Multiple co-existing Ontologies in the Paraná Delta

BY ODILIA MATHILDE SERENA SCHÖLVINCK

“The future engineer should be an alpha, beta, gamma in one”

Jan Mengelers, former chairman of the TU Eindhoven, 2019

Multiple co-existing ontologies in the Paraná Delta

An action-research approach to the case of the Paraná Delta, Argentina

By

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Cover image: Own picture of Paraná Delta

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TU Delft

|Preface

With this report, a journey to finish two theses for the master's program's Engineering and Policy Analysis and Water Management is completed. One and half year ago, I was doing my internship in Argentina and learned about the issues in the Paraná Delta. I immediately felt a sense of curiosity to contribute to the domain of Adaptive Delta Management for the Paraná Delta. I feel fortunate that I was able to do my thesis on this subject. The thesis period has been a highly inspiring period for me, being gathered by many intelligent and wise people, teaching me knowledge and life lessons. The extended length of this project has provided the opportunity to delve into the subject and make new research choices later on. I was able to make several visits to Argentina and I performed many activities there as organising workshops,measurements, modelling, group model building, interviews and participated in many activities and workshops related to the topic myself. This report is the accumulation of knowledge I gathered along the way.

|Acknowledgements

Doing a combined thesis project resulted in a big team of supervisors. I would like to thank the members of my graduation committee for their support, for providing me with valuable feedback, and for directing me in new directions which I might not have discovered if not guided there, and for having the patience and stimulation that all the challenges of combining two theses gave. First of all my daily supervisors, Maurits Ertsen and Jan Kwakkel have been a great support throughout the process. Thank you, Jan Kwakkel, for teaching me ADM and accepting my participatory approach in your computational world. The rest of the committee also gave me many insights and input. I would like to say thank you to: Markus Hrachowitz, for supporting the ontological way of thinking in the faculty of CiTG. Bert Enserink, for teaching me how to use social science principles in the engineering world and supporting me throughout the entire EPA studies. Alex Curran, for guiding me through modelling and always being supportive in your comments. Martin de Jong, for deciding it was time for me to graduate, and finally Matthijs Kok for supporting me from the domain of hydraulic engineering.

I would like to acknowledge Deltares for giving me this opportunity of a thesis. Judith ter Maat, thank you for taking up the difficulty for supervising me in this chaos of a thesis and stimulating my many visits to Argentina. And of course, William Oliemans for getting me on this project and making this research possible. Furthermore, I would like to thank all the employees and interns of Deltares and the staff and students of TU Delft that have given me input throughput this thesis.

Maurits, I want to thank you especially for enlighten me with new ideas, making my brain sometimes hurt, but always being there for me. I appreciate the time you have spent to support me; I look forward to many more intellectual conversations we still may have in the future.

Then, I would like to pay gratitude to all my colleagues and friends in Argentina who have supported me throughout the project. My Argentinean counterpart, Sabrina, my partner in crime throughout this project. We set up such great workshops together, and I'm sure we will stay friends for the rest of our lives. Also, I would like to thank all the Argentinean partners that have been very supportive, all the researchers of INA and INTA, and especially without Martin Sabarots and Adrian Claudio Gonzalez, this research would not have been possible. Thanks to Veronica Zagare for being our local supervisor, and Pablo Arecco for giving me an office to work in and a friendly smile in the moments when it was difficult. Also, big thanks to my former colleagues at the embassy of the Netherlands in Argentina, who were also helpful throughout this thesis

Then, of course, a big thanks to my dear friends who have supported me throughout my thesis and giving me enjoyable moments during this time. A big hug for my (former) roommates at the KM39 for their warmth and laughs. Maarten for being so supportive during the stressful first months of the set-up phase. Especially I would like to thank Sarah, Anita, Anna, Begona, Christianne and Sophie for correcting my thesis so thoroughly, and Diede and Niels for giving me designer input.

Last but not least, I want to thank the people who have always have been there for me, my very loving parents, I want to say thank you for supporting me in all possible ways throughout the years, without your input, care and love I would not be the person I'm today.

|Main Article: Multiple co-existing ontologies in the Paraná Delta

MULTIPLE CO-EXISTING ONTOLOGIES IN THE PARANÁ DELTA

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ABSTRACT

Adaptive delta management (ADM) deals with making flexible and robust plans in the uncertain environment of deltas. ADM receives increasing attention to be applied globally, including in Argentina. In this research, I have studied how modelling can assist ADM in Argentina through action research by applying various participatory methods like workshops, group model building and interviews. In the exploratory phase, I could make several observations regarding the application of ADM in Argentina. I discovered something unexpected: Multiple co-existing ontologies of the Paraná Delta were shaped in practice, influencing the ADM process. The Paraná Delta seemed to be continually changing per actor, time and space in the Delta. In order to introduce the reader to this multiplicity, I offer an approach to formulate these ontologies and provide several examples of ontologies in the Delta. Next, I propose a structured approach to connect ontologies to modelling. The added value of using ontologies for the modelling of the Paraná Delta was discussed with experts. The results indicate that by connecting ontologies and modelling, the ADM process (in the Paraná Delta) will be strengthened, since ontologies (1) illustrate modellers assumptions, (2) improve stakeholders and politicians understanding of the Delta, (3) guide research and data collection to verify assumptions on the Delta, and (4) strengthen the understanding of one's own ontology. Therefore, the results show that incorporating ontologies in ADM research is a valuable approach. Future research should focus on formulating models to support the claims made in this article. Further, a theoretical investigation is needed to incorporate the use of ontologies in the ADM process. In order to guide future researchers to incorporate ontologies in their modelling, a framework is constructed based on my research experience: 'the Kite framework'.

Keywords: Adaptive Delta management, Ontological policies, ontological politics, ontologies in Delta, Decision making, Water management, modelling of ontologies, Paraná Delta, wicked problems

1. INTRODUCTION

I began…this research with the idea to do a modelling analysis of the Paraná Delta to support ADM

Delta's and coastal cities around the world are becoming more vulnerable to several uncertain threats, such as climate change, relative sea level rise and population growth (Jeuken, Haasnoot, Reeder, & Ward, 2014). In order to provide guidance to decision-makers in such uncertain environments, the concept of Adaptive Delta management (ADM) has been developed. It originated in the Thames Estuary 2100 project (Walker, Haasnoot, & Kwakkel, 2013) and was further developed in the Netherlands (Delta Program, 2015). ADM was implemented in the Delta program to deal with the uncertainties of climate change and socio-economic developments while making policies to protect the Netherlands against flooding and safeguard its fresh water supply (Delta Program, 2015). The government of Argentina expressed the desire of an ADM plan to the

Netherlands. In this study, I contributed to this request by fulfilling two separate MSc thesis projects, both related to ADM in Argentina[1].

The research presented here is for the degree of Civil Engineering. My initial research aim was to investigate the quantification of the water system of the Paraná Delta for an ADM application. Due to earlier experiences in Argentina and inspired by literature (Blanco & Méndez, 2010; Bucx, van Driel, et al., 2014; Fundación Metropolitana, 2015; PIECAS-DP, 2011; Zagare & Sepúlveda Carmona, 2013), I soon found out that the stakeholders of the Paraná Delta had different perspectives on the functioning of the Delta and on its desired development. From literature, polders in the Paraná Delta are considered to be problematic, and especially the gated communities are an issue of debate (Bó et al., 2010; Fabricante, Minotti, & Kandus, 2012). However, it was challenging to understand the issues in the Delta only from literature. Therefore, I decided to perform action research[2] to increase my system understanding of the Paraná Delta by including opinions and perspectives of a variety of stakeholders. To that purpose, I organized group model building exercises, interviews and several workshops with experts, stakeholders and local people. Also, I attended different workshops about the planning of the Paraná Delta; I participated in a training mission of Argentinean researchers for ADM. I read literature and policy documents both in English and Spanish. I took many Spanish classes in order to be able to communicate with the stakeholders in their own language. I performed measurements and made overnight visits by sleeping in measurement stations in the Delta or by making day visits leaving home in the early morning and coming back in the night. Additionally, I discussed my findings with supervisors and experts both in Argentina and the Netherlands, and finally, I had daily discussions with an Argentinean student working on the same domain. I performed all these activities in order to understand the Delta, with the aim to model the Delta and give answers to the main problems suggested by stakeholders.

I found….that the complex nature of the Paraná Delta challenges a direct application of ADM

I found that even though ADM is considered an appealing approach for the Paraná Delta, the complex nature of the Paraná Delta is a challenge a direct application of ADM. The difficulties lie in describing the system, dealing with the broad range of uncertainties, formulating and quantifying objectives, dealing with the variety of actors and the complex system, and in the complexity of the method. These findings can be related to other published cases (Aguiar et al., 2018; Allan & Stankey, 2009; Bosomworth, Leith, Harwood, & Wallis, 2017; Carstens et al., 2019; Lawrence & Manning, 2012; Lin et al., 2017; Loorbach & Rotmans, 2010; D. J. Murphy, Yung, Wyborn, & Williams, 2017; Rosenzweig et al., 2011; Timmermans, Haasnoot, Kwakkel, Rutten, & Thissen, 2015; van der Brugge & Roosjen, 2015; Wise et al., 2014; Zevenbergen, Khan, van Alphen, Terwisscha van Scheltinga, & Veerbeek, 2018; Zevenbergen, Veerbeek, Gersonius, & Van Herk, 2008).

I thought about the findings I observed regarding the implementation of ADM, and I wondered whether there could there be an overarching reason for the difficulties of implementing ADM for the Paraná Delta.

I realized …. that multiple ontologies exist in the Paraná Delta

I started to discuss with my supervisors: it almost seemed as if the stakeholders were not talking about the same system, as if they were not sharing the same ontology[3] of the Paraná Delta, as if there was more than one Paraná Delta. This made me quite confused; How can a delta, a physical phenomenon, consist of different forms? This was certainly not something I could trace back to my civil engineering knowledge.

[1] I performed two MSc thesis projects simultaneously regarding the implementation of ADM in Argentina. This thesis, for the MSc Civil Engineering (water resource management) and one thesis for the MSc Engineering and Policy Analysis, in which I investigate the usage of scenarios in participatory ADM for the Paraná Delta. The two thesis are highly related, and the work for one continuously inspired the other.

[2] This paper draws on 1.5-year action research project for the MSC. Water management (TU Delft) and in high integration with research for the MSC. Engineering and Policy Analysis (TU Delft). Furthermore, I collaborated with several organisations on their work on the Paraná Delta in order to set-up this actions research: Deltares and several architects to develop ADM in Argentina, research institutes INA (Institute Nacional del Agua) and INTA (Institute National de Agropecuaria) and Delta Alliance the Paraná Delta. Furthermore, the project was set-up in coordination with an Argentinean thesis project for the Post-master sustainable urbanism (UBA).

3 I define ontology as a descriptive account of existence, in which concepts and relations can be represented. See Chapter 2.3 for a detailed explanation what an ontology is

Luckily, my supervisors and I were not the first ones to think about this. Mol (2002) describes the ethnography of a disease (atherosclerosis) for a hospital ('Hospital Z') in the Netherlands. She argues thoroughly in her book that reality is multiple in 'Hospital Z', and that the disease, which is her object to be considered, changes, and shows up in entirely new forms. As she suggests:

> *"It is possible to refrain from understanding objects as central points of focus on people's perspectives. It is possible to understand them instead, as things manipulated in practices. If practices are foregrounded, there is no longer a single passive object in the middle, waiting to be seen from the point of view of a seemingly endless series of perspectives. Instead, objects come into being-and disappear-with the practices in which they are manipulated. And since the object of manipulation tends to differ from one practice to another, reality multiplies.*(Mol, 2002, p. 5)*"*

These insights seem to have a high value for the Paraná Delta as well. I will give away the plot right here, at the beginning of the article. It is this:

In practice, multiple co-existing ontologies on the Paraná Delta are brought into being. From one moment, time, location or actor, to the next, a slightly different delta is being discussed, measured or observed when considering the practices in the Paraná Delta.

This seems to influence all identified limitations on the application of ADM. ADM struggles with the fact that problem definition can be contested and change throughout the process, as well as the system boundary (Kwakkel, Walker, & Haasnoot, 2016). For example, as one participant would see a high influence of the river Uruguay as the greatest threat for the Delta, another would ignore this aspect and would stress the danger of climate change. Another would see the Delta as a collapsed system, while another would see the system full of potential ready to exploit. These insights made it necessary for me to make a shift in thinking; I realized that I had to extend my thinking in engineering theories with empirical philosophy. I had to go out of my comfort zone, should not look at individual limitations of ADM, but should investigate the implications of a multiple Paraná Delta's for adaptive planning. This article can be seen as a contribution to the calls made by Timmermans et al. (2015), Lin et al. (2017), Bosomworth et al. (2017), Zandvoort et al. (2017) and Carstens et al. (2019) to connect the theoretical underpinnings of ADM to on-the-ground practices.

I propose…. an ontological approach to modelling

Although there is much empirical material in this study, it is not a representative field report or a modelling study of a delta: it is an exercise in the modelling of empirical philosophy (Mol, 2002). I propose a way to connect ontologies and modelling in order to support ADM. Therefore, I will take the reader with me on an 'ontological exploration' to use the principles as suggested by Mol (2002) and apply these to modelling of the Paraná Delta. I examined the case by means of a multi-method approach: group model building exercises, interviews, literature analysis and focus groups to understand the primary ontologies on the Paraná Delta. By developing an approach to structure ontologies from my field material, first into narratives and stories, then into a structured table, I showed that it is possible to translate ontologies into model input. Afterwards, I discussed the use of ontologies for modelling with experts. In order to guide future researchers facing the same issues I faced, I present the design of an ontology-structuring method for ADM: the so-called 'Kite framework'. The 'Kite framework' provides guidance for modellers using ontologies in their work.

I structure…. this article

The research is structured in four parts, of which the results of the former phase are used as input for the next: (1) observations regarding ADM, (2) discovery of multiple co-existing deltas, (3) description of multiple ontologies in the Paraná Delta and (4) discussion on connecting ontologies and modelling.

In Section 2, I describe the setting of this research, including the case and the main theoretical foundations, in greater detail. In Section 3, I present the main methods used for action research on the application of ADM

in the Paraná Delta. In Section 4, I present the observations on the application of ADM for the Paraná Delta. In Section 5, I argue that the observations can be explained by the occurrence of multiple ontologies in the Paraná Delta. In Section 6, I present a method to construct these different ontologies, and I give various examples of ontologies in the Paraná Delta. In Section 7, I discuss how experts thought ontologies could be used to support modelling. Finally, in Section 8, I give the conclusions for this work, discuss the usage of ontologies for ADM, and I present the so-called 'Kite framework' and (other) directions for future research.

In order not to confuse the reader, I only show the methodology of observations on ADM in Section 3. The methodologies for ontology generation and modelling will be described after the introduction of the claims of ontologies. In section 6, I will describe the methods used to create ontologies, while in section 7; I will describe the methodology for the different modelling efforts.

