Paving the Swamp: Consequences of Land Use Regulation Under the Clean Water Act*

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Abstract

How does environmental regulation of land use affect the environment and the economy? We analyze how dramatic recent changes in Clean Water Act regulation due to White House and Supreme Court rules, measured using geophysical data and machine learning algorithms, affect property values and land use. Four findings emerge. First, recent rule changes greatly alter regulatory stringency. Second, regulation substantially decreases values of non-residential land parcels with water resources. Third, regulation decreases development activity, as measured from permitting and satellite data. Fourth, we calculate implied costs of this regulation.

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1 Introduction

Many prominent environmental policies restrict land development. The US Endangered Species Act, for example, constrains land use in habitats of critically threatened species. The National Environmental Policy Act requires developers to undertake a costly planning process intended to minimize environmental damage due to development.[1]

Such environmental regulation of land use attracts substantial controversy over whether it optimally balances environmental benefits and economic costs. Land use restrictions constrain the supply of developed land, and Hsieh and Moretti 2019 estimate that labor misallocation due to such restrictions decreased US growth over four decades by a third (2019). Undeveloped plots are increasingly in areas subject to climate change-related hazards like wildfires (Radeloff et al. 2018), and restricting land available for development could exacerbate those exposures. At the same time, restricting development can preserve ecosystem services that undeveloped lands provide, such as flood mitigation, wildfire mitigation, biodiversity, pest control, and air quality.

The 1972 Clean Water Act provides an important setting to study these tradeoffs. Although the Clean Water Act directly regulates pollution in US waterways, its implementation ultimately affects land use and real estate development. Section 404 of the Act restricts the discharge of "dredge and fill material" into jurisdictional waters, and delegates implementation to the US Army Corps of Engineers. In the early 1970s, the Army Corps interpreted Section 404 to regulate traditional navigable waterways, i.e., rivers that a boat could navigate, which Congress regulated under the Constitution's Interstate Commerce Clause.

In the late 1970s, however, the Environmental Protection Agency interpreted that the Clean Water Act protected water resources upstream of traditional navigable waters. This interpretation eventually expanded Clean Water Act jurisdiction to wetlands where water is present infrequently or even only historically; desert washes, and ephemeral streams, where water is present only a few days per year; and other areas where land development could otherwise easily occur. These restrictions limit most construction activity involving heavy machinery like bulldozers and excavators and thus translate a statute focused on protecting pollution in US surface waters to a statute restricting development across many US lands.

Since its inception, acrimonious debates have occurred about the appropriate jurisdiction of the Clean Water Act, and especially Section 404. One third of US Supreme Court environmental rulings since 1972 address the Clean Water Act, more by far than for any other

[1] Many other countries use such environmentally-driven land use regulations; Table A6 provides a partial list of related policies in the European Union, Brazil, China, India, and other countries.

environmental law (Zellmer 2013). In just the last decade, regulatory ping-pong due to judicial and executive branch rulings has dramatically and repeatedly changed Clean Water Act jurisdiction. These reforms provide both reason to study the Act's impacts and a research design to estimate those impacts. Until 2015, Justice Kennedy's concurring opinion in the Supreme Court's *Rapanos* decision guided jurisdiction, and directed that the Clean Water Act protected waters which were a "significant nexus" to navigable waters, including a biological, physical, or chemical connection—a decision which ultimately regulated many wetlands and ephemeral streams. In 2015, the Obama Administration issued the Clean Water Rule, which clarified which waters were protected and did not seek to substantially change jurisdiction. Twenty-seven states litigated and never implemented this rule.

Our analysis focuses on the largest recent change in Clean Water Act jurisdiction—the Trump Administration's Navigable Waters Protection Rule (NWPR), which essentially required a continuous and relatively permanent surface water connection between a regulated water and a traditionally navigable waterways. NWPR substantially limited jurisdiction for isolated wetlands (i.e., wetlands without a surface water connection) and ephemeral streams.

Clean Water Act jurisdiction is controversial due to its potential economic and environmental consequences. To determine whether the Clean Water Act regulates parts of a potential development site, landowners or developers typically hire a wetland consultant to conduct a field survey indicating whether any water features may be regulated. If so, developers must obtain a permit and incur substantial costs, such as minimizing impacts to regulated waters, purchasing environmental offsets from wetland banks, and in many cases leaving the area of the jurisdictional water resource undeveloped. These regulations affect any land development project and prominent examples include factories, renewable or fossil fuel power plants, roads, airports, golf courses, oil and gas drilling, mining, housing, warehouses, and others. At the same time, isolated wetlands, ephemeral streams, and other water resources that are not traditionally navigable account for a large share of water flow and potential ecosystem services such as pollution filtration and flood mitigation (Brinkerhoff et al. 2024).

Our analysis of this regulation proceeds in four steps. First, using data on legally-binding Approved Jurisdictional Determinations (AJDs) from the Environmental Protection Agency and Army Corps, we examine how NWPR affected regulatory stringency. We find that NWPR decreased the share of Army Corps-evaluated sites that are jurisdictional by 6 percentage points for non-water resource sites, but up to 20 percentage points for sites with water resources.

Second, we examine how variation in jurisdiction affects development. We report event study

analyses of changes in remotely-sensed measures of development in years surrounding project-level Army Corps jurisdictional determinations. Development becomes substantially more likely following a jurisdictional determination, particularly when the site is not regulated.

Third, using parcel-level data from CoreLogic on the near-universe of US land transactions, we study how the introduction of NWPR affected land markets. We focus on non-residential parcels, where development is more likely to occur after a sale. We find that NWPR substantially increased the value of water resource parcels, though only on non-residential properties. Relative to non-residential parcels with no water resources present, we estimate that NWPR increased the value of a non-residential parcel fully covered by water resources by 16 percent.

We then incorporate a machine learning model of regulation to obtain estimates of how the predicted probability of jurisdiction affects property values. Although Army Corps data reveal how NWPR changes the regulatory stringency of the Clean Water Act, and land market data reveal how NWPR changes property values, due to extremely limited spatial overlap between the Army Corps and land market data, we cannot use standard instrumental variables models to estimate the effects of regulation. Instead, we use a model based on prior work (Greenhill et al. 2024) to predict a given location's probability of being regulated under different Clean Water Act rules. We then estimate how the probability of jurisdiction under the rule in force at the time of the property sale affects land values.

Several aspects of the analysis help assess internal validity. First, event study analyses permit assessment of how property values changed when NWPR began in early 2020, versus when a judicial ruling stayed NWPR in late 2021. Second, because the period when NWPR was in force largely overlaps with the COVID-19 pandemic, we investigate the sensitivity of our results to adding parcel-level controls for three proxies for the COVID housing boom (Ramani et al. 2024): the share of individuals who can work from home, the distance to the closest central business district, and population density. Third, we compare NWPR's land market effects for non-residential parcels, where development is likely following a transaction, versus residential parcels, where single-family homes or other buildings constrain new development. Fourth, semi-parametric bin estimates show that non-residential parcels with relatively larger shares of area deregulated experienced relatively larger changes in property values, while residential parcels show no such pattern. Fifth, we find similar effects of NWPR on non-residential land values in both regions with large and small COVID housing booms.

The fourth and final part of our paper estimates the economic cost of Clean Water Act regulation by combining the results of our regulatory stringency and land market impacts analyses.

This paper departs from existing work in several ways. We believe it provides the first ex post estimate of the costs or impacts of the Clean Water Act's land use regulation. The leading estimate of the cost of Clean Water Act land use regulations comes from a survey measuring fees and time completing paperwork (Sunding and Zilberman 2002). An EPA Economic Analysis of the Biden Administration's Clean Water Act rule assumes these regulations require permit fees and mitigation costs but do not change property values (EPA and USACE 2021). Prominent media stories describe these reforms (Davenport 2020; Ferek and Puko 2020; Daly 2021) and describe how these changes in Clean Water Act rules have allowed large construction projects (Cassels 2021; Magill 2021). Five *Science* papers debate NWPR's scientific justifications, but do not study its ex post economic or environmental effects (Boyle et al. 2017; Sullivan et al. 2020; Keiser et al. 2021; Brinkerhoff et al. 2024; Greenhill et al. 2024). In contrast, there exists much economic research estimating ex post costs of other major environmental regulations, including the Clean Air Act (Becker and Henderson 2000; Greenstone 2002; Walker 2013; Shapiro and Walker 2024) and the Endangered Species Act (Auffhammer et al. 2020; Frank et al. 2025).

We also believe this paper provides the first comprehensive analysis of the Clean Water Act's Section 404 regulation of land use. A few studies analyze the Clean Water Act's grants for abatement technology at wastewater treatment plants (Keiser and Shapiro 2019; Flynn and Marcus 2021; Jerch 2021). Other work studies the Clean Water Act's abatement technology requirements for industrial plants (Behrer et al. 2021; Earnhart and Segerson 2012). These are separate from the regulations we study. Because most factories and municipal wastewater treatment plants discharge into relatively permanent streams or rivers, Section 404 rule changes have not affected the Clean Water Act's regulation of such plants.[2]

More broadly, this paper provides novel estimates of the cost of protecting wetlands, which are a critical natural resource globally. Wetlands create a classic positive externality since they mitigate floods, improve water quality, and provide other benefits to other properties, which do not directly accrue to the owner of a given wetland (Heimlich 1998; Turner et al. 2000). A few papers analyze particular aspects of wetlands: Taylor and Druckenmiller (2022) use spatial and temporal variation in US wetlands to estimate their flood protection benefits; Aronoff and Rafey (2023) studies offset markets for wetlands in Florida; Stavins and Jaffe (1990) model how flood prevention and land use projects in the Mississippi Valley change supply of forested wetlands. Our sense is that economic research on wetlands is inef-

[2] Using colorful language about not fouling one's own swimming pool, several regulators have explained to us that discharging even treated wastewater from industrial or wastewater treatment plants into water resources that do not regularly or ever flow, like isolated wetlands or ephemeral streams, would essentially be polluting the plant's backyard, which is unwise.

ficiently scarce relative to wetlands' global environmental and economic importance, which is arguably given wetlands' potential role in climate adaptation via flood mitigation.

We proceed as follows. Section 2 provides background. Section 3 describes data and Section 4 discusses the research design. Section 5 presents the results, with section 5.1 analyzing how rule changes affected regulatory stringency, section 5.2 investigating how Clean Water Act regulation affects property values, and section 5.3 presenting several extensions. Section 6 computes the economic costs of the regulation and section 7 concludes.

2 Background: Policy and Water Resources

2.1 Example of Wetland Development

Houston, Texas, regularly suffers flooding due to heavy rainfall and low-lying housing. On the periphery of Houston's growth, thirty miles Northwest of the city center, a development called Bridgeland covers 11,500 acres, is intended to have 20,000 homes, and is one of the country's top-selling planned communities (Groves 2021; Mizan 2024; Bridgeland 2025). Bridgeland is just south of Cypress Creek, a perennial stream which sometimes floods parts of the area, and which flows downstream through Houston. Bridgeland broke ground in 2011 but initially avoided developing several areas near Cypress Creek.

In October 2020, the Army Corps provided Approved Jurisdictional Determinations for 90 water resources near the Bridgeland area around Cypress Creek. These AJDs collectively covered 80 acres of wetlands and basins plus 20 linear miles of ditches and streams (U.S. Army Corps of Engineers 2020).The Corps concluded that none of the resources were jurisdictional under the Navigable Waters Protection Rule. Many of the water resources were near Cypress Creek but lacked a continuous surface water connection.

After the AJDs, Bridgeland rapidly developed the area (Figure A1). Google Earth aerial imagery from 2021 shows bulldozed land and a built pond near the creek. Imagery from 2025 show many homes built and under construction. Zillow lists homes for sale in early 2025 with prices of $300,000 to $700,000. Bridgeland includes 250 miles of trails, 3,000 acres of open space, and 900 acres of lakes and waterways and describes one of its built water features, named Josey Lake, as "Bridgeland's crown jewel of coexistence"[3] (**?**) . The development

[3] The Bridgeland website further describes Josey Lake as "...the manifestation of our community's goal for development and nature to coexist in a responsible way that preserves, provides utility, and enhances life through outdoor connections. Plus, it's a happening hot spot for canoeing, kayaking, paddle boating, bird watching, zip lining and communing with nature in myriad other ways."

has won many national awards including Master Planned Community of the Year and Best Landscape of a Community. Chevron purchased a large component of Bridgewater area to provide offices for its research and development staff.

This example illustrates the tradeoffs we analyze. By building impervious surfaces on historically wet areas near perennial streams, development can increase flood risk and limit other ecosystem services like water purification. At the same time, the many half-million dollar homes, the research campus for a Fortune-500 company, and the natural amenities demonstrate the demand for such development on wetlands, and the potential costs of regulation that restricts such development.

2.2 Clean Water Act

Section 404 of the Clean Water Act restricts land use around regulated waters. Formally, Section 404 restricts the discharge of "dredge and fill material" into jurisdictional waters, which are often referred to as 'Waters of the United States' (WOTUS). In practice, since any type of construction activity creates such material—moving dirt to clear and level a building site, setting a foundation, cutting an access road, etc—Section 404 regulates most commercial activity around regulated water resources.

These regulations are implemented as follows: a landowner wishing to undertake development around an aquatic resource must request a determination from the Army Corps of Engineers whether each water feature is regulated. An Army Corps engineer may visit the project site or, in nearly half of cases, use electronic information like land cover and topographic maps and aerial imagery to determine whether the water features are regulated under the Clean Water Act. For each water resource, the engineer files a form (an "Approved Jurisdictional Determination," or AJD) which indicates whether it is jurisdictional (i.e., regulated) or not.

If a water resource is deemed jurisdictional, a landowner may choose not to develop it. If the landowner pursues development, the landowner must also obtain a permit from the Army Corps that describes the project and what the landowner must do to minimize impacts on regulated waters. In some cases, developers are restricted from disturbing areas near the regulated waters to the extent that the project is rendered uneconomic. The permit may require the purchase environmental offsets through mitigation banks or the direct mitigation of impacts on site. A schematic showing the process for obtaining jurisdictional determinations and permits is included in Appendix A2.[4]

[4] There is also a parallel process involving a "Presumed Jurisdictional Determination," or PJD, for approved types of projects (e.g., transmission lines, pipelines, and levee maintenance) whose impacts are

Any development activity that affects regulated waters without receiving a Section 404 permit is illegal. If there is ambiguity as to whether a water feature is regulated, the only way for a landowner to get secure protections is to obtain a jurisdictional determination from the Army Corps before developing the site. Upon discovery of a violation, the landowner is fined and must pay to remediate the project site to its original state (e.g., demolish and bulldoze whatever has been built, then hire environmental engineers to restore the original aquatic features).[5]

By contrast, if the Army Corps determines that a water feature is not jurisdictional, the landowner can undertake development without any requirements or constraints—notwithstanding any state or local regulations. Such actions can include designing drainage systems or adding fill materials that re-route, bury (e.g., through underground channels like culverts), or completely eliminate a water resource.

The jurisdictional status of a water feature can substantially affect a property's development potential. Determining that a wetland is jurisdictional can prevent the building of housing, factories, roads, or other development projects; whereas determining that a wetland is not jurisdictional means its area can be used for any development purpose the owner chooses, without requiring a federal permit under Section 404. This makes it plausible that reforms that change the jurisdictional status of water resources will also change willingness-to-pay for lands that include them.

As the introduction mentions, this is completely separate from the Clean Water Act's two other main activities: the State Revolving Fund, which provides subsidized loans to municipal wastewater systems to improve abatement technology; and Section 402, which creates the National Pollutant Discharge Elimination System (NPDES) that sets emission limits and requires abatement technology investments for industrial and municipal plants.

The legal changes we analyze apply to all parts of the Clean Water Act. However, as mentioned in the introduction, the changes in the definition of jurisdictional waters (WOTUS) we analyze primarily affected water resources that are small, isolated, non-flowing, or non-permanent. The industrial and municipal plants that are regulated under non-Section 404

generally well understood and small (less than 0.1 acre). In such cases, a developer assumes the water feature is regulated and obtains a 'nationwide permit' that is faster and less costly than a standard permit.

[5] While such enforcement does occur, it is costly and unpopular. Regulators identify violations from visits to nearby properties, remote sensing imagery, other development permitting, and information from industry contacts and other sources. Developers and real estate agents are highly aware of Section 404 and wetland regulation. Land clearing and development is difficult to hide, particularly with freely available aerial imagery. While attempts to develop wetlands and other water features without consulting the Army Corps do occur, our sense is that they are rare.

Clean Water Act provisions generally discharge polluted wastewater directly into permanent water resources which always flow—and thus are always regulated. As such, the rule changes we analyze have generally not affected industrial regulation or wastewater treatment under these other sections of the Clean Water Act.

2.3 Rule Changes to the Clean Water Act

While the Clean Water Act was passed by Congress in 1972, how the law is interpreted and implemented has evolved over time. This occurs through the process of administrative rulemaking, whereby federal agencies can i) provide clarity on vague or broad statutory provisions, ii) update implementation practices based on new scientific or economic data, and/or iii) align regulatory practices with the current administration's priorities. Under Section 404 of the Clean Water Act, rulemaking authority is shared by both the Environmental Protection Agency and the Army Corps of Engineers.

