Water governance in Brazil

The need to share water in the anthropocene

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3.

3. WATER PARADIGMS AND THE PHASES OF RIVER BASIN DEVELOPMENT

3.1. Introduction

Water governance is often based on a world view regarding how governance should be undertaken. This has been captured in the literature in terms of the concept of water paradigms. This chapter discusses how water governance paradigms have changed over time (Biswas & Tortajada, 2010; Gupta, Pahl-Wostl & Zondervan, 2013; Pahl-Wostl, 2017) and how they have influenced water management and water sharing. In different parts of the world, the paradigms are at different phases of evolution (Allan, 2005; Agyenim & Gupta, 2013).

This chapter explores the question: How does the existing literature on water governance paradigms address water sharing? In exploring this question, this chapter begins by outlining the three main paradigms for water governance: hydraulic engineering (see 3.2.2), IWRM (see 3.2.3), and adaptive water governance (see 3.2.4). It then discusses the phases of river basin development (see 3.3) and proposes a framework (see 3.3.3) that links the governance paradigms to various components of river basin development. The chapter concludes with a reflection on the value of recognizing inclusive adaptive water governance as a paradigm for governing water (see 3.4). This reflection is further developed in the last chapter as a key paradigm for governing water in the Anthropocene.

3.2. Key paradigms

3.2.1. Introduction

The literature on water addresses many kinds of governance paradigms. Hassan (2010) identifies eight paradigms: 1) spiritual-religious, 2) aesthetic–recreational, 3) scientific, 4) ecological, 5) hydraulic engineering, 6) financial-economic, 7) managerial governance, and 8) legal–ethical. The spiritual-religious paradigm is deeply embedded in indigenous and religious beliefs (Hassan, 2010). The aesthetic–recreational paradigm recognizes water as a source of relaxation, pleasure, and revitalization beyond the utilitarian function (Hassan, 2010). The scientific paradigm considers water characteristics such as chemical elements, purity, and bacterial pollutants (Hassan, 2010; Baird et al., 2021). The ecological paradigm highlights the importance of water for ecosystems (Dunlap et al., 2000; Hassan, 2010). The hydraulic engineering paradigm emphasizes the role of technology in controlling water (Pahl-Wostl et al., 2007; Lopez-Gunn, 2009). The financial-economic paradigm examines how water is embedded in our economic-financial system (Ramachandraiah, 2008; Hassan, 2010). The managerial paradigm deals with the increasing demand for water by multiple users and advocates for governance and integrated water resource management (Rahaman & Varis, 2005; Jones et al., 2006; Abdullah & Christensen, 2004; Butterworth et al., 2010). The legal – ethical paradigm focuses on how people and communities develop ethical rules to deal with water and institutionalize them in their legal instruments (Hassan, 2010).

The spiritual-religious and legal-ethical paradigms have the oldest roots. They can be traced back to early civilizations as in Egypt, where it was unethical to pollute water, and to Islamic law, which included provisions on sharing water (Delapenna & Gupta (eds.), 2009; 2021). The hydrological engineering paradigm arose in the first millennium BCE. It gained momentum with the spread of Roman and later Islamic water technologies and became a major paradigm during the industrial age. This was followed by aesthetic-recreational, scientific, and ecological approaches to water governance along with the growing realization of the importance of water for the economy, which led to increasing economic valuation and financialization of water.

These disciplinary paradigms eventually fed into interdisciplinary paradigms. The literature reveals three key interdisciplinary paradigms, namely: hydraulic engineering, Integrated Water Resource Management (IRBM/IWRM), and Adaptive water governance. Scientific elements are included in all the interdisciplinary paradigms; however, most inadequately cover spiritual religious approaches (Hassan, 2010). Ecological approaches are probably accounted for most in adaptive water governance, but also included in IWRM. While hydraulic approaches emphasize an engineering approach, IRBM and IWRM emphasize also social engineering and adaptive water governance also looks at nature based solutions (Schoeman, Allan & Finlayson, 2014). Table 3.1 shows the ideal-typical characterizations of the paradigms within the water sector which is then systematically explained in the following sections.

Table 3.1. Ideal-typical characterizations of the three paradigms

Main characteristic	Hydraulic engineering	IWRM	Adaptive Water Governance
Purpose	Using hydraulic and engineering knowledge to address specific goals	Using transdisciplinary knowledge to address multiple goals in an integrated manner	Using transdisciplinary knowledge to address multiple goals under conditions of uncertainty
Governance structure	Water governance is centralized and hierarchical, with narrow stakeholder participation	Water governance is decentralized with stakeholder participation and aims at an integrated solution; a tendency to emphasise efficiency	Water governance is polycentric and horizontal, with broad stakeholder participation; aims at diversity of solutions and adaptive capacity; plural approach
Coverage	Sector-specific	All sectors	Cross-sectoral analysis
Scale	Single level	All levels; linear	Cross levels; non-linear
Information management	Focus on limited information	Encourages sharing information	Accepting the uncertainty of information
Infrastructure	Centralized massive infrastructure	Decentralized infrastructure, diffuse control	Decentralized infrastructure with diverse goals
Finances and risk	High concentrated use of finances, sunk costs	Diverse financial resources; hybrid finance instruments	Diverse financial resources; hybrid finance instruments
Practices	Hard engineering	Hard and soft engineering, public participation, cost recovery	Hard, soft and nature-based solutions; continuous learning; risk management, experimentation
Expected consequences for society (focused on water sharing)	Can address water for irrigation/ storage/ electricity, but can also lead to new problems: equity & environmental issues often neglected; power is concentrated	Can address water problems, but tendency to commodify and privatize water, insist on cost-recovery, thereby reproducing inequalities and marginalizing nature	Can address changing and uncertain water problems, but tendency to commodify and privatize water, insist on cost-recovery, thereby reproducing inequalities and marginalizing nature

Source: This table builds on Pahl-Wostl et al. (2007); Agyenim (2011)

3.2.2. Hydraulic engineering paradigm

The hydraulic engineering paradigm can be defined as a technocratic "command-and-control" approach (Pahl-Wostl et al., 2007), which aims to divert water for single or complex specific uses often related to national priorities (Lopez-Gunn, 2009). It is based on planning and building physical water structures such as hydropower facilities, irrigation canals, sewage systems, storage dams, and inter-basin transfer infrastructure (Bell, Design & House, 2020). These structures can be recognized as instruments of water management and taken as symbols of modernization (Linton, 2010). The development of infrastructure relies on technical fixes and often overlooks issues related to negative social and environmental consequences.

