Geosyntec consultants

City of Klamath Falls

Review of Oregon Water Resources Department model for Fremont and Wocus wells, and the Conger well field

Dr. Rob Annear, P.E., Cindy Bartlett, R.G., and Erin Dunbar

Purpose and Scope

Purpose

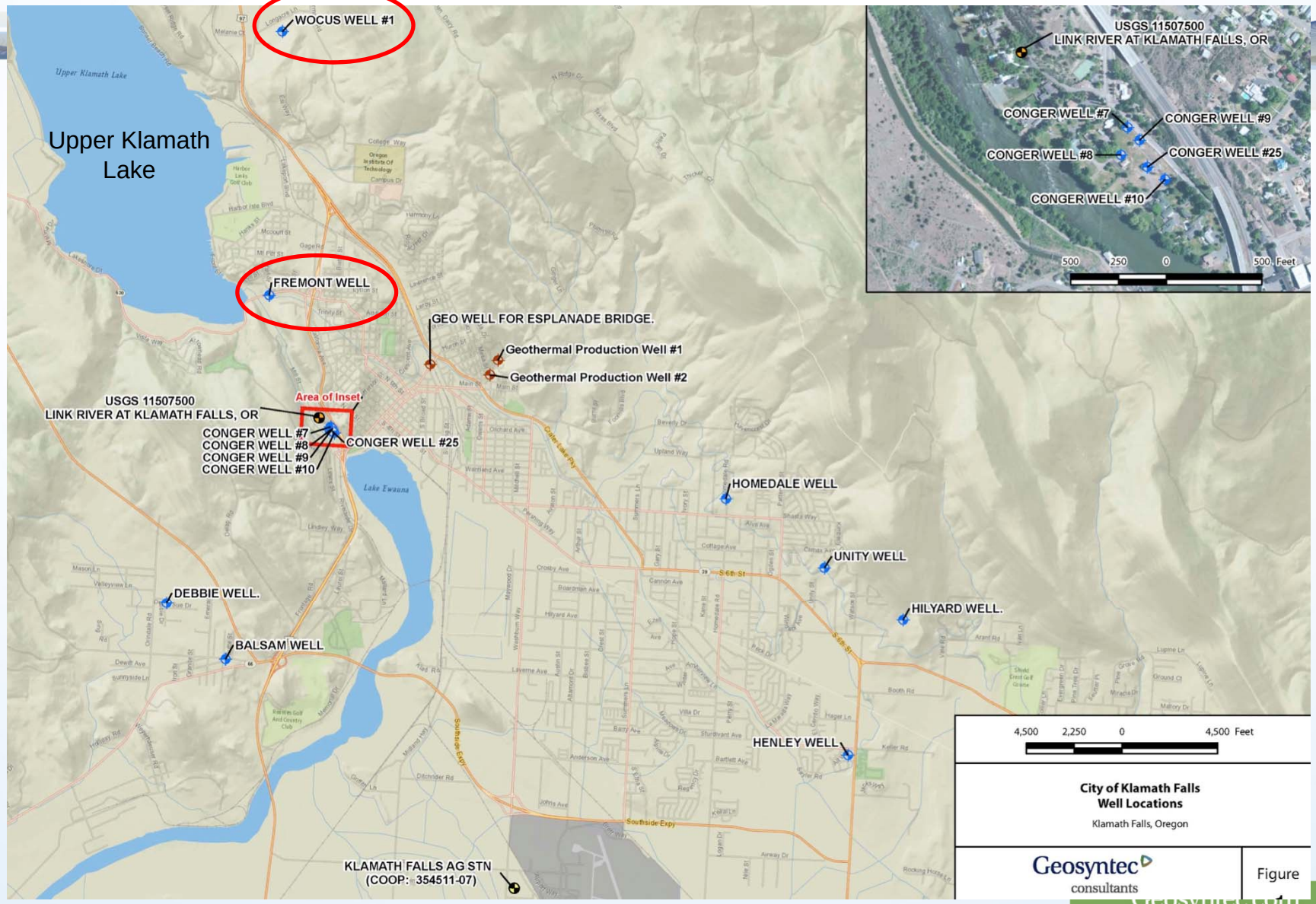
1. Understand technical basis for OWRD shutoff notice issued to City for two wells, Wocus and Fremont;
2. Conduct analyses/modeling to potentially challenge the OWRD model; and
3. Address City questions and concerns about the future stability of their groundwater supply and geothermal wells.

Scope

1. Review background information:
   a. Review existing City well data for Wocus, Fremont, and Conger wells
   b. USGS Reports and Model Findings
   c. Reviewed geology and hydrogeology
2. Review OWRD Model (based on Hunt, 2003)
3. Evaluate Alternative Model
4. Evaluate Geothermal Sustainability
5. Provide advice and next steps

Geosyntec consultants

Well Locations



Preliminary and Confidential

Geosyntec consultants

Background

- Geologic stratigraphy for Wocus, Fremont, and Conger wells:
  - A mix of volcanic (basalts) and sedimentary (clays, sands) formations
  - Very different hydrogeologic properties for water flow both horizontally and vertically
- Daily pumping activity for Wocus, Fremont, and Conger wells
  - In 2013 for example:
    - Wocus well was operated 2 days
    - Fremont well was operated from May - October
    - Conger well field was operated at 100%, but each well intermittently.
  - Fremont and Conger pump more in summer.
  - Average pumping rates for Fremont and Conger have not increased over the last 15 years.