2. SETTING: ADM, DAPP AND CASE PARANÁ DELTA

2.1 CASE: LOWER PARANÁ DELTA

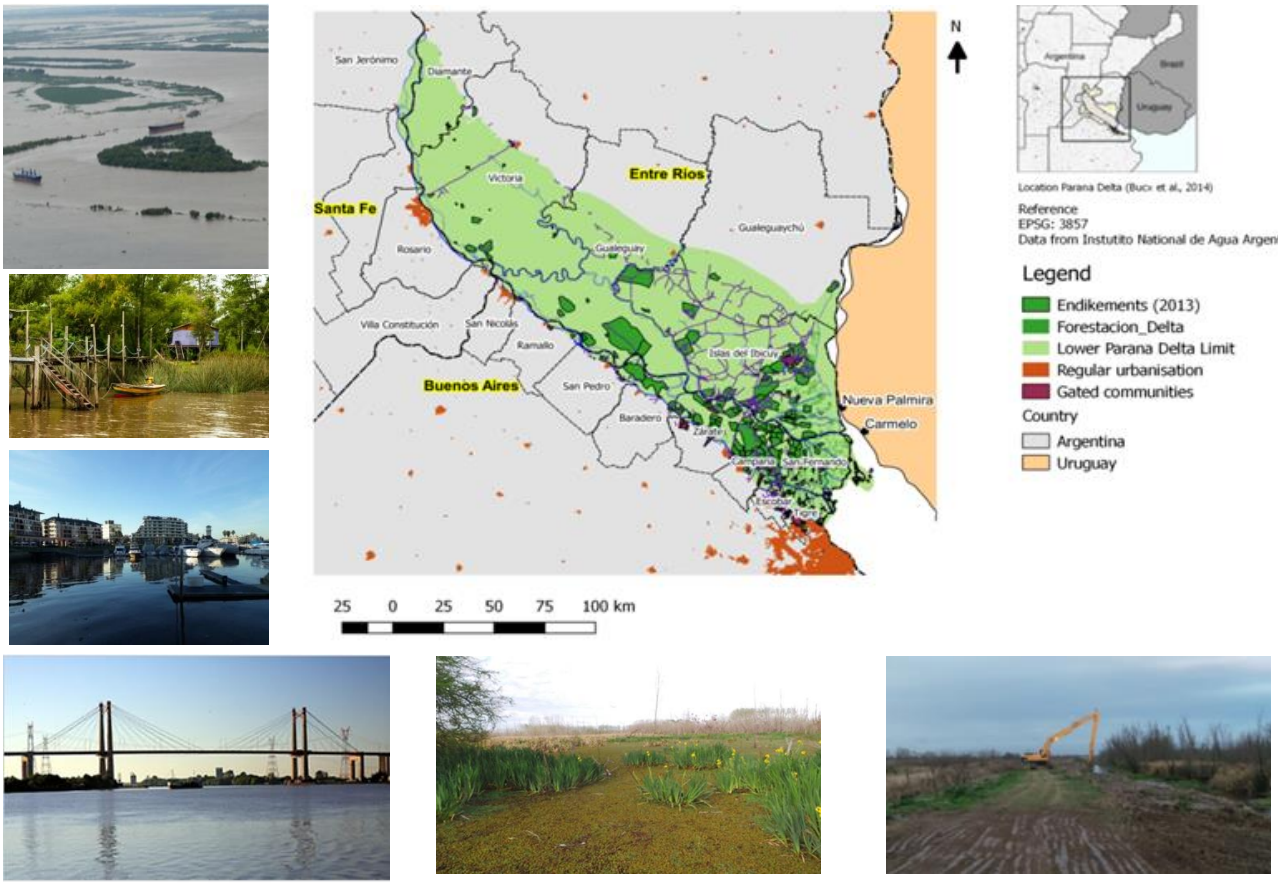


FIGURE 1 OVERVIEW OF PARANÁ DELTA

In this section, I will provide a short explanation of the study area (See Appendix Case description for more information).

Note: I understand that describing the case and thus providing one ontology, is contradictory to the claims I made in the introduction of a multiple existing Delta. However, I do not seek to suppress the idea or hide the idea of multiple ontologies while giving the first case description. I think it is essential that the reader has an initial idea of the Paraná Delta, and that of the many agents, such as rivers, polders and people, which play a role in shaping this. I present you the ontology I myself had in the beginning of this research, based on literature. I try to avoid words as' the Delta'. And later in this article, I try to justify the ideas of multiple ontologies on the Paraná Delta.

The Paraná river starts in Brazil, flows through Paraguay and Argentina, and ends up in the Rio de la Plata (Zagare, 2014). The focus of this research is on the Lower Paraná (see figure 1), situated from Entre Rios until to coast of the La Plata river (Zagare, 2018). The Lower Paraná has a length of approximately 320 km and a maximum with of 60 km (Badano, Sabarots Gerbec, Re, & Menendez, 2012). In the north the city of Rosario is situated, in which 1.2 million inhabitants live (Zagare, 2018). In the south, the river faces the greater Buenos Aires, with a population of around 12.8 million inhabitants (Zagare, 2018). It can be seen as different physical systems: a delta, a wetland and an estuary (Zagare, 2014). The Lower Paraná can be seen as a delta since it is an area dominated by sedimentation and due to the interaction of fluvial and marine forces (Marcolini & Parker, 1992). Secondly, wetlands are terrestrial and aquatic ecosystems along watercourses that are permanently flooded, making a connection with the groundwater (Junk & Piedade, 2010). The floodplain river-fed wetlands are recognized for their possibility to adsorb floods. Finally, it is also an estuary since it is a transition of two distinct water bodies: a river and a sea (Savenije, 2005). The Paraná Delta is a complex estuarine system since it does not discharge its sediments on the Sea, but first on the river Rio de La Plata (Marcolini & Parker, 1992).

The Rio de la Plata is formed by the confluence of the Rio Paraná and the Rio Uruguay. From the North, the influence can be found of the Paraná river. In the investigated area, the Rio Paraná splits between Rosario in the Paraná de Las Palmas and the Guazu river, with average river flow of 18000 m3/s (Bucx, Driel, Boer, & Graas, 2014). Furthermore, the river transports 160 million ton/year (Badano et al., 2012) of sediments, causing a continuous growth of the Delta front of approximately 72 m/year of the Paraná de las Palmas along its 60 km frontline and 27 m/year m northern sub front close to the Guazu river (Badano et al., 2012). The Delta itself is new land, formed by sediments of the Paraná's tributaries, while the edges of the Delta are ancient (Zagare, 2014). From the South-west, flooding occurs due to strong South-east winds (Sudestada) that steer up to the water level of the Rio de la Plata. The time of a Sudestada is also variable (it can be hours or days) Also, the recurrence is variable, in Tigre, for example, the recurrence of a Sudestada is between 4 and 8 weeks (Fundación Metropolitana and Municipio de Tigre, 2013). Furthermore, Sudestadas are associated with the El Niño Southern Oscillation (ENSO) cycle, which is a phenomenon that takes place in the tropical Eastern Pacific Ocean and is characterised by a change in temperature and pressure of surface waters. The ENSO is the leading cause of climate variability in South America (Berbery et al. 2006). From the West, flooding takes place, due flooding of the tributaries (as for example the Lujan river). Finally, from the west, the influences of the Uruguay river can be found (Guizzardi & Sabarots Gerbec, 2018). The influence of climate change was investigated by various studies (Barros, Clarke, & Silva, 2006; Barros, Menéndez, & Nagy, 2003; Medina & Codignoto, 2013; Re & Menéndez, 2006). However, the exact implications on water level and water flow variations are still debated.

During the 1990s, a state reform occurred, resulting in the privatization of public services (Zagare, 2014). This gave a possibility to private developers for the development of large gated communities along the border of, and sometimes even in the Delta (Zagare, 2014). A gated community is a neighbourhood that is closed from the rest of the urbanisations (Zagare, 2014). For the formation of these gated communities, polders are created. Also, industries can be found along the edges of the Delta (Fabricante et al., 2012). In the Delta's islands, polders can be found for forestry, agriculture and housing purposes (Minotti & Kandus, 2013). The government has not installed any system for the prevention of the floods on the islands, meaning that all flood protection is made by individual actors (Bucx, Driel, et al., 2014). Another technique that can be found

is " attajerepuntes", lower dykes in which flooding can occur to let sediments in. Often a second dyke is placed behind the attajerpunte, in which gates regulate the water system for irrigation purposes (Bucx, Driel, et al., 2014) By using an open ditch system (Sistema de zanja abierta) water can run off by gravity from the fields by means of open ditches (Bucx, Driel, et al., 2014).

The national government, three provinces, and 18 municipalities have authority in the Delta (Zagare & Manotas Romero, 2014). In order to simplify responsibilities, the national government is responsible for a healthy environment, the province is responsible for natural resources, and the municipalities are responsible for urban development (Zagare, 2014). Attempts are made by the current government to investigate the development of the Paraná Delta (binational conference). Other planning attempts can be found as a regional plan (PIECAS-DP, 2011), local municipal plans (Fundación Metropolitana, 2015) and local workshops (Wetlands international, architects Zarate). The government of Argentina has expressed its interest in ADM. Due to the context of many uncertainties and the request for planning ADM, the case study could benefit from an adaptive planning approach.

2.2 *ADM AND DYNAMIC ADAPTIVE PATHWAYS (DAPP) PLANNING*

ADM is described as 'a smart and intelligent way of taking into account uncertainties and dependencies of decision-making on Delta management with a view of reducing the risk of overspending or underinvestment' (van Alphen, 2016). Main elements include linking short-term decisions on the fields of water, land use and spatial planning to long-term issues in the fields of the water system and other ambitions such as nature and construction, by using scenarios (Deltacommissaris, 2018a; Gersonius et al., 2015; van Rhee, 2012; Zevenbergen, Rijke, Herk, & Bloemen, 2015). Furthermore, stakeholders are included in the model in a joint decision-making process to enhance legitimacy and feasibility (Zevenbergen et al., 2015). Various applications can be found of ADM in other contexts for national plans: in New York city strategy after Hurricane Sandy (New York City Panel on Climate Change, 2013; Rosenzweig et al., 2011), the Jakarta Coastal Defense (JCDS, 2011), in Vietnam, Bangladesh, Myanmar and Australia (Zevenbergen et al., 2015; Zevenbergen et al., 2018). Participatory approaches of ADM are increasingly receiving attention (Barnett et al., 2014; Campos et al., 2016; Carstens et al., 2019; Lawrence & Haasnoot, 2017; Murphy et al., 2017). Zandvoort et al. (2017) show in their comparison of cases that participatory research was most successful in reaching the objectives of ADM in comparison to other studies. See Appendix 'Background information', for more information on ADM.

While ADM is used as an overarching framework for different adaptive planning methods (Timmermans et al., 2015), Dynamic adaptive Pathways (DAPP) method (Haasnoot, Kwakkel, Walker, & ter Maat, 2013) is a commonly cited method to represent ADM (Timmermans et al., 2015; W. Walker et al., 2013, Denton et al. 2014, Maru and Stafford Smith 2014). The key of DAPP is firstly to plan possible actions, then to evaluate under which circumstances an option might fail, and then to identify actions that can be triggered later and lastly to represent these actions, visualized by an 'adaptation pathways map' (Haasnoot et al., 2013). DAPP planning comprises several stages to be approached in an iterative cycle:

1. Describe the current situation, objectives and uncertainties
2. Analyze possible futures by using uncertainties. Several problems, vulnerabilities and opportunities are analyzed to describe the future. Furthermore, the malfunctioning of the status-quo policy is evaluated.
3. Identify actions
4. Assess sell-by date actions with the scenarios and reassess vulnerabilities and opportunities
5. Develop adaptation pathways and map, selection preferred pathway
6. Determine contingency actions and triggers
7. Specify, implement, monitor, evaluate, report, and improve

Several strengths of DAPP are described in literature, including its easiness to explain adaptive planning to policymakers (Ray & Brown, 2015). Furthermore, the method also encourages decision-making to think about a context of uncertainty. DAPP helps to access path dependencies and lock-ins. Also, the method is a way to frame that adaptation is a constant process over time, in this way transient scenarios are encouraged to be used instead of a few points in time (Haasnoot et al., 2013; Jeuken & Reeder, 2011; Ray & Brown, 2015; van Veelen, Stone, & Jeuken, 2014). In this research, I followed the principles of DAPP to formulate my research activities.

2.3 ONTOLOGIES

Ontology is the part of philosophy that deals with the nature of existence[4]. Ontology refers to the study of being and existence, first suggested by Aristotle, also described as the study of attributes that belong to things because of their nature (Guarino & Oberle, 2009). In computer science, an ontology is defined as "a formal, explicit specification of a shared conceptualization (Borst, 1997; Guarino & Oberle, 2009). Other definitions in artificial intelligence suggest, "a specification of conceptualization. A data model/ description that represents knowledge as a set of concepts within a domain and the relationships between these concepts (such as agents and communities of agents) (Guarino & Oberle, 2009) [5]". In the work of Mol (2002), an ontology is used as "a descriptive account of existence, in which concepts and relations can be represented". I will use this last definition throughout this article. In the following paragraphs, I will discuss several relevant studies in which the work of ontologies can be found.

As a major author in the field, Mol (2002) shows that many of the things which we assume to be objective, measurable, scientifically quantifiable, and observable, are actually not fixed objects in the real world. Instead, they are multiple. Reality itself multiplies when we focus on artefacts or practices, even though theoretically, they would be independent artefacts. Or, as Law (2004, p.61) mentions:

> *"It does not imply that reality is fragmented. Instead, it implies something much more complex. It implies that the different realities overlap and interfere with one another. Their relations, partially coordinated, are complex and messy."*

Esbjörn-Hargens (2010) shows objects to be considered can vary when comparing the 'who-what-how'. Three leading different ontological positions can be found in literature: modern positivism, postmodern relativism, and integral ontological pluralism. The first assumes that one single object exists, while the second assumes multiple different objects, however integral ontology, recognizes that all ontologies can be enacted whether they are singular, relativistic or multiple. The positions are visualized in Figure 2. In this article, I posit the integral ontological pluralism position, as suggested by Mol (2002).

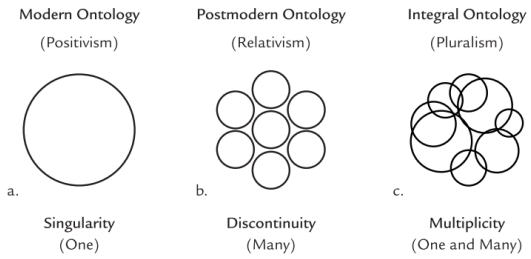


FIGURE 2 ONTOLOGICAL POSITIONS (ESBJÖRN-HARGENS, 2010, P. 149)

[4] Oxford english dictionary: https://www.oed.com/

Let's start with an example to explain this idea of multiplicity better: 'Hospital Z' of Mol (2002). In this hospital multiple versions of atherosclerosis exist, simplified for the treating doctor the disease is a medical condition, in the outpatient clinic it's the pain when patients are walking, for the vascular surgeon it is blood, for the pathologists it is a body part, for the technician it is what the diagnosis says, and for patients it is the pain they feel; the disease is multiple in practice, it varies in hospital floors, in between surgeons, it depends on measurements of the doctors, it is everywhere.

The logic of multiple ontologies has many similarities with ill-structured problems. Ill-structured problems are wicked problems in which the problem formulation itself is uncertain and uncontested (Webber & Rittel, 1973). Wicked problems are problems that include many different stakeholders and decision makers, whom all have their own values and ideas of solutions (Kwakkel et al., 2016). Interestingly, in such issues, the decision maker cannot afford to be wrong (Kwakkel et al., 2016). An approach to deal with wicked problems is to find a shared understanding of the system functioning through the debate of the decision makers and stakeholders (Kwakkel et al., 2016). The wicked problem literature is highly valuable and evolved regarding a shared learning process of decision makers and stakeholders to cope with wicked problems. Dewulf and Termeer (2015) show that ADM, when addressing wicked problems, could improve regarding learning among stakeholders. Wicked problems strongly focus on the 'problem' dimension (Dewulf, Craps, Bouwen, Taillieu, & Pahl-Wostl, 2005; Kwakkel et al., 2016), while considering ontologies as such, an apparent problem is not needed (Mol, 2002). Furthermore, by showing that the Delta has various shapes, I demonstrate by using an ethnographic approach, that different ontologies co-exist, and these can be harmonious or tense for the actors in the Delta. The actor aspect is thus of importance, as well as the creation of ontologies in practices. Whereas, literature on wicked problems aims to find frameworks to cope with the wickedness. Therefore, the wicked problem approach has value in structuring and coping with wickedness, while studying multiple ontologies broadens the understanding of the mind to the things that is actually happening in the Delta.

It is also possible to find multiple ontologies in literature related to water management. Carolan (2004) shows the co-existence of multiple crises in a watershed. Junier (2017) showed the existence of different ontologies of experts and stakeholders while developing a planning instrument for the water framework directive. Especially fascinating for this study is the multiple understanding of the modelling of the water system. Furthermore, different actors did not define the quality of a well-functioning decision support instrument in the same way. All these elements were observed in practice, while experts still argued that modelling would be a way for objective judgment. Poolman (2010) shows, by providing a drawing method, that actually farmers and the water board were sharing the same ontology, while they were not aware of this. Furthermore, the work of Wolf (2008) on water conflict shows the existence of multiple positions, objectives and values in a conflict situation. By going through these different layers and finally comparing the values of the actors involved; an understanding arises to the ontological multiplicity of water conflict. According to Scheer (1996), in his analysis of irrigation in Senegal, multiple ontologies can be discovered. Furthermore, Esbjörn-Hargens (2010) presents a multiplicity on climate change ontologies. Pesch, Correljé, Cuppen, and Taebi (2017) seem to highlight the existence of multiple ontologies for the implementation of sustainable energy. Finally, Dewulf et al. (2005) show that natural resource management deals with ambiguous issues, multiple actors and diverging frames.

3. METHODS: TOWARDS THE APPLICATION OF ADM/DAPP

By organizing research activities and cooperating with other organizations, it was possible to set up multi-method action research (Blair, 2016) to investigate the use of modelling of ADM for the Paraná Delta. In order to do so, in the first place, I aimed to investigate the applicability of ADM for the Paraná Delta by investigating the reaction of stakeholders to ADM. Next, I applied ADM to the Paraná Delta.

