Lessons that may or may not have been learned from the 17 10 year USGS Groundwater Study of the Yakima basin

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The Discovery Center, The Dalles, OR
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Outline of talk

- Disclaimers - 20 minutes
- Talk - 4 minutes
- Questions - 1 minute

The Obligatory Disclaimers
- I am not the Yakama Nation
- I work there, in the unsavory interface between the laws of nature and the laws of man
- I do not speak for the Tribe, I am staff
- No Treaty Rights were killed or injured in the making of this talk (or defined, diminished, impaired, abrogated......)
Hanging around the Yakima Basin since 1980
My Day Job

Discussing Water Rights, A Western Pastime
Mr. Ring goes to Yakima

• Attended meeting in May 1993 at Ecology CRO
• Ecology announced intention to issue hundreds of new groundwater permits for hundreds of cfs
• 17 years of my life later, this talk
• Lesson Learned: Don’t go to meetings on Tuesday nights at Ecology
Mr. Ring Reviews the Literature

REVIEW OF LITERATURE PERTINENT TO IMPACTS OF FURTHER GROUNDWATER DEVELOPMENT
BLACK ROCK - MOXEE STUDY AREA, WASHINGTON

Prepared by Tom Ring, Hydrogeologist
Yakima Indian Nation
Water Resources Planning Program

May 13, 1993
Revised June 2, 1993
and offers such remarkable insights as

- Inflow = outflow plus change in storage i.e. mass is conserved in the hydrologic cycle
- Groundwater flow down hydraulic gradient in accordance with Darcy’s Law
- Groundwater in the basalts of the Moxee Valley is tributary to Yakima River
- Pumping will diminish flow, maybe soon
The Laws of Man
Washington Groundwater Law

• 1945 Groundwater Code
• Prior Appropriation
• Recognizes connection to surface water

– The rights to appropriate the surface waters of the state and the rights acquired by the appropriation and use of surface waters shall not be affected or impaired by any of the provisions of this supplementary chapter and, to the extent that any underground water is part of or tributary to the source of any surface stream or lake, or that the withdrawal of ground water may affect the flow of any spring, water course, lake, or other body of surface water, the right of an appropriator and owner of surface water shall be superior to any subsequent right hereby authorized to be acquired in or to ground water (RCW 90.44.030, emphasis added)
The Laws of Nature
The Two Basic Laws

1. Groundwater flows under the force of gravity from high head (energy) to low head (Darcy’s Law, most important thing to learn)
   - That allows us to know where it is coming from and going to (by measuring water levels)

2. Water is not being created or destroyed in the hydrologic cycle (the Continuity Equation)
   - Mass is conserved, we aren’t making any more water, the water budget must add up to zero
   - Productive aquifers, producing wells – not!

Groundwater computer models are built from these two laws
Figure 1.1 Schematic representation of the hydrologic cycle.
From Groundwater, Freeze and Cherry, 1979, Prentice Hall
Figure 4. Simplified surficial geology of the Yakima River Basin, Washington. From Fuhrer and others, 1994.
A Slice of Yakima

From: Field Trip Guidebook to the Natural History of Kittitas County
Jana Jones Mabry

Synclinal Basin in Yakima Fold and Thrust belt

Not rivers, but leaky sheets of folded layer cake geology
In basalts, interflow zones most permeable
Alluvial aquifer water young like me, basalts old

Figure 3. The Three Principal Aquifer Systems in the Yakima River Basin
From U.S. Army Corps of Engineers, 1978, Yakima Valley Regional Water Management Study
Basalt Flow System
From USGS Columbia Plateau RASA

**EXPLANATION**
Direction of ground-water flow

**Figure 21.**—Generalized ground-water-flow pattern in the Columbia Plateau aquifer system.
The Yakima Basin lies on the Dry side of the Cascade Mountains: Snowmelt dominated streams drain the Cascades. Cascades block flow of moisture from Pacific Ocean. Streams flow east through semiarid lowlands and discharge to Columbia River.
The Evergreen State
"My name is America. And I am addicted to water."

- Stephen Colbert
So, who cares?
The effect on existing water users.

• The Yakima basin surface water rights are fully appropriated

• Every year during storage control all water released from reservoirs and flowing from other sources goes to meet an existing water right for
  – Irrigation
  – municipal supply
  – instream flow

• May 10$^{th}$, 1905 rights are “prorated” during droughts
Can We Talk?

