# Diagnosing Community-based Management of Groundwater in Peri-urban Areas

## A socio-ecological approach

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# Diagnosing Community-based Management of groundwater in Peri-urban Areas

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*Aashna Mittal*

*Den Haag, 2019*

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# List of Acronyms

| | |
|---|---|
| CBM | Community-based Management |
| CBNRM | Community Based Management of Natural Resources |
| CGWB | Central Ground Water Board (India) |
| CPR | Common Pool Resource |
| DLA | District Level Authority (Case North 24 Parganas or South 24 Parganas) |
| DP | Design Principle |
| DTW | Deep Tube Well |
| EKW | East Kolkata Wetland (Case South 24 Parganas) |
| EKWMA | East Kolkata Wetland Management Authority (Case South 24 Parganas) |
| GS | Governance System |
| hp | horse power |
| IAD | Institutional Analysis and Development |
| KMA | Kolkata Metropolitan Area (West Bengal) |
| KMDA | Kolkata Metropolitan Development Authority (West Bengal) |
| KMWSA | Kolkata Municipal Water and Sanitation Agency (West Bengal) |
| lpcd | Litres per capita per day |
| mbgl | meters below ground level |
| MIC | Minor Irrigation Corporation (West Bengal) |
| MoEF | Ministry of Environment and Forest (India) |
| NOC | No Objection Certificate |
| NRDWP | National Rural Drinking Water Program |
| NGO | Non-Governmental Organization |
| O&M | Operation and Maintenance |
| PCB | Pollution Control Board (West Bengal) |
| PHED | Public Health and Engineering Department (West Bengal) |
| RS | Resource System |
| RU | Resource Units |
| SES | Socio Ecological System |
| STW | Shallow Tube Well |
| SWID | State Water Investigation Department (West Bengal) |
| VWSC | Village Water and Sanitation Committee (Gram Panchayat) |
| WRDD | Water Resource Development Directorate (West Bengal) |
| TMC | Trinamool Congress (West Bengal) |
| TUDelft | Delft University of Technology (Netherlands) |
| TWO | Tube Well Operator |

# Executive Summary


Natural resources are essential lifelines of cities worldwide. Rapid urbanization and industrialization pose a marked threat to the 'common' natural resources. Cities experiencing unbridled expansion engulf their neighboring areas. As a result, peri-urban areas at the outskirts of cities often are the first to witness depletion of their commons.

Kolkata is one among many India cities characterized by such rapid urbanization and expansion. Peri-urban areas that lie around Kolkata are becoming largely dependent on groundwater. Lack of formal surface water supply, pressures of immigration, and conflicts between short-term groundwater use and sustainability in the long-term will only exacerbate this dependency.

Management of natural resources can be undertaken either by the state, private entities, local communities, or a combination of any of these. However, peri-urban areas lack the governance arrangements to ensure a sustainable use of groundwater. Under this scenario, this thesis questions whether local communities have the potential to manage groundwater in peri-urban areas. It attempts to understand the complexity of peri-urban areas and highlight the challenges that they face in managing groundwater.

For the purpose of this research, Badai and Tihuria, two peri-urban areas near Kolkata were studied. A socio-ecological approach was adopted to diagnose community-based management (or the lack thereof) in these areas. Interviews were used as the primary method of data collection to understand the groundwater problems faced by the study areas, their response to these problems, and the challenges faced to resolve them. Two main theoretical methods were applied in this research:

- Socio-Ecological Systems (SES) Framework (McGinnis & Ostrom, 2014)
- Design Principles for long enduring and robust common pool resources (Ostrom, 1990)

The SES framework was used to structure and analyze the interview data while the Design Principles were used to evaluate the performance of community-based management (CBM) in the study areas. This evaluation also provides insights into the barriers to collective action in the two study areas.

The peri-urban population were found to be comprised of multiple actors with different groundwater use, dependency, size, composition, norms, access to higher institutional levels, mental models, etc. Therefore, these populations were heterogeneous in nature and departed from the traditional notions of a community. Although the areas face severe problems of groundwater scarcity, groundwater management in these areas was found to be fragmented and not ‘community’-based. Actors follow their own individual strategies to cope with groundwater problems or seek short-term solutions whereas signs of community-wide collective action were found to be missing in both study areas.

Therefore, although community-based management of groundwater is a good idea in theory, peri-urban areas studied in this research face the following challenges:

- Low predictability and knowledge gaps about the groundwater resource
- Low autonomy to create and enforce collective rules
- Low levels of leadership to initiate collective action
- Varied perception on solutions to groundwater problems and low awareness of formal rules

Future policies promoting CBM in peri-urban areas must aim at reducing resource knowledge gaps among peri-urban groundwater users and formalizing the role of communities as managers of groundwater.

# PART I - DEFINE

# 1 Identifying the problem

## 1.1 Background: India's groundwater challenge

Groundwater is a vital source of freshwater that sustains our lives and livelihood. India is the largest user of groundwater in the world, using an estimated 260 cubic km per year – more than a quarter of the world's total consumption (World Bank, 2010). Groundwater forms the backbone of India's agriculture and drinking water supplies with more than 60 percent of irrigated land and 85 percent of drinking water supplies coming from this source. Urban and rural areas in India are both dependent on groundwater. Fifty percent of urban water supply in India comes from groundwater and at least 85% of its rural population depends on groundwater to meet their drinking water needs (Kulkarni, Shah, & Vijay Shankar, 2015). Moreover, the dependency on groundwater has increased in the past decades. However, unregulated extraction is leading to its contamination and rapid depletion.

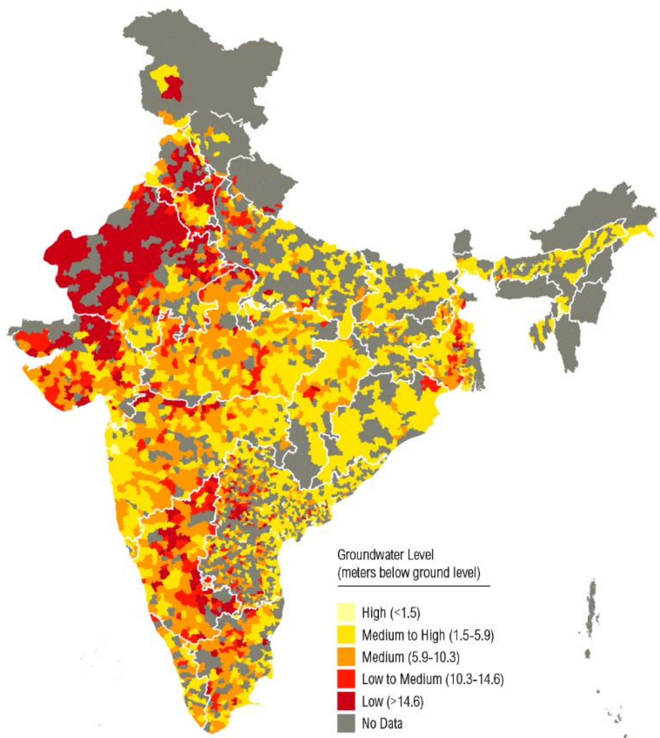



*Figure 1.1: Groundwater levels in India (Source: Shiao, Maddocks, Carson, & Loizeaux, 2015)*

Recent groundwater level assessments show declining trends in 54 percent of the 4000 wells studied across India, with 16% of these wells decreasing by more than 1 meter per year (Shiao et al., 2015). Figure 1.1 shows the groundwater levels across India with Northwestern and Southern parts standing out as the most vulnerable regions, and few districts in Eastern India also showing a similar trend. The expansion of groundwater use in India has been made possible due to a multitude of factors; flexibility and timeliness of the resource, availability of new pumping technologies, credit facilities, and provision of electricity subsidies to the farmers (Garduño, Romani, Sengupta, Tuinhof, & Davis, 2011). Overexploitation of the resource has further triggered the emergence of groundwater quality problems, from salinity intrusion in coastal regions to the spread of natural geogenic contamination (Kulkarni, Shah, & Vijay Shankar, 2015). Therefore, as people engage in the race to drill tubewells and pump water, the sustainability of the resource is under threat.

Exploitation of natural resources such as groundwater is not new, but a key dilemma that still remains around such resources is how to govern them. Traditional approaches to managing natural resources include privatization of the resource or putting it under state control. However one approach that has become popular in recent times and has proved to be somewhat effective is the increased involvement of communities in managing the resources they depend on. Community based management (CBM) of natural resources argues that communities can manage natural resources in a sustainable, equitable way given their local customs, knowledge and technology (Blaikie, 2006). Multiple case studies by Ostrom (1990) have resulted in success stories for small, homogenous communities for the management of groundwater basins, forests, and irrigation systems.

India, too, shows a strong trend in increasing the role of communities in managing their daily affairs through policies on decentralization. The 73rd Amendment to the Indian Constitution in 1992 established Gram Panchayats as the bodies of local self-governance, in charge of governing a (group of) village(s) (National Portal of India, n.d.-b). However, their role in the management of groundwater is limited (Prasad, 2008). Upcoming national policies in India aim to correct this and devolve more power to communities in managing groundwater. For instance, the draft of Model Bill 2016 (hereafter Model Bill 2016) aims to make local communities, governed by Panchayats, responsible for conservation, protection, regulation and management of groundwater (Ministry of Water Resources, River Development and Ganga Rejuvenation, 2016). Policies and interventions that promote CBM are a step in the right direction; however, there is a fundamental issue in how these policies perceive communities.

Communities are envisioned as small spatial units with shared norms and a homogenous social structure (Agrawal & Gibson, 1999). However, this may not be the case. Peri-urban areas that lie on the fringe of rapidly developing cities present a special case for CBM. These areas don't possess 'stable' communities. The size of the spatial unit in a peri-urban area keeps changing as more land is acquired for urban use, and its population is heterogenous - always in a state of flux as migrants from both urban and rural areas make these places their homes (Narain, 2010a). Further peri-urban communities may consist of actors that have different resource use, varied interests, and unequal power to influence the decision-making process and thereby the rules that govern them. Therefore, it is imperative to take the context of peri-urban areas into account for CBM, more so when policies are being drafted in India promoting this approach.

## 1.2 Societal Problem: Threats to groundwater sustainability in Peri-urban areas

Cities are the drivers of economic growth and prosperity. They bring about economic and social transformations that lead to poverty reduction and development in both urban and rural areas. Globally more people live in urban areas compared to rural areas. As the urbanization process continues, most of it is expected to be concentrated in Asia and Africa in the coming years (UNDESA, 2014). India alone is expected to add about 404 million urban dwellers by 2050. As cities expand outwards, their interactions with the surrounding rural areas gradually change their land use and occupation converting them into semi-urban or peri-urban areas (Shaw, 2005). This expansion raises concerns about the negative impacts of urbanization on peri-urban areas. Without any official urban status, these fringe areas lack the institutional and governance structures to respond and overcome the new reality that faces them – land use change, land degradation, changes in use of natural resources such as water depletion and pollution, etc. (Shaw, 2005).

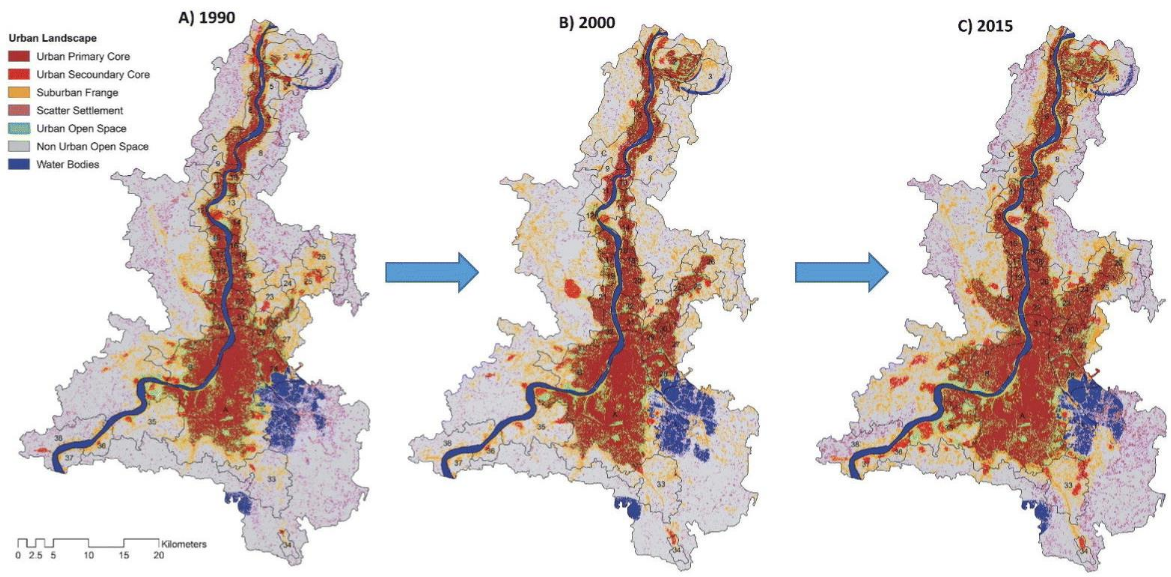



*Figure 1.2: Urban expansion in Kolkata, India. Source: Sahana, Hong, & Sajjad (2018)*

Kolkata is one such large metropolitan city in India which has undergone rapid urbanization in the past decade and continues to expand, engulfing nearby towns and villages in this process. The city lies in the state[1] of West Bengal, traditionally considered as a water rich state. It lies on the banks of the Hooghly river and spreads over an area of 185 square kms with a population of 4.5 million people. The larger metropolitan area, called the Kolkata Metropolitan Area (KMA) comprising the city and its outgrowths is home to 50% of the total population of West Bengal (14 million) in an area of 1886 square kms. Bhatta (2012) notes that while the core areas of KMA showed one of the slowest growth rates in 1991-2001 compared to 1981-1991, the peri-urban areas grew by a factor of 3. Figure 1.2 shows the transformation of the city between the years 1990 to 2015. As the main city gets congested, the municipalities lying in the South Eastern and North Eastern parts of the KMA have experienced rapid growth in their suburban fringe areas (Sahana, Hong, & Sajjad, 2018).

As the Kolkata Metropolitan Area expands its reach, the provision of basic services like drinking water do not match this expansion. Banerjee & Jatav (2017) capture the supply gap and its implications. With limited formal distribution of surface water, peri-urban areas adjoining Kolkata city increasingly depend on groundwater as a source for their livelihoods, drinking and domestic use. Provision of water for drinking and domestic purposes through shallow tubewells (STW) and deep tubewells (DTW) is common in these areas (refer to Appendix F.1 for difference between the wells). Furthermore, rich aquifers, availability of cheap boring technologies, suitable soil conditions and state policies that provide financial assistance to farmers has incentivized the cultivation of water intensive crops such as Boro paddy. The increasing dependency of peri-urban areas in Kolkata on groundwater and its unregulated extraction has led to declining groundwater levels in these areas.

As peri-urban areas grapple with this new reality of groundwater use and extraction, the rural bodies of self-governance called Gram Panchayats lack the capacity and resources to meet the peri-urban needs and face the reality of incoming actors. Lax regulations and easy permits for setting up industries allow

[1] India follows a federal structure which distributes administrative power over the Centre, State, and Local governments. The country is divided into 28 states. Here, the term 'State' is used for a provincial government.

new actors to tap into the groundwater reserves and extract unlimited water Banerjee & Jatav (2017). Weak implementation of formal rules further worsens the resource outcomes observed in these areas. Previous research in peri-urban areas of Kolkata have highlighted the limited capacity of the formal institutions in enforcing rules that monitor groundwater abstraction and quality in these areas (Gomes, 2019). Increasing dependency on groundwater coupled with weak institutional capacity of the state therefore threatens the long-term sustainability of the groundwater resource and the livelihoods that depend on it.

What remains to be seen then is, given the ongoing trend towards decentralization, what is the potential of bottom up approaches for sustainable groundwater management in peri-urban areas. How do peri-urban communities manage the new reality that they face, what problems do they face pertaining to groundwater and how do they manage their groundwater resources, what practices do they follow and what are the difficulties that they face in doing so?

## 1.3 Research gap: CBM as a solution for GW management in peri-urban areas

CBM has gained tremendous popularity among policy makers, NGOs, and academicians as the alternative for overcoming state and market failures. Multiple studies have been conducted that use the principles of CBM to explore and demonstrate its success or failure. These studies, however, are mostly concentrated in traditional rural or urban areas and therefore, major gaps remain on how this approach plays out in transitioning spaces like peri-urban areas (Adams & Zulu, 2015). Existing studies further consider communities as homogenous entities with common interests and shared norms (Agrawal & Gibson, 1999). However, they fail to take into account the dynamic reality of peri-urban areas, one where the boundaries of the spatial unit keep changing, new actors are constantly introduced each with their own resource use, interests, and motivation for resource conservation. Peri-urban areas, therefore, need attention.

Further, among the literature that is coming up for CBM in peri-urban areas (Adams & Zulu, 2015; Vasquez, 2004), they are primarily focused on the role of communities in provision of piped water supply. CBM of groundwater still remains under investigated. Although studies (Allen, Dávila, & Hofmann, 2006; Banerjee & Jatav, 2017) have highlighted the increased dependency of peri-urban communities on groundwater resources, gaps still exist to understand how they are managed. Therefore, this thesis aims to close these research gaps through two case studies conducted in peri-urban areas of Kolkata that are extensively dependent on groundwater for drinking, domestic, agriculture, and industrial purposes.

## 1.4 Research Questions

Limited capacity of formal institutions coupled with declining groundwater levels in peri-urban areas of Kolkata necessitate the need to focus on CBM as a solution. This coupled with decentralization trends in India and formulation of new policies such as Model Bill 2016 provides a solid foundation to investigate this approach. Therefore, the main research question (MRQ) for this study is:

*"What is the potential of CBM of groundwater in peri-urban areas of India?"*

The research objective can be broken down into the following research questions (RQ):

1. *What is the need for CBM in peri-urban areas and how can we study it?*
2. *What groundwater problems does a peri-urban community near Kolkata face and how does it respond to these problems?*
3. *What are the challenges facing the community in resolving their groundwater problems?*

4. *How relevant are these challenges to other peri-urban communities near Kolkata?*

## 1.5 Analytical Foundation

The research approach adopted in this thesis is a combination of deductive and inductive approaches. While a deductive approach starts from a theory, builds a hypothesis, collects data and aims to verify/reject that hypothesis, an inductive approach is the opposite (Walsh et al., 2015). It starts from the real-world phenomena and identifies patterns in the data to build a theory. In short, a deductive approach is a top down approach to research while an inductive approach is bottom-up. This thesis follows a combination of the two approaches as shown in Figure 1.3.

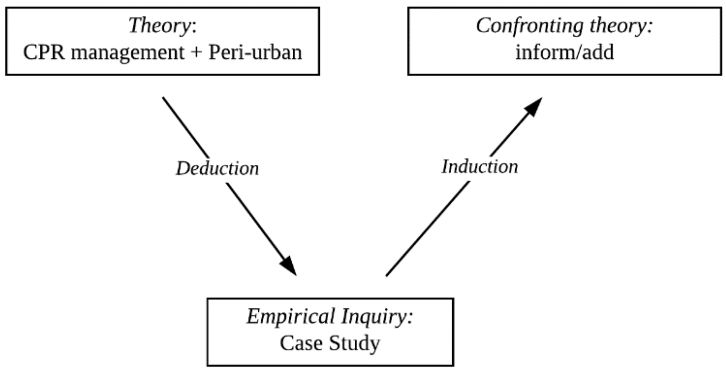



*Figure 1.3: Research approach (Inspired by Bal, 2015)*

The theories surveyed in the literature guide the conceptual model and the type of data that needs to be collected, and the observations from two case studies confronts, informs, or adds to the theory. The conceptual model followed in the thesis is that of the Socio-Ecological Systems (SES) framework developed by Elinor Ostrom and her colleagues which helps understand and explain management of natural resources such as groundwater. This framework tailored for application in peri-urban areas forms the deductive part of this thesis. The aim of the research is not to test a hypothesis but to explore the context of peri-urban areas through the lens of CPR theories. Therefore, insights from the case studies are used to draw conclusions on the performance of CBM in peri-urban areas and understand what makes peri-urban areas special for CBM. This forms the inductive part of the research approach.

## 1.6 Research Scope

This thesis explores CBM in peri-urban areas by conducting case studies in two peri-urban villages near Kolkata named Badai and Tihuria. The villages were chosen based on availability of data, and an earlier site selection study undertaken as part of the Shifting Grounds project (Banerjee & Jatav, 2017; Thissen et al., 2013). Multiple choices have been made to further sharpen the focus of this research. Firstly, although groundwater management in India involves multiple stakeholders at different administrative levels (refer to Appendix A), the focus of this research is on the lowest level of governance i.e. village level. Wherever necessary, the analysis also describes decision making at the higher administrative levels to highlight their interaction with the communities and their role in affecting the outcomes observed at the community level. Secondly, although groundwater and surface water are interlinked systems, only groundwater is considered as the focal resource for analysis. These choices demarcate the scope of this research.

## 1.7 Storyline ahead

The thesis document can be divided into four parts as shown in Table 1.1. Part I defines and describes the problem, its theoretical foundation and develops the methodology of inquiry into CBM in peri-urban areas. Part II presents the background and results from Badai and provides an in-depth description of how this peri-urban community manages groundwater. Part III evaluates the performance of CBM in peri-urban areas to highlight the challenges faced for CBM of groundwater and tests the generalization of these findings by applying them to another case study - Tihuria. This sets the road for Part IV that concludes the analysis, provides recommendations to government actors in West Bengal, and reflects on the thesis journey.

*Table 1.1: Thesis Structure*

| | |
|---|---|
| Part I – Define | Chapter 1 – Identifying the problem |
| | Chapter 2 – Literature Review |
| | Chapter 3 – Method |
| Part II – Case Study | Chapter 4 – Introduction to study area |
| | Chapter 5 – Groundwater Management in Badai |
| Part III – Evaluate | Chapter 6 – Challenges for CBM in peri-urban Badai<br>Chapter 7 – Generalizing results from Badai to other peri-urban areas |
| Part IV – Conclude and Reflect | Chapter 8 – Discussion and Conclusion |
| | Chapter 9 – Reflection |

# 2 Literature Review

*“The power of a theory is exactly proportional to the diversity of situations it can explain” (Ostrom, 1990, Page 38). This chapter reviews the literature on CBM and peri-urban areas. Based on the theory discussed, it answers RQ1 of this thesis: “What is the need for CBM in peri-urban areas and how can we study it?”*

## 2.1 Managing natural resources

Growing disenchantment with state control and privatization paved the way for increased involvement of communities in managing natural resources. This approach called Community Based Natural Resource Management (CBNRM) evolved as a response to the limitations of a resource management worldview which emphasized on technical expertise, western forms of science, and bureaucratic centralization (Armitage, 2005). The basic premise of this approach is that local populations have a greater interest in sustainably using their resources compared to the state or corporate managers, and given their knowledge of the local ecological processes they are better positioned to manage these resources (Brosius, Tsing, & Zerner, 1998). Furthermore, this approach is also appealing as it helps achieve the theorized benefits of increased participation, empowerment, more autonomy, and sustainable resource outcomes (Adams & Zulu, 2015).

Although the implementation and design of community-based approaches can vary, there are some commonalities observed in the strategies adopted. CBNRM strategies are viewed as a mechanism to achieve balance between resource exploitation and conservation; they involve some devolution of decision-making power to local communities, and are expected to solve the issues of access and control over natural resources (Armitage, 2005). Although promising, the CBNRM approach faces multiple obstacles. Armitage (2005) warns against the ‘simplifications’ on which community-based approaches are premised. The assumption that traditional resource uses are inherently sustainable maybe flawed. A community might not be homogenous and may not exist as an entity separate from the state. Armitage (2005) further continues that the local property rights system may not recognize ownership or access of communities over natural resources. CBNRM also needs to overcome differences between local, regional and national interest groups, and further with increasing privatization of the resource, changing access rights and resource use patterns may challenge the local resource management practices.

Although the CBNRM approach has its limitations and its performance has been mixed, some successful cases using this approach have been documented all over the world for resources such as forests (Sudtongkong & Webb, 2008; Pagdee, Kim, & Daugherty, 2006), irrigation systems (Lam, 1998 as cited in Ostrom, 2000; Ostrom, 1990), fisheries (Coombs, 2011; Johannes, 2002), etc. This approach is usually (but not exclusively) applied to common pool resources. This section presents the key characteristics of CPRs and the frameworks available to analyze their management.

### 2.1.1 Common Pool Resources and Institutions

Natural resources such as groundwater basins, irrigation systems, fisheries and grazing lands that are used in common, either for consumption or economic benefit, are termed as common pool resources (CPR). A CPR is characterized by rivalry in consumption - one person’s resource extraction decreases the amount of resource available for the other persons, and non-exclusion - it is difficult and costly to exclude other potential beneficiaries from harvesting the resource (Ostrom, 2010). Groundwater is one such CPR found in aquifers; materials such as sand, clay, limestone, and shale that have the capacity to store and transmit water. It is an invisible, mobile and a ‘fugitive’ resource that does not respect any land boundaries (Kulkarni, Shankar, & Krishnan, 2011). Furthermore, the connectivity of aquifers allows for spillover effects of one's own actions since extraction of groundwater under one's land not only squeezes the water under the neighbor's land but also from the 'common' aquifer.

Hardin (1968) posited that rational beings acting in their own self-interest are bound to overexploit resources, a behavior which he termed as the "tragedy of commons". To overcome this problem, Hardin suggested that the resource should either be privatized or entrusted to the government. He believed that "*Freedom in a commons brings ruin to all*" (Hardin, 1968). However, through her empirical work Ostrom proposed a third way of managing CPRs - through self-governance where people self-organize and engage in collective action to setup institutions for governing common pool resources. Ostrom (2009) admits that predictions of resource collapse are supported in large, highly valuable, open-access resources where appropriators are diverse and do not communicate with each other. However, these predictions do not hold for situations that allow appropriators or leaders to self-organize and establish institutions to manage the resource.

North (1991) defines institutions as "humanly devised constraints that order social, political and economic interactions". These constraints could either be formal rules such as constitutions, laws and property rights or informal constraints such as sanctions, taboos, customs, traditions, and codes of conduct. Ostrom & Crawford (1995) further this distinction between the formal and informal by introducing a grammar of institutions where they divide institutions into rules, norms and shared strategies. While shared strategies are everyday habits that humans undertake, norms are prescriptive in nature, and rules are not only prescriptive but also impose a sanction (Bots, 2016). Therefore, institutions can be understood as rules that shape human interactions and help us set our expectations from others; either in the form of socially appropriate behavior or actions approved or forbidden by law.

Ostrom (1990) lists down multiple problems that are at the heart of managing common pool resources and need to be overcome by a set of well-crafted institutions. These include the temptations to free ride, shirk or act opportunistically. She says, "*At the most general level, the problem facing CPR appropriators is one of organizing: how to change the situation from one in which appropriators act independently to one in which they adopt coordinated strategies to obtain higher joint benefits or reduce their joint harm*" (Ostrom, 1990, page 39). Ostrom theorizes that given legal resource rights and incentives that make the perceived benefits for most users exceed the costs, users are likely to invest time and energy into crafting institutions and sustainably manage the resource (Ostrom, Burger, Field, Norgaard, & Policansky, 1999 cited in Adams & Zulu, 2015). Further, she acknowledges that multiple factors may affect the likelihood of self-governing associations to form. These could be attributes of the resource such as level of deterioration, predictability, spatial extent, and availability of resource indicators or attributes of the group itself such as shared understanding, dependency on the resource, discount rate, trust and reciprocity, autonomy and leadership (Ostrom, 2000). Therefore, there is no one condition or blueprint that leads to successful management of common pool resources but a plethora of factors that together decide whether the situation is conducive to self-organization or not.

### 2.1.2 Long-enduring robust CPRs

In her book, *Governing the Commons*, Ostrom (1990) elaborates multiple cases where appropriators were able to break the temptation of free riding and effectively manage natural resources, such as the irrigation system in Spain and Philippines and grazing lands in Switzerland and Japan. Analyzing the successful cases, she narrowed down commonalities in long enduring, robust[2] CPR institutions that

[2] Robust here means that these institutions have stood the test of uncertainties or disturbances thrown at them while long-enduring means that they have been able to sustain over long periods of time (Ostrom, 1990).

sustained over a minimum of 100 years. These commonalities, termed as ‘design principles’ (Ostrom, 2005), are:

1. *Clearly defined boundaries*: Boundaries of resource system and the individuals or households with rights to harvest resource units are clearly defined.
2. *Proportional equivalence between benefits and costs*: Rules that specify the amount of resource product allocated to a user match local conditions and rules requiring labor, materials, and/or or money inputs
3. *Collective-choice arrangements*: Individuals affected by harvesting and protection rules are included in the group who can modify these rules.
4. *Monitoring*: Monitors who audit the biophysical conditions and user behavior are at least partially accountable to the users and/or are the users themselves.
5. *Graduated sanctions*: Rule violators are subjected to graduated sanctions either by the users, from officials accountable to the users, or both.
6. *Conflict-resolution mechanisms*: Users and their officials have access to rapid low-cost local arenas for conflict resolution among users or between users and officials.
7. *Minimal recognition of rights to organize*: The rights of users to devise their own institutions are not challenges by external governmental authorities and users have long-term tenure rights to the resource.
8. *Nested enterprises (for resources part of larger systems)*: Activities like appropriation, provision, monitoring, enforcement, and conflict resolution are organized in multiple layers of nested enterprises.

The performance of self-governed CPR systems may vary over systems and time (Ostrom, 2000). While some institutions may survive over years, others might try and fail. Moreover, there can be systems that never self-organize in the first place. Therefore, the design principles can be seen as a set of conditions which if present increase the likelihood of successful CPR management. A meta-analysis of case studies on CPR institutions conducted by Gari, Newton, Icely, & Delgado-Serrano (2017) reveals that these principles have been applied in all inhabited continents. This emphasizes the usefulness and popularity of this tool in diagnosing the performance of CPR institutions.

### 2.1.3 Analyzing Management of CPRs

Now that it is established what a common pool resource is, and that it can be managed successfully by communities, the next step is to understand how this management can be studied. This section lists down two such frameworks[3] developed by Ostrom and her colleagues – the Institutional Analysis and Development (IAD) Framework and the Social-Ecological Systems (SES) Framework.

#### *IAD Framework*

Institutions are *situated* i.e. only rules relevant to the situation being analyzed should be considered e.g. while driving a car, only traffic rules are relevant (Bots, 2016). The IAD framework (Figure 2.1) revolves around an action situation which refers to a social space where actors with varied preferences interact, exchange goods or services, solve problems, dominate or fight each other (Ostrom, 2005). These actors

[3] Ostrom (2011) distinguishes between a framework, theory and model. These represent nested levels of concepts – from the most general to the most specific. A framework is a collection of most generic set of variables that can be used to analyze all types of institutional settings. A theory on the other hand makes specifics assumptions about parts of the framework in order to diagnose a phenomenon, explain processes and predict outcomes. Models make precise assumptions about a limited set of parameters and variables to test a selected theory.

may be individual agents or composite actors such as organization or associations. Interactions in an action situation are guided by the specific institutions that apply to the action situation. For a particular action situation, institutions determine which actors can participate and in what role or capacity, which actions are assigned to an actor in a position, what information can be shared among actors, what are the outcomes of the situation, how would participants' decision impact the final outcomes and lastly, how are benefits and costs distributed to actors in different positions (Ostrom, 2005).

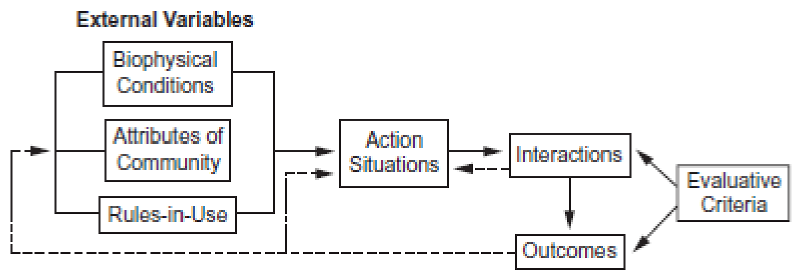



*Figure 2.1: The IAD Framework (Ostrom, 2011)*

The IAD framework further posits that external factors such as attributes of the community, rules in use, and biophysical conditions of the resource (left half of Figure 2.1) impact what happens inside the action situation resulting into interactions and outcomes (right half of Figure 2.1) that further feedback into the external variables and the action situations. The IAD framework thus enables institutional analysts to understand how people interact under a set of external conditions and predict or evaluate outcomes resulting from these interactions.

Ostrom (2011) points out that the IAD framework due to its focus on unpacking variables related to the social world, fails to consider the nuances of the resource itself. The framework clubs resource characteristics into one variable - biophysical conditions, whereas the resource is more nuanced. This shortcoming led to the development of a more generic framework called the SES Framework. Bal (2015, Page 55) sums up this development by saying that "*The main area of advancement from the IAD to the SES is the shift from an institutional analysis to a combined institutional and ecological analysis.*"

### *SES Framework*

All resources used by humans are embedded in complex socio-ecological systems. A core challenge in diagnosing why some systems are sustainable while others are not is to identify and analyze the relationships between multiple levels of these systems across different spatial and temporal scales (Ostrom, 2009). Building on the IAD framework, Ostrom (2007; 2009) introduced the SES framework with an aim to harness and combine knowledge from different fields of science. The SES framework is intended to provide policymakers, ecologists, institutional analysts, and concerned citizens with a foundation to organize their knowledge relevant to an SES. It is a diagnostic tool that assists in identifying key elements of a CPR, its use, governance, and the relationships between them.

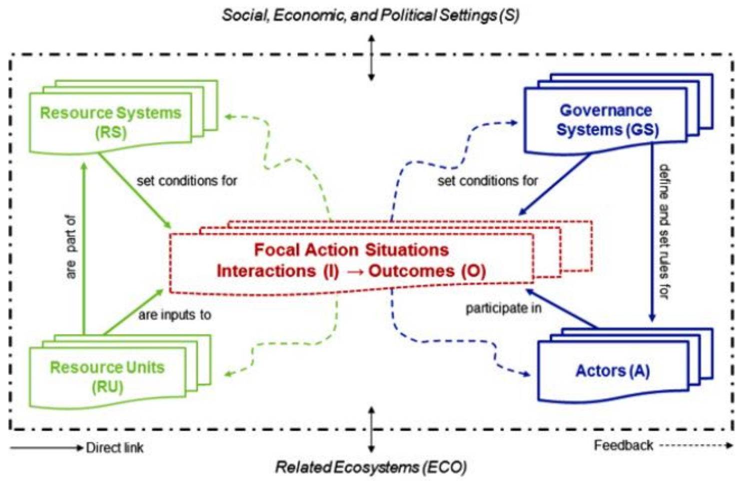


*Figure 2.2: Components of the SES Framework (McGinnis & Ostrom, 2014)*

At the highest level, the framework consists of the following four sub-systems called the first-tier variables - Resource System (e.g. aquifers), Resource Units (units extracted from the resource system e.g. cubic meters of water), Governance System (government or non-governmental organizations that influence the management of the resource system, and the rules associated with the use of the resource) and Actors (users who depend on the resource for consumption, recreation, or economic activities). Multiple instances of first-tier components may exist which is captured by multiple boxes in Figure 2.2. Each subsystem is further composed of second-tier variables as shown in Table 2.1 that can be further broken down into deeper level variables. Although the subsystems are separable, they interact to produce outcomes which further feed back into the subsystems and their components (Ostrom, 2009). These interactions between the subsystems may affect or get affected by other related ecosystems and socio, political and economic settings.

The SES framework can be used as a diagnostic tool to understand which variables are important in explaining the outcomes of an action situation. For instance, Ostrom (2009) identifies 10 first-tier variables that are linked to the likelihood of self-organization (marked by asterisks in Table 2.1). These variables provide an explanation to the question "*when will the users of a resource invest time and energy to avert a tragedy of commons*?". Recent studies by Azizi, Ghorbani, Malekmohammadi, & Jafari (2017) and Nagendra & Ostrom (2014) have used these 10 second-tier variables either as a primary focus or a starting point in diagnosing barriers and facilitators to collective action for management of groundwater and urban lakes, respectively. Therefore, the 10 second-tier variables are useful indicators to diagnose collective action for CPR management.

*Table 2.1: First tier and second tier variables of the SES Framework* (McGinnis & Ostrom, 2014)

| ***Socio, Economic, and Political Settings (S)***<br>*S1 – Economic development S2 – Demographic trends S3 – Political stability*<br>*S4 – Other governance systems S5 – Markets S6 – Media organizations S7 – Technology* | |
|---|---|
| ***Resource Systems (RS)*** | ***Governance Systems (GS)*** |
| RS1 – Sector (e.g., water, forests, pasture, fish) | GS1 – Government organizations |
| RS2 – Clarity of system boundaries | GS2 – Nongovernment organizations |
| RS3 – Size of resource system* | GS3 – Network structure |
| RS4 – Human-constructed facilities | GS4 – Property-rights systems |
| RS5 – Productivity of system* | GS5 – Operational-choice rules |
| RS6 – Equilibrium properties | GS6 – Collective-choice rules* |
| RS7 – Predictability of system dynamics* | GS7 – Constitutional-choice rules |
| RS8 – Storage characteristics | GS8 – Monitoring and sanctioning rules |
| RS9 – Location | |
| | |
| ***Resource Units (RU)*** | ***Actors (A)*** |
| RU1 – Resource unit mobility* | A1 – Number of relevant actors* |
| RU2 – Growth or replacement rate | A2 – Socioeconomic attributes |
| RU3 – Interaction among resource units | A3 – History or past experiences |
| RU4 – Economic value | A4 – Location |
| RU5 – Number of units | A5 – Leadership/entrepreneurship* |
| RU6 – Distinctive characteristics | A6 – Norms (trust-reciprocity)/social capital* |
| RU7 – Spatial and temporal distribution | A7 – Knowledge of SES/mental models* |
| | A8 – Importance of resource (dependence)* |
| | A9 – Technologies available |
| | |
| ***Action Situations*** | |
| ***Interactions (I)*** → | ***Outcomes (O)*** |
| I1 – Harvesting | O1 – Social performance measures (e.g., efficiency, equity, accountability, sustainability) |
| I2 – Information sharing | O2 – Ecological performance measures (e.g., *overharvested*, resilience, biodiversity, *sustainability*) |
| I3 – Deliberation processes | O3 – Externalities to other SESs |
| I4 – Conflicts | |
| I5 – Investment activities | |
| I6 – Lobbying activities | |
| I7 – Self-organizing activities | |
| I8 – Networking activities | |
| I9 – Monitoring activities | |
| I10 – Evaluative activities | |
| ***Related ecosystems (ECO)***<br>*ECO1 – Climate patterns ECO2 – Pollution patterns ECO3 – Flows into and out of focal SES* | |

***Levels of action situations***

In terms of the SES framework, an action situation can be understood as a place where actors come together to interact and produce outcomes under conditions set by the governance and resource systems. These action situations are nested and can be divided into three levels: *operational-choice, collective-choice, and constitutional-choice*. This divisions implies that rules that govern an action situation at one level are an output of the action situation at the higher level. Hinkel, Bots, & Schlüter,

(2014) capture how action situations are related to each other. They define 'process relationships' that show how SES variables interact to produce an outcome. Representing the legal, biophysical, political, and social context as "…", these process relationships can be represented as:

1. *Constitutional-Choice: (Actors, …) → Collective Choice Rule*
2. *Collective-Choice: (Actors, Collective Choice Rule, …) → Operational Rule*
3. *Operational-Choice: (Actors, Operational Rule, …) → Resource System*

Therefore, actors at constitutional choice level come together, under a certain set of contextual factors, to change collective choice rules which decides who gets to participate in the collective choice action situation. Based on the collective choice rules, actors at the collective choice action situation formulate or change the operational level rules. And finally, actors at the operational level action situation use the operational choice rules to interact with the resource system. This division of action situation facilitates the analyst to structure the analysis and identify levels at which individual actors interact and where self-organization takes place (Bots, 2016). The use of these divisions to structure the analysis conducted in this thesis is described in Chapter 3.

### 2.1.4 Critiques to CPR theories

Although CPR theories have been successful in explaining management of common pool resources, they are criticized for their simplistic view of communities, excessive focus on informal rules compared to formal rules, and inadequate attention on how power relations impact outcomes (Adams & Zulu, 2015). Communities are traditionally conceptualized as a small spatial unit with a homogeneous social structure and shared norms (Agrawal & Gibson, 1999). This notion paints an appealing vision, where small integrated communities manage their resources in a sustainable and equitable manner using agreed upon norms. However, according to Agrawal and Gibson (1999), this view of community is at very best "mythic" as it fails to consider the differences and divergent interests within a community and ignores the impact of these differences on interactions within community, the decision-making process, and the resource outcomes. To overcome this limitation, they proposed a more political approach to examining communities – one that focuses on community characteristics and their impact on institutional arrangements and resource outcomes. This new understanding of communities is captured in Figure 2.3.