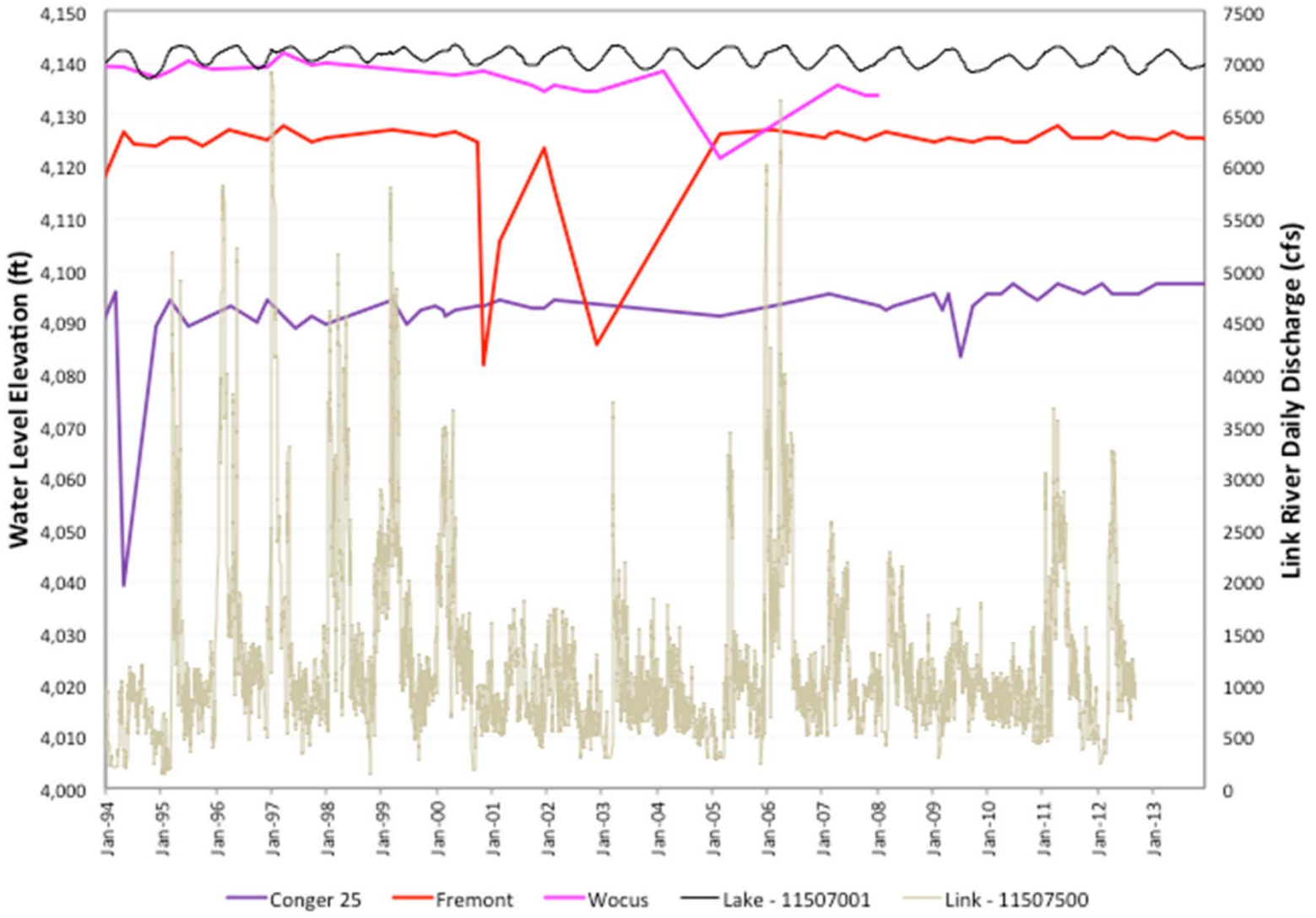
Geosyntec consultants

Background

- Local hydrology reviewed
  - Link River discharge, regulated by dam and lake level management.
  - Klamath Lake surface water elevations.
  - Precipitation record at Klamath Airport, increased precipitation is reflected in increased flows in the Link River.
- Water levels of Wocus, Fremont, and Conger wells
  - Water levels general stable to slightly declining at a couple wells.
- Aquifer pump test data for Wocus well (1991 and 1992)
  - Water level data from observation wells don't show significant influence.
  - The shallow well observation data establish that pumping has:
    - little influence on shallow groundwater; and
    - little influence on surface water.

Geosyntec consultants

Local Hydrology



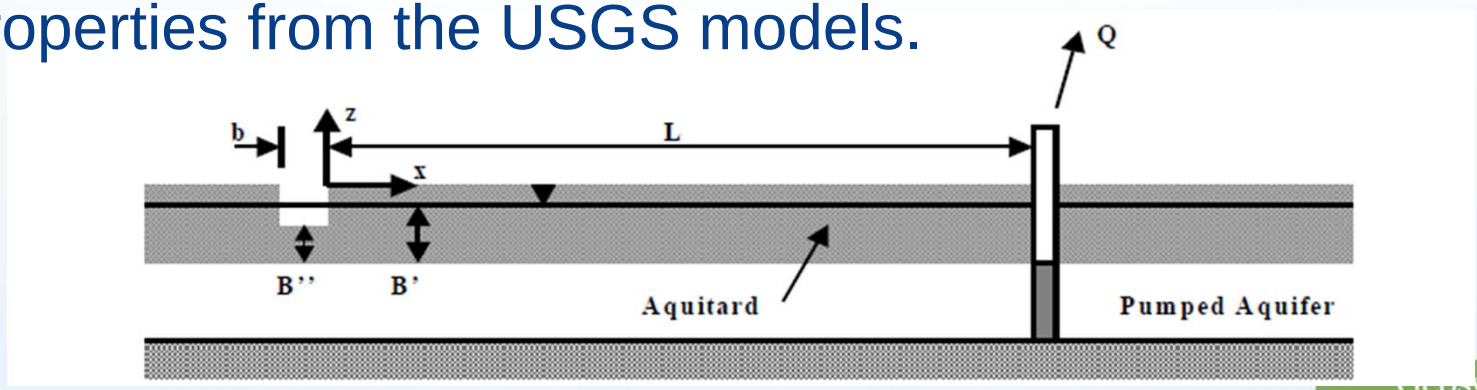
Geosyntec consultants

Review of USGS Reports

- Groundwater Hydrology of the Upper Klamath Basin (Gannett et al., 2007)
  - General descriptions of regional groundwater flow
  - Geologic units (9 total)
  - Aquifer properties estimated from selected wells
- Groundwater Simulation and Management Models for the Upper Klamath Basin (Gannett et al., 2012)
  - Basin-wide groundwater model (MODFLOW)
  - Assigned geologic unit thicknesses and aquifer properties

