Advances in Irrigation Technology

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Dyck Arboretum of the Plains
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Knowledge for Life

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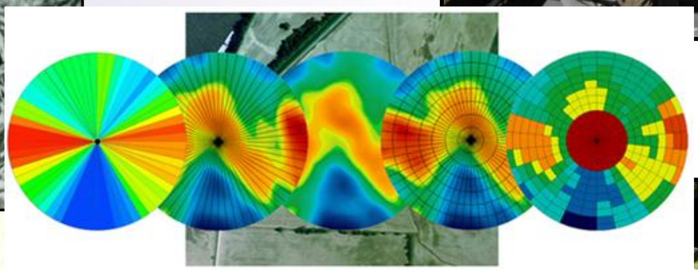
Advances in agriculture.



Adapted from http://cropmetrics.com/features/variable-rate-irrigation/

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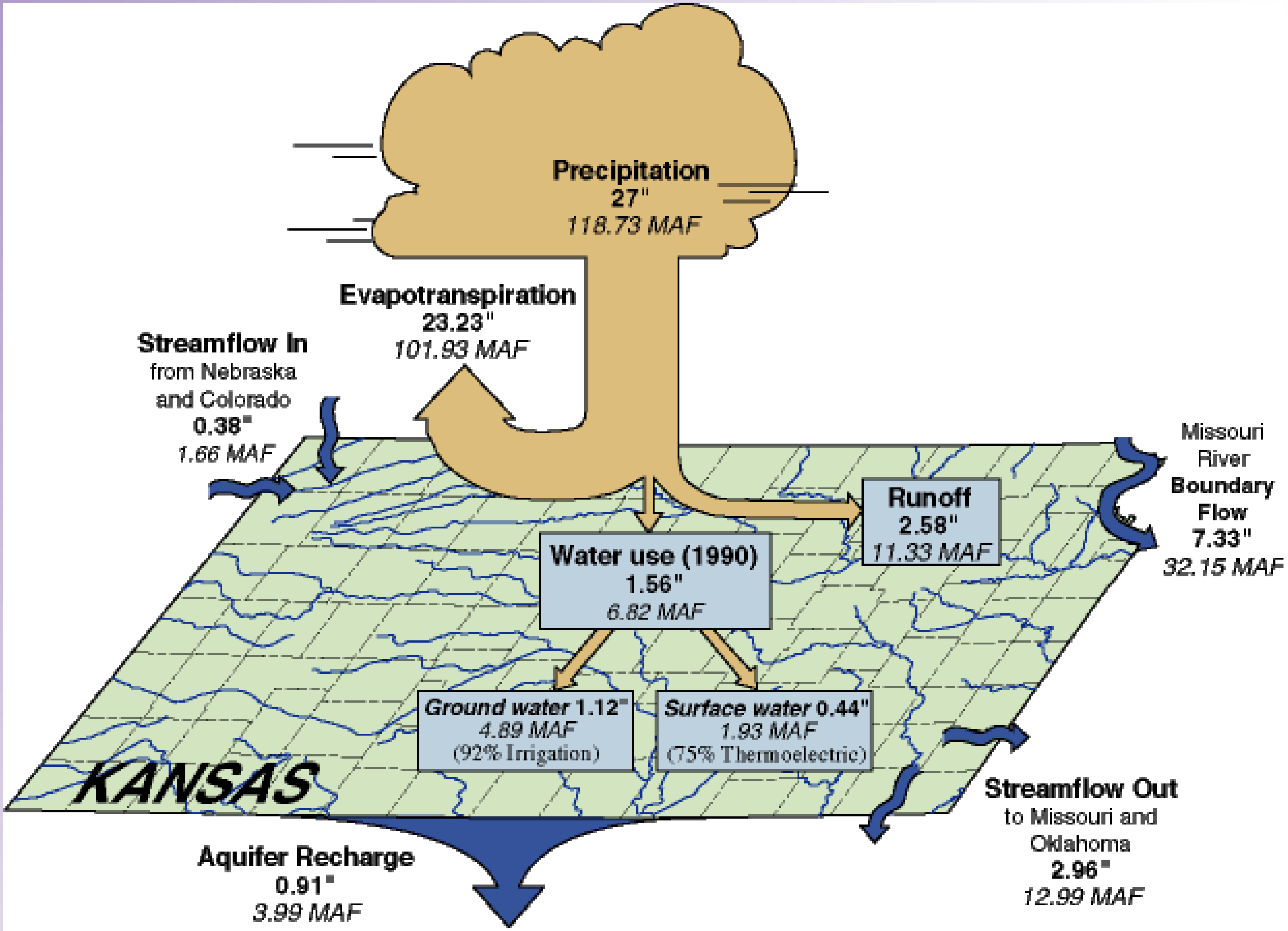


Figure 5. Water budget components for Kansas. Values are in inches per year and million acre-feet per year (MAF). (Adapted from Sophocleous, 1998)

Kansas Precipitation versus Crop Water Use

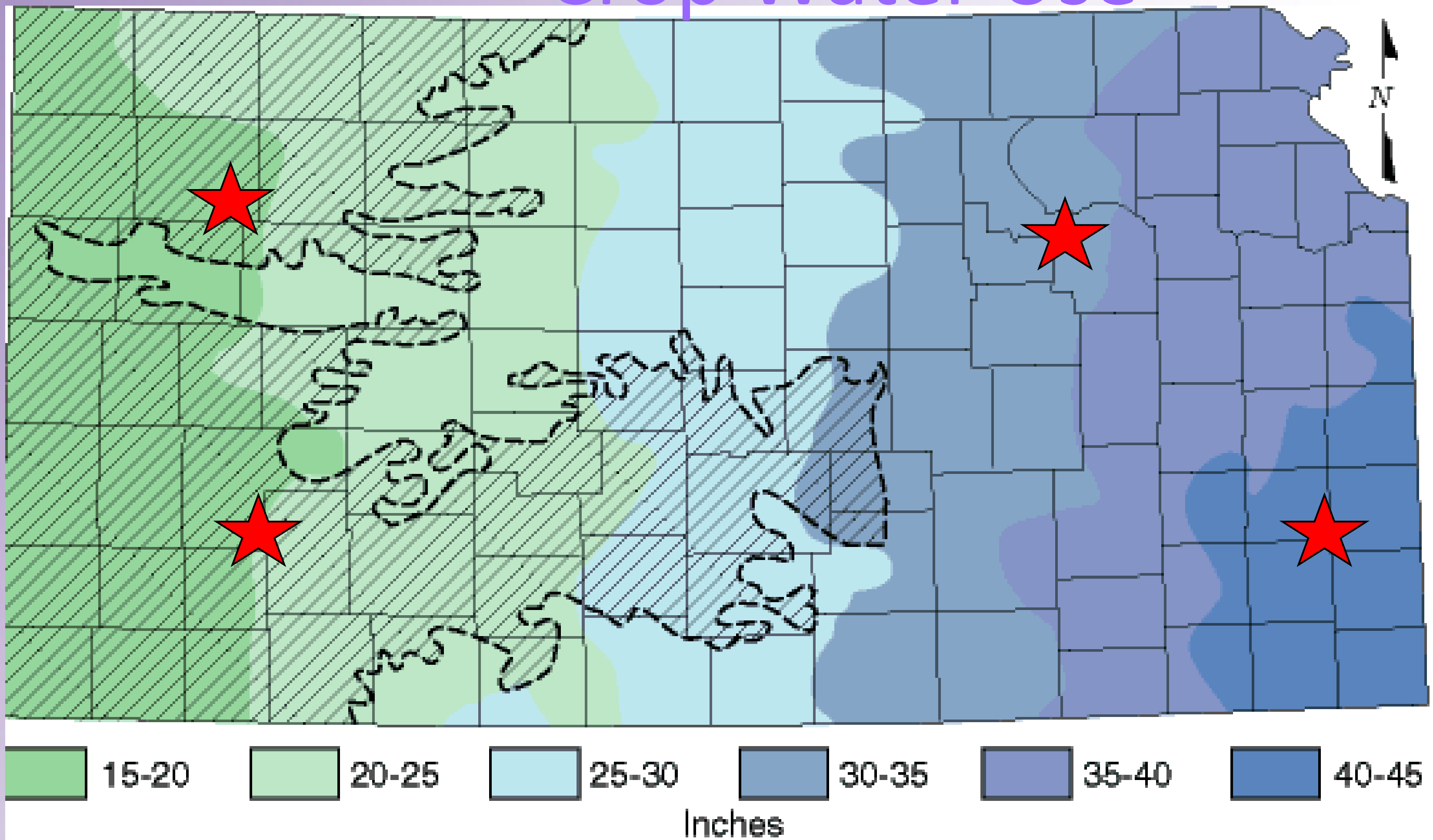
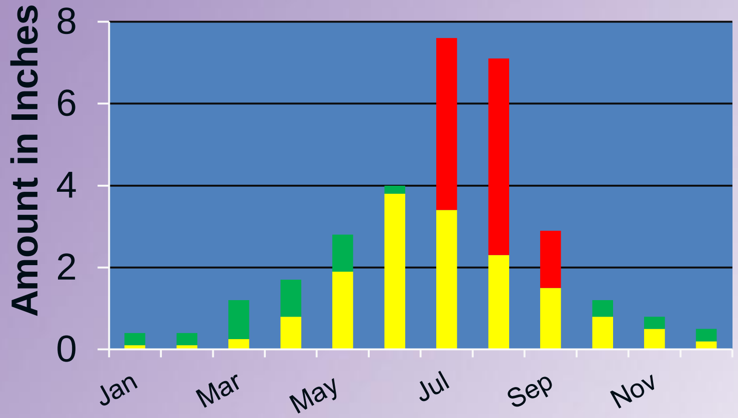


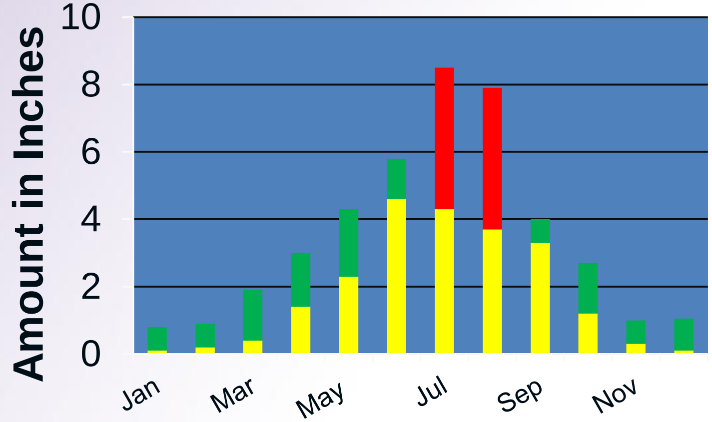
Figure 3. Normal annual precipitation (1961 - 1990) in Kansas. The area west of the dashed line shows the extent of the High Plains aquifer in Kansas (from Goodin et al., 1995).

Crop Water Budget

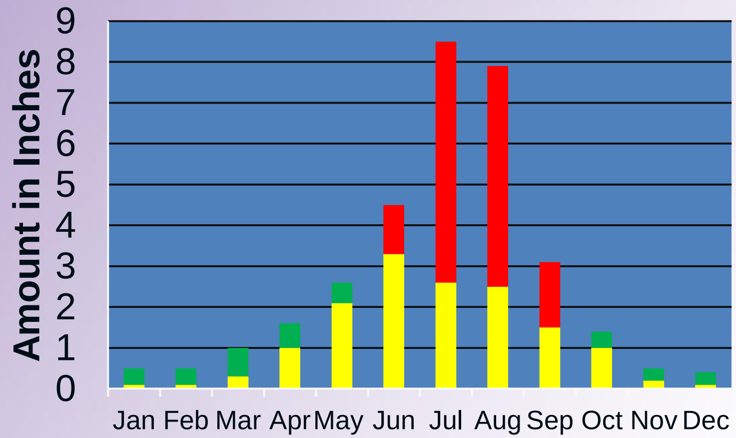
Colby Annual Water Budget



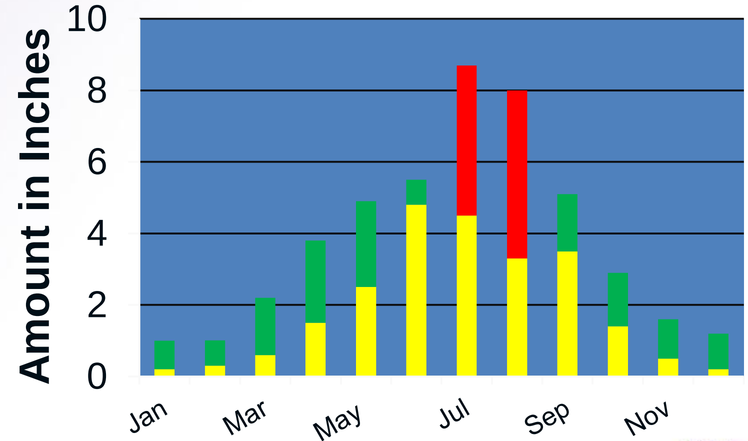
Manhattan Annual Water Budget



Garden City Annual Water Budget



Iola Annual Water Budget



ET not filled by Rain | Surplus Rain | Corn ET filled by rain

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Kansas Precipitation

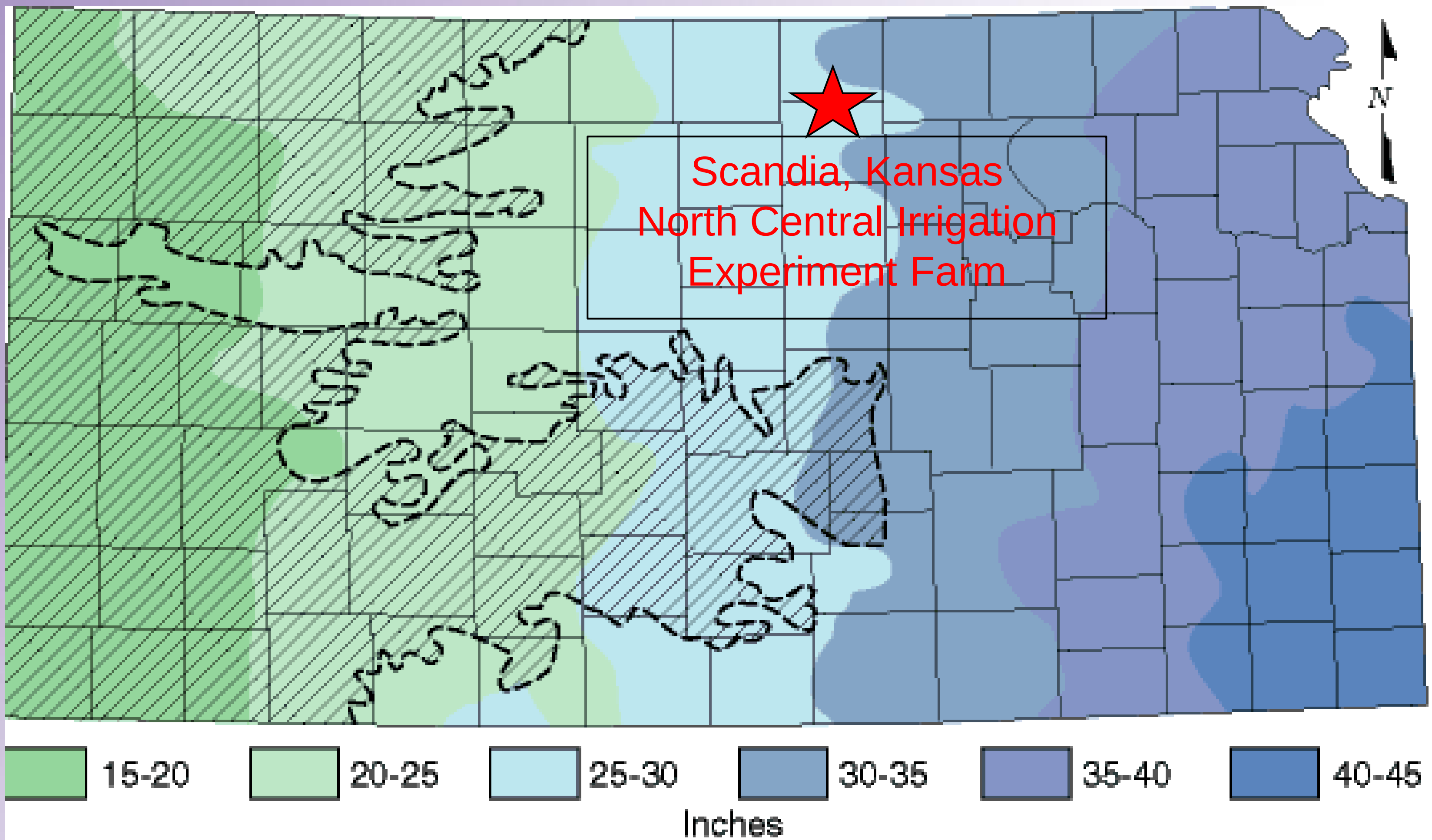
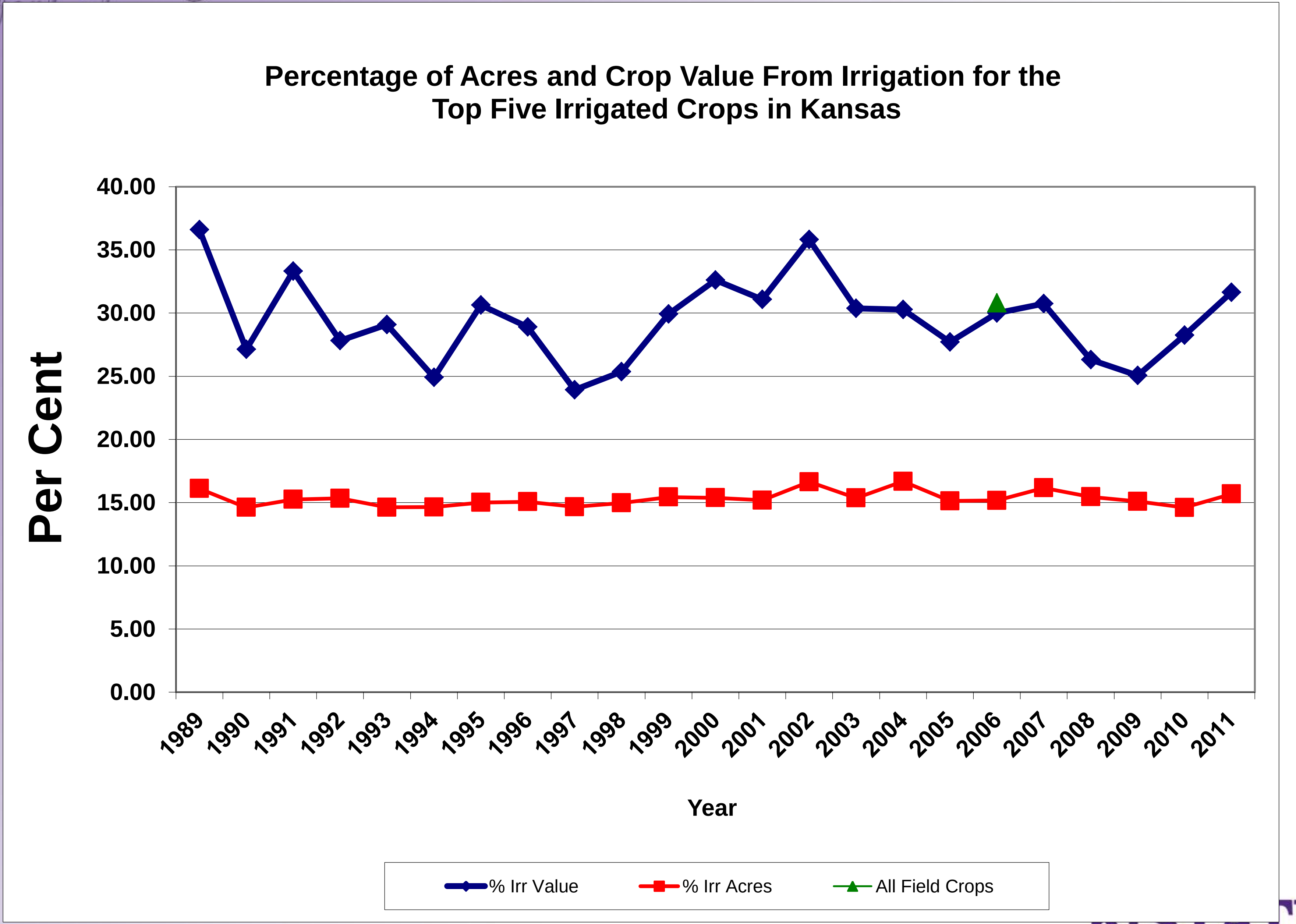


Figure 3. Normal annual precipitation (1961 - 1990) in Kansas. The area west of the dashed line shows the extent of the High Plains aquifer in Kansas (from Goodin et al., 1995).

Why Irrigate?

Improve yield, stabilize yield, improve quality, improve economy, etc

Time of Irrigation Study at Scandia Exp. Farm	1991 Yield Bu/Ac	1980-1991 Bu/Ac	1991 Irrigation Date
No Irrigation	3	56	None
Tassel	124	141	7/8
Tassel + 1 week	148	159	7/8, 7/15
Tassel + 1 + 2 week	155	164	7/8. 7/15, 7/25
65% depletion	159	172	7/1, 7/23



Percentage of Acres and Crop Value From Irrigation for the Top Five Irrigated Crops in Kansas
Per Cent
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Year
% Irr Value
% Irr Acres
All Field Crops

Western Kansas crop production statistics for wheat, grain sorghum, corn, soybeans, and alfalfa*

Location	Total of Irrigated and Dryland (1000s of acres)		Total Value of Irrigated and Dryland Production (1000s of $)		Irrigation Percentage of Total Area		Irrigation Percentage of Total Value	
	2002	2009	2002	2009	2002	2009	2002	2009
Western KS	5,372	6,899	905,163	2,333,500	36.7%	28.3%	70.2%	48.3%
Southwest KS	2,532	3,042	565,555	1,120733	53.5%	44.0%	85.8%	70.4%
	2000	**2007**	**2000**	**2007**	**2009**	**2002**	**2000**	**2007**
Haskell County	224.2	274	63,783	134,174	74.9%	62.0%	94.3%	81.6%

* Other crops not included are silage, sunflower, cotton, and dry beans.

Crop	Seasonal Crop Water Use (ET) (Inches)	Generalized or Reported Maximum Daily Peak Crop Water Use (ET) (Inches)
Alfalfa	31.5 - 63	.55
Corn	15.6 – 31.6	0.50
Soybean	17.36 – 27.56	0.49
Grain Sorghum	16 – 30.6	0.51
Sunflower	16 – 39.37	0.28*
Wheat	15.4 – 25.59	0.54
*Value appears low; see Table 2 discussion.		

Plant growth, and therefore food production, is production is water intensive

- An acre-inch of water is 27,154 gallons
- Therefore, on a hot, sunny day, a quarter acre lawn could transpire about 3500 gallons of water.

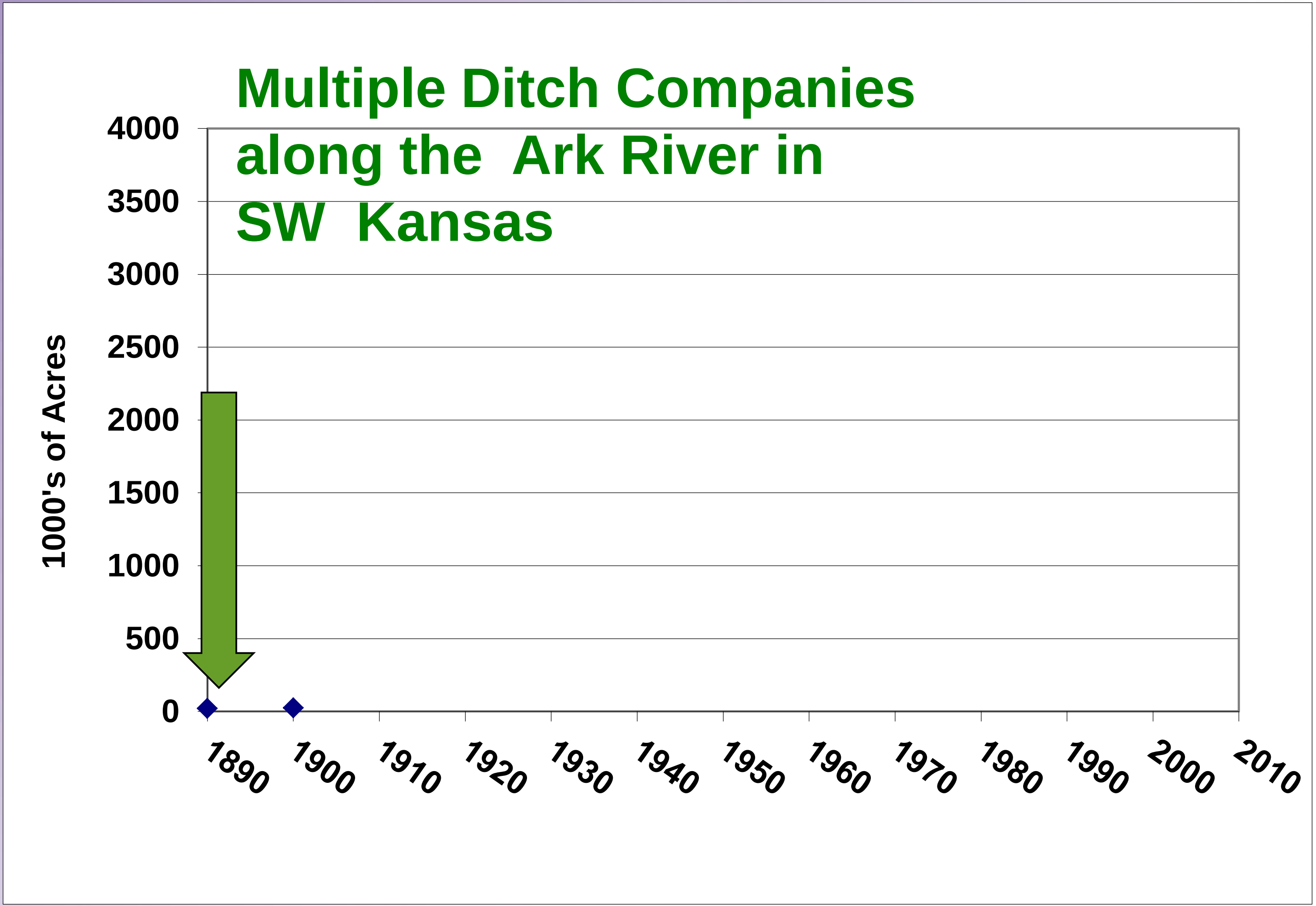
Water Requirements for a Holiday Dinner

(4 Adults and 4 Children)

Item	Gallons of Water Needed
20 lb. Turkey	16,300
Stuffing	6,004
Potatoes	72
Scalloped Corn	1,824
Green Beans	1,000
Carrots	1,000
Waldorf Salad	580
Fresh Fruit Salad	2,000
Bread	300
Margarine (incl. cooking)	2,212
Pumpkin Pie	1,240
Ice Cream	1,142
Milk for Four	1,000
Wine for Four	8,000

42,674 Gallons of Water

Kansas irrigation development 1890 -



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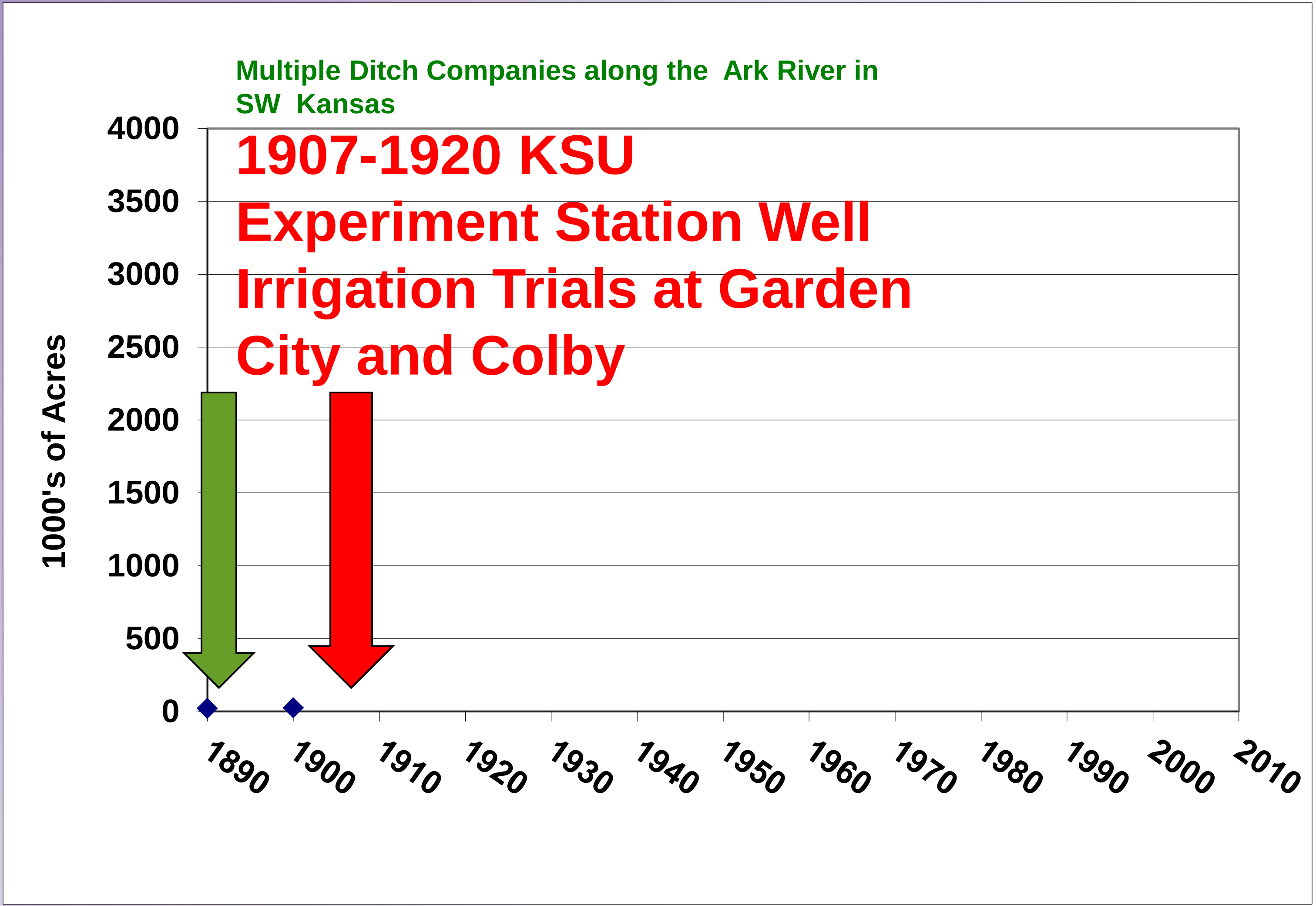
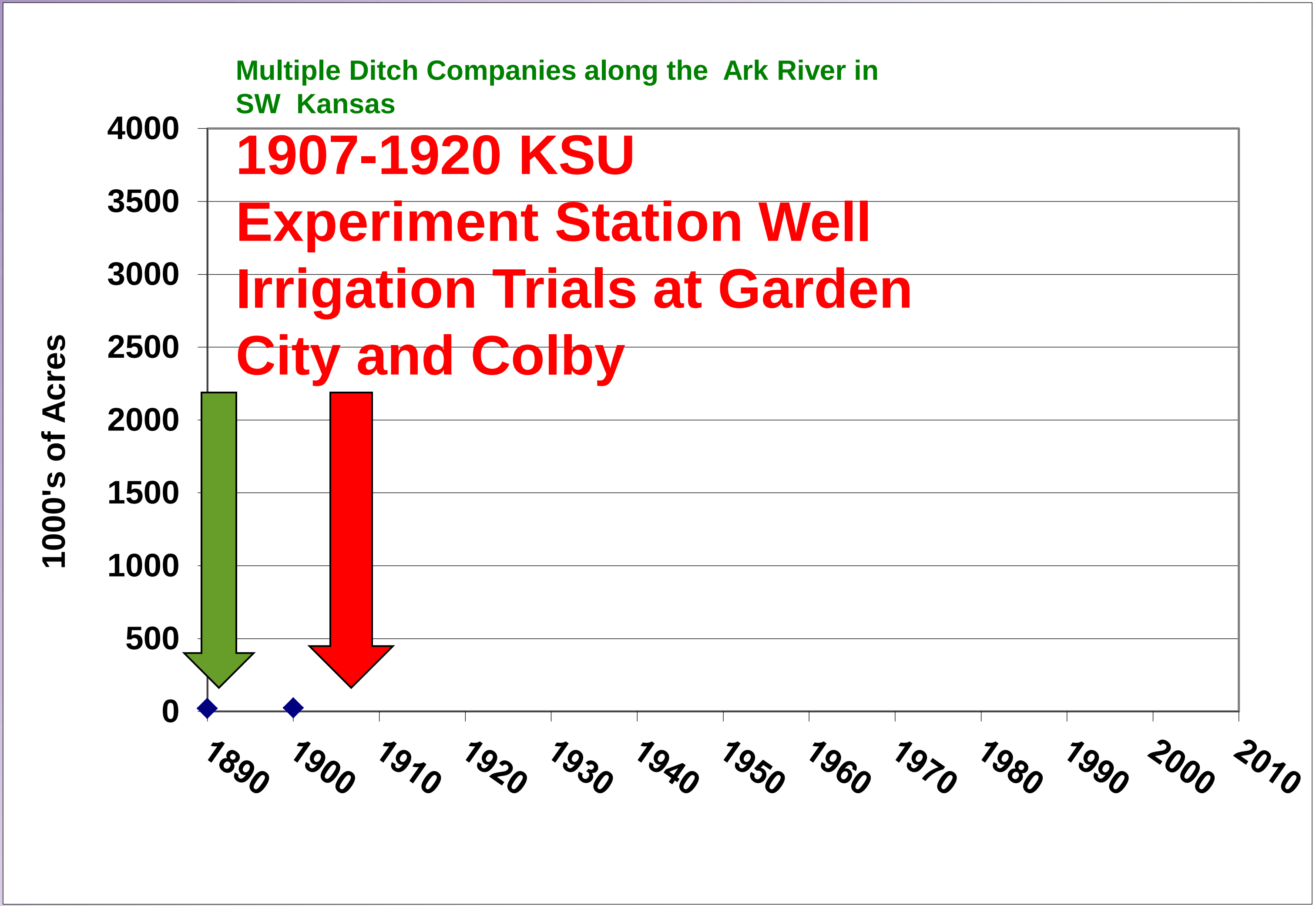
Kansas irrigation development 1890 - 1920



Kansas irrigation development 1890 - 1920



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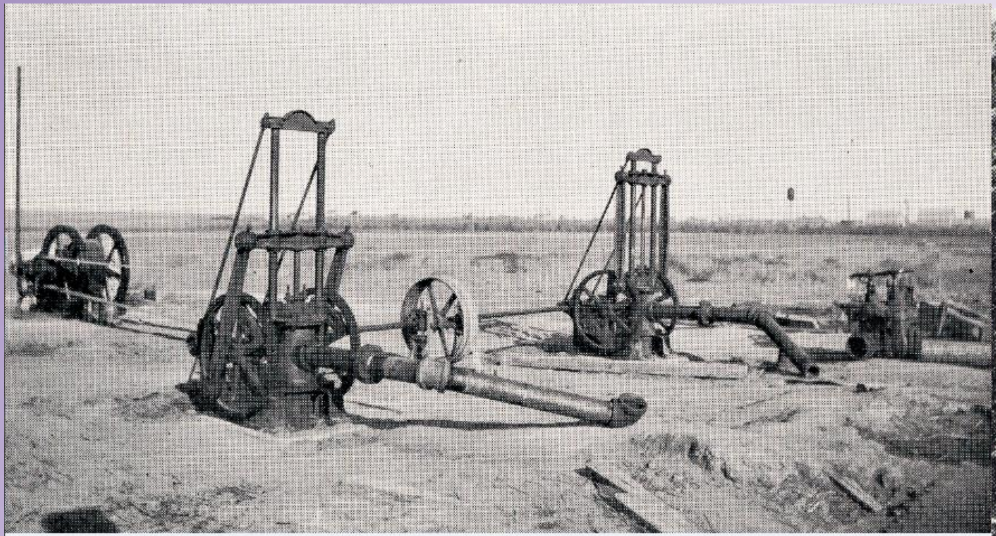
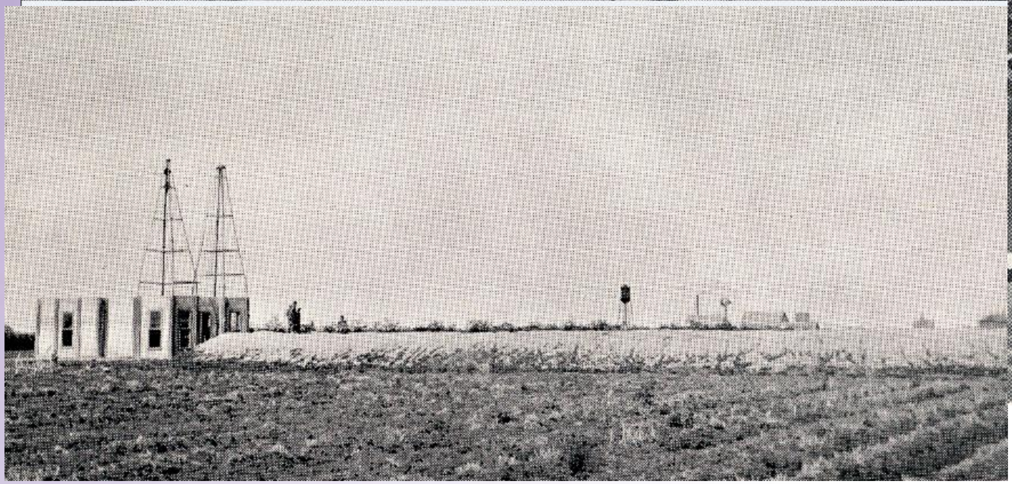
Colby Irrigation Project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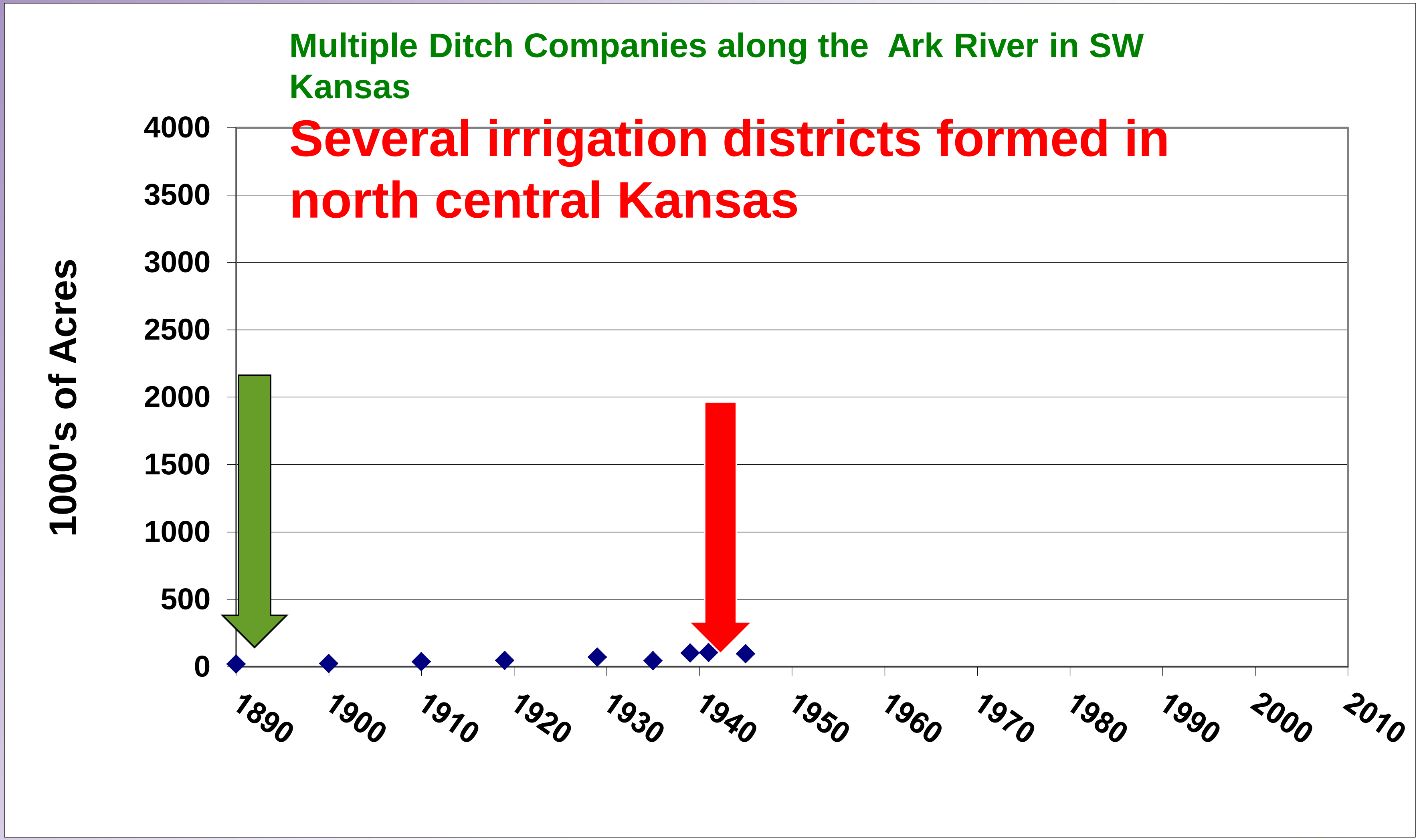
Best Use of Irrigation Reservoir?