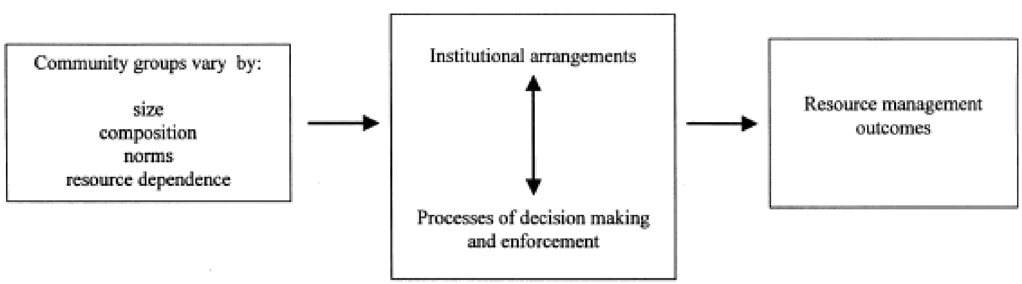



*Figure 2.3: An alternate view of communities and conservation by Agrawal and Gibson (1999).*

The revised notion of communities holds implications for conceptualizing peri-urban areas. These areas depart from the traditional notion of communities and hence they must be viewed from the lens of diversity rather than homogeneity. The next section discusses the key characteristics of peri-urban areas and how can CPR theories be applied to these areas.

## *2.2* Peri-urban areas

### 2.2.1 Definitions and conceptualization

The growing recognition and interest in the dynamics of spaces that are transitioning from rural to urban areas has led to the emergence of the peri-urban. Peri-urban is a new addition to the traditional binary between urban and rural areas. While it is difficult to settle on a single definition of these areas, multiple attempts have been made. Iaquinta & Drescher (2000) interpret peri-urban as a derivation of the urban. Their argument is that as peri-urban has some level of urban-ness, what holds true for urban areas applies for the peri-urban too. Therefore, peri-urban areas are characterized by increasing population size and density, primarily non-agricultural activities and labor force, and shift in people's lifestyle from rural to urban. Prakash(2014) defines peri-urban areas as a confluence of rural and urban, a transition space which is neither completely urban or rural in its outlook.

Drawing from debates on how to conceptualize peri-urban areas, Narain (2010) talks about three ways of understanding these spaces:

1. *A place*: Spatially, a peri-urban area is a rural fringe area located at the periphery of urban cities, that might or might not lie in the jurisdiction of urban authorities. The terms used to describe these areas include urban outgrowth, hinterland, peri-urban settlements, and rural-urban fringe.
2. *A process*: Defining peri-urban areas in terms of a place might not capture their characteristics fully. Therefore, peri-urban areas can be described as a process of transition from rural to urban areas with an accompanying flow of goods, services, and resources between them.
3. *A concept*: The linkages that exist between urban and rural areas perform important functions e.g. they maintain the social bonds between migrants and residents. Understanding and characterization of peri-urban areas requires an appreciation of these linkages. Therefore, the word peri-urban can also be used as an analytical construct to study the relationship between the core and periphery or as an interface of rural and urban activities and institutions.

Narain & Nischal (2007) divide the peri-urban characteristics into three themes: environmental, institutional, and social. From an environmental perspective, peri-urban areas represent an interface of natural resources that are used for both urban and rural activities. Here one typically sees competition between agriculture, industrial and residential land use. The use of peri-urban resources might be further stressed by external pressures and policies that incentivize shifting away from agriculture, promotion of industrial activities, and migration of farmers from rural areas in search for better livelihoods (Narain, 2010a). Institutionally, peri-urban areas may either fall outside the purview of strict rural-urban jurisdictions or are faced with overlapping rural and urban laws, thereby creating a situation of legal pluralism. Narain & Nischal (2007) discuss an interesting example of peri-urban areas in the Hubli-Dharwad region in India where it was difficult to install a sewage treatment plant as it was not clear which government – urban or rural – would pay for it. Socially, a peri-urban area is dynamic in nature consisting of heterogenous groups. Small farmers, industrial entrepreneurs, informal settlers, and urban middle class may coexist in the same space each having their own perceptions, interests and practices.

This research follows a process-based conceptualization of peri-urban areas. Although it is difficult to settle on a single definition of a peri-urban area, in this thesis it is taken as a place transitioning into an urban area where markers of a rural area may remain, but the mindset and livelihoods of people are becoming increasingly urban in nature. The case study used for the research lies at the outskirts of

Kolkata and is also under a state of transition from rural to the urban. It possesses the following peri-urban characteristics:

- Environmental: Groundwater, land, and surface water is used for both rural and urban activities.
- Social: Heterogenous groups with different land tenure, income, and livelihoods coexist in the same peri-urban village.

### 2.2.2 Need of CBM in Peri-urban areas

Even though peri-urban areas lie close to metropolitan cities and urban centers, they are often marginalized in the provision of basic amenities like water. Adams & Zulu (2015) argue that given the high upfront financial and infrastructure costs but no guarantee of cost recovery, these areas are not attractive for investments by government agencies and private companies. With no provision of formal water supply, the peri-urban poor are consequently left on their own to meet this supply gap. Allen, Dávila, & Hofmann's (2006) analysis of peri-urban areas in five different countries shows that in absence of "policy driven" initiatives, peri-urban communities rely on "needs-driven" informal practices such as buying water in the informal markets, using private wells or clandestine connections, and seeking water as a gift through their solidarity networks. Under these circumstances, groundwater has become the most dependable source of drinking water for millions of peri-urban residents (Allen et al. 2008 cited in Banerjee & Jatav, 2017).

In response to state and private failures various models of management and service provision have come to light. Adams & Zulu (2015) point out that in addition to partnerships between public, private, non-governmental organizations (NGOs) and Water Users Associations (WUAs), CBM has become a popular approach in the recent years (2000s). They further say that although the performance of this approach has been poor, or at best mixed, growing interest in communities coupled with poor resource outcomes for peri-urban dwellers has marked a shift in policy debates from supply-driven to demand-driven and more decentralized approaches to service provision and resource management.

Although CBNRM approaches have mostly been applied to traditional rural areas, Vasquez (2004) shows examples from peri-urban spaces in the provision of water supply. One such example is the autonomous community water boards or *juntas* in Itagua, Paraguay who supply water to communities of less than 4000 people. The junta are believed to be successful owing to large community participation and minimal involvement from the municipal governments. Gomes & Hermans (2018) show that when faced with institutions that are not credible, local communities in peri-urban areas of Khulna, Bangladesh do engage in collective action; either to challenge the higher-level rules to protect their groundwater resources or establish social norms for sharing the resource. Therefore, it can be concluded that CBM is a promising, albeit not perfect, approach to tackle resource problems faced by the peri-urban communities. Furthermore, since development has not taken place to its fullest expected extent in peri-urban areas and the de-facto governance of urban commons might still be vested with the local communities, these areas provide a fertile ground for CBM (Colding et al., 2006 & Elmqvist et al., 2013 cited in Nagendra & Ostrom, 2014).

## 2.3 Studying CBM in peri-urban areas

The literature review above presents key theories for management of CPRs and frameworks to study it. It also brings to light factors that may pose a challenge for CBM in peri-urban areas. This section builds on these theories and presents a conceptualization of a peri-urban community and further argues the choice of framework to study CBM in peri-urban areas of India.

### 2.3.1 Conceptualizing a peri-urban community

Peri-urban areas present a unique case for CBM as they challenge some of the assumptions inherent in this approach. These areas do not have a 'conventional' community with shared norms. Instead, they consist of heterogenous social groups that are in constant transition as new actors are incorporated continuously. Here, social arrangements are continuously created, modified, and discarded (Iaquinta & Drescher, 2000). Furthermore, these heterogenous actors have competing interests, practices and perceptions that may act as a hurdle in establishing long-term institutions for effectively managing natural resources (Allen, 2003). Therefore, peri-urban areas need a different conceptualization compared to the traditional notion on communities that perceives them as a distinct spatial unit with homogenous social structure and shared norms.

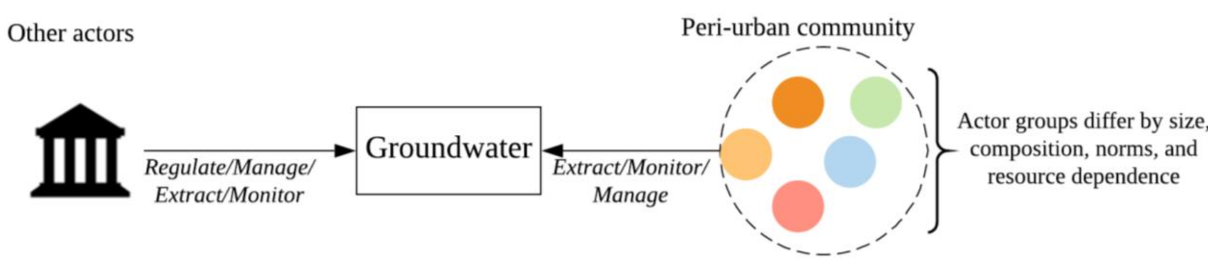



*Figure 2.4: Conceptualization of a peri-urban community with respect to the groundwater resource and other actors*

This thesis adopts the conceptualization proposed by Agrawal & Gibson (1999), based on which a community can be defined as groups that share a location and a resource but may vary by size, composition, norms, and resource dependence. A peri-urban community is simplified based on existing administrative boundaries in India that divides rural or semi-urban areas into wards and villages. Although multiple rural, urban, or peri-urban areas may extract groundwater from a common area, a single administrative unit is taken as the peri-urban community of interest. This community may further consist of different actor groups that use the common pool resource. In the context of groundwater extraction, these groups within a peri-urban community may extract groundwater and manage or monitor its consumption to ensure sustainability of the resource (as shown in Figure 2.4).

A peri-urban community, however, does not exist in isolation. Interactions of the community with other government actors in the system will also impact their social and ecological outcomes e.g. since groundwater is regulated by the government in West Bengal, they dictate the formal rules that determine groundwater extraction. These rules will be elaborated in 4 and 5. In addition to that other government bodies may extract groundwater from the community's aquifers to provide drinking, domestic, or irrigation water to the peri-urban population. These actors are considered to lie outside the peri-urban community as shown in Figure 2.4.

Based on the above conceptualization, a community refers to a peri-urban administrative unit near Kolkata (a village or a ward) whereas the term actor refers to the different groups within the community.

### 2.3.2 Choice of SES framework

Peri-urban areas are marked by peculiar environmental, social, and institutional characteristics and these characteristics pose challenges for CPR management. The SES framework offers a diagnostic tool to investigate all these aspects of peri-urban areas and their impact on CBM of groundwater. The ecological component of SES allows us to consider the unique characteristics of aquifers containing groundwater such as unclear resource boundaries, mobility, subtractability of the resource etc. Since peri-urban communities depart from the usual assumptions about communities, the division of social part of SES framework into actors and governance system allows to study differences between actors and their interplay with institutions. This type of diagnosis also fits nicely with how communities have been conceptualized in the previous section as the *Actors (A)* subsystem of the framework provides multiple variables e.g. number of relevant actors, socio-economic attributes, mental models, etc. that help distinguish between groups within a peri-urban community.

Furthermore, the SES framework is not rigid and presents an exhaustive list of variables important for CPR management. This allows the analyst to select relevant variables for the specific SES and context under study. Moreover, the framework also captures the essence of the IAD framework in the form of action situations. Zooming into an action situation enables understanding how the contextual variables impact interactions between community actors and external actors and how these interactions generate the outcomes of interest. The SES framework therefore helps to answer the 'how' questions around CBM in peri-urban areas which resonates with RQ2 of this research that aims to understand how a peri-urban community responds to its groundwater problems. All in all, these reasons make the SES framework a useful tool to study CBM in peri-urban areas.

### 2.3.3 Contextualizing the SES framework for peri-urban areas

Now that the SES framework is selected as a suitable framework for this research, it needs to be contextualized for peri-urban areas. A starting point to investigate CBM in peri-urban areas are the 10 variables identified by Ostrom (2009) that are linked to the likelihood of self-organization. Although these variables are important to consider, they need to be extended with factors from peri-urban literature that may pose a challenge for collective action and groundwater extraction. These additional factors a for peri-urban areas are:

1. *Income levels and technology used*: Narain (2010b) reports that while urban elites in peri-urban Gurgaon extract groundwater using high-cost submersible pumps, small and marginal farmers lose out as they cannot bear the high costs of extraction. Therefore, socio-economic attributes such as income (A2a) and technology (A9) used to access groundwater are strongly linked and may vary significantly across the peri-urban actors.
2. *Land tenure*: Peri-urban communities are also known to possess insecure land tenure (Narain, 2010a) and since access to groundwater is tied with access to land, land tenure (A2b) is also an important socio-economic attribute relevant for peri-urban actors.
3. *Migration:* In terms of migration (S2), peri-urban areas play a 'mediating' role between urban and rural areas (Iaquinta & Drescher, 2000). On the one hand, they act as transit points for people migrating from rural areas who seek better living conditions and jobs in urban areas and on the other hand, urban residents also migrate to peri-urban areas seeking cheap land for

accommodation (Narain, 2010a). Incoming actors there add to the heterogeneity of peri-urban areas and also put pressure on the available resources such as land and water.

The ten SES factors identified by Ostrom (2009) along with the peri-urban factors identified above provide a minimum set of analytical variables that must be considered to diagnose CBM in PU areas of India. More factors which are specific to the peri-urban context of Kolkata also emerge in the case study which are discussed in Chapter 5. The final theoretical SES framework applied for the case study is presented in Chapter 3.

## 2.4 Chapter synthesis

Groundwater, a common pool resource, has the potential of being managed effectively by communities as posited by the theories on CPR management by Elinor Ostrom. This approach is needed in the peri-urban areas given the limitations of the state and market forces to fulfill the water demands of the peri-urban communities. Given these limitations the dependency of peri-urban areas on groundwater is increasing and the sustainability of the resource is under threat. Neglect by the formal institutions coupled with the urgency of possible resource depletion necessitates the adoption of other approaches to resource management. Community-based management of CPRs is one such promising alternative. However, given the inherent assumptions of this approach, the characteristics of peri-urban areas present a challenge to implement this.

Ostrom provides useful tools to investigate CPR management in peri-urban areas as reviewed in this chapter. The SES framework provides the flexibility to incorporate social, ecological, and institutional characteristics of peri-urban areas. It provides a starting point to identify factors relevant for peri-urban resource and social outcomes. Further, action situations in the SES framework helps to analyze *how* communities conduct the CPR management. Action situations when unwrapped reveal how actors in a peri-urban community interact with each other and other governmental actors, and how these interactions affect their outcomes of concern. Therefore, the framework provides a good starting point to investigate CBM in peri-urban areas when contextualized to account for peculiar peri-urban characteristics. Extension of the 10 second-tier SES variables with income levels and technology used, land tenure, and migration accounts for the context of these areas as identified in the literature on peri-urban areas.

# 3 Methodology

*After establishing the need for CBM in peri-urban areas and selecting an appropriate framework for this research, this chapter presents the methodology adopted in this thesis. The research methods used to answer RQ2-RQ4 are presented in four stages of execution – Phase I (literature survey and desk research), Phase II (data collection), Phase III (qualitative data analysis), and Phase IV (evaluation and generalization).*

## 3.1 Research Approach

***Qualitative Approach***

To understand how peri-urban communities manage groundwater, it is important to first understand their perceptions and the local context in which they operate. Therefore, a qualitative approach was adopted in this thesis as it seeks to explore and understand the ecological and institutional context of peri-urban areas in detail. Such embedded studies are recommended to be qualitative in nature (Creswell, 2009). The local context was understood by visiting two peri-urban areas near Kolkata and gathering information through interviews. Qualitative research can be carried out by different types of inquiries. This thesis follows a case study approach.

***Case study***

The way in which peri-urban communities respond to their groundwater problems cannot be separated from ecological and social context in which they operate. Therefore, understanding CBM necessitates understanding the local context. A case study is a versatile form of qualitative inquiry that is suitable when contextual conditions are highly relevant for a study. Further, since this research aims to answer descriptive ("what are the groundwater problems faced by peri-urban communities") and explanatory ("how they respond to these problems") questions, the case study method is pertinent (Yin, 2011).

Although a case study has the advantage of surfacing rich descriptions and insightful explanations of the phenomenon of interest, one common concern associated with this inquiry is that it provides little scope for generalizing the findings. Instead of claiming statistical generalization, this study aims at analytical generalization (Yin, 2011). That is, the findings of this study cannot be generalized to all peri-urban areas across the world or even in India. Rather, peri-urban communities that show similar characteristics as the case study can be expected to respond to their groundwater problems in a similar way. An attempt at generalizing the findings is made in this research by answering RQ4. Further, case studies may be susceptible to the researcher's bias. The possibility of bias cannot be completely eliminated in a case study. However, this has been partially addressed by conducting regular reviews of the research by peri-urban experts and being transparent about the sources of bias in Chapter 9.

In this research a peri-urban village is selected as the unit of analysis or a 'case'. Two peri-urban villages in Kolkata - Badai and Tihuria, were chosen based on availability of data, accessibility to the study areas, and an earlier site selection study undertaken as part of the Shifting Grounds project (Banerjee, 2016; NWO, 2014). While Badai is used as the main case study for an in-depth analysis, Tihuria is used for testing the generalizability of the findings from Badai in line with RQ4. Further, since the focus of the research is on peri-urban communities, not all administrative levels of groundwater governance were studied in equal detail. The data collection primarily focused on groundwater users within the case, i.e. the village. In addition to that, key government officials at different administrative levels – Panchayat and District level were also interviewed to understand the formal rules that impact groundwater extraction and institutional mechanisms available to communities to resolve their problems.

## 3.2 Research Methods

Research methods are specific ways of data collection, analysis, and interpretation (Creswell, 2009). Different research methods were deployed in this thesis to answer the research questions as shown in Table 3.1. These methods were executed in four phases: literature review and desk research, followed by a field visit to Kolkata for data collection, data analysis and application of the SES framework, and evaluation and generalization of results. This section explains these phases in detail.

*Table 3.1: Research Methods deployed for answering research questions*

| No. | Research Question | Research Method |
|---|---|---|
| *2* | *What groundwater problems does a peri-urban community near Kolkata face and how does it respond to these problems?* | Application of the SES framework + Qualitative data analysis |
| *3* | *What are the challenges faced by the peri-urban community in resolving their groundwater problems?* | Design Principles + 10 second-tier variables from Ostrom (2009) |
| *4* | *How relevant are these challenges to other peri-urban communities near Kolkata?* | Comparison of case findings |

#### *3.2.1.1 Phase I –Literature Review and Desk Research*

In preparation for the field visits, desk research was conducted to gather background information on the study areas and identify key stakeholders in the village. Secondary data in the form of groundwater assessments and policy documents was collected from the official websites of the Central Ground Water Board (CGWB), West Bengal State Water Investigation Directorate (SWID), and the Ministry of Rural Development (MoRD). The introduction to chapter 4 presents the institutional overview for the Badai case study. Primary and secondary data collected by Gomes (2014) as part of a pre-scoping study and a field visit (Gomes, 2017) for the Shifting grounds project (NWO, 2014) was used to understand key groundwater problems. The desk research revealed increasing dependency of dyeing industries on groundwater as the main problem in Badai, therefore, this was taken as the starting point to identify relevant actors to be interviewed.

#### *3.2.1.2 Phase II – Data Collection*

The second phase of the research revolved around data collection: a) selecting actors to be interviewed b) designing interviews and c) conducting interviews. This phase was focused around collecting the information required to answer RQ2 and RQ3. Since these questions are about understanding community responses and challenges faced by them, data was collected using interviews to understand how different people perceive and respond to their groundwater problems. "*When we interview, we ask people to share their stories*" (Jacob & Furgerson, 2012) and therefore understand how they perceive the world. Interviews allow some control over the line of questioning and is a useful method to adopt when participants cannot be directly observed in their natural settings such as an ethnographic study (Creswell, 2009).

***Selection of actors to be interviewed***

As explained in the previous section, desk research based on Banerjee & Jatav (2017) and Gomes (2014, 2017) was used as the starting point for selecting actors to be interviewed. Farmers, households, real-estate developers, and dyeing industries were selected as the key groundwater users of interest. Within households, migrants were a special group that was interviewed given their insecure land tenure and loose social ties to the peri-urban areas. Panchayat forms the first level of governance for peri-urban communities and plays a key role in provision of infrastructure for drinking water. Furthermore, West Bengal has its own policy to regulate groundwater whereby the District officials monitor and sanction groundwater extraction. Therefore, Panchayat and District officials relevant for the study area were also interviewed. Lastly, the selection of stakeholders was also guided by the SES framework developed in section 2.3.3. Leadership is identified as an important variable by Ostrom (2009) for self-organization, therefore local leaders were selected as an actor group to be interviewed. Table 3.2 presents an overview of the type of actor interviewed and the purpose behind interviewing the actor.

*Table 3.2: Overview of actors selected for interviews*

| ***Type of Actor*** | ***Purpose of the interview*** |
|---|---|
| Groundwater Users | To understand how users extract groundwater, what equipment or technology they use, what rules they follow, what are the problems faced during extraction of groundwater and how do they respond to these problems or perceive a solution for it. |
| Local leaders | To understand the role of local political leaders or active social workers in resolving groundwater problems faced by the users. |
| Village organizations | To understand the goals and role of collective organizations that exist in the village to represent the interests of groundwater users. |
| Gram Panchayat | To understand the role of village Panchayat in supplying drinking water in the village, managing groundwater extraction, and resolving problems faced by groundwater users. |
| District departments | To understand the role of District departments in groundwater extraction, formal rules and norms followed to regulate groundwater extraction, and challenges faced in its enforcement. |

This research does not aim to statistically compare responses across actors but rather incorporate different viewpoints within and outside peri-urban communities, and therefore, *diversity of interviewees* instead of *number of interviewees* was used as the guiding principle for selecting participants in the field.

### *Interview Design*

The SES variables identified in Section 2.3.3 that combines the 10 variables identified by Ostrom (2009) and variables specific to the peri-urban areas provide the initial list of variables to be investigated through the field study. Instead of assigning a specific question to each second-tier SES variable, the interview design was kept simple in order to enable the interviewee to tell a coherent storyline, starting from problems and ending with solutions. This design was chosen to allow for more second-tier SES variables relevant to the case study to emerge during the interviews. The interview design uses the approach proposed by Cunningham & Hermans (2018) to map actor perceptions. Actor perceptions can be deduced through four key elements: actions, goals, system factors, and external factors. A logical reasoning is constructed around these elements where actors reason about the impact of actions (own or another's) on their outcomes of interest under a given set of external factors that are outside their control. Moreover, since the focus of the thesis is on CBM and institutions setup for the same, topics of formal and informal rules, leadership, and self-organization were also touched upon.

A semi structured approach was used to collect responses from the interviewees. Since the research aims to understand perceptions of diverse actors rather than aggregating data across interviewees, semi-structured interviews were chosen as a suitable approach (McLaughlin, 2006). It also allowed the interviewer to touch upon a few predefined themes while leaving room for open-ended discussions (Bryman, 2015). A questionnaire guide (refer to Appendix B.1) was prepared which was kept flexible to allow probing into interesting responses given by the interviewees. The guiding questions were kept same across groundwater users in the village. However, separate questionnaires were prepared for each government official depending on the specific information required from their department.

In total 30 interviews were conducted – 18 in Badai and 12 in Tihuria. In addition to the interviews, field notes and pictures were also taken to capture the observations of the author. The list of interviewees can be found in Appendix B.2. A code has been assigned to each interview for easy reference throughout the thesis. Appendix B.3 provides the top 10 keywords used in each interview. This gives an overview of the frequent topics touched upon.

### *Interview Process*

The field study to Kolkata was planned over a period of three weeks in March and April 2019 (refer to Appendix C for the weekly field diary). The data collection process was supported by staff from a local research organization - The Researcher[4]. They acted as the point of contact for arranging meetings with stakeholders and providing support for translation of interviews. The initial set of participants to be interviewed were selected based on the suggestions and contacts of the accompanying staff. Additional participants were selected while walking through the village and observing people in their natural setting. Further, snowballing technique was also used to identify additional interviewees. In this method the researcher establishes contact with a small group of people and uses them as informants to establish contact with others (Bryman, 2015).

*Figure 3.1: An interview in progress with a farmer*

The interview was mostly initiated by the translator and conducted in the local language, Bengali. An interview protocol was followed based on tips given by Jacob & Furgerson's (2012). The interview started with a brief introduction of the interviewer and a description of the research: what is being studied, why is it being studied, how will the author use their data, etc. Next, the interviewee was asked to introduce themselves followed by a series of questions. The interview concluded by thanking the interviewee for their time.

All the interviews were translated on the spot to allow room for clarifications and delve deeper into interesting responses. The translation was not done word to word, but only the meaning of the

[4] Link to website of The Researcher: https://www.theresearcherwb.net/

conversation was captured by the translator and conveyed to the author. On an average, each interview lasted for one hour. These were voice recorded where possible and then transcribed by the author. Hand written notes were also taken during the interview to conduct a quick and dirty analysis during the field trip and to ease out the transcription process. Interviews were mostly conducted in the natural setting of the interviewee, either at their residence or work place. Figure 3.1 shows one such interview in progress.

#### *3.2.1.3 Phase III – Qualitative Data Analysis*

The next phase of the research was aimed at making sense of the data collected. This section elaborates on the use and application of the SES framework in this research and further details out the steps that the interview data went through.

### ***Application of the SES framework***

RQ2 is a broad research question that seeks to understand the groundwater problems faced by peri-urban communities and how they respond to it. The SES framework is applied to answer this RQ for the Badai case study by segregating it into two institutional levels as shown in Figure 3.2. At the operational level, actors in the community harvest groundwater and at the collective choice level they attempt to resolve their problems. This segregation was done to answer RQ2 i.e. to first understand how communities extract groundwater and then understand how communities self-organize to respond to their problems.

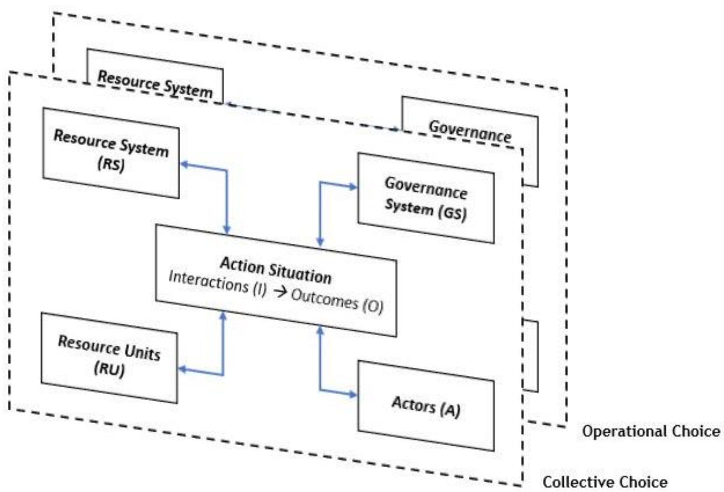



*Figure 3.2: Application of the SES framework to the case study*

Since institutions are 'situated', the analysis starts from the outcomes of interest. The SES variables and interactions relevant to the outcomes in the individual action situations are explained. Since the focus of the research is on community responses, only the action situations in which most peri-urban actors interact with the resource and collectively respond to their problems are discussed in detail. Therefore, constitutional-choice action situation is considered out of the scope for this analysis and the state-level rules are taken as a *given* condition under which the communities operate. Additional action situations that impact how communities harvest the resource or respond to their problems are also mapped in the form of a network of action situations to present the overall picture. This provides an overview of how decisions taken in additional arenas impact the peri-urban communities and their groundwater extraction. This analysis is presented in Chapter 5 for the Badai case study.

### *Final SES framework*

In addition to the second-tier SES variables shortlisted for peri-urban areas in Section 2.3.3, more variables were found that help explain the context of the Badai case study. Therefore, the final SES framework applicable to the case study is captured in Table 3.3. The reasons behind choosing these variables and their definition adopted in this thesis can be found in Appendix D.

A few third-tier variables were added to the framework to capture the specifics of the Badai case study (marked in red in Table 3.3). Firstly, *number of relevant actors* (***A1***) and *socio-economic attributes* **(*A2)*** were broken down into more third-tier variables to capture different actor groups and their socio-economic attributes. Similarly, ***t****echnologies available* ***(A9)*** was divided into two third-tier variables to distinguish between the type of infrastructure used by the actor – *public* (***A9a***) or *private* (***A9b***). Under *deliberation processes (**I3**)*[5]*,* two activities undertaken by the government were defined, *licensing activities* (***I3a***) and *planning activities* (***I3b***). The former captures the activities related to giving out licenses and the latter captures planning activities undertaken by the government to improve the resource system. Lastly, two *outcomes* are analyzed for the case study – *collective action (**O1a**),* and *groundwater harvesting levels (**O2b**).* While the former emerges from the case study as explained in Chapter 5, the latter is taken as the social outcome of interest given the focus of this research on understanding if groundwater is collectively managed by the peri-urban communities.

[5] Deliberation activities are defined as the activities that involve or emerge out of deliberation by government organizations.

*Table 3.3: Final SES framework used for the case study. Adapted from Ostrom & Mc Ginnis (2014)*

| **Socio, Economic, and Political Settings (S)**<br>*S2 – Demographic trends S3 – Political stability*<br>*S4 – Other governance systems S5 – Markets* | |
|---|---|
| ***Resource Systems (RS)*** | ***Governance Systems (GS)*** |
| RS1 – Sector (e.g., water, forests, pasture, fish) | GS1 – Government organizations |
| RS2 – Clarity of system boundaries | GS4 – Property-rights systems |
| RS3 – Size of resource system* | GS5 – Operational-choice rules |
| RS5 – Productivity of system* | GS6 – Collective-choice rules* |
| RS7 – Predictability of system dynamics* | GS6 – Collective-choice rules* |
| RS8 – Storage characteristics | GS8 – Monitoring and sanctioning rules |
| | |
| ***Resource Units (RU)*** | ***Actors (A)*** |
| RU1 – Resource unit mobility* | A1 – Number of relevant actors*<br>*A1a: Households, A1b: Farmers, A1c: industries, A1d: Real-estate developers* |
| RU6 – Distinctive characteristics | A2 – Socioeconomic attributes<br>*A2a: Income, A2b: land tenure, A2c: Occupation* |
| | A5 – Leadership/entrepreneurship* |
| | A6 – Norms (trust-reciprocity)/social capital* |
| | A7 – Knowledge of SES/mental models* |
| | A8 – Importance of resource (dependence)* |
| | A9 – Technologies available<br>*A9a: Public, A9b: Private* |
| | |
| ***Action Situations*** | |
| ***Interactions (I)*** → | ***Outcomes (O)*** |
| I1 – Harvesting | O1 – Social performance measures<br>*O1a: Collective Action* |
| I2 – Information sharing | O2 – Ecological performance measures<br>*O2a: Groundwater harvesting levels* |
| I3 – Deliberation processes<br>*I3a – Licensing activities*<br>*I3b – Planning activities* | |
| I6 – Lobbying activities | |
| I7 – Self-organizing activities | |
| I9 – Monitoring activities | |
| | |
| ***Related ecosystems (ECO)***<br>*ECO1 – Climate patterns ECO2 – Pollution patterns* | |

### *Deductive Coding*

The division of action situations along with SES variables (Table 3.3) guided the deductive coding scheme to analyze the interviews. In this scheme the second-tier SES variables were used to divide the data into meaningful chunks. The interview data went through the following stages in this process (Creswell, 2009):

1. Organizing and preparing the data
2. Reading through the data
3. Coding the data
4. Describing the data

The analysis of interviews was initiated by preparing the data. Notes taken during the interviews were used to write preliminary reports. These reports were later detailed out by listening to the voice recordings of the interviews. Given the barriers of translation, verbatim transcripts were not generated for the interviews, rather, the essence of the interviewee's response captured by the translator was documented. All the interviews were read through extensively to get a *general sense* of the data before coding them (Creswell, 2009).

Coding is the process of dividing data into chunks e.g. segmenting sentences in an interview and assigning a term to it (Creswell, 2009). After preparing the interview data, the Atlas.ti software (Version 8.3.16.0; ATLAS.ti, 2018) was used to store, organize, and code it. The software allows creating quick codes and provides the functionality of querying across codes, which is a tedious process if done manually. For this research, the interview data was coded to find out the values of second-tier SES variables. The coding scheme used in Atlas.ti is shown in Table 3.4. Individual codes were created for second-tier SES variables which were aggregated to form corresponding code groups representing sub-systems in the SES framework (Actors, Governance System, Resource Systems, and Resource Units). Further, individual codes were used to demarcate the institutional level, i.e., operational-choice and collective-choice. These were further subdivided into finer levels to describe the network of action situations in the case study as will be explained in Chapter 5.

*Table 3.4: Interview coding scheme*

| ***SES framework codes*** | |
|---|---|
| ***Code Groups*** | ***Codes*** |
| Actor System (A) | A1 – A10 |
| Governance System (GS) | GS1 – GS8 |
| Resource System (RS) | RS1 – RS9 |
| Resource Units (RU) | RU1 – RU7 |
| Interactions | I1 – I10 |
| Outcomes | O1 – O3 |
| Socio Economic Political Settings (S) | S1 – S7 |
| Related Ecosystems (ECO) | ECO1 – ECO3 |
| | |
| ***Institutional level codes*** | |
| Operational- Choice, Collective - Choice | • Operational Village,<br>• Collective 1 Panchayat Admin,<br>• Collective 1 Panchayat Regulation,<br>• Collective 2 District |

To implement the coding scheme, each interview text was divided into segments called *quotations* in the Atlas.ti environment. Each quotation was thereafter assigned two codes; one that represents a second-tier SES variable and another that represents the institutional level to which that information belongs. Then, to structure the information in terms of the SES framework, the coded data was queried to retrieve information. An *intersection* query was used in the Atlas.ti software to the find the second-tier variables belonging to the action situation of interest. E.g. if one needs to query the number of actors (A1) active at the operational choice action situation, then an intersection of the *A1* code and the *Operational-choice* code will be used. The coding process is shown in Figure 3.3. The results from the deductive coding process are visualized in Chapter 5 through maps of SES framework for focal action situations.

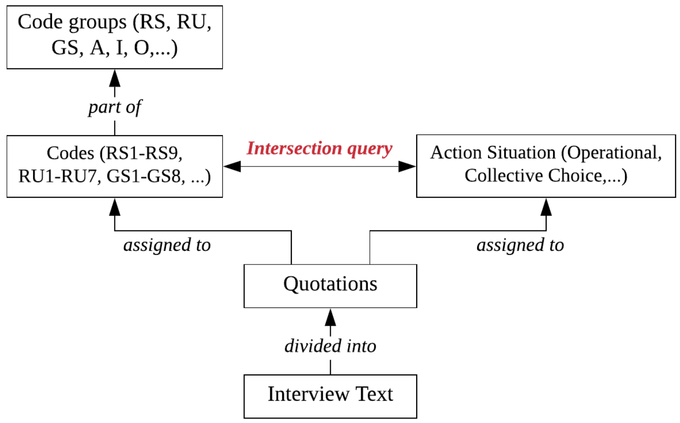



*Figure 3.3: Coding process followed for interviews*

### *3.2.1.4 Phase IV - Evaluation and Generalization*

This phase of the research deployed methods to answer RQ3 and RQ4. Before diving into the challenges faced by peri-urban communities in managing groundwater, first CBM in Badai is evaluated to check its overall performance – whether it shows signs of best practices found in successful cases of CBM. This evaluation is done through the application of Ostrom's (1990) design principles. The performance of case study results on *each* design principle is measured on an ordinal scale – weak, moderate, and strong. An overall qualitative assessment on *all* the design principles is then made to term it as a success or a failure - as a rule of thumb, if more than 6 design principles are strongly met then the case is termed as a success while if less than 2 principles are strongly met, it is termed as a failure.

Next, the specific barriers to self-organization and collective action in Badai are evaluated using Ostrom's (2009) 10 second-tier variables. As explained in Chapter 2, these variables are linked to the likelihood of users self-organizing to manage their natural resources and tell us the reasons why strong collective action is (not) seen in Badai. Therefore, evaluation of case study results on these 10 factors pinpoints the factors that might impede self-organization in the Badai community. Here too, qualitative assessments on an ordinal scale – weak, moderate, strong are made to understand whether the case study results match the expected value of the variable. Therefore, RQ3 is answered by combining the results from the application of design principles and Ostrom's second-tier SES variables. While the former conveys the overall success or failure of CBM, the latter tells us the specific barriers in achieving collective action. The evaluation of case study results using these two methods is presented in Chapter 6. Findings from this evaluation are applied to the Tihuria case study to check whether challenges faced by Badai are also relevant for other peri-urban areas thereby answering RQ4. The results from this comparison are presented in Chapter 7.

## 3.3 Research Flow Diagram

This chapter described the research methods deployed in this thesis which were executed in four phases. These phases have been mapped to the corresponding research questions and chapter numbers in Figure 3.4 in the form of a research flow diagram. The subsequent chapters in this thesis follow this structure.

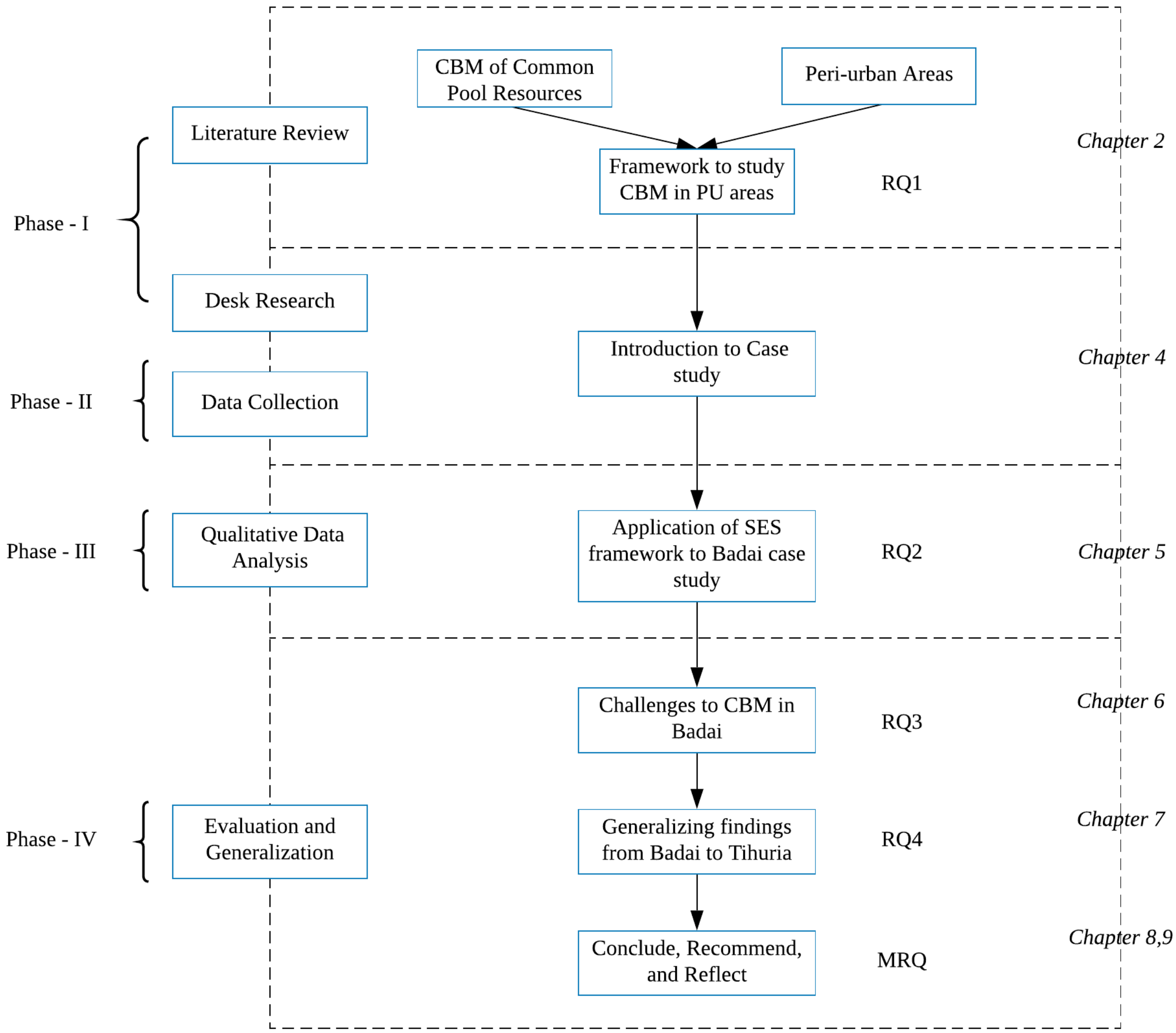



*Figure 3.4: Research flow diagram*

# PART II- CASE STUDY

# 4 Introduction to study area

*This chapter presents the background information on the first case study - Badai and sets the foundation for the upcoming chapters. Relevant institutions for groundwater management in West Bengal along with the specifics of the case study – location, demography, infrastructure, etc. are discussed in detail.*

## 4.1 Institutional Overview of West Bengal

This section maps the formal institutions that govern groundwater in Badai. Furthermore, since governance of an area is determined by its urban or rural nature, administration structure of West Bengal is first described to highlight the administrative bodies responsible for peri-urban areas near Kolkata.