OWRD Shutoff Basis, OWRD Model Review

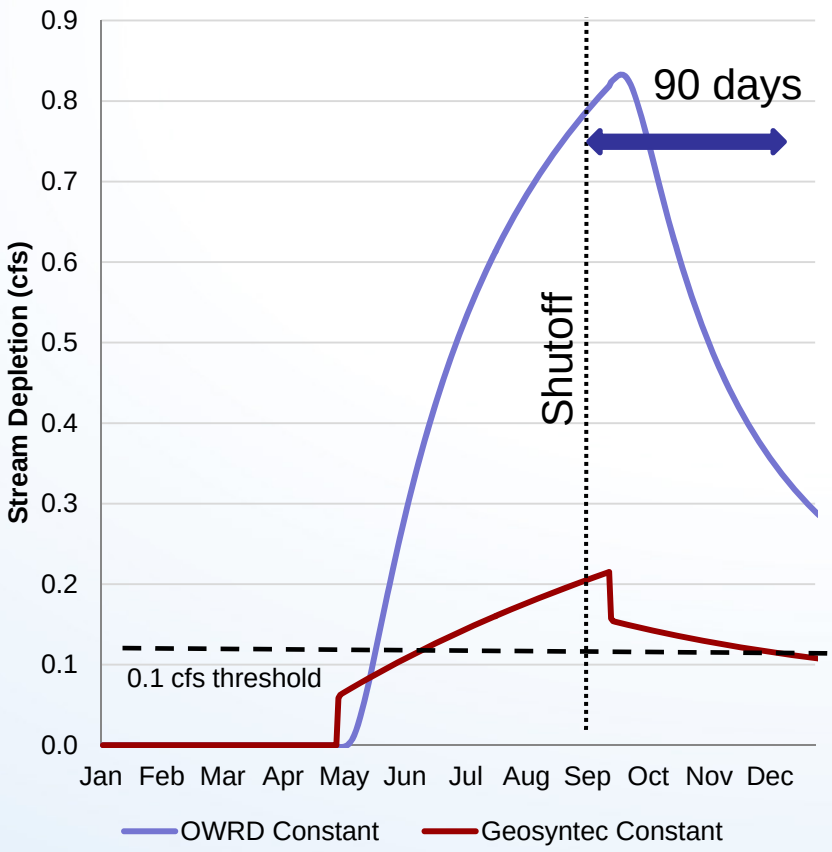
- A shutoff notice based on OWRD's model and "draft" OAR guidance was provided to the City in June 2014.
- OWRD provided a copy of their spreadsheet model in August 2014, which was developed in March 2014 based in part on the model by Hunt (Hunt, 2003).
- Used to calculate stream depletion and recovery based on a pumping scheme.
- The OWRD model was re-run using updated aquifer properties from the USGS models.



