# Assessing local planning to control groundwater depletion: California as a microcosm of global issues

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Received 16 May 2011; revised 8 November 2011; accepted 15 November 2011; published 5 January 2012.

[1] Groundwater pumping has caused excessive groundwater depletion around the world, yet regulating pumping remains a profound challenge. California uses more groundwater than any other U.S. state, and serves as a microcosm of the adverse effects of pumping felt worldwide—land subsidence, impaired water quality, and damaged ecosystems, all against the looming threat of climate change. The state largely entrusts the control of depletion to the local level. This study uses internationally accepted water resources planning theories systematically to investigate three key aspects of controlling groundwater depletion in California, with an emphasis on local-level action: (a) making decisions and engaging stakeholders; (b) monitoring groundwater; and (c) using mandatory, fee-based and voluntary approaches to control groundwater depletion (e.g., pumping restrictions, pumping fees, and education about water conservation, respectively). The methodology used is the social science-derived technique of content analysis, which involves using a coding scheme to record these three elements in local rules and plans, and State legislation, then analyzing patterns and trends. The study finds that Californian local groundwater managers rarely use, or plan to use, mandatory and fee-based measures to control groundwater depletion. Most use only voluntary approaches or infrastructure to attempt to reduce depletion, regardless of whether they have more severe groundwater problems, or problems which are more likely to have irreversible adverse effects. The study suggests legal reforms to the local groundwater planning system, drawing upon its empirical findings. Considering the content of these recommendations may also benefit other jurisdictions that use a local groundwater management planning paradigm.

**Citation:** Nelson, R. L. (2012), Assessing local planning to control groundwater depletion: California as a microcosm of global issues, *Water Resour. Res.*, *48*, W01502, doi:10.1029/2011WR010927.

## 1. Introduction

[2] Around the world, groundwater pumping has turned arid landscapes green. Globally, groundwater supplies 43% of irrigation water, which itself constitutes about 90% of consumptive uses of freshwater [*Siebert et al.*, 2010]. Yet groundwater pumping has also caused significant groundwater depletion around the world [*Wada et al.*, 2010; *Konikow and Kendy*, 2005]. Decreasing groundwater levels cause subsidence, which is particularly notable in Mexico City, Bangkok, and Shanghai, but widespread worldwide [*Konikow and Kendy*, 2005]. It can also impair water quality, rendering a groundwater resource unusable, for example, by lateral seawater intrusion—a problem thought to affect over 1400 million km$^2$ worldwide [*van Weert et al.*, 2009]. Pumping groundwater may also compromise dependent ecosystems—a problem that only relatively recently has attracted legal attention at the international and national levels [*Eckstein*, 2010]. At the same time, the Intergovernmental Panel on Climate Change predicts with high confidence that climate change, combined with increases in population and water demand, will increase pressure on groundwater resources in arid and semiarid areas globally [*Kundzewicz et al.*, 2007].

[3] Regulating groundwater pumping remains challenging. Various levels of government step in to address the problem—in the European Union, this occurs at the supranational level [*Eckstein*, 2010]; in Australia, recently at the federal level [*Nevill*, 2009]; in the United States, predominantly at the state level [see, e.g., *Bryner and Purcell*, 2003]. In many places, however, local governments bear this responsibility. Even where higher-level governments step in, *Sagala and Smith*'s [2008] global survey suggests that such measures fail to have any effect in a significant proportion of cases. Indeed, they suggest that "inadequate laws" are a key groundwater problem. The significant global reliance on local action to control groundwater depletion warrants particular study of measures at that level. California provides such an opportunity. Its intensive groundwater use causes an array of familiar adverse effects that are dealt with primarily by local groundwater planning.

[4] California uses groundwater primarily for irrigation (81% of groundwater use)—the focus of this article—though it is also important for municipal and domestic supply (12% and 4%, respectively) [*Kenny and U.S. Geological Survey*, 2009]. Groundwater depletion in California, recently

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0043-1397/12/2011WR010927

quantified by *Famiglietti et al.* [2011], has led to demands made over more than a century that legislators improve State laws to control it [e.g., *Hanak et al.*, 2011; *Langridge*, 2009; *Sax*, 2003]. Californian politics prescribe local groundwater regulation and management. This involves potentially thousands of small independent agencies that supply or manage groundwater, generally governed by elected local landowners, currently operating with minimal State oversight. The State manages groundwater only indirectly, through legislation that allows the extensive and complex network of agencies to be established; a groundwater planning framework; and funding for groundwater projects.

[5] Groundwater depletion causes severe problems in California. At least 11 major basins suffer from "critical conditions of overdraft," meaning that "continu[ing] present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts" [*California Department of Water Resources*, 2003, p. 98]. Groundwater extraction has lowered groundwater levels by over 200 feet (61 m) in some parts of California [*U.S. Geological Survey*, 2003], and ground subsidence affects over half of the agriculturally significant San Joaquin Valley [*Zekster et al.*, 2005]. Elsewhere, groundwater depletion has caused seawater intrusion and mobilized contaminants [*California Department of Water Resources*, 2003]. In other places, like Lake Merced near San Francisco, Redwood Creek and the Shasta River in northern California, the Cosumnes River near Sacramento, and the Owens River Valley and Santa Clara River in southern California, groundwater depletion has diminished streamflow and lake levels, damaged vegetation, and affected fish and migratory birds [*Hall*, 2010; *Little Hoover Commission*, 2010; *Zekster et al.*, 2005]. Even so, groundwater use is increasing, and is projected to increase at a greater rate, as climate change reduces the reliability of surface supplies [*California Department of Water Resources*, 2008].

[6] Yet there has been little sustained research on how local water agencies control groundwater depletion in California, outside of legally adjudicated areas, which are rare [*Sandino*, 2005; *Blomquist et al.*, 2004; *Blomquist*, 1992]. Apparently there has been no geographically comprehensive empirical legal work. This gap leaves calls for reform largely without a basis in practical local experience. This project aims to provide the first description and analysis of how local rules and plans work within the loose framework of California State laws to control groundwater depletion, using selected key principles of modern water resources management to structure the evaluation. Pressure on scarce water resources is leading to water law reform worldwide [*Hodgson*, 2006]; Californian experiences may also inform reform efforts in other places.

[7] Section 2 sets out the internationally accepted theoretical principles of modern water resources management, which structure the study. Section 3 describes the legal context for controlling groundwater depletion in California. Section 4 outlines the methodology used to conduct the empirical work. Section 5 (descriptive component) describes how California State-level legal arrangements for local groundwater management, and local implementation plans, express the study's three central topics: decision making and stakeholder engagement, information gathering, and methods of controlling groundwater depletion. Section 6 (analytical component) explores how the frequency of an approach to controlling depletion varies with local conditions, and with the function and revenue of the entities involved. It hypothesizes that agencies are more likely to take more legally robust approaches where depletion is serious and worsening, where depletion is causing potentially irreversible impacts, where an agency is responsible solely for groundwater management, and does not supply water, or where agency revenue is comparatively low. Section 7 further discusses the empirical findings with reference to the principles introduced in Section 2 and argues that, while current laws provide agencies with many tools to combat groundwater depletion, they do not provide adequate incentives to use these tools. Section 8 sets out reform recommendations, which work within California's current legal standard of a "safe yield" level of extraction and its existing groundwater management planning framework, followed by concluding remarks.