3.1 OBSERVATION REACTION STAKEHOLDERS

To investigate the reaction of Argentinean stakeholders to ADM, I performed several research activities (see Figure 3). In the first place, I performed a participatory observation of the Argentinean research visit to the Netherlands (Figure 3) to understand the possibility for ADM for researchers. Then, I made observational notes during an ADM workshop on basin level regarding key themes or issues, and attitudes. Notes were made by different observers, and later, we compared these responses and notes. Together with the Argentinean student, I organized five 1-day workshops with selected stakeholders in order to apply the DAPP framework in a participatory format.

Observational notes were made regarding the outcomes of the workshops and regarding the attitudes and responses of the respondents. Furthermore, by using the critical incident method (Witteveen & Enserink, 2007) we described critical incidents that took place during the workshops, and these were discussed in a multi-cultural workshop team afterwards, with an expert on the Delta not involved in the workshops. Also, we distributed surveys before and after the workshops in order to understand the learning of the participants (For all research, methods and data of the workshops see Appendix comparison workshops)

The results of the different research activities were memoed and coded, and identified limitations of ADM for the Paraná Delta were highlighted. The results were compared with findings from the literature. Articles showing critiques on the paper of Haasnoot et al. (2013) were used, or cases in which DAPP was applied, by using snow-balling new relevant literature was found. Also, experts were consulted for the suggestion of relevant literature.

3.2 DELTA UNDERSTANDING

In order to improve my own understanding of the issues and functioning of the Paraná Delta, several activities were organized (see also Figure 3). Early scoping exercises involved focus groups, and individual interviews with over 30 experts on the Delta to gain a detailed contextual understanding of the issues in the system, the system understanding and main indicators to be researched (See Appendix Scoping mission for detailed information and results). Further, a workshop was organized in which the stakeholders had the possibility to comment on the differences in the system diagrams. Experts were selected based on literature studies, and suggested by key informants. In each of the focus groups or interviews group model building exercises (Basco-Carrera, Warren, van Beek, Jonoski, & Giardino, 2017) took place in which the stakeholders were suggested to make a system diagram of the Delta and participatory actor mapping, in which the experts were asked to fill in a power-interest diagram of the main stakeholders (Enserink et al., 2010) to understand the social system of the Delta. Furthermore, semi-structured interviews were done with local island inhabitants regarding their perception of flooding by visiting the inhabitants by boat (See Appendix measurements). Also, semi-structured interviews were done on the 'Dia de islenios' regarding their perception of the Delta and its related social system of the island inhabitants. Then, for each of the five workshops, observational notes were taken during workshops regarding key themes or issues, attitudes and responses by different observers. Later these notes were compared (See Appendix workshop comparison).

The participants were asked to draw the main dynamics of the Delta and the actions they suggested for improvement on a map. GIS-files were made of these drawings (See Appendix Results workshops). Furthermore, they could highlight the opportunities and threats and describe actions to implement over time (See Appendix workshop comparison). Also, they were asked to construct their vision on the Delta. Observational reports were written for all activities (See Appendix workshop comparison). In the next section, I will present the results of these observational activities.

Observation ADM researchers | System dynamic exercises | ADM participatory workshop | Local interviews | Large Delta workshop

FIGURE 3 VARIOUS RESEARCH ACTIVITIES

4. RESULTS: OBSERVATIONS OF APPLICATION ADM

By applying the methods mentioned in the previous paragraph, I got many observations and ideas of applying ADM in Argentina. It seemed to me that while ADM was found to be conceptually appealing to the respondents, several points of consideration could be made regarding its utility for the Paraná Delta. I will discuss the essential outcomes which I identified (together with my stakeholders) on the applicability for ADM related to literature.

4.1 MANY UNCERTAINTIES: A COMPLEX PROBLEM

Most studies that are found for the application of ADM in workshop format only deal with a limited amount of uncertainties on the tipping point axes (see, for example, Haasnoot et al., 2013). However, in the Paraná Delta, many uncertainties and issues regarding the development of the Delta and the functioning of the Delta were found. I use the word 'uncertainties' existing in the DAPP language since they were points on which the stakeholders contradicted each other and about which they could not reach one system description. Uncertainties that were highlighted were: the influence of Sudestada, the frequency of Sudestada, the height of Sudestada, increase/decrease in rainfall of the delta, increase/decrease of the flow of the river Paraná and the influence of the river Uruguay. Furthermore, contrasting views existed on, for example, the influence of the dykes, the sediments etc. Moreover, looking at the more social aspects of the Delta, the government presence in the Delta, the social conflicts happening, and the popularity of the Delta right now and in the future were ambiguous. Furthermore, contradictions existed regarding future developments such as: the price of soy, wood, houses, the creation of infrastructure, the change of livestock to agriculture and the price of a man hour in order to construct dykes.

Furthermore, in this environment with many different ideas of the functioning of the Delta, I struggled how to formulate the main problem of the Paraná Delta in order to inform my model. From literature (Bucx, van Driel, et al., 2014; Fabricante et al., 2012; Zagare, 2018) I got initially the idea that the pressure of the gated communities was the cause for many flooding's in the Paraná Delta and its surrounding informal settlements. However, by having interviews with various researchers, it became obvious that the forestry polders in the Paraná Delta were the main cause of change in water flow. Though, local forestry companies contradicted this during my field visits and measurements. They highlighted that they managed their polders in a sustainable way without harming significantly water levels or nature. Furthermore, they showed that often, the water could enter the fields, and thus were not such fixed structures. Then, while discussing this issue in

the workshops, polders actually seemed to change from forestry to agriculture functions, which also implied different water management practices. When people asked me both in Argentina and in the Netherlands *"so what is the real issue that you are aiming to solve?",* I still could not answer. I only knew it had something to do with polders and their development in the Paraná Delta.

By practitioners of DAPP (Warren, 2019, personal conversation), it was suggested to me to find one overarching tipping point condition (one main uncertainty) in participatory settings of ADM. However, this seemed very challenging due to the high amount of uncertainties to be found in the Paraná Delta. Only, the tipping point condition is crucial since it influences the actions to take to achieve identified long term objectives. When the participants were asked about their overarching uncertainty, a researcher commented:

> *"You in the Netherlands have a much more simple system, with only climate change, sea level rise and rivers as your main concern. We have so much more to think about, so many social issues as well. It is impossible to simplify the complex Paraná Delta to your way of planning".*

It can be argued that in the Netherlands by discussing the Delta development for at least 100 years, the number of perspectives on development is lower in the Netherlands than in Argentina, or that the planning in the Netherlands does not pay well attention to the various uncertainties/perspectives (anonymous expert, 2019, personal conversation). When we relate this to published policy literature on DAPP it is highlighted that much more uncertainties can be found in Bangladesh, than in the Netherlands (Zevenbergen et al., 2018). Therefore, Zevenbergen et al. (2010) advise to adapt the framework to embrace a variety of uncertainties. Also, Wise et al. (2014) suggest that decision trees may form a solution in handling the high amount of uncertainties in a workshop format. By using the decision tree schematic (Ray & Brown, 2015) in which, by suggesting different decision steps, uncertainty of climate may be addressed at first by going to a tree of detailed modelled steps, suggesting the formulation of different models, and as a final step the inclusion of an ex-post scenario elaboration, followed by a methodology of decision making under uncertainty (Ray & Brown, 2015). Also, ideas could be found in decision tree induction, Classification and Regression Trees (CART), (Breiman, Friedman, Olshen, & Stone, 1984). These could help to focus on the relevant or limited uncertainties.

4.2 OBJECTIVE FORMULATION

In order to specify the objectives for ADM, exercises were done in a variety of workshops to create a vision of the Delta. The idea was that participants, after having created their visions on the future Delta, would be able to discuss in more detail which objectives they aimed to reach. In the five workshops I organized myself, we played with a ball, on which different questions were written down, and participants were asked to answer questions regarding their vision. However, many participants indicated they did not prefer to tell their vision. Instead, they preferred to mention their most likely scenario. I observed that many participants did not have the feeling they could create a future for the Delta like they wanted to have. A participant commented:

> *"It is not possible to make a vision since, in Argentina, so many things can go wrong, everything is always different than we expect or want. What is the point of thinking about our ideal future if it is never going to happen?"*

However, in the evaluation of the workshop, an architect working in the Delta made the following remark:

> *"Thank you for giving me the feeling that I can create my own future, sometimes in Argentina, I forgot this, but now I feel empowered to change my own future.'*

However, after giving several examples to the participants of visions and pushing the participants to think in this way, they created different visions. These visions often related to the sustainable development of the Delta, though, sometimes the vision was more on the extreme end: a vision regarding massive production in the Delta or a vision of the Delta to be given back to nature. Afterwards, participants were asked to translate this vision and quantify in objectives. Participants had great difficulties in developing these, and a lot of

debate occurred regarding which objectives were important, regarding the exact formulation and often, the objectives were not related to the previously proposed vision. Furthermore, often, the previously discussed key performance indicators were re-discussed again, and highly varying opinions were found.

When we relate the findings to previous publications, it becomes clear that the challenge is to formulate the main goals and criteria that were both specific, but agreeable for the participants, and are identified as a limitation of DAPP (Bosomworth et al., 2017; Carstens et al., 2019; Wise et al., 2014). Wise et al. (2014) criticizes the pathway approach to focus only on context with unambiguous goals and not able to handle a more complex context of multiple conflicting objectives. A context, which one can argue that can be found in the Paraná Delta as well. However, the lack of identifying objectives can also be explained by the fear of some participants that this research would influence further development in the Delta, and therefore, they only wanted to make a well-considered decision. A researcher commented:

> *"Even though this is a scientific work, most likely it will end up somewhere, and politicians can find it in their planning. Therefore, we should not make specific statements."*

Another possibility is that culture played a role, and participants had difficulties in framing long term objectives, as Hofstede, Jan Hofstede, & Minkov (2010) suggest. Furthermore, participants wanted to change objectives also during later stages of the process; it is also highlighted by Zandvoort et al. (2017), in a Portuguese participative study that a constant debate took place regarding the redefinition of the objectives.

4.3 MANY ACTORS

The Paraná Delta consists of 18 municipalities and 3 provinces. These have very different legislation. A limited amount of planning instruments is present, and the general basin authority is in lack of power. These authorities take all kind of different, and sometimes conflicting actions. Furthermore, the Delta functions a bit like a wild west. Farmers take individual actions as building dykes. Nature organizations make development plans, and so does the forestry sector. This means that all actions are individually made in the Delta; the government has minimal control over the region. This can also imply that some actions might harm other individuals. No compensation structure exists in such cases. In the workshops, it was highly difficult to set-up adaptive pathways of different actions since it was unclear who was responsible for the actions or who would act. Then, if only individual actions were taken, these could also lead to conflicting objectives, and therefore it was challenging to represent them together in one adaptation pathway map. It was chosen to 'pretend' as if one basin authority existed with authority, to construct the pathways map, while the reality of the Paraná Delta is that many actors have conflicting strategies.

In literature, it is mentioned that DAPP is a relative unicentric framework: it assumes a clear decision maker, enabling governance and presents little attention to the decision-making process (Bosomworth et al., 2017; Timmermans et al., 2015; Wise et al., 2014). In reality, the context is much more complex, and various actors can play a role (Wise et al., 2014). These actors can have vested interests and might constrain the actions of others (Wise et al., 2014). Clearly, in the Paraná Delta, vested interests of several actors could be seen in the planning of the Delta, even the participation of this study did not always seem to be welcomed. For the implementation of the Delta Plan in the Netherlands, the governmental authority, 'the Delta commission', can be found, which has a clear authority to implement the ADM decisions (Deltacommissaris, 2018b).

Several suggestions have been formulated to address relative unicentricity. Rosenzweig et al. (2011) developed an approach of flexible adaptation pathways, which has high similarities with DAPP, but also a strong focus on the interaction between scientists and local stakeholders. The approach describes how to include decision makers from various levels and how to enclose uncertainties to the general public to enhance actions that induce small changes as well as significant transformative actions of global change. Also, transition management highlights that the system contains multiple domains, levels and actors, and by including focuses on a transition area, these domains can be included (Loorbach, 2010; Loorbach & Rotmans, 2010). An alternative to the adaptive pathways could be 'pathway

thinking' which might enable to investigate next to the implications of climate change also change due to drivers and other actors responses (Wise et al., 2014). In order to address the issue of such a complex socio-cultural and institutional system, Van der Brugge & Roosjen (2015) add additional dimensions in the analysis of the strategies to highlight the different actions of the different actors and their position to each other. Furthermore, they highlight how institutions would change in different scenarios. Murphy et al. (2017) highlight that ADM is too little seen as a process of social change, and too much as an end-product or a plan to develop. How this social change occurs is not considered in the pathways approach. Notably, in the context of Paraná Delta, this is interesting, since many different development efforts are taking place, top-down, bottom-up, as a chaotic transforming network. For example, by participating in the workshops, some stakeholders wanted already apply ADM to their case areas. Murphy et al. (2017) propose situated pathways approach, taking into consideration how cultural and political dynamics animate diverse trajectories of change over time. This work especially is interesting for communities were existing livelihoods are unlikely to be maintained (Murphy et al., 2017), since the vulnerable communities of the Delta, in this case, may not be sufficiently be protected in the general DAPP framework

4.4 DIFFICULTY TO SELECT ACTIONS

While DAPP suggests providing long-term dynamic adaptive strategies (Haasnoot et al., 2013), the actions suggested by the respondents for the Paraná Delta were related to short term implementation. The participants showed that the current system is already not functioning well. As a respondent commented:

> *"What is the point of thinking about the future and everything that can happen if we really need to improve our current system."*

In DAPP, the assumption is made that the current system is functioning correctly, and it is assessed when the system is not functioning correctly anymore (Walker, Marchau, & Kwakkel, 2019). The participants preferred to spend the resources on an improvement of the current system, such as additional research, zoning, the instalment of an early warning system, etc. The only reason for not applying all actions at this moment was the lack of available resources. The DAPP framework does not give a possibility to set out preparatory actions in time based on urgency. Furthermore, adaptive strategies such as room for the river on an increase of dykes were not seen to bring the value of the respondents. In some cases, the participants accepted the proposed strategies, once the facilitators pointed out the need to consider uncertainties. In other cases, the participants said the facilitators could write them out, but they would not consider them in reality. As a researcher mentioned:

> *"It is all nice to do this methodology here with you on paper, but in reality, this will never work in the future. The government of Argentina may go bankrupt tomorrow. It is smarter to spend the money that we have right now than wait, and we possible don't receive any money at all."*

The lack of formulation of long term strategies of DAPP can be traced back to literature. It might be that the actions were simply not well for the Delta, or that as the participants highlighted, tomorrow the government of Argentina can completely change. Also, the funding issue is a real problem. Notably, unstable governmental structures do not seem to guarantee a successful continuation of the project. This was also seen as one of the main barriers to implementation for local adaptation in Europe (Aguiar et al., 2018). For example, in adaptive management, this issue is addressed in which knowledge is created for a long term implementation, while at the same time there is a focus on successful short term outcomes based on current knowledge (Allan & Stankey, 2009).

Another argument is that participants have difficulties in accessing the long term future, as Hofstede, Jan Hofstede, & Minkov, (2010) suggest (de Rijke et al., 2018; Timmermans, Haasnoot, Hermans, & Kwakkel, 2016). In a similar study in Sweden, it was shown that participants preferred static actions, and they used uncertainties to justify their short term actions, instead of using it to explore the decision space (Carstens et al., 2019). Also, Wise et al. (2014) show that the actions that are implemented in ADM approaches are mostly focused on short term change and less on sizeable societal change. Various researchers show that the methodology is simply too complex and therefore,

cannot be used appropriately to formulate long term action (Bosomworth et al., 2017; Carstens et al., 2019). Furthermore, I applied an adapted, simplified version of the DAPP-methodology, in which scenarios were introduced in a later stage of the research, and thus experiential learning effects could be reached (Kolb & Kolb, 2012). Participants were more willing to select adaptive strategies.

4.5 CHALLENGE TO DETERMINE BOUNDARIES

For the workshops and the modelling, it was necessary to formulate the boundary condition of the system. This appeared to be highly complex due to the connection with the greater Paraná Delta by means of natural processes, due to the growth of the Delta, the influence of surrounding rivers and its proximity to the city of Buenos Aires, due to the migration of its inhabitants, the influence of the surrounding communities to the continent, and due to international wood prices to the broader international area. In the workshops, we did not want to discuss the entire lower Paraná because it is a large area consisting of many complex dynamics. However, all these dynamics still had an influence in the regions of the Delta.

In literature, the influence of the surrounding system is also highlighted, especially in the case of a complex legal environment turned out to be an issue (Carstens et al., 2019; Wise et al., 2014). Furthermore, (Zevenbergen et al., 2008) show that local adaptation is influenced by other interventions, of multiple scales and multiple times .