### 4.1.1 Governance of peri-urban areas

The 73rd and 74th amendment to the Indian constitution established elected bodies of local self-governance for urban and rural areas (National Portal of India, n.d.-b, n.d.-a). While villages are governed by Gram Panchayats, urban local bodies are divided into three types – Nagar Panchayats for areas transitioning from rural to urban areas, Municipal Councils for small urban areas, and Municipal Corporations for large urban areas. This division has implications for the amount of taxes collected by these bodies and therefore the provision of basic amenities. Areas that are granted an *urban* status enjoy services such as piped water supply, garbage collection and disposal, street cleaning and lighting, etc. which are not considered as rural responsibilities (Shaw, 2005). The setup of Nagar Panchayats has been non-existent in West Bengal. Here, small towns and settlements, although urban in nature, continue to be governed by rural local bodies with limited capacities (Samanta, 2014). Peri-urban villages near Kolkata follow a similar pattern and are still governed by a Gram Panchayat.

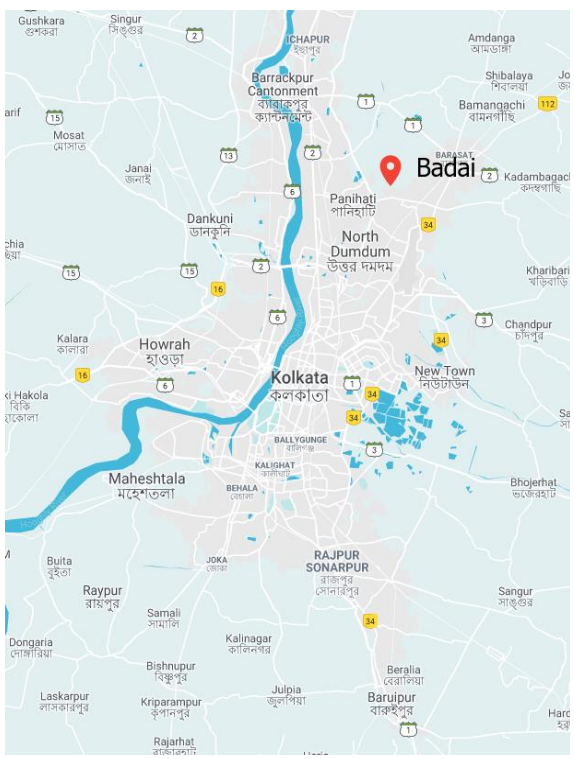



*Figure 4.1: Location of study area: Badai* (Google, n.d.-a)

The Kolkata Metropolitan Area (KMA) is the urban agglomeration of the city of Kolkata in West Bengal state of India. It is the third largest metropolitan area in India after Delhi and Mumbai. The area is administered by the Kolkata Metropolitan Development Authority (KMDA) and consists of three municipal corporations, 38 municipalities, 77 non-municipal towns, and 445 rural villages (Bhatta, 2012, Page 90). Surface water projects in KMA are insufficient to supply piped water to the entire metropolitan area and therefore, provision of water through STW and DTW is common (Banerjee & Jatav, 2017). Towns and villages lying at the outskirts of KMA that can be classified as peri-urban areas often depend on groundwater for meeting their drinking and domestic needs. Badai is one such village. Figure 4.1 shows the location of this village with respect to the Kolkata city and KMA.

### 4.1.2 Groundwater management and provision

Water is a State subject in India i.e. the State governments are responsible for the proper use, conservation and control of this resource (Cronin, Prakash, Priya, & Coates, 2014) while the Central government provides policy guidelines and technical expertise to the states or launches its own schemes. Groundwater management follows a top down approach in West Bengal. The key policy that governs groundwater in West Bengal is the Groundwater Resources Act 2005 (SWID, n.d.-b)(refer to Appendix E.1 for key policy highlights). It lays down the rules to regulate indiscriminate extraction of groundwater and prevent widespread contamination of aquifers. The State Water Investigation Directorate (SWID) is established as the key authority for implementing the policy.

As per the Groundwater Resources Act 2005, users who wish to sink a well installed with an electrical/mechanical device must apply for a permit. This permit is handed out by the District Level Authority (DLA). The DLA consists of representatives from departments such as the SWID (District Geologist), Public Health and Engineering Department (PHED), Pollution Control Board (PCB), etc. who collectively issue permits. The groundwater permit is provided by the DLA upon careful scrutiny of applications based on assessments conducted by SWID that takes multiple factors into consideration: groundwater balance, its quality, and quantity. Moreover, industries are also recommended to maintain a minimum distance of 200m between their wells (Sengupta, 2011). Therefore, permits and distancing norms are the key rules that govern industrial groundwater extraction in West Bengal.

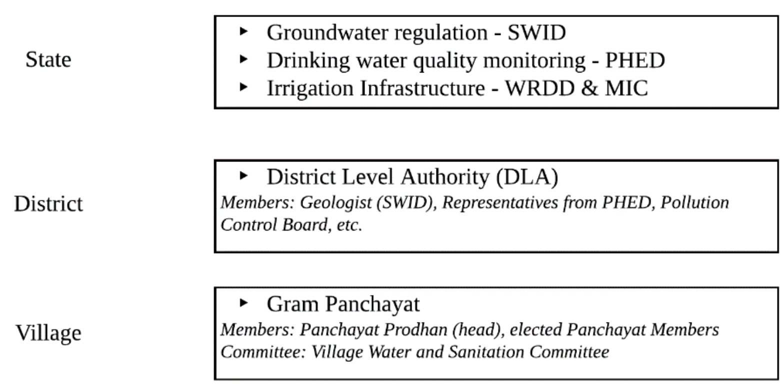



*Figure 4.2: Institutional Overview of Groundwater Management in study areas*

Groundwater for irrigation purposes is provided by the West Bengal Water Resource Development Directorate (WRDD) and The State Minor Irrigation Corporation Ltd (MIC). The departments install STWs or DTWs in areas where irrigation is not covered by surface water and hand over the infrastructure to users for operation, management, and maintenance (WRDD, n.d.). In areas classified as rural areas, the Public Health Engineering Department (PHED) is responsible for the provision of safe drinking while

Gram Panchayats are responsible for the operation and maintenance (O&M) of the drinking water infrastructure (*Interview 13*).

Gram Panchayats form the smallest unit of governance in West Bengal. The Panchayat comprises of members elected from each village in its jurisdiction and is headed by a *Prodhan*. A Panchayat is directly connected with the daily lives of villagers and forms the first level of interaction between communities and the government. A Panchayat is primarily responsible for provision of infrastructure, resolution of village disputes, and implementation of National and State level policy schemes. Under the guidelines of the National Rural Drinking Water Program 2010, a Village Water and Sanitation Committee (VWSC) is instituted under each Gram Panchayat (Ministry for Drinking Water & Sanitation, 2010). The committee forms an integral part of the Gram Panchayat and is responsible for planning, monitoring, implementation and operation of the Panchayat's water supply schemes with active participation of the villagers (Ministry of Panchayati Raj, n.d.; refer to Appendix E.2). Therefore groundwater management for peri-urban areas in West Bengal involves multiple governmental actors at different administrative levels as captured in Figure 4.2.

## 4.2 Badai; the tale of a peri-urban village

### 4.2.1 Location

Badai is one of the most industrialized villages in the periphery of Kolkata. Situated about 30 kms away from the main city, the village lies in the North 24 Parganas district of West Bengal and is well connected by road. The village spreads over an area of 338 hectares with one third of the area occupied by industries and households currently. The village is flanked by an upcoming real estate colony called Debrupayan Nagar on the west and *Noai* canal on the East. One can spot agricultural fields, households, and industries cohabitating with each other in the village (Figure 4.3).


*Figure 4.3: Satellite view of Badai village* (Google, n.d.-c)

### 4.2.2 Demography

According to the Census of India (2011), the village houses 737 households or 3068 people out of which 1692 are males and 1376 are females. The village residents speak the local language – Bengali, although some migrants from nearby states of Uttar Pradesh and Bihar are also well versed in Hindi. According to a survey conducted in the village that covered 130 out of the 737 households, the primary sources of income in Badai are cropping, manufacturing, repairing and construction, transport, and storage and communication (Banerjee & Jatav, 2017). The survey also demonstrates diversification of income sources in Badai with 41.4% of the households surveyed having a secondary source of income. Considering religious aspects, the village has a heterogenous social structure and consists of two main dominant religious groups – Hindus and Muslims. Muslims form approximately 60% of the village population and among Hindus, the village is predominantly occupied by the Scheduled Castes[6]. No communal tensions between the two groups have been reported in the village (*Field Visit 1*).

### 4.2.3 Governance

As with most villages in India, Badai is governed by a Gram Panchayat – Bilkanda I and is one of the eight villages governed by the Panchayat. Two elected members represent Badai in the Gram Panchayat.

### 4.2.4 Peri-urbanization in Badai

Like its neighboring villages, Badai is undergoing rapid urbanization. As the village gets encircled by towns, the 'rural' atmosphere of the village is slowly withering away. While agriculture was the predominant occupation in the village 20 years ago, the onset of industries has slowly changed the village landscape. Moreover, with the construction of the Kalyani express highway, the connectivity of the village to nearby towns and Kolkata city has improved leading to incoming migrants in search of cheap land for living or setting up industries. The village is home to more than 130 industries, mostly consisting of small and medium scale manufacturing units that dye cloth or produce soaps, glycerin, cosmetics, plastic chairs, etc (Banerjee & Jatav, 2017). However, the village struggles to match up with this industrial growth as evident from the inadequacy of infrastructure - broken roads and drainage lines overflowing with colored water discharged from the dyeing industries is a common sight here.

### 4.2.5 Water supply and infrastructure

With no formal piped surface water supply, Badai primarily depends on groundwater to meet its drinking, domestic, industrial, and agricultural needs. The major users of groundwater in the village are households, farmers, and dyeing industries. Groundwater is primarily extracted by wells using different types of pumping technologies, either manually operated hand pumps or electrically operated submersible pumps (Refer to Appendix F.1 for more details). This infrastructure can be further divided into two types – *public* (provided by the government) and *private* (personal ownership). Table 4.1 summarizes the public and private infrastructure present in Badai.

*Table 4.1: List of water sources available in the Badai village mapped to its usage (created by the author)*

<table>
<tr><th>Type of infrastructure</th><th>Infrastructure</th><th>Source</th><th>Type of Use</th></tr>
<tr><td rowspan="5">Public</td><td>PHED water supplied through stand-posts (three times a day)</td><td rowspan="2">GW</td><td rowspan="2">Drinking and cooking</td></tr>
<tr><td>Panchayat wells (handpump)</td></tr>
<tr><td>Ponds</td><td>SW</td><td>Domestic use</td></tr>
<tr><td>MIC Irrigation DTW</td><td>GW</td><td>Agriculture</td></tr>
<tr><td>Noai canal</td><td>SW</td><td>Agriculture</td></tr>
<tr><td rowspan="3">Private</td><td>Wells with submersible pumps</td><td rowspan="2">GW</td><td>Industrial use</td></tr>
<tr><td>Wells with handpumps</td><td>Domestic and drinking</td></tr>
<tr><td>Bottled water</td><td>Unknown</td><td>Drinking</td></tr>
</table>

[6] The Hindu religion follows a socio-political division of the society called the caste system. Communities who lie outside this framework of caste system adopted the name 'Dalits' and are collectively referred to as Scheduled Castes. Historically, Schedules Castes have faced oppression and social isolation given their perceived 'low' status in society and discrimination against them continues even today.

### *4.2.5.1 Public infrastructure*

Traditionally, the Panchayat supplies drinking water to the villagers through STW or DTW handpumps. In Badai, there are a total of 22 handpumps installed by Panchayat – out of which 5 are of the type "Mark-II" that tap into deep aquifers at a depth of 450ft (*Interview 15*). However, given the insufficiency of Panchayat infrastructure, the PHED department also installed a DTW in 2013 to supply drinking water to all the 8 villages in the Bilkanda-I Gram Panchayat (*Interview 17*). Under the department's scheme, a bore-well is dug deep into the ground which extracts water and stores it in an overhead tank to be distributed to the village via stand-posts (see Figure 4.4).

*Figure 4.4: PHED drinking water supply – extraction and storage (L) Local distribution via standpoints (R)*

In addition to the tube-wells provided by the Panchayat and stand-posts provided by the PHED, multiple ponds can also be spotted in the village which are commonly used for domestic use such as bathing, and washing utensils and clothes (Figure 4.5).

*Figure 4.5: Use of village ponds for washing utensils*

Although Badai is experiencing a shift in livelihoods from agriculture to non-agriculture sectors, cropping still remains the primary source of income for about 40% of the households (Banerjee & Jatav, 2017). An interview with a local farmer and a visit to their field revealed the irrigation infrastructure and crops grown by the farmers (*Interview 9*). Boro (summer) and Aman (winter) paddy, vegetables such as brinjals, chilies, pumpkin, and gourds are some of the crops grown in Badai. Farmers irrigate their fields using water extracted from a DTW installed by the MIC department at a depth of 750 ft. This water is distributed to the farms via three irrigation channels (Figure 4.6). Another farmer interviewed explained that although the Noai canal is polluted (with industrial waste), they still use it for irrigating their fields wherever the tube-well irrigation water is not available (*Interview 12*).

*Figure 4.6: End-point delivery of water from irrigation DTW.*

#### *4.2.5.2 Private infrastructure*

Households, which are one of the major users of water in the village, differ in their preference of infrastructure to access drinking and domestic water. They also rely on their private wells which may be fitted with handpumps or submersible pumps (see Figure 4.7). Among households, the dwellers of Debrupayan Nagar colony are entirely dependent on private wells as there is no provision of public infrastructure for that area. Based on the visit through the village, drinking water packed in 20L plastic bottles was also spotted in offices of industries and one household. Banerjee & Jatav's (2017) survey points to a meagre dependency of villagers on bottled water as only 3% of 130 households surveyed in Badai use bottled water as their primary source of drinking water.

*Figure 4.7: Groundwater being extracted from a private handpump (L), Use of drinking water cans (R)*

Apart from domestic and drinking water needs, groundwater also serves as a key input to industrial production. An interview with the owner of a medium-sized dyeing industry revealed the process followed for dyeing the cloth (*Interview 3*). These industries use private tube-wells fitted with a submersible pump. The dyeing process usually involves 8-10 steps, each of which uses water. After going through the production process, the waste water is discharged via the drainage channels that empty into the Noai canal. Figure 4.8 shows the water discharged from this dyeing factory.

*Figure 4.8: Dyeing process in action in an industry in Badai (L). Waste water discharged from the industry (R)*

## 4.3 Chapter synthesis

This chapter presented the background of the case study used in this research. Peri-urban areas in West Bengal, although urban in nature, are still governed by rural governance bodies or Gram Panchayats. For groundwater management, the key decision-making body is SWID at the state level and DLA (constituted under the Groundwater Resources Act 2005) at the district level. Other departments such as the PHED and the MIC are responsible for the provision of infrastructure for extracting groundwater for drinking, domestic and agricultural purposes. Lying at the outskirts of the KMA, Badai is a peri-urban area governed by a Gram Panchayat. It has a diverse population with people dependent on rural or urban activities for their livelihoods. The village is industrializing rapidly and is home to more than 130 micro industries. With no formal surface water supply, groundwater forms the primary source of water in Badai and is accessed using public or private infrastructure. The next chapter analyzes the groundwater problems faced by actors in Badai community and their responses to these problems.

# 5 Groundwater Management in Badai

*This chapter presents the results from application of the SES framework to Badai through deductive coding of the interview data. The analysis presented in this chapter answers RQ2: "What groundwater problems does a peri-urban community near Kolkata face and how does it respond to these problems?".*

## 5.1 Introduction to groundwater problems: Outcomes of Interest to key actors in Badai community

Before diving into the problems faced by actors in Badai, it is important to demarcate which actors form the Badai community. As explained in Chapter 4, households, farmers, and dyeing industries are the key users of groundwater in Badai. Among households, a further distinction can be made between those that reside in the main village and in the upcoming real-estate colony. This is due to two reasons. Firstly, the real-estate colony is spatially separated from households in the main village thereby limiting interaction between the two groups. Secondly, since the colony is targeted at middle-income families, significant income differences may exist between the two household groups. This may impact the technology available to the two groups, and consequently the nature of groundwater problems faced by them. Therefore, in addition to farmers, dyeing industries, and households in the main village, the real-estate colony is taken as a separate actor group within the Badai community.

These actors face different groundwater problems which indicate the outcomes they care about. This section discusses these outcomes as deduced from the interviews conducted in Badai. Appendix G maps these outcomes to the interview responses.

***Households***

Local women in Badai face both quantity (O2a) and quality (O2b) issues with respect to groundwater (refer to *Interview 5* in Appendix G). During summers, the flow of water in Panchayat handpumps decreases. Although they face this issue throughout the year, it gets aggravated in the summer season. This leads to long waiting times while fetching water. Moreover, water fetched from the handpumps is not potable as it is contaminated with iron. Therefore, they must let the water rest while the iron precipitates.

The issue of iron contamination in Panchayat handpumps was also confirmed in another interview with a migrant (refer to *Interview 6* in Appendix G). They also complained that in the past water could be extracted through a boring 40 ft below the ground, but now, due to declining groundwater levels, a cylinder needs to be dug till at least 80ft. Furthermore, issues of timing and availability of water in the PHED line are also common. The PHED water supply is only limited to a maximum of 5 hours during the day thereby forcing them to fetch poor quality water from Panchayat handpumps during an emergency situation.

Another migrant who has settled in Badai from another State faces no problems in extracting water from their tube-well (refer to *Interview 7* in Appendix G). Water is generally fetched from a tube-well installed by the landlord in the premise of their house. This tube-well is used both for domestic and drinking purposes.

As evident from Appendix G, overall, two out of three households interviewed in Badai reported both quality and quantity problems in the wells they use among other issues, while one household did not report any problems.

***Farmers***

Farmers form another actor group in Badai who use groundwater for irrigation purposes. They mostly face issues pertaining to the quantity of groundwater (O2a), i.e., they face periods of groundwater scarcity especially in the months from March to May (the summer season). Narrating an incident, a farmer told that two years back (in 2017), farmers did not get enough water due to depletion of the aquifer. Without any alternatives available, they were bound to cultivate with the water available (refer to *Interview 9* in Appendix G). Furthermore, discharge of polluted waste-water by nearby industries onto their fields is decreasing the fertility of their land. Pointing to the upcoming real-estate colony, the farmer said that this colony has been setup by buying agricultural land that was no longer productive.

***Dyeing industries***

Two dyeing industries were interviewed in Badai and they reported no problems pertaining to groundwater use or extraction (refer to *Interview 3* and *Interview 4* in Appendix G). While one dyeing industry was only setup recently, the other has been operating in the village since 2000. The tubewell used by the older industry was installed 20 years back and they have not experienced any scarcity issues since then (*Interview 3*). Dyeing industries in Badai are mostly concerned about the provision of infrastructure such as electricity, roads, and drainage. However, an interview with a representative from the Badai Industry Association revealed that adherence to well distancing norm, which recommends a distance of 200m between adjacent wells, is a key issue for them. Five to seven years ago, one industry in Badai was denied permission to install a tubewell since it did not maintain this distance (*Interview 1*). This issue was taken by the Industry Association as will be explained later in this chapter. Therefore, while groundwater quality or quantity does not concern dyeing industries in Badai, difficulties in adhering to formal rules is a problem.

***Real-estate developers***

The upcoming real-estate colony in Badai faces no quality issues in the water extracted through their tube-wells (*Interview 2*). Households mostly install their own filtration units to purify water for drinking purposes. However, like farmers and other households they also face a decreased flow of groundwater in the summer months i.e. April and May.

*Table 5.1: Groundwater problems faced by actors in Badai. 'X' represents presence of the issue*

| ***Outcomes of Interest →<br>Actors ↓*** | ***Groundwater scarcity*** | ***Groundwater quality*** | ***Tubewell regulations*** | ***Other (timing, maintenance)*** |
|---|---|---|---|---|
| Households | X | X | | X |
| Dyeing industries | | | X | |
| Real-estate developers | X | | | |
| Farmers | X | | | |

Based on the discussion above, groundwater problems faced by actors in Badai are summarized in Table 5.1. As evident from Table 5.1, a shared problem faced across - households, real-estate developers, and farmers is scarcity of groundwater (O2a) while the only groundwater problem faced by the dyeing industries related to the tubewell distancing norms. Groundwater scarcity being the shared problem across community actor groups is taken as the focal outcome of concern for further analysis. Moreover, given the focus of this research on CBM, collective action (O1) as a response to groundwater problems is the social outcome of interest in this research. The next section unwraps the two action situations that generate these outcomes.

## 5.2 Understanding groundwater scarcity and responses using the SES framework

In this section the SES framework is applied to the Badai case study to see how actors in Badai extract groundwater and how they respond to scarcity of groundwater. Two action situations are distinguished based on the outcomes identified in the previous section. These action situations belong at two different institutional levels and are as follows:

1. ***Groundwater extraction****:* At the operational-choice level, actors engage in harvesting groundwater and their extraction is governed by formal and informal rules.
2. ***Response to groundwater scarcity***: At the collective-choice level, actors self-organize to resolve groundwater scarcity.

These action situations are explained by first unwrapping the SES and mapping the six subsystems of the SES framework – Resource System (RS) and Resource Units (RU), Governance System (GS), Actors (A), Socio, Economic, and Political Settings (S), and Related Ecosystems (ECO), as shown in Figure 5.1. Further, the second-tier variables in each subsystem that explain the outcomes of interest in the corresponding action situation are described in detail.

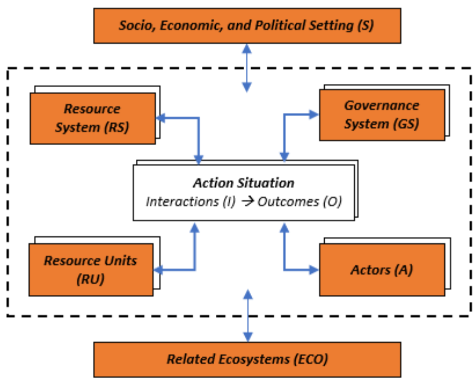



*Figure 5.1: Unwrapping the SES subsystems*

Next, since institutions are 'situated' around an action situation, the heart of the SES Framework is mapped as shown in Figure 5.2. Interactions between different actors within the action situation are presented to understand how they generate the outcome of interest. Multiple interactions may exist in one action situation.

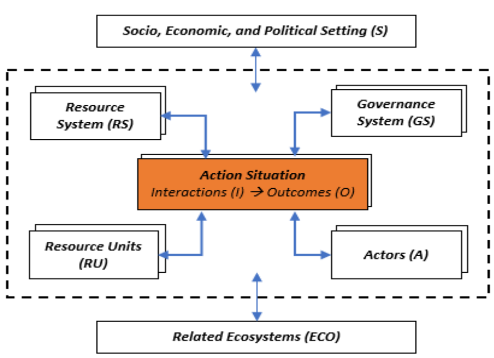



*Figure 5.2: Mapping the heart of the SES*

### 5.2.1 Factors affecting groundwater extraction in Badai

This section unwraps the SES subsystems for the *groundwater extraction* action situation. Here, actors extract resource units (groundwater) from the resource system (aquifers). Groundwater is extracted for different needs, in different amounts, and through varying infrastructure. Resource characteristics, actor attributes, and operational choice rules together determine the resource outcome – groundwater scarcity. Although 'scarcity' cannot be directly measured, it is caused by depletion of the groundwater levels. Therefore, harvesting levels of actors is taken as the indicator to measure this outcome.

#### *5.2.1.1 Resource System and Resource Units*

Badai consists of two main resource systems: land, and aquifer. The land system lies between the surface water and the aquifer systems (***RSL1***). Land is strongly interlinked to access of groundwater as its ownership determines the right to extract groundwater. It is used for agricultural purposes, habitation for households, operating industrial units, and constructing public infrastructure (*FieldVisit1*). The boundaries of the land system are well defined with agricultural land divided into plots and households visibly having a clear demarcation of their areas (***RSL2***).

Groundwater (***RU1***) is the resource unit which is extracted from the village aquifer system (***RSA1***). The village aquifer is reported to be of the shape of a "*cauldron" (or a deep bowl)* i.e. users need to dig deeper and install more pipes to get water compared to the nearby areas that get water from shallow aquifers (***RSA8***) (*Interview 9*). Although the exact characteristics of the aquifer at village-level are not known, rough estimates can be made depending on the data available for the broader regions in which Badai lies. The North 24 Parganas district lies in the upper delta plain of Ganga-Bhagirathi river systems. The aquifer is primarily made up of sand, silt, and dark grey clays (SWID, n.d.-a). The district consists of three aquifer systems: shallow aquifer till a depth of 80 meters below ground level (mbgl), second aquifer system from 100m till 180 mbgl, and a third aquifer system between 200-335 mbgl (India Water Portal Hindi, n.d.). Furthermore, the aquifer is contaminated with arsenic in the upper shallow aquifers (between 15-70 mbgl). Arsenic contamination affects the quality of drinking water that is extracted from the aquifers ***(RU6)*** and motivates the PHED department to dig deeper in search for arsenic-free water. The department typically extracts groundwater from a depth of 100-120m (*Interview 13*). Although the productivity of the aquifers is not known, a CGWB report (2013, Page 128) has marked the block in which Badai lies – Barackpore II, as '*semi-critical*' which means that at least 70% of net groundwater available annually is withdrawn (***RSA5***). Therefore, the aquifer system of Badai may also support groundwater depletion and contamination.

#### *5.2.1.2 Governance System*

Actors interact with the resource system under the influence of rules that check their behavior. The governance system in Badai dictates formal rules that determine which actors operate in the village, and what permissions they need to extract groundwater (***GS5***). The head of the Gram Panchayat (*Prodhan*) grants trade licenses to industries that want to operate in the village. This license is the first step for establishing a business in the Panchayat area and must be renewed every year (*Interview 1*). Before digging a tube-well to extract groundwater, rules and norms established in the Groundwater Resources Act 2005 mentioned in Chapter 4 must be followed. These rules, however, differ across actors.

On the one hand, households and farmers are exempt from taking any permission for digging a tube-well of up to 5 hp in safe blocks (SWID, n.d.-b). This is confirmed in the interviews conducted with a farmer and local women (*Interview 5* and *Interview 9*). One woman had recently installed a private well at a depth of 280 ft for drinking water did not have to take any permission for the same. The farmer also confirmed that they do not need any permission for the installation of shallow wells. However, according to an official from the Panchayat administration, installation of a well beyond 330 ft by any villager must be permitted by the PHED (*Interview 15*). On the other hand, industrial extraction of groundwater up to 50m3/hr. must be permitted by the North 24 Parganas DLA (SWID, n.d.-b). Therefore, dyeing industries and real estate developers in Badai must obtain a one-time license before sinking a well. Moreover, although industries are recommended to maintain a distance of at least 200 meters between two adjacent wells, this rule is not strictly implemented i.e. the distance could be more or less than 200 meters (*Interview 12*). Furthermore, the relaxation of this norm depends on the decisions taken in the DLA meetings.

Failure to abide by the rules set by the governance system may lead to sanctions. If the industries fail to take the groundwater license, a fine maybe imposed on them *if* the defaulter is caught (***GS8***). These defaulters are caught based on surprise checks or complaints received by the DLA on illegal extraction. The penalty for installing a pump without seeking permission is decided by the DLA. At present, the amount mentioned in the Groundwater Resources Act is charged from the defaulters which is around 64 €[7] (*Interview 12*). In the past, the minimum value of the fine has gone up to 960 € based on the decisions of the DLA (*Interview 11*). In addition to the fines, the DLA grants the groundwater license to industries subject to some rules: users are recommended to implement rainwater harvesting schemes and submit reports of groundwater quality tests reports every year, or else, the DLA may cancel their license (*Interview 12*).

Different property rights for land and groundwater can be observed among actors in the Badai community (***GS4***). Land is either privately owned and occupied or rented out from landlords (refer to A2b in the next section). Further, operational rules (GS5) for groundwater extraction decide who has access to the groundwater resource. For households and farmers, groundwater is practically an open-access resource under the Groundwater Resources Act 2005 since they not require any permission to sink wells up to a depth of 100m or higher than a capacity of 5hp, respectively (*Interview 15*). For dyeing industries and real-estate developers, ownership of land does not imply access to groundwater in Badai since access and withdrawal rights are subject to attainment of a groundwater license from the DLA.

#### *5.2.1.3 Actors*

The Badai community is comprised of four key actors who are the major users of groundwater: households (***A1a***), real-estate colonies (***A1b***), farmers (***A1c***), and dyeing industries (***A1d***). The number of members in these actor groups vary - there are 737 households in the village and approximately 80 farming households (Banerjee & Jatav, 2017), 1 real-estate colony with 10 out of the planned 400-500 families currently residing (*Interview 2*), and 25 – 7 medium, 18 small dyeing industries (*Interview 15*).

Actor groups identified above are characterized by varying socio-economic attributes. While occupation (***A2c***) determines the purpose of using groundwater, income (***A2a***) and land tenure (***A2b***) decide the affordability of infrastructure and the right to install it, respectively. Households including those residing in the real-estate colony use groundwater for fulfilling their drinking and domestic needs, and farmers and industries use groundwater as an input for production. Income levels vary among households - a migrant working in a dyeing industry earns about 153 € a month (Interview 7), whereas the real-estate colony is bringing in more middle-class families that pay approximately 35000 € to purchase one duplex (FieldVisit1). Land tenure also varies among actors. Two migrants interviewed in Badai resided on land rented from the landlord, whereas a farmer owned about 0.6 acre of land for residential purpose and 4.6 acres of agricultural land. Dyeing industries too operate on the land they own and so is the case for

[7] A conversion rate of 78 INR (Indian rupee) = 1 Euro is used throughout the document, as of June 2019.

real-estate housing as it is only available for ownership (Refer to variable A2b for households and farmer interviews in Appendix G).

With regards to infrastructure, actors in Badai use different technologies or infrastructure to extract groundwater. As introduced in Chapter 4, infrastructure in Badai is either provided by the government (***A9a***) or owned privately (***A9b***) (refer to the values of A9a and A9b in Appendix G to see the kind of infrastructure available to actors in Badai). One out of the four households interviewed entirely depended on public infrastructure (*Interview 6*), while others either had their own private wells or stand-posts (*Interview 8*), used wells installed by the landlord (*Interview 7*), or used a mix of public and private infrastructure (*Interview 5*). The affordability of a private wells is decided by income levels of actors. According to an interviewee, "*Minimum Rs. 30000 (384 €) is required to install a private handpump. Therefore, it is not possible for everyone to construct it"* (*Interview 6*). They further said that installing personal wells on rented land is not allowed by the landlord. In contrast to this, dyeing industries rely on private wells to extract groundwater, whereas farmers depend on the common irrigation well provided by the MIC department to irrigate their fields. Although other actors do not pay a fee for extracting groundwater, farmers must pay a seasonal irrigation fee per acre of land to access groundwater from the irrigation DTW – 10.4 € for Boro paddy and 5.12 € for growing vegetables (*Interview 9*).

Although all actors in Badai are dependent on groundwater (***A8***) – their dependency varies based on the alternatives available (ECO2 and S4). Since the village does not have a formal surface water supply, households, industries, and farmers rely on groundwater for meeting most of their domestic, drinking or production needs. Households and farmers still have access to surface water in the form of *Noai* canal and ponds, but their usage depends on how polluted they are. A representative from a dyeing industry told that "*Water is a must for our industry* "(*Interview 4*). However, this dependency might decrease in future. Another owner of a dyeing industry mentioned their plans for reducing the industry's dependency on groundwater, "*We have started modernizing our machines. Apart from that we are also taking up the rain water harvesting scheme (as required by SWID)"* (*Interview 3*). These initiatives show that these dyeing industries are taking measures to reduce their dependency on groundwater.

##### *5.2.1.4 External factors and externalities*[8]

Extraction of groundwater by actors in Badai is impacted by external factors that are outside their control. This extraction also leads to negative externalities for other ecosystems such as surface water. These factors are discussed below:

*External factors*

1. *S2 – Incoming Industries*: The onset of industries in Badai since 2000 has marked a considerable shift in its agricultural landscape. Although incoming industries have led to the development of the village, it has also put tremendous pressure on the aquifers. Good connectivity of the village, easy permits for RED category (highly polluting) factories, relatively less habitation around industries, and availability of cheap land are some of the 'pull' factors that have attracted dyeing industries to the village (*Interview 3*). Furthermore, it is expected that the village will attract more industries in the future as it is perceived as an 'industrial zone'. Only last year (2018), 20 new dyeing industries have been approved by the Panchayat (*Interview 1*).

[8] Although the SES framework divides factors affecting the focal SES into Socio, Economic, and Political Settings (S) and Related Ecosystems (ECO), I prefer dividing them into external factors and externalities since it allows to differentiate between cause and effect. While *external factors* are outside the control of peri-urban communities, *externalities* are caused by their own actions.

2. *S4 – Surface water provision[9]:* Policies on availability of surface water for drinking, domestic or industrial purposes impact the dependency of peri-urban actors on groundwater. The PHED is emphasizing the use of surface water for drinking purposes as it is free from arsenic contamination and is easier to filter compared to groundwater (*Interview 13*). However, the department faces challenges in transporting this water from its source (rivers flowing across West Bengal) to the destination. Moreover, surface water projects require high initial investments and can only be carried out at large scales. Presently, Badai is not covered by a surface water scheme, thereby forcing actors to depend on groundwater.
3. *S4 and S5 – Introduction of Boro paddy:* Prior to the introduction of Boro paddy crop in Badai, the farmers were mostly dependent on rains or lifting water from surface water canals. However, their dependency on groundwater increased with Boro paddy cultivation (*Interview 9*). Ghosh & Ray (2007) note that the reasons for increasing popularity of the Boro crop were a suitable soil substrate, availability of copious amounts of groundwater, good economic returns, and the stability of the Left Front government in West Bengal.
4. *S5 – Consumer markets for dyed cloth*: The production of dyed cloth which is a water intensive process is incentivized by consumer markets flourishing in the cities. Kolkata has a huge market for this dyed knit fabric. This cloth produced by one of the industries operating in Badai is supplied to companies like Lux, Rupa, Dollar, Amul, and Reynolds (*Interview 3*).
5. *ECO1 – Climate change*: Natural variations such as scarcity of rains may not only lead to lower recharge of aquifers but also increase the dependency of farmers on groundwater.

*Externalities*

1. *ECO2 – Surface water and land pollution*: Once the lifeline of the village, the *Noai* canal was used for irrigation, bathing and catching fishes, but is now polluted with waste (*FieldVisit1*). Groundwater extracted by dyeing industries in Badai is discharged through drainage channels that finally empty into the *Noai* canal. Although industries must establish their own effluent treatment plants to remove harmful chemicals from the discharge water, this practice has not been adopted by dyeing industries (*Interview 3 and Interview 4*). This produces knock-on effects for farmers since poor quality of canal water forces them to shift to groundwater for irrigating their fields (*Interview 8*). Moreover, some industries have also been reported to discharge their wastewater directly into the agricultural fields thereby deteriorating its fertility. When asked about this issue, a farmed said "*All lands are turning into fallow lands because of the polluted discharge water being released from the factories and in future a time will come when agriculture will not be possible here. Farmers will be bound to sell their land*" (Interview 9). Thereby, groundwater extracted by dyeing industries in Badai when discharged as surface water creates negative externalities for farmers.

The mapping of the sub-systems discussed above have been summarized in Figure 5.3.

[9] Note: This provision of surface water for drinking purposes is from outside the boundaries of Badai.

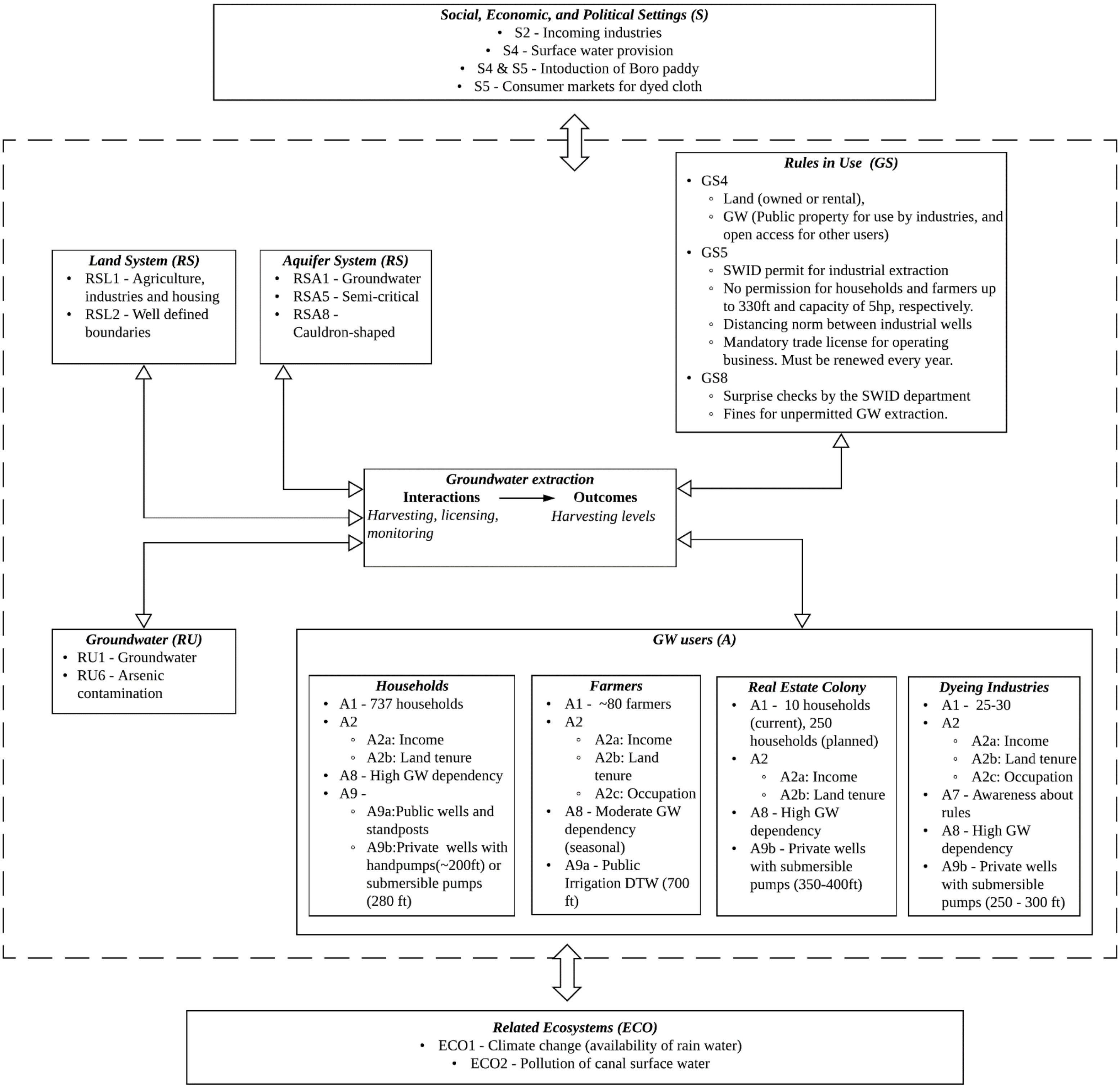



*Figure 5.3: SES subsystem variables that determine groundwater extraction*

#### *5.2.1.5 Interactions and Outcomes*

Now that the surrounding subsystems that impact the interactions and outcomes in the action situation are mapped in Figure 5.3, what goes inside the action situation is analyzed. Three major interactions take place in this action situation that revolve around extraction of groundwater are:

1. *Harvesting* (I1): actors extract groundwater
2. *Monitoring* (I9): government departments or actors monitor each other's extraction
3. *Licensing* (I11): government departments give permission to actors to run their business in the village or install a well to extract groundwater.

Based on the type of infrastructure used by actors in Badai, the action situation for extracting groundwater can be further broken down into interactions around public and private infrastructure as shown in Figure 5.5.

### *Public infrastructure*

Groundwater is *extracted* through public infrastructure such as tube-wells, stand-posts and irrigation wells which are *installed* by different government departments. Panchayats install DTWs in the village, the PHED department installs stand-posts to supply 70 liters per capita per day (lpcd) of drinking water, and lastly the MIC department installs a DTW to provide irrigation water to farmers. The source of the water supplied by the PHED department is groundwater which is extracted through two wells of 21hp and 11.5 hp each and supplied to the village through stand-posts (*Interview 17*). Households and farmers in Badai *use* public infrastructure to meet their drinking, domestic, and livelihood needs. Usage of groundwater by farmers depends on the availability of rains (***ECO1***) i.e. they don't use groundwater in the rainy season. Typically, irrigation water is most needed during the sowing of Boro paddy crop and for vegetables it is required once a week per cropping season which lasts for 3 months (*Interview 9*). *Noai* canal and ponds also *contain* surface water that are used by households and farmers for domestic and irrigation purposes respectively. However, the dependency on these surface water bodies is weak owing to their pollution. Thus, the harvesting interaction in Badai is an interplay of finer interactions that involves **installation** of infrastructure, followed by its **use** to **extract** groundwater from the resource system (see Figure 5.5).

