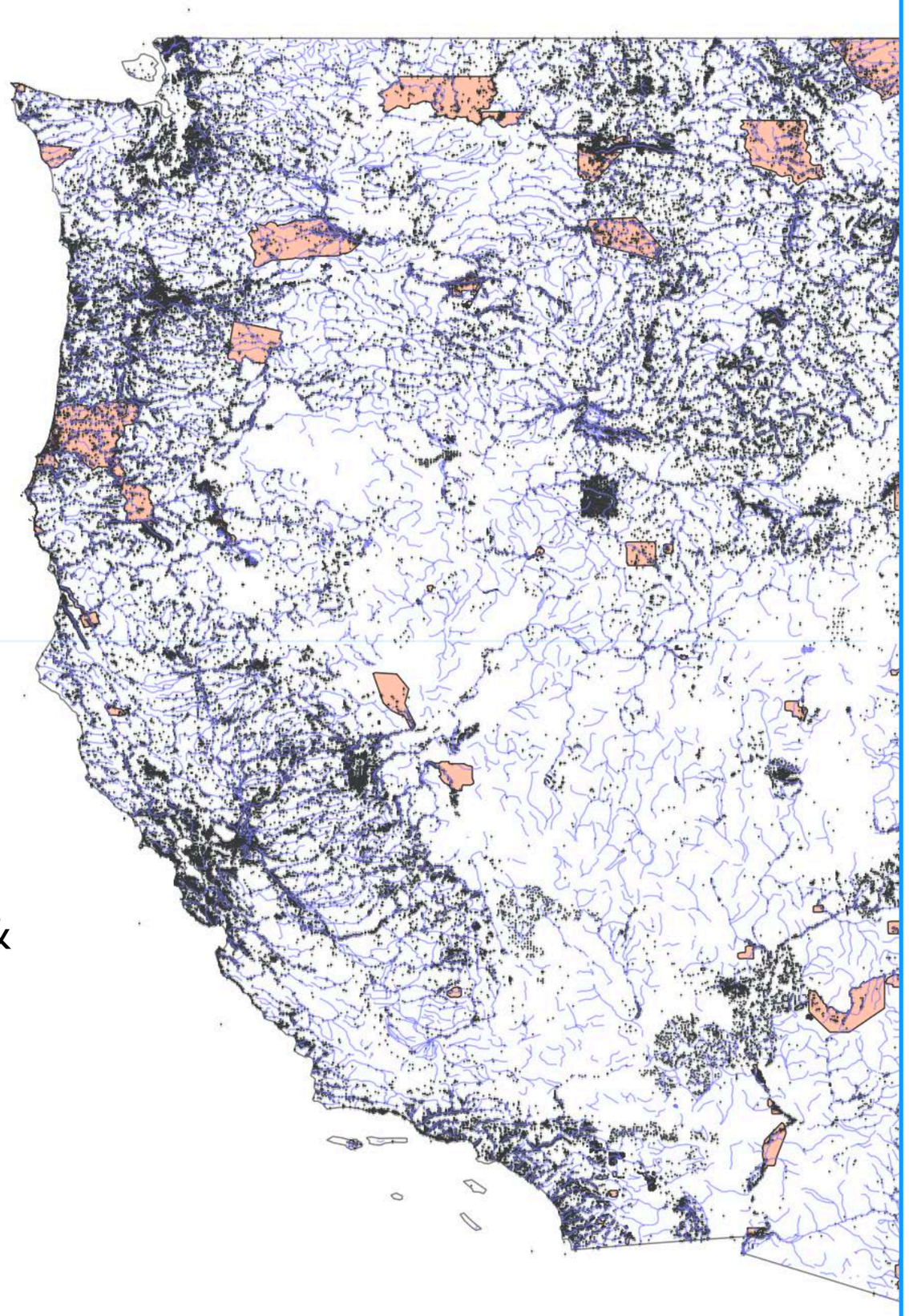
How Damaging is Uncertainty?

Mapping and Networking Water Quality Amid Strategic Bargaining for Rights



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Today

- I study the impact of policy *processes* on water quality
    - —> conflicts and negotiations over water rights in the western United States.
- The law introduces uncertainty over rights to water
- Does this impact how people use (or overuse) the resource in question?

Water Rights, Quality, and Institutions

- **Context**: American Indian tribes in the western United States

    - Many long-held rights to water have been legally recognized, but not enforced or implemented.

- Processes to claim back these rights in practice is long and extremely costly

    - creates uncertainty in property rights for current users

Legal Process and Resource Degradation

- First granular spatial dataset that maps, networks, and connects millions of water quality readings over time with American Indian reservation boundaries and timing of water rights negotiations between tribes and other stakeholders.

