2022-04

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Version	Published version
Citation (published version):	A.R. Bell, M.A.A. Shah, A. Anwar, T. Sam. 2022. "Crafting Spaces for Good Water Governance in Pakistan" Water Resources Research, Volume 58, Issue 4. https://doi.org/10.1029/2021wr031265

AGU ADVANCING EARTH AND SPACE SCIENCE

Water Resources Research

RESEARCH ARTICLE
10.1029/2021WR031265

Key Points:

- We present a stylized model of irrigation water resource planning that delineates management from governance
- We identify requirements for scaling up irrigation from small to large scale, in the context of Pakistan's recently ended efforts at irrigation management transfer
- We propose a problemshed approach to identifying communities of common interest, rather than a reliance on hydraulic boundaries

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Citation:
Bell, A. R., Shah, M. A. A., Anwar, A., & Sam, T. (2022). Crafting spaces for good water governance in Pakistan. *Water Resources Research*, *58*, e2021WR031265. https://doi.org/10.1029/2021WR031265

Received 21 SEP 2021
Accepted 1 APR 2022

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Crafting Spaces for Good Water Governance in Pakistan

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Abstract The most significant investment in improved water governance for Pakistan in recent decades—irrigation management transfer under the PIDA Act of 1997—ended with repeal in 2019 in the province of Punjab. Before embarking on the next major experiment, we wish to examine what the opportunity space for improvement in Pakistan's water governance is. We develop a conceptual model that maps the roles of hydrology, infrastructure, management, governance, and learning in shaping water supply. We are motivated by the overarching question of where the best opportunities to improve water governance in Pakistan lie, and suggest in our analysis that the hydraulic constraints of the Indus Basin Irrigation System (IBIS) that have previously been the basis for consideration of scale in water (irrigation) governance are inappropriate. Our key recommendation is instead to identify the key "problemsheds" for the IBIS as a vehicle for identifying scales of intervention and communities of common water interest (possibly at village, union, or tehsil administrative levels) that can allow irrigators to transcend the rigid hydraulic user groupings that irrigation channels impose, and contribute more meaningfully to good local water governance.

Plain Language Summary The Indus Basin Irrigation System (IBIS) is the world's largest gravity-fed irrigation system, embedding more than a century of capital investments and crumbling infrastructure. Identifying a robust approach to maintaining the IBIS and reliably meeting water needs for all across its reach has proved challenging over recent decades. In this article we examine the most recent efforts in Pakistan (irrigation management transfer, or IMT, reform) in the context of what we understand good water management and good water governance to be, and suggest how an alternative approach to examining the system (the "problemshed" approach, where a set of related water problems is used as a basis for identifying the best scale and space for management and governance) could offer more.

1. Introduction

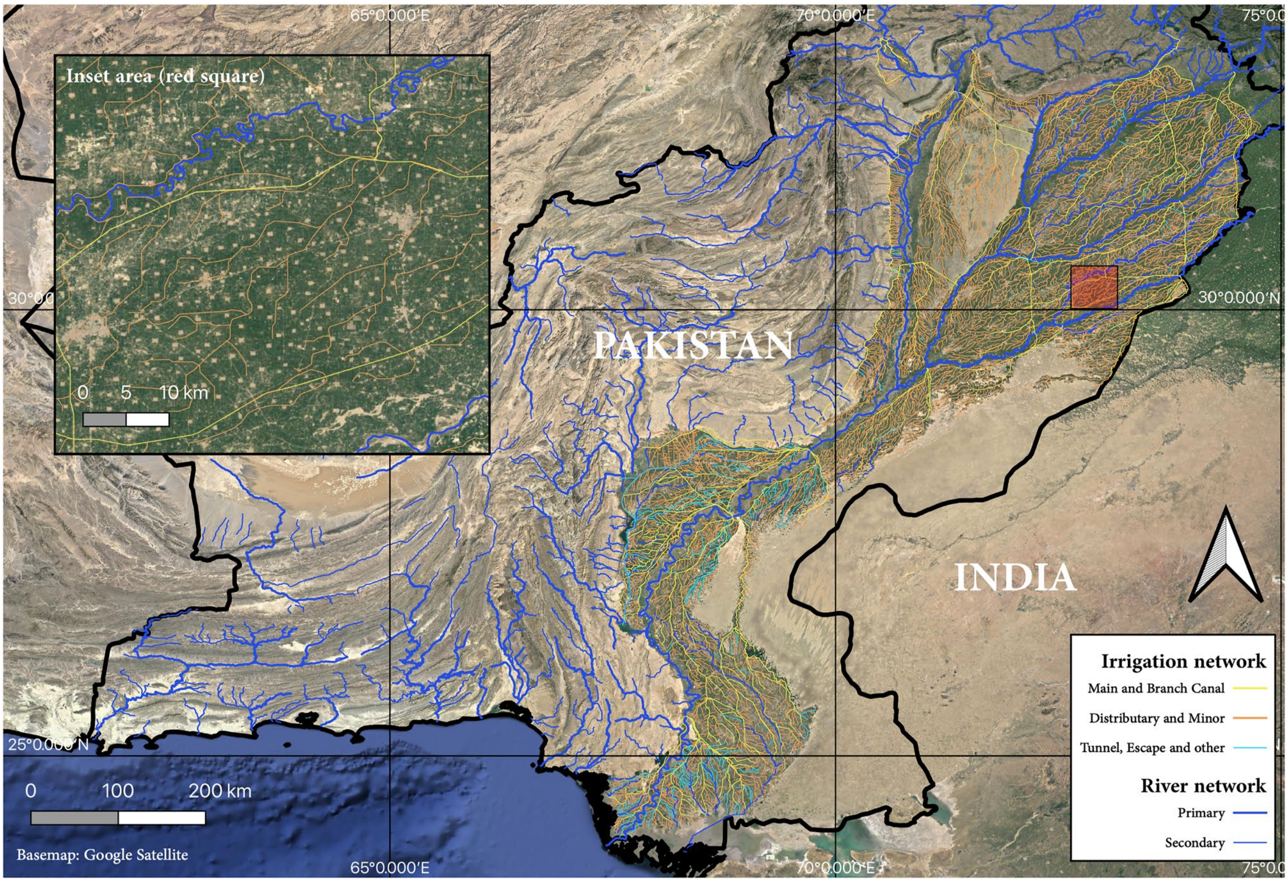
Pakistan's challenges with water resources are well examined in the scientific literature, gray literature, and media. Writing of Pakistan's water as running "dry" (Briscoe & Qamar, 2005) or "on empty" (Altaf et al., 2009), this literature has a focus on the Indus Basin Irrigation System (IBIS), responsible for more than 90% of Pakistan's available surface water withdrawals (World Bank, 2019, pp. 69, 70), and on the performance of institutions for water management both inside and outside of a decades-long process of participatory irrigation reform (e.g., Asrar-Ulhaq, 2010; Ghumman et al., 2011). Across these literature are no shortage of specific recommendations to address failures in water security; Young et al. (2019) (as a current example) offer 12 broad recommendations for improved water security in Pakistan, specifying in turn 76 specific policy reforms and investments (Young et al., 2019, p. Table ES.1) spanning water management at basin and provincial scales, service delivery investments across sectors, and risk mitigation in the face of climate change and an increasingly coupled water-energy nexus. Contemporaneously, a separate World Bank publication makes a related (but different) set of recommendations (World Bank, 2019, pp. 69, 70) to improve irrigation and sanitation performance, and move toward efficient water pricing. With so many different ways to spend money on water, it can be challenging to make sense of both the potential costs, as well as the potential for change and improvements to water processes and outcomes that these specific investments may bring. Importantly, the most significant investment in improved water governance for Pakistan in recent decades—a reform to participatory irrigation management (PIM), also labeled irrigation management transfer (IMT), under the PIDA Act of 1997—ended (for the province with the largest water share, Punjab) with repeal in 2019. Considering jointly (a) the struggles in realizing PIM in Punjab and (b) the volume of specific, costly recommendations for next steps, we suggest a pause before embarking on the next major experiment, and an examination of what the *opportunity space* for improvement in Pakistan's water governance is.