In the late nineteenth and throughout the twentieth century, the hydraulic engineering paradigm influenced water management around the world with the aim to control the natural environment through human transformations (Swyngedouw, 1999; Lopez-Gunn, 2009; Custódio, 2012). State-led projects and centralized institutions dominated the development of physical water infrastructures (Varady, Meehan & McGovern, 2009). Large hydraulic bureaucracies were established, supported by the United States' liberal notion of development (Gleick, 2000; Klingensmith, 2007; Ahlers et al., 2014). This led to the construction of dams of monumental scale, first in the global North and then in the global South (Lehner et al., 2011; Zarfl et al., 2015). These projects were considered evidence of economic development and technological progress (Ahlers, 2020). The resulting 'hydrocracies' intended to produce hydro-political systems in which rivers were controlled by dams and dykes (Rap, 2006; Boelens, 2008; Philippus Wester et al., 2009, p.395).

During this period, water governance was centralized and hierarchical with limited stakeholder participation. Hard engineering (i.e., large dams, mega-hydraulics, and hydropower projects) was used to dictate water-sharing processes. In fact, hard engineering has often been intentionally used by states as a political strategy for controlling space, water, and people in many countries (Worster, 1992; Wehr, 2004; Swyngedouw, 2007; Boelens, 2008; Wester, 2008; Wester, Rap & Vargas-Velázquez, 2009; Rap & Wester, 2017). The purpose of this, as is the case in Brazil (Chapter 5), is to ensure allocation of water resources to specific users, particularly energy, agriculture, and human consumption sectors. In doing so, there was an implicit emphasis on meeting the needs of society.

Hydraulic engineering has four major benefits: First, it benefits large segments of populations. Many have gained access to water world-wide through infrastructural works even in the developing world (Cashman & Ashley, 2006; Tockner et al., 2016). They have gained access to electricity through the implementation of hydroelectric plants (Ledec & Quintero, 2003). Second, it has provided efficient solutions to control rivers to protect cities and dryland agriculture from flooding (Pahl-Wostl et al., 2007), and removing sewage as in ancient Rome. Third, hydrologists and engineers have addressed pollution through wastewater treatment plants (Pahl-Wostl et al., 2007). Fourth, they have often effectively predicted water demand and supply curves.

However, it has five major drawbacks. First, supply of water and electricity has often exacerbated inequalities world-wide but especially in many Southern countries, including Brazil, not least by ignoring existing water access rights. When such water supply has been subject to pricing and cost recovery, it has adversely affected poor farmers and households (Grafton, Chu & Wyrwoll, 2020). Second, it is based on a utilitarian perspective that aims at maximising resource exploitation for economic gain (Lopez-Gunn, 2009). Third, infrastructure often leads to relocating people and such relocation costs and loss of livelihoods have been underestimated in physical water infrastructures (Ahlers, 2020, p. 4), often being justified by the intention of providing water services for the greater good by increasing food production and controlling floods. Fourth, hydrologists and engineers have usually dealt with water-related environmental problems in isolation, not considering long-term consequences (Pahl-Wostl et al., 2007), cumulative damage (Voroosmarty et al. 2010) and climate change. They have mainly focused on technological possibilities and characteristics of rivers while overlooking negative ecological issues, such as: fragmentation of river ecosystems (e.g., blocking the fish migration to spawning areas); disruptions of river flows by the installation of dams; the ecological flow necessary to guarantee adequate development of aquatic life and ecosystem services; and were slow to respond to biophysical feedbacks (Corenblit et al., 2007; Gupta, Pahl-Wostl & Zondervan, 2013). Fifth, in such large capital intensive decision-making procedures, there is little space generally for public participation.

In relation to inclusive development and water sharing, the hydraulic engineering paradigm addresses water-sharing with a focus on the distribution and conveyance of water resources through hard engineering systems (e.g., dams, hydropower, irrigation systems, and water treatment facilities) (Allan, 2003). This mainly entails water-sharing between three sectoral users: energy, agriculture, and human consumption (Bell, Design & House, 2020). Water management is centralized, sectoral, inflexible, and concentrated in the organization that regulates the engineering facility, such as irrigation canals, storage dams, and inter-basin transfer infrastructures.

3.2.3. IWRM paradigm

The relatively narrow focus of the hydraulic paradigm gave rise to the integrated water resources management paradigm (IWRM). IWRM is defined by the Global Water Partnership as

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

IWRM simultaneously characterises water as a finite resource and an 'economic good', focusing on integrating sectoral responses to water management and water uses for people, food production, nature, industry, and other aspects. It emphasizes stakeholder participation and combines diverse viewpoints and objectives (Medema et al., 2008; Jønch-Clausen & Fugl, 2001). It also seeks to achieve cross-agency coordination for equitable allocation of water and protection of ecosystems (Hooper, 2005; Agyenim, 2011; Gain, Rouillard & Benson, 2013) and sees the river basin as the most appropriate scale for water management (van den Brandeler, 2020).

IWRM became more prominent following the 1992 International Conference on Water and the Environment in Dublin (see 1.6) and the United Nations Conference on Environment and Development in Rio de Janeiro (see 1.6), which called for integrated and participatory water management at the lowest appropriate level (Savenije et al., 2014; ICWE, 1992). IWRM initiatives have been influencing academic and professional circles and IWRM has been promoted by international organizations such as the World Bank, the Global Water Partnership (GWP), the International Water Association (IWA), the World Water Council (WWC), the International Network of Basin Organisations (INBO), the International, American, and Canadian Water Resources Associations, the Stockholm Water Symposium (Hooper, 2005; Abers, 2007; Abers & Keck, 2013), many development banks; and the 2030 Agenda (see Table 1.4).

