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Comparative Analysis of Institutions to Govern the Groundwater Commons in California

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ABSTRACT: The management of groundwater, a common-pool resource, is a fundamental collective action problem that can lead to over-exploitation. Our paper examines the management of two groundwater basins in California's Central Coast region whose geographic proximity, land use patterns, socioeconomic characteristics, and timing of institutional formation provide an ideal basis for comparative study. However, each basin is governed by a distinctive institutional configuration. The Pajaro Valley Water Management Agency is a legislatively created Special Act District with a collective public management focus, while the Santa Paula Groundwater Basin is managed through a court adjudication with a rights-based focus. We compare the legal and administrative foundations of these institutional arrangements and examine their implications for the polycentric regulation of sustainable groundwater use. We find that while adjudication may specify groundwater rights, an approach that scholars argue can be critical for achieving sustainability, it also promotes insularity with a wider polycentric system and this ultimately limits its management strategies. The Special Act District, by contrast, does not encourage as clear an allocation of water rights, but does encourage a broad sustainability mission and wider polycentric engagement, though it still struggles with declining groundwater levels. Ultimately, neither institutional arrangement fully addresses the problem of groundwater sustainability. This suggests the need for further research on how institutional configurations and developmental pathways impact resource outcomes.

KEYWORDS: Groundwater management, comparative study, adjudicated groundwater basins, special act groundwater districts, polycentric, facilitating conditions, California

INTRODUCTION

The management of common-pool resources such as fisheries, forests, grazing lands, and groundwater is a fundamental collective action problem that can lead to the over-exploitation of natural resources. While researchers have examined the challenges of sustaining common-pool resources over time (Ostrom, 2000; Agrawal, 2001, 2014; Ostrom and Hess, 2007; Bakker, 2010; Araral, 2014), there is still much to learn about the legal and institutional dynamics that affect resource sustainability, the focus of this paper.

Groundwater is considered a classic common-pool resource. Moreover, it is a critical and life-sustaining resource for billions of people worldwide and a central water supply source for irrigated agriculture and for many ecosystems (Giordano, 2009; Siebert et al., 2010). The problem is that unsustainable depletion of groundwater is now documented on both regional (Rodell et al., 2009) and global scales (De Stefano and López-Gunn, 2012; Wada et al., 2012; Konikow, 2011). Groundwater depletion is particularly acute in California (Famiglietti et al., 2011; Nelson, 2012; LAO, 2014; Leahy, 2015). Understanding how institutional arrangements impact on-the-ground management of groundwater is clearly essential to sustaining the resource.

Groundwater has also been the focus for theorising about institutional arrangements to govern the management of common-pool resources (Ostrom, 1990; Ostrom et al., 1994; Schlager et al., 1994; Theesfeld, 2010; Madani and Dinar, 2012; Enion, 2013). For at least two decades, Elinor Ostrom and the Indiana Workshop in Political Theory and Policy Analysis provided the principal theoretical framework for understanding the governance of common-pool resources. Their perspective emphasised two core ideas:

1. *Self-organisation* – referring to rules cooperatively established by resource users themselves to govern their joint use of common-pool resources, and
2. *Polycentricity* – referring to the creation of diverse centres of institutional authority for managing the commons that interact and overlap within a general system of rules (Ostrom, 1999; Aligica and Tarko, 2012).

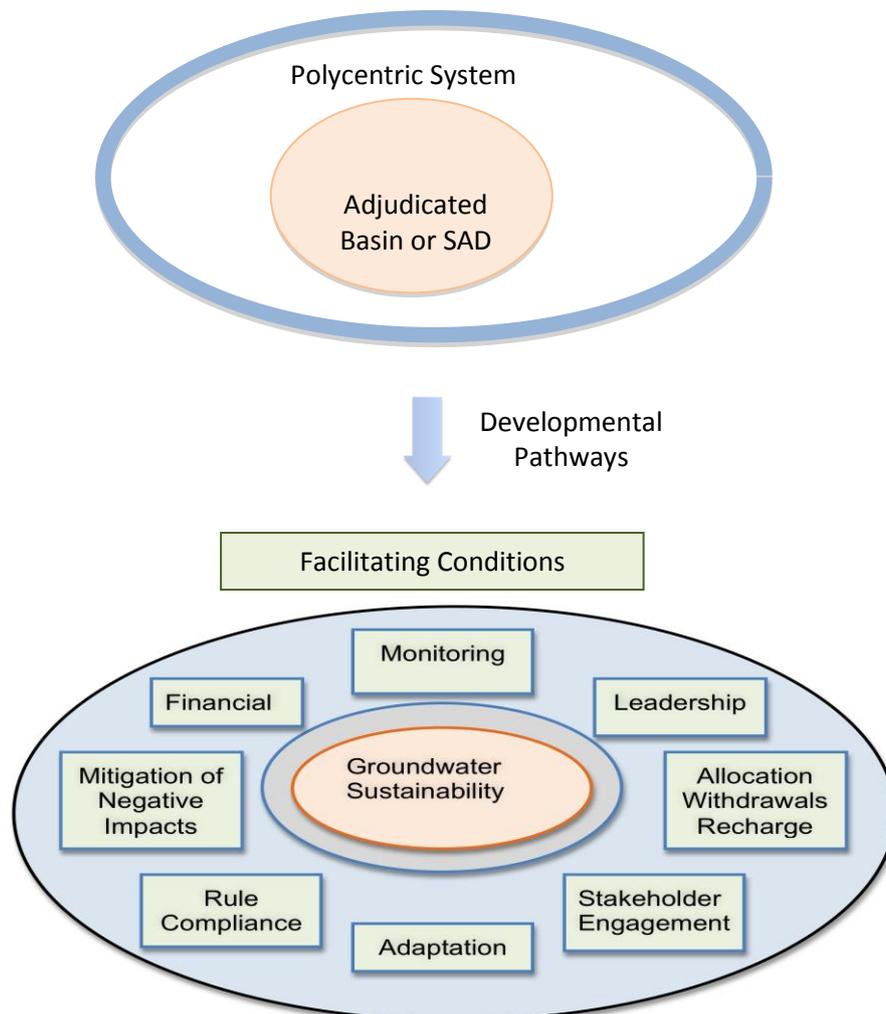
Ostrom's earliest research on common-pool resources focused on groundwater management (Ostrom, 1965), which was featured in her classic text, *Governing the Commons* (1990). Her student, William Blomquist, went on to produce a detailed monograph that examined the management of eight southern California groundwater basins, analysing the capacity of local users to craft effective collective solutions to groundwater overuse (Blomquist, 1992). In seven of the eight basins, communities used *court adjudication* to define and assign private property rights to groundwater and to oversee the rules governing basin management. In the eighth basin, Blomquist examined a different model, the *Special Act District (SAD)*, created by the legislature to allow for enhanced local public regulation of groundwater use. In examining the benefits of these two models, Blomquist along with other scholars, depicted adjudication as an effective self-organising and polycentric model for groundwater management through the court's allocation of private rights to groundwater (Blomquist, 1992; Tarlock, 1989; Zasloff, 2012; Enion, 2013). Although the Special Act District model also has both polycentric and self-organising features, it was considered to be less effective due to a lack of clarity in the allocation of groundwater rights (Blomquist, 1992).

The Ostrom tradition provided convincing theoretical and empirical work demonstrating that local, self-organised systems of common-pool management are feasible (Agrawal, 2003; Schlager and Heikkila, 2011). Other scholars subsequently examined the characteristics of groundwater governance institutions (Megdal et al., 2015; Molle and Closas, 2017), and the specific definitions (Schroder, 2016) and characteristics of polycentric systems (for example the extent of autonomy, cooperation and conflict) (Lubell et al., 2010; Aligica and Tarko, 2012). But there has been less research examining how different institutional arrangements embedded within polycentric systems affect groundwater outcomes with respect to the long-term sustainability of the resource.

To advance this agenda, this paper compares the different legal and administrative foundations of these two institutions, both embedded within a polycentric system where they interact with other federal, state and local institutions. The Pajaro Valley Water Management Agency (PVWMA) was created by the legislature as a special act district to manage groundwater in the Pajaro Valley, while in the adjudicated Santa Rosa groundwater basin, a court-appointed Watermaster committee manages the basin. Similarities in their timing of institutional formation, proximate locations along California's Central Coast, land use, and demographics, led to the selection of PVWMA and Santa Paula for this comparative study.

We observe how each institution interacts with other agencies within a polycentric system, and the emergence of facilitating conditions that affect sustainability. Then we assess the extent to which each basin's subsequent management strategies result in meeting our defined criteria for groundwater sustainability. Figure 1 illustrates our research framework, discussed in more detail under research approach. That section also defines facilitating conditions and specifies our criteria for groundwater sustainability.

Figure 1. Research framework.



THEORETICAL FRAMEWORK

The challenge of managing common-pool resources such as groundwater was vividly brought to light in a 1968 article by Garrett Hardin. Hardin's invocation of the 'tragedy of the commons' galvanised attention to a fundamental collective action problem that leads to resource over-exploitation. In response, scholars initially focused on two different solutions: privatisation via the allocation of private property rights for the resource, and state regulation that enforced public rules of resource access and use (Araral, 2014). Elinor Ostrom and fellow scholars suggested a powerful third option (Wade, 1987; Ostrom, 1990). Arguing that assigning private rights to a resource does not prevent resource degradation (Larson and Bromley, 1990; Enion, 2013) and that state regulation often produces inefficient rules and limited compliance (Wade, 1987; Tang, 1991), these scholars suggested that local communities could prevent the tragedy of the commons by creating cooperative 'self-organised' institutions. If resource users can communicate, sanction one another, and establish their own rules, they may engage in reciprocal cooperation (Ostrom, 1998). Drawing on trust, reciprocity and reputation within a community of users, norms can be developed that provide for more sustainable use.