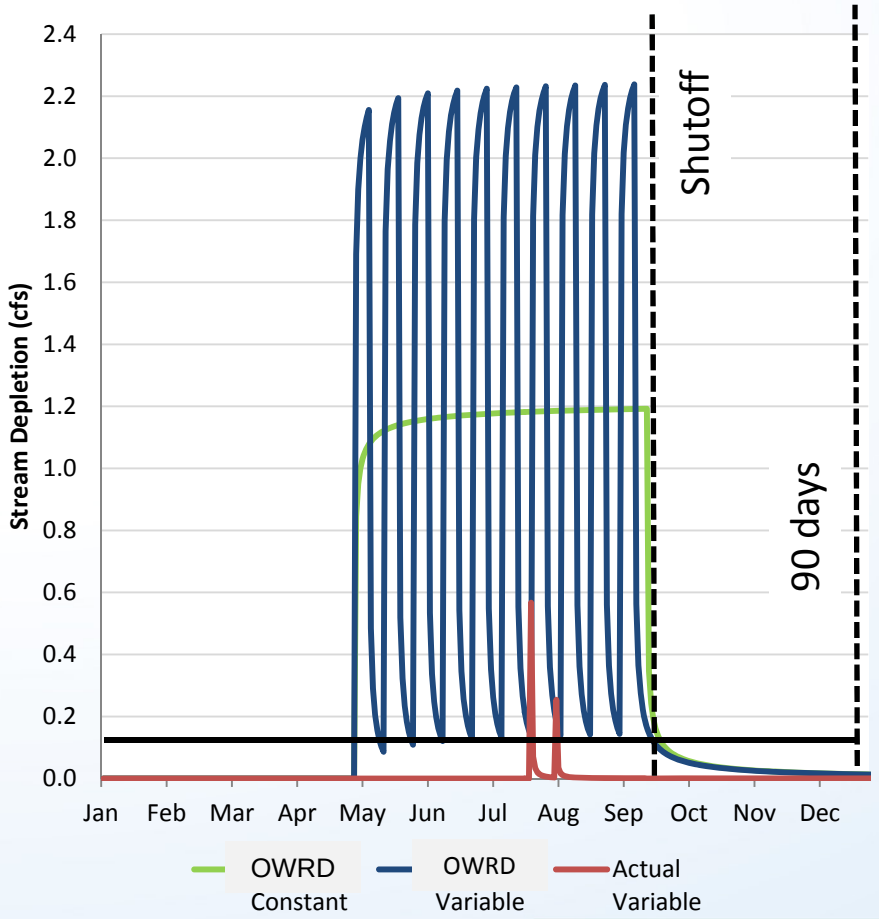
Geosyntec consultants

OWRD Model Stream Depletion Results
Constant & Variable Pumping

Wocus Well



Fremont Well



Preliminary and Confidential

Geosyntec consultants

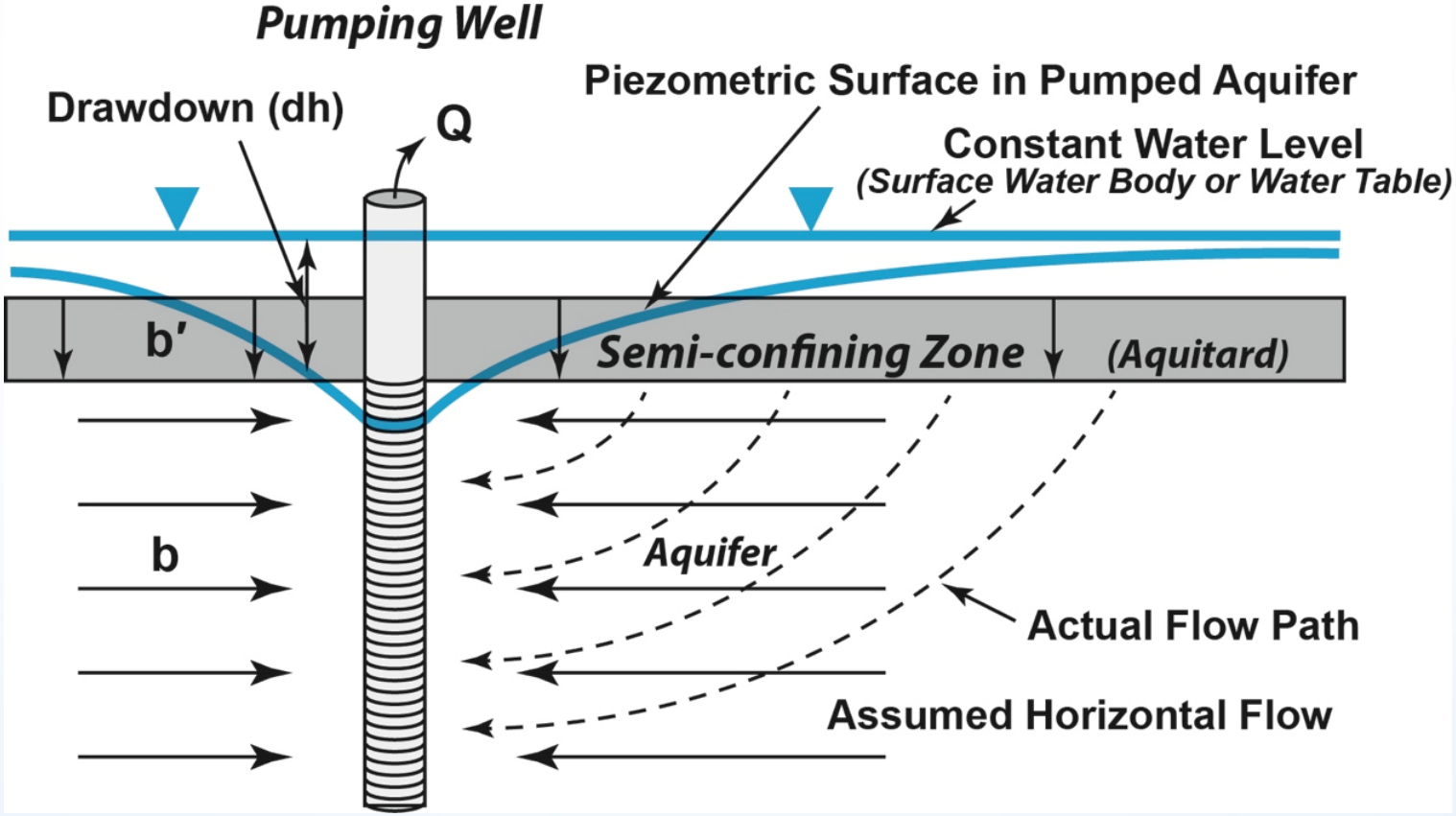
OWRD Model Review Results

- OWRD Model Review Findings:
  - Assumes the ***only*** *source of water* to the well is coming from the **nearby surface water**.
  - The vertical hydraulic conductivity is ***too high*** relative to the horizontal hydraulic conductivity.
  - Assumes the wells are pumped as ***irrigation wells*** (not as municipal supply).
  - Assumes ½ of the maximum pumping rate (per water rights), *instead of* ***actual pumping rates.***
  - **No** accompanying report to explain the basis for decision making for shutoff.
  - States it uses aquifer properties from USGS basin-wide model, but **values cannot be replicated**.

OWRD Model Review Results

- Modified the OWRD model
  - Used USGS aquifer properties.
  - Used actual City pumping rates.
- Results
  - Almost no impact from Fremont and Wocus wells, and considerably less impact from the Conger well field to local stream depletion.
  - Model assumptions for municipal supply are flawed.
  - Use of alternate model was recommended.