Integrated River Basin Management and IWRM often use river basins as management units and entail deliberation between users, the development of management plans, water pricing, and payment for ecosystem services (van den Brandeler, Gupta & Hordijk, 2018). IWRM practices have been integrated in national-level legislation, policies, and organizations (Rahaman & Varis, 2005; Jones et al., 2006; Abdullah & Christensen, 2004; Butterworth et al., 2010). IWRM deals with water resources in terms of surface and groundwater, upstream and downstream, and quantity and quality, considering these aspects as a whole system influenced by supply and demand (Butterworth et al., 2010; Molle, 2009; Savenije & Van der Zaag, 2008). This helps in prioritizing efforts towards better governance, mobilizing financial resources, building capacity, and sharing knowledge (Rahaman & Varis, 2005).

Compared to the hydraulic engineering paradigm, IWRM has incorporated many ecological protection measures, and recognized ecosystems as legitimate water 'users' (Volenzo & Odiyo, 2018). Social measures have been accounted for by encouraging decision-making based on hydrological boundaries and broad stakeholder participation providing a political platform for basin planning, negotiation, and promotion of shared values (Schoeman, Allan & Finlayson, 2014) (Section 4.3.2.1). However, this paradigm is strongly linked to neo-liberal capitalism and simultaneously prioritizes economic development through the commodification and privatization of water, cost-recovery and instruments such as water markets (Bakker, 2014).

IWRM has been criticized for being too broad, vague and unimplementable (Biswas, 2008; Agyenim & Gupta 2012), too expensive to implement (Agyenim, 2011; Crase & Cooper, 2015), and its prioritization of economic profits often leads to externalization of environmental goals and the prioritization of certain sectors (Biswas, 2008; Siegmund-schultze et al., 2015). Although it encourages participation, this is often not taken seriously resulting in symbolic or manipulative participation (Crase & Cooper, 2015; Anggraeni, Gupta & Verrest, 2019). Its emphasis on the commodification and privatization of water can make water unaffordable for the poor (Rahaman & Varis, 2005) and can reproduce existing inequalities where or when cost-recovery is prioritized (Rusca & Schwartz, 2018). It has also been accused of lack of transparency (Gerlak & Mukhtarov, 2015).

With respect to inclusive development and water sharing, the IWRM paradigm addresses water-sharing using mechanisms such as participation, which deal with water-sharing mainly between sectoral users. However, it focuses on "de-politicizing water allocation dilemmas by advancing optimization models" (Gerlak & Mukhtarov, 2015, p. 266). This notion is based on water markets, which is also considered a sharing mechanism, and the reallocation of water from lower to higher value activities (Brewer et al., 2008). Furthermore, although IWRM intends to ensure water for nature and marginalized groups through participatory approaches (e.g., river basin committees), it has often not been sufficiently effective in achieving this goal (van Koppen & Schreiner, 2014).

3.2.4. Adaptive water governance paradigm

Adaptive water governance is an emerging paradigm. It broadens the lenses of the two paradigms presented before, bringing together scholars from additional disciplines and taking into account growing global ecological challenges. Adaptive governance can be defined as "a collaborative, flexible, learning-based approach to ecosystem management that relies on a diverse network of institutions and organizations across multiple levels from the local to the international" (Akamani, 2016, p. 6; Hughes et al., 2005; Olsson et al., 2005). It encourages rethinking key assumptions and coordinating water resources systems on account of the complexity and uncertainty associated with climate variability and change in the Anthropocene. This paradigm recognizes the interdependencies and feedback loops between systems and across scales. It is characterized by: risk assessment, adopting redundancy rather than efficiency, polycentric and horizontal governance, public participation, learning and experimentation, fair governance, and a bioregional approach (Huitema et al., 2009; Gupta et al., 2010).

Adaptive water governance is rooted in the adaptive management approach proposed in the early work of Carl Walters at the end of the 70s

(Walters & Hilborn, 1978; Medema, Mcintosh and Jeffrey, 2008). It has a multi-decade history of development and application, as does IWRM, both perspectives influencing the emergence of global water management in the late twentieth and twenty first centuries. Adaptive water governance recognizes people and ecosystems as "complex, unpredictable and difficult to control, and encourages ongoing learning, rather than reduction (of water use), as the key to coping with complexity and uncertainty" (Schoeman, Allan & Finlayson, 2014, p. 382).

Adaptive water governance practices encourage the use of nature-based solutions to mitigate water-related risks (Nesshöver et al., 2017), incorporating adaptive capacity and process-based learning in complex systems. The adaptive capacity of institutions has six main properties: (i) variety (considering diversity and redundancy); (ii) learning (single, double, and some aspects of triple-loop learning); (iii) room for autonomous change (enabling people to respond); (iv) leadership (enabling different types of leadership); (v) resources (adequate quantities of different types of resources), and (vi) fair governance (considering fairness and legitimacy over efficiency) (Gupta et al., 2010; Hurlbert, 2016). Accordingly, adaptive capacity allows for continuous learning (Smit & Wandel, 2006; Hurlbert, 2016).

Adaptive water governance is remarkably similar to IWRM considering their shared goals of human well-being, and sustainability (Schoeman, Allan & Finlayson, 2014). In contrast, adaptive water governance addresses social and ecological inclusiveness in terms of uncertainties in the environment and unpredictable human relationships (Gunderson et al. 1995). It has proven to have relational strengths as it incorporates process-based learning in complex adaptive systems and enables decision-making despite uncertainties (Pahl-Wostl et al., 2007) through learning about the process of governance (Shea et al. 1998). It also deals with the application of quasi-experimentation to improve responsiveness to biophysical feedbacks and make learning from policy and management more efficient (Schoeman, Allan & Finlayson, 2014). Unlike the hydraulic engineering paradigm, adaptive water governance considers nature-based solutions in the provision of infrastructure services (Nesshöver *et al.*, 2017).

