Water and Coastal Management (Double Degree Master of Science)

Master Thesis

Integrating a Network Perspective towards adaptability – The Case of Groundwater Salinization in Lower Saxony

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Master research in partial fulfilment of the requirements of the degrees:

M.Sc. Water and Coastal Management
University of Oldenburg, Germany

M.Sc Environmental and Infrastructure Planning
University of Groningen, The Netherlands

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Oldenburg, January 2018

Abstract

This master thesis explores the contributions of networks to develop institutional adaptability. It is the institutional ability to adjust to and to take advantage of disturbances. This ability is examined within institutions in natural resource governance systems which are dealing with the subject groundwater salinization in north-west Lower Saxony (Germany). For this exploration, this study connects institutional adaptability with learning concepts and generates an institutional analytical framework. The framework accommodates involved networks by institutions which are placed in relation to learning processes to trace learning outcomes stimulating the courses of actions (policies, programs, projects or rules) relevant for institutional adaptability. A qualitative content analysis based on expert interviews revealed the extent of contributions of involved networks. The results showed relevance for planners, decision makers and actors in the field of natural resource governance to recognize networks as a resource to reinforce institutional adaptability for dealing with issues such as groundwater salinization.

Keywords: *Adaptive capacity; networks; water resources; natural resource governance; social-interaction based learning; experienced-based learning; relational practices*

Acknowledgements

First and foremost, I would like to express my gratitude to Dr. Leena Karrasch at the University of Oldenburg for supervising my thesis. The door to her office was always open whenever I ran into a trouble spot or had questions about my research topic. She consistently allowed this thesis to be my own work, but steered me in the right direction whenever she thought I needed it.

I would also like to acknowledge Dr. Elen-Maarja Trell at the University of Groningen as the second reviewer of this thesis. I am grateful she supported me in my studies in Groningen and continued to support me to finalize my master thesis in Oldenburg.

Finally, I must express my very profound gratitude to my parents, my friends and to my partner Steffen Schüle for providing me with unfailing support and continuous encouragement throughout my process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Johanna Godt

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1 Introduction

Today, the thorough and comprehensive results of scientific research indicate that climate change is undoubtedly taking place and results show evidence of human influence (IPPC, 2014). The likely impacts pose threats to all branches and fields of life, especially at the coasts and river deltas. As the sea level is rising and weather patterns are altering on the regional scale, these impacts are causing a change at the hydrological regime, thus, creating a chain of multidimensional stressors to our society (Mitrovica et al., 2001; Mustari et al., 2016; Pannell, 2001a; Seneviratne et al., 2012; Warrick, et al., 1993). Two of climate change impacts are groundwater salinization due to sea level rise and changed weather patterns (IPPC, 2014; Mitrovica et al., 2001).

Considering potential fresh water shortage, this master thesis explores institutional adaptability to adjust and take advantage of disturbances. This ability, known as adaptive capacity, is examined in the thesis within institutions that are involved in the natural resource governance system in north-west Lower Saxony (Germany) and which are engaged with the subject groundwater salinization. *"Natural resource governance refers to the norms, institutions and processes that determine how power and responsibilities over natural resources are exercised, how decisions are taken and how citizens – women, men, indigenous peoples and local communities – participate in and benefit from the management of natural resources"* (IUCN, 2016, p 1).

The following work sets its main research focus on exploring the role of networks regarding their effects on intuitions to attain an adaptive capacity (institutional adaptability) in natural resource governance systems. To underpin this perspective, the present research approach connects institutional adaptability with learning concepts and generates an institutional analytical framework. The framework accommodates involved networks by institutions[1] which are placed in relation to learning processes to trace learning outcomes referred as actions (policies, programs, projects or rules) relevant for institutional adaptability.

[1] The term "institution" refers to a regulating body, which can be formal, such as laws or informal like norms and rules that govern or determine the behaviour of actors (North, 1990). Institutions are not organisations in form of physical structures. However, organisations can codify a regulatory frameworks and can determine the nature of processes of development, codification, communication and enforcement (Pahl-Wostl, 2009).

For that approach, a synthesis of three analytical frameworks has been employed. One is the Institutional Development Analysis (IAD) framework (Ostrom, 2011). The Institutional Development Analysis framework helps to *"identify components and relationships among these components that are considered important"* for outlining institutional adaptive measures (Ostrom, 1992, p. 13). Another is the driver-pressure-state-impact-response (DPSIR) framework which emphasizes the aspects of socio-economic and environmental components relevant for institutions to allocate adaptive measures in the field of natural resources. The third component of the synthesized framework consists of the social learning framework for interdependence on natural resources (Bouwen & Taillieu, 2004). It highlights the inteconnection between learning notions, contextual components and adaptive measures through the facilitation of relational practices which are established through social interaction. Those interactions are in this thesis referred to networks.

The role and effects of networks to achieve institutional adaptability have been then explored and analyzed by a qualitative research approach. By utilizing expert interviews in the field of natural resource governance and a qualitative content analysis, the effects of networks have been traced on actor level of their respective institution and, thus, implications on institutional level and on natural resource governance level have been made.

The results aim to support the development of recommendations relevant for planners, decision makers and actors in the field of natural resource governance to obtain new resources embodying a potential to reinforce institutional adaptability for dealing with issues such as groundwater salinization.

2 Problem statement

In 2002 it has been estimated that 23% of the world's population lives within 100 kilometers of the coast (Small & Nicholls, 2003). Within the EU, 41% of the population is living less than 50 kilometers from the sea (Eurostat, 2010). It is also expected that 75% of the world's population will be living within 60 kilometers of the shoreline by 2020 (Povh, 2000). Considering that population density and economic activity in the coastal zone increases, pressures on coastal ecosystems increase (IPCC, 2014). In this connection, the risk of freshwater shortage is increasing regarding the densely populated coastal areas with growing demand of fresh water (IPCC, 2014). Risk is the "combination of the probability of an event and its negative consequences" (UNISDR,

2009, p. 25). Moreover, climate change impacts further add the probability of groundwater shortage as several climate change impacts can be accounted to be a source that trigger groundwater salinization, especially in coastal areas.

Global sea-level rise is expected because of melting ice near the Earth's poles which increases the amount of water in the sea and thermal expansion of water due to heating (Mitrovica et al., 2001; Seneviratne et al., 2012; Warrick et al., 1993). Both effects are driven by rising atmospheric temperatures (IPCC, 2014). As a result of the general rise in the sea-level, saline seawater moves into inland freshwater aquifers on a large scale causing saltwater intrusion (LBEG, 2017). S**altwater intrusion** refers to the movement of saline water into freshwater aquifers which can lead to contamination of freshwater sources (figure 1).

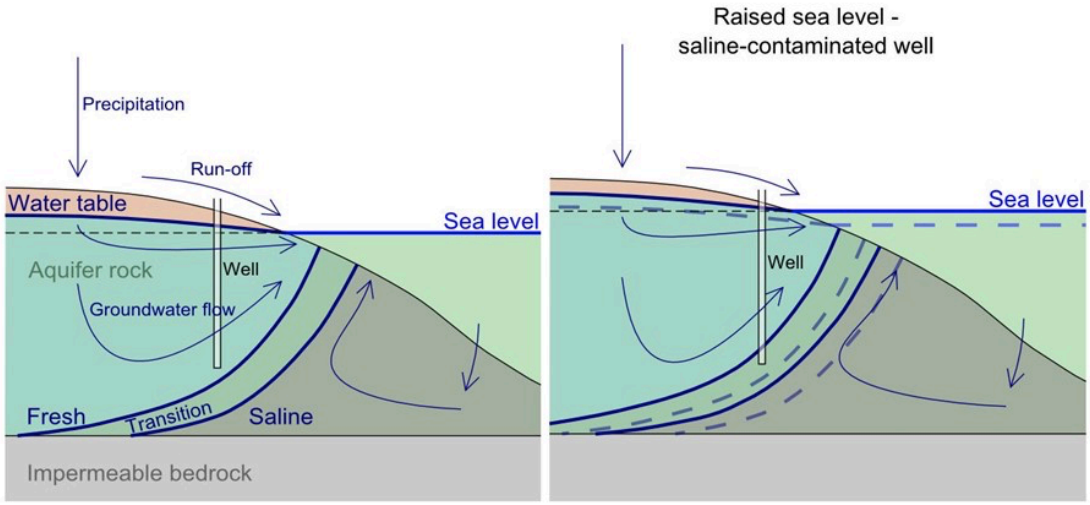


Figure 1: Salt water intrusion edges ahead following sea level rise (Barry, 2016)

Their different densities separate saline and fresh water. Fresh water is less dense than saline water, so it lies above the saline water. In coastal areas, it is natural that saline seawater and fresh water meet and mix through dispersion and diffusion in a transition zone containing brackish water (freshwater-seawater interface). This zone continues underground (figure 1) as saltwater can push inland beneath freshwater. Due to sea level rise, the transition zone shifts towards inland enabling saltwater intrusion. The extent of the saltwater intrusion is considered dynamic as it depends on different factors. One factor accounts for subsurface conditions (Kooi et al. 2000). Some layers contain fine sand which gives more resistance to water than other grainy, more permeable sand. Another factor accounts for the extent of the sea-level rise (Green et al., 2011). Depending on how these factors interact, the subterranean brackish water zone can expand farther inland than seawater at the surface of the coast.

The saltwater intrusion process is also triggered through estuaries and waterways connected to the sea, since they act as channels for tidal currents carrying saline water which shift farther inland under the influence of the sea level rise (Yang et. al., 2015). Hence, adjacent aquifers may become threatened by saltwater intrusion by the sea far more inland than via direct seawater intrusion. Saltwater intrusion can also happen at an event of flooding as it can cause a recharge of saline water of adjacent aquifers.

In developing countries the loss of groundwater resources has serious impacts determining their livelihood (Mustari & Zehadul Karim, 2016). While industrialized countries face other challenges, such as economic impacts. Removing salt can be relatively expensive since desalination (e.g. through distillation or membrane processes) is costly and energy consuming (Pannell, 2001a). For many coastal regions, this would be fatal, since they are largely dependent on groundwater for their drinking water supply, especially with regards to the rising demands on fresh water supply at coastal areas. Also in this regard, human induced behavior further triggers salinization process: If more water is withdrawn from aquifers than recharged by rain, the geostatic pressure decreases and triggers upconing effects of saline groundwater that is lying beneath fresh groundwater wells (Essink, 2001). Saline water can completely mix with fresh groundwater in an extreme case (figure 2). In this connection, the amount of withdrawing fresh water is further dependent to changing weather patterns impacting groundwater recharge (IPCC, 2014).

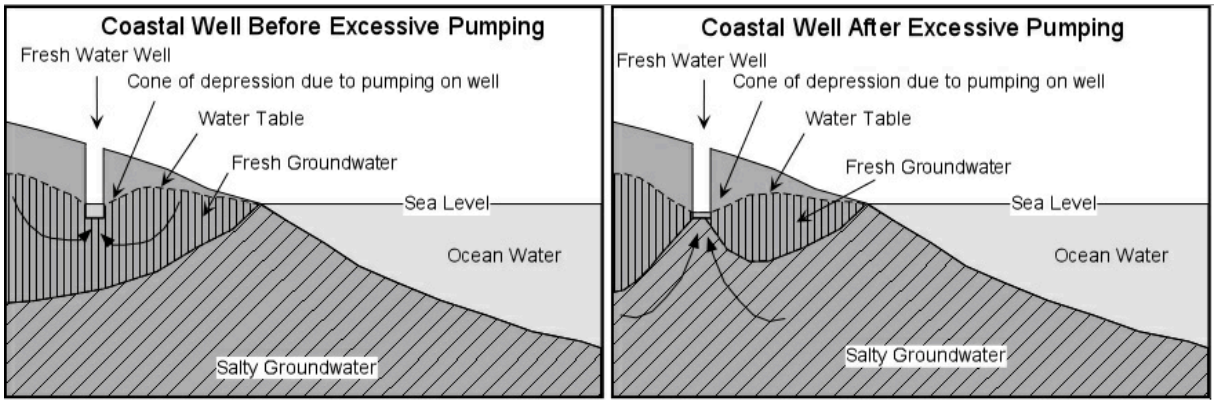


Figure 2 Salt water intrusion by human influenced endeavour through excessive withdrawing of water in freshwater aquifers near coastal areas (Earth Science Australia, n.d.)

In any case, the process of salt water intrusion is an extremely slow process due to sub-surface properties and unfolds a delay effect in which the time phase between the physical event and the damage is not immediate (Pannell, 2001b). Delay effects are considered as creeping disasters, as its effects are not felt at once (see also Diamond, 2005; Giddens, 2009; Schneider et al., 2013). Unlike earthquakes, hurricanes and other

rapid-moving weather, salinization processes are slow relative to time scales. As a result, the relative slow process does not raise immediate attention or awareness to the broad public to call for immediate action (Pannell, 2001b). Henceforward, inaction might ultimately lead to issues regarding wide-ranging losses of fresh water supply. Creeping impacts such as salinization pose a long-term encounter that governance systems and environmental planning need to tackle yet in the present. Whereas governance systems have been addressing major global environmental change problems, the deficiency of sufficient and effective responses to bring long term problems into the core of formal institutions to initiate addressing actions is still present (Brousseau, Dedeurwaerdere & Siebenhüner, 2012; Hovi, Sprinz, & Underdal, 2009; Sprinz, 2009).

In North Germany freshwater sources are already at risk of saltwater intrusion. Parts of the groundwater can not be used as drinking water already (LBEG, 2015). To maintain the essential resource, water supply needs to be prepared for the challenges that climate change and other factors bring. There can be no universal pattern of action, instead, regional conditions should be considered and regional adaptation concepts developed. Technology, institutions, economics and socio-psychological factors are all elements affecting the ability of nations to build capacity and implement adaptation measures (Nederveen et al., 2003).

So far, salinization management and scholars largely focus on technical measures to respond, while socio-economic aspects are seen as subordinate (Guo et al., 2013; Javadi et al., 2015; Saidi et al. 2013; Singh, 2015). The problem unfolds as the sole focus on technical solutions implies the assumption of rational and centralized decision-making. This approach, however, neglect regional settings, various interests and other determining factors in these processes as well as non-formal institutions or habits (Budds, 2009). There is a lack of analyses of the relevant factors, such as stakeholder interests and governance approaches initiating actions to encounter salinization processes (Landauer et al., 2014; Mitchell et al., 2012). Moreover, relying solely on optimization techniques to develop policies based on the projections of a single model will produce static policies (Bankes, 2002). Adaptive management, however, yields on flexibility with regards to uncertainty (Parry et al., 2007).

3 Objective of the thesis

The emphasized **hypothesis** of this thesis draws upon the assumption that networks function as a carrier to complement the capacity building of institutions in the field of natural resource governance to facilitate adaptive measures. The **underlying working hypothesis** is that networks embody the potential to call attention to problems and deliver new perspectives relevant for organisations. Hence, the following work sets its main research **objective** on exploring the role of networks with regard to their effects to achieve institutional adaptability in natural resource governance systems. For that objective the central **research question** of the thesis is as follows:

How are networks in natural resource governance systems linked to actions and what kind of networks play a role as a source for building adaptive capacity? Answering these questions follows the objective of the work for the development of recommendations for planners to make existing institutions and networks reinforce each other in order to build capacities to tackle the issue of salinization, as a long-term governance challenge and feature of a creeping disaster.

The **context** of the approach by this thesis reflects on the "Nerves of Government Analogy" introduced by Deutsch (Deutsch, 1963). Society acts like in a nervous system that is backing up communication and decision making. After Deutsch, a government process is about communication expressed by a collection of feedback processes leading towards political control. In that line, the task of control is a form of consciousness in which various parts of a society are integrated in feedback processes (Deutsch, 1963). Control is based on an ensemble of collective behaviour that form a consciousness which is a result of an ensemble of dialogues and, thus, learning processes, where observations and perceptions are communicated between the components. Hence, the underlying ensemble of self-regulating mechanism functions like a nervous system. Reflecting on this analogy by Deutsch, feedback processes can result to the contribution of problem solving and adaptation.

While several conceptual implications to knowledge transfers have been made (see e.g. (Healey, 1998; Mizruchi et al. 2006; Nooteboom, 2006; Powell et al., 2016; Strang & Meyer, 1993) research on intellectual knowledge transfer between networks and institutions is lacking (Owen-Smith & Powell, 2008). It is, however, not the intention of the thesis to review existing points of contact between theories of institutional theory or network theory which is already done by Owen-Smith & Powell (2008). This thesis sets

its focus exclusively on the variables of network structure and, more specifically, on particular aspects of network structure and outcomes in terms of adaptability.

4 Scientific concepts

To provide a theoretical background for the empirical exploration of the role of networks with regard to their effects to achieve institutional adaptability in natural resource governance systems, the following chapter reviews associated scientific concepts related to the research field. In the first section, theoretical concepts of adaptation including key concepts of institutional adaptive capacities have been reviewed. In the light of these reviews the subsequent theoretical sections focus on theoretical learning concepts and network theory. These existing analytical frameworks have been depicted to provide a basis for research approach, presented in chapter 5.

4.1 Theoretical concepts of adaptation

4.1.1 Adaptation in the field of natural resource governance

Since natural resources are affected by various and changing social and ecological factors (Kinzing et al., 2000), such as in the case of groundwater salinization, one of the challenges comes from the fact that natural resource governance systems must relate and adjust to a complex and ever-changing environment. The term governance describes *"the patterns that emerge from the governing activities of social, political and administrative actors"* (Kooiman, 1993, p. 2). Thus, it "*embraces governmental institutions, but also subsumes informal, non-governmental mechanisms*" (Rosenau, 1992, p. 4) covering the *"whole range of institutions and relationships involved in the process of governing"* (Pierre & Peters, 2000, p. 1).

The effectiveness of natural resource governance critically determines the extent to which ecosystems contribute to human well-being (IUCN, 2016). This is especially relevant in the field of water management which comprises fields of governmental and non-governmental jurisdictions, such as agriculture, recreation, ecology, environmental affairs and urban and regional planning (Edelenbos & Teisman, 2013; Lubell & Lippert, 2011). Actions or events in one of these fields pose repercussions through the system in unforeseen forms which are adding up to unpredictable and unintended outcomes (Wagenaar, 2007). This features the contemplation that changes in ecological systems are depended on the extent, intensity and type of human activity (Kinzing et al., 2000). Due to anthropogenic caused effects on saltwater intrusion, it becomes important that

the whole range of institutions in field of natural resource governance system gets well equipped to meet urgent but also unforeseen challenges. To address this desirable quality the concept of adaptive management is used (Folke et al. 2002; Olson et al., 2004).

4.1.2 Adaptive Management

The **objective** of adaptive management *"is to maximise social well-being (which incorporates environmental and economic well-being) for a given set of climatic conditions. Such well-being has to be maximized over a span of this and succeeding generations. To achieve this, society has to take advantage of any positive impacts resulting from climate change, while also reducing negative impacts. Thus, another adaptation objective would be to place society in a position to respond rapidly and efficiently to the impacts of climate change*" (Pentland et al., 1990, p. 173).

Adaptation is therefore understood to be achieved through purposefully adaptation planning; "*replacing the reactive adaptation often seen in response to an extreme"* event (Sayers et al. 2013, p. 21). Hence, adaptive measures must integrate social, economic and environmental objectives in a way that is continually modified and flexible to unplanned events reflecting a process-oriented conceptualization of adaptation (Gunderson, 1999). To achieve adaptation, the whole range of institutions in natural resource governance system need to advance on adaptive capacities.

Adaptive capacity is here institutional ability to adjust and take advantage of disturbances (Pahl-Wostl 2009). Implementing adaptation measures presuppose integrated systems understanding of the interdependencies between technologies, social, ecologic and economic factors and formal and informal institutions (Pahl-Wostl et al. 2007; Pahl-Wostl et al. 2005).

Adaptive measures refer to actions embodying policies, rules[2], projects or programs. Adaptive measures require an increasing ability of a management system to learn about a problem's context and is able to change its context through institutional changes, such as new rules, policies, programs and decision-making procedures (Lebel et al., 2010; Pahl-Wostl et al., 2005). In this connection, the term adaptive management refers to natural resource governance system to fulfil a societal function such as water supply to advance adaptive capacities, thus, to enable adaptive measures.

[2] Rules are referred to institutions and indicate established and prevalent social rules that structure social interaction such as language, money, law, systems of weights and measures, table manners and firms (adapted from Hayden, 2006, p. 2).

Hence, **adaptive management** is defined as a process of *"ongoing adjustment in natural, engineered or human systems in response to actual or changing expectations in climate or other drivers of risk"* (Sayers et al. 2013, p. 21). Hereafter, institutions within the natural resource governance system need to strive towards an adaptive capacity.

4.1.2 Key concepts of adaptive capacity

With emphasis on the process-oriented conceptualization of adaptation, the following key concepts are denoted to be inherently determining for the adaptive capacity of governance and are, thus, recognized to be relevant for adaptive management.

The **concept of learning** is central to adaptive management (see e.g. Folke et al., 2005b; Lebel et al., 2010; Margaret, 2015; Olsson, et al., 2006; Pahl-Wostl et al., 2007; Van Bommel, et al., 2009). In this connection, scholars refer to the process of learning, indicating that learning from experience and modifying subsequent behavior in light of that experience enables to better cope with and adapt to pressure and change of these interlinked human and natural systems (Fernandez-Gimenez et al., 2008; Huitema et al., 2009; Pahl-Wostl et al., 2007; Voß & Bornemann, 2011). In this context, adaptive management is understood as a learning based process to improve knowledge and to understand the complex changing social and ecological system. Hence, institutionalizing a learning capacity may support the adaptive capacity (Pahl-Wostl et al. 2007).

Adaptive management also strives on the acknowledgement of the **concept of uncertainty**, because social and ecological systems are extremely complex and evolve through time. Thus, knowledge of those systems is not always complete (Walters & Holling, 1990). Hence, uncertainty represents a task that is approached by increasing knowledge from various sources. Uncertainty can also be reduced by increasing data collection and public participation (Lee, 1993). Further, suggestions have been made that adaptive governance systems need to involve heterogeneous actors and cross-scale interactions (see e.g. Cash et al., 2006; Fabricius et al., 2007; Folke et al., 2002; Olsson et al., 2004). Actors are here referred to individuals or groups of individuals. On the one hand, these perspectives follow the insight that communication processes between actors reduce uncertainty. As a result, planned adaptive measures become more predictable (Albrecht, 1984; Berger, 1987; Farace et al., 1978; Gunderson et al., 1995; Miller & Steinberg, 1975). Correspondingly, learning comprises uncertainty as learning processes evolve in negotiations processes for agreements despite different perspectives

(Pahl-Wostl et al., 2005). On the other hand, a diversity of perspectives result into a diversity of means available to address a challenge (Pahl-Wostl et al., 2007). This underpins the consideration that a single method could constrain adaptiveness over the longer term with regard to uncertainty of an approach (Pahl-Wostl et al., 2007). Uncertainty unfolds no ideal path to adaptiveness (Pahl-Wostl et al., 2007). Hence, choosing the most appropriate adaptive measure may depend on how well it satisfies certain criteria at a certain stage of development (Pahl-Wostl et al., 2007).