Kansas irrigation development 1890 – 1940's



Surface Irrigation

Water supplies from reservoirs and rivers then conveyed by canals

Surface Irrigation

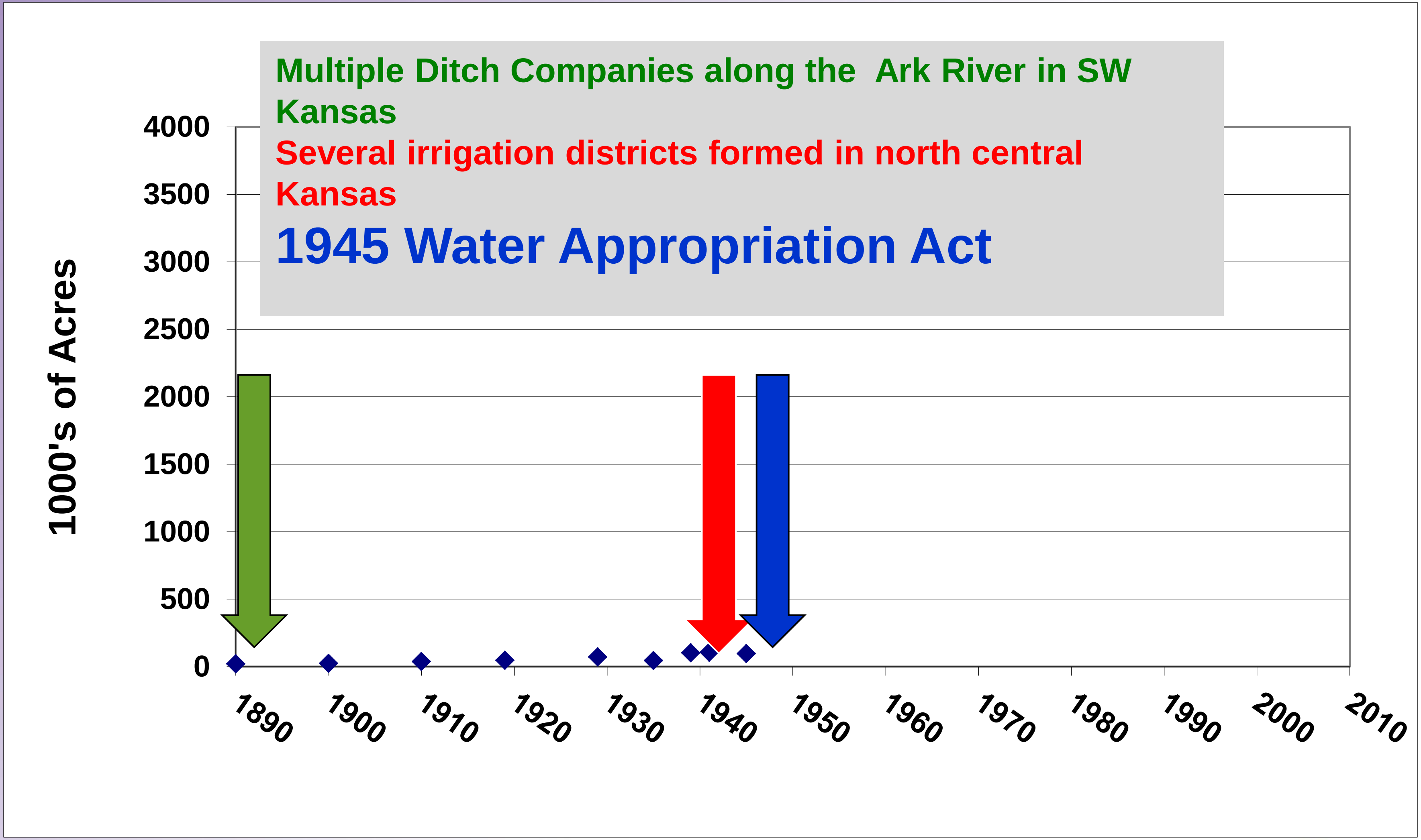
Temporary earthen canals or laterals delivered the water to the fields.

Surface Irrigation

Field distribution methods include basin, border, and furrow

Field Water Diversions

Kansas irrigation development 1890 - 1945



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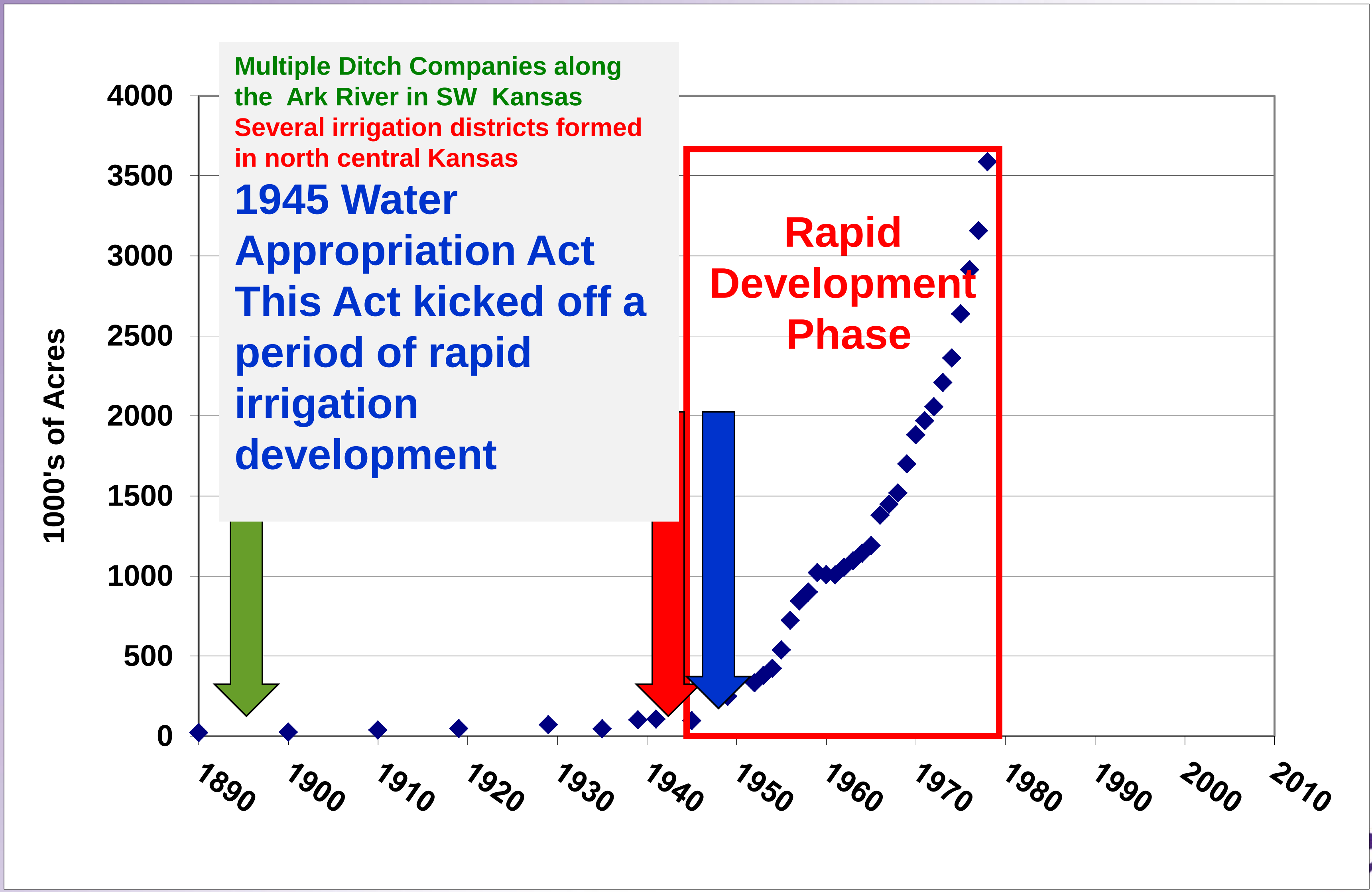
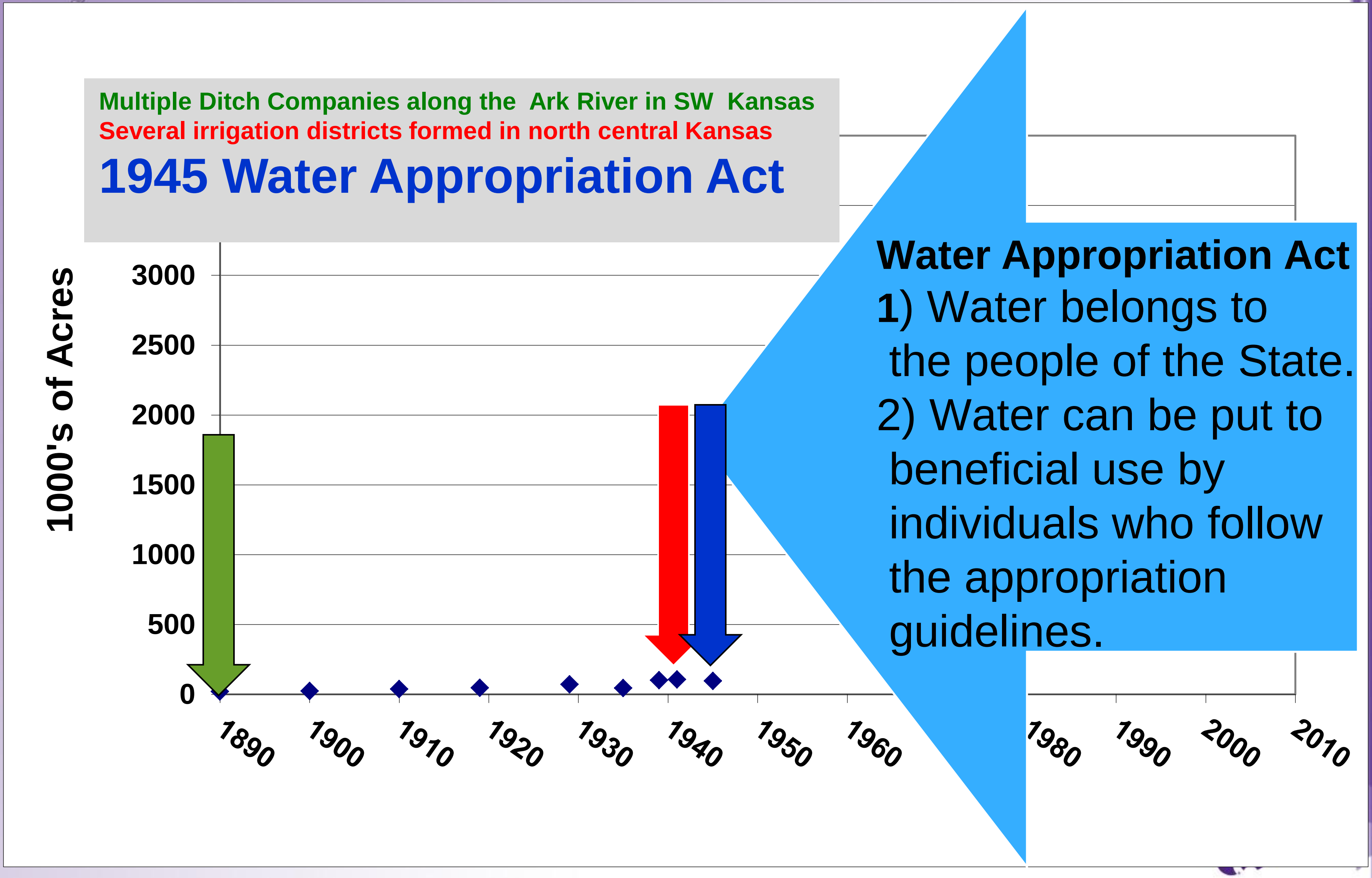
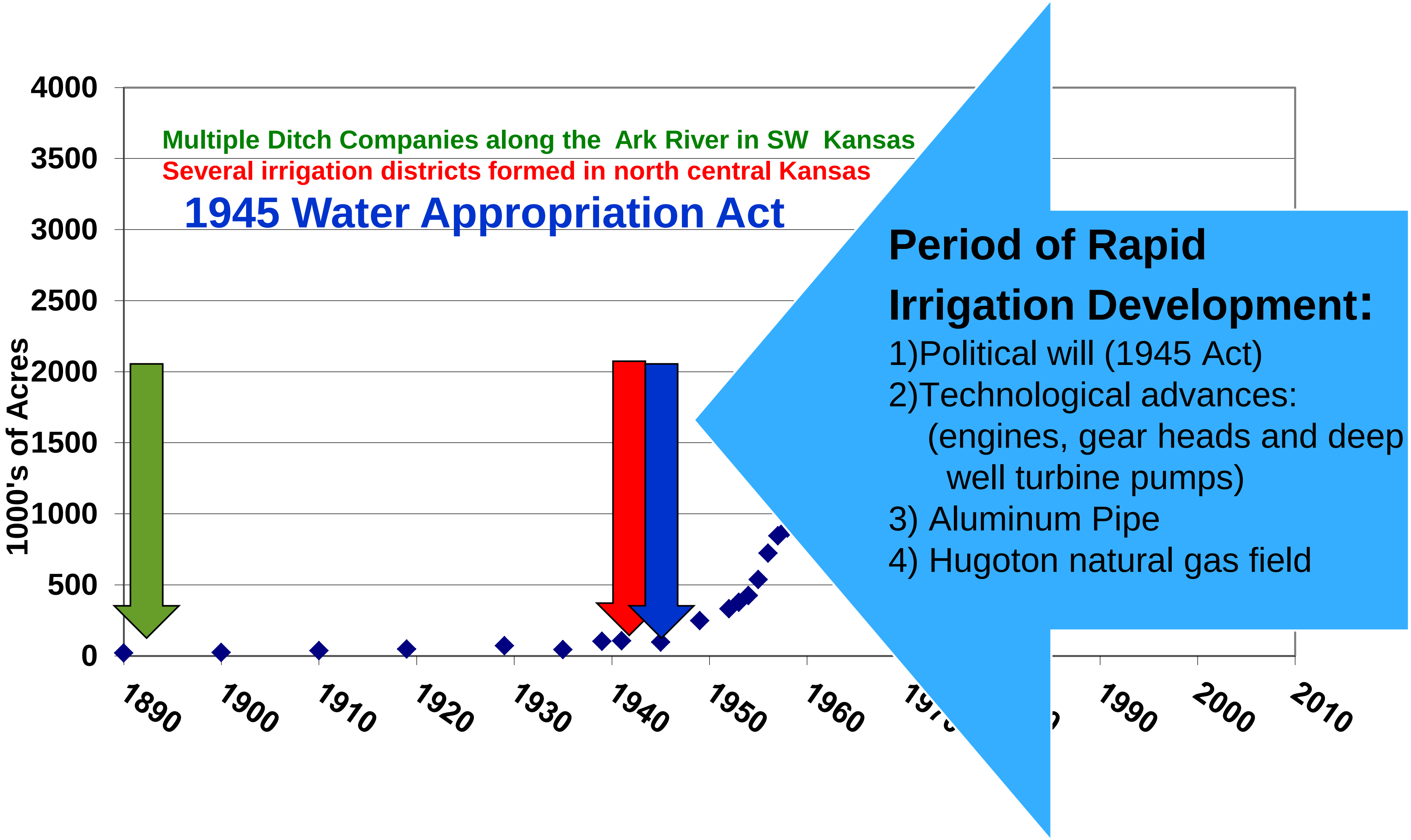
Kansas irrigation development: 1890 -1978



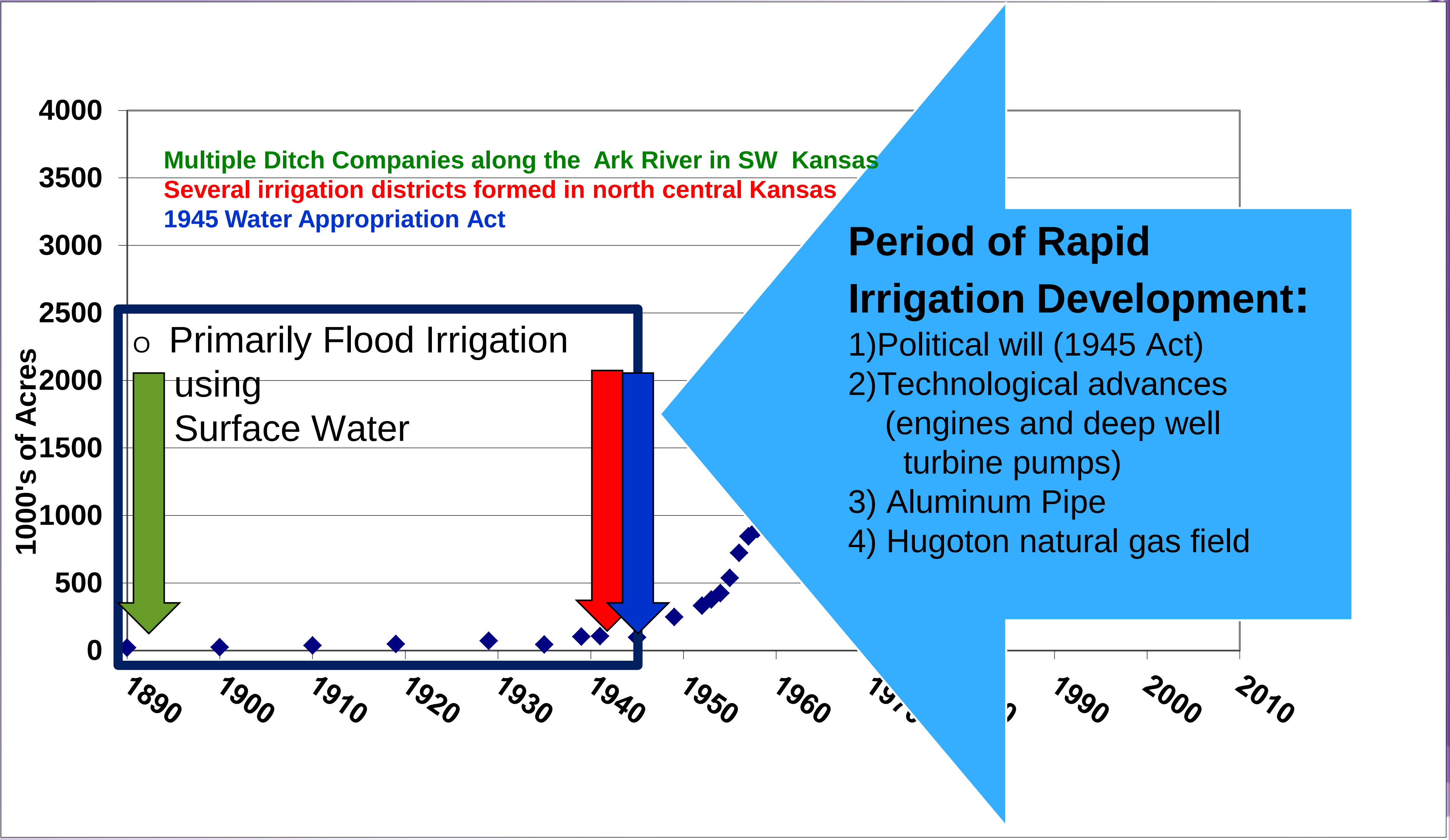
Kansas irrigation development



Kansas irrigation development



Kansas irrigation development



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When surface irrigation was common, well water was pumped into the canal system or field lateral

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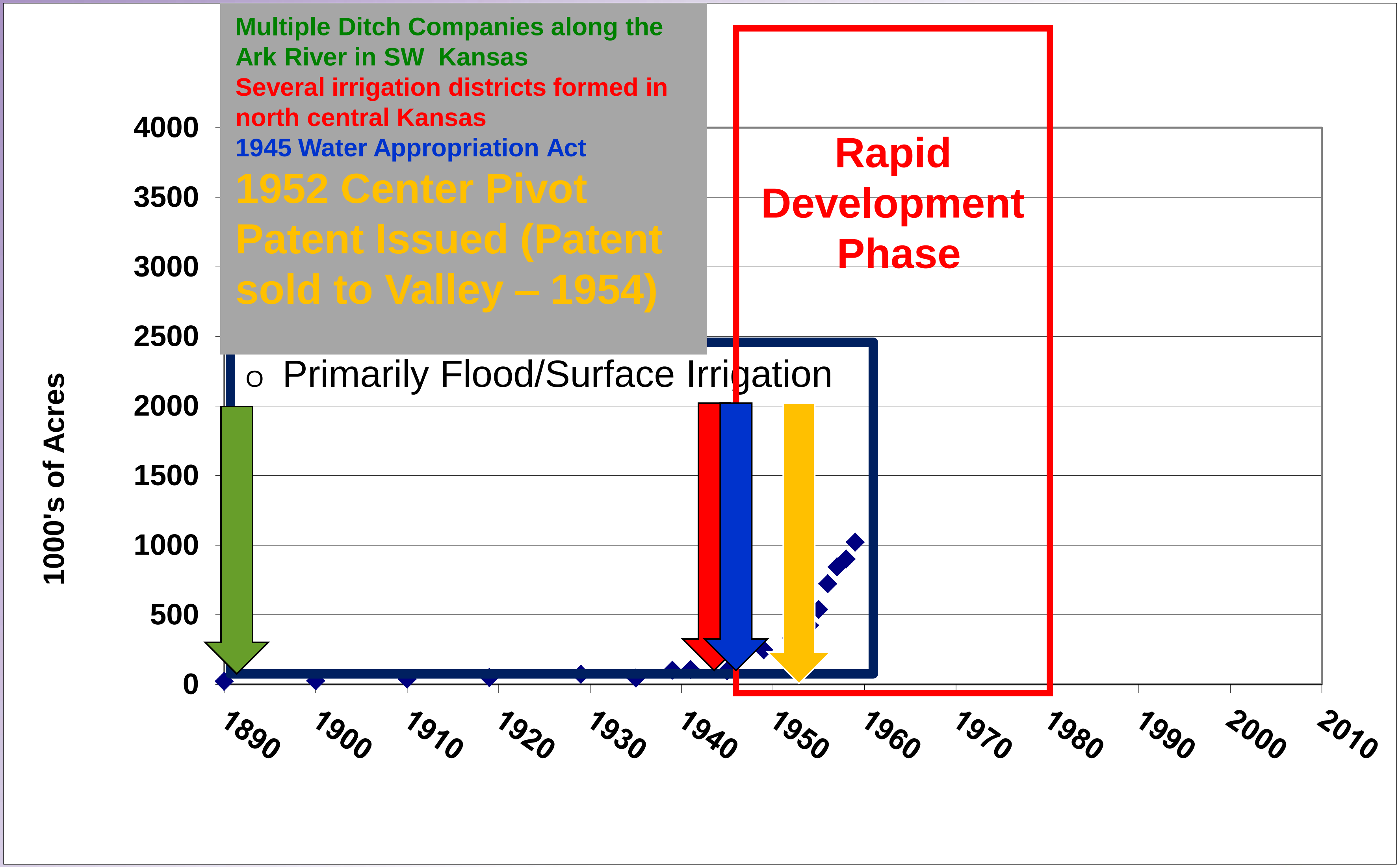
Gated Pipe

Lay-flat plastic pipe

Kansas irrigation development since 1890



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Center Pivot Sprinkler Irrigation Systems

SELF-PROPELLED SPRINKLER SYSTEM BY FRANK ZYBACH (1948)

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Center Pivot Equipped with Corner System

Linear Move

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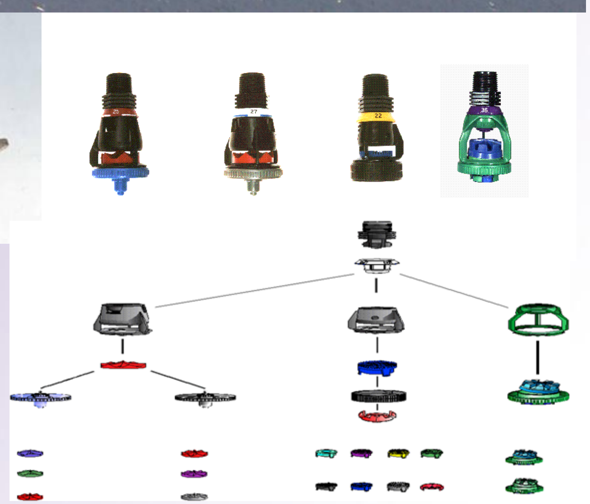
Center Pivot Nozzle Options: Many possibilities



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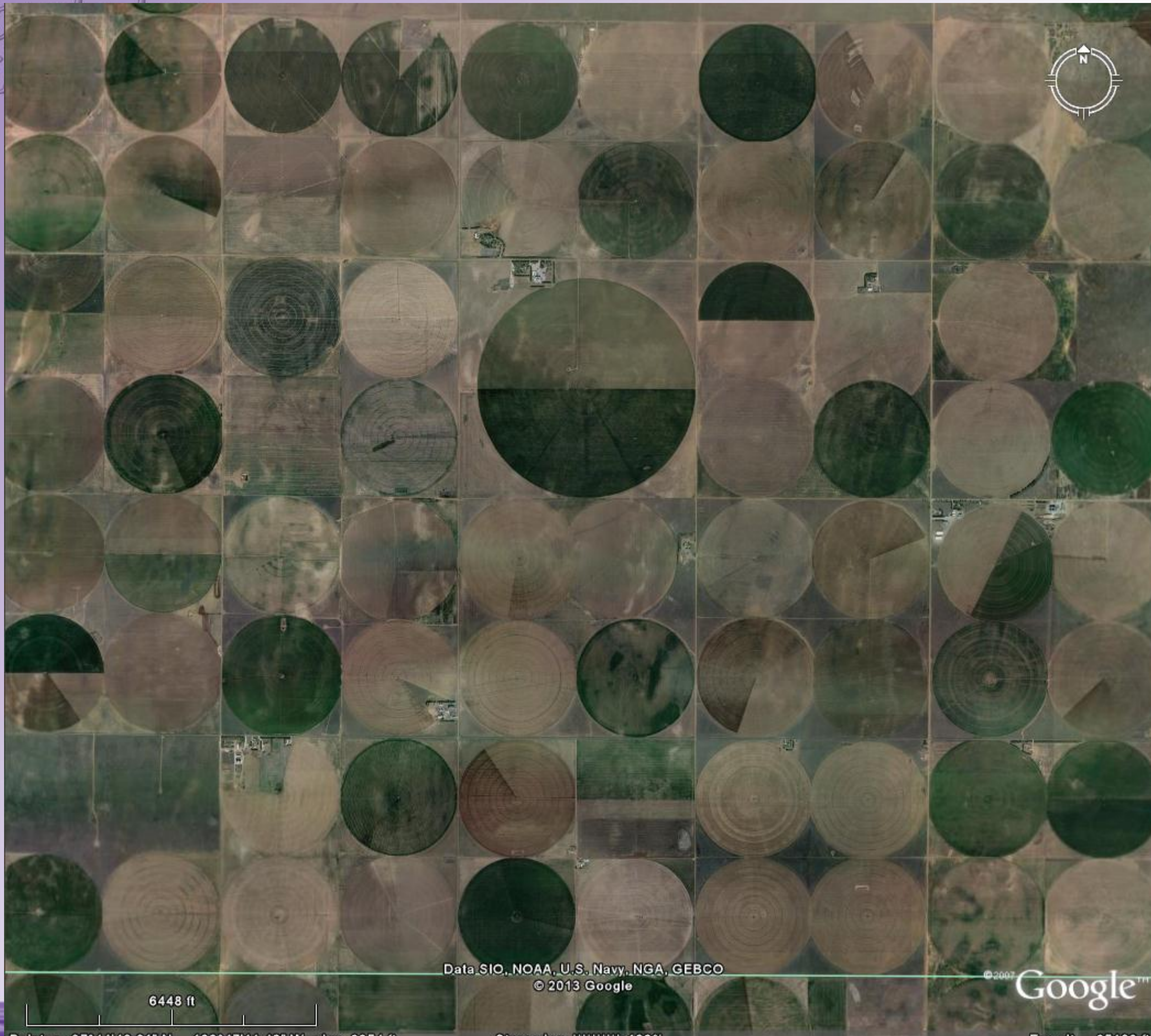
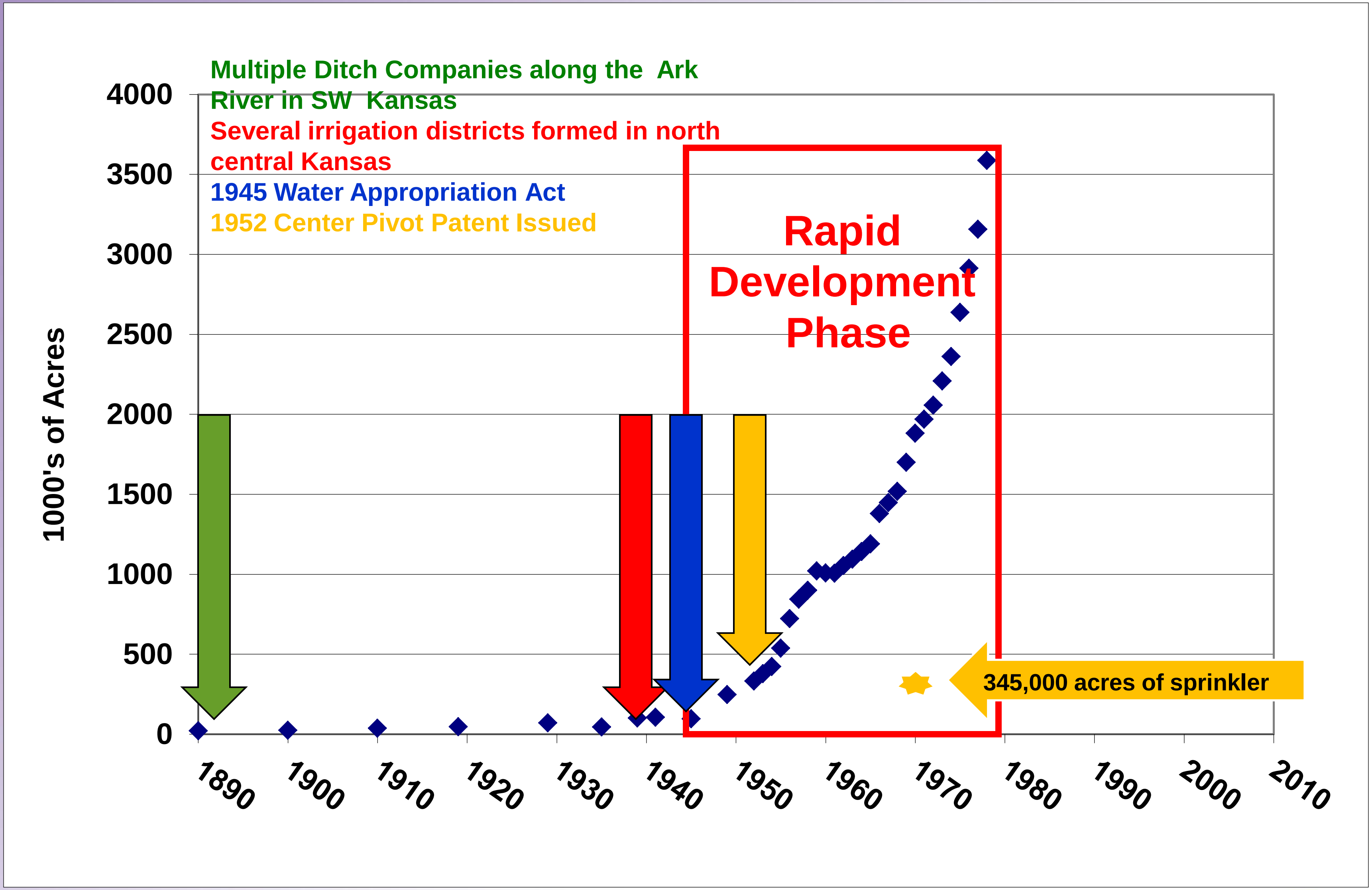
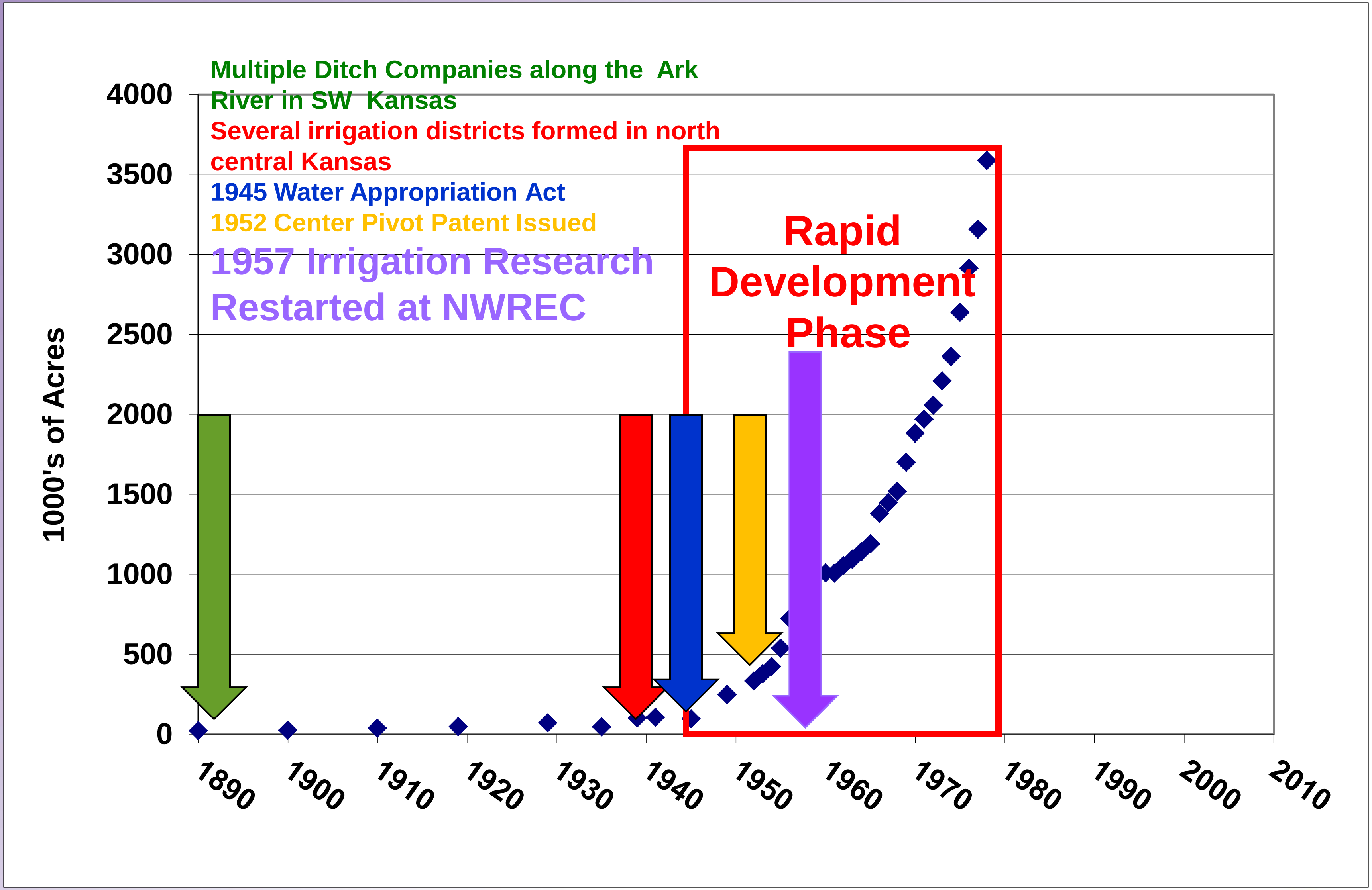


Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2013 Google
6448 ft
Google

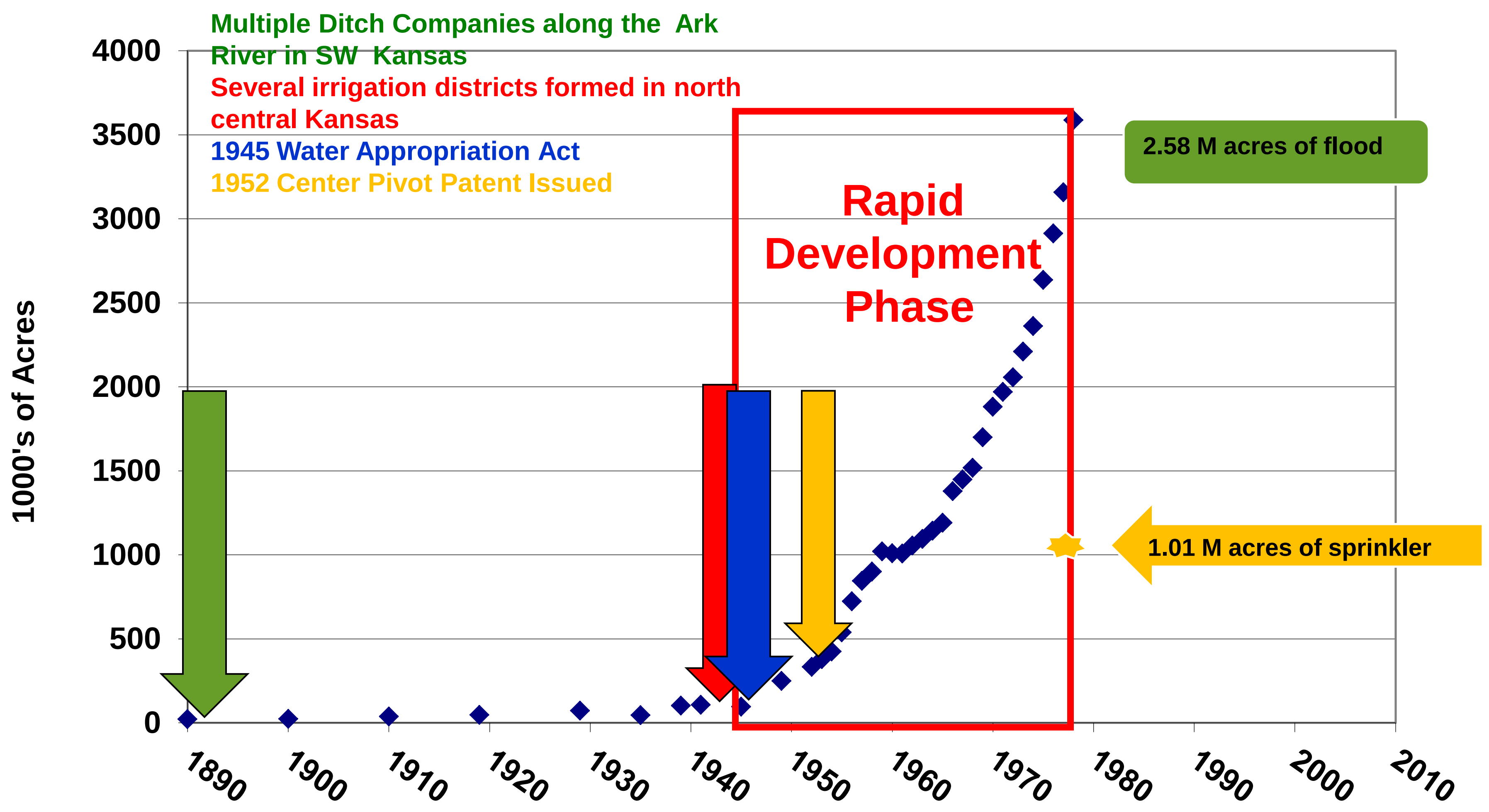
Kansas irrigation development: 1890 -1970



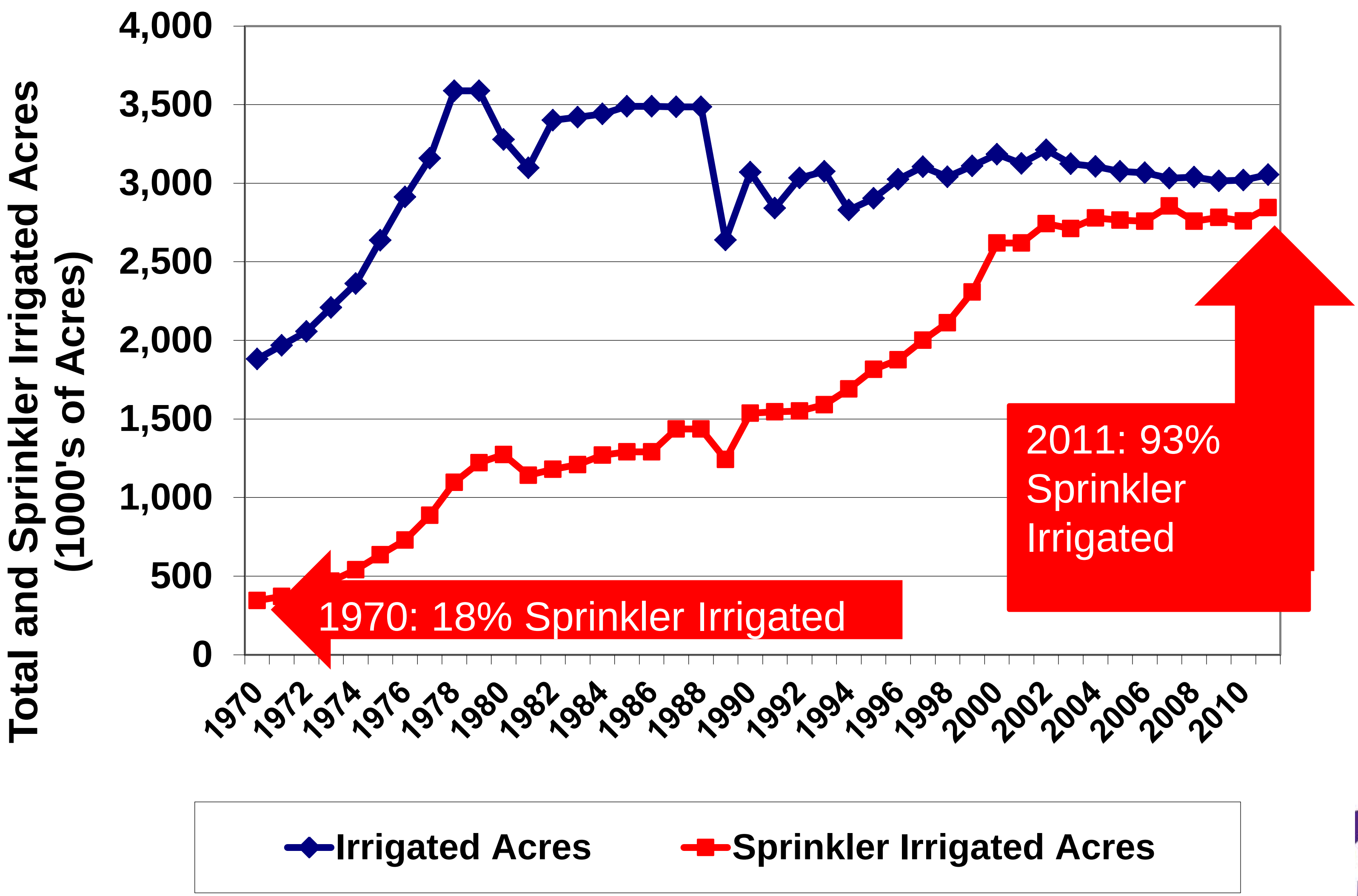
Kansas irrigation development: 1890 -1970



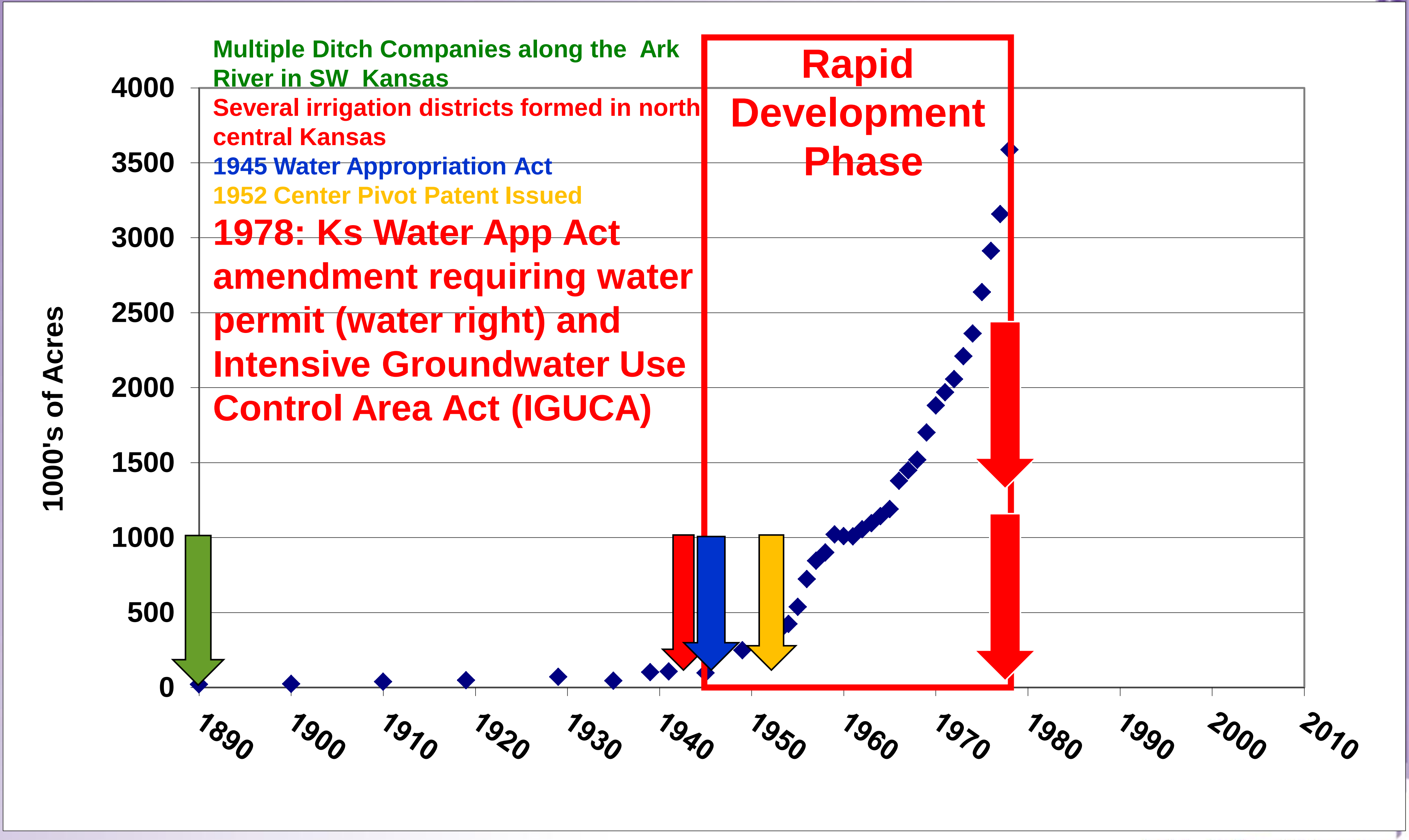
Kansas irrigation development: 1890 -1978



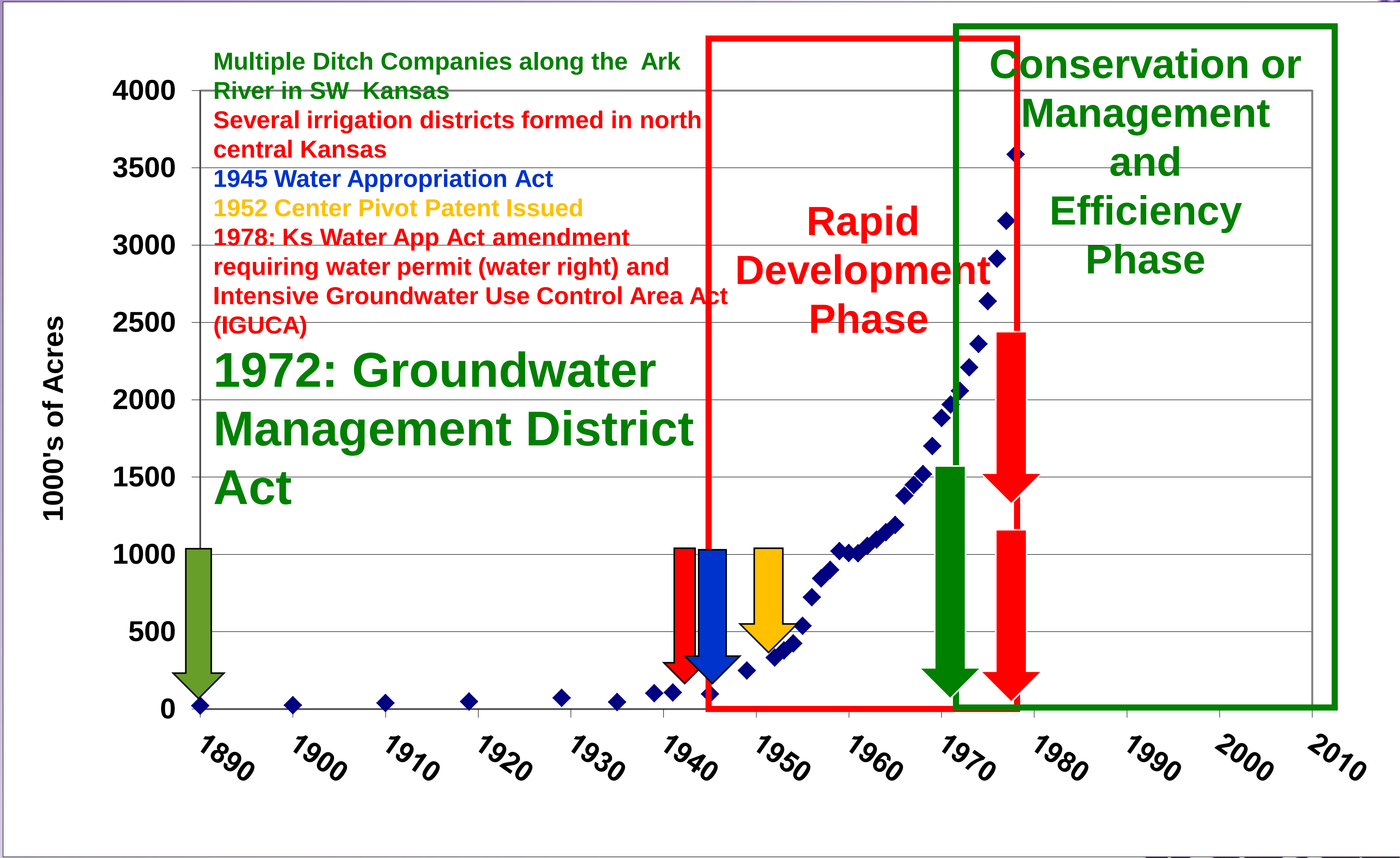
Kansas irrigation development: 1970 - 2011



Kansas irrigation development: 1890 -1978



Kansas irrigation development: 1890 -1972



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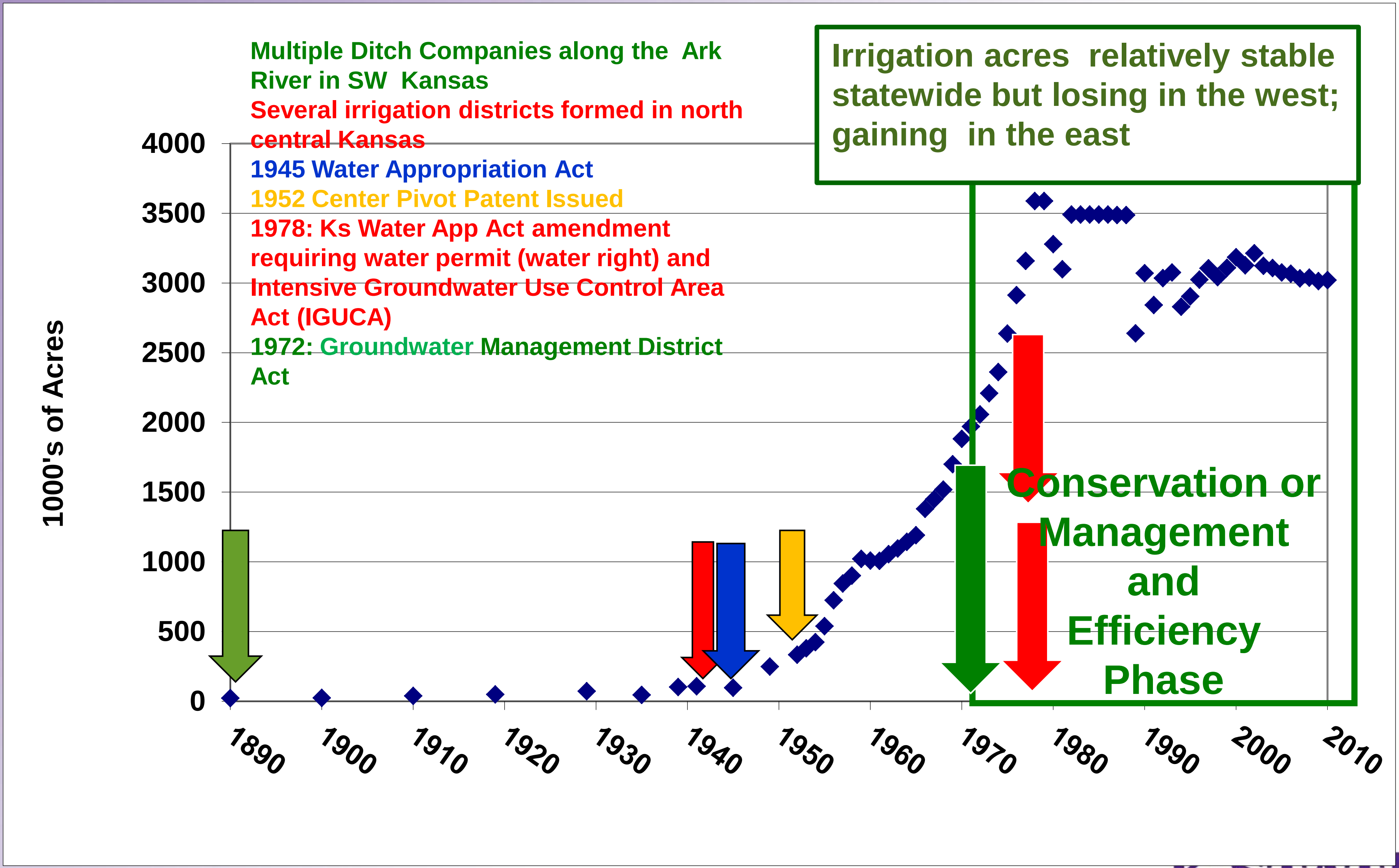
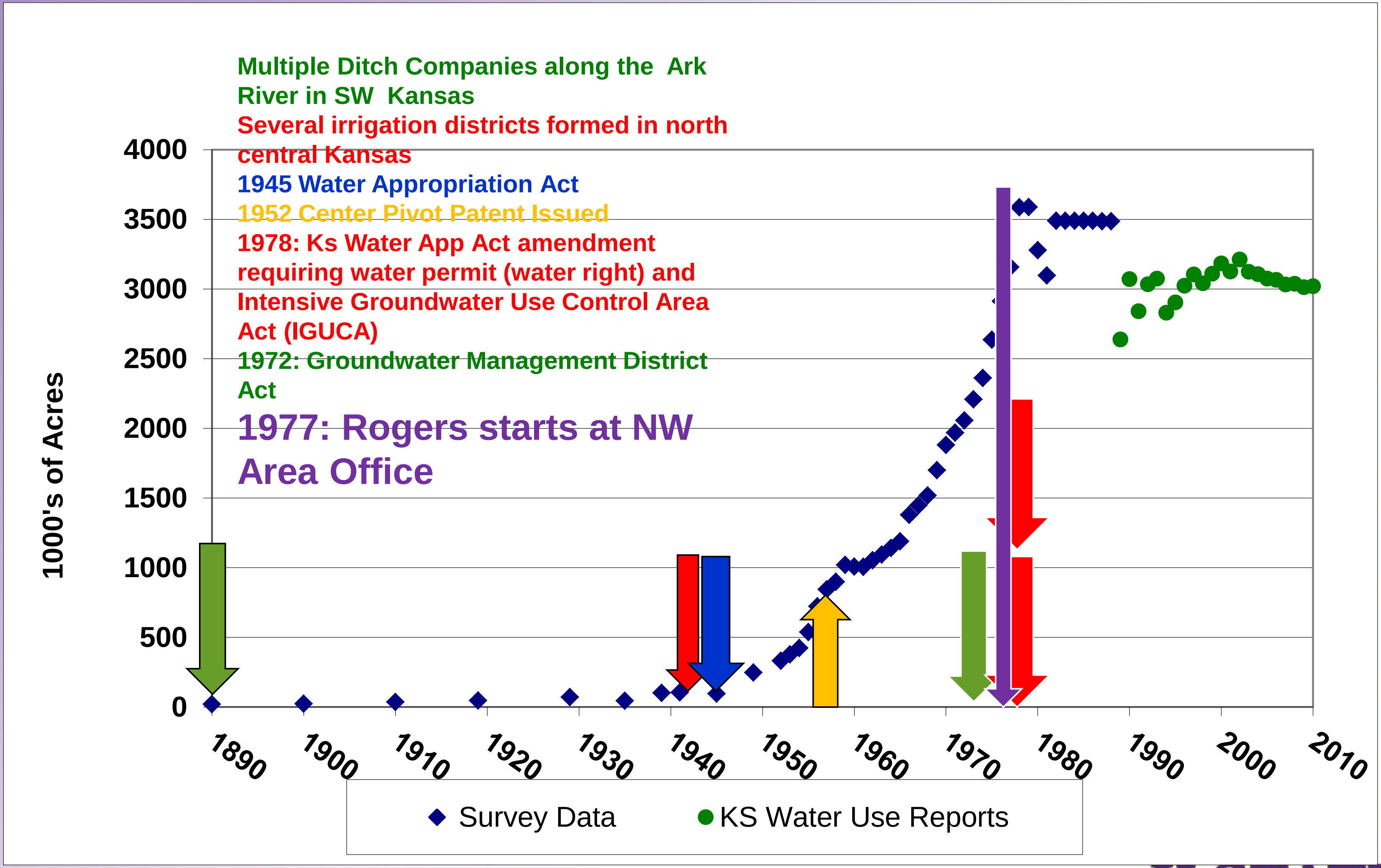
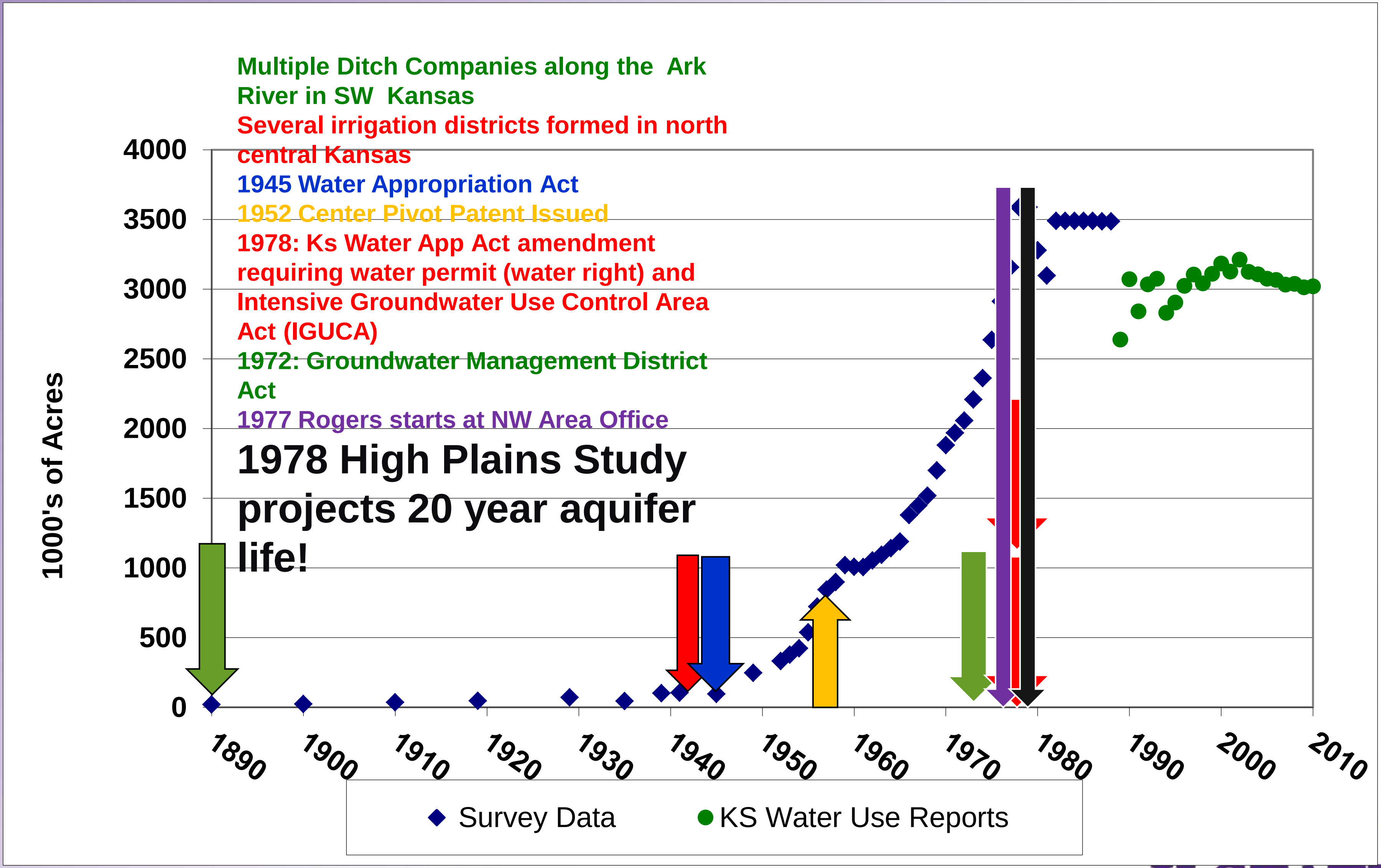
Kansas irrigation development: 1890 -2015



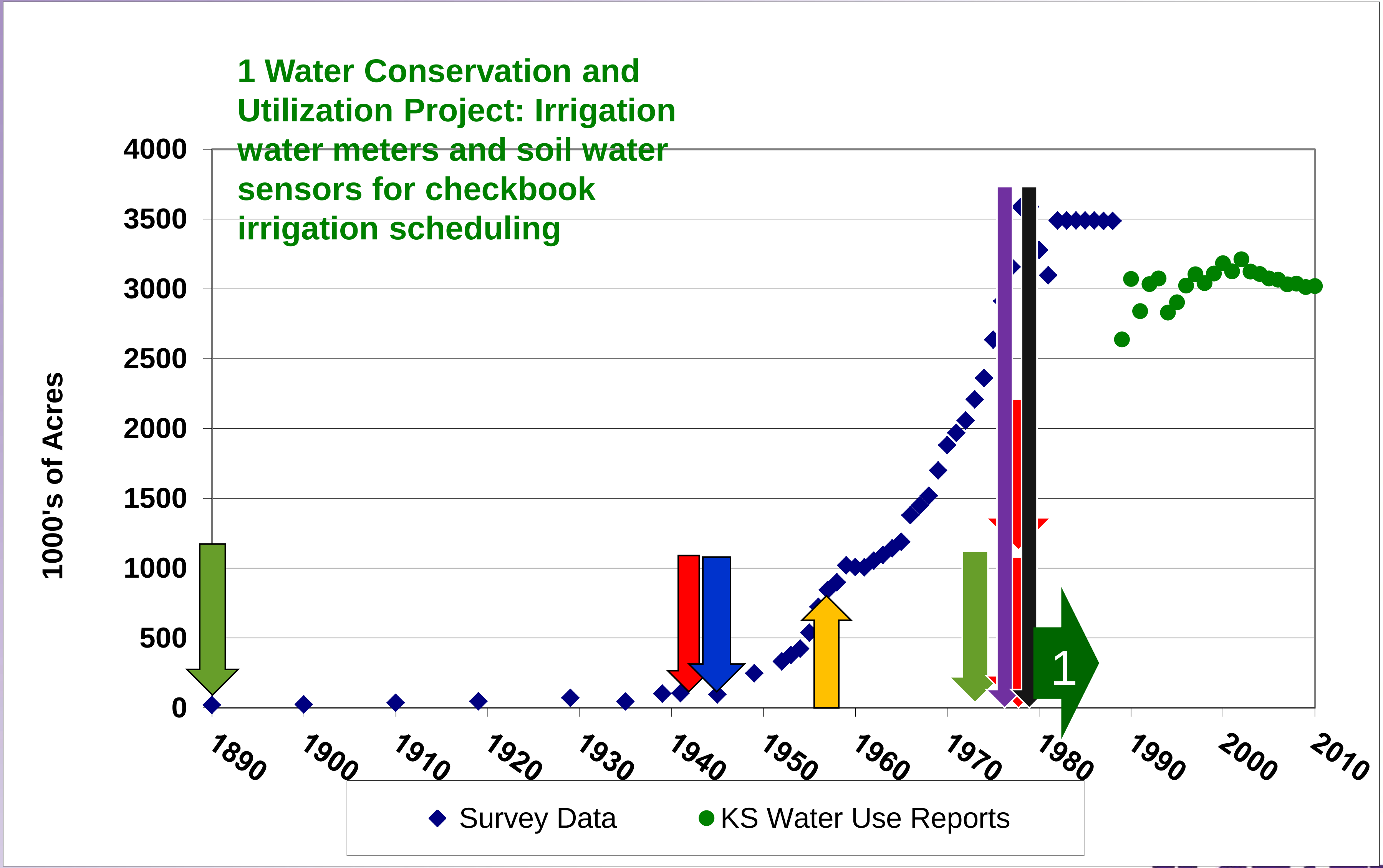
Kansas irrigation development: 1890 -2015



Kansas irrigation development: 1890 -2011



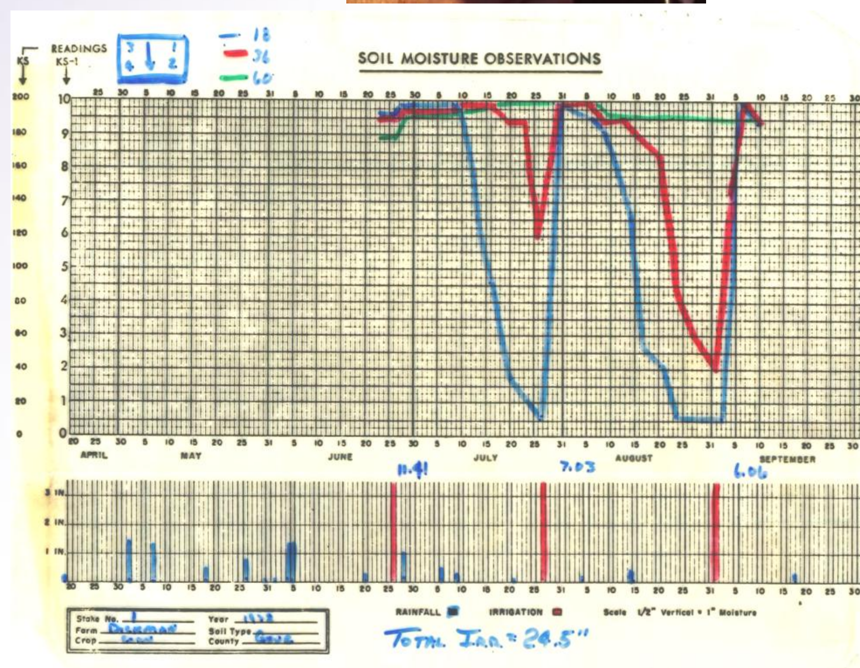
Kansas irrigation development: 1890 -2015



Monitor the Pressure and / or Flow Rate

- *One of cheapest ways to monitor your machine*
- *Know what the pressure should be*
- *If pressure is wrong, the system can't be right.*

Although Kansas requires flow meters, they should be viewed as management tools.