However, adaptive governance remains rooted in the neo-liberal paradigm and many question its relevance (Hurlbert & Diaz, 2013). Despite being an operational approach, adaptive governance has only been effectively applied in a small number of cases (Allan & Stankey, 2009; Hurlbert, 2016). Generally, this paradigm "remains more an ideal than a reality" (Allen & Gunderson, 2011). This is due to the ambiguity in how the paradigm is defined, its complexity, certain institutional barriers, risks, and costs (Medema, Mcintosh & Jeffrey, 2008).

In relation to inclusive development and water sharing, the sharing principles of adaptive management build on the IWRM approach, taking it a step further by addressing the uncertainty and inseparability of social and ecological systems. Adaptive management has a polycentric nature wherein water management is not concentrated in one facility (Pahl-Wostl et al., 2007) and draws more attention to nature and the importance of learning. Through its principle of redundancy, it advocates for multiple water sources and supply systems, which, in theory, also ensures multiple water sources for different users and thereby enabling sharing. The paradigm lacks a measuring mechanism beyond "normative judgments of researchers ranking institutional practices" (Huitema, Mostert & Pahl-Wostl, 2009, p. 49). Moreover, adaptive governance does not specifically deal with sharing, equity and justice issues (nor do the hydraulic engineering and IWRM paradigms).

3.2.5. Analysis of water-sharing in the basin

Although, as mentioned above, the three paradigms do not specifically deal with water-sharing or equity issues in their conceptualization, their implications for water-sharing and justice can be inferred. This section compares how the three main paradigms address inclusive development and water-sharing considering their positive and negative effects.

The hydraulic-engineering paradigm addresses water-sharing with a focus on distribution and division of water resources through hard engineering systems (Allan, 2003), the IWRM paradigm and adaptive water governance address water-sharing primarily in terms of the market (i.e., those who can pay for water) and participation.

Regarding inclusiveness, I assess these paradigms taking into account their social, ecological, and relational components (see Table 3.2). First, the hydraulic engineering paradigm has proven to have social strengths as it benefits large segments of populations (Gupta & van der Zaag, 2008; Molle, Wester & Hirsch, 2009); that is, on a social level, it increases standards of living through infrastructural projects and at-

Table 3.2. Assessing the paradigms in terms of water-sharing

Hydraulic engineering

Water-sharing relations		Focused on water sharing (distributing-dividing) between users of hard engineering (between three sectors: energy, agriculture, and human consumption)	
ID	Social	[+] Increases standards of living through infrastructural works (e.g. energy access; irrigation systems); predicts water demand and supply curves;	[-] Supply of water and electricity aggravate inequality (e.g., affordability is a barrier for low-income households); Utilitarian view of the water; underestimates costs of relocating people and loss of livelihoods
	Ecological	[+] Contributes to flood management control (e.g., large dams); Addresses pollution through wastewater treatment plant	[-] Dominance of human activities over natural processes overlooking many negative ecological issues
	Relational	[+] Creates new relations in terms of those who own and control the distribution of water and related benefits; this is positive in that it enables water distribution and food production	[-] narrow stakeholder involvement creating issues of integrating information sources, legitimacy, and justice

IWRM

Water-sharing relations		Focused on water sharing dividing between sectoral users using the basin as the natural management unit through mechanisms (e.g., water pricing, payment for ecosystem services); Control is diffuse through deliberative bodies, and not concentrated in one facility	
ID	Social	[+] Aims at addressing social challenges with respect to water	[-] Pricing mechanisms tend to make water unaffordable for the poor
	Ecological	[+] Recognizes ecosystems as legitimate 'users' of water	[-] Inadequately accounts for uncertainty in the bio-physical system
	Relational	[+] Provides a political platform for broad stakeholder participation, negotiation, and promotion of shared values	[-] Inadequately accounts for the different abilities of different stakeholders to influence decisions, and may thus exacerbate inequalities in sharing water with nature and other humans

Table 3.2. Assessing the paradigms in terms of water-sharing

Adaptive water governance			
Water-sharing relations		Focused on water-sharing mainly through sectoral users considering uncertainty; control is extremely diffuse and organized through deliberative bodies (polycentric)	
ID	Social	[+] Aims to address social issues [+] Aims to be fair	[-] Pricing mechanisms tend to make water unaffordable for the poor; fairness inadequately operationalized
	Ecological	[+] Considers nature-based solutions in the provision of infrastructure services; systemic ecosystem rehabilitation is encouraged to build resilience	
	Relational	[+] Incorporates process-based learning in complex adaptive systems and enables decision-making despite uncertainties	[-] Inadequately accounts for the different abilities of different stakeholders to influence decisions, and may thus exacerbate inequalities in sharing water with nature and other humans

Source: Author's elaboration, building on Schoeman, Allan and Finlayson, 2014

Key: [+] = positive effects in terms of inclusiveness; [-] = negative effects in terms of inclusiveness

tempts to forecast water supply and demand, the latter of which adds a necessary layer of certainty to freshwater management. Second, compared to the hydraulic engineering paradigm, IWRM has incorporated many ecological protection measures, including recognizing ecosystems as legitimate water 'users' and participatory processes (Volenzo & Odiyo, 2018), which makes commendable strides towards an ecologically inclusive water management scheme. Moreover, IWRM provides a political platform for broader stakeholder participation and negotiations, which is critical from a relational inclusiveness perspective. Third, the Adaptive Water Governance paradigm has proven to have relational strengths as it incorporates process-based learning in complex adaptive systems and enables decision-making despite uncertainties (Pahl-wostl et al., 2017) and unlike the hydraulic engineering paradigm, adaptive water governance considers nature-based solutions in the provision of infrastructure services – resonating with the ecological inclusiveness indicators – while attempting to address social issues (and hence also embodies socially inclusive elements). However, the adaptive water governance paradigm does not prioritize equity issues, nor do the hydraulic engineering and IWRM paradigms, therefore, I believe, it is important to include the Inclusive Adaptive Paradigm (see 3.3 and Figure 3.3).