Subsequent research established this approach as a dominant perspective in common-pool resource management and illuminated many factors affecting the robustness of community-based governing arrangements (Agrawal, 2003; Schlager and Heikkila, 2011). Ostrom (1990) summarised findings of much of this research in the form of eight 'design principles', and argued that 'bureaucratic' systems are less effective in rule enforcement than community-based self-organised systems (Tang, 1991). She did not reject the role of the state entirely, but rather advocated 'polycentric' systems. These can be characterised as governing authorities that are disaggregated and typically composed of multiple centres of semiautonomous decision making, sometimes with overlapping functional or spatial jurisdictions that take each other into account in competitive and cooperative relationships (Carlisle and Gruby, 2017, Heikkila et al., 2018). They are generally state, federal and/or multilevel systems with specialised institutions 'nested' at different scales (Ostrom, 2010a,b,c; Mansbridge, 2014, Ostrom, 2014), but with considerable independence to establish norms and rules within their domain (Ostrom, 2010b; Schroder, 2016).¹ A chief advantage of polycentric systems is that horizontal specialisation (e.g. each groundwater district manages its own basin) and vertical nesting (e.g. a groundwater district interacts with state agencies on management issues) allow governance arrangements to be tailored to specific functional needs and contexts thereby potentially promoting greater citizen access to decision-making and adaptation (Carlisle and Gruby, 2017). Horizontal specialisation facilitates self-regulation of local resource users, taking advantage of local knowledge and social capital, and avoiding inefficient 'one size fits all' regulation. At the same time, overlapping functional and spatial jurisdictions combined with nesting can also create a system of checks and balances that reduces opportunism and contributes to system resiliency (Bissonnette et al., 2018; Nagendra and Ostrom, 2012). Heikkila and Gerlak (2018) point to the need to build new insights on the dynamics of polycentric systems by building on comparative case studies.

Both the Santa Rosa adjudicated basin and the PVWMA special act district are embedded within a polycentric system. Our paper explores how their different legal and administrative foundations, and developmental and political dynamics within that polycentric system, affect groundwater sustainability. We are interested in whether: (1) the overarching management focus of special act districts will lead to a wider and more cooperative engagement with other agencies and stakeholders that are part of the polycentric system, and (2) whether this will result in more robust sustainable groundwater management strategies and better basin outcomes when compared to the court-centred and rights-based approach of adjudicated basins.

BACKGROUND

California groundwater management

For most of its history California's groundwater was minimally regulated, and disputes over the resource were primarily settled in court (Sax 2006). The state still has no permit system for withdrawals and, for over a century, groundwater law allowed for essentially unregulated pumping by all landowners overlying a groundwater basin (Katz v. Walkinshaw, 1903). While groundwater provides

¹ Five key features of polycentric resource management systems identified in the literature are: 1) Customized boundaries and management - where rules are tailored to the social and natural scale of the resource ; 2) Multiple management units with some jurisdiction over the resource. They may be general purpose (e.g. a county) or limited purpose (e.g. a water district) governments and public (e.g. a public agency) or private (e.g. a private water user association); 3) Nestedness - management units may operate at different levels; 4) Overlapping jurisdictions - while management units craft their own rules and can act independently, their jurisdictions, missions, capacities, and interests may 'overlap' and be interdependent; 5) Inter-organizational cooperation - achieved by negotiation and mutual adjustment. Based on Ostrom (1990, 2010a, 2010b, 2010c), Andersson and Ostrom (2008), McGinnis and Ostrom (2012), Aligica and Tarko (2012), Nagendra and Ostrom (2012), and Mansbridge (2014).

40% of California's total water supply on average, and significantly more during dry years (California Department of Water Resources (DWR, 2013), many basins are both degraded and depleted (Famiglietti et al., 2011; Leahy, 2015).

California's water rights regime plays an important role in how communities, individuals and the courts address groundwater management, and it is particularly important in adjudication. The state recognises a system of water rights that distinguishes between surface water and groundwater (legally defined as percolating groundwater). Groundwater rights in California are specified in Table 1.²

Table 1. California groundwater rights.

	Correlative doctrine	Appropriation doctrine	Mutual Prescription doctrine
Type of water right	Equal rights to reasonable and beneficial use of the basin	First in time, first in right	Rights based on highest continual pumping amounts in the five years following the beginning of overdraft conditions
Type of pumper	Overlying landowners (overlyers) (mostly agriculture)	Groundwater exporters – rights are junior to overlyers (mostly municipalities)	All pumpers
In times of shortage	All share in cutbacks	Limited to water not needed by overlyers	All pumpers cut back equally

Prior to the passage of SGMA, local districts with varying but limited regulatory powers managed most of California's groundwater basins. Special act districts and adjudication Watermasters managed a smaller number of the state's groundwater basins, but these basins encompass major and diverse municipal and agricultural areas. Our project specifically focuses on comparing adjudicated basins and special act districts, as both are institutions that scholars have identified as having a stronger potential for sustainable resource management than general local districts.

Adjudication

The first adjudication in 1924 addressed groundwater declines in the Lytle Creek Basin in southern California and 27 more groundwater basins have since followed this institutional path (Langridge et al., 2016a). In adjudication, the courts generally quantify and determine private water rights for all users and provide court-supervised basin management by a Watermaster, generally appointed by the court to ensure that the basin is managed in accordance with the court's decree. Adjudications rely on a mix of prescriptive, overlying and appropriative doctrines to define water rights. Key users often negotiate a physical solution prior to adjudication that details basin management. The court can then accept it in whole or in part, or reject it and craft a different solution to managing the basin.

Adjudication is a long and expensive process, yet as noted, many scholars propose that it is the best solution for managing California's groundwater, positing that a court determination of each user's groundwater rights will allow all users to accurately predict the risks of curtailment in times of shortage, and reduce negative impacts from overuse (Heikkila, 2003; Foley-Gannon, 2008; Pitzer, 2011). The two most detailed California groundwater studies prior to 2016 were by Lipson (1978) and Blomquist (1992). Both studied just seven adjudications completed prior to 2000, and their work included some of

² Rights to groundwater for Native American Tribes and for other federal reserved lands are currently being litigated.

the same adjudications. They emphasised the development of local organisations, spearheaded primarily by the dominant groundwater producers, who promoted court adjudication as a way to settle water rights claims that could determine who would be responsible to address overdraft issues. The focus was on these large groundwater users who pushed for flexible operating criteria to support their needs, and who promoted imported water as an alternative to significantly reducing demand. Lipson pointed to hydrologic characteristics, legal frameworks, and political factors as variables contributing to the development of management solutions. But there was no discussion of how these variables affected outcomes. Blomquist drew on Ostrom's concept of self-organised polycentric systems and his findings pointed to good compliance because large users often developed the rules as part of a physical solution. He discussed how adjudication was effective because it encouraged conjunctive use of surface water and groundwater through the importing of surface water, albeit with some restrictions on demand.

In addition to the Lipson and Blomquist studies, Porse et al. (2015) investigated adjudicated groundwater basins in Los Angeles, arguing that adjudication provided the basis for institutions to evolve in an adaptive fashion to meet groundwater needs, but that adaptiveness was made easier by the ability to transfer water from other sources. Steed (2011) examined four adjudicated groundwater basins underlying Los Angeles County and pointed to variable results with respect to whether institutional arrangements were effective in responding to change. Enion (2013) analysed six California basins adjudicated prior to 2000, concluding that adjudication, while not ideal and requiring reform, may still be the most efficient institutional approach to manage groundwater via the assigning of property rights. Finally, Skurray (2015) favourably compared compliance in the adjudicated Central Basin in southern California with weaker outcomes in the state-regulated Gngangara Basin in Western Australia.

Some scholars were more critical of adjudication. Tarlock (1989) pointed out that a reason cited for adjudication – that it will improve conditions and produce security – may be inconsistent with the reality of the process and the nature of a water right. Unlike land property rights, a surface water or groundwater right in California is subject to the public interest constraint that it must be put to non-wasteful and beneficial use, and the interpretation of that requirement can change over time. Additionally, other legal provisions, including federal statutes such as the Endangered Species Act, may affect the water right. Other scholars pointed to the coercive nature of adjudication, as well as to a frequent lack of compliance with court orders and agreements (McGillis and Mullen, 1977). Moreover, courts sometimes lacked sufficient expertise and there were limited processes for collaboration (Goldberg et al., 1992). Langridge et al. (2016a) investigated all groundwater basins adjudicated prior to 2016, and discussed some of the issues with adjudication including, for example, that environmental uses and accumulated overdraft are rarely addressed in adjudication judgments. Their report provided baseline information on the Santa Rosa adjudicated basin.

Special Act Districts (SADs)

Special act districts represent an important alternative to adjudication for groundwater management in California. They are distinguished by a legislative act that establishes the district and provides for enhanced authority to regulate groundwater within the boundaries of their service areas. California's 15 special act districts vary considerably in size and they exemplify the state's social, institutional and physical diversity. They enjoy many of the same governing powers as cities and counties and can impose taxes, levy assessments, and charge fees for their services, though importantly they do not provide users with private water rights (Langridge et al., 2016b).

'Special districts' are perhaps the most common form of government in the U.S. though they tend to operate in the shadows of 'general purpose' governments such as cities or states. They are more prominent in the management of water resources. Advocates of municipal reform generally regard

'special purpose' government such as special act districts as leading to fragmented governance, to unaccountable decision making, and to capture by special interests (Mullin, 2009). Alternatively, public choice theorists and advocates of 'polycentricity' tend to regard the decentralised organisation and focused mission of special districts as promoting governing efficiency and responsiveness to voters. Mullin argues that the truth is often somewhere in between and depends on the details of institutional design and the organised interests at stake in the management of the resource.