Successful adaptive measures need to be flexible and thus changeable themselves (Difrancesco & Tullos, 2014). Consequently, the **concept of integrated system's understanding** is essential for adaptive management**.** Adaptive measures must be repetitively reviewed and modified in line with what is known about the socioecological environment (Walker et al., 2004). Although scientists have frequently examined social systems and ecological systems separately, the way in which social and economic systems evolve depend on the ecological conditions of a region (Kinzig et al., 2000; Walker et al., 2004). Changes in ecological systems are depended on the extent, intensity and type of human activity (Kinzig et al., 2000). On the one hand this needs the involvement of heterogeneous actors and cross-scale interactions to interconnect implications of planned adaptive measures (see for e.g. Cash et al., 2006; Fabricius et al., 2007; Folke et al., 2002; Olsson et al., 2004). On the other hand, the extent of a governance system providing flexible adaptive measures deems on the system's capacity to be flexible. This means the governance system needs to be able to change its system's context through institutional changes by developing new policies, programs and decision-making procedures (Lebel et al., 2010; Pahl-Wostl et al., 2005).

Subsequently the **concept of change** is here considered as an outcome, but also as a continuing process of adaptation to keep pace with induced environmental and societal changes. Change as transformation describes actions for change that lay beyond limits of incremental adaptation (Dow et al. 2013). Change is either "*forced by systems failure or chosen in anticipation of collapse and movement to a novel social-ecological systems state*" (Pelling et al. 2014, p. 2). For instance, instruments of policy-making are insufficient to meet the requirements of an increasingly interdependent world in a timely and efficient manner. Therefore, a shift is taking place and the old national and centralized command-and-control approach is been substituted by new forms of governance (see for e.g. Duit & Galaz, 2008; Streck, 2012).

Today, the understanding of governance as a formal, legalistic process dominated by the public sector changed to a new conception that emphasizes a less formal, more collaborative and integrated approach (Streck, 2012). The idea of governance *"challenges the hierarchical, state-centric approach of […] politics, as it reflects an increasingly complex, multi-layered policy"* (Streck, 2012, p. 7). Folke et al. (2005) suggests that successful social transformations[3] involving adaptive capacity are often preceded by the **emergence of informal social networks**. To conclude networks and learning capacity may develop changes, comprise uncertainty and enable systems understanding and, therefore, advance adaptive capacity.

4.1.3 Institutional capacity

Advancing on the adaptive capacity in natural resource governance systems presuppose that associated institutions are the transferring factors. Consequently, the institutional capacity[4] plays a significant role for that process of advancing on the adaptive capacity to evolve.

Institutional capacity is *"the combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals. Capacity may include infrastructure and physical means, institutions, societal coping abilities, as well as human knowledge, skills and collective attributes such as social relationships, leadership and management"* (UNISDR, 2009, p. 5). Translated into competences, institutional capacity is a combination of social, intellectual and political capital (Innes & Booher, 2003; Innes et al., 1994) that could be activated in relationships between actors.

Social capital is regarded as the understanding of each other's perspective and the existence of significant trust (Innes et al. 1994). Given this condition, Innes and Booher (2004) further argue that if social capital grows and spreads into interlocking networks members become more knowledgeable, competent and believing in their self-efficacy to make a difference which can be attributed to ***intellectual capital***. Also Nahapiet and Ghoshal (1998) reveal that social capital facilitates the creation of new intellectual capital and that organisations, as institutional settings, are conducive to the development of social capital. Further, the processes of collaboration and its relational practices are

[3] Transformation describes actions for change that lay beyond limits of incremental adaptation (Dow et al. 2013).

[4] Broadly taken, capacity can be defined "as the ability to perform tasks and produce outputs, to define and solve problems and make informed choices" (European Commission, 2005, p. 6).

related to learning aspects (Innes et al. (2002). This composition, in turn, creates also new forms of power as members *"develop shared heuristics"* and information flows through the network (Innes et al., 2004, p. 429). The consequence is seen as a form of ***political capital*** relevant for decision making. Reflecting on such capital is useful to explore the dynamics of an institutional situation and how adaptability might be achieved. Moreover, it draws attention to the range of capital that may be activated through networks.

4.2 Learning concepts

In light of interaction and change relevant for adaptation, the aspect of learning receives recognition in the fields of risk management research (see Ahrens & Rudolph, 2006; Komac et al., 2010; Pelling, O'Brien, & Matyas, 2014;), in adaptive governance research (see e.g. Huitema et al., 2009; Pahl-Wostl, 2009; Pahl-Wostl et al., 2007) and participatory governance regimes (e.g. Wildemeersch, Jansen, Vandenabeele, & Jans, 1998). Learnig is recognized as an influential factor for outcomes and changes on various elements for and of governance. Learning involves accumulating information and insights. It is therefore a creative process, where information is transformed into new insights (Komac et al., 2010). New insights are regarded to be crucial to ensure adaptiveness, because they enable actors to feedback on current policies and strategies which can help to revise existing or create new strategies (Pahl-Wostl, 2008).

In order to assess learning types, scale and scope relevant for change in the frame of adaptiveness different concepts exist. Following the approach of Halbe (2016) learning concepts are related to 1) learning outcomes 2) learning processes and 3) learning contexts defined as units, where learning takes place. This review seeks to provide an analytical background to trace factors that enabled systems understanding. Based on that, influential factors on applied adaptation measures can be reflected. Therefore, reviewed learning concepts are used in chapter 5 for an analytical framework on which the empirical analysis can be reflected.

4.2.1 Learning outcomes

"The outcomes of learning can include changes to every-day practices, behaviours and values as well as institutional changes, such as new policies, programs, rules and decision-making procedures" (Lebel et al., 2010, p. 334). Reflecting on changes, learning outcomes are associated along several stages of learning intensity (Argyris & Schön, 1978; Keen et al., 2005; Keen & Mahanty, 2006; Claudia Pahl-Wostl, 2009).

The first stage is about learning about the consequences of specific actions such as adjustments made in response to errors without questioning the underlying assumptions (single-loop learning). The second stage refers to learning about the assumptions and values underlying actions indicating a reframing of a problem (double-loop learning). The last stage is about learning that involves fundamental or paradigm changes by challenging the values and norms that underline assumptions and actions (triple-loop learning) (table 1). Learning intensities appear to facilitate the adaptive potential of an organisation (Argyris, 1996). Therefore, intense learning processes can serve as an objective to be addressed by adaptive management approaches.

Learning Intensity	**Learning outcomes**
Single-loop Routine learning	Error detection "*permits the organization to carry on its present policies or to achieve its present objectives*" (Argyris & Schön, 1978, p. 2). It refers to iterative improvement of strategies (Argyris and Schön, 1978) and actions (Sabatier, 1988) within existing mental models (Sterman, 2000). Single-loop learning addresses the question whether people do things right (Romme & Witteloostuijn, 1999).
Double-loop Reframing	An "*error is detected and corrected in ways that involve the modification of an organization's underlying norms, policies and objectives*" (Argyris and Schön, 1978, p. 3). Double-loop learning indicates changes in the organization's knowledge and competency base by reframing problems. This leads to developing new policies, objectives or mental maps (Snell & Chak, 1998). Double-loop learning addresses the question whether people do the right things (Romme & Witteloostuijn, 1999).
Third-loop Paradigm change	Reconsideration and revision of values and beliefs (Flood & Romm, 1996). Triple loop learning links single- and double-loop learning. It is addressing the question "*whether people really have the opportunity and competence to participate in making well-informed choices in the process of discussing and managing issues that concern them"* (Romme & Witteloostuijn, 1999, p. 452).

Table 1: Learning intensities with primary learning objects (adapted from Halbe, 2016)

4.2.2 Learning processes

Learning processes describe mechanism or factors that explain how the object of learning can be altered (Halbe, 2016). From this perspective, learning is conceived as processes and not in terms of outcomes (Kolb, 1984). The learning process is mainly understood as a form of transaction between the person and the environment describing a communicative action or activity involving two parties or things that reciprocally influence each other (see e.g. Halbe, 2016; Kolb, 1984; Wenger, 1998, 2000).

In this line, adaptive management is understood by definition as a learning process to improve knowledge and understanding of the complex changing social and ecological system.

Halbe (2016) and differentiates two groups of learning processes:

i) learning based upon experience and experimentation through interactions with the actual (problem) situation/environment and
ii) learning based on social interactions as learning about the behavior, values, goals and beliefs of others.

4.2.2.1 The experience-based learning concept

Halbe frames under this concept the experiential learning concept which involves a process of concrete experience, reflective observation, abstract conceptualization and active experimentation (Halbe, 2016). After Kolb (1984, p. 41) experience-based learning is a "*process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience*". Learning from experience and modifying subsequent behavior is regarded as an enabling factor to cope with and adapt to pressure and change of interlinked human and natural systems (Fernandez-Gimenez et al. 2008; Huitema et al., 2009; Claudia Pahl-Wostl et al., 2007; Voß & Bornemann, 2011).

4.2.2.2 The social-interaction based learning concept

Halbe (2016) associates learning based on social interactions with a social learning concept. After Bandura, social learning theory emphasizes the importance of observing and modeling the behaviors, attitudes and emotional reactions of others (1977). The theory does not only consider behavioral processes based on observation, it also includes mediational processes based on modelling. Here, mental factors or events mediate the learning processes as information are processed within a cognitive approach. Hence, social learning is a process in terms of continuous reciprocal interaction between cognitive, behavioral and environmental influences (Bandura, 1977). Also, learning through interactions in a cluster or group setting embed a certain biophysical and sociocultural context. Therefore, the context influences the nature of social learning processes (Pahl-Wostl, 2006). The unit which takes up the learning processes is therefore bound on its context. So, interaction patterns can reflect learning outcomes.

4.2.3 Learning environments in social units

Environments of learning are here referred to social units that primarily take a learning process to addresses an issue. Each unit is understood to take up experience based and social-interaction based learning processes within and outside their respective unit (figure 3, p. 20). Halbe (2016) differentiates four learning units: the individual, group, organizational and network learning units.

Within the **individual learning unit**, an individual (e.g. a policy maker, scientist or any actor) takes action to tackle a problem (Halbe, 2016, p. 9). The individual, however, can also belong to a social group (e.g. member of a community), but acts on her/his own behalf. The learning process can base upon social interactions and/or experiential learning (see also section 4.2.2 Learning Processes). In the **group learning unit,** a group takes collective action to address a problem. For instance, if a group tackles a problem in a collaborative way, learning processes take place within two learning units: group members within the group and the group within its environment (Halbe, 2016). The **organizational learning unit** consist of individuals or groups that act as representatives of the organization or a sub-division to accomplish a certain task or problem. The **network learning unit** embodies an interaction composition of the individual, group and organizational learning units (Provan et al., 2007). The network unit is therefore the connection of these units. The connection enables a social-interaction based learning, where each connected unit takes up their own experience-based learning process. The roles of social units in which learning processes take place are here recognized as target units for achieving adaptive management objectives to increase adaptive capacities within institutions.

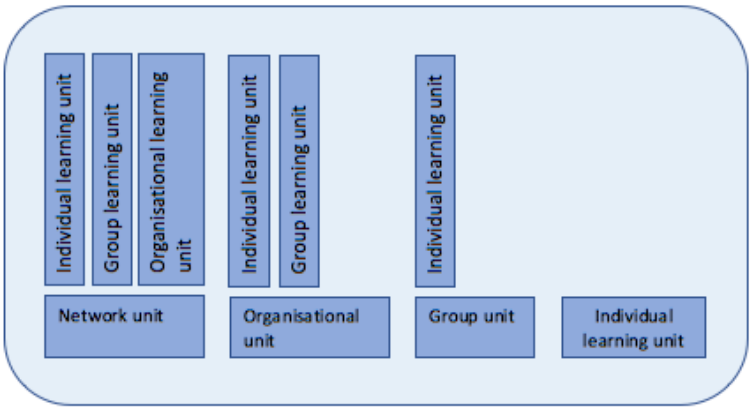


Figure 3: Learning environments in social units (own compilation)

4.3 Theoretical aspects of networks

The composition of a network can influence learning processes, thus, impacting each involved unit (Ahuja, 2000; Bell, 2005; Powell, Koput, & Smith-Doerr, 1996; G. Walker, Kogut, & Shan, 1997). To trace intellectual effects of networks along its connected actors (i.e. learning units), the composition of the network regarding its structural characteristics is the focus of this chapter. Therefore, the following section describes networks in its key meaning, characteristics and functions to provide a conception where to locate networks in the map of governance regimes.

4.3.1 Defining networks

From a science-policy point of view, the term "network" is understood as clusters of different kinds of actors who are linked together in political, social or economic life. *"Networks may be loosely structured but still capable of spreading information or engaging in collective action"* (Peterson, 2003, p. 1). Organizational scholars use the term networks to highlight linkages in form of partnerships, strategic alliances, interorganisational relationships, coalitions, cooperative arrangements, or collaborative agreements (Provan, et al. 2007).

Brass et al. (2004, p. 795) define networks as *"a set of nodes and the set of ties representing some relationship, or lack of relationship, between the nodes"*. They further note, that the substance of the relationships (ties) between nodes is *"limited only by a researcher's imagination"* (Brass et al., 2004, p. 795). Hence, for the effort of this research, networks are understood as complex sets of social relations which are subsequently formally or informally bounded by counting only those organisations, actors and individuals embodying resources such as knowledge, physical resources and capacities, that connect with another to exchange information or other resources on a shared issue.

4.3.2 Network characteristics

By communicating with each other, actors form a network that consists of links that connect them. These connections within the network can be strongly or weakly linked. Strong ties (i.e. strong connections) within a network indicate relationships which share more close, supportive and durable ties and, thus, form a solid basis for trust. They are characterized by high frequency of contact. Weak ties are between actors who do not have much in common, including other contacts and the information they have access to tend to be different (Kazi et al. 2007; Shi et al. 2007). In contrast to strong ties, weak ties may provide access to a large variety of resources, rather than homogenous

resources (see also "strength of weak ties" by Granovetter, 1973). Therefore, network actors (nodes) can be connected (tied) to various types of resources such as information, services, materials, resources and social support (Provan et al., 2007).

These links can be either informal and established based on trust or these links can be formal by contract (table 2, p. 22-23). Formal networks are typically vertical, follow rigid chain of command and relies on leaders that manage the interaction (Hillier, 2000). Informal networks are less rigid and allow its members to move in any direction, skip authorities and are more socially structured and ad hoc, mobilizing various actors based on their perceived needs. However, actors may formally and informally backup and rely on multiple individual ties in selecting interaction based on a common theme (Hillier, 2000).

An actor's multiple ties to a given issue can embody for example throughout a squash partner, who is a lawyer, a relative, who is a planning among the formal networks with others through business and/or political contact. Bounding a network can be thus regarded as clear, when they are formally established or fuzzy as when the membership is self-defined.

Network	**Description of the network configurations**	
Frame	**Formal networks** are typically vertical, follow rigid chain of command and rely on leaders that manage the interaction (Hillier, 2000).	**Informal networks** are less rigid and allows its members to move in any direction, skip authorities and are more socially structured and ad hoc, mobilizing various actors based on their perceived needs (Hillier, 2000).
Relationship between actors	**Strong ties** Connections are characterized by high frequency of contact, trust, durability, access to information are similar as they have common contacts; access to homogenous resources (Kazi et al. 2007; Shi et al. 2007).	**Weak ties** Connections are characterized by low frequency of contact; actors between those connections do not have much in common regarding access to information or contacts; access to a variety of resources (Kazi et al. 2007; Shi et al. 2007).
Aggregation of connections	**Closed networks** are formed by strong ties; they are considered to enhance collaboration and to facilitate the creation of a common priority process for the creation of rules; they are recognized to increase the capacity of networks to create, support and maintain rules (Sandström & Rova, 2010)	**Heterogenic Networks** show structures with bridging connections to otherwise weakly connected actors, or sets of actors; involves a rich diversity of actors, representing various sectors of society which also can include many bridging ties; those structures mobilize diversified resources (Argote et al., 2003; Carlsson & Sandström, 2008; Granovetter, 1973; Reagans & Zuckerman, 2001).

Table 2: Network characteristics (own compilation)

4.3.3 Relationship between network performances and network characteristics

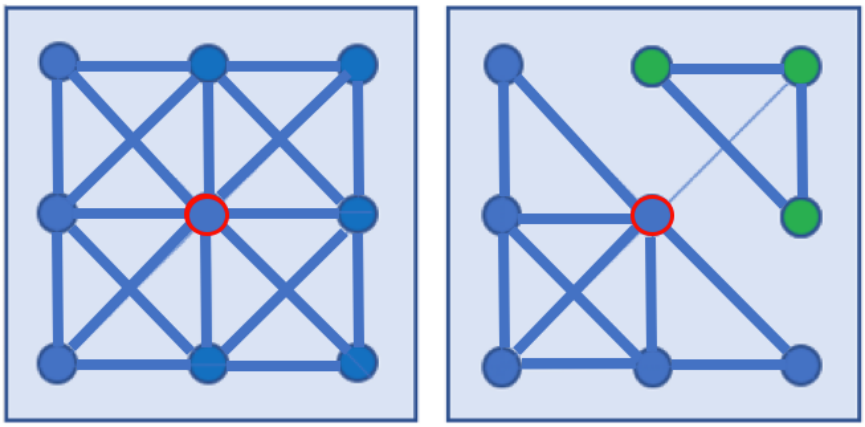
The composition of aggregated webs of interactions can lead to outcomes which are

considered to dynamically feed back to institutional settings and can, thus, change existing rules (Amin & Thrift, 1995; Carlsson, 2000; North, 1990; Ostrom, 2005). Institutions, both formal and informal[5], are referred as rules to govern the behaviour of actors (North, 1990) and denote to the nature of processes of development, codification, communication and enforcement (Pahl-Wostl, 2009). Hence, networks which affect rules, can be also seen as institutional entities (Granovetter, 1985, 1992). Burt (2000) further extent the theory of a relationship between network performances and network structures.

Network structures embodying strong ties are recognized as closed network (figure 4A, table 2) (Sandström & Rova, 2010). The concept of closure refers to structures in which actors are well-integrated, either through coordinating actors (formally or informally) or through many connections (Burt, 2000) like the concept of strong ties (Lin, 2002). Those structures enhance collaboration and facilitate the creation of a common priority process for the creation of rules. Similar implications were made in Coleman's (1990) notion of effective norm generation and trust building in closed structures, drawn by the strengths of strong ties (Lin, 2002). Closed structures are, thus, assumed to increase the capacity of networks to create, support and maintain the rules (Sandström & Rova, 2010).

Network structures showing bridging connections to otherwise weakly connected actors, or sets of actors (figure 4B, table 2) in order to mobilize diversified resources are regarded as indicators for network heterogeneity (Argote et al., 2003; Carlsson & Sandström, 2008; Granovetter, 1973; Reagans & Zuckerman, 2001). A heterogenic network involves a rich diversity of actors, representing various sectors of society which can include many bridging ties.

[5] "*Formal institutions are connected to the official channels of governmental bureaucracies. They are codified in regulatory frameworks or any kind of legally binding documents. Correspondingly they can be enforced by legal procedures. Informal institutions refer to socially shared rules such as social or cultural norms. In most cases they are not codified or written down. They are enforced outside of legally sanctioned channels*" (Pahl-Wostl, 2009, p. 356).



A: closed networks (strong ties) B: network heterogeneity (strong ties bridging to weak ties)

Figure 4: Network arrangements with focus on ties (adapted from Sandström & Rova, 2010)

To conclude, the relationship between network performances and network structures can be used to foster adaptive capacities of institutions for example through the facilitation of access to diverse actors.

4.4 Analytical frameworks

The following section describes the DPSIR (driver-pressure-state-impact-response) framework, the Institutional Analysis and Development Framework (IAD) and the social learning framework for interdependence on natrual resources. The review follows the working objective to outline an analytical framework that interconnect the impacts of networks relevant for adaptation on institutional level. Therefore, the DPSIR framework is selected to provide the analytical elements for planned adaptive measures in the context of in natural resource governance. The review of the IAD is considered, because it places an empahsis on the insititonal elements to develop adaptive measures. The social learning framework for interdependence on natrual resources is reviewed, because it integrates an analytical framework for learning concpets. Therefore, these reviews provide thereofore a background to synthesize the analytical frameworks for the research approach (chapter 5) to explore the role of networks with regard to their effects to achieve institutional adaptability in natural resource governance systems.

4.4.1 DPSIR

The **DPSIR (**driver-pressure-state-impact-response**) framework** is based on the concept of causality (Curtin & Prellezo, 2010). It frames and structures indicators which are used to assess different states of the interaction between human activities and its environment (figure 5, p. 25). Human activities (*drivers*) are the source for *pressures* on the environment by changing the quality and quantity or *state* of the resources. *Impacts*

are the share of the effects on human welfare induced by the state of changes. Society then *responds* to these changes through economic and social policy. Responses are in this thesis refereed as adaptive measures. Regarded as an iterative process, responses in turn are affecting future drivers and pressures, thus completing the process loop (Langmead et al., 2007).

The DPSIR framework is widely used for a holistic view of causal relationships and simplifies the comprehension of the complex interlinkages between multi-sectoral human action and the co-evolution of ecological, economic and social states. It has been developed to support political decision makers in checking the effectiveness of their legal instruments, in prioritizing the problem and in allocating resources accordingly (Curtin & Prellezo, 2010). Therefore, the framework aims to facilitate a common understanding of the problem which should best lead to an effective decision making process and to a proposal relevant for decision-maker and stakeholders. Figure 5 shows driving forces, pressures, states, impacts and responses in relation to groundwater salinisation. The interpretation into categories of the Driver, Pressure, State and Impact factors is based on the reveals of Essink (2001), Green et al. (2011), Grube (2000) and Mustari et al. (2016).