3.3. Phases of River Basin Development

3.3.1. Introduction

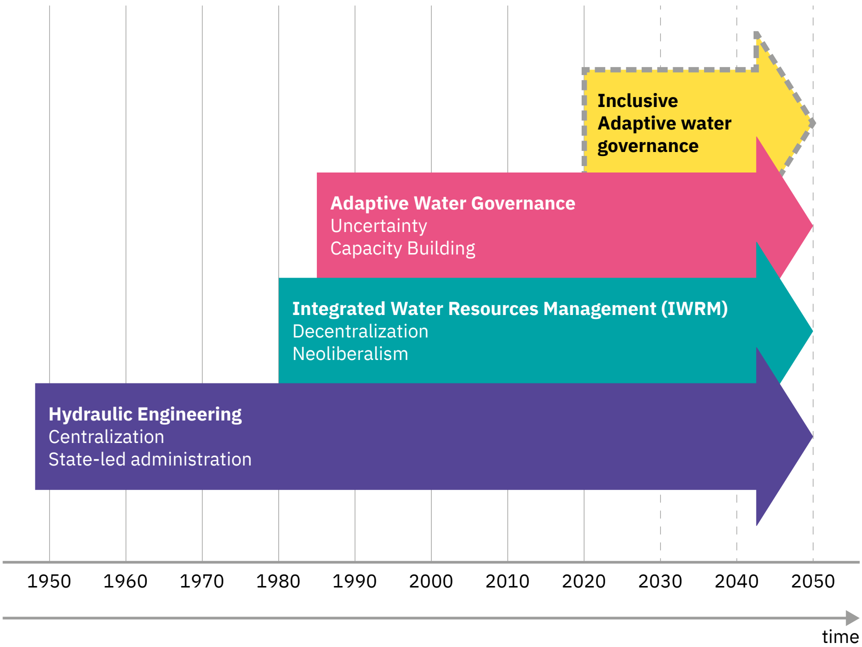
This chapter has discussed the three main paradigms and has evaluated these paradigms from an inclusive development perspective. I now move to assess the phases of river basin development and how these have been influenced by different paradigms. I use the strengths and weaknesses of the different paradigms (see Table 3.2) to build an Inclusive Adaptive Water Governance approach to suggest a fourth paradigm. This is necessary not only because of the damage to ecological systems (see 1.2.1), the uncertainty in feedback effects (IPCC, 2021), but also because social issues are becoming increasingly important and raise the need for sharing (see 1.2.2).

Figure 3.1 shows how these interdisciplinary paradigms have developed over time to influence water governance. Phase 1 sees the dominance of the hydrological paradigm. Phase 2 builds on hydrological aspects but shifts to an IWRM paradigm. Phase 3 introduces capabilities to address the uncertainties in the socio-ecological system. I will argue in this thesis that while these paradigms address different aspects of the equity problem, we are rapidly moving into Phase 4 where sharing water will become central. This idea is further developed in chapter 8.

3.3.2. State-of-the-art of phases of river basin development

River basin development can be understood as a manifestation of how societies have tried to control and use water over time. Several scholars have described and analyzed river basin development along historical lines. They have identified different phases of development and key dimensions, assuming a sequential model of the basin trajectory (Keller, Keller & Davids, 1998; Molden et al., 2001; Kikuchi et al., 2002; Molle, 2003; Molle & Wester, 2009b).

Figure 3.1. Evolution of water governance (1950 – 2050)



Source: Author's elaboration

Keller et al. (1998, 2000) divide the river basin development sequences into three phases, each one further divided into two sub-phases. The first phase is *exploitation*, in which demand is satisfied by pumping water from shallow aquifers and simple diversion of river water. The second phase is *conservation*, wherein pressure on water and problems with water quality (e.g., pollution and salinity) increase. The third phase, *augmentation*, is when the basin is empty and additional external water supply must be sourced through water transfers from neighbouring or distant basins and the creation of freshwater by desalting seawater.

Molden et al. (2001) also identify three phases: development, utilization, and allocation. In the first phase of basin *development*, dams are constructed in the most convenient locations for hydropower and irrigation. Ecological systems and environmental functions are not significantly altered, and water supply for domestic purposes remains quantitatively insignificant. In the second phase of *utilization*, adequate sites for further reservoir development are rare and, consequently, water management faces challenges with balancing supply and demand as competition between sectors and users escalates. In the third phase, management efforts are directed towards the *allocation* of water to the most economically valuable uses and new institutions are established to manage basins in an integrated manner. The framework model proposed by Molden et al. (2001) follows a linear logic, through which water resources are directed towards activities with high economic value. They suggest combining the three phases with an accounting methodology as applied in the East Rapti Basin of Nepal and the Fuyang River Basin in China (Molden et al., 2001).

Hayami et al. (1976) and Kikuchi et al. (2002) present a framework based on the economic development of the basin, considering the marginal cost of producing a unit of agricultural output, water development, and time. Water development is related to the idea of using plans and projects for the economic development of specific regions or river basins. The first phase of this framework deals with the *expansion* of rainfed agricultural land. The second phase involves the *construction* of irrigation systems, taking into account the rising costs of surface irrigation systems as irrigatable lands increasingly expand into marginal areas. The third phase focuses on the *control and management* of water utilization and allocation and improving existing irrigation infrastructure.

Turton& Ohlsson (1999) offer an interpretation similar to that of Hayami et al. (1976). However, their analysis of river basin development goes beyond the quantitative consideration of imbalances in supply and demand and looks at collective responses in the management thereof. Their framework identifies three phases: *supply*, *demand*, and *adaptive*. In the supply phase, the responsibility to build large-scale hydraulic infrastructure is bestowed upon individuals. In the demand phase, the focus is on increasing water use efficiencies and intra- and inter-sectoral reallocation of water resources. The adaptive phase is concerned with society coping with limited water demand to sustainable levels.