Conceptual Model of Leaky Aquifer

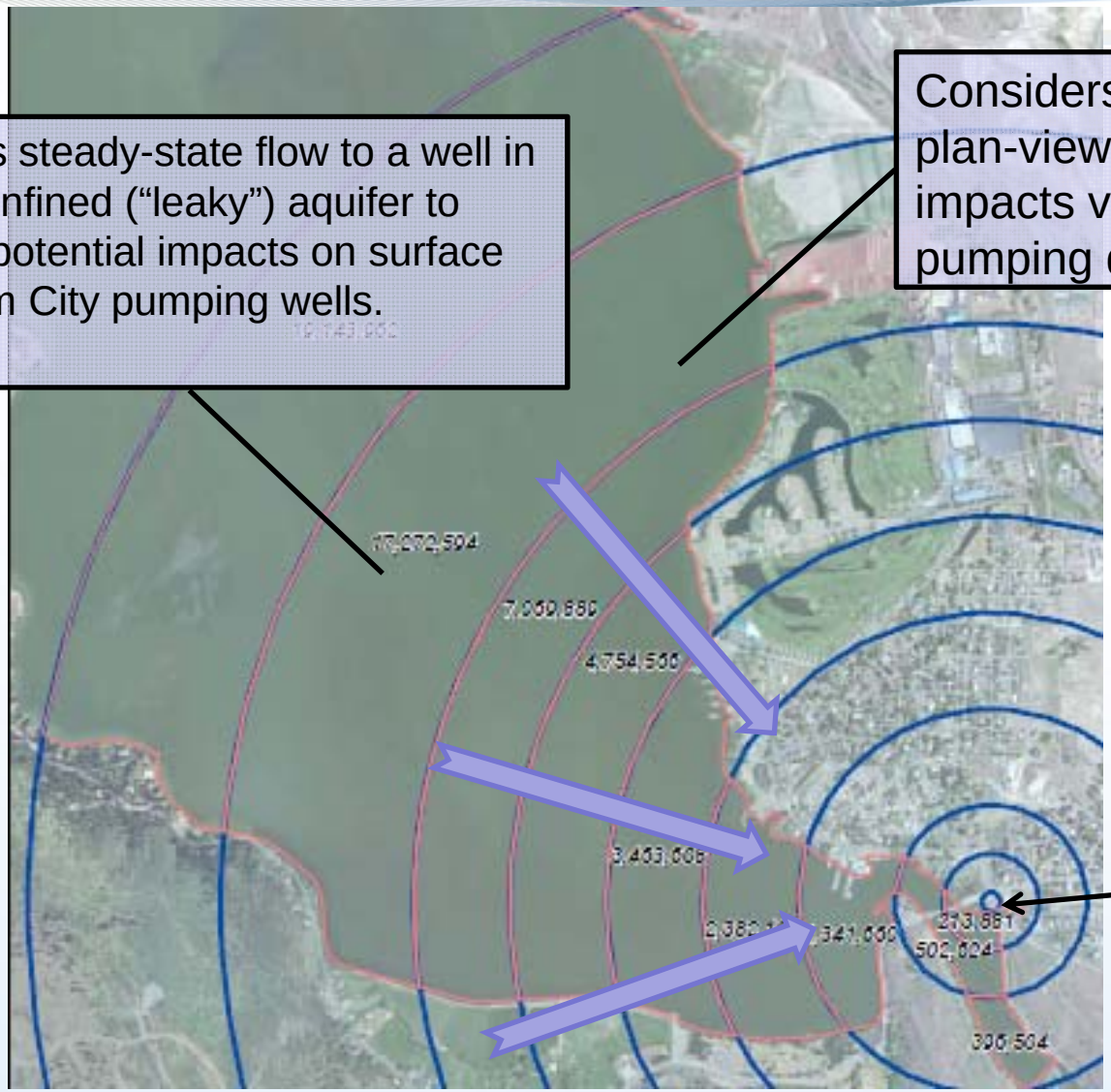


Geosyntec consultants

Alternate Model, Leaky Aquifer Analysis Differences with OWRD Model

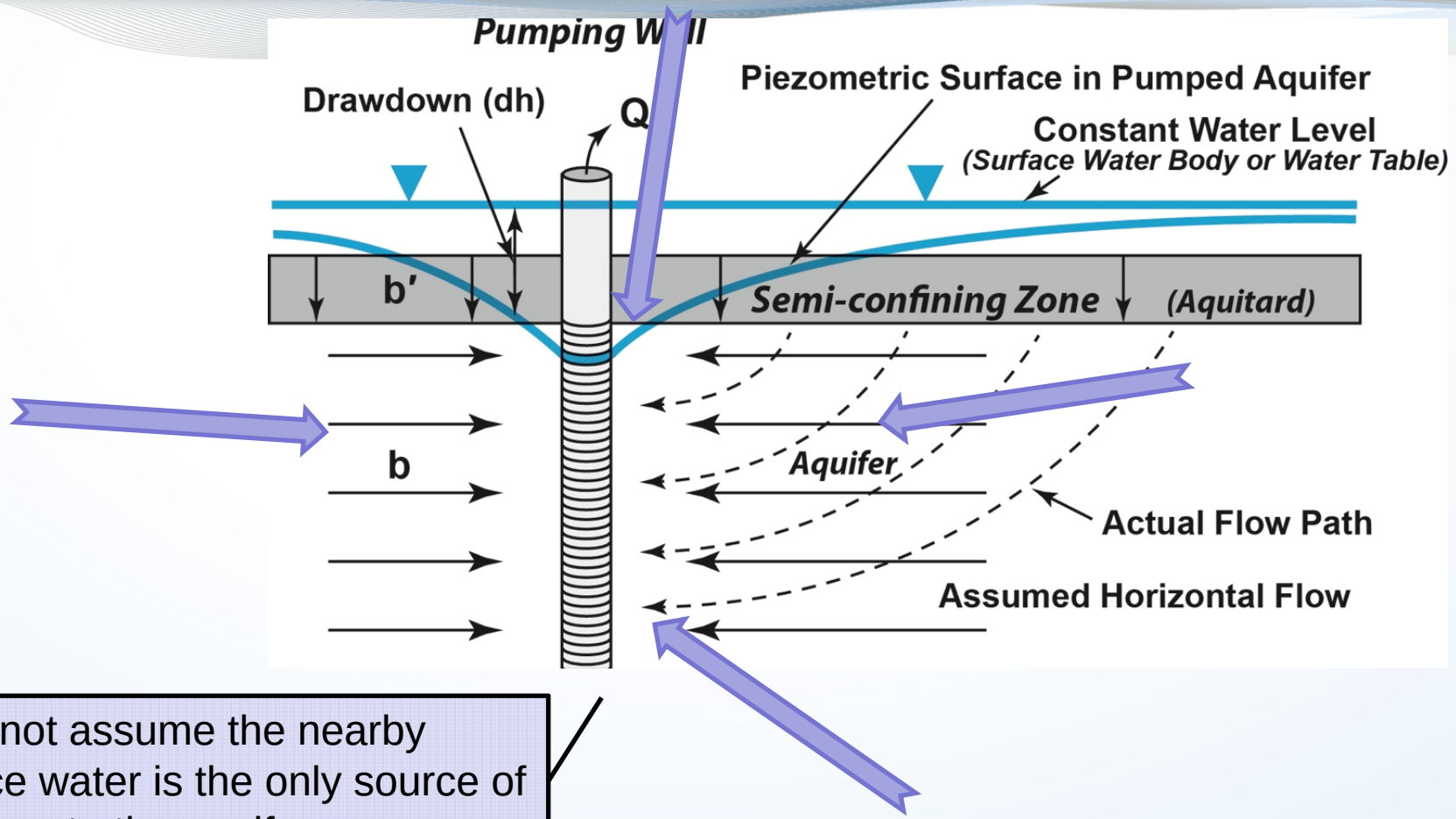
Considers steady-state flow to a well in a semi-confined ("leaky") aquifer to estimate potential impacts on surface water from City pumping wells.

