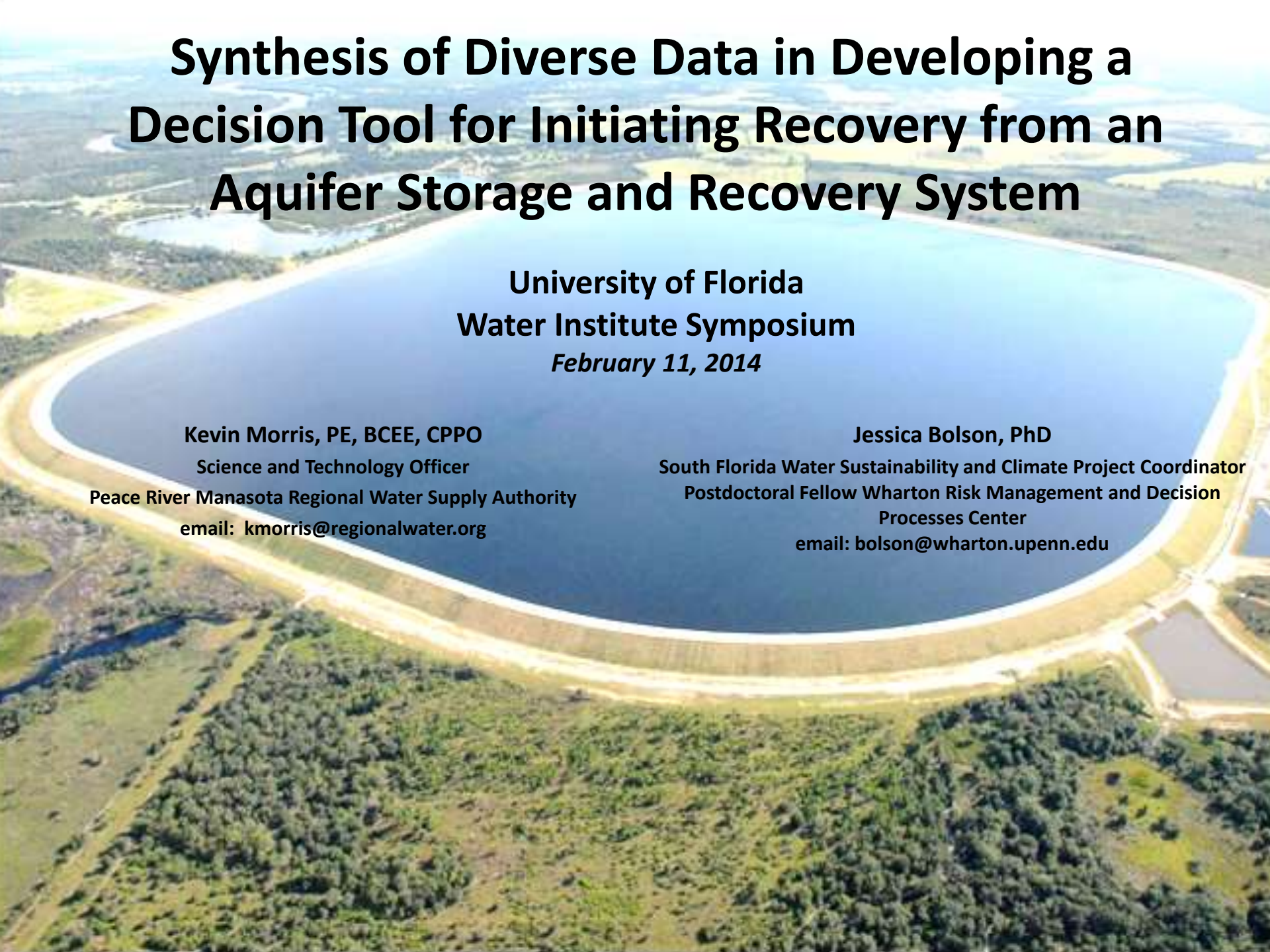
Synthesis of Diverse Data in Developing a Decision Tool for Initiating Recovery from an Aquifer Storage and Recovery System