With this context, we discuss four major Clean Water Act rules, though we focus on two. *Rapanos*, reflecting Justice Kennedy's 2006 concurring US Supreme Court decision, requires that waters be a "significant nexus" to navigable waterways in order to be regulated. It recognizes that biological, chemical, and physical connections, including groundwater and subsurface aquifers, can constitute such a nexus, even if surface water connections do not.

The Obama Administration's Clean Water Rule sought to clarify jurisdiction under *Rapanos*, though not to change it substantially. The Clean Water Rule applied for a number of months beginning in 2018, though only in 23 US states (its implementation was delayed and then stopped in the other 27 states due to litigation). Due to the short period of its implementation and relative similarity to *Rapanos*, we do not discuss or distinguish it further.

The Trump Administration's 2020 Navigable Waters Protection Rule (NWPR) implements Justice Scalia's opinion from the *Rapanos* case. NWPR changed jurisdiction in several ways. It deregulated wetlands which have a biological, chemical, or physical connection to navigable waters, but which lack a relatively permanent surface water connection to such waters. For example, a wetland that is separated from the Mississippi River by 10 feet of dry ground forest would likely be jurisdictional under *Rapanos* but not under NWPR. In addition, NWPR deregulated ephemeral streams, which flow infrequently and only after rainfall, and are very common in the western US. These were the two major changes, though the Navigable Waters Protection Rule also restricted coverage of other types of water resources.

The Supreme Court decision in *Sackett v. Environmental Protection Agency*, first im-

plemented in late 2023, has many similarities to NWPR. It clearly strikes down Justice Kennedy's significant nexus standard, and the prevailing interpretation of *Sackett* also applies the relatively permanent standard for federal waters. Thus, both NWPR and *Sackett* exclude jurisdiction of many isolated wetlands and ephemeral streams.

Our data begin in 2017, when *Rapanos* was en force. The timing of NWPR's rollout is relevant to our empirical analysis. Although the Obama Administration promulgated the Clean Water Rule in 2015, it was not immediately implemented, and in 2017 the Trump Administration delayed its implementation. In August 2018, a judge ruled for the Clean Water Rule to extend to the 27 states where implementation had been delayed due to litigation.

The EPA and Army Corps first published an interim version of NWPR on October 22, 2019. Although the Trump Administration discussed relaxing jurisdictional definitions for the Clean Water Act in the 2016 presidential campaign, and issued an executive order in 2017 directing the EPA and Army Corps to issue a rule relying on Justice Scalia's *Rapanos* plurality opinion, October 2019 was the first date when the public, including developers and landowners, had precise information about what a Trump Clean Water Act rule would deregulate, and when the deregulation would occur. The EPA and Army Corps formally repealed the Obama administration's Clean Water Rule on December 23, 2019, which made all regulatory decisions revert to *Rapanos*. The EPA published the final NWPR rule in January 2020, published it in the Federal Register in April 2020, and Army Corps began implementing NWPR in June 2020. Although seventeen states sued to delay NWPR, only Colorado succeeded, delaying the implementation of NWPR until March 2021.[6]

Based on this timing, we expect NWPR to begin affecting land markets between October 2019 and June 2020. In quarterly graphs, we interpret the first quarter of 2020 as the initial period of possible impact of NWPR, since this covers publication of the final NWPR rule. But we note that a) precise information about NWPR was available in the fourth quarter of 2019, b) certainty over NWPR was available in the second quarter of 2020, and c) that implementation of NWPR began in the second to third quarter of 2020. Thus, a developer who purchased a property in the first or especially second quarter of 2020 could expect to receive a jurisdictional determination that applied NWPR standards in the near future.

NWPR was vacated on August 30, 2021 in federal court. At that point, jurisdiction again reverted to *Rapanos*, and later to the Biden Administration's 2023 rule that reflected *Rapanos*. The information held by developers after NWPR was vacated is ambiguous. The

[6] The opposed states to NWPR were California, New York, Connecticut, Illinois, Maine, Maryland, Michigan, New Jersey, New Mexico, North Carolina, Oregon, Rhode Island, Vermont, Washington, Wisconsin, Massachusetts, Virginia, North Carolina, plus Washington DC.

Supreme Court at that time had a solid conservative majority and had indicated willingness to decrease federal regulation. Given the considerable ongoing debates over Clean Water Act jurisdiction, many observers anticipated that the Supreme Court would provide a Clean Water Act ruling that would narrow the scope of jurisdiction. Indeed, *Sackett* was the first case on the first day of the Court's 2023-24 term. Because land purchases and development are long-term investments, they reflect both current and expected future regulation. Thus, we do not interpret August 2021 as a uniform change from NWPR to *Rapanos*, but recognize that developers post August 2021 may see additional value in wetland properties in anticipation of a Supreme Court decision supporting deregulation. We therefore interpret the August 30, 2021 court ruling as an increase in jurisdiction (i.e., more regulation), though not a full diminishing of the expectation of deregulation brought about by NWPR.

While the end of our sample period covers the *Sackett* ruling, our analysis examines it more briefly given limited post-period data relative to the NWPR or *Rapanos* rules.

3 Data

Approved Jurisdictional Determinations. We use data on Clean Water Act jurisdiction from Approved Jurisdictional Determinations (AJDs) made by the US Army Corps of Engineers. AJDs are case-by-case decisions about whether an individual water resource is jurisdictional under the Clean Water Act. AJDs are available at the individual waterbody level from the EPA (https://watersgeo.epa.gov/cwa/CWA-JDs/). The database has approximately 150,000 AJDs. The data cover all states and Army Corps districts, though prevalence varies across districts (Greenhill et al. 2024).

Property values. We use land transaction data from CoreLogic spanning 2017 to 2023. Our extract includes approximately 3.3 million land transactions categorized as non-residential (CoreLogic land use code >= 200). Such non-residential categories include vacant, agricultural, commercial, and industrial land transactions. In addition, we extract a random sample of 6 million residential transactions over the same time period. We choose this sample size to mirror the non-residential transactions sample and also to reflect computational tractability given that the full residential number of transactions is much larger. The CoreLogic data report the date of sale, the sale amount, and many property characteristics. For geolocation (latitude/longitude), we use CoreLogic's proprietary parcel-centroid coordinates.We follow best practices in creating an extract of the CoreLogic data for analysis (Appendix **??**). Summary statistics for our main sample of CoreLogic non-residential property transactions in the US from 2017-2023 are reported in Table 1.

National Wetlands Inventory. We use the National Wetlands Inventory (NWI), the most comprehensive national dataset describing the area of known wetlands and water bodies, to identify water resources. NWI divides water resources into palustrine (wetlands) and then other categories like lacustrine (lakes) and riverine (streams). While NWI has known errors of inclusion and exclusion, we use NWI because it provides a well-documented and easily-understood proxy for exposure to Clean Water Act jurisdiction under different rules. Specifically, we proxy for exposure to Clean Water Act jurisdiction using the "water resource share" of each site, calculated as the share of area within a 100 meter buffer around a site covered by any NWI polygon.

Jurisdictional probabilities. We also measure exposure to Clean Water Act regulation using predictions from a machine learning algorithm that estimates property-level probabilities of jurisdiction under different Clean Water Act rules. Following 2024, the algorithm is trained and evaluated on AJDs. The outcome is a binary indicator equal to one if the site was determined to be jurisdictional. The predictors include a set of local characteristics: the share of a 100-meter radius around the site centroid covered by each NWI class (e.g. freshwater emergent wetland, estuarine and marine wetland, riverine, lake, etc.), stream classification and flow measures from the National Hydrography Database, elevation, soil characteristics from the Gridded National Soil Survey Database, climate measures from PRISM, land cover from NLCD, Army Corps administrative districts, satellite imagery embeddings[7], and an indicator for whether NWPR was in force at the time of the determination.

While 2024 use a Convolution Neural Network (CNN) to predict regulatory probabilities, we find that a ridge regression with two-way interactions between all features achieves comparable performance at a fraction of the computational cost, allowing us to apply this procedure to our sample of millions of real estate transactions. The algorithm is trained on 80% of the AJD observations and evaluated on a spatially held-out test set of 20% of observations.[8] Overall, it achieves 77% accuracy at predicting jurisdictional status on the held-out test set. Accuracy is comparable for determinations made under *Rapanos* (75%) and NWPR (78%).

The algorithm outputs a continuous score between 0 and 1. These scores are well-calibrated to jurisdictional probabilities; that is, they provide an unbiased estimate of the probability of jurisdiction. For example, when the algorithm outputs a score between 0.3 and 0.4 for test-set AJDs, 34% of those AJDs are regulated. When it outputs a score between 0.9 and 1, 96% of those AJDs are jurisdictional. Hence, following 2024, we interpret the scores as

[7] Imagery embeddings are obtained from the MOSAIKS API (https://api.mosaiks.org/) which provides imagery embeddings constructed from 4 meter Planet imagery at 0.1 degree resolution. We use 1,000 MOSAIKS features, with 500 each constructed using patch size 4 and patch size 6.

[8] We assign train/test on a 0.1 degree grid.

predicted jurisdictional probabilities.

The predicted probabilities among the AJDs are shown in the left column of Figure A5. The top row corresponds to the predicted probability of jurisdiction for each case, conditional on the WOTUS rule in force at the time of the determination. The mean predicted probability of jurisdiction is 0.32. The second row plots the site-level jurisdictional probabilities if all AJDs were decided under *Rapanos*, hereafter $p(Rapanos)$. The third row shows the site-level jurisdictional probabilities if all decisions were made under NWPR, hereafter $p(NWPR)$. As expected, the jurisdictional probabilities tend to be higher under *Rapanos* (mean = 0.36) than under NWPR (mean = 0.25). The fourth row shows the site-level change in jurisdictional probability when moving from *Rapanos* to NWPR, which we define as $\Delta\text{Jurisdiction} = p(NWPR) - p(Rapanos)$. Most sites (>80%) are predicted to have lower jurisdictional probabilities under NWPR, with a mean change in probabilities of −0.11.

Finally, we apply the ridge regression model trained among AJDs to predict jurisdictional probabilities of each CoreLogic transaction under both *Rapanos* and NWPR.[9] These predicted probabilities are shown for non-residential and residential property transactions in the center and left columns, respectively, of Figure A5. Non-residential transactions have similar jurisdictional probabilities as AJD sites, both with a mean of 0.32 at the time of determination/sale. Residential properties are slightly less likely to be jurisdictional, on average, with a mean of 0.3. Among both non-residential and residential properties, the mean change in jurisdictional probabilities when moving from *Rapanos* to NWPR is −0.15.

Land cover. To assess land use change pre- and post a jurisdictional determination and NWPR, we derive data on the spatial extent of developed and wetland area from USGS's National Land Cover Database (NLCD). This remotely-sensed product provide annual nationwide data on land cover at 30-meter resolution (Homer et al. 2020; Brown et al. 2020).

4 Empirical Approach

In the section, we discuss several analyses: how NWPR affected regulatory stringency, how NWPR affected land markets, and how Clean Water Act jurisdiction affects land use change.

Regulatory stringency. We first test how NWPR affected regulatory stringency, allowing for differential responses to the rule change based on our two proxies for exposure to Clean

[9] The reader may wonder whether it is appropriate to apply a model trained in AJDs to out-of-sample sites. Encouragingly, 2024 demonstrate that a machine learning model trained among AJDs has comparable performance among sites that resemble a random sampling of locations across the United States as among sites that closely resemble the mean AJD location.

Water Act regulation — water resource share and predicted jurisdictional probabilities. We view these two exposure measures as complementary. Water resource share is straightforward to measure and easy to understand. It is intuitive that the amount of water resources on a parcel should affect its exposure to Clean Water Act regulation. The predicted jurisdictional probabilities from the machine learning algorithm are heavily modeled and therefore less intuitive, but this measure captures more of the spatial variation in exposure deregulation under NWPR and the resulting estimates are directly interpretable as the impact of Clean Water Act regulation on our outcomes of interest.

We model jurisdiction as a function of Clean Water Act rules and water resource share following the equation:

$$Y_{idt} = \alpha W_i + \gamma \mathbb{1}[R_t = NWPR] + \beta W_i \mathbb{1}[R_t = NWPR] + \eta_d + \varepsilon_{idt} \tag{1}$$

where Y represents an indicator for whether the US Army Corps of Engineers determined that an Approved Jurisdictional Determination at site i located in Army Corps district d made at time (day) t was jurisdictional (i.e., regulated). The term W_i measures the share of area within 100 meters of site i that has an NWI water feature present. The indicator function $\mathbb{1}[R_t = NWPR]$ equals one if NWPR was in force at the time of the determination and zero otherwise. The equation also includes Army Corps district fixed effects η_d to account for differences in regulatory stringency across administrative regions. The interaction term estimates differential jurisdiction for water resources under NWPR; *Rapanos* and the Clean Water Rule are the reference category. Finding that $\beta_1 < 0$ would indicate that NWPR disproportionately deregulated areas with more water resources.

Similarly, we test whether our machine learning-generated jurisdictional probabilities reflect NWPR deregulation using the equation:

$$\begin{aligned} Y_{idt} = \alpha_1 p(Rapanos) + \alpha_2 p(\text{NWPR}) + \gamma \mathbb{1}[R_t = NWPR] \\ + \beta \Delta\text{Jurisdiction} \mathbb{1}[R_t = NWPR] + \eta_d + \varepsilon_{idt} \end{aligned} \tag{2}$$

where Y_{idt} (jurisdictional outcome), R_t (NWPR indicator), and η_d (district fixed effects) are defined as in equation 1. Here, $p(Rapanos)$ and $p(NWPR)$ are the predicted jurisdictional probabilities under *Rapanos* and NWPR, respectively. The variable $\Delta\text{Jurisdiction}_i$ is defined as the change in jurisdictional probabilities between NWPR and *Rapanos*; that is, $\Delta\text{Jurisdiction}_i = p(\text{NWPR}) - p(Rapanos)$. Critically, this equation is estimated in a

held-out test set of AJDs that was not used in model training. The results therefore reflect the out-of-sample relationship between predicted jurisdictional probabilities and true jurisdictional outcomes.

In equation 2, α_1 estimates the impact of the predicted probability of jurisdiction under *Rapanos* on jurisdictional status under *Rapanos*. If the machine learning model were perfectly accurate, α_1 would equal 1. α_2 estimates the impact of the predicted probability of jurisdiction under NWPR on jurisdictional status under *Rapanos*. Our treatment effect of interest, β, estimates the effect of the change in jurisdictional probabilities under NWPR during the period when NWPR was in force. Once again, if the model were perfectly accurate, β would equal 1.

Property values. Next, we study how Clean Water Act rule changes affect land market outcomes at the property level using estimating equations that closely mirror the regulatory stringency analyses described above.[10]

We examine how deregulation affects property values by water resource share using the equation:

$$\begin{aligned} P_{izt} = \alpha W_i + \beta_1 W_i \mathbb{1}[R_t = NWPR] \\ + X'_{izt}\gamma_1 + X'_{izt}\mathbb{1}[R_t = NWPR]\gamma_2 \\ + \eta_{zt} + \varepsilon_{izt} \end{aligned} \tag{3}$$

where P_{izt} represents the log sale price for parcel i in zip code z sold at time (year-month) t. The terms W (water resource share) and R_t (NWPR indicator) are defined as in equation 1. Here, the interaction term estimates the differential price impact of water resources on property values under NWPR, where NWPR is an indicator for the period spanning February 2020 to August 2021. The controls X_{izt} include lot size and proxies for the COVID housing boom from Ramani et al. 2024: the distance of site i from the closest metropolitan center and town center, the population density, and the share of people who work from home. Importantly, we interact these controls with the NWPR indicator to allow for differential impacts of these COVID-related features on property values during the Clean Water Act rule change, which overlaps with the timing of the pandemic. The regression includes zip code-by-year-month fixed effects η_{zt} to adjust for overall changes in local regulatory practices, local housing market shocks, and other unobserved factors that may vary differentially for areas with more water resources during the periods when NWPR was in force. The level

[10] We examined how AJDs affect property values directly, though given the small sample size of AJDs, the results had wide confidence intervals and we do not pursue them further.

effects of NWPR are perfectly collinear with the fixed effects η_{zt}, so we do not include them. The term ε_{izt} represents the regression error. We cluster standard errors by commuting zone.

The main coefficient of interest, β_1, represent the mean change in log property values for water resource parcels under NWPR, relative to *Rapanos* and the Clean Water Rule. Finding that $\beta_1 > 0$ would indicate that NWPR disproportionately increased the value of parcels with water resources relative to those without water resources.

We also use the following equation to report event study graphs corresponding to this equation:

$$P_{izq} = \alpha W_i + \sum_{\tau} \left(\beta_\tau W_i \mathbb{1}[q_q = \tau] + X'_{izq} \mathbb{1}[q_q = \tau] \gamma_\tau \right) + \eta_{zt} + \varepsilon_{izq} \tag{4}$$

where q denotes the year-quarter of the property sale. We plot the β_τ coefficients against the year-quarters they represent, and highlight periods when NWPR was in force. This graph permits a visual inspection of pre-trends and assessment of how property values change in time periods around rule changes.