We focus our attention on irrigation and the IBIS, as a central driver of infrastructure and policy development in the assessments cited above. We are motivated by the overarching question of where the best opportunities to improve water governance in Pakistan lie, and following on this, how much should planning be irrigation-led in future developments. We draw on recent literature in water governance to build a conceptual framework for thinking through the dynamics of water supply, as a co-product of hydrology, infrastructure, operational management, and governance. We point in our analysis to the concept of the "problemshed" (Griffin, 1999; Mollinga et al., 2007) as a framework for identifying what locus of issues—in the water resources space, and perhaps beyond—offers the greatest opportunities for improvement.

2. Background

2.1. Pakistan's IBIS

Pakistan's IBIS distributes an annual recharge of around 200 bcm (billion cubic meters) of surface flow from snow and glacier melt, an additional 50 bcm of rainfall, and groundwater usage of about 50–60 bcm; these volumes of water are apportioned across three major reservoirs, 19 barrages, 43 canal commands, and an abundance of shallow aquifers radiating from existing, leaking canals (Basharat, 2019). Storage in reservoirs adds to a little under 18 bcm, a fraction of annual surface water flows and a per-capita storage of about 1,000 m^3 or 30 days (Basharat, 2019). The IBIS (Map 1) distributes its annual flow through a myriad of main canals (primary channels); branch canals, minors, and distributaries (secondary channels); and into the more than 100,000 watercourses (tertiary channels) along which farm households draw water for irrigation. Water is released to main canals by the irrigation department based on 10-day programs, and flows by gravity through to tertiary watercourses, with State responsibility ending at the offtake to the watercourse (*mogha*; Basharat, 2019). Water provi-



Map 1. Pakistan's Indus Basin Irrigation System (IBIS). Showing primary and secondary channels; tertiary channel data is not widely available. Light brown circles throughout inset map show urban areas co-located within dark green, irrigated space.

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sion to channels, measured by the ratio of actual flows to design capacity (or delivery performance ratio, DPR) ranges from 0.43 to 1.57 (Basharat, 2019)—that is, from receiving less than half of the design flow to receiving more than half again the design flow.

Monitoring of water provision below the secondary channels (distributaries and minors) is non-existent (Nagrah et al., 2016). Within watercourses, farmers receive the entire flow of the watercourse on a timed basis, with turn duration dependant on the size of a farmer's landholding, and the rotation of turns specified in a 7-day cycle called *warabandi* (Bandaragoda, 1998; Basharat, 2019). Usage fees for water, *abiana*, are based on crop and cropped area, charged once per crop-season, and are low in design (USD1-2 per acre, per season, with variation across provinces) with incomplete recovery and no mechanism to exclude farmers from water due to non-payment (Pakistan, 2012). *Abiana* has not had the potential to cover operation and maintenance costs since the 1970s when the Zulfiqar Ali Bhutto administration chose not to raise it (Khan, 2009), highlighting the jointly political and technical roots of Pakistan's water management problems; in recent years *abiana* has failed to cover more than 20%–30% of operation and maintenance costs (Pakistan, 2012), which Young et al. (2019) estimate at around USD 102 per hectare of command area per year.

2.2. IBIS Infrastructure as Colonial Governance

A key point to emphasize is that neither farmers along watercourses, nor groups of farmers in watercourses along secondary channels, are now or ever were equal in power or access to water resources. This owes to the prevailing power relations at the time of construction being encoded, in part, into the hydraulic infrastructure of the IBIS.