With regards to **monitoring**, although a VWSC is responsible for monitoring PHE stand-posts and detecting any clandestine connections (*Interview 13*), in Badai, this committee is not involved in monitoring the extraction of groundwater (*Interview 14*). Groundwater infrastructure used by the farmers, however, is managed by a tube-well operator (TWO). A village-level committee consisting of 7-8 members appoints the TWO who distributes water between the three channels along which farmers are located, providing them with water for a fixed number of hours depending on the size of their fields (Gomes, 2017).

**Licensing** is undertaken in this action situation since groundwater extracted by the MIC or the PHED must be permitted by the DLA (*Interview 13 and Interview 19*).

### *Private infrastructure*

With respect to private infrastructure, households, dyeing industries, and real-estate colonies in Badai *install* their own private wells to *extract* groundwater. These wells are either based on electrical submersible pumps or manual handpumps. Dyeing industries typically extract water using a submersible pump. One industry interviewed extracted water from 76mbgl with a pump capacity of 5 hp. Running for six days a week, the industry's daily consumption of water ranges between 70000 to 80000 liters of water (*Interview 3*). In order to increase their access to groundwater infrastructure, households also install their own private wells and private connections to the PHE distribution line. This is evident from the increase in the number of stand-posts in the whole Panchayat. When the PHED project started in 2013, only 47 stand-posts were installed by PHED in the whole Panchayat, however, this number has grown to 900 over the years. "*The installation of new stand-posts is going without on without any impediment"* (*Interview 18*). Although the daily consumption of each household in the village is not known, the PHED department attempts to supply 70 lpcd (*Interview 13*). However, this water is being used for washing clothes and even cattle (*Interview 18*). Therefore, the pressure on this drinking water supply is increasing as more water points are being installed and are used for purposes other than drinking. Although such 'private' connections maybe shared with other villagers, people who install these stand-posts assume priority over their infrastructure (*Interview 8*). As can be seen in Figure 5.4, dedicated pipes supply water into households that installed these stand-posts.

*Figure 5.4: Private stand-posts installed in Badai*

Installation of private infrastructure to extract groundwater needs permission from the DLA. Real-estate developers and dyeing industries *apply for a* **license** to legally extract groundwater and are only allowed to install their wells after being granted the license. Households, on the other hand, are exempted from taking any permissions to install a private well in their house up to a depth of 100m. However, households that live in rental houses may not be allowed to install a well on the rented land without *taking permission* from the landlord (*Interview 6*). Installation of private stand-posts is made possible by taking permission from local political leaders or Panchayat members. Groups of 5-6 families who live nearby pool in money and install a stand-post by deploying their own mechanic (*Interview 8*).

Private infrastructure installed by actors is **monitored** to make sure they abide the operational rules. On the one hand, private infrastructure installed by households is not monitored, rather, facilitated by the local leaders and Panchayat administration. A Panchayat representative told that "*Although tapping of the PHE line is illegal, it is a general practice here*" (*Interview 16*). On the other hand, installation of private infrastructure used by real-estate colonies and dyeing industries is monitored by the SWID department. This monitoring depends on site visits and surprise visits undertaken by the department to check whether appropriate license have been taken by industries and infrastructure projects (*Interview 12*). The department receives only 10-15 applications in month which implies that clandestine connections are taking place in the district (*Interview 10*). Furthermore, the SWID department faces constraints of low manpower as there is only one officer, the District Geologist, responsible for monitoring illegal connections in the entire district. With regards to taking a permit from the DLA, the adherence to rules in Badai is low at best. Out of the two industries interviewed, one of them had only recently taken the permit (almost 10 years after the Groundwater Resources Act 2005 was established), while the other was not aware (***A7***) about such permission (*Interview 3 & 4*). Further distancing norms recommended by the DLA are usually not followed by industries as they are located next to each other. This goes on to show the limited monitoring of 'illegal' groundwater extraction in the village.

Lastly, monitoring of trade licenses is also weak in Badai. An interviewee mentioned that "*We have no idea of industries that are running without trade licenses*" (*Interview 15*). Industries that do not renew their trade license are summoned by the Panchayat via notices, however, the sanctions for the same are not known. Furthermore, although Panchayats have the right to cancel a trade license, no such cancellations have been reported in the village so far due to violations of groundwater extraction rules.

### *Outcomes*

The interactions mapped above impact the groundwater harvesting levels of actors in Badai. Although the exact amount of groundwater extraction by each actor is not known, rough estimates of these extraction levels are presented in Table 5.2 (Refer to Appendix H for calculation details behind these numbers). Since groundwater scarcity is a major concern in Badai during the summer season, extraction levels of all actors are compared over the summer season and also throughout the year.

*Table 5.2: Estimated groundwater harvesting levels of different actors in Badai*

| ***Actor*** | ***Total water extracted in summer season*** *(in Liters)* | ***Total water extracted per year*** *(in Liters)* | ***Value assigned*** |
|---|---|---|---|
| Farmers | 306,665,100 | 316,188,600 | High |
| Dyeing Industries | 63,360,000 | 253,440,000 | Medium |
| Households | 23,184,000 | 92,736,000 | Low |
| Real-estate colony | 252,000 | 1,008,000 | Low |

As shown in Table 5.2, all actors are responsible for tapping into the village's aquifers. While extraction level of farmers can be termed as high, that of dyeing industries are relatively moderate. Surprisingly, although households have the highest population among the actors, their extraction is low compared to other actors in Badai. One plausible explanation for this is that since majority of households depend on public infrastructure such as stand-posts, which is limited to a supply of 5 hours a day, their consumption is therefore limited. Although extraction of groundwater by farmers is kept in check by the TWO, high amounts of water required for cultivating Boro paddy trumps the groundwater consumption of other actors, not only in the summer season, but also throughout the year. This points to the water-extensive nature of Boro paddy crop being cultivated in Badai. Lastly, although extraction of groundwater by dyeing industries is moderate as of now, incoming industries are bound to increase the pressure on the village aquifer.

In addition to the focal outcomes of harvesting levels, one social outcome can also be identified that feedbacks into the actor sub-system. Use of polluted surface water by farmers disconnected from the irrigation channels may prevent an increase in their income levels (A2a) thereby reinforcing their dependency on the polluted water and preventing them to switch to other means of irrigating their fields.

To sum up, SES factors and interactions captured in this section explain the resource outcomes observed in Badai i.e. the lowering of groundwater level. Groundwater scarcity faced by actors may lead them to seek resolution for their problems and self-organize. This action situation is explored in the next section.

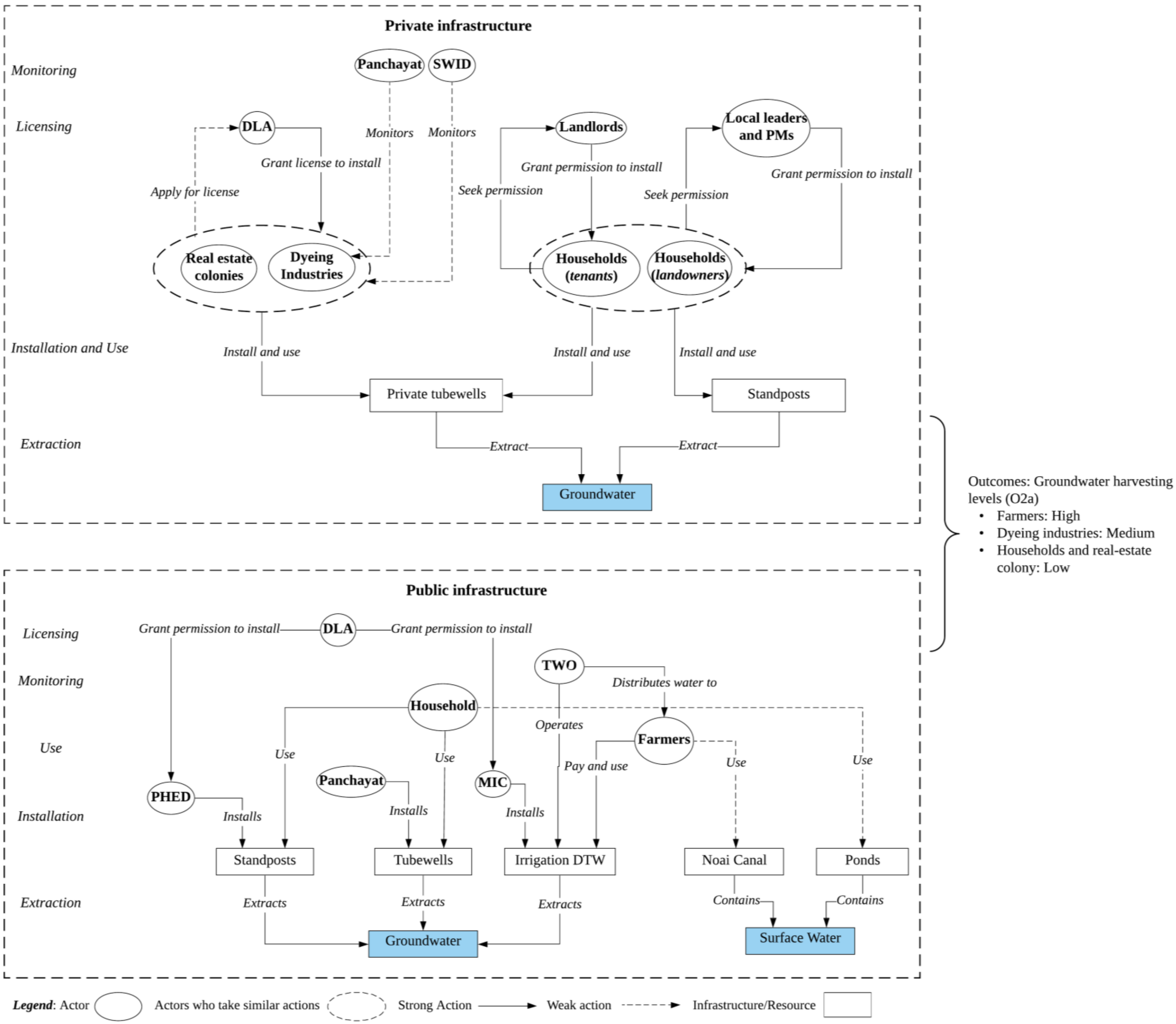



*Figure 5.5: Groundwater extraction action situation (Badai)*

### 5.2.2 Responses to groundwater problems by actors in Badai

When actors in Badai extract groundwater from a common aquifer, they face scarcity of groundwater or problems in adhering to the harvesting rules. This leads them to self-organize to change the operational rules or seek redressal for their problems. This section presents the explanatory second-tier SES variables and interactions that explain the outcomes of collective action in response to groundwater problems.

#### *5.2.2.1 Resource System and Resource Units*

The aquifer system of Badai presents typical CPR problems. The mobility of groundwater for the Badai aquifers is unknown (***RU1***). As explained in the previous section, the productivity of the aquifer (***RSA5***) is 'semi-critical' which is also evident through scarcity problems reported by actors in Badai (refer to the value of O2a in Appendix G). Interviewees also point to the difficulty in predicting the system dynamics of aquifers (***RSA7***). When asked about groundwater sustainability, an interviewee said that it is difficult for them to comment since "*I (they) cannot measure how much water is in the aquifer and how much is extracted*" (*Interview 1*). Another interviewee, a local woman, had a general sense of how the groundwater level gets recharged and she could correlate groundwater extraction with the depletion of water table. She said that "*If all submersible pumps stop, this problem (of groundwater scarcity) with be solved. Water level will rise*" (*Interview 5*). Therefore, although actors seem to have an understanding of the water cycle and can correlate groundwater extraction to depletion, they cannot quantitatively estimate the stock and flows of the resource. Therefore, unclear mobility and boundaries of the resource (***RSA2***), and low predictability of its system dynamics pose a challenge for self-organization in Badai.

#### *5.2.2.2 Governance System*

At the collective-choice level, the governance system in Badai is dominated by the Bilkanda-I Panchayat and its members ***(GS1)*** whose activities are governed by the West Bengal Panchayat Act 1973 ***(GS6)***. Two elected representatives from Badai form the first point of contact for villagers who seek redressal for their groundwater problems. The Panchayat, however, has no role in matters pertaining to groundwater extraction. Although the Panchayat is concerned about depleting water tables in the village (from 200 ft bgl to 300 ft) and attributes this to huge extraction by the dyeing industries, they have no formal role in monitoring their extraction (*Interview 14*).

The MIC department which provides irrigation infrastructure to farmers forms their first point of contact to resolve problems related to groundwater scarcity. Apart from the formal organizations, presence of civil society organizations in the village is weak (***GS2***) – there are no NGOs in the village, 1 women's organization, a social club for cultural and sports-related activities and 6 Self Help Groups (SHGs) that collectively apply for bank loans and health insurance from the West Bengal government (*Interview 16*). Apart from this, recent research projects (NWO, 2014) in the village have initiated conversations and knowledge sharing around groundwater issues.

#### *5.2.2.3 Actors*

In Badai, there are 737 households (***A1a***), 1 real estate colony (***A1b***), 25 dyeing industries (***A1c***) and 80 farming households (***A1d***) as described in Section 5.2.1.3. These actors differ in their harvesting levels, with farmers extracting the maximum amount of groundwater in the summer season and throughout the year, followed by dyeing industries, households, and real-estate colony. While households and real-estate colony are dependent on groundwater for domestic and drinking needs, dyeing industries and farmers depend on it for their livelihoods and income ***(A8, A2).*** Moreover, actors may have different bargaining powers depending on whether they act individually or in a group[10]. Industries in Badai are part of an Industry Association whose main goal is to "*protect industries from inspector raj* (rule)" and develop infrastructure for them (*Interview 1*). A total of 100 industries in Badai are part of this association, however, not all 25 dyeing industries in Badai its members (*Interview 1*). Distribution of irrigation water among farmers is managed by a village-level committee consisting of 7-8 members and headed by the Panchayat Prodhan (Gomes, 2017). The TWO is selected from this committee who manages the pump and distributes water between the farmers. Based on the needs of the farmers, the committee decides the distribution of irrigation water and conveys it to the TWO. Other actors in the village, i.e., households and real-estate colony, act individually for groundwater related issues and are not represented by any committee or association.

Actors in peri-urban Badai have their own mental models about the causes behind the groundwater scarcity they face ***(A7).*** Households and farmers attribute groundwater scarcity to high extraction by dyeing industries. Talking about this issue, a local woman said, *"We used to get much water before the factories were setup here. Nowadays as the factories are growing, now we see that the water flow is decreasing"* (*Interview 5*). Although agriculture is also a major user of groundwater, households believe that their use of groundwater is only seasonal, i.e., for summer crops, whereas industries use it throughout the year, running their pumps 24*7. This is also confirmed by another user who reiterated this cause saying that dyeing industries extract a lot of groundwater, and this is evident through the amount of discharge water that can be spotted in the drainage canals (*Interview 6*). Furthermore, farmers also claim that wells setup by dyeing industries are too close to their DTW and this negatively impacts the amount of groundwater available to them.

Actors also perceive different solutions for their groundwater scarcity issue. While some users expect the government to address this issue (*Interview 8 and Interview 9*), others believe that limiting their consumption and reducing wastage (*Interview 7*) or stopping the use of submersible pumps (*Interview 5*) is the only way to solve this problem. Moreover, households and farmers lack awareness about the formal rules that dyeing industries must follow to challenge their extraction. None of the interviewees were even aware of the names of district departments responsible for regulating groundwater extraction (author's own observation).

Although households and farmers seem certain about the cause of depleting groundwater levels, they don't know a way out of this problem. Local women are uncertain about whom to approach for this issue since elected Panchayat members are already aware of the situation. Households have internalized that they need to adjust their behavior and therefore, they fall back on social norms ***(A6)***. *"We are common people, what we do is adjust" (Interview 5*). Given the uncertainty of supply, households adjust by adopting the following norms:

1. *Hoarding:* When good quality of water is available, women resort to hoarding. They keep water in 4 pots instead of 2 since good quality of water is not always available (*Interview 5*)
2. *Queuing*: When there's scarcity of water, women patiently queue up to fetch water from the public handpumps. They spend about 1-1.5 hours collecting water and have to fetch water at

[10] Depending on whether actors act individually or in a group, they can be divided into individual or composite actors. Composite actors are characterized by the action they take (individual or joint), the purpose behind that action (individual or collective), the control over resources required to take action (individual or collective) and the decision-making arrangement within the group (explicit agreement, voting, or consensus). An association is characterized by joint action, collective purpose, collective resources and a voting style of decision-making (Scharpf 1997 cited in Bots, 2016)

least 2-3 times a day. Their waiting times have reduced after the installation of the PHE stand-posts in the village (*Interview 5*).

3. *Emergency sharing*: When their own wells are not functional, households may take water from their neighbors' handpumps (*Interview 7*). Usually, no permission is required for this. Households who have electrically operated wells restrain from sharing water from their personal wells due to electricity cost considerations (*Interview 5*).
4. *Prioritizing use*: Washing utensils or clothes and bathing using water from the stand-posts is not considered socially appropriate and commotions are common if these norms are not adhered to (*Interview 6 & 16*).
5. *Installation of private stand-posts*: Norms of installing private stand-posts are common in the village as explained in Section 5.2.1.5.

Lastly, farmers in Badai are not united and lack leadership to initiate collective action ***(A5)***. They are not represented by any organization or association in the village to tackle their problems with dyeing industries. Talking about the issue of polluted waste-water discharged into agricultural fields, an interviewee said that "*Farmers are not united, so they can't move unitedly to fight for their issue* "(*Interview 9*). They further went on to say that although there is a need to make a collective, no one comes forward to do this. On the other hand, industries in Badai are represented by an Association that represents their interests. For households, Panchayat members and local political leaders have been somewhat successful in increasing their access to infrastructure by approving private stand-post points.

#### 5.2.2.4 External factors and externalities

The ability to engage in collective action in Badai is affected by external factors such as the influence of politics. This factor is explained below:

***External factors***

- **S3** – Politics: Badai has a strong presence of the local political party, the Trinamool Congress (TMC). The change in political regime from the previous Left Front government has led to greater access to water infrastructure for the villagers. The PHE stand-post scheme which is seen as a solution to groundwater water scarcity was led by the TMC (*Interview 5*). Furthermore, initiatives taken by the local party leaders in facilitating the construction of more stand posts has enabled villagers get more access to drinking water. Politics, however, has another side to the story. Past experiences (***A3***) with political leaders have deterred farmers' hopes in resolving their issues with dyeing industries. Agitation created around the issue of polluted water being discharged into the fields only led to money exchanging hands between industries and the political leaders (*Interview 9*). Furthermore, the political party is fully represented at the Gram Panchayat which deters access to fair conflict resolutions mechanisms. Bypassing the party system is therefore difficult in Badai. Involvement in politics is a precursor to collective action. As one interviewee said, "*In Badai, there is no association or organization without politics*" (*Interview 7*).

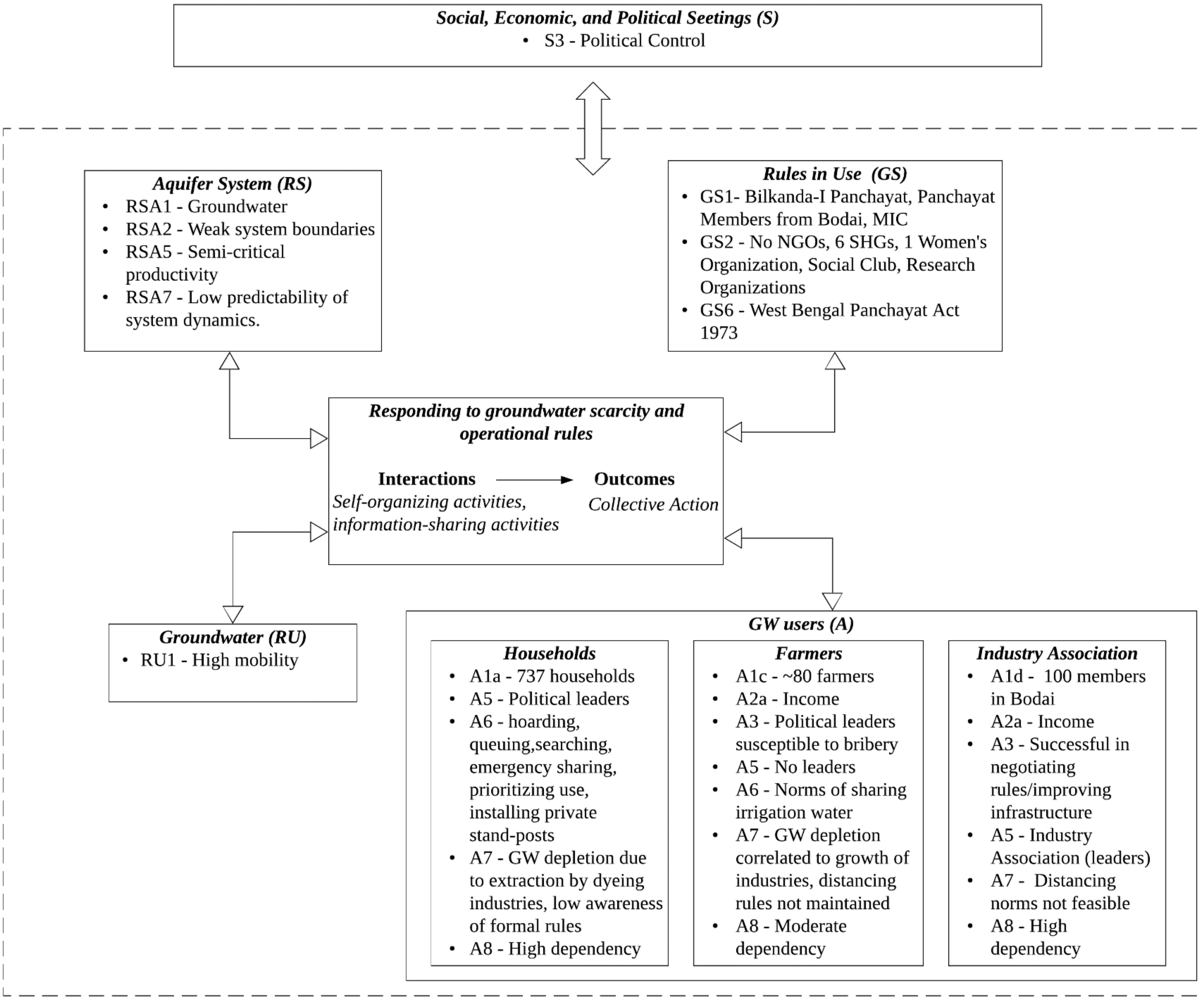



*Figure 5.6: Subsystem map for Action situation: responding to groundwater scarcity and operational rules (Badai)*

#### *5.2.2.5 Interactions and Outcomes*

When actors interact to respond to depleting groundwater levels, the major interaction that takes place between them is that of **self-organizing activities** (***I7***)*, and* **information-sharing activities** (***I2***). Actors respond in different ways and approach different actors to resolve their scarcity issues.

When farmers face issues of groundwater depletion, they either *make do* with whatever water they have or seek short-term solutions. Two years ago (2017), when farmers realized that the groundwater level is depleting, they wrote a mass petition and *complained* to the MIC department. The department *inspected* the DTW and *sunk* it 20 feet deeper into the ground to extract more water (*Interview 9*). After the re-sinking of the tube-well, they have not faced more issues and this 'fix' is working as of now.

As part of self-organizing activities, industries in Badai pay a monthly fee and *join* the Industry Association (*Interview 4*). They try to unitedly solve infrastructure issues related to roads, electricity, and drainage. Being a part of the association provides them with better bargaining powers. One of its members said that "*When we appealed unitedly (to the district administration) we got an advantage – roads got better. If we go alone, we don't get a response*" (*Interview 3*). This association has demonstrated leadership in the past in *negotiating* the rules for installing industrial tube-wells. In the past, when a dyeing industry was denied the permission to install a well due to distance violations, the Association reached out to the district administration to negotiate the rules. This interaction is represented in Section 5.2.3.2. Although industries in Badai do not self-organize specifically in response to groundwater scarcity, negotiation of rules with higher institutional levels helps them maintain their groundwater harvesting levels.

To address their scarcity issues, households mostly draw the attention of Panchayat members or local political leaders who relay their complaints to the Panchayat. Political leaders, however, have a limited role in resolving the problem of groundwater scarcity. An interview with a local leader revealed that their response to this issues is to approach mechanics for possible repairs in the wells. Apart from that, "*we have nothing to do with decreasing GW levels*" (*Interview 18*). Scarcity issues in the past have been resolved by the Panchayat by *installing* more DTWs in areas with an acute crisis (*Interview 15*). Now, the PHED line is seen as one of the 'solutions' of the scarcity problem in the village. Before the PHED line was installed, households used to get agitated about the extraction and pollution of dyeing industries. Now, the PHE line has been successful in pacifying the villagers to some extent and the focus has shifted to pollution problems being caused by industries (*Interview 15*). According to an interviewee, "*There's no severe problem in the summer time (now) and the users don't approach the Panchayat (anymore); they approach the Panchayat for pollution problems (, i.e., discharge of polluted wastewater by dyeing industries)*". Therefore, the issue of groundwater scarcity has lost its urgency. The upcoming real-estate colony in Badai also faces a similar situation. Since they have not yet reached a situation of severe crisis which forces them to fetch water from other sources or attempt to solve the issue, there only response to groundwater scarcity is to consult a mechanic (*Interview 2*).

With regards to information sharing, villagers approach Panchayat members or go directly to the Panchayat office to report any illegal extraction of groundwater (*Interview 15*). This information is further passed on to the higher administrative levels. According to an interviewee, communities generally report to their Panchayat or the Block Development Office (BDO) by signing mass petitions (*Interview 12*). These petitions are then taken up in the meetings of the DLA. The department, therefore, depends on information shared by groundwater users about any illegal extraction. However, the barrier to complaining is high since local people are dependent on the industries for employment (*Interview 12*). This dependency coupled with low awareness about formal rules limits the complains and subsequent information sharing between Panchayats and the DLA.

***Outcomes***

The interactions that take place as a response to groundwater scarcity determines the level of collective action in Badai. This is mapped in Figure 5.7. Households mostly resort to complaining and agitating to local leaders and the Panchayat either for access to more infrastructure or complaining about groundwater extraction by other actors. Moreover, with the advent of the PHE line that has been able to somewhat meet the present water needs, the urgency of groundwater scarcity has decreased and so has the level of collective action among households. Even within households, migrants are a specific group that is left out of any form of collective action. An interview with a migrant from Orissa revealed that none of the migrants are involved in local politics in Badai since "*We (they) have come here to earn and live*. *Will politics give us food?"(Interview 7).* Therefore, signs of strong collective action among households in Badai in the form of an association or a collective are missing.

In response to groundwater scarcity, farmers approach the MIC to attain short-term solutions for overcoming the scarcity problem. There is no collective organization that represents their interests, unlike the industries, which hampers their bargaining power in other problem arenas such as taking up wastewater pollution problems with dyeing industries. In contrast to this, industries become part of the Industry Association, in order to attain better bargaining power for negotiating infrastructure issues with the Panchayat and operational rules for groundwater extraction with the DLA. Therefore, while industries in Badai resolve their issues collectively, collective action among farmers and households is low, at best.

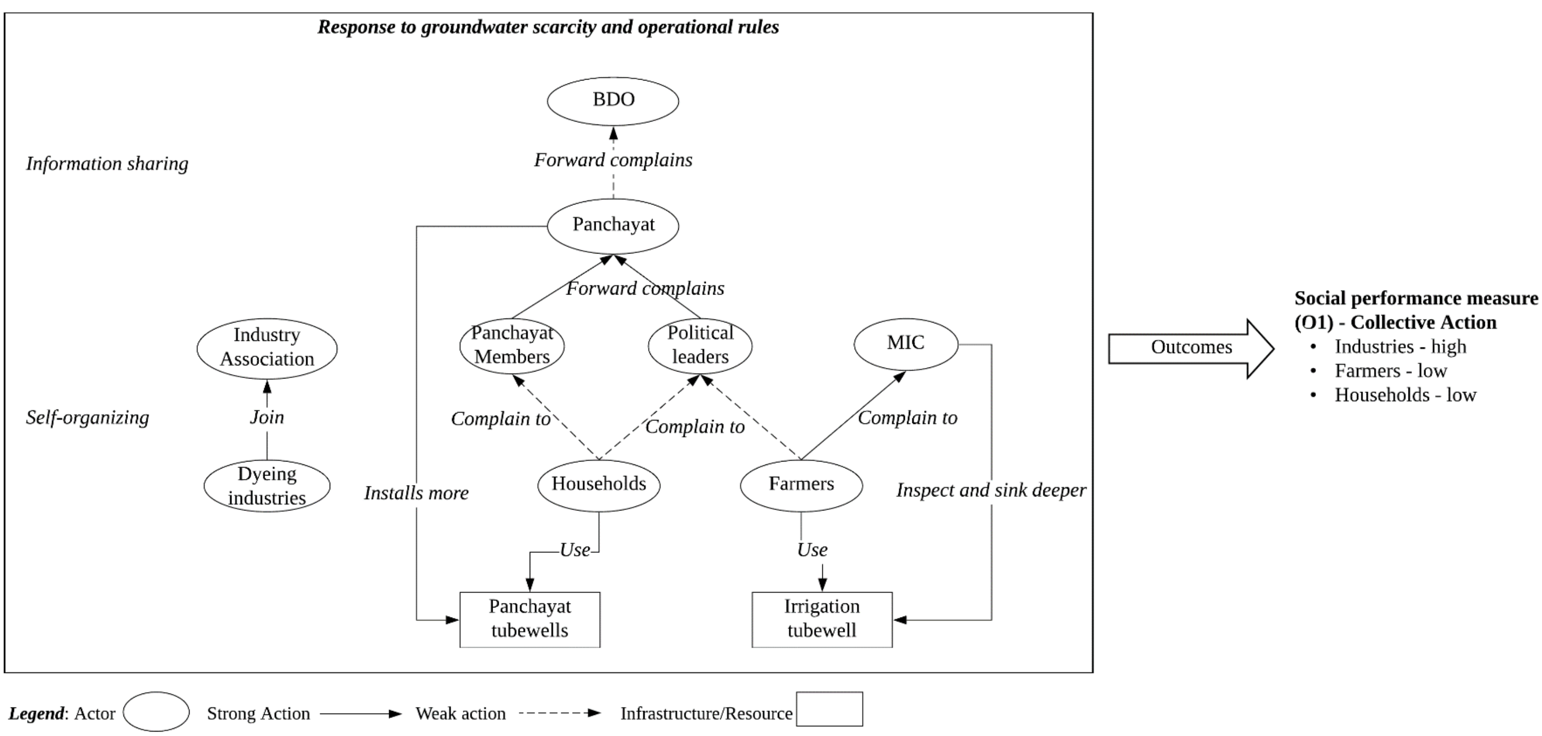



*Figure 5.7: Actor interactions and outcomes for responding to GW scarcity and operational rules action situation*

### 5.2.3 Impact of higher institutional levels on outcomes and responses

Based on the discussion above, we can see that at the operational-choice level actors interact and harvest groundwater while at the collective-choice level they attempt to respond to their problems of groundwater scarcity and dissatisfaction with the operational rules. In addition to these, two more action situations can be identified whose outcomes impact the operational rules that peri-urban actors in Badai follow to extract groundwater. The collective-choice level can be further divided into two levels depending on the degree of separation from the peri-urban communities. While *Level 1* consists of actors that form the first point of contact for the peri-urban communities consisting of the Panchayat, local political leaders, and MIC, *Level 2* operates at the District that only industries in Badai can access. This distinction is important in order to highlight the difference among actors in Badai in accessing higher institutional levels. Therefore, additional action situations that operate at Collective-choice Level 1 and Collective-choice Level 2 are described below. Given the focus of the thesis on understanding community responses plus limited knowledge on the 'internal' details of these action situations, they are not further unwrapped. All the four action situations that explain groundwater management in Badai, including the two new action situations explained below are visualized in Figure 5.8

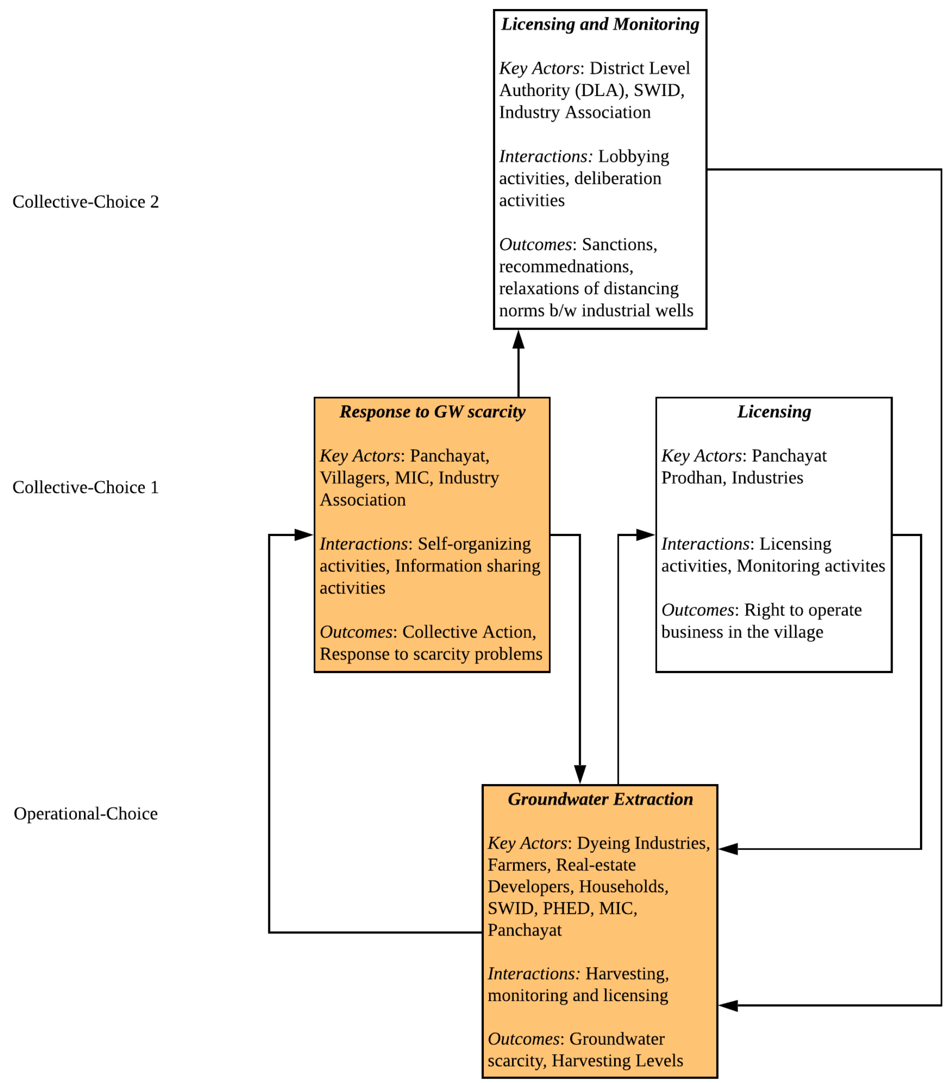



*Figure 5.8: Overview of Action Situations at different institutional levels*

#### *5.2.3.1 Trade permitting by Panchayats*

Parallel to the action situation “response to GW scarcity and operational rules”, the Bilkanda-I Gram Panchayat regulates the operational rules that decide which industries can operate in the village. One key interaction takes place in this action situation; **licensing activities (*I3a*)**. Gram Panchayats have the authority to issue a trade license to an industry under Rule 58 of the Gram Panchayat Administration Rules, 2004 (Department of Panchayats and Rural Development, 2004). The trade license is the first license sought by an industry. All other licenses - fire, electricity, pollution control, and water are taken after a valid trade license and a No Objection Certificate (NOC) has been received from the Panchayat. The Panchayat scrutinizes an industry’s application and grants a trade permit to the industry which must be renewed every year.

Describing the challenges in this action situation, one interviewee said that “*there is no mechanism, knowledge or sensitization. (There are) No specialists for vetting the projects/industries (that are not feasible)*” (*Interview 10*). Panchayats lack the infrastructure to properly scrutinize the industries that they approve. Furthermore, the short-sighted response of the Panchayats is valid, since giving out a trade-license earns a revenue for the Panchayat.

In Badai, the decision to grant a trade license is taken by the Prodhan of the Panchayat (*Interview 16*). The criteria followed for the same is a valid land deed and an industrial plan along with payment of the required taxes (*Interview 14*). The Panchayat Prodhan therefore decides which industrial actors (***A1c***) can operate in the village thereby determining the actors that are part of the groundwater extraction action situation (See link between *licensing* action situation at collective-choice level 1 and *groundwater extraction* action situation at operational-choice level in Figure 5.8).

#### *5.2.3.2 Groundwater management by the DLA*

The DLA provides a license to industries which gives them the right to harvest groundwater. Decisions taken by the DLA decides the operational-choice rules that govern groundwater extraction. Moreover, the authority also decides the monitoring mechanisms and fines to be charged from defaulters, which impacts the enforcement of the operational-choice rules. The main interaction that occurs in this action situation are **lobbying activities** (***I6***), and **planning activities** (***I3b***)**.**

Difficulties faced by dyeing industries in Badai in complying with the rules and norms of the Groundwater Resources Act 2005 are taken up by the Badai Industry Association. In the past, when an industry was denied permission to install a well due to well distancing violations, the Association moved to the district authorities (*Interview 1*). The Association posits that it is not feasible to maintain a distance of 200m between adjacent wells in an industrial complex and proposes that these norms should be changed (*Interview 1*) to match the ground reality. Being part of a dense industrial belt, dyeing industries in Badai are located next to each other. The distancing norm is meant to be a technical recommendation by SWID based on the cone of depression (refer to Appendix F.2) created by a well (*Interview 28*). Therefore, it is in the industries’ own interest to maintain the distance to be able to extract groundwater over a long period of time. Although the industries acknowledge that this violation may lead to problems in the future, their focus, however, is set on short term goals (*Interview 1*).

As part of its planning activities, the DLA decides the amount of fine to be charged in case of rule violation i.e. operating wells without a license. The fine acts as a price signal to the industries determining their adherence to the rules. Although, value of the fine has gone up to 960€ in the past, which was effective to control illegal GW extraction (Gomes, 2017), its current value stands at 64€. Further, the authority also takes day to day decisions and proposes recommendations to groundwater users such as rain water harvesting. Furthermore, installation of water meters is also being discussed as a future step to improve groundwater management as it is considered an important measure to document the usage of groundwater by different users (*Interview 12*).

Therefore, the outcomes of the interactions that place in the action situation involving the DLA and the Badai Industry Association results into decisions about the relaxation of distancing rules, value of the sanctions charged to the groundwater users, and recommendations for decreasing the burden on the groundwater resource (see link between *licensing and monitoring action* situation at collective-choice level 2 and *groundwater extraction* action situation at operational-choice level in Figure 5.8).

Although most of the interactions around groundwater management in Badai takes place closest to the groundwater resource (action situations at operational-choice level and collective-choice level 1), key decisions taken at higher levels (collective-choice level 2) significantly impact the ground reality. Since most of the powers of forming, amending, and enforcing groundwater harvesting rules lies with the DLA, the role of Panchayats in matters of groundwater extraction is indeed limited. Furthermore, as can be seen from Figure 5.8, the Gram Panchayat and DLA exist in isolation as there is no direct interaction reported between them (missing link between *licensing* action situation at collective-choice level 1 and *licensing and monitoring* action situation at collective-choice level 2).

## 5.3 Coping and solving strategies for groundwater scarcity problems

From the above discussion it is evident that the Badai community does not respond to their groundwater problems as a whole. Rather actors within the Badai community – households, farmers, real-estate colony, and dyeing industries, respond to their groundwater problems differently. Key responses observed among community actors can be said to revolve around two key strategies: coping with groundwater scarcity or attempting to solve groundwater scarcity through short-term solutions. These strategies have been visualized in Figure 5.9. In the context of the Badai case study, coping can be defined as a strategy to mitigate the problem i.e. reduce its intensity.

Households cope with groundwater scarcity by establishing the following norms for water sharing and increasing access to infrastructure:

- *Queueing*: Line-up patiently at the public wells
- *Prioritizing*: Avoid using PHE water for washing utensils or clothes
- *Hoarding*: Store water when available
- *Sharing*: Fetch water from households who have private wells
- *Investing in private stand*-posts: Pool money to install private access to the PHE line

Farmers either make-do with available water in periods of scarcity or run their irrigation pumps for more hours to fetch the required amount of water. Further they share water from the common irrigation tube-wells by rotating the distribution across all agricultural fields.