University of Florida
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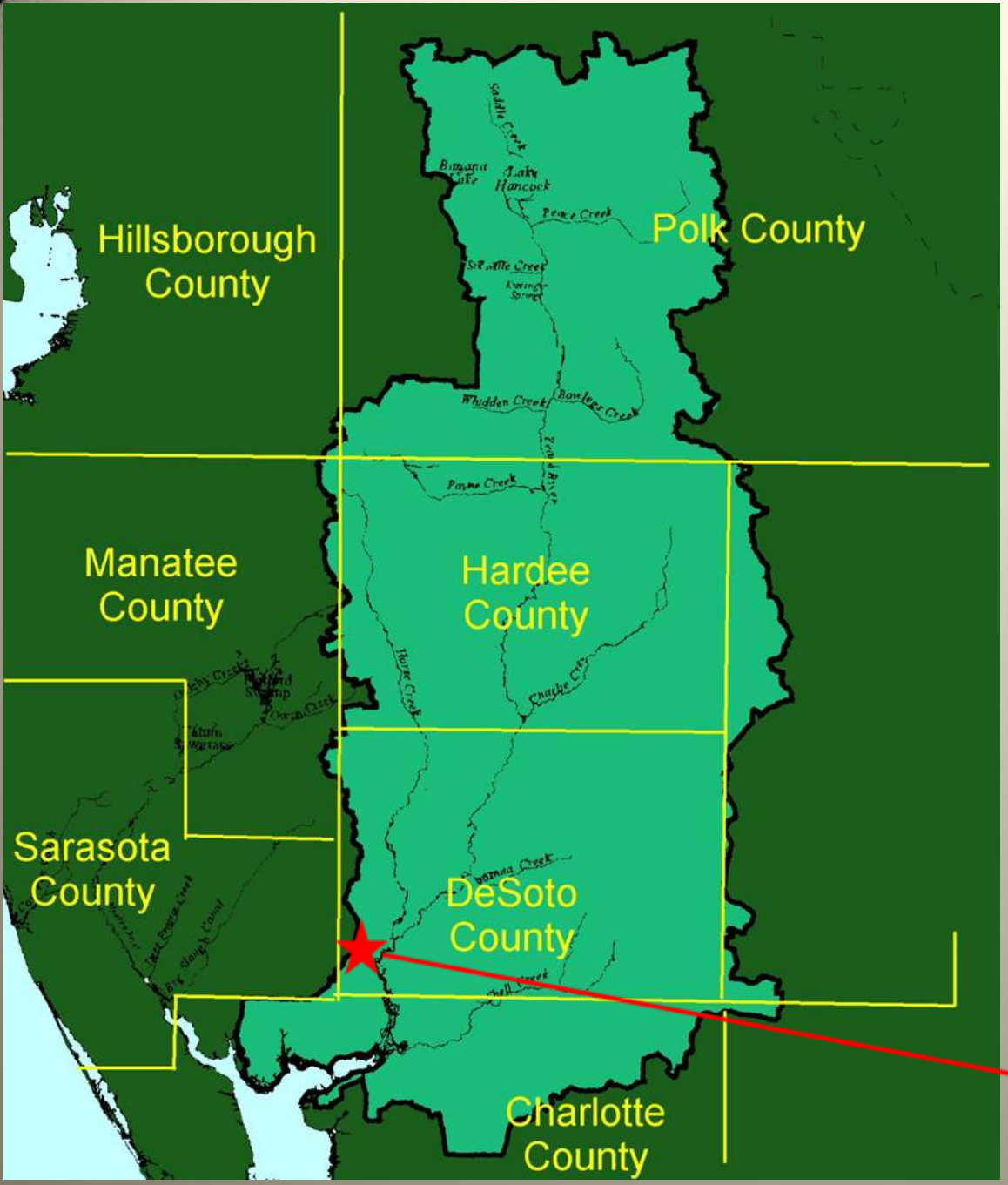
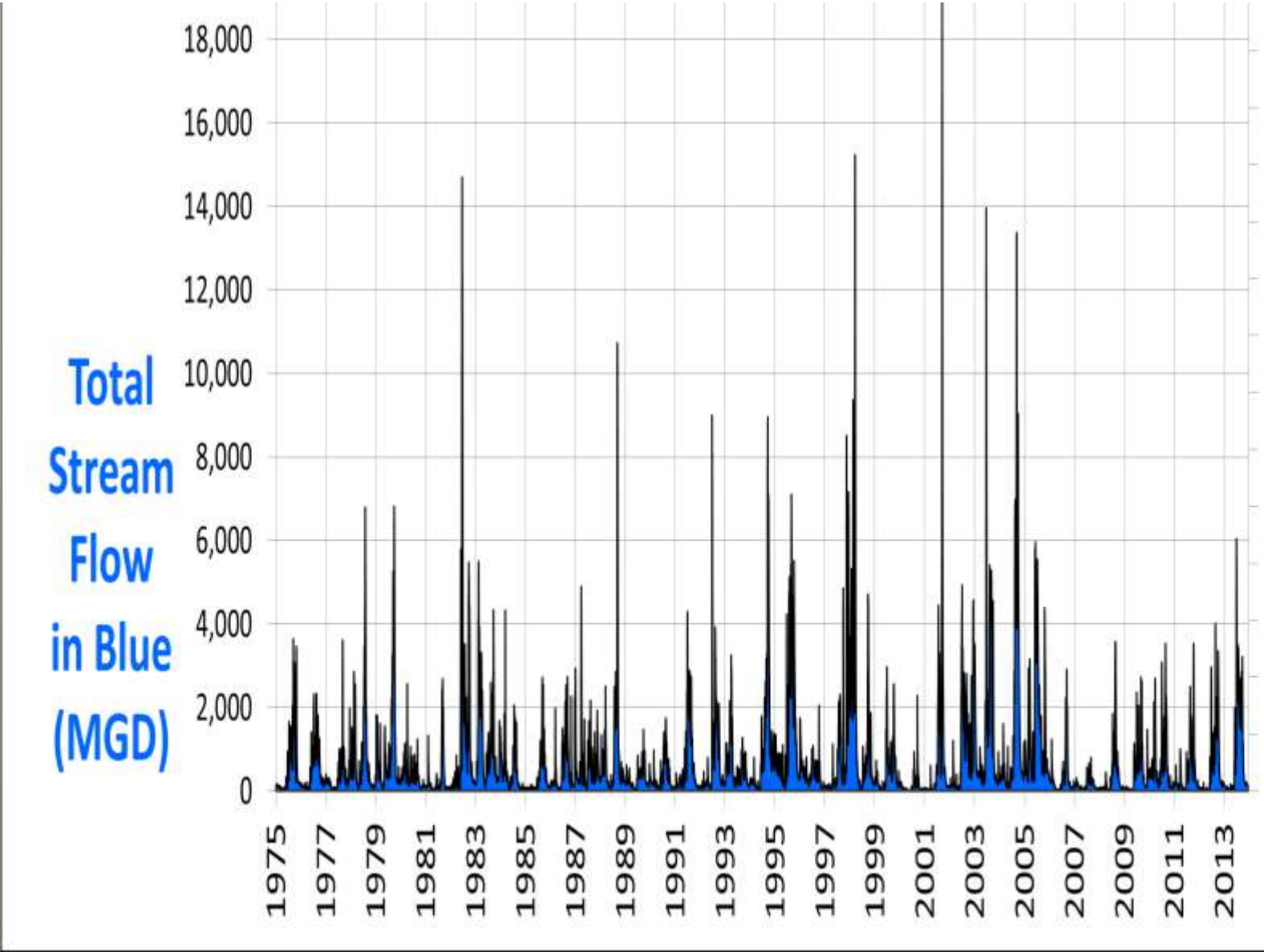