YN and Ecology staffs meet in Toppenish

- Shared the literature review
- Yeah, you’re right, according to the “hypothetical hydrologic cycle”
- Maybe, but it would take hundreds or even thousands of years
- If your were right the Yakima River would be dry today.
  - Really, how much groundwater pumping is there?
  - I don’t know, a lot
Why you can’t pump the river dry

- Reservoirs
- Diversions

Map showing:
- KRD Diversion
- WIP Diversion
- Roza Diversion
- Sunnyside Diversion
- Yakima Reservation
- Yakama Reservation
- Reservoirs
- Diversions
June 4, 1993

Mr. Doug Clausing, Section Manager
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Regarding the following applications for permits for new groundwater development within the Black Rock - Moxee Study Area

G4-26446, G4-26563, G4-26562, G4-27812, G4-27851, G4-28341, G4-28555, G4-28653, G4-28665, G4-28670, G4-28674, G4-29138, G4-29179, G4-29307, G4-29359, G4-29472, G4-29482, G4-29573, G4-29653, G4-29657, G4-29667, G4-29893, G4-29919, G4-30246, G4-30418, G4-30752, G4-30770, G4-30767, G4-30864, G4-30942, G4-31348, G4-31350, G4-31351, G4-31364, G4-31407, G4-31681, G4-31684:
The 43 Decisions
Inferring the policy

- Direct vs. Indirect Hydraulic Continuity: a difference without a distinction
- Only permit deep wells except for some shallow ones
- No mining = no impact to surface water
- Supplemental ok, primary not ok, except where it is
- Hydrocooling and frost protection not in public interest
- Most recharge from irrigation water
- BR study dismisses capture concern
  - A well interference study, not a capture study
Three-Dimensional Groundwater Flow Through Multiple Hydrogeologic Units from Recharge Area to Discharge Area (from Winter et al., 1998)
Suppose your (overlying) aquitard leaks into your confined aquifer

Heath, p. 50
USGS WSP 2220

Theis: Impermeable aquitard, no leakage

Hantush-Jacob: Permeable aquitard
Leakage from overlying unconfined aquifer
Not easy, but basic. Pumpage affects vertical leakage.

\[ \frac{\partial^2 h}{\partial r^2} + \frac{1}{r} \frac{\partial h}{\partial r} - \frac{(h_0 - h)K'}{Tb'} = \frac{S}{T} \frac{\partial h}{\partial t} \]

\[ w = K' \frac{h_0 - h}{b'} \]

Pre-pumping water table = potentiometric surface
Why necessary?

Land surface
A 4-year delay for timeliness  
(or how I spent the 1990’s)

• YN appeals (1993)
• Timeliness challenged
  – 3 answers, 4 years
  – 25 out of 43 spring back to life in 1997
• Meanwhile...
• Statewide cases
  – Ecology changes course
  – Court says, “Hydraulic continuity is a scientific fact”
• Hubbard
  – One molecule of impairment is impairment
• Changing of the Guard: Chain of command changed from permit writer to Governor
• Capture Committee
Capture Analysis Should Be Based on Accepted Scientific Principles

The Committee agrees that the technical analysis of surface-water capture by wells should be rooted in broadly accepted, state-of-the-art, scientific principles governing ground-water and capture effects on surface-water flow, including the law of conservation of mass and Darcy’s Law. Based upon these principles, the Committee agrees that, in the long run, any ground-water withdrawal will reduce (‘capture’) surface-water flow in one or more hydraulically connected water bodies, and may also affect other parts of the water cycle, such as the amount of water returned to the atmosphere through evapotranspiration. Questions that may require further analysis are: how much of a surface-water body’s flow will be captured, where will water be captured (i.e., which surface-water bodies will be affected); when will the effect occur, and how long will the effect last.
Enter the 800 Pound Gorilla: Reclamation Rings In

• Hey, Buddy, that’s my WSRF
• Affidavit
  – If continuity exists, and it appears to, then it’s our water and you’re impairing our contractors’ rights and interfering with our duties to protect and enhance the river
• Amicus (denied)
Depositions & Summary Judgments

• You said it
• Pumping from wells will capture river flow over time
• Gw is cooler and cleaner; pumping will make river hotter and dirtier
• Every drop is important
• Denied
The 3 Sovereigns Agree to Agree

• Ecology letter to permittees
  – We’ve learned a thing or two
  – If we had it to do over again...
  – We won’t defend the permits

• Settlements
  – Permittees to pay replacement cost for water into BOR water acquisition fund

• The MOA
Memorandum of Agreement
among the

Yakama Nation
and
United States Bureau of Reclamation
and
Washington State Department of Ecology

related to
Ground Water Management in the Yakima River Basin

I. INTRODUCTION

This Memorandum of Agreement (MOA) is entered into by the Yakama Nation (Yakama), United States Bureau of Reclamation (Reclamation) and Washington State Department of Ecology (Ecology) for the purposes stated below.