Additionally, we estimate the impact of the change in jurisdictional probabilities under NWPR on property values using the following equation:

$$\begin{aligned} P_{izt} = {} & \alpha_1 p(Rapanos) + \alpha_2 p(\text{NWPR}) + \beta \Delta\text{Jurisdiction} \mathbb{1}[R_t = NWPR] \\ & + X'_{izt}\gamma_1 + X'_{izt} \mathbb{1}[R_t = NWPR]\gamma_2 + \eta_{zt} + \varepsilon_{izt} \end{aligned} \tag{5}$$

where the treatment variable, $\Delta\text{Jurisdiction}\mathbb{1}[R_t = NWPR]$ is defined as in equation 2 as the change in jurisdictional probabilities under NWPR during the period when NWPR is in force. As in equation 2, we control for the predicted jurisdictional probabilities under *Rapanos* and NWPR during the period when *Rapanos* was in force. Further, we include the same parcel-level controls (X_{izt}) and zip-year-month fixed effects (n_{zt}) as in equation as in equation 3.

The coefficient of interest is β, which can be interpreted as the effect of a change in probability of Clean Water Act jurisdiction on property values. Here, we expect β to be negative if more stringent regulation reduces property values. Since ΔJurisdiction is negative for the vast majority of properties, a negative β would imply that NWPR increased property values for parcels that were likely to be deregulated under the rule change.

The identifying assumption is that the change in jurisdictional probabilities between NWPR

and *Rapanos*, ΔJurisdiction, only affects property values through changes in Clean Water Act rules, conditional on our set of controls and fixed effects. In other words, ΔJurisdiction is uncorrelated with unobservable determinants of property values. To test this identifying assumption, we implement an event study version of equation 5, where we estimate the impact of ΔJurisdiction by year-quarter. This event study allows us to test for parallel trends in the periods before NWPR is implemented.

We note that equation 5 is equivalent to the equation:

$$\begin{aligned} P_{izt} = &+\alpha_1 p_i(Rapanos) + \alpha_2 p_i(NWPR) + \beta \text{Jurisdiction}_i \\ &+ X'_{izt}\gamma_1 + X'_{izt}\mathbb{1}[R_t = NWPR]\gamma_2 + \eta_{zt} + \varepsilon_{izt} \end{aligned} \tag{6}$$

where Jurisdiction_i is the probability of jurisdiction at the time of the property sale. That is, $\text{Jurisdiction}_i = p_i(Rapanos)\mathbb{1}[R_t = Rapanos] + p_i(NWPR)\mathbb{1}[R_t = NWPR]$. Re-writing the equation this way allows for the straightforward interpretation as the effect of the probability of jurisdiction on property values. Further, it allows us to estimate a non-parametric specification that allows for non-linear effects of jurisdictional probabilities on property values. Specifically, we estimate the following binned dose-response function:

$$\begin{aligned} P_{izt} = &\sum_m \Big(\alpha_{1m}\mathbb{1}[p_i(Rapanos) \in m] + \alpha_{2m}\mathbb{1}[p_i(NWPR) \in m] + \beta_m \mathbb{1}[\text{Jurisdiction}_i \in m]\Big) \\ &+ X'_{izt}\gamma_1 + X'_{izt}\mathbb{1}[R_t = NWPR]\gamma_2 + \eta_{zt} + \varepsilon_{izt} \end{aligned} \tag{7}$$

where the indicator variables $\mathbb{1}[\text{Jurisdiction}_i \in m]$, $\mathbb{1}[p_i(Rapanos) \in m]$, and $\mathbb{1}[p_i(NWPR) \in m]$ are set equal to one if property i's jurisdictional probabilities at time of sale, under *Rapanos*, and under NWPR, respectively, are in the mth bin. We use ten bins ranging from 0 to 1 in equal increments of 0.1.

Land use change. Finally, in order to provide evidence for the causal pathway where Clean Water Act deregulation increases property values by increasing the development potential of water resource parcels, we examine land use change after jurisdictional determinations, allowing for differential responses by jurisdictional status. While we would ideally estimate the impact of NWPR on land use change directly, this is not possible given the limited post-NWPR period and the time lag in the availability of remotely sensed land cover products (i.e., NLCD is only available through 2023). Instead, we examine how land use changes in

the years leading up to and following an AJD using the equation:

$$L_{i,t} = \sum_{\tau} \Big(\beta_\tau \, WOTUS_i \, \mathbb{1}\{\tau(i,t) = \tau\} + \gamma_\tau \, \mathrm{W}_i \, \mathbb{1}\{\tau(i,t) = \tau\} \Big) + \lambda_{ct} \; + \; \eta_i \; + \; \varepsilon_{i,t} \qquad (8)$$

where $L_{i,t}$ is the percentage of a given land use (i.e., developed, wetland) within 100m radius of a site i with an AJD in year t. The indicator function $\mathbb{1}\{\tau(i,t) = \tau\}$ equals 1 if $\tau(i,t)$ is equal to τ, and 0 otherwise. $\tau \in \{-4, -3, -2, 0, 1, 2, 3, 4\}$ denote event year dummies with $\tau = -1$ omitted as the reference period and $\tau = -4$ and $\tau = 4$ inclusive of all event times ≤ -4 and ≥ 4, respectively. $WOTUS_i$ is the treatment indicator (e.g., = 1 for jurisdictional, = 0 for non jurisdictional). W_i is a non-time varying share of area within 100 meters of site i that has an NWI water feature present (as defined in equation 1). The equation includes parcel fixed effects η_i and commuting-zone–year fixed effects λ_{ct}. $\varepsilon_{i,t}$ is the error term. Standard errors are clustered by commuting zone.

5 Results

5.1 Changes in Regulatory Stringency under NWPR

We first demonstrate that regulatory stringency was impacted by NWPR, and exposure to deregulation is strongly predicted by our two proxies for Clean Water Act exposure — water resource share from the NWI and predicted jurisdictional probabilities from the machine learning algorithm.

Figure 1 shows the share of AJDs that are jurisdictional in each year-quarter by water resource share. Red points indicate sites with no water resources (36% of all AJDs) and blue points indicate sites with high water resource shares, defined as those in the top quartile of share of area within a 100 meter radius covered by an NWI water feature ($\geq$ 19% water resource share). The red vertical lines indicate the period when NWPR was being promulgated (early 2020 through late 2021). Figure 1 shows that before NWPR began, jurisdictional shares had fairly stable trends, with high water resource properties hovering around 60% jurisdictional and sites without water resources around 30% jurisdictional. NWPR decreased jurisdiction, and disproportionately so in areas with more water resources. This figure provides the intuition behind our research design that uses water resource share to assess how changes in Clean Water Act jurisdiction affects property values.

Table 2, Column (1) provides corresponding regression estimates from equation (1). The first row reports the coefficient on water resources share. We find that, under *Rapanos*, sites where all of the area within 100 meters are covered in NWI water features are 47 percentage points more likely to be jurisdictional than sites with no water features. It is unsurprising that this coefficient is large and positive; NWI provides information on the location of surface water resources and Army Corps staff consult NWI in determining jurisdiction. This coefficient is below 1 because *Rapanos* does not regulate all water resources and because NWI has both type I and type II measurement error. The coefficient reported in the second row shows that NWPR modestly decreased jurisdiction (by about 6 percentage points) for sites with no water resources within 100 meters. The third row shows that NWPR especially decreased jurisdiction for sites with NWI water resources. The estimate suggests that for sites where the entire surrounding area is covered by NWI water features, NWPR decreased jurisdictional probabilities by 17 percentage points, from about 47 percent jurisdictional under *Rapanos* to about 30 percent jurisdictional under NWPR.

Table 2, Column (2) shows the estimates from equation 2, which evaluates the out-of-sample relationship between the machine learning-predicted jurisdictional probabilities and the true jurisdictional statuses of AJD sites. The coefficient for $p(Rapanos)$, which represents the effect of the predicted probability of jurisdiction under *Rapanos* for the period when *Rapanos* was in force, is 1.017 (p-value < 0.0001). The coefficient for ΔJurisdiction $\times$ NWPR, which represents the change in jurisdictional probabilities under NWPR when NWPR was in force, is 0.997 (p-value < 0.0001). Encouragingly, both of these coefficients are very close to 1, which is the value we would expect if the machine learning algorithm performed perfectly out-of-sample.

Together, these analyses indicate that NWPR significantly decreased jurisdiction on water resource parcels and that our two proxies for regulatory exposure, water resource share and predicted jurisdictional probabilities, capture meaningful spatial variation in which types of parcels were deregulated under the rule change.

5.2 Impact of Regulation on Property Values

We now turn to studying how NWPR affected the values of deregulated parcels. We begin by presenting the results that proxy for regulatory exposure using water resource share and follow with the results that use jurisdictional probabilities.

Property value impacts by water resource share

Figure 2 Panel (A) shows an event study graph of how NWPR affected the value for non-residential parcels with NWI water features, corresponding to equation 4. The horizontal axis shows year-quarters, ranging from the beginning of 2017 to the mid-2023.[11] The vertical axis shows the coefficient on the interaction of a parcel's water resource share with an indicator for the year-quarter. The value for the first quarter of 2019 is normalized to zero. The dependent variable is the log transaction value of the parcel.

The results indicate that NWPR enormously increased values of non-residential parcels with waters present. Before NWPR began in early 2020, parcels with water resources had similar values to parcels with no water resources present. Only one of the year-quarter interactions is statistically significant, most are smaller than 10 percent in absolute value, and the point estimates vary sign about zero. Beginning in the second quarter of 2020, after NWPR was implemented, property values for parcels where all of the area within 100 meters is covered by water resources increased by over 20 percent. These point estimates remain large, positive, and statistically distinguishable from zero through the third quarter of 2021, when NWPR was in force.

In the last quarter of 2021, a judge struck down NWPR, and Clean Water Act jurisdiction reverted to *Rapanos*. As discussed above, landowner expectations at this point were complex. Because land transactions represent an enduring capital investment, developer and landowner expectations are relevant to interpreting land transactions. Clean Water Act litigation was ongoing (the *Sackett* case was initially filed many years earlier), the Supreme Court had a conservative majority, the Supreme Court had repeatedly ruled on Clean Water Act jurisdiction, and landowners may have believed there was some probability that future Clean Water Act rules would return that might be closer to NWPR. At the same time, the law of the land as of late 2021 was *Rapanos*, so many isolated wetlands and ephemeral streams were jurisdictional.

Figure 2, Panel (A) suggests a modest decrease in the values of water resource properties when NWPR was vacated in late 2021, relative to their values under NWPR. Most of the point estimates have smaller value than under NWPR, and none of the seven quarters is statistically significant. Although these point estimates do not completely reverse the pattern of land market outcomes under NWPR, they do suggest that land markets no longer fully incorporated the value of deregulation under NWPR.

[11] *Sackett v. Environmental Protection Agency*, a Supreme Court case which reinterpreted which waters could be considered jurisdictional, was decided on May 25, 2023 so we end our sample on this date.

Table 3, Panel (A) shows the corresponding regression estimates. Our preferred model with fully saturated controls is shown in Column (5). We find that NWPR increased the value of non-residential parcels where all area within 100 meters is covered by water resources by 16.2%. Omitting parcel-level controls that proxy for the COVID housing boom – distance to metro area, population density, and work from home share — in Columns (2-4) does not meaningfully impact the point estimates.

In contrast, Table 3, Panel (B) shows the value of residential parcels does not respond NWPR deregulation. The point estimates for all models are near to and not significantly different from zero. Moreover, the event study version of the regression, which is shown in Figure 2 Panel (B), shows no change in the value of water resource parcels for the period when NWPR was in force. These results support the internal validity of the research design. Despite the smaller confidence intervals in Panel (B), nearly none of the residential quarterly point estimates over this seven-year period are statistically distinct from zero. During the quarters when NWPR was operating, the point estimates are smaller than 0.05 in absolute value, most are slightly negative, and none are statistically distinct from zero. These patterns follow what one might expect since most residential properties already have housing units built, so are unlikely to depend on Clean Water Act jurisdiction (unlike non-residential parcels, which require development).[12].

Finally, Panel (C) of Table 3 shows a triple difference specification where residential properties are used as an additional control group. This specification is motivated by our view that residential properties serve as a quasi-placebo and can therefore be used to control for housing market trends that may differentially impact the value of water resource and non-water resource parcels within locality, such as greater demand for natural amenities during the COVID-19 housing boom. Encouragingly, the point estimates reported in Panel (C) are nearly identical to those from our main specification in Panel (A).

Table A10 shows property value impacts by land use, according to the properties assessment records. Panel (A) replicates our results from the full sample of non-residential properties. Panels (B-G) report point estimates for agricultural, commercial, vacant, industrial, public, and other properties. We find large and highly significant price impacts on vacant lots, where making development less costly should intuitively have large benefits. Public properties also have large price impacts, but these estimates are less precise given the small sample

[12] We calculate that the share of residential parcels with an AJD is 0.0001, which is 115 times smaller than the share of non-residential parcels with an AJD. The few AJDs in residentially zoned areas have extremely different characteristics from the mean transacted residential parcel, so are not in typical residential areas–they have 11 times larger acreage, one-third the value per acre, one-third the buildings per acre, and four times greater water resource share.

size (N=50,177). Estimated magnitudes are similar for commercial, industrial, other properties, although these point estimates are less precisely estimates. The impact of NWPR on agricultural lands is notably smaller, possibly because many farming, construction, and maintenance activities on agricultural lands and any wetlands converted to cropland prior to 1985 ("prior converted cropland") are except from Section 404 regulation.

Given the evidence presented so far that water resource share is strongly predictive of NWPR deregulation, and that the value of water resource parcels increases during NWPR, it might seem natural to use NWPR interacted with water resource share as an instrumental variable to estimate the effect of Clean Water Act jurisdiction on property values. We have few parcels, however, with both AJDs (to measure jurisdiction) and CoreLogic transactions (to measure values). Standard instrumental variables estimates are therefore infeasible. We therefore turn to an alternative approach where we estimate the impact of jurisdiction on property values using property-level predictions of jurisdictional probabilities from the machine learning algorithm described in Section 3.

Property value impacts by probability of jurisdiction

Table 4 reports the impact of predicted jurisdictional probability on the value of non-residential properties. As in Table 3, our preferred specification is the fully saturated model reported in Column (5). The coefficient estimates reported here are from equation 5, where the coefficient on ΔJurisdiction $\times \mathbb{1}[R_t = NWPR]$ represents the price impact of the change in jurisdictional probabilities between NWPR and *Rapanos* while NWPR was in force. The estimate of -0.563 suggests that a change in jurisdictional probability from 0 to 1 reduces property values by approximately 56%. The sign of this point estimate is as expected: Clean Water Act regulation makes development more costly and should thus decrease the value of jurisdictional properties. NWPR decreased the probability of regulation for most properties; the mean change in jurisdictional probabilities when NWPR took force was -0.15. Multiplying -0.563×-0.15, we calculate that NWPR increased the value of the mean non-residential property by 8.2%.

Figure 2 Panel (C) shows the corresponding event study graph. Dots denote the coefficient estimates for ΔJurisdiction by year-quarter. The impact of ΔJurisdiction only becomes negative once NWPR takes force in early 2020 and the point estimates return towards zero once NWPR is vacated in late 2021.

We evaluate the impact of jurisdictional probabilities on residential parcels in Table 4, Panel (B) and Figure 2, Panel (B). In every case, the price effects are near to and not significantly

different than zero for residential properties. As described above, this finding is consistent with our hypothesis that Clean Water Act jurisdiction should not meaningfully impact the value of residential properties since these properties are already built-up and therefore are rarely impacted by jurisdictional status or changes.

Lastly, Panel C of Table 4 shows the results of a triple difference specification where residential properties are used as an additional control group. Reassuringly, the coefficient estimates closely mirror those for non-residential parcels reported in Panel (A).

In summary, we present robust findings that the value of non-residential properties declines with the probability of Clean Water Act regulation. This set of results is consistent with our findings that NWPR increases the value of non-residential properties that contain water resources. We view these two sets of results as complementary. While the effects of jurisdictional probabilities on property values have a more straightforward interpretation, they rely heavily on our machine learning algorithm used to predict these probabilities.

5.3 Mechanisms, extensions, and interpretation

The remainder of this section reports several extensions of our main analysis. These extensions seek both to clarify the effects of Clean Water Act rules and to assess whether other explanations could account for the patterns of property values highlighted in the previous subsection.

Mechanism: Permitting and land use change

Why do parcels with water resources command such a large price premium under NWPR? Here, we provide evidence that NWPR deregulation increased the development potential of water resource parcels, which got capitalized into property values. For this mechanism, we first investigate the developer response to NWPR by examining changes in requests for approved jurisdictional determinations (AJDs) from the Army Corps when the rule was implemented. We then show how on-the-ground development activity changes in response to increased AJD activity and outcomes.

Figure 4 shows the number of AJDs under each of the four rules by month. The light blue dashed line shows *Rapanos*, the red dotted line shows the Clean Water Rule, and the solid black line shows NWPR. Before NWPR was enacted, the Army Corps provided around 1,000 AJDs per month. Once NWPR began, the number of AJDs rose to 4,500 per month, a 4.5 fold increase over the rate before NWPR. This rate was steady until NWPR was vacated in

late 2021, at which point the number of AJDs per month immediately declined to around 1,500. The flood of AJD requests during NWPR suggests that developers were aware of Clean Water Act deregulation under NWPR, and responded accordingly.