Peace River Watershed is 2,350 square miles

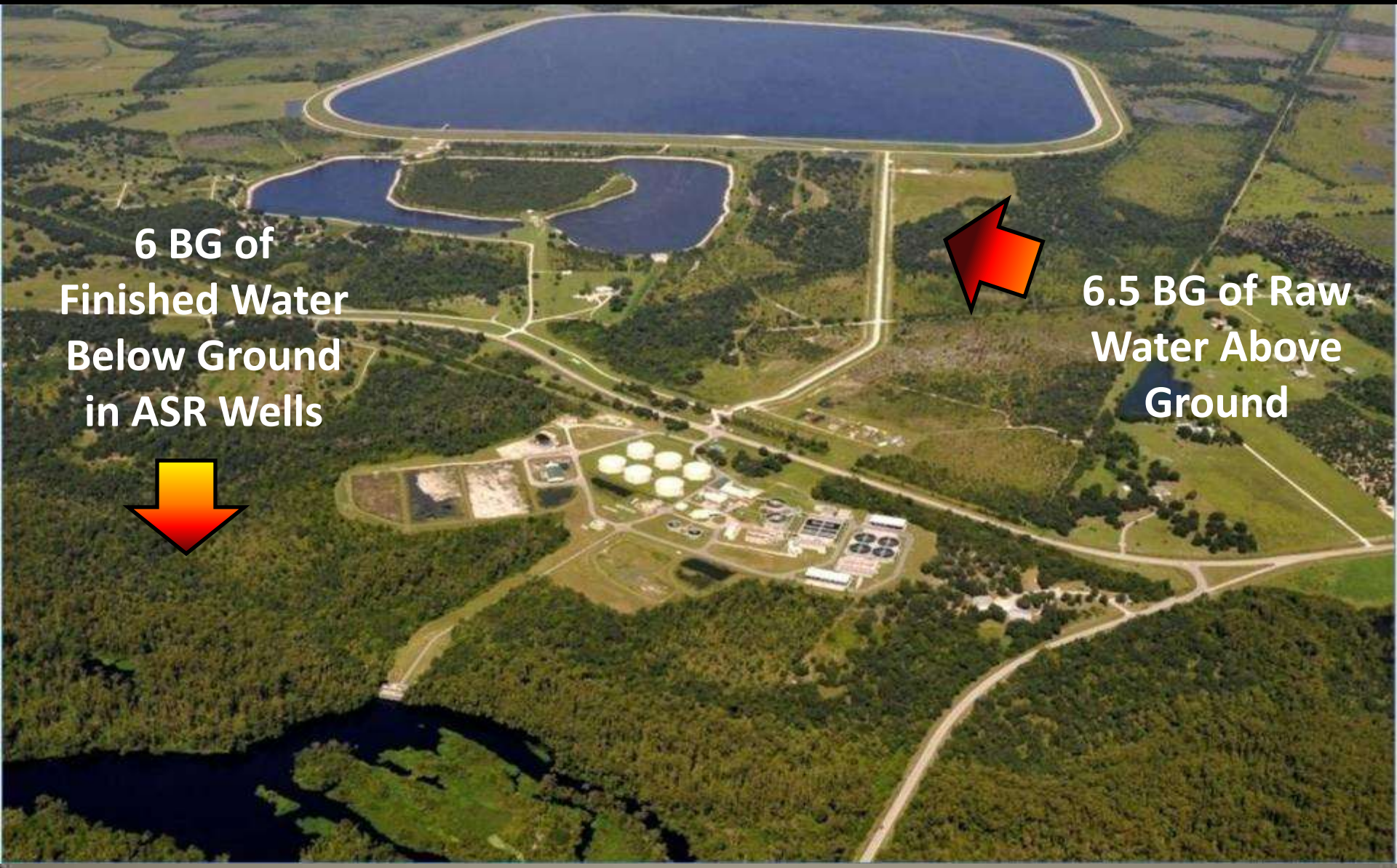
The Peace River's Flow is Highly Seasonal in Nature

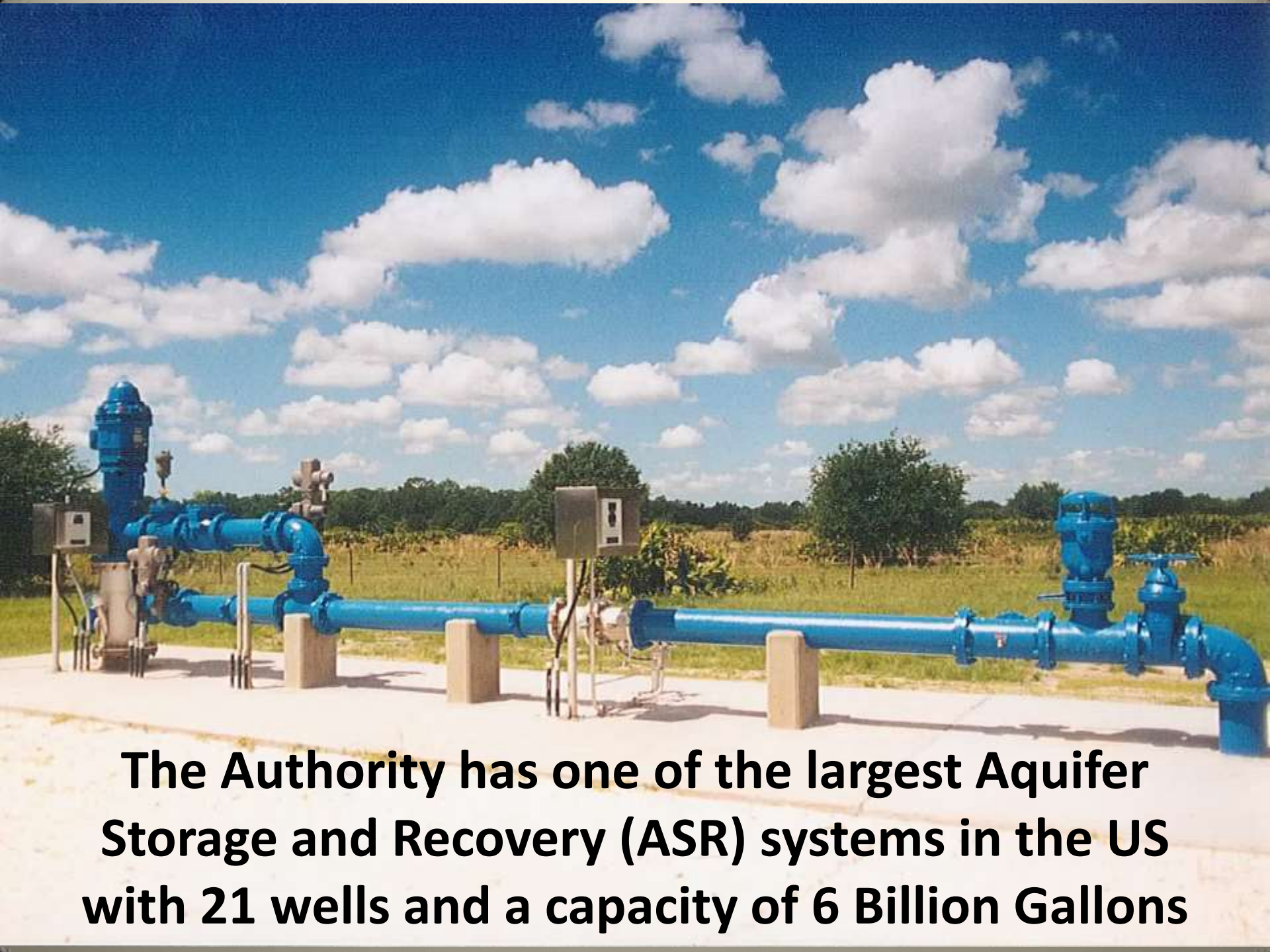
Dry Season

Wet Season


Total Stream Flow in Blue (MGD)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013

