Hello, colleagues,

Thanks again to Caltech for sponsoring this outstanding event. What an honor to be here!

A caveat on my presentation: this work Is not a RAND output, and it has not been vetted by RAND's internal quality control process. It is mainly from my research when I was an academic in New Zealand.

I repeat my request for reviewers for my forthcoming book, *Smart Markets for Water Resources*. I and my co-author Mark Milke need people who are willing to read and comment on the draft. Even a review of a section would be helpful.

And please sing out if you're in Santa Monica, I'm always happy to share a coffee and talk about water allocation.

Warm regards,

Fritz

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A Smart Market Design for Water Resources

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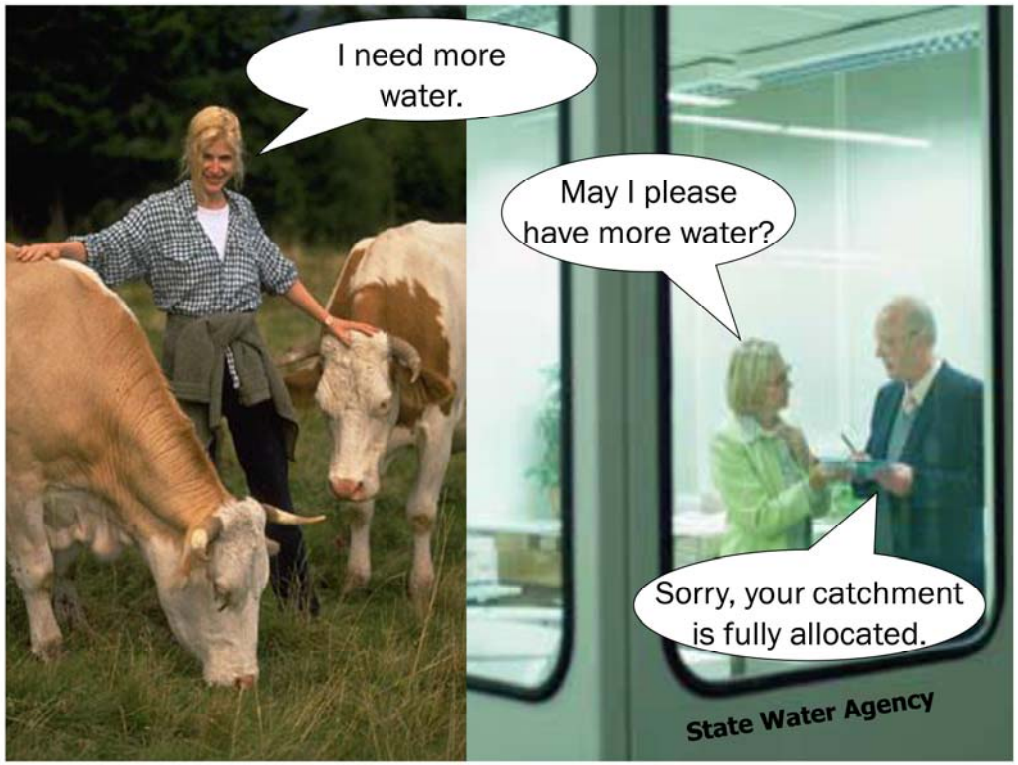
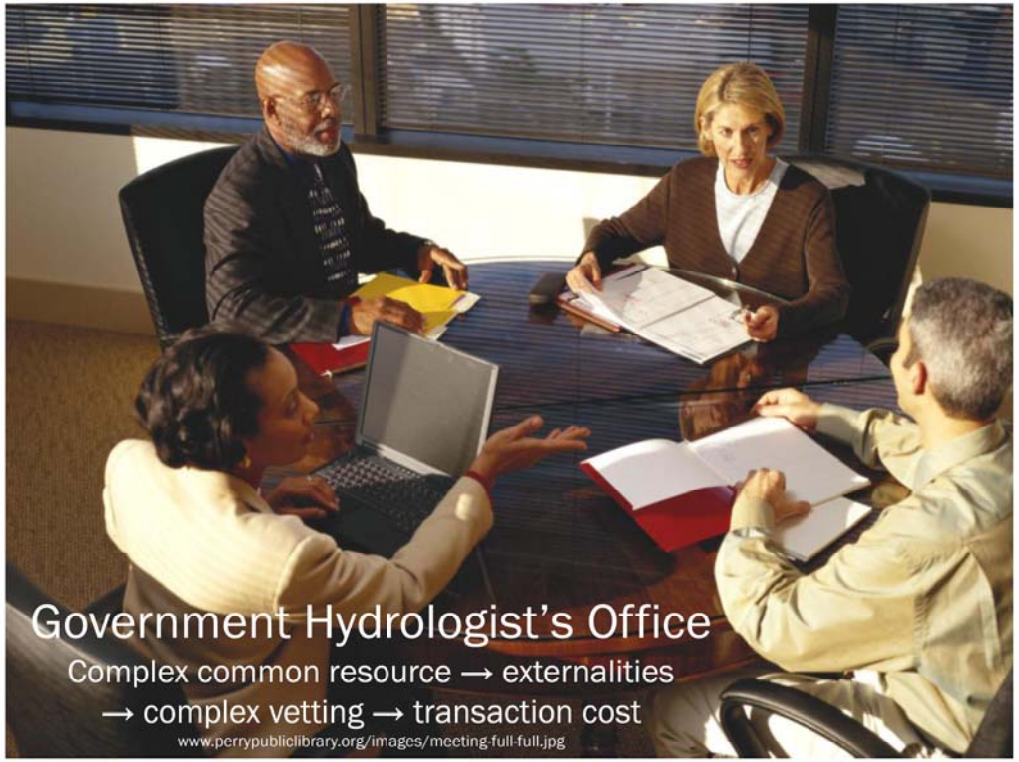
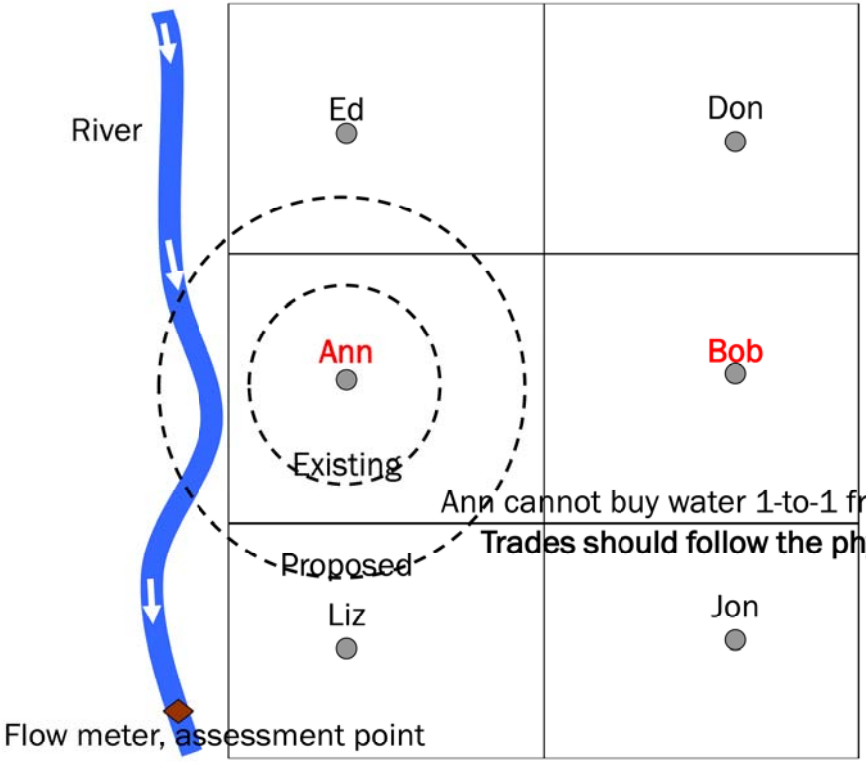
RAND CORPORATION Water and Climate Resilience Center (www.rand.org/water)