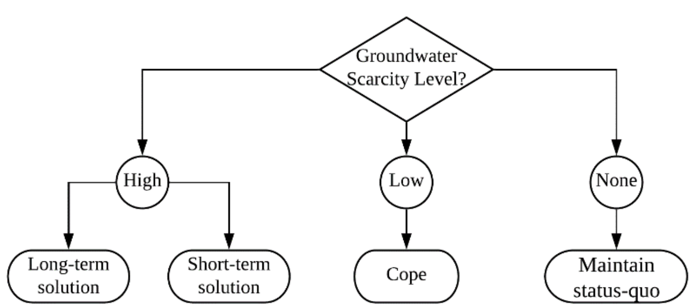



*Figure 5.9: Response strategies towards groundwater scarcity in Badai*

In times of high groundwater scarcity, actors within the Badai community resort to stronger measures. Farmers solved their scarcity problems by writing mass petitions to the MIC that led to deeper sinking of their DTW. However, this can only be termed as a short-term solution since it does not 'solve' the groundwater scarcity issue, but rather delays it. During times of high scarcity, households resort to agitation. In the past, the Panchayat has also responded to this problem by using short-term solutions such as installing DTWs. A large-scale solution to the problem was provided by the PHED supply which managed to pacify households and reduce the supply gap. Although the PHED supply has been successful in providing more water to the villagers by tapping into deeper aquifers and using high capacity pumps, given the pressures of migration and unregulated extraction by other actors, it is a matter of time when this groundwater source may also face a similar scarcity issue.

Lastly, although dyeing industries do not face any scarcity in extracting groundwater, they are successful in maintaining the status quo by negotiating well distancing rules with the DLA. However, this response only delays future groundwater scarcity. Extracting groundwater from wells located closer than the recommended distance makes industries susceptible to future declines in the water table thereby necessitating deeper drilling of wells.

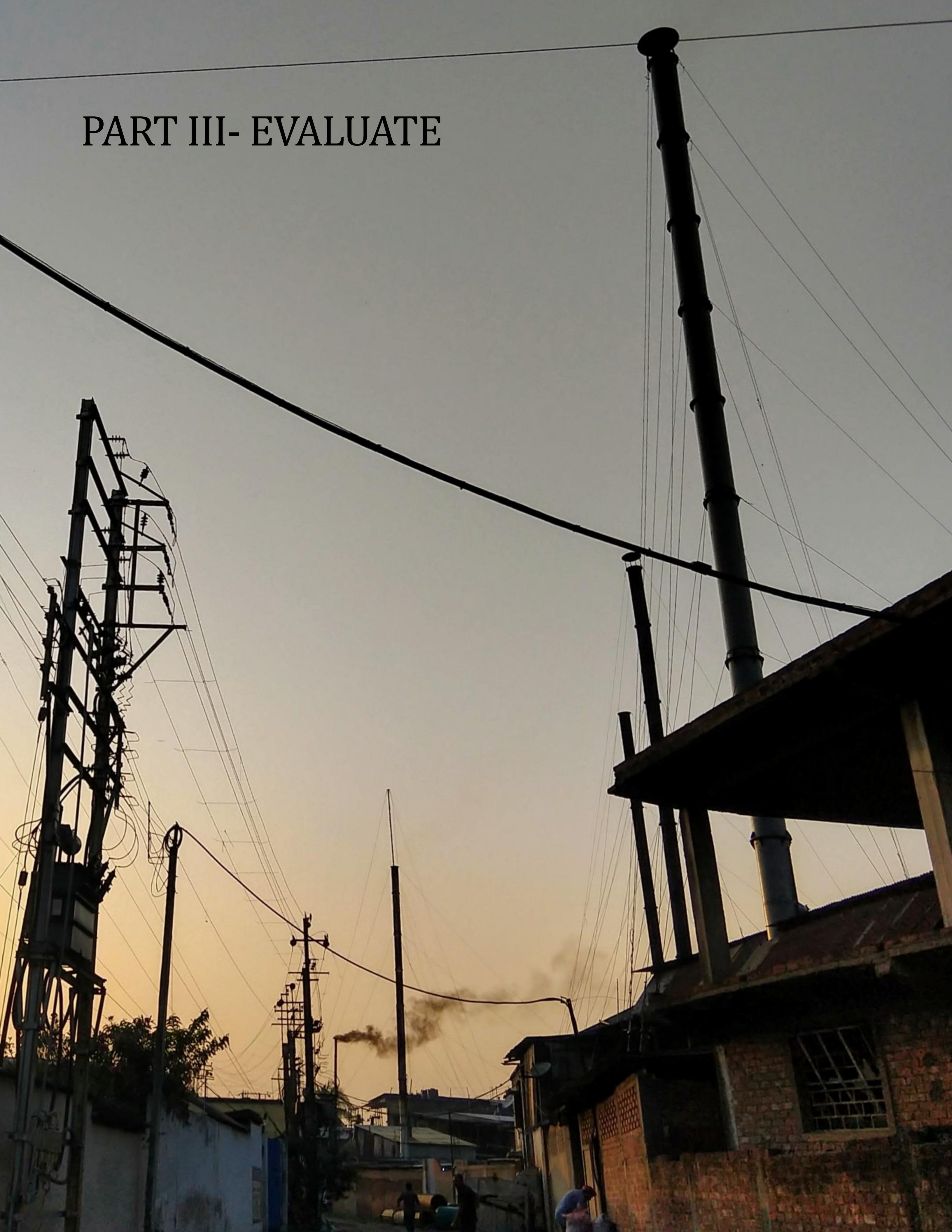
## 5.4 Chapter synthesis

This chapter set out to understand the problems faced by a peri-urban community near Kolkata and how they respond to these problems. As the analysis conducted in this chapter shows, actors in Badai face different problems with respect to groundwater. On the one hand, a common problem that exists among real-estate developers, households, and farmers is summer groundwater scarcity. On the other hand, dyeing industries face no issues with groundwater extraction but rather face difficulties in adhering to the operational rules for groundwater extraction.

Groundwater scarcity which is a shared problem across most of the actors in Badai was discussed and elaborated in this chapter by applying the SES framework. The application of the framework helped to understand the factors that generate high groundwater extraction levels thereby leading to groundwater scarcity outcomes. Rough estimates of the ecological outcomes in Badai reveal that farmers are the major extractors of groundwater followed by dyeing industries, households, and the real-estate colony. However, these number should be seen in the context of external factors that operate in the village. Incoming industries mean that extraction levels will increase in the future while those of farmers may decline as their lands are occupied for real-estate development or polluted by the discharge of industrial waste.

Different actors within Badai respond differently to groundwater scarcity. While some actors cope with scarcity issues, others are able to resolve it only temporarily. While households rely on norms of hoarding, emergency sharing, queuing, prioritizing use, and installing private stand-posts, farmers and dyeing industries are able to attain short-term solutions to their problems. Strategies of writing mass petitions have been successful in giving farmers access to more irrigation water, whereas, dyeing industries have been able to access higher institutional levels to negotiate rules detrimental to their harvesting levels. Although actor responses observed in Badai resolve groundwater scarcity on a short-term level, community-wide collective responses aimed towards sustainability of the resource are not seen in the village. The subsequent chapter evaluates the reasons behind low community-wide collective action in Badai.

# PART III- EVALUATE



# 6 Challenges for CBM in peri-urban Badai

*The case study analyzed in chapter 5 presents the values of second-tier SES variables that explain the ecological and social outcomes of interest in Badai. Using these observations, this chapter evaluates the performance of CBM in Badai and highlights the specific challenges faced by different actors in the Badai community. The results of the evaluation provide an answer to RQ3, i.e., "What are the challenges faced by the peri-urban community in resolving their groundwater problems?"*

## 6.1 Evaluating the performance of community-based groundwater management in Badai

Long-enduring, robust CPRs are characterized by the presence of commonalities called as design principles. As described in Chapter 2, a design principle is an essential element or condition that accounts for successful CPR management. Application of the design principles to a peri-urban community is challenging. Since Badai is composed of different actors who vary by their resource use, dependency, harvesting levels, norms, etc., each actor in Badai can be considered a community in itself. However, since sustainable management of groundwater by one part of the community (an actor such as farmers in Badai village) does not necessitate sustainable management by the whole community (Badai village), these principles are evaluated to check for their presence at the community level.

Table 6.1 summarizes the application of the design principles to groundwater management in Badai. Since the design principles are embedded in the IAD framework (described in Section 2.1.3) which is further embedded in the SES framework, parallels can be found between the eight design principles and the SES framework (Bal, 2015). Each design principle can be linked to second-tier variables in the SES framework as shown in the first column of Table 6.1. Therefore, results from the case study in the form of values of second-tier SES variables are used to reason out the application of the design principle.

*Table 6.1: Application of Ostrom's (1990) design principles to CBM of groundwater in peri-urban Badai*

| ***SES variables*** | ***Design Principle*** | ***Results from Badai*** |
|---|---|---|
| RS2: Clarity of systems boundaries | DP1: Well defined boundaries | Land (Yes), Aquifer (No), Users (No) |
| GS5: Operational Rules | DP2: Congruence between costs and benefits | Yes (public infrastructure) |
| GS6: Collective Choice Rules | DP3: Collective Choice Arrangements | No |
| GS8: Monitoring and sanctioning rules | DP4: Monitoring | Yes, but low enforcement |
| | DP5: Graduated sanctions | Yes, but weak monitoring |
| I4: Conflicts | DP6: Conflict resolution mechanisms | Yes, but low access |
| I7: Self organizing activities | DP7: Minimal recognition of rights to organize | Yes |
| GS7: Constitutional rules | DP8: Nested enterprises | No |

Observations from Badai are qualitatively assessed in Table 6.1 to be performing poorly, moderately or strongly on the design principles - principles that are not present are considered as 'weak' and marked in red, principles that are partially present or are present but not fully enforced are considered 'moderate' and marked in yellow, whereas those that are present and enforced are considered as 'strong' and marked in green. The design principles applied to the findings from the case study are presented below:

### *1. Well defined boundaries*

The first design principle requires that the boundaries of the resource system such as an irrigation or a fisheries system and the users who have the right to harvest resource units from the resource system are clearly defined. Adherence to this principle implies that users are able to define the boundaries of the resource system and close it to 'outsiders' who do not abide by the rules to use the resource, thereby preventing the problem of free-riding (Ostrom, 2005).

In Badai, both the boundaries of the resource and users are unclear. At the village level, although the boundaries of the land system (***RSL2***) are clearly defined, boundaries of the aquifer system (***RSA2***) from which the community extracts groundwater is unknown. Moreover, the administrative lines across which villages are divided in West Bengal do not necessarily match the boundaries of the underlying aquifers. This leads to 'fuzzy' boundaries where resource users are drawn from a larger community beyond one village (Quinn, Huby, Kiwasila, & Lovett, 2007) i.e. considering the aquifers, there are more resource users than the inhabitants of the Badai community alone. Even within the village, boundaries of actor groups keep changing as new actors enter the village and gradually start increasing in number. Back in the year 2000, it was the introduction of industries in Badai and more recently, the real-estate colony.

### *2. Proportional equivalence between Benefits and Costs*

According to this principle, users who harvest a resource over the long run must devise rules to determine how much, when, and how the resource units are to be harvested (Ostrom, 2005). When the rules for distributing benefits are proportional to the distribution of costs, users are likely to contribute towards the sustainability of the resource. This principle advocates for congruence between resource provision and use, and between rules and local resource conditions (Bal, 2015).

Benefits derived from the Badai aquifer largely exceeds the costs incurred by the actors. As explained in Section 5.2.1, farmers are the highest extractors of groundwater, followed by dyeing industries, households, and real-estate colony. Among farmers, one can observe rules (***GS5***) that limit the timing or amount of groundwater used by them in proportion to the costs borne. Farmers pay a nominal seasonal fee to use groundwater for irrigation purposes and furthermore, the amount of water distributed to their lands is decided by a village level committee and controlled through a rotation system. On the other hand, extraction of groundwater by households, real-estate developers, and dyeing industries is uncharged. Although public infrastructure such as stand-posts is governed with social norms that prohibits excessive use of water, private infrastructure is largely unregulated. Apart from bearing the costs to install a well, dyeing industries and households who have private wells pay no fees thereafter to extract groundwater, and with no upper limit on the amount of water withdrawn. Therefore, although proportional equivalence between provision and use is observed among farmers, for the remaining actors, it is largely absent.

### *3. Collective-choice arrangements*

According to this principle, users who interact with the resource must have the ability to craft and modify them according to the local conditions. This is of importance since as resource conditions change over time, officials located far away may not know of the change compared to people who live closest to the resource (Ostrom, 2005).

Groundwater management in West Bengal follows a centralized top-down approach with no involvement, autonomy or recognition given to communities who lie closest to the resource. The ability to craft and modify operational rules to harvest groundwater largely lies with the District Authorities and the State-level SWID department in West Bengal (***GS6***). They are the legal regulators of the resource who decide who has access to the resource. Amendments have been made since the passing of the Groundwater Resources Act in 2005, whereby first households were exempted from registering their wells, and then farmers were exempted from taking a license up to an extraction of 5hp (Refer to Appendix E.1). Therefore, the legal power to craft rules that govern groundwater harvesting lies with the District Administration which is far separated from the local communities.

Under this scenario, presence of collective-choice rules at the village level in Badai to regulate the extraction of groundwater is minimal. As explained in Chapter 5, the Badai community either uses norms to cope with groundwater scarcity, approach local political leaders and Panchayat administration, or use short-term solutions that increase their access to groundwater. Collective-choice rules for sharing groundwater are observed among farmers who have setup rules to share water among their agricultural fields. However, the presence of collective-choice arrangements across actors i.e. the whole village community is missing in Badai. Although Panchayat forms the formal governance layer at the collective choice level that can formulate rules across actors, they have no jurisdiction over groundwater extraction. They mostly resort to providing short-term solutions to the villagers through the supply of more infrastructure to extract groundwater.

### *4. Monitoring*

This design principle posits that long-surviving resource regimes either select their own monitors who are accountable to them, or they themselves monitor the resource and harvesting activities (Ostrom, 2005). This principle therefore stresses on the fact that not only the rules, but their *enforcement* is also critical to the success of CPR management.

Monitoring of groundwater in Badai is not undertaken at the village level but the District level. Monitoring is undertaken by the SWID department by conducting surprise checks of industrial groundwater users and acting on complaints filed by users reporting illegal extraction (***GS8***). However, there are two major drawbacks to the proper implementation of these rules. Firstly, low staffing[11] of the SWID department limits the frequency of conducting surprise checks and secondly. Secondly, low awareness of formal rules among the interviewees in Badai points to the information gap between SWID and groundwater users. Therefore, monitors who are in charge of the resource are not directly accountable to groundwater users and further are limited in their ability to effectively enforce the rules. At the village level, there is no committee responsible for monitoring the extraction of groundwater in Badai (*Interview 14*).

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[11] To put things into perspective, **one** District Geologist is responsible for monitoring groundwater users in the whole North 24 Parganas district which consists more than **10 million** people.

### 5. *Graduated sanctions*

This design principle implies the use of gradually increasing sanctions to punish the rule breakers either by officials who act on behalf of the users or by the users themselves (Ostrom, 1990). Usually, in such arrangements, the fine starts with a low value and punishes repeat offenders with an increasing penalty.

According to the Groundwater Resources Act 2005, the first offence of unpermitted groundwater extraction is charged with a fine of 64 € which may be doubled on the second offence (SWID, n.d.-b) (***GS8***). However, sanctioning is subject to the defaulter being caught which as explained in the previous design principle is constrained due to low monitoring and poor enforcement of the formal rules. Therefore, although graduated sanctions are present in the formal rules, their enforcement is limited by weak monitoring.

### 6. *Conflict resolution mechanisms*

This design principle requires the presence of rapid, low-cost arenas where users can resolve conflicts among themselves or between them and the officials (Ostrom, 2005). In Badai, the Gram Panchayat is the body responsible for local conflict resolution. Although no conflicts around groundwater extraction were reported in Badai, conflicts occur in other arenas (refer to the occurrence of variable ***I4*** in Appendix G) e.g. conflict between farmers and industries on the discharge of polluted waste-water into agricultural fields. Access to low-cost arena for this issue is limited as suggested by an interview with a farmer. Farmers merely resort to expressing their frustration by smashing factory buildings as strong influence (***S3***) of the local political party deters a fair resolution of this issue (*Interview 9*).

### 7. *Minimal recognition of rights to organize*

The application of this design principles to the case study is through the self-organization interaction (***I7***). Industries in Badai can organize and form an association to represent their interests and agree upon internal rules to make decisions. Although farmers are not represented by a collective organization for resolving their problems with other actors, they can set up rules to maintain and manage the irrigation well. Among households, norms of setting up private connections to the PHE supply line are commonplace, known to the Panchayat officials, and in fact approved by them. Therefore, it is not evident in the case study that norms or rules setup at the lower level will be challenged by higher authorities.

### 8. *Nested enterprises*

The eighth and the last design principle stresses on the presence of multiple levels of institutional arrangements for the governance of complex systems (Ostrom, 1990 in Quinn et al., 2007). Although multiple administrative levels exist in West Bengal – villages, block, and district, the power to craft operational rules and enforce them resides only at the district level. This power is provided by the higher-level constitutional rules, the Groundwater Resources Act 2005. Lower administrative levels, the Gram Panchayat and the Block Development Officers (BDOs) are not formally involved in the governance of groundwater.

As highlighted in Table 6.1 and explained above, three out of the eight design principles in Badai are weak, four are moderately successful, whereas one is strongly present. Although not all the principles need to be realized, the likelihood of sustainable management of a CPR increases if more principles are in place (McGinnis, 2011). Based on this evaluation the performance of CBM in Badai is poor since taking into account the weak implementation or enforcement of the design principles, groundwater management in Badai falls short on seven out of eight design principles. Although actors have the right to self-organize in Badai as identified in DP7, collective action at the community level remains low. The next section delves deeper into the barriers to self-organization in Badai.

## 6.2 Barriers to self-organization in Badai community

As concluded from the case study analysis in Chapter 5, actors in Badai only cope with groundwater scarcity and resort to short-term solutions to overcome it. Collective action varies among actors within the community where each actor group adopts different strategies for overcoming their problems and community-wide collective action is not observed in Badai. This section evaluates the results of Badai against the 10 second-tier SES variables to highlight factors that impede or sustain self-organization in the Badai community. As explained in Chapter 2, these variables, proposed by Ostrom (2009), are linked to the likelihood of resource users engaging in collective action to sustainably manage their CPRs.

The comparison between the case study results and the expected value of the 10 second-tier SES variables is presented in Table 6.2. A qualitative assessment is made to highlight whether the observations match the expected value - results that do not satisfy the expected value are marked in red, those that partially match the expected value are marked in yellow whereas, those that satisfy the expected value are marked in green.

*Table 6.2: Comparison of results from Badai with 10 second-tier variables from* Ostrom (2009)

| ***SES variable*** | ***Expected value*** | ***Results from Badai*** |
|---|---|---|
| *RS3 – Size of resource system** | Moderate sized resource systems are conducive to self-organization | Unknown |
| *RS5 – Productivity of system** | Users should observe some scarcity to invest in self-organization | Summer scarcity observed by farmers, households, and real-estate colony. |
| *RS7 – Predictability of system dynamics** | System dynamics should be sufficiently predictable (water systems tend to be unpredictable compared to forests) | Low predictability. General sense of water cycle principles but no information on exact stock and flows. |
| *RU1 – Resource unit mobility** | Mobile resource units are less conducive to self-organization. | Unknown |
| *GS6 – Collective-choice rules** | Full autonomy at collective-choice level to craft and enforce own rules leads to low cost of defending resource against invasion | Autonomy to craft and enforce rules resides with DLA, not the Badai community. |
| *A1 – Number of relevant actors** | Large group size hinders self-organization but may lead to mobilization of important resources such as labor. | Moderate population size (~3600) |
| *A5 – Leadership/entrepreneurship** | Self-organization is likely if local leaders are present | Leadership present among dyeing industries and households |
| *A6 – Norms (trust-reciprocity)/social capital** | Presence of social norms of trust and reciprocity facilitates agreements and reduces costs of monitoring | Social norms present among farmers and households. |
| *A7 – Knowledge of* | Costs of organizing are low if users | Perception of same cause |

| | | |
|---|---|---|
| *SES/mental models** | share common knowledge about the SES, how their actions affect each other and rules relevant to the SES. | for groundwater depletion but different solutions. Low awareness of formal harvesting rules. |
| *A8 – Importance of resource (dependence)** | Users either depend on the resource for significant proportion of their livelihood or attach importance to resource sustainability | High dependency on groundwater among all users, for livelihood, drinking, and domestic purposes. |

From Table 6.2, we can observe that the observations from Badai perform well on some variables whereas fail on the others. Four factors – productivity of system (RS5), number of relevant actors (A1), norms (A6), and importance of resource (A8) are conducive to collective action in Badai while the remaining six factors impede it. Out of these six factors, collective-choice rules (GS6) also forms part of the design principles – DP3 and is already discussed in the previous section. The remaining five factors are discussed below (factors covering resource and resource unit characteristics have been grouped into one common theme).

### 1. *Groundwater resource; a known unknown*

Actors in Badai are faced with the challenge of managing a complex resource with multiple unknowns – size (***RS3***), predictability (***RS7***), and mobility (***RU1***). Although actors have a general sense of how the aquifers get recharged, they cannot estimate the exact stock and flows of the resource i.e. storage capacity and withdrawal of groundwater, natural variations in the groundwater levels, etc. Without understanding these resource characteristics, villagers cannot establish whether changes in groundwater stock and flows occur due to overharvesting or due to external variables outside the control of villagers. Although harvesting rules may be setup among actors as observed in water-sharing among farmers, it is difficult to predict how significantly it will reduce the burden on the aquifer system. Moreover, unknown resource size and mobility implies that users cannot estimate whether it is sufficient to observe and manage the local village aquifers or if their resource forms part of a larger system that they cannot control. These knowledge gaps further reduce resource predictability.

### 2. *Lack of leadership*

In Badai, no signs of leadership were found at the village level which attempts to negotiate or setup rules at the community level constraining groundwater use by different actors. Leadership is therefore fragmented and varies across actor groups. On one hand, collective interests of industries are well represented by the Industry Association in Badai, other actor groups lack this leadership (***A5***). On the other hand, absence of leaders has failed to initiate collective action among farmers. Although water sharing among farmers is handled by a village level committee, they are not part of any collective organization that represents their conflicting interests with other actors. Although households are represented by local political leaders and Panchayat members, their solution space for resolving the issue of groundwater scarcity is limited.

Collective action supported by strong leadership also has implications on the group's access to higher institutional levels and bargaining power as observed in Badai. While the industrial association can negotiate the rules that impact them, other peri-urban actors are disconnected from the District departments to complain or voice their concerns. They can only access local Panchayats which are weak particularly in matters related to groundwater extraction.

***3. Varied perceptions on solutions and low awareness of rules***

Actors in Badai share a common understanding on the causes behind groundwater scarcity. Households and farmers attribute groundwater scarcity to high extraction by the dyeing industries. As the estimates from Section 5.2.1.5 show, these mental models (***A7***) may be misplaced as the amount of groundwater extracted by farmers in the summer season is significantly higher than other actors. Moreover, actors lack convergence of solutions to resolve their groundwater problems - some interviewees felt that the 'government' should solve the issue, others felt that all villagers need to limit their consumption, while some have internalized that the village is bound to become an industrial area. With respect to mental models about formal rules, actors have lack awareness about the rules that apply to industries in Badai. Interviews conducted with households and farmers in Badai revealed that none of the interviewees knew the formal rules that dyeing industries must follow for extracting groundwater. They had not even heard the name of the SWID department (*author's own observation*).

Evaluation of collective action in Badai community based on the 10 second-tier SES variables marked as indicators of self-organization in the SES framework reveals four key challenges for the community to self-organize and sustainably manage their resource – low knowledge of the aquifer resource and its resource units, no formal autonomy to craft rules to limit groundwater extraction, lack of leadership in the community and lastly, divergence in mental models among different actors that form the community.

## 6.3 Discussion

The evaluation of groundwater management in Badai fails on most of the design principles or 'best practices' for successful CBM posited by Ostrom (1990). Although actors have the minimal right to self-organize in Badai, as evident through the formation of the Badai Industrial Association, collective action at the community-level still remains low. Actor groups individually respond to their groundwater problems by following or setting up norms or forming associations but the community as a whole lacks collective action for sustainably managing groundwater. These findings show that groundwater management in Badai is not necessarily 'community'-based but rather fragmented across actors.

Closer evaluation of self-organization in Badai through the 10 second-tier variables posited by Ostrom (2009) reveal important barriers at play - low knowledge about the aquifer resource and its resource units, lack of community-wide leadership, varied mental models among the actors and lastly, absence of formal autonomy to the community to craft and enforce their own rules to limit groundwater extraction. A critical barrier among these are formal institutions. Existing policies on groundwater management in West Bengal do not provide the autonomy to communities to formulate their own rules for managing groundwater extraction in their community. This power, at present, is concentrated at the district level, which as the case-study shows is far separated from the local community.

Although the 10 SES variables marked by Ostrom (2009) highlight challenges to CBM in Badai, they are not sufficient to explain its poor socio-ecological outcomes. Evaluation of groundwater management in peri-urban Badai through the design principles sheds light on additional important second-tier SES variables critical for CBM. As can be seen from Table 6.1, these variables are *system boundaries* (RS2), *operational rules* (GS5), *monitoring and sanctioning rules* (GS6), *constitutional rules* (GS7), and the *conflict* interaction (I7). These variables too act as barriers in initiating or achieving CBM in peri-urban areas but are not accounted for in the 10 variables marked with an asterisk in the SES framework.

Therefore, an evaluation of peri-urban areas based only on these 10 variables will be incomplete. This insight also makes peri-urban areas theoretically 'special' for CBM.

Additional SES variables highlighted by the design principles also reinforce the critical role played by formal institutions in deterring CBM in Badai. Present rules for groundwater extraction do not provide incentives to the users to sustainably manage the resource (GS5). Groundwater being free of cost can essentially be mined under the present rules without incurring any costs. Although monitoring and sanctioning (GS6) is taken up by government bodies external to the community, weak enforcement and low accountability of the regulator towards the community fails to protect the resource from unregulated extraction. Lastly, the current policies in West Bengal – the Groundwater Resources Act 2005 and the Panchayati Raj Institutions (GS7), that decide the collective-choice rules, fail to setup multiple institutional levels that also involve local communities. Therefore, formal institutions act as a barrier rather than a facilitator of CBM in peri-urban Badai.

Findings on CBM in peri-urban in Badai are specific to its local context and might not apply to other peri-urban areas near Kolkata. The next chapter explores the generalizability of these findings by validating them through another case study of a peri-urban village near Kolkata.

# 7 Generalizing results from Badai to other peri-urban areas

*Now that CBM in peri-urban Badai is evaluated, it is pertinent to check whether the findings from Badai also hold significance for other peri-urban areas near Kolkata and to what extent can these findings be generalized. In this chapter, the findings on the performance of CBM in Badai are applied to a second case study – Tihuria.*

## 7.1 Tihuria – tale of another peri-urban village

As with areas lying North to the city of Kolkata, areas lying South to the city have also experienced rapid urban growth (Sahana et al., 2018). Tihuria is a village in the Sonarpur block of South 24 Parganas district that lies 20kms South of the Kolkata city and spreads over an area of 385 hectares (see Figure 7.1). At the onset, the village looks largely rural in nature, with vast areas of land covered with agricultural fields and fish ponds (locally called '*bheris*') lightly interspersed with settlements. However, on a closer look, interviews with villagers reveal that the area has undergone huge transformations in the past 30 years. Coming up of new schools, paving of roads, conversion of '*kucha'* (temporary) houses to more solid and permanent houses, increase in the number of migrants buying land and settling in the village, increase in tubewells and introduction of piped drinking water infrastructure are some of the major changes reported by a villager (*Interview 20*).

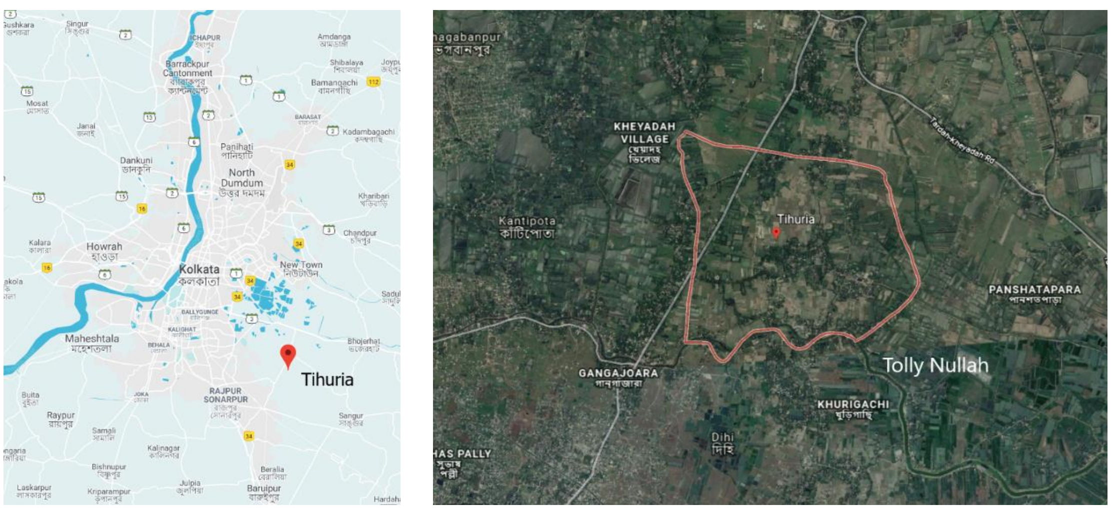


*Figure 7.1: Location (L) (Google, n.d.-b) and satellite view of Tihuria (R) (Google, n.d.-d)*

Tihuria has a unique relationship with the Kolkata city – its farmers process the city's waste and produce food that feeds the city. On its Southern borders, the village receives the *Tolly Nullah*, one of the significant streams of the Hooghly river that carries wastewater generated by Kolkata (Mukherjee, 2016). This canal is the lifeline of farmers in Tihuria sustaining both agriculture and aquaculture i.e. the cultivation of Boro paddy and fishes such as hybrid catfish. Over the years, diversification of occupation and shifts away from traditional Boro paddy agriculture can be seen in the village as residents are engaging in other livelihoods such as aquaculture, construction, manufacturing, and repairing (Banerjee & Jatav, 2017). Although the village is not as industrialized as Badai, bottling companies that sell packaged drinking water started coming up in the village 5-6 years ago (*Interview 30*). Tihuria's peri-urban nature can therefore be attributed to multiple characteristics - gradual shift in livelihoods from farming to non-farming activities, gradual industrialization, and its connectivity and interactions with the city – villagers travelling to the city for work and exchange of food and 'waste-water' between the city and village.

## 7.2 Water infrastructure and groundwater problems in Tihuria

Multiple public sources of drinking water can be found in Tihuria mostly provided by the PHED department. In addition to Panchayat tubewells, the PHED department delivers drinking water, which is a mix of surface and groundwater, through stand-posts and a piped network (*Interview 23*). Use of private infrastructure in the village is mostly limited to extraction of groundwater by bottling industries that produce packaged drinking water and households that use STWs to extract groundwater for domestic purposes like washing, cleaning, bathing, etc. Farmers predominantly depend on the waste-water flowing in the Tolly Nullah - a public surface water source (*Interview 24*). During periods of low availability of this water, some farmers also use groundwater from STWs (*Interview 22*). Table 7.1 summarizes the public and private infrastructure available in the village along with its source of water and type of usage.

*Table 7.1: List of public and private infrastructure in Tihuria mapped to its water source and usage (created by the author)*

| ***Provision of infrastructure*** | ***Infrastructure*** | ***Source*** | ***Type of use*** |
|---|---|---|---|
| *Public* | PHED water supplied through stand-posts (three times a day) and household connections | GW + SW | Drinking or cooking |
| | Panchayat wells (handpump) | GW | |
| | Ponds | SW | Domestic use |
| | *Tolly nullah* | SW | Agriculture and aquaculture |
| *Private* | STWs | GW | Agriculture |
| | | GW | Domestic use |
| | DTWs | GW | Packaged drinking water |

Based on the interviews conducted in Tihuria, key problems faced by households is the poor quality and availability of drinking water. Quality issues are reported in both private and public infrastructure used by the households. An interview with a household revealed their preferences for fetching drinking water (*Interview 20*). Due to the presence of iron contamination, foul smell, and yellowish turbidity in groundwater withdrawn from private STWs, this water is generally not used for consumption. Furthermore, even the quality of water available in the public infrastructure is not up to the mark as the household refrained from consuming water available in the PHED stand-post near their house. Instead, bottled water is used for drinking purposes. In addition to quality issues, summer scarcity is common in private shallow handpumps. During the months of April and June, groundwater level decreases and one of the villagers reported that it takes twice the time to lift the same amount of water in summer compared to other seasons (*Interview 29*).

Availability of drinking water is also impacted by poor maintenance of public infrastructure. This problem is evident in South Tihuria which is disconnected from the main village due to a bad road network (Gomes, 2019). Moreover, a villager reported that past floods in the village destroyed and contaminated the PHED pipelines in South Tihuria and their condition has not improved for the past 10 years (*Interview 29*). Therefore, drinking water crisis is severe in South Tihuria where although there are a lot of PHED points, there is no water available in them. This situation makes it difficult for households, especially women and children, to fetch drinking water (Figure 7.2). Villagers must walk long distances, at least 2kms, to fetch water either from other parts of Tihuria or neighboring villages (*Interview 29*).

*Figure 7.2: Drinking water infrastructure and collection in Tihuria (Photos courtesy of The Researcher, 2019 and Gomes, 2016)*

Increasing population and poor availability of good quality drinking water has created a market for packaged drinking water in Tihuria and increased the dependency of villagers on bottled water (*Interview 30*). The supply gap has been filled by bottling companies operating illegally in Tihuria that extract groundwater, purify it, and sell it in the form of 20l bottles at the price of 0.12€ - 0.15€ (see Figure 7.3). A primary survey conducted in 2016 confirms the dependency of villagers on bottled water. Out of 128 households surveyed in Tihuria in 2016, 34.4% used bottled water as their primary source of water for drinking purposes (Banerjee & Jatav, 2017). However, even this water is not affordable by all villagers pointing to the economic condition of the villagers (*Interview 29*).

*Figure 7.3: (L) A bottling plant in operation in Tihuria (R) Bottles being transported to vendors (Photo courtesy of The Researcher 2019)*

## 7.3 Comparison of Tihuria with Badai case study

From the brief case introduction above, we can see that like Badai, Tihuria is also a peri-urban village near Kolkata which is dependent on groundwater and is gradually transitioning from rural to an urban area. This section compares the two case studies to highlight similarities and differences in the SES subsystems of the two villages.

### 7.3.1 Resource System and Resource Units

The aquifer system in Tihuria shows significant similarities to aquifers in Badai. Quantity and quality concerns are common in local aquifers and the complexity of the resource remains largely unknown and unpredictable. Similar to Badai, two main resource systems can be observed in Tihuria - land, and aquifers. The characteristics of the local aquifers – boundaries, size, mobility, etc. are largely unknown. Interviews conducted in Tihuria confirm salt and iron contamination in water withdrawn through shallow private tubewells (*Interview 20, 21, 29*) while recent water quality tests conducted under the Shifting grounds project also confirm the presence of arsenic in public and private wells in Tihuria (Hermans & Gomes, 2018; Refer to Appendix I for the arsenic map of Tihuria). The stock and flows of groundwater remain largely unknown. Although summer scarcity is observed in the village, the natural variations in the aquifer and the exact reasons behind the decline in groundwater levels are not known.

### 7.3.2 Actors

The major users of groundwater in TIhuria are households and bottling companies. According to the Census of India (2011), Tihuria Is home to 3773 people and approximately 920 households. These households extract groundwater using public and private infrastructure similar to that found in Badai i.e. PHED stand-posts, Panchayat tubewells and private STW or DTW. Unlike Badai, Tihuria is homogeneous along the lines of caste and religion, comprising of Hindus belonging to the Schedule Caste category. However, these factors do not play a role in sharing water (*Interview 25*).

Parallels can be found in the norms that govern extraction of groundwater in Badai and Tihuria. Villagers in Tihuria also queue to fetch water from public infrastructure, and commotion is common if households extract a lot of water (*Interview 20*). Furthermore, households also share water from their private wells in case a neighbor's well is defunct. An interview with a local informant revealed that practices of pooling money and installing 'private' stand-posts by households, with the Panchayat's approval, are also common in Tihuria (*Interview 23*). Originally, only 65-70 stand posts were installed by the PHED department for the whole Panchayat in 2004 which have increased to at least 250 as of 2019.

*Figure 7.4: Apparatus used for filtering groundwater installed in one of the bottling companies in Tihuria.*

Similar to dyeing industries in Badai, Tihuria has three operational bottling companies (*Interview 29*) that use groundwater as the primary input for production. An interview with the owner of a bottling company revealed that they extract groundwater from a depth of 620 ft bgl and filter it through a 5-step process[12] (*Interview 19*, see Figure 7.4). The filtered water is sold in the form of 20l bottles at a price of 0.1 € to customers through a middleman. The company refills approximately 80000 bottles every month.

In addition to the similarities mentioned above, a few significant differences can also be observed between the two villages. Firstly, unlike Badai, farming is sustained by surface water, and not groundwater, in Tihuria. Boro paddy and fish farmers mostly depend on wastewater flowing in the *Tolly nullah* to irrigate their fields or breed fishes (*Interview 24*). One Boro farmer reported that they only use groundwater when wastewater in the canal dries and, in that situation, they usually buy groundwater from villagers with private wells (*Interview 22*). Although groundwater offers advantages for fish farmers in terms of reduced input costs and less vulnerability of fishes to diseases, high investment costs in installing DTWs deters them from extracting groundwater (*Interview 21*).

Secondly, location is a key determinant in accessing drinking water within the village as the Southern part of the village lacks access to functional public infrastructure. Lastly, compared to Badai, dependency on bottled water is relatively higher in Tihuria (Banerjee & Jatav, 2017). Moreover, recent campaigns conducted as part of the Shifting grounds project have increased local awareness on the health impacts of drinking arsenic infested water (Hermans & Gomes, 2018). An interviewee reported that owing to this awareness, they have stopped drinking water from their private handpumps and switched to bottled water (*Interview 29*). Increased use of bottled water, therefore, creates interesting dependencies between the bottling companies and the villagers. On the one hand, extraction by bottling companies threatens the depletion of groundwater level and on the other hand, this extraction also fills the supply gap in drinking water.

### 7.3.3 Governance System

Groundwater extraction in Tihuria is also governed by the Groundwater Resources Act 2005. Moreover, Tihuria is part of the East Kolkata Wetlands (EKW)[13], a site deemed to be of international importance under the Ramsar Convention 1971 - an intergovernmental treaty for conservation and wise use of wetlands and their resources (The Ramsar Convention Secretariat, n.d.). Therefore, rules under the Groundwater Resources Act 2005 are followed stringently for the EKW Area which means that licenses for industrial extraction of groundwater are not given (*Interview 27*). This was confirmed by a representative from one of the bottling companies in Tihuria who was denied the license by the district SWID department since the application was from a wetland area (*Interview 19*). However, bottling companies are still operating in the village which points to the weak monitoring of these industries even after their application is denied.

Being part of a wetland area imposes additional rules in Tihuria. A separate government body called the East Kolkata Wetland Management Authority (EKMWA) has been instituted under the The East Kolkata Wetlands (Conservation and Management) Act to preserve the wetlands and prevent unauthorized

[12] One interesting aspect of this process is that for one part of purified water, at least three parts of water are wasted which is collected in a pond and used for cultivating fishes (Interview 19).

[13] A wetland is an area where land meets water (Ghosh, 2005). The Ramsar Convention uses a broad definition of wetlands that includes "lakes and rivers, underground aquifers, swamps and marshes, wet grasslands, peatlands, oases, estuaries, deltas and tidal flats, mangroves and other coastal areas, coral reefs, and all human-made sites such as fish ponds, rice paddies, reservoirs and salt pans." (UNESCO, 1994)

development and land conversion in the area among other things (Government of West Bengal, 2006). Moreover, other national policies - The Wetlands (Conservation and Management) Rules, 2010 also restrict activities such as reclamation of land, setting up of new industries or expanding existing industries, etc. in the EKW area (Ministry of Environment and Forest, 2010).

As with other transitioning spaces in West Bengal, Tihuria is also governed by a Gram Panchayat – the Kheadaha-I Panchayat. In addition to that, presence of civil society organizations and NGOs in the village is weak (*Interview 24*).

Therefore, Badai and Tihuria have a similar institutional structure with Panchayats forming the local governance body and the South 24 Parganas District Level Authority governing groundwater extraction. However, differences exist between the two villages in the stringent application of the rules owing to the wetland status of the village and additional rules that apply further restricting land conversion and construction activities in the village.

### 7.3.4 External factors

Like Badai, major external factors that impact the focal SES in Tihuria is the availability of surface water – both the wastewater flowing in the Tolly Nullah (*Interview 22*) and the surface water available for drinking purposes (*Interview 23, 24*). While the former impacts the dependency of farmers on groundwater, the latter impacts the dependency of households on groundwater for drinking purposes. In addition to that, increase in population and incoming migrants also exert pressure on the existing drinking water infrastructure available in the village (*Interview 23*).

### 7.3.5 Interactions and Outcomes

As explained in Section 7.2, key groundwater problems facing the Tihuria community and therefore, their key outcomes of concern are groundwater scarcity, poor quality of groundwater, and lack of availability of infrastructure to fetch groundwater. Among these, one problem that has led villagers in South Tihuria to organize in the past is scarcity of groundwater and its illegal extraction by the bottling companies. This problem brings forth both social and ecological outcomes to the forefront i.e. *scarcity* of groundwater and *equity* in its distribution as the villagers have attempted to fight the illegal and unfair extraction of groundwater in the village while their own wells are running dry.