We note two caveats in interpreting the AJD data. First, the AJDs we analyze from the Army Corps and the EPA are incomplete. Two states (Florida and Michigan) have a state AJD program and we lack data on their AJDs, while other Army Corps districts may not have fully machine-readable AJDs, so some may be missing from our data. Thus, it is possible that some of the increase in total AJDs under NWPR reflects increased coverage of the EPA's AJD data. However, we do not think an increase in data coverage can explain the full spike in AJDs under NWPR since request levels return to pre-NWPR levels when the rule is vacated. Second, development activity on wetlands can also occur with a "Preliminary Jurisdictional Determination" (PJD)[13] rather than an AJD, or by directly obtaining a wetland permit without any type of jurisdictional determination. Further, some landowners may develop parcels without a jurisdictional determination or a wetland permit under the assumption either that they are not violating the Clean Water Act or that they will not get caught. Although Figure 4 reflects only one type of regulatory indication of development, it strongly suggests a surge in landowner interest in developing water resources under NWPR.

Next, we show that AJDs are associated with an increase in on-the-ground development using remotely-sensed NLCD land cover maps. Figure 5 uses the event study framework outlined in equation 8 to evaluate how land use within a 100 meter radius of an AJD site changes after the jurisdictional determination. Blue dots correspond to sites that were found to be non-jurisdictional while red dots correspond to jurisdictional sites.

For both types of AJDs, the percentage of developed land increases substantially in the years following an AJD (left panel of Figure 5). After four years, AJD sites with non-jurisdictional outcomes have 7 percentage points (p.p.) higher share of developed land than non-AJD sites. Notably, jurisdictional sites have a smaller response, with only 5 p.p. more land developed four years after an AJD. Both of these findings are expected; for parcels with potentially-regulated water features, AJDs are requested as the first step in the development process, and development becomes more costly if the parcel is deemed jurisdictional and thus requires a Section 404 permit. This provides a second piece of evidence that the increase in AJD requests and non-jurisdictional outcomes during NWPR likely led to increased development activity on (and thus demand for) water resource parcels.

[13] PJDs do not question the jurisdictional status of water resources, but rather treat all water resources within the review area that could be jurisdictional as if they are jurisdictional for purposes of permit processing.

The right panel of Figure 5 examines the impact of AJDs on wetland area within a 100 meter radius of the AJD centroid using the same event study framework. There is no detectable change in wetland area on properties with jurisdictional waters (red). However, properties deemed to have non-jurisdictional waters (blue) show a significant decline in wetland area, with 0.4 p.p. less wetland area share after four years. The loss of wetlands only begins in the years after the AJD. Taken together, these results suggest that Clean Water Act regulation reduces the probability of wetland development.

We conduct several tests to check the robustness of our estimates to different assumptions and specifications. Table A8 shows the same set of results in regression form, allowing for different land development pre-trends. Further, Figure A6 shows that our estimates are robust to using the imputation estimator proposed by Gardner (2021) to address potential biases in staggered difference-in-differences estimators.

Tests of internal validity

One threat to the internal validity of our estimates is that the timing of the COVID-19 pandemic overlapped with the period when NWPR was in force. Prior work documents significant changes in the housing market during the pandemic (2024). Indeed, the pandemic increased demand for properties on the urban periphery, where wetlands and other water resources tend to be more common than in the urban center. This pattern motivated our inclusion of zip-year-month fixed effects in our estimating equations, which control flexibly for local-level trends in the housing market. Furthermore, residential properties were greatly affected by the COVID housing boom, so our finding of a null response to NWPR among residential properties indicates that our research design effectively separates the effects of NWPR from COVID.

Table A9 shows another way of assessing whether the land market patterns we observe reflect the COVID housing boom or features specific to Clean Water Act regulation. We divide the US into three sets of areas: one which had a large increase in residential housing values during the pandemic (top quarter), one which had little change in residential housing values during the pandemic (bottom quarter), and one which had a moderate response (interquartile range).[14] We then test for differential responses to NWPR deregulation by the size of the area's COVID housing boom. The estimates in Table A9 show that there is no detectable difference between the price response of properties in high- versus low- COVID housing boom

[14] These areas are determined at the zip code-level by finding areas in the top and bottom quartile of price trend breaks starting in March 2020.

zip codes, relative to those with moderate COVID housing booms (the reference category).

We also estimate semi-parametric dose-response functions that relate the effect of NWPR on property values to the share of a parcel covered in water resources. We divide parcels into ten groups in increments of 10%; for example, those where 0 to 10 percent of the area within 100 meters is water resources; those where 10 to 20 percent of the area within 100 meters is water resources; etc. We use parcels with no water features within 100 meters as the reference group. We regress property values on the interaction of NWPR with these indicators, separately for residential and for non-residential parcels.

The blue lines and shaded confidence intervals in Figure 3, Panel (A) show a clear positive relationship between the share of a parcel that is water and the property value among non-residential parcels. For example, relative to parcels with no water, parcels where 0 to 10 percent of the area is water had a value increase of only 1.2% under NWPR; parcels where 30 to 40 percent is water had an increase of 9.2% under NWPR; and parcels with 60 to 70 percent water had an increase of 13% under NWPR. The pattern is monotone except for the parcels that are 70 to 100 percent water, which are statistically indistinguishable from parcels where 60 to 70 percent are water. This pattern suggests that the share of a parcel that is protected (as proxied by water resource extent) strongly predicts the cost of regulation.

The brown points and confidence intervals in Figure 3, Panel (A) show again that under NWPR, a residential parcel's water extent had no relationship to the change in property values. All of the point estimates for the various water shares have magnitude below 3 percentage points in absolute value, and we observe no pattern of point estimates increasing with water share.

Figure 3, Panel (B) shows the semi-parametric dose-response functions that relates the jurisdictional probabilities to property values. We find a negative, monotonic relationship among non-residential parcels (blue lines). There is little effect of jurisdictional probabilities (< 50 percent) on property values, but jurisdictional probabilities above 70 percent have large and statistically significant effects; relative to properties with a jurisdictional probability of zero, properties with jurisdictional probabilities between 70 and 80 percent sell at a price discount of 10%; properties with jurisdictional probabilities between 80 and 90 percent sell at 15% price discount; and, properties with jurisdictional probabilities between 90 and 100 percent sell at a 25% discount. Once again, for residential parcels (brown lines) we find no relationship between property values and the probability of jurisdiction.

Finally, we estimate interactions of our treatment variables with other property amenities.

Three-way interactions with lot size had small magnitude, were statistically indistinguishable from zero, and did not meaningfully change the main effects. We do not pursue other three-way interactions (e.g., with local population demographics) since they would be complex to interpret through the lens of the hedonic model (Roback 1982), which argues against estimating the hedonic price function by interacting amenities with shifters like population demographics.

Interpretation of property value estimates

Here, we discuss the interpretation of the property value estimates presented in section 5. Two features of the housing market complicate interpretation. First, the price responses we document are equilibrium responses; they could represent the effect of both changes in demand for deregulated parcels (what we seek to estimate) and/or changes in the supply of these parcels. In most housing market settings, if demand for a feature (e.g. environmental quality) increases and puts upward pressure on prices, we would expect to see a corresponding increase in the supply of properties with that feature. We note that our setting is different because we study vacant undeveloped lands. The supply of such land is fixed; suppliers cannot make more of vacant parcels in the same way that they build houses in response to higher housing prices.

Still, we can observe liquidity changes in the supply of vacant lands available for sale at any given time. To explore this possibility, we test for differential price impacts in locations with higher versus lower housing supply elasticities, following Krause and Chakma 2024. In particular, we use MSA-level housing supply elasticity estimates from Saiz 2010 and create eight bins of equal size. We then interact the treatment variable in equation 3, 'Water resource share' $\times$ NWPR, with the housing elasticity supply bins. The results are shown in Figure A7. The coefficients are stable across all eight housing supply elasticity bins, suggesting that the price response of water-intensive parcels to NWPR does not vary with local housing supply elasticities. Because we find no evidence of a meaningful supply response to NWPR deregulation, we interpret our estimates as the demand response, or equivalently, landowner willingness to pay for deregulation.

The second feature of the housing market that complicates interpretation is that we cannot observe property buyers' expectations about regulation. Because land is an enduring investment, the price a buyer is willing to pay for a parcel depends not only on its current regulatory status, but also the buyer's expectations over its future regulatory status. Our estimates rely on a sharp change in regulatory status at the time NWPR was implemented.

However, property buyers' expectations could have been changing in the years or months leading up to NWPR's enactment as information became available about prospective Clean Water Act rule changes. For example, buyers may have updated their expectations about the probability of deregulation when Trump was elected in November 2016, when he issued an Executive Order in February 2017 directing the EPA to revisit the definition of WOTUS, or when a draft of NWPR was first released for public comment in February 2019. If these events increased buyers' subjective probabilities of deregulation prior to the time the NWPR rule was finalized in January 2020, our approach that assumes a sharp discontinuity at this date would underestimate the impact of regulation on property values. To test for this possibility, Figure A8 extends the event study shown in Figure 2 Panel (A) back to the year 2010. We find no detectable change in the value of water resource parcels until the rule is finalized in early 2020, lending confidence to our approach.

Comparison to cost of wetland mitigation credits

As one point of reference, we compare our estimated regulatory cost to landowners against with the cost of mitigating wetland impacts. In much of the US, developers can purchase credits from wetland mitigation banks that have restored or enhanced wetlands to offset unavoidable impacts. The number and type of credits required generally must match both the scale and type of wetland impacted (e.g., riparian freshwater wetlands) and come from the same watershed. Although the price of mitigation credits is often not public, many states provide an "In Lieu Fee" option where private mitigation credits are unavailable. These fees are typically published and tend to track private-market credit prices. For example, North Carolina's In Lieu Fee schedule[15] lists fees of $77,000 to $157,000 per credit for freshwater wetland impacts, depending on the watershed. While the offset ratio can vary based on the nature of the wetland impact, one credit generally corresponds to one acre.

Taking $100,000 as the cost of a one acre mitigation credit implies the following comparison. Fitted values from our property price regressions, combined with the wetland share of US properties, imply that NWPR increased mean values of non-residential properties by $2,000 to $4,000. The mean non-residential property is 27 acres, of which 1 to 2 acres are wetlands. NWPR deregulated 17% of wetlands, implying deregulation of about 0.2 to 0.4 acres of wetlands for the mean property. At a cost of $100,000 to mitigate one acre of wetlands, if all wetlands required mitigation banking then NWPR would save $20,000 to $40,000 per non-residential property (=0.2 to 0.4 acres times $100,000 per acre) in mitigation banking

[15] See North Carolina Department of Environmental Quality website http://www.deq.nc.gov/about/divisions/mitigation-services/customers/current-rate-schedules, persistent linkhttps://archive.is/qeI9l

costs. This would completely explain our property value regressions if developers had to purchase offsets on 10% of wetlands (since the $2,000 to $4,000 property value impact is around ten percent of the $20,000 to $40,000 cost of mitigation banking for every acre of wetlands). For example, if developers only have to offset 2.5% of wetlands, then this back-of-the-envelope calculation would imply that mitigation banking costs account for a fourth of our property value estimates (=0.025/0.10). The remaining costs would include delays, uncertainty, property redesigns, permit and wetland consultant fees, etc.

While this calculation only provides a rough approximation, it suggests both that mitigation banking costs can be substantial, and that such costs likely account for a meaningful share of our property value estimates. It also provides one benchmark suggesting that our large property value estimates are not out of line with the main available market benchmark for compliance costs.

6 Economic Impact of Deregulation

We conclude by computing the cost of Clean Water Act regulation implied by the impacts of NWPR on regulatory stringency and land market. Based on the CoreLogic assessment records used in this analysis, which include the near-universe of properties in the United States, there are approximately 27 million non-residential properties with a total value of nearly $10.8 trillion. We calculate aggregate property value impacts using our two sets of estimates, those from the water resource share estimation strategy and those from the jurisdictional probability estimation strategy. We then compare the implied aggregate effects.

Using the water resource share estimates, we calculate the total property value impact of NWPR deregulation among non-residential properties using equation:

$$\frac{\sum_w (\beta_w \times TV_w)}{\sum_w TV_w} \times PV \tag{9}$$

where β_w are the coefficients estimates for the impact of NWPR on property values by water resource share from the binned dose-response function shown in Figure 3, Panel (A). That is β_1 is the effect of NWPR for properties with a 0 to 10 percent water resource share, β_2 is the effect of NWPR for properties with a 10 to 20 percent water resource share, and so on. TV_w is the total transacted property value in each bin w of water resource share.

The first term in equation 10 represents the weighted average of the binned treatment effects, where the weights correspond to the share of total property value in each bin among trans-

acted properties. Plugging in our estimates of β_w and the values of TV_w, this term equals 0.009. This implies that NWPR decreased the value of the average non-residential property in the US by 0.9%. Finally, we multiply this value by the total value of all non-residential properties in the US, PV, to arrive at the total impact of NWPR on non-residential properties. This suggests that NWPR increased non-residential property values by $97.6 billion.

Using the jurisdictional probability estimates, we calculate the same figure – the impact of NWPR deregulation on aggregate non-residential property value – using the equation:

$$\frac{\sum_j(\beta_j \times \Delta Jurisdiction_j \times TV_j)}{\sum_j TV_j} \times PV \tag{10}$$

where β_j are the coefficients estimates for the impact of jurisdictional probabilities on property values from the binned dose-response function shown in Figure 3, Panel (B). That is β_1 is the effect of a jurisdictional probability between 0 and 10 percent, β_2 is the effect of a jurisdictional probability between 10 and 20 percent, and so on. Here, we multiply by $\Delta Jurisdiction_j$, the change in jurisdictional properties when moving from *Rapanos* to NWPR in each bin j of jurisdictional probabilities. TV_j is the transacted property value in bin j.

Plugging our estimates for β_j and $\Delta Jurisdiction_j$ into the first term, we estimate that NWPR increased the value of the average non-residential property by 0.7%. This implies that NWPR increased the value of all non-residential properties across the US by $76.7 billion. This value is comparable to, although 20% lower than, the aggregate impact produced using the estimates from the water resource share estimation strategy.

To provide a sense of scale, by one estimate, the costs of compliance with the Clean Air Act are $65 billion *per year* (Holladay 2011). In ongoing work, we are comparing the economic costs of Clean Water Act land use regulation estimated in this study to the environmental costs of regulation estimated in prior work (e.g. Taylor and Druckenmiller 2022; Aronoff and Rafey 2023).[16]

One important caveat is that our calculation assumes that environmental benefits of wetlands are not being capitalized into properties values prices, which would offset some of the forgone development costs. This assumption is broadly consistent with empirical evidence (Keiser and Shapiro 2019; Taylor and Druckenmiller 2022), and reasonable given a lack of clear information on wetland benefits and the fact that most wetland benefits (i.e., flood

[16] This calculation requires estimating how much wetland area was converted to other land cover classes as a result of NWPR. Since this analysis requires several years of post-NWPR data, we are waiting on the new release of NLCD (expected in October 2024) to estimate this effect.

mitigation, water quality, potential carbon storage) are enjoyed downstream or as public goods—with the possible exception of more localized values from a recreational and wildlife perspective.

Additionally, a number of assumptions and processing steps go into this back-of-the-envelope calculation. To compute the universe of "All properties", including ones that did not transact between 2017-2023, we use CoreLogic assessor data, limiting properties to the same set of non-residential land use codes as our main analysis. We further filter out properties using the same data cleaning process laid out in Section 3 (i.e., removing properties with missing location information, or missing or unrealistic assessment values and acreages), resulting in a total of 27 million properties, which is a reduction of 30% relative to 38.7 million raw unfiltered records. With an average property size of 27 acres, these 27 million properties cover 731 million acres.

For reference, there are 1.9 billion acres of land in the continental US, of which 1.5 billion acres are not owned by the federal or state government (Vincent et al. 2017). Thus our CoreLogic dataset of non-residential properties encompasses about 50% of private US land.[17] The assessor data does not have sales price, and assessed values are computed for property tax purposed and generally lower than sale values. To this end, to compute the $10.8 trillion figure for all non-residential properties, we multiply the sum of assessed values by 1.85, which is the ratio of the average sales price to assessed value in our main sample of 4 million properties that were transacted between 2017 and 2023. This $10.8 trillion figure is comparable to a US Bureau of Economic Analysis estimate of the underlying land value of the entire continental US of $23 trillion (Larson 2015).

7 Discussion

Our analysis shows that changes in land use regulation can have a significant impacts on land markets. We focus on Section 404 of the Clean Water Act, the main federal law governing land development around water bodies, wetlands and streams. We find that the reduction in regulatory oversight under the Trump Administration's 2020 Navigable Waters Protection Rule (NWPR) led to substantial increases in the value affected properties. Wetland and water-intensive areas, which are subject to regulation due to their environmental importance, saw notable gains in property values when restrictions were eased, suggesting that land markets respond quickly to changes in environmental policy that increase the development

[17] Properties in Corelogic assessor data that are coded as residential but have at least one acre account for an additional 181 million acres.

potential of previously restricted lands.