## 2. Theoretical Framework: Water Resources Management Planning

[8] Internationally accepted water resources management planning theories form the backbone of this study, against which California State legislation and local rules and plans are evaluated. These theories see water resource problems not as "technical challenges to be resolved through purely technical means," but rather as candidates for improved management, negotiation with stakeholders, "accommodation of different social values," and consideration of environmental impacts [*Feldman*, 1991]. They rely on water resources plans as "the basic instrument" for rational water management, with an important place in law [*Caponera*, 2007]. Planning is considered vital for anticipating and dealing with variable water availability in arid and semiarid areas, and as groundwater extraction and resource stress intensify—both of which are the case in California. Contemporary water resources management embraces the following three key elements, which this study later translates into a coding scheme to analyze the research subjects (section 4).

[9] 1. *Decision-making and stakeholder engagement*: A "participatory approach" to management [*Wengert*, 1971] holds that "everyone is a stakeholder" in water matters, including disadvantaged groups, individuals, NGOs, and local groups of all kinds [*Global Water Partnership Technical Advisory Committee*, 2000; *Iza and Stein*, 2009]. Expanding stakeholder participation beyond groundwater pumpers whose extraction has caused depletion problems can encourage a move away from the status quo [*Nelson*, 2005]. Rather than merely "legitimiz[ing] decisions already made" [*Global Water Partnership Technical Advisory Committee*, 2000], stakeholder participation should make "significant contributions to outcomes" [*Bergkamp et al.*, 2009]. For example, in the groundwater sphere, stakeholders may be involved in determining extraction limits [*Alley et al.*, 1999; *Nevill*, 2009]. This study analyzes decision making and stakeholder engagement by considering how State laws and local implementation allow for a variety of interest groups to participate in decision-making bodies and advisory committees.

[10] 2. *Information*: Pumping groundwater without monitoring extraction or the state of the aquifer is like a business continually withdrawing money from a bank account

without any bookkeeping system [*Bartolino and Cunningham*, 2003]. Groundwater "bookkeepers" require information on groundwater levels, quality, and extraction, preferably using representative wells monitored appropriately frequently [*Taylor and Alley*, 2001], and ideally, information on the wider local impacts of depletion, for example, on ecosystem health or ground subsidence. Registration and metering of wells and reporting of groundwater extraction give local agencies crucial information about the condition of the resource, and human and natural stresses on it. This study analyzes the extent to which State laws and local implementation provide for measuring groundwater conditions and metering extraction, as a key prerequisite to controlling groundwater depletion effectively.

[11] 3. *A portfolio of approaches for controlling groundwater depletion*: Water resources literature is filled with different methods of dealing with groundwater depletion (for a particularly comprehensive list, see *Schiffler* [1998]). Although the local context will determine which measures are likely to be effective, both theoretical and empirical studies of aquifer depletion suggest that having a larger and more diverse suite of management actions to combat depletion is likely to make management more effective and robust [*Cash*, 2006; *Hanak et al.*, 2010]. This study uses three categories of approaches to controlling groundwater depletion to analyze the strategies provided by State laws and used by local entities.

[12] (a) Mandatory measures, which involve limiting extraction to a target level by mandating reductions in existing pumping, or limiting the construction of new wells. Ideally, the target extraction level should: avoid irremediable impacts on immediate and downstream freshwater ecosystems and maintain their integrity; consider water quality; and include "measures aimed at coping with droughts" [*Dellapenna*, 2004; *Flint*, 2004; *Nevill*, 2009]. Opposition to mandatory methods can lead to political interference in decision making, which can be reduced by setting limits well before usage approaches those levels [*Nevill*, 2009].

[13] (b) Fee-based measures, which entail charging fees for groundwater extraction, preferably ensuring that water users pay for water on a full-cost recovery basis, including costs in terms of "nonmarket values to human capital and ecosystem service values" [*Lant*, 2007]. However, there is strong pressure to under-account for such costs, which are often difficult to calculate [*Connell*, 2007]. Resistance can be lessened by using tiered charges and water markets to provide large users with operational flexibility [*Bjornland and Kuehne*, 2009; *Schiffler*, 1998].

[14] (c) Voluntary and/or physical measures. The latter entail either constructing or changing the operation of infrastructure without imposing legal requirements or charges. Large-scale infrastructure measures include importing water from other basins (which also invites sustainability concerns), replenishing aquifers using spreading basins or injection wells, and conjunctively using surface water and groundwater, depending on availability. Smaller-scale solutions include changing the spatial or temporal management of pumping, or treating and recycling wastewater. Voluntary approaches include educating the public about conservation and individual water users undertaking small-scale water efficiency projects.

## 3. The Legal and Institutional Context of Controlling Groundwater Depletion in California

### 3.1. The Common Law and Groundwater Depletion

[15] In theory, common law rules in California in most cases apply to limit groundwater extraction to the "safe yield," being the volume of natural and artificial recharge of the aquifer, which is shared by overlying landowners on an "equitable" basis, and by nonoverlying landowners if there is sufficient water available (Katz v. Walkinshaw, 74 p. 766 (Cal. 1903)). Globally, laws limiting groundwater pumping to the safe yield are not uncommon [*Eckstein*, 2010]. In their Californian guise, these rules rarely control groundwater depletion. They require an individual user to endure an expensive and time-consuming lawsuit to settle all the groundwater rights in a basin (since under California's common law rules, the quantity of one user's rights is affected by each other basin user's rights). Unsurprisingly, these "adjudications" are rare—they cover only 22 of California's 431 basins [*California Department of Water Resources*, 2003; "Court Adjudications," 2009, available from http://www.water.ca.gov/]. Without basin adjudications, the system probably encourages overpumping [*Krieger and Banks*, 1962; *Sandino*, 2005]. This system also relies on an adversarial, rather than potentially more constructive, creative, collaborative process [*Sheer*, 2010].

### 3.2. Institutional Legislation—General Agencies and Special Districts

[16] California lacks uniform groundwater legislation, which applies throughout the State. In most areas, well owners can pump groundwater without holding any administrative permit [*Sax*, 2003]. However, legislation establishes over 20 types of independent local water agencies (on the ground, numbering around 2300) [*California Department of Water Resources*, 2003; *California State Controller*, 2010], and empowers them to regulate groundwater extraction in various ways (though only rarely requiring them to do so). These "general agencies" may be involved in groundwater management because they supply groundwater to users, or supply surface water to users who also use groundwater, or they may wish to protect the resource because they plan to use it in the future. Of these 20, key agencies for present purposes (in that they appear in this study's sample of local rules and plans) are California water districts, county water districts, irrigation districts, reclamation districts, water conservation districts, water replenishment districts, water storage districts, and waterworks districts. There are around 600 of these particular types of general agencies in California [*California State Controller*, 2010].

[17] In addition to general agencies, "special districts" are sometimes established in areas suffering from groundwater depletion. Californian legislation establishes 17 special districts, as defined in this paper (see section 4.1). These districts are established in an ad-hoc way, in response to local demand (particularly where locals fear groundwater exports from the local area), rather than through a coordinated State effort to identify basins in trouble [*Weber*, 1994]. They have various special powers, for example, to control pumping in situations of actual or threatened overdraft, limit exports, require well spacing to minimize well interference, and impose groundwater-related fees. Due to these special powers, this study analyzes special districts separately from

general agencies. While the former are sometimes claimed to have addressed overdraft problems successfully (though by what yardsticks, it is unclear), establishing them requires political will that is rarely forthcoming [*Sandino*, 2005].

### 3.3. Groundwater Management Planning Legislation

[18] Water planning legislation is increasingly favored as an approach within water law globally [*Caponera*, 2007]. Overlaying California's common law rules, and its complex network of water agencies, the Ground Water Management Act (AB 3030) (GMA) encourages a proactive local groundwater management planning approach in basins with significant water use, which are not adjudicated (Cal. Water Code §§ 10750(a), 10750.2, 10752(b)). It permits a local agency, which includes a special district or a group of agencies, to adopt and implement a groundwater management plan (GWMP) for all or part of the agency's service area (Cal. Water Code §§ 10752(g), 10753(a), 10755.2).