READINGS KS-1
KS
18
36
60
SOIL MOISTURE OBSERVATIONS
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
11.41
7.03
6.06
RAINFALL
IRRIGATION
Scale 1/2" Vertical = 1" Moisture
Stake No. 1
Farm
Crop
Year
Soil Type
County
TOTAL IRR. = 24.5"

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Soil Sensor Demonstration Project – Field Instrumentation

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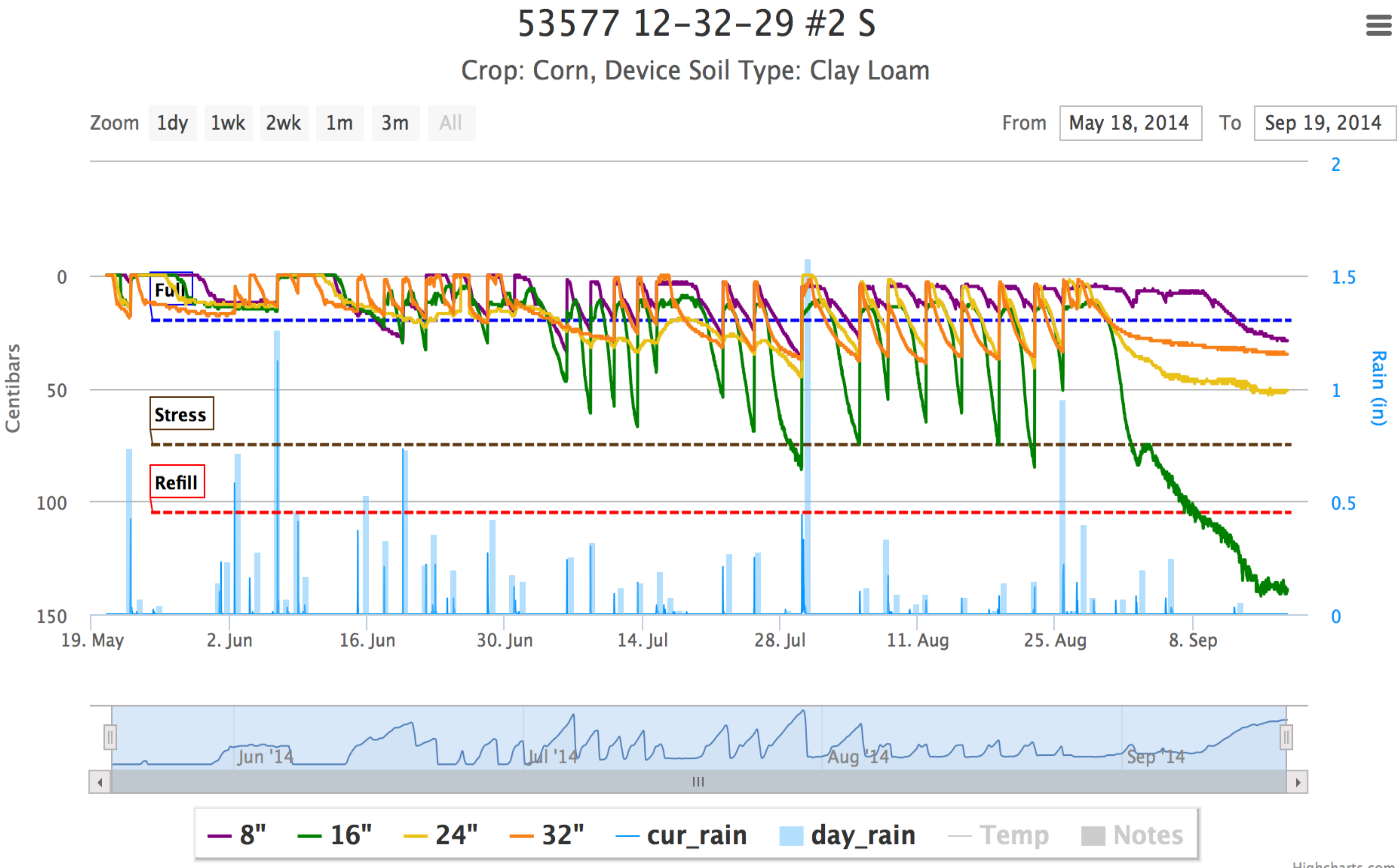

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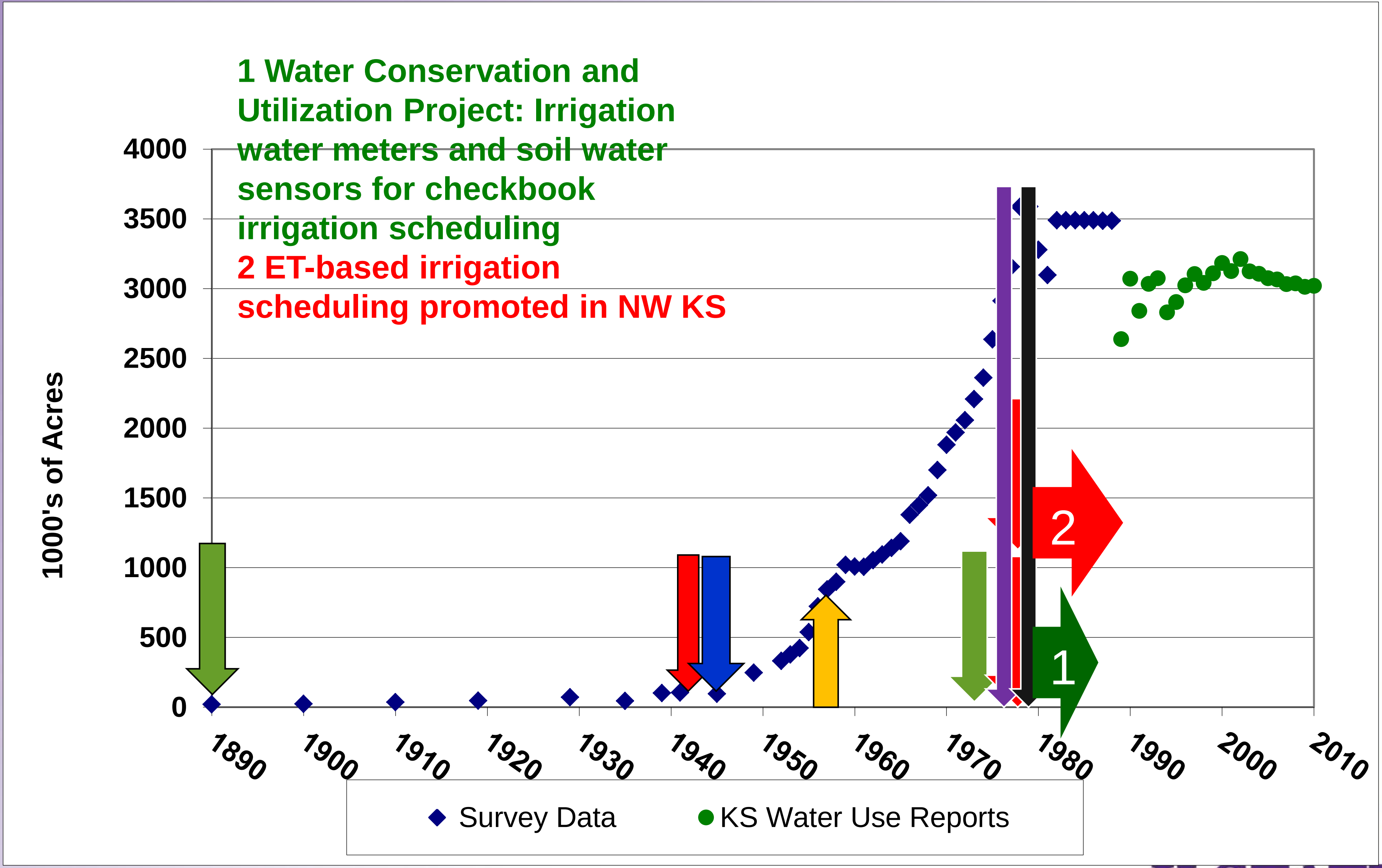
Kansas irrigation development: 1890 -2015



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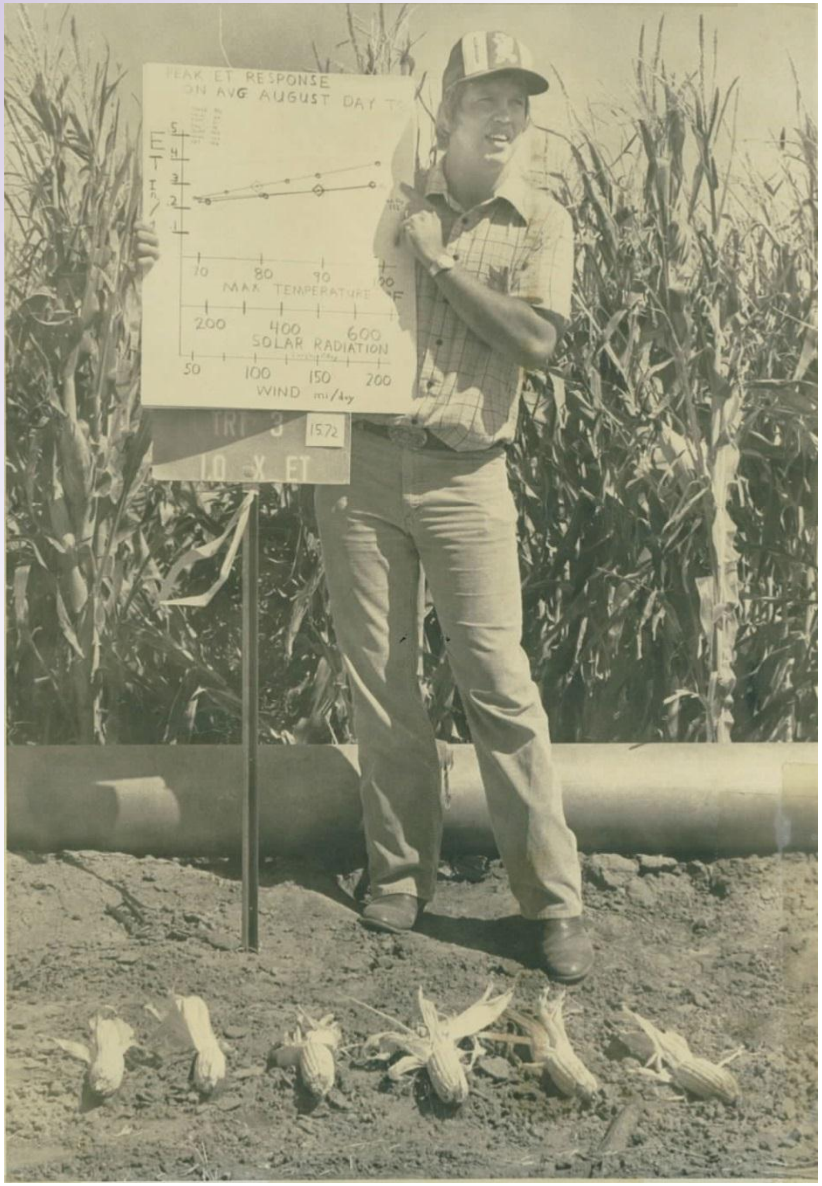
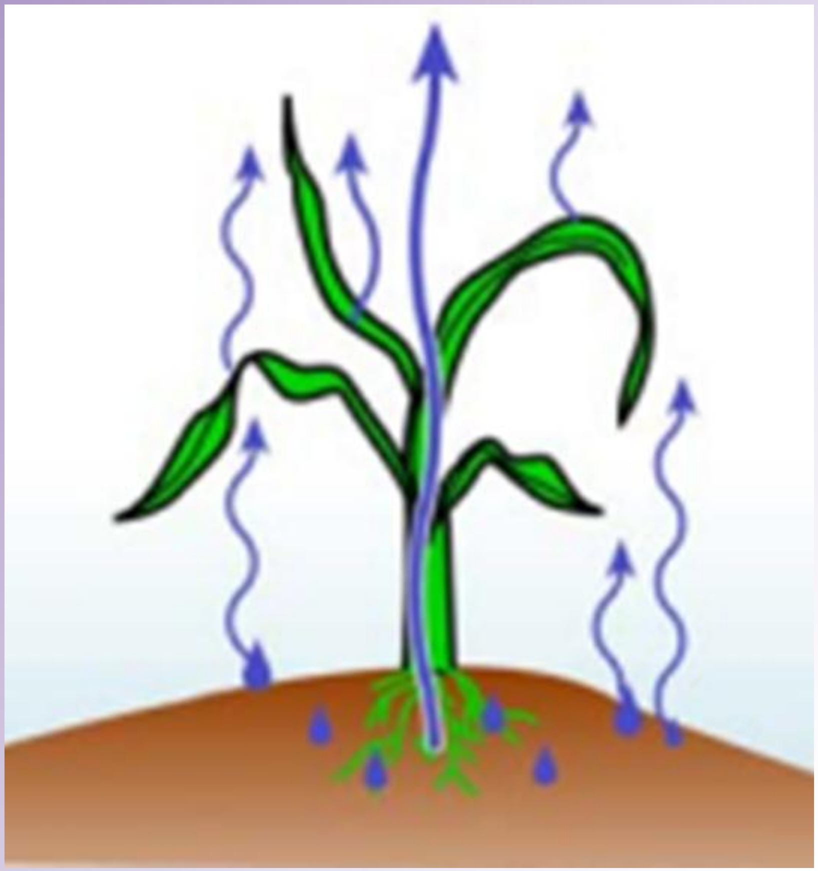
Colby Branch Experiment Station Field Day Tour
Report on ET Study

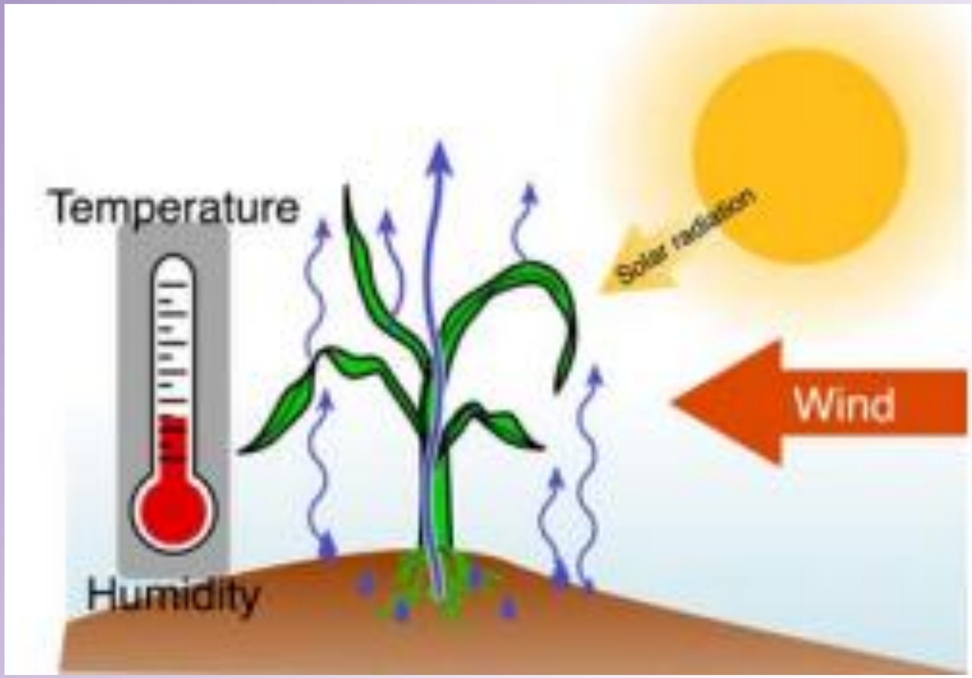


Crop Water Use or Evapotranspiration



- ET is the combination of evaporation and transpiration
- Evaporation is the water movement from wet soil and leaf surfaces
- Transpiration is water movement through the plant

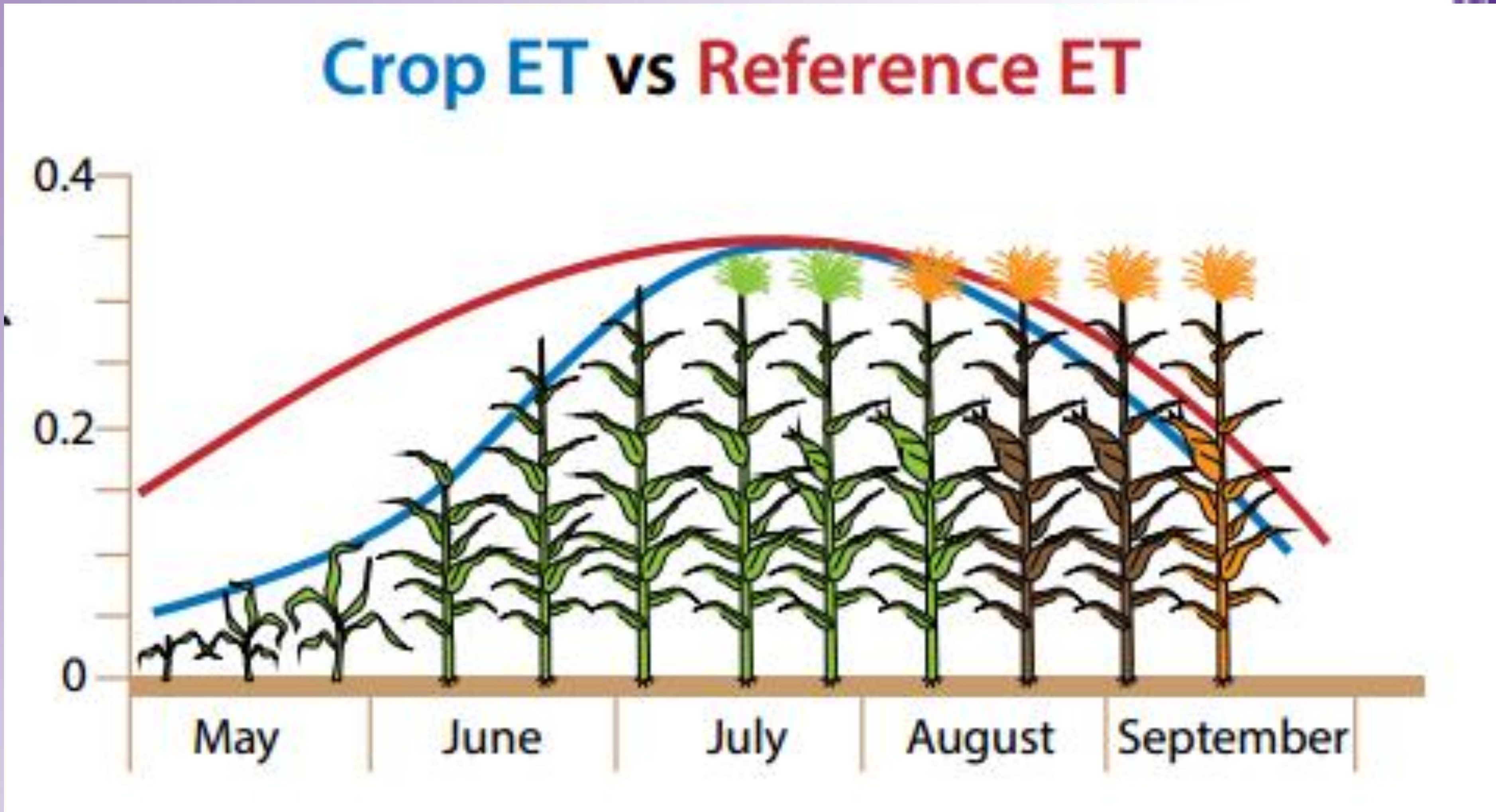
Evapotranspiration (ET)



- ET is an energy driven process
- ET increases with increasing temperature, solar radiation, and wind
- ET decreases with increasing humidity

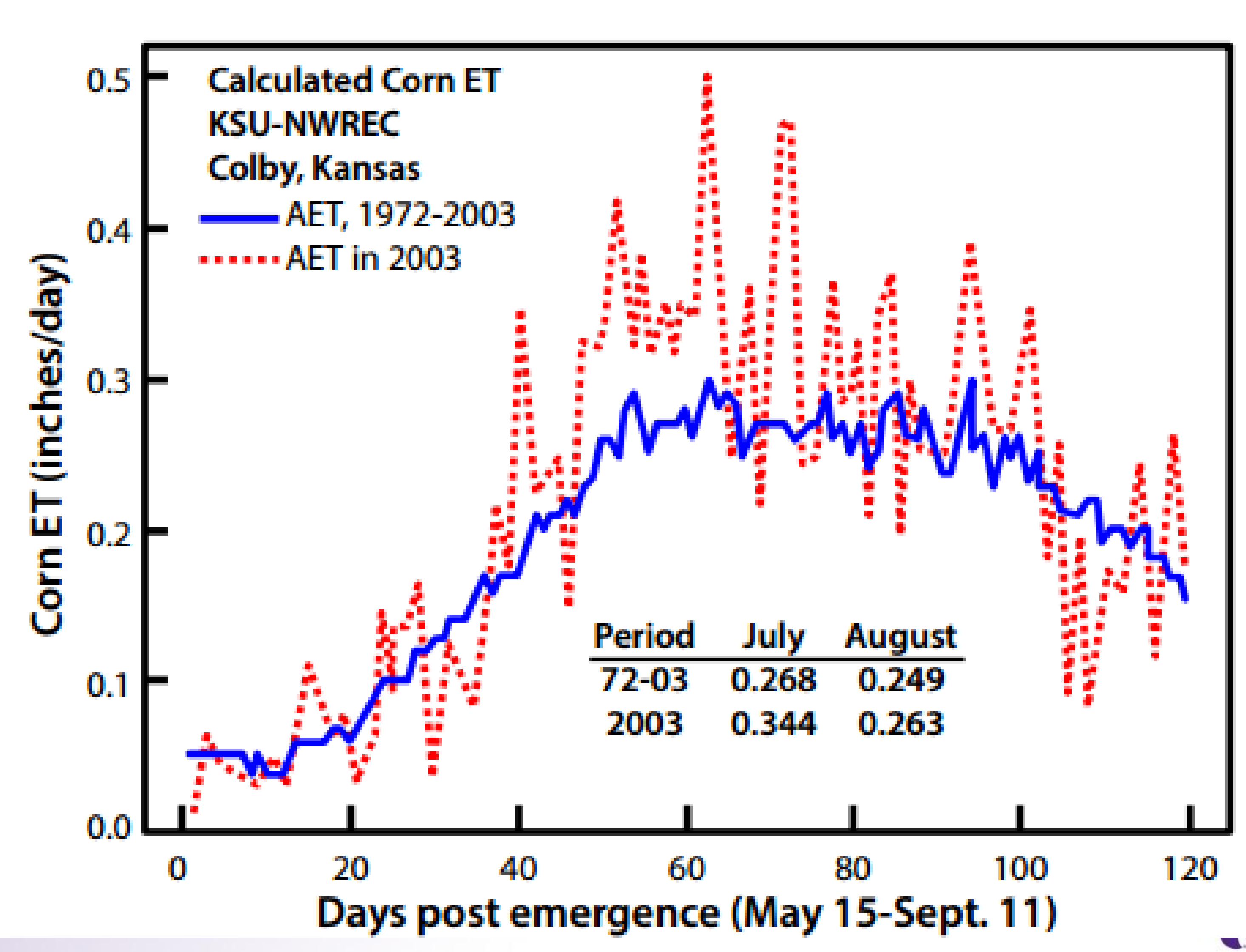
Generalized Crop ET versus Reference ET.

(Rogers, 2007).



Actual seasonal daily ET and long-term average ET rate for corn

(Lamm, 2004).



Period	July	August
72-03	0.268	0.249
2003	0.344	0.263

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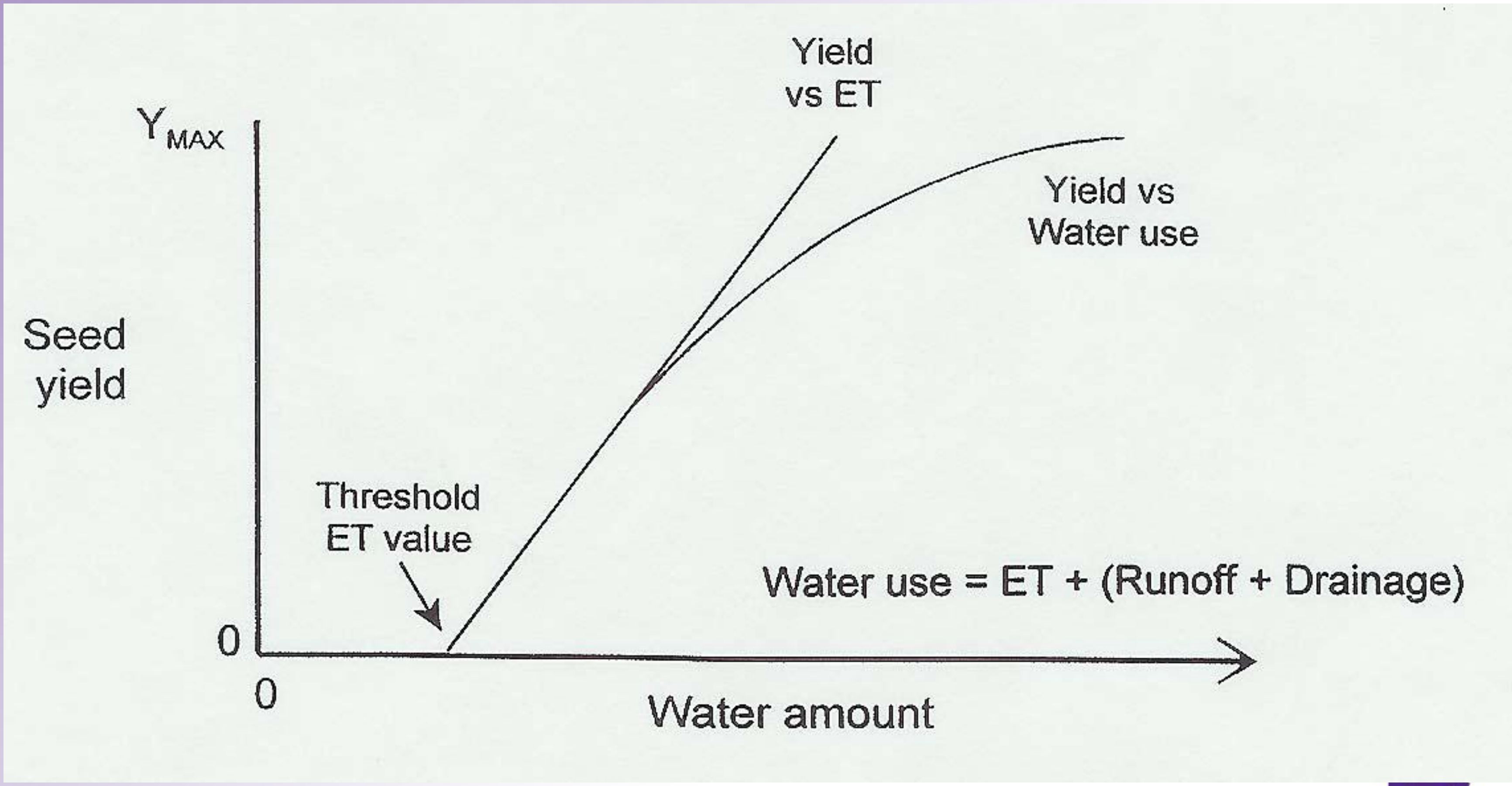
Generalized relationship between yield and water amount (ET or water use)

(Stone, L. and A. Schlegel. 2006).



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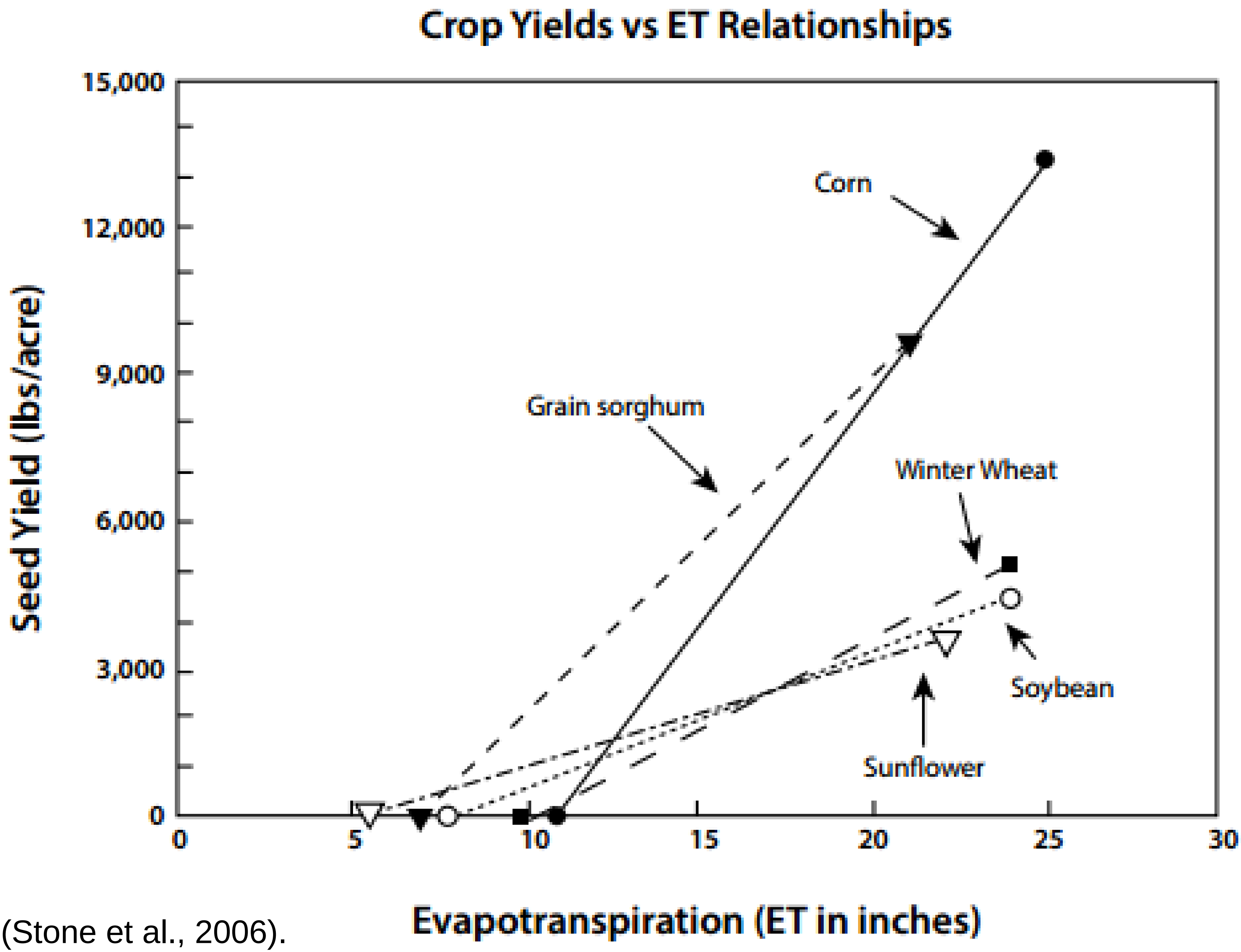
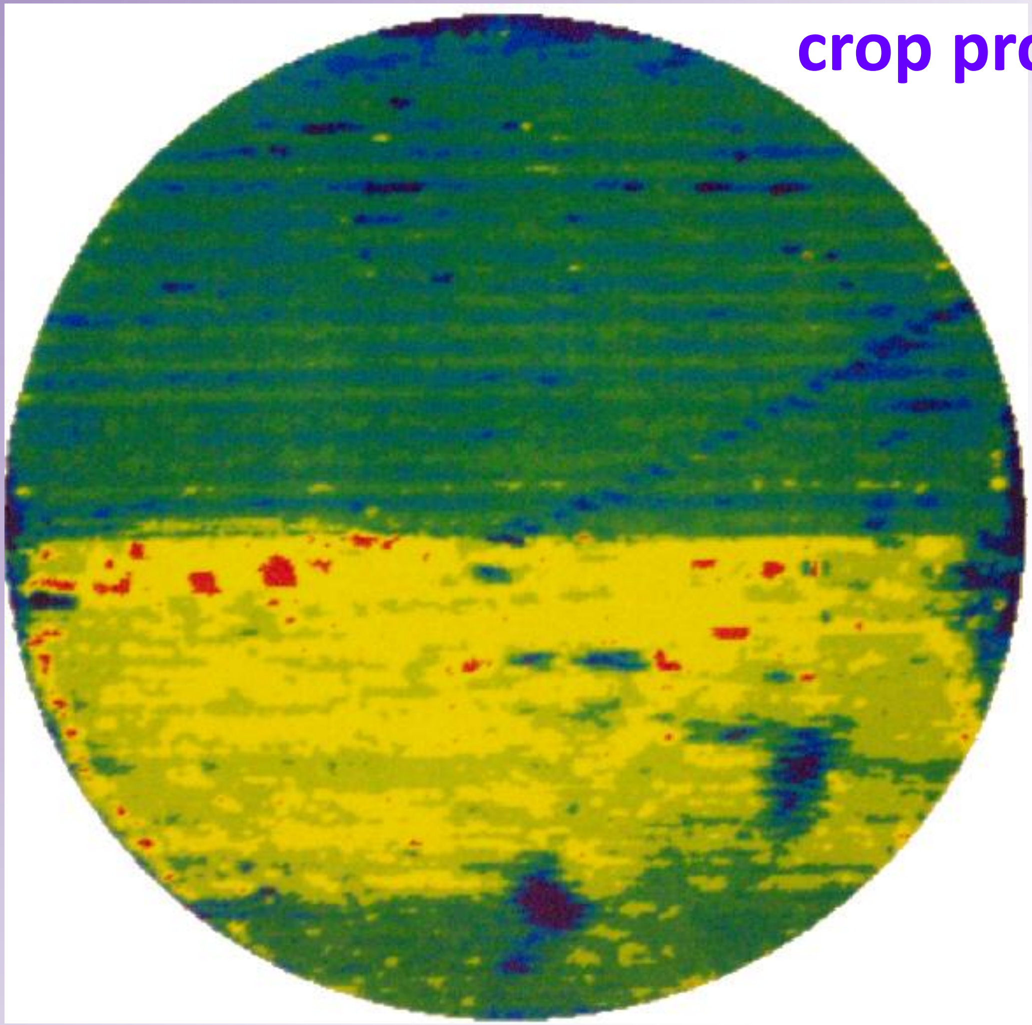
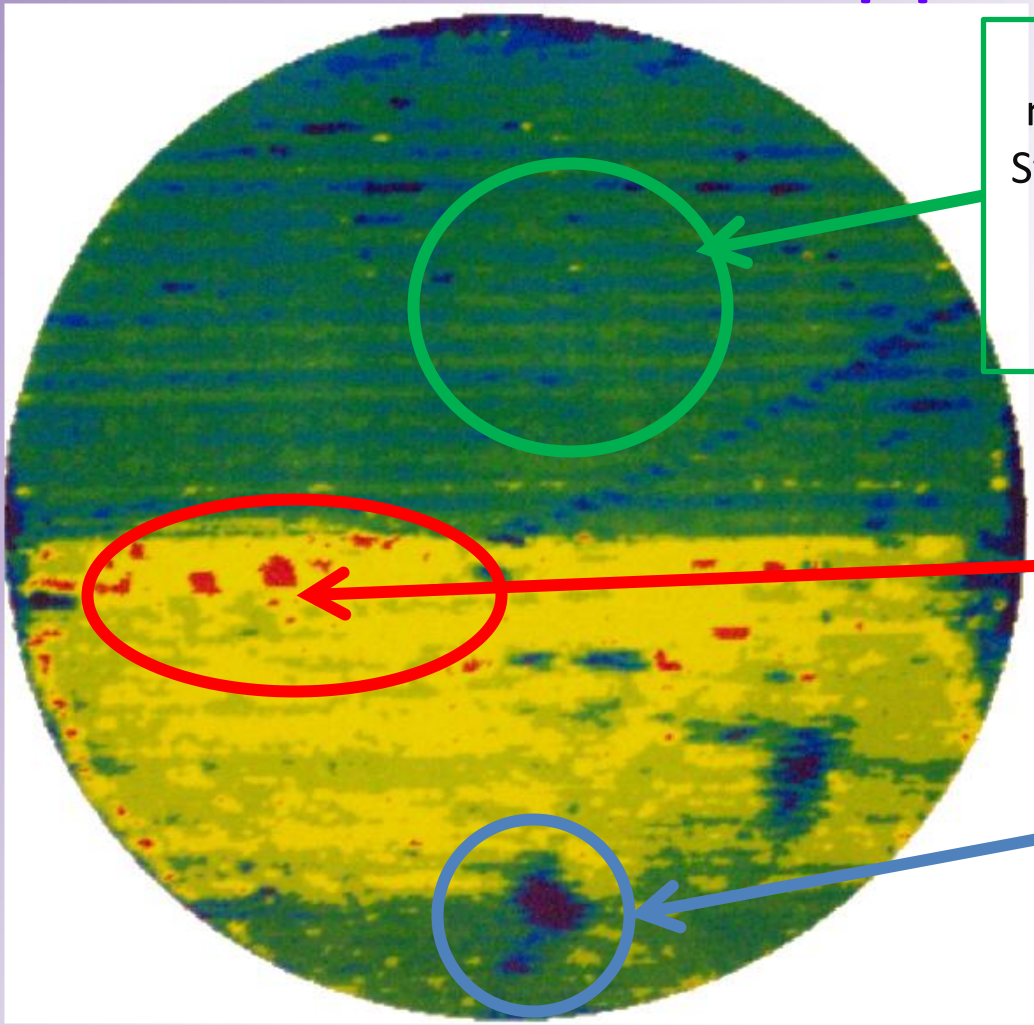


(Stone et al., 2006).

Example from a yield map to illustrate the importance of understanding all aspects of crop production



Example from a yield map to illustrate the importance of understanding all aspects of crop production



Area planted late due to multiple days of rain delay. Striping effect due to change of corn in one planter to adjust for late planting but not changed in other.

Red and yellow area of high production, this area was planted at targeted time

Blue area areas of no production

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For years, K-State has had good extension publications explaining how ET reports are used for irrigation scheduling.

K-STATE Kansas State University

IRRIGATION MANAGEMENT SERIES

Using Evapotranspiration Reports for Center Pivot Irrigation Scheduling

Danny H. Rogers
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Extension Irrigation Specialist

Kansas State University Agricultural Experiment Station and Cooperative Extension Service Manhattan, Kansas

Improving production efficiency should be a goal of anyone producing a market item. The irrigation farm manager is no exception. Any new technique or information should be critically investigated and incorporated into the management decision-making process if it benefits the overall program. The use of crop evapotranspiration reports should benefit irrigation farm managers by minimizing excess or deficit irrigation, minimizing leaching of crop chemicals, and providing a favorable soil water environment for crop growth and development.

What is Evapotranspiration

Evapotranspiration is the term coined to describe the consumptive water use of crops — the amount of water used by a growing crop (not the amount applied by an irrigation system). The word is the combination of two words, evaporation and transpiration, and is often referred to as ET. Any water, whether deposited by precipitation, dew, or irrigation, can be consumed by the crop to fulfill the ET requirement. K-State Research and Extension publication MF-2389 *What is ET?* provides additional information on the topic.

The amount of ET is influenced by climatological factors such as temperature, relative humidity, wind, and solar radiation. In addition, crop conditions such as stage of growth and plant health will affect the amount of ET that occurs. Procedures to calculate ET based on weather and crop data have been developed for many Kansas crops and are available for use.

ET information generated by climatological factors gathered at a weather station is generally referred to as reference ET or ETr. ETr values must be customized or modified by factors, called crop coefficients, to properly estimate crop ET or water use of a specific crop for its particular growth stage. This modified ET value is referred to as either actual ET or crop ET or ETc.

ETr values are generated at a number of weather stations across Kansas. Some network of stations are operated and maintained by local Groundwater Management Districts, and ETr data can be accessed by telephone. The Weather Data Library at K-State Research and Extension operates or has access to a number of weather stations throughout Kansas. While the data from some of these stations can be accessed locally, all can be accessed via the Web at *www.oznet.ksu.edu/wdl.*

How to use ET Information

Irrigation scheduling using ET information is like a checkbook accounting procedure. ET is the amount of crop water withdrawal that must be balanced against water deposits of rainfall and irrigation. The water balance must be kept within the limits of crop stress as determined by the field condition, irrigation capacity, and crop type. Through the scheduling procedure, the amount of water application required and the time of application can be determined.

Even irrigation systems with capacities that limit the irrigator's management flexibility can use ET information to benefit water management. The benefit can come from helping to determine when to start and end irrigation. This benefit generally translates into increased economic return, possibly through a lower fuel bill as a result of reduced overwatering, or as increased yield due to fewer periods of crop water stress.

Irrigation scheduling can be accomplished using the following methodology and charts. The ETr information is assumed available via a weather station. The process of irrigation scheduling is then largely a series of simple additions and subtractions that calculate a soil water balance for a given site in a field. While the math is simple, the number of repetitions required for a field throughout a growing season can become tedious. The scheduling process however, lends itself well to computerization. Irrigation scheduling using ET data is the essence of KanSched, an ET based irrigation scheduling software package available through Mobile Irrigation Lab (MIL) project of K-State Research and Extension. Contact your local K-State Research and Extension office, or check out *www.oznet.ksu.edu/mil* for

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ET based irrigation scheduling irrigation for many crops in research at Colby for nearly 35 years.

Originally, the water budgets were tabulated by hand. This single study from 1982 required 18 pages to manage 6 treatments.