5. MULTIPLE CO-EXISTING DELTAS

5.1 THE INSIGHT: MULTIPLE DELTAS

In this paragraph, I will highlight the main claim of this paper: multiple ontologies in the Paraná Delta are created in practice. In Section 4, I have shown that different observations can be made regarding the implementation of ADM in the Paraná Delta, and I was able to relate these observations to existing ADM literature. However, in all these studies, the assumption is made that stakeholders may have different perspectives on the Delta. However, in the end, they consider it as one Delta. A different point of view is given in the work of Carolan (2004). He realized in his basin analysis Klamath Basin (USA) that the initial problem of water scarcity was far more complicated than he had assumed: a crisis multiple occurred, which is a single debate around a multiplicity of objects (Carolan, 2004). The problems constantly manoeuvred and shifted from water quantity to water quality, to safety, to social issues, to heart attacks etc. Similar, Mol (2002) showed the constant shifting of atherosclerosis in 'Hospital Z'. This idea of a multiple existing Delta is highly interesting to explore further. As I described in Section 4.1, it was not possible for me to describe the system and the main problem, which is the first step of DAPP (Haasnoot et al., 2013). The Delta was changing in practice depending on whom I spoke with.

"The Delta was changing in practice depending on whom I spoke"

The Delta alternated for me: from a system with conflict to a harmonious delta. I shifted from a delta in which flooding due to extreme urbanization played a role, to a delta with as a sole purpose to produce trees for forestry, to a delta that has an agriculture purpose. It changed from a delta full of dykes to a delta with collapsed or abandoned dykes. It became a delta in which floods meant domestic violence for women or a delta in which drought meant that a grandmother could not go to her granddaughter's birthday. I found a delta in which the water ruled the system , but also a delta in which humans dominated nature.

In other words, the Paraná Delta is not singular, it is multiple when we consider it in practice. I argue that the use of multiple ontologies can be an explanation for the found observations of applying ADM (see Section 4). In Section 5.2, I will explore if this idea further.

Note: To clarify, I discuss the creation of multiple Delta's in practice, following the argument of Mol(2002). This article does not aim to add to the discussion if in principal one delta exists (one sub-structure of reality), and that multiple Delta's are changing through translation by people (see Esbjörn-Hargens, 2010), or that not one reality can be found. I will briefly touch upon this issue in the discussion, but it is not part of my argument.

5.2 MULTIPLE ONTOLOGIES AS AN EXPLANATION FOR FOUND OBSERVATIONS ON ADM

Let's see if it is possible to use this idea of a multiple existing Delta for an explanation of the previously identified points.

Note: dear reader, let me first give you a disclaimer: I lack the vocabulary required for the description of these multiple ontologies, therefore I'm still forced to use words as system, Paraná, Delta, solution etc. I hope you understand that by using such words, I again do not aim to suppress my own claims of multiple ontologies.

Regarding the system's understanding and uncertainties, participants seemed to have a different understanding of the dynamics of the water system and the social system. As Esbjörn-Hargens (2010, p. 148) mentions in his ontological multiplicity on climate change

> *"I am not disputing that all the stakeholders are speaking more or less about the same thing. But that is the point- more or less."*

The same issue is of consideration for the Paraná Delta. In the first step of ADM, a system description has to be made (Haasnoot et al., 2013). However, if the participants do not have a similar system understanding, it will give high difficulties in the remaining steps, as Kwakkel et al. (2016) highlight the difficulty for DAPP to cope with diverging problem understandings. Furthermore, stakeholders had such different understandings of the current delta. While having to cooperate when making a plan, a conflict arose, and they refused to cooperate afterwards. The same is found by Carolan (2004), by mapping an ontological diverse conflict.

Regarding the objectives, Wise et al. (2014) criticize the pathway approach for focusing only on context with unambiguous goals. As we saw in the workshop, multiple conflicting objectives could be found. Furthermore, participants wanted to change their objectives throughout the workshop. This situation is also highlighted in a participative ADM study in Portugal by Zandvoort et al. (2017), showing that a constant debate took place regarding the redefinition of the objectives. I also found that participants had great difficulty in defining the objectives. An explanation could be that due to the multiple-coexisting ontologies, not one single set of objectives can be found. Objectives again will be multiple, overlapping and changing in time and space of the Delta.

Furthermore, DAPP has a limitations to include multiple decision makers and bring attention to the multi-stakeholder decision process (Bosomworth et al., 2017; Timmermans et al., 2015; Wise et al., 2014). This implies that only one ontology of one decision maker can be taken into account. While in the Paraná Delta multiple ontologies of various decision-making authorities could be observed.

The static short term actions which were suggested by the participants versus long-term dynamic actions showed a difference in ontologies of DAPP practitioners and local inhabitants. Local stakeholders understand their delta as a currently failing delta. While DAPP pre-supposes that the Delta is a currently well functioning delta, but may fail in the future if no policies are implemented

Finally, in multiple ontological environments, it would be highly challenging to define boundary conditions of the Delta or of the exact study area, since the boundaries may be defined differently for all of the ontologies.

By discussing the main observation of applying ADM in the Paraná Delta, several difficulties could be found during implementation. I have shown that the difficulties can be explained by the existence of multiple ontologies in the Paraná Delta, which is not addressed in ADM.

"Multiple ontologies can be used as an explanation for difficulties of ADM implementation in the Paraná Delta."

Let's go back to the initial aim of this paper; modelling the Paraná Delta for ADM. As Carolan (2004) mentions "Why should environmental-minded scholars concern themselves which such a seemingly detached issue as an ontology?" He argues that by addressing the issue of multiple ontologies, many environmental conflicts can be understood better. As Mol states (2002) it is not something wrong or good to have multiple ontological environments, however, it is important to be aware of these, so we can take it into consideration when answering the question 'what to do? The same holds for the Paraná Delta, in which I observed many debates and sometimes strong competing views, causing a delay of the ADM process or sometimes even conflict. I argue that the ontology of the Paraná Delta that engineers perceive is highly valuable, but it's one of the many ontologies we can find. However, this perception has a great influence on politics related to adaptive planning. I argue that due to limited awareness of the existence of multiple ontologies of the Delta, the stakeholders have misunderstood each other. Or, maybe being aware, some stakeholders pushed for their own ontology, to become dominant, steering the ontological politics and pushing research and policy in their direction. Eventually, the aim of modelling is to aid in the formulation of policy decisions. By acknowledging multiple ontological environments, I hope to bring insights into policies. As Mol (2002) shows, if reality has the potential to be multiple, it will also have the potential to be political. If practices are plural, it is argued, the realities they enact are as well. However, since we do not experience the world as multiple, politics is made based on one ontology. Therfore, Mol (2002) argues that evaluating the concept of multiple ontologies can help to formulate policies.

By being aware of the multiplicity, modelling could benefit and eventually the ontological politics (Mol, 2002). Therefore, I will present a *pragmatic ontology* (Carolan, 2004) to describe the multiplicity of the Paraná Delta, In the next paragraph I will present examples of ontologies I found in the Paraná Delta, followed by a discussion of how to address ontologies for the modelling of the Paraná Delta

6. ONTOLOGY DISCOVERY

6.1 METHODS AND MATERIALS

As described in Section 3, I have performed action research to investigate the application of ADM in Argentina. After my visits to Argentina, I realized that multiple ontologies in the Paraná Delta existed. I used the previously gathered material to describe these ontologies.

Several methods and results described earlier were used to construct different ontologies. Firstly, the group building exercises, including the drawing of system diagrams, main indicators and participatory actor mapping, were used to construct different ontologies. Secondly, the description of the Delta in the ADM workshops, I participated in (See Appendix Workshop Deltares/INA) or organized myself (See Appendix Workshop Comparison) were used. The participants were asked to draw the main dynamics of the Delta and to draw the actions they needed to improve the Delta for its objectives. Furthermore, they could highlight the opportunities and threats and describe actions to implement over time. Also, they were asked to construct their vision on the Delta. Furthermore, semi-structured interviews were performed with local island inhabitants regarding their perception of flooding. Also, semi-structured interviews were performed on the 'Dia de islenios' (island day) regarding their perception of the Delta and its related social system of the island

inhabitants. Observational reports were written for all activities by different observers; notes were later on compared.

The description of the occurrence of a multiplicity of ontologies in the Klamath Basin by Carolan (2004) is of great help for structuring my work. Ideas for crafting and understanding multiple ontologies of change can be found in Mol (2002). Furthermore, in group model building in system dynamics, the initial standpoint is that stakeholders may have different world views, and thus create different models. By making use of causal loops, the system perception of the stakeholders can be described (Basco-Carrera, Warren, van Beek, Jonoski, & Giardino, 2017) and by participatory discussing the system one ontology can be created among the stakeholders.

Memos and notes were made regarding the different ontologies found in the reports and discussed with colleagues on the project; initial ontologies were suggested. In the published examples on ontologies (Carolan, 2004; Esbjörn-Hargens, 2010; Mol, 2002) I could not find guidelines on how to describe narratives of different ontologies. However, Carolan (2004), Esbjörn-Hargens (2010;) and Mol (2002) give a suitable description of ontologies. Therefore, I have formulated several questions based on Carolan (2004), Esbjörn-Hargens (2010) and Mol (2002) to guide me in the improvement of the initial ontologies constructed. Possibly, these questions could inspire future engineers/researchers regarding ontology creation as well. The questions are:

1. What is the main object of consideration? In which versions can it be found (Mol, 2002)?
2. Which main events take place that shapes an ontology (Mol, 2002)?
3. Do specific actors have specific ontologies dependent on a time or place (Mol, 2002)?
4. Are the ontologies of a similar level of comparison, or on different levels, such as with Mol (2002), where an ontology can be both a condition and a process
5. Does a dispute or conflict take place (Carolan, 2004)?
6. Can we define ontologies based on profession, work style or view (Esbjörn-Hargens, 2010), or can we see different ontologies in these domains (Carolan, 2004)?
7. Can gender can be related to ontologies (Mol, 2002)?
8. Does a competition exist by the different ontologies (Mol, 2002)?
9. How do the who-how-what of each of the enactments of the Paraná Delta differ (Carolan, 2004) ?
10. Do the ontologies change over time (Mol, 2002)?
11. Politics of who and politics of what, what do the ontologies dictate (Mol, 2002)?

By using these questions, I was able to construct the different ontologies, which I'll present in Section 6.2. Different from Mol (2002), who did not observe interactions between the different ontological actors, I organized workshops in which many interesting encounters could be observed. I aimed to show some of these interactions as well. In order to construct the main ontologies, which I wanted to prepare for modelling, a structural comparison is highly beneficial. Latour and Strum (1986) provide an excellent comparison of ontologies of social change. I used their points for comparison to structure the main ontologies; Esbjörn-Hargens(2010) used catchy names in his comparison of climate ontologies, which I implemented as well. By having a creative session with the Argentinean student involved in the research, and discussing all materials. The main ontologies were structured and discussed with the supervisors of this thesis.

6.2 RESULTS

In section 5, I presented the idea of multiple co-existing ontologies in the Paraná Delta. The section that follows provides a glimpse of such a multiple deltas. In this section, I intentionally do not try to tie these multiplicities tightly together; what will be implemented in Figure 5 at the end of this chapter. Instead, the

purpose here is to open our intellectual minds to the possibility of ontological multiplicity within a delta. What I provide in these sections, then, is a sketch of ontological multiplicity. Now, on to that shifting reality.

ONTOLOGIES ON ACTORS

When I was trying to sketch examples of these various ontologies, I immediately faced an issue: whose ontologies did I have to consider? Multiple ontologies already seemed to exist regarding the actors to be included in the Delta. By doing participatory actor mapping, people started to give the contact details of people they advised immediately. Some experts were convinced to include the local population and affected users, for example, a rowing society that would suffer by low or high water levels, and some stimulated me to include various governmental organisations. However, others mentioned that many of these organisations did not have any influence and could be left out. I aimed to have contact with diverse types of stakeholders.

Note: It can be debated if individuals can have their entire own ontology, or that ontologies per definition are created in practice, thus by the connection human agents encounter. I argue here that we can assign specific ontologies to specific humans. Of course, I understand it is not practical to discuss the ontologies of all the people having to do anything in the Delta, and of course since actors encounter in relations in practice many ontologies will have an overlap. But still it is interesting to investigate the ontologies of the human agent, to observe the diverging ontologies.

THE INITIAL PROBLEM STATEMENT

Initially, the 'problem' in the Delta seemed relatively straightforward: gated communities are a high threat for local flooding of informal settlements and flooding in the Paraná Delta, due to their construction of dykes and elevate the land (Bucx, Driel, et al., 2014). Combinations of high floodings of the Sudestada and rainfall of rivers as the Reconquista and the Lujan were suggested to cause flooding in the lower informal areas around the gated communities (Zagare, 2014). These mega urbanisations lead to a reduction of the floodplain, causing the flow in forced channels during the period of peak flows (Machain, 2013). When I started discussing these ideas with local activists, they argued that these gated communities could influence the stability of the entire delta.

However, by listening to individuals and organizations embedded within the Delta, it did not take long for me to understand that the problem is not fixed merely to the issue of the flooding due to the gated community. What seemed to be one Delta, quickly revealed to be more than one. It's multiple. The issue of the gated communities consists of more than only the flooding issue. I'll demonstrate several other problems these gated communities initiated.

The provincial authorities mentioned the following sequence of activities of the development of gated communities:

> *"It is forbidden by the national government to build below 5 m above ground level; this makes the low ground at the layers around the Delta unusable for the building of houses. However, what happens is that private developers start to give free roads and bridges to the municipality, and the municipality looks the other way. The developers let canals be excavated, have trenches dug, and they use the soil to increase the level of the land. They build fancy houses and infrastructure. Remember that these developers still not have a permit. But when the houses are sold than the municipality gives the permit since the condition is fulfilled of housing. Then, the only thing the province can do is accept as well, even though they disturb the watercourses, which are the responsibility of the government."*

Polders were seen as illegal constructions, while also obstructing the natural flow, causing floodings in the lower areas around them and inside the system, resulting in high environmental degradation. The only thing the provincial authorities could do was accept these structures. This was also highlighted by an activist protesting against these gated communities:

"Polders represent the idea of powerful developers that only care about financial gains."

Others researchers highlighted the strong social exclusion the gated communities made, forcing impoverished people to live around the border of these communities in villa's (slumps). Some researchers related this to the flooding of the lower areas; others attributed it to the social system. They highlighted that separating an exclusive neighbourhood from the rest of the world, also separated people socially. However, it was also argued that many job opportunities were created due to the establishment of the gated communities for people living in the informal areas around them, as household work or gardening.

It became clear to me that the feeling about these gated communities differed. A respondent making a day trip to a gated community mentioned

"I would really like to live here, the beautiful natural environment, the nautical atmosphere, the safety; it is really a possibility to relax from the city. If I had the money I would really buy a house here".

However, others mentioned that

"I believe that in a few years these gated communities will be completely abandoned. Who can live here? Just to buy a pack of milk, I have to drive a minimum of 15 minutes. And the time it takes to go to work is a few hours every day. More and more people will go back to the city, mark my words."

Another respondent said she was quite unhappy with living in a gated community

"We had to live in this house, since my husband is an architect and constructed the house, to sell afterwards. But nobody wanted to buy it, and now I have to keep on living here, being alone with my child during the day. In what kind of protected fake world will my son grow up? This is not a type of society I want him to only know, like all these other spoiled children".

These examples showed me that for many of the respondent's gated communities had a different meaning; it did not take long to realize that the problem wasn't merely fixed to the issue 'flooding due to gated communities'. Howeverr, did the problem actually have anything to do with flooding at all? A dispute occurred on this issue.

DISPUTE

A GIS expert on the Delta mentioned:

"Nobody seems to understand the functioning of the Delta properly; even I did not understand this well before. I had to study the movement of a fish population, but I did not understand why the fish were migrating a certain way. Therefore, I started to study the geological formation of the Delta. Listen carefully since nobody understands this. The Delta is a build-up of different geological layers, the borders where the gated communities are situated are outside the Delta, outside the floodplain. They are a build-up of new land, and they have nothing to do with the Delta. They cannot be the reason for flooding in the Delta. It would be more interesting if you study the Lujan river, in which we can find many gated communities and informal settlements, and for which we can see local influences".

Also, hydraulic researchers of the water institute mentioned that these gated communities are only expected to have minimal hydraulic effects due to their small surface in comparison to the Delta, and the issues that are found in the Lujan river, of gated communities flooding informal areas, are actually translated to the Paraná Delta, while the Delta has an entirely different system. As a researcher explained:

"The issues of social separation are very high, and the flooding issue is used as an argument to stop gated communities. Forestry polders which are present in large quantities in the Paraná Delta are much more likely to block the water flow."