Much like NWPR, the current interpretation of WOTUS requires a "continuous surface water connection" to traditional navigable waterways for water resources to be considered jurisdictional under the Clean Water Act. By our estimates, this narrower regulatory regime increases US land values by $77 to $97 billion, relative to the prior interpretation of WOTUS under *Rapanos*. Our findings indicate that while environmental protections serve crucial functions——such as flood mitigation, water quality improvement, and biodiversity conservation——they also carry significant economic costs. The interaction between environmental regulation and land markets will continue to be a source of controversy as the White House and Supreme Court revisit the scope of federal environmental protections in the coming years.

While we believe our analyses makes progress in understanding the costs of land use regulation, we note several important limitations to our work. For one, we examine one prominent environmental policy that restricts land use, the Clean Water Act, but we note that not all regulations will impact land markets in the same way. Furthermore, the Clean Water Act is one of many land use regulations that affects property development; just because a property is deregulated under the Clean Water Act does not mean it will not face other regulatory barriers to development, such as state and local zoning laws and permitting requirements. Second, we believe computing aggregate property value impacts of NWPR provides an important to decision-making; however, we note that this back-of-the-envelope calculation requires applying estimates of marginal effects to non-marginal amounts of land. We do not attempt to model the general equilibrium response here, but rather present these aggregate statistics to provide an initial sense of scale for the costs of Clean Water Act regulation in terms of foregone development opportunities. Third, we are unable to compare the estimated economic benefits of NWPR to the full environmental costs introduced by narrowing the scope of regulation. There simply do not exist comprehensive estimates of the value that water resources provide to society. This is the subject of ongoing work, including by members of our team.

From a policy perspective, our results highlight the need to balance economic growth with environmental protection. As housing crises plague many parts of the US, policymakers must weigh the costs of limiting real estate development near water resources against the long-term benefits that these ecosystems provide. More flexible regulatory frameworks, like those under NWPR and now under *Sackett*, should proceed alongside monitoring to ensure that deregulation does not lead to unintended environmental costs, particularly as climate change intensifies the need for resilient landscapes in the face of increasing flood risk.

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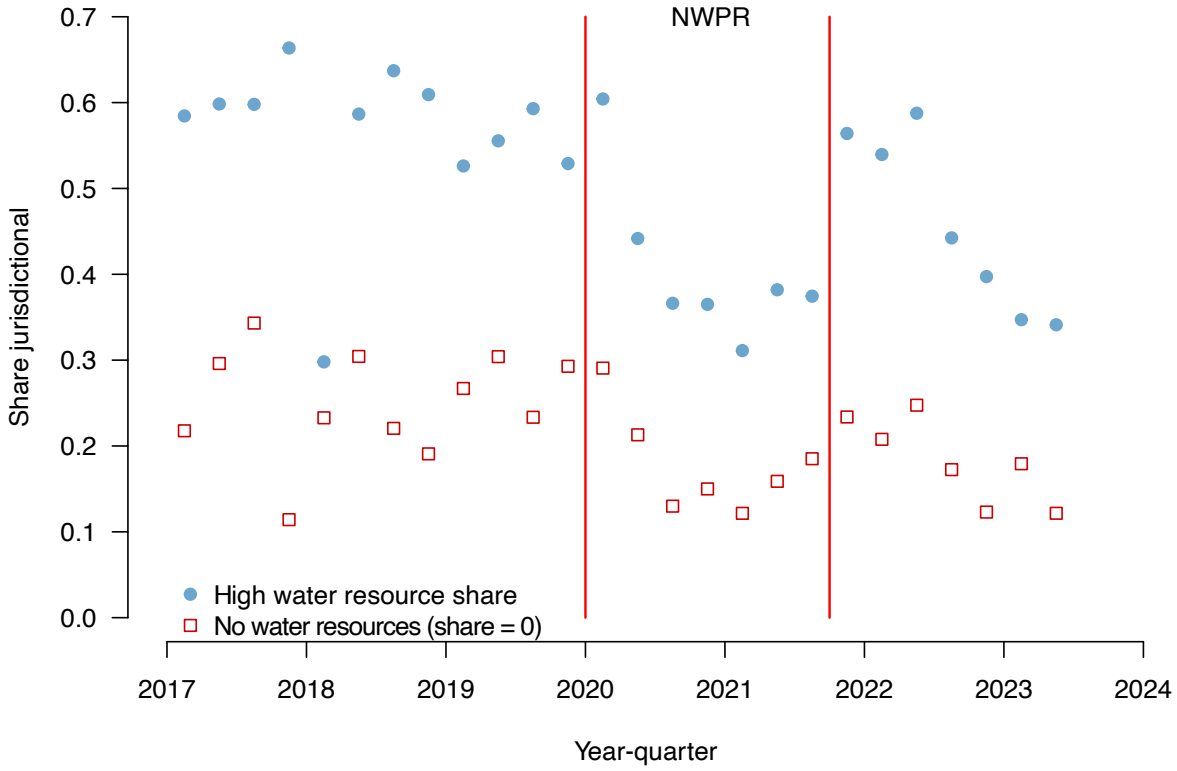
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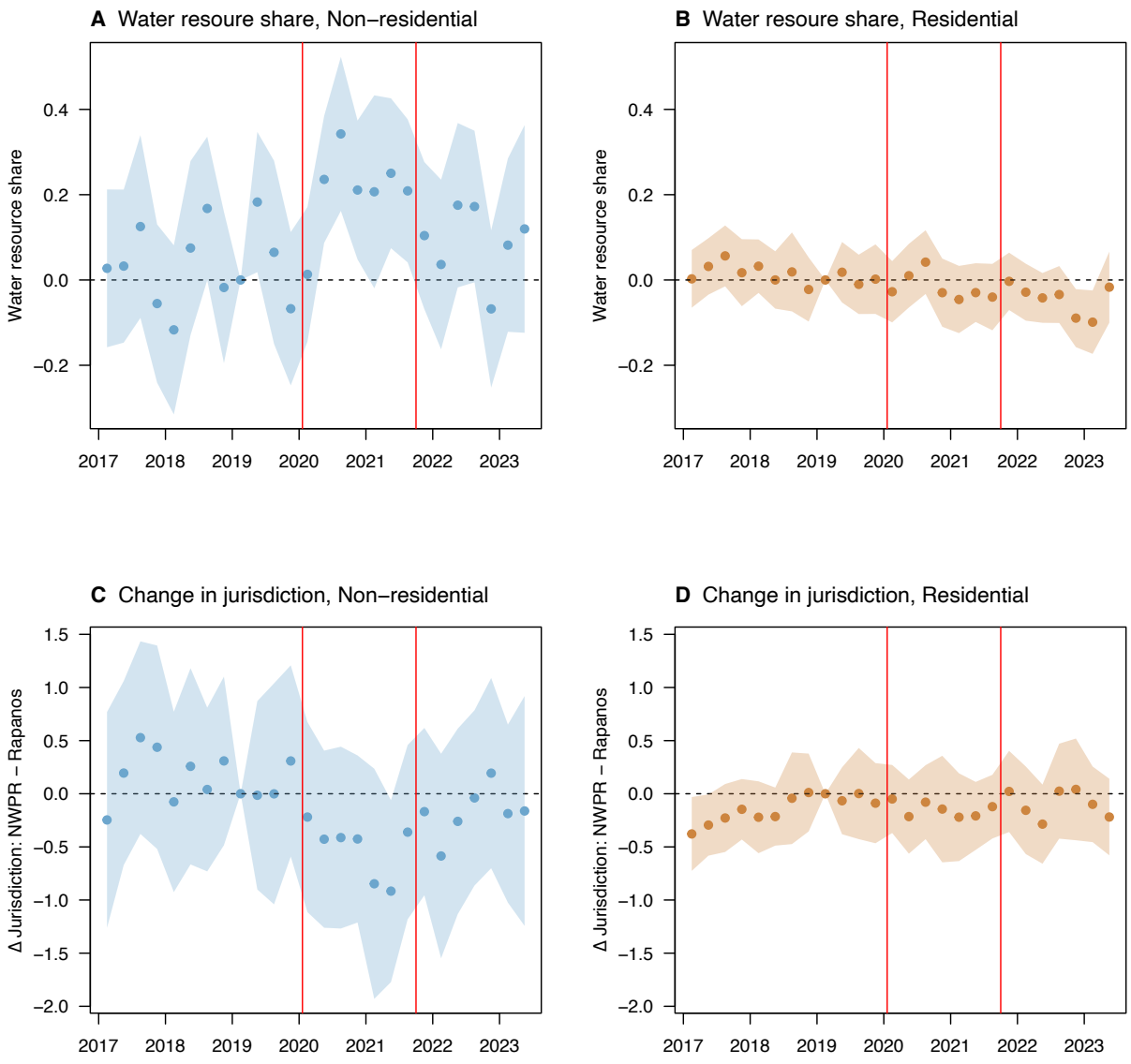
Figures and Tables

Figure 1: Share of AJD sites that are jurisdictional, by quarter and water resource share



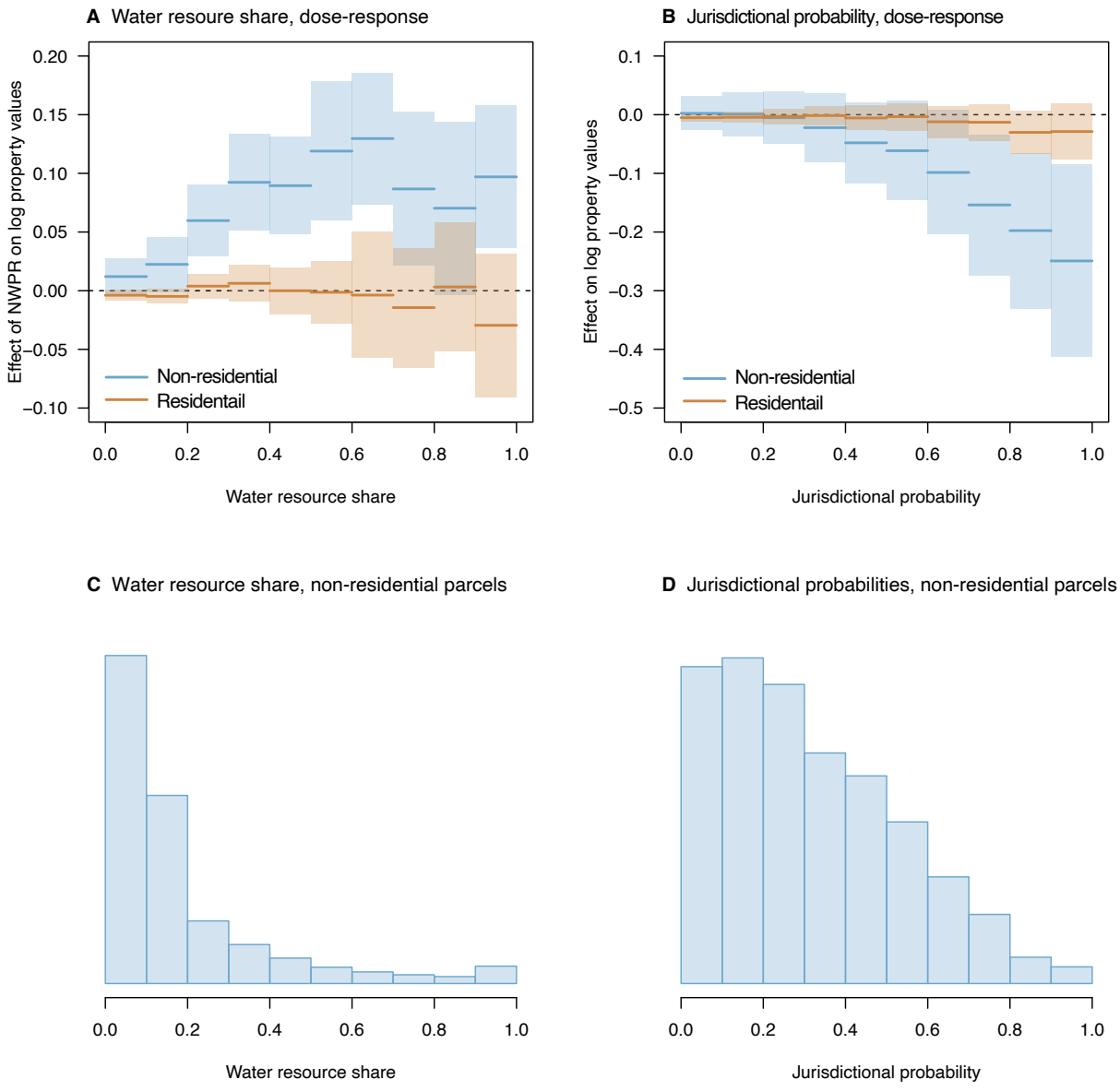
Notes: Points show the share of AJD sites that are jurisdictional in each quarter. For each site, we calculate the water resource share as the area within a 100 meter radius circle filled with National Wetland Inventory polygons. Blue circles describe properties above the 75th percentile of water resource share (19% of sites); red squares describe properties with zero water resource share (36% of properties).

Figure 2: Event studies for the effect of NWPR on property values



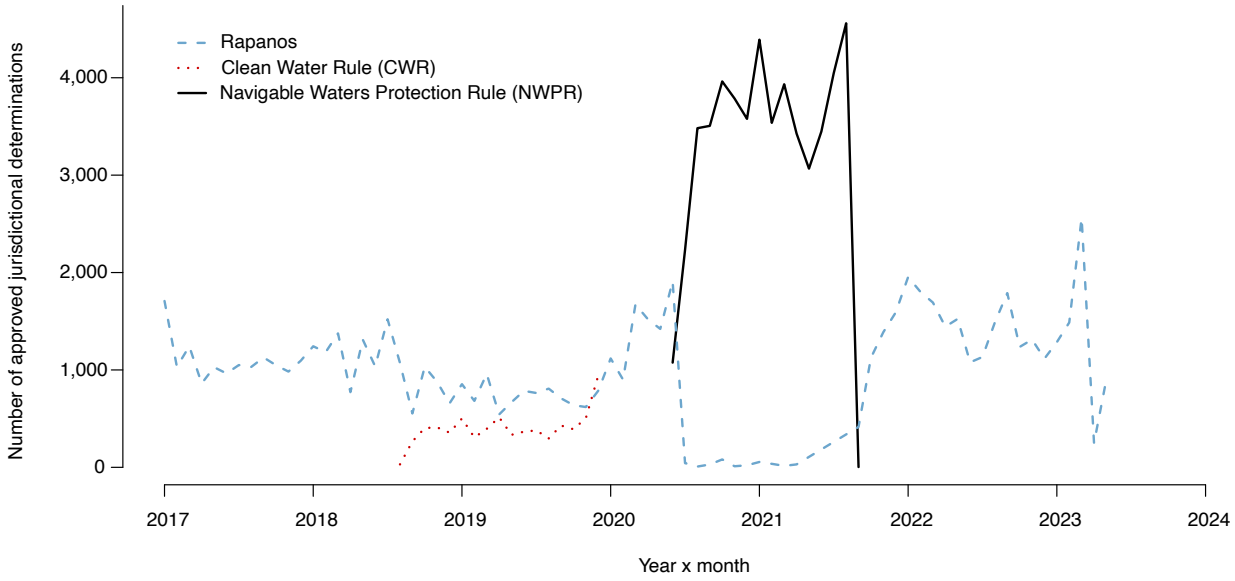
Notes: Panels (A) and (B) show the effect of water resource share on log property values by year-quarter from equation 4 for non-residential parcels and residential parcels, respectively. Panels (C) and (D) show the effect of the change jurisdictional probabilities during NWPR ($\Delta Jurisdiction = p(NWPR) - p(Rapanos)$) by year-quarter for non-residential and residentail properties, respectively. Dots show point estimates and shaded areas show 95% confidence intervals. Sstandard errors are clustered by commuting zone. Red vertical lines indicate months where NWPR was in force.