CROP CORN

EMERGENCE MAY 15, 1982

ET FACTOR 1.0

DAY	DATE	PET	K_c	AET	Rain	Irr.	Σ ET	Σ ET SINCE RECHARGE	DEPLETION	GD
1	MAY 15	.198	.2	.040			.04	.04	.04	
2	16	.117	.2	.023			.063	.063	.063	
3	17	.120	.2	.024			.087	.087	.087	
4	18	.165	.2	.033			.120	.120	.120	
5	19	.248	.2	.050			.170	.170	.170	
6	20	.230	.2	.046			.216	.216	.216	
7	21	.233	.2	.047			.263	.263	.263	
8	22	.122	.2	.024			.287	.287	.287	
9	23	.122	.2	.024			.311	.311	.311	
10	24	.084	.2	.017	.58		.328 *		.00	
11	25	.123	.21	.026	.45		.354 *		.00	
12	26	.123	.21	.026			.380	.026	.026	
13	27	.214	.22	.047	.36		.427 *		.000	
14	28	.088	.23	.020	.89		.447 *		.000	
15	29	.105	.23	.024	.78		.471 *		.000	
16	30	.138	.24	.033	.10		.504 *		.000	
17	31	.141	.25	.035			.539	.035	.035	
18	JUNE 1	.110	.26	.029	.44		.568 *		.00	
19	2	.045	.27	.012	.04		.580 *		.00	
20	3	.044	.28	.012	.05		.592	.012	.012	
21	4	.080	.29	.023			.615	.035	.035	
22	5	.163	.30	.049			.664	.084	.084	
23	6	.173	.31	.054			.718	.138	.138	
24	7	.165	.33	.055			.773	.193	.193	
25	8	.226	.34	.077			.850	.270	.270	
26	9	.168	.35	.059			.909	.329	.329	
27	10	.200	.37	.074	.17		.983	.403	.233	
28	11	.086	.38	.033	.11		1.016	.436	.156	
29	12	.158	.40	.063	.47		1.079 *		.00	
30	13	.165	.41	.068			1.147	.068	068	
31	14	.175	.43	.075	.04		1.222	.143	.103	
32	15	.087	.44	.038	.28		1.260 *		.00	
33	16	.160	.46	.074			1.334	.074	.074	
34	17	.095	.47	.045	.34		1.379 *		.00	
35	18	.075	.49	.037	.04		1.416 *		.00	
36	19	.152	.51	.078			1.494	.078	.078	
37	20	.159	.52	.083			1.577	.161	.161	
38	21	.214	.54	.116	.14		1.693	.277	137	
39	22	.164	.56	.092			1.785	.369	.229	
40	23	.158	.57	.090			1.875	.459	.319	
41	24	.115	.59	.068			1.943	.527	.387	
42	25	.121	.61	.074	1.87		2.017 *		00	
43	26	.124	.62	.077	.13		2.094 *		00	
44	27	.131	.64	.084			2.178	.084	.084	
	28	.186	.66	.123			2.301	.207	.207	

Weather-based irrigation schedule for corn from 1982, F.R. Lamm, Colby Kansas

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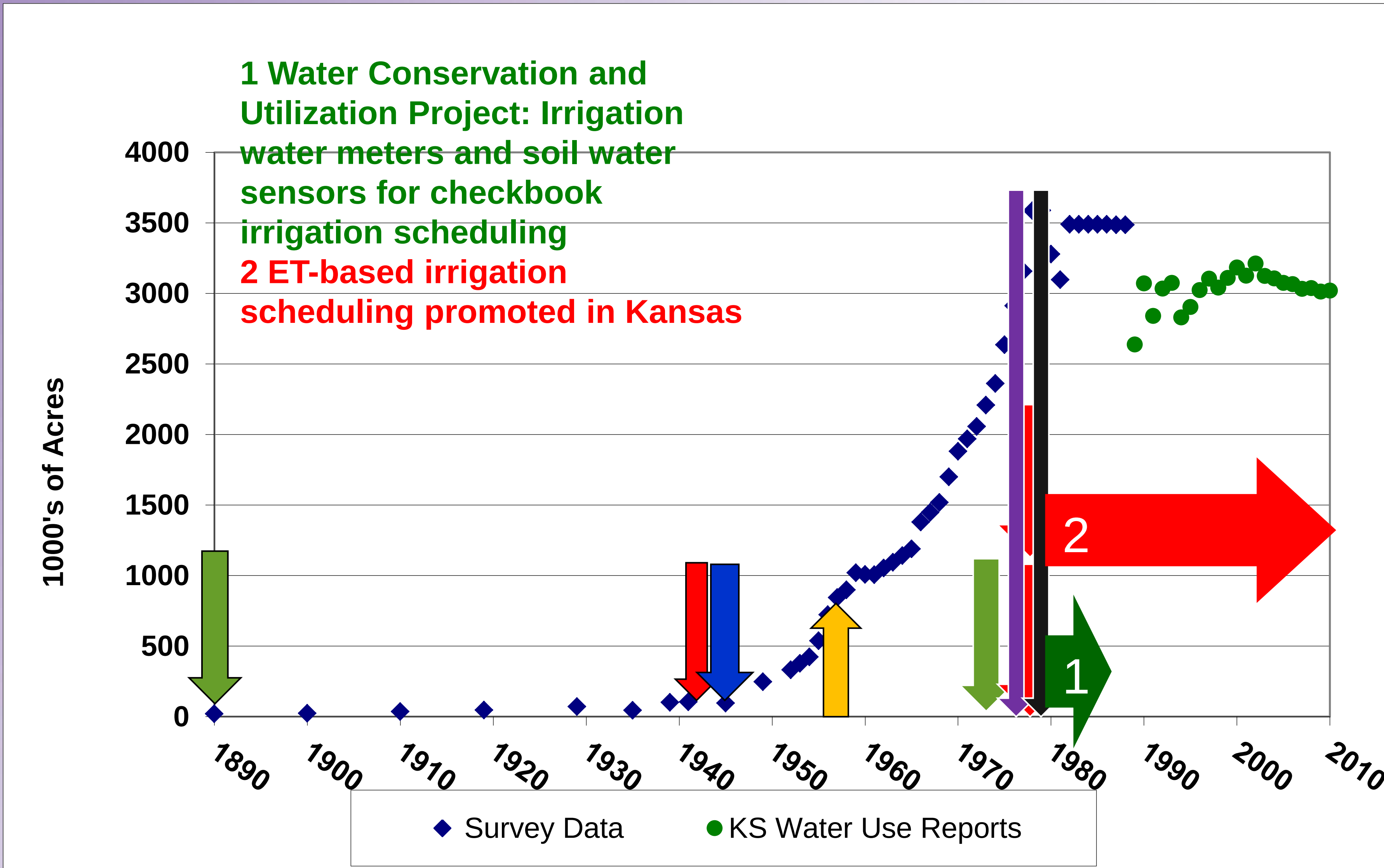
Kansas irrigation development: 1890 -2015



Knowledge for Life

Today with computers, my (Lamm's) irrigation scheduling essentially follows the same routine. Each irrigation treatment has its own irrigation schedule.

In 2013, we managed 10 studies that required a grand total of 51 different weather-based irrigation schedules.

Corn Hybrid x Irrigation Study, 2013

CORN

							Full Season 100% ET Trt 1		Pre-Anthesis Period 50% ET Trt 2		Pre-Anthesis Period 75% ET Trt 3		Post-Anthesis Period 50% ET Trt 4		Post-Anthesis Period 75% ET Trt5				
	Mon.	Day	Kc	ETr	AET	Rain	Irr	Dep	Irr	Dep	Irr	Dep	Irr	Dep	Irr	Dep	DOY	CumET	CumRain
1	MAY	18	0.20	0.30	0.06	0.00		0.06		0.03		0.04		0.06		0.06	138	0.06	0.00
2	MAY	19	0.20	0.27	0.05	0.00		0.11		0.06		0.08		0.11		0.11	139	0.11	0.00
3	MAY	20	0.20	0.37	0.07	0.00		0.19		0.09		0.14		0.19		0.19	140	0.19	0.00
4	MAY	21	0.20	0.28	0.06	0.00		0.24		0.12		0.18		0.24		0.24	141	0.24	0.00
5	MAY	22	0.20	0.29	0.06	0.02		0.28		0.13		0.21		0.28		0.28	142	0.30	0.02
6	MAY	23	0.20	0.23	0.05	0.00		0.33		0.15		0.24		0.33		0.33	143	0.35	0.02
7	MAY	24	0.20	0.34	0.07	0.00		0.40		0.19		0.29		0.40		0.40	144	0.42	0.02
8	MAY	25	0.20	0.41	0.08	0.00		0.48		0.23		0.35		0.48		0.48	145	0.50	0.02
9	MAY	26	0.20	0.35	0.07	0.00		0.55		0.26		0.41		0.55		0.55	146	0.57	0.02
10	MAY	27	0.20	0.24	0.05	0.00		0.60		0.29		0.44		0.60		0.60	147	0.62	0.02
11	MAY	28	0.21	0.31	0.06	0.00		0.66		0.32		0.49		0.66		0.66	148	0.68	0.02
12	MAY	29	0.21	0.32	0.07	0.78		0.00		0.00		0.00		0.00		0.00	149	0.75	0.80
13	MAY	30	0.22	0.21	0.05	0.08		0.00		0.00		0.00		0.00		0.00	150	0.79	0.88
14	MAY	31	0.23	0.38	0.09	0.00		0.09		0.04		0.07		0.09		0.09	151	0.88	0.88
15	JUN	1	0.23	0.24	0.06	0.00		0.14		0.07		0.11		0.14		0.14	152	0.94	0.88
16	JUN	2	0.24	0.35	0.08	0.00		0.23		0.11		0.17		0.23		0.23	153	1.02	0.88
17	JUN	3	0.25	0.43	0.11	0.04		0.30		0.13		0.21		0.30		0.30	154	1.13	0.92
18	JUN	4	0.26	0.20	0.05	0.53		0.00		0.00		0.00		0.00		0.00	155	1.18	1.45
19	JUN	5	0.27	0.10	0.03	0.08		0.00		0.00		0.00		0.00		0.00	156	1.21	1.53
20	JUN	6	0.28	0.22	0.06	0.00		0.06		0.03		0.05		0.06		0.06	157	1.27	1.53
21	JUN	7	0.29	0.30	0.09	0.57		0.00		0.00		0.00		0.00		0.00	158	1.36	2.10
22	JUN	8	0.30	0.18	0.05	0.02		0.03		0.01		0.02		0.03		0.03	159	1.41	2.12
23	JUN	9	0.31	0.34	0.11	0.00		0.14		0.06		0.10		0.14		0.14	160	1.52	2.12
24	JUN	10	0.33	0.45	0.15	0.00		0.29		0.13		0.21		0.29		0.29	161	1.67	2.12
25	JUN	11	0.34	0.45	0.15	0.00		0.44		0.21		0.33		0.44		0.44	162	1.82	2.12
26	JUN	12	0.35	0.39	0.14	0.00		0.58		0.28		0.43		0.58		0.58	163	1.96	2.12
27	JUN	13	0.37	0.35	0.13	0.00		0.71		0.34		0.52		0.71		0.71	164	2.08	2.12
28	JUN	14	0.38	0.32	0.12	0.05		0.78		0.35		0.57		0.78		0.78	165	2.21	2.17
29	JUN	15	0.40	0.27	0.11	0.06		0.83		0.35		0.59		0.83		0.83	166	2.31	2.23
30	JUN	16	0.41	0.28	0.11	0.81		0.13		0.00		0.00		0.13		0.13	167	2.43	3.04
31	JUN	17	0.43	0.24	0.10	0.00		0.23		0.05		0.08		0.23		0.23	168	2.53	3.04
32	JUN	18	0.44	0.30	0.13	0.17		0.19		0.00		0.00		0.19		0.19	169	2.66	3.21
33	JUN	19	0.46	0.35	0.16	0.00		0.35		0.08		0.13		0.35		0.35	170	2.82	3.21
34	JUN	20	0.47	0.37	0.17	0.00		0.53		0.17		0.26		0.53		0.53	171	3.00	3.21
35	JUN	21	0.49	0.58	0.28	0.00		0.81		0.31		0.47		0.81		0.81	172	3.28	3.21
36	JUN	22	0.51	0.39	0.20	0.00		1.01		0.41		0.62		1.01		1.01	173	3.48	3.21
37	JUN	23	0.52	0.32	0.16	0.00		1.17		0.49		0.74		1.17		1.17	174	3.64	3.21
38	JUN	24	0.54	0.46	0.25	0.00		1.42		0.61		0.93		1.42		1.42	175	3.89	3.21
39	JUN	25	0.56	0.35	0.19	0.00		1.61		0.71		1.07		1.61		1.61	176	4.08	3.21
40	JUN	26	0.57	0.36	0.20	0.00	0.96	0.86	0.96	0.00	0.96	0.26	0.96	0.86	0.96	0.86	177	4.29	3.21
41	JUN	27	0.59	0.38	0.22	0.00		1.08		0.11		0.43		1.08		1.08	178	4.51	3.21
42	JUN	28	0.61	0.32	0.20	0.00		1.28		0.21		0.58		1.28		1.28	179	4.71	3.21
43	JUN	29	0.62	0.29	0.18	0.00		1.46		0.30		0.72		1.46		1.46	180	4.89	3.21
44	JUN	30	0.64	0.24	0.16	0.00	0.96	0.66		0.38		0.83	0.96	0.66	0.96	0.66	181	5.04	3.21
45	JUL	1	0.66	0.26	0.17	0.00		0.83		0.46		0.96		0.83		0.83	182	5.21	3.21
46	JUL	2	0.67	0.28	0.19	0.00		1.01		0.56		1.10		1.01		1.01	183	5.40	3.21
47	JUL	3	0.69	0.41	0.28	0.00		1.29		0.70		1.31		1.29		1.29	184	5.68	3.21

Weather-based irrigation schedule for corn from 2013, F.R. Lamm, Colby Kansas

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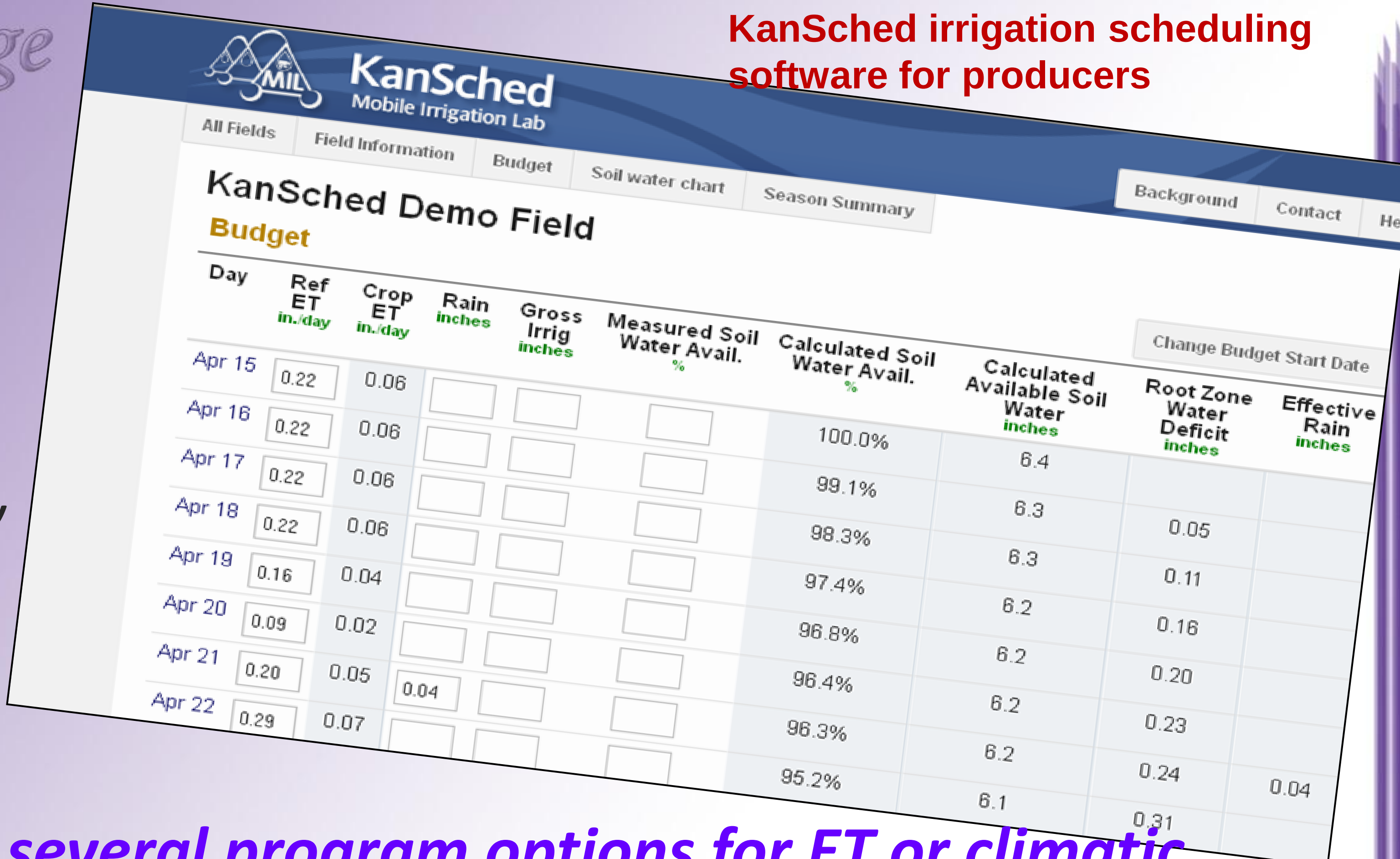
KanSched irrigation scheduling software for producers

As you can surmise, irrigation scheduling is easier to implement now than it was in 1982.



KanSched Demo Field

Budget

Day	Ref ET in./day	Crop ET in./day	Rain inches	Gross Irrig inches	Measured Soil Water Avail. %	Calculated Soil Water Avail. %	Calculated Available Soil Water inches	Root Zone Water Deficit inches	Effective Rain inches
Apr 15	0.22	0.06				100.0%	6.4		
Apr 16	0.22	0.06				99.1%	6.3	0.05	
Apr 17	0.22	0.06				98.3%	6.3	0.11	
Apr 18	0.22	0.06				97.4%	6.2	0.16	
Apr 19	0.16	0.04				96.8%	6.2	0.20	
Apr 20	0.09	0.02				96.4%	6.2	0.23	
Apr 21	0.20	0.05	0.04			96.3%	6.2	0.24	0.04
Apr 22	0.29	0.07				95.2%	6.1	0.31	

There are several program options for ET or climatic based irrigation scheduling. This is the budget page from the KSRE KanSched2 program. KanSched3 is the web based version that will lead to a smart phone application version.

Knowledge for Life

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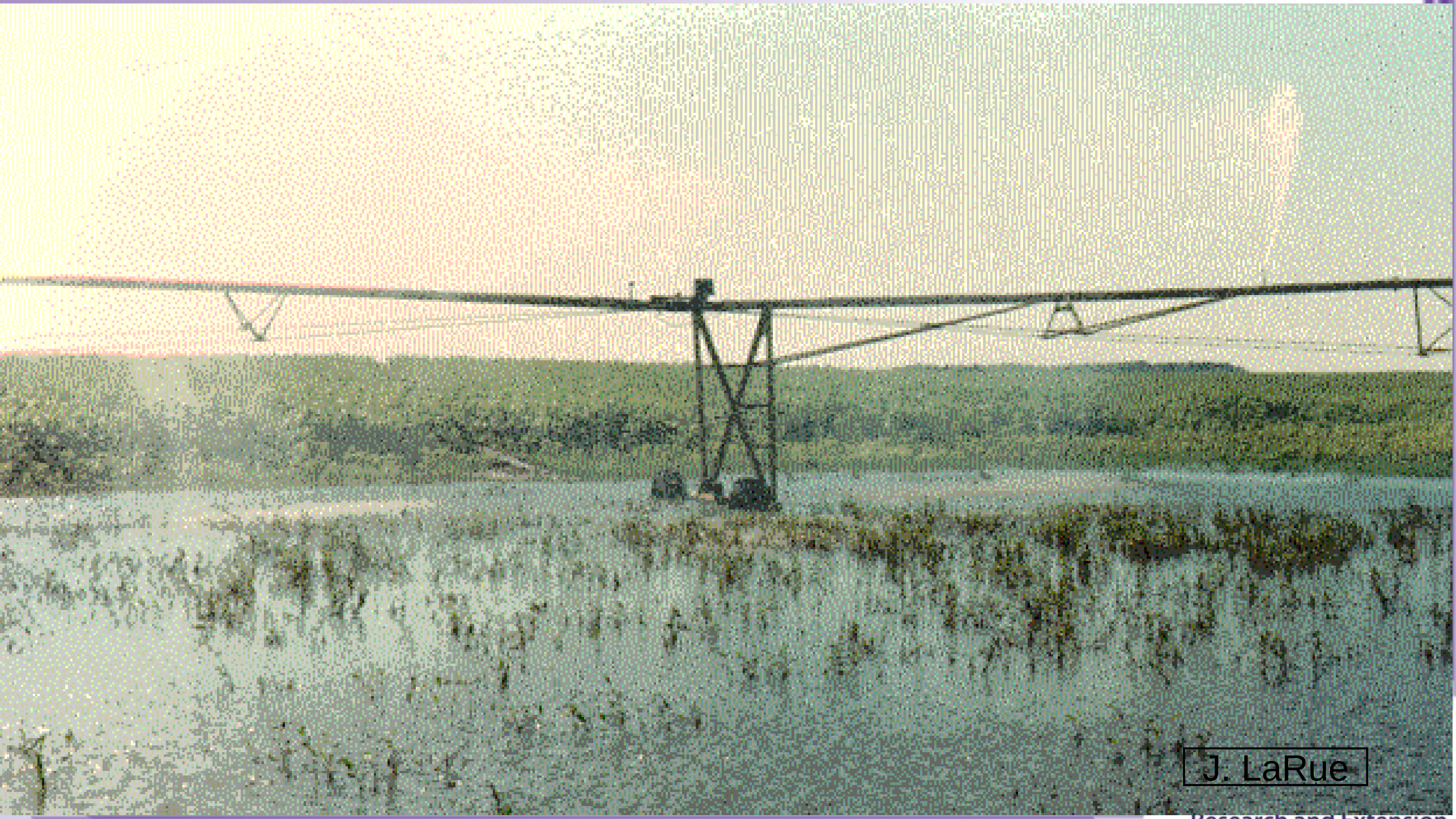
Knowledge for Life

Irrigation scheduling can help you prevent ….

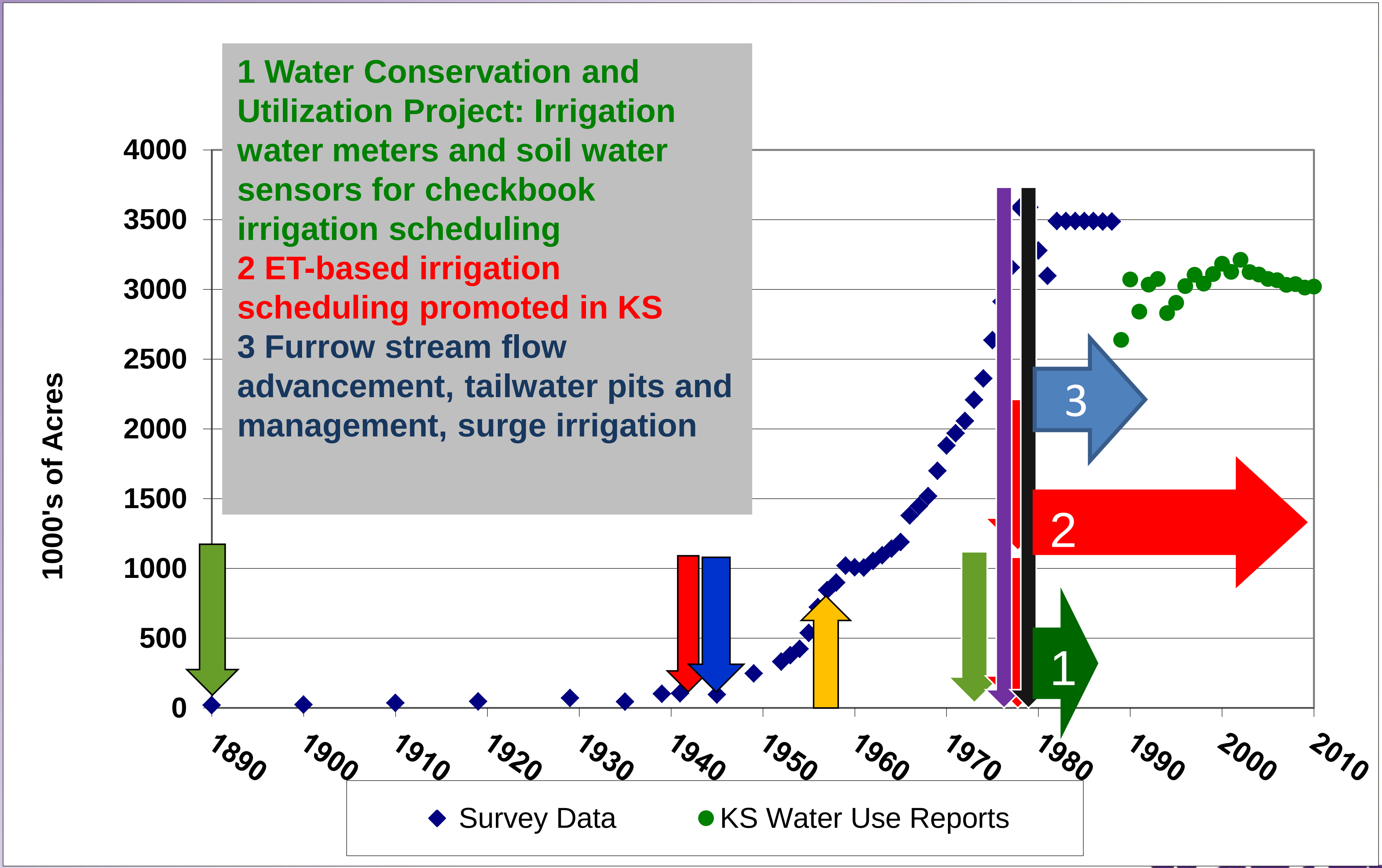
Over Irrigation



Under Irrigation

(not always possible to prevent under irrigation)

Kansas irrigation development: 1890 -2015



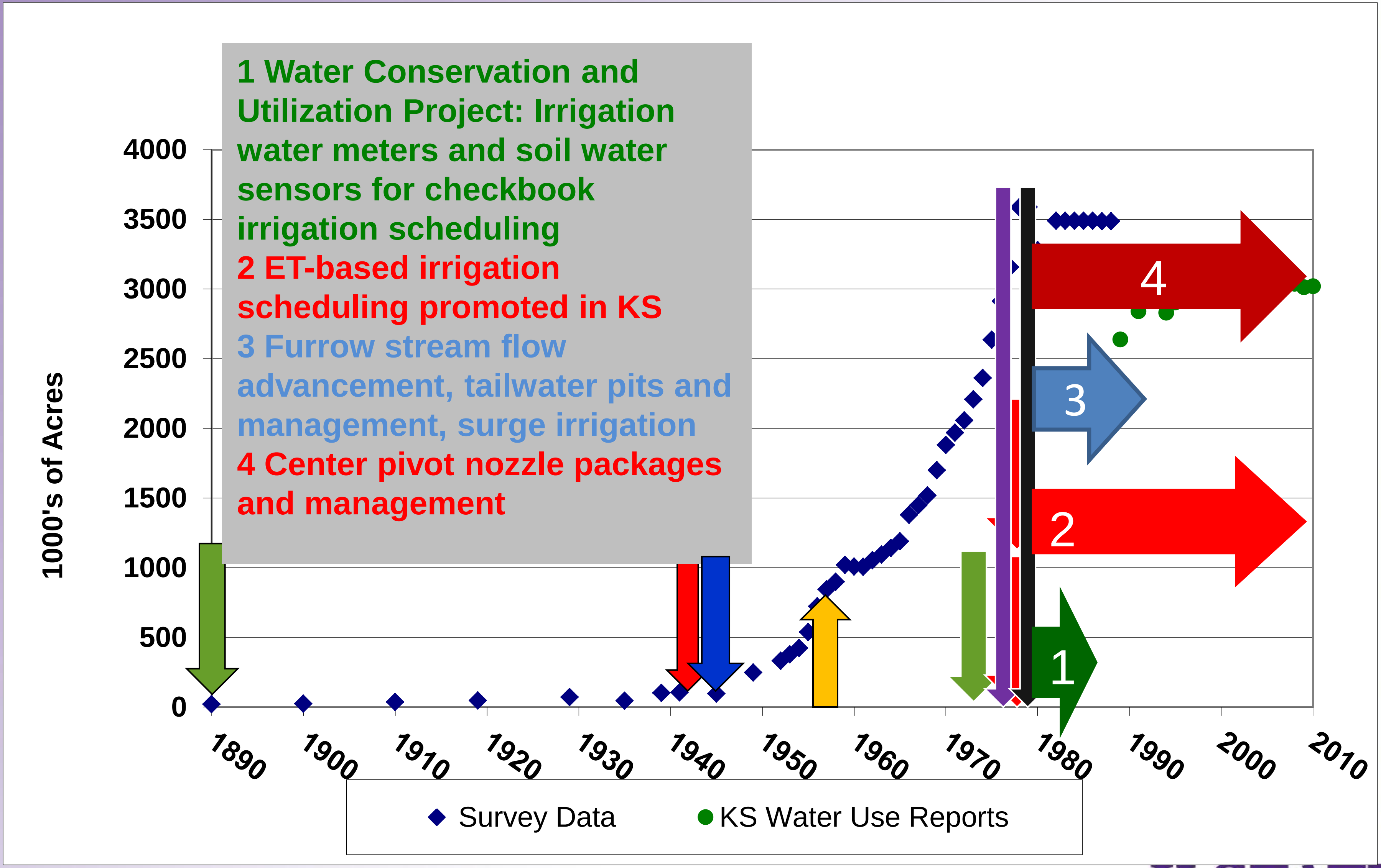
Knowledge for Life

Surface, Flood, or Gated Pipe Irrigation

Surge Irrigation

Tailwater Management

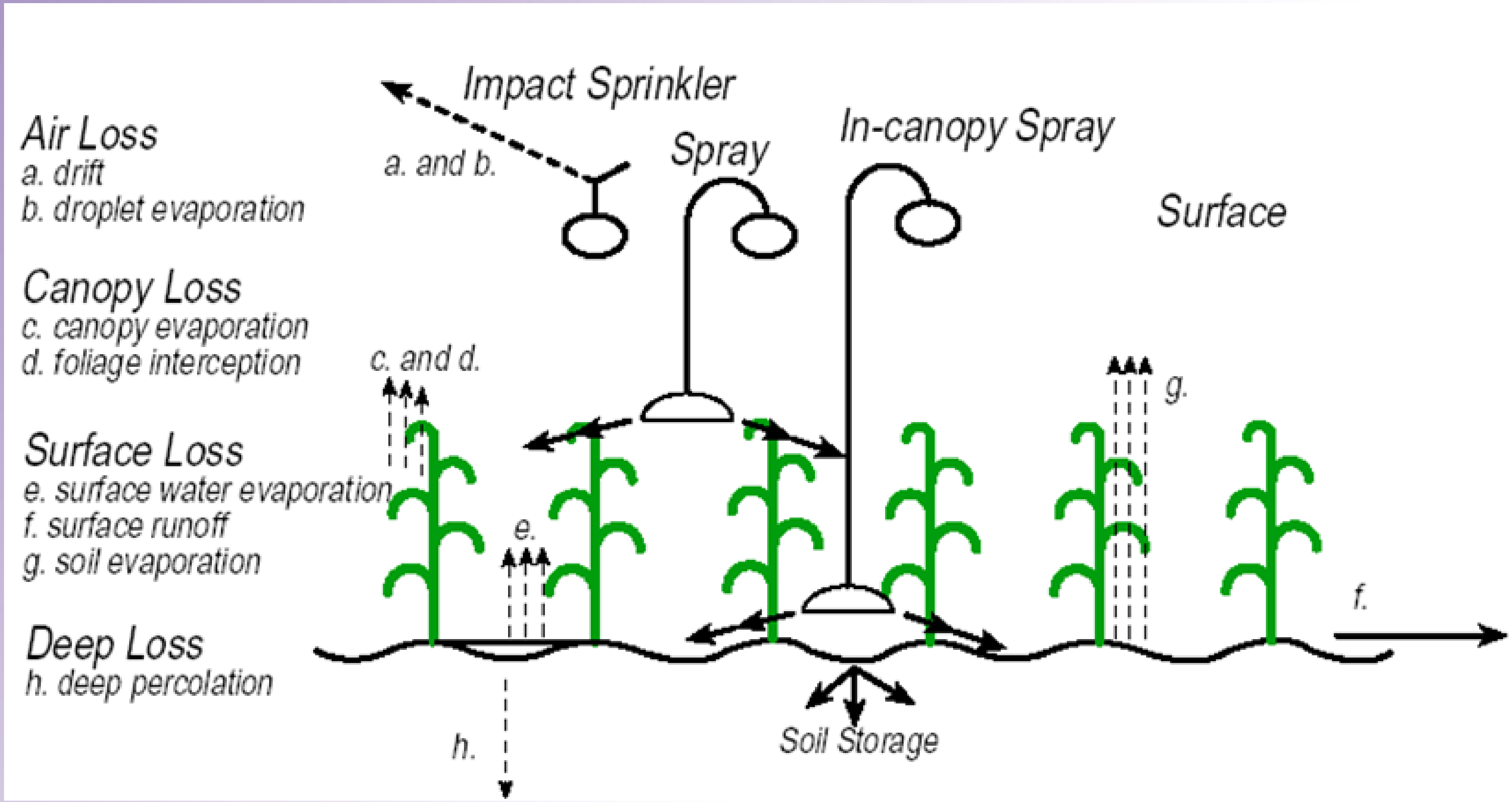
Kansas irrigation development: 1890 -2015



Center Pivot Irrigation Systems: Efficient and uniform application requires proper design and operation.

Center Pivot Irrigation Efficiency

Illustration of where irrigation water losses can occur for a center pivot nozzle package



Center Pivot Irrigation Efficiency

The nozzle package selection criteria should give runoff control the highest importance!

Knowledge for Life

Runoff from Center Pivots should be controlled first!

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Water Application Uniformity
Center Pivot Irrigated Corn,
South Central Kansas, 2002.

Suppressed growth due to a plugged nozzle.

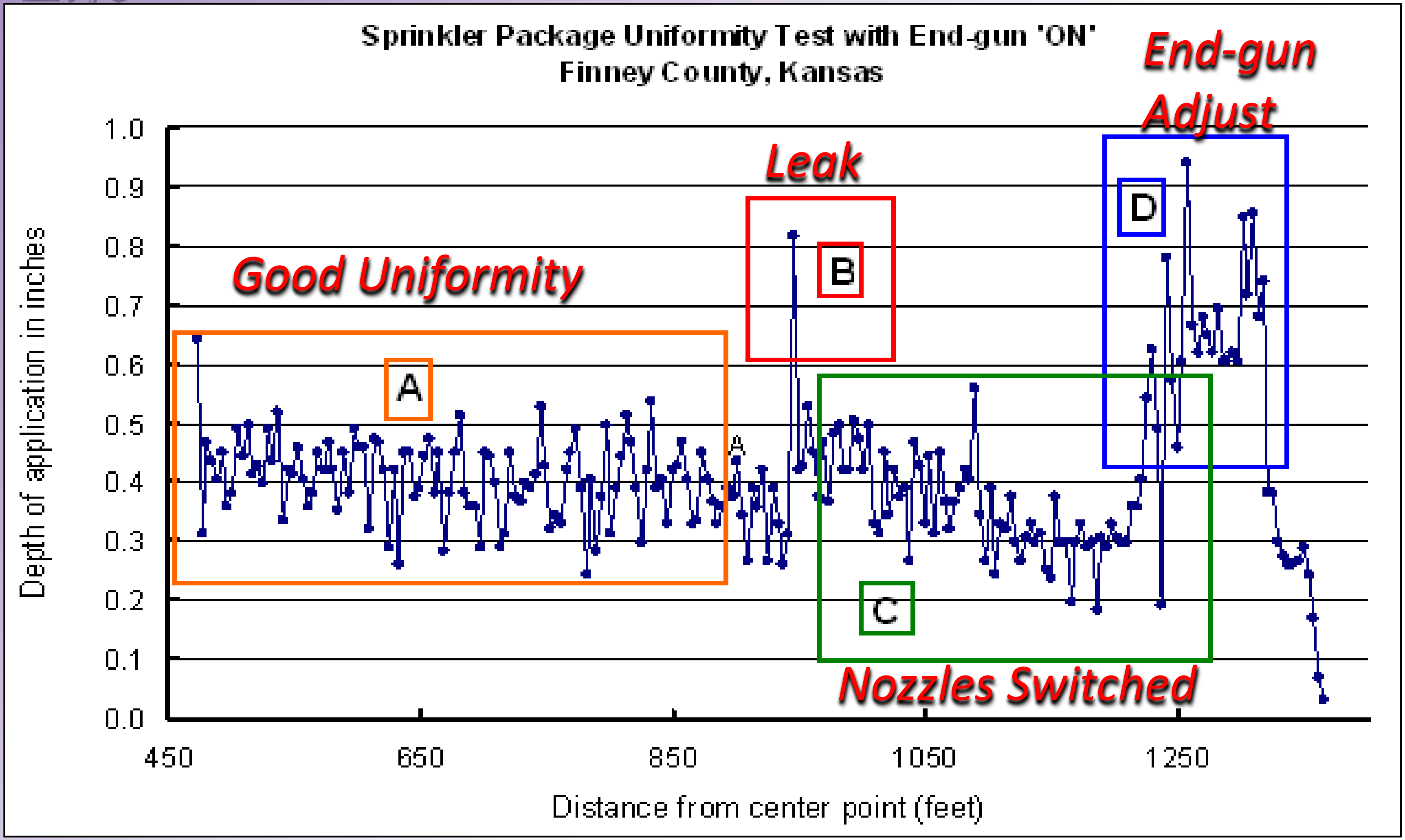
MIL IrriGages

- IrriGages non-evaporating in-field measuring devices.
- IrriGages are relatively easy to install.
- IrriGages can be left unattended in the field.
- IrriGages are durable and fairly light and easy to store.