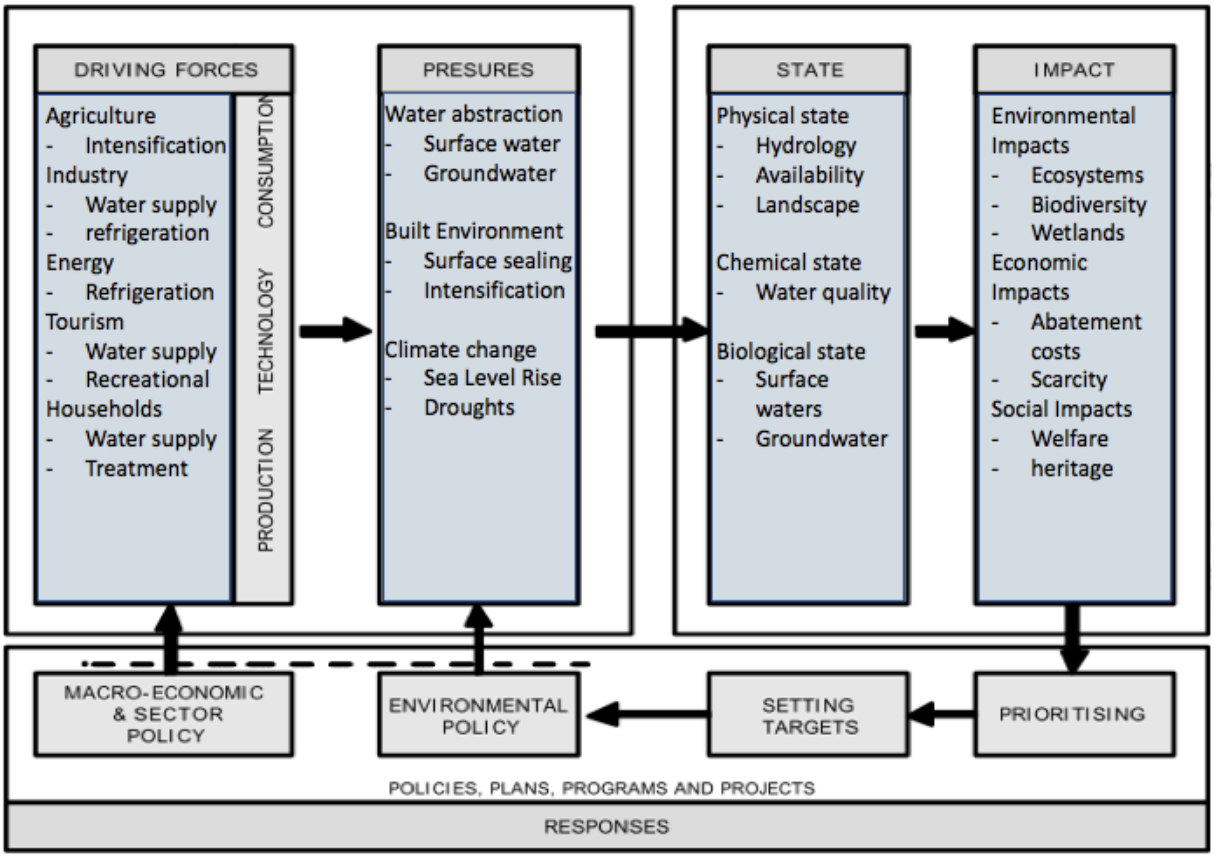


Figure 5: The DPSIR Framework (adapted from Feas et al., 2004)

4.4.2 Institutional Analysis and Development Framework (IAD)

The Institutional Analysis and Development Framework (IAD) helps to *"identify components and relationships among these components that are considered important"* for outlining institutional adaptive measures (Ostrom, 1992, p. 13). It supports drawing an analysis of relevant components that are considered important of how governance (e.g. decision making) is approached. It provides therefore a map to draw institutional arrangements associated with the implementation of outcomes which are in this thesis adaptive measures embodying policies, rules, projects, programs or other forms of actions. Institutions can be embodied by families, local governments, government agencies and most organizations, *"since they are defined by rules, norms and shard strategies"* (Ostrom et al., 1993, p. 6). Central in the analysis is the insight, that "*rules, norms and shared strategies are constituted and reconstituted by human interaction in frequency occurring or repetitive situations*" (Crawford & Ostrom, 1995, p. 582). Accordingly, at the center of the framework is an "action arena", consisting of an "action situation" which is the social domain where individuals or groups of individuals (actors) interact and adaptive measures are produced. The outcomes as regarded as adaptive measures in turn affect the actors and the actions situation (Crawford & Ostrom, 1995).

The action arena is in this thesis understood as a conceptual space, in where the adaptive measures such as institutional rules, programs and projects are constituted and reconstituted. Here, actors inform themselves through social interactions and experiences, consider alternative courses of action, make decisions, take action and experience the consequence of these actions. The action arena denotes who is present in this situation, the roles they play and the adaptive measures they take. However, the action arena is influenced by three sets of contextual factors (exogenous variables): One is the nature of the biophysical resources and material conditions (physical conditions) which are covered in detailed by the DPSIR framework. The other influential contextual factors are the attributes of the community (social and cultural context) and the rules (i.e. institutional arrangements) of and for the respective institutions, in where the actors are associated (figure 6, p. 27).

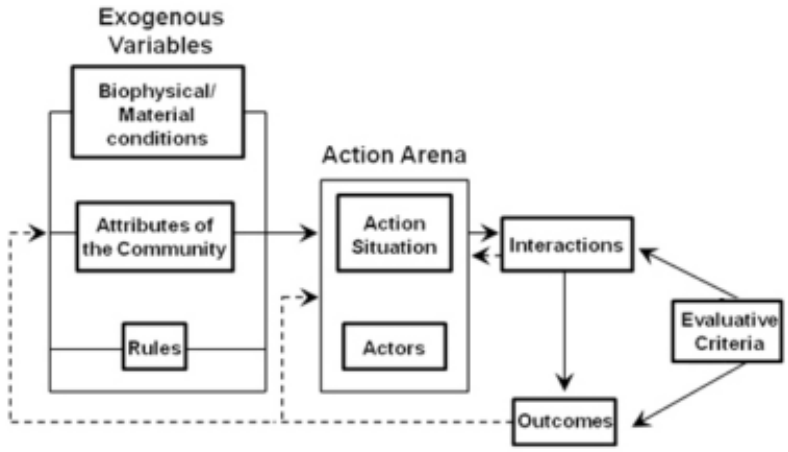


Figure 6: Institutional Analysis and Development Framework (Ostrom, 2005)

Focusing on the action situation in detail (figure 7), Ostrom (1990) highlights detailed influencing components consisting of participants who engage positions, that allows the participant (being assigned to) to undertake certain actions. The actions however are dependent on how much information a participant possess about each available action, how actions are linked to potential outcomes, the degree of control individuals exercise over these outcomes and the costs and benefits they assign to them (Ostrom, 1990). Those influencing components are thus determined by the institutional rules addressing each component.

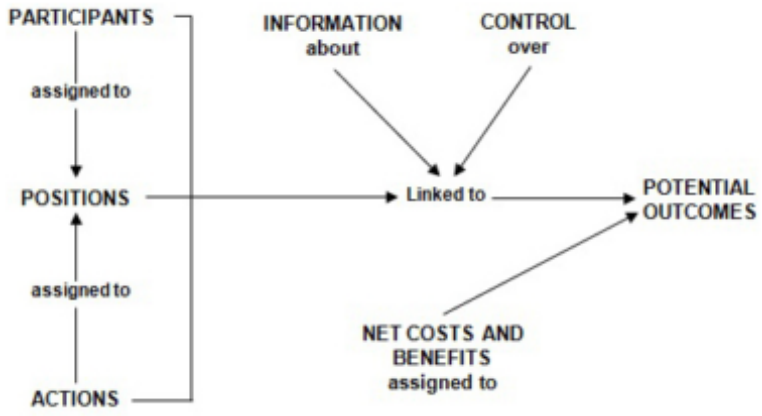


Figure 7: Action Situation (Ostrom, 2005)

Addressing the focus on changing the rules, three level of rules cumulatively affect the actions taken and outcomes obtained in any policy situation. The linkages among the level of rules are diagrammed in figure 8. Operational rules choices in this level affect the physical world. Rules guide individual decisions, strategies, monitoring, enforcement (e.g. amounts of fines), pay-offs (e.g. incentives to break/follow the rules). Changes at the operational level come from the collective choice level. At the collective choice level rules determine who is eligible to make policies /operational rules. At the

constitutional level rules define who is eligible to participate in shaping "*collective-choice rules and how these rules may be changed*" (Polski & Ostrom, 1999, p. 19).

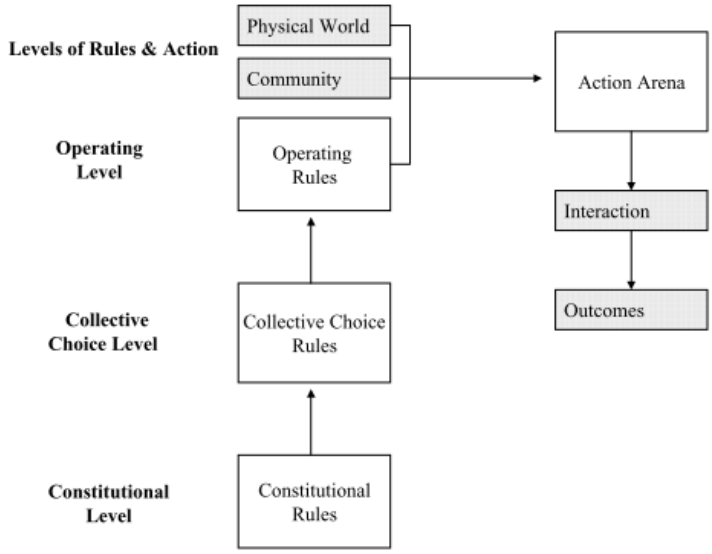


Figure 8: Three level of rules cumulatively affect actions taken and outcomes obtained (adapted from Ostrom, 1990)

4.4.3 The social learning framework for interdependence on natural resources

The social learning framework for interdependence on natural resources was developed by Bouwen and Taillieu (2004). It is structured into context, process and outcomes, plus a feedback loop to account for change in a cyclic and iterative learning process. The context contains actors and regulations within the governance context and the biophysical components of the natural environment. The DPSIR and IAD framework refer to similar contextual components.

Changes in the state of an natural resource triggers the process for improvement which result into outcomes that are in this thesis adaptive measures. This process is undertaken between various actors working together on a natrual resource issue. Each actor (individuals or groups) are influenced by the context in which they are embedded and relates therefore to the issues with social issues (social-relational issues) within their context. Throughout interaction between actors a relational practices is enacted to deal with the issue (problem/task management). The relational practice embodies a social learning process and is referred to an iterative cycle (Bouwen, 2001). Within the relational practice interactions faciliate an interactive bounded context in where social relations to the issues among the actors and their problem management approach to deal with the issue continously change. "*Those practices occur in different contexts […] and*

on different levels (local, intermediary, national) and interfaces among levels" (Bouwen, 2001, p. 144). Whether this relational practice takes place formally or informally, it has a consequence for the relationship between the actors, their perceived environment and their produced outcome (Bouwen, 2001). The whole process deliver therefore outcomes that lead to specific management tasks (technical qualitities) and a changed social relation (relational qualtities). Those outcomes unfold therefore a perspective (negotiated order) which invovled actors influenced (figure 9).

Bouwen and Taillieu (2004) critically highlight learning aspects which are based on social interactions within the relational practices. A significant factor for learning is here the acknowledgement of interdependencies.

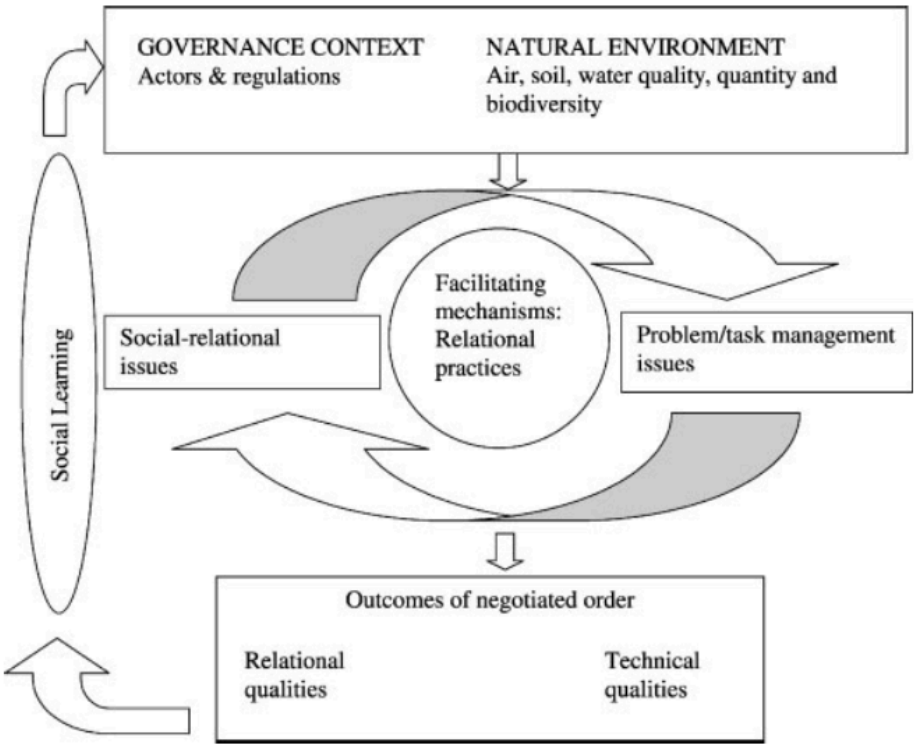


Figure 9: The social learning framework for interdependence on natural resources. Source: Bouwen and Taillieu (2004)

5 Research approach

To explore the role of networks with regard to their effects on institutional capacity building to progress institutional adaptability in natural resource governance systems, the impact of networks is subject of examination for which a network perspective is applied. The social network perspective, which is herewith approached, refers to a tradition in social science which focuses on the joint activities of and recurrent exchanges between, participants in a social system (see Freeman, 2004 and Wellman & Berkowitz, 1988 for detailed explanations of the origins of this perspective). Focusing at the level of the network provides access to understand the impact of network structures and behaviours on individual institutions (see e.g., Ahuja, 2000; Bell, 2005; Powell et al., 1996).

Taking this into consideration, the following section provides a synthesis of the DPSIR framework, the Institutional Analysis and Development Framework (IAD) and the social learning framework and includes elements of the network perspective coupled with learning concepts. The synthesised analytical framework is developed to analyze institutions in the natural resource governance regime with the objective to outline and analyze the impacts of networks. Hence a detailed review of the influence of networks on the institutional adaptive capacity is targeted to be traceable.

Central outlook of the synthesized analytical framework (figure 10, p. 31) is the localization of the influence of networks on learning outcomes. The learning capacity is considered as fundamental pillar for the adaptive capacity of institutions. The outcome of learning processes is argued to embed intellectual capital, a relevant pillar for creating institutional capacity (see chapter 4.1.2) to develop adaptive measures. Therefore, the two learning processes, experience-based and social-interaction based learning processes are contextual domains which influence actors in their process to draw actions.

Analytical framework for the localization of the influencing components of networks towards learning outcomes and their resulting adaptive measures

The **experience-based learning domain** embodies the contextual units of the analytical frameworks where "*knowledge is created through the transformation of experience*" (Kolb, 1984, p. 41). Each actor (individuals or groups) is influenced by the context in which they are embedded throughout experiences and differ from actor to actor (Bouwen and Taillieu, 2004). The experience-based learning domain highlights those embedding factors, which are embodied in form of information (knowledge) domains

about biophysical conditions, attributes of the community and rules. They provide an overview of learnt and accordingly experienced aspects.

The biophysical conditions are split in details, emphasizing only DPSI (drivers, pressures, states and impacts) components as outlined in the DPSIR framework. The knowledge about these domains differ among actors. The same applies to the variety of experiences towards attributes of the community and institutional rules. Rules indicate established and prevalent social rules that structure social interaction. Depending on the profession, employed organisation or general experience actors are embedded within a different set of rules. They can be operational, collective or constitutional rules, each type of rule have different influential ranges (see chapter 4.4.2 and figure 8, p. 28).

When reciprocity and reflection take place within the relational practice, social learning processes feed back the experience-based learning domain as knowledge is transmitted through other actors. The respective actor can represent therefore an individual unit, part of the organizational, group or network unit. The conceptual space, where social-interaction based learning process takes place, is the **social-interaction based domain.** This conceptual space refers to learning processes based on social interactions among the units the respective actor embodies. The respective actor can embody therefore the individual, the group and the organisation (see chapter 4.2.3). The respective actor can be moreover connected to other groups, organisations, actors and networks, each representing different learning units. The sum of the units is the actor's network. The composition of the actor's network embodies the network characteristic structure from the perspective of the respective actor. Only those connections are considered, when they are based on the subject groundwater salinization within the context of this thesis. The focus of the analysis is placed on the actor's network as it facilitates the interconnection between these units throughout social interaction.

Following Bouwen and Taillieu (2004) the **relational practice for interdependence** is in this thesis a processing unit, where the influences of both domains are processed by the actor to draw actions. In this unit, both, the experience-based and social-interaction based learning processes, take place and interrelate between two or more actors, ensured that there is some sort of communicative exchange. Within the relational practice the respective actors represent the institution (i.e. group, organisational or network), in which each actor, as a learning unit, is identified to take up the learning process. The interrelated learning process generate learning outcomes that lead to actions (i.e. adaptive measures).

The relational practice for interdependence consist of two elements; the actor and the action situation. The **actor** is the respective unit that takes up the learning process (experienced-based and social interaction-based) and who draws within this unit subsequent actions. The action situation is the actual context, in where the learning process in interrelation takes place. The action situation is analogous to Ostrom's concept of the **action situation** (see figure 7, p. 27) (Ostrom, 1992). The action situation entails determining components relevant for the development of adaptive measures. One of the components refers to the *positions* to which the actor is engaged. The position is associated to the institution (i.e. group, organisational or network) and represent, thus, the learning unit in which the actor takes actions.

Other components that influence the development of adaptive measures depend on the *extent of information* (learning outcomes) an actor possess about each *available action*, how actions are linked to *potential outcomes*, the *degree of control* individuals exercise over these outcomes and the *costs and benefits* they assign to them (Ostrom, 1990). Those components are influenced by the institutional rules addressing each component. For example, power dynamics, however, can influence the interactions and with it the learning capacity by restricting or bringing different knowledge holders to get together. This, in turn, influences the subsequent learning outcome and therefore the intellectual capital building (see also Wildemeersch, 2007; Wildemeersch et al., 1998). Thus, those components can determine the extent of any planned adaptive measure.

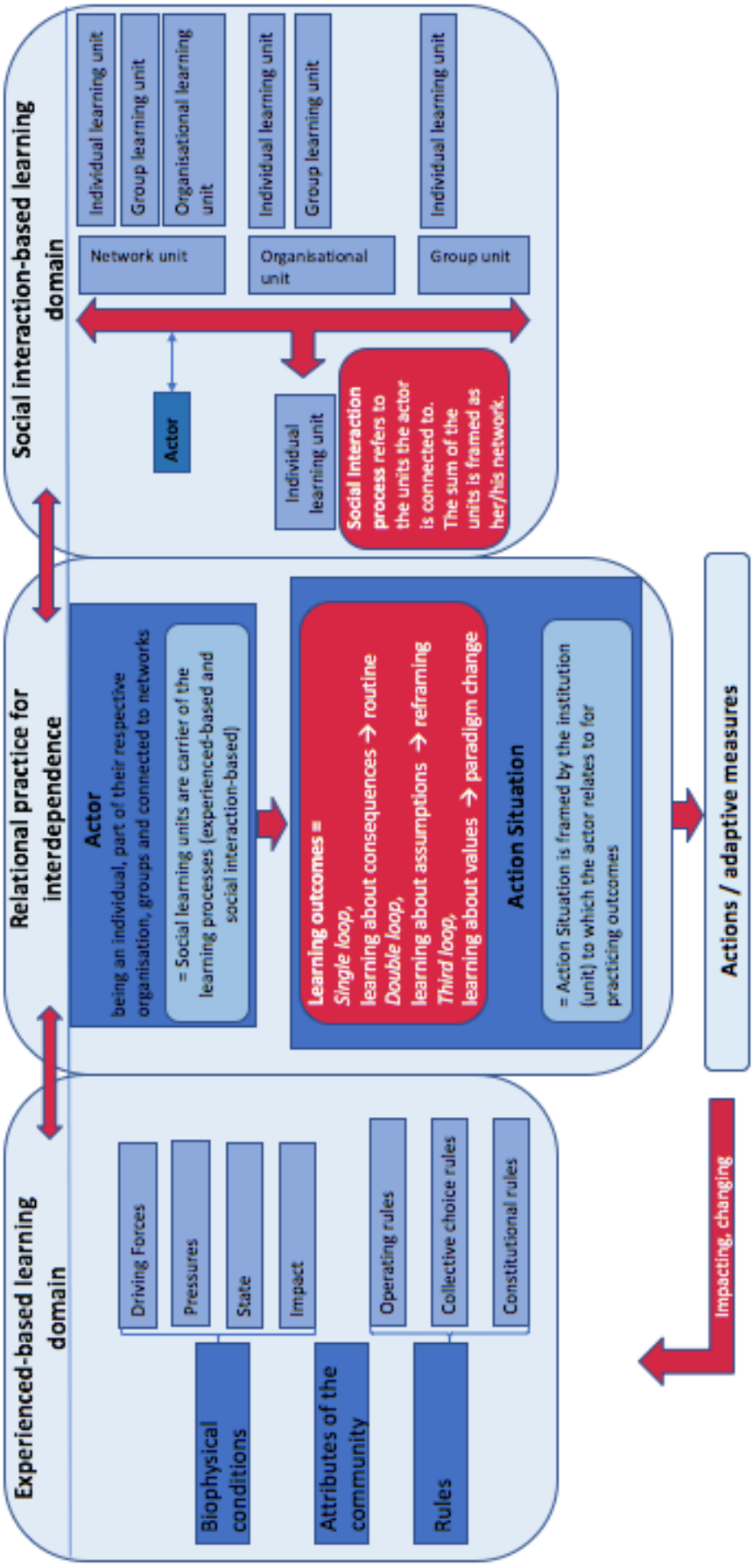


Figure 10: Analytical framework for the localization of the influencing components of networks towards learning outcomes and their resulting adaptive measures (own compilation based on (Bouwen, 2001; Feas et al., 2004; Ostrom, 1990)

6 Material and methods

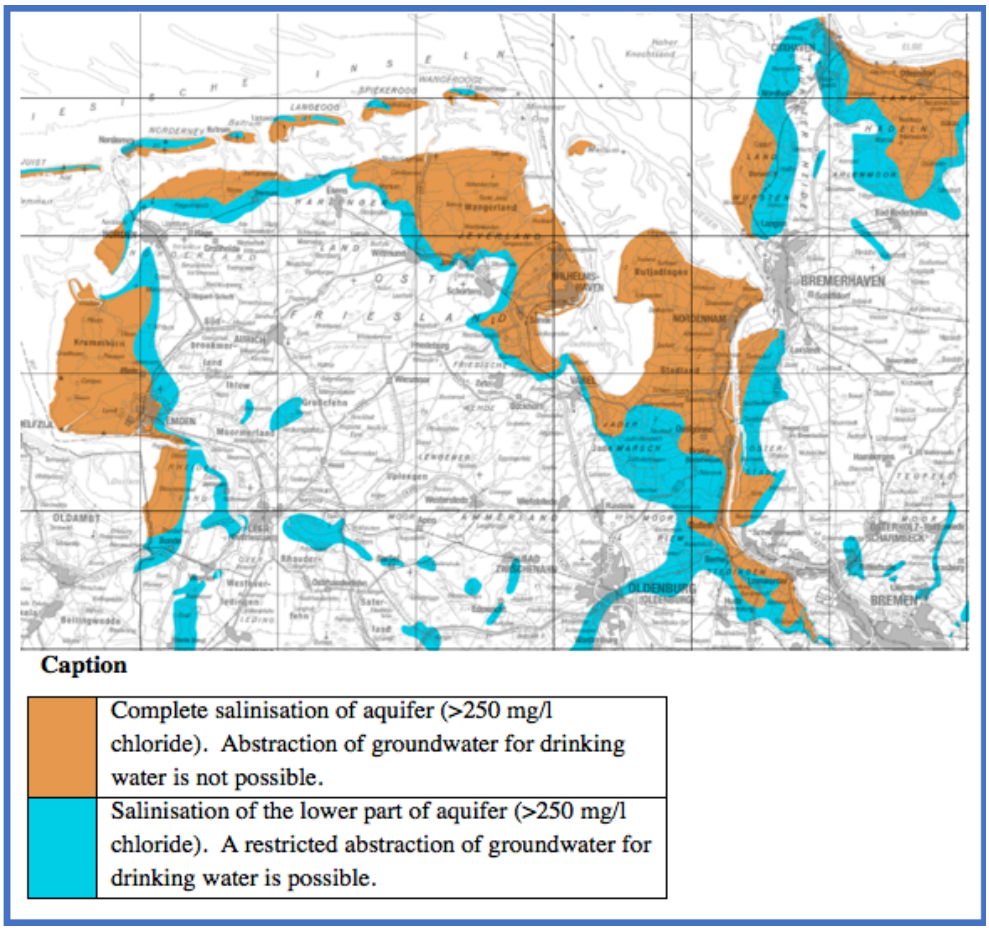
6.1 Case study area: north –west Lower Saxony, Germany; salinization sources and drivers

Groundwater plays an important role in securing water supplies in Germany. More than 70% of Germany's drinking water supply comes from groundwater (BGR, 2017). Of particular interest is the case study area which is located in the north west of the state (Bundesland) Lower Saxony, because the region is facing a risk of saltwater intrusion. In Lower Saxony freshwater filled aquifers are limited to a depth of max. 300 meters (LBEG, 2015). Usable freshwater aquifers are restricted to those areas in which there is a constant exchange of water through percolating precipitation. If more water is withdrawn from aquifers than recharged by rain, the geostatic pressure decreases and triggers upconing effects of saline groundwater that is lying beneath fresh groundwater wells (Essink, 2001). Thus, salt water can completely be mixed with fresh.

