Kyle E. Murray, PhD, Hydrogeologist

Presents:

Sustainability of Oklahoma Groundwater Systems? Climate versus Human Impact
Index Wells/Springs

Est Rech Rate 634 Mgal/d
Est Areal Rech 10.7 in/yr
Response time for an aquifer, may range from minutes to millions of years (Sophocleous, 2012).
Adaptive Management

### San Antonio Pool

<table>
<thead>
<tr>
<th>Critical Period Stage*</th>
<th>J-17 Index Well (feet above msl)</th>
<th>Comal Springs Flow (cfs)</th>
<th>San Marcos Springs Flow (cfs)</th>
<th>Withdrawal Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&lt; 660’ msl</td>
<td>&lt; 225 cfs</td>
<td>&lt; 95 cfs</td>
<td>20%</td>
</tr>
<tr>
<td>II</td>
<td>&lt; 650’ msl</td>
<td>&lt; 200 cfs</td>
<td>&lt; 80 cfs</td>
<td>30%</td>
</tr>
<tr>
<td>III</td>
<td>&lt; 640’ msl</td>
<td>&lt; 150 cfs</td>
<td>n/a</td>
<td>35%</td>
</tr>
<tr>
<td>IV</td>
<td>&lt; 630’ msl</td>
<td>&lt; 100 cfs</td>
<td>n/a</td>
<td>40%</td>
</tr>
</tbody>
</table>

### Average Monthly J-17 Levels

**January 1993 to December 2012**

- Record Low: 612.5’ (August 17, 1956)
- Record High: 703.3’ (June 14, 1992)

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**Aquifer Conditions**

<table>
<thead>
<tr>
<th>Area Index</th>
<th>Daily Readings</th>
<th>Ten Day Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bexar (J-17)</td>
<td>639.9</td>
<td>637.9</td>
</tr>
<tr>
<td>Uvalde (J-27)</td>
<td>837.4*</td>
<td>836.9*</td>
</tr>
<tr>
<td>Comal Springs</td>
<td>136</td>
<td>131</td>
</tr>
<tr>
<td>San Marcos Springs</td>
<td>129</td>
<td>119</td>
</tr>
</tbody>
</table>

Provisional Daily water readings as of 9:00 AM Oct 18, 2013

*J-27 reading on Oct 18, 2013

Understanding the readings: Display our readings on your website

San Antonio: Stage 3, 35%**

Uvalde: Stage 5, 44%**

**Withdrawal Reductions

Data from: USGS Water Resources Division, San Antonio, Edwards Aquifer Authority
Aquifers examined in this presentation

Dynamics of a groundwater system must be well understood to effectively manage the resource, especially for unconfined aquifers that are closely tied to surface water systems (Sophocleous, 2012).
High Plains (Ogallala) Aquifer

Est Rech Rate 232 Mgal/d
Est Areal Rech 0.7 in/yr

http://www.ncdc.noaa.gov/temp-and-precip/time-series/
http://waterdata.usgs.gov/nwis

Water Use Category
- Public Supply: 25%
- Livestock and Aquaculture: 25%
- Irrigation: 25%
- Other: 25%

Total Aquifer Withdrawals: 40 Mgal/d
Mgal/d, million gallons per day

OK Avg. Ann. Precip. (in)

Water Level Elevation (ft)

- Ann Prec
- 1% Wetter
- 50% Wet/Dry
- 1% Drier
- High Plains (Ogallala)
Rush Springs Aquifer

Est Rech Rate 208 Mgal/d
Est Areal Rech 1.8 in/yr

Water Use Category

- Public Supply: 25%
- Livestock and Aquaculture: 25%
- Irrigation: 25%
- Other: 25%

Total Aquifer Withdrawals: 40 Mgal/d

Mgal/d, million gallons per day

OK Avg. Ann. Precip. (in)

- Ann Prec
- 1% Wetter
- 50% Wet/Dry
- 1% Drier
- Rush Springs

Water Level Elev. (ft)

1375 1385 1395 1405 1415

18 22 26 30 34 38 42 46 50
Central Oklahoma (Garber-Wellington) Aquifer

**Central Oklahoma**
- 25% 40 Mgal/d
- 66%
- 3%

**Water Use Category**
- Public Supply 25%
- Livestock and Aquaculture 25%
- Irrigation 25%

***Est Rech Rate 220 Mgal/d***

***Est Areal Rech 1.6 in/yr***

![Graph showing historical water level elevation and annual precipitation trends in Central Oklahoma.](image-url)
Arbuckle-Simpson Aquifer

Est Rech Rate 141 Mgal/d
Est Areal Rech 5.6 in/yr

Water Use Category
- Public Supply: 25%
- Livestock and Aquaculture: 25%
- Irrigation: 25%
- Other: 25%

Total Aquifer Withdrawals: 40 Mgal/d

OK Avg. Ann. Precip. (in)


Water Level Elev. (ft)
1025 1035 1045 1055 1065

- Ann Prec
- 1% Wetter
- 50% Wet/Dry
- 1% Drier
- Arbuckle-Simpson Confined

Mgal/d, million gallons per day
Arbuckle-Simpson Aquifer

Est Rech Rate 141 Mgal/d
Est Areal Rech 5.6 in/yr

Water Use Category
- Other: 25%
- Public Supply: 25%
- Livestock and Aquaculture: 25%
- Irrigation: 25%

Total Aquifer Withdrawals: 40 Mgal/d

OK Avg. Ann. Precip. (in)
- Ann Prec
- 1% Wetter
- 50% Wet/Dry
- 1% Drier
- Arbuckle-Simpson Unconfined

Water Level Elevation (ft)
Relations between climatic variability and hydrologic time series?