Considers the distance and the plan-view area of surface water impacts via leakage from pumping drawdown.



Fremont Well

Alternate Model, Leaky Aquifer Analysis Differences with OWRD Model



Does not assume the nearby surface water is the only source of recharge to the aquifer.

Geosyntec consultants

Alternate Model
Leaky Aquifer Analysis

Leaky aquifer model simulations for the Wocus, Fremont, and Conger wells

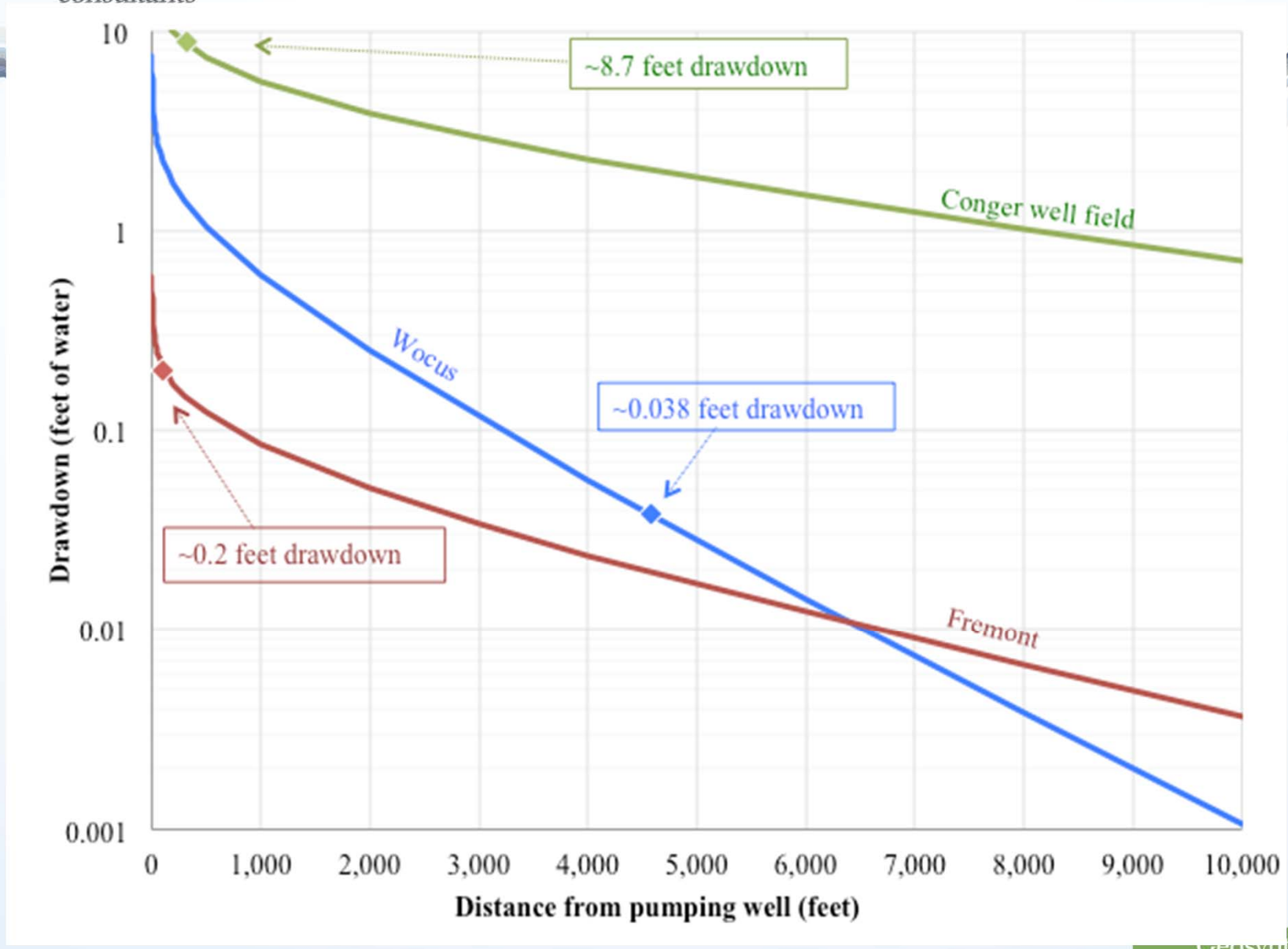
- Used aquifer characteristics from the USGS.
- Used City pumping data; Conger well field analyzed as a group.

Steps for Alternate (Leaky Aquifer) Model

- Determine the flux of water in the aquifer and across an aquitard (leakance).
- Determine the groundwater drawdown at a distance from the pumping well.
- Determine the flow depletion at a distance from the pumping well.

