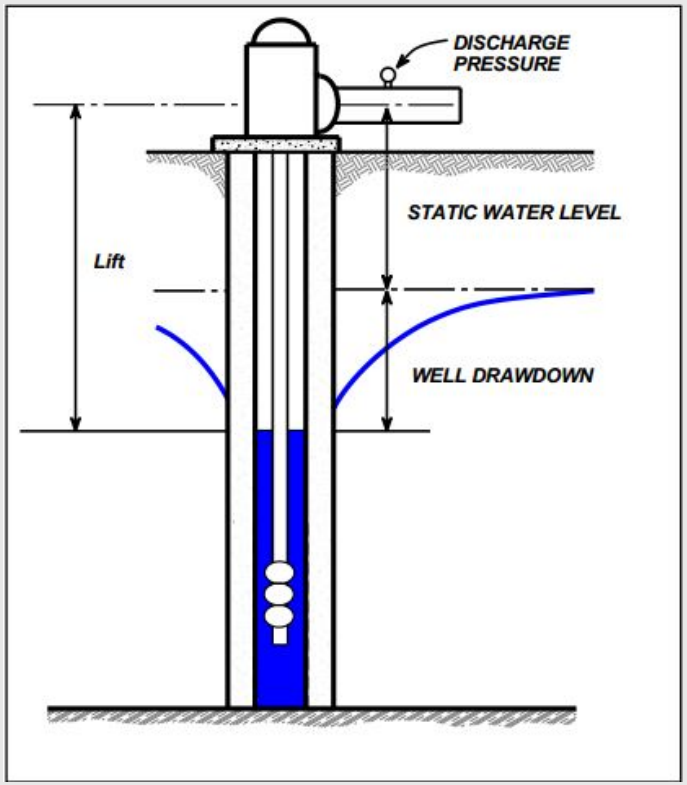
EXCELLENT PERFORMANCE

Average catch (in)	0.18	CU	92%
DU	86%	WAE	96%



ENERGY AUDIT

Field measurements



(Derrel, et al., 2011)

- Input power (kW-hr for electricity & ft^3/hr fuel)

Overall Pumping Efficiency (OPE)

$$OPE = \frac{Q * TDH}{(3960 * HPin)}$$ *(Kenny, 2013)*

Nebraska Pumping Plant Performance Criteria (NPPPC)

Power Source	Power Unit Efficiency (%)	Overall Efficiency (%)
Electric	88	66
Diesel	33	24
Natural Gas	24	17

(Fipps, 1995)

ENERGY AUDIT

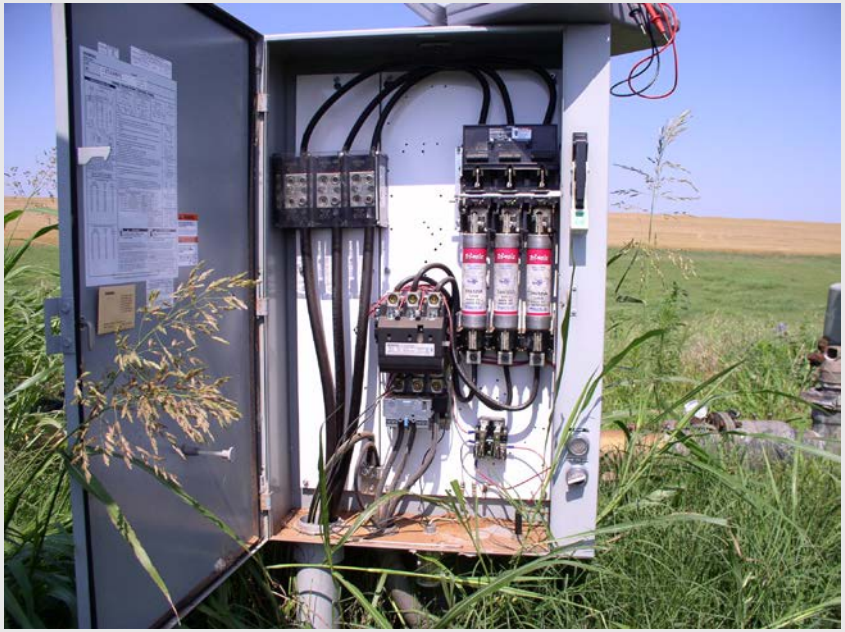
WATER FLOW (ULTRASONIC METER)