Molle (2003) later presents the concept of the basin development trajectory. This is "the development path of a river basin over time and space until closure" (Komakech et al., 2011, p. 1741). It is a graphical framework, revealing how water problems have been addressed at micro/local and macro/global scales. The framework consists of three phases dealing with water scarcity in the basin: supply augmentation, conservation, and allocation. The schematization of these phases occurs according to the variety of societal responses to water scarcity and the complexity of determining which particular response appears at a certain point in time (Molle, 2003).

Komakech et al. (2011) applied Molle's typology to describe the basin trajectory of the Pangani River Basin in Tanzania and expanded the theory to local processes. They introduced a *meso-layer* phase, which deals with the interface between state and local level initiatives. In the past fifteen years, several studies have developed the basin trajectory theory in different regions of the world, with most of them addressing the diverse direct and indirect impacts of basin infrastructure (Molle, 2008; Molle & Mamanpoush, 2012; Berbel, Pedraza & Giannoccaro, 2013).

Molle & Mamanpoush (2012) describe the historical evolution of water use in the Zayandeh Rud Basin of Iran where priority in the governance of the basin was given to large-scale infrastructure development, paying less attention to the hydrological interconnectedness of local-level processes (ibid.). In Europe, Berbel et al. (2013) analyzed the Guadalquivir River Basin, which is considered a closed basin due to the development of a large and profitable agricultural sector. The analysis shows the evolution of water management instruments, such as water markets, tradable quotas, and income insurance (Berbel, Pedraza & Giannoccaro, 2013; Expósito & Berbel, 2019).

River basin closure is mostly an anthropogenic phenomenon, and has societal as well as ecosystem implications (Molle, Wester &Hirsch, 2009). A river system reaches "closure" when available water resources are utilized to their maximum capacity, leaving little to no margin for additional development without affecting existing user demands (Keller, Keller &Davids, 1998; Komakech et al., 2011). Authors from "hydrology and agronomy use the concept of 'basin closure' to define the anthropogenic process that leads to total allocation of water resources among alternative uses at a river basin scale (Molle et al., 2010)" (Expósito & Berbel, 2019,p.141). Seckler (1996) and Wester (2009) define basin closure as the progressive consumption of water that is imminent or equal to the level of annual renewable water. In this context, closure means that supply cannot support any additional quantity demanded.

There are various examples across the world of "closed" basins, where water consumption cannot be increased due to the river basin not having enough water supply to meet increasing demands, nor even for rivers to reach the sea (Molden et al. 2007: p. 2). Explanations suggested for the gradual closure of basins include increasing direct and indirect drivers on water resources by population growth, inadequately targeted investments, and ineffective institutional governance (Molden et al., 2007). It is a contemporary challenge for many societies to learn to deal with this issue (Molle, 2003). Many river basins around the world are overexploited (Molle, Wester & Hirsch, 2009; Wester, 2009) (see Table 3.3). Several basins are under stress for one to six months a year. Tributaries can be under much higher water stress. Some stress could be natural depending on climate and annual variability. The Yellow River in China is an example of an overexploited river basin, which dried up for the first time in 1972 and again in 1997, lasting 226 days and reaching 700 kilometers (km) upstream (Ren & Walker, 1998). The Colorado River in the United States, the Indus in India and Pakistan, the Murray-Darling in Australia, and most rivers in the Middle East and Central Asia are other critically overused rivers (Molle et al., 2007).

In monsoon regions, such as the Chao Phraya River in Thailand (Molle, 2004) and the Cauvery River in India, rivers have been experiencing months of closure "when salinity creeps inland or outflows are zeroed as a result of upstream diversions" (Molle et al., 2007, p. 589). Many basins located in arid regions are also closed. This is the case of the Jordan River, the Dead Sea, the Amu Darya and Syr Darya Rivers, the Aral Sea, the Tarim River, and Lop Nor Lake (Molle et al., 2007). Closure can also occur in sub-basins or small catchments while the wider basin remains open (Molle, Wester & Hirsch, 2009), as is the case of the Greater Ruaha Basin, a sub-basin in Tanzania that contributes to the Rufiji (Molle, Wester & Hirsch, 2009).

Largely inspired by the hydraulic engineering paradigm, water development has been ''overbuilding'' water infrastructure in river basins for the abstraction of surface and groundwater to respond to the increasing demands of users, such as agriculture, industry, and humans (Molle et al., 2007; Wester, 2009). These developments include macro-scale technical and engineering performances, such as river diversion structures, canals, and dams. They determine the level of access and control of water in many societies.

A basin can be "reopened" by reaching a new increment in supply through costly investments that may have formerly been considered technically unviable or financially unfeasible (Molle, 2003). This is also possible through a change in development strategies, from a supply-oriented to a demand-oriented focus, which reflects the IWRM paradigm.

Table 3.3. Non-exhaustive overview of river basins worldwide described using the typology of the basin trajectory

Country	Basin	Length (km)	Countries in the drainage area	Typology of the basin	Reference
Australia	Murray-Darling	3.672	Australia	Closing basin	(Molle, Wester & Hirsch, 2009)
Europe	Guadalquivir River	657	Spain	Closed basin	(Berbel, Pedraza & Giannoccaro, 2013; Expósito & Berbel, 2019)
Asia	Yellow River	5.464	China	Closing basin	(Yang and Jia, 2008)
Asia	Chao Phraya River	372	Thailand	Closed basin	(Molle, 2004)
Africa	Pangani River	500	Tanzania	Closing basin	(Komakech et al., 2011, 2012)
Middle East	Zayandeh Rud	400	Iran	Closed basin	(Molle & Mamanpoush, 2012)

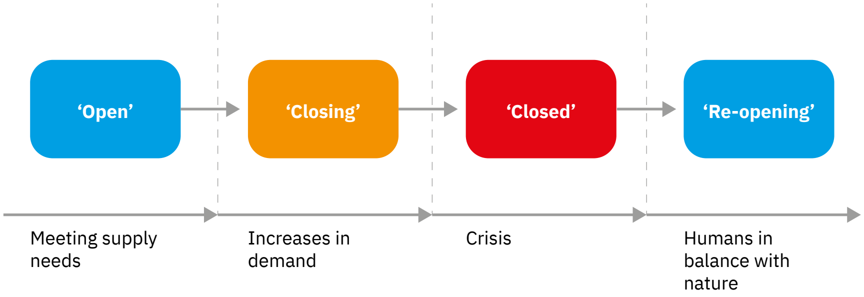
Source: Author's elaboration

Among the aforementioned frameworks, this thesis builds on that of Turton & Ohlsson (1999) in recognizing the need to consider adaptive capacity if society intends to cope with the challenges of water scarcity and adopts the concept of river basin trajectories presented by Molle (2003).