[19] Adopting a GWMP involves formal procedural steps, including making specific resolutions, issuing public notices and conducting public hearings (Cal. Water Code §§ 10753.2–10753.6). If landowners representing more than 50 percent of the assessed value of the land within the local agency protest against the GWMP, the local agency may not adopt it (Cal. Water Code § 10753.6). A GWMP may cover 12 enumerated matters. The quantity-related matters are: mitigating conditions of overdraft, replenishing extracted groundwater, monitoring groundwater, facilitating conjunctive use operations, and constructing and operating groundwater recharge, conservation, water recycling, and extraction projects (Cal. Water Code § 10753.8). An agency "shall adopt rules and regulations to implement and enforce" a GWMP (Cal. Water Code § 10753.9(a)).

[20] When a local agency adopts a GWMP, it gains special powers. It may limit or suspend groundwater extractions, provided it "has determined through study and investigation that groundwater replenishment programs or other alternative sources of water supply have proved insufficient or infeasible to lessen the demand for groundwater" (Cal. Water Code § 10753.9). It may also impose charges for groundwater extraction or replenishment if a majority of voters endorses this (Cal. Water Code § 10754.3). On the other hand, failing to adopt a GWMP makes a water agency ineligible to receive water grants and loans from the State (Cal. Water Code § 10753.7(b)).

[21] Several things are noteworthy about this legal structure, against the theoretical framework presented in section 2. First, in relation to the institutional legislation, few types of agencies have specific legislative mandates to address depletion, and none has an express mandate to consider the broader ecological and social effects of depletion, beyond water supply concerns. This is despite numerous formal legislative findings about the severity of these broader effects (e.g., Cal. Water Code §§ 12926(b), 13701(c)). Second, GWMPs are voluntary, and they fundamentally prioritize augmenting supply over pumping restrictions, even in cases of severe overdraft [*Cooley et al.*, 2009; *Hanak*, 2003]. Third, a local agency is not required to review its GWMP for effectiveness, or keep it up-to-date, and agencies sometimes adopt GWMPs purely to head off state intervention, without a strong intention to implement them [*Hanak*, 2003]. These GWMP provisions are substantially less stringent than comparable legislation that requires large water suppliers to adopt urban water management plans (UWMPs) (Cal. Water Code §§ 10610–10656). That legislation requires a water supplier to involve disadvantaged groups in the planning process; focus on managing demand; include methods for evaluating the effectiveness of demand management measures; prohibit and penalize wasteful uses; evaluate climate-related risks; consider environmental, social, and technological factors in some contexts; review and update the UWMP every five years; and implement the UWMP or become ineligible for water management grants or loans from state water agencies. UWMPs are also much more accessible, transparent, and subject to accountability requirements than GWMPs. These differences are likely to be explained, at least in part, by the UWMP provisions being more frequently and recently amended than is the case for the GWMP provisions; regulating urban water supply also attracts much less political controversy than regulating agricultural water rights, which are considered a bastion of private property.

[22] In addition to the laws described above, other Californian laws and policy provide additional methods for controlling groundwater depletion. These methods are not analyzed here, since they apply only to narrow situations, for example drought plans, controlling out-of-basin groundwater exports under State (Cal. Water Code §§ 1215–1222) or local rules [*Sandino*, 2005], restraining urban water use [*California Urban Water Conservation Council*, 2009], or restraining the depletion of certain narrow legal categories of aquifers. Integrated regional water management plans (Cal. Water Code §§ 10539–10550), cover water supply more broadly, and at a higher geographic level, and may include GWMPs, but are not intended to replace them as the key groundwater planning mechanism in California [*California Department of Water Resources*, 2007].

## 4. Methodology

[23] This study investigates how California State legislation provides for controls on groundwater depletion, and how local agencies use these controls in local rules and plans. It uses content analysis systematically to code State legislation and local plans and rules. This has two aims: first, to describe local groundwater management from a bird's eye view, showing its variation; and second, to analyze simply how an agency's likelihood of adopting more legally robust measures (in ascending order: voluntary/physical, fee-based, and mandatory approaches) relates to that agency's characteristics.

### 4.1. Descriptive Component

[24] This study analyzes 25 Californian State water laws, which establish the institutional and planning frameworks for groundwater resources: (1) eight acts providing for the establishment of general agencies under the Californian Water Code: these are acts corresponding to the implementing agencies of GWMPs in the random study sample of GWMPs described below; (2) 16 acts providing for the establishment of 17 special districts; and (3) the GMA.

[25] At the local level, the study analyzes a randomly selected sample of: (1) 46 GWMPs for which general agencies—36 agencies established under the Californian Water

Code, and 10 cities, counties and joint powers authorities—were the implementing agencies, and any accompanying rules (from an estimated population of 130 GWMPs); and (2) 12 special districts' ordinances, resolutions, and GWMPs (noting that only nine special districts had made a GWMP).

[26] The sample was randomly selected, with the following adjustments, in order to be representative of areas with agricultural groundwater use where groundwater depletion may be a concern: the study excluded agencies in whose territory the only water uses were urban or municipal, since controlling depletion in these areas most heavily relies on UWMPs; it also excluded areas in which an excessively high groundwater table (rather than depletion) was the main groundwater quantity problem, because of the study's emphasis on depletion. The study included areas which used very small groundwater volumes, since in some areas even low pumping intensity gives rise to environmental concerns [*HydroMetrics LLC*, 2007].

[27] A population of 132 GWMPs was determined by searching the Californian Department of Water Resources (DWR) online *Integrated Water Resources Information System* (IWRIS). A random sample of plans and their accompanying rules was then gathered, mainly by contacting local agencies directly, with a minority of plans available online through IWRIS or agency websites. Although there is a risk that the contact person did not provide all relevant local rules, the risk of entirely missing a strategy for controlling groundwater depletion is considered acceptably small, since an agency has an incentive, if anything, to overstate its groundwater management actions in a GWMP to deter State intervention, as discussed below. Of the top 84 randomly ordered GWMPs in IWRIS, 19 were discarded because they involved no agricultural water use, or were made by agencies that were later dissolved, or were duplicate entries; 10 were repeatedly requested but not received; and 4 were received too late to be included. This left 51 current GWMPs, which were obtained and included, supplemented by four further GWMPs that were obtained specially (i.e., outside of this randomized method) because they were made by special districts, for which a census of documents was sought (though see the exclusions noted in Table 3).

[28] The population of special district acts was determined using the table entitled "Special act districts with groundwater management authority in California" in DWR's official Groundwater Bulletin [*California Department of Water Resources*, 2003], which displays 13 districts, established by 12 acts (Cal. Water Code §§ 10700 et seq.; Cal. Water Code App. 40, 60, 100, 118, 119, 121, 124, 128, 129, 131, 135). Searching the Lexis commercial database *CA—Deering's California Codes Annotated* uncovered an additional four acts establishing four unique agencies with the same types of groundwater management powers as those included in the DWR's list, which were not in adjudicated basins (Cal. Water Code App. 61, 70, 103, 137). Special district acts and general agency laws were accessed through the same Lexis database. District ordinances and resolutions were sourced mainly by contacting districts directly, with a minority of these documents available from agency websites.