PUMP DISCHARGE PRESSURE (PRESSURE GAUGE)

ENERGY AUDIT

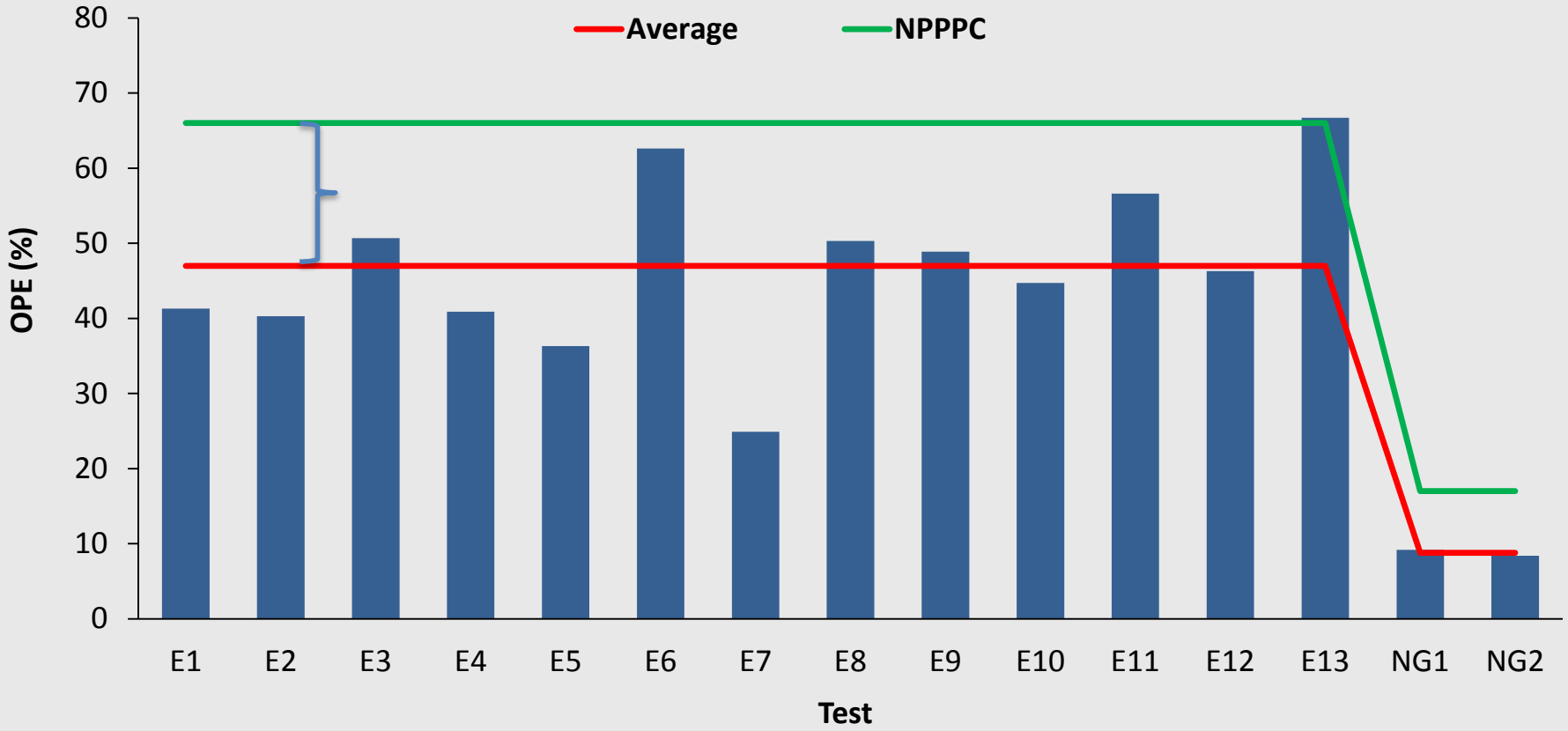
WATER LEVEL MEASUREMENTS

INPUT POWER MEASUREMENT (ELECTRIC)