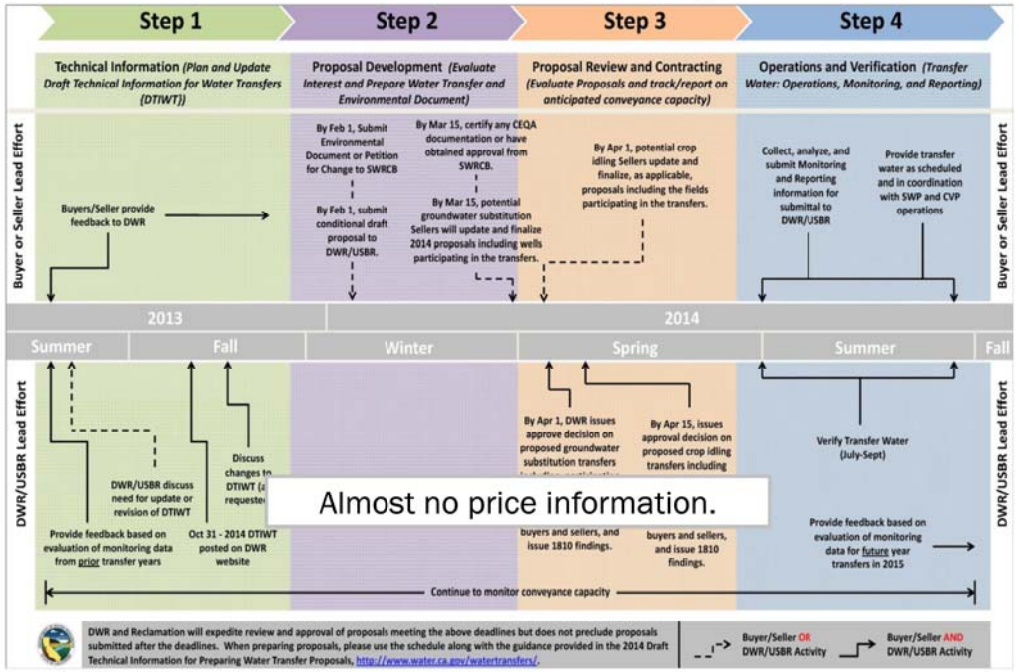




Ann cannot buy water 1-to-1 from Bob.

Trades should follow the physics.

California's "stream-lined" process



Almost no price information.

Possible solution: a smart market

A central spot market auction cleared with optimization.

Works well for complex pooled commodities,
- e.g., electricity, radio spectrum, natural gas in pipes, …, when pair-wise trade is hard due to system constraints.

Managed by an independent system operator.
- Users submit bids to the ISO.
- ISO uses a linear program to match supply & demand, meeting physical, environmental & regulatory constraints.
- Users trade with the ISO.

Trade short-term leases. Need not change the permanent right.

Key: reduce transaction costs.

Environmental and Resource Economics **17:** 375–394, 2000.

The Design of "Smart" Water Market Institutions Using Laboratory Experiments*

JAMES J. MURPHY[1], ARIEL DINAR[2], RICHARD E. HOWITT[3], STEVEN J. RASSENTI[4] and VERNON L. SMITH[5]

Simplified linear program

1. Maximize $\sum_{users\ i}\sum^{T}_{time\ u=1} BidPrice_{i,t} q_{i,t}$
2. Bids: $0 \le q_{i,t} \le Maxbuy_{i,t}$ for each user *i* and period *t*. *Price* $p_{i,t}$.
3. Mass balance: streamFlow + groundwaterFlow – q = outflow for each flow connection, for every time period.
4. Capacities: conveyance flows ≤ Capacity for each conveyance, for every time period.

MODFLOW → GWM2K → linear program

5. Sustainability: Flows – $q \le MaximumDrawdown_{k,t}$ for each assessment point *k* & time period *t*.

Refs: Hoffman et al 1993? Hoffman et al 1996, Dinar et al 1998, Murphy, Dinar, Howitt, Rassenti, Smith 2000, Murphy et al 2006, 2009, Raffensperger, Milke, Read 2009.

Each constraint gives a price, spatial & temporal. Capacities are rights.

Customize for local hydrology. Easy to trade env water.

Could use a variation of Jay Lund's CALVIN model for California.

Buy from & sell to the manager.

7 a.m.

8 a.m.

Apr 24-30
Sell ○ Buy 1 ML $ 3 /ML
Sell ○ Buy 1 ML $ 1.5 /ML

May 1-7
Sell ○ Buy 1 ML $ 3 /ML
Sell ○ Buy 1 ML $ 1.5 /ML

Submit bid

8:30 am.

Maximize $\sum_{users\ i}\sum^{T}_{time\ u=1} BidPrice_{i,t} q_{i,t}$
Bids: $0 \le q_{i,t} \le Maxbuy_{i,t}$ for each user *i* and period *t*. *Price* $p_{i,t}$.
Mass balance: streamFlow + groundwaterFlow – q = outflow, for each flow connection, for every time period.
Capacities: conveyance flows ≤ Capacity, for each conveyance, for every time period.
Sustainability: Flows – $q \le MaximumDrawdown_{k,t}$, for each assessment point *k* & time period *t*.