Hence, the close relationship between freshwater resources and active water exchange makes groundwater dynamics a central criterion in assessing the usability of aquifers (LBEG, 2015). However, there is an increasing salinization of groundwater recognizable (LBEG, 2015). Altogether around 25 % of North German aquifers are affected by inland salinization and about 5 % by sea water intrusion (Grube, 2000). In Lower Saxony, the risk of saltwater intrusion also emerges from another source: by inland salinization. Inland salinization refers to upconing deeper salt waters and salt diapir (Grube, 2000). Salt diaper indicate geological movements of sediment layers that result to a rise of saltwaters from deeper layers. Subterranean saltstoves are reaching from the Netherlands across the northern German lowlands to Denmark which are below freshwater aquifers. Nearly 100 water works that are affected by salinization and 16 of them had to be shut down mainly because of influence of geogenic salt water (Grube, 2000). Hence, the relevance of salinization for public water supply can be recognized.

The case study area, which is focus if this thesis, is situated at the north-west of Lower Saxony in Germany. Map 1 displays groundwater salinization of the case study region. The highlighted areas show that the use of groundwater (mainly in marsh areas) is difficult to impossible. A water is said to be salinized if its chloride content exceeds 250 mg / l (LBEG, 2015). The entire marsh region is already affected by inland salinization and by seawater intrusion. Table 3 (p. 36) shows which sources for groundwater salinization can be taken into consideration in the case study area. However, taking into

consideration the impacts of climate change along with human developments, following outlined repercussions specify an intensification of the source effects.



Map 1: Groundwater salinization in north-west Lower Saxony (adapted from LBEG, 2017)

In the case study area (see map 1), saltwater intrusion mainly appears at the coast of the North Sea, prone to further saltwater intrusion as a consequence of the general sea-level rise after the last ice age (LBEG, 2017). Seawater intrusion also appears in the Weser estuary into adjacent aquifers and is further intensified by the predominance of west winds and the effects of storm tides leading to a flooding of fresh water aquifers that increase salt concentration (Martens & Wichmann, 2007). In this connection, climate change is expected to increase extreme windstorms and flood catastrophes (IPPC, 2014). Another repercussion of climate change are changing precipitation patterns. If the evaporation rates increase, less water will be available for groundwater recharge (BGR, 2017b). On the contrary, if precipitation rates increase, the risk of flooding of fresh water aquifers during storm flood growths which result to increasing salt concentrations (BGR, 2017b). The result is an increase of salt concentrations in fresh water aquifers (Grube, 2000).

Geogenic ground water salinization	Anthropogenic ground water salinization
- salt water intrusion by o River infiltration o Sea water by the North Sea - inland salinization o upconing deeper salt waters o salt diapir dilution	- anthropogenically induced o road salts, fertilizers, old waste deposal sites - anthropogenically influenced o as a result of withdrawing o dewatering

Table 3: Differentiation of sources for groundwater salinization in North-Germany (adapted from Grube, 2000)

However, many of the slow changes in groundwater can not be traced to climate impacts in a monocausal manner, as they are also affected, for example, by population growth, changes in settlement patterns, nature of use of the natural environment, or economic or social change in general (Bundesregierung, 2008). As a result, regional and / or seasonal bottlenecks in the water supply can lead to conflicts of use. For example, at this time Lower Saxony's maritime economical sector is dependent on access to waterways for transportation of goods. Waterways interfere, however, with the groundwater recharge system (Yang et. al., 2015). Lower Saxony's second biggest economy sector is agriculture. The Land Lower Saxony provides the most food for Germany (Nds. Ministerium für Wirtschaft Arbeit und Verkehr, 2015). Therefore, the provision of fresh water through, for example, rivers is essential for sustaining this industry. The biggest industry is the automotive industry manufacturing the most cars within Europe. The manufacturing industries need fresh water since saline water leads to corrosion in the fabrication process. Additionally, this sector is dependent on transportation exporting goods and relates therefore to the maritime economy.

Water resource management an administrative overview

Formally, water resource management in Germany is distributed between the federal government and the states. The federal government has legislative competence with regard to the hydrological regime as outlined in the Federal Water Act (WHG) 2009. The WHG states basic requirements relating to water resources management (i.e. management of water quality and quantity[6]). It declares that "*waterbodies, as a component of the ecosystem and as a habitat for fauna and flora, must be protected and managed in such a way as to serve the general public interest and, in harmony with this, must benefit the individual, in a manner which refrains from any avoidable impairments to its ecological function (precautionary principle)*" (Jekel et al., 2014, p. 35). Therefore waterbodies (inland surface waterbodies, coastal waters and

[6] For example, if saltwater contamination is a result of high levels of water abstraction, the groundwater body is considered to have a poor quantitative status. Saltwater contamination of groundwater bodies due to wastewater discharges, as from fertilizers, are labeled as poor chemical status.

groundwater) are controlled by the government. This means in practice that all uses of water (such as the abstraction of water) must be officially authorized, apart from minor significant exceptions. The intention is to prevent impairments to the water regime and to enforce a precautionary principle for water protection.

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) addresses fundamental issues relating to water resources management. It is authorized to adopt detailed regulations on water resources management (such as the Federal Water Act, the Wastewater Charges Act, the Detergents and Cleansing Agents Act, the Federal Soil Act and the Federal Nature Conservation Act). The enforcement of the provisions relating to water and the exercising of executive powers in water resources management is the responsibility of the states (Jekel et al., 2014). However, the Federal waterways are an exception to this rule. Here, the federal government (Federal Ministry for Transport and Digital Infrastructure) administrate and control the maintenance and development of traffic requirements. Still, the federal government is required to reach mutual consent with the states, so with Lower Saxony in protecting the interests of land improvement and water resources management (Jekel et al., 2014). Within the states, as in Lower Saxony and its municipalities (administrative districts (Landkreise) and independent cities) inhabit the power for sole enforcement and responsibility of water resources management regulations.

In Lower Saxony, water resources management follows a two-tier structure of administration. The primary tier as the supreme authority has the Lower Saxony Ministry for the Environment and Climate Protection with duties on water management control and superior administrative procedures. The second tier is inhabited by the lower water authorities which are embodied by the districts and independent cities. Those local authorities proceed under the Water Act as well and are thus responsible for water supply and wastewater disposal and their monitoring. As the licensing authority, the lower water authority deals, thus, with all issues related to surface and groundwater, which also includes rainwater fall. In the north-west of Lower Saxony the following administrative districts are part of the focus of case study area: Cuxhaven, Osterholz, Wesermarsch, Wilhelmshaven, Friesland, Wittmund, Aurich, Emdne, Leer, Ammerland and Oldenburg.

Map 2: Administrative districts in north-west Lower Saxony. Source: (Maps.com, n.d.)

The municipalities also enforce the environmental legislation of the Federal Government and of the states and perform environmental protection-related tasks. Based on their constitutional self-administration, their decisions shape the local environment for residents (Jekel et al., 2014). Also town planning (Bauleitplanung) is another shaping instrument of the local authorities. Within the context of town planning, the local authorities can play a vital role in flood prevention or groundwater recharge in urban areas. However, local authorities (municipalities) executing their tasks in the field of water resources management, get assistance by research institutions and technical authorities (technische Fachbehörden) (Jekel et al., 2014).

Besides that, there are several technical/scientific associations which generally represent scientists, water supply associations and politicians on the federal, state and municipal level. Some of them have prepared numerous technical guidelines that are recognized and applied as technical standards (i.e. the German Association of Gas and Water Experts, DVGW). Additionally, the general public is by law also associated to the governance of water resource as the general public must be consulted and invited to present its opinion in written or verbal form on large projects such as waterbody development projects (Jekel et al., 2014). This entails the participation of the wider public and the organized public, i.e. environmental protection organizations and other interest groups from industry, agriculture, shipping and tourism.

6.2 Methods

Multiple case studies are used as the leading research method (figure 11). "*The essence of a case study, the central tendency among all types of case study, is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented and with what result*" (Yin, 2009, p. 17). What Yin (2009) refers as 'decisions' (is in this thesis understood as adaptive measures.

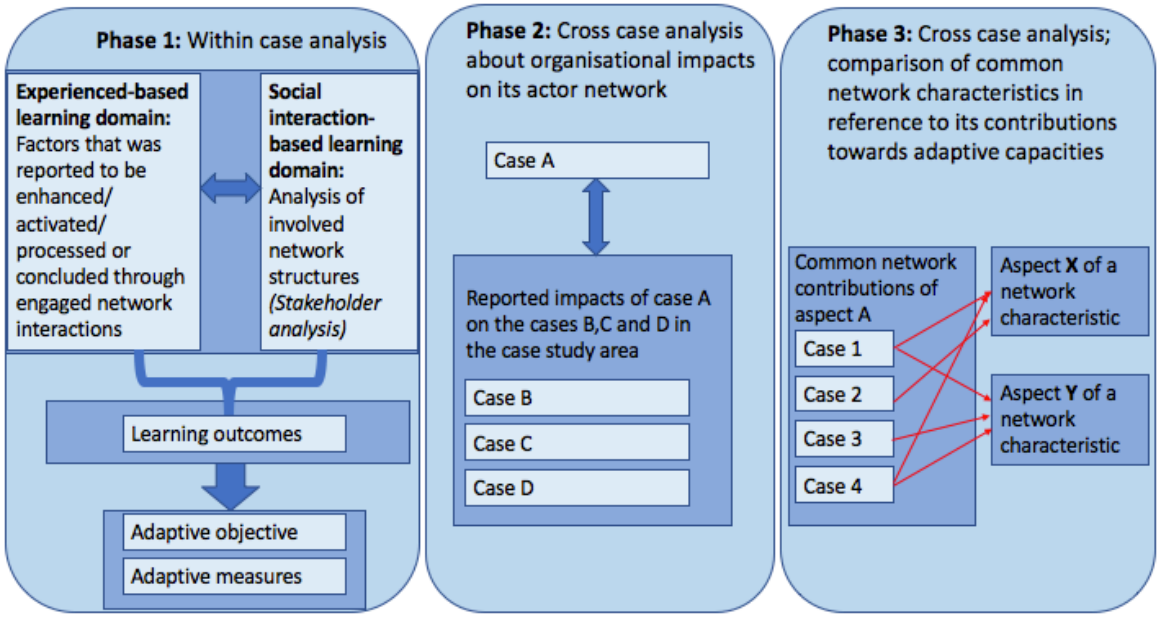


Figure 11: Methodical approach of the multiple case study analysis

In a **first phase**, each case in the case study area was treated individually. In this phase, reported adaptive measures were first highlighted. Based on these results, accompanying learning outcomes were revealed. Hereinafter the role of networks was explored. Focus of the exploration was the specification of impacts for the respective learning outcome activated by network interactions and at the same time, the exploration of the quality of the respective network regarding its structure. This assessment was successively proceeded within a stakeholder analysis. The cross-case analysis was applied in a **second phase**. Here, focus was the exploration of the narrated impacts of a respective case[7] (i.e. organisation) on their network. Therefore, all other cases were examined whether they were connected to the respected case and whether these connections showed any impacts.

Within the **third phase,** a cross case analysis after Yin (2009) was undertaken with

[7] "Individual cases in the collection may or may not be known in advance to manifest some common characteristic. They may be similar or dissimilar, with redundancy and variety each important. They are chosen because it is believed that understanding them will lead to better understanding and perhaps better theorizing, about a still larger collection of cases" (Stake, 2005, p. 445).

focus on a comparison of learning outcomes in connection to the role of involved network characteristics (see figure 11, p. 39). Common outcomes with regard to network characteristics lead to the explanation of how networks in natural resource governance systems are linked to actions. These results aim to embody a guiding model for actors, decision-makers and planners and managers in the field of nature resource governance.

6.2.1 Stakeholder analysis

A stakeholder analysis has been applied to supplement the qualitative content analysis for the exploration of the role and qualities of networks dealing with adaptive measures on the topic groundwater salinization in the case study area. A stakeholder is any person, group of persons or institutions with a justified interest in the respective field of groundwater salinization. In this thesis stakeholder are defined as actors which connect to the topic groundwater salinization in the case study region. Since networks are by definition sets of social relations by actors that formally or informally connect with another on a certain topic, the objective of this analysis was to provide an overview of the actors in the case study area to assess network structures.

In a **first step**, field of interests for the issue of groundwater salinization have been identified for an overview: water quality, nature conservation, shipping and ports, regional development, flood protection, tourism and recreation, agriculture, forestry, research and consulting. The category established networks refers to associations, projects or other institutions embodying a plurality of members with diverse interests.

In a **second step**, reported connections to actors (nodes) were identified, portrayed and then associated towards these categories. A differentiation was also made between formal and informal contacts. For the portray of identified actors or group of actors, brochures and the website of the actors were examined based on a qualitative text examination. The qualitative text examination is more about finding interesting passages, working out coherent lines of argument, or *"gaining a first impression of the content and less about counting predetermined characteristics"* (Kromrey, 2006, p. 396). The information of all actors is enclosed in the appendix 10.5. The portray of existing network structures is based on a qualitative text examination based on a primary source analysis. The overview of reported connections in each case is enclosed in the appendix 10.6.

The overview was used in a **third step** to support the evaluation of the network arrangements by regarding the network structures in relation to revealed learning processes. The results of the identification of network structures in connection to learning outcomes has been derived by a qualitative content analysis of semi-structured expert interviews.

6.2.2 Selection criteria of the cases

The selection of cases was based on subject matter; the exploration of the role of networks connected to the issue of groundwater salinization on regional level. Thus, any organisation active in the case study region was the primary selection criterion. The second criterion was that the organisation is concerned with the theme of groundwater salinization. The third criterion were that the organisation is related to the field of natural resource governance. The fourth was that the concerned organisations are not active in the similar business field (i.e. two water supply companies).

6.2.3 Semi-structured expert interviews

Meuser and Nagel, 2002 regard experts as people to whom this status is granted by the researcher. An expert is a person who contributes in any way to or is responsible for the design, implementation or control of problem solving and who has privileged access to information about individuals or groups of decision-making (Meuser & Nagel, 2002). The selection criteria for choosing experts were that the expert has (i.) work experience within the field of the investigated case study area, has (ii.) knowledge and comprehension about groundwater salinization (iii), has been connecting with other actors about the topic of groundwater salinization and (iv) inhabits a leading position or a responsible positon to be eligible to draw actions. Additional focus was placed (v) on diversity of the business areas. Hence, the selected experts should differ from each other in their business area. Four interview partners have been selected.

Description of the interview partner

Expert 1 is head of the department geohydrology. His case interests are for the organisation LBEG which represents the interest field research and consulting (see description of case 1). **Expert 2** is employee in the field of statutory duty to perform tasks of water management and nature conservation. His case represents the interest of the NLWKN active in field water resource management, thus, unfolding tasks with the interest field water quality, nature conservation, regional development and research and consulting (see description of case 2). **Expert 3** is an executive director active in the

field of duty of care for water supply. His case represents the interests of the water supply association Wesermünde unfolding the interest of water quality (see description of case 3). **Expert 4** is managing director in the field of lobby within agricultural associations. His case represents the interests of the Kreislandvolk Wesermarsch unfolding the interest field agriculture (see description of case 4).

Interview Guideline

In the context of this study, the conducted interviews are based on the concept of semi-structured interviews with experts. The orientation of a guideline with open questions, to which the interviewee can answer freely, promotes comparability and the structuring of the data obtained (Mayer, 2009; Scholl, 2009). In addition, the guideline helps to focus the interview on topics of interest and exclude the excesses of those who have nothing to do with the object of research (Meuser & Nagel, 2002). Since the questions were not processed systematically, this form of interview granted qualitative research claims for openness and certain points of detail could be in demand. The disadvantage, however, is the possibility of unconscious manipulation (e.g. by suggestive questions, tone, etc.) (Atteslander, 2010). The interview guideline can be found in the appendix 10.1.

Data Processing

The interviews of four experts about the case study area in Lower Saxony have been acquired. An additional pilot interview has been performed to check the application of the method. The interviews took place in September and October 2017 on the telephone and lasted between 30 to 55 minutes. In agreement with the experts, the interviews were recorded in order to focus exclusively on the survey. Breaks, tones of voice, other nonverbal elements, but also utterances and decorating words were left out. The transcription system of the interview material was the technique of a clean read transcript (Mayring, 2014, p. 45). The transcription was done word for word. The transcript provides a coherent text and represented the original wording and grammatical structure. The protocol of the transcripts can be found in the appendix 10.4.

6.2.4 Method of evaluation

For the analysis of texts based on the transcripts of the interviews, a qualitative content analysis was applied. The emphasis is on the interpretation of the obvious, unobstructed communication content. Though, transcripts are never complete representations of their raw material (Mayring, 2014, p. 43). Within this research method textual information were coded from primary sources. A total of four text units of the interviews, equivalent

of 58 pages of interview transcripts, were deductively coded. In the deductive structuring process after Mayring, the categories are set up and defined before the analysis of the data material (Mayring, 2014). The assigned deductive codes are based on the existing theory on how adaptive capacity is created through learning and which role networks play in this regard. The derived deductive codes were orientated on criteria which are relevant for answering the research question. They orientation of the deductive codes was about to

- outline actors, who were mentioned in connection to groundwater salinization
- evaluate the structure of the actor's networks
- reveal activities of actor addressing the problem of groundwater salinization
- identify experienced based and social interaction based situations that influenced problem solving and adaptation (to identify connections between network interactions and learning)

The assigned deductively codes are shown in table 4 (pp. 43-43). The author coded text documents using a qualitative software called MAX QDA. The software assists the analyst to assign specific parts of text to one or more of dozens of possible thematic codes (MAXQDA, 2017). This way allows a systematic coding of relevant variables and a comparison of these variables across cases (i.e. each expert's case/network).

Deductive categories	**Definition**
Adaptive measures	Any reported action that was taken within the respective case (organisation)
Adaptive objective	Any reported objective that was targeted for adaptive measures
Single loop learning outcome	Single loop learning outcome is based on reported error detection that lead to any improvement of strategies and actions within existing mental models. It addresses the question whether people do things right.
Double-loop learning outcome	Double-loop learning outcome is based on any reported error detection that lead to corrections which involve the modification or development of an organization's underlying norms, policies, mental maps and objectives. The process indicates changes in the organization's knowledge and competency base by reframing problems. It addresses the question whether people do the right things.
Third-loop learning outcome	Third-loop learning outcome is based on reconsideration and revision of values and beliefs. It links single- and double-loop learning. It is addressing the question "whether people really have the opportunity and competence to participate in making well-informed choices in the process of discussing and managing issues that concern them" (Romme & Witteloostuijn, 1999, p. 452).
Attributes of the community	Any trait about groups of people which were reported in connection to draw adaptive measures.
Rules	Any established and prevalent social rules that structure social interaction such as language, money, law or measures which were reported in connection to draw adaptive measures.
Biophysical conditions	Any reported biophysical conditions that has been recalled in connection to draw adaptive measures. These biophysical conditions can include driving forces, pressures, state and/or impact factors.

Actor network	Any reported actor, groups of actors or organizations to which the interviewed actor (expert) of the respective case was connected to.
Network impacts on the respective case	Any understandings, proceedings, insights, considerations or perceptions of the interviewed actor that were reported to be produced across engaged social interactions and which were reported in connection to draw adaptive measures.
Network characteristics	Any reported network qualities such as frequency of interactions, diversity of involved interests/sectors, frame of connections or any other traits of the respective actor network of each case.
Impacts of the respective case on its actor network	Any understandings, proceedings, insights, considerations or perceptions which were reported in connection to taken adaptive measures and which were reported to be disseminated by the interviewed actor within his actor network and.
Diversity of network	Interactions with diverse actors. Diverse actors are here referred to be active in the different business field (e.g. actors in the field of science, water supply and agricultural sector were involved for interactions on a specific issue).
Homogeneous network	Interactions with similar actors. Similar actors are here referred to be active in the same business field (e.g. only water supply companies, or only farmers were mentioned for interactions on a specific issue).