As an engineering feat, the use of gravity to apportion water to more than 100,000 watercourses is remarkable, but it is important to challenge any assumptions that IBIS construction was rooted in hard science, as "this ignores that the construction of the irrigation systems was a learning process of colonizers who did not practice irrigation within their own country" (Wegerich et al., 2014, p. 14). Politics and privilege of the nineteenth century are embedded in the IBIS design alongside hydraulics, as local elites were engaged in the process of canal digging (Mustafa, 2011; Shahid et al., 2019), with State management at the time limited only to the main canal and local communities applying for the rights to build and connect their own secondary and tertiary channels as they were able (Wegerich et al., 2014). Elite privilege in the IBIS structure may have been exacerbated further with Pakistan's 1947 independence from Britain, as the evacuation of Hindus from their homes along the IBIS without any subsequent land tenure reform left a vacuum in which a strong landholding class could grow (World Bank, 2019). Today, owing to issues of privilege as well as luck and a lack of support for maintenance (Bell et al., 2016; the cycle of "build-neglect-rebuild"; Venot & Suhardiman, 2014), irrigators in the IBIS suffer from head-tail inequity in water distribution both within watercourses (where there is in principle a *warabandi* schedule that could adjust and account for it, but which in practice is skirted by wealthier landholders; Khan, 2009) as well as across watercourses (where there is no such mechanism; Basharat, 2019).

2.3. Theory of Water Governance

We hope in our analysis to place past investments in improved IBIS water resources, as well as the recommendations for next steps, in context—at what problem scale do they offer opportunity for change? We do not intend to summarize the massive literature of water governance here; rather, we dip lightly into it to reach a working contrast of water governance with management, and to highlight a few issues central to governance of the IBIS as introduced above.

Governance in practice takes many different forms, with different modes of governance bringing different tools for management. An enduring conceptualization of the modes of governance distinguishes hierarchy (government), markets, and networks (civil society actors; Collins, 2008; e.g., Thompson, 1991). Among other contributions, hierarchy brings rules, taxes, and sanctions to the management toolkit; markets bring trading and prices; networks bring social norms and oversight. Different tools have different roles to play in achieving objectives such as equity, efficiency, autonomy, sustainability, etc. Importantly, in water governance as elsewhere, these idealized modes do not typically exist in isolation, with multiple modes brought to bear on specific problems at different scales in what might be better described as polycentric, hybrid governance (Pahl-Wostl, 2019).

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Comparing definitions of good governance from the World Bank, the OECD, and UNDP, Schmidt and Matthews (2017) note common features of "enhanced transparency in decision making, fair processes for participation, and subsidiarity—the devolution of decision-making powers to the most appropriate level" (p. 14). Specifically, good water governance is about creating the space in which objectives for its use can be defined in a way that is informed and legitimate. Management is then about meeting those objectives as defined, given hydrologic input, and evaluated by specific resource outcomes.

As a corollary, following Lautze et al. (2011), if one is discussing resource outcomes, one is more likely discussing a management issue. While resource problems are not uncoupled from governance (e.g., objectives are poorly set and difficult to meet), they are more directly linked to management (e.g., poor use of available tools to meet objectives), or just "bad hydrology" (Briscoe, 2009)—conditions more prevalent in poorer countries of frequent floods and droughts, with higher uncertainties that can confound even careful management and governance. For example, the "bad hydrology" of the South Asian Monsoon is characterized by year-to-year variation in snowmelt, glacier melt, and rainfall that confound streamflow prediction in the Indus (e.g., Bocchiola & Soncini, 2019). Various definitions of water governance feature no mention of specific water outcomes nor specific water measures, as they recognize governance as "a means to an end, rather than an end in itself," as Akhmouch et al. (2018) explain in their introduction of the OECD's principles on water governance. Lautze et al. (2011) are explicit in their definition for water governance as "the processes and institutions by which decisions that affect water are made. Water governance does not include practical, technical and routine management … Water governance does not include water resources outcomes" (p. 7).

Importantly as well, good governance does not guarantee good resource outcomes. Natural variation and underlying hydrology play a foundational role in the range of water resource outcomes possible, as well as do socio-economic and cultural factors outside of water systems that nevertheless constrain the scope for governance—Schmidt and Matthews (2017) highlight as an illustrative example that no amount of transparency on its own can necessarily surmount systemic racism or sexism, or other inequities imposed by rule of law.

2.4. Water Governance as Triple-Loop Learning Processes

Pahl-Wostl (2009) and Huntjens et al. (2012) port the organizational theory of triple-loop learning (Flood & Romm, 1996; Hargrove, 2008) to the water resources domain as a means of understanding learning in governance as a dynamic process. We follow this approach to better situate governance processes (setting and meeting objectives) in the hydrology-infrastructure-management space. Huntjens et al.'s (2012) adaptation of triple-loop learning examines water outcomes as being proximally the result of actions, selected as part of some frame of reference (e.g., set of guiding assumptions), shaped by a broader context (of norms, worldviews, actors and viewpoints, etc.). Single-loop learning refers to incremental adjustments to actions in response to suboptimal outcomes, without questioning what those actions are (e.g., adjusting gate closure schedules, outlet diameters, or penalty levels without challenging the schedules or programs they represent). Double-loop learning goes further to adjust the frame of reference—reconsidering the guiding assumptions and possibly putting different tools in place (e.g., discarding a time-share irrigation schedule, gravity-fed delivery system, or program of allocation for something different). Triple-loop learning then refers to adjustments in the broader context within which guiding assumptions are discussed and selected—for example, challenging the set of views, needs, and priorities that are represented in shaping the frame of reference.

The triple-loop learning approach allows us to link the idea of "meeting objectives" to single-loop learning—tuning prices, fees, schedules, etc. to address water supply challenges within a fixed set of rules and infrastructure. It then lets us break apart the idea of "setting objectives" into double- and triple-loop learning. Choosing appropriate toolkits (water markets, seniority water rights, etc.) and infrastructure investments based on critical observations of water resources and management performance lines up with double-loop learning, and the question of "have we set the right objectives?" In turn, establishing whether the appropriate set of needs, priorities and voices are represented in making these selections lines up with triple-loop learning and the question "have we created the appropriate space to set objectives?"