Geosyntec consultants

Drawdown with Distance

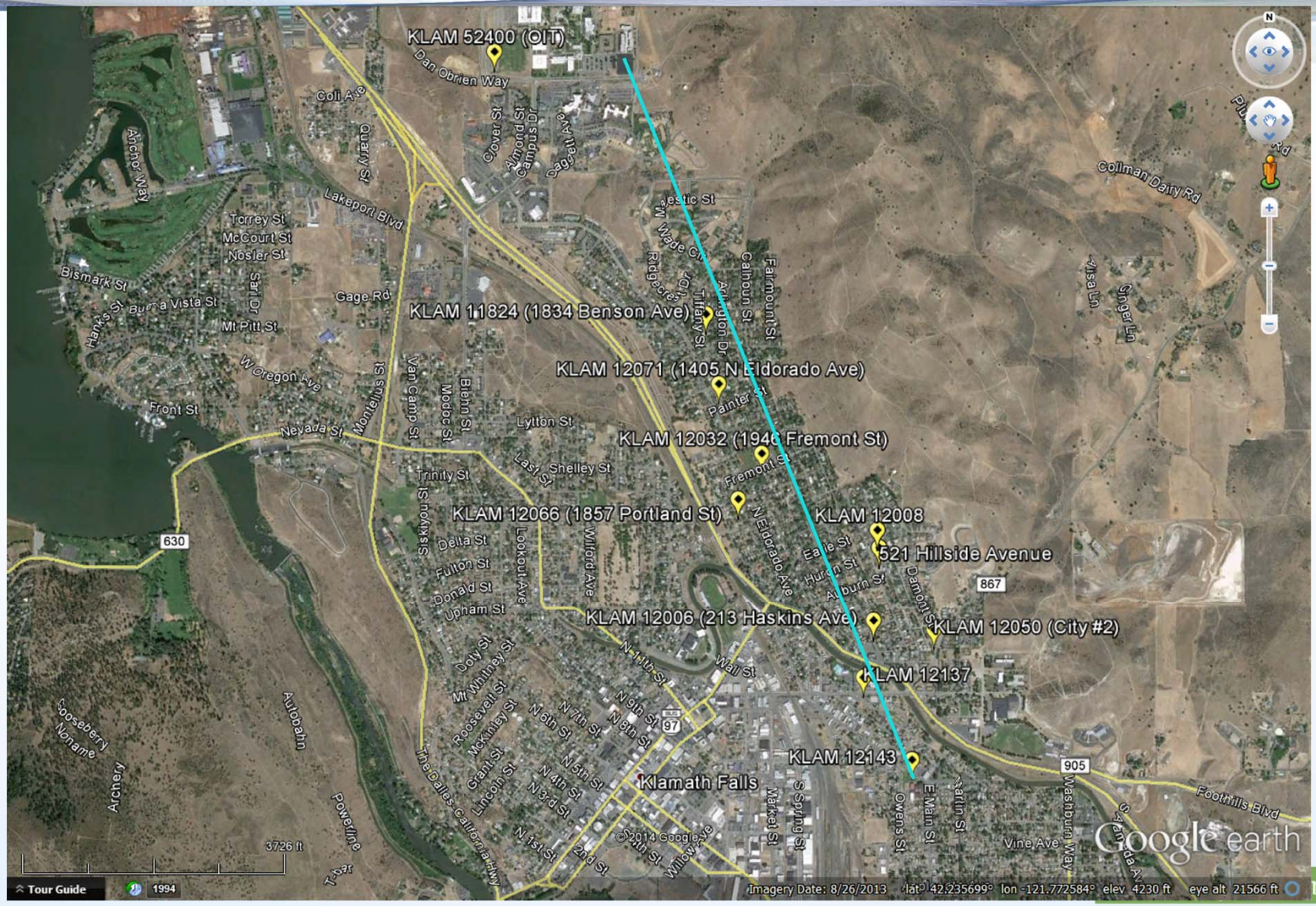


Leaky Aquifer Model Results

- Wocus
  - Total flux: 0.0251 cfs (11.3 gpm)
  - No recovery calculated because depletion is below OWRD criteria of 0.1 cfs.
- Fremont
  - Total flux: 0.00985 cfs (4.42 gpm)
  - No recovery calculated because depletion is below OWRD criteria of 0.1 cfs.
- Conger well field
  - Total flux: 1.0431 cfs (468.1 gpm)
  - Calculated recovery results in complete recovery within a few days of shutoff.