Table 4: Assigned deductive codes

6.3 Description of the cases

6.3.1 Case 1: Lower Saxony Water Management, Coastal Defence and Nature Conservation (NLWKN)

The Lower Saxony Water Management, Coastal Defence and Nature Conservation (NLWKN) is a technical authority (technische Fachbehörde). They are subsidiary to the supreme authority, the Lower Saxony Ministry of the Environment, Energy and Climate Protection (NLWKN, n.d.). The NLWKN is a central state entity for water resources management and other designations (i.e. lower authority for environmental protection and coastal management). The subject of water resource management is managed and processed by the NLKWN on state level.

Therefore, the NLWKN has several business sites in Lower Saxony to maintain the local context in their management planning. The business environment of this case is embedded in Aurich which is situated at the very north west of the case study area. The hydrological data, on which tasks of water resource management are based on, are delivered by Hydrological Land Service (GLD). The GLD is a body set up by a federal state that determines, prepares and collects hydrological data which are required for water management planning, decision-making and other water related measures. Both, the NLWKN and the State Office for Mining, Energy and Geology (LBEG) are authorized to perform tasks of the Hydrological Land Service (GLD). Usually the NLWKN operates the tasks of the GLD. The LBEG as a Hydrological Land Service (GLD) is only to be involved in water-legislative procedures which imply state-wide impacts or involvements. Generally, the GLD is to be involved if decisions, measures

or plans are expected to have a significant impact on the water balance. The GLD explains which hydrological requirements must be met, still the recommendation of the GLD are non-binding (NLWKN, n.d.).

6.3.2 State Authority for Mining, Energy and Geology (LBEG) - Case 2

The State Authority for Mining, Energy and Geology (LBEG) inhabits the role of Lower Saxony State Geological Survey (SGD) and is a subordinate authority of the Lower Saxony Ministry of Economics, Labor and Transport. State Geological Surveys (SGD) collect and compile technical information on the nature of the subsoil. The perspective of the organizational unit is focused state wide. The LBEG is only involved in water resource management if tasks relate to the field of hydrogeology. They provide hydrological/ pedological consulting. Their tasks relate to water management planning procedures, questions to groundwater use, pollution and assessment on state scale. As a service of the Hydrological Land Service (GLD) they provide consulting on procedures on water protected areas and water-legislative procedures. They provide therefore specialist information on geoscience, geospatial data, maps and specialized publications. Thus, it supports the state government, the rest of the public administration within Lower Saxony in matters relating to geology (LBEG, n.d.). Moreover, the LEBG provides consultation on superordinate water management issues, in particular for the tasks of the European Water Framework Directive at the Lower Saxony groundwater bodies based on digitally available data as they deliver and process specialist information on geoscience, geospatial data, maps and specialized publications (LBEG, n.d.).

6.3.3 Case 3: Water supply association Wesermünde

The water supply association Wesermünde is a special-purpose organisation under public law. The supply area of the water association Wesermünde is situated in the southern part of the district Cuxhaven and east of the river Weser. It provides the public water supply in the affiliated member communities (Beverstedt, Hagen im Bremischen, Loxstedt, Sadt Geestland and Schiffdorf). The association is a result of an area cooperation between local communities. Generally, water supply companies are controlled by the communities, either publicly owned, operated by the municipality, owned by the community or the plant operation is operated by a private contractor, whereby the responsibility for the completion of tasks stays within the community (Jekel et al., 2014). The association operates the water supply system, monitors water

protection areas and the raw water and they provide the maintenance and expansion of the pipeline network in the supply area (Wesermünde, n.d.). To gain the right to withdraw water within a district, an application has to be made at the respective lower water authority.

6.3.4 Case 4: The rural population district association Wesermarsch (Landvolk - Kreisverband Wesermarsch)

The rural population district association Wesermarsch (Landvolk - Kreisverband Wesermarsch) is the largest interest representation of the farmers in the Wesermarsch district. The district is situated west of the river Weser, east of the Jade Bay and is surrounded by the North Sea in the north. The agricultural association provides agricultural policy advocacy and represents the agricultural interests of the region at municipal, county, state, federal and EU level across discussions with parliamentarians, ministries, business and administration at all levels. Their objective is to strengthen rural areas and cooperation with local institutions. They also provide advisory in questions of nature conservation, landscape protection, water protection, immission control and fertilizer (Kreislandvolksverband Wesermarsch, n.d.).

7 Results

The following outline describes the results from the multiple case study analysis. The first part describes the cases to the reader to provide an overview. The second part describes the actual results of the analysis Chapter 7.1 to 7.4 show the results of each case, assessed and treated as separated cases. Chapter 7.5 shows the results of the evaluation of the cross case analysis. The tables 5 and 6 (p. 48-49) below shows the summary of main results.

The results of each case organisation revealed in some cases two adaptive measures. As each adaptive measure was treated within the case study individually the adaptive measures were distinguished with a reference number (e.g. Case 1.1 = Case organisation 1 in reference to a certain adaptive measure 1). Moreover, adaptive measures were reported with the help of given examples. For their distinction letters (e.g. *A,B,C*) were given to each example.

Table 5: Main research results

Case	Case 1.1 (Chapter 7.1.1)	Case 1.2 (Chapter 7.1.2)	Case 2 (Chapter 7.2.1)	Case 3.1 (Chapter 7.3.1)	Case 3.2 (Chapter 7.3.2)	Case 4 (Chapter 7.4.1)
Adaptive measure	Increasing system knowledge within the NLWKN	The occupation of the capacity to operate models to draw scenarios throughout forthcoming job occupations within the NLWKN	New mapping methods	Methodological Improvements	Openness and information dissemination	Gaining new knowledge and mobilizing affected stakeholder
Objective	To provide the capacity for consulting in the field of water resource planning to improve information dissemination	To create additional value for the provision of knowledge and expertise in the field of water resource planning	To improve the dissemination of information	To maintain the provision of good water quality	To convince his network to maintain water in the upper levels in groundwater bodies in good quality	To defend agricultural interests
Learning outcome	Single loop	Double-loop	Double-loop	Single-loop	Double-loop	Triple-loop
Impact of a network on an individual organization	*Growth of intellectual capital:* Actor's network contributed to the **awareness/cognition** - About a pivotal **biophysical condition** (groundwater recharge plays a key role to maintain a hydrostatic pressure)	*Growth of intellectual capital:* Actor's network contributed to the **awareness/cognition** of - a new technical approach (a particle transport model) to be relevant for the supply of knowledge and expertise about **biophysical conditions**	*Growth of intellectual capital:* Actor's network provided a **starting signal** - to **reconsider** the supplied map information - to the **cognition** to work on new mapping methods Actor's network enhanced the **progress** of adaptive measures - as the experienced based learning domain grew through the search and discovery for a new technical approach for mapping. This progress was pursued throughout network interactions	No indications were reported	*Growth of intellectual capital:* Actor's network contributed to **awareness/ recognition** - of a relevant **attribute of the community** that was considered to take a leading/inducing role for the decline of water quality	*Growth of intellectual capital:* Actor's network provided a **starting signal** - to question / reconsider the given expert's report Actor's network enhanced the **progress** of adaptive measures - as the experienced based learning domain grew with knowledge about **biophysical conditions and attributes of the community**
Network structures that triggered the impact on an individual organisation	The **awareness/ recognition** of a relevant biophysical conditions emerged from the quality of interactions in terms - **Intense** knowledge exchange (time scale), **heterogeneous actors** in a **formal** network, a research project	The **awareness/ recognition** of a new technical approach to better measure biophysical conditions emerged from the quality of interactions in terms of - **Intense** knowledge exchange (time scale), **heterogeneous actors** in a **formal** network, a research project	The **starting signal** to reconsider the supplied map information emerged from the quality of interactions throughout - **Intense** (time scale) and **heterogeneity** of network interactions; no differentiation between formal and informal contacts were mentioned Enhancing the **progress** of the development of the adaptive measure: - One actor of the actor's network facilitated a **bridging tie** as this actor had a connection towards new resources /information and delivered these information **informally** to the interviewed actor - **Experienced based learning domain**: The trial and error process (search and discovery) was pursued throughout **selected** actors within the actor's network - The **individual role** of the interviewed actor: o he established a relational practice within selected actors to pursue the progress o and he pursued an institutional interface	-	The **awareness/ recognition** of a relevant attribute of the community emerged from the quality of interactions in terms of - **intensity** and partly throughout a **homogeneous**, but also **heterogeneous** actor's network	The **starting signal** to question the expert's report emerged from the quality of interactions within a - **homogeneous** network; no differentiation between formal and informal contacts were mentioned Enhancing the **progress** of the development of the adaptive measure: - The development of knowledge about **biophysical conditions** grew with **heterogeneous** actors - The development of awareness about an **attribute of the community** grew alongside with interactions with **heterogeneous** actors - One actor of the actor's network facilitated a **bridging tie** as this actor had a connection towards new resources /information and delivered these information **informally** to the interviewed actor - The **individual role** of the interviewed actor: o he established a relational practice within selected actors to pursue the progress o and he pursued an institutional interface

Table 6: Main research results

Case	Case 1 (Chapter 7.1.1)	Case 1 (Chapter 7.1.2)	Case 2 (Chapter 7.2.1)	Case 3 (Chapter 7.3.1)	Case 3 (Chapter 7.3.2)	Case 4 (Chapter 7.4.1)
Adaptive measure	Increasing system knowledge within the NLWKN	The occupation of the capacity to operate models to draw scenarios throughout forthcoming job occupations within the NLWKN	New mapping methods	Methodical improvements	Openness and information dissemination	Gaining new knowledge and mobilizing affected stakeholder
Objective	To provide the capacity for consulting in the field of water resource planning to improve information dissemination	To create additional value for the provision of knowledge and expertise in the field of water resource planning	To improve the dissemination of information	To maintain the provision of good water quality	To convince his network to maintain water in the upper levels in groundwater bodies in good quality	To defend agricultural interests
Impacts of an individual organisation on a network	***Intellectual capital:*** This adaptive measure served to create awareness among colleagues and partner for those topics. **Political power:** This measure (distribution of knowledge) also aimed to influence the definition of points of view.				***Contributed to the growth of intellectual capital*** as he disseminated information to activate actors associated to natural resource governance to develop adaptive measures (A) informed the NLWKN about the issue of salinisation in groundwater and demanded that they should do anything about it " impacts: not revealed (B) informed other water supply companies about his adaptive measures, the interests had grown for his applied technical approach to locate the salt-fresh water transition zone " impacts: growth of interests (C) disseminated information and to talked openly about the impacts of the agricultural sector on the quality of groundwater " impacts: not revealed	***Intellectual capital and political power:*** The interviewed actor created an artificial relational practice for interdependence as the interviewed actor communicated his learned experiences with selected actors, which lead to a mobilization of his actor's network to rise formal objections against a planned project.
Network structures	Not specified				(B) homogeneous network: only water supply companies were informed	The impact was created with the mobilisation of homogeneous actors as farmers and landowners were informed

7.1 Case 1: Lower Saxony Water Management, Coastal Defence and Nature Conservation (NLWKN)

7.1.1 Increasing system knowledge within NLWKN (Case 1.1)

The interviewed actor, whose profession is in the field of chemical hydrology, referred to several adaptive measures taken within the NLWKN. Those measures were targeted to increase *"system knowledge"* [8] (C.1; l. 134) [9]. The term *"system knowledge"* was used in connection to increase experiences, thus, knowledge about factors of the biophysical environment which are involved in the process of groundwater salinization. The reported objective for those measures was about to provide the capacity for consulting in the field of water resource planning. Therefore, an improved system knowledge within the NLKWN was recognized as an instrument to better provide expertise about relevant information (C.1; l. 140-143). An improvement of system knowledge is here recognized as an adaptive measure. What kind of measures[10] and how system knowledge was improved is described in the following section.

7.1.1.1 A single-loop learning outcome

The applied adaptive measures were largely based on new research projects to gain system knowledge to better provide expertise. This outcome is based on single-loop learning effect. Single-loop learning is denoted on improvement of strategies and actions within current mental models (Sterman, 2000; Argyris and Schön, 1978; Sabatier, 1988).

In one case (in the following referred to example A) the interviewed actor highlighted actions which were about analyzing and specifying the different chemical salt substances found in the aquifers to differentiate sources for salinization. In the case study area sources for salinization were experienced to be either the result of the 'driver' inland salinization or coastal salinization, or both sources at the same time. A differentiation of the sources was reported to enable the interviewed actor to better recommend adaptive measures, such as the development of water management plans or the elaboration of strategies for water supply companies (C.1; l. 590- 612). Therefore, the NLWKN collects data from water supply companies for the chemical differentiation. For an exchange, the NLWKN provided the supply companies with the

[8] All quotes in chapter 7 are based on own translations.
[9] The reference with the abbreviation *C.1* refers to the transcription protocol of case 1 which can be found in the appendix 10.4. The abbreviation *l.* indicates the line within the transcription protocol.
[10] The described measures are reported examples of the interviewed actor. The examples were given a letter to differentiate them from each other.

latest research results (C.1; l. 661- 679). In this reported example system knowledge and technical expertise were used by the NLWKN for consulting purposes (C.1; l. 225; l. 466-48). The provision of system knowledge and technical expertise is here recognized to an iterative improvement of current strategies (Argyris and Schön, 1978) and actions (Sabatier, 1988) within existing mental models (Sterman, 2000), since system knowledge was only improved. This is here considered as single-loop learning. The outcome is here recognized to serve the organizational objective to provide the capacity for consulting in the field of water resource planning (C.1; l. 225; l. 466-484), thus the objective of the NLWKN remained within the same frame.

Another exemplified adaptive measure (in the following referred to example B) is also based on a single loop learning. The action is based on the understanding that climate change is a driver for future challenges. The experienced pressure factor was brought into connection with the insight that groundwater recharge plays a key role to maintain a hydrostatic pressure with regard to sea level rise. This insight was communicated and experienced through a research project throughout project partners and scenario models (C.1; l. 275-285; 320). The outcome of this relational practice was to communicate and distribute the gained new knowledge of the research project to other colleagues of the NLWKN. He further highlighted that he has been working on a *"publication of the project results"* (C.1; l. 279-280). The adaptive measure remained within the same value frame of reference that system knowledge and technical expertise served the targeted objective; to provide the capacity for consulting in the field of water resource planning (C.1; l. 225; l. 466-484).

7.1.1.2 The role of specific networks traits for building adaptive capacities

The following section describes both, the revealed impacts of a network on the individual organisation and the impacts of the organisation on its network in connection to the adaptive measure described in chapter 7.1.1. The description entails the perspective of the interviewed actor, hence, only the impacts of and from the actor's network are here described. A complete overview of reported interactions about the issue groundwater salinization is shown in chapter 7.1.3 (Social interaction map).

Impacts of a network on an individual organisation

Impacts of a network for example A were neither indicated nor mentioned. However, the reported example B stands in connection to the growth of intellectual capital. The interviewed actor reported throughout the participation within a research project he learnt that groundwater recharge plays a key role to maintain a hydrostatic pressure with

regards to sea level rise. This insight was communicated and experienced throughout project partners and scenario models (C.1; l. 275-285; 320). The reported NAWAK research project is in this thesis considered by definition as a network. It is a formal temporary established network. It connected actors (project partners) with diverse professions and different field of interests with emphasis on a specified topic. The collaboration of project partners facilitated interaction in the context of the issue groundwater salinization. *"There, intensive knowledge exchange took place"* (C1; l. 281-282).

Impacts of an individual organisation on a network

As outlined above, the adaptive measure of the interviewed actor is about improving the capacity to provide expertise relevant for consulting in the field of water resource planning. This measure is here recognized to create an impact within the network in which the NLWKN is engaged throughout the interviewed actor.

Regarding example 'A' for adaptive measures, the NLWKN artificially facilitated relational practices relevant for adaptive measures. The NLWKN communicated actively experienced and distributed the information within its network. *"We disseminated the results of our research projects within our region. We targeted especially water supply companies, who were not project partners, so they can somehow participate"* (C.1; l. 324-317). The NLWKN pursued the working objective to gain *"system knowledge"* relevant to better target the issue of salinization (C.1; l. 134-161). Therefore, the interviewed actor is connected to several actors in the field of research to pursue this task. As a follow up, he provided the research results to a diversity of actors. Water supply companies, districts, technical experts (engineering agencies) and partner and colleagues were part of this network (C.1; l. 676-680). *"This action serves to create awareness among colleagues and partner for those topics"* (C.1; l. 676-677). Thus, his network was updated from the latest insights, so they can adapt to changes within their context accordingly. That way the NLWKN mediated their experiences such as knowledge or research results in a planned manner. The interviewed actor further highlighted that he actively maintained intensive knowledge exchange (interaction) throughout his network (C.1; l. 676-680).

With these activities, a relational practice was created. The actor enabled his network partners to become more knowledgeable and created therefore intellectual capital among his network. Thus, the NLWKN is recognized to inhabit a proactive role to generate adaptation measures within their network partners. If his actions contributed to

adaptive development within his actor's network or not, was not declared by the interviewed actor. It can be assumed that those reported actions pointed into this direction.

The emphasized active role of the NLWKN towards adaptation can be also recognized at another referred example in the field of water-legislative procedures the permission for supply companies to withdraw and supply water must be renewed every 30 years (C.1; l. 210-220). Based on this background the preliminary focus of the NLWKN was to include the whole federal state Lower Saxony and not selected points only (C.1; l. 225; l. 466-48). With perspective to future challenges, system knowledge and technical expertise were used to *"influence the direction"* of the water-legislative procedure (C.1; l. 225). Example were given about the location of wells, its depth range and amount of planned extraction of groundwater (C.1; l. 222-225). *"In those procedures"*, the NLWKN maintained therefore "*very intensive interactions"* to water supply companies and stakeholder involved within water-legislative procedures (C.1; l. 246-255). Concluding these aspects, the role of the NLWKN is interpreted to create an impact within its network. Based on the creation of intellectual capital (i.e. network partners were targeted to become more knowledgeable) the creation of shared information and information flows is argued to build political capital, relevant to influence the definition of points of view.

The referred impact of the individual organisation on network level was here revealed within the cross-case analysis. All three interview partner from the LBEG, Kreislandvolkverband Wesermarsch and Water Supply company Wesermünde mentioned independently from each other that the NLWKN is a provider of relevant information (C.2; l. 98-119; C.3; 310-317; C.4; l. 398-403). Throughout the NLWKN, the connected partners have gained awareness about the topic of salinization, gained deeper knowledge or received results or insights from research projects (appendix overview). Thus, the impact of the NWKN on its network can be recognized to create intellectual capital within its connected actors.

7.1.2 The occupation of the capacity to operate models to draw scenarios as an adaptive measure (Case 1.2)

Another exemplified adaptive measure was reported by the interviewed actor. He stated that he recognized that an operation of a particle transport model is relevant for the work of the NLWKN (C.1; l. 305-324; 701-718). It is considered to draw more precise scenarios as it describes the transport of substances dissolved in water. The result of a

transport simulation is the temporal and spatial course of substance concentrations in groundwater. Transport models are used to interpret measured concentration data to account for the presence of pollutants in the environment, to predict the spread of water pollution, to plan and develop hydraulic defense and remediation procedures, to plan exploration and surveillance programs and to assess risk in contaminated site assessment and location selection (Spektrum Akademischer Verlag, n.d.). Therefore, the next job occupation within the NWKN should entail workforces that bring in the technical skills to operate such transport models. The planned adaptive measure is here associated with the objective to create additional value for the provision of knowledge and expertise.

7.1.2.1 A double-loop learning outcome

The planned adaptive measure of the next job occupation within the NWKN should entail workforces with technical skills to operate such transport models which is here recognized as a double loop learning outcome. Double-loop learning indicates changes in the organization's knowledge and competency base by reframing problems. This leads to developing new policies, objectives or mental maps (Snell and Man-Kuen Chak, 1998).

The actor learned throughout a research project (NAWAK project) new technical approaches, such as a particle transport model relevant to track salt substances within aquifers on a volume and time scale (C.1; l. 305-324; l. 707-715). The application of this technic was acknowledged as new and highly relevant for the work of the NLWKN (C.1; l. 707-715). With this insight, the interviewed actor recognized that besides the distribution of system knowledge, system knowledge supports the operation of those models further assists the NLWKN to gain better expertise in the field of water resource planning (C.1; l. 305-324; 701-718). The models can be used for the planning of groundwater bodies and for the assessment of risks of salinisation at certain localities. From the perspective of the NLWKN, the problem of salinisation became reframed in terms of planned changed practices. Salinisation can not only be dealt with system knowledge, but system knowledge can be further used to support the application of technical expertise to model salinisation developments. Thus, salinisation can be better dealt with in terms of planning.

However, the know-how and the technical groundwork to apply such models were considered to involve extensive knowledge that cannot be gained throughout project partners or students. This expertise was therefore recognized that a new job occupation

within the NLWKN can cover this new objective (C.1; l. 709-718). Hence, expectancy was placed on the next generation of employees within the NLWKN (C.1; l. 709-718).

7.1.2.2 The role of specific networks traits for building adaptive capacities

The following section describes the revealed impacts of a network on the individual organisation in connection to the adaptive measure described in chapter 7.1.2. Impacts of the organisation on its network were not reported. The description entails the perspective of the interviewed actor, hence, only the impacts of and from the actor's network are here described. A complete overview of reported interactions about the issue groundwater salinization is shown in chapter 7.1.3 Social interaction map.

Impacts of a network on an individual organisation

The contribution of networks to build learning outcomes relevant for adaptive measures is here recognized in connection to build the notion to employ workforce for the operation of a particle transport model. The interviewed actor learned that technical skills for modelling and know-how for such operation require a whole job occupation. This relevant conclusion was made within the gained experiences throughout the research project (NAWAK project) (C.1; l. 305-324; l. 707-715). The NAWAK project was a network by definition. It is a formal temporary established network. It connected actors (project partners) with diverse professions and different field of interests which facilitated interaction in the context of the issue groundwater salinization. They approached the issue throughout the operation of different scenarios about climate change which was processed throughout interaction of the project partner about the topic. In a formal frame the interviewed actor learned about the development of scenarios and the use of technical approaches such as a particle transport model relevant to track salt substances (C.1; l. 305-324; l. 707-715). The knowledge and know-how, however, was communicated by the project partners to which the NLWKN was connected. *"There, intensive knowledge exchange took place"* (C1; l. 281-282). Thus, the interviewed actor drew conclusions for adaptive measures in this regard (C.1; l. 305-324; l. 707-715). *"Every project has yet resulted into an improved system knowledge or closed knowledge gaps. You get to know new technics and learn how to apply them like the particle transport model for salt, I mentioned. That has been the first time that we applied and used this model"* (C.1; l.701-705).