These researchers actually believed that the forestry polders in the Paraná Delta were changing the water level in the Paraná Delta. They are developing models in order to study this issue. Previously, a model was created regarding the influence of one very long dyke on the water level (with 7cm). However, semi-static flooding's conditions were present in this case, since the Delta was flooded in 1982/1983 for one year. On the other hand, representatives of the forestry organizations mentioned that the forestry dykes do not enhance any flooding, often the water can flow into the polder during high water levels. They mentioned that only the newly formed gated communities are increasing the flood risk. Another hydraulic engineer mentioned that the urbanized polders also could harm the flood plain and block the river, and thus cause flooding in their surrounding areas. Nature organizations expect that the dykes and polders of both types can cause flooding's and change the water level significantly in the Paraná Delta.

I aimed to show so far that both conflicting ontologies can be found regarding the main issue 'Which type of polders causes the flooding', and also slightly diverging ontologies can be found on the issue 'the problem of the gated community'. In the next section, I will highlight that the 'problems' defined can be both conditions and processes.

CONDITION OR PROCESS

So far, what is interesting is not only that each person shows something different when pointing out the problem. But also, as the quotes reveal, 'the problem' is formulated as a condition. Mol (2002) shows that 'the problem' can also be a process. This distinction can also be found in the Paraná Delta. Defining a forestry polder is a clear example of this.

Even though I was not able to define the problem in the Paraná Delta clearly. I knew that Polders were a reoccurring topic in the ontologies. So let's investigate the concept of a polder. In my hydrology classes in the Netherlands, I learned that a polder is a separated hydrological unit. This implies that both the water system inside and outside the polder can be managed separately. In this way, a polder is defined as a condition. The definition of polders as a condition can be seen as well in the gated communities; the height of the polder is defined regarding the possibility of material present with a minimum of 5 m. For the forestry sector polders a forestry owner commented:

> *"The maintenance and building of dykes are really expensive. In the case that the value in the dyke does not give enough profit, I will not maintain the dyke, and the area will go back to nature".*

This shows that polders are defined as a condition (economic consideration) and a process (flowing in of water). On what moment does the polder stop being a polder, and will turn into a wetland? One moment the natural forces of the Delta will take over, and the dyke structure will collapse, and water may flow in continuously (See figure 4 for a picture of a forestry polder).

A conflicting understanding could also be found here. A researcher mentioned that these abandoned polders are actually the worst. They do not have any water management, block the river flow, do not consider nature and are not implemented in delta planning. Therefore, these are extreme cases of polders and dykes. Thus, the condition of abandoned polders makes them a polder, even though water can flow in and parts of the dykes are broken.

What about other cases? Forestry developers mentioned that often they just do not have the time to maintain all their dykes, and due to lack of maintenance, these often collapse. Can we then still say that these forestry areas are polders? Other examples are the atajerepuntes (see figure 5 for an example), in which the water can overflow in case of high water levels, or water can be let in by gates for its nutrients. Are these still dykes? How often can a dyke flood to still be a dyke? The process of water flowing into the polder may determine

the definition one uses of a polder. However, the definition is related to one's ontology of the Delta as a whole. This I will discuss in the next paragraph.

FIGURE 4 PICTURE OF A FORESTRY DYKE WITH PUMP

FIGURE 5 ATTAJEREPUNTE

THE DOING OF THE DELTA

Yet if we leave aside, this detailed discussion, the issue what a delta is itself, is far from centred and coherent. So let's show the multiple different ontologies co-existing ontologies on the Paraná Delta. What is a delta for my interviewed stakeholders? It depends on what the Delta is doing, *the doing of the ontology*.

When the polder development was discussed, provincial officials asked the national agriculture organization representatives "why do you always promote these polders, while they are clearly harmful to the environment"? A provincial representative mentioned

> *"Nature will take over the polders, due to extreme climate change the polders will not be able to hold all water, and the system will collapse, and the Delta will be given back to nature". Or as a researcher of the forestry institute mentioned "Since the climate is so harsh, people are moving away from the Delta; the salaries are simply not high enough. Now we see immigrants coming to the Delta, but I do not mean this necessarily has to be a bad thing".*

On the other hand, others stressed the full potential of the Delta, once being rich, and now underdeveloped, and its high potential for the development of industry, housing and infrastructure in a sustainable way *"the Delta should be seen as a brand"*. While environmental activists mentioned that a constant polderisation is taking place in the Delta:

> *"The polders remove wetlands, cause flooding's, cause a huge decay of environmental quality and water quality."*

One might argue that these environmental researchers present the dominant discourse in the Delta; they present many academic studies and organize many activities in order to stimulate an environmental focus on the Delta. They have strong funding. Agriculture organizations perceive the Delta differently:

> *" The Delta is the livelihood for the local population; these people live with the water, and need the Delta to survive. After the major floods in 1982/1983, many people moved away from the Delta because all their fruit trees were gone. We helped them to re-establish their livelihood, learned them to construct polders, because it is not possible to grow anything in the Delta without polders."*

In this view, a delta with dykes seems to be the creator of livelihood and growth. Flooding's pose threats to the functioning of the Delta, but it is possible to manage these by dykes.

When taking gender and feminist studies into account, a completely different understanding can be found by a local woman:

> *"During flood periods or droughts, often the transportation systems do not work, so what do men start to do? Yes, as you can imagine, they start to drink and become violent against their wives, and the women have nowhere to go. Also, most of the work in the Delta is physical, such as woodcutting, and for men. So women have very few possibilities for a social network."*

Somebody else found the Delta a paradise. She meant that due to the lack of basic facilities, it was not possible to live in the Delta, but the Delta itself was something pure to be untouched. Local inhabitants said:

> *"Living in the Delta, nature, the quietness, was amazing. We lived there when my son was a small baby. However, we had to move away due to the lack of good schooling".*

> *"Living in the Delta is only for strong people, due to the lack of signal and wifi. Often the boats are on strike. The children may spend 8 hours per day going to school. Only we, real island people, can handle this. But it is also so so beautiful; the Delta is part of our identity."*

All the thoughts, quotes and statements make clear that the Paraná Delta means something else for so many people. The Delta, which is a study object for one, is a fear for somebody else. For another, it determines his/her entire identity. We cannot find one delta.

IS THE PARANÁ DELTA A DELTA?

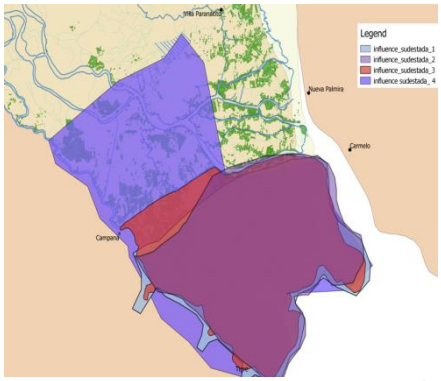
Let's turn our attention a bit further to the water system of our delta of consideration. This immediately raises the question, is the Delta actually a delta? What can we find in the literature about this? It can be seen as a delta since it is an area dominated by sedimentation and due to the interaction of fluvial and marine forces (Marcolini & Parker, 1992). Secondly, a wetland, which are terrestrial and aquatic ecosystems along watercourses that are permanently flooded, making a connection with the groundwater (Junk & Piedade, 2010). Wetlands are known for their possibilities to observe floods, depending on the type of wetlands (Acreman & Holden, 2013). The floodplain river-fed wetlands, as can be found here, seem to have the highest possibilities to adsorb floods (Acreman & Holden, 2013). Finally, the Delta is also an estuary, since it is a transition of two distinct water bodies; a river and a sea (Savenije, 2005). Riverine characteristics are the flowing water with sediment transport, and in the upper area, the availability of fresh water (Savenije, 2005) can be found as well as marine characteristics are the presence of tides and saline waters(Savenije, 2005). In an estuary, these two regions interact, given a dynamic environment, a funnel shape and full of nutrients. This lead to a high presence of flora and fauna (Savenije, 2005). All these phenomena can be clearly observed in the Paraná Delta. But also, the Paraná Delta is seen as a complex estuarine system, since it does not discharge its sediments on the sea, but first on the river Rio de La Plata (Marcolini & Parker, 1992). The Rio de la Plata is formed by the confluence of the Rio Paraná and the Rio Uruguay. Then, as a researcher commented, due to the geological existence, the Paraná Delta is actually not a typical delta, it is formed of different ancient lands. Furthermore, it is seen as a system subjected to pulses of floods and droughts (Kandus et al., 2011).

Which of these descriptions fits best? Can they all be found, or is one dominant? Little data is present of the Delta; researchers are thinking from their own discipline. But an important question seems is how to measure and model if multiple ontologies exist on the type of water system.

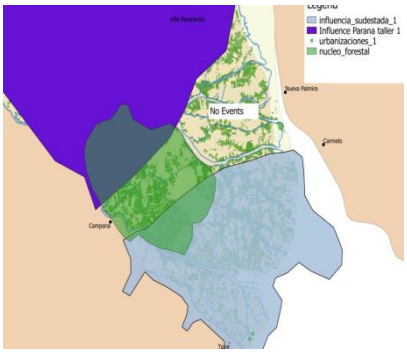
INFLUENCE OF RIVERS AND PHYSICAL SYSTEMS ON THE DELTA

Well, maybe we cannot agree upon the definition if the Delta, but let's have a look at the physical system. Also, here, multiple ontologies can be observed. Regarding the main drivers as the Rio Paraná, Sud-estadas, Rio Uruguay and lateral inflow clear differences could be found on their influences. For example, while some suggested that the Rio Uruguay could be eliminated, others mentioned it is one of the main rivers to influence the coastal processes of the Delta. Furthermore, also the future climate scenarios were overlapping and diverging. From extreme climate scenarios, facing major pressures for the Delta, towards relatively limited climate scenarios can be found. In the first instance, the Delta itself seemed to become the driving actors, while in the limited climate scenarios, humans would be able to construct without having to fear the climate. Also, multiple ontologies were found regarding the dyke breaches and the influences these had on the rest of the Delta. Also, the influence of rain was considered differently. While some suggested it highly influenced the water level in the Delta, others mentioned it only to influence the water flow at the boundary conditions. While some focused mostly on the forestall nucleus, others highlighted the impact on the surrounding areas. Furthermore, multiple ontologies are occurring regarding the current usage of the Delta. The question arises: what is the function of the polders (agriculture, forestry, housing)? Do they pollute? Are they part of an increasing or decreasing trend? No clear answer could be given on these points. Figure 6 show these diverging ontologies.

Influence of Sudestada different workshops



Ontology relative limited influence rivers



Ontology strong influence rivers

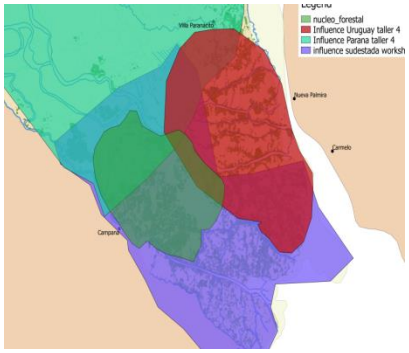


FIGURE 6 VARIOUS INTERPRETATIONS OF THE WATERSYSTEM

TOWARDS A COMPARISON OF ONTOLOGIES

By listening to peoples' stories, I found that the Paraná Delta involves more than gated communities, polders and water. It involves the division between rich and poor communities, quick profit wins, migration outside and to the Delta, wetlands, estuaries, flora and fauna, influencing of different rivers, and a lot of flooding. It is something done to the population of the Delta, but it is also something that the inhabitants do. In the Paraná Delta, multiple ontologies are created in practice, involving hydrological systems, agronomical systems, eco-systems and socio-cultural systems (dear reader again I do not know another word than 'system' for this description). This makes the Paraná Delta more diffuse to investigate than investigation of the disease of Moll (2002). Still, it helps us to formulate policies. Decisions regarding further polder development are related to the ontology that actors may have.

"Ontologies on the Paraná Delta are created in Practice"

I aimed to show that multiple ontologies can be found created in practice in the Paraná Delta, sometimes conflicting, sometimes slightly diverging. As Mol (2002) suggests, ontologies can be both singular and multiple. I have presented an overview of these multiple existing ontologies in Figure 7. In this way, the

ontologies are already structured for further discussion. By making illustrative figures, the aim is for the reader not to have to read a full book, but quickly be able to understand the ontologies. I believe this can give great value to the reader, who is not used to or does not have the time to read an ethnographic description.

However, the discussion remains in the anthropological domain, which gives great insights. However, it is still challenging to be used for Delta planning, since computational models are often used as a base for planning in Delta studies. Therefore, an understanding of the different ontologies of a delta, in computational terms, would be of great value. Models are articulations of how we are looking at the world and thus ontologies. By comparing the various ontologies by means of an (existing) model, insight can be made regarding the key performance indicators (KPI's) of the various ontologies. In this way, by providing quantitative information, a greater understanding could be made of multiple ontologies, outside the anthropological world, but also in the engineering domain. We will be able to understand if KPI's in the various ontologies have highly diverging values, or actually are very much alike. We can use these inputs to formulate our policies. The method and discussion regarding the modelling of these ontologies are presented in the next section.

Narrative

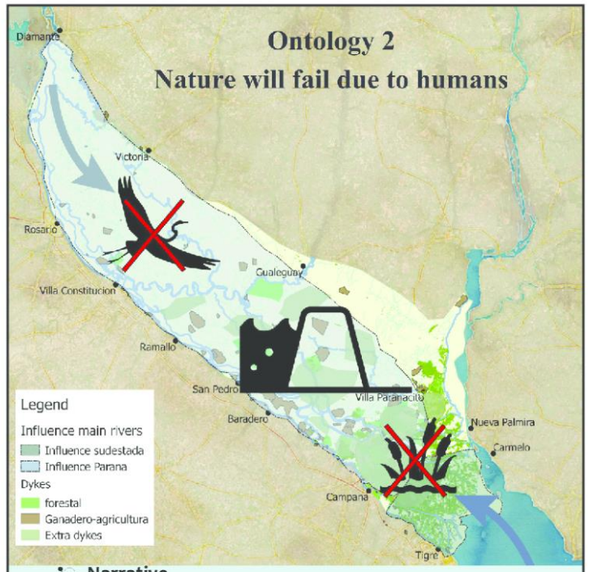
Due to extreme climate change, water level will rise, dykes will not be able to protect polders and the Delta will be highly flooded, human interventions will be impossible and the entire Delta will become a nature reserve.

Agents

Pressure from water outside the system is reason for collapse

KPI's

Water level, production, people living in the Delta and ecology



Narrative

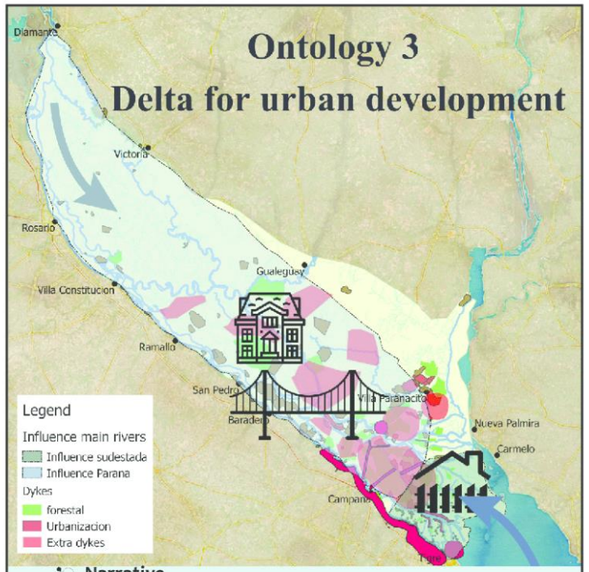
Developers will increase the already high amount of polders , and thus remove many more wetlands. Polders and abandoned polders will continue to block the water flow. This gives a rise in water level, causing more new polders to be built, and destroying nature and wetlands. An irreversable damage will be done to the ecosystem.

Agents

Forestry developers

KPI's

Water level, flow, loss of wetland and species



Narrative

The current delta gives a high potential for urbanization, infrastructure and industrial developments. The Delta will become a strong urbanized metropole, in which the climate consequences can be controlled by humans.

Agents

Urbanization Developers and inhabitants

KPI's

Number of houses, water level, flow and revenue

Narrative

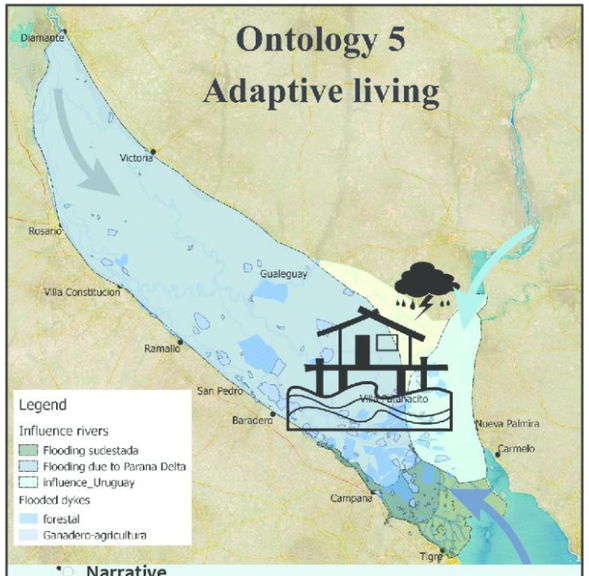
Developers will do a marketing campaign on the Delta. The delta will become highly attractive for people to visit the delta, the infrastructure will increase, as well as dykes for productive areas (beside forestry other products will be made). Also, many tourism houses will be constructed. Many visitors will come to visit the Delta.