Geosyntec consultants

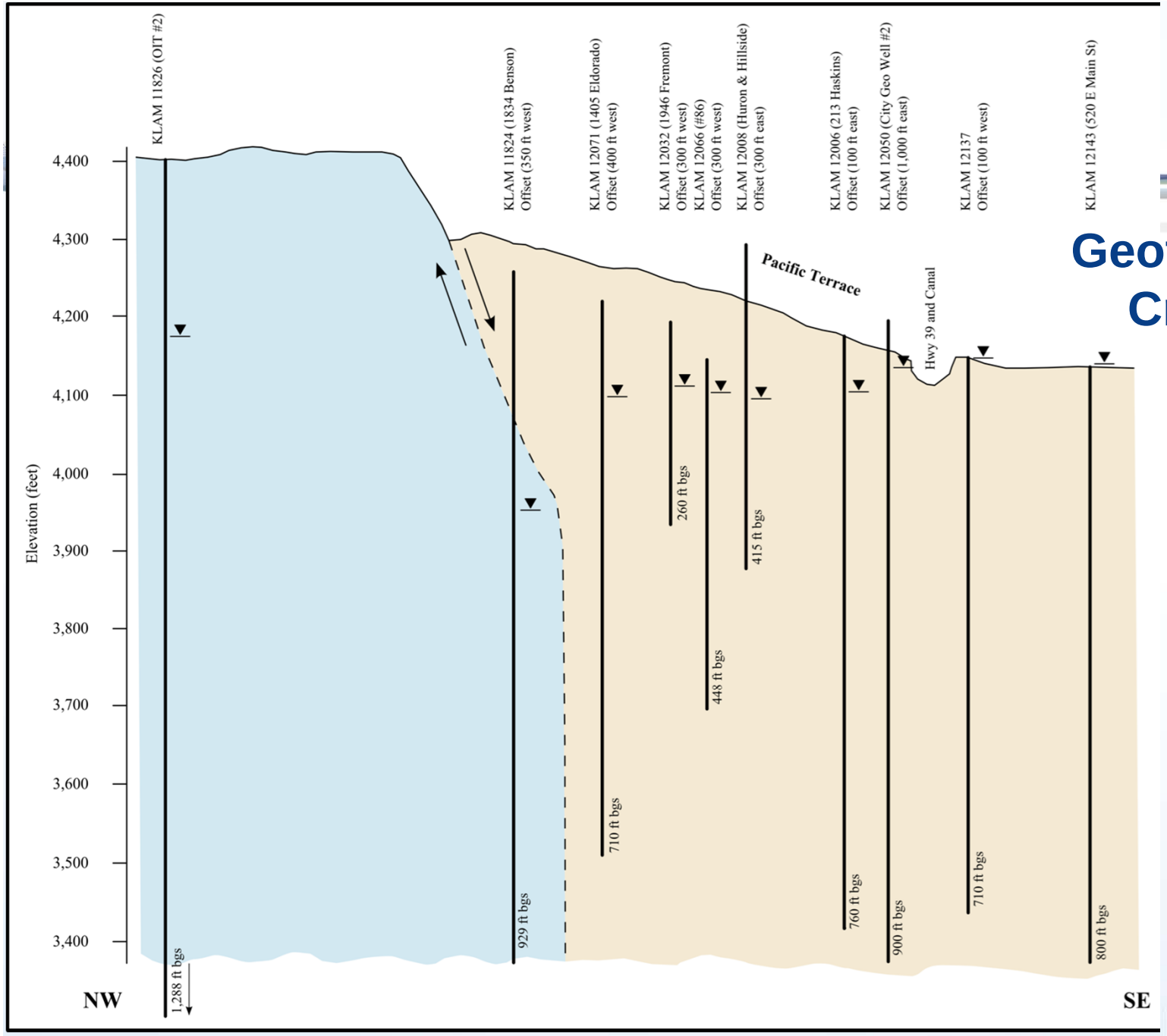
Geothermal Wells Review and Analysis



Preliminary and Confidential

engineers | scientists | innovators

Geothermal Well Cross Section

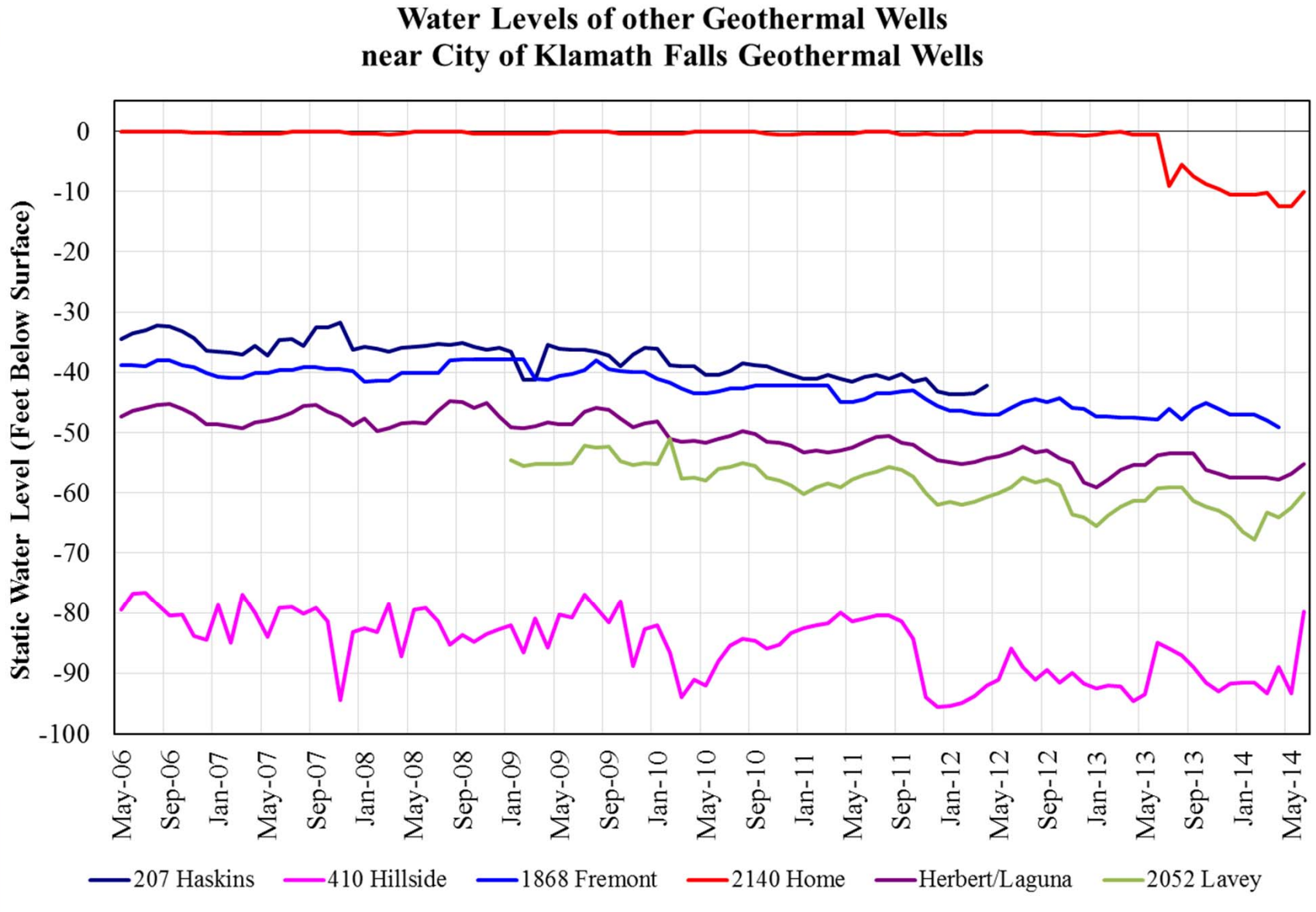


Preliminary and Confidential

Geosyntec.com

engineers | scientists | innovators

Water Levels from the Surrounding Wells



Geothermal Discussion

- Water levels in two City and some residential wells indicate slight declines in water levels over the last eight years.
- Overall there do not appear to be significant declines in water levels or temperatures over the time period reviewed.
- Additional and more expanded monitoring is recommended to “fill in” the network.
- Measuring reference point elevations for the well network are needed.

Geosyntec consultants

Summary

- The OWRD model is flawed for municipal use for several reasons.
- The modified OWRD model reveals considerably less impacts, but is still problematic.
- The alternative model is more appropriate.
- Results of the alternative model shows no impacts.

Geosyntec consultants

Next steps

- Possible meeting with OWRD to present results and discuss shutoff notice.
- Continue to monitor water levels from the City's and other private and geothermal wells.
- Expand geothermal monitoring network and survey measuring points.
- MODFLOW could be a useful tool going forward with more functional properties in the model for long-range planning.

Geosyntec consultants

Questions?