Thus, the research project facilitated a relational practice relevant for adaptive measures. The project structure pursued the mediation of research results (i.e. experiences) in a planned manner by actively get together diverse project partners (i.e.

actors) to facilitate knowledge exchange (i.e. interaction). Thus, the formally established network facilitated intellectual capital**.** The learning outcome of the NLWKN in this case was the recognition of the relevance to operate models in their daily business.

7.1.3 Social interaction map

The following map shows the revealed interactions of the interviewed actor made with organisations, groups, individuals and formally established networks. Based on the literature review (compare chapter 6.2.1 and results in appendix 10.5), the outlined categories distinguish between formal and informal contacts and further differentiates between field of interests to exemplify diversity of resources, e.g. knowledge, physical resources or capacities based on the business field.

NLWKN		
	Formal/daily business	Contacts based on additional informal/ business/ efforts
Water Quality		
Lower Saxony Water Management, Coastal Defense and Nature Conservation (NLWKN)		Disseminated information to other colleagues within the NLKWN.
Part of the NLWKN: Hydrological Land Service (GLD), *Gewässerkundlicher Landesdienst*	Together, they issued statements of relevance for water management	
Water Supply Companies Wasserversorgungsunternehmen (WVU)	Supervision of WVU, maintained intensive partnerships for data exchange	Explicitly referred to the OOWV for being an important project partner (NAWAK). Shared insights and knowledge from the project NAWAK to other WVU.
Subordinate Water and soil protection authorities are the administrative districts	Daily business contact to issue statements of small relevance for water management	
Nature Conservation		
Lower Saxony Water Management, Coastal Defence and Nature Conservation (NLWKN)		Deliberated with the department for the subject of groundwater extraction to protect dune valleys.
Research, expertise and consulting		
Lower Saxony State Agency for Mining, Energy and Geology (LBEG)		Scientific knowledge exchange, because the LBEG was considered to be engaged in fundamental research
Universities/ Research Institutes		Gained knowledge through students along with their master thesis projects. The Lichtweiß Institute at the University Braunschweig had been a scientific partner in the project NAWAK. Students from the University Wilhelmshaven and University of Applied Sciences Emden delivered useful information.
Engineering agencies	Regular contact with consultants for small business matters. They inquire the GLD for data which are edited in turn for their clients, the WVU.	
Associations, projects or working groups (recognized as formal networks)		
NAWAK, project		Had been a project partner

KLIWATT, project		They delivered data, but interviewed actor was not further involved.
Drinking water protection cooperations - Working groups	Accompanies these cooperation by providing information and for monitoring	Shared informally some information about groundwater salinization.

Table 7: Social interaction map of the NLWKN circled around the topic groundwater salinisation (own compilation)

7.2 Case 2: State Authority for Mining, Energy and Geology (LBEG)

7.2.1 New mapping methods as an adaptive measure for improving information dissemination

The official task (i.e. institutional rule) of the LBEG respectively the Hydrological Land Service is to supply maps serving the public interests. According to the interviewed actor, an experience of accumulated demand for more map details with regard to groundwater salinization have been made in 2010. The demand was communicated by various organizations (local authorities, engineering companies and water supply companies). This has led to further elaborations on the communicated issue to supply a map that features more details.

Consequently, new technical approaches had been searched. In 2012, a new technical approach was found within the national research institute LIAG (Leibnitz Institute for Applied Geophysics). The increased demand in 2010 and the discovery of an approach in 2012 were a reported *"starting signal"* to formally deal with the topic groundwater salinization within the LBEG hydrology working group in the year 2012 (C. 2; l. 561 – 598). The LBEG hydrology working group found with the LIAG institute a research partner and started a pilot-project. Students of the University Hannover were recruited for their master thesis to investigate whether the data derived from airborne geophysical methods can be interpreted in the study field groundwater salinization or not. The objective was to reveal if data could be used to for mapping purposes. Considering to the taken adaptive measure, the objective of the LBEG is recognized to improve the dissemination of information.

7.2.1.1 A double-loop learning outcome

The setup of a new mapping method to better illustrate groundwater salinization in Lower Saxony is here considered as adaptive measure to improve the dissemination of information. This measurement was a result of experiences and interactions which were processed by the interviewed actor. The outcome of the development is here recognized as a result of a double loop learning effect. The taken adaptive measure indicate changes in the organization's knowledge and competency base as a problem became reframed

(Argyris & Schön, 1978; Snell & Chak, 1998). Further, a double-loop learning outcome is based on any reported error detection that lead to corrections which involve the modification or development of an organization's objectives.

The background is here that the LBEG supplies maps to serve the public interests. The development of new mapping techniques is here recognized as a modification of the organization's objective and competencies. The underlying new objective is here recognized to improve the dissemination of information with more details. The prevalent map from 1980 showed at a scale of 1:200.000 which was experienced to be *"too broad for planning purposes"* C. 2; (l. 57-58). *"On the one hand the scale of the map is not good and on the other hand the outlined units to catalog groundwater salinization is not very fortunate"* (l. 52-53). This conclusion was drawn by previous interactions with *"local authorities, engineering companies and water supply companies"* (C. 2; l. 590-591) as "*they questioned more often the interpretation of the prevalent map and its details like what does salinization of the lower part of the groundwater aquifer mean and so on."* (l.567-569).

The drawn conclusions from those interactions are here considered to be pivotal, since the reported operational rule of the organisation LBEG did not allow to follow any topic of demand since the provision of task force is limited and should be concentrated (C. 2; l. 585- 597). The desired outcome that the map needs to serve public interests revealed a mismatch. Hence, the underlying assumption that the map from 1980 should serve these interests was reconsidered. The outcome of this reframed problem led to changes in the organization's **competency** as new a technical approach was applied that show more detailed features. The new technical approach is about data which were derived from airborne geophysical methods that were used to map salinization in groundwater in Lower Saxony.

7.2.2.2 Revealed network characteristics in connection to their role towards adaptability

The following section describes the revealed impacts of a network on the individual organisation in connection to the adaptive measure described in chapter 7.2.1. Impacts of the organisation on its network were not reported. The description entails the perspective of the interviewed actor, hence, only the impacts of and from the actor's network are here described. A complete overview of reported interactions about the issue groundwater salinization is shown in chapter 7.2.2 Social interaction map.

Impact of a network on an individual organization

The contribution of networks to build learning outcomes relevant for adaptive measures is here recognized in the connection of two incidences that led to the development to setup a new mapping method to better illustrate groundwater salinization.

One incident is that networks triggered a starting signal for the development of adaptive measures. The demand came from diverse social interactions with *"local authorities, engineering companies and water supply companies"* (C. 2; l. 590-591). The interviewed actor understood other perspectives and became more aware about the problem. Thus, the actor's network facilitated the growth of social capital into intellectual capital as the interviewed actor started to reconsider the supplied map information and lead to the cognition to work on new mapping methods. The quality of these interactions was based on the factors frequency *"accumulation of demand"* (C. 2; l. 566-568) and diversity of actors as "*local authorities, engineering companies and water supply companies"* were mentioned (C.2; l. 566). There was no difference whether these interactions were based on a formal or informal frame (compare 7.2.2 social interaction map).

The other incident refers to the connection between the role of networks and the progress of building adaptive measures: The search and discovery for a new technical approach for mapping was pursued throughout interactions connecting with various actors. The connection to the LIAG research institute represented a bridging tie for LBEG. The LIAG institute had resources and connections which were relevant information and capacities for the LEBG. The LIAG was active in a research project (i.e. BurVal project) that dealt with geophysical methods to gauge structural and hydrological properties of deeper groundwater resources. In that matter, the LIAG institute provided the LBEG access to information (C.2; l. 82-88). The whole search and discovery process was undertaken by the interviewed actor to find better mapping methods. It is here regarded as a trial and error process. *"And then we started to look after new technical approaches. We found an approach within the Geocenter LIAG and started therefore a pilot project for which we utilized a few master theses from students of the University Hannover. There, we tested, if this technical approach is applicable for groundwater salinization in Lower Saxony"* (C.2; l. 571-575). The success of the discovery of a new technical approach was the result of social interactions and experiences that progressed the intellectual capital of the interviewed actor. The success of the result enabled the hydrology working group of the LBEG to map state-wide groundwater salinization in the year 2014 (C.2; l. 561 – 598).

The interviewed actor as an individual in connection to his network performed a pivotal role for the institutional performance to build adaptive measures. On the one hand, the interviewed actor established a relational practice as he selected actors within his network to perform this trial and error process. The experiences were made interdependently from the interactions and built intellectual capital. Thus, the progress of development for the aimed adaptive measure reflected the relational practice of interdependence. On the other hand, the interviewed actor occupied the role of an interface between the network in which he was engaged and the institution in which context he developed adaptive measures. He recognized the need to act and translated the conclusion into tasks for the LBEG. This reveal is drawn in consideration that the institutional rule of the LBEG permitted work force only to issues of priority. *"Since our possibilities are not endless and we cannot cover all topics, even though there are many fields, we must concentrate on our resources. So, we choose one field, that covered many interests and demands. That is why we do work on the topic of groundwater salinization."* (C.2; *(l. 591-98)*.

7.2.2 Social interaction map

The following map shows the revealed interactions of the interviewed actor made with organisations, groups, individuals and formally established networks. Based on the literature review in chapter (compare chapter 6.2.1 and results in appendix 10.5), the outlined categories distinguish between formal and informal contacts and further differentiates between field of interests to exemplify diversity of resources, e.g. knowledge, physical resources or capacities based on the business field.

LBEG		
	Formal/daily business	Contacts based on additional informal/ business/ efforts
Water Quality		
Lower Saxony Water Management, Coastal Defense and Nature Conservation (NLWKN)	LBEG recognized that salinization is a topic that has to be further dealt with by the NLWKN.	Stood in contact for knowledge and experience exchanges. LBEG gained information about projects (e.g. NAWAK).
part of the NLWKN: Hydrological Land Service (GLD)	Exchanged data exchange with the GLD LBEG formally collaborates with the NLWKN to issue statements of relevance for water management and water-legislative processes. The GDL requires maps of the LBEG.	
Water Supply Companies Wasserversorgungsunternehmen (WVU) e.g. Wasserverband Wesermünde, Oldenburgisch-Ostfriesische Wasserverband		Following WVU were kept in mind for being in contact regarding the topic salinization for research and data exchange: OOWV, Inercity Stadtwerke Hannover; WVU were demanding on more details

(OOWV)		groundwater salinization.
Subordinate Water and soil protection authorities (UWB) are the administrative districts	Provide advisory to UWB about complex hydrogeology tasks. If measures reveal changes of the quality in the groundwater LBEG informs UWB.	UWB were demanding on more details groundwater salinization. Recognized that salinization is a topic for the UWB and that they are already dealing with it and that they are aware of the issue
Regional Development		
Lower Saxony Ministry of Food, Agriculture, Consumer Protection and Development (ML)		Recognized that the Ministry is aware of the problem groundwater salinization.
Local and regional planning authorities		Recognized that they are aware of the problem groundwater salinization
Research, expertise and consulting		
Federal Institute for Geosciences and Natural Resources (BGR)	Received raw data from the BGR derived from airborne geophysical methods to evaluate them to map salinization	
(LIAG) Leibniz-Institute for Applied Geophysics		Gained information about the BurVal pilot project
Universities/ Research Institutes		Carl von Ossietzky University, Oldenburg: Attended to scientific events as the from the NAWAK project (reported was the connection to the actor Mr. Siebenhüner) and made connections and data exchange for the Saltsa project (reported was the connection to the actor Mrs. Massmann) Leibniz University Hannover: Gained knowledge through participating students along with their master thesis.
Engineering agencies	The LBEG have been checking the water balance calculations of the specialists. Calculations are needed in the framework of water permitting for estimating groundwater withdraws.	Engineering agencies posed a demand on more details on groundwater salinization.
Associations, projects or working groups (recognized as formal networks)		
TopSoil, project	Produced together with LIAG models on groundwater currents	Project partner turned out to be useful contacts for learning new methods.
Aerogeophysik, project		Revealed data were useful for new approaches to map salinization.
NAWAK, project		LBEG got invited to be a guest speaker.
BurVal, project		Learned about how to gain data through a new method, useful for the follow up project Aerogeophysik. However, LBEG was no partner, but has learned about the method through the connections with LIAC.
SaltSa, project		Started to have contact for data exchange
SWIM - Salt Water Intrusion Meeting		Was aware of the meetings, organised one by himself, considered to be useful to recognize people
ARGE North Germany Working Association of Geologists		Attended to meetings once a year to exchange experiences. Working group is considered to be relevant as it is viewed to be diverse by its participants.
DVGW German association of gas and water with its working group on groundwater salinization		Recognized the DVGW working group on groundwater salinization for expertise, but considers them as an inactive connection as no exchange has been taken place recently.

Table 8: Social interaction map of the LBEG circled around the topic groundwater salinisation (own compilation)

7.3 Case 3: Water supply association Wesermünde

7.3.1 Methodological improvements for maintaining water supply (Case 3.1)

The interviewed actor, who is the director of that water supply company, pointed out methodological improvements as adaptive measures which were taken within the qater supply association. One was about mixing extracted water from different sources to dilute prevalent salt concentrations for the supply of water in good quality. The other was about to change the setting of the wells in terms of location or their depth range. The latter methodical approach was based on improved measurement technics. In this connection, the actor pointed out an experience in 2008 that has led to this development. He reported that in the north of their supply area (in Bederkesa) extracted water showed increased salt concentrations (C.3; l. 28-35). For that reason, he and his colleagues started measurements to reveal the transition zone between fresh and salt water in the groundwater body through (induction-logging) measurements. As he recognized that the transition zone has been located within a certain depth reaching over a whole area, he further complemented the measurements. He introduced geophysical methods to observe upconing effects within along the whole withdrawing area in the years 2013 and 2014. These measures were taken with the knowledge background that the closer a well is placed to a transition zone between freshwater and saltwater, the higher the risk of salinization, because of caused pressure differences by the wells. To prevent an upconing effect the depth of the wells for water extraction were shortened as old wells were shut down and new wells were set up (C.3; l. 53-60). So, the distance between the transition zone and the well have been increased. To maintain this status, every three to four years he resumes this investigation to locate the transition zone. However, in the case of Bederkesa, another technical example of an adaptive measure was taken. Hereafter, the water supply association mixes the saline water with other fresh waters from other operation areas, so that the supplied water conforms the Drinking Water Ordinance (C.3; l. 110-113).

7.3.1.1 A single-loop learning outcome

The applied adaptive measures were largely based on the problem detection of salinization within the groundwater body of the supply area which led to monitoring and adjustments of the well arrangements. This is here regarded as single-loop learning outcome. Henceforward, an iterative improvement of the organisational actions took

place. This learning outcome is here recognized to be a result of the experienced based learning domain. Here, mainly the biophysical conditions (figure 5, p. 25) were recognized to be a factor for the learning outcome. The interviewed actor only referred to the drivers, pressures, states and impacts of groundwater salinization (C.3; l. 47-51; 103-108). For this learning outcome, no social interactions for the context of this adaptation measure were mentioned in this reported example.

7.3.2 Openness and information dissemination as an adaptive measure for maintaining fresh water supply (Case 3.2)

The interviewed actor pointed out an additional adaptive measure which was about sharing his knowledge and experiences with actors of his network. The objective he followed is to convince his network to maintain water in groundwater bodies in good quality. He reported keen interests that other water supply companies, water and technical authorities and other actors should become aware of the risk of salinization, so that they can introduce adaptive measures, too (C.3; l. 311- 314; 371-386; 394-397). Moreover, he actively searched for affected parties to exchange and gain deeper knowledge (C.3; l. 363-367).

In one example (A), he informed the NLWKN about the issue of salinization in groundwater and demanded that they should do anything about it (C.3; l. 231-233). According to him, this has happened at a time before the NLWKN was active in that field (C.3; l. 231-233).

In a second example (B) he further exemplified that throughout interactions in which he informed other water supply companies about his adaptive measures. As he informed about his methodical improvements (see chapter 7.3.1) to supply water in good quality with the help of technical measurements (through induction-logging measurements and geophysical methods), the interests had grown for his applied technical approach to locate the salt-fresh water transition zone. He recognized in this connection that *"applying new methods can enable someone for new dimensions for adaptive measures."*(C.3; l. 382-386). That is why he shared his knowledge.

Within a third example (C), he communicated in working groups about economic drivers and resulting pressure factors that are pose additional impacts for quality of groundwater (C.3; l. 302-305). He highlighted the intrusion of fertilizers and interconnected those impacts with the impacts of groundwater salinization. He underlined the sum of these factors to be back-breaking (C.3; l. 255). To achieve a relief

of one of those pressure factors, he disseminated information and to talked openly about the impacts of the agricultural sector on the quality of groundwater. All these exemplified measures of the interviewed actor aimed to activate actors associated to natural resource governance to develop adaptive measures (C.3; l. 273-275; 302-205).

7.3.2.1 A double-loop learning outcome

The actions taken by the actor are here recognized to be the result of a double-loop learning outcome. Double-loop learning is denoted on reframing values within current mental models.

Regarding the third outlined example (C), the interviewed actor reframed the problem of groundwater salinization within a greater context. The factor of an inland moving transition zone between fresh and salt waters triggered by sea level rise was recognized to be a pivotal pressure factor (C.3; l. 184-191). Additionally, he concluded that the problem of coastal saltwater intrusion is out of his influence for his organisation. *"Our company has not the possibility to bring this development into a halt."* (C.3; l. 420-422). As already outlined, his adaptive approach is to withdraw water with greater distance to the transition zone. This means that water from the upper part of the waterbody must be withdrawn. Here, additional experiences contributed to reframe his objective that resulted into convincing actors in his network to maintain water in the upper levels in groundwater bodies in good quality.

The interviewed actor made the experience that water in these upper levels of the groundwater are prone to metabolite which are residual substances from fertilizers (C.3; l. 62-67). Thus, he associated those pressure factors to a so called 'sandwich' problem situation regarding the decreasing scope to withdraw groundwater (C.3; l. 253-258).

Further, he also highlighted that some water supply companies do not communicate openly about problems of those substances (C.3; l. 265-268; 272-283). This aspect is here recognized to expose an attribute community that is experienced throughout social interactions (C.3; l. 265-268; 272-283). He saw the reason for this attribute in the political arena. *"And the major of the municipalities and towns are part of our board members. They get informed about such subjects. And they are very restrained with such subjects, especially with regards to nitrates"* C.3; l. 290-292), *"[…] because the majors become elected by people, who are from the agricultural sector"* (C.3; l. 289-298). So, the agricultural sector was perceived by the interviewed actor to have great influence.

Based on this greater context he defined his point of view that it was very important to communicate openly about the issue of metabolite so that adaptive measures can be taken (C.3; l. 273-278; 302- 305; 353-355). Within this conception, the actor reframed the problem of groundwater salinization within a greater context. He interconnected the impacts of fertilizers with the impacts of groundwater salinization. Both impacts were recognized to pose a threat for the water quality. However, the intrusion of metabolite was recognized for counteractive measures to gain a greater scope to withdraw groundwater in good quality since coastal saltwater intrusion was recognized to be out of his institutional influence (C.3; l. 420-422).

7.3.2.2 The role of specific networks traits for building adaptive capacities

The following section describes both, the revealed impacts of a network on the individual organisation and the impacts of the organisation on its network in connection to the adaptive measure described in chapter 7.3.2. The description entails the perspective of the interviewed actor, hence, only the impacts of and from the actor's network are here described. A complete overview of reported interactions about the issue groundwater salinization is shown in chapter 7.3.3 Social interaction map.

Impact of a network on an individual organization

The contribution of networks to build learning outcomes relevant for adaptive measures, was in example (C) in connection to the experienced attribute of the community that was experienced throughout social interactions (C.3; l. 260-268; 272-283). The KOWAS cooperation (Kooperation der Wasserversorgungsverbände Elbe-Weser-Raum) which is a cooperation between water supply associations in the Elbe-Weser area and other water supply associations Wasserverband Wesermünde Nord and the OOWV (Oldenburgisch-Ostfriesischen Wasserverband) were mentioned in connection to exchange information and gaining deeper knowledge (C.3; l. 363-367). The interviewed actor is a member in the KOWAS cooperation. The meetings take place four times a year which was considered to be intensive (C.3; l. 206-223).

Therefore, in terms of network characteristics of these interactions, intensity of interaction and homogeneity actors regarding their business fields were pivotal to draw the experience about the attribute of the community (C.3; l. 391-397). His interaction network facilitated the development of social capital into intellectual capital. Here, other perspectives were understood and the interviewed actor became more knowledgeable about the background why his interaction partners were not open about the problem of fertilizers (C.3; l. 260-268; 272-283). In connection to the topics saltwater intrusion and

the intrusion of fertilizers in groundwater bodies other groups were mentioned. He referred to the Water Association Council (Wasserverbandstag) and to working groups installed by the German Association of Water and Gas (DVGW) to be in continuous information exchange. Into those working groups external experts from other business fields (i.e. experts from the Lower Saxony Chamber of Agriculture, NLWKN, LBEG) were invited. Within this diverse interaction network, the same experiences were also made that those associations do not communicate openly about the intrusion of metabolite (C.3; l. 304-305). To conclude, the quality of interactions indicated both, a diversity and homogeneity of connections within his network. Both attributes enabled the interviewed actor for the recognition (i.e. intellectual capital) about the attribute of the community that was then perceived in connection for inducing the decline of water quality of groundwater. The intellectual capital contributed the interviewed actor within his institutional context to approach adaptive capacity. His adaptive measure, as a director of the water supply association, was about the open dissemination of knowledge and experiences to convince actors within the natural resource governance system to counteract the decreasing scale for groundwater with good quality.

In another example (B), he exemplified to network with affected actors to exchange more intensively about experiences. Throughout interactions in which he informed other water supply companies about his adaptive measures regarding saltwater intrusion he mentioned that the interests had grown for his applied technical approach to locate the salt-fresh water transition zone. *"Applying new methods can enable someone for new dimensions for adaptive measures"* (C.3; l. 382-386). The exchange of information and the understanding of each other was recognized as social capital targeting the development of intellectual capital.

Impacts of an individual organisation on a network

As outlined above, the adaptive measure of the interviewed actor is about dissemination of knowledge and experiences. This measure is here recognized to create an impact within his network, so that his interaction partners apply adaptive measures to counteract the decreasing scale to withdraw groundwater with good quality.