- Causal evidence that water pollution **worsens** during negotiations upstream of, and especially when close to, a reservation border for a tribe that has initiated proceedings.

- Worsening typically stops once property rights are settled and uncertainty is resolved.

Water Distribution in the American West

- In most western states, water is distributed and governed by the doctrine of **Prior Appropriation**:
    - First in time, first in right
    - Water must be used to retain a right to it
    - Seniority matters
- Historically, American settlers in the 1800's and early 1900s were able to appropriate the majority of water.

Federally Reserved Tribal Water Rights

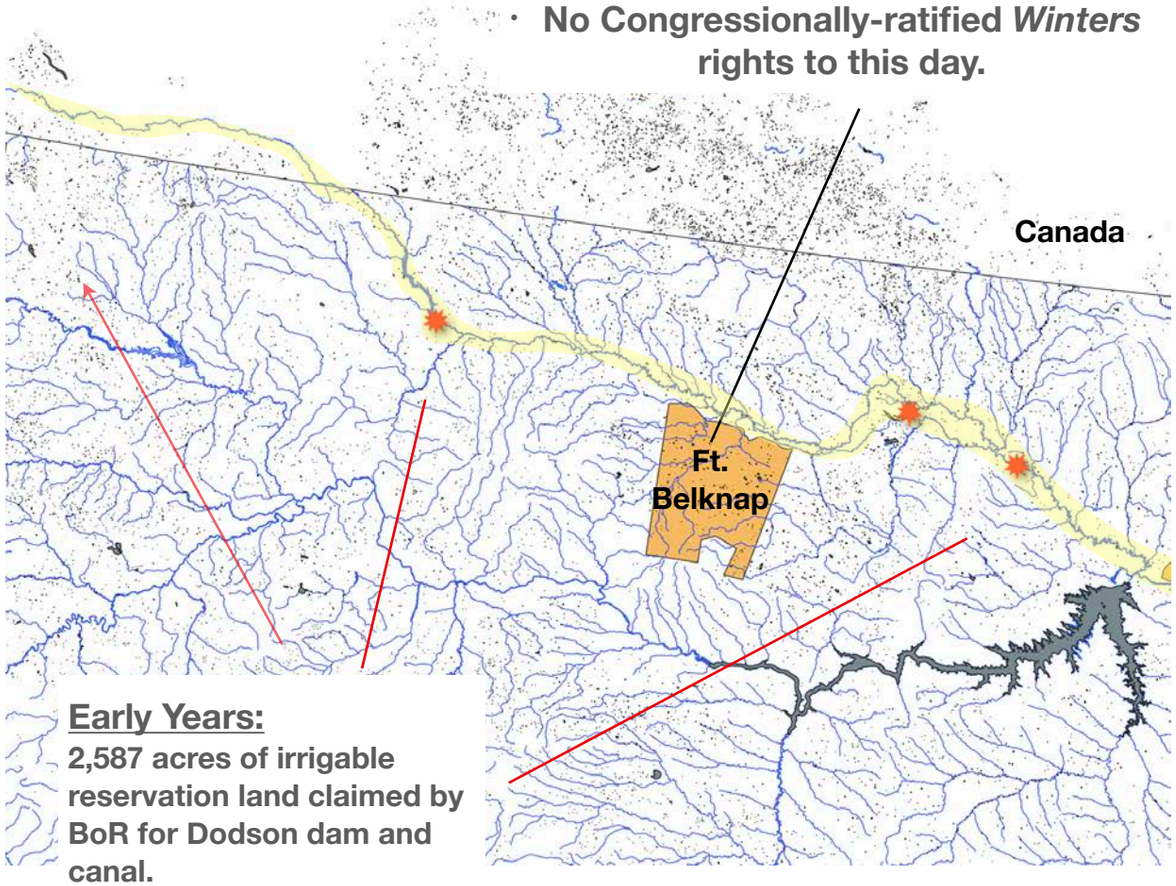
- American Indian tribal rights to water:
  - 1908 U.S. Supreme Court case - *United States v Winters* (207 US 577), Milk River water users and the Ft. Belknap Indian Reservation.
  - water rights reserved when establishing federal tribal reservations.
- **But:** The USSC and federal government did not define and quantify those rights for many decades.
- Allowed for rampant appropriation of water to other stakeholders.