In the conceptual model and discussion that follows, we link these planning and governance-side processes of meeting objectives, setting objectives, and building spaces for setting objectives with the hydrology, infrastructure, management, and competitive use processes they are intended to address.

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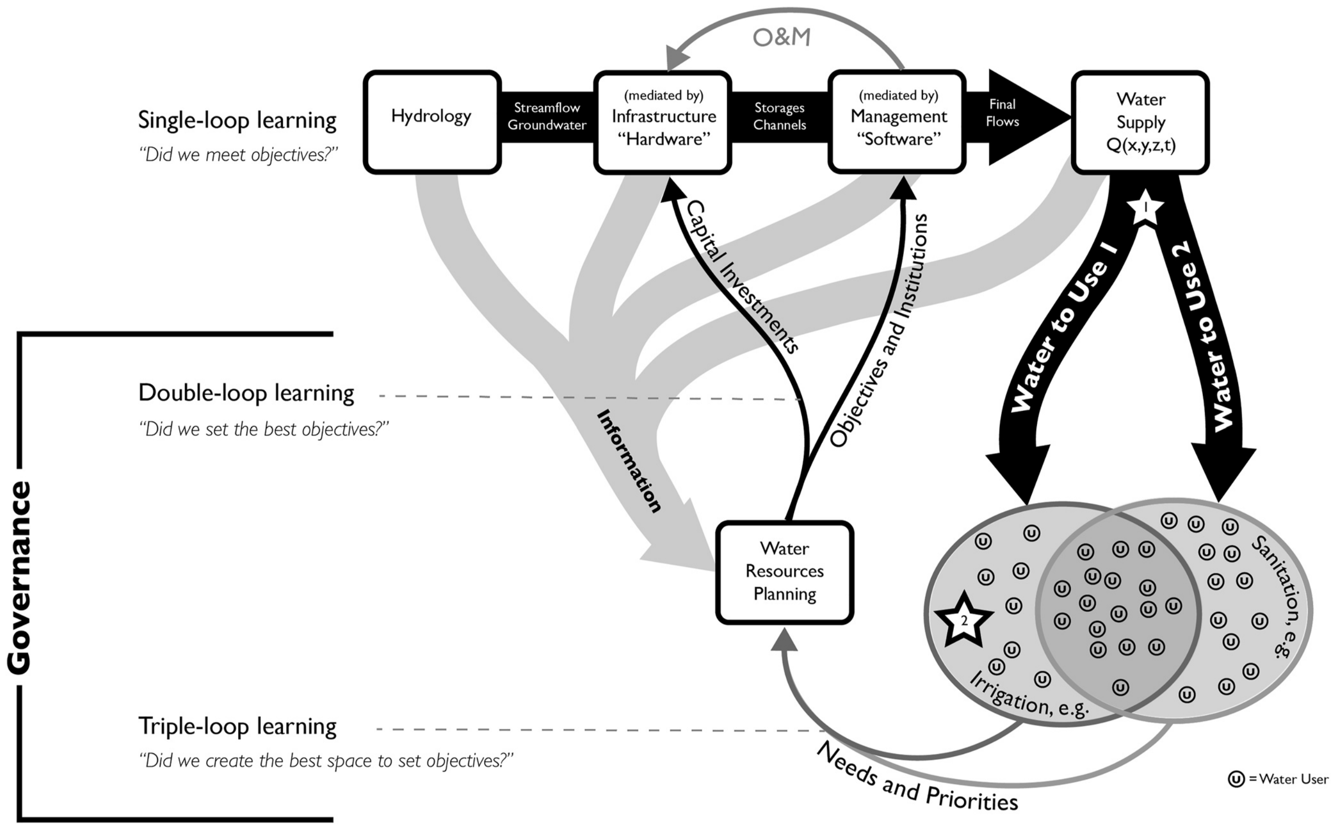

Figure 1. Conceptual model for the construction of some water supply $Q(x,y,z,t)$. Spaces for improved governance are marked with dashed lines following Pahl-Wostl's (2009) application of triple-loop learning (Flood & Romm, 1996) to describe dynamic water governance. Key governance challenges (marked by stars in figure) for a realized water supply are (a) allocation across different uses and (b) allocation across users within a particular use.

3. Conceptual Model

The progression across the top from left to right in Figure 1 outlines the realization of water supply at a given point in space and time. Flows shaped by the hydrology of the catchment are mediated first by any built water infrastructure (such as storage reservoirs, watercourse diversions and channels, or groundwater pumps), and second by management of how and when water resources flow through these natural and built channels; the complementary roles of infrastructure and management shine through their long-held labeling in the literature as "hardware" and "software," respectively (Meinzen-Dick, 1997; Singh et al., 2014). Ideally, water management is informed by data on actual water supplies, and includes active operation and maintenance of existing water infrastructure. We intend for "water supply" in Figure 1 to mean the volumes of water accruing from the actual flows realized through hydrology, infrastructure and management, available for supply to different water uses and thence to users. The package of infrastructure and management instruments in place along this top row follow from some set of defined objectives, and the realized water supply $Q(x,y,x,t)$ is a signal of how well that package harnesses underlying hydrology to meet those objectives. Feedbacks from the "software" in place to incrementally adjust rules or allocate resources to maintain infrastructure correspond with single-loop learning.

The processes below the top line in Figure 1 fill out the processes we have defined as water governance, where those objectives are set. Objectives may be set for hardware or software—infrastructure maintenance or development, new allocations for water supply, or new institutional arrangements (e.g., rights, prices, etc.) to best meet the needs or priorities identified, with informed changes to these objectives lining up with double-loop learning. In turn, competing needs and priorities for water may inform the planning process of "setting objectives," whether by observation, representation, or direct participation. Deliberate adjustments to the space in which needs can be brought, and how well competing priorities are represented in the name of "good governance" line up with triple-loop learning.