[29] This method does not examine areas in which groundwater depletion may be a problem, but neither a GWMP nor a special district applies. Nor does it examine areas covered by a GWMP which was not submitted to the State. However, it seems reasonable to assume that such areas will be few, given that receiving State groundwater funds depends on submitting a GWMP, and agencies strongly desire to retain local control by demonstrating local management to the State. It also seems reasonable to assume that the current plan represents the implementing agency's current management approach, since agencies have incentives to update their plans to make new projects or management approaches eligible for State funds.

[30] The coding scheme derives from the study's theoretical framework (section 2), comprising three topics: decision making and stakeholder engagement, information gathering, and methods of controlling groundwater depletion. It uses a number of categories and subcategories for these topics, amounting to some 70 codes. Table 1 represents this scheme in simplified form (see supplementary materials for complete list).[1]

[31] Coding proceeded using a low threshold for affirmative coding; where it seemed that a document adopted an approach to addressing groundwater depletion, but did so relatively briefly, for example, this was coded affirmatively. Accordingly, the study may generally overestimate the degree to which the research population adopts the coded elements. Note also that the relatively detailed coding scheme used means that some categories contain few elements; tables and figures should be read with this in mind. Coding was carried out solely by the author, which may increase consistency, but is limited in not allowing for a line of interpretation to be verified.

### 4.2. Analytical Component

[32] The study hypothesizes that agencies are more likely to take more legally robust approaches in each of the following physical or institutional circumstances: first, where depletion is serious and worsening; second, where depletion is causing potentially irreversible impacts, such as seawater intrusion or inelastic ground subsidence; third, where an agency is responsible solely for groundwater management, and does not supply water (since it would be more likely to accept a controlling function as part of its institutional mandate); and fourth, where agency revenue is comparatively low (since higher revenue would enable the agency to use a physical solution such as importing water, eschewing the need for a more coercive approach). Conversely, a less legally robust approach to controlling depletion is expected if depletion problems are stable or not evident, or do not include potentially irreversible effects, or if the implementing agency supplies water or has relatively high revenue. The study does not attempt to prove causal links in relation to any of these points, but rather to investigate expected associations, in a descriptive way.

[33] The relevant agencies for this analysis were determined as follows: (1) for each special district act, the agency for which the act provides (at most, two agencies); and (2) for each GWMP, the "implementing agency" noted in the IWRIS entry for the plan, excluding special districts, which are considered under (1). As indicated above, the type of implementing agency then determined the corresponding State law investigated; the study did not include

[1] Auxiliary materials are available in the HTML. doi:10.1029/2011WR010927.

**Table 1.** Simplified Representation of Coding Scheme

| Topic | Codes for State Documents | Codes for Local Documents |
|---|---|---|
| Decision making and stakeholder engagement | (1) Method of selecting directors; voter population; (2) representation of interest groups through decision-making body; (3) representation of interest groups through advisory group | Interest groups represented on groundwater advisory group (if any) |
| Information collection | (1) Explicit powers to collect water information; (2) explicit powers relating to well registration, metering, extraction reporting | (1) Monitoring ambient groundwater conditions; (2) well registration, metering and extraction reporting |
| Methods of controlling groundwater depletion | Explicit powers to institute: mandatory measures (e.g. extraction limits); fee-based measures (e.g. for self-supplied extraction); voluntary or physical measures (e.g. importing surface water, encouraging conservation) | (1) Identified management issues (e.g., overdraft, subsidence); (2) use or *planned* use of measures described in column to left[a] |

[a]Treating use and planned use identically matches the central normative tenet of the study, being the value of a planning approach to managing water; announcing a planned limit could affect pumping behavior in anticipation of a situation that could arise later.

State legislation for types of general agencies for which no GWMP was sampled, nor did it include legal arrangements for cities, counties, and joint powers authorities, maintaining a focus on water legislation instead. All State-level laws investigated form part of the Californian Water Code.

[34] Beyond legislation, plans and rules, information was collected about: (1) the groundwater conditions in the relevant agency's geographic area of responsibility—whether groundwater depletion in the area is serious and worsening, a past problem that has stabilized or improved, or neither a past nor a present problem; (2) whether the relevant agency supplies water for agricultural or other purposes, or only manages groundwater; (3) the relevant agency's total revenue; and (4) whether local depletion problems included seawater intrusion or ground subsidence. Information on (1) was sourced from a combination of the relevant GWMP and the online State groundwater basin descriptions [*California Department of Water Resources*, 2011]. Information on (2) and (3) was obtained from the most recent reports of the State Controller [*California State Controller*, 2009a, 2009b, 2010]. Information on (4) was derived from the management issues identified in the local-level documents, as set out in Table 1. Note that GWMPs do not always detail the service area of the implementing agency, and California provides no centralized information on this point. Accordingly, it was not possible to standardize revenue on this basis, or to check whether special districts and general agency areas included in the sample overlapped. But note that a general agency that chose to rely on the measures of a special district in the same area would likely set this out in its GWMP, and the use of these measures would be attributed to that GWMP accordingly.

## 5. Findings and Discussion—Descriptive Component

### 5.1. State Legislation for Local Groundwater Management

[35] The study analyzed 25 items of Californian State legislation, which establish the framework for groundwater management by local water agencies through laws for: (1) creating these agencies, and their structures for making decisions and engaging stakeholders; (2) collecting groundwater information; and (3) using particular methods for addressing groundwater depletion. This section sets out and discusses the results of this analysis. It concludes that Californian laws, while privileging agricultural interests above others, and while exhibiting some weaknesses (relative to theory) in relation to gathering information, generally provide local agencies with a wide range of potent powers to control groundwater depletion—though it says nothing regarding how frequently they are used, or legal or other incentives for their use.

#### 5.1.1. Decision Making and Stakeholder Engagement

[36] Twenty-four pieces of Californian water legislation provide for establishing the general agencies and special districts that undertake groundwater management (broken down at Table 2). These laws set up many different arrangements for electing or appointing members of decision-making bodies (for simplicity, here referred to as "directors"), establishing advisory groups, and ensuring the representation of particular interest groups.

[37] Local agencies use varying methods to select directors (Table 2(a)). All directors of general agencies are elected; only 38% of special district acts use elections to select all directors, more commonly using some elected directors and some appointed by local government or water agencies (44%). All directors across both broad agency types must be local residents or landowners. In 38% of general agency acts, electors' votes are weighted by the value or size of their landholding, thus privileging the management preferences of large landholders and likely over-representing agricultural interests. While this is rare for special district acts (8%), over a third of the special district acts mandate some form of agricultural representation; for example, requiring a proportion of directors to derive mostof their income from agriculture, or to own high-capacity pumps (e.g., Cal. Water Code App. §§ 124–402, 128–401(a)(3)).

[38] Advisory groups represent an important opportunity for predominantly production-oriented decision-making bodies to obtain low-cost specialist or technical expertise, and to benefit from alternative perspectives. However, no general agency act, and only a third of special district acts provide for such groups. The GMA explicitly allows, but does not require, a local agency to consult with a "a technical advisory committee consisting of interested parties" in relation to preparing, adopting, and implementing a GWMP (Cal. Water Code § 10753.4).