3.3.3. Proposal

Drawing on the above frameworks, I have further developed a theoretical model that distinguishes four phases of river basin development: (1) meeting supply needs, (2) increase in demand, (3) crisis where demand exceeds supply leading to a closed water basin, and (4) humans in balance with nature (Figure 3.2). This model considers the 'openness' of a river basin, and the use of this terminology is clarified in each phase of the model. These phases of river basin development are not mutually restrictive and they can overlap.

Figure 3.2. Schematic representation of how a river basin is overexploited in terms of Humans in balance with nature



Source: Adaptation inspired by Turton & Ohlsson (1999); Molle (2003); Molle et al., (2007)

3.3.3.1. Meeting supply needs

In the meeting supply needs phase, water supply is higher than water demand (S>D).

The '**open**' *stage* is the natural phase of the basin when there are no challenges or limitations to its development. Water availability is stable and there is enough water for nature. For instance, the dams are constructed in the most convenient locations for hydropower and irrigation. And the increasing demand is satisfied by supply which diverts and pumps from shallow groundwater aquifers. Water availability is not limited and thus not competed for. However, basins located in both dry and wet regions can still be affected by climate variability, such as drought and flooding (Molle, 2003). In such events, the availability of water is limited to those who have access to it.

The water is generally free, and developing water sharing policies or instruments, or institutions are not urgent. Water sharing is not (considered) an issue and tends to be divided between users of hard engineering. In this phase, the emphasis on the role of technology in controlling water, and the domestic use remains quantitatively insignificant. Water quality remains good, ecological systems and environmental functions are not significantly altered or are not perceived to be significantly altered. Therefore, there is enough water for nature. This is the phase in which water is exploited, developed, and water use is expanded in the language of other authors cited in this chapter.

3.3.3.2. Increase in demand

Increase in demand phase begins as soon as demand increases, and water supply is becoming equal to water demand (D=S).

The basin begins to reach the '**closing**' *phase*, when there is a high and growing demand for water resources and further exploitation is no longer possible. This means that the use of available water resources is reaching maximum capacity (i.e., when supply is almost equal to demand). Normally this occurs as a result of the damming process of a river basin. The increased demand is met through infrastructure and technology development. Thus in this phase, there is increased construction of water works and at the same time, there is some effort at water conservation.

Water is treated as scarce and hence an economic good, prioritizing economic development through the commodification and privatization of water. Thus, the development of water policies, instruments, or institutions becomes important. As there is little or no margin for additional development without affecting user demands, the main concern is to manage water supply for its various uses, and possibly to optimize economic returns by allocating water to its most profitable uses. The demands of nature may be marginalized through the focus on optimizing economic returns.

Water allocation is becoming important and water governance focuses on implementing water policy instruments such as water markets. Pollution problems and competition between users, such as commercial farmers become more apparent.

3.3.3.3. Crisis

Once demand increases beyond supply, the crisis phase begins (D>S).

The basin reaches maximum capacity, entering the '**closed**' phase. This is when "there is little or no margin for further development in one area without reducing demands in another area or *augmenting* existing supply" (Keller, Keller &and Davids, 1998, p. 146). This occurs due to the pervasive overexploitation of the basin, and this can be aggravated by extreme natural events such as droughts and floods. Technologies are used to extract water from groundwater or to transfer water from one basin to another.

In this phase, **water becomes a critical issue and the need to recognize water as a human right becomes increasingly important**. "Demand control and re-allocation become the only way to reduce pressure on the resource" (Expósito & Berbel, 2019, p. 1441). Crisis phase is marked by intense water competition and an urgent need for resolutions and regulations of water distribution. Therefore, some instruments need to be considered such as water markets and tradeable quotas between users.

Water allocation is challenging (and combined with increasing water pollution) becomes an increasingly urgent problem and water governance deals with a closed water system, which requires a change in strategies to reach the re-opening phase.

3.3.3.4. Humans in balance with nature

In the humans in balance with nature phase, water supply is again higher than demand (S>D).