Agents

Investors, craftsmen and forestry developers in the Delta

KPI's

Revenue, visitors Delta, brand awareness delta and water level



Narrative

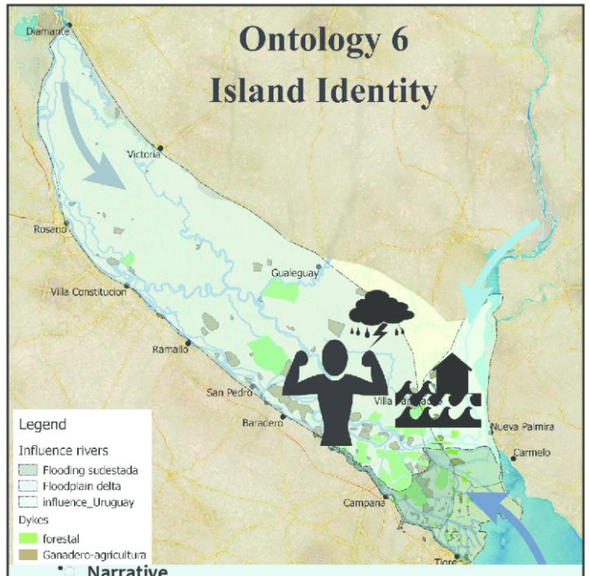
The current delta is not used for its full potential for urbanization, however climate threats are noticeable. Only way to live in harmony with the Delta is by living adaptive. Therefore, adaptive houses are constructed and also forestry is produced in an adaptive style.

Agents

Developers and rivers

KPI's

Number of inhabitants and water level



Narrative

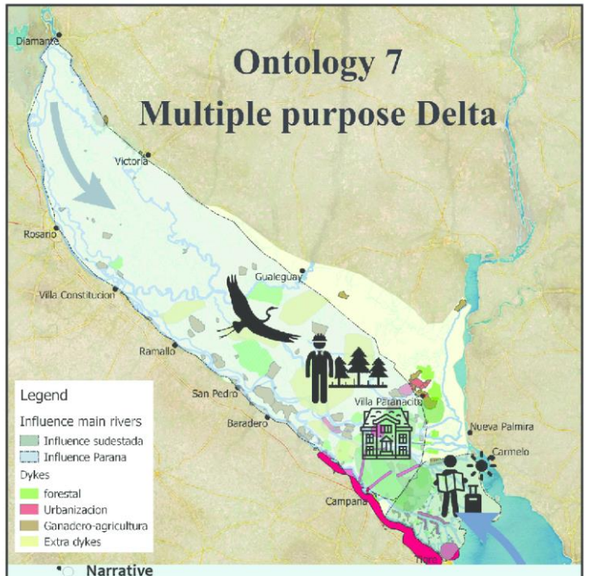
Only strong delta people can live in the delta, you have to be able to live with the nature. It is a beautiful peaceful environment, however basic functions are lacking, and that is the reason why people are leaving. New people will leave quickly when flooding occurs.

Agents

Local island inhabitant, new inhabitants and rivers

KPI's

Number of inhabitants, water level and discharge, Wifi access and transportation



Narrative

Opposition to gated communities uses the flooding argument, however development continues. Gated communities can only grow in the delta, if logistical issues are solved. In this case, access to services will increase and new inhabitants will enjoy this good quality of life, while old inhabitants will have jobs in the Delta. A competition with forestry exists for space. In case no zoning is made by municipalities, the sector with most power (forestry, nature, urbanization) will be dominant in the Delta.

Agents

Forestry developers, urbanization developers, municipalities, Delta Basin organizations and Nature NGO's

KPI's

Number of houses, forestry production and wetlands and transportation

Narrative

In high flood events and droughts, the public transportation system does not function; people will be stuck in their homes. Men start to drink and will become violent to their wife's and children. These women cannot leave due to limited connection to other areas; also due to the isolation of their house they do not have a strong social network. If the climate will become more harsh and the transportation system will not improve violence will increase, unless social programs are implemented in the Delta.

Agents

Rivers, violent husband and transport system

KPI's

Number of violations, water level and alcohol usage, % of public transport functioning

FIGURE 7 OVERVIEW OF ONTOLOGIES

7. EXPERT & MODEL DISCUSSION

7.1 METHODS AND MATERIALS

I translated the ontologies described in section 6 into a modelling format. For this, I got inspiration from several authors: Latour and Strum (1986) provide a great work of serving a comparative analysis of agents in the origin of society. Also, the work in agent-based modelling (Ertsen, Murphy, Purdue, & Zhu, 2014; Ertsen, 2016) regarding the description of (non)-human agencies in modelling terms, was of value for the description of ontologies in modelling terms as agents, actions, events, time-steps etc. Murphy (2012) presents a modelling approach for a Hohokam water management simulation. He models different levels of scope, scale, temporal and spatial resolution. He also models various compositions of elements, coherence between elements and different goals. This indicates the transparent modelling of different ontologies. Furthermore, separation into main agents and relations of ontologies is shown in artificial intelligence and computer engineering (Guarino & Oberle, 2009). The idea of making various modelling conceptualizations and exploring its effect is highly developed in SD literature, in which it is accepted that people have different worldviews that can be modelled: Pruyt and Kwakkel (2014) apply three different models for the explanation of homegrown terrorists. Kwakkel, Auping and Pruyt (2013) study two different conceptualizations of the system under study, by applying scenario discovery. Finally, Auping, Pruyt, and Kwakkel (2015) use three different conceptualizations on how public support for societal models develop.

Based on these sources, I decided to structure the ontologies based on key performance indicators, as well as the framework of events, and the main agents of the ontology (Figure 7) and the current and future land use and current and future river influence (Table 1). Furthermore, I aimed to translate the ontologies into an existing model format and also translate into a most suitable modelling format. I aimed to investigate if with an existing model, the various ontologies could be investigated.

In order to find an applicable model already available describing the Paraná Delta to model the different ontologies, I searched for the available models on the Delta. This analysis was done by literature analysis by applying 'Modelo' and 'Paraná Delta' in Google scholar, and snowballing from the articles found with these links. Furthermore, technical experts of various authorities (province, national water institute and university) were interviewed about the current availability of models (See Appendix Scoping mission). Technical interviews were done with the model maker in order to understand the characteristics of the various models. It was shown that the current HEC-RAS 1D model seemed to be most applicable for further development since it was the only model available describing the hydrodynamic conditions of the entire Paraná Delta. In order to improve the model, a measurement campaign was set-up, and field visits were made, together with the model developer. Ontologies were set-up in a modelling format for the HEC-RAS model, and other suggestions were made for an improved modelling representation. These were discussed by expert judgment (Pramana & Ertsen, 2016).

Furthermore, with several water modelling experts (Pramana & Ertsen, 2016), the following topics were discussed:

- How these ontologies could be modelled using HEC-RAS or other model types
- Theory of ontologies for water modelling
- The value of modelling of ontologies
- Application in their own work

I organised an expert workshop with researchers of the TU Delft, had two official interviews with researchers at the TU Delft, a small workshop at Deltares to discuss various modelling practices, and I had several informal chats at Deltares on how to model these ontologies.

In Section 7.2, the results of connecting ontologies with modelling are presented.

Note: This brings us to the complicated issue of connecting model and ontologies: a model is also an ontology that we create. Also, the HEC-RAS software gives us an ontology. This gives the following discussion (1) Do we model ontologies, (2) do we approach ontologies and (3) do we ontologize models?. I believe that researching this field is on the boundary of all these questions. By investigating if we can use a current model to analyse ontologies, we aim to understand our ontologies better and improve our models in the end.

7.2 RESULTS

STRUCTURING OF ONTOLOGIES

For each of the ontologies, a description is given of the main indicators, the events and the main agents (See figure 7 and Table 1). As can be seen, all ontologies often have water level or flow as a common indicator. However, varying indicators can be found. For example, ontology 8 shows 'violence to local women' as an indicator, while ontology 2 highlights 'loss of wetlands'. The events describing the ontologies also vary. For example, ontology 1 shows the events that lead to a situation in which all human constructions are flooded away, while ontology 2 shows a delta full of human constructions. Then, the primary agents vary greatly as well. For example, in some ontologies, the water is the main agent, while in other ontologies these are the developers, the violent husbands, etc.

CURRENT MODEL AND DATA

It was possible to find different previously set-up models, all describing other aspects of the Paraná Delta. I will describe a few models of interest for this research. Firstly, a study was set up to improve the digital elevation model (DEM) (Martin Sabarots Gerbec, Storto, & Re, 2017). Based on this DEM a 1-D hydrodynamic simulation model was made by Martin Sabarots of the Argentinean National Water Institute (Re, Sabarots Gerbec, & Storto, 2015; Sabarots Gerbec, 2014; Sabarots Gerbec et al., 2017). This model aims to predict and forecast different water levels in the Paraná Delta. Furthermore, a hydrodynamic quasi-2D model was constructed of a tidal wetland (Wester, Grimson, Minotti, Booij, & Brugnach, 2018). A coupled hydro-sedimentological model was constructed to assess the advance of the Paraná river delta front (Badano et al., 2012). Moreover, a model was constructed describing flooding risks in the estuary of the La Plata delta (Re & Menéndez, 2006), and risk analysis was performed (Lecertua, 2010). A hydrodynamic model was constructed describing the upper area of the Paraná Delta, from the border with Brazil until the city of Paraná (Jaime & Menéndez, 1997). A 2D model was set up, describing the Paraná Delta in the fully flooded conditions of the years 1982 and 1983. Moreover, 1D and 2D hydrodynamic models were made by a private consultancy company in Argentina for a world bank project of the province of the tributary of the Paraná River: the Lujan river (Province of Buenos Aires, 2019, private conversation) (See Appendix Lujan Data). Also, a hydrological and hydrodynamic model was made describing the Uruguay river (Guizzardi & Sabarots Gerbec, 2018), which is suggested to influence the Paraná Delta .

The 1D Hydrologic engineering centers-River Analysis System (HEC-RAS) model was available to me. It was the only model available describing the entire Paraná Delta, also in non-static conditions. After discussion with researchers of the National Water Institute in Argentina, the 1D HEC-RAS model was chosen to investigate further the description of the ontologies, due to it's possibility to describe the hydrodynamic conditions of the Delta. I believe this is valuable when investigating water levels and polders (See Appendix HEC-RAS model, HEC-RAS set-up).

Note: It is important to stress, that I only had this model available to investigate ontologies in the time available. Modelling of ontologies of course does not pre-suppose the use of one model.

HEC-RAS is an open software made by the army corps of engineers of the USA. The 1D HEC-RAS model is visualized in figure 8; it represents the main rivers of the Paraná Delta (Paraná river and Guazu river) of a length of 320 km (Re et al., 2015). Time steps are 30 minutes and spatial steps 5000 m. The upstream boundary point is made by averaging the water level of the main upstream tributaries around Santa Fe and Paraná (see Re et al., 2015). The downstream boundary condition of water level is constructed by time series available at different inlet points in the La Plata delta at the beginning of the Delta front (see Re et al., 2015). The model consists of two lateral inflows: the Uruguay river and the Lujan river modelled as stationary discharges. Cross sections are based on the DEM mentioned earlier (Martin Sabarots Gerbec et al., 2017), and dykes are added manually to investigate the potential influence of these dykes. The Delta Superior and Delta Medio are visualized as the main rivers, while in the Delta Bajo where many tributaries and dykes can be found, also smaller rivers are modelled. The following rivers are modelled: Paraná (main river), Victoria, Paraná Pavón, Paraná Ibicuy, Paraná de las Palmas, Paraná Guazú, Pasaje Talavera, Barca Grande, Paraná Mini, Sauce, Bravo y Carabelas Grande, y Los Canales Gobernador de la Serna, Gobernador Arana, Irigoyen, Laurentino Comas, 4, Seoane y Zanja Mercadal. The Manning coefficient is chosen to conform to the observed data and varies over the model; standard values are chosen to be n=0.022 for the watercourses and n=0.2 for the mainland. While in general, the average water levels seem to be well represented when verifying with water levels, the outliers seem to be over or under-represented (M. Sabarots Gerbec, 2014).

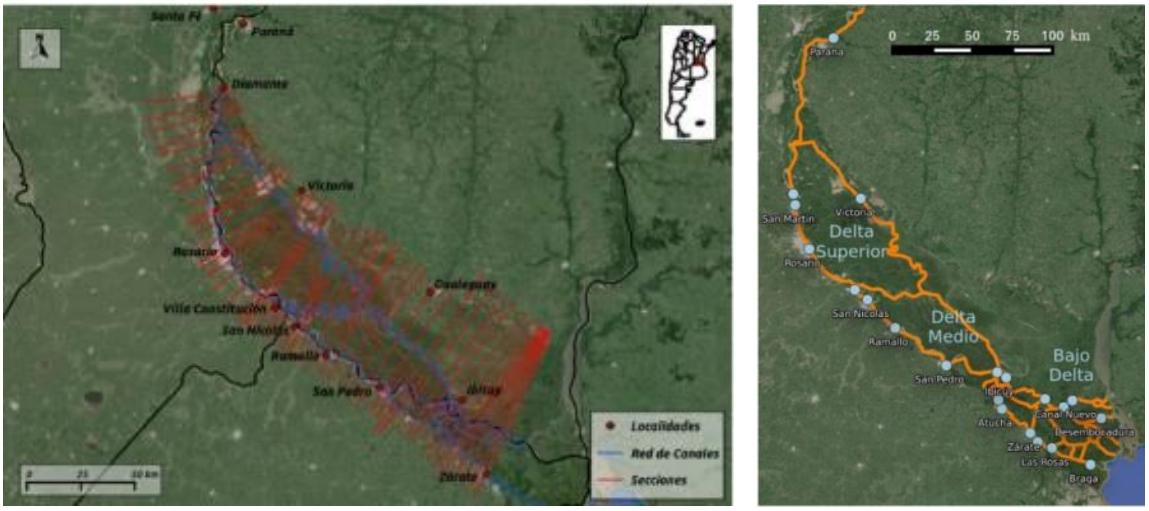


Figure 8 HEC-RAS model with crosssections (Sabarots Gerbec, 2016)

Measurements for validation vary from a times series of 20 years upstream, until 2 years downstream. Data were made available by INA.

As was presented in chapter 6 and in the overview Table 1, dykes were important factors in many of the ontologies. Together with INA, I set up a study to investigate the cross-sections of the polders in the Delta because no measurements were done regarding dyke profiles in the Delta. Different types of dykes were investigated: Forestry dykes (approximately 5 m above the feet of the dyke), atajerepuntes (approximately 2 meters above the feet dyke) and touristic/living dykes (approximately 3 m above the feet of the dyke). A Map is provided in figure 9. Measurements were done with GPS in order to relate all measurements to reference point (IGN), at the La Plata coast. A differential GPS (DGPS) was used to make the terrain measurements at different locations, in order to make a profile of the height of the dykes to a given reference location (IGN, la Plata). The observations of the mobile GPS receiver (rover) were adjusted in such a way to the main GSM station. The position of the device was determined from at least 4 satellites, giving an accuracy of a few decimeters to centimetres (Swisstopo, 2018). The results are not affected by cloud cover or forest cover. The

disadvantage of the approach is the time to load the connection between the reference station and the main station. In the Delta, this was approximately 2 hours (See Appendix HEC-RAS set-up and measurements, Appendix shapes measurements and Appendix Measurement files).

A previous study was performed by INA and INTA to translate all local measurements to IGN (Sabarots Gerbec, 2014). Furthermore, discharge measurements were performed to verify the water flow using a river surveying. Also, interesting phenomena were measured, such as a dyke breach by measuring the cross-sections of the river, and the hole in the river due to the dyke breach, this was measured by using an ecosonda[6]. The measurements are visualized in figure 7.