Post *Winters* Implementation

- Large federal subsidies facilitated diverting water elsewhere in the west.
- By 1970's, "300%" of water supplies were allocated.
- Ft. Belknap Indian Reservation still has no quantified water right.
- Several tribes languish with limited access to water.

Fort Belknap:

- **Oldest Federal Indian irrigation project in the country (1889), unfinished.**
- **No Congressionally-ratified *Winters* rights to this day.**



Early Years:

2,587 acres of irrigable reservation land claimed by BoR for Dodson dam and canal.

Sherburne Dam
Milk River Dam & Headwater Canal
Milk River Siphons
Vandalia Dam
Fresno Dam
Nelson Reservoir

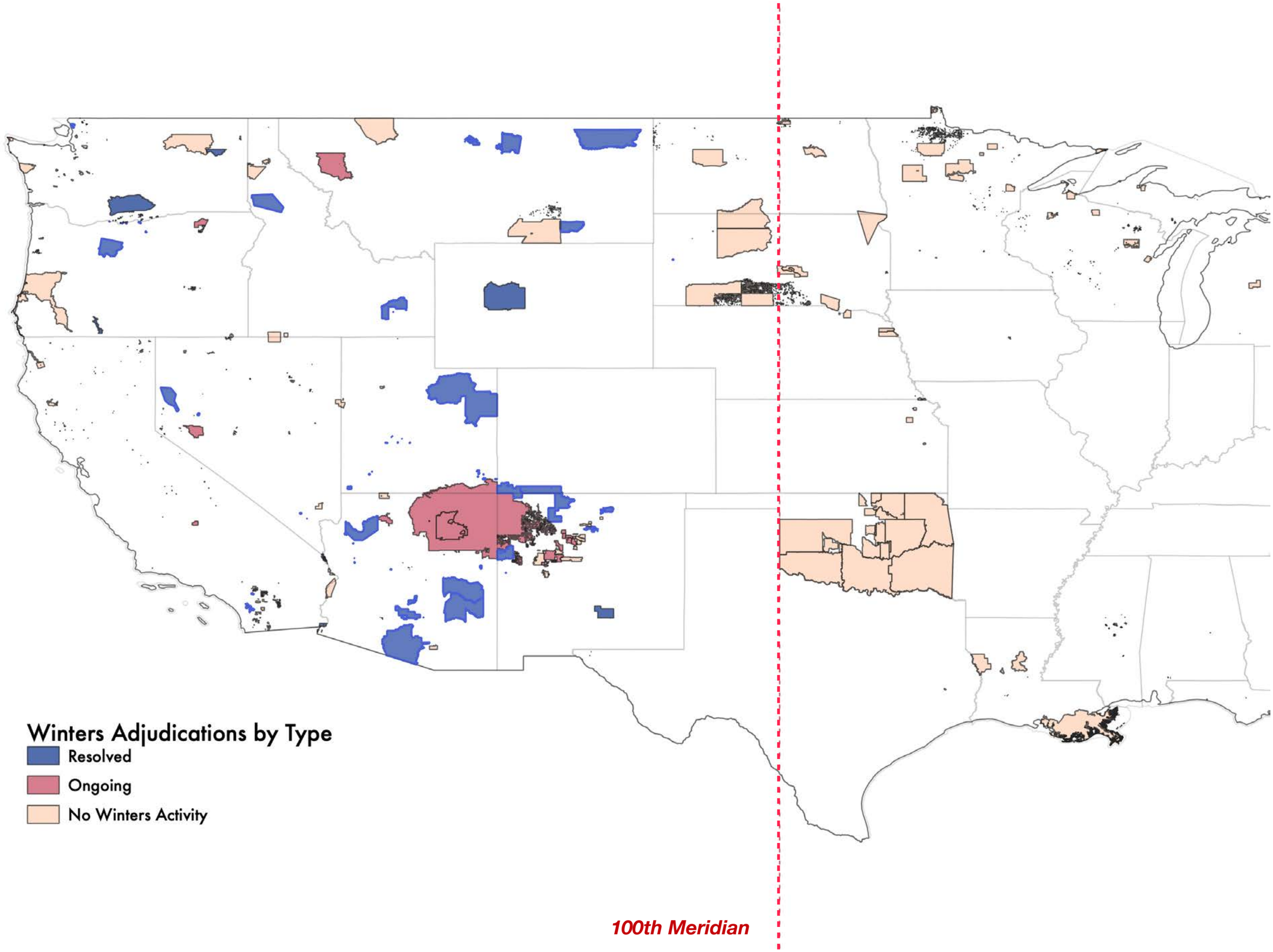
Claiming Back Water

- Two ways only in recent decades to claim back water:
    - Litigation
    - Negotiated Settlement
    - —> Initiation triggers property rights uncertainty

- **Over 200 tribes have claims to potentially vast quantities of water.** As of 2020:
    - **80** Initiated
        - **56** Resolved
            - **44** Out of Court Settlement
            - **12** Litigated
        - 24 settlements include **environmental clauses**
        - 36 allow **water marketing**

- Mean negotiating duration: **25 years** (many have been ongoing for decades - ex: LCR).