Research has given much more attention to adjudicated basins than to special act districts and has primarily focused on Southern California and the Orange County Water District (OCWD). Lambert (1984) examined how OCWD's use of pump taxes to regulate groundwater use led to effective groundwater replenishment. Endo (2015) compared OCWD with a nationally subsidised system of groundwater management in the Tokyo metropolitan region in Japan, finding advantages and disadvantages for both regimes. Megdal et al. (2017) also examined OCWD, noting its prominent role "at the forefront of water reuse, measures to prevent saltwater intrusion, and sustainable groundwater use". The most detailed examination of special act districts by PI Langridge (Langridge et al., 2016b) provided important baseline information on the PVWMA.

RESEARCH APPROACH

A central question we explore is which institutional arrangement is more likely to develop the internal capacity and interactive relationships within a polycentric system to sustain the groundwater resource over the long-term – legislatively created special act districts with their more overarching mission though specialised role – or court adjudicated basins with their focus on the allocation of water rights?

Sustainable groundwater management

Our analysis requires a definition of '*sustainable groundwater management*'. This is a complex and multifaceted concept with ambiguities in deciding what is to be sustained – e.g. the long-term sustainability of the resource, benefits from the resource, or equity in the distribution of benefits (Agrawal, 2014). Studies focused on institutional development generally define sustainability in terms of the effectiveness of institutions, although sustainability of the resource and the institution are often conflated. Hydrogeologists initially focused on the physical resource and the concept of 'safe yield' where the goal was to establish a physical metric to determine the dynamic response of an aquifer to pumping (Alley and Leake, 2004; Kalf and Woolley, 2005; Zhou, 2009; Gleeson et al., 2010; Bredehoeft, 1997). The term 'sustainable yield' was subsequently used to reflect the more complex relationship between socio-political factors and groundwater withdrawals (Kalf and Woolley, 2005; Rudestam and Langridge, 2014), and the focus shifted to the sustainability of the resource and the communities that rely on the resource.

California legislators confronted the challenge of defining sustainable groundwater management when it passed the 2014 Sustainable Groundwater Management Act (SGMA – AB 1739, SB 1168, SB 1319). The SGMA establishes new requirements for 127 high and medium priority groundwater basins that were either in, or vulnerable to, overdraft (long-term groundwater depletion). These basins were required to form groundwater sustainability agencies (GSAs) by 2017, and they are now required to develop groundwater sustainability plans (GSPs) to manage the basins, with the state evaluating local GSPs and their implementation. Adjudicated basins are exempt from SGMA, but the law provides special act districts with the option to be the exclusive local GSA within their respective statutory boundaries, potentially extending their legislated authority to manage their groundwater. The special act district for our comparative study, PVWMA, is currently a GSA.

Molle and Closas (2017) point to the difficulty of considering hydrologic complexity in defining metrics for many different basins. To address this, the SGMA defines sustainable groundwater

management as: "The management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results". SGMA defines undesirable results as one or more of the following effects caused by groundwater conditions throughout the basin:

- chronic lowering of groundwater levels that indicate a significant and unreasonable depletion of groundwater storage and supply;
- a significant and unreasonable increase in seawater intrusion, degraded water quality; and land subsidence over time;
- depletions of interconnected surface water that has significant and unreasonable adverse impacts on beneficial uses of surface water

Additionally, SGMA strongly recommends that stakeholder engagement be an important component of sustainable groundwater management, and provides an explanation of how (stakeholder) interests will be considered in the development, operation, and implementation of the GSA and GSP (CA Water Code: §§10720-10737).

We also focus on SGMA's criteria for sustainable outcomes as it acknowledges the difficulty of assigning specific metrics to the wide range of groundwater conditions in multiple basins. While it is too soon after SGMA's passage to evaluate the act's influence on groundwater management in California, our analysis can potentially provide additional and early insights into the effect of additional regulation by the legislature, as opposed to court regulation under adjudication. This is important as adjudication is still an alternative option for groundwater basin management in the state under SGMA, and basin management in many areas of the state will be evaluating whether adjudication is potentially a more sustainable route.

Operationalising sustainable groundwater management: Facilitating conditions and management strategies

Researchers have examined the significance of different factors that affect the sustainability of (a) institutions and of (b) common-pool resources (Ostrom, 2008; Agrawal, 2003; Pandey et al., 2011). These are sometimes conflated in the literature and our focus is on the sustainability of the resource.

Ostrom's (1990) eight design principles point to the participation of users, monitoring, sanctions, and conflict resolution. She also notes the importance of achieving accurate and relevant information, encouraging adaptation to new information and technology, and providing infrastructure (Ostrom, 2008). Varady et al. (2016) and Jackman et al. (2016) also stress the importance of robust stakeholder engagement and inclusion of the wider community in the decision-making process. Molle and Closas (2017) provide a detailed look at other examples that can affect resource sustainability including the importance of rule enforcement, a lack of sufficient resources that can result for example in inadequate meters, legal constraints, political issues including vested private interests, and inequalities in distribution. Pandey et al. (2011) elaborate on a specific 'groundwater sustainability infrastructure' index with broad categories for specifically measuring the sustainability of the groundwater resource. It includes five facilitating components: monitoring, knowledge generation, regulatory interventions, public participation and institutional authority and responsibility. Many of the conditions identified by these scholars overlap. An earlier review by Agrawal (2001) presents a useful summary of 41 facilitating conditions, drawn from the literature, of many of these factors for commons sustainability.

Utilising this work and 2016 detailed reviews of the 41 adjudicated basins and special act districts (Langridge et al., 2016a,b), our project distils eight common factors – that we call them 'facilitating conditions' – that are particularly relevant for adjudicated basins and special act district to achieve *sustainable groundwater outcomes*. These are:

- *Precise and comprehensive monitoring of the groundwater resource* including trends in groundwater levels, quality and extraction volume, as well as monitoring trends in land subsidence, saltwater intrusion, ecosystem integrity, and interconnected surface water;
- *Allocation, withdrawal and recharge approaches*, including conjunctive use of surface water and groundwater, that balance demand and supply and reduce unacceptable impacts as well as accumulated overdraft over time;
- *Opportunities and incentives to mitigate negative impacts to the resource and adaptation opportunities* that provide procedures to alter strategies after analysis of available data and information;
- *Stakeholder engagement opportunities* to facilitate the active involvement of diverse social, cultural, and economic elements of the population in decision making, and incentivise their engagement in knowledge co-production, including participation at public hearings and regular agency/district meetings, and integration and dissemination of basin information using on-line and user-friendly tools for communication;
- *Rule compliance* including reporting systems and the ability to sanction non-compliance;
- *Leadership that is representative of the basin users and other stakeholders*, and that reduces the possibility of capture by elites, such as whether management is elected or appointed and whether management is local or contracted out;
- *Financial resources* that are perceived to be fair by users and are sufficient to manage the basin. These can include taxes, replenishment assessments and trading opportunities.

Facilitating conditions describe general factors that characterise institutional approaches to sustainability and they can materialise from the foundational mandates of an adjudicated basin or special act district as well as interdependencies within a polycentric system. They yield specific strategies that can determine the actual effectiveness of groundwater management with respect to our sustainability criteria (Table 2).

Table 2. Summary of facilitating conditions and examples of strategies.

Facilitating condition	Examples of strategies
<i>Monitoring</i>	Comprehensive monitoring including trends in groundwater levels and storage, subsidence, salt water intrusion, water quality, ecosystem integrity and extractions
<i>Allocation, withdrawals and recharge</i>	Sustainable water rights allocation and use conditions, as well as appropriate limits on withdrawals. There are active recharge projects
<i>Mitigation of negative impacts</i>	Strategies to address negative impacts (e.g. saltwater intrusion) including, for example, seawater barriers
<i>Adaptation</i>	Procedures to alter practices after analysis of available data and information
<i>Stakeholder engagement</i>	Incentives for participation at public hearings and regular agency/district meetings, and on-line and user-friendly communication tools
<i>Rule compliance</i>	Appropriate sanctions for non-compliance including penalty fees
<i>Leadership</i>	Opportunities for diverse stakeholder representation on decision-making bodies

RESEARCH METHODS

Our approach is situated in the realm of interpretative qualitative research (Miles and Huberman, 1994) where scholars address the significance of documents by reading each closely and looking for common themes (Hall and Wright, 2008). We use a process tracing method to examine related processes that unfold over time (Collier, 2011; Mahoney, 2012; Befani and Mayne, 2014), drawing descriptive as well as causal inferences from evidence that is part of a temporal sequence of events or phenomena. Using a close examination of the conditions that affect a basin's facilitating conditions, as well as the subsequent strategies that are engendered by the facilitating conditions, we illuminate each basin's developmental pathways over time and then provide an assessment of the conditions under which adjudicated basins and special act districts produce more, or less, robust sustainable groundwater outcomes.

We searched for established patterns in the interactive relationships that exist between each basin and the other institutions within a polycentric system; criteria for sustainable outcomes that are being met; any regularities in the relationships between 1 and 2 (e.g. what are the patterns in the connections and conditions that connect institutional interactions, developmental pathways and sustainable outcomes? Then, to evaluate our central question, we assessed patterns in any developmental and interactive pathways and basin outcomes, evaluated any differences in these processes between our paired basins and then, evaluated whether there are also difference in sustainable outcomes using our sustainability criteria

Our data sources included documents relating to the background of the adjudication, the adjudication judgment, Watermaster annual reports, the special act district enabling legislation and district annual reports. For both institutions: other district/agency reports, government and technical reports, USGS data banks, district/agency meeting minutes, local General Plans, Urban Water Management Plans, Groundwater Management Plans and media articles. Management strategies and criteria to determine sustainable resource management were used to develop key themes to guide analysis. We also conducted telephone-based oral history interviews with a few personnel in the basins. We analysed textual documents through content analysis (Patton, 2002). A strategy of triangulation between different data sources was utilised to substantiate information.