Figure 3: Semi-parametric dose-response functions for Clean Water Act rules



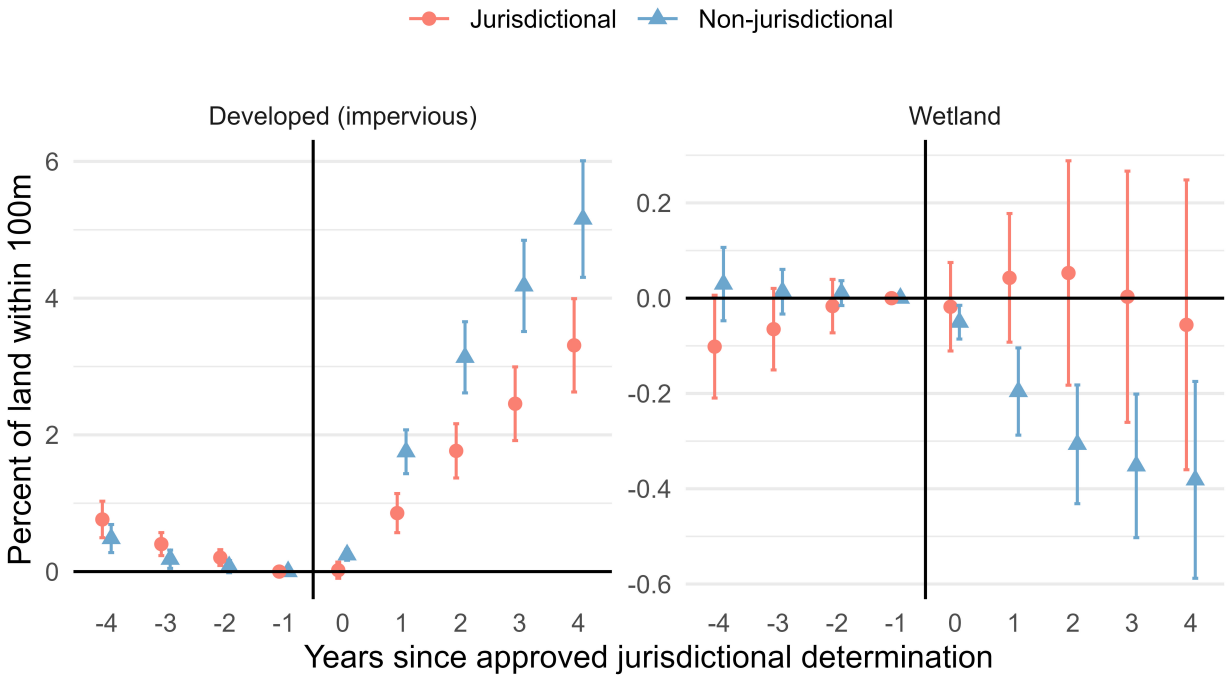
Notes: (A) Lines show point estimates for the effect of NWPR on property values by the share of the parcel covered by NWI water resources. Shares are binned in increments of 0.1 from 0 to 1 in increments of 0.1. The reference category is parcels with no NWI water resources (share = 0). Bars show 95% confidence intervals. Blue lines denote point estimates for non-residential parcels. Brown lines denote point estimates for residential parcels. Shaded areas show 95% confidence intervals. Standard errors are clustered by commuting zone. (B) Shows the same, but for the effect of jurisdictional probabilities on property values. (C) and (D) show the distribution of water resource shares and jurisdictional probabilities, respectively, among non-residential property transactions in our sample.

Figure 4: Clean Water Act Approved Jurisdictional Determinations (AJDs), by rule



Notes: The number of Clean Water Act approved jurisdictional determinations (AJDs) each month, separately by rule.

Figure 5: Land development and jurisdictional determinations, event study estimates



Notes: Points show the share of developed (impervious) land (left) and wetland (right), as measured by the 2024 National Land Cover Dataset (NLCD), in the years preceding (negative x-axis values) and following (positive x-axis values) a jurisdictional determination (AJD). For our development proxy, we use the NLCD imperviousness product, which is a continuous measure of the impervious share of land within each 30m pixel (rather than binary land use categorization). Event study regressions include commuting zone-by-year and transaction id fixed effects, as well as a control for the static NWI share-by-event time. All land use values computed based on share within 100m radius of site centroid. Bars show 95% confidence intervals, with standard errors clustered by commuting zone.

Table 1: Mean characteristics of non-residential property transactions

	Non-NWI Parcels	Difference NWI–non-NWI	Difference conditional on zip-month-year FE
	(1)	(2)	(3)
Year of sale	2020	0.05	—
	(1.82)	(0.00)	—
Latitude	37.37	-0.43	-0.00
	(5.17)	(0.01)	(0.00)
Longitude	-91.26	1.63	0.01
	(14.52)	(0.02)	(0.01)
ln(Property area)	0.25	0.60	0.34
	(2.24)	(0.00)	(0.03)
ln(Price)	11.81	-0.22	-0.00
	(1.70)	(0.00)	(0.01)
ln(Assessed value)	10.83	-0.17	-0.03
	(1.92)	(0.00)	(0.02)
NWI share (percent)	0.00	18.00	15.83
	(0.00)	(0.02)	(0.59)
Wetland share (percent)	0.00	10.47	8.42
	(0.00)	(0.02)	(0.63)
ln(Distance to town)	7.94	0.32	0.19
	(1.14)	(0.00)	(0.01)
ln(Distance to metro)	3.36	0.25	0.02
	(1.21)	(0.00)	(0.00)
ln(Population density)	4.98	-0.87	-0.39
	(2.39)	(0.00)	(0.02)
WFH share (percent)	34.73	-0.29	0.19
	(10.19)	(0.01)	(0.03)
Share in Northeast	0.13	-0.03	—
	(0.33)	(0.00)	—
Share in Midwest	0.25	-0.00	—
	(0.43)	(0.00)	—
Share in South	0.42	0.08	—
	(0.49)	(0.00)	—
Share in West	0.21	-0.05	—
	(0.40)	(0.00)	—
N	1,888,743	2,913,860	—

Notes: Data are from CoreLogic and include non-residential property transactions in the United States from 2017 to 2023. Total transactions: 2,913,860. Unique properties: 2,460,711. Standard deviation in parenthesis. P-values from a two-sided t-test of equality of means for NWI vs non-NWI parcels. Parcel classified as NWI if nonzero NWI share. Acronyms are defined as follows: NWI: National Wetlands Inventory; WFH: work from home. Final rows represent indicators for which census region the transaction took place in.

Table 2: Effect of NWPR on jurisdiction

	Dependent Variable: WOTUS	
	(1)	(2)
Water resource share	0.4731***	
	(0.0667)	
NWPR	-0.0626*	0.0046
	(0.0327)	(0.01600)
Water resource share × NWPR	-0.1682**	
	(0.0777)	
$p(Rapanos)$		1.0171***
		(0.0961)
$p(NWPR)$		0.0662
		(0.1073)
ΔJurisdiction × NWPR		0.9971***
		(0.1079)
Observations	148,631	22,571

Notes: Column (1) shows estimates from equation 1. The dependent variable is an indicator for whether the AJD site was found to be WOTUS (i.e., regulated). "Water resource share" equals share of area within 100 meters of the property centroid that is covered by any type of NWI water feature. NWPR is an indicator for whether NWPR was in force at the time of the determination. This regression is estimated in the full sample of AJDs. Column (2) shows estimates from equation 2. $p(Rapanos)$ is the predicted probability of regulation under *Rapanos*, $p(NWPR)$ is the predicted probability of regulation under NWPR, and ΔJurisdiction is the change in predicted probabilities between NWPR and *Rapanos*, i.e. $p(NWPR) - p(Rapanos)$. This regression is estimated in the held-out test set of AJDs, which were not used to train the machine learning algorithm. Standard errors are clustered by USACE district: ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

Table 3: Effect of NWPR on property values, by water resource share

	Dependent variable: *Log property value*				
	(1)	(2)	(3)	(4)	(5)
Panel A: Non-residential properties					
Water resource share × NWPR	0.135***	0.169***	0.158***	0.162***	0.162***
	(0.027)	(0.025)	(0.024)	(0.025)	(0.025)
Adj. R^2	0.49152	0.53612	0.54783	0.54863	0.54864
N	2,913,860	2,913,860	2,913,860	2,913,860	2,913,860
Panel B: Residential properties					
Water resource share × NWPR	-0.014	-0.009	-0.005	-0.006	-0.006
	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)
Adj. R^2	0.58054	0.59508	0.59745	0.59899	0.60111
N	5,122,772	5,122,772	5,122,772	5,122,772	5,122,772
Panel C: Non-residential vs. residential					
Water resource share × NWPR × Non-residential	0.149***	0.178***	0.164***	0.169***	0.169***
	(0.030)	(0.028)	(0.027)	(0.028)	(0.028)
Adj. R^2	0.57885	0.60866	0.61602	0.61697	0.61765
N	8,036,632	8,036,632	8,036,632	8,036,632	8,036,632
FE: Zip × year × month	Yes	Yes	Yes	Yes	Yes
Log property acres	No	Yes	Yes	Yes	Yes
Log distance to city	No	No	Yes	Yes	Yes
Log population density	No	No	No	Yes	Yes
Work from home share	No	No	No	No	Yes

Notes: Estimates from equation 3. Panel A estimates on a sample of non-residential properties. Panel B estimates on a sample of non-residential properties. Panel C estimates a triple difference on the full sample, treating the residential properties as a control group. All controls include their interactions with NWPR. Distance to city controls include distance to town center and distance to metro area."Water resource share" equals share in any type of water resource polygon. Standard errors are clustered by commuting zone. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

Table 4: Effect of NWPR on property values, by change in jurisdictional probability

	Dependent variable: *Log property value*				
	(1)	(2)	(3)	(4)	(5)
Panel A: Non-residential properties					
Δ Jurisdiction × NWPR	-0.527***	-0.759***	-0.567***	-0.564***	-0.563***
	(0.187)	(0.285)	(0.173)	(0.172)	(0.173)
Adj. R^2	0.49152	0.50397	0.54749	0.54830	0.54832
N	2,913,860	2,913,860	2,913,860	2,913,860	2,913,860
Panel B: Residential properties					
Δ Jurisdiction × NWPR	0.003	-0.002	-0.012	-0.034	-0.036
	(0.033)	(0.032)	(0.033)	(0.033)	(0.034)
Adj. R^2	0.57996	0.59436	0.59674	0.59834	0.60047
N	5,122,772	5,122,772	5,122,772	5,122,772	5,122,772
Panel C: Non-residential vs. residential					
Δ Jurisdiction × NWPR × Non-residential	-0.521***	-0.628***	-0.543***	-0.519***	-0.517***
	(0.177)	(0.170)	(0.162)	(0.161)	(0.161)
Adj. R^2	0.57848	0.60776	0.61534	0.61641	0.61710
N	8,036,632	8,036,632	8,036,632	8,036,632	8,036,632
FE: Zip × year × month	Yes	Yes	Yes	Yes	Yes
Log property acres	No	Yes	Yes	Yes	Yes
Log distance to city	No	No	Yes	Yes	Yes
Log population density	No	No	No	Yes	Yes
Work from home share	No	No	No	No	Yes

Notes: Estimates from equation 5. Panel A estimates on a sample of non-residential properties. Panel B estimates on a sample of non-residential properties. Panel C estimates a triple difference on the full sample, treating the residential properties as a control group. All controls include their interactions with NWPR. Distance to city controls include distance to town center and distance to metro area. ΔJurisdiction equals the change in jurisdictional probabilities when NWPR is implemented (i.e., ΔJurisdiction = $p(Rapanos) - p(\text{NWPR})$. Standard errors are clustered by commuting zone. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

Table 5: Impacts of Clean Water Act Deregulation under NWPR

	Transacted properties		All properties	
	Mean	Total	Mean	Total
Property characteristics, general				
Number of properties	—	3,377,000	—	27,098,000
Property value ($ million)	0.496	1,675,000	0.399	10,801,000
Property area (acres)	16.55	55,889,000	26.97	730,755,000
Property characteristics, aquatic resources				
Water resources (acres)	1.06	3,566,000	1.67	45,307,000
Wetland (acres)	0.60	2,023,000	0.94	25,576,000
Water resources share	0.064	0.093	0.062	0.062
Wetland share	0.036	0.066	0.035	0.035
Estimated effect of NWPR on sale value of				
Property with 100% water resource share (logs)	0.158	—	—	—
Property with 100% wetland share (logs)	0.110	—	—	—
Property with mean water resource share (logs)	0.010	0.015	0.010	0.010
Property with mean wetland share (logs)	0.004	0.007	0.004	0.004
Property with 100% water resource share ($ million)	0.079	—	0.063	—
Property with 100% wetland share ($ million)	0.055	—	0.044	—
Property with mean water resource share ($ million)	0.005	24,675	0.0039	106,070
Property with mean wetland share ($ million)	0.002	12,160	0.0015	41,582

Notes: Data are for non-residential properties in the contiguous United States. Property numbers, values, and acreage come from CoreLogic. Water resource and wetland acreage and shares are estimated using the National Wetlands Inventory. We combine property characteristics with our estimates from Table 3 (Column 2) to estimate the economic impacts of NWPR.

Appendix

A.1 Background on Wetlands

Wetlands are areas where water covers the ground at least some of the time. Wetlands are also called swamps, bogs, and include specific water resources known as playa lakes, prairie potholes, Carolina and Delmarva Bays, pocosins, and vernal pools (Sullivan et al. 2020). Scientifically, streams, lakes, ponds, estuaries, and other waters are types of wetlands (Cowardin et al. 1979). Wetlands can provide a range of ecosystem services including water quality improvements, flood mitigation, species protection, and others. Identifying wetlands is not trivial. Some scientific definitions of wetlands define them by areas where hydrophytic (water loving) plants grow. Many scientists delineate a wetland's boundary according to the area where a majority of plants are hydrophytic.

In the 1700s, wetlands were estimated to cover 221 million acres (89.4 million hectares) of the continental US. Since then, over 50% percent of these original wetlands were lost (Dahl 1990). In response to concerns about continued wetland loss, in 1989 George H. W. Bush set a policy goal of 'No Net Loss' of wetlands. This goal, upheld by subsequent administrations, meant that any wetland loss due to economic development had to be offset by an comparable increase in wetland area through restoration. While at a federal level wetlands are officially regulated under Section 404 of the Clean Water Act, US Army Corps districts are tasked with achieving this policy goal as part of their responsibility in administering Section 404.

To monitor No Net Loss, the US Fish & Wildlife Service (FWS) is tasked with producing publicly available maps of US wetlands, as well as report to Congress every decade on wetland trends. This is carried out by FWS's National Wetlands Inventory (NWI) program, which is the main wetland dataset used in our analysis. As of 2019, NWI estimates that are 116.4 million acres (47.1 million hectares) of wetlands in the continental US, or 6% of US area.[18]

In terms of the No Net Loss goal, it is important to note that the National Wetlands Inventory identifies wetlands based on their biological definition in terms of hydorolgy, which is independent of the federal regulatory definition of 'Waters of the United States' and rule changes like NWPR—and thus does not imply regulatory jurisdiction.

[18] For the most recent FWS report, see "Status and Trends of Wetlands in the Conterminous United States 2009 to 2019", U.S. Fish Wildlife Service, Report to Congress (link).

A.2 Data Appendix

CoreLogic Property Transactions

We use land transaction data from CoreLogic spanning 2017 to 2023. Our extract includes approximately 3.3 million land transactions categorized as non-residential (CoreLogic land use code >= 200) and a random sample of 6 million residential transactions over the same time period. We follow best practices in cleaning the CoreLogic data. In particular, we:

1. Drop transactions with a missing value for sale amount, sale date, latitude/longitude
2. Drop likely duplicate transactions that contain the same value for the sale amount, sale date, and location (latitude/longitude)
3. Drop transactions that are not arms length or that are coded as interfamily transfers
4. Drop transactions where property area equals zero or is missing, or the acreage is 100,000 or greater
5. Drop transactions where the price (sales amount) is $1,000 or less, the price is $10,000,000 or more, or the price per acre is $100 or less
6. Drop transactions where the ratio of price/assessed total value or assessed total value/price is 50 or greater

Approved Jurisdictional Determinations (AJDs)

We use data on Clean Water Act jurisdiction from Approved Jurisdictional Determinations (AJDs) made by the US Army Corps of Engineers. AJDs are available at the individual water-body level from the EPA (https://watersgeo.epa.gov/cwa/CWA-JDs/). The database has approximately 150,000 AJDs. The data cover all states and Army Corps districts, though prevalence varies across districts (Greenhill et al. 2024).

Figure A3 maps the locations of the Approved Jurisdictional Determinations we analyze. These AJDs cover most areas of the continental US, including rural and urban areas, and all 48 states. They tend to be more common in major metro areas, where development is prevalent, and less common in sparsely populated rural areas, where development occurs less. AJDs are more common in the wetter areas of the eastern US, which have more water resources and development, and less common west of the 100th meridian, where more arid climate means fewer water resources are present to require AJDs.

Figure A3 also reveals spatial patterns of jurisdiction. Green points are jurisdictional, according to ACE's ruling. Brown points are not jurisdictional. Among all AJDs in our sample, 31% are jurisdictional. Some of the spatial patterns in jurisdiction reflect geophysical features—for example, many coastal wetlands in the South and Mid-Atlantic are jurisdictional, while few ephemeral streams in the more arid West are jurisdictional. Other patterns reflect Army Corps district boundaries—few AJDs in the St. Paul Army Corps district, which covers Minnesota and Wisconsin, are jurisdictional, while many AJDs in the Chicago district are jurisdictional. Although these spatial patterns describe broad trends, some metro areas like Portland, OR and Houston, TX, have a more even mix of jurisdictional and non-jurisdictional sites. A zoomed in map of AJD outcomes for greater Houston is shown in Figure A4 for illustrative purposes.

AJDs have an uneven distribution across land cover classes, as reported in the 2021 National land Cover Database (Table A7). The largest share of AJDs represent developed ares (31%), which makes sense since AJDs typically represent a site with development potential, and development disproportionately occurs surrounding developed areas like cities. Additional large shares of AJDs occur on cropland (19%), forested lands (19%), and wetlands (12%). Wetlands are common since AJDs focus on water resources; cropland and forested land account for a large share of US total area. AJDs are uncommon in open water (3% of total AJDs), partly because areas like the Great Lakes or Mississippi River are obviously jurisdictional as 'navigable waters' under the Clean Water Act, so developers of ports and docks in such areas may skip the AJD process. Water is also uncommon because a limited amount of development occurs in the center of open water (e.g., few buildings are constructed on open water). Barren land has few AJDs, perhaps in part because barren land has few water resources, and therefore fewer sites where a developer would request Army Corps to determine jurisdiction (which is usually requested when some indication of water is present).

