Context for Central Sands Water Use Trends and Impacts

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History of studies near the Little Plover River
The Little Plover movie (1963) documents a field demonstration of how pumping a well near the river depleted the river’s flow.

From the movie (29:11):
“...we can now also predict what effect groundwater withdrawal from wells at different locations will have on streamflow. ...we have the information to predict changes in this system caused by artificial withdrawals.”

Previous work

Weeks, 1965: “The withdrawal of either ground water or surface water for consumptive use may cause both a decrease in streamflow and a lowering of ground-water levels...Frequently, the seasonal effects of water development are more critical than the effects on the total supply.”

Weeks and Stangland, 1971: “Extensive development of ground water for irrigation, in the sand-plain area has affected streamflow and water levels.”

Kraft and others, 2012: “…irrigation water availability in the northern lake states and other regions with strong groundwater-surface water connections is tied to concerns for surface water health, requiring a focus on managing the upper few meters of aquifers on which surface waters depend rather than the depletability of an aquifer.”
A misconception about groundwater availability. The aquifer can provide lots of water for wells, but…

GW stored vs. GW available

…only the top few feet are available for the stream. This is the case in the Sand Plain.
Objectives

This project developed the following:

1. A groundwater flow and optimization model as a science-based expert system for decision support of water management in the Little Plover River Basin. The Little Plover is a pilot location to evaluate techniques that might later be expanded to the entire central sands region.

2. A platform to demonstrate fundamental scientific constraints inherent to the hydrologic system and context for the costs and benefits for differing scenarios.

3. An educational tool for fostering science-based discussion for both the public and the technical community.
Conceptual model

The conceptual model summarizes the features included in the computer simulation.

Examples

The model can be used to evaluate alternative management scenarios, such as reducing pumping of specific wells or changing land use or irrigation rates.

Here we present two examples:

1. Simulating a single new well.

2. Determining where groundwater discharging to the river originates and how cumulative pumping might have altered river flows.
How the well affects the river:

At steady state, and with irrigation return, 65% of the well discharge is water that would otherwise have discharged to the Little Plover River.

This represents a base flow decline of 0.2 CFS at the Hoover gage.

<table>
<thead>
<tr>
<th>Gage site</th>
<th>Baseline baseflow, CFS</th>
<th>Baseflow with well, CFS</th>
<th>change, CFS</th>
<th>change, ft³/d</th>
<th>% change</th>
<th>% of well discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kennedy</td>
<td>1.0</td>
<td>0.9</td>
<td>0.1</td>
<td>4320</td>
<td>5.1</td>
<td>18</td>
</tr>
<tr>
<td>Eisenhower</td>
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<td>2.1</td>
<td>0.1</td>
<td>10368</td>
<td>5.5</td>
<td>44</td>
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<tr>
<td>Hoover</td>
<td>5.4</td>
<td>5.2</td>
<td>0.2</td>
<td>15552</td>
<td>3.3</td>
<td>65</td>
</tr>
</tbody>
</table>

Steady-state, Q=23,800 ft³/day

Transient response: one year

Change in base flow and drawdown in response to pumping a single well.

There is a delay of weeks to months between changes in pumping and impacts to the river.

Note that drawdown recovers much faster than streamflow.
What is the cumulative impact of existing pumping on the Little Plover River?

This is a difficult question, because it depends on many variables, including:
• Land use
• Well construction and pumping history
• Crop type, planting and harvest dates (changes every year)
• Irrigation practices (varies between Growers and between years)
• Timing of land use change
• Variations in weather
  • Long-term (decades)
  • Short-term (weeks or months)

However, we can use the model to estimate the impacts…
The simulated contributing area shows the source of groundwater discharging to the river today. Jagged appearance occurs because wells interrupt some of the flow.

Now remove all the wells and change recharge to non-irrigated land use....

....this gives us an approximation of pre-pumping conditions...
The simulated "no-pumping" contributing area is significantly larger than the contributing area today.

River flow is proportional to size of the contributing area.
Difference in water table levels. Water levels rise by about 2-6 feet; greater adjacent to specific wells.

Implication: pumping has reduced water-table levels by 2-6 feet

Steady-state simulated flows

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Flows</th>
<th>Basin recharge</th>
<th>Basin Pumping</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kennedy</td>
<td>Eisenhower</td>
<td>Hoover</td>
</tr>
<tr>
<td>present day</td>
<td>cfs</td>
<td>cfs</td>
<td>cfs cfs in/yr</td>
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<tr>
<td></td>
<td>1.0</td>
<td>2.2</td>
<td>5.4</td>
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<tr>
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<td>16.3</td>
<td>10.4</td>
<td>5.9 3.8</td>
</tr>
<tr>
<td>pre-development</td>
<td>2.7</td>
<td>5.5</td>
<td>9.9</td>
</tr>
<tr>
<td>change</td>
<td>-1.7</td>
<td>-3.4</td>
<td>-4.5</td>
</tr>
<tr>
<td>Percent change</td>
<td>-63%</td>
<td>-61%</td>
<td>-45%</td>
</tr>
</tbody>
</table>

Under steady-state conditions, the model indicates that under no pumping and non-irrigated land use the average flow would increase by approximately 1.7 to 4.5 cfs at the gaging sites along the Little Plover River during an “average” year (similar to 2013).
Depletion Potential: The amount of groundwater discharge that is intercepted or diverted to an extraction well that would otherwise go to a stream.

“Depletion potential” ($R$), is a ratio between 0 and 1.0 that is the change in streamflow at a specified location (stream gages) due to a change in pumping rate at a well through either interception, diversion or reversed flow.

$$R = \frac{\Delta Q_{stream}}{\Delta Q_{well}}$$

$\Delta Q_{stream}$ is the change in flow at a stream constraint location
$\Delta Q_{well}$ is the change in well pumping simulated

Key Findings about the Little Plover

The river is closely connected to the groundwater system; vulnerable to impacts from nearby pumping.

Irrigation accounts for about 80% of total water use in the basin, primarily during the summer.

Land use and crop patterns affect recharge rates, which in turn affect groundwater levels and stream flows.

River base flow is proportional to the groundwater contributing area, and the contributing area was greater under pre-development conditions than current.

There can be a delay of weeks to months between changes in pumping and impacts on the river, depending on the distance between the well and the river.