[39] In summary, institutional arrangements for selecting directors strongly defer to agricultural producers, which pump most groundwater. Such decision-making bodies

**Table 2.** State Institutional Legislation—Special District Acts and General Agency Acts

| | | Special Districts | General Agencies | GMA |
|---|---|---|---|---|
| | *Decision-Making Body and Advisory Group* | | | |
| Method of selecting directors | All elected | 38% | 100% | na |
| | All appointed | 13% | 0% | na |
| | Some elected, some appointed | 44% | 0% | na |
| | No particular selection method mandated | 6% | 0% | na |
| Qualified electors (expressed as % of acts using elections) | One person–one vote | 92% | 63% | na |
| | Vote by value of land | 8% | 38% | na |
| Representation on decision-making body | Provision for agricultural representation[a] | 38% | 0% | na |
| | Provision for other representation | 6% | 0% | na |
| | No provision for particular representation | 56% | 100% | na |
| Advisory groups | Provision for agricultural representation[a] | 19% | 0% | 0% |
| | Provision for other representation | 13% | 0% | 0% |
| | No provision for particular representation | 13% | 0% | 100% |
| | No provision for advisory group | 69% | 100% | 0% |
| | *Information Collection* | | | |
| Info re GW conditions | Power to collect groundwater information | 100% | 25% | 100% |
| Info re GW extraction | Mandatory well registration | 38% | 25% | 0% |
| | Entity may require well registration | 44% | 0% | 0% |
| | Mandatory well metering | 13% | 13% | 0% |
| | Entity may require well metering | 56% | 13% | 0% |
| | Mandatory well reporting | 38% | 25% | 0% |
| | Entity may require well reporting | 50% | 0% | 0% |
| | *Methods of Controlling Groundwater Depletion* | | | |
| Only voluntary and/or physical approaches | | 0% | 25% | 0% |
| Fee-based but not mandatory approach | | 19% | 25% | 0% |
| Mandatory but not fee-based approach | | 6% | 25% | 0% |
| Both mandatory and fee-based approaches | | 75% | 25% | 100% |

[a]Agricultural representation is found when either directors or electors must have a high-capacity well pump, or agricultural interests.

may lack the opportunity and the incentive to obtain specialist information about the significant social, cultural and environmental effects of groundwater depletion, in contrast to their interest and experience in relation to its short-term economic advantages. Contrary to contemporary water resources management theory, State legislation does not provide an adequate structure for agencies to balance or complement an agricultural perspective with other relevant expertise or other interests, including nonlocal interests.

#### 5.1.2. Information Collection

[40] State legislation empowers all agency types to collect information about groundwater conditions if they have a GWMP (Table 2(b)). Around three quarters of special district acts provide for registering wells, and metering and reporting groundwater extraction, though many express this as a power, not as an obligation; only one quarter of general agency acts do so. This stark difference is unsurprising, given that special districts typically are established in response to critical groundwater problems, and obtaining groundwater information (particularly metering) is highly politically controversial in California. The GMA contains no explicit provisions in relation to registering wells, or metering and reporting groundwater use.

#### 5.1.3. Approaches to Controlling Groundwater Depletion

[41] Special district and general agency acts explicitly envisage a wide range of methods for dealing with groundwater depletion (Table 2(c)), which fall into three approaches—mandatory, fee-based, and voluntary/physical. Three quarters of special district acts allow for both mandatory and fee-based approaches, although sometimes a district must first make a formal determination before using these approaches, for example, about a threat of overdraft existing, or the need for a charge. No special district act relies solely on voluntary or physical approaches. This suggests the Legislature's conviction that they are inadequate means, by themselves, to deal with critical groundwater conditions. By contrast, three quarters of general agency acts provide for neither or only one of mandatory or fee-based measures, indicating that before the passage of the GMA, these agencies lacked a full portfolio of powers to address groundwater depletion.

[42] Overall, it is clear that local agencies have a broad range of explicit legal powers to address groundwater depletion, and that for many general agencies, adopting a GWMP can be a new source of potent powers.

### 5.2. Implementing Local Groundwater Management

[43] Examining how local agencies use GWMPs and local rules to implement the State laws analyzed above reveals that although State laws give local agencies powerful tools to control groundwater depletion, they are generally very reluctant even to contemplate using these tools. This is likely due to the political and electoral ramifications of using unpopular and restrictive measures. This section presents and analyzes data on key issues in local implementation derived from the water resources planning theories introduced in section 2—the stakeholder engagement structures involved, the information available to the agencies, the depletion problems perceived to be of concern and their gravity, and the approaches they plan to use to control depletion (Table 3).

[44] As for their constitutive legislation, general agencies that are the implementing agencies for GWMPs, and

**Table 3.** Local Groundwater Management Special Districts and General Agencies

| | | Special Districts[a] | General Agencies |
|---|---|---|---|
| | *Stakeholder Engagement* | | |
| Advisory group | Agricultural representation | 25% | 24% |
| | Environmental representation | 17% | 20% |
| | Urban/municipal representation | 33% | 30% |
| | Other representation | 33% | 35% |
| | Advisory representation unclear | 25% | 15% |
| | Advisory group not mentioned | 42% | 50% |
| | *Information Collection* | | |
| Info re GW conditions | Groundwater levels | 92% | 96% |
| | Groundwater quality | 83% | 85% |
| | New/enhanced need to monitor | 67% | 67% |
| | Other groundwater-related parameter | 92% | 50% |
| | No mention | 25% | 4% |
| Info re GW extraction | Well registration | 83% | 15% |
| | Well metering | 75% | 13% |
| | Well extraction reporting | 75% | 15% |
| | *GW Depletion Problems Viewed as Management Issues* | | |
| Sustainable/safe yield/overdraft | | 92% | 83% |
| GW levels/quantity | | 83% | 89% |
| GW quality: seawater intrusion | | 42% | 11% |
| GW quality: other extraction-related | | 42% | 48% |
| GW quality: other/unspecified | | 67% | 61% |
| Effects on ecosystems | | 33% | 24% |
| Ground subsidence | | 42% | 54% |
| Other | | 58% | 59% |
| | *Gravity of Depletion Problems* | | |
| Serious & worsening present problem | | 42% | 39% |
| Past problem, now stable or improved | | 42% | 22% |
| No past or present serious problem | | 17% | 39% |
| | *Methods of Controlling Groundwater Depletion* | | |
| Both mandatory and fee-based measures | | 42% | 0% |
| Mandatory without fee-based measures | | 17% | 17% |
| Economic without fee-based measures | | 25% | 2% |
| Only voluntary and/or physical measures | | 8% | 76% |
| Monitoring only | | 8% | 4% |

[a]12 special districts are analyzed here. Though 16 acts provide for the creation of 17 special districts, the analysis here excludes five dormant or only minimally active districts, which focus only on groundwater export problems, rather than broader management [e.g. *Brown & Caldwell*, 2007].

special districts are analyzed separately. These entities take two further functional categories: those that supply surface water or groundwater to users, and those that only manage groundwater that users extract directly. Most general agencies (70%) and half the special districts supply water as well as managing groundwater. Note also that GWMPs vary in terms of date, length, complexity, and the extent to which they are directed to implementation, with more recent plans tending toward greater length, complexity and apparent inclination toward implementation.

### 5.2.1. Stakeholder Engagement

[45] Stakeholder advisory groups feature strongly in Californian groundwater management, although they are optional. These groups help to prepare at least 50% of GWMPs, and assist around 60% of special districts. Special districts and general agencies use advisory groups that contain environmental representation at about the same, relatively low, rate (~20%) (Table 3(a)).

### 5.2.2. Collecting Groundwater Information In Practice

[46] Most special districts and general agencies gather local information on groundwater quantity (92% or over), groundwater quality (around 85%), and other related parameters, which include farm conservation practices, ground subsidence, surface water flows and quality, surface water-groundwater interaction, and precipitation (Table 3(b)). However, it is unclear whether monitoring systems are comprehensive, high quality, or tailored to groundwater depletion issues. Indeed, two thirds of general agencies and special districts claim that they require improved groundwater monitoring systems. Although some note that groundwater depletion may affect ecosystems (section 5.2.3), no document reviewed mentions monitoring ecological or species health.