Center Pivot Uniformity Testing

- Spacing set to less then nozzle spacing.
- Top of IrriGage above canopy and at least 3 ft below nozzle.
- Line of IrriGages set outside the beginning throw of the nozzles.

Example of Nozzling Problems with Pivots



Rogers et al. , 2009

If sprinklers are not properly installed / maintained high efficiency is not possible

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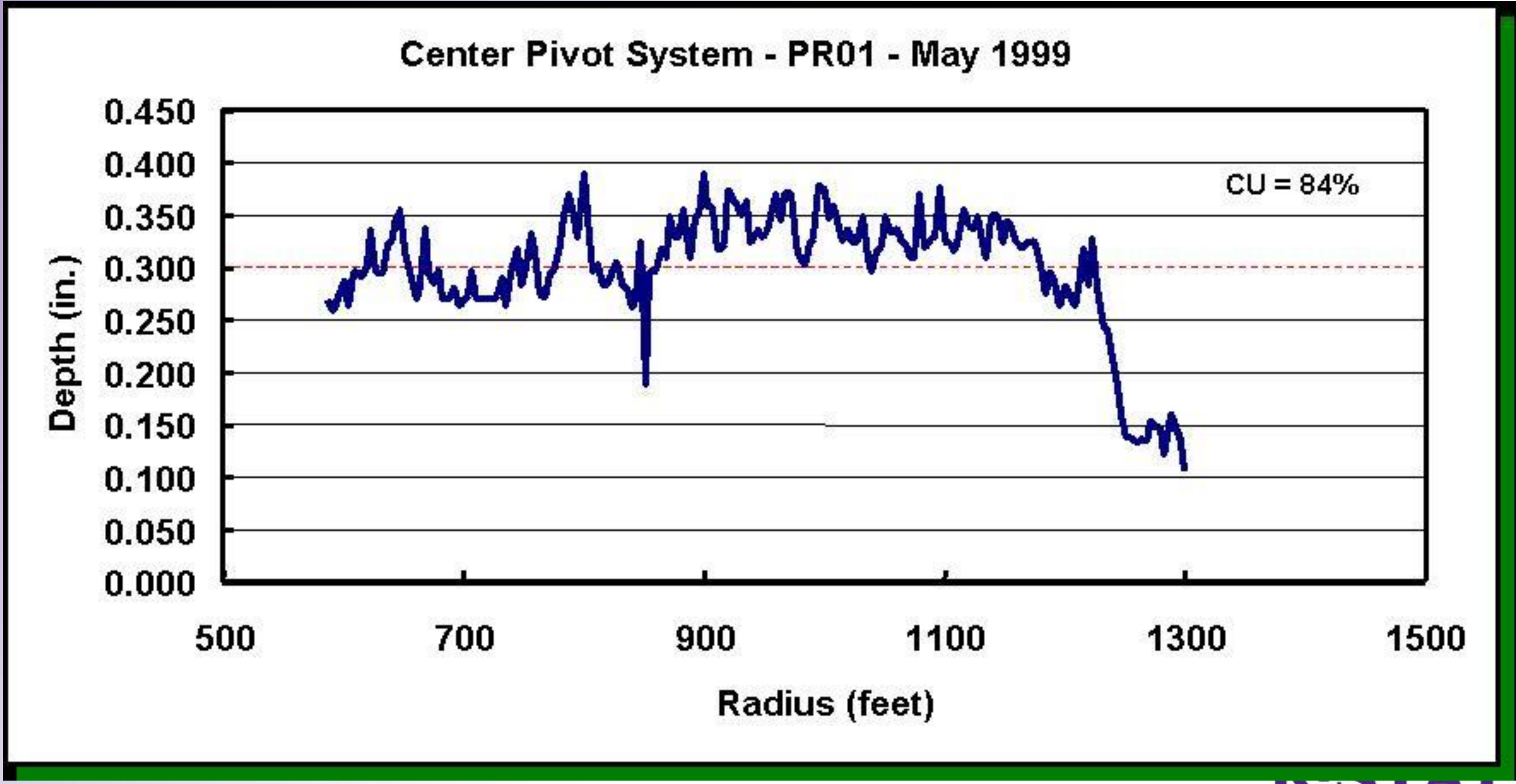
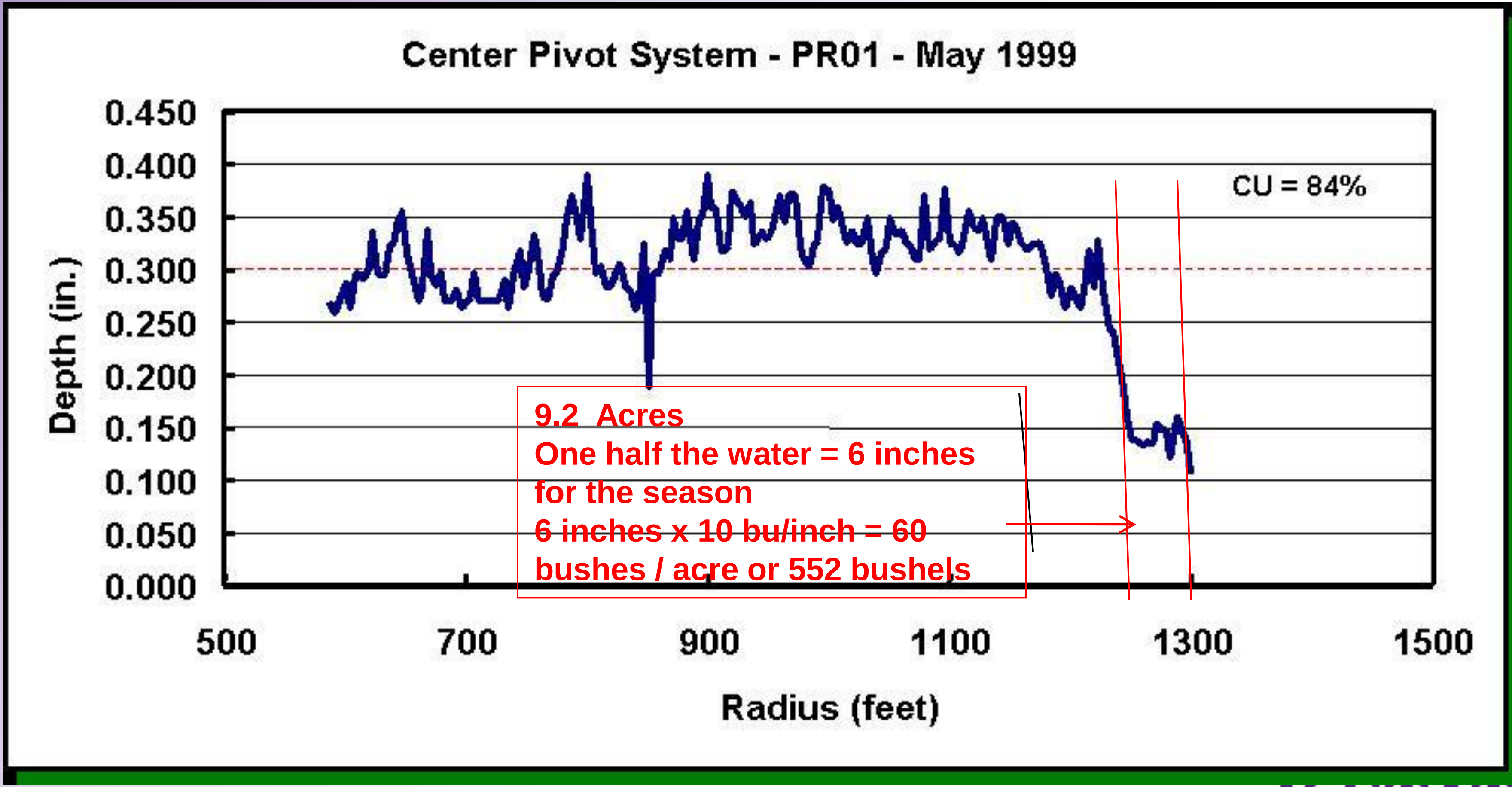
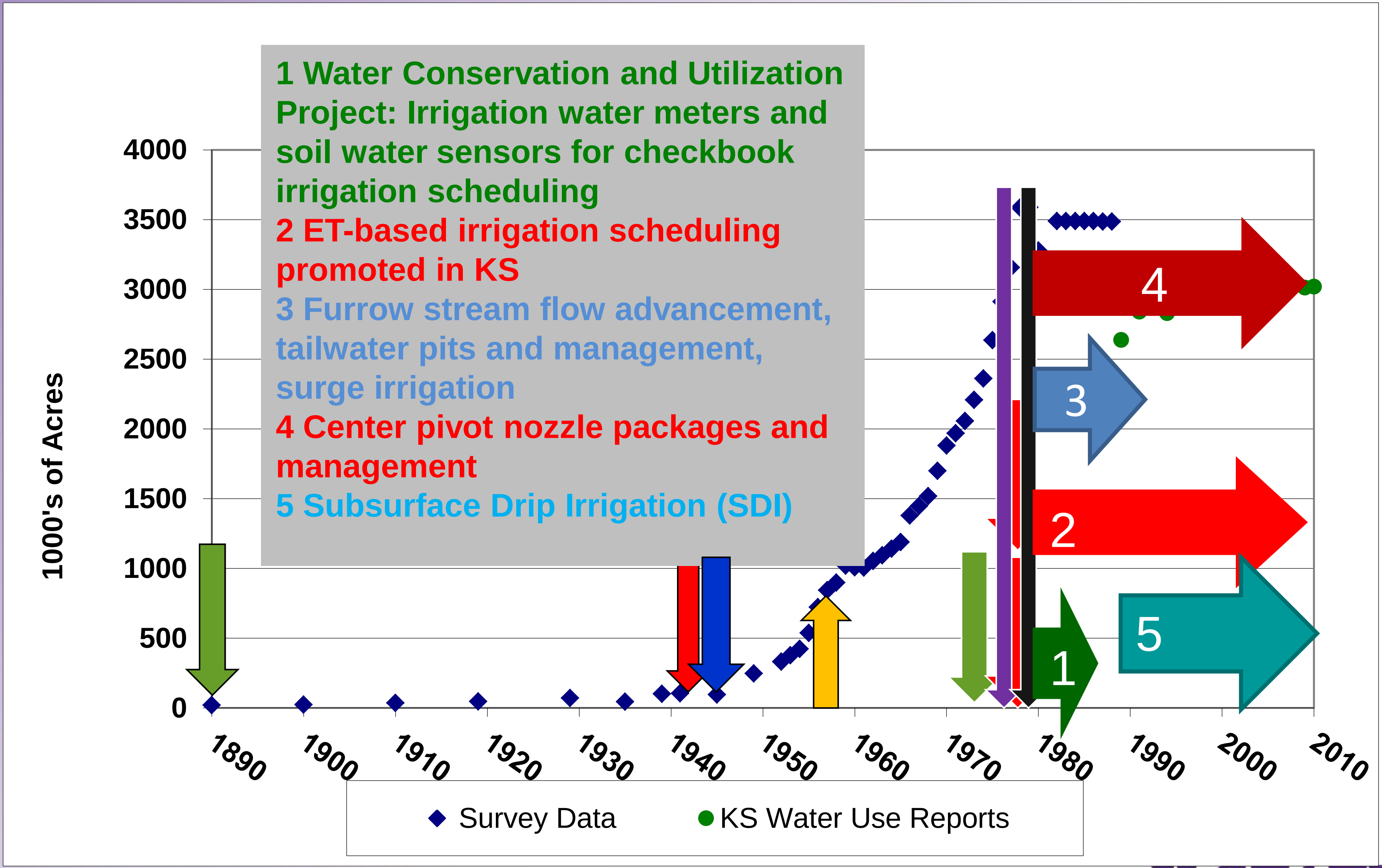
Center Pivot with un-installed drop nozzle and under sized orifices at outer edge.



Center Pivot with un-installed nozzle and under sized orifices at outer edge.



Kansas irrigation development: 1890 -2015



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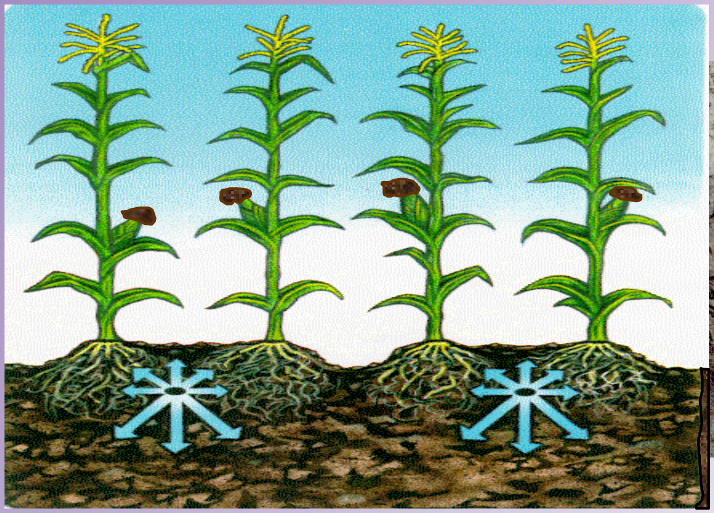
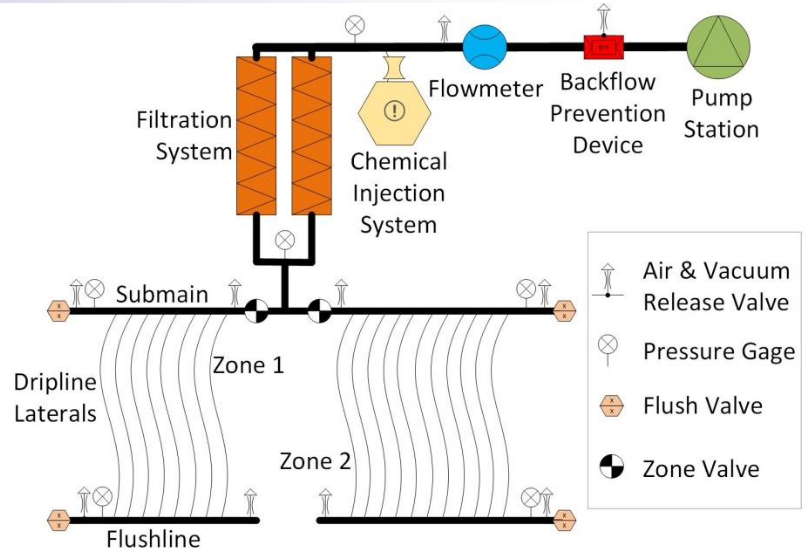
Subsurface Drip Irrigation - SDI





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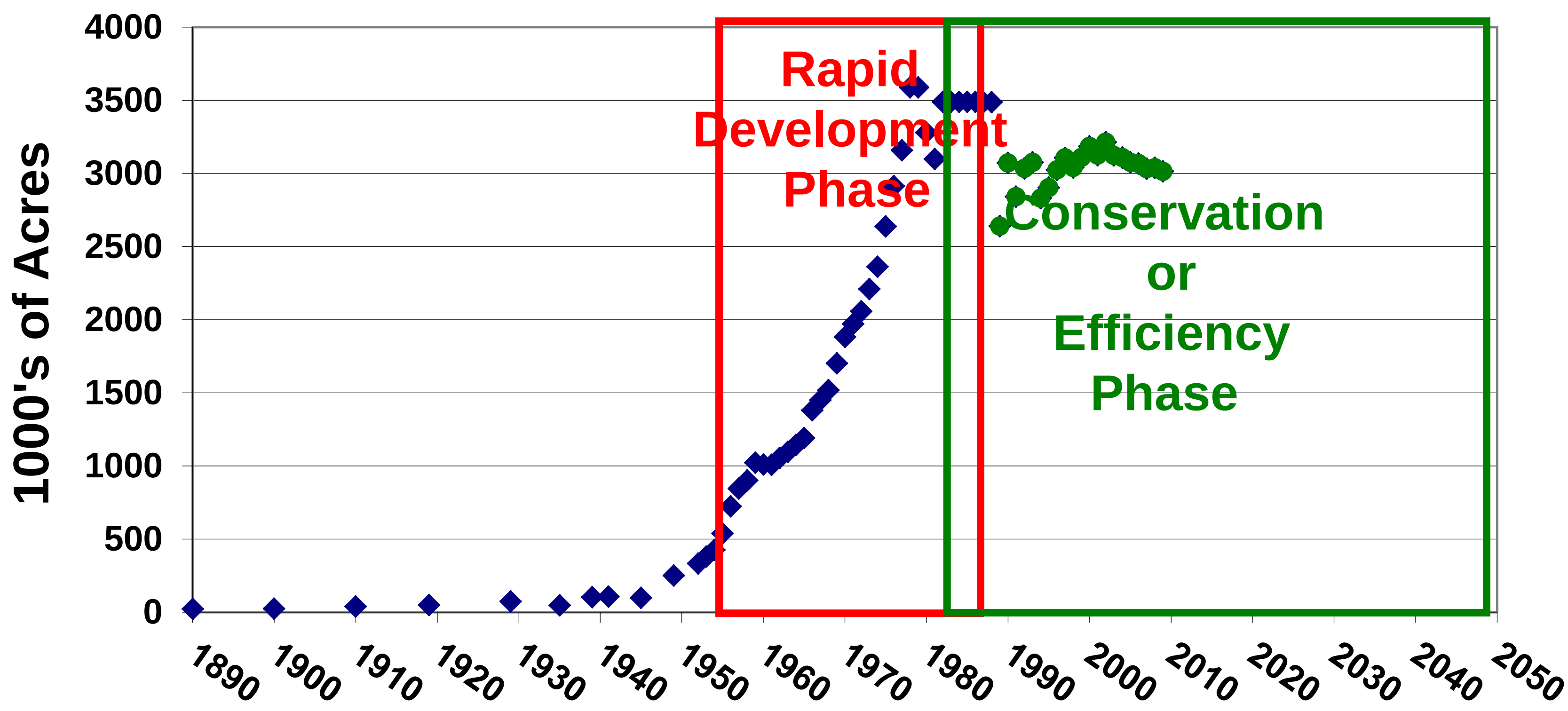
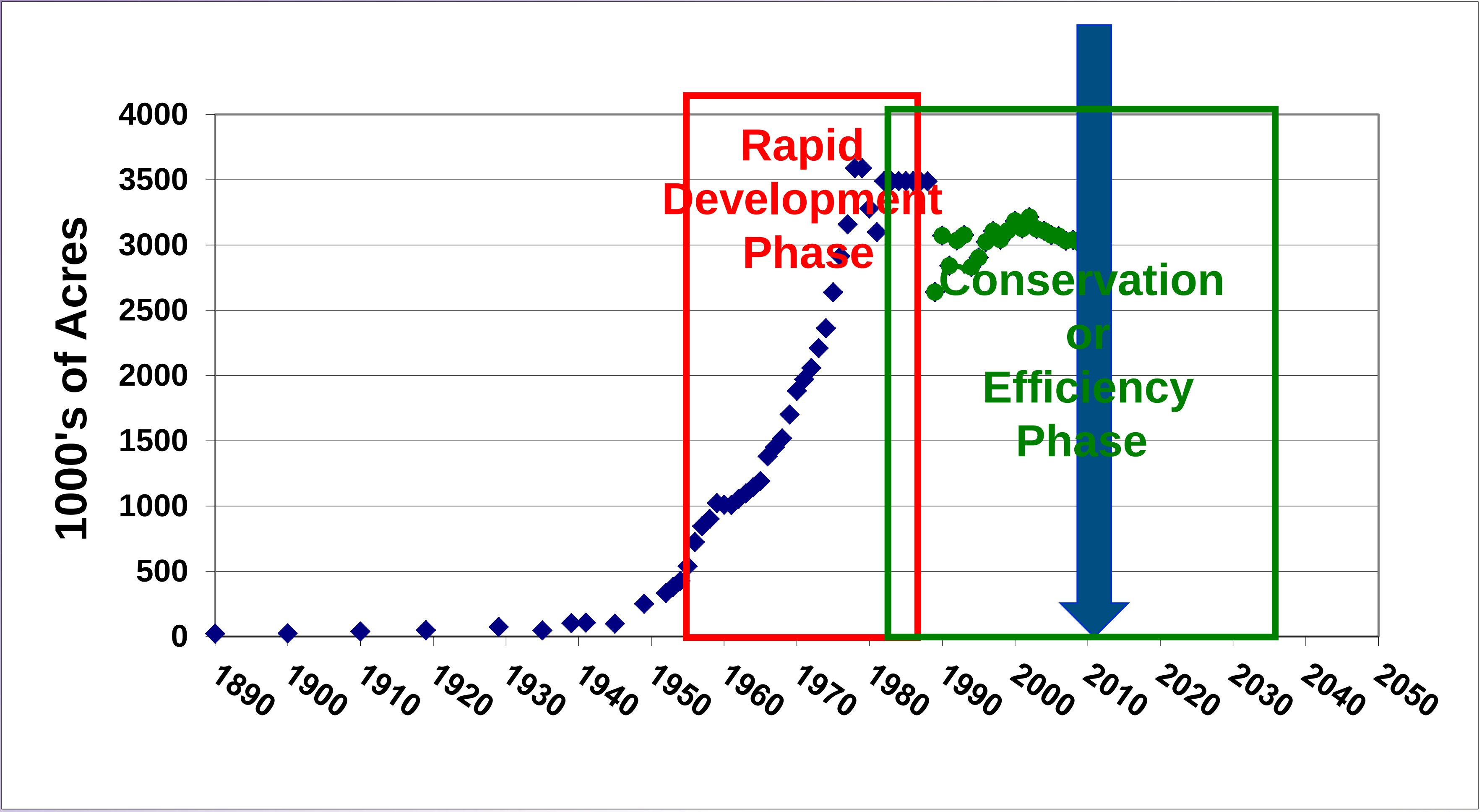
Kansas Irrigation Development: What next?



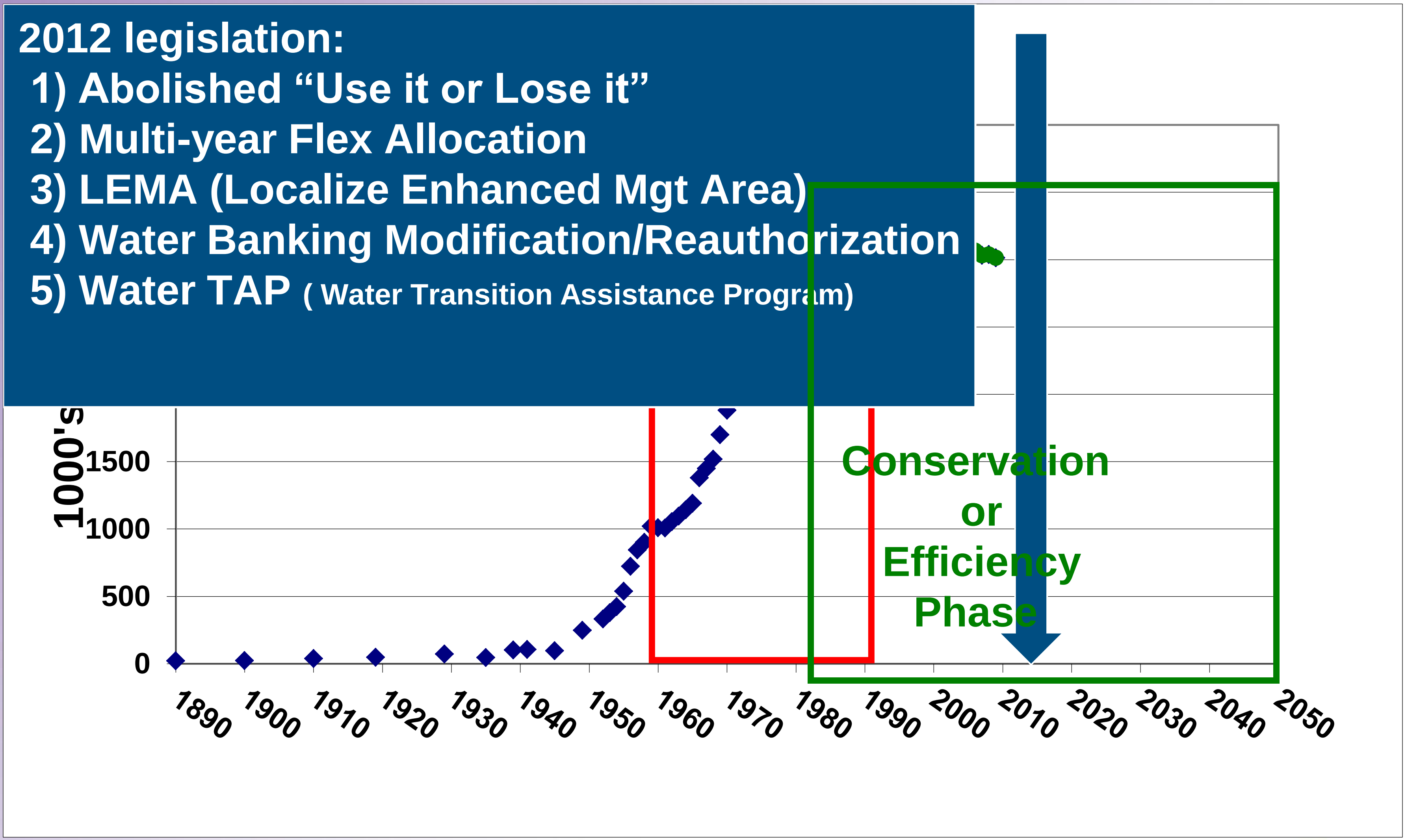
Kansas Irrigation Development: since 1890



Kansas Irrigation Development: since 1890

2012 legislation:

1) Abolished "Use it or Lose it"
2) Multi-year Flex Allocation
3) LEMA (Localize Enhanced Mgt Area)
4) Water Banking Modification/Reauthorization
5) Water TAP (Water Transition Assistance Program)



Knowledge for Life

Kansas Irrigation Development: since 1890

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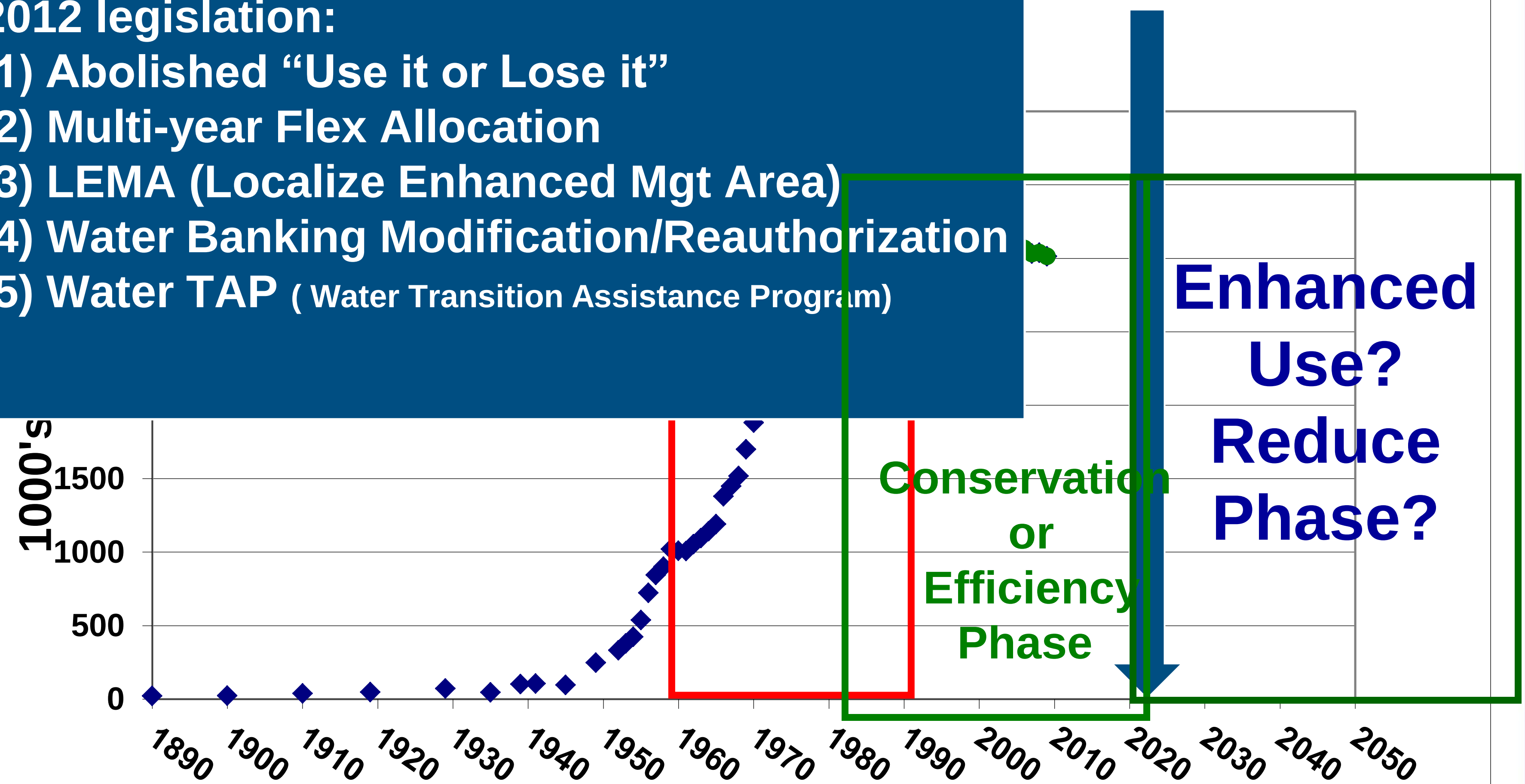

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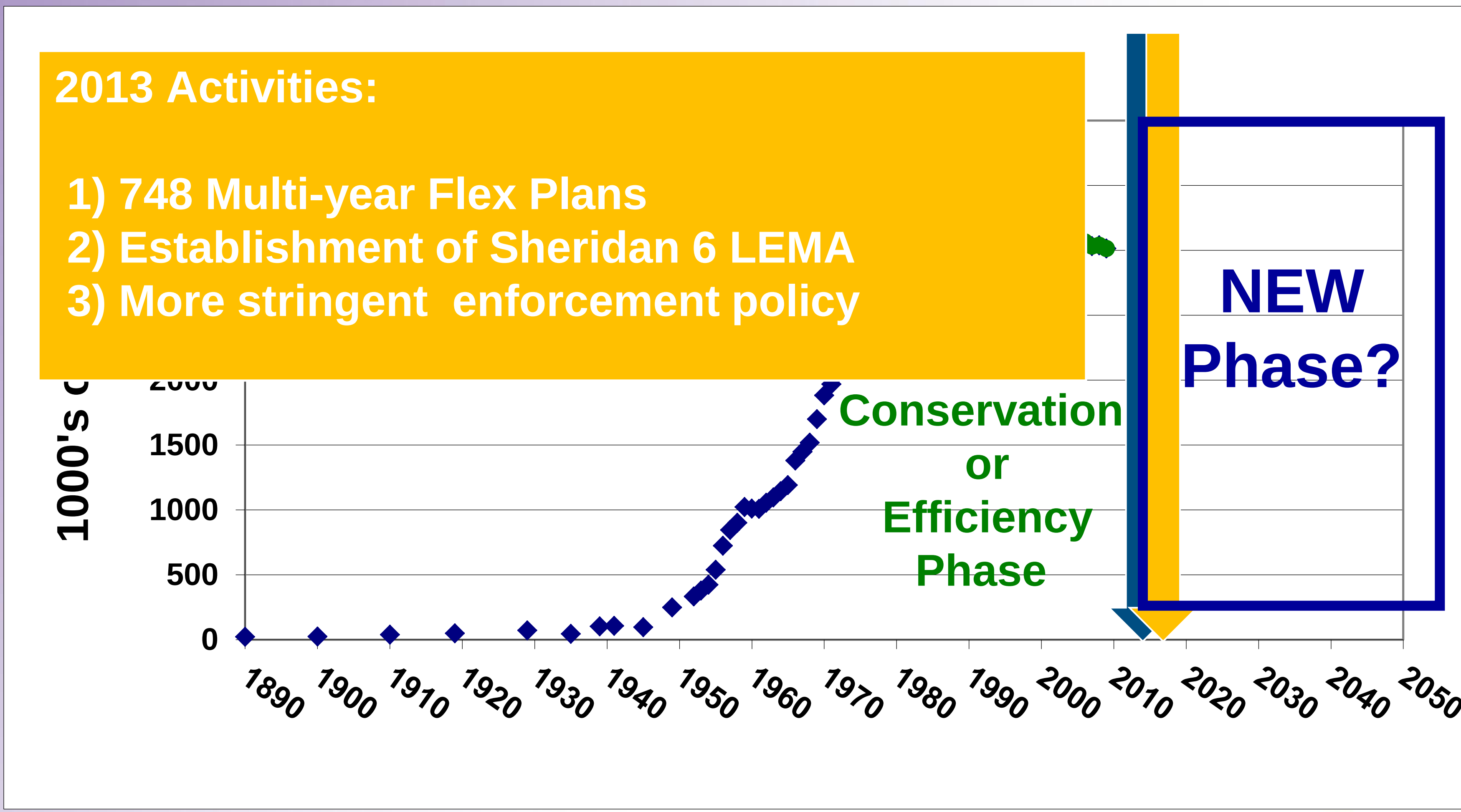
Knowledge for Life

Kansas Irrigation Development



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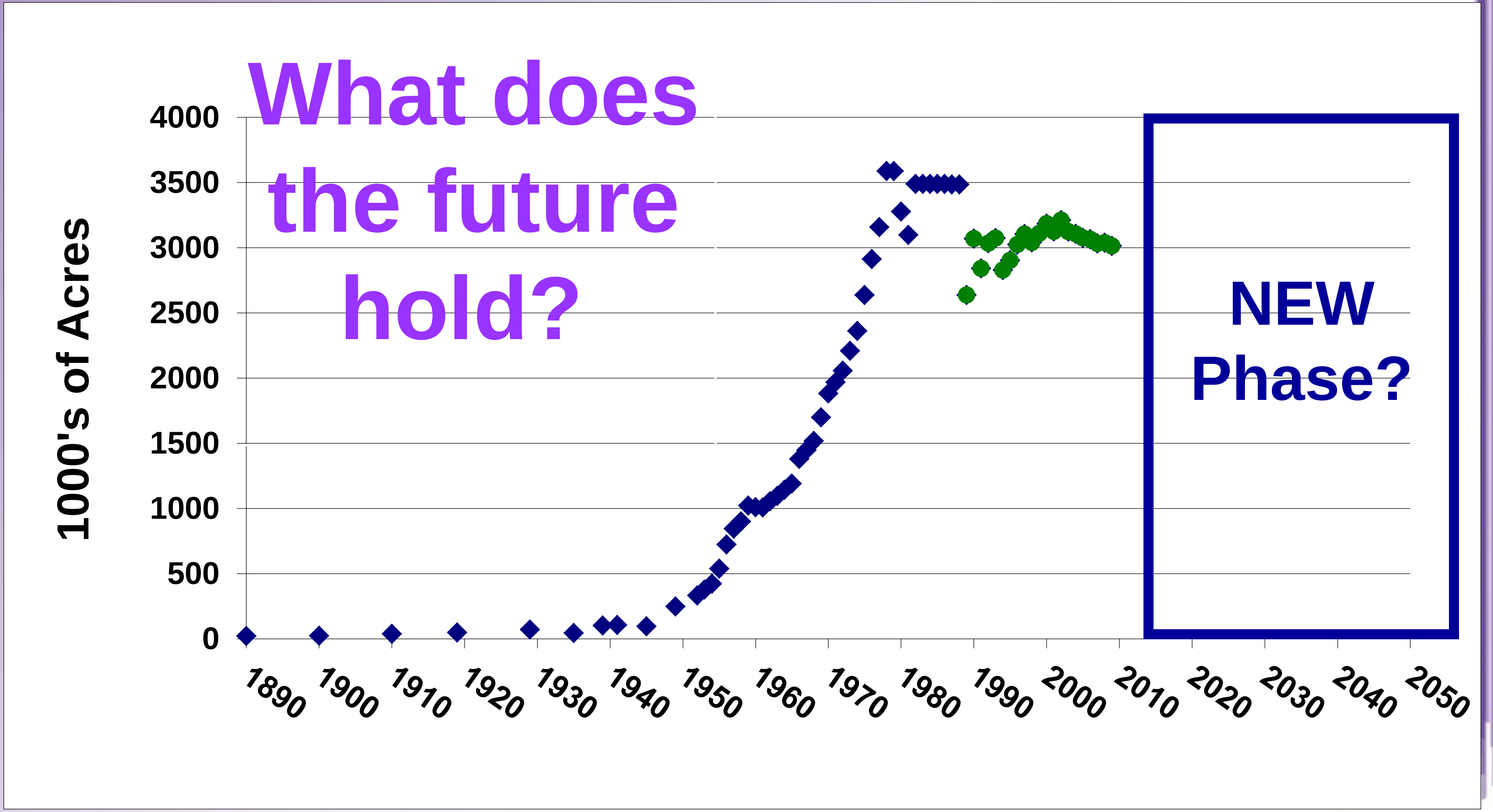
Kansas Irrigation Development