II. PURPOSE AND SCOPE

A. Purpose

The Parties agree that there is a need to compile and synthesize existing information and to develop a common technical platform for making sound, efficient, and consistent water resource management decisions in the Yakima River Basin including future government management, allocation and mitigation decisions.
The MOA

• The 3 govs will contract USGS to develop a model to simulate effects of existing and proposed groundwater pumping
• Model will serve as technical platform for future decisions
• Study team (hg’s from 3 govs) will draft scope and oversee project
• Ecology will not issue permits during study
The Study

http://wa.water.usgs.gov/projects/yakimagw/

Yakima River Basin

The Yakima River flows 215 miles from the outlet of Keechelus Lake in the central Washington Cascades southeasterly to the Columbia River, draining an area of 6,155 square miles. The Yakima River Basin is one of the most intensively irrigated areas in the United States. Population in the Yakima River Basin was about 238,000 in 1990.

Increasing demands for water for municipal, fisheries, agricultural, industrial, and recreational uses will affect the ground-water resources of the basin. A better understanding of the ground-water flow system and its relation to rivers and streams is needed to effectively manage the basin's water resources.

In cooperation with the U.S. Bureau of Reclamation, the Washington Department of Ecology, and the Yakama Indian Nation, the USGS is studying the ground-water system in the Yakima River Basin and how it interacts with rivers and streams in the basin. The study includes data collection, mapping of hydrogeologic units and ground-water levels, and a computer numerical model to bring together all the information.
Let’s Get Ready to Model

Yakima River Basin
Publications and Products

Jones, M.A., and Julich, R.J., 2008, *3D hydrogeologic framework of basalt and interbed units, Yakima, Washington*


Bachmann, Matt, 2008, *Approaches for assessing ground water availability under competing demands and climate change [poster]: American Geophysical Union Fall Meeting, San Francisco, California, December 15-19, 2008, PDF, 6.7 MB.*


One Stop Shopping

Framework Report compiles task reports and synthesizes

- Geology: Stratigraphy and Structure
- Hydrogeologic Units
  - Hydraulic Characteristics
    - Lateral and Vertical Hydraulic Conductivities
      - Necessary to calculate horizontal and vertical groundwater flow (Darcy’s Law)
  - Storage Coefficients
    - Necessary for transient simulations of pumping
- Hydrochemistry
- Groundwater
  - Recharge
  - Water levels
  - Flow System
  - Pumpage
    - Turns out “a lot” is about 312,284 acre-ft (about 430 ft³/s) (in 2000)
- Water Budget
Conclusions

- Hydraulic conductivities range widely
  - Vertical K’s are lower then lateral (as usual)
- Groundwater residence time range from a few tens to many thousands of years
- Irrigation has increased recharge
- Groundwater moves from topographic highs in the uplands to topographic low areas along the streams
- Regional groundwater flow discharges to surface drainage features in the lowlands in the structural basins and to the Columbia River
  - The ridges (anticlines) compartalize flow into local systems
  - Groundwater (including all but the deepest basalts) discharges to surface water at the downgradient end of the structural basins
  - Flow from one structural basin to another is via surface water
Lesson: Deep waters still run  
or  
Even Basalt Aquifers follow the laws of physics
Prediction is very difficult, especially about the future.

(Niels Bohr)
America’s Next Top Model
MODFLOW, e.g.

USGS Yakima Model has 4 million cells
Work Needed

Obs Well 1  Obs Well 2

Drop in Head

→ Energy consumed by friction →
Oh yeah, did I tell you mass is conserved?

Think model grid cell.
Water Budget Components

Model allows calculation of components and changes caused by e.g. wells, irrigation, etc.

FIGURE 32.--Schematic budget of the hydrologic system in the Toppenish Creek basin. Values are in thousands of acre-feet per year. Values in parentheses are in millions of cubic metres per year.
Preliminary Model Results
(from my notes)

• Unusual for USGS to release preliminary results
  – Did so because of urgency of ongoing processes
• Existing rates of groundwater use will result in about 200 cfs reduction in surface water budget (at equilibrium)
  – About 30 cfs from exempt pumpage (may change)
  – Effects increase as increased pumpage is modeled
    • Pending applications would take 70cfs more
• Effects felt almost instantaneously
  – About 50% of pumpage shows up annually in SW budget
  – Some effects take 10 years
• Basalt response is complex
  – Pressure effects propagate
  – Effects from basalt pumpage attenuated in space and time
Lesson Learned: Lessons hard learned are easily forgotten

or

Why this talk is not a victory lap

or

Every Day is Groundhog Day in Water Resources

• The return of “indirect hydraulic continuity”
• Black Friday
  – Only ….. are in likely in hydraulic continuity
• Come back in 2028 for “Lessons learned from 34 year study of groundwater in the Yakima basin”.
• Lesson Learned: Never quit paying attention