We mark with stars in Figure 1 two central but distinct governance challenges of water supply—the allocation of water resources (a) across different uses and (b) across different users within a particular use—and follow the processes through which governing agencies may address them. We are not concerned with the details of the water planning space and how decisions are made—this is already well mapped by Pahl-Wostl et al.'s (2010) Management and Transition Framework. Rather, we are focused on the question of how best the needs of competing uses and users can be represented in water planning and decision-making in Pakistan (i.e., how to achieve triple-loop learning), viewed through the lens of the IBIS. Extending this simple model to the massive IBIS requires us first to consider how things change as shared water systems get bigger, beginning with the challenge of defining what precisely *is* the water supply.

3.1. Scaling up

In small systems—where many participants are the same across uses (e.g., both irrigators and household consumers from the same water source), are known to each other, have face-to-face interactions and are able to build shared norms of trust and reciprocity—users may resolve competing needs across uses, and across users within uses, among themselves (McGinnis & Ostrom, 2008). As systems grow in scale, these governance challenges grow more difficult to address, nonlinearly (Lankford et al., 2016), as real system complexities challenge the simple model we propose in Figure 1—where a distinct water supply and clearly identified users are assumed. Large water user systems are not simply scaled-up versions of small water user systems (Lankford et al., 2016), so that the approach to address a particular problem in one system may not be the appropriate approach for the same problem in a larger (smaller) system (Woodhouse & Muller, 2017).

In particular, water "supply" may be increasingly segmented (across surface and groundwater components, or accessible asymmetrically across space to different users) and technically challenging to monitor or control. Water is a "fugitive, unequally distributed, highly variable yet renewable natural resource" (Woodhouse & Muller, 2017), such that across large systems of flowing water there are limits to who we can meaningfully group together as communities of competing users. Users across uses may grow increasingly separated—physically, socially, economically, etc.—as may users within the same use, adding to the challenge of reaching shared objectives on how water ought to be allocated. Per Claudia Pahl-Wostl, "an 'optimal' spatial or temporal scale on which water should be governed or managed does not exist. Water-related problems are always multifaceted and addressing them requires the inclusion of more than one scale in space and time. Different aspects of water management issues need to be addressed at different scales." (Pahl-Wostl, 2015, p. 107) Theory around governance of common property resources (CPR) pioneered by Elinor Ostrom deals explicitly with this need for "polycentric" governance—centers of decision making at different scales to address different challenges. While the richest part of the CPR literature is case studies of small systems, McGinnis and Ostrom (2008) provide a road map of what the design principles for robust CPR institutions (Box 1) require for larger scale systems with polycentric governance.

Distilling these eight principles, for large resource systems with governance challenges spanning multiple scales, a first criterion for a meaningful center of governance is that it covers a clearly bounded resource and corresponding user community, who are able to adjust their rules and institutions in a way that is consistent with local conditions (Principles 1, 2, 3, and 7). A second criterion is that the user community must be able to make the rules matter—through monitoring, sanctioning, and conflict resolution (Principles 4, 5, and 6). And third, all of this must be compatible with other centers of governance lower or higher in scale (Principle 8). It is through these distilled criteria that we examine previous efforts at improved water governance for Pakistan and look for alternatives. To guide our discussion, we first take a critical look at the modern flagship for polycentric water governance, the Integrated Water Resource Management (IWRM) paradigm.

3.2. IWRM as a Flagship for Water Governance Across Scales

IWRM is defined by the Global Water Partnership (2000) and widely cited thereafter (Ahmed, 2008; Gupta et al., 2013; Lautze et al., 2011; Schmidt & Matthews, 2017) as

Box 1. Design Principles for Robust CPR Institutions (From McGinnis and Ostrom, 2008)

1. *Clearly defined boundaries*: Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself.
2. *Congruence between appropriation and provision rules and local conditions*: Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labor, materials, and/or money.
3. *Collective-choice arrangements*: Most individuals affected by operational rules can participate in modifying operational rules.
4. *Monitoring*: Monitors, who actively audit CPR conditions and participant behavior, are accountable to the participants or are the participants.
5. *Graduated sanctions*: Participants who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other participants, by officials accountable to these participants, or by both.
6. *Conflict-resolution mechanisms*: Participants and their officials have rapid access to low-cost local arenas to resolve conflicts among participants or between participants and officials.
7. *Minimal recognition of rights to organize*: The rights of participants to devise their own institutions are not challenged by external governmental authorities.
8. *Nested enterprises*: Appropriation, provision, monitoring, enforcement, conflict-resolution, and governance activities are organized in multiple layers of nested enterprises.

> "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." (Global Water Partnership, 2000, p. 22)

Core elements of IWRM systems reflect many of the principles of scaled-up CPR from Box 1: Clear definition of a river basin as a resource and user boundary; and flexible, participatory, financially sustainable mechanisms to develop regulatory frameworks, monitor outcomes, and adapt (Borchardt et al., 2016). However, critics of IWRM question how much of successful governance outcomes in IWRM systems owes to IWRM implementation. Bandaragoda and Babel (2010) examine the evolution of IWRM in both developed and developing country contexts, and note that much of what makes IWRM work in practice are traditional, integrative management concepts that predate the formalization of IWRM. They also note that attempts to reform water management in developing country contexts by imposing the institutional structure of IWRM (specifically, organizations to manage competing water needs at a basin scale, or river basin organizations) often end up creating additional institutions rather than replacing older ones, limiting their jurisdictional clarity, and the support they receive. Giordano and Shah (2014) are critical of how narrowly formalized IWRM is; while many traditional practices for integrated management noted by Bandaragoda and Babel (2010) enter into modern IWRM, many do not, and Giordano and Shah (2014) argue that the pursuit of IWRM as a formal goal often takes place at the expense of locally tailored practices that better set and met objectives for water use. They lament that good water governance does not always need to take place in basins, that water scarcity does not always need to be communicated with pricing, and that more participation is not always better. Instead of pushing toward IWRM as an end, they suggest a return to practical, locally tailored water problem solving. Lautze et al. (2011) note that the formalization of specific objectives (such as water pricing) within the IWRM framework circumvents the role that governance ought to play in allowing such objectives to be locally defined. Tying these raised flags together, we suggest that good integration of broad socio-economic and environmental objectives into water governance might better rely on existing cultural and institutional opportunities than on a new layer of imposed institutions. Furthermore, we allow for the possibility that these opportunities may not be tethered to a basin or catchment as the unit of community and objective setting. With this in mind, we turn to examining water governance in Pakistan's IBIS through the conceptual framework we have developed.