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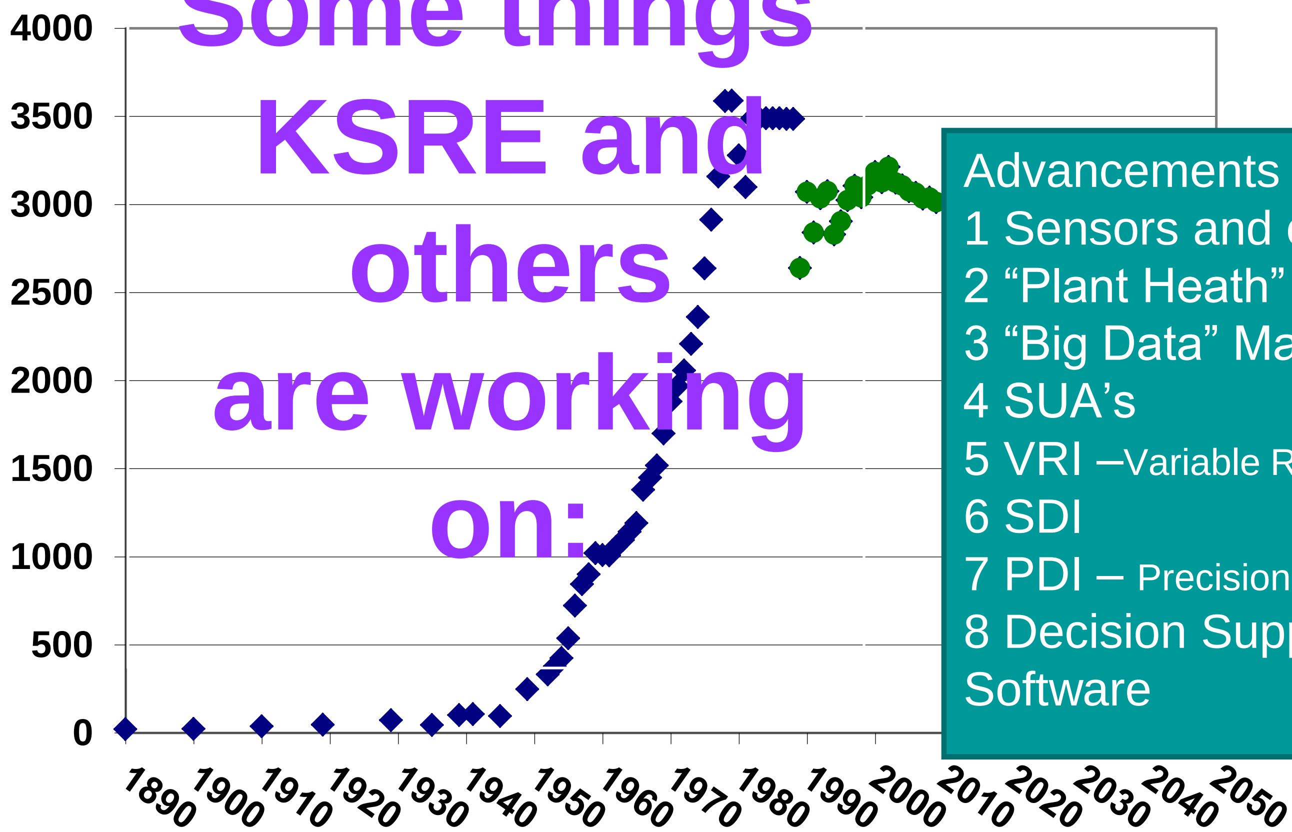
Kansas Irrigation Development



Some things KSRE and others are working on:

Advancements in:

1 Sensors and controls
2 “Plant Heath” sensors
3 “Big Data” Management
4 SUA’s
5 VRI –Variable Rate Irrigation
6 SDI
7 PDI – Precision Drip Irrigation
8 Decision Support Software

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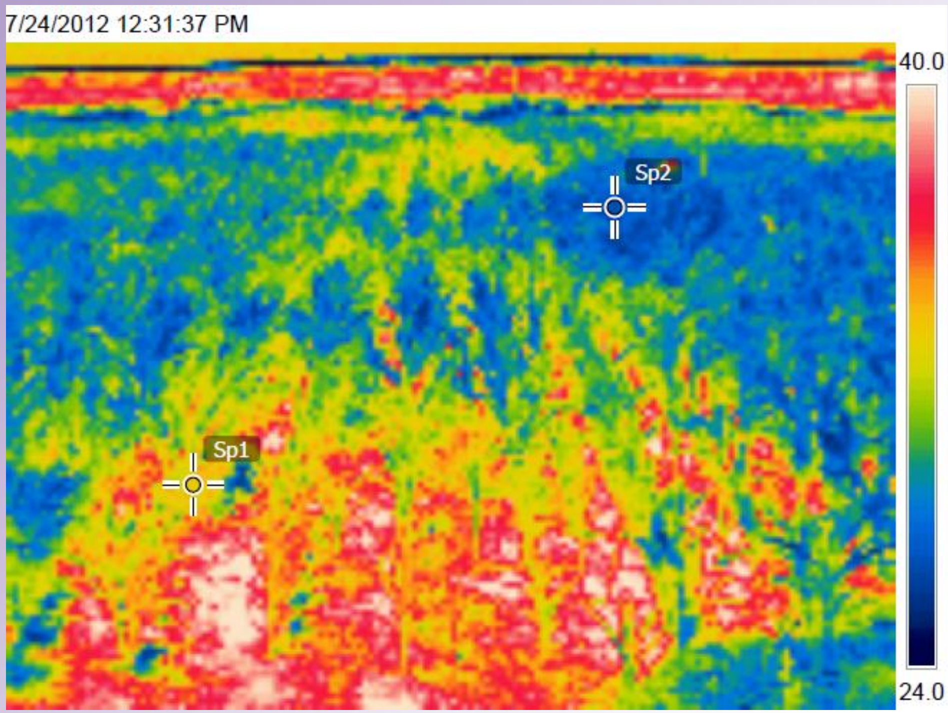
Knowledge for Life

Using Crop Water Stress Indexes (CWSI)

Using the plant for irrigation scheduling

Thermography

Thermometry



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Knowledge for Life

Crop Water Stress Index (CWSI)

- Simultaneously measure air temperature (T_a) and relative humidity (RH), with a thermometer and humidity sensor,
- Measure crop canopy temperature (Tc) with an infra-red thermometer,

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CWSI Method

$$CWSI = \frac{dT - dT_{mn}}{dT_{mx} - dT_{mn}}$$

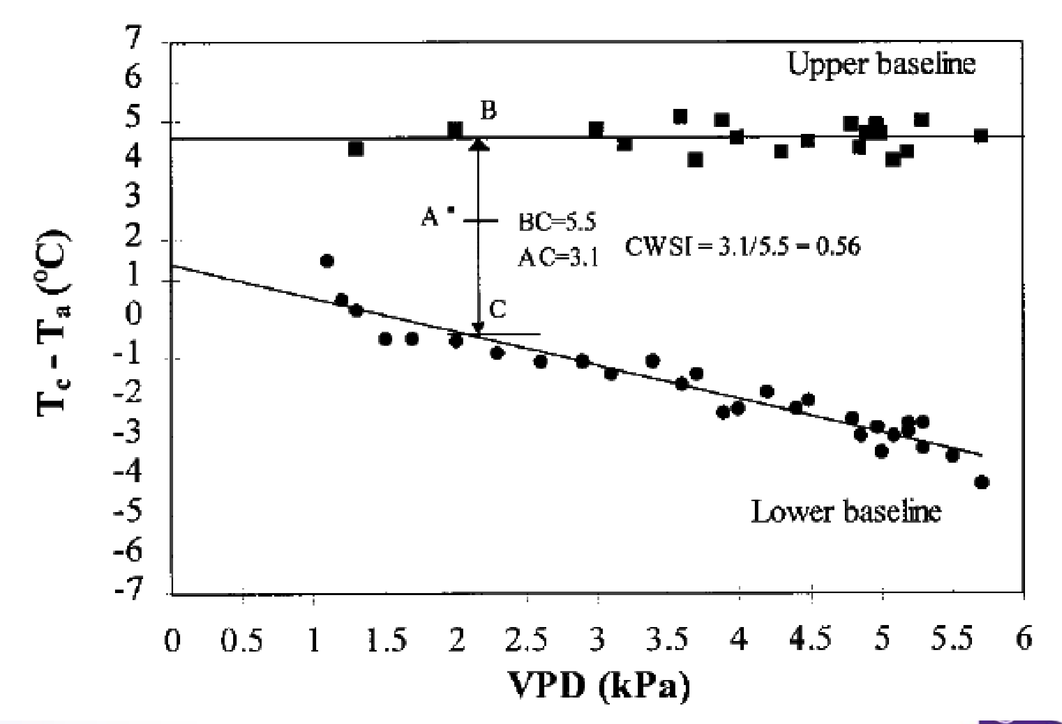
$dT = T_c - T_a$

dT_{min} = a (VPD) + b

dT_{max} = a (VPG) + b

Slope: "***a = -1.99***" and

Intercept "***b = 3.04***"

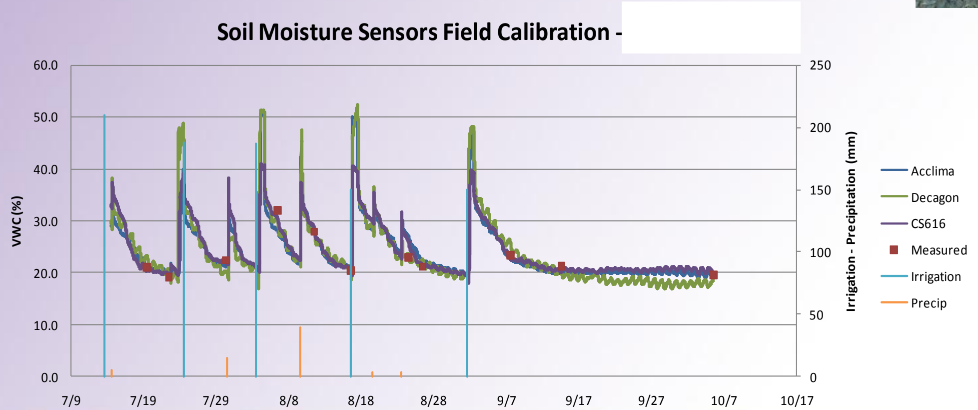


Evaluating CWSI with Volumetric Soil Water Content

$VWC_t = VWC_{FC} - (MAD \times AV)$

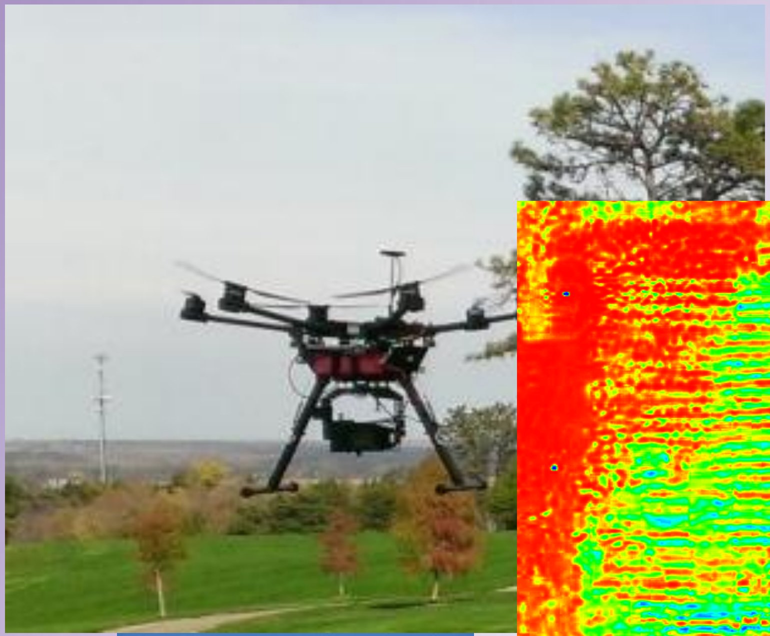
$AV = VWC_{FC} - VWC_{WP}$

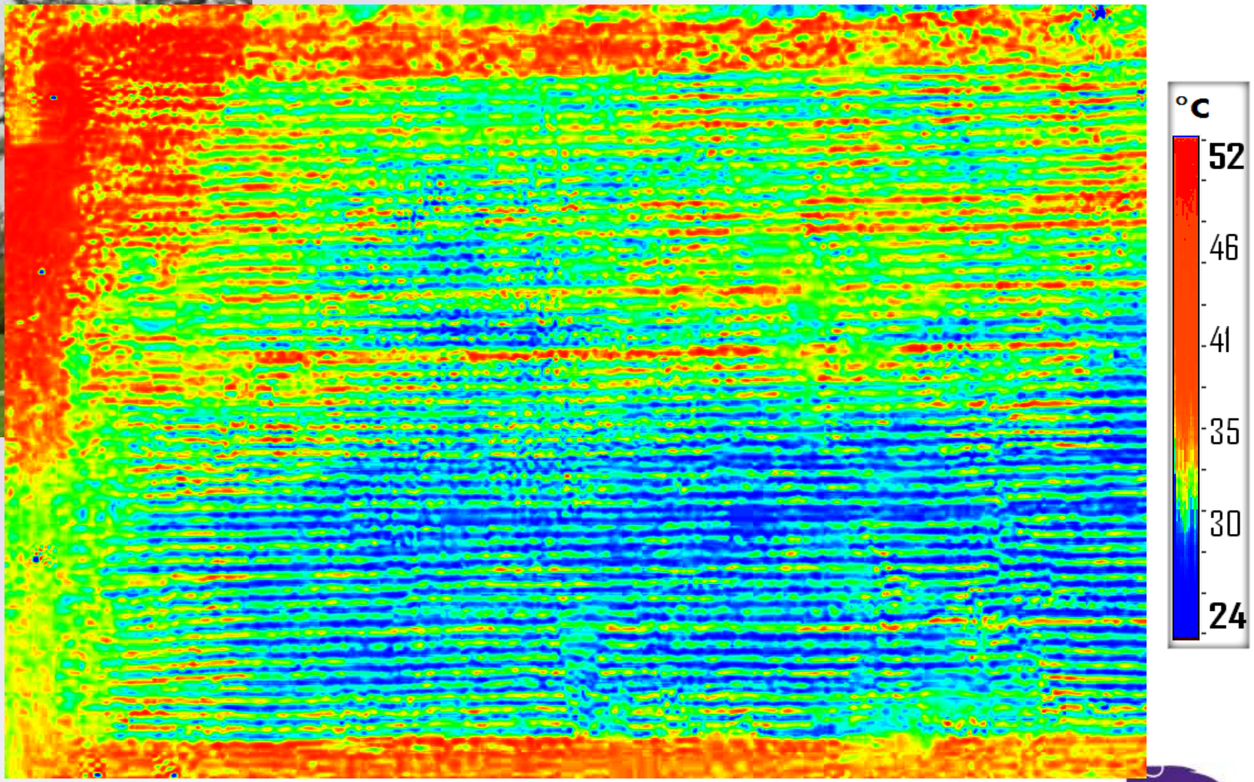
VWC = volumetric water content (%)
VWC_t = irrigation threshold VWC (%)
MAD = management allowed depletio
AV = available water (%)



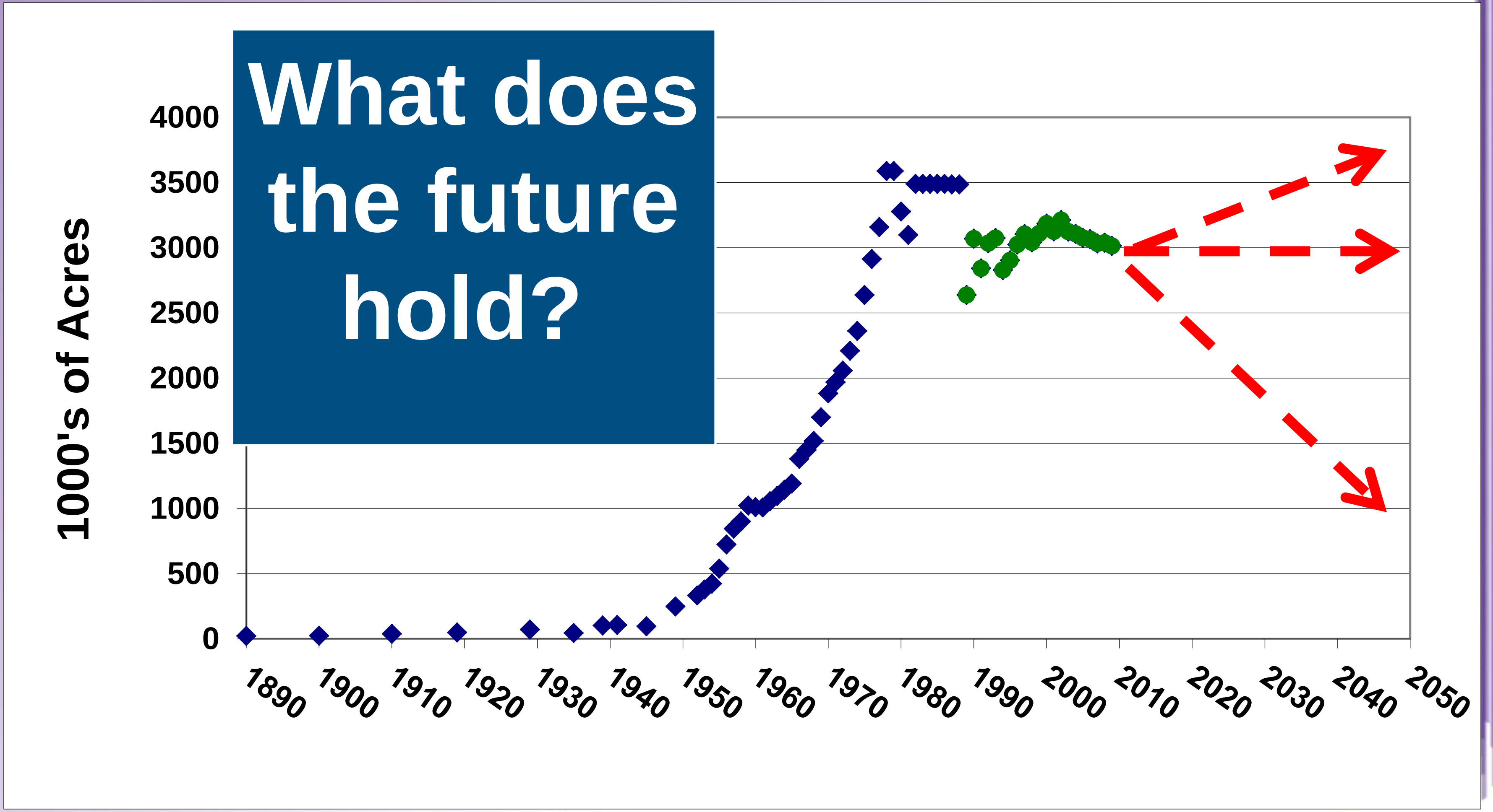
sandy clay loam soil

Moving from plot to field scale

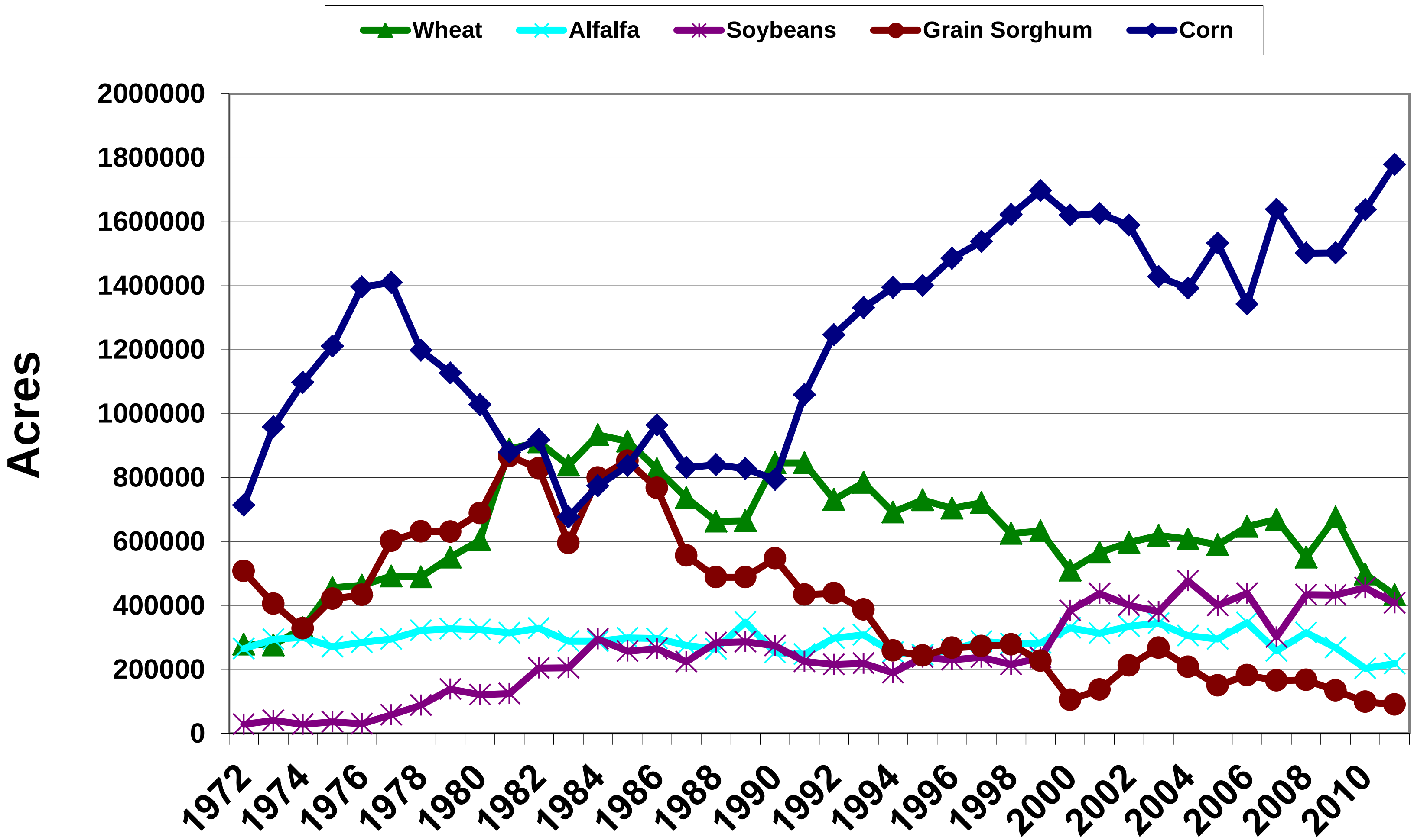




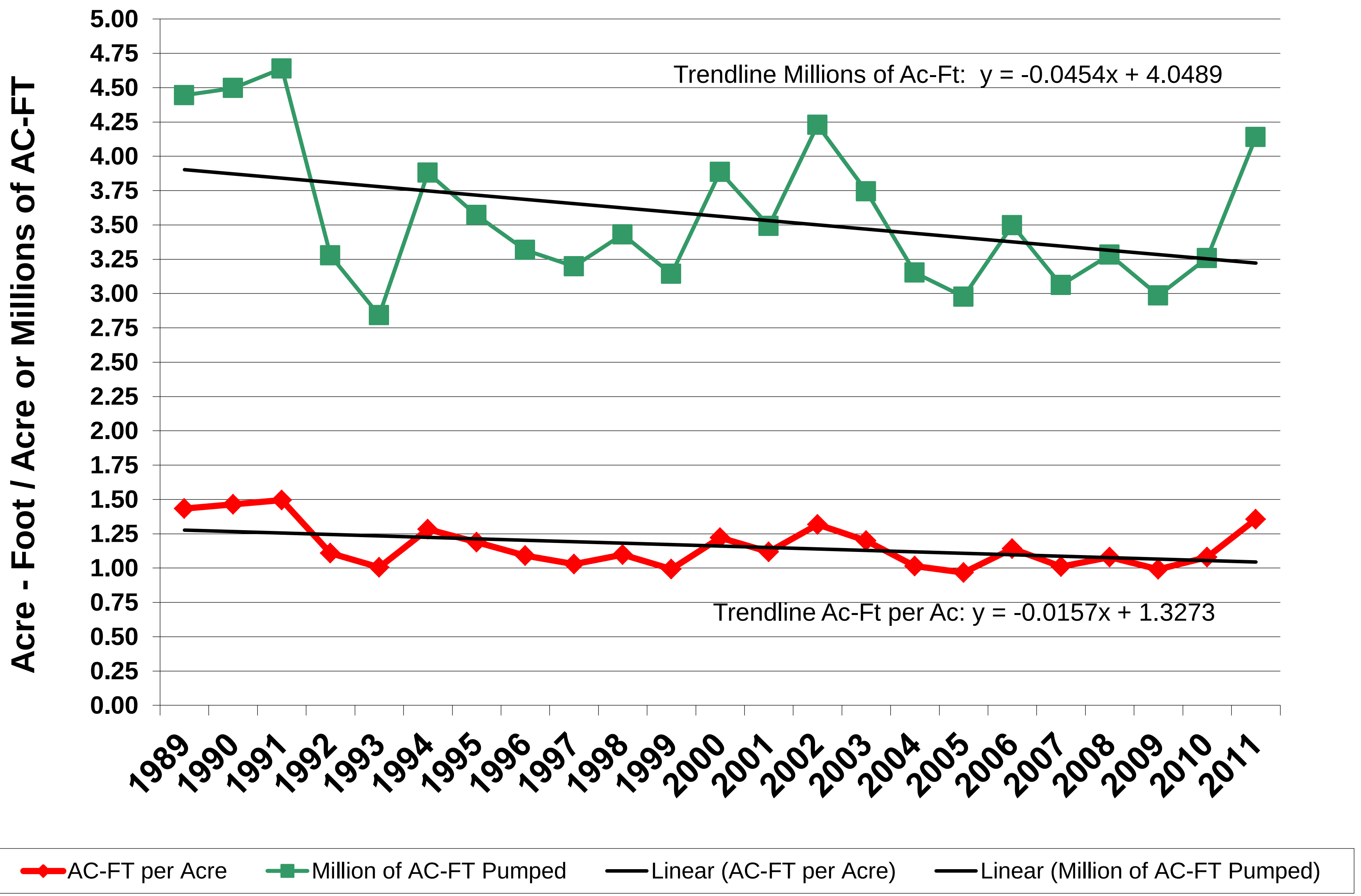
Kansas Irrigation Development



Major Kansas Irrigated Crop Acreage- 1972 to 2011

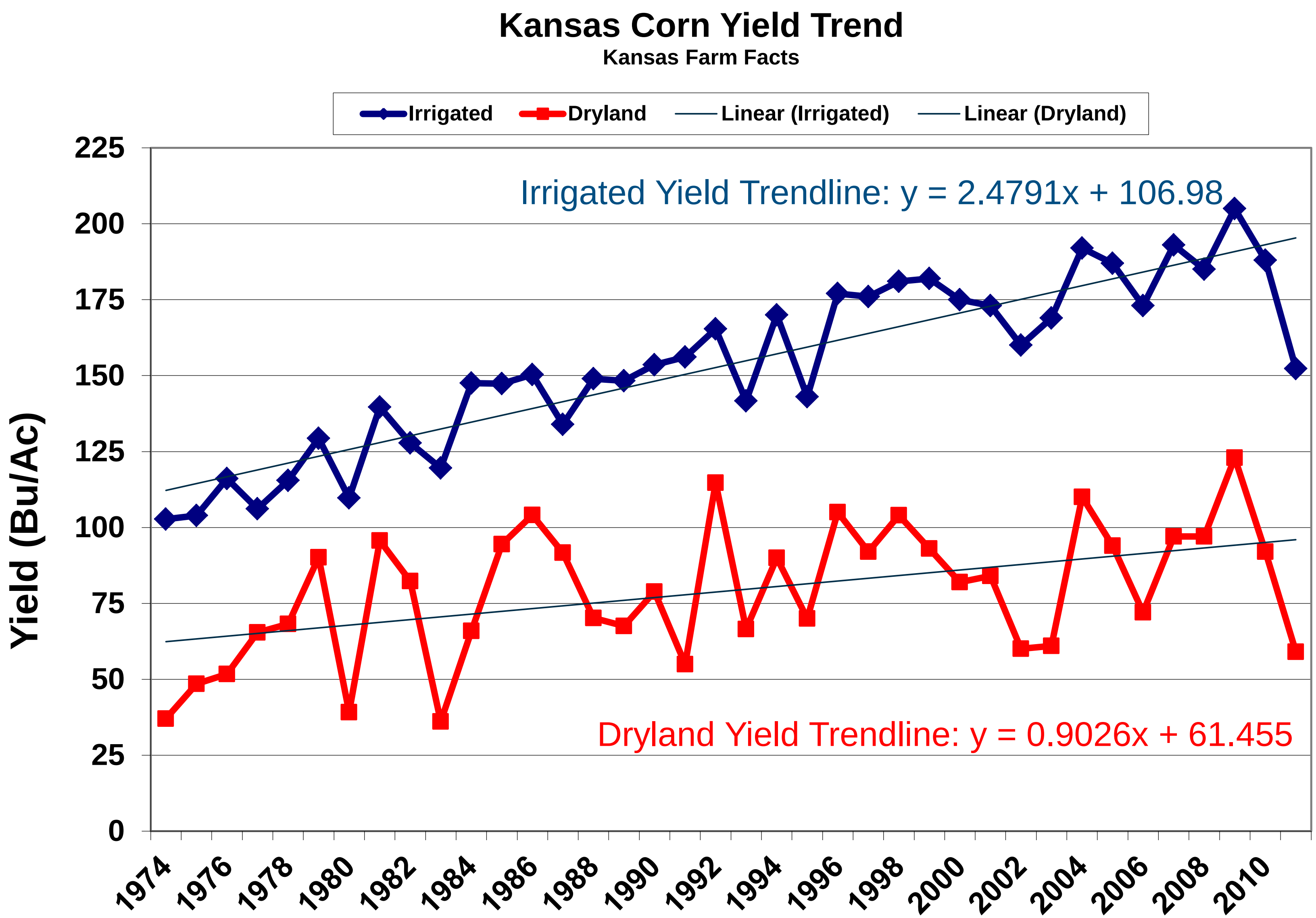


Total Irrigation Water and Average Acre-foot per Acre of Water Pumped in Kansas by Year



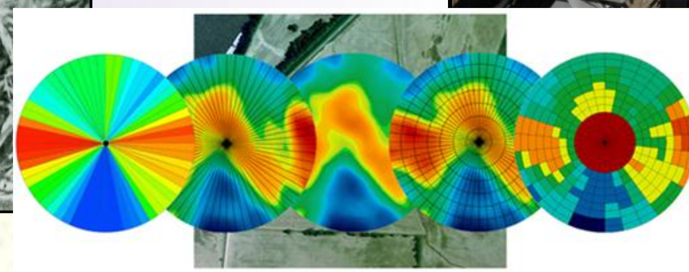
Knowledge

Research and Extension



K·STATE Research and Extension

How far can we go?



Adapted from http://cropmetrics.com/features/variable-rate-irrigation/

The Good Ole' Days

- In 1787 farmers:
  - Seldom fertilized
  - Seldom rotated crops
  - Little interest in improved varieties
- Results:
  - Yield: Wheat 15 bu/ac, Corn 25 bu/ac
  - Labor: Wheat -373 hours/100 bushels, Corn-344 hours/100 bushels
  - Cost ($8.00/hour labor): Wheat-$29.83/bu, Corn- $27.52/bu

K-State Research and Extension Website:

www.ksre.ksu.edu

General Irrigation: www.ksre.ksu.edu/irrigate

Subsurface Drip Irrigation: www.ksre.ksu.edu/sdi

Mobile Irrigation Lab:

http://www.bae.ksu.edu/mobileirrigationlab

Summary of Kansas State University Irrigation Research Topics

- Crop Water Use for various crops:
  - Seasonal and daily ET; stage of growth
- Agronomic Studies:
  - Planting date, depth, plant maturity, plant density and configuration, fertility, pest control, crop rotation, performance trials
- Water Productivity Studies:
  - Pre-season irrigation, irrigation scheduling (soil-based, ET-based, crop-based), full and deficit irrigation, effect of irrigation capacity, soil evaporation, plant canopy evaporation, appropriate land allocation
- Irrigation Systems:
  - Surface: Surge Irrigation
  - Center pivot: sprinkler configuration effect on uniformity, irrigation water partitioning, above and in-canopy application
  - SDI (Subsurface Drip Irrigation): Design, management, maintenance and economics – application of microirrigation technology to High Plains (relatively low value crops) irrigated agriculture

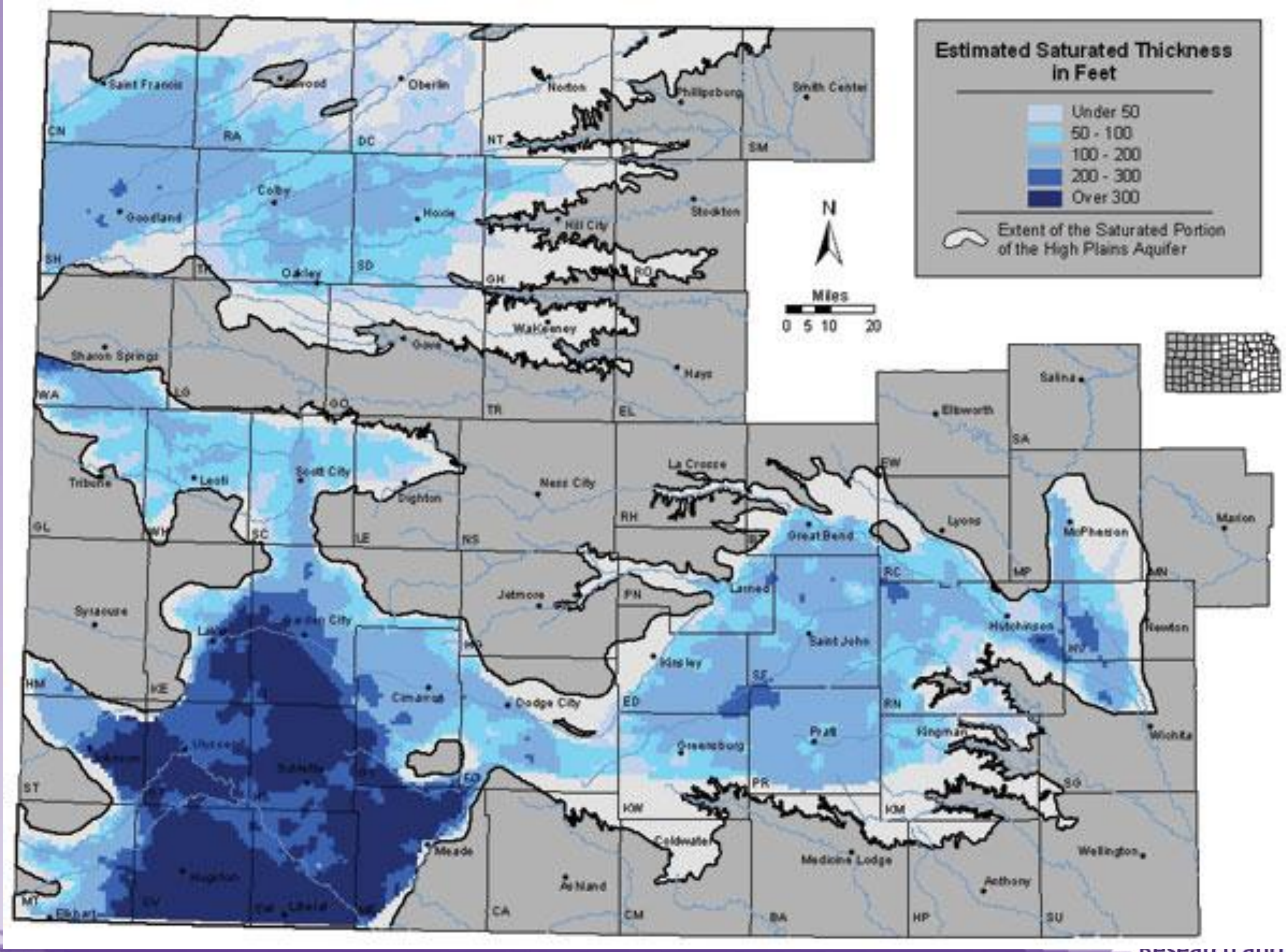
Summary of Kansas State University Irrigation Extension Topics:

Delivered via Programs, Bulletins, Demonstration Sites, and Web

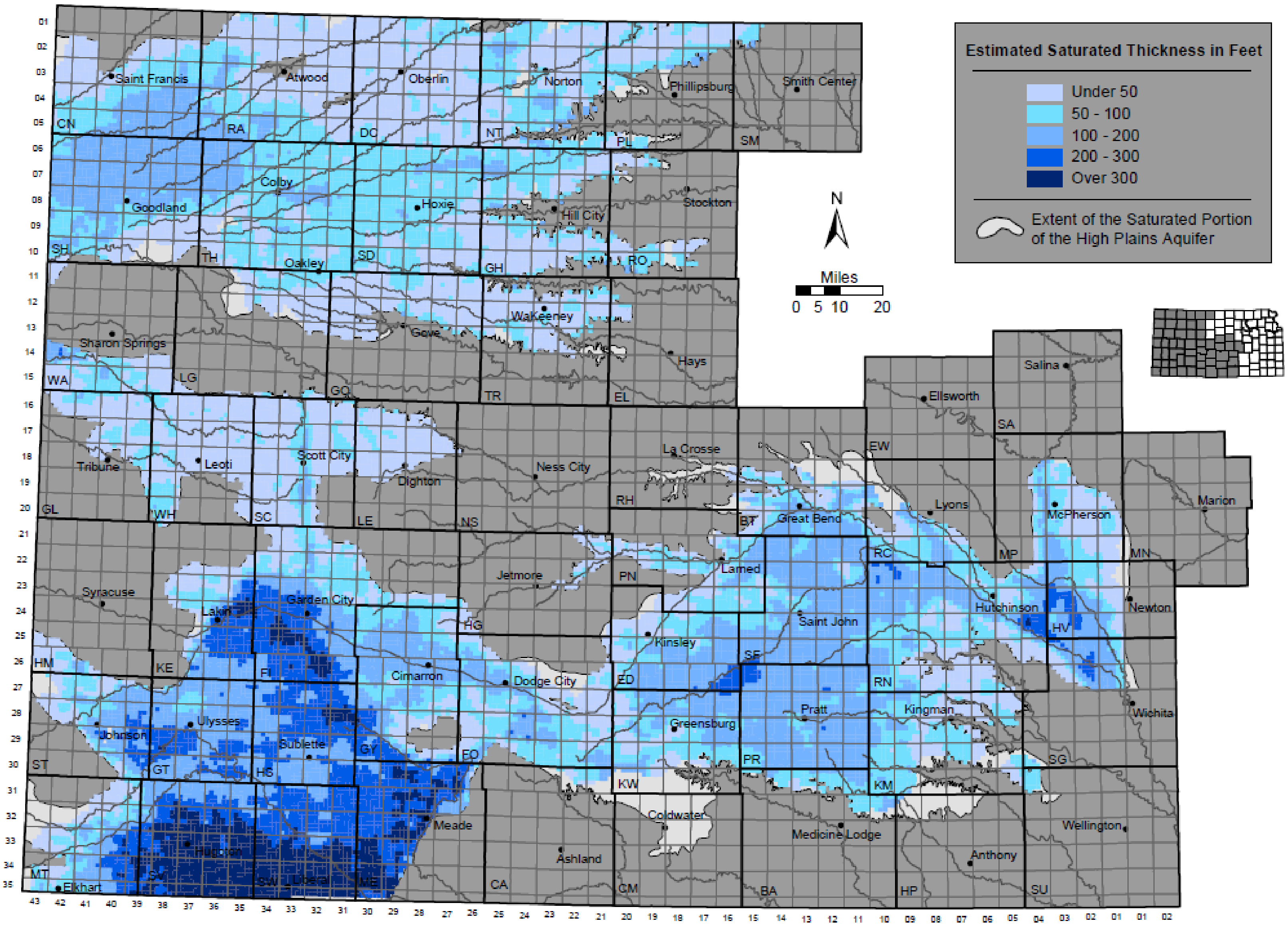
- Irrigation water management
  - Irrigation water measurement; Irrigation Scheduling (soil-based, ET-based) Pre-irrigation, Full and limited irrigation management strategies for high and low irrigation system capacity; Irrigation water supply, Irrigation water quality
  - Irrigation Decision Support Software: KanSched; FuelCost, Crop Water Allocator, Crop Yield Predictor
- Water Productivity Information:
  - Effect of crop residues on soil evaporation and precipitation capture; crop yield /water use response curves
- Irrigation Systems:
- General design and operational characteristics, Irrigation system efficiencies; Field evaluation of sprinkler package performance uniformity
- Irrigation Energy:
  - Pumping Plant Efficiency: In-field evaluations, energy audits, comparing energy sources

Predevelopment saturated thickness for the High Plains aquifer.