CASE STUDIES

The geographic proximity, land use patterns, socioeconomic characteristics, and timing of institutional formation of our two Central Coast groundwater basins provide an ideal basis for a comparative study. Both basins are predominantly agricultural. Since a 1996 court adjudication, the Santa Paula Groundwater Basin (SPGB) has been managed under the terms of a court judgment, with an ongoing court review. In contrast, the Pajaro Valley Groundwater Basin (PVGB) has been managed since 1984 by a legislatively created special act district, the Pajaro Valley Water Management Agency (PVWMA). In 2017 it was designated as a GSA under SGMA.

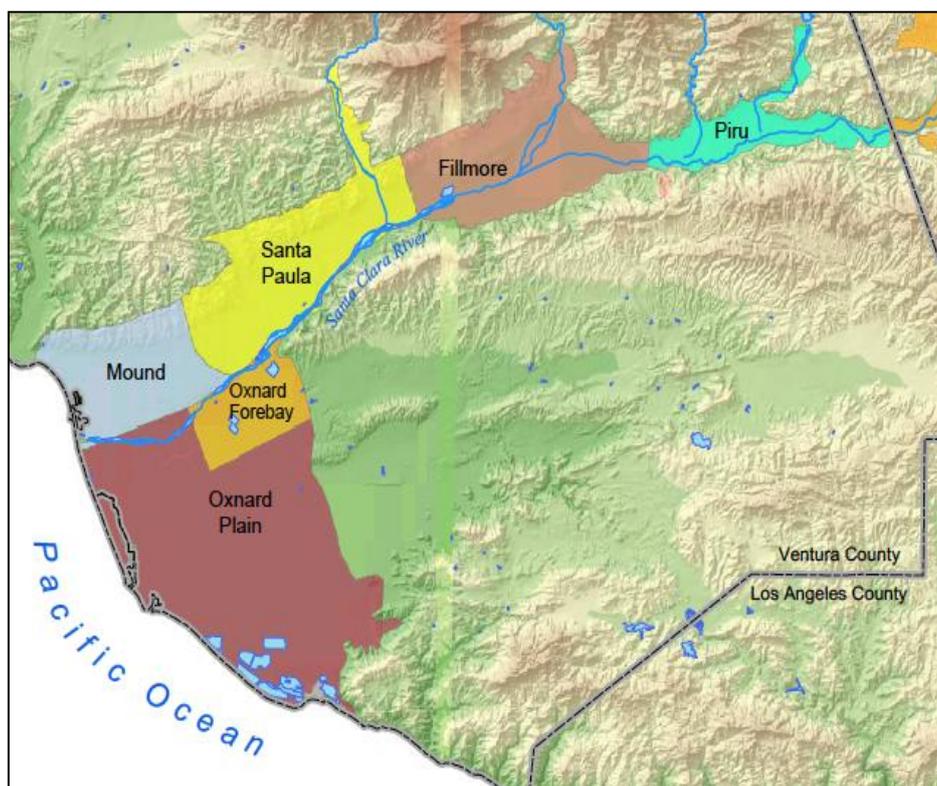
Both basins rely on local water sources and depend heavily on groundwater. In the SPGB, agriculture is the major user, but groundwater is also a major source of water supply for the cities of Ventura (located outside of the basin boundaries) and Santa Paula (located inside the basin boundaries). The SPGB saw sharp declines in nearly all of its monitoring wells during the 2012-2015 drought (Langridge et al., 2016a). Agriculture is also the dominant user in the PVGB, and the Pajaro Valley is almost entirely reliant on groundwater for consumptive use. Seawater intrusion is the basin's most significant threat, and although identified prior to the agency's formation in 1984, it is continuing today, albeit at a reduced rate (Langridge et al., 2016b).

The Santa Paula Basin: An adjudicated basin

Background

The SPGB is located in Ventura County in southern California (Figure 2). The 13,000-acre basin is a subbasin of the larger Ventura Central Basin. Groundwater flow is generally east to west, parallel to the Santa Clara River (United Water Conservation District 2012). The basin contains two distinct aquifer systems. One consists of relatively shallow unconfined alluvial deposits associated generally with the Santa Clara River floodplain. The other comprises deeper, confined aquifer systems (United Water Conservation District v. City of San Buenaventura, 1996). The SPGB is one of several basins that lie within the jurisdiction of the UWCD, created in 1950 as an umbrella water district to manage several groundwater basins in the Oxnard Plain and to conserve and enhance water resources in the Santa Clara River Valley (DWR, 1980).

Figure 2. Santa Paula Groundwater Basin (Source: Luhdorff and Scalmanni).



Fluctuations in groundwater levels correlate with precipitation, averaging 17.51 inches per year from 1890 and 2011 (United Water Conservation District 2013). Recharge to the basin is primarily from groundwater underflow from the up-gradient Fillmore Basin, infiltration of surface water from the Santa Clara River and Santa Paula Creek, direct percolation of precipitation, and household and agricultural irrigation return flows. State Water Project water released from Lake Piru also percolates into the basin. Underflow from artificial recharge in the adjacent Oxnard Plain Forebay Subbasin also contributes to recharge (United Water Conservation District 2017).

Similar to the Pajaro groundwater basin, the area served by the SPGB is a mixed urban-agriculture system. Groundwater from the basin is the sole source of water for the city of Santa Paula (United

Water Conservation District 2000, 2009, 2013) and provides 14% of the water supply for the city of Ventura (City of Ventura, 2018). Agricultural land, however, accounts for the lion's share of groundwater use in the basin, with groundwater irrigation being used to grow lemons, avocados, strawberries, and other crops.

Adjudication

The SPGB was adjudicated in 1996. In May 1991, the last year of a six-year drought, the city of Ventura began pumping increased amounts of water from its wells in the east end of the city that draw from the SPGB. Groundwater pumpers in the basin, including the city of Santa Paula and local agricultural interests, became concerned that water supplies in the SPGB were threatened by the proposed increase in groundwater extractions to 6000 acre feet/year (AFY).³ Water levels had already dropped to historical lows in 1990 at the end of a dry period (Los Angeles Times 1996). In 1991, the United Water Conservation District (UWCD) initiated court action for adjudication on behalf of local stakeholders against the city of Ventura. The lawsuit alleged a violation of the California Environmental Quality Act (CEQA) with respect to the installation of the new wells that would draw groundwater from the SPGB. UCWD claimed the basin was "in a condition of overdraft or threatened overdraft" and that Ventura's additional pumping would exceed the safe yield of the basin (United Water Conservation District vs. City of San Buenaventura, 1996). The Santa Paul Basin Pumpers Association (SPBPA), a consortium of water users that includes farmers, the City of Santa Paula, and a number of other small users, joined the UWCD as plaintiffs in the court action.

After studying the basin's potential safe yield during the litigation process (City of Santa Paula, 2007), the Superior Court of the State of California for the County of Ventura entered a 1996 stipulated judgment that allocated groundwater within the SPGB following common-law water right priorities (see Table 1). The judgment established an "assumed initial yield" of 33,500 AFY corresponding to the amount of recent pumping, and allocated 3000 AFY to the junior appropriator, the City of Ventura, and 27,500 AFY to SPBPA, with 3000 AFY held in reserve. The judgment also specified the allocation of water among the 75 members of the SPBPA, with over two thirds of the water allocated to the three largest users – a local water company, the Farmer's Irrigation Co. (9406 AFY), the city of Santa Paula (6805 AFY), and a major citrus grower and real estate company, the Limoneira Corporation (3173 AFY). Parties can produce more or less of their allocation in any particular year as long as their rolling seven-year average does not exceed their allocation. Under the judgment, the SPBPA was obliged to try to bring non-parties under the terms of the agreement (legally, if necessary, and an amended judgment in 2010 joined most of these non-parties to the agreement (Santa Paula Basin Annual Report 2016).⁴

To carry out the terms of the adjudication, the judgment established a Technical Advisory Committee (TAC) with equal representation by the UWCD, the SPBPA, and the city of Ventura and with committee members appointed by their respective organisations. The judgment encourages the TAC to make decisions by consensus, but if that proves impossible, to settle disputes through independent arbitration or by returning to court. In practical effect, the TAC serves the same role as Watermaster in other basins.

To verify that users remain within their allocated amounts, the judgment established a programme to monitor groundwater levels and to verify that users remain within their allocated amounts. The UWCD was given primary responsibility for conducting monitoring tasks and reporting to the TAC. The judgment incorporated provisions to make the agreement flexible and adaptable over time, for example, by averaging use over a seven-year period to account for the variations in pumping demand

³ An acre foot /year (AFY) is equal to 1232.66 cubic meters.

⁴ The SPBPA received an additional 280.2 AFY for the new pumpers. The 2010 amendment also clarified shortage conditions, responsibilities, and groundwater production of SPBPA and members and pumping allocation transfer procedures.

over time, and approving pumping beyond allocated amounts as warranted by needs and hydrological conditions.⁵ The judgment also suggests that the TAC may develop a "more flexible management plan" that could be ratified by the court.

The most important consideration for long-term groundwater sustainability in the judgment was a decision to review safe yield after the first seven years, with the TAC to undertake additional monitoring and research. UWCD believed the yield set at 33,500 to be too high, but the court also observed that neither the SPBPA nor the city of Ventura agreed with the UWCD on this point. After seven years, any party can request that the court adjust this yield upwards or downwards and the judgment sets out a detailed procedure for both augmenting and reducing individual allocations with a six-stage process that specifies how allocations will be reduced. The judgment recommends that the TAC can develop 'triggers' to help decide the timing of these cuts, with the decision reverting to the court if the TAC fails to do so.

Based on a seven-year yield study completed in 2003, the TAC concluded that continued pumping at current average rates (1996-2003) of approximately 26,000 AFY "should not adversely affect the basin" and is sustainable (Santa Paula Basin Experts Group, 2003). Therefore, the TAC did not make any recommendation to the court to change the basin yield at that time. Subsequently, from 2005 to 2011, eight producers (out of 125) extracted most of the groundwater (approximately 22,000 AF), with the total extractions at approximately 27,500 AF (United Water Conservation District, 2013).