The share of AJDs that are jurisdictional also varies by land cover class (Table A7). AJDs on wetlands and water are just over 50 percent likely to be jurisdictional. AJDs on developed land and cropland are just over 25 percent likely to be jurisdictional. AJDs on barren land are only about 20 percent likely to be jurisdictional.

A.3 Supplementary Figures and Tables

Figure A1: Wetland development example in the Bridgeland housing development



Notes: Panels shows imagery of the Bridgeland housing development near Cypress Creek in Northwest Houston, TX, which received jurisdictional AJDs under NWPR in October 2020. Panel (a) shows aerial imagery from Google Earth of flooding in 2016. Panel (b) shows recent aerial imagery from Google Earth. Panel (c) shows Google Street View imagery of one location in the development. Panel (d) shows a screenshot of the development website, https://www.bridgeland.com/, visited March 7, 2025.

Figure A2: Jurisdictional determinations and permitting process

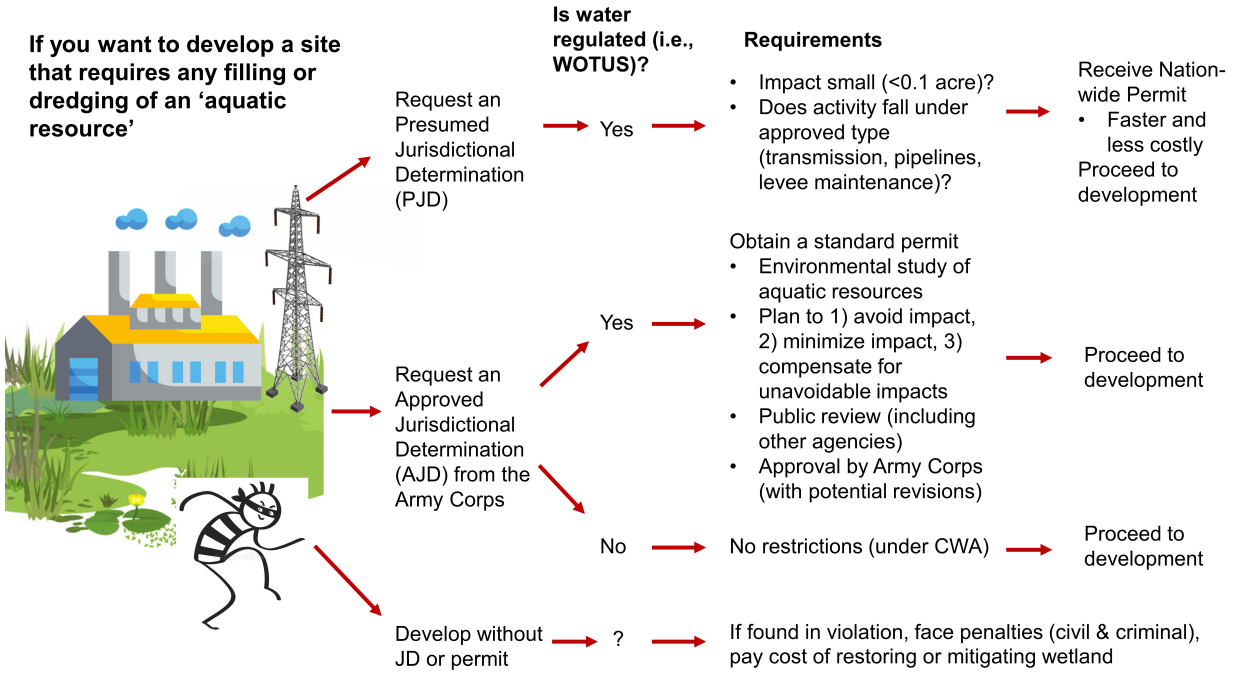
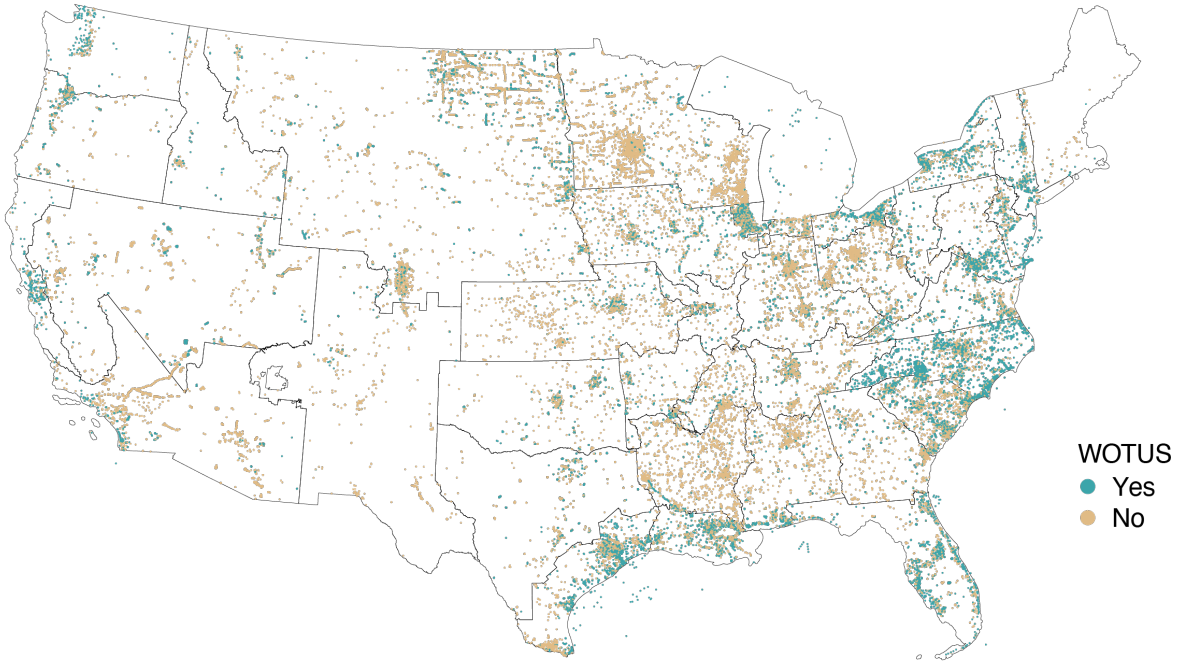
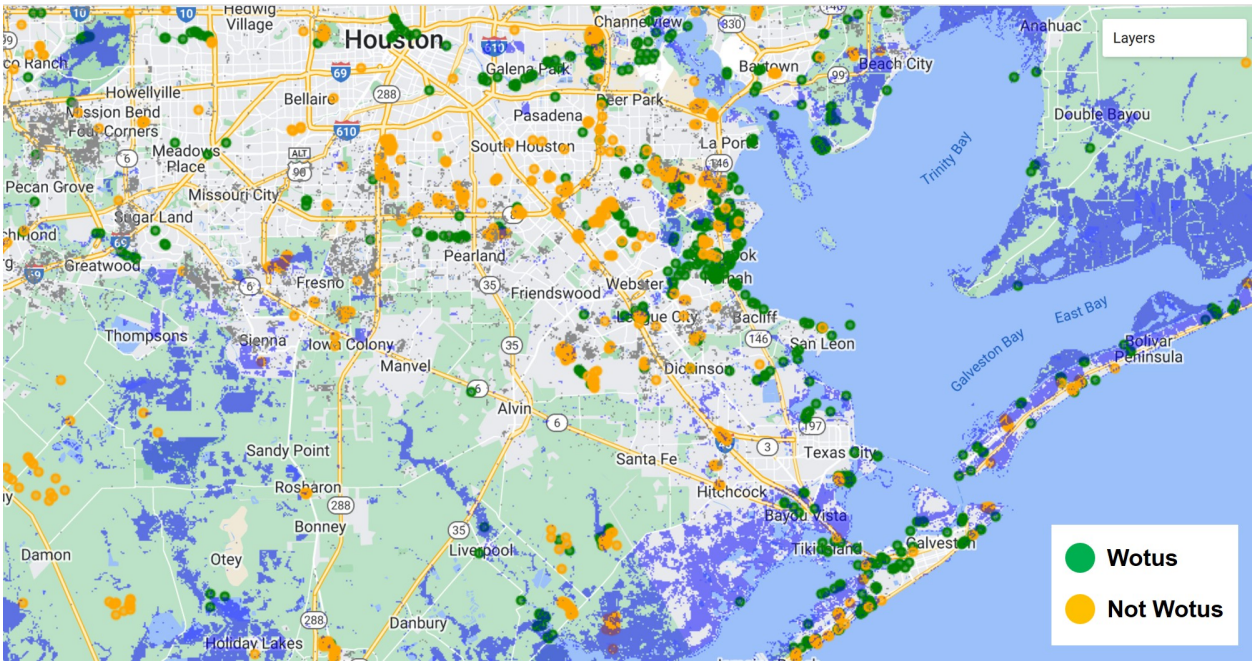


Figure A3: Locations and outcomes of jurisdictional determinations



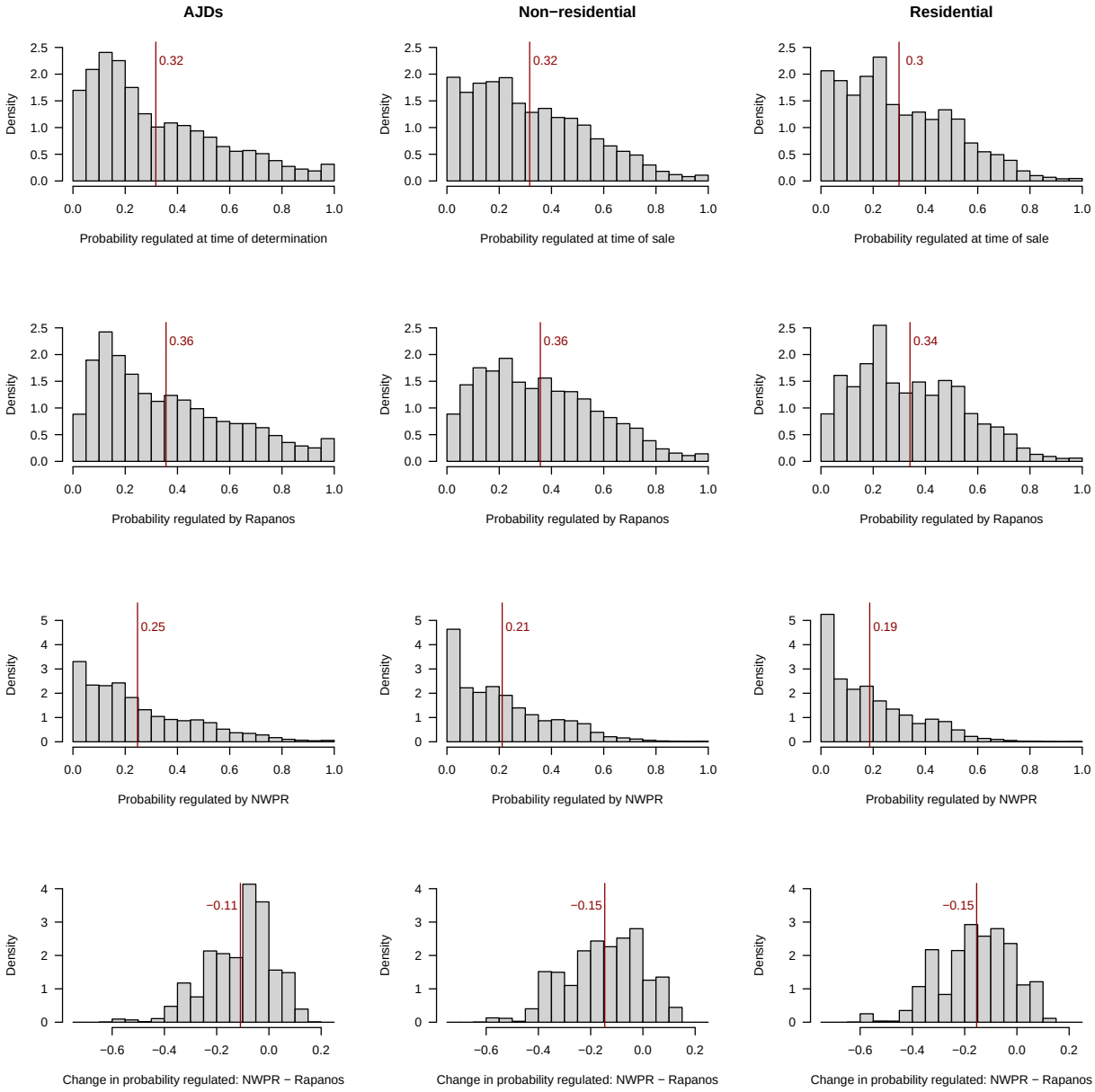
Notes: Map shows US Army Corps districts overlaid with the locations and outcomes of Approved Jurisdictional Determinations (AJDs). Blue dots show jurisdictional sites. Brown dots show non-jurisdictional sites.

Figure A4: Jurisdictional determinations around the Houston-Galveston region, TX



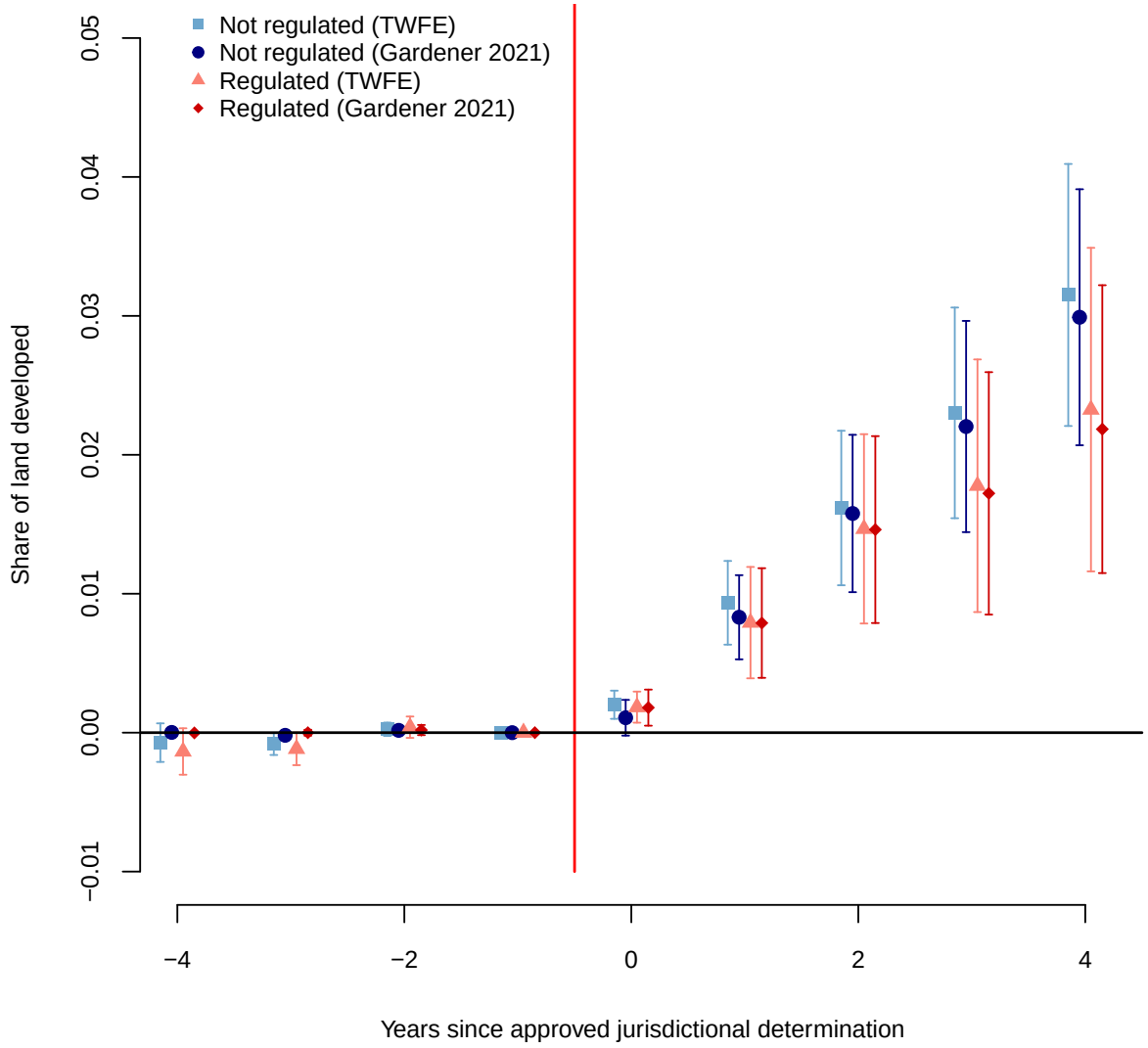
Notes: Green dots represent AJDs with outcomes that are jurisdictional (i.e., WOTUS, or Waters of the United States), and orange dots are non-regulated (i.e., Not WOTUS). Blue lands show wetland coverage.