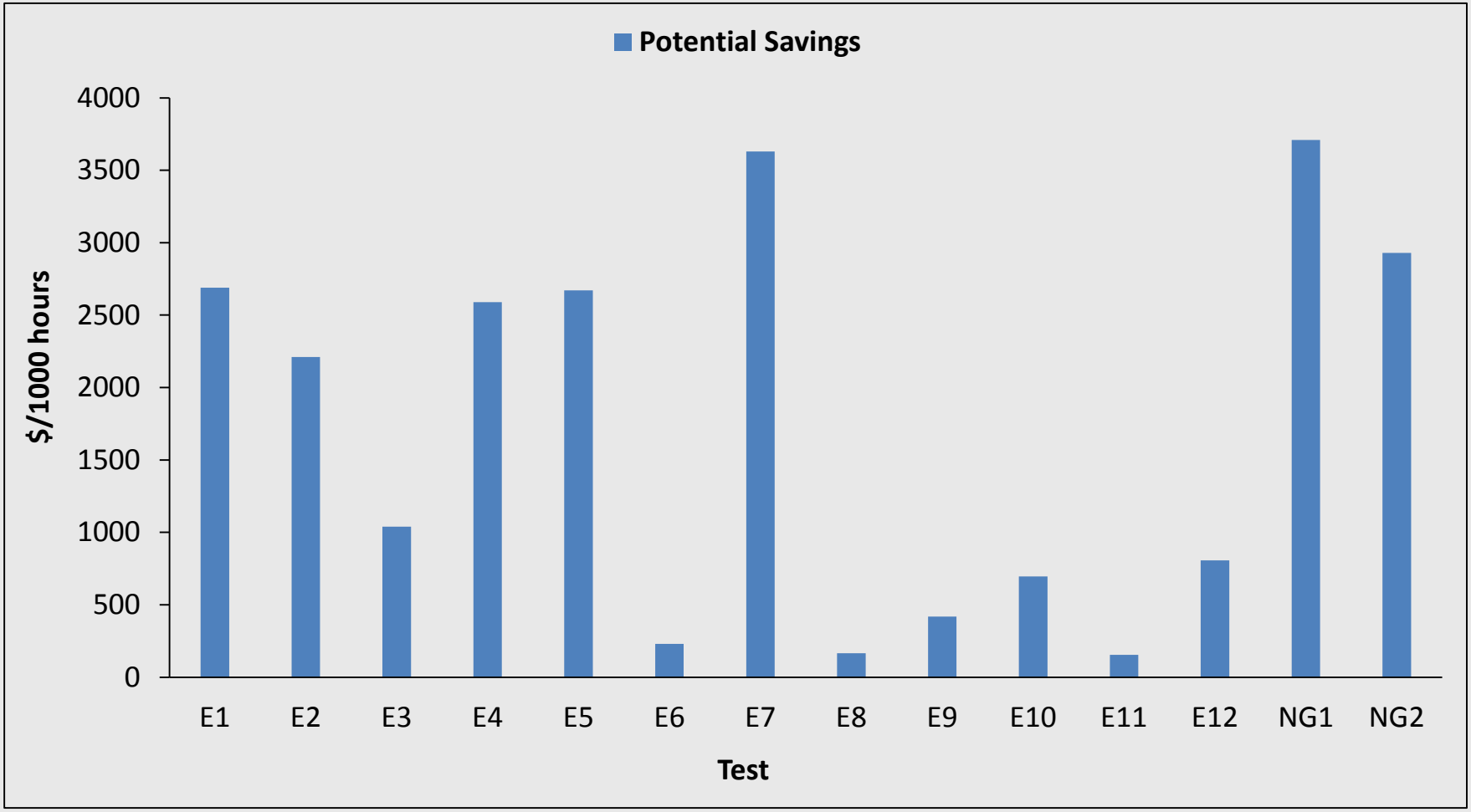


OVERALL PUMPING EFFICIENCY (OPE)