Polycentric governance

How does the Santa Paula adjudicated basin fit the model of self-governance and polycentricity? The adjudication is a negotiated outcome of four major parties – the SPBPA, the UWCD, the City of Ventura, and the Superior Court of the State of California – with each having their own constituencies and jurisdictions. As well, the SPBPA is a multi-stakeholder organisation that includes a wide range of members. One of its members, the city of Santa Paula, is a general-purpose government that independently manages its own groundwater resources, as does the City of Ventura. The adjudicated basin is also 'nested' in a wider system of governance that needs to account for other state agency requirements (e.g. the Regional Water Quality Control Board on water pollution, the California Department of Water Resources and the U.S. Geological Service). Most importantly on a local scale, the UWCD has jurisdiction over eight interconnected groundwater basins and is thus actively involved in groundwater management issues on a wider geographical scale. In managing these water resources, the UWCD interacts with other neighbouring water districts such as the Calleguas Municipal Water District, the Casitas Municipal Water District, and the Fox Canyon Groundwater Management Agency, and with other local, state and national bodies including the Ventura County Watershed Protection District and the Watershed Coalition of Ventura County (which is responsible for the region's Integrated Regional Water Management Plan).

While UWCD adopts a regional perspective on groundwater management, the adjudication itself appears to encourage a more insular and closed perspective. In reviewing groundwater management issues in the wider Ventura region, we are struck that the Santa Paula basin is typically treated as special case exempt from wider regional issues.⁶ This makes sense when you appreciate that the adjudication creates a defined and bounded resource with stable but clearly delimited water use allocation. The court does set out clear resource boundary rules and crafts rules that reflect the local

⁵ For example, in a Class I emergency (flood, earthquake etc), the city of Ventura is allowed to pump an additional 300 AFY and in the event of a Class II emergency (long-term drought), with TAC approval, the city can use the unallocated 3000 AFY.

⁶ Using the keywords 'groundwater' and 'Santa Paula', we searched the *Ventura County Star's* article database from 1996 through February 2018. We found a number of articles about groundwater issues in the region (including articles about the UWCD), but little about the SPGB.

context, but on-going management of these rules is delegated to the TAC – composed of the three principal stakeholders.

Facilitating conditions and strategies

How well does this self-governing, nested system work in producing the facilitating conditions for long-term sustainability of the groundwater basin? The strength of the adjudicated system is that it creates a legal mechanism that sets clear limits on groundwater extraction through the ongoing determination of the safe yield and the allocation of water rights. In 2010, the TAC formed a working group of experts representing each of the stakeholders to develop specialty studies on the basin, including studies that would allow a revised safe yield (Santa Paula Basin Annual Report, 2016). UCWD has since commissioned a third-party independent evaluation of the safe yield, while the SPBPA has focused on how to increase the yield of the basin. UWCD indicates that they are planning to study groundwater underflow as one area of uncertainty that needs to be addressed in a future assessment of the safe yield, but they accuse the SPBPA and the City of Ventura of dragging out the process. Those stakeholders argue that they are close to reaching agreement on the scope of the study (Kirst, 2014).

The judgment requires annual reports and these primarily detail the condition of the basin with essentially no discussion of additional strategies to manage the basin beyond the focus on determining the safe yield. The monitoring regime that reports to the TAC allows for enforcement of pumping limits. But enforcement is voluntary with SPBPA in charge of its members' compliance. While legal means can be used, they may be lengthy and costly and are envisioned as a last resort, and the TAC is encouraged to work by consensus if possible and to return to the court only if necessary.

UWCD has a number of programmes to recharge the basins under its purview including an artificial recharge project at spreading grounds in the adjacent Oxnard Plain forebay subbasin that would affect the Santa Paula Basin. The judgment also indicated that the TAC should monitor water quality, though without further detail.

Sustainability outcomes

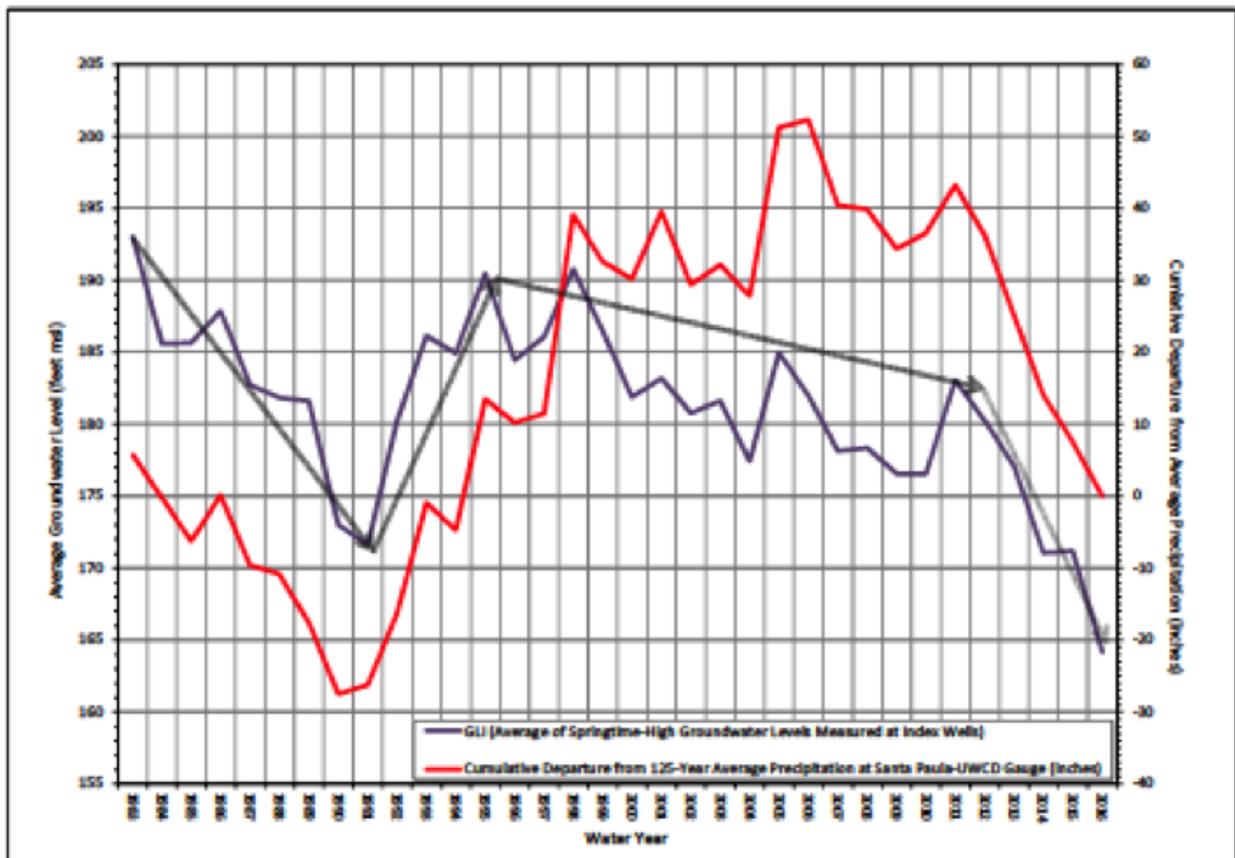
How have the facilitating conditions affected the sustainability of the groundwater basin?

Extractions have been less than the allocations set forth in the judgment and generally remained flat, and the basin's water levels have stabilised in some areas, but there are declining levels in other parts of the basin that remain of concern, with a gradual, long-term decline in groundwater elevations evident since the mid-1990s.⁷ The trends are summarised in the SPGB through the use of a 'groundwater level index' (GLI), calculated as the average of spring-high groundwater elevations measured each year at nine key wells selected for their relatively long record and their geographic distribution across the basin.

Figure 3 shows the GLIs for 1983-2016 (blue line), and the cumulative departure from average precipitation over the same period (red line) (Santa Paula Annual Report, 2016).

⁷ After gravel mining in the Santa Clara River ceased and the Freeman Diversion (1991) was built, groundwater levels in the SPGB largely recovered from a low period, but downstream from the Freeman Diversion levels did not recover to pre-1950 levels. From 1983-1995, the average drop in water levels was 4.9 feet, most pronounced in the basin's far west end. Wells also experienced groundwater level declines, albeit modest, from 1998-2005 and 2005-2010, with 70-100% of the wells displaying declines (UWCD, 2009-2010, 2013). Consistent with previous observations, every evaluation period in a 2013 study showed a modest decline in groundwater levels for the majority of wells represented (UWCD, 2013b).

Figure 3. Groundwater Level Index, 1983-2016 (Source: UWCD 2017b, Appendix⁸).



Water quality in the basin has not changed substantially since 2007 (City of Ventura, 2012), and is variable throughout the basin. It is generally worse in the western portion due to total dissolved solids (TDS) but usable for irrigation for most crops. Nitrates and other inorganics can fluctuate significantly in the basin. Deeper wells tend to have elevated iron and manganese, and the cities of Santa Paula and Ventura operate treatment facilities to reduce these constituents in delivered municipal water. While, and the UWCD has faithfully conducted and reported on groundwater quality, we find no evidence that the TAC has developed programmes or strategies to further address some of these issues.

Beyond setting limits and monitoring groundwater extraction and providing a mechanism for ongoing review of safe yield, the judgment also signals that basin stakeholder’s may pursue a wider agenda of groundwater management and conservation, including studies to "identify other replenishment sources" and to develop "conjunctive use" and that these studies may contribute to the development of a management plan for the basin.⁹ Although the TAC has conducted a number of specialised studies and taken some steps toward a comprehensive groundwater management plan, such a plan has not yet been produced. The 2003 Experts Report did however develop a number of "management considerations and concepts". The report notes that 1) activities outside the basin may affect safe yield

⁸ A water year (WY) is defined as the period from October 1 of the previous year through September 30 of the year indicated. For example, WY 2015 is 10/1/2014- 9/30/2015.