- ENSO – El Nino / Southern Oscillation (2 – 6 year cycles)
- PDO – Pacific Decadal Oscillation (10 – 25 year cycles)

Climatic variability versus Human Impact?

- **ENSO** – El Niño / Southern Oscillation (2 – 6 year cycles)
- **PDO** – Pacific Decadal Oscillation (10 – 25 year cycles)

Temporally Varying Data

Independent Natural Variables

- El Nino Southern Oscillation (ENSO) Index
- Pacific Decadal Oscillation (PDO) Index
- Precipitation
  - Local station
  - Local tree ring study
- Temperature
- Groundwater recharge as a function of land cover/geology

Independent Human Impact

- Groundwater withdrawal
- Surface water withdrawal
- Land-use change

Dependent Hydrologic Measures

- Surface water discharge (Spring, Creek and River)
- Groundwater levels
  - Mesonet site [https://www.owrb.ok.gov/studies/groundwater/gw_monitor_sites.php](https://www.owrb.ok.gov/studies/groundwater/gw_monitor_sites.php)
Normally distributed hydrologic time series?

Annual Precipitation in Climate Division 08

[Graph showing annual precipitation data from 1895 to 2015 with departures from the annual mean in units of standard deviation]

Fraction of Occurrence

[Fraction of occurrence histogram for Departure from Annual Mean (Units of Standard Deviation)]

Legend:
- Fittstown Well Water Level
- Annual Precipitation
- Byrds Mill Spring
Co-variation of hydrologic time series?

For Fittstown Well Water Level vs. Byrds Mill Spring Discharge:
- Scatter plot with a trend line.
- R² = 0.8164

For Treering Precipitation vs. Fittstown Well Water Level:
- Scatter plot with a trend line.
- R² = 0.4212
Co-variation of hydrologic time series? 

**Graph 1:**
- **Variables:** Departure from annual mean (units of standard deviation) vs. ENSO Index.
- **Plot:** Depiction of scatterplot and trendline.
- **Metrics:** $R^2 = 0.0141$.

**Graph 2:**
- **Variables:** Departure from annual mean (units of standard deviation) vs. PDO Index.
- **Plot:** Depiction of scatterplot and trendline.
- **Metrics:** $R^2 = 0.0104$.
Adaptive Management Approach
• Develop a flexible conservation and water use plan
• Identify needs of each unique groundwater system

Current and Future Data
• Report accurate, annual water use data for all sectors
• Measure daily/monthly groundwater levels in ‘index’ wells
• Measure and estimate seasonal groundwater recharge

Past Data
• Backcast water use for all sectors
• Estimate historic regional precipitation from tree-ring studies

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Importance of Groundwater Management

Human activities can directly trigger a drought unlike other natural hazards, with exacerbating factors such as overfarming, excessive irrigation, deforestation, over-exploiting available water, and erosion, adversely impacting the ability of the land to capture and hold water.

How does today compare to historic dry cycles?

## Oklahoma Groundwater Resources

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Storage (AF)</th>
<th>Wthdrwl in 2005 (AF)</th>
<th>Avg Ann Rech (AF)</th>
<th>Rech Rate (in/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 High Plains (Ogallala)</td>
<td>90,590,000</td>
<td>282,615</td>
<td>259,943</td>
<td>0.7</td>
</tr>
<tr>
<td>2 Rush Springs</td>
<td>79,838,000</td>
<td>57,844</td>
<td>233,250</td>
<td>1.8</td>
</tr>
<tr>
<td>3 Central Oklahoma</td>
<td>58,583,000</td>
<td>45,210</td>
<td>246,676</td>
<td>1.6</td>
</tr>
<tr>
<td>4 Antlers</td>
<td>53,570,000</td>
<td>9,988</td>
<td>228,252</td>
<td>1.0</td>
</tr>
<tr>
<td>5 Roubidoux</td>
<td>43,029,000</td>
<td>9,842</td>
<td>618,451</td>
<td>2.5</td>
</tr>
<tr>
<td>6 Boone</td>
<td>33,751,000</td>
<td>9,842</td>
<td>1,716,598</td>
<td>10.5</td>
</tr>
<tr>
<td>7 Pennsylvanian</td>
<td>26,382,000</td>
<td></td>
<td>148,089</td>
<td>1.1</td>
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<tr>
<td>8 El Reno</td>
<td>18,750,000</td>
<td></td>
<td>241,143</td>
<td>0.8</td>
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<tr>
<td>9 Vamoosa-Ada</td>
<td>14,931,000</td>
<td>8,576</td>
<td>145,150</td>
<td>1.1</td>
</tr>
<tr>
<td>10 North-Central Oklahoma</td>
<td>14,250,000</td>
<td></td>
<td>154,116</td>
<td>1.0</td>
</tr>
<tr>
<td>11 East-Central Oklahoma</td>
<td>13,940,000</td>
<td></td>
<td>226,477</td>
<td>2.8</td>
</tr>
<tr>
<td>12 Woodbine</td>
<td>12,630,000</td>
<td></td>
<td>264,599</td>
<td>2.2</td>
</tr>
<tr>
<td>13 Arbuckle-Simpson</td>
<td>9,470,000</td>
<td>7,365</td>
<td>158,163</td>
<td>5.6</td>
</tr>
<tr>
<td>28 Blaine</td>
<td>1,403,000</td>
<td>30,771</td>
<td>58,186</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Estimates from OWRB (2012) Comprehensive Water Plan