How does this process impact water quality?


Winters Adjudications by Type
Resolved
Ongoing
No Winters Activity
100th Meridian

Motivation

- After tribes go through this lengthy process, has the health of the resource been affected?
    - —> Observable data on negotiation timing
- **Hard science + social science**: information on water quality, climate, weather, and streamflow connected with data on negotiations, policies, socio-economic conditions
    - —> Allows for analysis of how specific policy/ institutions affect environmental conditions.

Quantity and Quality

- I focus on impacts to <u>quality</u>, not quantity used.
- Quantity used is extremely difficult to monitor in real time
  - Hydrology and diversions
  - Incentive to hide real usage quantities
- Degradation in quality is an overlooked issue, but a potential large and costly consequence of the legal procedures.

Research Question

Does property rights uncertainty with *Winters* proceedings worsen water pollution?

Empirical Strategy

- I estimate the causal relationship between being in a negotiation period on water quality.

  - Control group: pollution readings at stations before *Winters* begins.

- I compare average readings before, during, and after Winters negotiations for upstream, on-reservation, and downstream samples.

- Sub-samples by distance-to-reservation border.

Data

- Water quality (streamflow and pollutants): EPA STORET database. Intraday data spanning back from early 1900s, mostly from 1960s onwards. Located at distinct monitoring stations.
    - Study Area: west of the 100th meridian (186,720 monitoring stations)
    - 7% (12,773) of monitoring stations intersect with western reservations
- Streams and Rivers location and network: USGS National Hydrography Dataset HD. Split by HUC-4 boundary areas
- Weather Data (PRISM): Monthly average precipitation and temperature at each station (1960-2020).
- Climate Data: Palmer's Drought Severity Index (higher is wetter, lower is drier). Monthly (1895-2016)

Data

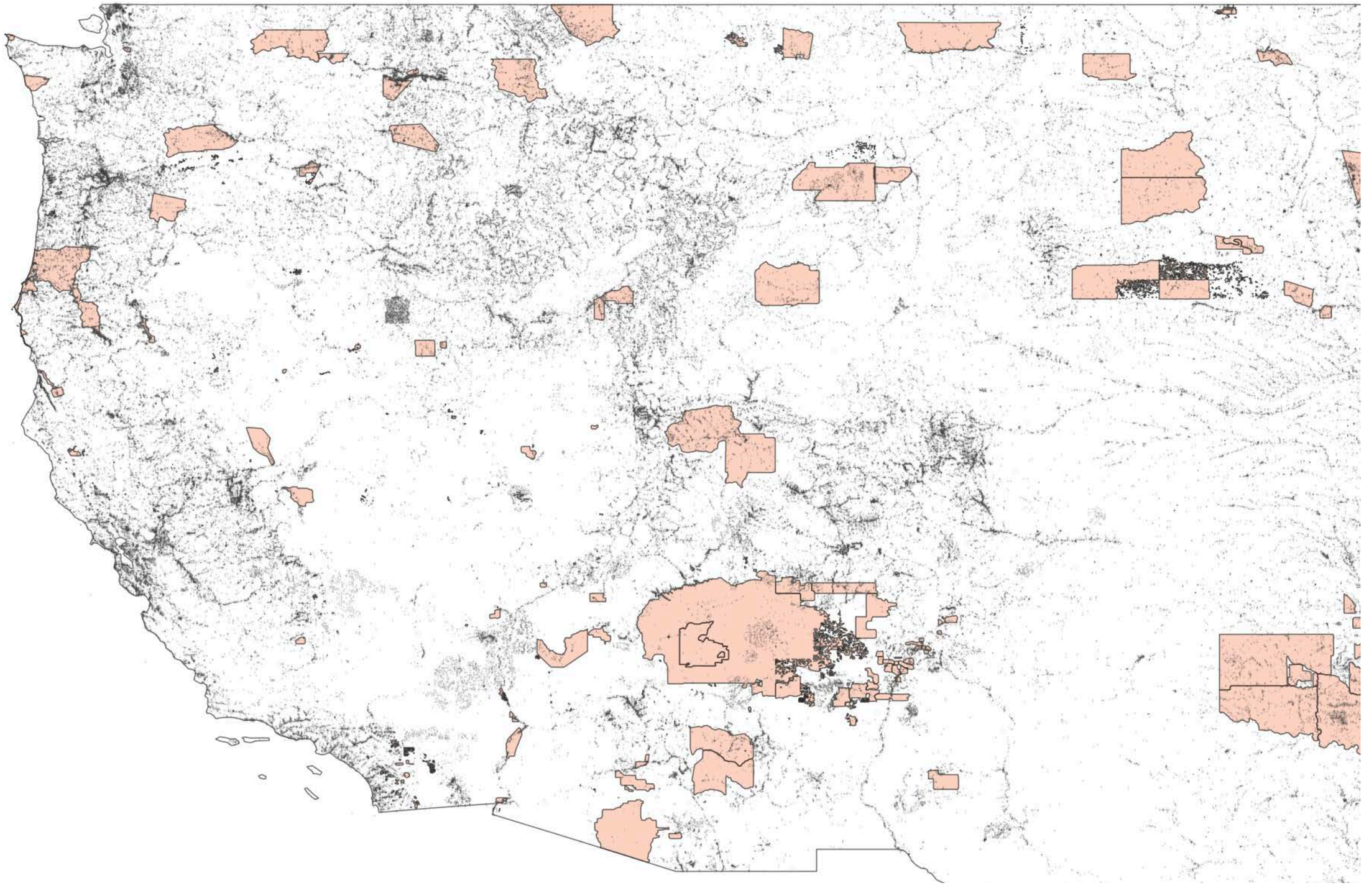
- Spatial Indicators: Distance from station to reservation (calculated); network upstream/downstream position (calculated)