⁹ The judgment did not specifically call for the development of a groundwater management plan; however, the judgment language implied that the court expected a plan would be forthcoming. UCWD Watermaster, pers. com.

within the basin (and vice versa) and thus coordination with external management efforts was necessary; 2) various strategies (e.g. lower Santa Clara River levels) could be used to increase groundwater recharge; 3) the city of Santa Paula could treat its wastewater to allow it to be used for various purposes in lieu of groundwater; 4) State Water Project water (and other water resources) could be used in lieu of groundwater; 5) water production could be shifted to areas with faster recovery (the eastern portion of the basin); 6) water conveyances could be built to facilitate efficient water exchanges; 7) local drawdowns need to be carefully monitored (Santa Paula Basin Experts Group, 2003).

We make two observations about these management considerations. First, while they demonstrate concern about the long-term sustainability of the resource, they primarily focus on increasing the supply of water as well as moving water around to make its use more efficient (for a wider discussion, see Lach et al., 2005). Moreover, there is no evidence that these considerations go beyond a concern with long-term water supply to encompass considerations about resource conservation, water quality, or groundwater-dependent ecosystems. Second, although the TAC working group has conducted a number of specialty studies to improve their understanding of basin dynamics and safe yield (see UWCD 2016, ii, for a list of studies), we observe relatively little follow-through on the development of a more comprehensive strategy of sustainability.

Pajaro Valley Groundwater Management Agency-Special Act District

Background

The Pajaro Valley Groundwater Basin (PVGB) underlies three Counties, Santa Cruz, Monterey and San Benito, with the largest portion in the southeastern portions of Santa Cruz County (Figure 4).

Figure 4. Pajaro Valley (Source: Lockwood, 2017).



The PVGB contains several water-bearing geologic units. The Aromas Red Sands Formation consists of recently recharged shallow ground water; it is the primary water-bearing unit and provides most of the groundwater pumped from wells in Pajaro. The Purisima Formation is the deepest and oldest water-bearing unit in the PVGB, and important outcrops to this formation are found along the north and east of the Pajaro Valley where this unit acts as a source of recharge to the PVGB. A small number of deeper wells pump older groundwater that was recharged thousands of years ago. Impermeable volcanic rocks juxtaposed against the marine sediments to the east of the San Andreas fault act as a barrier to groundwater flow into or out of the PVGB. Relatively impermeable clays found in Elkhorn Slough form a barrier to north-south groundwater flows near the mouth of the slough (PVWMA-CE, 2014).

Despite its relatively small geographic size, average annual precipitation totals vary widely across the basin's surface area, ranging from about 15 inches near the coast to more than 40 inches over areas of the Santa Cruz Mountains that provide drainage for the PVGB. PVGB recharge occurs through direct percolation of rainfall, through streamflow seepage from the Pajaro River and its tributaries, and through irrigation return flows. Coastal inflow as seawater intrusion has replaced much of the potential storage depletion in the coastal regions (DWR, 2006; Hanson et al., 2014).

Pajaro Valley is one of the most productive agricultural regions in the world. However, increases in population and transitions to crops that consume additional water have increased the demand for water in the valley. While it is a mixed urban-agricultural system, groundwater is the sole source of native water for irrigated agriculture that uses most of the groundwater in the basin. Raspberries, strawberries and vegetables use a high percent of agricultural water and the Pajaro Valley's water use, the bulk of this being used by a small number of large growers (United Farm Workers, 1999). Crops have shifted from vegetable row crops and apples to berries and vines with additional rotational plantings. This has increased demand on the region's limited groundwater resources (Hanson et al., 2014).

The largest city is Watsonville with an estimated population of in 2014 of 53,111. Median household income for city residents (in 2014 dollars) for the period 2010-2014, was USD46,691 and the poverty rate was 20.6% (U.S. Census 2018). The city provides water for over 66,000 customers in the Watsonville area, with most of the water coming from groundwater wells and only about 10% coming from local creeks (Watsonville Public Works and Utilities, 2018).

Reliance on groundwater for irrigation was central to the development of agriculture in the Pajaro Valley beginning with Anglo settlement. Artesian wells met basic irrigation needs, but the early to mid-twentieth century saw many of these springs run dry due to overproduction. In the 1940s growers began adapting deep well turbine pumps from the oil industry allowing them to switch to deeper wells to draw water from the underlying alluvium and other deeper water-bearing formations (Pajaro River Community, 2016). By the 1970s, water levels west of Watsonville were consistently below mean sea level from approximately May to December, often never recovering, providing the conditions necessary for seawater intrusion (PVWMA-BMP, 2012).

District formation

Seawater intrusion in the Pajaro Basin, a result of groundwater overdraft was first documented in 1953 (State Water Resources Control Board, 1953). In 1980, the DWR identified 11 groundwater basins that were believed to be in severe overdraft, with the PVGB ranking near the top of that list (PVWMA BMP, 2012). A group of local stakeholders, including many major agricultural operators drafted proposed legislation for the creation of a locally controlled groundwater management agency. A local state senator spearheaded the initial legislation in Sacramento, and a voter ballot initiative formally approved the establishment of the PVWMA in 1984 (PVWMA, 2016). The enabling legislation (Agency Act) has been updated several times since ratification (PVWMA, 2013).

In contrast with the adjudicated Santa Paula Basin, a seven-member Board of Directors was established to govern the PVWMA. It includes four Directors serving a particular sub-area within the

PVWMA service area. They are elected directly by registered voters living within that service area. In contrast to the governance of Santa Paula, this provides a broad segment of the population with the direct ability to participate in managing the basin. All Directors must live within the PVWMA boundaries and be registered voters. The three general purpose governments that overlie the PVGB (Santa Cruz County, Monterey County, and the City of Watsonville) appoint the remaining three Directors, who serve only two-year terms. They must earn at least 51% of their net income from agriculture. There are no term limits for any Director (PVWMA, 2016).

The Agency Act also provides PVWMA with a different mandate to manage the basin's groundwater 'in the public interest' and with the following sustainability requirements:

- Local groundwater resources should be managed for the avoidance and eventual prevention of long-term overdraft, land subsidence, and water-quality degradation.
- Local economies should be built and sustained on reliable, long-term supplies and not long-term overdraft as a source of water supply.
- Water management programmes should include reasonable measures to prevent further increases in the amount of long-term overdraft and to accomplish continuing reduction in long-term overdraft, realising that an immediate reduction in this type of overdraft may cause severe economic loss and hardship.

To accomplish these goals, PVWMA has a much broader set of authorities than the adjudicated Santa Paula Basin. It has the sole right to: store, recapture, distribute, and sell supplemental water in the PVGB, subject to conditions, and the right to enjoin unreasonable uses of water (PVWMA, 2016). It can also:

- Regulate groundwater replenishment programmes and recapture supplemental groundwater resulting from agency programmes. But property taxes cannot be used for payment of costs, and agricultural uses have priority over other uses.
- Determine the amount of groundwater basin storage space available and allocate that space after completion of a groundwater basin study.
- Treat, inject, or extract water, including, but not limited to, control of extractions, and construction of wells and drainage facilities. This includes the right to regulate, limit, or suspend extractions and, the construction or enlargement of extraction facilities, or the reactivation of abandoned extraction facilities.
- Document and manage water withdrawals from rural, agricultural wells, and impose spacing requirements on new extraction facility constructions to minimise well interference.
- Purchase and import water into the basin but only for agricultural purposes.

PVWMA is not authorised to deliver potable water, and its activities have focused on eliminating groundwater overdraft and halting seawater intrusion into the aquifer system (PVWMA, 2016).

Polycentric governance

How does the PVWMA fit the model of self-governance and polycentricity? First, PVWMA is nested within a polycentric system in several respects. Its elected Directors represent their specific sub-areas, and its appointed Directors represent the three political jurisdictions that overlie PBGB. In the Pajaro River watershed, the Santa Clara Valley Water District (SCVWD) and the San Benito County Water District (SBCWD) share an interconnected groundwater basin connection that links the two agency's groundwater management activities.

PVWMA collaborates more actively with other local institutions than does the adjudicated SPGB.

Through partnerships in the Integrated Regional Water Management Programme (IRWM), PVWMA has received over USD45 million for the Pajaro River watershed since 2006. In 2014, with Santa Clara Valley Water District, San Benito County Water District, and City of Watsonville, PVWMA received an award of USD12.3 million from the DWR Emergency Drought Funding Programme (Watsonville Patch, 2014). It collaborated with two other groundwater agencies, the Santa Margarita Groundwater Agency (SMGWA) and the Santa Cruz Mid-County Groundwater Agency, for grants to develop groundwater management plans (Santa Cruz Mid-County Groundwater Agency, 2018). Additionally, in managing the basin, the PVWMA continues to interact with a multitude of other state and federal agencies including the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the State Water Resources Control Board, the Central Coast RWQCB, the California Department of Fish and Game and the DWR, on land use planning, permit approvals, water quality control and endangered species consideration.

PVWMA has also put into practice more collaborative management strategies and programmes that are responding to local needs and context. The agency joined with the City of Watsonville to provide recycled water to farmers throughout coastal areas of South Santa Cruz and North Monterey counties through Watsonville's Water Recycling Project. The water is made available to the local agricultural industry and protects against further groundwater depletion. The recycled water replaces over 20% of coastal pumping and is used to reduce seawater intrusion into the local aquifer. In addition, the plant significantly reduces wastewater discharges into the Monterey Bay National Marine Sanctuary (PVWMA, 2018).

Facilitating conditions and strategies

A second important question is how well does this system work in producing facilitating conditions for long-term sustainability? As noted, its legislative mandate is to manage for sustainability as its primary purpose. Thus, in line with facilitating conditions, it can replenish the basin, control extractions, develop infrastructure to reduce overdraft, and document and monitor the basin. PVWMA also has the sole right to store, recapture, distribute, and sell supplemental water in the groundwater basin, subject to conditions, and the right to enjoin unreasonable uses of water (PVWMA ACT, 1904). By comparison with the adjudicated Santa Paula Basin, it appears that PVWMA has expended considerable effort to broadly manage the basin for sustainability as defined by SGMA.