[47] Groundwater extraction information is comparatively rare. Only one fifth the proportion of general agencies as special districts provides for well registration, metering and extraction reporting, and sometimes large categories of wells are exempt, e.g., wells pumping water for in-basin use [*Glenn County*, 2000].

### 5.2.3. Groundwater Depletion Problems Viewed as Management Issues

[48] Groundwater managers wrestle with a wide range of problems associated with groundwater depletion (Table 3(c)), the most prevalent being overdraft and declining water levels. Few entities report concern for the ecological effects of groundwater depletion (24% for general agencies; 33%

for special districts). Interestingly, no general agency identified adverse ecosystem effects in the absence of an advisory group, and 73% of these advisory groups involved environmental stakeholders. Depletion-related groundwater quality issues are reported more commonly (48% for general agencies; 42% for special districts). This confirms the importance of monitoring groundwater quality where depletion is of concern. It also suggests that the State Water Resources Control Board may have occasion to use its powers to adjudicate groundwater rights to protect groundwater quality (Cal. Water Code § 2100) across many such areas. Notably more special districts than general agencies face issues of seawater intrusion (42% compared to 11%), possibly indicating that seawater intrusion is seen to require particularly active management, due to its potentially irreversible effects. Over half of each entity type reports concern with other matters related to groundwater depletion. These include depleting stream base flow, decreasing surface water quality, the potential effects of a more uncertain future climate, and increasing groundwater demand as a result of greater urbanization.

[49] Local agencies confront depletion issues across a spectrum of seriousness (Table 3(d))—about the same proportion of each entity type (~40%); they also operate in areas that have never experienced groundwater problems (39% for general agencies; 17% for special districts), and where conditions have stabilized or improved (22% and 42% respectively), suggesting that each entity type is capable of mitigating these problems (though the severity of problems, and natural mitigating events, may be different).

#### 5.2.4. Approaches to Controlling Groundwater Depletion in Practice

[50] Most general agencies (76%) use voluntary and physical measures, or monitoring only, without other approaches of controlling groundwater depletion (Table 3(e)). For example, they conjunctively use groundwater and surface water (sometimes subsidizing surface water to discourage groundwater use), import water from other basins, undertake aquifer replenishment activities, and encourage agricultural water conservation and public education measures. Despite their GMA powers, they almost never foresee imposing fees (2%), and rarely (17%) mandatory measures such as limiting extraction, requiring well licenses or mandating agricultural conservation. Such measures tend to be rejected outright, or contemplated only as a last resort.

[51] Special districts use mandatory and fee-based measures much more frequently (84% using one or both). Examples are requiring groundwater extraction permits that mandate "best management practices," imposing efficiency requirements, only permitting volumes of extraction set out in "water use standards," and permitting only recycled water to be used for nonpotable purposes. Nonetheless, explicit penalties for violating these mandates seem rare.

## 6. Findings and Discussion—Analytical Component

[52] Having seen how local groundwater management entities vary in controlling depletion, how does the frequency of an approach vary with local conditions, and with the function and revenue of the entities involved? First, in serious or worsening groundwater situations, special districts use more legally robust approaches to groundwater depletion much more frequently than general agencies (Figure 1a). Special districts are more likely to use mandatory or fee-based measures, or both, in such situations, and where historic depletion problems have been alleviated, than where such conditions are not present (100%, 80%, and 50%, respectively). Surprisingly, among general agency areas, those that have suffered no past or present groundwater depletion are most likely to plan mandatory or fee-based measures (33%, compared to areas with serious and worsening problems, 11%). While initially puzzling, this may be explained by the comparative political ease with which an agency may announce a strategy of limiting extractions in response to overdraft, where there is no looming overdraft threat. Although voluntary and physical approaches were universally used (and apparently effective) in the general agency areas in which historic groundwater depletion problems were alleviated, it seems such approaches have been insufficient for the vast majority of general agency areas with serious and worsening groundwater conditions (89%), which restrict themselves to these methods, since conditions are still deteriorating.

[53] Second, whether an agency adopts mandatory or fee-based measures appears only weakly related to whether the local area is threatened by seawater intrusion or ground subsidence (Figure 1b). General agencies and special districts are only slightly more likely to adopt more legally robust measures where these potentially irreversible threats are present, than when they are not (23% compared to 16% for general agencies; 86% compared to 80% for special districts). The high level of general agencies that restrict themselves to voluntary/physical approaches to control groundwater depletion in the face of potentially irreversible effects (78%) is troubling, given that 43% of these cases also experience serious and worsening conditions.

[54] Third, whether an agency has a water supply function appears unrelated to its approach to controlling groundwater depletion (Figure 1c). General agencies that do not supply water are only slightly more likely to use or foresee using mandatory or fee-based approaches than those which do supply water (21% versus 19%). There is no difference for special districts. A potential explanation is that the hypothesized impulse of a water-supplying agency to avoid accepting a controlling function is balanced by a long-term view of the need to maintain water supplies into the future.

[55] Finally, an agency's approach to controlling groundwater depletion varies dramatically with its median total revenue. Unsurprisingly, the median revenue of an entity that imposes fees is much higher than one that does not, since extraction or replenishment charges contribute revenue (Table 4). More interestingly, the total revenue of agencies that use only voluntary or physical measures is more than double that of agencies which use only a mandatory approach, possibly because the latter's approach is driven by being unable to fund expensive infrastructural approaches.

## 7. Discussion

[56] Before reflecting upon local groundwater planning in California, it is useful first to consider the influence of State law. It is surprising that despite the significant