Key interactions that regulate groundwater extraction and its regulation in Tihuria which are also observed in Badai are: a) ***harvesting*** of groundwater b) ***self-organizing*** as a response to groundwater problems evident in the prevalence of norms for water sharing and installing private stand-posts c) ***monitoring*** and ***licensing*** activities done by the South 24 Parganas DLA to give groundwater licenses and d) ***licensing*** activities by Panchayat to give trade licenses. Compared to Badai, interactions related to lobbying activities for negotiating groundwater extraction rules are not observed in Tihuria. This absence can be attributed to the lack of a collective organization that represents bottling companies, similar to the Badai Industrial Association, or the strictness of the groundwater extraction rules given the wetland status of Tihuria.

> *There is no water in our own handpumps – then why should our water go outside the village?" (Interview 29)*

In addition to the above interactions, one striking interaction peculiar to Tihuria is the occurrence of ***conflicts*** between bottling industries and villagers of Tihuria. An interview with a key informant (*Interview 29*) revealed that 3-4 years ago, villagers on South Tihuria gathered and staged a protest against a bottling company. Their concerns were that rampant extraction[14] of groundwater by the company led to groundwater scarcity in their area. Moreover, they claimed that the plant had not been setup for the benefit of the villagers. Rather, groundwater extracted from the local aquifers was being exported to the city where people can pay a higher price for a bottle of water. Concerns were also raised about the quality of drinking water being supplied by the company and all these factors led the villagers to file a complaint with the Wetlands department eventually leading to the temporary shutdown of the plant. However, three more bottling plants have come up in the village since the protest (*Interview 29*). Therefore, as the groundwater levels are perceived to be decreasing in the village, its distribution remains largely inequitable, with bottling companies extracting water from the common aquifers free of cost, while villagers struggle to fetch drinking water to sustain their lives.

## 7.4 Application of findings from Badai to Tihuria

Now that the similarities and differences between Badai and Tihuria are highlighted, it can be concluded that similar patterns of groundwater extraction and regulations are observed in both villages. Both Tihuria and Badai are dependent on groundwater for drinking, domestic and livelihood needs. Although the complexity of the groundwater resource remains unknown in both the villages, there is a growing perception of groundwater contamination and depletion. Institutionally, both the villages are governed by Panchayats and groundwater extraction is regulated by the same rules under the Groundwater Resources Act 2005. Socially, similar actors can be found in both the villages as households and industries compete for a limited groundwater resource. However, agricultural practices and their dependency on groundwater show vast differences between the two villages.

Similarities between Badai and Tihuria highlighted above provide a basis for comparing CBM in the two peri-urban areas. This section applies the findings from Badai case study to Tihuria. Factors critical for CBM in Badai that were identified through the application of design principles and 10 second-tier SES variables are applied to Tihuria to check if they are valid for this village. This application is shown in Table 7.2.

*Table 7.2: Application of findings from Badai to Tihuria*

| ***Findings from Badai*** | ***Factor for evaluation*** | ***Found in Tihuria?*** |
|---|---|---|
| Groundwater resource: known unknown | 10 second-tier SES variable | Yes |
| Low autonomy | 10 second-tier SES variable | Yes |
| Lack of Leadership | 10 second-tier SES variable | **No** |
| Varied mental models | 10 second-tier SES variable | **No** |
| No well-defined resource boundaries | Design Principle | Yes |
| Poor enforcement of monitoring and sanctioning rules | Design Principle | Yes |
| Disproportionate costs and benefits | Design Principle | Yes |
| Limited access to conflict resolution mechanisms | Design Principle | **No** |
| Absence of nested enterprises | Design Principle | Yes |

[14] Rough estimates of groundwater extracted by a bottling company in Tihuria are around 213,333 litres per day. A company refills about 80000 20-litre bottles a month and for each part of filtered water, three parts of water are wasted (Interview 19). Therefore, a total of 6400000l of water is extracted per month i.e. 80000 * 20 l * (1 + 3). Or 213, 333 litres per day.

As can be seen from column 3 of Table 7.2, most of the findings in Badai are also found in Tihuria (indicated by a ‘yes’). The overlap in these findings is evident from the similarities between the two case studies mapped in the previous section. Firstly, the characteristics of local aquifers in Tihuria are largely unknown which means that users cannot establish the size and boundaries of the local aquifers and it cannot be estimated how groundwater extraction outside the boundaries of the community impacts local groundwater extraction. Secondly, since the two villages operate under the same formal institutions i.e. the Groundwater Resources Act 2005, the Panchayati Raj Institutions, and the NRDWP 2010, parallels can be found in the lack of autonomy, disproportionate costs and benefits, and absence of nested enterprises in the two villages. Operating under the same set of rules means that in Tihuria too, policies do not provide autonomy to communities to craft and enforce their own rules. Costs and benefits remain disproportionate since the amount of groundwater extracted is uncharged and unregulated in West Bengal, especially for the industrial users. Nested enterprises are also not found in the village as groundwater management essentially remains top down and centralized with the District DLA primarily responsible for regulating the resource. Although Village Water and Sanitation Committees do exist in Tihuria, they remain only partially functional and their initiatives are restricted to conducting arsenic tests in the village as of 2019 (*Interview 25*). Lastly, enforcement of monitoring and sanctioning rules also remains weak in Tihuria. Similar staffing constraints can be found in district SWID department where only one officer is responsible for monitoring groundwater users in the entire district (*Interview 27*).

While most of the findings from Badai also hold for Tihuria, three findings stand out. These are:

### 1. Presence of leadership

In Tihuria, the Gram Panchayat and their elected members are the de-facto leaders of the community. They form the first point of contact for reporting problems related to water, toilets, or provision of other basic amenities (*Interview 20, 25*). For tackling the problem of groundwater scarcity, the Kheadaha-I Panchayat assumes a more active role compared to Badai. The Panchayat is not only aware of the scarcity issue, but efforts are being made to curb the spread of bottling companies and negotiate with them (*Interview 24*). Furthermore, trade licenses of bottling companies operating illegally in the village are no longer renewed.

Within the Tihuria community, households and bottling companies are largely dispersed and no separate associations exist to represent their interests. However, South Tihuria shows significant signs of leadership. These leaders have a strong connection to the village and are enthusiastic about improving the condition of the village through their initiatives (*Interview 29*). In the past, these leaders have been successful in initiating collective action to resolve their groundwater scarcity problems. This led to villagers staging a protest against a bottling company which was eventually shut down. Therefore, strong leadership is present in the Southern part of Tihuria and at the community-level.

### 2. Access to conflict resolution mechanisms

Incidents such as the protest against a bottling company in Tihuria that led to shutting down of the company indicate the availability of low-cost resolution mechanisms to the villagers. A key informant reported how the events of the protest unfolded (*Interview 29*). The villagers took pictures of the plant and submitted a complain to the Wetland Department and eventually the police came and raided the plant. However, the villagers claim that they did not get adequate support from the Panchayat who maintained its position that land ownership allows private extraction of groundwater. This incident shows that households in Tihuria were able to take the legal route and access conflict resolution mechanisms outside the community.

**3. *Common mental models***

Groundwater users in Tihuria attribute a similar cause to groundwater depletion i.e. over extraction by other users in the village. While one household linked groundwater decline to high extraction by shallow private pumps (*Interview 20*), another attributed it to extraction by the bottling companies (*Interview 29*). In South Tihuria where scarcity of drinking water is much more severe due to poor availability of functional public infrastructure, villagers have collectively responded to the problem by challenging the extraction of bottling companies. Therefore, residents of South Tihuria display a common mental model both about the cause and the solution of the problem.

Interviewees also displayed common mental models about the awareness of water cycle principles as they were aware of how groundwater gets recharged (*Interview 19,20*). However, awareness of formal rules for groundwater extraction is fragmented in the village. One key informant was not formally aware of the district bodies responsible for regulating groundwater and the specific rules that apply for industrial groundwater extraction. However, they were aware that the village lies in a wetland area and therefore construction activities and setting up of industries is not permitted in the village (*Interview 29*). One bottling company interviewed was aware of the formal rules as stated under the Groundwater Resources Act 2005 and had applied for the groundwater license but is still under operation even after the license was denied (*Interview 19*).

## 7.5 Discussion

The analysis conducted above shows that most of the findings from Badai are also relevant for Tihuria. The similarities in findings show that the nature of the groundwater resource and gaps in understanding its dynamics poses challenges for CBM in both Badai and Tihuria. Moreover, since groundwater management is driven by the same formal institutions in both the villages, overlaps can be found in findings related to institutions. Also, from Table 7.2 we can see that the design principles explain critical factors acting as barriers for CBM in Tihuria that are not covered by the 10 second-tier SES factors. Therefore, similar to Badai, Tihuria also presents a special case for CBM.

Badai and Tihuria show differences on three aspects – presence of leadership, common mental models, and access to conflict resolution mechanisms which were not (or moderately) found in Badai. These differences can be attributed to local conditions peculiar to Tihuria. Firstly, active leadership which is only found in the Southern part of Tihuria might have emanated from the severity and urgency of drinking water scarcity in that area. This scarcity is not as urgent in the rest of the village and also Badai which shows no clear signs of leadership.

Secondly, convergence in mental models is possibly easier to attain in Tihuria since there are only two major groundwater users in the village - households and the bottling companies. This makes it easy to pinpoint the cause of groundwater scarcity to the ‘other’ user. Compare this to Badai where multiple groundwater users exist, and it is difficult to estimate the major culprit for groundwater scarcity. Moreover, the explicit ecology of Tihuria and its recognition as a wetland area means that there is some awareness among people that the local environment should not be disturbed with construction activities or setup of industries. This also reinforces the mental model against rampant groundwater extraction in the village.

Lastly, being part of the EKW means that there are other departments such as the EKWMA who are also mandated to prevent the ecological balance of Tihuria. This provided an opportunity to groundwater users to access other conflict resolution mechanisms than the local Panchayats or the DLA. Fragmented institutions therefore work in favor of groundwater users in Tihuria who have access to multiple conflict resolutions mechanisms. In Badai, conflicts between dyeing industries and the farmers remained restricted only to the local Panchayats.

Even if Tihuria performs well on more indicators of successful CBM compared to Badai, its performance still remains low. Indeed, collective action was successful among households in the past, however, it was only found in the Southern part of the village and not the overall community. Moreover, although the village Gram Panchayat shows some leadership at the community-level, their role as facilitators or barriers for collective action in the village is not clear. Past protests in the village have been challenged by the Panchayat who believe that villages do not have the right to question private groundwater extraction (*Interview 29*). Moreover, strong political influence and musclemen has deterred villagers from engaging in similar collective action in the future. In a poignant phrase narrated by an interviewee, they said that *"people in this village will support any initiative to solve the water crisis, however, they don't have the power to fight the establishment*" (Interview 29). Furthermore, even after the protest, three more bottling companies have come up in the village pointing to the strengthening of the bottling lobby. Therefore, it remains to be seen if collective action in the village sustains in the future.

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# PART IV – CONCLUDE

# 8 Discussion and Conclusion

*This research set out to diagnose CBM in peri-urban areas using the theoretical lens of the SES Framework. This chapter discusses the results from the two case studies presented in Chapters 5,6, and 7 and presents answers to the research questions. The chapter concludes by putting forward a few recommendations for governmental actors in West Bengal.*

## 8.1 Heterogeneous communities, fragmented groundwater management

This thesis studied two peri-urban communities and attempted to understand their complexity with respect to groundwater management and as a 'new' area where CBM could be undertaken to sustain groundwater. Broadly, it was observed that Badai and Tihuria show poor social and ecological outcomes with respect to collective action and groundwater scarcity. Peri-urban actors in Badai and Tihuria respond to their groundwater problems in their own individual ways and not collectively as a community. Groundwater management in peri-urban areas is therefore, fragmented across actors and not 'community'-based. Moreover, groundwater scarcity is perceived to be high in both the villages.

***Collective Action***

The observation of low collective action in Badai and Tihuria is not 'new' per se and can even be said to be the expected outcome. Heterogenous communities have always posed a dilemma for CPR management and there is still no consensus on its impact on collective action (Ostrom, 2000). Peri-urban areas are known for their heterogenous nature (Narain, 2010a), and when it comes to groundwater management, more sources of heterogeneity can be observed in peri-urban Kolkata. In addition to differences in income, land tenure, and occupation, the SES framework helped capture other attributes that vary among actors. Actors vary in their bargaining power as collectives. While some groups exist as associations, others are dispersed and fragmented. This difference impacts their access to higher institutional levels to negotiate rules or seek solutions to their problems. Actors also differ in their mental models about the causes behind groundwater scarcity and its solutions, i.e., they do not share a common understanding of their situation. In fact, results from Badai show that these mental models are rather unfairly tipped against one actor in the community. Although farmers are the major groundwater extractors in the village compared to other actors, mental models for groundwater scarcity consider dyeing industries as the root cause. Lastly, political influence also varies across actors in peri-urban Badai and Tihuria in favor of industrial actors.

There are two competing schools of thought on the impact of heterogeneity on collective action – one that argues that heterogeneity is conducive to collective action and the other which believes that cooperative behavior is difficult to attain in a heterogeneous community (Adhikari & Lovett, 2006). Olson hypothesized that collective action is possible when those with the most economic interests and power initiate collective action (Olson, 1965 as cited in Adhikari & Lovett, 2006). In Badai and Tihuria, these groups are the industrial lobby and they show no signs of initiating collective action towards sustainable management of groundwater. The results from the thesis, therefore, agree with the latter school of thought, that heterogeneity might impede collective action in peri-urban areas.

However, heterogeneity may not be the only broad factor in explaining low collective action in the peri-urban areas. The analysis brings forth another facet of peri-urban complexity. Peri-urban areas present multiple examples of interdependencies among actors. In Badai, this manifests in the dependency of households on dyeing industries for employment. In Tihuria, households rely on purified drinking water provided by the bottling companies. Thus, in both cases, those who are seen as the causes of groundwater scarcity also serve as the providers of livelihoods and basic necessities. This interdependency may also impact collective action against the interests of industries. In Tihuria, households did manage to self-organize against the bottling company; however, their key interest was that the village did not accrue benefits from the export of its groundwater resource.

These interdependencies thus serve a positive or a negative role depending on the context. On the one hand, they provide opportunities. On the other hand, they may impede self-organization, when the interests of industries conflict with those dependent on it. These interdependencies also have implications for institutions that govern groundwater in these areas, as simple solutions, like shutting down the industries will be ineffectual, and possibly detrimental to the peri-urban communities.

Another major factor that is not directly evident in the analysis but forms the undertone in barriers to self-organization is the presence of strong political control over village activities. The Gram Panchayats and their members are believed to be the only legitimate leaders of the community and it is expected that parallel organizations and associations in the village shall not come up. Theoretically users have the right to self-organize in peri-urban areas, but its political implications and repercussions deter even the initiation of self-organization. Moreover, the process of setting up industries in peri-urban areas is also political in nature, and once they are setup, it is extremely difficult to challenge their groundwater extraction.

Although low levels of collective action are found in both peri-urban villages, the analysis done in Chapter 6 and Chapter 7 also highlights areas of opportunities. Groundwater users in both Badai and Tihuria have the fundamental right to self-organize. This is evident from their history of collective action in the form of creating associations, staging protests, and writing mass petitions. The size of the community is also not large enough to impede self-organization. Moreover, groundwater users in both the villages experience groundwater scarcity, which is conducive for users to self-organize. This indeed translated to a protest in Tihuria, but whether this scarcity continues to sustain that self-organization remains a question. Moreover, strong social norms are observed in both the villages that enable users to cope with groundwater scarcity, if not solve it completely. Traditional fault lines of religion and caste in India are not observed to impede cooperation in these villages, which holds promise for future initiatives that demand cooperation. Lastly, peri-urban actors also show ingenuity in using the complexity of their areas in their favor. Although fragmented institutions are generally seen as a deterrence for peri-urban areas (Narain & Nischal, 2007), results from Tihuria highlight that multiplicity of formal government bodies provides them with access to multiple conflict resolution mechanisms. This factor has been key in turning collective action among households in Tihuria into a success.

### *Groundwater scarcity*

Peri-urban areas studied in this research show high levels of groundwater scarcity. Resource collapse is predicted in large, valuable, open access systems with diverse users, who do not communicate with each other, and fail to develop institutions for managing the resource (Ostrom, 2009). That is, the tragedy of commons as predicted by Hardin (1968) is bound to be achieved for such situations. The ecological outcomes observed in the two peri-urban areas seem to match the expectations from an open-access resource. Although formal institutions restrict access to the groundwater resource for industrial users, in reality, it is an open-access resource for everyone due to poor implementation of the rules. Therefore, it is not a surprise that periods of groundwater scarcity are common in Badai and Tihuria. Moreover, as explained above, poor social outcomes may reinforce ecological outcomes in the future, as low collective action fails to sustainably manage groundwater.

## 8.2 Answering the research questions

*RQ1: What is the need for community-based management in peri-urban areas and how can we study it?*

Lying at the outskirts of rapidly developing cities, peri-urban areas are often ignored in the provision of formal water supply, and therefore, there access to water is a result of “needs-driven” rather than “policy-driven” approaches. As peri-urban areas try to bridge the supply gap, groundwater has become the most dependable source for the peri-urban communities. The stress on peri-urban groundwater resources is likely to increase in the future due to the rapid migration from rural and urban areas, thereby threatening its sustainability. With low incentives for state and market forces to address the sustainable use of groundwater, there is a need for alternative approaches to groundwater management in peri-urban areas. Considerable success in “conventional” communities makes CBM a promising alternative for peri-urban areas.

In order to explore and understand this approach, theories on CPR management pioneered by Elinor Ostrom helps to conceptualize and study CBM in peri-urban areas. Recent developments in this field in the form of the SES framework stress upon the necessity of taking both ecological and social aspects of CPR management into account. The SES framework developed by Ostrom and her colleagues provide a useful tool to unwrap the complexity of peri-urban areas. By providing an exhaustive list of variables, it provides flexibility to the analyst to tailor the framework for the context under study. Therefore, the SES framework is contextualized using the peri-urban literature in Chapter 2 to account for peculiar characteristics that define peri-urban areas and is used in this research to investigate two case studies – Badai and Tihuria.

*RQ2: What groundwater problems does a peri-urban community near Kolkata face and how do they respond to these problems?*

Groundwater problems differ across actors in peri-urban Badai as shown in Chapter 5. Households face multiple problems: poor quality of groundwater extracted from the Panchayat handpumps, timing and maintenance issues in the PHE supply line, and depletion of groundwater in the wells they use which gets aggravated in the summer season. Farmers also experience groundwater scarcity in the irrigation wells they use, along with the discharge of polluted waste-water onto their agricultural fields. Real-estate colony faces groundwater depletion in the private wells. Therefore, across households, farmers and real-estate developers, groundwater scarcity is a common problem. Industries on the other hand face problems in adhering to the norms that prescribe a minimum distance between two adjacent industrial wells. Operating in a dense industrial area, industries are often located closer to each other than the recommended minimum distances.

Actors respond differently to their problems. Households cope with groundwater scarcity either using norms or approaching the Panchayat that responds by implementing short-term solutions. Farmers use strategies of mass petitions to approach the district departments that also respond by utilizing short-term solutions such as deepening the irrigation wells. Lastly, dyeing industries are able to access higher institutional levels and negotiate well-distancing rules with the district administration, thereby maintaining their short-term harvesting levels.

*RQ3: What are the challenges faced by these communities in resolving their groundwater problems?*

Badai faces multiple challenges in resolving their groundwater problems as presented in Chapter 6. Firstly, the resource itself poses challenges which hinder collective action to manage groundwater as a community. Secondly, formal institutions do not recognize the autonomy of communities to formulate their own operational rules for limiting groundwater extraction. The institutions that are setup under the Groundwater Resources Act 2005 are limited in their implementation and enforcement, due to which groundwater is practically an open-access resource for private extraction. Although licenses are required for digging a private well by industrial users, poor monitoring, sanctioning and awareness of rules results into unregulated groundwater extraction. Even if the community is not dependent on formal rules and attempts to setup its own rules, self-organization within the community is restricted due to multiple factors: undefined boundaries of the aquifers and users, lack of community-level leadership that can mediate between actors and initiate collective action, and varying mental models among actors that seem unlikely to converge.

*RQ4: How relevant are these challenges to other peri-urban communities near Kolkata?*

Results from peri-urban Badai were generalized to another case study in Chapter 7. Tihuria is a peri-urban area near Kolkata which is similar to Badai in many aspects – heterogeneity of groundwater users, high dependency on groundwater, and working under the same set of formal institutions. Most of the findings from Badai are also relevant for Tihuria. Groundwater users in Tihuria also struggle to establish aquifer characteristics that can be conducive to self-organization. They operate under the same set of rules as Badai, and hence the autonomy to craft and enforce their own rules for groundwater management. Like Badai, nested enterprises are not found in Tihuria. Enforcement of existing rules is weak and extraction by industrial users, in this case the bottling companies, remains unchecked. Tihuria, however, diverges from Badai on some key aspects. Strong leadership can be found among the households in the Southern part of the village and even at the community-level, the village Gram Panchayat shows positive signs of leadership. Moreover, incidents of collective action which are geared towards seeking sustainability of groundwater resource and equity in its sharing are also found in Tihuria. Past protests in the village have been somewhat successful in resolving groundwater conflicts between the bottling companies and households. This indicates access to conflict resolution mechanisms and common mental models in the village, which was not found in Badai. However, increase in the number of bottling companies in Tihuria poses a challenge for sustained collective action.

*MRQ: What is the potential of community-based management of groundwater in peri-urban areas of India?*

Peri-urban communities analyzed in this research underscore the complexity of managing CPRs such as groundwater in these areas. In contrast to conventional communities consisting of homogenous resource users with shared norms, peri-urban communities near Kolkata consists of multiple actors that vary in their interests, have different socio-economic attributes, mental models, and differ in their influence on local politics and ability to negotiate rules with higher authorities. Further, pull factors such as availability of cheap land, success of present industrial units in maintaining their groundwater extraction levels, connectivity to markets and urban centers, further brings in more actors adding to the heterogeneity of the place. This puts peri-urban areas at a disadvantage in initiating or sustaining collective action for sustainable use of groundwater.

Results from the case studies show that actors within the community respond to groundwater scarcity as separate groups, instead of opting for collective action. In Badai, while farmers self-organize to seek short-term solutions such as drilling their irrigation well deeper, households cope with groundwater scarcity through social norms or seeking short-term solutions that provides them with more infrastructure to extract groundwater. Dyeing industries, on the other hand, self-organize to maintain their groundwater harvesting levels. Tihuria shows similar patterns, but for different actors. Here, bottling companies and farmers are largely dispersed and do not engage in collective action, while households in the Southern part of the village have shown strong collective action in the past. As a whole, peri-urban communities studied in this thesis lack a collective response that cuts across all actors. Involvement of local communities in formulation of institutions to manage groundwater is low, per se. "Community-based" groundwater management in peri-urban Badai and Tihuria, is therefore absent.

Although peri-urban communities have the fundamental right to self-organize, the current formal institutions do not actively support this right for groundwater management. The formal autonomy to craft and enforce rules lies with the district departments and peri-urban communities are merely a subject to the formal policies, and not an active player. Moreover, the formal institutions create skewed incentives that allow peri-urban actors to extract as much groundwater as they want, thereby failing to trigger sustainability concerns. Even without the support of formal institutions, peri-urban communities face multiple challenges in terms of gaps in resource knowledge, community-wide leadership, and varying mental models on how to solve groundwater scarcity problems. Therefore, peri-urban communities face challenges both within and outside the community.

Poor performance of CBM in peri-urban communities does not mean that actors within the community do not engage in collective action. Case study results in Chapters 5 and 7 show multiple examples of 'success' too. Farmers in Badai have managed to setup rules and norms to distribute groundwater for irrigation. Households in Tihuria have engaged in collective action to prevent over-extraction from their aquifers. Moreover, these actors have also demonstrated ingenuity in accessing conflict resolution mechanisms beyond the villages, thereby using fragmented institutions to their advantage. This silver lining, therefore, present opportunities for CBM to institute and flourish in peri-urban areas someday.

### *Academic and societal relevance*

The research carried out in this thesis shows two points of departure on the academic front. Firstly, it addresses research gaps in studying how CBM plays out in peri-urban areas (Adams & Zulu, 2015). The potential of CBM in peri-urban areas remains understudied, and this research throws light on the challenges faced by two peri-urban communities in India that are heavily dependent on groundwater as a source of drinking water and inputs for sustaining livelihoods. Secondly, this research also presents a 'complete' application of the SES framework as shown in Chapter 5. Most existing applications of the SES framework are focused on generating long list of factors (Azizi et al., 2017; Blanco, 2011; Nagendra & Ostrom, 2014) that impact outcomes but fail to identify and analyze sets of focal action situations (Cole, Epstein, & McGinnis, 2019). The application of the SES framework in this thesis attempts to combine both aspects – mapping the second-tier SES variables and also detailing out the action situations critical to groundwater management in peri-urban Badai in Chapter 5. Moreover, Chapter 5 presents a new way of visualizing action situations-that are primarily, a black box. The conceptualization of action situations around groundwater extraction and response to scarcity problems help capture all three aspects of groundwater management in Badai: social, technical (infrastructure), and institutional. Furthermore, these action situations bring forth finer interactions moderated by the infrastructure (*installation and use*) which are not captured in the SES framework. Therefore, this research presents a detailed and a full-fledged application of the SES framework.

Our society today faces numerous challenges in protecting our commons and growing urbanization trends pose a threat to their sustenance. As cities gradually expand, peri-urban areas face a threat to safeguard their natural resources. This research sheds light on the social and ecological challenges faced by two peri-urban communities near Kolkata in managing their groundwater resource. The complexity of peri-urban areas highlighted in this thesis also reflects the challenges faced by present-day urban cities where heterogeneity is abundant but collective action is scarce. The grand challenges of tomorrow such as climate change, resource depletion, etc. requires collective action that bridges across the lines that divide us and studying per-urban areas presents a small peak into what the future may hold if this heterogeneity is not harnessed.

## 8.3 Recommendations for government actors in West Bengal

The evaluation of groundwater management in peri-urban Badai and Tihuria conducted in Chapter 6 and Chapter 7 reveal gaps in the formal institutions that must be addressed to support more decentralized management of groundwater in peri-urban areas. This section puts forward recommendations for governmental actors and policy makers to improve aspects where groundwater management in Badai and Tihuria performs poorly. These recommendations are divided into recommendations for different administrative levels in West Bengal starting from the State level policy makers and moving down the administrative level to Gram Panchayats.

***Recommendations for State-level Policy Makers***

Complex resources such as groundwater require multiple levels of institutions for its proper management. Current institutions fail to take into account principles of decentralization that established Gram Panchayats as local self-governing bodies in India. The analysis conducted in this research points to the top-down centralized approach for groundwater management in West Bengal and shows the gap between groundwater regulators and peri-urban communities. This gap deters proper enforcement and monitoring of groundwater extraction. Therefore, the current policy must formalize the role of local communities and Gram Panchayats and involve them in planning, monitoring, and regulating the use and extraction of groundwater to aid bottom-up management of the groundwater resource.

It is critical to note here that the recommendation does not propose complete devolution of power to Gram Panchayats but rather formulation of multi-tiered administrative structure for groundwater management in West Bengal. A results from Badai and Tihuria show, inequities may persist if Gram Panchayats are not fair in executing their responsibilities and therefore, it is necessary that groundwater users still have access to higher institutional levels for conflict resolution. Therefore, the key recommendation to State-level policy makers would be to apply the principle of decentralization to groundwater management. Moreover, these institutions should be setup in a way to clarify both resource and user boundaries, i.e., where aquifers cover multiple communities, groundwater management should be done at both local level and aquifer level.

***Recommendations for District officials***

The current policy that governs groundwater management in West Bengal, the Groundwater Resource Act 2005, follows a regulatory approach to groundwater extraction whereby it establishes district level departments to grant groundwater licenses to industrial actors based on the local conditions of the aquifer. However, the *implementation* of the Act needs to be strengthened. Presently, the Gram

Panchayats give out trade licenses which allows industries to start operating in the Panchayat area *without* taking the groundwater permit. To avoid this, information sharing between the district departments and Gram Panchayats must be strengthened to facilitate vetting of industries *before* they setup in the Panchayat area. Gram Panchayats must be trained to understand their local geology and the type of industry that is safe to approve keeping the condition of local aquifers in mind.

### *Recommendations for Gram Panchayats*

Panchayats form the first layer of governance closest to the communities and therefore their role in initiating or sustaining CBM of groundwater is critical. Results from Badai and Tihuria show that without the support of formal institutions, the solution space available to Panchayats for managing groundwater is limited. This subject currently falls outside their jurisdiction and hence, they do not have official powers to manage groundwater. However, existing policies on drinking water supply and security (NRDWP, 2010) provide opportunities for Gram Panchayats to initiate community-wide collective action around groundwater.

First and foremost, Panchayats must ensure a functional VWSC under the NRDWP. Smaller initiatives such as monitoring, and maintenance of public groundwater infrastructure, such as those seen in Tihuria, can help build credibility of the VWSC as a community-wide leader in addressing problems around groundwater scarcity. Results from Badai and Tihuria also show that peri-urban actors have different mental models pertaining to the causes and solutions of groundwater scarcity. Moreover, these mental models may unduly tipped against the industries whereas agriculture may actually be the biggest contributor towards groundwater depletion. Therefore, VWSC meetings can be used as a mediating platform to converge these mental models and develop a shared understanding of the village groundwater situation. This can be the first step towards developing a long-term groundwater security plan for the village that is able to satisfy the minimum needs of different actors. Finally, solutions for reducing the dependency on groundwater such as transitioning to less water-intensive crops or recycling of wastewater as undertaken by dyeing industries in Badai should be supported by the VWSC. Initiatives by the VWSC need to be undertaken in close collaboration with SWID to fill knowledge gaps about the local aquifers.

# 9 Reflection

*Any research is incomplete without reflecting on the limitations of the study. This chapter presents a reflective critique of various academic and personal aspects that were encountered during this research.*

## 9.1 Limitations and recommendations for future work

### 9.1.1 Research Scope

The scope of the research was limited by a few choices made in making the analysis manageable. Firstly, given the focus on groundwater depletion as the key problem that guided this research, issues of groundwater quality were not analyzed in detail. As pointed out in Chapter 5 and Chapter 6, Badai and Tihuria not only face groundwater scarcity but quality of drinking water is also an urgent concern. This issue was not considered for further analysis due to lack of information on the causes behind the problem and limited interactions around the problem. However, it must be taken up for future research. Groundwater quality and quantity are also interrelated as quality concerns motivates groundwater extraction from deeper layers of aquifers which may further worsen groundwater scarcity. Therefore, it will be interesting to understand the interrelation between the two issues for peri-urban areas.

Secondly, this research only focuses on groundwater systems as the focal SES but results from the case studies, both Badai and Tihuria, show that surface water system also forms a major source of livelihoods in peri-urban areas. The narrow scope on groundwater systems has consequences for capturing the complexity of peri-urban areas as the ecological linkages between surface water and groundwater remain unexplored. The dynamics of surface water systems are important for livelihood choices made by peri-urban actors, further increasing or decreasing their dependency on groundwater.

Thirdly, the analytical lens used in this thesis is limited to Elinor Ostrom's theories on CPR management. This choice was made due to the popularity and relevance of the literature and frameworks, and its focus on both social and ecological aspects of the groundwater resource. But, this research is limited in its review of other frameworks for analyzing groundwater management. Binder, Hinkel, Bots, & Pahl-Wostl, (2013) present an overview of at least 10 other frameworks that can be used for analyzing social-ecological systems. Key frameworks among these are the Human Environment Systems Framework (HES) (Scholz & Binder, 2003) and the Management and Transition Framework (MTF) (Pahl-Wostl, Holtz, Kastens, & Knieper, 2010). Both these frameworks resemble the SES framework in three aspects a) reciprocity between the social and ecological, b) anthropocentric perspective of the ecological system i.e. as a utility to humans and being c) analysis oriented (Binder et al., 2013). Similar to SES, these frameworks can be applied to study issues that require a dynamic perspective on the social systems and its interaction with the ecological system. It would be interesting to analyze the groundwater management problem in peri-urban areas through the lens of other frameworks and compare the barriers to its sustainable management.

Lastly, the use of the SES framework in this thesis was limited to creating an overall SES diagram for the case study only mapping the relevant second-tier SES variables that explain the resource outcomes. Moreover, a qualitative analysis of action situations is performed in this research. This leads to interesting ideas for future work:

1. Expand the SES framework to include surface water as endogenous to the peri-urban SES
2. Explore the relationship between second-tier SES variables and outcomes of collective action and groundwater levels either through a correlation analysis or causal diagramming as done by Cox (2014)

3. Conduct quantitative modelling of the action situations using agent-based models to further understand *how* action situations produce the outcomes observed.

### 9.1.2 Research Design

In order to study why peri-urban areas are special for CBM, the research focused on two peri-urban villages as the unit of analysis. Although this choice aided understanding the complexity of a peri-urban area, the narrow focus on a specific village meant that the interconnectedness of the peri-urban areas could not be captured. What makes peri-urban areas special is also connectedness to the cities, both for ecological and social reasons. As seen in Badai and Tihuria, users of groundwater in peri-urban areas are not only restricted to the community itself. e.g. groundwater is used in Badai to color clothes to fulfill the demand of users in cities, and similarly in Tihuria, groundwater is filtered and packaged to be supplied to the cities. Therefore, urban actor systems although considered external to the SES also impact the local groundwater extraction and ecological outcomes in peri-urban areas i.e. the 'real' boundaries of a peri-urban SES would extend far beyond the administrative boundaries of the village.

While conceptualizing communities for this research and its composite parts, a simplistic notion of heterogeneity is considered to divide actor groups such as households, industries, farmers, etc. This distinction was made based on the different types of groundwater users present in the village and is only a simplification made by the analyst. It is pertinent to note here that these actor groups may not exist as separate entities within the village e.g. households may have finer sub-communities inside them based on location, religion, migrant status, income etc. Tihuria and Badai consist of sub-parts inside the village that are governed by different Panchayat members e.g. Badai is divided into two smaller parts - one is dominated by the industrial units, while the other which is more farming oriented. It is very likely that households from one part of the village have different norms and mental models compared to the other. The choice of defining broad actor keeps the research manageable, however, future work on CBM should keep the finer variances within the community in mind, especially while planning any community initiative.

The choice of methods used to execute this research also demands attention. Firstly, the motivation behind choosing the SES framework was to capture both social and ecological aspects of groundwater management in peri-urban areas and exploit its detailed specification of sub-system variables to capture attributes of heterogenous peri-urban actors. The SES framework did satisfy these advantages. However, lack of data on hydrogeological attributes of the resource led to ecological parts of the SES framework being underrepresented. Moreover, the excessive attention on variables inbuilt in the SES framework took the focus away from its heart, the action situation. Ultimately researchers are left with a choice between a detailed but static analysis with the SES framework or a more dynamic but underspecified analysis with the IAD framework (Cole et al., 2019). Combination of the IAD and the SES framework such as the one proposed by Cole et al. (2019) would have been more suited for the analysis.

Secondly, although interviews as a method was a good choice to map the actor and governance subsystems of the framework, understanding the resource system requires quantitative measurements and modelling of the local aquifers to establish their characteristics such as mobility, storage, and draft. Although performing a quantitative study on the local aquifers was beyond the scope of this research and the author's field of study, future design on the application of the SES framework should consider this aspect more thoroughly for a justified focus on both social and ecological systems. The use of interviews as a method to map the SES framework only captures how the resource is perceived by the users, and the actual characteristics of the groundwater resource cannot be discerned through this method.

*Recommendations*

1. Expand the boundaries of the peri-urban SES system to capture its ecological connectedness to surface water and social connectedness to the city.
2. Create quantitative models of the aquifers to present an equal focus on the social and ecological systems.

### 9.1.3 Research methods

This section reflects upon the limitations in the application of various research methods deployed in this thesis and presents recommendations for future use of these methods.

#### *9.1.3.1 Interviews*

Interviews provide a gateway into the mental models of people and help us understand how they perceive the world. This method formed the backbone of data collection for this thesis. As with any data collection method, and especially with qualitative data, risks of bias, inaccuracy, and representation remain. Following are a few limitations of the use of interviews as a data collection method.

***Representation***

Since the focus of this research was on diversity and not on number of interviewees, this research assumes that people interviewed are an acceptable representation of the mental models of the actor group they belong to. However, the author acknowledge that this might not be an accurate representation. For example, one or two interviews with an industry in Badai or Tihuria does not necessarily represent the view point of their collective. Since the interviews only represent a plausible explanation, these perceptions should be validated by conducting more rigorous surveys to further understand their mental models.

***Quality and loss of information***

Firstly, the quality of information collected varied across the participants depending on their availability, openness, and trust in the researcher. Moreover, while conducting the interviews, stray conversations could not be avoided e.g. due to misinterpretation of the questions or additional follow-up questions asked by the translators. Initially, these conversations took away considerable amount of the allotted time, but this aspect was later improved upon after aligning with the translators as the interviews progressed. Furthermore, since most interviews were held in the natural setting of the interviewee, disturbances could not be avoided which frequently led to breaks in the interviewee's narration. All in all, these factors contributed to decreasing the quality of the data collected.

Secondly, the field visits were organized just before the national election season in India which meant that the government officials were either not able to give enough time for the interview or were not willing to reveal information or data. Given the enforcement of modal code of conduct during elections in India, they were apprehensive that their information may be twisted and represented in the media. Some officials, therefore, did not give the permission to voice record their interviews which may have led to some loss of information.

Thirdly, although I went back to her home country for this research, I was visiting a State where I did not speak the local language. Therefore, it took at least 2 interviews to get used to working with a translator. There were times when the translator would only succinctly summarize a long conversation with the interviewee. Although attempts were made to consistently align the translator's interpretation of the interview with my interpretation, it did lead to some loss of information. To partially overcome this, interviews were conducted in my native language, wherever possible, provided the interviewee was comfortable with it.

Fourthly, an interesting challenge that surfaced while conducting interviews was that few interviewees were skeptical about the intentions of the research. One interviewee in Badai even walked out of the interview when questions related to groundwater licenses were asked. Although the purpose of conducting the research were told to the interviewees at the beginning of the interview, interviewees were still doubtful that I was might represent a media organization or a government authority. This lack of trust can also be attributed to the sensitive and somewhat political nature of the issue. Therefore, it is likely that interviewees might have self-censored themselves to only reveal the information that shows their organization or company in a good light.

Lastly, the selection of case studies that were researched under the Shifting grounds project was a convenient decision as it provided access to a lot of primary data and background information on the areas. However, conducting interviews in a village that has already experienced research activities around similar topic led to stakeholder fatigue among the interviewees. Although caution was taken to avoid interviewing people covered in past research projects, some overlaps in interviews with government officials could not be avoided and hence, research fatigue might have impacted the quality of their responses.

#### *Missing stakeholders*

Given limited time for conducting the field study, not all stakeholders mentioned in the research could be interviewed, for instance, the District Minor Irrigation Corporation and the Village Committee that manages the distribution of water among farmers in Badai or the EKWMA in Tihuria. Although this was partly resolved by using interview data from the Shifting Grounds research project, some stakeholders such as the EKWMA and the MIC still remain un-interviewed.

#### *Information validation*

While conducting the field study, interviews had to be scheduled around the availability of government officials. This meant that some government officials were interviewed at the start of my research, when my understanding of the case study was still nascent without having talked to the groundwater users first. Therefore, some aspects of groundwater management that were highlighted in the following interviews could not be discussed with the government officials. Moreover, conflicting pieces of information that emerged as the interviews progressed could not be validated with the previous interviewees due to limited time spent on the field.

#### *Possibility of bias*

Given the qualitative nature of the research, it is difficult to separate the research from the researcher. It needs to be acknowledged that the data collected for the interviews is filtered through the worldview of the researcher. Moreover, since the interviews were translated, there was an additional layer of distortion in the interview data. Therefore, this research is observer dependent and only presents **the researcher's interpretation** of **the translator's interpretation** of **the interviewee's mental model** about **the world** (Adapted from Igor Nikolic, personal communication, January 30, 2019)**.**

### *9.1.3.2 SES Framework*

This section discusses some of the challenges faced in the application and operationalization of the SES framework and the limitations it resulted in.

***Operationalization***

The application of the SES framework to the case study was not an easy task. A recurrent hurdle faced in using the framework was the lack of clear definitions of the second-tier SES variables in the literature. Although Ostrom (2009) presents the relationship between 10 critical SES variables and self-organization while variables such as collective-choice rules, constitutional rules, monitoring and sanctioning rules, etc. are already defined in her previous works, ambiguity about the meaning of a lot of variables in the SES framework still remains. Firstly, many variables such as "Mental models", "predictability of system dynamics", "social capital", etc. are broad terms that can be interpreted and operationalized in different ways by researchers. Although this nature of the SES framework provides flexibility to researchers from different disciplines to define these variables based on their own academic background, it limits comparison across case studies. Therefore, future development of the framework should aim at semantic clarification. In order to overcome this challenge and be transparent of the interpretation of the SES variables, these variables have been defined an operationalized in Appendix D.