In the example C of the outlined 'sandwich' problem situation, the interviewed actor aimed to approach the development of political capital to develop shared heuristics and information. The composition of the intrusion of fertilizers and the impacts of groundwater salinization was perceived to decrease the scale to withdraw groundwater in a good state, that is why he defined actions to address pressure factors (i.e. emission

of fertilizers) driven by the agricultural sector. Pointing out the role of the agricultural sector towards their impacts was recognized to resolve the one of the pressure factors since the salinization by the sea was recognized to be out of influence in this context (C.3; l. 420-422). Thus, addressing the role of the agricultural sector is a way to create active influence. *"We always tell the water supply companies and associations, that they have to be more active and inform the public. They should not be restrained to communicate this problematic subject"* (C.3; l. 303-304). He tried to encourage his interaction partners (KOWAS cooperation and the working groups of the DVGW and the Water Association Council) to publicly talk about the issue. Whether an impact was created that way or not was not shown. However, he mentioned the case of tightening of the Fertilization Ordinance. *"The reason for the change is because state control had been in the past too loose in connection whether farmers remained within the requirements of the Fertilization Ordinance or not. The Fertilization Ordinance became tighter, because it had been not sufficient in the past"* (C.3; l. 507-510). Whether his actions contributed to this development can be only argued, but not proved by mentioned evidence. It is yet certain that his actions pointed into this direction for adaptive measures.

In example B, he exemplified to a network with affected actors regarding saltwater intrusion. He referred that he triggered an impact among his network for the creation of adaptive measures. He informed other water supply companies about his applied adaptive measures to which he recognized growing interests about his technical expertise. *"And the showed interests have been big for such technical measures. They now consider using such technical approach for themselves, because it is a relative easy approach that needs relative little efforts"* (C.3; l. 379-380)

In example A the interviewed actor informed the NLWKN about the issue of salinization in groundwater and demanded that they should do anything about it (C.3; l. 231-233). In this context, he mentioned that the NLWKN was inactive in the field of groundwater salinization induced by climate change, until they started a research project (C.3; l. 231-233). Here, a direct connection of his request initiating adaptive measures of the NLWKN was not revealed. Still, evidence was revealed in another context. Next to the NLWKN, the interviewed actor mentioned that he was in continuous exchange with the LBEG and talked about the issue of coastal salinization. The impact of the individual organisation on network level was here revealed within the cross-case analysis. The LEBG developed adaptive measures based on the accumulation of

demands to deal with groundwater salinization in more detail was pivotal. In this connection, the adaptive measure of the LEBG was triggered by the intensity of requests of water supply companies amongst other actors. Thus, the interviewed actor is here recognized to contributed an impact within his network.

7.3.3 Social interaction map

The following map shows the revealed interactions of the interviewed actor made with organisations, groups, individuals and formally established networks. Based on the literature review in chapter (compare chapter 6.2.1 and results in appendix 10.5), the outlined categories distinguish between formal and informal contacts and further differentiates between field of interests to exemplify diversity of resources, e.g. knowledge, physical resources or capacities based on the business field.

Water Supply Association Wesermünde Wasserversorgungsverband Wesermünde		
	Formal/daily business	Contacts based on additional informal/business/efforts
Water Quality		
Lower Saxony Water Management, Coastal Defense and Nature Conservation (NLWKN)		Got informed by the NLWKN about a project that is about coastal salinization. Informed the NLWKN about groundwater salinization in order to progress on that topic
Water Supply Companies Wasserversorgungsunternehmen (WVU)		Following WVU were kept in mind considering the issue: Land Hadeln and the OOWV for knowledge exchange. The OOWV was reported to be active and well informed.
Subordinate Water and soil protection authorities are the administrative districts	The authorities demand data about groundwater bodies. Subordinate water authorities enable a participation in decision-making processes, when other businesses apply to extract groundwater.	
Flood Protection		
Water and soil associations (WVG) e.g. Kreisverband der Wasser- und Boden- verbände		Recognized that the land associations have influence on the groundwater level, thus, on groundwater recharge as they pump away rainwater.
Agriculture		
Lower Saxony Chamber of Agriculture	Had contact with them through a working group within the drinking water protection cooperations and communicated the problem of metabolite	
Research, expertise and consulting		
Lower Saxony State Agency for Mining, Energy and Geology (LBEG)		Gained information through maps and data
Associations, projects or working groups (recognized as established networks)		

DVGW German association of gas and water (Deutscher Verein des Gas-Wasserfaches) with its working group on groundwater salinization	Provide a set of rules which WVU have to obey. WVU has to elaborate a risk management plan that considers groundwater salinization. DVGW provides technical support.	Contact is based on meetings (4 times a year). Meetings are considered to be platform to talk about political capital, nitrate pollutants and other issues.
Water Association Council *Wasserverbandstag Hannover*		Holds membership. Talked about the issue of metabolite in groundwaters
KOWAS (cooperation of WVU in the Elbe-Weser area)		Is member of the cooperation. Meetings were used to exchange information for methodical approaches.
Drinking water protection cooperations - Working groups	Talked openly about the role of metabolite in connection to groundwater salinization that they decrease the scale to withdraw water in good quality together with groundwater salinization	

Table 9: Social interaction map of the Water Supply Association Wesermünde circled around the topic groundwater salinisation (own compilation)

7.4 Case 4: The rural population district association Wesermarsch (Landvolk - Kreisverband Wesermarsch)

7.4.1 Gaining new knowledge and mobilizing affected stakeholder as an adaptive measure for defending agricultural interests

The interviewed actor, who is the managing director, reported several adaptive measures which were taken within the association, but he also referred to adaptive measures which had been subsequently activated by the association. The adaptive measure which was taken within the association, was about the development of new knowledge for defending agricultural interest and mobilizing potentially affected stakeholders. The background was a public participation occasion within the decision-making process for the plan to deepen the lower Weser river to improve the waterway for the shipping industry. As the association became involved in that planning process, the association started to question the communicated impacts. As a result, intensive connections have been activated to investigate the planned condition towards estimated impacts. The consequence was the activation of the development to gain of new knowledge to respond to the planned river deepening. The achievement of the new knowledge was relevant to achieve the capacity to defend the interests of the association. Throughout this development, the context specific objective of the association evolved which was about to maintain agricultural land and fresh water resources for cattle breeding.

As a result, the planned action of the Weser river deepening became rejected as formal objections had been raised by the association, who mobilized potentially affected farmers and landowners. The rejection based on the lack of considered impacts. As a

follow up of this process, the plan of a river deepening must now consider salinization specific compensation measures within its implementation. *"As a result, a planning association was created and managed by the Lower Saxony Ministry of Environment. This planning association has the task to create and execute an irrigation plan that transports fresh water from the south of the Wesermarsch to the north of the area. That is the result of our rebellion, also because we said that we do not want to prevent a river deepening per se, but we want our problems to be solved"* (C.4; l. 268-272).

7.4.1.1 Third loop-learning outcome

The interviewed actor referred to his learning outcome a reconsideration of his beliefs in context of the impacts the lower Weser river deepening would cause. *"Once we started questioning, we figured different views and statements"* (C.4; l. 224-226). The turn towards this appraisal was the result of learning outcomes based on actions that have been taken and connections that have been made by the actor. In terms of learning outcomes reconsideration of beliefs and values are here associated to highly intensive learning processes which is considered as third loop-learning outcomes (Argyris & Schön, 1978; Flood & Romm, 1996). This is also referred by the actor, who considered "*the appraisal of new conceptions is a result of dealing with a subject in an intensive manner" (*C.4; l. 226-228).

The development of a third-loop learning outcome is traceable in learning stages by the reported background story. As the plan of a river deepening got publicly accessible in 2005, the actor first mentioned his first impression that there will be no problematic impacts relating to saltwater intrusion in the district of Wesermarsch. This impression was created by the report of the expert opinion for the planned action. *"And then our people questioned the report whether it is true. So, we replied: 'we are going to check that'"* (C.4; l. 220-222). This hint marks the transition of a single-loop learning outcome to a double loop learning outcome. The first stage of a learning outcomes (single-loop learning outcome) marks the participation at the decision-making process because of the duty of the association. The duty is about representing the interests of farmers and land owners. Representing them in this decision-making process indicates an enlarging the range of actions with the same routine (Argyris & Schön, 1978; Sabatier, 1988).

The transition into a double-loop learning outcomes symbolizes the reframe the problem as he questioned the statements of the expert report which have led to the modification of the association's competencies and knowledge (Argyris & Schön, 1978). Background

is here, that these working tasks were usually not occupied by the association within their daily business: *"That is not our day-to-day business. Our business is particularly different. However, we are stipulated through such topics like these. So, we have to check questions like 'what happens if?' and 'what is the result?'"* (C.4; l. 215-218). The act to gain new knowledge about the question whether a river deepening causes impacts on the salt concentrations or not marks the last stage of the learning outcome (triple-loop learning outcome).

Hereafter, a paradigm change occurred as the beliefs about the impacts of the plan have been reconsidered and revised by the actor (Flood & Romm, 1996). Throughout social interactions with various actors and groups of actors the interviewed actor enriched his experienced based learning domain in context of groundwater salinization. Thus, he gained deeper knowledge. Further, he also denoted that he also learned how to proceed as a stakeholder in context of public participation processes in planning contexts (C.4; l. 215). Throughout this development, the context specific objective of the association evolved which was about to maintain agricultural land and fresh water resources for cattle breeding (C.4; l. 116-143). Consequently, the interviewed actor gained competences to make well-informed choices in the process of discussing and managing issues caused by the planned river deepening which is associated to third-loop learning outcome (Romme & Witteloostuijn, 1999). At this end, the actor gained the intellectual capacity for adaptive measures as he distributed information to the association's clients (farmers and landowners) to mobilize them to rise formal objections against the project and succeeded.

7.4.1.2 Revealed network characteristics in connection to their role towards adaptability

The following section describes both, the revealed impacts of a network on the individual organisation and the impacts of the organisation on its network in connection to the adaptive measure described in chapter 7.4.1. The description entails the perspective of the interviewed actor, hence, only the impacts of and from the actor's network are here described. A complete overview of reported interactions about the issue groundwater salinization is shown in chapter 7.4.2 Social interaction map.

Impact of a network on an individual organization

Several impacts of networks were exemplified by the interviewed actor in connection to these learning outcomes which resulted into adaptive measures. The starting signal to investigate and question the estimated impacts of the plan have been activated by a

social interaction-learning process. The author referred to a social interaction where the question about the transition zone between fresh and salt waters became issued (C.4; l. 219-226). *"And then our people questioned the report whether it is true."* (C.4; l. 220-222). The term "our people" is here understood as a referring to farmers and implies therefore interactions within homogenous network connections. The starting signal enhanced the development of adaptive measures. Based on this recognition of unawareness towards the topic of salinization regarding driver and pressure factors, he made actively efforts to connect to scientists, experts and environmental lawyers, but he also made use of existing connection such as working groups to gain information about impacts (C.4; l. 189-192; 223; 408-418). Throughout these diverse connections with different interests and knowledge background, the actor enriched his experienced based learning domain as he gained knowledge about the biophysical conditions that contribute the salinization of surface and groundwater.

That way connections within the network of the interviewed actor facilitated his intellectual capital to respond to the planned river deepening. In context of the experienced learning domain, two factors of experiences were revealed that played a role; the attributes of the community and the biophysical conditions. The experience about the attribute of the community was referred to biased expert opinions for the plan of the Weser river deepening (C.4; l. 259-260). *"The scene is thin and restrained, because, as I just said, they all work for the project developers. That has been the case for the port of Hamburg and that has also been the case for the Elbe river deepening. The same is now here in the Weser river deepening. Due to this background, I might cautiously highlight, that we do not have many experts, who are not biased"* (C.4; l. 257-260).

Thus, he implied economic reasons, that the issue of groundwater salinization had not been indicated within the report of the expert opinions. This insight emerged as he started to search for background information on the biophysical conditions regarding salinization processes (C.4; l. 189-192; 223; 408-418). Based on this context specific attribute of the community the actor made additional efforts to find experts who were providing reliable expert opinion towards *"such complex systems"* (C.4; l. 244-256). Throughout the contacts of his lawyer, he found an expert who was considered to be trustworthy. *"We received hints and suggestions. However, they were rather themed as 'these information are not from me that you take a look on this, that you are aware of that or you raise the question towards this topic'. So, we received suggestions that*

enabled us to see the different side of the page" (C.4; l. 253-256). At this end, the actor gained the intellectual capital for the adaptive capacity which resulted into the adaptive measure to disseminate his information to the association's clients (farmers and landowners) in order to mobilize farmers and landowners to raise formal objections.

In connection to the development of intellectual capital the role of networks is here revealed in reference to a particular network quality: Despite the diversity of interaction partners, the interviewed actor highlighted the role of one connection within his network who provided information informally. Thus, the lawyer represented a bridging tie for the association as the lawyer had made the connection to the trusted expert.

The other network characteristic which is associated towards building adaptive capacity, is the role of the interviewed actor. The interviewed actor as an individual performed a pivotal role for the institutional performance to build adaptive measures. The progress of his intellectual capital is here associated to the relational practice of interdependence which was dealt by the interviewed actor. The learned experiences were made interdependently from the interactions and built intellectual capital. Beginning with the starting signal that has been triggered throughout interactions he made and ending with the intellectual capacity he learned through experiences throughout followed interactions. That way he occupied the role of an interface between the network in which he was engaged and the association in which context he developed adaptive measures.

Impacts of an individual organisation on a network

The impacts of the individual organisation on network level is here revealed in connection to the result that the planned action of the Weser river deepening became rejected. The association mobilized his clients, who were potentially affected farmers and landowners. Background is here that the interviewed actor created events within this association to provide his clients with relevant information. An artificial relational practice for interdependence has been created. *"We started to lead an open discussion with our farmers. We informed them about the interrelations and the resulting problems. We further appealed them to go to further events and to raise questions and to question the answers. The result of these efforts had led to 400 objections within the planning assessment procedure*" (C.4; l. 227-234). The interviewed actor communicated learned experiences and appealed social interactions, so that his clients received the practicing opportunity to relate to the information they have gained. In that way, the association created social capital by facilitating a relational practice. Thus, the

development of shared heuristics and information flows have been created through a planned social interaction domain by connecting to the farmers which are here considered to represent a heterogenetic network.

These outcomes of these gathering strengthened social capital and throughout the information exchange intellectual capital increased. At this end, the measure to build social and intellectual capital is here associated to serve the objective of building political capital to mobilize farmers and landowners to rise formal objections against the project. To this end, the mobilization of association's network enabled adaptive measures.

7.4.2 Social interaction map

The following map shows the revealed interactions of the interviewed actor made with organisations, groups, individuals and formally established networks. Based on the literature review in chapter (compare chapter 6.2.1 and results in appendix 10.5), the outlined categories distinguish between formal and informal contacts and further differentiates between field of interests to exemplify diversity of resources, e.g. knowledge, physical resources or capacities based on the business field.

Rural population district association Wesermarsch ***Kreislandvolkverband Wesermarsch***		
	Formal/daily business	Contacts based on additional informal/business/efforts
Water Quality		
Lower Saxony Water Management, Coastal Defense and Nature Conservation (NLWKN)	Gain awareness about the topic by the NLWKN	
Water Supply Companies Wasserversorgungsunternehmen (WVU)		Following WVU were kept in mind considering the issue: OOWV, EWE, Stadtwerke Varel und Wilhelmshaven
Shipping and ports		
Federal Waterways and Shipping Administration *(WSV)*	Committed to attend on public procedures.	
Flood Protection		
Water and soil associations (WVG) e.g. Kreisverband der Wasser- und Boden- verbände	The association mentioned the WVG as they took a vote on the project about the deepening of the river Weser	
Agriculture		
Chamber of Agriculture	They attend to the meetings of thedrinking water cooperations and thus, he meets with them.	
Agricultural Associations *e.g. Deutscher Bauernverband e.V., Kreislandvolkverband Wesermarsch e.V.*		Delivered its clients with extensive information on the subject river deepening of the river Weser and appealed a decision.

Research, expertise and consulting		
Universities/ Research Institutes	Students provided them useful information. Scientific events stated awareness about the topic.	
Lawyer	Hired an environmental lawyer, who had access to relevant networks, thus to valuable information	
Engineering agencies	They attend with their hired consultant on public procedures to which they are committed in order to gain awareness. They hired the engineering agency Ingeneursdienst Nord about their expertise.	Assumes that many engineering offices with specialty in the field of salinization and river deepening might not be independent
Associations, projects or working groups (recognized as established networks)		
Storing instead of pumping, project		The project showed effect in rising knowledge and awareness.
Drinking water protection cooperations - Working groups	Got invited to a water related working group as an interest representative, Attends to meetings 2-3 times a year	Gained awareness about the topic through the cooperation
Area cooperations	Obligatory participation in the area cooperation number 26 transported knowledge.	

Table 10: Social interaction map of the Rural population district association Wesermarsch circled around the topic groundwater salinisation (own compilation)

7.5 Cross Case Analysis Results

The following results of the cross case analysis are about the dimensions of network contributions towards adaptive measures in relation to network configurations. Table 11 shows the main results. *The reported adaptive measure of case 3.1 is not included as no network contributions were indicated.*

Network contributions	Network configurations/characteristics	Case
Political capital	Use of day-to-day network	1.1, 3.2, 4
Intellectual capital	All kind of network structures	1.1, 1.2, 2, 3.2, 4
Single-loop learning outcomes	Formally established heterogeneous actor network, intense exchange, growth of new knowledge/insights	1.1,
	No changes in the actor's network	1.1
Double–loop learning outcomes	Intense interactions and heterogeneous actors contributed to the growth of new knowledge/insights	1.2, 2
	Intense interactions with heterogeneous actors but also actors with similar professional backgrounds contributed to the growth of knowledge	3.2
	Formal network interactions	1.2
	Informal network interactions	2
	Mix of informal or formal network interactions	2, 3.2

	New actors were targeted to become involved; a changed actor's network involving new actors	1.2, 2, 3.2
	Actor's network enabled a bridging tie to new resources (information)	2
Triple-loop learning outcomes	First a closed actor's network contributed to grew awareness, then interactions were proceeded informally with heterogeneous actors to gain new knowledge. The result of the learning outcomes led to enabling new roles of the day-to-day network.	4
	A changed actor's network involving new actors; actors of the actor's the day-to-day network occupied a new role	4
	Actor's network enabled a bridging tie to new resources (information)	4

Table 11: Cross case analysis results. Dimensions of network contributions towards adaptive measures in relation to network structures

7.5.1 Intellectual capacity

The outcomes of adaptive measures in all cases were influenced by interactions of each expert's network (i.e. actor's network). The significant contribution of all reported network interactions led to an increased intellectual capacity of the interviewed **expert**. The extent of network contributions was manifold. In case 2 and 4 reported network interactions obtained a starting signal to become aware of a problem situation. Next to these initiating impulses, all cases revealed also a growth of intellectual capacity as network interactions were identified to have contributed to new cognitions. The dimensions of new cognitions, however, differed in terms of knew knowledge about biophysical conditions, attributes of the community and technical approaches. The learning outcomes have led to changes of the operations.

Thus, network interactions can be accounted to the progress to develop adaptive measures throughout an enriched experienced based-learning domain. The within case analysis revealed that the acquired new insights are pivotal for the development of reported actions which led to changed operational rules within the respective organisation.

7.5.2 Interconnections between network configurations and learning outcomes

This study also explored the interconnection between learning outcomes and network configurations.

Single-loop learning outcomes – Remained network structures

In case 3.1 a single-loop learning outcome was identified but without contribution of network interactions. An actor's network played only in one reported example within case 1.1 a role for the single-loop learning outcomes. There, the actor's referred network was formally established and the exchange of information of was intense

within diverse actors. The same network, however, was also referred for the contribution to a double-loop learning outcome. No changes within the actor's network were stated.

Double-loop learning outcomes – Changed network configurations

Case 1.2, 2 and 3.2 revealed double-loop learning outcomes. Within case 1.2 a formal network with diverse actors and intensive knowledge exchange interaction has contributed to new cognitions that led to the development of new objectives. Thus, the learning outcome resulted into the objective to recruit specific people with certain skills to work in the respective case organisation. The action to engage new actors were also stated in case 2 and 3.2. Here new actors were explicitly searched from the interviewed actor, thus, new connections were made. The expert in case 2 reported that new connections were established to further progress on their chosen adaptive measure to create a detailed map. The pattern of a changed actor's network in case 3.2 indicated the same course, but with the difference that no new connections were targeted, but existing connections were intensified. The intensification was targeted by the actor as means to an end; to convince his actor's network to maintain water in the upper levels in groundwater bodies in good quality. Here, cases reveal that changes were explicitly made outside the actor's day-to-day network interactions to gain or to provide access to information.

Triple-loop learning outcome – Changes in the roles within the actor's network

A triple loop-learning outcome was only revealed in case 4. First, the insight within an already established network provided the starting signal for the definition of a problem situation. In the further reported development, new connections were advanced as an actor of the expert's actor network provided a bridging tie to actors with relevant information. This new connection (i.e. bridging tie) facilitated new insights relevant for the development of adaptive measures. The third stage is marked with active information dissemination of new insights within a day-to-day network. This network involved actors with similar professional backgrounds (i.e. only farmers). The consequence was that the interviewed actor triggered with this approach a mobilization of his network to rise formal objections against the river deepening. The purpose of the mobilization served the objective to defend agricultural interests. Thus, the actor equipped his day-to-day network with information that lead to new roles of the actors towards joint approaches.

7.5.3 The role of the actor's network to stimulate an increased adaptive capacity throughout learning outcomes

This study also explored the role of the network configurations to which extent learning outcomes were induced. The cross-case analysis revealed no significant relationship between formal or informal network interactions in connection to specific a learning outcome. Also, the configuration between closed and heterogenic networks did not show any tendency for any certain learning outcome. However, in every learning outcome of case every case, the concerned actors reported that they were connected to heterogenic actors. Moreover, intense interactions were reported in all case studies to be meaningful for their learning outcome. Here, prior to any learning outcome, intensive interactions were mentioned in all cases and at all stages of a learning outcome.

7.5.4 Political capital

Reported examples in cases 1.1, 3.2 and 4 revealed that the role of networks was not only relevant to enlarge intellectual capital, but also to enforce political capital. The three interviewed actors of these cases indicated that they used their contacts within their network as a channel to disseminate information which were considered to serve their objectives. With the determined share of information, they built shared heuristics. The expert in case 1 denoted that the explicit provision and dissemination of information served the objective to influence the definition of points of view in context of water-legislative procedures. In case 3.2 the actor reported that he disseminated customized information to actors within they field of activity. These specified information served his strategy to activate them for adopting adaptive measures for the objective to maintain water in the upper levels in groundwater bodies in good quality. In case 4 the interviewed actor also used his day-to-day network to mobilize farmers to rise formal objections against a river deepening project. This was initiated through the creation of informative events in which the interviewed actor used this event as a channel to share his knowledge and to motivate the actors of this network to develop counteractive measures.