4. Application to Pakistan

The "supply" of water for the Indus Basin is less the shared pool of Figure 1, and more the scaled-up water resource paradigm: a segmented cascade of interlinked local supplies, spanning international and provincial boundaries. We constrain our scope at the outset by noting that, though the Indus is a transboundary river shared internationally with India, and shared interprovincially across Pakistan, these competing uses are governed by the enduring (and well regarded; Brichieri-Colombi & Bradnock, 2003) Indus Water Treaty between India and Pakistan (1960) and the Water Apportionment Accord of Pakistan (1991). Institutionally, decision-making regarding the distribution of surface water across the provinces (i.e., interprovincial "setting objectives") lies with the Indus River System Authority; while the technical capacity to build, maintain, and monitor the water systems that distribute available water resources across provinces (i.e., interprovincial "meeting objectives") lies with the Water and Power Development Authority. While these institutions are not without problems and do not resolve all asymmetries in water resources development and access (Mustafa, 2011), as Michael Kugelman notes, "[p]rovincial water distribution has traditionally dominated debates about how Pakistan's water supplies should be divided up. This broader focus, however, masks the troubling state of water distribution on the micro level" (Kugelman, 2009). Of greater interest to us are the governance challenges that arise across uses and among users *within* Pakistan's provinces. Most prominent among efforts at improved water governance in recent decades is the World Bank-funded PIM reform.

4.1. Improving Governance Among Users—IMT in Pakistan

Pakistan's experiment in IMT/PIM began across the nation in 1997 with the Provincial Irrigation Authority Act (PIAA; Bell et al., 2013) The PIDAs were meant to take responsibilities traditionally held by provincial irrigation departments (PIDs) and pass them down through a hierarchy of representative organs—(a) Area Water Boards composed of farmers and engineers at the Canal Circle level, responsible for volumetric contracts with distributaries; (b) Farmer Organizations (FOs) composed of representatives from water user associations (WUAs) at the distributary level, responsible for maintaining distributaries and collecting *abiana* from WUAs; and (c) WUA composed of elected farmers from the watercourse, responsible for collecting *abiana* from farmers and resolving local disputes (Nagrah et al., 2016). In our conceptual model, the IMT reform might be thought of as an instance of double-loop learning—modifying the set of objectives (tools of governance including mechanisms for *abiana* collection, conflict resolution, and representation) to be met, and in particular, modifying the "software" to operate differently with existing "hardware."

For Punjab Province, whose share of IBIS resources is the largest, the PID itself bore responsibility for establishing PIDA, with limited results; the experiment ended with its repeal in 2019 and a renewed ordinance for WUAs. For the downstream province of Sindh, where appetite for reform was perhaps greater and the Sindh Irrigation and Drainage Authority held autonomy from the PID from the outset, IMT reform yet survives (Ul Hassan, 2011). We will not provide a structured critique of the reform here as others have done (e.g., Asrar-Ulhaq, 2010), but instead draw from other authors' efforts to highlight the locally specific issues their analyses raise, and link back to our conceptual model of scaled up CPR governance.

Prominent among management outcomes evaluated in this literature is the level of *abiana* collection; studies focusing on FOs and WUAs find recovery of charges to be both incomplete (Ghumman et al., 2011) and declining over time (Asrar-Ulhaq, 2010). Also prominent are measures of inter-channel equity measured as differences in DPR (Ghumman et al., 2014; Shah et al., 2016), tail discharge (Jacoby et al., 2018), or agricultural productivity (Raza et al., 2009); these studies generally—though not universally (e.g., Shah et al., 2016)—observe lower reliability to persist in irrigation water provision for middle and tail reaches than for head reaches. Jacoby et al. (2018) go further to find inequity in water outcomes *enhanced* under participatory management, most acutely in channels whose upstream users were wealthy landholders with large holdings.

While many studies find positive effects on water outcomes in the presence of strong WUAs (e.g.,Mekonnen et al., 2015), the more careful among them offer a criticism that mirrors some criticism of IWRM. Acknowledging selection bias and a lack of opportunity for controlled study, they note that many WUAs were formed based on perceived feasibility so that successful outcomes can in many cases simply be a signal of strong underlying community and collective action (Chaudhry, 2018; Nagrah et al., 2016). This parallels Bandaragoda and Babel's (2010) observation that collective action in communities leads to successful IWRM outcomes and not the other way around. The appropriate forum within which millions of irrigators sharing tens of thousands of interdependent watercourses can experience those criteria for good governance—transparency, fair participation, and subsidiarity to appropriate scales—remains elusive. The watercourse and the WUA—though retained as a unit of management under the 2019 WUA ordinance—is an imperfect forum as farmers are "members by default" (Wegerich et al., 2014) and do not have the choice to be participants, a key criterion for success in the CPR literature (McGinnis & Ostrom, 2008; Ostrom, 1992). However, above the watercourse scale in the hydraulic hierarchy (e.g., at distributary scales), any meaningful sense of community is lost. It may be that better governance of irrigation water use may be achieved by transcending hydraulic organization and finding opportunities for community formation across (water) channels.