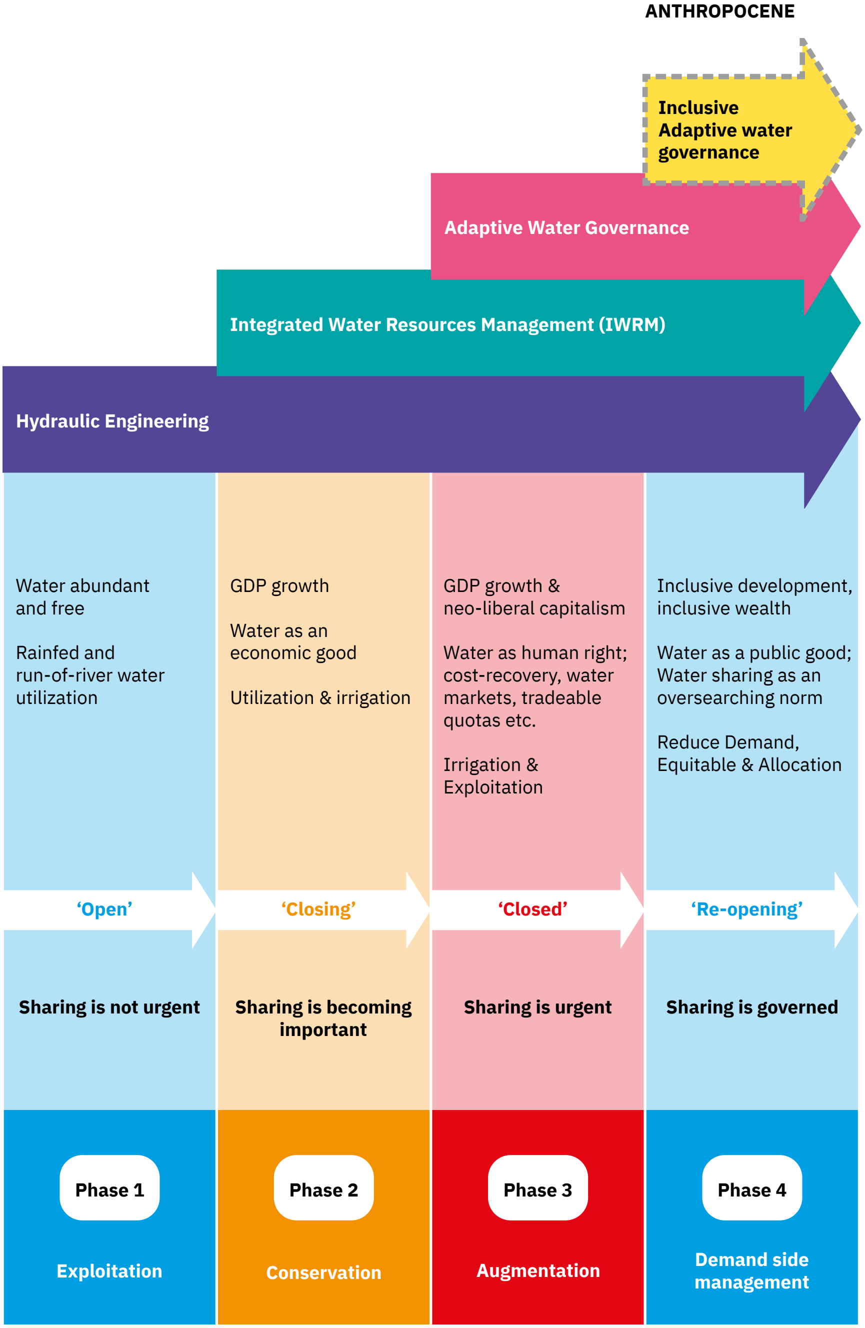
The basin becomes **re-opened**, referring to the opening of the system and both supply and demand are governed. Herein, water allocation and re-allocation are considered part of the water governance routine. Allocation is not just a matter of dividing water, but is now becoming a matter of sharing water.

In this phase, the hydrological system is considered as a public good and water sharing needs to become a key norm. This phase requires reserving enough water for nature to flourish. This phase occurs when there is water reallocation from one user to another, either within the same sector or across sectors (Molle, 2003; Molle et al., 2007) and nature is recognized as a water user. This phase will be developed further in the last chapter.

3.3.4. Proposed phases of water-sharing

This section presents how the different disciplinary approaches have influenced my proposal of an interdisciplinary paradigm of Inclusive Adaptive Water Governance and how the four water governance paradigms (hydraulic engineering, IWRM, adaptive water governance, and inclusive adaptive governance) have influenced water-sharing within the proposed phases (meeting supply needs, increase in demand, crisis, and humans in balance with nature).

Figure 3.3. Schematic representation of how a river basin is overexploited in terms of water-sharing



Source: Author's elaboration

The Inclusive Adaptive Water Governance (IAG) paradigm integrates water allocation and re-allocation as part of the water governance routine and focuses on principles of sharing. This new paradigm is highly influenced by disciplinary paradigms such as Hydrological, Ecological and Social. But it also overlaps with the interdisciplinary paradigms (i.e., Hydraulic Engineering, IWRM, Adaptive Water Governance, and Inclusive adaptive governance).

Figure 3.3 shows the phases of river basin development in terms of the four governance paradigms (Hydraulic Engineering, IWRM, Adaptive Water Governance and Inclusive Adaptive Water Governance), they are not mutually restrictive and can overlap and each paradigm can respond differently to what happens in each phase.

The phase of Inclusive Adaptive Water Governance aims at '**re-opening**' a river basin by actively considering inclusivity or sharing principles and instruments. The needs of marginalized communities and nature are considered in the redistribution of water resources, placing implementation costs on the most powerful users as they are better able to shoulder these costs. This entails different forms of sharing, reduction of demand for different uses and users, and redistribution within ecological limits. I return to this in the last chapter.

3.4. Conclusions

This chapter draws the following conclusions. First, there are three different paradigms (hydraulic engineering, IWRM, and adaptive governance) that have influenced water governance. These paradigms have responded to different challenges – the need to bring water to where it is needed and to control water for human development; the need to recognize the ecological, social and economic dimensions of water; and the need to recognize the uncertainties in social and ecological systems. All three have addressed many social issues – with hydraulic engineering bringing water, energy and other related provisioning services closer to humans; with IWRM ensuring greater participation in the management of water; and with adaptive governance promoting greater experimentation and redundancy to ensure that water is governed keeping in mind different uncertainties. However, all three have also had negative impacts on water-sharing with the hydraulic paradigm concentrating control in the hands of infrastructure managers;

IWRM concentrating control in the hands of those who price water and demand cost-recovery; adaptive governance focusing on allocation, but not necessarily equitable governance.

Second, the phases of water governance begin with water supply being greater than demand; growing demand; and demand being greater than supply as in the phase of water crises or 'closed water basins' (see 3.3.3.3) and day zero (see 3.3.3.4). Reopening a water basin can be undertaken through technological measures that enhance water supply or reduce water demand and nature based solutions, but this may not be adequate to reduce water demand sufficiently to enable demand to be less than or equal to supply. Given that water demand tends to grow with GDP growth, there is need to reconsider the development model. And such a model must increasingly take water sharing at multiple levels of governance into account.

Third, hence, this chapter proposes a new phase of water governance that is focused on prioritizing water and environmental justice issues through an inclusive adaptive approach. This will be developed further in the last chapter.