Kansas Geological Survey, Public Information Circular (PIC) 18



Average 2004 - 2006 Saturated Thickness for the High Plains Aquifer in Kansas

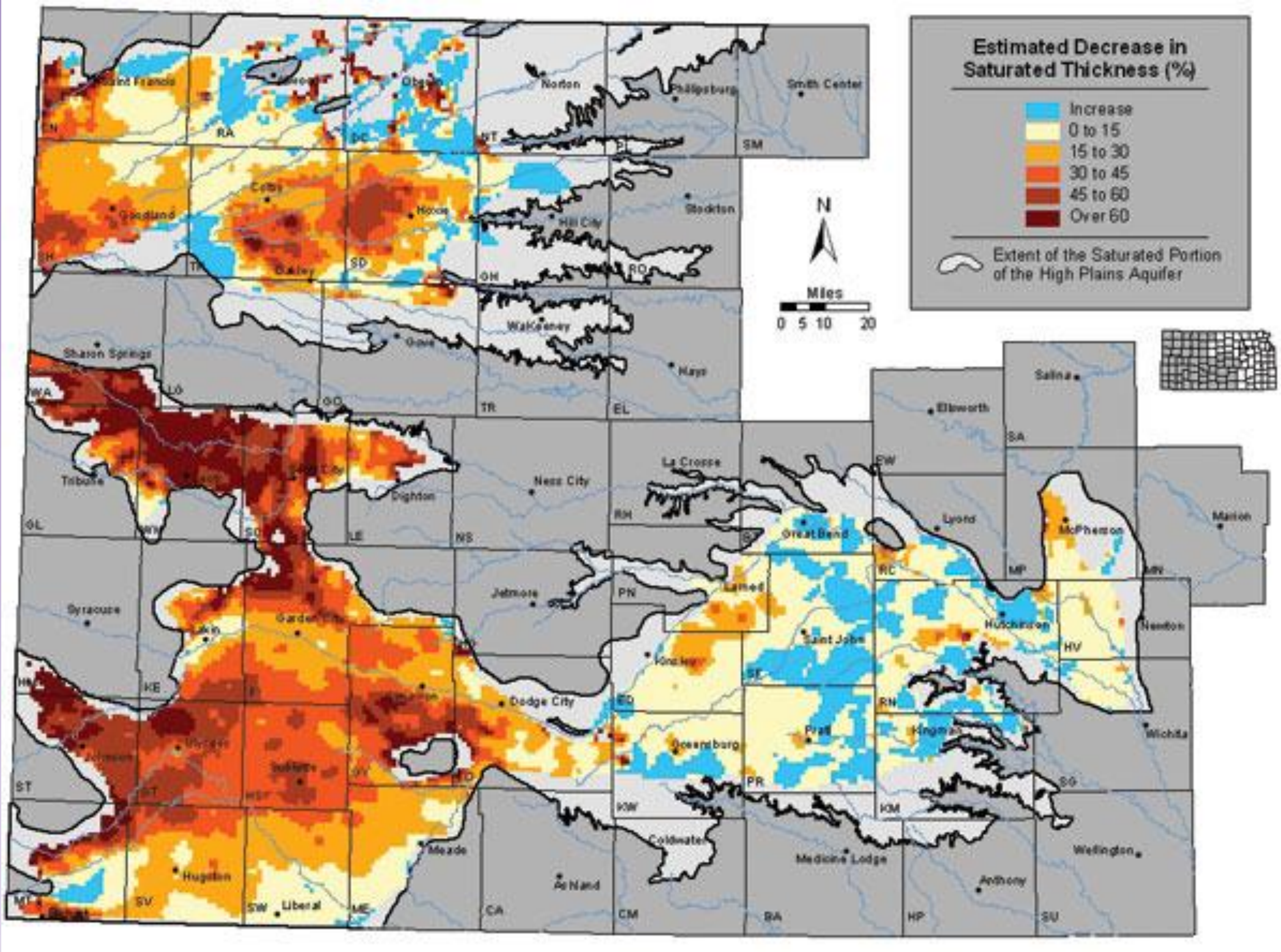


Kansas Geological Survey Open-File Report 2007-1

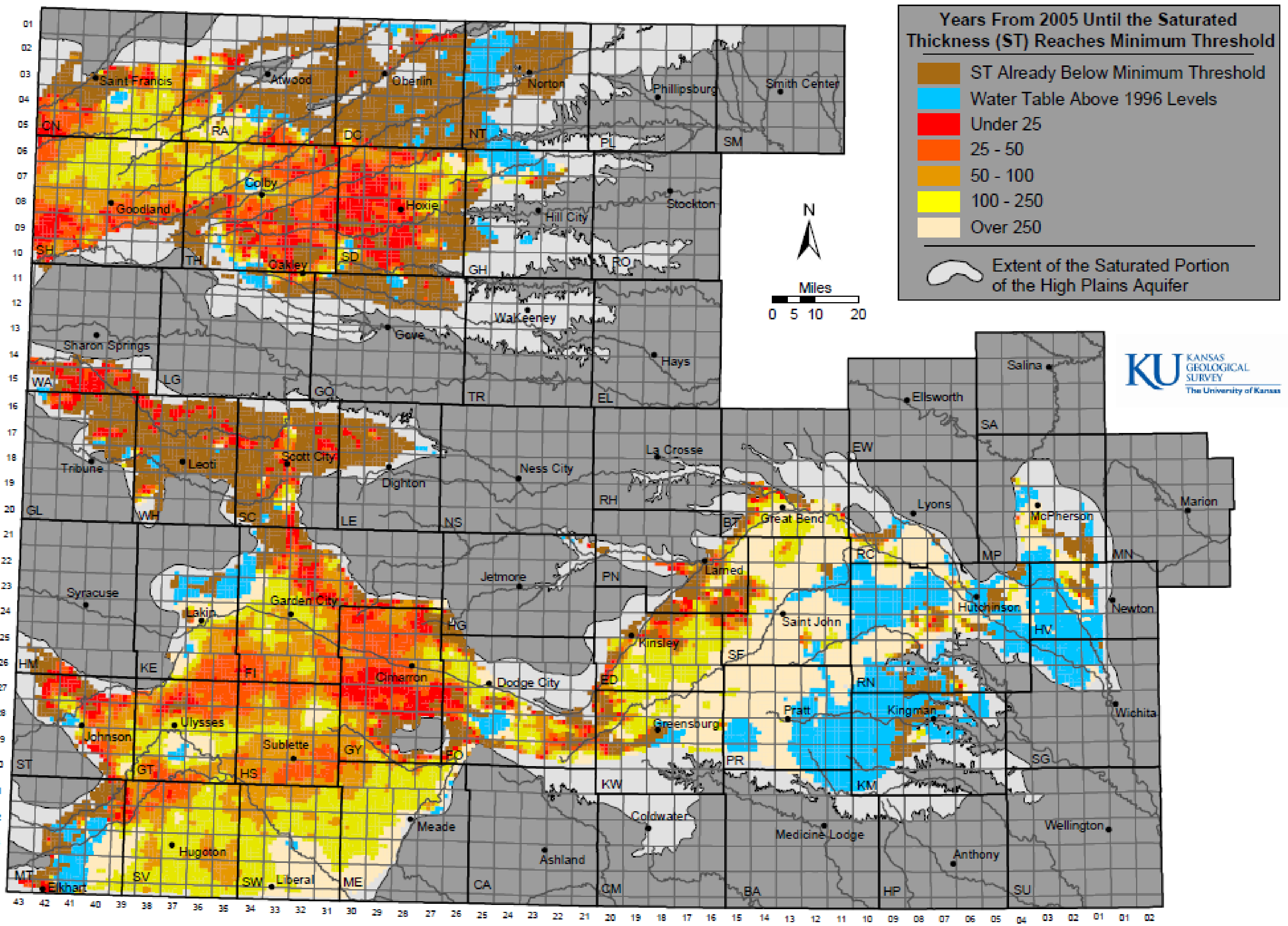
Research and Extension

Estimated Percentage Decrease in Saturated Thickness

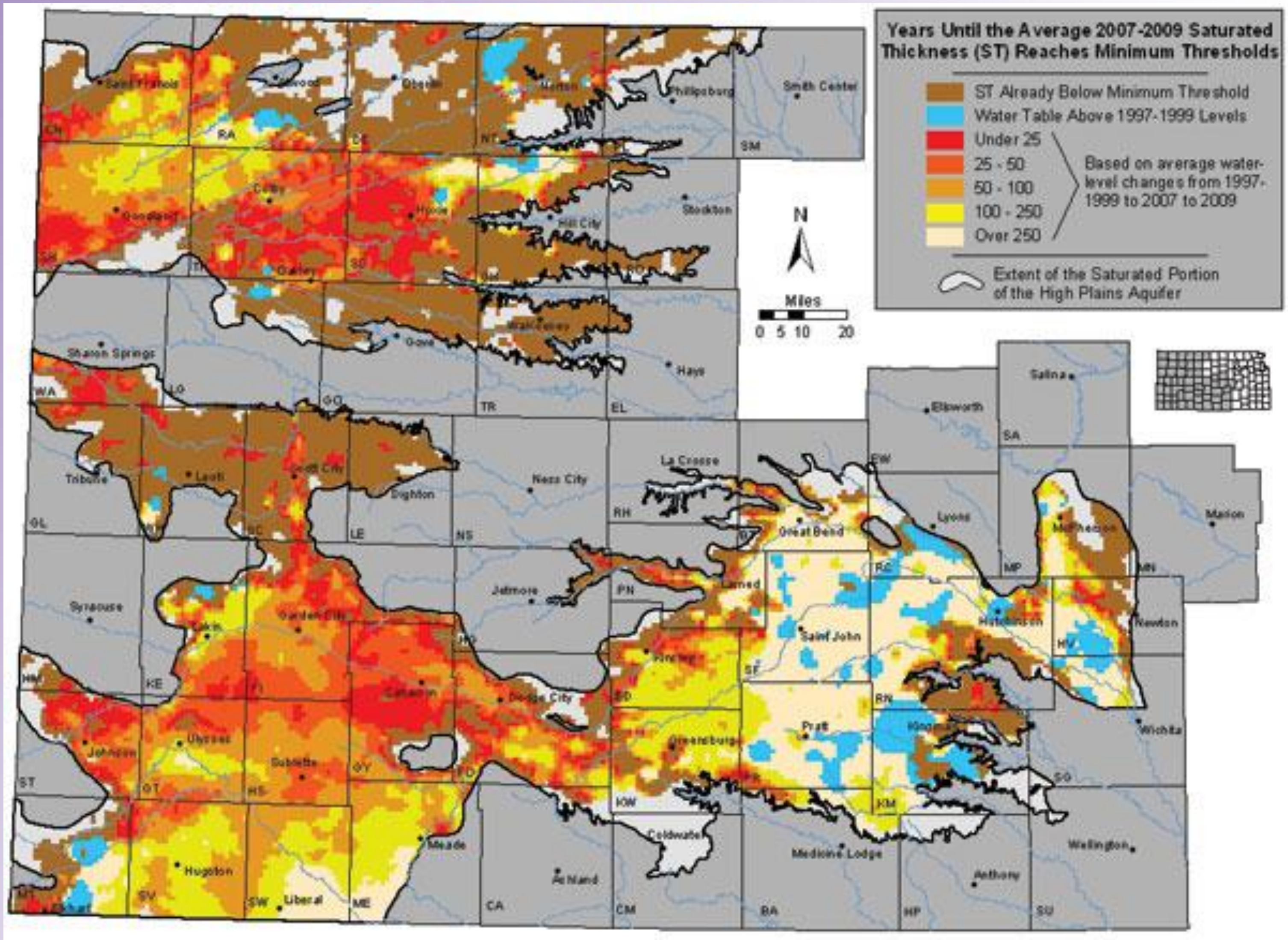
Kansas Geological Survey, Public Information Circular (PIC) 18



Estimated Usable Lifetime for the High Plains Aquifer in Kansas
(Based on ground water trends from 1996 to 2006 and the minimum saturated thickness required to support well yields at 400 gpm under a scenario of 90 days of pumping with wells on 1/4 section)

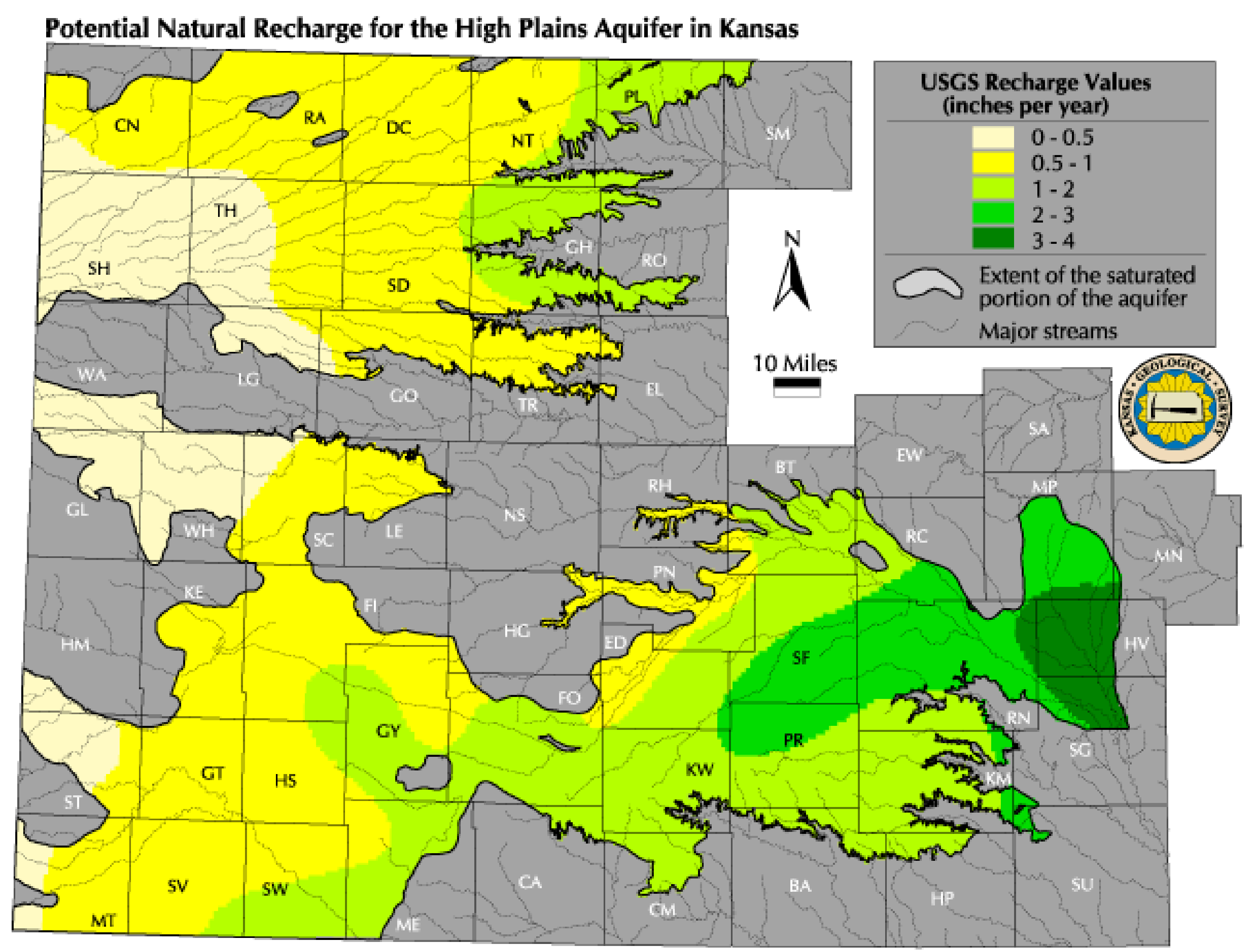


Estimated usable lifetime (1998-2008) trend.

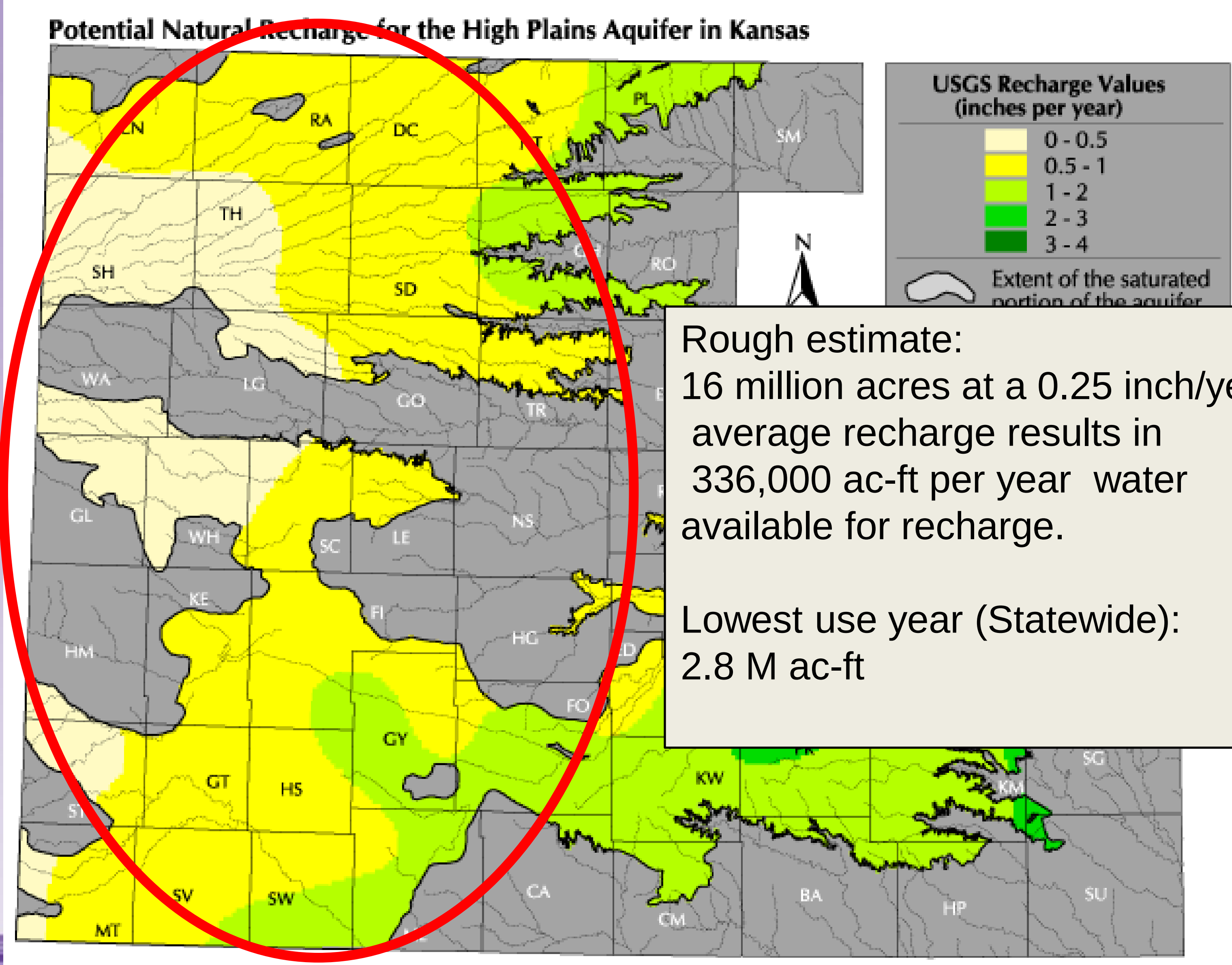


Kansas Geological Survey, Public Information Circular (PIC) 18

Potential Natural Recharge for High Plains Aquifer in Kansas



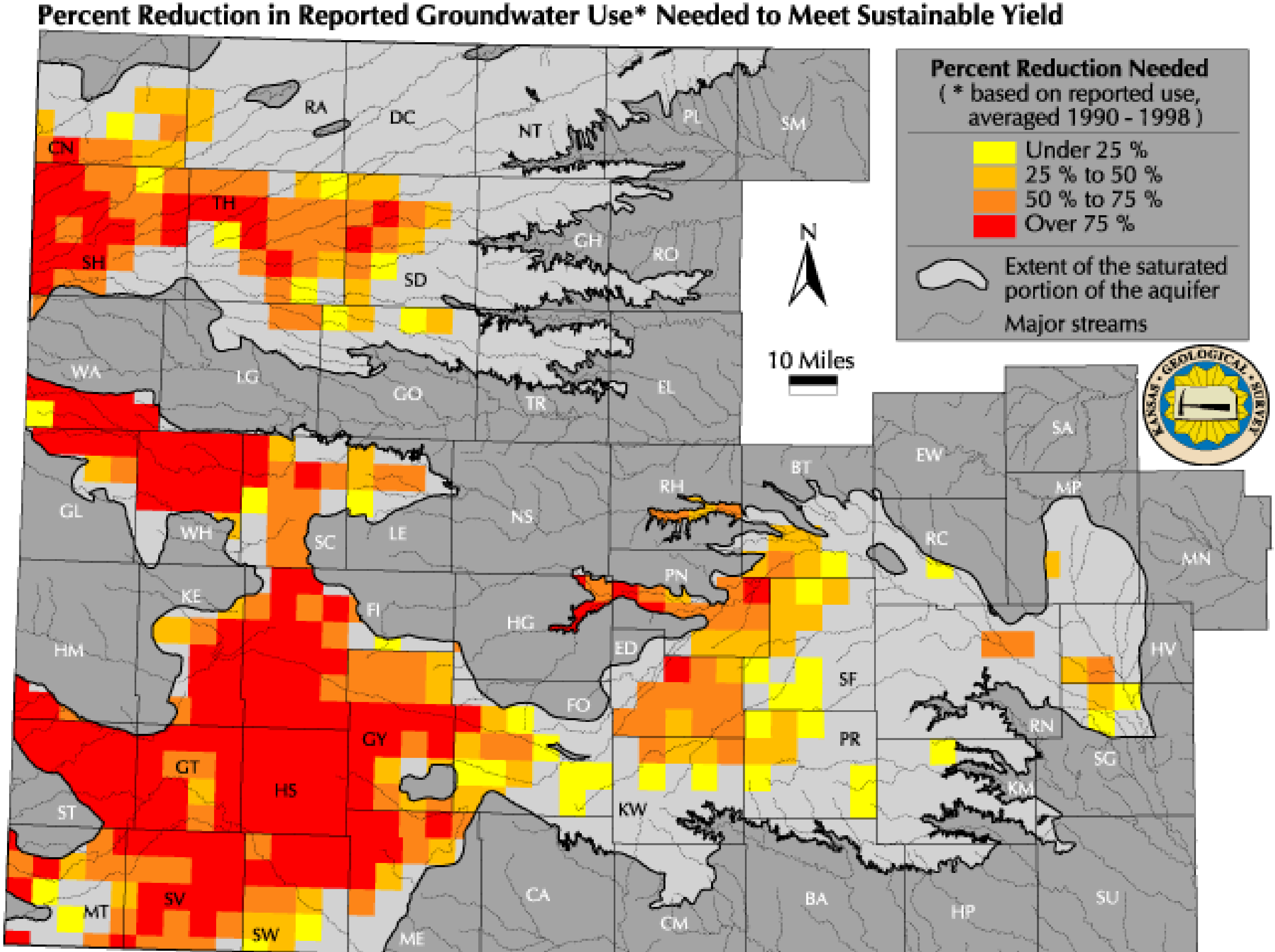
Potential Natural Recharge for High Plains Aquifer in Kansas



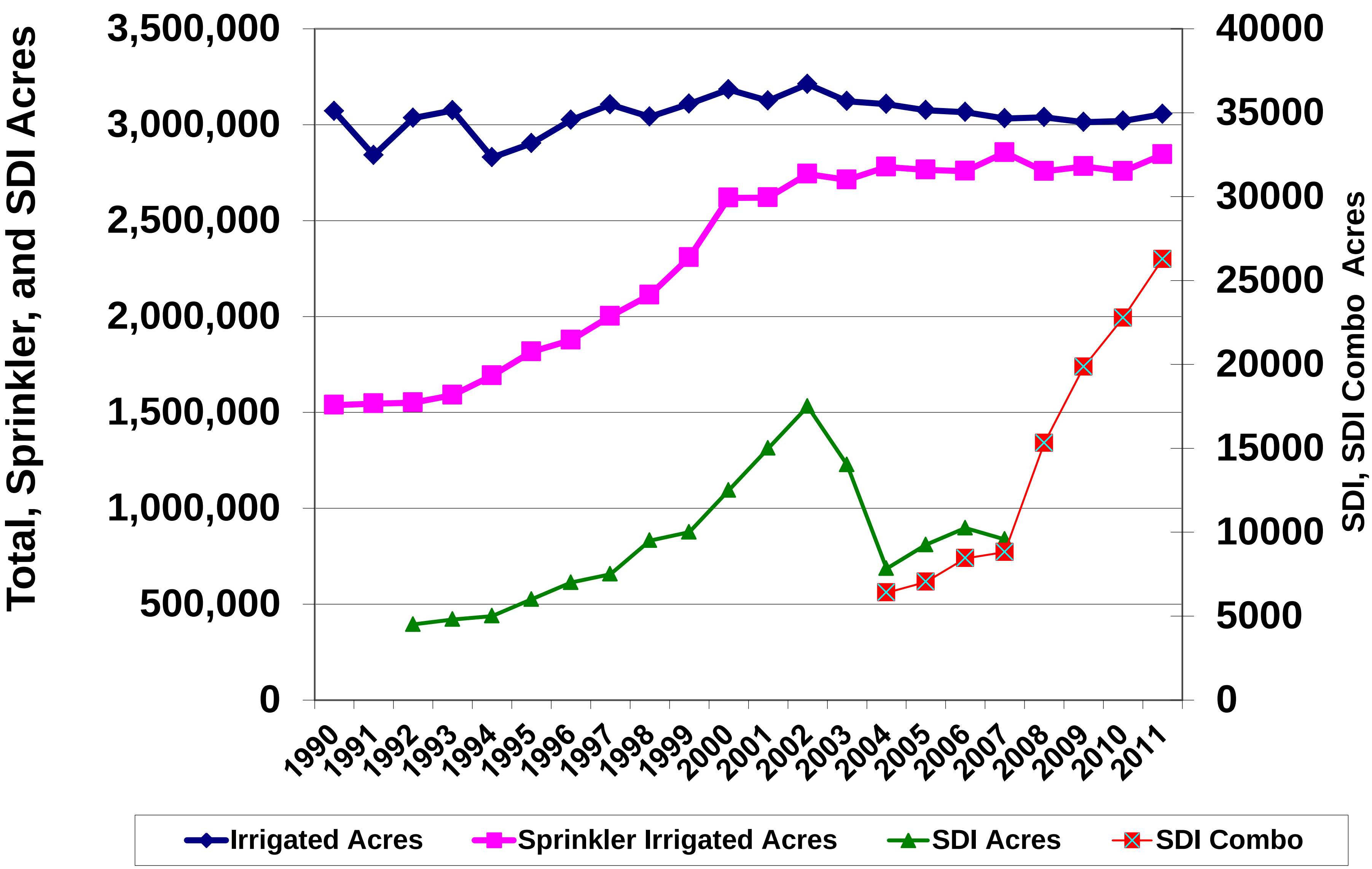
Rough estimate:
16 million acres at a 0.25 inch/year average recharge results in 336,000 ac-ft per year water available for recharge.

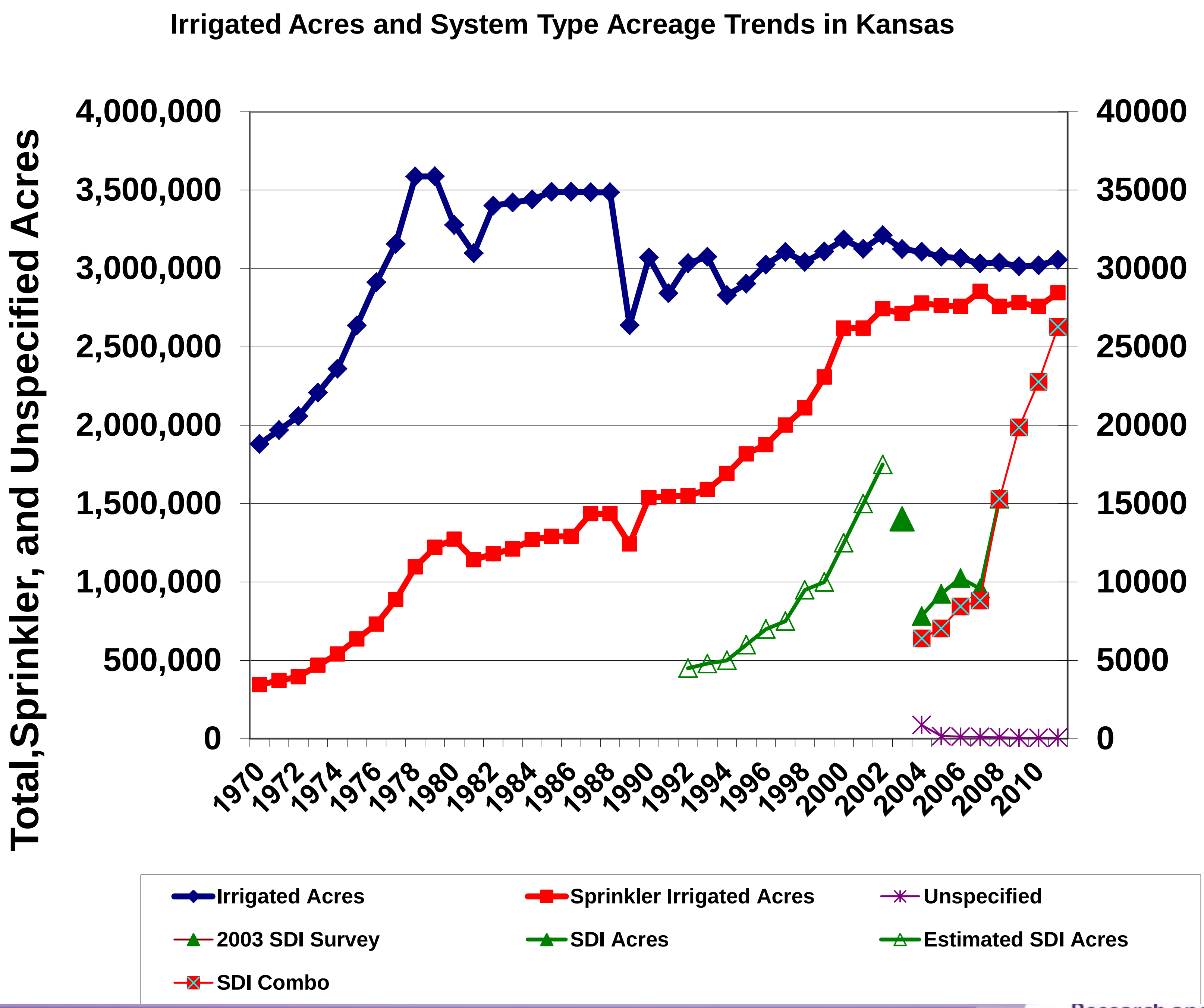
Lowest use year (Statewide):
2.8 M ac-ft

Percent Reduction in Reported Groundwater Use



Kansas Irrigated Acres and System Type Trends since 1990





Research and Extension

Kansas Net Irrigation Requirement

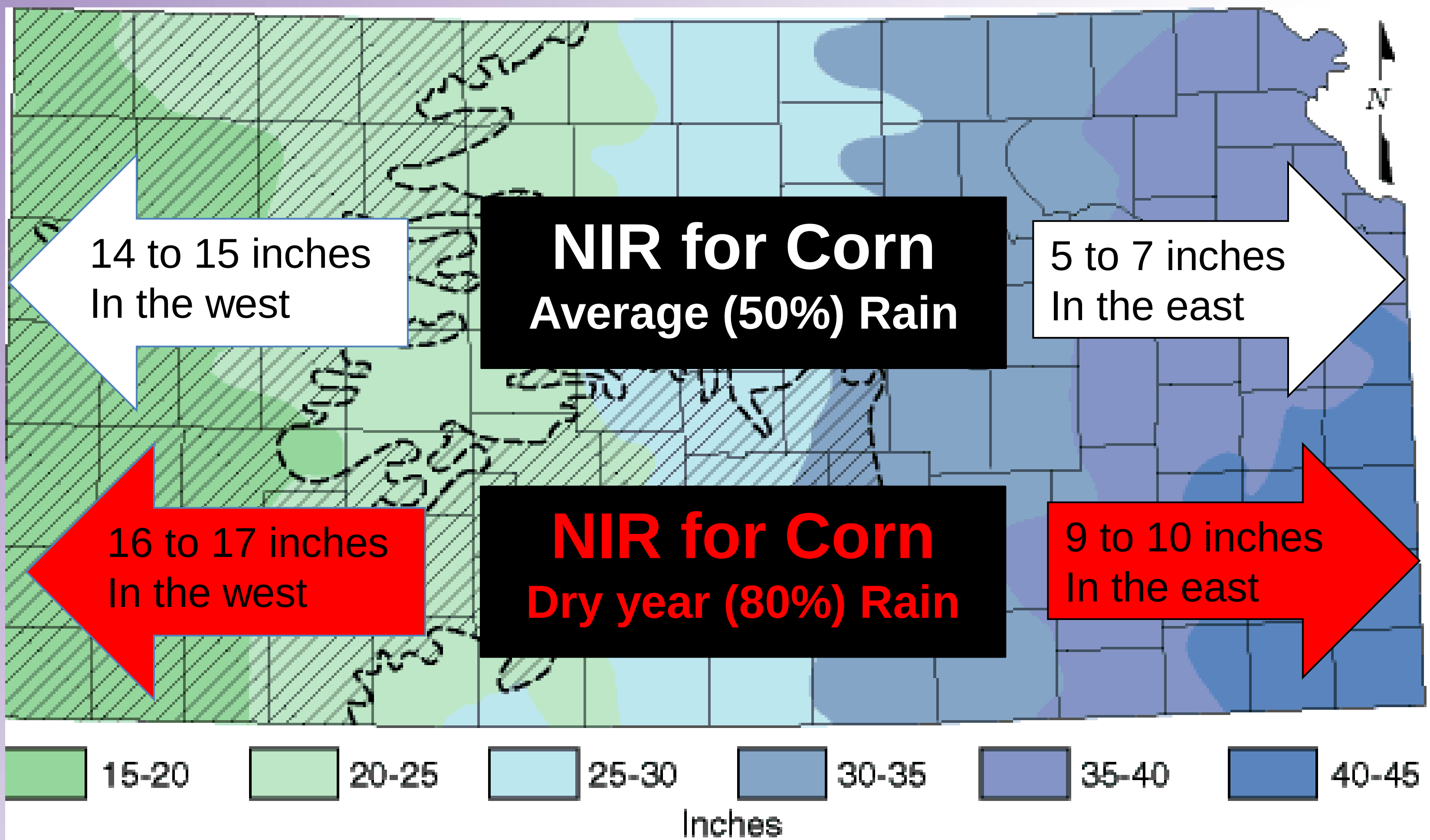


Figure 3. Normal annual precipitation (1961 - 1990) in Kansas. The area west of the dashed line shows the extent of the High Plains aquifer in Kansas (from Goodin et al., 1995).