Figure A5: Predicted jurisdictional probabilities, AJDs and real estate transactions



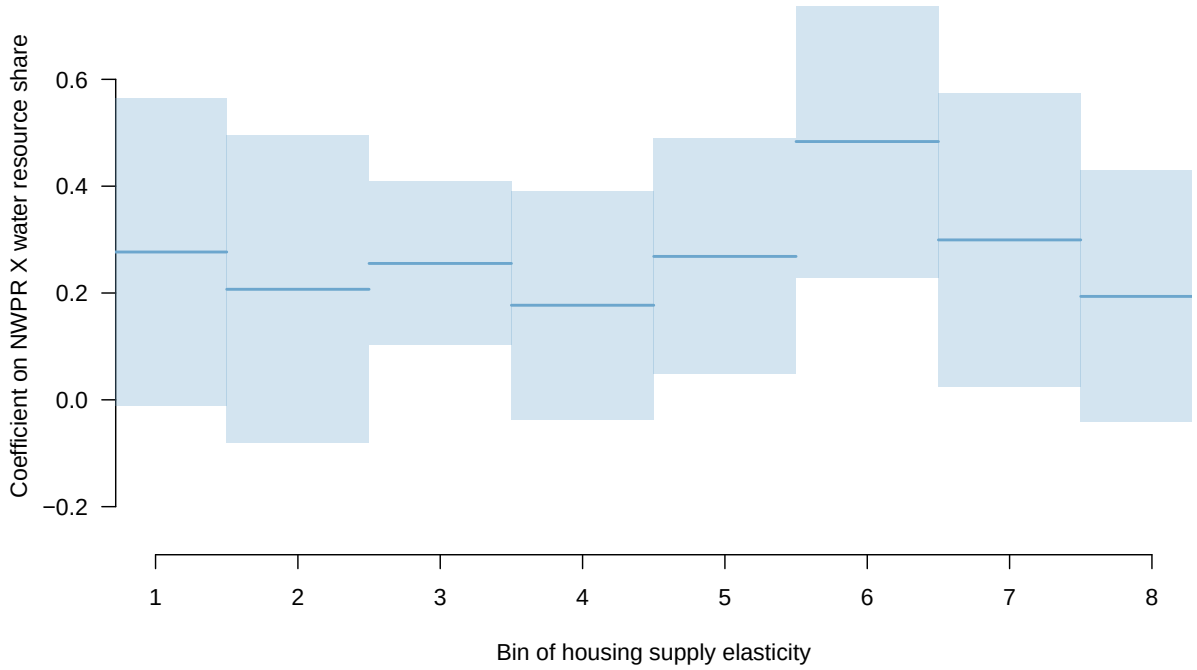
Notes: Predicted probabilities of jurisdiction from the machine learning algorithm. Top row shows the jurisdictional probability under the rule in force at the time of the AJD or property sale. Second row shows the predicted jurisdictional probability under *Rapanos*, $p(Rapanos)$. Third row shows the predicted jurisdictional probability under NWPR, $p(\text{NWPR})$. Fourth row shows the change in jurisdictional probabilities under NWPR: $p(\text{NWPR}) - p(Rapanos)$. The first column shows probabilities among AJDs, the second column shows probabilities among non-residential property transactions, and the third row shows the probabilities among residential property transactions.

Figure A6: Comparison of event study and Gardner (2021) estimates for the effects of AJDs on development



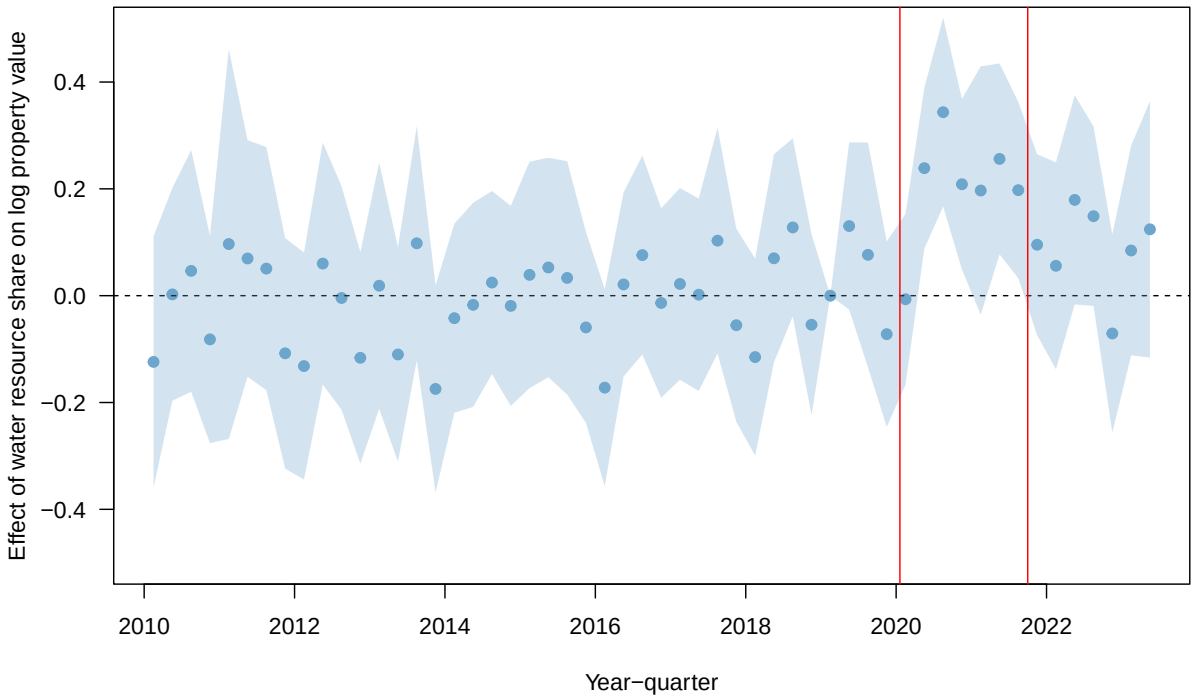
Notes: Points show the share of developed land, as measured by Land Change Monitoring, Assessment, and Projection (LCMAP), in the years preceding (negative x-axis values) and following (positive x-axis values) an AJD. Bars show 95% confidence intervals. Jurisdictional determinations (AJDs) determined to be jurisdictional (WOTUS) are shown in red and AJDs determined to be non-jurisdictional (non-WOTUS) are shown in blue. TWFE estimates correspond to the standard event study estimates, Gardner (2021) corresponds to the imputation estimator proposed in Gardner 2021 and R package Butts and Gardner 2021. All specifications include year and transaction id fixed effects as opposed to commutingz zone-by-year and transaction id fixed effects in Figure 5 due to lack of untreated outcomes in commuting zone-by-year strata needed to impute potential outcomes. Standard errors are clustered by commuting zone.

Figure A7: Effect of NWPR on property values, by MSA-level housing supply elasticity



Notes: Lines show heterogeneous price responses by housing supply elasticity bin. Shaded areas show 95% confidence intervals. Estimates are obtained by interacting the term water resource share × NWPR in equation 3 with 8 equally-sized bins of MSA-level housing supply elasticity obtained from Saiz (2010).

Figure A8: Effect of NWPR on property values, extended panel



Notes: Estimates from equation 4, but using CoreLogic non-residential property transaction records extending back to 2010. Points show the coefficient estimates for Water Resource Share × NWPR by year-quarter. Shaded area shows 95% confidence intervals where standard errors are clustered by commuting zone. Vertical red lines indicate the period when NWPR was in force.

Table A6: Examples of environmental policies around the world that limit land use

Country	Policy	Description	Impact on land use	Reference
Australia	Environment Protection and Biodiversity Conservation Act 1999	Legal framework for the protection and management of nationally and internationally important flora, fauna, ecological communities, and heritage places.	Requires assessments of proposed projects on protected matters, which determines which development projects are allowed.	Department of Climate Change, Energy, the Environment and Water (2024)
Brazil	Forest Code (Código Florestal)	Mandates landowners in the Amazon rainforest and other sensitive biomes to maintain a certain percentage of their land as natural forest.	Limits deforestation and land conversion, affecting agricultural expansion and construction activities.	Amazon Environmental Research Institute (2017)
Canada	Fisheries Act	Prohibits activities that result in the harmful alteration, disruption, or destruction of fish habitat.	Restricts land development and industrial activities near water bodies to protect fish habitats.	Government of Canada (2024)
China	Environmental Protection Law (2015 Revision)	Enhances regulatory oversight on pollution and mandates stricter environmental assessments for projects.	Restricts or halts development projects that fail to meet environmental standards.	Zhang et al. (2015)
European Union	Water Framework Directive	Comprehensive framework aimed at achieving good qualitative and quantitative status of all water bodies (including rivers, lakes, groundwater, and coastal waters).	Requires member states to develop river basin management plans and restricts activities that could deteriorate water quality, effectively controlling certain types of land development and industrial activities near water bodies.	European Commission (2024)
India	Coastal Regulation Zone Notification	Regulates activities, including waste treatment plants, mining, and construction, on zone of coastal ecosystems.	Designates zones with specific restrictions on construction and land use.	FAO Legal Office (2015)
New Zealand	Resource Management Act	Manages air, soil, fresh water, coastal marine areas as well as land use and provision of infrastructure.	Activities affecting land, air, or water require authority approval, and local governments can impose restrictions on land use to protect the environment.	New Zealand Government (1991)
South Africa	National Environmental Management Act	Provides the framework for environmental governance including principles for decision-making on matters affecting the environment.	Requires federal agencies to submit an environmental impact statement prior to some development projects, which determines which projects are allowed.	Government of South Africa (1998)

Table A7: Distribution of jurisdictional determinations by land cover

	AJD count (1)	AJD share (2)	WOTUS (3)
Barren	1,997	0.01	0.21
Cropland	30,238	0.19	0.26
Developed	47,333	0.31	0.29
Forest	29,593	0.19	0.47
Herbaceous	11,753	0.08	0.28
Shrubland	10,958	0.07	0.21
Water	4,237	0.03	0.54
Wetland	18,995	0.12	0.57

Notes: Approved Jurisdictional Determinations (AJDs) by land cover, as measured by the 2024 National Land Cover Database (NLCD). Column (1) shows the count of AJDs and Column (2) shows the share of AJDs by land cover class. Column (3) shows the share of AJDs determined to be jurisdictional (WOTUS) by land cover class.

Table A8: Effect of Approved Jurisdictional Determinations on land use

	Developed (impervious)			Wetland		
	(1)	(2)	(3)	(4)	(5)	(6)
Post	2.30***	2.22***	1.39***	-0.222***	-0.199***	-0.175***
	(0.197)	(0.198)	(0.139)	(0.047)	(0.041)	(0.037)
Post × WOTUS	-1.24***	-0.939***	-0.551***	0.323***	0.239***	0.246***
	(0.176)	(0.163)	(0.142)	(0.108)	(0.090)	(0.092)
WOTUS × τ		-0.084***	-0.089***		0.024*	0.034***
		(0.023)	(0.030)		(0.012)	(0.012)
Post × τ			0.879***			-0.027
			(0.088)			(0.020)
Post × WOTUS × τ			-0.207**			-0.019
			(0.090)			(0.042)
Fitted effect: $\tau = 5$						
Non-WOTUS	2.30	2.22	5.79	-0.222	-0.199	-0.310
WOTUS	1.06	1.28	4.20	0.102	0.040	-0.160
P-value difference	[0.000]	[0.000]	[0.001]	[0.003]	[0.008]	[0.469]
Dep. var. mean	33.78	33.78	33.78	11.63	11.63	11.63
NWI×τ interactions	Yes	Yes	Yes	Yes	Yes	Yes
Property FE	Yes	Yes	Yes	Yes	Yes	Yes
CZ-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,411,904	1,411,904	1,411,904	1,411,904	1,411,904	1,411,904
R^2	0.945	0.945	0.946	0.990	0.990	0.990
Within R^2	0.019	0.020	0.034	0.005	0.005	0.005

Notes: Linear regression. Outcome is percentage of a given land use within 100m radius of an AJD site for developed (impervious) land (Cols 1-3) and wetland (Cols 4-6) using the 2024 National Land Cover Dataset (NLCD) at 30m resolution. The developed proxy uses the NLCD imperviousness product, which is a continuous measure of the impervious share of land within each 30m pixel rather than binary categorization of development. Post is a dummy for years following a jurisdictional determination (AJD). Event time is captured by τ (year minus year of AJD) and includes the years 2016 to 2023. WOTUS is a dummy for whether a property was deemed to be jurisdictional under the AJD. Cols (2) and (5) allows for a differential linear trend among WOTUS properties, coles (3) and (6) further allows the trend break in the post period. Regressions include commuting zone (CZ)-by-year fixed effects and a property level fixed effect, as well as a control for the static NWI share-by-event time to account for differing geophysical fundamentals. Standard errors clustered by commuting zone. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

Table A9: Effect of NWPR on property values, by size of COVID housing boom

	Dependent variable: *Log property value*	
	(1)	(2)
Water resource share × NWPR	0.1586***	
	(0.0295)	
Water resource share × NWPR × Low COVID	-0.0002	
	(0.0548)	
Water resource share × NWPR × High COVID	-0.0038	
	(0.0595)	
Jurisdictional		-0.5557***
		(0.1768)
Jurisdictional × Low COVID		0.2190
		(0.3226)
Jurisdictional × High COVID		0.0024
		(0.3348)
FE: Zip × year × month	Yes	Yes
Log property acres	Yes	Yes
Log distance to city	Yes	Yes
Log population density	Yes	Yes
Work from home share	Yes	Yes
Observations	2,776,563	2,776,563
R^2	0.69114	0.69098

Notes: Column (1) shows the estimates from equation 3 of the effect of water resource share during NWPR on log property values, but allowing for differential responses in locations with low versus high COVID booms. Column (2) shows the estimates from equation 6 of the effect of the jurisdictional probability on log property values, again allowing for differential responses in locations with low versus high COVID booms. We proxy for the size of the COVID housing boom using the trend-break in residential housing values at the zip code level in March 2020. "Low COVID" locations are in the bottom quarter of the trend break and "high COVID" locations are in the top quarter of the trend break. The reference category is zip codes with trend breaks between the 25th and 75th percentiles. Standard errors are clustered by commuting zone. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

Table A10: Effect of Clean Water Act on Property Values, by Land Use

	Dependent variable: *Log property value*				
	(1)	(2)	(3)	(4)	(5)
Panel A: All non-residential properties					
Water resource share × NWPR	0.135***	0.169***	0.158***	0.162***	0.162***
	(0.027)	(0.025)	(0.024)	(0.025)	(0.025)
Adj. R^2	0.49152	0.53612	0.54783	0.54863	0.54864
N	2,913,860	2,913,860	2,913,860	2,913,860	2,913,860
Panel B: Agriculture properties					
Water resource share × NWPR	0.046	0.053	0.053	0.054	0.054
	(0.055)	(0.048)	(0.048)	(0.048)	(0.048)
Adj. R^2	0.48523	0.53123	0.53191	0.53192	0.53194
N	551,716	551,716	551,716	551,716	551,716
Panel C: Commercial properties					
Water resource share × NWPR	0.002	0.079	0.072	0.084	0.082
	(0.125)	(0.125)	(0.127)	(0.128)	(0.128)
Adj. R^2	0.51056	0.57434	0.57624	0.57664	0.57671
N	730,575	730,575	730,575	730,575	730,575
Panel D: Vacant properties					
Water resource share × NWPR	0.113**	0.129***	0.125***	0.134***	0.135***
	(0.044)	(0.033)	(0.034)	(0.034)	(0.034)
Adj. R^2	0.54111	0.58893	0.59185	0.59276	0.59282
N	1,375,451	1,375,451	1,375,451	1,375,451	1,375,451
FE: Zip × year × month	Yes	Yes	Yes	Yes	Yes
Log property acres	No	Yes	Yes	Yes	Yes
Log distance to city	No	No	Yes	Yes	Yes
Log population density	No	No	No	Yes	Yes
Work from home share	No	No	No	No	Yes

(Continued next page)

Table A10, continuation from previous page

	Dependent variable: *Log property value*				
	(1)	(2)	(3)	(4)	(5)
Panel E: Industrial properties					
Water resource share × NWPR	0.111	0.074	0.089	0.096	0.095
	(0.423)	(0.376)	(0.380)	(0.380)	(0.380)
Adj. R^2	0.68176	0.74229	0.74255	0.74268	0.74269
N	120,895	120,895	120,895	120,895	120,895
Panel F: Other properties					
Water resource share × NWPR	0.075	0.078	0.065	0.059	0.061
	(0.278)	(0.239)	(0.247)	(0.244)	(0.245)
Adj. R^2	0.66271	0.67978	0.68023	0.68031	0.68042
N	26,488	26,488	26,488	26,488	26,488
Panel G: Public properties					
Water resource share × NWPR	0.305	0.118	0.140	0.156	0.191
	(0.372)	(0.388)	(0.398)	(0.399)	(0.404)
Adj. R^2	0.81014	0.81839	0.81875	0.81876	0.81911
N	50,177	50,177	50,177	50,177	50,177
FE: Zip × year × month	Yes	Yes	Yes	Yes	Yes
Log property acres	No	Yes	Yes	Yes	Yes
Log distance to city	No	No	Yes	Yes	Yes
Log population density	No	No	No	Yes	Yes
Work from home share	No	No	No	No	Yes

Notes: Estimates from equation 3. Panel A estimates on the entire non-residential sample, panels B-H estimate on subsamples as defined as their panel title. Standard errors are clustered by commuting zone. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$