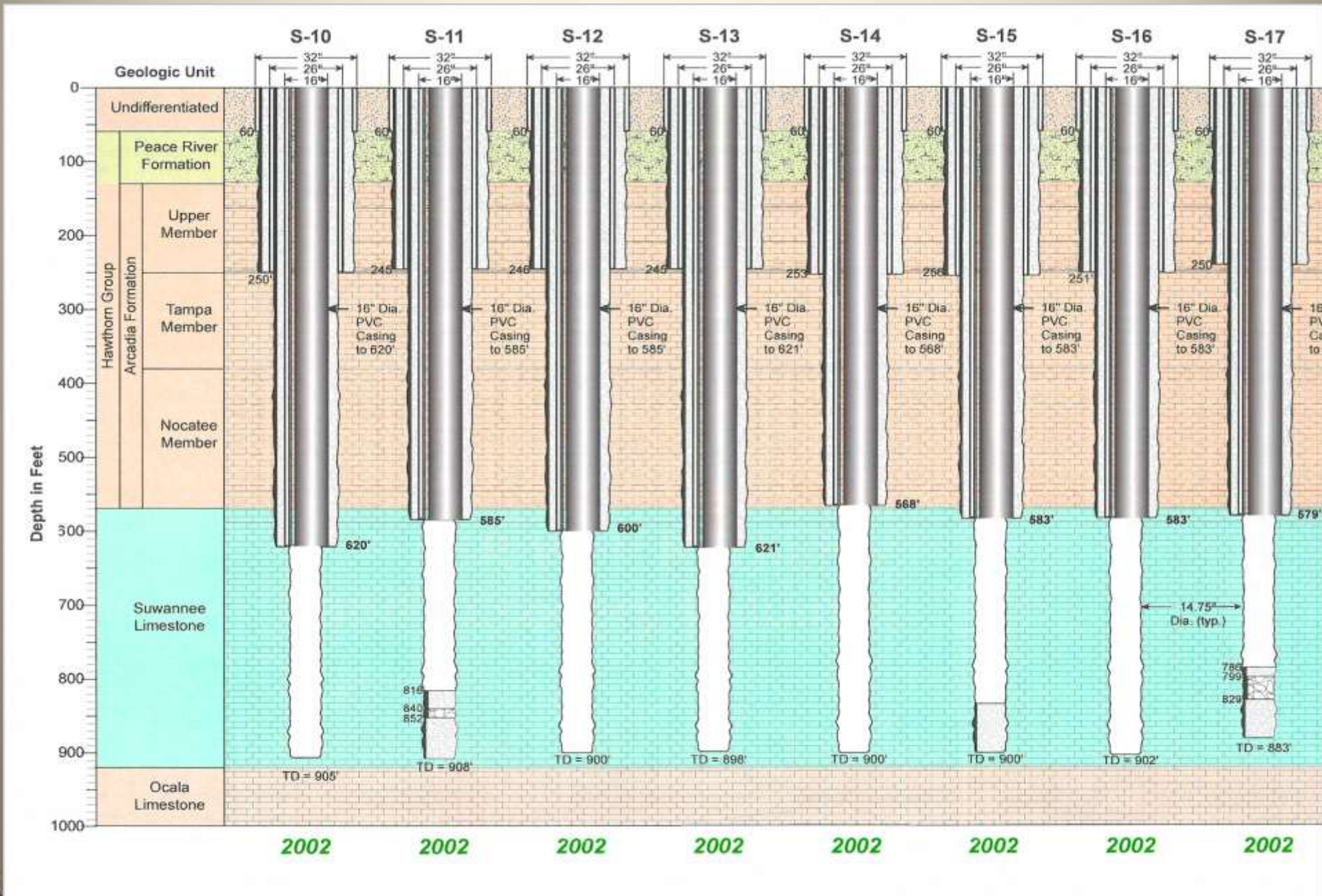
Storage is the Key to Resiliency for this System which Serves 300,000 in SW Florida



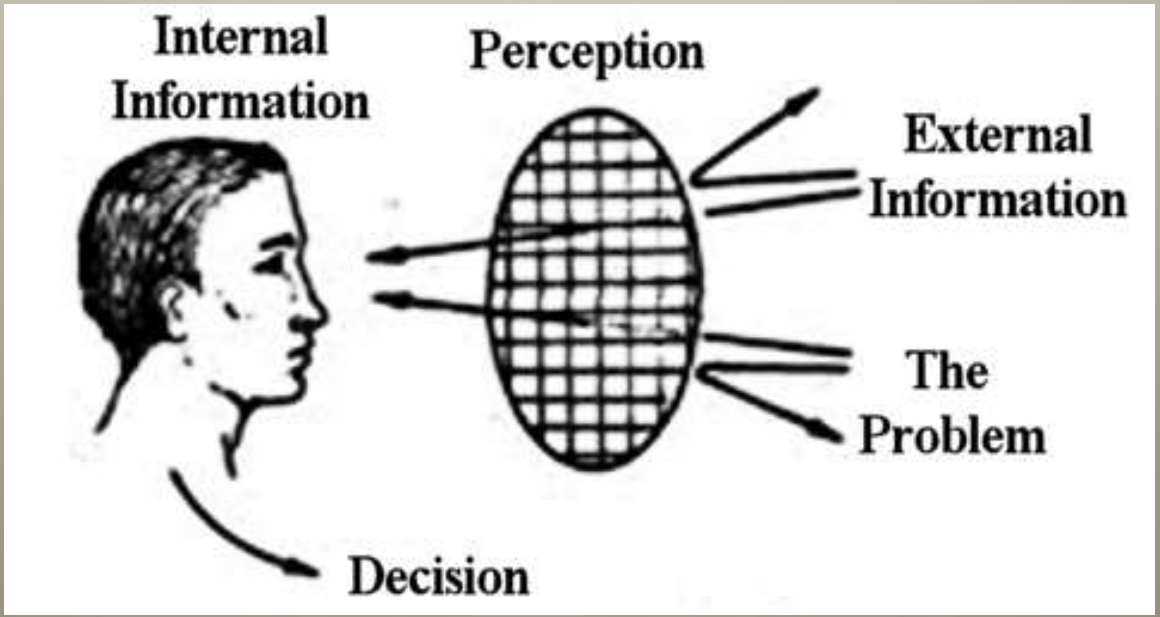


The Authority has one of the largest Aquifer Storage and Recovery (ASR) systems in the US with 21 wells and a capacity of 6 Billion Gallons

Cross Section of ASR Wells



- **Water Management Decisions involve:**
  - Processing great amounts of external data
  - Judgment synthesized from managers' understanding of external data and internal factors (past experiences, personality & emotions)



Focusing Efforts on a Central Question: "When to Start ASR Recovery?"