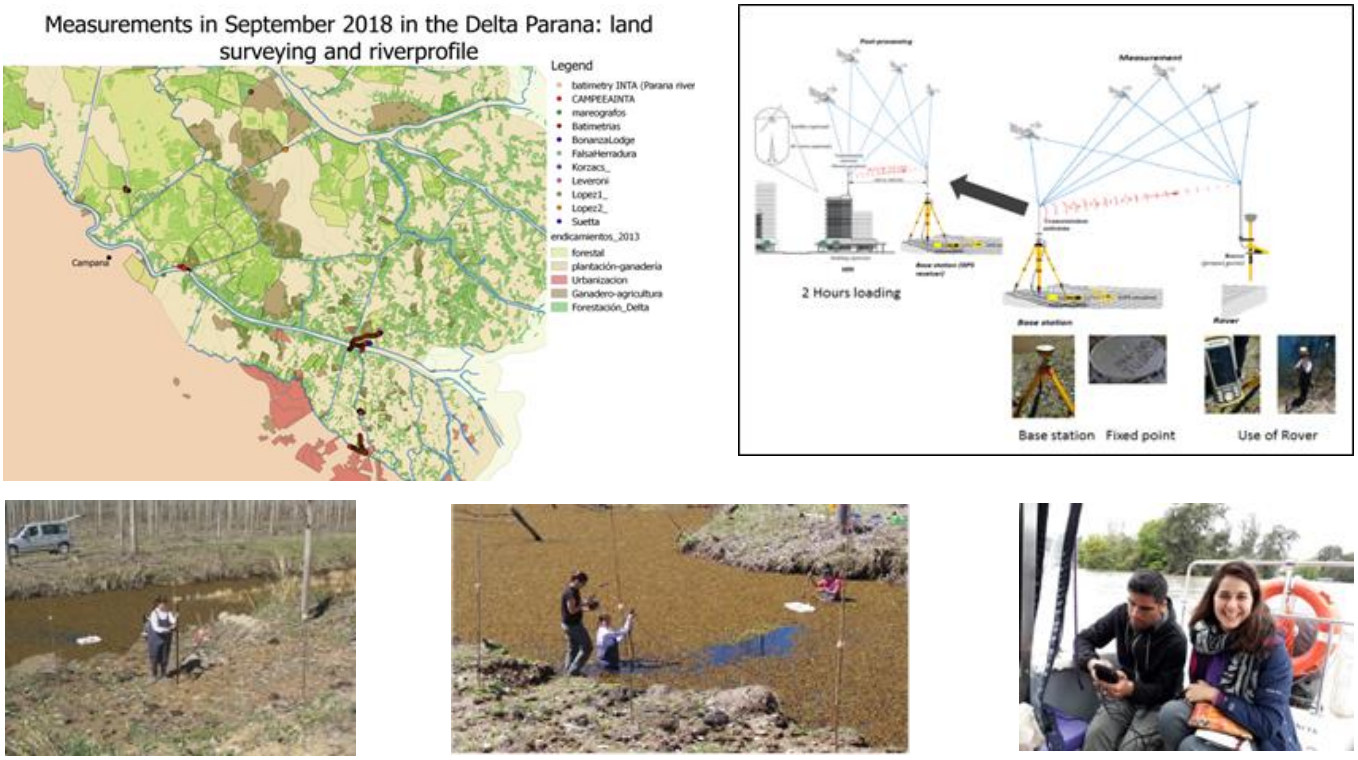


FIGURE 9 MEASUREMENTS

TRANSLATION IN MODEL TERMS

As can be seen in Table 1, the ontologies were translated to be able to be modelled using the HEC-RAS 1D model, the boundary conditions, cross-sections and the internal system. Several comments can be made when translating the ontologies to HEC-RAS. In Table 1, for each of the ontologies is shown how it could be implemented in model terms, in the current HEC-RAS model, or in another type of modelling. Several comments can be made regarding the modelling of these ontologies. These will be discussed in the paragraphs below. My own ideas will be combined with the ideas of experts on these issues.

ONTOLOGIES ON INFLUENCE OF DYKES

The ontologies clearly show a difference in their perception on the influence of the dykes on the water level. If I would aim to show the influence of dykes from one ontology, then I should model with a self-fulling prophecy because I will model with a clear goal in mind, for example, that the dykes have an influence on the water level. The value of making a model that aims to represent an ontology, is in fact a way to illustrate one's own ontology, just as narratives and pictures can do. The results the are predictable but it is important to be aware that many models are set-up in this way.

[6] https://www.ecured.cu/Ecosonda

Table 1 : Ontologies in modelling description

Ontology	*Units and qualities*				*HEC-RAS*			*Improved modelling*
Name Ontology	***Influencing rivers***	***Land use***	***Future water system***	***Future land use***	***BC***	***Cross-sections***	***Add. set-up***	***Suggestion***
1. Collapsing Delta	Strong influence of Rio Uruguay, Paraná and Sudestada	Delta full of dykes, gives production	Extreme scenarios, Delta as a lake as 1982/1983	People will move away Dykes will collapse The decline of productive activities and little non-flooded areas in the system	*Extreme scenarios all rivers*	*Include crss dykes*	*Adjust dykes so they can collapse*	*Would be a self-fulling prophecy to model already a system that will collapse. A way to visualize the ontology would be to make a 2D flood model with time series of 30 years. Dykes are modelled as structures that can breach, maintenance and fail. Wetlands dynamics are modelled (HeC-HSM could be used limited)* *An ecological growth model can be used in which the old situation is compared with the new ecological state. Inclusion of climate change model, to show extreme climate scenarios*
2.Nature will fail due to humans	Moderate influence rivers	*Delta full of dykes*	Moderate to strong climate scenario	*Dykes and will increase, almost no wetlands*	*Medium scenarios all rivers*	*Include extreme crss dykes*	*Polders block water flow*	Polders *could be modelled as blocked obstructions. A 2D flooding mode* can be set upl*, that presents the flooding, with a hazard model giving weights to nature and wetlands as well. Cost-benefit analysis* could be made to compare the loss in wetlands vs developments. By combining this *system dynamics model,* different stocks of taxes, ecology and profit can be represented. With a *risk analysis to show how ecology dies out*, and how risk increases in case of developments. *Criteria have to be formulated when the system has failed.*
3. Controllable Delta for urban development	No influence of Uruguay river, little Paraná and Sud-Estada.	Current system has a lot of space for development	Low climate scenario	*Many dykes for urbanization: urbanized metropole*	*Low climate scenario*	*Include extreme crss dykes*	*No add.*	A land use model that *can be represented in GIS. By using a 2D hydrodynamic model the flooding can be simulated, and by using Flood impact modeling the different impacts of floods can be simulated. Moreover, a final hazard map can be represented of the risks. An economic analysis is desired comparing the increased risks,* together with *the new gains.*
4. Delta as a brand	Little influence of Uruguay, Rain has a local effect, Paraná river is the main disturbance to take into account. Sud-estada for the areas close to the la Plata. Rain mostly influential in cities.	*Current many activities in the Delta which are not used and promoted to the full potential*	*Continuation of status quo or a moderate climate scenario*	Urbanization remains in the border of the Delta, dykes for urbanization are seen as most harmful. Abandoned polders do not count as polders, these are spaces for nature. Production is highly increased by making new and more productive polders.	*Medium scenarios all rivers*	*Include crss dykes+ increase over time*	*No add.*	*A land use model in which, land use can be represented in GIS. By using a 2D hydrodynamic model the flooding can be simulated, and by using Flood impact modeling the different impacts of floods can be simulated. Moreover, a final hazard map can be represented of the risks. Risk analysis* can be *combined with a hydrodynamic model,* in order to show the *hydraulic impact assessment, for the different groups of people.* *A combination can be made with an agent based model, that describes the dynamics of new people in the Delta.*
5. Adaptive living	Strong influence of Rio Uruguay, Paraná and Sudestada, give flooding to the Delta	Current system has a lot of space for development	Moderate to strong climate scenario	*Adaptive houses are constructed; many current infrastructures will not survive due to the* flooding's.	*Extreme scenarios all rivers*	*Remove crss dykes ver time*	*No add.*	This model also shows a self-fulfilling prophecy since the *pre-condition of model* is, *that collapse of current infrastructure will take place* *A hydrodynamic model can be set-up that, together with climate change models. To show when dykes will break, the adaptive houses can be model*led as local disturbing factors, while the other polders as large structures. *The effect on increase of the upstream water level will be investigated. A risk analysis has to be performed for the situation of gated communities and adaptive houses. The local pollution effects are investigated of the gated communities (nutrient pollution and retention time).*
6. Island identity	Strong influence of Rio Uruguay, Paraná and Sudestada, give flooding to the Delta	*Adapted housing*	*Strong climate scenarios*	*Adapted houses, but with Wi-Fi and improved transport networks*	*Extreme scenarios all rivers*	*Limited polders*	*No add.*	*System dynamics/ agent-based model* can be *linked to the water model to describe the migration. A cost-benefit analysis could be used to support decisions regarding investments in the Delta: that shows the cost to make constructions for local people and their benefits, in comparison with cost-benefits for new people.*
7. Multiple purpose Delta	Strong influence Paraná river Strong influence Sudestada, high frequency, no Uruguay	*Urbanisation at the border and forestry in the Delta*	*Medium climate scenarios*	*Competition between gated communities and forestry polders*	*Medium climate scenarios*	*Include extreme crss dykes scenarios on type of polders*	*No add.*	An i*nvestigation of multiple scenarios* is proposed with a , *multi-criteria analysis, hazard and resilience investigation to main vulnerabilities of the area. Which areas are prone to disaster, how does the risk increase? Which robust decisions can we make considering all the scenarios, hazards and vulnerabilities to guide developments* *Creation of land-usage scenarios. A hydrological model simulating the evaporation and the run-off for each of the land use scenarios,* a vegetation model (metaswap) or *erosion model* could be included. Furthermore, an i*nvestigation* to the social, economic impact can take place.
8. Oppressing Delta	Strong influence of Rio Uruguay, Paraná and Sudestada (extremely high frequency of events)	*Currently, adapted urbanisation at the border and forestry in the Delta. Houses are highly separate*	*Medium/high climate scenarios*	*Adaptive housing will stay*	*Extreme scenarios all rivers*	*Limited polders*	*No add.*	*Data collection by founding an app/sms system to receive data when violation to link to high water levels.* A hydrodynamic model can be set-up to predict the water levels, and this can be connected to a system dynamics model or an agent-based model. *Based on interviews/*psychologists *an agent-based model can be set-up* *A link can be made with a transport model*

Note: I do not argue that dykes are a single case of an ontology, it is one aspect of ontologies of Table 1. However, since it is essential agent in the modelling, similair to the other agents and events specified in Table 1, I give specific individual attention to these aspects of the ontology to simplify the modelling discusison.

Furthermore, by using a different type of modelling, ontologies can be checked if they fit in the ontology of others. In order to verify an ontology, a model could be made to check this ontology (van Nooyen, 2019, personal conversation). As suggested by van Nooyen (2019, personal conversations) when modelling the effect of dykes a comparison would have to be made with the 'old delta' (without dykes) without dykes. Furthermore, it can be investigated how much influence the height of the dykes has on the water level. However, historical data is essential to check whether the model represents the modeller's ontology.

If one long dyke is built, this can be modelled in 1D. However, in case that many small rivers and separate canals are present, the wisest is to model in 2D or 3D (van Nooyen, 2019, personal conversation). Such a model should not be set up as a bucket model, but as a model with a detailed terrain description, in which the wetland function (i.e. the wetland's capacity to absorb remaining water) is modelled (Wester et al., 2018) accounting for retention time, local influences, overland flow. Yet, to model this we need available data to verify the results, while in the Paraná Delta we have a data limitation (van Nooyen, 2019).

The modelling of the gated communities is rather difficult, with little available data, especially given the specific local flooding that can be found. One gated community does not separately influence the water level but a variety of gated communities might (van Nooyen, 2019, personal conversation).

Delta of collapse versus development

Similar to the discussion about modelling the influence of a dyke (i.e. with a pre-determined goal in mind), modelling the collapse of the Delta requires modelling with a pre-established goal in mind. The model would then become a self-fulfilling prophecy: flooding of the entire delta. The only reason to model as a separate ontology would be to illustrate the ontology. Again, it is important to be aware that many models can be set-up with an initial goal in mind.

Even more value can be found by 'testing the ontology'. By comparing ontologies, we can aim to understand the ontologies better and see if they would also be 'true' in our own ontology. Aspects of the ontology 'Collapsing Delta' can be compared with the ontology 2 'Nature will fail to humans'. As van Nooyen (2019, personal conversation) suggests, it is useful comparing the ontologies by means of economic analysis. Risk and economic analyses are already accepted approaches in water resource management, hydraulic engineering and ADM. This way of thinking is not new. However, I argue that often, modellers tend to forget the ontologies of others.

A first study could calculate the old system in which we can evaluate the costs of losing everything in the current area. What is acceptable? How much new wetland, and flora and fauna is gained? How much can be retained? A second study can involve itself with the calculation for the new system. For both analyses, a risk calculation should be done, in which the risk of the old situation is compared to the new situation. In the new situation, it is important to consider that the water level can be highly increased due to the constructed dykes, and due to the newly built infrastructure. Furthermore, if the entire Delta becomes a dyke, the water will flow to the surrounding areas, where the gated communities are located. This would suggest that the risk of flooding would increase severely. Therefore, the costs of removing the water that cannot leave the Delta, due to the dykes and polders should be considered as well.

Furthermore, as Altamirano (2019, personal conversation) suggests the traditional way of looking at the environment as an externality should be changed. She suggests that the impacts on the environments and people can be internalized by looking at the system from an economic perspective. Risk is defines as impact

times probability. By making the Delta safer (and thus lowering the flooding probability), more people will come, more infrastructure will be built (and thus increasing the impact). If the increase in impact, exceeds the decrease in probability, the risk in the Delta will increase. She suggests a system dynamics way of thinking of making three different main stocks: the taxes, the natural system and the wealth. By connecting these stocks, it is possible to show how one stock influences the other, and which feedbacks occur in order to have harmony in the entire system. For example, if a part of the wetlands is used for forestry development, investments can be made, strengthen the quality of other wetlands.

BOUNDARY CONDITIONS

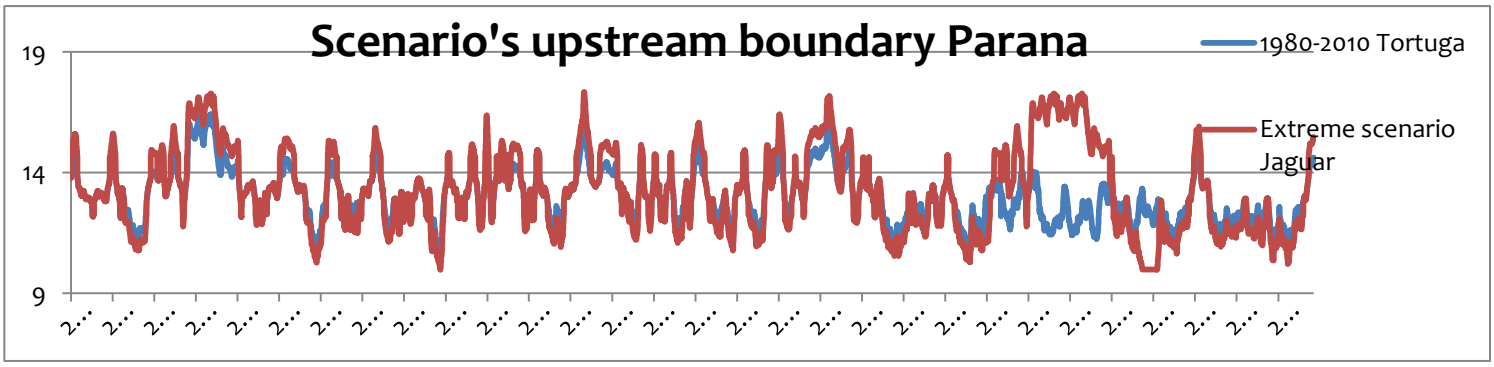
In order to mimic the different ontologies, boundary conditions can be translated in HEC-RAS as can be shown in Table 1. To set up the conditions of climate change, extreme time series are created by means of expert judgement and literature (See Appendix climate series). An example of the simulation in HEC-RAS of the comparison of different climate events in the Rio Paraná can be found in figure 10. The graphs show that in extreme scenarios polders will be flooded. However, while in some locations in the extreme scenario flooding will take place; in other locations even in the extreme scenario the water will not overtop the levee. Therefore, it is useful to know the critical locations in the Delta to be able to make a comparison. Curran (2019, personal conversations) suggests to present the model to stakeholders, and let them discuss/exchange/agree what the sensitive locations are (such as Poolman (2010) shows that even though disagreement could be found between the stakeholders regarding sensitivity, that fact that location exist is not debated). Therefore, the point of debate is: what is considered 'sensitive'. An exchange procedure between stakeholders to agree (or to disagree) regarding the determination of sensitive locations could help with this.