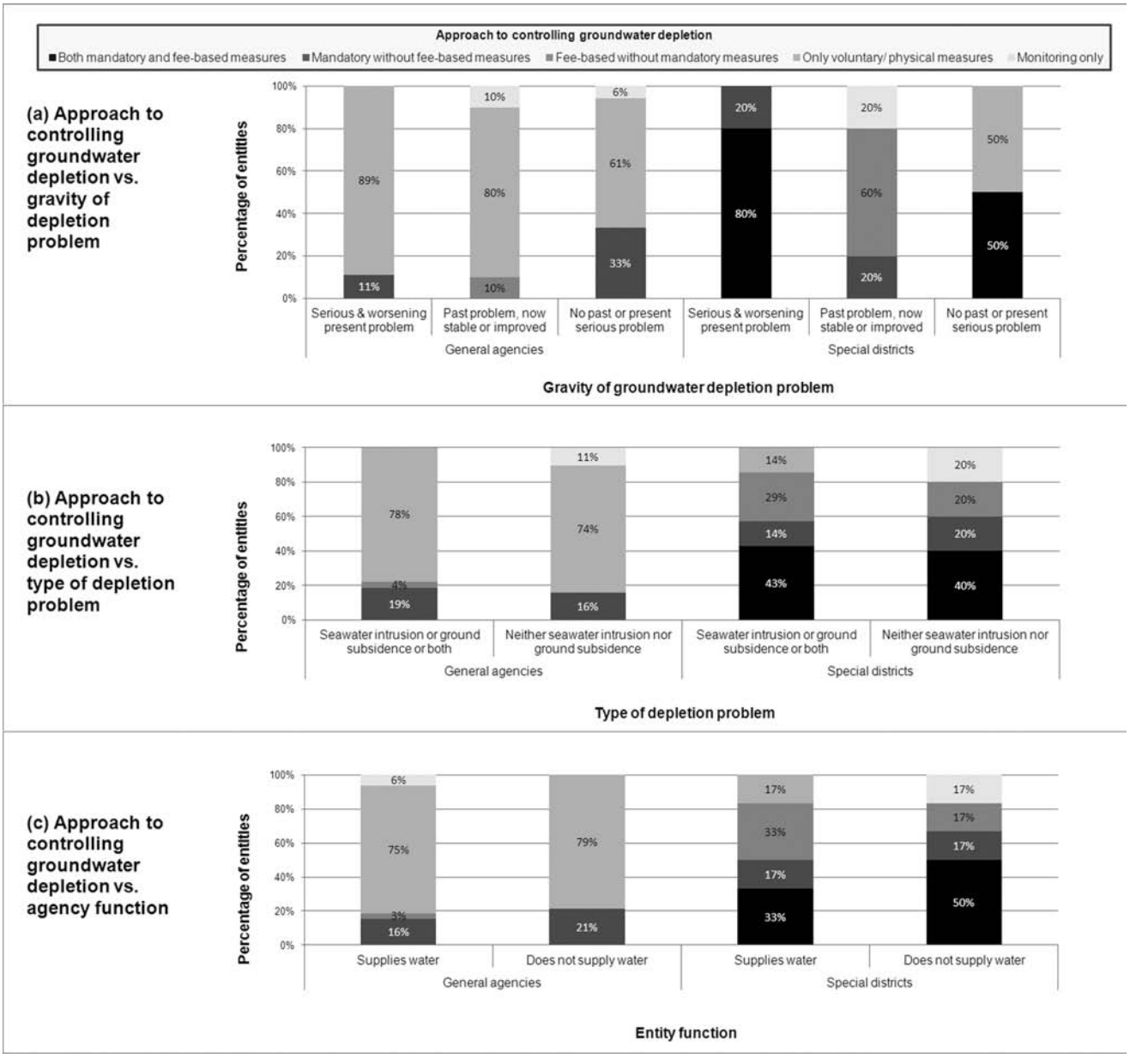


**Figure 1.** Approaches to controlling groundwater depletion versus characteristics of groundwater depletion and entity function.

economic, environmental, and social effects of groundwater depletion, few local agencies have specific legislative mandates to address depletion, and none is required to consider its broader effects (such as those discussed in the introduction to this article), beyond those on water supply. This reflects the fact that the GMA grafts its GWMP provisions on to old, established institutions—general agencies—which have legislative mandates that lag decades behind contemporary water policy. To what effect? While it is beyond the scope of this study formally to gauge the philosophies of local agency staff toward groundwater depletion problems, informal conversations with agency staff while

**Table 4.** Approaches to Controlling Groundwater Depletion by Median Entity Revenue[a]

| Approach of Special Act District or General Agency to Controlling Groundwater Depletion | Both a Mandatory and Fee-Based Approach | Mandatory Without Fee-Based Approach | Fee-Based Without Mandatory Approach | Only Voluntary or Physical Measures | Only Monitoring |
|---|---|---|---|---|---|
| Number of entities | 5 | 10 | 4 | 32 | 3 |
| Median total revenue ($) | 15,501,109 | 5646,043 | 99,155,550 | 13,777,439 | 514,972 |

[a]Note: This table excludes the four joint powers authorities, for which revenue data was not available. All four JPAs use only voluntary or physical measures to control depletion.

gathering local documents suggest that many agencies do not see themselves as groundwater managers, or stewards attentive to the full range of consequences of its overuse, but as water suppliers, period, regardless of whether they have adopted a GWMP. Accordingly, California faces the basic question of how to turn hundreds of water suppliers, the progeny of decades-old State laws, into groundwater stewards in a sense that encompasses adverse social, economic, and environmental impacts more expansively than is presently the case.

[57] At the local level, California's groundwater managers often do not fully implement all aspects of modern water planning: engaging stakeholders, gathering groundwater information, and using a suite of approaches to control groundwater depletion. First, as noted above, advisory groups are important for complementing the dominance of agricultural interests, which law often entrenches in local decision-making structures. However, although advisory groups are explicitly permitted by law, they are not always used; where they are used, they often ignore key stakeholders. Restricting advisory groups to local landowners, for example, not only excludes disadvantaged nonlandowning groups, but also water users who rely on a part of the aquifer outside the entity's territory, or who rely on a connected groundwater or surface water resource, not to mention stakeholders who are not directly economically affected (for example, environmental interest groups). Pragmatically, shutting out environmental stakeholders may harm agencies in the longer term: GWMPs often note that local irrigators are affected by environmental lawsuits. Involving environmental groups in groundwater management could increase water agencies' awareness of potential environmental impacts, demonstrate good faith, and on both counts, ward off future legal challenges.

[58] Second, groundwater conditions are generally monitored in at least a cursory way, but the comprehensiveness, quality, and appropriateness of monitoring for active groundwater management is an open question. Measuring groundwater extraction is rare where it is not mandatory, despite both State laws and local documents recognizing its critical importance. Ecological monitoring systems appear completely absent, perhaps reflecting a supply-oriented mindset and a perception that environmental issues are the domain of specialist agencies. This misses an opportunity to connect groundwater monitoring and metering data to ecological health data, which would facilitate identifying or ameliorating the ecological effects of groundwater depletion, or at least determining a baseline of ecological health against which to recognize a future problem. However, substantial barriers obstruct ecological monitoring efforts. Groundwater users may resist investigations that could found supply restrictions or disruptions, as have followed Endangered Species Act litigation in the surface water context; groundwater agencies would rarely have ecologists on staff, and consultants are costly. New groundwater information legislation in California (Cal. Water Code §§ 10920–10936) touches neither agricultural groundwater metering, nor monitoring the environmental effects of groundwater depletion. Developing a simple index of aquifer health with an ecological component could feasibly address the latter gap. Translating ecological concern into recognition, and then into action, remains an outstanding challenge.

[59] Third, general agencies almost overwhelmingly ignore the mandatory and fee-based powers that the law grants them (albeit as secondary measures available only when physical measures prove insufficient). Ironically, this is particularly the case where groundwater conditions are serious and worsening. Rather, general agencies take a narrow approach to planning to control groundwater depletion that seems unconnected to the seriousness of its physical effects. They do not use, and do not foresee using, any form of mandatory or fee-based measure (which may simply prohibit inefficient use) in 89% of situations of serious and worsening groundwater depletion, and in 78% of situations in which potentially irreversible problems like seawater intrusion and inelastic ground subsidence threaten. This overwhelming reliance on voluntary and physical methods is troubling where it is clear that groundwater conditions are worsening, since it suggests that in these areas and by themselves, these measures have not been enough.

[60] Arguably, agencies even in areas not presently experiencing worsening groundwater conditions should be thinking more broadly. While importing water (one of the most prevalent measures) can be effective in some places, climate change and environmental claims may reduce the availability and reliability of surface water sources. State policy may also interfere, in light of the new State "guiding principle" of increasing regional self-sufficiency by depending less on long-term imports of water from other hydrologic regions [*California Department of Water Resources*, 2009]. Physical measures are also expensive, and ongoing State subsidies far from certain [*Hanak et al.*, 2011]. They also do not correct underlying problems, such as agricultural trends toward higher water-use crops, which lead to increasing demand and potential future problems. Planning water management strategies and instituting legally robust measures take time and stakeholder acceptance—waiting until water supplies are threatened or groundwater problems become established before even considering these measures, or when they should be triggered, risks later political interference [*Nevill*, 2009] and being unable to use them in a timely fashion when the need arises.