- Difficulty in developing a decision tool increases proportionally to the number of questions and variable interdependencies

- For this exercise, we Chose one Big Picture Question, that we struggle with annually **"When to Start ASR Recovery?"**

If ASR Recovery is Started **Too Soon**:

- Costs rise because ASR Water is treated twice, once before it is placed underground and upon recovery to remove arsenic

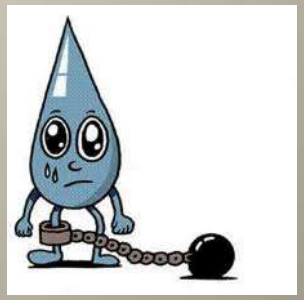
- "Clear" water in the reservoirs can contribute to algal blooms

- ASR Recovered water has higher TDS, too much can lead to water quality concerns

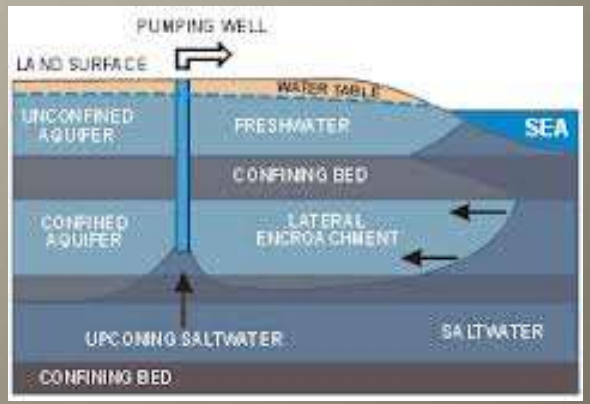
If ASR Recovery is Started **Too Late**:

- Less “good” quality water in the reservoirs to blend away effects of higher TDS ASR water

- Greater risk of running short = watering restrictions



- Having to pull too hard on the wells increases upconing from lower, higher salinity formations



Development of the Decision Tool

A = raw water reserves
< 1 BG = 1.00
1-2 BG = 0.75
2-3 BG = 0.50
3-4 BG = 0.25
4-5 BG = 0.00
5–6 BG = -0.10
> 6 BG = -0.20

B = month
January = 0.00
February = 0.08
March = 0.12
April = 0.25
May = 0.25
June= 0.12
July = -0.15
August = -0.25
September = -0.25
October = -0.10
November = 0.00
December = -0.05

C = ASR reserves
0-1 BG = 0.20
1-2 BG = 0.12
2-3 BG = 0.08
> 3BG = 0.10

D = Keetch Byram Index for watershed
0–100 = -0.10
100-200 = -0.05
200-300 = 0.00
300-400 = 0.03
400-500 = 0.08
500-600 = 0.10
600-700 = 0.12
> 700 = 0.15

E = USGS river flow at Arcadia (cfs)
< 75 = 0.35
75–130 = 0.25
130-300 = 0.15
300-600 = 0.05
600–1,000 = 0.00
1,000-3,000= -0.15
> 3,000 = -0.30

ASR Recovery Initiation Decision: $F(A+B+C+D+E+F+G+H+I+J) = X$

where:

if $0<X<1$, the decision is "No"

if $X>1$, the decision is "Yes"

F = CPC 1 Month Precip Outlook
Above Normal = -0.10
Normal/EC = 0.00
Below Normal = 0.15

G = CPC 1 Month Temp Outlook
Above Normal = 0.07
Normal/EC = 0.00
Below Normal = -0.05

H = CPC 3 Month Precip Outlook
Above Normal = -0.15
Normal/EC = 0.00
Below Normal = 0.20

I = CPC 3 Month Temp Outlook
Above Normal = 0.10
Normal/EC = 0.00
Below Normal = -0.08

J = Demands
< 90% RAA = -0.08
90 - 95% RAA = -0.04
95 - 105% RAA = 0.00
105 - 110% RAA = 0.04
> 110% RAA = 0.08

Choosing Variables and Scaling According to Importance

Some variables are more important than others

Table 1

Decision Tool Variables In Order of Decreasing Importance

Rank	Variable	Range of Values
1	Raw Water Reserves	1.20
2	River Flow	0.65
3	Month	0.50
4	3 Month Precip Forecast	0.35
5	KBDI	0.25
6	1 Month Precip Forecast	0.25
7	ASR Reserves	0.20
8	3 Month Temp Forecast	0.18
9	Demands	0.16
10	1 Month Temp Forecast	0.12

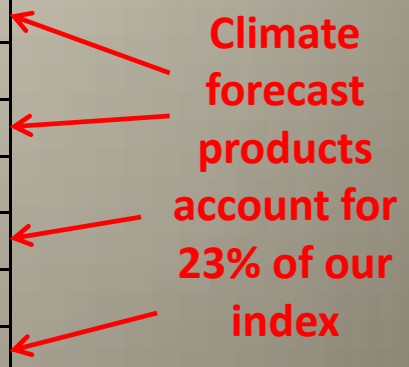
Top 3 variables count for 60% of our index