- Annual County Census Data: Real per capita income; population density of county

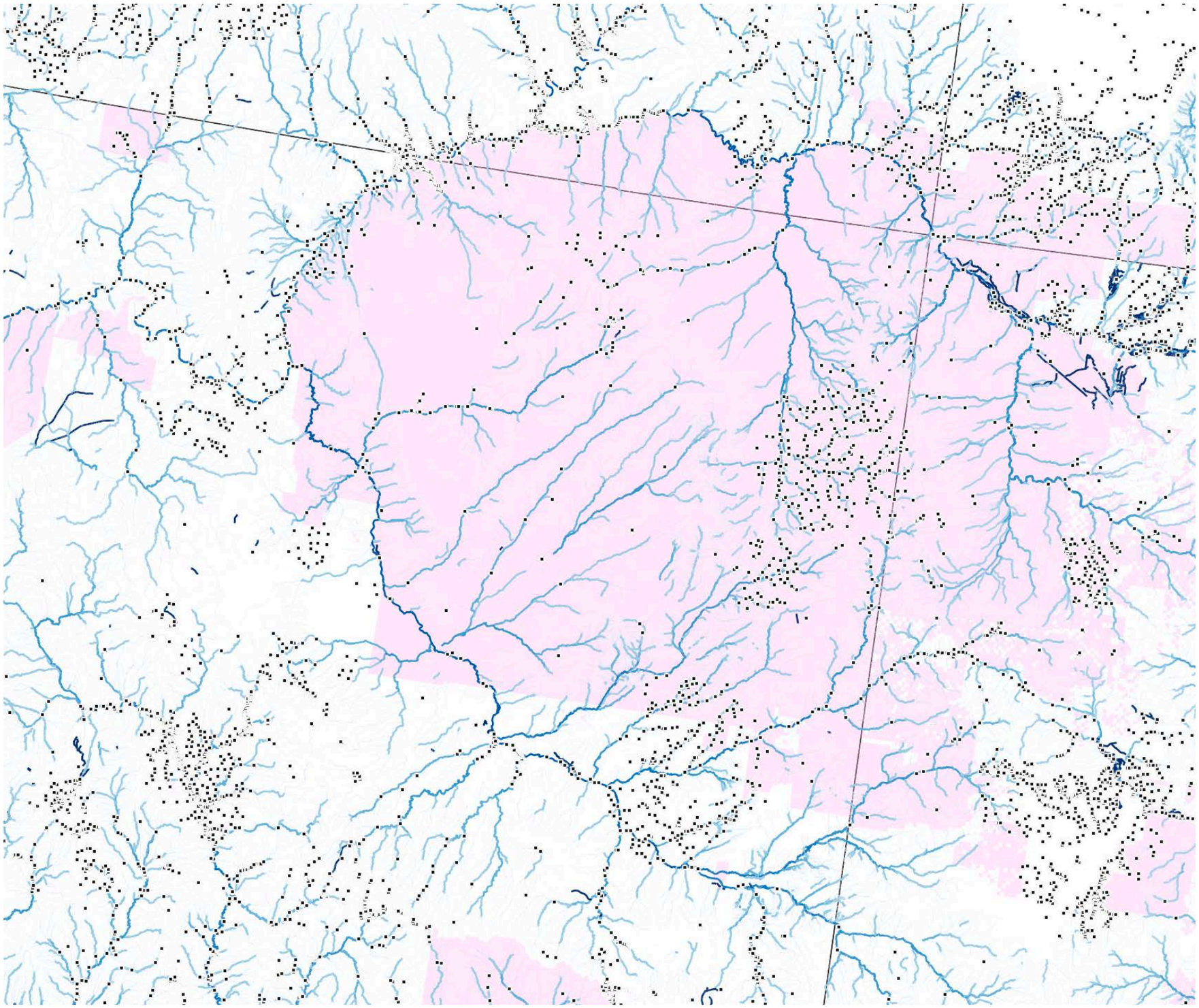
- American Indian Reservation Areas: 1990 boundaries (census geographies); Historic boundaries and land loss. There are 233 reservations in the study sample.