Secondly, it seems that some overlaps exist between a few second-tier SES variables e.g. the infrastructure used for extracting groundwater may be classified both as human-constructed facilities (RS4) and technologies available (A9) to the actors and the distinction between these variables is not clear. This further necessitates work on clearer descriptions and clarifying the meaning of second-tier SES variables.

*Recommendations*

Future work should be focused on creating a repository of definitions for all second-tier SES variables and clarify the meanings of the variables and mapping overlaps between them

***Diagnosing vs scoping***

Although the SES framework offers flexibility in choosing the variables of interest, it becomes difficult to draw the boundaries. During the application of the SES framework, I consistently struggled to draw the boundaries of the research. Since the purpose of the research was to ***diagnose*** groundwater management in a peri-urban village, including more SES variables in the analysis facilitated in capturing the complexity of the issue and providing a richer description of the case study. But on the other hand, it also significantly broadened the analysis and put constraints on drawing precise conclusions.

***Interdependencies between actors***

The SES framework does not capture interdependencies between actor e.g. in Badai and Tihuria industries and villagers are dependent on each other for employment and drinking water, respectively and the SES framework in its current does not take this into account. These interdependencies may be analyzed through the steps proposed by Enserink et al., (2010; Page 96) to understand the motivation behind an (the lack of) action taken by an actor in an action situation.

#### *9.1.3.3 Coding process*

The use of Atlas.ti to code all interviews did give a benefit of time and speed as it allowed to organize documents and query codes across the documents. However, the use of a computer-aided tool may distract the researcher into coding 'too much' and lose a sense of the bigger picture. Because of a lack of clarity of the definition of SES variables, I had to redo the coding of the interviews as the concepts became clearer prompting me to fix the definitions of the variables. In hindsight, this should have been the first step that I should have undertaken in the application of the framework. Moreover, since the research was carried out by a single researcher, the implementation of the codes could not be cross-checked across researchers.

*Recommendations*

Given the ambiguity around the second-tier SES variables, future applications of the framework should stress upon the importance of cross-checking the codes across researchers.

#### 9.1.3.4 Application of Ostrom's design principles

The application of the design principles to peri-urban Badai was challenging. Firstly, since the resource being studied is not limited to a single village and extends beyond the boundaries of the village, it was not clear whether design principles should be applied at the community level or the actor level in peri-urban areas. Secondly, although the design principles are mostly embedded in the SES framework, their exact linkage with the framework is not clear. Lastly, it is also not clear whether how strictly the principles should be applied, whether the mere presence of a sanctioning mechanism is enough, or it should be 'effectively' functional and enforced too. Therefore, choices were made in this research to overcome the above limitations or lack of clarity in the application of the method. These choices have been elicited in Chapter 6.

## 9.2 Looking back at the research process

My motivation for pursuing this research was both a personal and an academic one. I wanted to work on a topic that allowed me to contribute to an issue that is relevant to my country. Moreover, having built quantitative models during my master's so far where I would simplify complexity by making sweeping assumptions, I wanted to understand the richness of the real-world through my thesis. Hence, I decided to pursue a qualitative study. Moreover, ever since I started reading about Elinor Ostrom's work, the idea of people successfully taking charge of their resources and coming up with innovative institutions to sustain them fascinated me. My interest in CBM started with the conventional view; one that envisioned communities living harmoniously with each other and the resource. However, studying peri-urban areas shattered this notion. Peri-urban areas are 'messy', one where there are no clear-cut 'communities' but instead multiple actors fulfilling their short-term resource needs.

Although I started out with a qualitative study as a conscious choice, as the thesis progressed, I gradually realized my own limitations in grasping this research approach. Firstly, I struggled to separate my own interpretation of the data from the data itself. This becomes all the more critical in qualitative research since the results can become easily biased by the author's own perception of the data. I have tried to take a neutral approach in the thesis in presenting perspectives of all the relevant actors and used quotes extensively to present the exact viewpoint of the interviewee in my arguments. However, gaps may still remain which can be attributed to my lack of experience in using this approach. Secondly, as the thesis progressed, the research kept becoming more uncertain for me as I failed to envision the exact 'output' of a qualitative research. This coupled with frequent revisions of my research questions were some of the hurdles I faced in executing a qualitative research.

Looking back at the research process, I would have designed it better and initiated the case studies with a clear goal in mind. Elections in India can easily turn violent, especially in West Bengal, and therefore I had to plan my field work so as to avoid being engulfed in the election fever in the months of April and May. This gave me less time to prepare a theoretical foundation for the research and scope my data collection process. While I had a broad main research question in mind before going to the field visit, I did not have clarity on the specific things I wanted to study. This led to many iterations in the research where I went back and forth between the theory and data. If I were to perform the study again, I will plan the interviews later in my execution and give myself enough time to make strong connections with the theory before going to the field.

The thesis journey brought both the best and worst out in me. As the end of the thesis drew nearer, the stress finally got to me in the month of June. However, as I write the last few words of my thesis, I feel proud that I have been able to produce this report. If I were to do this thesis again, I would maintain a better work-life balance, be more kind to myself, and take better care of my physical and mental health.

To sum up, I would like to share some of my own learning through the research process. I realized that embracing complexity is fun. There are no clear-cut solutions (or as Elinor Ostrom calls them – a panacea) to the problems we face around us today, especially those that intertwine the natural and the social world. However, we must continue to understand them better. Lastly, there are many things that we take for granted in our daily lives that are still not a reality for many villages in India – especially drinking water and sanitation. Travelling to peri-urban Kolkata made me realize my privilege in accessing clean water at the turn of a tap. This thesis, therefore, helped me change my own mental model about water and its access.

# APPENDICES

# Appendix A : Indian Administrative Structure

India is a quasi-federal union consisting of 29 states and 7 union territories (Census of India, 2011). The quasi-federal structure means that it is neither purely federal nor purely unitary, but it is a combination of both. The Constitution of India strongly emphasizes that that India is a single united nation. However, decentralization of authority in India was introduced to facilitate smooth governance of a large nation that India is. This is done through subject "lists", which divides power between various levels of power. For instance, subjects like "Law and Order" and "Water" are the sole responsibility of the individual State Governments, while subjects like Telecommunications fall under the Union (or Federal) government.

In continuation of this hierarchical structure, the states and union territories themselves are further subdivided into smaller administrative divisions and districts. As of 2011 there are a total of 593 districts in India (Census of India, 2011). The difference between rural and urban areas begins at the level of districts. In case of urban areas, the districts are divided into Municipalities (or some minor variation) and further into wards (See Figure A.1). In case of rural areas, these districts are divided into "blocks" and further into Villages. Thus, a village forms the smallest governed entity in the Union of India. There are about 250, 000 Gram Panchayats in India each serving a population of about 5000 (Chaturvedi, 2012; Page 74). The villages are governed by Gram Panchayats, a term when translated from some Indian languages, literally means the "village council". The Gram Panchayats are a formalized local self-governance system in India at the village or small-town level. The gram panchayat is divided into "wards" (similar to urban areas), each represented by a Panchayat Member, who is directly elected by the villagers. The panchayat is chaired by the president of the village referred to as a Sarpanch or a Pradhan. The term of the elected representatives is five years. The primary responsibilities of a Gram Panchayat among many others are infrastructure provision such as roads and schools, health, minor irrigation, supply of drinking water, etc.

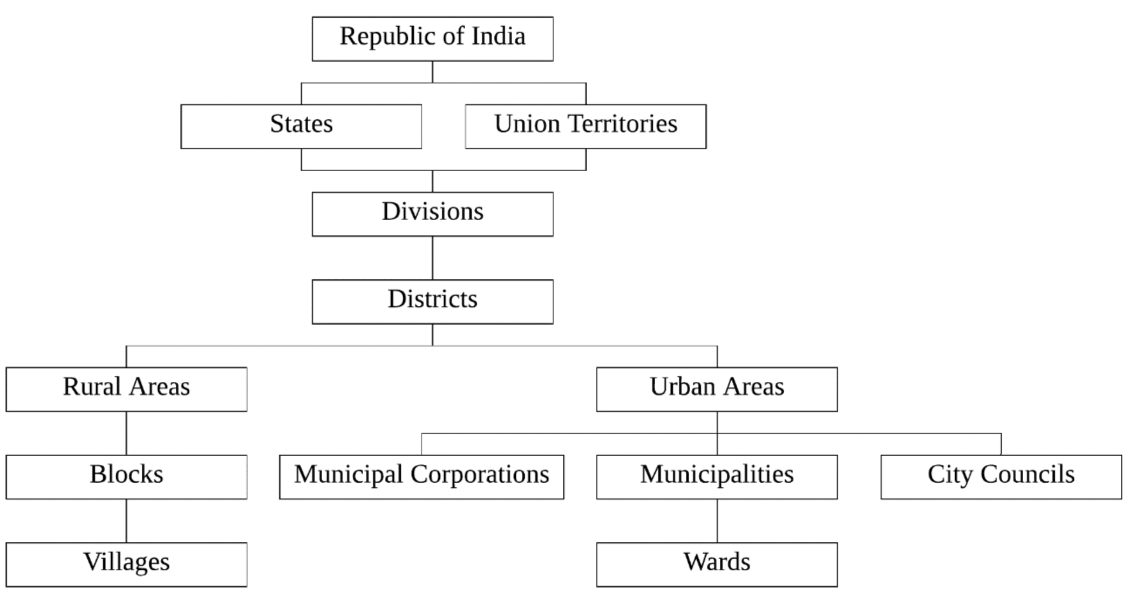



*Figure A.1: Administrative structure of India, adapted from The Civil India (n.d.)*

# Appendix B : Interviews

## B.1 Interview: Questionnaire

| | |
|---|---|
| Name | |
| Age | |
| Occupation | |
| Work location | |
| Education Level | |
| Duration in the Village | |
| Position in the village | |
| Land tenure | |

### B.1.1 Groundwater Users

1. *Introduction:* Can you please introduce yourself?
    a. How long have you been staying in the village?
    b. Why did you come to this village?
    c. Do you own this house or is it on rent?
    d. Till which class did you study?
    e. Are you part of any organization or committee in the village?

2. *Resource Extraction:*
    *a.* Can you describe your day to me?
    b. When do you use water and for what purposes? Where do you fetch it from?
    c. Out of this water, how much of it comes from below the ground? For what purpose?
    d. Roughly how much groundwater do you extract per day? How often do you extract GW? [Extraction]
    e. Which pump do you use? What horsepower is it? For how many hours does the pump run daily?

3. *Problems*:*
    a. Do you face any problems or challenges in extracting groundwater? What is it? [Outcomes]
    b. Do you face any problems in using the wells? What is it?
    c. When do you face this problem? [e.g. at the time of applying for license, in summer seasons, etc., seasonal dependency]

4. *Causes:*
    a. What are the causes of this problem? [Actions, Rules]
    b. How do you know that this is the cause of this problem?

5. *Formal Rules:* If rules are not touched upon, explicitly ask
    a. Are you aware of the formal rules that exist to manage this problem? What do you think about them?
    b. Do they work? Why/why not?
    c. What other norms/customs do you follow then?

6. *Actors:* If Q4 does not explicitly refer to the actors, ask
    a. Who are the people involved in this problem?
        i. Within the community/village?
        ii. Outside the community - governmental officials?

7. *Collective Choice Level [Interactions]*
    a. Whom do you approach to resolve this problem? How?
    b. Are there any active leaders that you approach to discuss your problem?
    c. Are you part of any organization or association that represents your interests related to this problem?

8. *Reponses to the problem*
   a. Has your community responded to this problem in the past? [Past experiences]
   b. Was it successful? Why or why not? [Actor attributes or Interactions]
   c. Are you aware if any initiatives are being taken to resolve this problem presently [Present experiences]? Do you think they solve the problem? Why/why not?

9. *Solutions to the problem*
   a. What do you think should be done to improve this situation? [Actions for solving the problem]
   b. **If the answer is 'don't know' here*:
      a. Are you aware if any initiatives are taken by other people to resolve the issue?
   c. Why do you think this solution would work? [Interactions or Actor Attributes]
   d. Who should take the actions to implement this solution? [Dependency on other actors]
   e. *Why is it that this solution is not implemented yet? [Interactions or actor attributes or issues with governance system]*
   f. *Is there anyone who stands in the way of resolving this problem? [Blocking actors]*

10. *Other Interactions*
    a. Monitoring of groundwater use by any one another? Govt. officials?
    b. Any conflicts with other users or government officials?

11. *External factors:*
    Are there any factors which are outside your department/community's control that influence this problem [External factors e.g. politics, climate change, etc.]?

### B.1.2 Government Officials

#### B.1.2.1 *State Water Investigation Department*

1. *What is your organization's role in managing groundwater? Are there any other departments also involved in regulating the extraction of GW?

*Extraction*

2. How have the rules for groundwater extraction changed in the past years?
3. *Who are the major users of groundwater in your district?
4. *What is the process followed for acquiring the GW license?
5. *What are the criteria followed to grant the license?
   a. *Have any licenses been denied since the passing of the Act in 2005 in North 24 Parganas district? How many? (for well distancing rule)
   b. *What are the current sanctions for using GW without the SWID permission? How are they decided?
6. Do you coordinate with any other department in the provision of licenses? How?

*Monitoring*

7. *How does SWID monitor the legitimate extraction of GW?
   c. Does SWID actively monitor if users have taken the license? If not, whose responsibility is it then?
   d. Do you depend on information from users or other departments? How do you share this information? [Information sharing]
8. Do you receive any complains by water users? In what form? What is done about it?

*Challenges*

9. What are the challenges faced by the SWID department to implement the formal policy?
10. What are the causes behind this? [Actors, Rules, Actions]

*Solutions*

11. Do you coordinate with anyone to resolve the problem?
12. *What do you think are the solutions to this problem?

*External factors*

13. *Are there any factors outside your department's control that positively or negatively affect this problem?

*Questions on future of the resource:*

14. Are there any plans to address this problem in the future?
15. Any plans on monitoring the **amount** of water extracted by different users in future?
16. Do you think local communities should be involved in monitoring the extraction of GW?

*Lobbying*

17. Are there any key lobbies in the groundwater licensing system for this district? What are they?

#### B.1.2.2 *District Magistrate*

1. What is the impact of urbanization on your district?
2. How has this impacted the use and extraction of groundwater in the district?
3. Who are the key users of groundwater in your district?
4. What are the key issues of importance related to groundwater and its management for the North 24 Parganas district?
5. Are there any ongoing or planned projects to address these issues?
6. Which departments are involved in the management of groundwater in this district? What aspects of groundwater do they manage?

#### B.1.2.3 *District Industrial Centre*

*Introduction*

1. What are the roles and responsibilities of the organization?
2. What are the keys services that DIC provides to industries?

*Licensing*

3. What are the advantages of coming to the DIC than going to different departments?
4. Who can approach the DIC to apply for licenses?
5. What is the process of applying for a license through DIC? How are the applications processed?

*Information sharing*

6. Does DIC inform industries about what licenses are required? How is a policy or a new rule conveyed to the industries? E.g. One dyeing industry that came to know about the SWID law only 2-3 years back while it was passed on 2005; how is the information conveyed?

*Monitoring*

7. Does DIC monitor whether industries have taken the appropriate licenses?

*Plans*

8. What are the key challenges faced by industries with regards to groundwater, its extraction and use?
9. What are the causes for these problems?
10. What are the solutions?
11. Are there any plans or initiatives being taken to reduce the dependency of industries on GW?
12. Can you explain the plan of making industrial clusters? What do you think will be the impact of such a policy on GW levels?

*Lobbying*

13. What are the key industry associations in the district?
14. How is the 200m distancing rule negotiated by the industries and other stakeholders?
15. Are there any lobbies?

#### B.1.2.4 *Public Health Engineering Department (PHED)*

*Roles and responsibilities*

1. What are the main roles and responsibilities of the PHE department? Does PHE coordinate with any other government department for provision of drinking water?
2. What is the area of jurisdiction of PHE?
3. How is drinking water supplied to the users?
    a. Process of extraction, and provision?
    b. Is any permission sought from other departments for the same?
    c. How are the PHE stand-posts distributed across a village? What is the criterion followed?
4. What standards are followed for drinking water quality?
5. Does PHE install any other infrastructure where stand posts are not viable?

*Operations*

6. What happens after installation of the stand-posts? Who is responsible for operation and maintenance?
7. Is any training/funding provided to the Panchayats for the same?
8. How is drinking water quality and quantity monitored in the villages?
9. Who should the users approach if they want to register a complaint or a grievance about the availability of water or timing issues?
10. What is the role of PHE in regulating the extraction of GW? DLA meetings that decide the approval of SWID licenses?

*Challenges*

11. What are the challenges faced by the PHE department in the provision of drinking water?
12. What are the causes for these challenges?
13. Any potential solutions?

*Future of the resource*

14. Can use of surface water for drinking provision eliminate the dependency on groundwater?
15. Is enough surface water available to satisfy the drinking water needs of the rural population?
16. Are there any planned projects for villages not yet covered by the surface water supply?

## B.2 List of interviews

*Note*: To maintain the privacy of interviewees and prevent any possible political repercussions for them, the transcripts of interviews and the interview key (mapping interviewee to the interview number) have not been included in this thesis. In order to access the primary interview data, please email Dr. Sharlene Gomes (S.L.Gomes@tudelft.nl) or Dr. ir. Leon Hermans (L.M.Hermans@tudelft.nl).

### B.2.1 Interviews conducted in Badai

| Actor | Administrative Level | Actor Type |
|---|---|---|
| ***Groundwater Users*** | | |
| Local women | Village | Household |
| Household (Local migrant) | Village | Household |
| Household (Outside State migrant) | Village | Household |
| Household (family) | Village | Household |
| Real Estate Developer | Village | Industry |
| Dyeing Industry | Village | Industry |
| Dyeing Industry | Village | Industry |
| Boro paddy Farmer | Village | Farmer |
| ***Representative of local organizations*** | | |
| Industry Association | Village | Industry |
| ***Government Officials*** | | |
| PHED | Village | Official |
| Panchayat Representative | Panchayat | Official |
| Panchayat Representative | Panchayat | Official |
| Panchayat Member | Panchayat | Official |
| District Magistrate | District | Official |
| DIC | District | Official |
| SWID | District | Official |
| PHED | District | Official |
| ***Leaders*** | | |
| Leader | Panchayat | Leader |
| ***Notes and observations*** | | |
| Field Visit and notes | Village | NA |

### B.2.2 Interviews conducted in Tihuria

| Interviewee | Administrative Level | Actor Type |
|---|---|---|
| ***Groundwater users*** | | |
| Bottling Company | Village | Industry |
| Local Family | Village | Household |
| Farmer (Hybrid catfish) | Village | Farmer |
| Farmer (Boro paddy) | Village | Farmer |
| ***Leaders*** | | |
| Leader | Village | Leader |
| Village elder | Village | Household |
| ***Government officials*** | | |
| PHED representative | Village | Official |
| Panchayat representative | Panchayat | Official |
| Panchayat representative | Panchayat | Official |
| BDO representative | Block | Official |
| SWID representative | District | Official |
| SWID representative | State | Official |
| ***Notes and observations*** | | |
| Field Visit | Village | NA |

## B.3 Interview-keywords table

Table B.1 and Table B.2 present the top 10 keywords of each interview in descending order of word count. This table has been generated using the word list feature of Atlas.ti (ATLAS.ti, 2018). Common English words were filtered out using a *stopword list* https://www.ranks.nl/stopwords.

### B.3.1 Badai

*Table B.1: Interview keywords (Badai)*

| Interview No. | Actor | Keywords |
|---|---|---|
| 1 | *Dyeing industries* | industries, problem, rules, permission, association, license, meeting, department, development, fees |
| 2 | | municipality, buildings, project, building, area, boring, pumps, cost, real-estate, residents |
| 3 | | factory, process, village, industry, factories, license, dyeing, land, industries, required |
| 4 | | industry, license, setup, trade, association, company, problems, zone, factory, required |
| 5 | *Households* | handpumps, problem, fetch, handpump, people, factories, problems, industries, installed, years |
| 6 | | handpumps, house, business, handpump, people, problems, party, iron, supply, family |
| 7 | | people, factory, village, tubewell, faced, industries, problems, job, dyeing, machines |
| 8 | | stand-post, house, work, point, years, village, connections, installed, construct, agriculture |
| 9 | *Farmers* | agriculture, industries, fields, village, paddy, years, land, irrigation, tubewell, field |
| 10 | *District Officials* | license, district, industries, trade, check, groundwater, applications, monitoring, sense, required |
| 11 | | industries, setup, industry, guidance, rules, clearance, applications, setting, district, required |
| 12 | | industries, license, check, users, applications, extraction, rules, meeting, office, required |
| 13 | | schemes, supply, surface, infrastructure, district, areas, arsenic, drinking, contamination, groundwater |
| 14 | *Panchayat Officials* | license, industries, trade, problem, groundwater, extraction, village, tubewells, dyeing, control |
| 15 | | extraction, industries, level, permission, villagers, village, engineer, block, groundwater, install |
| 16 | | village, problems, board, villagers, members, people, groundwater, license, household, availability |
| 17 | *Others* | hours, stand-posts, time, installed, reservoir, years, day, defunct, slots, operators |
| 18 | *Leader* | stand-posts, village, party, industries, problems, pump, people, groundwater, demand, problem |

## B.3.2 Tihuria

*Table B.2: Interview keywords (Tihuria)*

| Interview No. | Actor | Keywords |
|---|---|---|
| 19 | *Industry* | bottling, company, bottles, business, shop, boring, land, number, started, area |
| 20 | *Household* | village, people, house, point, years, good, bottled, shallow, tubewells, quality |
| 21 | *Farmer* | fish, canal, cultivation, business, quality, good, pond, pump, months, village |
| 22 | | land, canal, village, years, required, house, cultivation, time, people, hours |
| 23 | *Panchayat Official* | supply, village, groundwater, surface, people, installed, boosted, points, house, pump |
| 24 | | village, issues, bottling, groundwater, people, problems, member, members, tubewells, handpumps |
| 25 | | water, bottling, plants, village, companies, groundwater, license, good, tubewells, level |
| 26 | *District/Block Official* | block, tubewells, supply, department, groundwater, surface, responsible, level, day, fish |
| 27 | | groundwater, aquifer, quality, based, assessment, people, amount, department, level, license |
| 28 | | wells, extraction, permission, industrial, assessments, purpose, based, license, required, land |
| 29 | *Leaders* | village, people, years, land, started, bottling, villagers, area, plant, company |
| 30 | | village, bottling, people, started, government, drinking, canal, groundwater, river, companies |

# Appendix C : Field diary

This field diary was published as a research story on the Facebook page of TU Delft | Global Initiative[15]. The organization provides a support grant for master's student who execute a research project in low-income and middle-income countries thereby contributing to the Sustainable Development Goals (SDG).

**Introduction to research**

I am Aashna Mittal, a second-year master's student pursuing Engineering and Policy Analysis at TU Delft. For my master's thesis research, I am going back to my home country to understand the management of groundwater in peri-urban areas of India. Peri-urban areas are the transition zones between rural and urban areas. Lying at the outskirts of major cities, these areas are marginalized in the provision of piped drinking water supply and hence, groundwater forms the major source of water for drinking and domestic use. Unregulated extraction of groundwater, however, threatens the sustainability of the resource and long-term needs of the peri-urban dwellers.

In collaboration with The Researcher and Centre for Studies in Social Sciences, I will be conducting a field study in two peri-urban villages near Kolkata - a rapidly urbanizing city in Eastern India. In the upcoming weeks I will be interviewing government officials and groundwater users (farmers, industries and households) to understand the gap between formal policy for use and extraction of groundwater, and its implementation on ground. Although community-based resource management is an attractive solution to manage groundwater, through my research I aim to understand the challenges and opportunities for this approach specifically in peri-urban contexts.

**End of Week 1**

I began the first part of my research by visiting a peri-urban village located in the Barackpore II area, north of the Kolkata city. As one travels away from the main city the markers of urbanization start fading away. With no formal surface water supply, my study village is completely dependent on groundwater for its survival. Here, one can spot small and medium industries juxtaposed with agricultural fields. In terms of groundwater use, this means that there is competition between different users and activities for the extraction of groundwater.

This week I interviewed households, farmers, owners/managers of dyeing industries and upcoming real estate projects in the village to understand their use and extraction of groundwater. Further, I also investigated local practices to distribute groundwater within farmers and approaches undertaken by communities to resolve their water problems. After getting myself acquainted with the local situation and challenges faced by different users, next week, I plan to interview government officials to understand the formal policies in place to check the extraction of groundwater and what challenges they face in implementing the same.

**End of Week 2**

This week I got the opportunity to meet a few government officials involved in the management of groundwater. Although election fever has engulfed the state of West Bengal, some of the officials were kind enough to take out some time from their super busy schedule.

[15] Website link: https://www.tudelft.nl/global/

I started with meeting the District Magistrate of the North 24 Parganas district to discuss the groundwater challenges faced by the district. Two key problem areas pertain to the quality and quantity of GW; arsenic and salinity contamination and effective monitoring and regulation of extraction, respectively. On her recommendation, I went on to meet the State Water Investigation Directorate (SWID) and the Public Health Engineering Department (PHED) to understand their role in groundwater management. The SWID regulates the extraction of GW by industrial and infrastructure users through a licensing mechanism and the PHED is responsible for the provision of drinking water supply. Presently the PHE extracts and filters groundwater but owing to arsenic contamination in the aquifers and decreasing GW levels in some areas, including my study village, they plan to shift to surface water supply schemes in the future.

The interviews conducted this week shed light on the tradeoffs involved in groundwater governance; short term vs long term, juggling between the needs of different type of users, and dealing with the challenges of implementing formal policies.

**End of Week 3**

This week, I moved my base to the South 24 Parganas district where I visited another peri-urban village, the second one in my case study.

This village is relatively less industrialized compared to my study village in North 24 Parganas district, although a few water bottling companies are mushrooming up gradually. Here, both agriculture and aquaculture are prevalent. However, both these forms of cultivation are not the dominant users of groundwater. Rather, water is fetched from a canal that flows through the village carrying the waste (sewerage) produced by the Kolkata city. For formal supply of drinking water, groundwater and surface water are mixed and stored in an overhead tank and supplied to the village via stand-posts. However, due to complaints in quality, some users rely on packaged water to meet their drinking water needs. Further, one can spot a handpump installed in almost every house of the village for domestic uses like bathing, washing, cleaning, etc. A pressing issue in the village is the rising spread of arsenic and salinity contamination in the shallow aquifers. Due to this, deeper aquifers are being tapped to extract good quality water for drinking.

This marks the end of my field visit and now I look forward to analyzing the data that I've collected to deduce the potential and limitations of community-based management of groundwater in peri-urban areas. The field visits were one of the key highlights of my Master's. Desk research only gives you a limited picture about the ground reality and this field work helped me to better visualize the groundwater management systems in peri-urban areas. A big shout out to The Researcher, Kolkata for helping me get acquainted with the local context in a short span of time and for translating my interviews.

# Appendix D : Selection, Definitions and Operationalization of SES variables

| SES variable | Reasons for selection | Definitions and operationalization |
|---|---|---|
| ***Resource Systems (RS)*** | | |
| RS1 – Resource Sector | Resource Sector of the focal SES e.g. aquifer, grazing lands, etc. | Aquifer and land; surface water is not considered as part of the focal SES given the focus on GW. |
| RS4 – Human constructed facilities | Emergent variable in the case study | Infrastructure used to extract groundwater. |
| RS5 – Productivity of system* | This variable has a curvilinear effect on self-organization. There needs to be some scarcity for users to invest in self-organization. Ostrom (2009). | For aquifer systems, this variable is taken as the perceived GW scarcity observed by users which leads them to self-organize. |
| RS7 – Predictability of system dynamics* | System dynamics need to be predictable for users to estimate the impact of institutions they set up. E.g. forest systems are more predictable compared to water systems. Ostrom (2009). | For aquifer system, this variable is taken as the predictability of the dynamics of groundwater flow from the perspective of the users i.e. understanding of basic water principles, and knowledge of stocks and flows. |
| ***Resource Units (RU)*** | | |
| RU1 – Resource unit mobility* | Self-organization is less likely when the resource is mobile due to costs of observing and managing the system. Ostrom (2009). | Mobility of groundwater |
| RU6 – Distinctive characteristics | Natural characteristics of the resource may affect its extraction levels | Distinctive characteristics of groundwater such as contamination. |
| ***Government Systems (GS)*** | | |
| GS1 – Government Organizations | Decisions taken by the government agencies impact the resource activities and the rules that actors must follow to harvest groundwater and are therefore, important to consider. | Government organizations at different administrative levels that implement or change the rules to harvest groundwater and monitor and sanction the adherence to harvesting rules. |
| GS4 – Property Rights System | In a common pool resource context, property rights include the right to access (enter a specified property), right to withdraw (harvest products from a resource system), right to manage (transform the resource), right to exclude (decide who will exclude, withdraw or manage), and right to alienate (right to sell or lease any of the previous four rights) (R. Kunneke, personal communication, September 26, 2018). Property rights determine who land ownership and groundwater access. | Based on who holds these bundles of rights, property regimes can be classified into private property, public property, communal or common property and open access (Bal, 2015). |
| GS5 – Operational rules | Since harvesting of groundwater is of interest for this thesis, it | Operational rules mean the rules that actors should |

| | | |
|---|---|---|
| | is imperative to consider the formal operational rules that determine its extraction. | follow in order to harvest groundwater. |
| GS6 – Collective-choice rules* | Users face low transaction costs and are successful in defending their resource against invasion by others when they have full autonomy to craft and enforce their own rules at the collective-choice level. Ostrom (2009). | Collective choice rules here mean the rules used to come to decisions that amend the operational-choice rules of harvesting groundwater. Further, these rules also decide the participants of operational choice action situations, i.e. who has the right to extract groundwater in the village. |
| GS8 – Monitoring and sanctioning rules | Monitoring and sanctioning rules ensure enforcement of the agreed upon rules and sanctioning rule breakers. Ostrom (2005, Page 266) sites multiple examples of studies conducted on forests where regular monitoring and sanctioning was linked to better forest conditions. | Monitoring rules are the rules used to monitor whether actors follow the operational rules for harvesting or not. E.g. conducting regular checks on whether actors have taken the appropriate licenses for groundwater extraction. Sanctioning rules are the rules that assign some form of penalty to the actor who violates the operational-choice rules |
| ***Actors (A)*** | | |
| A1 – Number of relevant actors* | More the number of users, higher is the transaction cost to setup rules and agree on changes. However, large groups have the advantage of mobilizing resources such as labor. Ostrom (2009). | This variable is defined as the number of members in each actor group that a similar groundwater use. E.g. households, farmers, etc. |
| A2 – Socio Economic Attributes a) Income, b) Land tenure c) Occupation | Socio-economic attributes specific to peri-urban areas:<br>1) Income: Varies among peri-urban actors as they welcome incoming actors and migrants. Income levels may decide their access to infrastructure to withdraw groundwater<br>2) Land tenure: Insecure land tenure is a characteristic of peri-urban areas. Land tenure may determine whether actors depend on public or private infrastructure for extracting groundwater.<br>3) Occupation: Emergent variable in the case study | Income is taken as a monthly measure.<br>Land tenure is taken as the ownership of the house that an actor stays in i.e. permanent of rental.<br>Occupation is taken as the livelihood of the interviewee |
| A5 – Leadership/entrepreneurship* | Likelihood of self-organization increases if there are some users who have entrepreneurial skills or are respected as local leaders due to past experiences of organization. Ostrom (2009). | This variable is taken as the presence of leaders that represent the interests of different actor groups found in peri-urban areas. |
| A6 – Norms (trust-reciprocity)/social capital* | Norms of reciprocity, and trust in one another to keep agreements leads to agreements and reduces monitoring costs. Ostrom (2009). Social capital is further characterized by | Informal rules setup to overcome resource scarcity problems are considered in this research. These include norms of reciprocity, sharing, monitoring or sanctioning. |

| | | |
|---|---|---|
| | trustworthiness, presence of networks, and formal and informal rules (Ostrom & Ahn, 2009). | |
| A7 – Knowledge of SES/mental models* | If users share common knowledge of the SES and how their actions impact each other they are likely to self-organize. Ostrom (2009). | Since this variable is quite broad in nature, given the context of the case study, it is defined as<br>1. awareness of basic principles of water cycle, groundwater recharge, etc.<br>2. awareness of formal groundwater harvesting rules that actors must follow<br>3. Cause of groundwater scarcity |
| A8 – Importance of resource (dependence)* | Users either consider resource sustainability important or are dependent on it for a significant share of their livelihoods. Ostrom (2009). | Dependency of actors on groundwater for their livelihoods and source of income. |
| A10 – Alternative available | | |
| ***Interactions (I)*** | | |
| I1 – Harvesting | Emergent variable in the case study | Extraction of groundwater |
| I2 – Information sharing | Emergent variable in the case study | Information sharing between groundwater users and government agencies and among government agencies |
| I4 – Conflicts | Emergent variable in the case study | Since the variable revolves around conflicts with respect to discharge of water to agricultural fields, it is considered as external to the focal groundwater SES and not considered for the analysis |
| I6 – Lobbying activities | Emergent variable in the case study | Lobbying to negotiate groundwater extraction rules |
| I7 – Self-organizing activities | Emergent variable in the case study | Self-organizing activities undertaken by the communities to respond to GW problems |
| I9 – Monitoring activities | Emergent variable in the case study | Monitoring of groundwater extraction either by communities or government agencies |
| I11- Licensing activities | Emergent variable in the case study | Provisions of licenses that legitimize GW extraction |
| ***Outcomes (O)*** | | |
| O1: Social Performance measures (Collective Action) | Key outcome to determine the 'success' of community-based management. | Level of collective action to sustain the groundwater resource i.e. prevent the resource from getting depleted. |
| O2: Ecological performance measures (Groundwater depletion) | Ecological condition of the resource | Harvesting levels of different users. |
| ***Socio, Economic, and Political Settings (S)*** | | |
| S2 – Demographic Trends | Important peri-urban characteristic. Incoming actors and migration | Incoming actors that are major users of GW e.g. industries |
| S3 – Political Stability | Emergent variable in the case study | - |

| | | |
|---|---|---|
| S4 – Other governance systems | Emergent variable in the case study | Government resource policies on availability of alternatives to groundwater |
| S5 - Markets | Emergent variable in the case study | Market incentives behind using water intensive production processes. |
| ***Related Ecosystems (ECO)*** | | |
| ECO1 – Climate patterns | Emergent variable in the case study | Availability of rain water |
| ECO2 – Pollution patterns | Emergent variable in the case study | Surface water pollution |

# Appendix E : Policy Notes

## E.1 West Bengal Resources (Management, Control and Regulation) Act, 2005

Since water is a state subject, the dominant policy that governs the groundwater resource in West Bengal is the Groundwater, Management, Control and Regulation Act 2005 (hereafter called the Groundwater Resources Act ) (SWID, n.d.-b). The aim of the Groundwater Resources Act 2005 is to manage, control, and regulate the indiscriminate extraction of groundwater in the state and further prevent widespread contamination of the aquifers. Further, it lays down the formal rules for extracting groundwater and sets up the authority that is responsible for the implementation of the Act.

The key highlights of the Act are:

1. The State Water Investigation Directorate under the Water Investigation and Development Department of the State Government acts as the functional organ for discharging the functions of the Act.
2. The Act establishes a two-tier governance system; the State Level Authority (SLA) as the apex body at the State level, the District Level Authority (DLA) for each district other than Kolkata and the Corporation Level Authority (CLA) for the Kolkata Municipal Corporation as specified in the Kolkata Municipal Corporation Act 1980.
3. The DLA and the CLA must scrutinize the applications for the extraction of groundwater and issue permits or certificate of registration up to an extraction rate of 50m3 or 100 m3, respectively. Any application beyond this approval limit should be forwarded to the SLA. The permit/certificate should be issues based on the assessments of groundwater balance, quality and quantity of groundwater made by the SWID.
4. The Act exempts users[16] who extract or use groundwater for irrigation or domestic purposes via a handpump, tube-well or any other well[17] in which extraction is made without a mechanical or electrical device.
5. Users who have sunk a well before the enforcement of the Act must register the well with the corresponding SWID authority to obtain a certificate of authorization for use and extraction of groundwater. No fee will be charged for this registration.
6. Users who wish to sink a well after the enforcement of the Act must obtain a permit from the corresponding SWID authority before sinking the well.
7. Failure to comply with the provisions of the Act may lead to a fine of up to 63 € for the first offence and 126 € for the second offense.
8. Apart from processing and approving applications to extract groundwater, the DLA and the CLA are also responsible for preparing the groundwater profiles of the district or corporation. They should monitor the quality and quantity of groundwater in their area of jurisdiction and notify the SLA on sudden deterioration or contamination of groundwater resources. In addition to this, they should also prepare a plan to conserve, maintain and utilize groundwater resources in their area, every five years.
9. For the successful implementation of the Groundwater Act 2005, the State Level Authority recommended a distance criterion to be followed while granting permission for digging a new well (Sengupta, 2011). According to this criterion, a minimum distance may be followed between two wells based on their capacity (Table E.1). This criterion was decided based on

[16] A user is defined as an a) individual, b) an institution, organization or establishment, c) a company – private or government and e) an industry of any size that owns or uses groundwater resources for any purpose (SWID, n.d.-b).

[17] A well refers to an infrastructure sunk in the groundwater for the extraction of groundwater and includes an open well, dug well, bore well, dug-cum-bore-well, tube-well, filter point, collector well or infiltration gallery. The Groundwater Act 2005 applies to all wells installed to extract groundwater with an exception of those sunk by the Central of the State Government for any scientific investigation or carrying out assessment or exploration work of the groundwater resource (SWID, n.d.-b).

the typical values of cone of depression (Refer to Appendix F.1) formed while extracting groundwater from a well of a certain lifting capacity (Interview 31).

10. An amendment to the Groundwater Act made in September 2011 exempted domestic users with a sump or an overhead tank up to 10000 l from taking any permission for groundwater extraction. Moreover, public institutions such as schools, universities, hospitals and places of worship were also exempted (*Interview 28*)
11. An amendment to the Groundwater Act made in November, 2011 exempted all farmers operating a pump of 5HP or less from seeking a permit to extract groundwater to a discharge limit of 30-meter cube per hour in 'safe' blocks (Refer to Appendix E.3 for categorization of safe, semi-critical, critical, and over-exploited blocks).

*Table E.1: Guidelines for distance criteria to be maintained between existing and proposed wells (Sengupta, 2011)*

| **Capacity of Proposed Well** | **Capacity of the Existing well** | | **Permissible distance** |
|---|---|---|---|
| | **From** | **To** | |
| Up to 50 Cubic meter per hour | 0 | 50 Cubic meter per hour | 200 meters |
| | 50 Cubic meter per hour | 100 Cubic meter per hour | 400 meters |
| | 100 Cubic meter per hour | 200 Cubic meter per hour | 600 meters |

## E.2 Village Water and Sanitation Committee

A Gram Panchayat or Village Water and Sanitation Committee (VWSC) is formed by the Gram Panchayat and works under the its guidance and direction. Its key functions include (Ministry of Panchayati Raj, n.d.) :

- Plan, design, and implement drinking water and sanitation activities;
- Provide facts and figures to GP to review water and sanitation issues;
- Provide inputs for village water security plan;
- Ensure community participation and decision making in all phases of scheme activities;
- Organize community contributions towards capital costs, both in cash and kind (land, labor or materials);
- Open and manage bank accounts for depositing community cash contributions, O&M funds and management of project funds;
- Commission and takeover of completed water supply and sanitation works through a joint inspection with line department staff;
- Collect funds through a tariff, charges and deposit system for O&M of water supply and sanitation works for proper managing and financing of O&M of the services on a sustainable basis; and
- Empower women in day-to-day operation and repairs of the scheme.

## E.3 Categorization of assessment units by CGWB

The CGWB uses two criteria for demarcating assessment units for groundwater development. These are a) stage of groundwater development, and b) long-term trend of pre and post monsoon water levels. The long-term trend of groundwater levels is considered over a period of 10 years. Depending on the local hydrogeological conditions, lowering of groundwater level by 10-20cm per year is considered significant. The stage of groundwater development is defined as:

$$Stage\ of\ Development = \frac{Existing\ Gross\ Draft\ For\ All\ Uses}{Net\ Annual\ Groundwater\ Availability} \times 100$$

Based on these two criteria, four categories are used to label groundwater assessment units – 'safe', 'semi-critical', 'critical', and 'over-exploited' areas. This categorization has been captured in Table E.2. Apart from these categories, blocks where assessment area contains poor quality groundwater are categorized as 'saline'.