Choosing Variables and Scaling According to Importance

Table 1

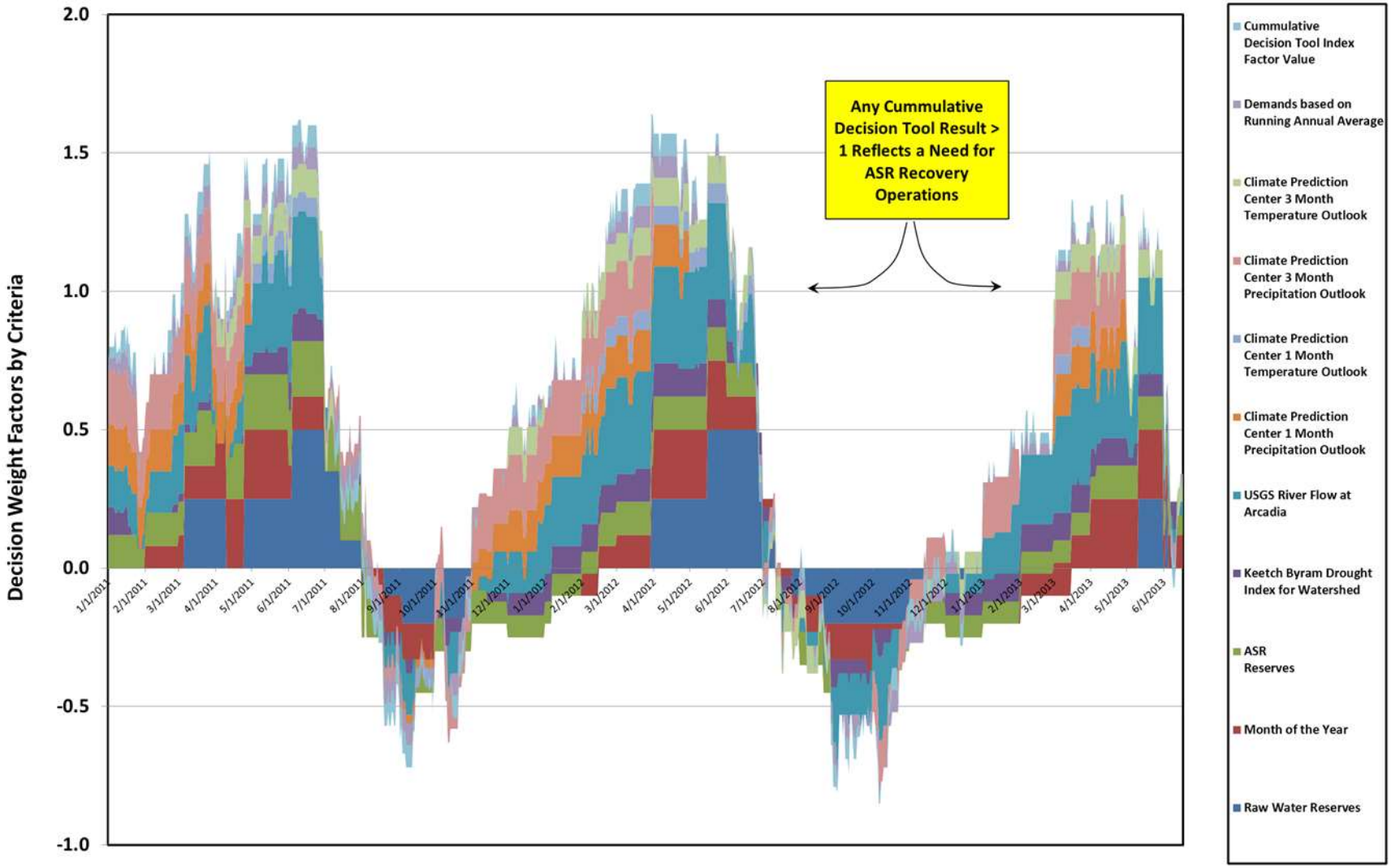
Decision Tool Variables In Order of Decreasing Importance

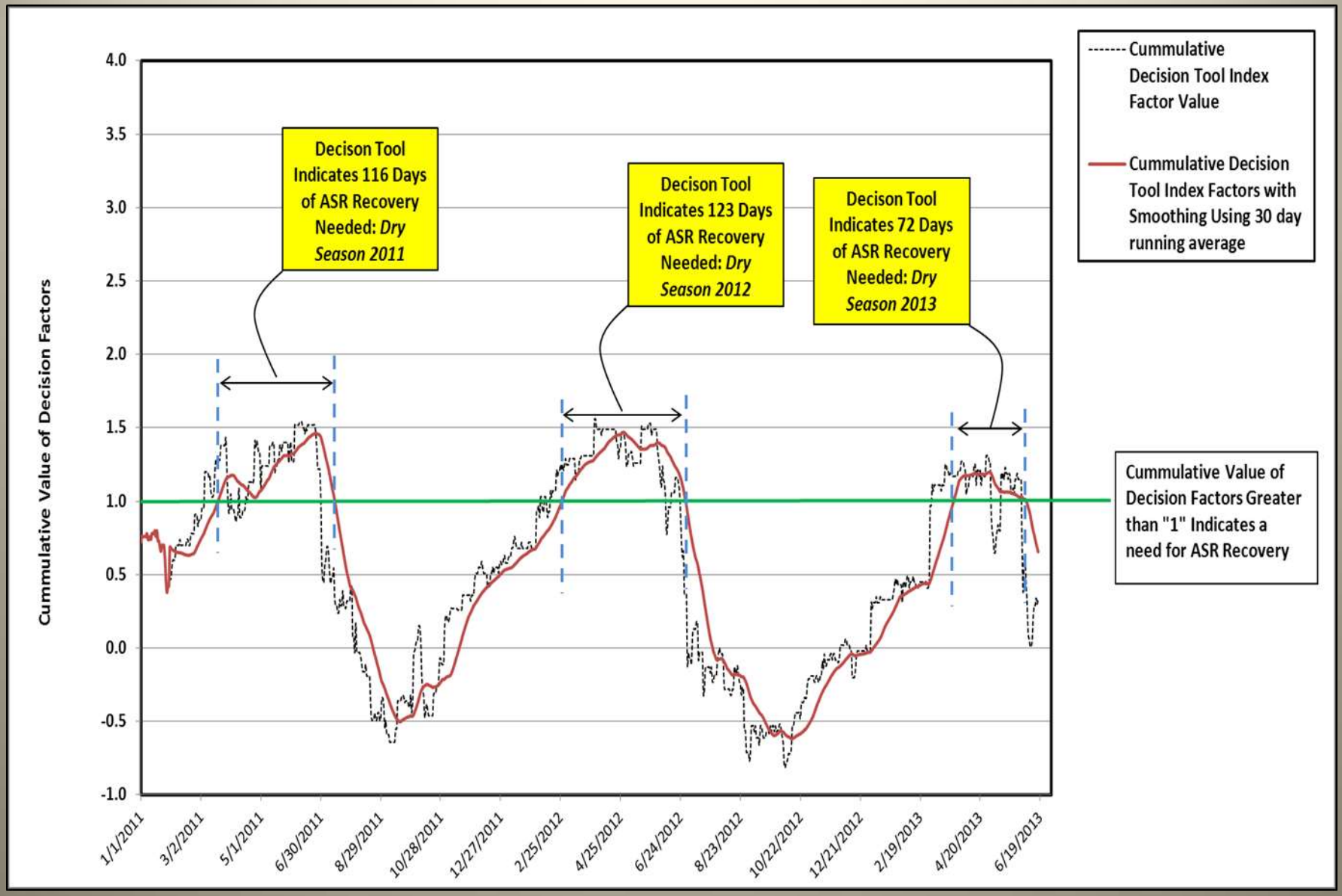
Rank	Variable	Range of Values
1	Raw Water Reserves	1.20
2	River Flow	0.65
3	Month	0.50
4	3 Month Precip Forecast	0.35
5	KBDI	0.25
6	1 Month Precip Forecast	0.25
7	ASR Reserves	0.20
8	3 Month Temp Forecast	0.18
9	Demands	0.16
10	1 Month Temp Forecast	0.12