- *Winters* Adjudication Dates and Types of Settlements: Start and end dates, including Congressional resolutions passed per tribe-process event.

1990 Reservations and STORET Stations



Example of Data - Navajo Nation, Hopi Reservation and others (AZ/NM/UT/CO)



Single Pollutant and System-Level Analysis

- A major challenge in assessing time-varying patterns in water pollution is the difficulty in *measuring* pollution in a continuous location, over time.

  - Non-uniform monitoring stations; varying time horizons per station.

  - Uncertainties in how pollutants travel through surface and groundwater hydrologically.

- To mitigate these issues, I first focus the analysis on one pollutant, which has a high signal-to-noise ratio:
  Dissolved Oxygen

Dissolved Oxygen

- All aquatic animals need dissolved oxygen to survive.
- Falling DO levels implies excessive nutrient loads in water.
- DO % saturation as a proxy for overall pollution:
  - Not overly difficult to detect.
  - Low oxygen levels often the result of pollution from urban or rural activities that create phosphorus and nitrogen, and other microorganisms that die and decay in the water. (Eutrophication)
  - Shown to require less sample frequency to reach a steady state of information collected.
- DO levels do fluctuate seasonally, and may be affected by temperature and aeration, but these are factors I control for in the model.

Estimating Changes to Pollution: Two-Way Fixed Effects Model

$$Pollution_{j,i,t} = \alpha_{j1} + \alpha_{j2}\mathbb{1}\{Negotiation_{ry}\} + \alpha_{j3}\mathbb{1}\{Resolution_{ry}\}$$
$$+ \alpha_{j4}Flow_{it} + \alpha_{j5}DroughtIndex_{im} + \mathbf{X}_{iy}\beta^{xj} + \mathbf{W}_{im}\beta^{wj}$$
$$+ \xi_{yj} + \eta_{seasonj} + \gamma_{ij} + \varepsilon_{ijt}$$

- ***j***: Pollutant. Biochemical Oxygen Demand (BOD) 5-day; Fecal Coliforms; Total Suspended Solids; Dissolved Oxygen (reported as difference from 100% Saturation); pH (reported as difference from 7)
- ***i***: station (lat x lon) ***r***: reservation/tribe
- Three dimensions of time: ***t***: time (day); ***m***: month; ***y***: year
- **X**: census data: population density; real per cap income by county/year
- **W:** mean monthly precipitation and temperature data, station level.
- Year, station, and station fixed effects
- Single-pollutant case (**dissolved oxygen**), and as a **system of equations** (allows errors to be correlated). Treatments are additive in nature.
- Samples: **upstream**; **on-reservation; downstream; varying distances**

OLS Results - Dissolved Oxy. % Sat. (Diff from 100)

	(1) All	(2) On	(3) Upstream	(4) Up, $\leq$ 100 miles	(5) Up, $\leq$ 50 miles	(6) Up, $\leq$ 25 miles
Negotiation:						
After Winters Start	5.328*	-0.553	1.304	1.184	6.786***	8.466***
	(2.494)	(10.63)	(2.013)	(2.403)	(1.330)	(1.660)
Resolution:						
After Winters Resolution	-2.758	4.669	-1.133	-1.107	-6.976*	-8.644**
	(1.844)	(5.088)	(0.936)	(1.011)	(2.321)	(2.192)
Constant	-7.944*	-31.48	-16.91***	-16.87***	-12.76**	-1.564
	(3.003)	(15.72)	(2.137)	(2.203)	(2.630)	(8.460)
Observations	42020	3688	9208	8753	5474	2907
Adjusted R^2	0.030	0.058	0.041	0.043	0.063	0.056