8 Reflection

8.1 Discussion on the research approach and research design

This study gave insights into existing networks in north-west Lower Saxony and how they were linked to actions regarding groundwater salinisation and what role they played as a source for building adaptive capacity. Thus, the research design provided an explanation how networks can facilitate adaptive capacities.

The aim of the empirical study was to reveal information about existing networks and their effects to achieve institutional adaptability in natural resource governance systems. Central for this method was the application of the synthesized analytical framework to assess adaptive measures in relation to learning outcomes. Relating outcomes as results of learning processes, the framework was also used to evaluate the contribution of network interactions. Thus, the learnt aspects, respectively impacts, that arose within the social interaction learning domain, were reflected and classified within the experienced-based learning domain (Halbe, 2016). With this approach, the impacts of networks on actor level, representing an institution in the field of natural resource governance for groundwater salinization, were analyzed. The results provide explanative information about how networks created adaptive capacities.

An empirically valid generalization of the explanative results based on few case studies, however, does not occur (Wrona, 2005). The aim of this case study approach was rather to develop recommendations for adaptive management which can be called more robust when using multiple case studies (Yin, 2009). This study did not use a fieldwork approach because it regards experts to be sufficient in revealing the relevant data, since experts were chosen according to their privileged access to information about individuals or groups of decision-making. This was a pragmatic approach. Still, fieldwork is a worthwhile method of generating insights and would provide more robust results, however, the budget and time limit would have been exceeded for this study.

8.2 Implications of networks for adaptation on actor level

The empirical results showed a relationship between networks and institutional adaptability throughout a facilitated learning process. This study reviewed individuals (interviewed actor) within network interactions, who are at the same time part of an organisation in the field of natural resource governance. The results revealed that learning process of the individual took place within network interactions which learning outcomes contributed the respective organization in which the actor is embedded to

develop actions. In that vein, the study revealed that the individuals as an institutional substitute performed the ability of institutions to develop these actions to deal with groundwater salinization is understood as adaptive capacity (Pahl-Wostl 2009).

The revealed important role of the individual actor for institutional adaptive capacity is here reasoned with the aspect that adaptive capacities of organizations are entailed throughout individuals, who in turn are engaged in network interactions and are, therefore, part of a network learning unit (Halbe, 2016). Also Reed et al., (2010) reviewed learning concepts and put emphasis that learning starts within the individual and further develops beyond the individual as it evolves in wider social units through interactions between actors within social networks. Other studies about adaptation and networks revealed different connecting foundations. The case study assessment of Gunderson (1999) revealed a connection between networks and effective adaptation through emerged ideas and perspectives that are enhanced by network inputs and feedbacks. Within a conceptual frame Pahl-Wostl (2009) also addressed the adaptive capacity of natural resource governance regimes as a learning process and considers that informal networks play a crucial role in learning processes. Nevertheless, these foundations are all linked to the individual, who can be either receptive for new ideas or not and who can take efforts to connect to various actors in a formal or informal way.

8.3 Implications for adaptive management

Based on the previous outlined implication that institutional adaptability is enabled within the individual actor, it is recommended that adaptive management acknowledge the active role of the individual to obtain institutional adaptability. Which traits those individuals should inhabit to further obtain adaptive capacities is a question of further research in the field of human resources. However, the general implication for policymaking processes is to set a new agenda to build on new relationships with stakeholders and tapping into the knowledge resources of their various networks. This is especially relevant when considering networks as tools that can enhance adaptive capacities. Still, the study revealed also a differentiated picture how and where networks can be used as a tool. In this connection, the following chapter discusses the reveals of different grounds of and for impacts and subsequent background mechanisms for adaptive capacities facilitated by network interactions that can be addressed within adaptive management:

1) **Networks affect the institutional adaptability**, as individual actors tap into the knowledge resources of actors in various networks. In that way the respective actor develops their intellectual throughout learning process that feed back to the institution in which the respected individual actor is embedded.
2) **Institutional actions affect networks** as networks stand under influence of its actors rendering the interests and objectives of the actor's institutional context.
3) **Learning outcomes create an impact on the arrangement of the actor's network**. Second loop or higher learning outcomes come along with changes of the actor's network as interviewed actors searched actively for new connections to tap into new knowledge resources.
4) A **certain arrangement of the actor's network an increased adaptive capacity** as the results show that strong ties to a heterogeneous network stimulates learning outcomes.

8.3.1 Networks can affect institutional actions

The relevant key result is that networks are recognized to affect institutional actions for the development of adaptive measures. Social interactions within the actor's network in all case studies (except for case 3.1) revealed an increased intellectual capital of the interviewed actor. The result led to new knowledge that was used within their institutional embedding. Also Sampson (2004) recognized that network ties function as conduits for the transfer of valuable knowledge and intellectual capital to other network members. Further, the results of this study showed that networks are influential as they affected actor's perceptions as they gained information which resulted into changed behaviour. Ahuja (2000) and Powell et al., (1996) studied the impacts of networks on individual organisations and revealed that learning through network interactions caused innovative performances. In a general context, Ahuja (2000) revealed the extent of those performances depends on the embeddedness and tie formation of networks.

The reason for changed perceptions is here recognized that network interactions facilitated a social learning process as information had been exchanged. The results showed that this information were gained within the context of the relational practice of the interviewed actor and were linked with the experience-based learning domain of the actor. Consequently, reciprocity and reflection took place within the relational practice that also portrayed factors of embeddedness of a network from the perspective of the actor within his organisation (Ahuja, 2000).

A comparison between the cases showed that the dimensions of new cognitions differed in terms of knew knowledge about biophysical conditions, attributes of the community, and technical approaches. Overall, new cognitions affect the individual actor in the performance to obtain adaptive measures, which mainly resulted into changed operational rules within the organisation. Similar, but more general implications were also brought up by Amin and Thrift (1995), Carlsson (2000), North (1990), Ostrom (2005) as they highlight that aggregated webs of interactions of networks have led to outcomes, which are considered to dynamically feedback to institutional settings and, thus, change existing rules.

Therefore, learning capacity is considered to be a fundamental pillar in the adaptation processes of institutions. The outcome of learning processes is argued to embed intellectual capital, a relevant pillar for creating institutional capacity to adopt an adaptive capacity. Healey (1998) associates intellectual capital with knowledge resources. She indicates that within networks knowledge can flow around and increase the intellectual capital. In this connection networks are here considered to embody social units in which the process of learning takes place. Hence, individuals tapping into the knowledge resources of actors in various networks invested into their intellectual development that feed back to the institution in which the respected individual actor is embedded.

8.3.2 Institutional actions can affect networks

Additionally, the results of case 4 show also that actors are also able to affect their network. There, the interviewed actor mobilized his actor's network to become self-organized to change the planned project of a river deepening as he shared information. On this remark Granovetter (1985; 1992) highlights that networks which change rules of other institutions are institutional entities themselves.

The study results are directly tied to the insight of Granovetter (1985; 1992), bcause the resuls of case 4 revealed that networks can be affected by actions of an individual and therefore used for the development of adaptive measures. This implication is rather rare researched (Provan et al., 2007). Studies which try to explain the phenomena of how actions affect outcomes at the network level are for example about networks effectiveness and their relationship to network structures (Provan et al., 2007; Sydow & Windeler, 1998). Here, the results of this explorative study reveal that attempts of interviewed actors to influence their actor's network with the share of information

addressed the creation of political capital. Similar implications were also made by Innes and Booher (2004) as they argue that collaborative arrangements can also develop into shared heuristics, joint objectives and shared knowledge and meanings, which create the basis for forms of power and action. Healey (1998) indicated that within networks knowledge can flow around and increase the intellectual capital.

Considering this condition, the power of networks can be harnessed and, therefore, used to mobilize, to develop and to deliver policy objectives of concern. This implication is also interesting for adaptive management as this also shows a way how to yield political capital (Innes & Booher, 2004). Hence actively creating sharing knowledge and enabling shared heuristics is a tool to harness power to create adaptive measures outside or to influence the act to set the agenda to introduce the act for decision-making. That aspect is considered to be crucial for contacting the threats creeping disasters impose: disregarding the importance to develop adaptive measures facing long term problems act in the present time (Schneider et al., 2013).

In this governance context, the study revealed one example in which an interviewed actor (case 1.1) used networks as a channel to convince other actors within his network to influence water-legislative procedures about the question where to locate new wells, and its depth range and amount of the planned extraction of groundwater. Another example is about to encourage one's actor network (case 3) to confront the problem of fertilizers openly so that a relief of upper groundwater bodies can be achieved which similarly implies a relief of the constrain to withdraw water at the lower groundwater levels near the transition zone between salt and fresh water.

Hence, institutional actions can create impacts at the network level that are transmitted by the individual actor. In a similar context Vasudeva et al. (2013) explored the environment in which networks are embedded and revealed that the *"institutional setting in which network participants reside has an important influence on their orientations and knowledge integration capabilities because of the norms and values that these institutions imprint on the societal actors comprising the network"* (p. 17). Moreover, networks stand under influence of its actors rendering the interests and objectives of the actor's institutional context (Vasudeva et al., 2013). Therefore, the critical viewpoint to harness adaptive capacities in the network lay within the individual actor, their institutional context and the person who participates in or has access to various networks.

8.3.3 Learning outcomes influence the arrangement of the actor's network

The results showed that the institutional interests which are conveyed through its actor dynamically feed back on the configuration of the actor's network. A generating factor for this change was identified in connection to learning outcomes. The cross-case analysis revealed that along the stages of double-loop learning and triple-loop learning outcomes the interviewed actors across these concerned cases changed their network interaction partners, thus, the configurations of their network. This result confirmed the theoretical assumption of Pahl-Wostl (2009) that different kinds of learning also require a change in the composition of the actor network and in the institutional setting. Along with the learning outcomes new perspectives and understandings evolved within the actors (cases 2, 3.2 and 4). Within this processes new interaction partner had been explicitly searched by the actor in order to gain more knowledge. Similar implications were made by Hillier (2000) in the research field of policy networks. She revealed that actors in policymaking processes build new relationships with stakeholders to tap into the knowledges of their various networks to reconcile potential conflicts.

Hence, the abilities of the individual actor to detect and to connect to relevant actors, to exchange and to perceive information, but also his/her position within the respective institution was recognized to play a pivotal role to gain relevant resources of the network. In a broader context, similar implications were made by Amin and Thrift (1995) and Healey (1997b), who highlight that the extent of the power of networks to increase the institutional capacity to enhance adaptability depends upon the collective abilities of the actors' interactions, memberships, businesses and by the grounds and contexts in which actors come together. The general conclusion is here that the embeddedness of the actor influences the learning outcomes, but the learning outcomes can also in turn impact the embeddedness of the actor.

Therefore, connecting to certain actors is also a choice of embeddedness and demands deliberate choices. For policymaking processes in natural resources this conception is relevant to gain awareness and knowledge of a likely creeping challenge such as groundwater salinization and to enable problem solving capacities (Schneider et al., 2013). The objective to maintain contact to actors which are involved in these challenges serves the purpose to bridge knowledge gaps and can prevent shortfalls to build adapt measures (Schneider et al., 2013). Thus, adaptive capacities can be obtained. However, limitations are seen within enabling an embeddedness that facilitate an intellect to recognize pathways on how to resolve resource problems (Olsson,

Gunderson, et al., 2006). Creating contexts in which social learning might take place entails a commitment to bring together people who have very different world views and knowledge systems (Evely et al., 2011).

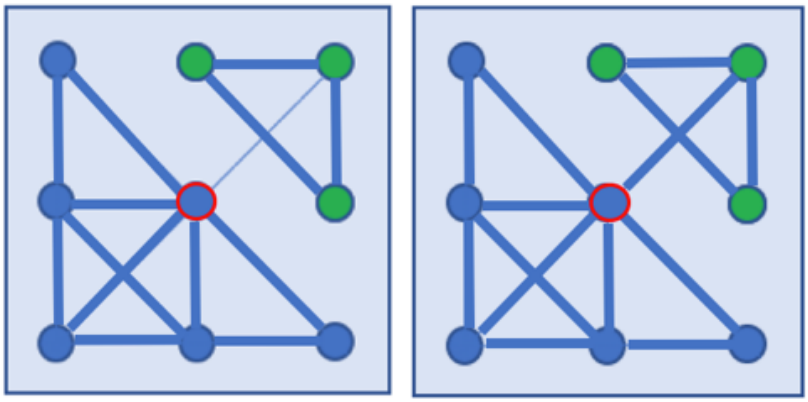
8.2.4 Arrangements of an actor's network that stimulate an increased adaptive capacity

This study explored the role of network configurations with a focus on the quality of ties and to which extent learning outcomes were induced. One main result was that a certain learning outcome (i.e. first loop, second loop or third-loop learning outcomes) had not been derived in relation to specific network arrangements.

Overall, intense interactions were testified in all four case studies to be meaningful for their learning outcome. Here, prior to any learning outcome, intensive interactions were mentioned in almost all cases (except for case 3.1) and at all stages of a learning outcome. Intensive interactions were understood within this thesis as strong ties. As described by Granovetter (Granovetter, 1973) a strong tie is "*a combination of the amount of time, the emotional intensity, and intimacy (mutual confiding), and the reciprocal services which characterize the tie*" (p. 1361). Prell et al. (2009) highlight that actors with strong ties are more likely to influence one another and by creating strong ties among diverse actors mutual learning through sharing of resources and advice can be enhanced.

The limitation in this regard is that this study did not reveal whether those strong ties were prevalent before a learning outcome was induced or not. Moreover, in every learning outcome of each case, the concerned actors reported that they are connected to heterogenic actors. The study did further not reveal, whether those connection to heterogeneous actors were prevalent before a learning outcome was induced or not. An indication which learning outcomes presuppose a certain network configuration was not derivable. However, the results showed general indications that intense connections to heterogeneous actors of one's actor's network were involved with learning processes (figure 12 B). A heterogeneous actor's network was considered with access to a variety of resources as diverse actors with different background were connected. As shown by Burt (2000) connections to otherwise unconnected actors, or sets of actors within the actor's network are recognized as bridges to mobilize diverse resources, such as understandings and perspectives, that can increase organisational performance.

Gunderson (1999) and Olsson (2006), however, noticed that weak ties play assumingly an important role to gain access to different resources and henceforth to new perceptions knowledge relevant for adaptation (figure 12 A). Weak ties are characterized by a low intensity of interactions but with access to a variety of resources (Sandström & Rova, 2010). In reference to this study, it can be assumed that weak ties have developed into strong ties as the interactions were reported to be intense. Consequently, the evolution of weak ties within a network become part of strong ties dependent on the actor, who provides or demands access to a variety of new resources.



A: heterogeneous network with (bridging) weak ties **B:** heterogeneous network with strong bridging ties

Figure 12: The arrangement of an actor's ties within his network to tap into a variety of resources (own compilation)

To conclude, the degree of intensity of interactions seems to be optional and depends therefore on the need of one's actor to gain access to resources each contact can provide. Network heterogeneity seems therefore to be pivotal with regard to access to diverse resources. Also Sandström and Rova (2010) made similar conclusions that network heterogeneity facilitates access to different types of ecological knowledge important to adaptability. Similar implications were also derived by Ostrom (1990), Sabatier et al. (2005) and Baland and Platteau (1996) as they revealed in their studies that collaborative arrangements, in which various actors from diverse sectors and user groups were involved, created more likely adaptive processes than other types of management arrangement.

So, the pathway to increase the interaction could be either planned formally demanded or informally introduced by self-organized approaches. That means an actor's network can be managed to serve an organization's adaptive capacity by guiding an actor to connect to diverse interaction partner and support intensive interactions. According to the results of this study, this may trigger learning outcomes to the profit of the organisation to where the actor is assigned to. This implication is based on the emphasis

that if efforts of adaptive management are an active process, rules need to be revised and changed based on a continuous inflow of ecological knowledge (Sandström & Rova, 2010).

8.4 Implications for adaptation on governance level

The recognition of the existence and relevance of interpersonal contacts of actors within networks and networks themselves for the planning process and decision-making has been transferred to the development of the broad conceptual field of policy network theory (Hillier, 2000) and has gained rising attention to planning scholars (Roo & Boelens, 2015). Relevant networks are recognized as forms of self-organization and self-governance (Pahl-Wostl, 2009; Roo & Boelens, 2015). In this context Meek (2008) recognized that actors connecting with public officials created a learning environment. Strong ties among these actors allow information exchange and mutual experiences. Meek (2008) argues in this connection that those patterns of relationships may lead to a new form participatory democracy entering a representative democracy.

Processes of self-organisation form new relationships between governmental institutions and civil society and may lead to a reorientation of existing democratic institutions (Edelenbos, 2005; van Meerkerk, 2014). In a similar direction Pahl-Wostl (2009) links networks to bottom-up approaches with regards to change in regimes, whereas hierarchical top-down government structures are associated with permanence. She argues that the "*absence of change results in the inability to adapt to changing circumstances triggered by internal and external events and trends*" (p. 358). Complete absence of permanence and predictability results in the inability of actors to develop expectations, coordinate collective action and improve routines and practices. These considerations suggest that rather than a "*dominance of one governance mode a more diverse governance system has a higher adaptive capacity and will lead to more sustainable resource governance"* (Pahl-Wostl, 2009, p. 358). Similar connections were also made by Bormann et al. (2012) based on the recognition of a systems' gap between bottom-up processes that thrive on local scale knowledge in climate adaptation processes and top-down approaches. Approaches to counteract these gaps between top-down and bottom-up approaches to cater adaptation are recognized within the fields of collaboration, integration and participation which are fields that networks also cover (de Bruin et al., 2009)

8.5 Implications on further research

Whereas no indication of network arrangements was derivable in connection to stimulate learning outcomes, the relevance of **learning outcomes** and their identification are still argued to be useful to assess the intensity of learning processes based on interactions. Whereas this study took an explorative approach on the role of networks in connection to adaptive capacities, a comprehensive focus undertaken with an additional research on learning outcomes in relation to network configurations may reveal how an intense learning outcome can be stimulated. This could be relevant for adaptive management for a planning problem that affect different interest groups in which conflicts are inevitable. The results could unfold some tools to enable affected actors to reframe a problem. This approach could be to adapt to an inevitable problem. Considering climate change and sea-level rise, induced repercussions seem to unfold those problems that demand for more innovative approaches to deal with them in the long term.

8.6 Conclusion

The search for approaches for adaptive management systems governing natural resources is a necessary and demanding task for present-day and future policy makers. Especially with regard to groundwater salinization which present characteristics of a creeping disaster. The relative slow salinization process was assumed not to raise immediate attention to call immediate action (Pannell, 2001b). In this vein, the potential of networks have been hypothesized that they can function as a carrier to complement the capacity building of institutions in the field of natural resource governance to facilitate adaptive measures. It was further assumed that networks embody the potential to call attention to problems and deliver new perspectives relevant for organisations. For this reason, this thesis undertook an explorative research approach to reveal *how networks in natural resource governance systems are linked to actions and what kind of networks play a role as a source for building adaptive capacity*. For this reason, an analytical framework has been developed to interpret results of the case study research. This supported the localization where, how and what kind of knowledge transfer has led to which adaptive measure with which learning outcome.

This study showed a connection between network interactions and institutional adaptability. The linking connection is enabled through learning processes in which the individual actor takes up these learning processes and functions at the same time as a trajectory between his or her network and the organisation in which the actor is

embedded. Here, network interactions facilitated intellectual capital on actor level which led to the development of adaptive measures on organizational level. Therefore, networks influenced running operational rules of organizations operating in the field of natural resource governance.

Moreover, the results showed that actors of organizations natural resource governance can change networks. Functions of the actors in a network can be changed in order to collaboratively deal with a threat that has been recognized through purposeful shared heuristics by one actor (case 4). Therefore, networks which have the capacity to enable actions are recognized as an institution itself. The results further showed that social interactions enabled by network interactions were pivotal for learning outcomes as the results showed that network interactions increased intellectual capital which led to the development of adaptive measures. Concluding these points, this study showed that networks can function as a carrier to complement the capacity building of institutions in the field of natural resource governance to facilitate adaptive measures. The carrier to facilitate adaptive measures is pursued throughout tapping into various resources that enabled the growth of intellectual capital to develop adaptive measures.

The results further showed that tapping into new resources developed analogues to the efforts of an actor to connect to various actors which indicate an expansion of the frame of network interactions. In this connection, the explorative approach of the study answered the question which kind of networks play a role as a source for building adaptive capacity. For example, the results showed that a certain arrangement of the actor's network increased the adaptive capacity of the organisation. The respective actors were generally stimulated for a learning outcome as the actors employed strong ties to a heterogeneous network. However, no certain arrangement of the actor's network derived a certain learning outcome (i.e. first-, second- or third-loop outcome). Learning outcomes created an impact on the arrangement of the actor's network. Here, second loop or higher learning outcomes came along with changes of the actor's network as actors searched actively for new connections to tap into new knowledge resources.

As indicated already, various resources to which actors are connected through networks enabled actors to advance on intellectual capital to develop adaptive measures within the organisation in which they are embedded. Hence the question about how networks in natural governance systems are linked to actions was answered within this thesis.

The case study analysis also revealed that groundwater salinization is already a recognized issue in the case study region of north-west Lower Saxony. Interviewed actors called attention to problems. For example, one actor (case 4) mobilized his actor's network to raise formal objections against a planned project. Background was that he developed reasonable suspicion that a river deepening stand in relation to groundwater salinization. The analysis showed that actors gained new perspectives throughout network interactions. For example, the actor in case 2 realized throughout interactions with various actors in the field of natural resource governance that his approach to map groundwater salinization is outdated. In that vein, the actor also gained new perspectives relevant for his problem-solving approach. Throughout network interaction he gained insights how to gain improved data to develop a more detailed map.

To this end, the conception of Pannell (2001b) must be considered to be limited to the aspect what is needed to build counteractive measures towards creeping disasters. According to his conception groundwater salinization present characteristics of a creeping disaster because of the relative slow salinization process which call not immediate attention within the broad public to call for immediate action (Pannell, 2001b). This study, however, revealed that not a broad public is necessary to trigger adaptive measures. Rather qualitative aspects of connections are here recognized to be pivotal. Just as Deutsch (1963) assumed, affected parties functioned like a nervous system as actors shared and gained formation within their network in a selective way. Using networks as channels for knowledge transfers enabled them to advance the development adaptive capacities throughout feedback processes.

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