	A		B		C		D		E		F		G		H		I		J					
	Raw Water Reserves		Month of the Year		ASR Reserves		Keetch Byram Drought Index for Watershed		USGS River Flow at Arcadia		Climate Prediction Center 1 Month Precipitation Outlook		Climate Prediction Center 1 Month Temperature Outlook		Climate Prediction Center 3 Month Precipitation Outlook		Climate Prediction Center 3 Month Temperature Outlook		Demands based on Running Annual Average				Cummulative Decision Tool Index Factor Value	Cummulative Decision Tool Index Factors with Smoothing Using 30 day running average
	Reserves (BG)	Factor	Month	Factor	Reserves (BG)	Factor	Value	Factor	Flow (cfs)	Factor	Prediction	Factor	Prediction	Factor	Prediction	Factor	Prediction	Factor	Range (% of Running Annual Average)	Factor				
	< 1	1.00	Jan	0.00	0 - 1 BG	0.20	0 – 100 = -0.20	-0.10	<75	0.35	Above Normal	-0.10	Above Normal	0.07	Above Normal	-0.15	Above Normal	0.10	< 90% RAA	-0.08				
	1 - 2	0.75	Feb	0.08	1 - 2 BG	0.12	100 - 200 = 0.00	-0.05	75 - 130	0.25	Normal/Equal Chance	0.00	Normal/Equal Chance	0.00	Normal/Equal Chance	0.00	Normal/Equal Chance	0.00	90 - 95% RAA	-0.04				
	2 - 3	0.50	Mar	0.12	2 - 3 BG	0.08	200 - 300 = 0.00	0.00	130 - 300	0.15	Below Normal	0.15	Below Normal	-0.05	Below Normal	0.20	Below Normal	-0.08	95 - 105% RAA	0.00				
	3 - 4	0.25	Apr	0.25	> 3 BG	0.00	300 - 400 = 0.00	0.03	300 - 600	0.05									105 - 110% RAA	0.04				
	4 - 5	0.00	May	0.25			400 - 500 = 0.00	0.08	600 - 1,000	0.00									> 110% RAA	0.08				
	5 - 6	-0.10	Jun	0.12			500 - 600 = 0.00	0.10	1,000 - 3,000	-0.15														
	> 6	-0.20	Jul	-0.15			600 - 700 = 0.00	0.12	> 3,000	-0.30														
			Aug	-0.25			> 700	0.15																
			Sep	-0.25																				
			Oct	-0.10																				
			Nov	0.00																				
Date			Dec	-0.05																	Demands (MGD)	Demands as a Percent of RAA	Factor	
1/1/2011	4.436	0.00	Jan-11	0.00	1.424	0.12	540	0.10	181	0.15	B	0.15	N	0.00	B	0.20	N	0.00	23.205	104%	0.00	0.72	0.72	
1/2/2011	4.424	0.00	Jan-11	0.00	1.424	0.12	542	0.10	175	0.15	B	0.15	N	0.00	B	0.20	N	0.00	23.386	105%	0.04	0.76	0.76	
1/3/2011	4.403	0.00	Jan-11	0.00	1.424	0.12	545	0.10	165	0.15	B	0.15	N	0.00	B	0.20	N	0.00	23.657	106%	0.04	0.76	0.76	
1/4/2011	4.361	0.00	Jan-11	0.00	1.424	0.12	546	0.10	155	0.15	B	0.15	N	0.00	B	0.20	N	0.00	23.53	106%	0.04	0.76	0.76	
1/5/2011	4.354	0.00	Jan-11	0.00	1.420	0.12	548	0.10	146	0.15	B	0.15	N	0.00	B	0.20	N	0.00	23.974	108%	0.04	0.76	0.76	
1/6/2011	4.344	0.00	Jan-11	0.00	1.415	0.12	507	0.10	159	0.15	B	0.15	N	0.00	B	0.20	N	0.00	24.288	109%	0.04	0.76	0.76	
1/7/2011	4.338	0.00	Jan-11	0.00	1.408	0.12	496	0.08	187	0.15	B	0.15	N	0.00	B	0.20	N	0.00	25.157	113%	0.08	0.78	0.78	
1/8/2011	4.309	0.00	Jan-11	0.00	1.402	0.12	497	0.08	225	0.15	B	0.15	N	0.00	B	0.20	N	0.00	24.129	108%	0.04	0.74	0.74	
1/9/2011	4.299	0.00	Jan-11	0.00	1.396	0.12	499	0.08	205	0.15	B	0.15	N	0.00	B	0.20	N	0.00	24.132	108%	0.04	0.74	0.74	
1/10/2011	4.290	0.00	Jan-11	0.00	1.390	0.12	501	0.10	182	0.15	B	0.15	N	0.00	B	0.20	N	0.00	24.132	108%	0.04	0.76	0.76	
1/11/2011	4.290	0.00	Jan-11	0.00	1.384	0.12	497	0.08	168	0.15	B	0.15	N	0.00	B	0.20	N	0.00	24.41	110%	0.04	0.74	0.74	
1/12/2011	4.279	0.00	Jan-11	0.00	1.378	0.12	498	0.08	159	0.15	B	0.15	N	0.00	B	0.20	N	0.00	25.684	115%	0.08	0.78	0.78	
1/13/2011	4.263	0.00	Jan-11	0.00	1.373	0.12	499	0.08	158	0.15	B	0.15	N	0.00	B	0.20	N	0.00	25.169	113%	0.08	0.78	0.78	
1/14/2011	4.252	0.00	Jan-11	0.00	1.367	0.12	499	0.08	149	0.15	B	0.15	N	0.00	B	0.20	N	0.00	25.135	113%	0.08	0.78	0.78	
1/15/2011	4.240	0.00	Jan-11	0.00	1.361	0.12	500	0.10	143	0.15	B	0.15	N	0.00	B	0.20	N	0.00	25.416	114%	0.08	0.80	0.80	
1/16/2011	4.226	0.00	Jan-11	0.00	1.356	0.12	502	0.10	136	0.15	B	0.15	N	0.00	B	0.20	N	0.00	24.452	110%	0.04	0.76	0.76	
1/17/2011	4.218	0.00	Jan-11	0.00	1.350	0.12	504	0.10	136	0.15	B	0.15	N	0.00	B	0.20	N	0.00	24.609	110%	0.08	0.80	0.80	