Standard errors in parentheses

Errors Clustered at Res-HUC level

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Subset of results - model controls included in estimation

Conclusions

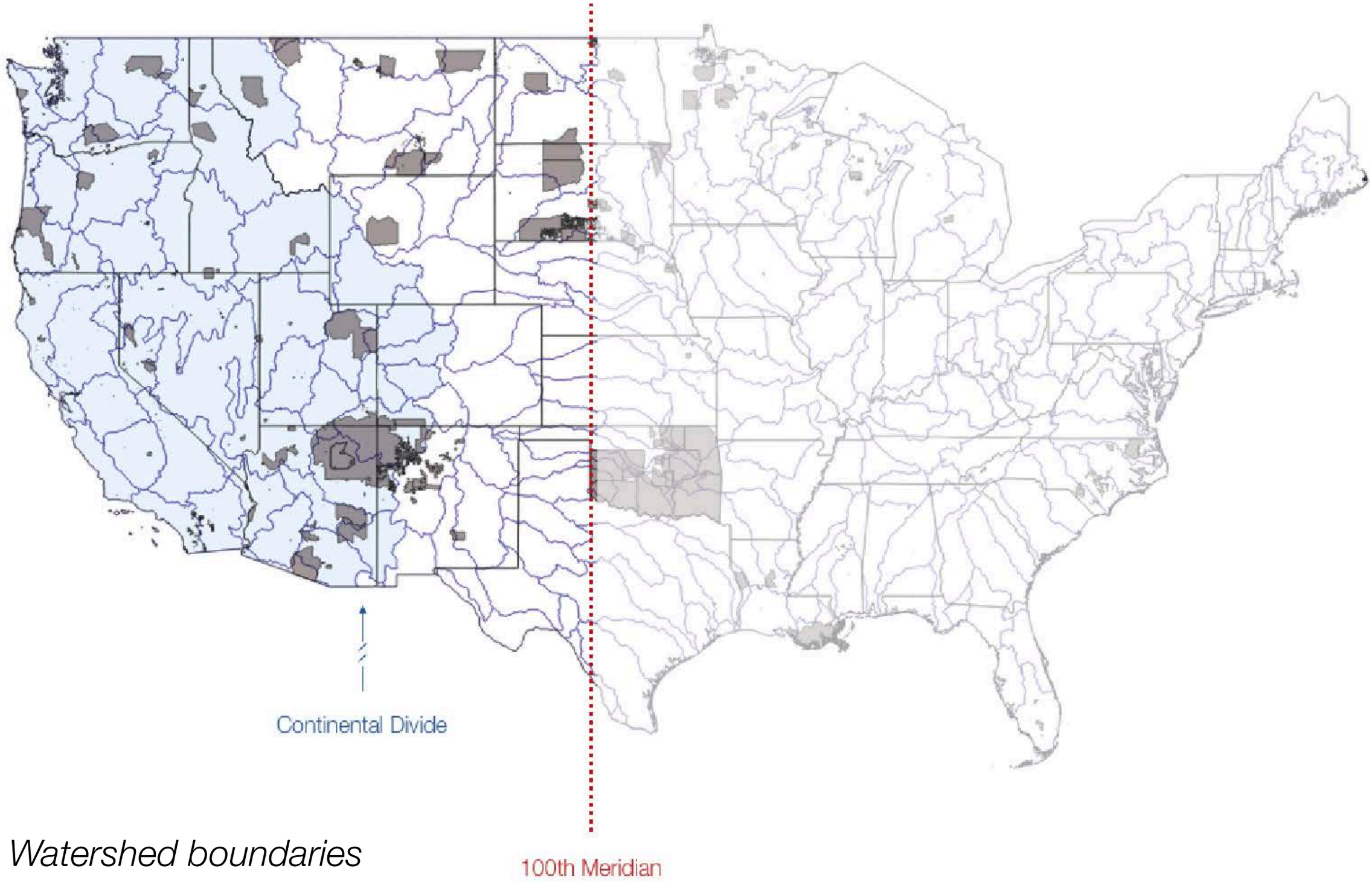
- Pollution worsens during negotiations, worsening stops once rights are settled.

- Similar results when in full panel. Fecal coliform, BOD, DO Saturation all worsen during negotiations.