[61] More generally, agencies seem rarely to consider a range of potential management options and their benefits and costs, even in cases of severe groundwater depletion. No plan that does set out, weigh and consider a number of options, quantifies or significantly explores the benefits of halting depletion (for example, avoiding degradation of water quality), but only considers and quantifies the costs of taking action; generally without considering ways to avoid or minimize these costs. Indeed, some agencies—both special districts and general agencies—reject mandatory approaches on principle, thereby dismissing out of hand potent management options that the law expressly grants them.

[62] Where mandatory approaches such as extraction limits are used, they tend to reflect a narrow range of concerns, and outdated science. Although the rationale behind a limit is often not explicit, where this is clear, "safe yield" is often the goal. While this reflects the common law, safe yield is widely criticized for (among other reasons) ignoring the effects of extraction on connected water resources and the environment [*Alley et al.*, 1999], and failing to provide for a buffer against imperfect knowledge of the

groundwater system, or a drought reserve. The significant proportion of managed areas with worsening groundwater suggests that current approaches are not sufficient to meet this goal. Local agencies have significant scope to introduce more robust measures.

[63] In the final analysis, Californian State laws provide local agencies with a full toolbox to deal with groundwater depletion, but they generally choose not to take up many of these tools—especially when they are most needed. Laws fail to provide agencies with adequate incentive to use these tools.

## 8. Recommendations

[64] California's system for regulating groundwater suffers from fundamental weaknesses. These derive from outdated institutional laws, which take a blinkered view of the impacts of groundwater depletion and appropriate responses; and insufficient incentives or requirements for local agencies to confront the issue in a balanced way. *Sagala and Smith*'s [2008] work suggests that regulatory weaknesses are unfortunately not uncommon around the world.

[65] However, undertaking large-scale reforms to a sprawling, decentralized, and politically charged groundwater management system such as California's would be a challenge of the highest order. Nonetheless, there is an urgent need to better address the "critical conditions of overdraft, depletion, sea water intrusion and degraded water quality causing great detriment to the peace, health, safety and welfare of the people of the State," in which the people of California have a "primary interest" (Cal. Water Code § 12922.1). Accordingly, these recommendations focus on enhancing California's present local groundwater management planning model—in admittedly ambitious ways—rather than reforming groundwater management, wholesale. They focus on ensuring that agencies with GWMPs adopt a more robust approach to controlling groundwater depletion, in line with the severity of depletion problems. Considering these recommendations may also benefit other jurisdictions that use a local groundwater management planning paradigm. Note that unsustainable "controlled depletion" would not be permitted under California's common law rules for groundwater use (see section 3.1), within which the groundwater management planning framework, which is the focus of this article, operates. This article does not attempt to make recommendations to change this fundamental aspect of Californian groundwater law.

[66] California should consider strengthening the present GWMP framework so that it includes stronger incentives to use currently available tools, institutional safeguards against depletion, and considers the broader social and ecological effects of groundwater depletion. The framework should be reformed so that it

[67] 1. Reflects the accountability requirements of the newer UWMP provisions (i.e., requires all GWMPs to be provided to the State; and requires regular plan reviews, including reviews as to the effectiveness of the measures in the plan).

[68] 2. Requires an agency in an area suffering from a predefined moderate or high levels of groundwater stress to adopt and implement a GWMP that: explores the full range of potential management actions, and their economic and noneconomic costs and benefits, rather than prioritizing physical solutions regardless of their comparative costs and benefits; and transparently explains why an approach is not appropriate for an area in the event of an option being dismissed. Potential concerns over the cost of requiring GWMPs can be addressed by agencies cooperating to prepare GWMPs—a current practice that not only enables cost sharing, but also improves interagency coordination [*Jones & Stokes Associates*, 1998].

[69] 3. Requires agencies in areas suffering from a high level of groundwater stress (e.g., "serious and worsening" depletion, involving irreversible impacts) to make a determination as to whether or not replenishment or alternative water supplies could alleviate these problems, and allows the State to intervene where an agency either determines that alternative supplies are feasible, and fails to act accordingly within some reasonable time period, or determines that there are no feasible alternative supplies and fails to take other action outlined in its GWMP (noting common law constraints to "controlled depletion").

[70] 4. Requires agencies to consider social and environmental issues associated with groundwater depletion, including groundwater dependent ecosystems, surface water-groundwater interaction and the effects of climate change impacts in their GWMPs.

[71] 5. Includes a provision enabling a citizen suit if an agency refuses to make a determination, or to make a GWMP, and the State refuses to take action. Such a provision has a precedent among the special district acts (Cal. Water Code App. § 103–15.1(e)(4)).

[72] These reforms would provide stronger external stimulus for water agencies to undertake more robust groundwater management in cases of serious depletion. At a higher level of generality, the content and accountability structure inherent in these recommendations also applies to other decentralized systems for groundwater management, globally.

[73] At a larger scale and a deeper institutional level, California could better align the legislative mandates of water agencies with the broader demands of contemporary water policy. One way to do this would be to combine agencies that have established environmental mandates, such as resource conservation districts, with traditional water suppliers. There is overseas precedent for such a move combining environmental and water supply functions, for example, in the case of the Murray-Darling Basin Authority in Australia. Alternatively, a reformed institutional structure could bestow upon each of the different statutory water supply agencies a legislative mission that includes considering the larger environmental, social and economic impacts of their actions, including those associated with groundwater depletion; judiciously pruning the institutional jungle to ensure greater resources for each entity to deal with broader concerns, and encourage more efficient operations and better environmental outcomes [*Martin*, 2002].

## 9. Conclusion

[74] Water problems "tend to be defined to fit solutions that are culturally acceptable" [*Connell*, 2007]. In California, local groundwater problems are defined primarily in terms of supply management and augmentation, with only a cursory nod to mandatory and fee-based measures—usually as a last resort—even where such measures would merely

mandate efficient use. Indeed, some groundwater managers use GWMPs to avoid submitting to the common law system of adjudication and the resulting likely pumping restrictions. Nonetheless, at its best, the present system contains elements that may well suggest the way forward.

[75] Groundwater depletion has the potential to cause irreversible results, to the detriment not only of present but also of future generations. If present models of groundwater regulation cannot control groundwater depletion in the present, they will face even further strain in the future. Faced with this future in California and in other areas presently suffering groundwater depletion around the globe, the question is not whether the battlefield terrain of present groundwater laws will transform, but only whether the wells will run dry before the battle begins.

## Glossary

| | |
|---|---|
| DWR | California Department of Water Resources |
| General agency | Type of independent local water agency, the establishment of which is provided for by the Cal. Water Code, and of which there are generally multiple instances in the State |
| GMA | Ground Water Management Act, Cal. Water Code §§ 10750–10767; provides for agencies to adopt GWMPs |
| GWMP | Groundwater Management Plan, made under the GMA |
| IWRIS | Integrated Water Resources Information System: online database of GWMPs kept by the California Department of Water Resources |
| Special district | Independent local water agency, with special powers to control groundwater depletion, which is established under a piece of legislation that is unique to it |
| UWMP | Urban Water Management Plan, made under the Urban Water Management Planning Act, CWC §§ 10610–10657 |

[76] **Acknowledgments.** This paper is based on research for a thesis written from 2009 to 2010 at Stanford University's Law School, in pursuit of the degree of Masters of the Science of Law, made possible by the generosity of the General Sir John Monash Foundation (Melbourne, Australia). I thank Michael Wara and Barton (Buzz) Thompson (Stanford University), for their comments and insights on my thesis, Sandford Clark (University of Melbourne), for sharing his wisdom on water law over many years, and the United States Studies Centre at the University of Sydney, for its support for the Comparative Groundwater Law and Policy Program, which grew out of this work. I also thank the many local water agency staff who took the time informally to speak with me about their agencies and respond graciously to my requests for local documents.

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