4.2. Water Needs and Supply Segmentation

A major hurdle in creating a space for intersectoral water governance is the set of qualitatively different demands for water that exist across sectors, resulting in infrastructural developments that segment existing water supply rather than invite joint objective setting. Specifically, water use for municipalities, for industries, and for cooling must typically be available regularly and on demand and be of high quality (Molle & Berkoff, 2009). Water for other uses, such as irrigation or hydropower, may have less restrictive demands. In practice this means a reliance on groundwater pumped through tubewells and possibly treated for industrial and municipal uses (e.g., Qureshi & Sayed, 2014), whereas agricultural supply is a conjunctive mix of surface water supply (subject to availability and received on a turn-cycling basis) and untreated groundwater. Molle and Berkoff (2009) highlight this difference as they examine the tension between cities and agriculture as water consumers, challenging the conventional notion that agriculture is simply wasteful of water (e.g., World Bank, 2019) by noting that in practice irrigators make use of flood flows and other water sources that do not match the reliability needs of other sectors. Thus, they argue, it is less apt to accuse agriculture of taking the "lion's share" (Kugelman, 2009) of water resources and more the "hyena's share"; in practice, they continue, agricultural uses yield to higher-valued industrial and municipal uses when those competing demands emerge (Molle & Berkoff, 2009, p. 8). There are two points in their argument that sit in tension—first, that irrigation water is typically in a form not useful to other sectors, and second, that should competing needs arise, irrigation water would be used by other sectors. These are not inconsistent, but rather, highlight that there do exist modes and scales at which the waters taken by irrigators can be made useful to industry and cities.

4.3. Trying Something Different for Improved Local Water Governance in Pakistan

Where Pakistan has previously approached improved water governance, it has had a basis in the irrigated sector and the hydraulic constraints of the IBIS, with decades of experimentation with irrigation management reform as a means toward good water governance. It is not alone in this approach—Senanayake et al. (2015) review participatory irrigation reforms across more than 40 countries—and the outcomes of reform have been well studied elsewhere (and cited in this review). Importantly, where resource outcomes at the level of WUA have been positive in Pakistan, researchers have been careful to suggest that these may stem from strong community institutions that pre-existed (and survived) IMT reform (Chaudhry, 2018; Nagrah et al., 2016), rather than being attributable unambiguously to IMT reform. In truth, though IMT may in some cases appear to show good governance processes and (related or not) good resource outcomes, theory on CPR governance suggests it is unlikely to be the cause.

We do not examine the functioning of the IBIS vis-a-vis these principles in detail, but highlight that Pakistan's design for IMT reform (in which users are constrained to participate in the WUA formed from their watercourse, with representatives from WUAs participating in higher levels of governance) violates our distilled criteria for scaled up CPR (most saliently violating Principles 3, 4, 5, and 7 of Box 1). Farmers are not strongly able to modify operational rules, nor is it clear that WUAs form a clear community of common interests that can be represented appropriately at higher scales of governance. Monitoring and sanctioning is non-trivially more complicated for large systems such as the IBIS. Perhaps most importantly, the organization of participants is baked into the hydraulic structure of the IBIS, with participants having no flexibility to self-organize. Our purpose here is not to belabor failures of IMT in Pakistan, but only to highlight that even where it may appear to be working in practice in places, our understanding of participatory governance suggests that this perhaps more due to the strength of pre-existing community governance than the reform itself. We propose that there may be other entry points,

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at alternative scales, for intersectoral good water governance in Pakistan, and we close our discussion with an attempt to redirect attention toward them.

4.4. Building Out to IBIS "Problemsheds"

In previous versions of this manuscript, we wrote prescriptively that rather than the hydraulic unit, the administrative unit (such as a district, tehsil, or village) more meaningfully embedded communities of common interest, mechanisms for people to care about what happened to other people across watercourses, and meeting points for multiple competing uses of water. In our view, this approach would be consistent with efforts at water districting, for example, which in some cases go further, by establishing special jurisdictional boundaries for water users with the purpose of best matching water supplies with users. In such systems, greater flexibility in matching supply with demand (through the capacity to shift boundaries or alternatively, allow interlocal exchanges; Mullin, 2009) of administrative units may more closely create the CPR conditions for scaled-up water governance (Box 1). However, a procession of reviewers with experience and history in Pakistan's water reform efforts correctly highlighted our folly in believing we knew what the next step was, without evidence to support it.

With this wisdom of experience, we instead draw on the suggestions made by critics of the prescriptive nature of IWRM, who highlight the importance of shifting from "watersheds" as the assumed scale of interest to identifying "problemsheds"—containments of inter-related problems, within some scale, whose joint solution includes a water resource strategy at that scale (Giordano & Shah, 2014; Woodhouse & Muller, 2017). Problemsheds have a history in environmental management going back at least a half century as a conceptual alternative to watersheds (Fisher, 1967; Thomas, 2020). Griffin (1999) proposed a widely cited geographic basis for the problemshed as "large enough to encompass the issues but small enough to make implementation feasible"; Mollinga et al. (2007) later translated problemsheds to "issue networks," formally marking out political spaces as complements or alternatives to physical, geographic spaces (i.e., watersheds) as bases for defining scope and scale in problemsheds. Mollinga (2020) further emphasizes the context specificity of water problems, and the importance within the problemshed approach of building a locally specific governance arrangement from the problem at hand, rather than seeking the "law-like, universally valid" approaches for which IWRM has been criticized.

Importantly, the problemshed is *definitionally* the locus of linked demand challenges (for water or beyond—energy, food, or other politically linked concerns) to resolve, whereas the watershed is only *assumed* to be, as a norm within IWRM approaches (Muller, 2018). Similarly, a problemshed approach would represent a demand-centric contrast to the supply driven thinking that places hydraulic structures within a command area as central to governance. For the Ganges-Brahmaputra-Meghna system, for example, the problemshed approach allows linkage from irrigation through to upstream storage, hydropower, flooding, and sedimentation problems (Hanasz, 2017). At a much smaller scale, a companion-modeling approach to problemshed definition in Northern Ghana moved outward from the issue nexus of riverbank erosion and flood planning to build a problemshed encompassing farm livelihoods, traditional authorities, local governments, and higher-scale ministries (Daré et al., 2018). In urban water spaces more specifically, this demand-centric approach allows both scientific reasoning and political reasoning to blend, with notions of watershed, problemshed, and "policyshed" converging into spaces that are (following Griffin) large enough to envelop issues but small enough that solutions are implementable (Coleman, 2018).