OPE COMPARED TO NPPPC ACCEPTABLE VALUES



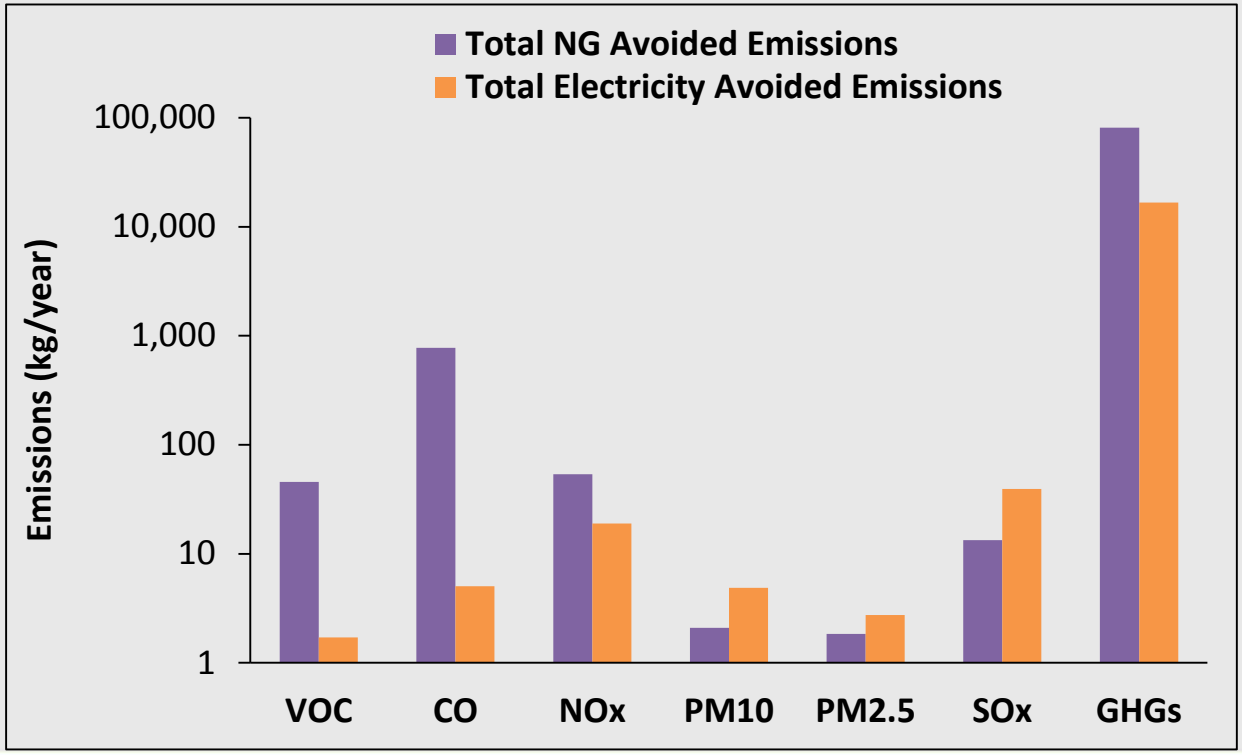
ENERGY COST ANALYSIS



LIFE CYCLE ASSESSMENT (LCA)

- Estimate the environmental impacts due to inefficiency
- Based on the NPPPC standards
- GREET v1.3.0.12704 (Argonne National Lab)
- Emissions: Greenhouse gases (GHGs) & Criteria pollutants

Preliminary LCA analysis results for 8 systems:



- Avoided emissions are negligible at the pumping site for electric powered plants
- Emissions have negative health and environmental impacts

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2. Fipps, G., & Neal, B. (1995). Texas irrigation pumping plant efficiency testing program. *Texas Energy Office Final Report*.
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ACKNOWLEDGEMENTS

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Thank You!

ENERGY AUDIT RESULTS

Energy Source	Test	Discharge (GPM)	Discharge Pressure	TDH (ft)	WHP (Hp)	Input power (Hp)	OPE (%)
Electricity	E1	658	47	202.0	33.6	81.2	41
	E2	618	40	210.5	32.9	81.6	40
	E3	546	70	301.0	41.5	81.9	51
	E4	650	63	247.9	40.7	99.4	41
	E5	614	32	160.0	24.8	68.3	36
	E6	613	56	216.4	33.5	53.5	63
	E7	396	38	187.8	18.8	75.5	25
	E8	300	19	91.3	6.9	13.7	50
	E9	583	28	100.2	14.8	30.2	49
	E10	593	32	109.0	16.3	36.5	45
	E11	635	39	130.0	20.8	36.8	57
	E12	466	58	186.4	21.9	47.4	46
	E13	775	49	177.5	34.7	52.1	67
Natural Gas	NG1	584	8.0	329	48.5	524.9	9
	NG2	473	30.0	321	38.9	464.2	8

LIFE CYCLE ASSESSMENT (LCA)