9 a.m.

Apr 24-30. You sold 0.8 ML, $1.76/ML.
Firm rights for 4.2 ML.
May 1-7. You bought 1 ML, $1.22/ML.
Provisional rights for 5.6 ML.

Prereqs for the market: good water mgmt

The market is just **one part of a complete water mgmt framework**.
The framework enables the market, not the other way 'round.

Count all the water.

- Meter all large users. Eliminate man-made uncertainty.
- Use the correct physics. Surface & ground water connect! Use a good hydrology model for decisions.

Count all the rights.

- Each right has a cap. Scale caps to water. Enforce the caps.
- Have a modern records system. Transparency, open data.

Specify env flows, by location & period. Meter & enforce env flows.

End trade-inhibiting rules, e.g., "Use it or lose it,"
"No water leaves this district," "Trades incur a tax..."
Substitute correct physics + env constraints.

All this should be done anyway. Not the market, but enables it.

Quotes

Murphy, Dinar, Howitt, Rassenti, Smith 2000:

> The development of 'smart,' computer-assisted markets provides the ability to incorporate the same allocation criteria utilized by regulators … the prices in this institution provide information about the current state of the system, and therefore, it is able to adapt rapidly to new information.

Raffensperger, Milke, Read 2009:

> Users do not need to search for trading partners…. This system therefore has per trade transaction costs close to zero… The highest bidder gets the water, but moderated by the hydrology and the environmental requirements, and only if other users are willing to sell.

In California

Hanak, Lund, Gray, Dinar, Howitt, Mount, Moyle, Thompson 2011 propose a limited or extensive independent system operator:

> …the ISO would act as a central market…for voluntary water transfers employing any unused system capacity, after existing water rights …, which would remain with their current owners.

Howitt 2014:

> A Water-ISO, like the current electricity ISO, would be a nonprofit public benefit corporation with an independent board… [T]he Water-ISO would not own any canals, conveyance, or dam facilities. It would be important, however, that the ISO control sufficient proportion of the water market to form stable prices.

These papers propose specific steps for California.

Can we have a simplified market?

Problem: we want pair-wise trades.

Solution: pretend the physics is simpler than it is.

- "zonal" prices,
- crude "transfer" coefficients,
- average flows over a year or decade.

webberenergyblog .files.wordpress.com /2010/03/texas-zonal1.png

Likely result: third party effects, people & env get injured, unless the regulator has a big planned-in buffer.

The market is broken to the extent it cheats the physics.

The market should capture the true spatial & temporal variation.

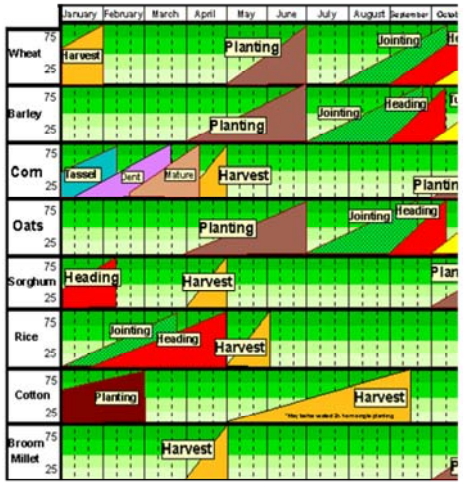
And using simplified physics is unnecessary.

Big change #1: trade quota by week or month

Users are trading quota, which is a rental by week. Book quota in advance.

Week 25 water is different from week 26 water! Bid for a **schedule**, with bids for future weeks.

Frequent dynamic adjustment. People can change their minds, or keep their current plan.



Big change # 2: precision.

Trades must have stream-lined regulatory approval. Reasonable, due to precision & short-term nature.

Users are incentivized to take their quota.

Rivers flows & user abstractions are likely close to the predicted values.

Big change #3: quota gets scaled each week.

License will be scaled by week, to adjust to inflows by week, so the money comes out even.

Scaled even for non-traders.

Requires a state-of-art licensing system.

Extensions

Phosphorus & nitrate: Prabodanie, Raffensperger, Milke, Read 2011.
With wetlands, combinatorial, Kostel et al 2014.

Sediment: Pinto, Raffensperger, Cochrane, Read 2008.

Impervious cover: Raffensperger & Cochrane 2010, Pinto 2013.

Hopefully 2016:
Raffensperger & Milke,
Smart Markets for Water Resources.
Reviewers wanted. Please let me know!

Done, thanks!