Griffin's (1999) definition is instructive in the IBIS case. Irrigation commands are watersheds in reverse—variation and uncertainty in water supply rises from main channel flow out to secondary and tertiary channels, amplified by all upstream hardware, software, and user decisions. Issues at irrigation command heads are thusly coupled to downstream outcomes across all watercourses, but the irrigation command scale is not feasible as a problemshed. Instead we suggest working outward from a core problem—as Daré et al. (2018) did for erosion and flood planning in Ghana, and as Mollinga (2020) described doing for supply inequality in irrigation in South India—to characterize meaningful problemsheds for the IBIS system. Drawing on our conceptual model (Figure 1) and the challenges of scaling up water governance, we suggest the core problem to be water supply reliability, with an associated question such as "what connection of linked water flows and related community of water uses/users maximizes supply reliability across this community?" Possibly, the appropriate problemshed might be better conceived in Mollinga's "issue network" sense, stepping beyond water to encompass linked challenges such as electricity generation, grain self-sufficiency, urban development, or others. Indeed, our core suggestion in this regard is to look beyond hydraulic communities, however far beyond that may be.

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Addressing this question will require a commitment to participatory processes to rival or exceed the efforts of Daré et al. (2018) and other examples of the companion modeling approach (e.g.,Naivinit et al., 2010)—multiple years of discussion, planning, role-play exercises, simulation modeling, etc. However, we suggest that the launch point and unit of analysis for this work is clear—it is the WUA, or *Khal Panchayat*. While imperfect as a "community of common interest" as we have already outlined, they have survived the end of PIM in Punjab province and continue as a unit of participatory local governance under the 2019 WUA ordinance. Moreover, our own work has demonstrated both their function and importance as a unit within the larger irrigation system. In a year-long study of the role that water flow information at the watercourse level could play in shaping water decision-making along watercourses in a distributary (Shah et al., 2022), we observed WUAs to be active spaces for irrigation conflict reporting and resolution (and flow information to be transformative in how conflicts were perceived). Moreover, through a years-long process to develop instrumentation for this study, we identified volumetric flow measurement below the watercourse outlet to be infeasible due both to fouling (by sediment-laden water at low flow rate) and tampering, with ultrasonic depth measurement at the outlet scale emerging as the most reliable mode and scale of measurement. This finding points to water supplies received at the watercourse level to be the finest-scale measure that is knowable at scale, in real resource time, and to WUAs as critical mechanisms for governing water resources below this.

Instrumented at scale across the IBIS, it is plausibly knowable what water receipts are and have been across different WUAs, and who potential other linked users, uses and issues—tied to other WUAs, municipalities, or industries, even—may be. The capacity for self-organized exchanges across WUAs or between WUAs and non-agricultural users could potentially transform the hydraulic system into something more consistent with Ostrom rules for CPR, decoupling the dependency of a given WUA from the infeasibly large irrigation command area, and link water outcomes to a more tractable, local problemshed.

We do not know from the outset what could emerge from this process, and would not know without committing to the kind of engagement undertaken by Daré et al. (2018). We strongly suggest that the imperfect community of a WUA is an inherent property of the IBIS (and other large-scale irrigation systems like it), while the scale and mode by which WUAs might meaningfully engage with each other (and potentially other uses/users) is neither inherent nor easily identified at present. A problemshed approach, engaging WUAs as a most basic community of users and building around the problem of water supply reliability, may be the best next (and in the spirit of adaptive management, not likely the last) step to demarcating the scale and scope of meaningfully connected water (and other resource) users in the IBIS and defining what local water supplies (with clear and connected groups of users, as imagined in our conceptual model) are. More broadly, we add this argument in support of problem sheds as a potentially useful entry point to identifying overlapping water resource problems, the human and physical scales they embed, and thus potential focal scales for future water resource investments. Importantly, in as much as problems and contexts may change over time, so then may problemsheds, issue networks, and appropriate scales; in this, a problemshed necessarily invokes an adaptive, continuous (double or triple-loop) learning approach and an expectation of shifting boundaries. By this, we are encouraging future efforts to set aside the expectation that hydraulic scales (of watercourses, distributaries, and canals) are necessarily focal points for governance solutions.

5. Conclusion

Theory tells us that interventions aimed at improving the governance of some water resource challenge at some scale should improve voice, representation, and control at that scale, and not simply add responsibility. Literature from across South Asia and Pakistan in particular tells us that IMT in practice is often just this—additional burdens for local bodies without the essential freedoms to self-organize, self-define and resolve conflicts that CPR theory tells us are necessary. Furthermore, for very large irrigation systems like the IBIS, the coupling of water outcomes in far reaches of the system to decisions and withdrawals made very far upstream make it difficult to bound people and resources together without drawing in the entire irrigated basin.

However, we emphasize to those thinking in irrigation terms that water supply challenges are not only about allocating resources among users, but also across different uses, and highlight the importance of finding places for the right voices (not necessarily "more" voices) in the water planning process to facilitate triple-loop learning and create the appropriate space for setting water objectives. Bringing diverse water uses together in a decision space is perhaps best enabled when those distinct use groups are part of communities of common interest, but it is not obvious what such communities of common interest are. Stepping outside of hydraulic divisions (and through issue networks, possibly even beyond water itself) to improve local water governance may be Pakistan's opportunity to bring surface water supplies to efficient, highly valued uses below the scale of a canal command, and possibly bring better focus to the challenge of reconciling groundwater and surface water use across sectors and linked issues.

Acknowledgments

The authors would like to acknowledge the suggestions of all reviewers of this and previous versions of the manuscript, all of which contributed to improving its critical contribution. This work was supported by the USAID-funded project (Grant Number 720391181O00003) "Water Management for Enhanced Productivity" led by the International Water Management Institute.

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