With respect to monitoring, PVWMA has an active monitoring regime. Unlike Santa Paula where users are self-monitored, large-scale wells have state-mandated metering and reporting requirements monitored by the district. Wells that produce greater than 10 AFY are required to have a meter, which staff maintain, test, and read on a regular basis.

To address its primary issue to reduce saltwater intrusion into the basin, PVWMA continues to develop new models and programmes to reduce the rate of seawater intrusion and eventually halt it. For example, a 1993 Basin Management Plan (BMP) (Montgomery Watson, 1993) is continuing to be refined to help provide more sustainable water management. A 2002 Revised Basin Management Plan continues to act as a guiding document in subsequent studies (PVWMA-CE, 2016), and a 2014 report modified a 2003 basin-wide hydrologic model. Other studies address groundwater levels and groundwater quality (Hanson et al., 2014). These reports and plans reflect the desire to adapt to new conditions.

Another contrast with Santa Paula is the aggressive attempt by the PVWMA to follow through on strategies to develop alternatives to groundwater pumping. Their BMP analysed components of 44 different potential projects and five different management strategies through a stakeholder-driven process that included conservation, increased recycled water storage and Harkins Slough recharge facility upgrades (PVWMA BMP, 2012). Along with other noted grant applications, PVWMA has applied for and received significant funding to develop new supply sources and reduce seawater intrusion. The Harkins Slough Recharge Facility diverts and filters excess wet-weather flows from Harkins Slough to a

recharge in the basin about a mile to the west of the slough. The diverted water infiltrates into the ground where it serves to both recharge the groundwater basin and remain in subsurface storage until it is needed for agricultural use. It is then extracted and conveyed to growers through a Coastal Distribution System (CDS) that consists of nearly 20 miles of pipeline to deliver the blended recycled water for agricultural use to the area most impacted by seawater intrusion to reduce groundwater pumping near the coast. In April 2009, the PVWMA began delivering tertiary treated, disinfected recycled water into the CDS from the Watsonville Recycled Water Facility (Watsonville Public Works and Utilities, 2018). Conservation is also a priority and actively promoted on the PVWMA website. Beginning in 2013 rebates were offered for diverting grey-water from washing machines to landscaping.

While not its major focus, PVWMA does address the sustainable yield of the PVGB in its reports. In contrast to the SPGB, four basin-wide models have been compiled for the Pajaro Valley Aquifer System.¹⁰ In 2014, the updated model for the PVGB identified inflows and outflows that can define the safe yield of the basin, including the movement and use of water from natural and human components (USGS, 2014). The emphasis continues to be on reducing the rate of saltwater intrusion (USGS, 2014).

PVWMA actively collaborates with local stakeholders. The Basin Management Plan Committee includes a group of local stakeholders who provided project recommendations to reduce overdraft. There is a technical advisory committee composed of scientists, other agency representatives and stakeholders, and a funding committee (Lockwood, 2017). There are recharge projects being planned through partnerships with landowners, growers, UC Santa Cruz, The Resource Conservation Districts, and others, to allow for the infiltration of water back into the aquifer (Community Water Dialogue, 2018). However, Brown et al. (2016) found that there is limited participation by some stakeholders in the community including small farmers and the Hispanic/Latino community.

Similar to the Santa Paula basin the management focus is primarily on increasing supply (e.g. using recycled water) to satisfy demand. Attempts by PVWMA to increase a pumping charge that could potentially act as an incentive to reduce withdrawals was litigated several times. The court initially required PVWMA to refund money that was considered to be over-collected fees over a three-year period (PVWMA v. Amrhein). However, in 2013, the Sixth District Court of Appeal (Griffith v. PVWMA) issued a ruling validating a revised augmentation charge adopted by PVWMA in 2010, finding that because all groundwater users in the basin benefit from the Agency's groundwater management activities, not just the coastal users receiving supplemental water, the charges were a valid property-related fee or charge. The Court also found that the augmentation charge was expressly exempt from the fee/charge voting requirement under Proposition 218 because it is considered a water service. Based on this decision, the Agency conducted a successful rate setting effort in 2015 but it primarily focused on providing revenues to implement the 2014 BMP Update projects and programmes that were focused on increasing supplies.

Sustainability outcomes

Have these positive approaches embodied in the facilitating conditions resulted in a more sustainable outcome for the basin? When balanced against precipitation trends, water use trends from 2000 to 2016 show that pumping increases during dry periods. Groundwater level trends were highly affected by the 1985-1992 drought. In March of 2000, 34 square miles of the 110 square mile basin had water levels below sea level. Groundwater use however has trended slightly down with ongoing efforts of PVWMA to provide supplemental irrigation water. However, existing well data maintained by USGS & PVWMA indicate that expanding areas of depressed groundwater levels, and groundwater elevations remain regularly below sea level across much of the groundwater basin (Figure 6). High chloride levels

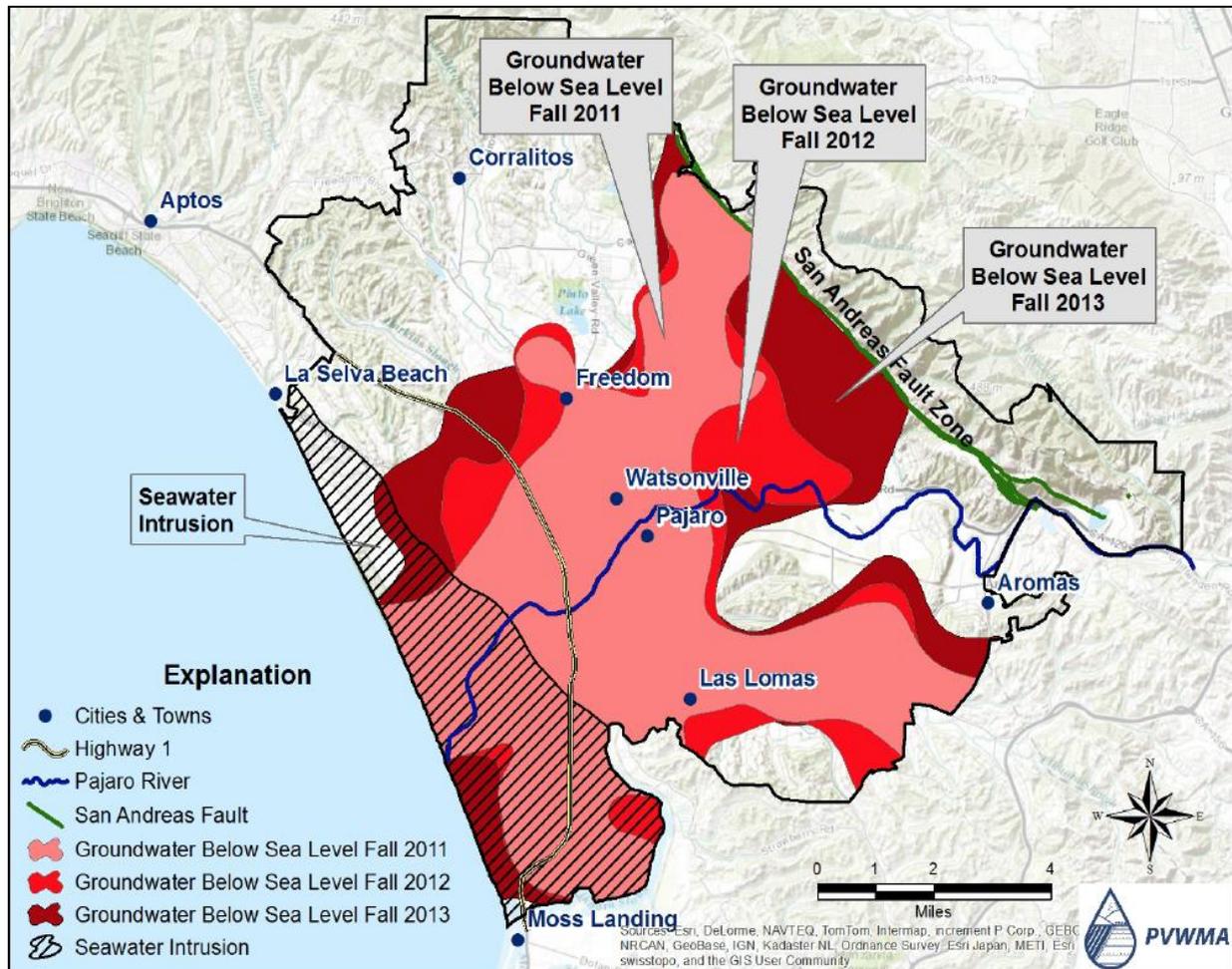
¹⁰ Three of the models utilised the Integrated Surface Water Groundwater Model (ISGM) code (Montgomery Watson et al., 1993) and one utilised Modflow, 1988 modeling code.

caused by seawater intrusion have led to abandonment of a number of coastal wells. This depletion is significant in some locations despite slightly higher than average rainfall over a defined long-term period.

In 2014, groundwater levels were 10-20 feet below sea level across much of the Basin. The 2014 USGS model showed that simulated long-term imbalance between inflows and outflows indicates overdraft of the groundwater basin averaging about 12,950 AFY over a 46-year period of water years (1964-2009). In 2014, the net coastal inflow, or seawater intrusion, ranged from about 1,000 to more than 6,000 AFY (Figure 6). Maps of simulated and measured water-level elevations indicate regions with water levels below sea level in the alluvium and Aromas layers (Hanson, et al., 2014).

But the rate of intrusion has slowed since the agency began to deliver recycled water, and projections from PVWMA’s new hydrologic model show that implementation of proposed projects could reduce the groundwater overdraft and seawater intrusion. So time will tell whether this is the case. There also remain high concentrations of nitrates in some shallow wells, especially in inland areas where rapid groundwater recharge occurs, but conditions have improved over time.