1/18/2011	4.198	0.00	Jan-11	0.00	1.344	0.12	373	0.03	139	0.15	B	0.15	N	0.00	B	0.20	N	0.00	24.833	111%	0.08	0.73	0.73	
1/19/2011	4.188	0.00	Jan-11	0.00	1.338	0.12	364	0.03	178	0.15	B	0.15	N	0.00	B	0.20	N	0.00	24.74	111%	0.08	0.73	0.73	
1/20/2011	4.164	0.00	Jan-11	0.00	1.332	0.12	369	0.03	211	0.15	B	0.15	N	0.00	B	0.20	N	0.00	23.872	107%	0.04	0.69	0.69	
1/21/2011	4.162	0.00	Jan-11	0.00	1.326	0.12	296	0.00	208	0.15	B	0.15	N	0.00	B	0.20	N	0.00	23.764	106%	0.04	0.66	0.66	
1/22/2011	4.158	0.00	Jan-11	0.00	1.320	0.12	275	0.00	222	0.15	B	0.15	N	0.00	B	0.20	N	0.00	25.041	112%	0.08	0.70	0.70	
1/23/2011	4.148	0.00	Jan-11	0.00	1.314	0.12	277	0.00	267	0.15	B	0.15	N	0.00	B	0.20	N	0.00	25.772	115%	0.08	0.70	0.70	
1/24/2011	4.126	0.00	Jan-11	0.00	1.308	0.12	279	0.00	257	0.15	B	0.15	N	0.00	B	0.20	N	0.00	25.449	114%	0.08	0.70	0.70	
1/25/2011	4.126	0.00	Jan-11	0.00	1.302	0.12	284	0.00	259	0.15	B	0.15	N	0.00	B	0.20	N	0.00	23.294	104%	0.00	0.62	0.62	
1/26/2011	4.184	0.00	Jan-11	0.00	1.298	0.12	164	-0.05	400	0.05	B	0.15	N	0.00	B	0.20	N	0.00	22.973	103%	0.00	0.47	0.47	
1/27/2011	4.180	0.00	Jan-11	0.00	1.292	0.12	169	-0.05	735	0.00	B	0.15	N	0.00	B	0.20	N	0.00	20.291	91%	-0.04	0.38	0.38	
1/28/2011	4.172	0.00	Jan-11	0.00	1.286	0.12	171	-0.05	760	0.00	B	0.15	N	0.00	B	0.20	N	0.00	21.495	96%	0.00	0.42	0.42	
1/29/2011	4.217	0.00	Jan-11	0.00	1.280	0.12	175	-0.05	630	0.00	B	0.15	N	0.00	B	0.20	N	0.00	22.931	103%	0.00	0.42	0.42	
1/30/2011	4.237	0.00	Jan-11	0.00	1.274	0.12	180	-0.05	530	0.05	B	0.15	N	0.00	B	0.20	N	0.00	21.96	98%	0.00	0.47	0.69	
1/31/2011	4.287	0.00	Jan-11	0.00	1.268	0.12	185	-0.05	466	0.05	B	0.15	N	0.00	B	0.20	N	0.00	21.3	95%	0.00	0.47	0.68	
2/1/2011	4.293	0.00	Feb-11	0.08	1.262	0.12	192	-0.05	415	0.05	B	0.15	N	0.00	B	0.20	N	0.00	21.608	97%	0.00	0.55	0.67	
2/2/2011	4.311	0.00	Feb-11	0.08	1.257	0.12	200	0.00	374	0.05	B	0.15	N	0.00	B	0.20	N	0.00	22.577	101%	0.00	0.60	0.67	
2/3/2011	4.315	0.00	Feb-11	0.08	1.251	0.12	208	0.00	338	0.05	B	0.15	N	0.00	B	0.20	N	0.00	21.997	98%	0.00	0.60	0.66	
2/4/2011	4.325	0.00	Feb-11	0.08	1.245	0.12	215	0.00	314	0.05	B	0.15	N	0.00	B	0.20	N	0.00	21.689	97%	0.00	0.60	0.66	
2/5/2011	4.340	0.00	Feb-11	0.08	1.239	0.12	223	0.00	297	0.15	B	0.15	N	0.00	B	0.20	N	0.00	22.34	100%	0.00	0.70	0.66	
2/6/2011	4.323	0.00	Feb-11	0.08	1.233	0.12	230	0.00	280	0.15	B	0.15	N	0.00	B	0.20	N	0.00	21.837	98%	0.00	0.70	0.65	
2/7/2011	4.345	0.00	Feb-11	0.08	1.227	0.12	225	0.00	267	0.15	B	0.15	N	0.00	B	0.20	N	0.00	21.688	97%	0.00	0.70	0.65	
2/8/2011	4.334	0.00	Feb-11	0.08	1.221	0.12	219	0.00	262	0.15	B	0.15	N	0.00	B	0.20	N	0.00	22.355	100%	0.00	0.70	0.65	

Individual Decision Tool Weight Components




Cummulative Value of Decision Factors
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1/1/2011
3/2/2011
5/1/2011
6/30/2011
8/29/2011
10/28/2011
12/27/2011
2/25/2012
4/25/2012
6/24/2012
8/23/2012
10/22/2012
12/21/2012
2/19/2013
4/20/2013
6/19/2013
Decison Tool Indicates 116 Days of ASR Recovery Needed: Dry Season 2011
Decison Tool Indicates 123 Days of ASR Recovery Needed: Dry Season 2012
Decison Tool Indicates 72 Days of ASR Recovery Needed: Dry Season 2013
Cummulative Decision Tool Index Factor Value
Cummulative Decision Tool Index Factors with Smoothing Using 30 day running average
Cummulative Value of Decision Factors Greater than "1" Indicates a need for ASR Recovery

In Summation

- **Recurring annual decision** every Feb - May
- **Stakes are High** - we could put ourselves at great disadvantage if we "miss" with our decisions
- **This is the Information Age -** data is readily available
- **Responsibility** to be good stewards and make resource decisions in thoughtful and deliberative manner
- **Political pressure** to exercise science and make defensible decisions

The End