*Table E.2: Criteria for Categorization of Assessment Units. Source: CGWB (2013, Page 10)*

| **Stage of groundwater development** | **Significant long-term water level decline trend** | | **Category** |
|---|---|---|---|
| | **Pre-monsoon** | **Post-monsoon** | |
| <=90% | No | No | Safe |
| >70% and <=100% | No | Yes | Semi-Critical |
| >70% and <=100% | Yes | No | Semi-Critical |
| >90% and <=100% | Yes | Yes | Critical |
| >100% | No | Yes | Over-Exploited |
| >100% | Yes | No | Over-Exploited |
| >100% | Yes | Yes | Over-Exploited |

# Appendix F : Technical groundwater terms

## F.1 Types of wells and their pumping systems

Two types of wells and have been referred to in the thesis – and shallow and deep tubewells. The difference between a shallow and deep well refers to the depth of the aquifer into which they tap. The "depth" here refers not to the absolute depth of the borewell, but how far the casing of the borewell extends **below** the water table (Mechenich & Shaw, 2011). Further, the borewells are broadly classified as:

1. Shallow (up to 100ft or 30m)
2. Deep (more than 100ft)

In addition, there are two distinct types of pumping systems, i.e. hand pumps (see Figure F.1) and submersible pumps (see Figure F.2). The nature of the pumping system used to extract groundwater differentiates a hand pump from a submersible pump. A hand pump is operated manually and works on the principle of pressure difference created when the pump handle is pressed down. On the other hand, submersible pumps are operated electrically and consist of a motor submersed in groundwater and installed in a borehole. Instead of relying on pressure difference, these pumps push fluid to the surface. Usually, there are multiple pumps installed for a single borewell, as water is brought to the surface in stages. With increasing depth of the borehole, the pump(s) require more pressure (to push the water up) and hence more power to operate.

*Figure F.1: A handpump installed in Badai*

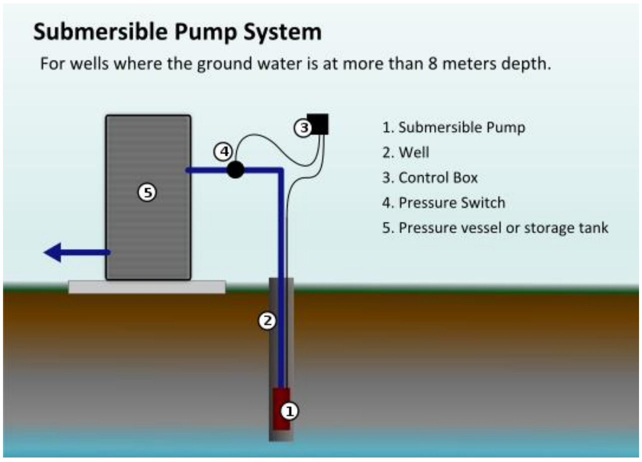



*Figure F.2: Diagram of an automated water well system powered by a submersible pump. Copyright 2008 by Samuel Bailey. (Bailey, 2008)*

## F.2 Cone of depression

Overuse of Groundwater does not have to cause land subsidence - the loss of surface elevation due to the removal of subsurface support - before it becomes a problem (Bralower & Bice, n.d.). In a local context, over pumping of groundwater resource leads to lowering of the underground water levels around it. This over pumping is usually caused by agriculture or industrial extraction, but its repercussions maybe faced by individual landowners (Bralower & Bice, n.d.). The dip in water levels ("depression") occurs in a radial fashion, i.e. the farther one gets away from the resource, the milder the effect gets, thus forming a "cone" (See Figure F.3).

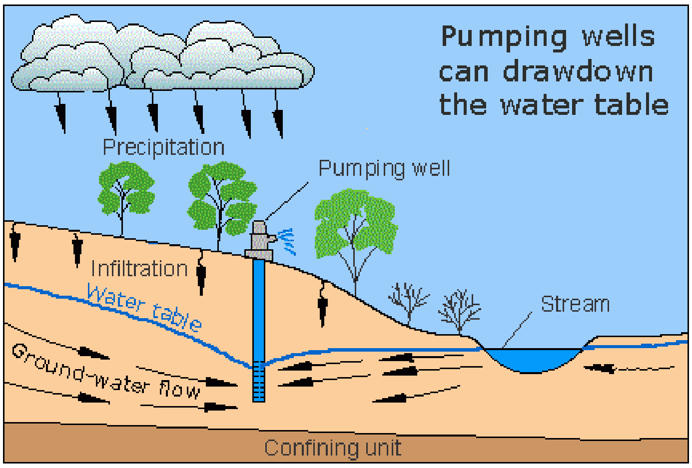



*Figure F.3: Cone of depression formed as a result of groundwater pumping (Bralower & Bice, n.d.)*

A cone of depression is important for 2 reasons. Firstly, as water naturally flows from higher to lower points, it could change the direction of flow of underground water. This has implications on the water quality. If there is a source of pollution near the borewell (for instance), cones of depression may affect whether the pollutant moves away or towards the borewell. Secondly, the shift in the movement of groundwater can also impact water availability. For instance, decreasing the water available for the wells located at the slope of the cone thereby necessitating deepening of the wells to reach the water table.

# Appendix G : Results from Atlas.ti

Figure G.1 maps the second-tier SES codes to interviews conducted in Badai. Each interview is presented as a column and each SES variable is presented as a row. A green box means that the corresponding SES variable was mentioned in the interview. The final column sums up the total number of interviews (out of 18) in which the code was mentioned. This mapping can be further verified through the keywords table presented in Annex B.3.

*Note: Although a code could have been mentioned multiple times in a single interview, only aggregated data is presented here i.e. presence or absence of the code in an interview.*

| | | *Actors* | | | | | | | | | *Government Officials* | | | | | | *Others* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Interview No. / SES variable** | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **Total** |
| | | **Industry** | | | | **Households** | | | | **Farmer** | **District** | | | | **Panchayat** | | | **Others** | **Leader** | |
| **A1a** | Households | | | ■ | | ■ | ■ | ■ | ■ | ■ | | | | | ■ | | | | | 7 |
| **A1b** | Real-estate | | ■ | | | | | | | ■ | | ■ | ■ | | | | | | | 4 |
| **A1c** | Farmers | | | | | | | | | ■ | | | | | ■ | | | | | 2 |
| **A1d** | Dyeing Industries | ■ | | ■ | | | | | | | | | | | ■ | ■ | | | | 4 |
| **A2a** | Income | | | | | ■ | ■ | ■ | | ■ | | | | | | | | | | 4 |
| **A2b** | Land tenure | | ■ | ■ | ■ | | ■ | | | ■ | | | | | | | | | | 5 |
| **A2c** | Occupation | | | | ■ | | ■ | ■ | | | | | | | | | | | | 3 |
| **A5** | Leadership | | | | | | | | | | | | | ■ | | | ■ | | ■ | 3 |
| **A6** | Norms | | | | | ■ | ■ | ■ | ■ | ■ | | | | | | | ■ | ■ | ■ | 8 |
| **A7** | Mental Models | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | | | | | | | | | ■ | 9 |
| **A8** | Resource dependence | | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | | | | | | | | | | 7 |
| **A9a** | Public Technology | | | | | ■ | ■ | | | ■ | | | | | | | | | | 3 |
| **A9b** | Private technology | | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | | | | | | | | | | 7 |
| **ECO1** | Climate patters | | | | | | | | | ■ | | | | | | ■ | | | | 2 |
| **ECO2** | Pollution patterns | | | | ■ | | | ■ | | | | | | | | | | | | 2 |
| **GS1** | Govt. organizations | ■ | | | | | | | | ■ | ■ | ■ | | ■ | ■ | | ■ | | ■ | 8 |
| **GS4** | Property rights | | ■ | ■ | | | ■ | ■ | | ■ | | | | | | | | | | 5 |
| **GS5** | Operational rules | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | | ■ | ■ | | | | 13 |
| **GS6** | Collective rules | ■ | ■ | ■ | ■ | | | | | | | | ■ | ■ | ■ | | ■ | | ■ | 9 |
| **GS8** | Monitoring and sanctionir | | | | | | | | | | | | ■ | | | ■ | ■ | | | 3 |
| **I1** | Harvesting | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | ■ | | | ■ | ■ | | 10 |
| **I3a** | Licensing activities | ■ | | | | | | ■ | | | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | 10 |
| **I2** | Informating sharing | | | | | | | | | | | ■ | ■ | | | ■ | | | | 3 |
| **I3b** | Future planning | | | | | | | | | | | | ■ | | | | | | | 1 |
| **I4** | Conflicts | | | | | | | | ■ | ■ | ■ | | | | | | | | ■ | 4 |
| **I6** | Lobbying activities | ■ | | | | | | | | | | | | | | | | | | 1 |
| **I7** | Self-organizing activities | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | | | ■ | ■ | ■ | | ■ | 11 |
| **I9** | Monitoring activities | | | ■ | | ■ | ■ | | | | ■ | | ■ | ■ | ■ | ■ | | | | 8 |
| **O1** | Collective action | | | ■ | | ■ | | ■ | | ■ | | | | | | ■ | ■ | | | 6 |
| **O2a** | Groundwater scarcity | | ■ | | | ■ | ■ | ■ | ■ | ■ | | | | ■ | ■ | ■ | ■ | | ■ | 11 |
| **O2b** | Groundwater quality | ■ | | | | ■ | ■ | | | | ■ | | | ■ | | | | | | 5 |
| **RS1** | Sector | | | | | | | | | | | | | | | | | | | 0 |
| **RS5** | Productivity of system | | ■ | ■ | | | | | ■ | | | | | | | | | | | 3 |
| **RS7** | Redictability of system | ■ | | | | ■ | | | | | | | | | | | | | | 2 |
| **RSA8** | Storage characteristics | | | | | | | | | ■ | | | | | | | | | | 1 |
| **RU6** | Distinctive characteristics | | | | | | | | | | ■ | | | ■ | | | | | | 2 |
| **S2** | Demographic trends | ■ | | ■ | ■ | ■ | ■ | | | | ■ | | | ■ | | | | | ■ | 8 |
| **S3** | Political stability | | | | | ■ | ■ | ■ | | ■ | | | | | | | | | ■ | 5 |
| **S4** | Other governance systems | | | ■ | | | | | | ■ | | | | ■ | | | | | | 3 |
| **S5** | Markets | | | ■ | | | | | | ■ | | | | | | | | | | 2 |

*Figure G.1: Code-document table for Badai*

# Appendix H : Estimation of groundwater extraction levels in Badai

This appendix presents rough estimates on the amount of groundwater extracted din the Badai village in the summer crop season.

Based on the interview conducted with a farmer in Badai (Interview 9), the following information is known which forms the basis for estimating the water consumption for the total irrigated land in Badai. Given limited use of *Noai* canal, it is assumed that all water for irrigation comes from groundwater to make a rough estimate. The farmer interviewed owns 14 bighas[18] of land, out of which 1 bigha is used for agriculture, 5.5. bighas is used for Boro paddy, and the remaining is used for orchards containing banana plantations. Among the vegetables, the farmer grows brinjal, chilies, pumpkin, cucumber, gourd, etc. Approximately 200 bighas of total land is cultivated using the water from the irrigation DTW. Table H.1 shows the calculation of the minimum and maximum irrigation water required for cultivated land in Badai starting from the initial values of the farmer's agricultural area and then extrapolating the proportions to the total area. These values are further multiplied with water required for the cultivation of the Boro paddy crop, vegetables, and banana in one crop season which is equal to three months. The best-case value or the minimum value of total water required per crop season is considered in the analysis.

*Table H.1: Calculation of groundwater extracted by farmers in Badai during the summer season*

| | **Land per crop in bighas** (Farmer in Interview 9) | **Fraction of farmer's land** | **Total irrigated land in Badai** (in bighas) | **Total irrigated land in Badai** (in m2) | **Min. water requirement per crop season**[19] (in m) | **Max. water requirement per crop season**[19] (in m) | **Min. water required per crop season** (Area x water required per m2) (in Liters) | **Max. water required per crop season**[20] (Area x water required per m2) (in Liters) | **Min. water required per year**[21] (Area x water required per m2) (in Liters) | **Max. water required per year** (Area x water required per m2) (in Liters) |
|---|---|---|---|---|---|---|---|---|---|---|
| Vegetables | 1.00 | 0.07 | 14.29 | 19,047 | 0.50 | 0.50 | 9,523,500 | 9,523,500 | 19,047,000 | 19,047,000 |
| Boro paddy | 5.50 | 0.39 | 78.57 | 104,761 | 1.20 | 1.50 | 125,713,200 | 157,141,500 | 125,713,200 | 157,141,500 |
| Banana Orchards | 7.50 | 0.54 | 107.14 | 142,857 | 1.20 | 2.20 | 171,428,400 | 314,285,400 | 171,428,400 | 314,285,400 |
| **Total** | **14.00** | **1.00** | **200.00** | **266,666** | **2.90** | **4.20** | **306,665,100** | **480,950,400** | **316,188,600** | **490,473,900** |

[18] Bigha is a traditional unit for measuring land that is used in West Bengal. In standard unit of measurements, 1 bigha = 1333 m^2.

[19] Values taken from http://agropedia.iitk.ac.in/content/irrigation-water-management-paddy (for paddy) and http://agropedia.iitk.ac.in/content/water-requirement-different-crops (for vegetables). Only chilies are considered for the estimates on vegetables given the lack of data on other vegetables.

[20] 1 crop season is equal to 3 months (Interview 9)

[21] DTW irrigation water is used primarily for Boro paddy crops during summer and may be used for winter vegetables (Personal communication with Partha Banerjee). Therefore, yearly calculations only include water consumed for vegetables.

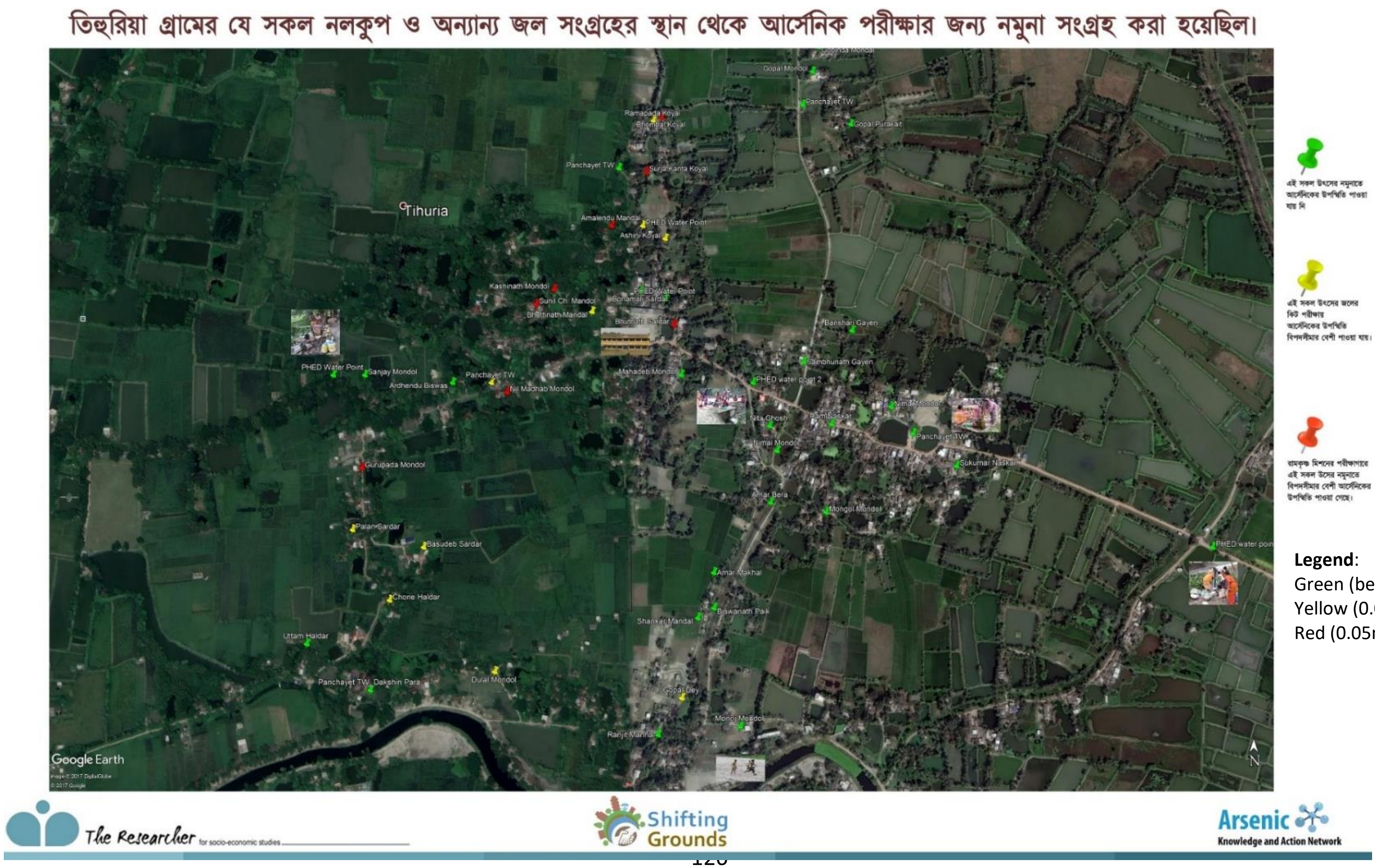
The calculation of groundwater harvesting levels for households, dyeing industries and rea-estate colony in Badai is shown in Table H.2. There are 920 households in Badai, and 10 families residing in the real-estate colony as of now. Assuming a family size of 4, the population for the households and real-estate colony is a 3680 and 40, respectively. The water consumption per person is taken to be the consumption estimate of the PHED department i.e. 70 liters per capita per day (*Interview 13*), assuming that all households extract this much water daily from below the ground without being dependent on the surface water in ponds. There are 25 dyeing industries in Badai – 7 medium and 18 small. One dyeing industry interview for the case study (*Interview 3*) is a medium sized dyeing industry that processes 2 tons of cloth per day and consumes 80000l of water per day while the other is much smaller in comparison that processes 800kgs of cloth per day and uses approximately 8000l of water per day. Based on this information, the daily amount of groundwater extracted is calculated which is further multiplied into 90 days to calculate the extraction per crop season, in order to be compared with the values obtained from the agricultural extraction.

*Table H.2: Calculation of groundwater extraction level for households and dyeing industries in Badai*

| ***Actor*** | ***Number*** *(Land area for farmers, no. of units for others)* | ***Water extracted per unit per day*** *(in Liters)* | ***Total water extracted per day*** *(in Liters)* | ***Total water extracted per crop season*** *(in Liters)* | ***Total water extracted per year*** *(in Liters)* |
|---|---|---|---|---|---|
| Household population | 3680 | 70 | 257,600 | **23,184,000** | **92,736,000** |
| Dyeing Industries | 7 (M) 18 (S) | 80000 (M), 8000 (S) | 704,000 | **63,360,000** | **253,440,000** |
| Real-estate colony population | 40 | 70 | 2,800 | **252,000** | **1,008,000** |

# Appendix I : Groundwater Quality Map of Tihuria

This appendix shows the results of arsenics tests conducted in the Tihuria village as part of the Shifting grounds project (Hermans & Gomes, 2018). Out of 50 samples of drinking water collected in the village, 29 were found to be safe (below 0.01 mg/l), 8 were found to be moderately safe (between 0.01 m/l and 0.05 mg/l), and 13 were found to be unsafe for drinking (above 0.05mg/l).




**Legend**:
Green (below 0.01 mg/l),
Yellow (0.01mg/l to 0.05 mg/l),
Red (0.05mg/l or above)



*Figure I.1: Map indicating results of arsenic tests conducted in Tihuria (Hermans & Gomes, 2018).*

# References


Adams, E. A., & Zulu, L. C. (2015). Participants or customers in water governance? Community-public partnerships for peri-urban water supply. *Geoforum*, *65*, 112–124. https://doi.org/10.1016/j.geoforum.2015.07.017

Adhikari, B., & Lovett, J. C. (2006). Institutions and collective action: Does heterogeneity matter in community-based resource management? *The Journal of Development Studies*, *42*(3), 426–445. https://doi.org/10.1080/00220380600576201

Agrawal, A., & Gibson, C. C. (1999). Enchantment and disenchantment: The role of community in natural resource conservation. *World Development*, *27*(4), 629–649. https://doi.org/10.1016/S0305-750X(98)00161-2

Allen, A. (2003). Environmental planning and management of the peri-urban interface: Perspectives on an emerging field. *Environment and Urbanization*, *15*(1), 135–148. https://doi.org/10.1630/095624703101286402

Allen, A., Dávila, J. D., & Hofmann, P. (2006). The peri-urban water poor: Citizens or consumers? *Environment and Urbanization*, *18*(2), 333–351. https://doi.org/10.1177/0956247806069608

Armitage, D. (2005). Adaptive capacity and community-based natural resource management. *Environmental Management*, *35*(6), 703–715. https://doi.org/10.1007/s00267-004-0076-z

ATLAS.ti. (2018). [Computer software]. Retrieved from https://atlasti.com/product/v8-windows/

Azizi, A., Ghorbani, A., Malekmohammadi, B., & Jafari, H. R. (2017). Government management and overexploitation of groundwater resources: absence of local community initiatives in Ardabil plain-Iran. *Journal of Environmental Planning and Management*, *60*(10), 1785–1808. https://doi.org/10.1080/09640568.2016.1257975

Bailey, S. (2008). Diagram of an automated water well system powered by a submersible pump [Photograph]. Retrieved from https://en.wikipedia.org/wiki/File:Submersible-pump_System.svg

Bal, M. (2015). *Socio Ecological System Framework: Understanding urban lake governance and sustainability in India (Doctoral dissertation)*. Erasmus University of Rotterdam, Rotterdam, Netherlands.

Banerjee, P. (2016). Report on case study selection (Working paper). *South Asia Consortium for Interdisciplinary Water Resources Studies (SaciWATERs)*. Retrieved from http://saciwaters.org/shiftinggrounds/pdfs/Report on case study selection - poulomi.pdf

Banerjee, P., & Jatav, M. (2017). Thematic paper on urbanisation and ground water use: Socio-ecomonic system mapping. Retrieved from http://saciwaters.org/shiftinggrounds/pdfs/Thematic report on urbanisation and ground water use.pdf

Bhatta, B. (2012). *Urban Growth Analysis and Remote Sensing*. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-4698-5

Binder, C. R., Hinkel, J., Bots, P. W. G., & Pahl-Wostl, C. (2013). Comparison of Frameworks for Analyzing Social-ecological Systems. *Ecology and Society*, *18*(4), art26. https://doi.org/10.5751/ES-05551-180426

Blaikie, P. (2006). Is Small Really Beautiful? Community-based Natural Resource Management in Malawi and Botswana. *World Development*, *34*(11), 1942–1957. https://doi.org/10.1016/J.WORLDDEV.2005.11.023

Blanco, E. (2011). A social-ecological approach to voluntary environmental initiatives: the case of nature-based tourism. *Policy Sciences*, *44*(1), 35–52. https://doi.org/10.1007/s11077-010-9121-3

Bots, P. W. G. (2016). Primer on Decision Science. Delft University of Technology.

Bralower, T., & Bice, D. (n.d.). Cone of Depression | EARTH 103: Earth in the Future. Retrieved August 16, 2019, from https://www.e-education.psu.edu/earth103/node/900

Brosius, J. P., Tsing, A. L., & Zerner, C. (1998). Representing communities: Histories and politics of community-based natural resource management. *Society and Natural Resources*. https://doi.org/10.1080/08941929809381069

Bryman, A. (2015). *Social Research Methods (4th Edition)*. *Oxford University Press*. https://doi.org/10.1017/CBO9781107415324.004

Census of India. (2011). Census of India. Retrieved June 29, 2019, from http://censusindia.gov.in/

Central Ground Water Board (CGWB). (2013). *Dynamic Ground Water Resources of India (As on 31 March 2011)*. Retrieved from http://cgwb.gov.in/Documents/Dynamic GWRE-2013.pdf

Chaturvedi, M. C. (2012). *India's waters. Environment, economy, and development*. CRC Press.

Cole, D. H., Epstein, G., & McGinnis, M. D. (2019). The Utility of Combining the IAD and SES Frameworks. *International Journal of the Commons*, *13*(1), 244. https://doi.org/10.18352/ijc.864

Coombs, M. (2011). Lobstering and Common Pool Resource Management in Maine. *Grassroots Economic Organizing (GEO) Newsletter*, *2*. Retrieved from http://hdl.handle.net/10535/7528

Cox, M. (2014). Applying a Social-Ecological System Framework to the Study of the Taos Valley Irrigation System. *Human Ecology*, *42*(2), 311–324. https://doi.org/10.1007/s10745-014-9651-y

Crawford, S. E. S., & Ostrom, E. (1995). A Grammar of Institutions. *American Political Science Review*, *89*(3), 582–600. https://doi.org/10.2307/2082975

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches (3rd ed)*. SAGE Publications. https://doi.org/10.1016/j.math.2010.09.003

Cronin, A. A., Prakash, A., Priya, S., & Coates, S. (2014). Water in India: Situation and prospects. *Water Policy*. https://doi.org/10.2166/wp.2014.132

Cunningham, S., & Hermans, L. (2018). *Actor and Strategy Models*. Hoboken, New Jersey: Wiley. https://doi.org/10.1002/9781119284772

Department of Panchayats and Rural Development, G. of W. B. (2004). *West Bengal Gram Panchayat Administration Rules, 2004*. Retrieved from https://wbxpress.com/wp-content/uploads/2014/03/GP-Administration-Rules-2004.pdf

Enserink, B., Hermans, L., Kwakkel, J., Thissen, W., Koppenjan, J., & Bots, P. (2010). *Policy Analysis of Multi-Actor Systems*. *Lemma*.

Garduño, H., Romani, S., Sengupta, B., Tuinhof, A., & Davis, R. (2011). *India Groundwater Governance Case Study* (World Bank Other Operational Studies). The World Bank. Retrieved from https://econpapers.repec.org/RePEc:wbk:wboper:17242

Gari, S. R., Newton, A., Icely, J. D., & Delgado-Serrano, M. M. (2017). An analysis of the global applicability of Ostrom's design principles to diagnose the functionality of common-pool resource institutions. *Sustainability (Switzerland)*, *9*(7). https://doi.org/10.3390/su9071287

Ghosh, D. (2005). *Ecology and traditional wetland practice : lessons from wastewater utilisation in the East Calcutta Wetlands*. Kolkata: Worldview. Retrieved from https://www.worldcat.org/title/ecology-and-traditional-wetland-practice-lessons-from-wastewater-utilisation-in-the-east-calcutta-wetlands/oclc/70133290

Ghosh, D., & Ray, S. (2007). Modern Agriculture and the Ecologically Handicapped: Fading glory of Boro paddy cultivation in West Bengal. *Economic and Political Weekly*, *42*(26). Retrieved from https://www.epw.in/journal/2007/26/review-agriculture-review-issues-specials/modern-agriculture-and-ecologically

Gomes, S. L. (2014). *Pre-scoping Visit - Field Report, Kolkata*. Delft.

Gomes, S. L. (2017). *Field Report - Peri Urban Problems in Tihuria and Bodai: Institutional Approach*. Delft.

Gomes, S. L. (2019). *An Institutional Approach to Peri-urban Water Problems: Supporting community problem solving in the peri-urban Ganges delta (Unpublished doctoral dissertation)*. Delft University of Technology, Delft, Netherlands.

Gomes, S. L., & Hermans, L. M. (2018). Institutional function and urbanization in Bangladesh: How peri-urban communities respond to changing environments. *Land Use Policy*, *79*, 932–941. https://doi.org/10.1016/J.LANDUSEPOL.2017.09.041

Google. (n.d.-a). [Location of Badai with respect to Kolkata city]. Retrieved August 20, 2019, from https://goo.gl/maps/psod33SvX7yYfxFE6

Google. (n.d.-b). [Location of Tihuria with respect to Kolkata city]. Retrieved August 20, 2019, from https://goo.gl/maps/qLCRHKtQHaYh73GeA

Google. (n.d.-c). [Satellite image of Bodai, West Bengal]. Retrieved June 11, 2019, from https://earth.app.goo.gl/K29ZFC

Google. (n.d.-d). [Satellite image of Tihuria, West Bengal]. Retrieved June 11, 2019, from https://earth.app.goo.gl/3MDVc5

Government of West Bengal. The East Kolkata Wetlands (Conservation and Management) Act (2006). Kolkata: Law Department. Retrieved from http://www.ekwma.in/ek/wp-content/uploads/2015/09/EKWCM-ACT-2006.pdf

Hardin, G. (1968). The Tragedy of the Commons. *Science*, *162*(3859), 1243–1248. https://doi.org/10.1126/science.162.3859.1243

Hermans, L. M., & Gomes, S. L. (2018). *Final Stakeholder Workshop Shifting Grounds Project India*. Retrieved from http://saciwaters.org/shiftinggrounds/pdfs/kolkata workshop report_shifting grounds_final.pdf

Hinkel, J., Bots, P. W. G., & Schlüter, M. (2014). Enhancing the Ostrom social-ecological system framework through formalization. *Ecology and Society*, *19*(3). https://doi.org/10.5751/ES-06475-190351

Iaquinta, D. L., & Drescher, A. W. (2000). Defining the peri-urban: rural-urban linkages and institutional connections. *Land Reform, Land Settlement and Cooperatives*, *2000*(2), 8–26.

India Water Portal Hindi. (n.d.). Arsenic in Ground Water of North 24 Parganas District, West Bengal. Retrieved June 17, 2019, from https://hindi.indiawaterportal.org/node/53084

Jacob, S. A., & Furgerson, S. P. (2012). Writing Interview Protocols and Conducting Interviews : Tips for Students New to the Field of Qualitative Research. *The Qualitative Report*, *17*(42), 1–10. Retrieved from https://nsuworks.nova.edu/tqr/vol17/iss42/3

Johannes, R. E. (2002). The Renaissance of Community-Based Marine Resource Management in Oceania. *Annual Review of Ecology and Systematics*, *33*(1), 317–340. https://doi.org/10.1146/annurev.ecolsys.33.010802.150524

Kulkarni, H., Shah, M., & Vijay Shankar, P. S. (2015). Shaping the contours of groundwater governance in India. *Journal of Hydrology: Regional Studies*, *4*(Part A), 172–192. https://doi.org/10.1016/j.ejrh.2014.11.004

Kulkarni, H., Shankar, P. S. V., & Krishnan, S. (2011). India's Groundwater Challenge and the Way Forward. *Economic and Political Weekly*, *46*(2), 37–45. Retrieved from https://www.epw.in/journal/2011/02/special-articles/indias-groundwater-challenge-and-way-forward.html

Lam, W. F. (1998). *Governing irrigation systems in Nepal : institutions, infrastructure, and collective action*. Oakland Calif.: ICS Press. Retrieved from https://www.worldcat.org/title/governing-irrigation-systems-in-nepal-institutions-infrastructure-and-collective-action/oclc/718106701

McGinnis, M. D. (2011). An Introduction to IAD and the Language of the Ostrom Workshop: A Simple Guide to a Complex Framework. *Policy Studies Journal*, *39*(1), 169–183. https://doi.org/10.1111/j.1541-0072.2010.00401.x

McGinnis, M. D., & Ostrom, E. (2014). Social-ecological system framework: Initial changes and continuing challenges. *Ecology and Society*, *19*(2), art30. https://doi.org/10.5751/ES-06387-190230

McLaughlin, B. (2006). Types of Interviews. University of Idaho. Retrieved from http://www.webpages.uidaho.edu/css506/506_Notes/TYPES OF INTERVIEWS.doc

Mechenich, C., & Shaw, B. (2011). Do Deeper Wells Mean Better Water? *Arizona Cooperative Extension*, (6), 1–6. Retrieved from https://oconto.extension.wisc.edu/files/2014/11/Do-Deeper-Wells-Mean-Better-Water.pdf

Ministry for Drinking Water & Sanitation. (2010). *National Rural Drinking Water Programme (NRDWP): Movements towards ensuring people's Drinking Water Security in Rural India*. *Government of India*. Retrieved from https://www.indiawaterportal.org/sites/indiawaterportal.org/files/National Rural Drinking Water Programme_MoRD_2010.pdf

Ministry of Environment and Forest (MoEF). (2010). The Wetlands (Conservation and Management) Rules. *India Water Portal*. Retrieved from https://www.indiawaterportal.org/sites/indiawaterportal.org/files/Wetlands_Rules_New_Delhi_MoEF_November_2010.pdf

Ministry of Panchayati Raj. (n.d.). *Drinking Water in Gram Panchayats: Active Panchayat Handbook II*. Retrieved from https://jalshakti-ddws.gov.in/sites/default/files/Gram_Panchayat_Report.pdf

Ministry of Water Resources River Development and Ganga Rejuvenation (MoWR). (2016). Model Bill for the Conservation, Protection, Regulation and Management of Groundwater [Policy document]. Retrieved from http://mowr.gov.in/sites/default/files/Model_Bill_Groundwater_May_2016_0.pdf

Mukherjee, J. (2016). The Adi Ganga. *Economic and Political Weekly*, *51*(8). Retrieved from https://www.epw.in/journal/2016/8/reports-states/adi-ganga.html

Nagendra, H., & Ostrom, E. (2014). Applying the social-ecological system framework to the diagnosis of urban lake commons in Bangalore, India. *Ecology and Society*, *19*(2). https://doi.org/10.5751/ES-06582-190267

Narain, V. (2010a). Periurban water security in a context of urbanization and climate change: A review of concepts and relationships (Discussion Paper No. 1; pp. 1-16). Retrieved from saciwaters.org/periurban/idrc periurban report.pdf

Narain, V. (2010b). *Water Security in Peri-urban South Asia Adapting to Climate Change and Urbanization, Scoping Study Report : Gurgaon*. Retrieved from www.saciwaters.org/periurban

Narain, V., & Nischal, S. (2007). The peri-urban interface in Shahpur Khurd and Karnera, India. *Environment and Urbanization*, *19*(1), 261–273. https://doi.org/10.1177/0956247807076905

National Portal of India. (n.d.-a). The Constitution (Seventy-fourth Amendment) Act, 1992. Retrieved August 19, 2019, from https://www.india.gov.in/my-government/constitution-india/amendments/constitution-india-seventy-fourth-amendment-act-1992

National Portal of India. (n.d.-b). The Constitution (Seventy-third Amendment) Act, 1992. Retrieved August 19, 2019, from https://www.india.gov.in/my-government/constitution-india/amendments/constitution-india-seventy-third-amendment-act-1992

North, D. C. (1991). Institutions, Institutional Change, and Economic Performance. *The Journal of Economic Perspective*, *5*(1), 97–112. https://doi.org/10.2307/2234910

NWO. (2014). Shifting Grounds: Institutional transformation, enhancing Knowledge and capacity to manage groundwater security in peri-urban Ganges delta systems. Retrieved January 20, 2019, from https://www.nwo.nl/en/research-and-results/research-projects/i/65/10965.html

Olson, M. (1965). *The logic of collective action : public goods and the theory of groups*. Cambridge Mass.: Harvard University Press. Retrieved from https://www.worldcat.org/title/logic-of-collective-action-public-goods-and-the-theory-of-groups/oclc/255205

Ostrom, E. (1990). *Governing the commons : the evolution of institutions for collective action*. Cambridge University Press.

Ostrom, E. (2000). Reformulating the commons. *Swiss Political Science Review*, *6*(1), 29–52. https://doi.org/10.1002/j.1662-6370.2000.tb00285.x

Ostrom, E. (2005). *Understanding institutional diversity*. Princeton University Press.

Ostrom, E. (2007). A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences*, *104*(39), 15181–15187. https://doi.org/10.1073/pnas.0702288104

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems.

*Science*, *325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Ostrom, E. (2010). Beyond Markets and States: Polycentric Governance of Complex Economic Systems. *The American Economic Review*, *100*(3), 641–672. Retrieved from http://www.jstor.org/stable/27871226

Ostrom, E. (2011). Background on the Institutional Analysis and Development Framework. *Policy Studies Journal*, *39*(1), 7–27. https://doi.org/10.1111/j.1541-0072.2010.00394.x

Ostrom, E., & Ahn, T. (2009). The Meaning of Social Capital and Its Link to Collective Action. In *Handbook of Social Capital: The Troika of Sociology, Political Science and Economics* (pp. 17–35). Northhampton, MA: Edward Elgar. Retrieved from https://ostromworkshop.indiana.edu/library/node/63914

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. (1999). Revisiting the Commons: Local Lessons, Global Challenges. *Science*, *284*(5412), 278–282. https://doi.org/10.1126/science.284.5412.278

Pagdee, A., Kim, Y., & Daugherty, P. J. (2006). What Makes Community Forest Management Successful: A Meta-Study From Community Forests Throughout the World. *Society & Natural Resources*, *19*(1), 33–52. https://doi.org/10.1080/08941920500323260

Pahl-Wostl, C., Holtz, G., Kastens, B., & Knieper, C. (2010). Analyzing complex water governance regimes: The Management and Transition Framework. *Environmental Science and Policy*, *13*(7), 571–581. https://doi.org/10.1016/j.envsci.2010.08.006

Prakash, A. (2014). The periurban water security problem: A case study of Hyderabad in Southern India. *Water Policy*, *16*(3), 454–469. https://doi.org/10.2166/wp.2013.140

Prasad, K. (2008). Institutional Framework for Regulating Use of Ground Water in India, 190. Retrieved from http://cgwb.gov.in/INCGW/Kamta Prasad report.pdf

Quinn, C. H., Huby, M., Kiwasila, H., & Lovett, J. C. (2007). Design principles and common pool resource management: An institutional approach to evaluating community management in semi-arid Tanzania. *Journal of Environmental Management*, *84*(1), 100–113. https://doi.org/10.1016/j.jenvman.2006.05.008

Sahana, M., Hong, H., & Sajjad, H. (2018). Analyzing urban spatial patterns and trend of urban growth using urban sprawl matrix: A study on Kolkata urban agglomeration, India. *Science of the Total Environment*, *628–629*(2018), 1557–1566. https://doi.org/10.1016/j.scitotenv.2018.02.170

Samanta, G. (2014). The Politics of Classification and the Complexity of Governance in Census Towns. *Economic and Political Weekly*, *49*(22), 55–62. Retrieved from https://www.epw.in/system/files/pdf/2014_49/22/The_Politics_of_Classification_and_the_Complexity_of_Governance_in_Census_Towns.pdf

Scholz, R. W., & Binder, C. R. (2003). The Paradigm of Human-Environment Systems. *Working Paper 37. Natural and Social Science Interface*. https://doi.org/10.3929/ethz-a-004520890

Sengupta, P. (2011). An analysis of West Bengal Ground Water Resources (Management, Control and Regulation) Act 2005. Retrieved April 25, 2019, from https://www.indiawaterportal.org/articles/analysis-west-bengal-ground-water-resources-management-control-and-regulation-act-2005

Shaw, A. (2005). Peri-Urban Interface of Indian Cities. Growth, Governance and Local Initiatives The. *Economic and Political Weekly*, *40*(2), 129–136. https://doi.org/10.2307/4416042

Shiao, T., Maddocks, A., Carson, C., & Loizeaux, E. (2015). 3 Maps Explain India ' s Growing Water Risks. *World Resource Institute*, 3–7. Retrieved from https://www.wri.org/blog/2015/02/3-maps-explain-india-s-growing-water-risks

Sudtongkong, C., & Webb, E. L. (2008). Outcomes of state- vs. community-based mangrove management in Southern Thailand. *Ecology and Society*, *13*(2), art 27. https://doi.org/10.5751/ES-02531-130227

SWID. (n.d.-a). DISTRICT NORTH 24 PARGANAS HYDROGEOLOGICAL MAP. Retrieved June 11, 2019, from http://wbwridd.gov.in/swid/mapimages/N 24 PGS.pdf#toolbar=0

SWID. (n.d.-b). State Water Investigation Directorate, Government Of West-Bengal. Retrieved February 20, 2019, from http://wbwridd.gov.in/swid/downloads/WB GW Act & Rules.pdf

The Civil India. (n.d.). Governance & Administration. Retrieved August 16, 2019, from https://www.thecivilindia.com/thecivilindia/pages/governence/country.html

The Ramsar Convention Secretariat. (n.d.). About the Ramsar Convention | Ramsar. Retrieved August 9, 2019, from https://www.ramsar.org/about-the-ramsar-convention

UN. (2014). *World Urbanization Prospects: The 2014 Revision*. *Department of Economic and Social Affairs*. https://doi.org/10.4054/DemRes.2005.12.9

UNESCO. Convention on Wetlands of International Importance especially as Waterfowl Habitat (1994). Paris: Office of International Standards and Legal Affairs. Retrieved from https://www.ramsar.org/sites/default/files/documents/library/scan_certified_e.pdf

Vasquez, G. (2004). *Good Governance and Users' Participation in Public Water Supply Management in Urban and Peri-urban zones from Developing Countries*. Retrieved from https://www.joinforwater.ngo/sites/default/files/library_assets/W_PPP_49_E9_good_governance.pdf?popup=true

Walsh, I., Holton, J. A., Bailyn, L., Fernandez, W., Levina, N., & Glaser, B. (2015). What Grounded Theory Is…A Critically Reflective Conversation Among Scholars. *Organizational Research Methods*. https://doi.org/10.1177/1094428114565028

World Bank. (2010). *Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India,*. Retrieved from www.macrographics.com

WRDD (Water Resource Development Directorate). (n.d.). Official website of WRDD, Government of West Bengal. Retrieved June 14, 2019, from http://wbwridd.gov.in/wrdd/ground_water_minor_irrigation.html#

Yin, R. K. (2011). A (VERY) BRIEF REFRESHER ON THE CASE STUDY METHOD. *Applications of Case Study Research*. https://doi.org/10.1080/07388940701860318