- First **empirical evidence** that the *Winters* process worsens water pollution upstream of reservations during tribal negotiations over water.

- Property rights often seen as a solution, but if incomplete, long and drawn-out processes to define them can lead to degradation.

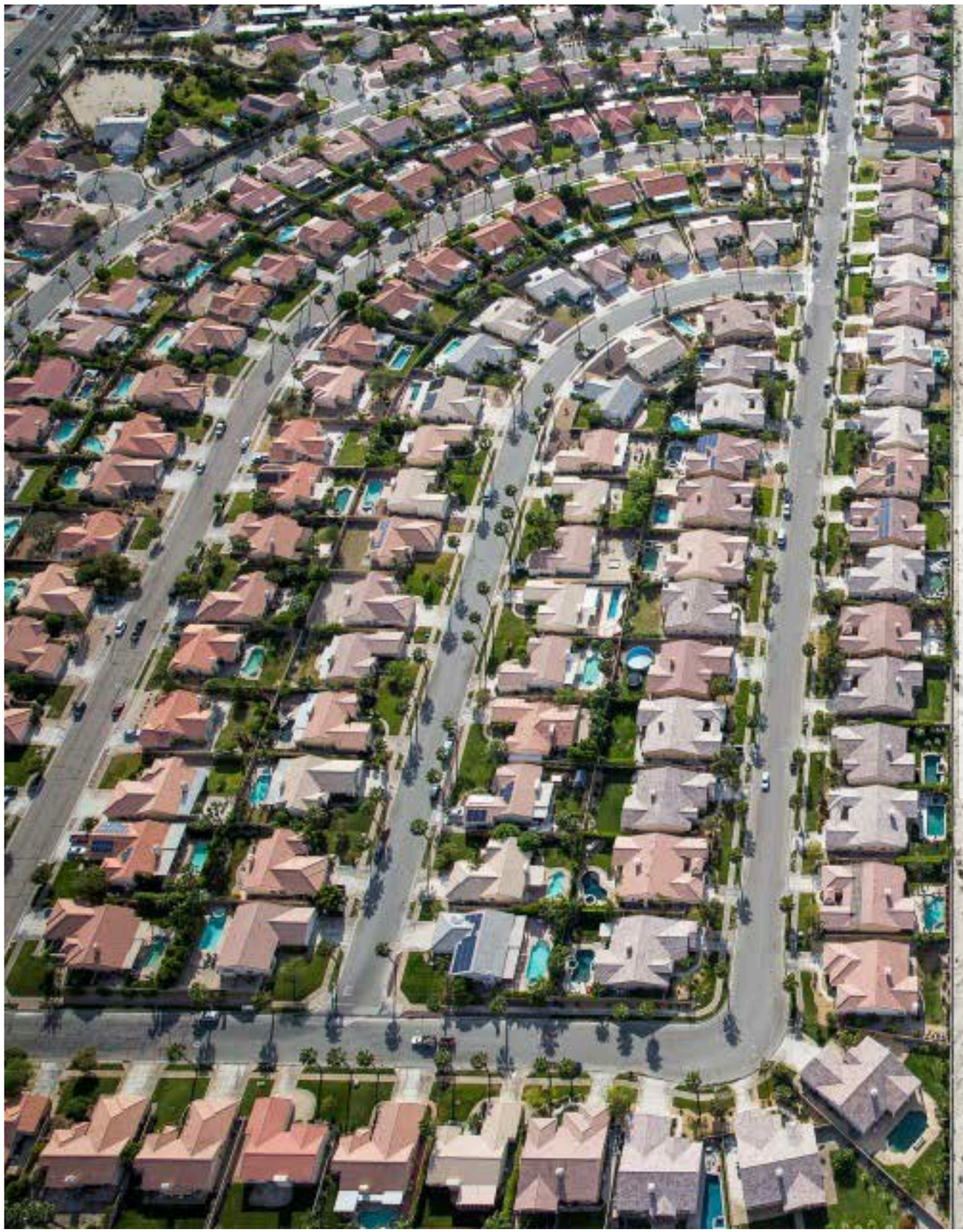
Dealing with Endogeneity (Identification Issues)



HUC4 Watershed boundaries

Conclusions

- Many enhancements for future work:
    - Better understanding of pollutants in surface and groundwater
    - Opportunity to use more granular information to better understand behavioral *and* natural resource responses and impacts relative to policy change.
- Ability to build in quality standards during legal process
- Government/Policy makers can consider these costs when designing, implementing or enforcing policy.



Thank you!

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