Figure 6. Seawater Intrusion Within the Pajaro Valley (Source: Lockwood, 2017).



DISCUSSION AND CONCLUSIONS

Background

The dates of formation of both basins are within 12 years of each other, both rely primarily on local water sources and agriculture is the major water user. However, Santa Paula utilised court adjudication to allocate groundwater rights and the court delegated management authority to a Watermaster (the TAC) composed of the three major stakeholders. PVWMA was established by the legislature as a special act district to develop and administer an ongoing management regime for local groundwater governance, administered by seven elected and appointed directors. While both are embedded within a wider polycentric system, their initial mandates and structures are thus quite different. The adjudication is court-centred and focused on managing specific water rights, while the legislatively created special act district is focused on managing groundwater as a public resource. The result has been different pathways of institutional development. Table 3 compares the background of the Santa Paula adjudicated basin and the PVWMA.

Table 3. Background comparison of the adjudicated Santa Rosa Basin and PVWMA.

Santa Paula – Court Adjudicated Basin	PVWMA – Special Act District
1996 Court adjudication	1984 Legislature creates PVWMA
Judgment focused on allocation and on reevaluating safe yield	Mandate was to manage the basin’s groundwater to prevent long-term overdraft, land subsidence and water quality degradation
Governed by a three-member Technical Advisory Committee appointed by the court that serves as Watermaster. The members include the SPBPA, a consortium of farmers; the City of Ventura; and UCWD.	Governed by a seven member Board of Directors representing different areas and constituencies, with four elected and three appointed by general purpose governments that overlie PVWMA boundaries
Relies primarily on local water sources Agriculture is the major water user	Relies almost entirely on local water sources Agriculture is the major water user
Management focus – re-evaluating safe yield	Management focus – eliminating overdraft and halting seawater intrusion
Groundwater level declines in monitoring wells	Critical groundwater level declines and ongoing seawater intrusion but rate of intrusion has slowed

Polycentricity

Both Santa Paula and Pajaro institutions can be characterised as polycentric. In both cases the institutions were organised around the natural scale of the groundwater resource, allowing rules and sustainability strategies to be tailored to a relatively bounded resource. Both interact with multiple overlapping institutions existing within larger watersheds – the Ventura County watershed and the Pajaro River Watershed – who are also engaged in water resource planning processes. Both basins adjoin neighbouring groundwater basins with their own management units and both exist within larger state and federal jurisdictions. State and federal agencies may enforce certain regulatory requirements of their own, albeit also providing valuable information and services.

Despite both institutions having similar polycentric characteristics, there is an important difference between how polycentric relations work in the two districts. In Santa Paula, the adjudication creates a

somewhat closed club of stakeholders who control an existing pie of groundwater resources whose focus is on determining who gets how much water, and then managing these allocations. This appears to provide less incentive to interact with a wider polycentric system. Indeed, we find limited interaction or coordination between the adjudicated basin and other local, state, or national water management units. The major exception is that UWCD, a member of the Watermaster committee, creates an important interface between the adjudicated basin and the wider world of water management. However, even UWCD treats the adjudicated basin as a special case in these interactions. By contrast, PVWMA operates as a much more active player within the wider polycentric environment, engaging in frequent and close interaction with multiple local institutions and stakeholders (Table 4).

Table 4. Polycentric characteristics.

Santa Paula – Court Adjudicated Basin	Pajaro Valley Water Management District -Special Act District
Nested in a wider system of governance including state and federal agencies	Nested in a wider system of governance including state and federal agencies
Frequently treated as a special case exempt from wider regional issues	Directly involved in multiple partnerships and collaborative projects with other agencies and cities and the Integrated Regional Water Management Programme

We believe that this contrast suggests an important theoretical point about the nature of polycentric governance arrangements. The Ostrom tradition of common-pool resource management suggests that well-bounded resource management units can help to address over-exploitation of common-pool resources. Adjudication, as both Ostrom, Blomquist and others have argued, can lead to clear resource boundaries and enforceable rules. The Santa Paula adjudication clearly delineates the groundwater resources, specifying who has a right to how much groundwater. It establishes a monitoring system to enforce these water rights. However, this clear specification also creates a quasi-private water management regime with little incentive to participate in the wider polycentric regime. The theoretical point can be stated in terms of the wider Ostrom tradition of common-pool resource management: *The more that self-governing local units are organised as closed private units, the less they will engage in wider polycentric arrangements.* In this case, the tension arises because of the legal and private nature of adjudication, in contrast with the legislative and public nature of special act districts.

Facilitating conditions and strategies

Santa Paula’s insularity compared with PVWMA is also reflected in the different on-the-ground management strategies that emerge from facilitating conditions (Table 5).

PVWMA has greater oversight over its monitoring process as compared with the self-monitoring and reporting in the Santa Paula basin. PVWMA actively updates its models and basin management plans to both provide for accurate information on the condition of the basin, and to adapt to changing climatic and land use conditions. Finally, PVWMA is attempting to mitigate negative impacts through the development of recycled water and recharge programmes, including a coastal distribution system that encourages in-lieu recharge along the coast to reduce saltwater intrusion.

One advantage of the Santa Paula adjudication is that the judgment does specify who can withdraw water from the basin or how much water. PVWMA does have the option of using a pumping charge to control withdrawals, but its attempt to increase pumping charges initially resulted in litigation. Its 2013 court victory (Griffith v. Pajaro Valley Water Mgt. Agency) now allows for an increase in these charges. However it is not clear how the agency will use this authority (Table 5).

Table 5. Facilitating conditions and basin strategies.

Facilitating Conditions	Santa Paula – Court Adjudicated Basin	PVWMA – Special Act District
Monitoring	UCWD oversees monitoring but wells are self-monitored	Active monitoring regime with state-mandated metering and reporting requirements monitored by PVWMA
Water rights allocation	Court allocates water rights. Total allocations are based on a safe yield that must be regularly re-evaluated	PVWMA does not allocate water rights. Rights are based on Correlative and Appropriative Doctrine. Four basin-wide models assess inflows and outflows that can define the safe yield
Recharge and other sustainability projects	Mostly focused on supply Limited attention to resource conservation, water quality, or groundwater dependent ecosystems Artificial recharge at the UWCD's spreading grounds in the adjacent Oxnard Plain Forebay Sub-basin	Major focus is on recycled water and other supply sources to curb seawater intrusion Conservation actively promoted on PVWMA website. Rebates now offered for diverting grey-water from washing machines to landscaping Significant recharge and recycled water projects being planned and implemented through partnerships with landowners, growers, UC Santa Cruz, Resource Conservation Districts. In 2009, PVWMA began its Coastal Groundwater Distribution Project
Withdrawal regulations	TAC can allow pumping beyond allocated amounts	After litigation, PVWMA can now charge an augmentation charge for pumping as an incentive to reduce withdrawals
Mitigation of negative impacts	Limited to safe yield determination in the adjudicated basin	Stated PVGMA goal is to reduce groundwater overdraft by 80% and seawater intrusion by 90% by 2025 (see sustainability projects)
Adaptation Rule compliance	Provisions to adjust judgment Independent arbitration or the court	Ongoing re-evaluation of basin water budget NA
Stakeholder engagement	Limited stakeholder participation – individual stakeholders may pursue programmes (e.g. identify replenishment sources-develop water conjunctive use)	Ongoing open meetings. Stakeholder committee of scientists and other local agencies. Limited participation by some stakeholders including small farmers and the Hispanic Latino community
Leadership	TAC has not yet produced a groundwater management plan but it has developed 'management considerations and concepts'	Over the years leadership has been strong

Sustainability outcomes

How do the two institutional arrangements compare with respect to resource sustainability outcomes for two important and relevant markers for each basin (Table 6)?

While extractions in Santa Paula have not noticeably increased, the change in groundwater storage has trended down. UWCD notes that this may be due to underflow between adjacent basins, a factor not yet incorporated into safe yield calculations. UWCD is planning to update its hydrologic model for the Santa Paula groundwater basin in the future (Detmer, 2018).

In Pajaro, current groundwater extractions remain higher than the rate of natural recharge, but analysis of the agency's 2014 hydrologic model simulation indicates that the magnitude of seawater intrusion has decreased, albeit a significant trough below sea level still exists throughout the valley floor, centred around the Pajaro River Channel (PVWMA, 2013, 2017) (Table 6). PVWMA is now working more actively to implement proposed projects and programmes, and these are projected to reduce groundwater overdraft by 80% and seawater intrusion by 90% by 2025 (Lockwood, 2017).

Table 6. Sustainability outcomes.

Sustainability criteria	Santa Paula – Court Adjudicated Basin	Pajaro Valley Water Management District -Special Act District
Chronic lowering of groundwater levels that indicate a significant and unreasonable depletion of groundwater storage and supply	Extractions have remained relatively flat, but longer-term groundwater levels have trended down	Current groundwater extractions are higher than the rate of natural recharge
A significant and unreasonable increase in seawater intrusion, degraded water quality and land subsidence over time	These problems have not increased over time, but they have not recovered further	Rate of seawater intrusion has decreased but there is still an area below sea level throughout the valley floor

Final thoughts

While the Santa Paula adjudication may provide specific water rights that many argue are critical for achieving sustainability, its insularity within a polycentric system negatively affects its ability to engage with a wider set of resources and limits its ability to develop more robust strategies for each of the facilitating conditions that affect resource sustainability. At the time PVWMA was created, its groundwater basin was critically overdrafted, and although its initial mandates enabled the agency to develop and implement a wider array of strategies to sustainably manage its groundwater basin, it still struggles to halt seawater intrusion. Ultimately, neither institutional arrangement fully addresses the problem of groundwater sustainability. This suggests the need for further research to better illuminate how institutional configurations and developmental pathways impact resource outcomes.

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