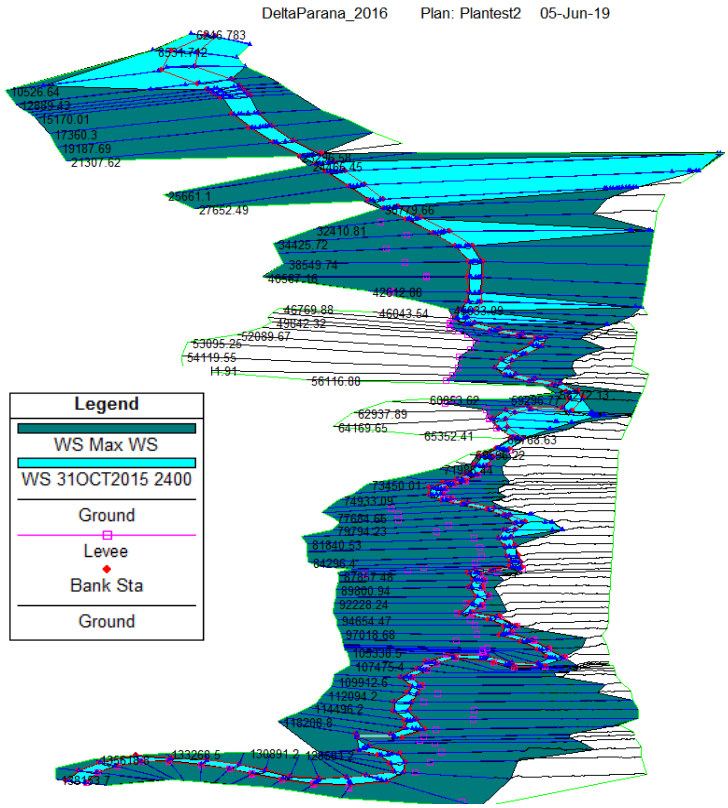
The dynamics or influence of the Rio Uruguay are not yet included in the model. In future models, it could be added by for example combining with the model on the Rio Uruguay of Guizzardi and Sabarots Gerbec, (2018), or investigating the influence on the groundwater level in the Delta which the Uruguay river may influences (Curran, 2019, personal conversation).

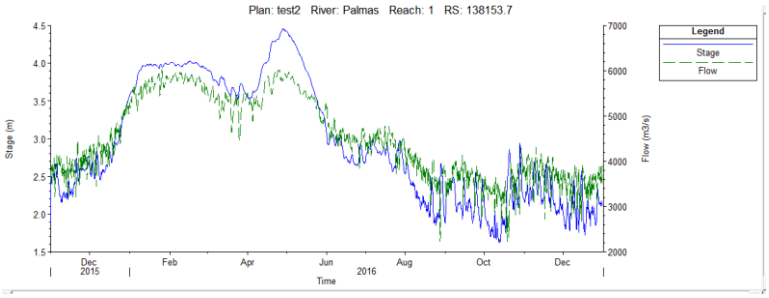
ONTOLOGIES REGARDING TYPES OF POLDERS

The understanding of a polder as a separate hydrological unit does not hold in the case of the Paraná Delta. In the various ontologies, polders are systems in which water can flow in and out naturally, systems in which water is managed, systems in which water can never enter and systems in which the water passes. Polders that are abandoned can be seen as polders, or as wetlands through which water can flow.

However, as mentioned before, the retention time of the water and the space taken by the dykes are not taken into account in the current 1D model. A way to model this is to make a 2D or 3D simulation to represent the wetland function, if the polder starts to behave as a wetland, and would be able to adsorb water. As van Nooyen (2019) suggests, a difference can possibly be found between the upstream dykes and downstream dykes. Downstream short term effects seem to be much more critical because the Sudestada water will go in and out the polders. Upstream, the water level will be higher; therefore the influence on the water, if water will flow on a short time scale into the polders, does not seem to be significant. Mostly, the long term effect of an obstructing structure, increasing the water level will matter (van Nooyen, 2019, personal conversation).







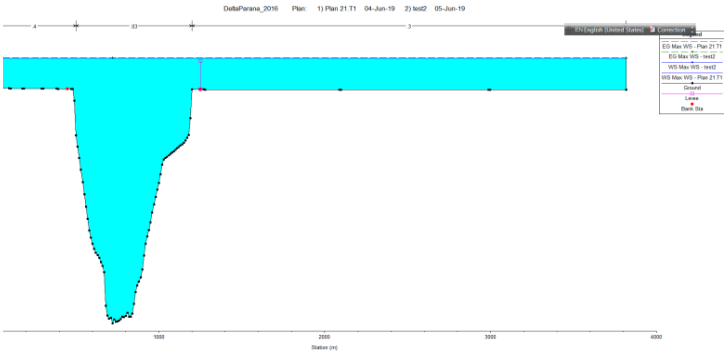


FIGURE 10 VARIOUS REPRESENTATIONS IN HEC RAS OF EXTREME SCENARIO AND AVERAGE SCENARIO SHOWING FAILURE OF LEVEES. AS CAN BE SEEN IN THE EXTREME SCENARIO ALL THE DYKES ARE FLOODED.

Furthermore, in the expert discussion, a discussion occurred regarding if the mechanism of dyke failure mattered. Some considered that it did not matter since these are constructions that retain water in the end. Other suggested that this influences the modelling profoundly and that it is essential to know the dyke properties.

These different ontologies can be represented in HEC-RAS, as well, by:

- Changing cross-sections of the rivers
- Increasing/decreasing the number of polders
- Changing the characteristics of the setting for a polder to overflow or not

I present two different cases, as can be seen in figure 11 and 12. In the first case, it is possible to present a polder in HEC-RAS as a levee (as it is currently done). This assumes no lateral inflow into the polder. An even stronger way to model this ontology would be as a blocked obstruction, which shows that no water can flow into a polder, as in ontology 2. Another way would be to model the polders as a lateral structure, including breaches. Failure could be mimicked by overtopping or by piping, with the piping coefficient the poor condition of the dyke can be demonstrated. By giving a certain failure height, or a time how often the failure would occur, dyke breach could be demonstrated. Furthermore, how often the dyke breach can be repaired can be adjusted. The progression of the breach can also be specified. However, given the discussion above the value of representation in HEC-RAS above since the retention of the water in the polder (soil retention) is not taken into account a 2D structure should be modelled, of a 2D flow area, storage area or another river reach. Furthermore, only one breach per section can be modelled. Also, the porosity of the dykes is not taken into account, the comparison of ontologies would not have value.

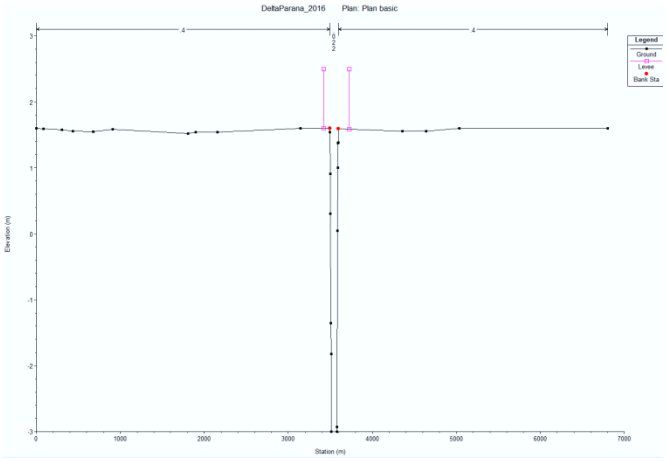


FIGURE 11 HEC-RAS REPRESENTATION OF LEVEE

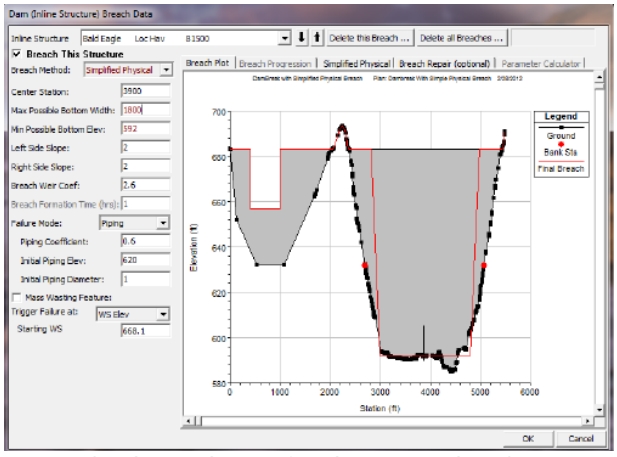


FIGURE 12 HEC-RAS REPRESENTATION AS A LATERAL STRUCTURE

DELTA CHANGING OVER TIME

The ontologies suggest the land use and the influence of the rivers are constantly changing over time. However, this appears difficult to represent in a model. This is due to the wetland adsorption of the water, which means that the old situation also influences the new situation in terms of how much water the wetland can adsorb. Furthermore, the 'new' water level depends on old structures, such as dykes, wetlands and rivers. This again will influence the building of new structures. The action of one actor, for example, a 'developer', to the water level and its feedback effect of building new constructions should be considered.

A way to mimic this would be to model the water level in HEC-RAS with a given set-up of polders, then change the set-up and model a new water level. However, the wetland or polder retention of the water is ignored. Furthermore, the dynamic continuously changing character of the Delta, including relevant feedbacks would be ignored.

DELTA IS AN ESTUARY, WETLAND AND DELTA

By formulating the model as an estuary model, a wetland or a delta, a decision is already made regarding the ontology of the object.

Coenders (2019, personal conversation) mentions that if the Delta was modelled as a delta, the tidal influence and the salt intrusion would be neglected, which is significant for the wetland quality. Van Nooyen (2019, personal conversation) argues that the most likely system should be chosen, and when the parameters are chosen that do not relate to the modeller's ontology, the modeller should be critical on its ontology.

However, in this case, data must be present for verification, and the modeller should be aware of possible assumptions made.

DELTA IN WHICH THE RIVERS DETERMINE THE SOCIAL SYSTEM

Regarding the modelling of domestic violence, the ontology would depend on multiple factors, including the social system, the water system and the transport system (van Nooyen, 2019, personal conversation). However, the identify of the people living in the Paraná Delta could also be of high importance. The economic and social consequences of interventions should be related to the interaction and the dynamics of the people living in the Delta. Also, other factors, such as stress, lower health, less movement could be of influence.

In the Delta, in which high rivers or drought will lead to a changing social system, the current model can be used together with a system dynamics model to illustrate the household dynamics. A causal loop diagram would be the first step to present such dynamics (Curran, 2019, personal conversation). A combination of the current model with a migration component would profoundly illustrate the migration increased flood risk, regarding the identity of people living in the Delta. Or possibly, agent-based modelling could be a way to describe the decisions and actions of actors in the Delta.

WHAT IS THE BORDER AND LEVEL OF DETAIL

All the different ontologies highlight various actors, events and relations to consider for modelling, and thus show which border of the system to consider. However, the border will vary, since modelling of the Delta as an estuary will consider different boundaries than modelling it as a delta. Furthermore, the level of detail in the ontologies also varies, since, for example, in ontology 1 a broader spatial scale can be taken, since all polders will be flooded, while in ontology 8 the level of detail should be taken on an actor level.

COMPARISON OF ONTOLOGIES

As can be seen in the tale of comparison, all ontologies aim to measure different objectives. The water level is a common indicator; however other indicators seem to be valuable for the objectives as well. This complicates the direct comparison of the ontologies. A Pareto optimum analysis could be considered (van Nooyen, Hrachowitz, 2019).

> *"Here we move from an objective, measurable reality into a multi-dimensional solution space, in which in many cases only trade-offs, i.e. Pareto-optimal solutions, can be obtained: as there is no one objective truth, there can never be one objectively best model output. In this case, our values and priorities, defined by our ontologies, shape the outcome." (Hrachowitz, 2019, personal conversation).*

However, the consideration of these different objectives, formed by modelling, should be further investigated.

DISCUSSION & REFLECTION

By describing the issues I faced when translating the ontologies, I demonstrated that the ontologies could not simply be implemented and evaluated in HEC-RAS. Regarding implementation, even though some elements of the ontologies can be translated into inputs in HEC-RAS, full ontologies will be misrepresented since the dynamics of the ontologies cannot be formulated in the current HEC-RAS model. Furthermore, the different ontologies required other system descriptions and elements in the model. Regarding comparison, the various ontologies give different indicators and different processes, and therefore only on a limited number of indicators comparison would be possible. But, on specific important indicatos for the ontologies no comparison can be made with other ontologies.

Of course, HEC-RAS itself is also an ontology, so it can be debated whether or not one fixed model architecture ontological comparison is possible. In the final column of table 1, I suggest various models that can present the ontologies based on the discussion with experts (See Appendix Expert meeting).

Due to the limited time available for this research, it was not possible to create the suggested models for ontology comparison. Another approach seems valuable, as for example, Murphy (2012) does: one model architecture is formulated; however for each ontology model aspects can be adapted. I will come back to this issue in the future research discussion. However, discussing ontologies and modelling the approach seemed to have a high value. In the following sections, I discuss the value of considering ontologies in modelling, together with several (theoretical) considerations.

"A model is an ontology, HEC-RAS is an ontology."

VALUE: MODELLING AS A PROCESS

By using ontologies, modelling can be used as a process to enhance stakeholder understanding and interaction and not as scientific evidence-based decision making. By discussing the variety of models, stakeholder connection can be enhanced through acknowledgement of the positions of others and by finding a common understanding of the various ontologies present. Ontologies can be used to illustrate different things: modeller's biases and model decisions, vulnerable stakeholders, the behaviour of agents, issues in a delta for decision-makers, and finally, definition issues. Representing ontologies can be done in different ways: as narratives (Chapter 6), like pictures (figure 7) or drawings (see Poolman, 2010), as model inputs or as model outputs (table 1). These are possibilities to show stakeholders of the various ontologies.

First of all, it is a way to have an improved understanding of the biases that modellers have when creating models, to understand model decisions, and to make modellers themselves aware of this (Coenders, van Nooyen, expert workshop, 2019; Junier, 2017). By adding components in models, or neglecting issues, the outcomes of models can be framed (Coenders, 2019, personal conversation). In the Nile basin, for example, different models can be found that can contradict each other, due to their different assumptions. The same can be found in climate change models (expert workshop). In the Paraná Delta, dykes can be modelled as for example concrete structures, or as structures that can collapse. Furthermore, by neglecting the infiltration of water or the evaporation in the wetlands, a different delta will be framed (Coenders, 2019, personal conversation). Or, when modelling the current irrigation system, a bucket model would be a suitable representation. When simulating for 20 years ahead, a sediment transport model would be valuable. When considering upstream conditions, a stochastic model could be suggested (expert workshop).

It becomes complicated when modellers perform tactical behaviour by striving for a certain output, but not clearly mentioning this. Yet by discussing these ontologies, tactical behaviour can be identified of other modelers (Nooyen, 2019). It could be useful to ask an independent party to set-up such a model (Nooyen, 2019). However, all these different independent parties have their own, models, values and beliefs, or build on local data and models (Coenders, expert workshop 2019). Therefore, these independent parties also have their own ontologies, not making them 'independent' anymore. Furthermore, in situations of data scarcity in which main ontologies steer the academic discourse, more insights can be obtained from the functioning of the Delta and motivations behind certain outcomes.

Secondly, ontology is a way to avoid forgetting to include vulnerable stakeholders, such as the local women, that otherwise might be overlooked. Certain decisions can be made by considering their ontology, such as empowering the women or enforcing policies to assist these women in moving to the mainland (van Nooyen, 2019, personal conversation). Furthermore, by describing the different ontologies, valuable insights, such as the relation between high water level and domestic violence, could be included in modelling. By considering

this ontology, it can be put higher on the agenda for the inclusion in modelling (van Nooyen, 2019, personal conversation). Therefore, it would allow for ontological politics (Mol, 2002). Data of ontologies could form a way (such as the number of women abused by their husbands) to show ontologies in modelling (expert workshop).

Furthermore, giving a quantitative representation of the ontologies (besides visual and by means of narratives) will stimulate discussion among stakeholders and politicians in a delta. The explicit discussion of these ontologies may help to decide on final objectives since all stakeholders will feel included. It would be vital to have a government officials present in these conversations (van Nooyen, 2019, personal conversation), so they can also learn that the reality is not so simple and that neither one model, nor one 'truth' exists. These officials then can stimulate the ontological way of thinking in the relevant government authority. Since current government officials want to have clear policy advice, a mind shift is required (Coenders, 2019, personal conversation). Also, by considering different ontologies, more trust in the models can be established by local stakeholders (expert workshop).

Finally, as the experts highlighted, confusion often exists regarding the use of specific definitions. By evaluating different ontologies, the differences in definition usages can be understood (van Nooyen, Coenders, expert workshop 2019).

VALUE: GOING FORWARD IN MODELLING: VERIFYING ONTOLOGIES, OR REALIZING NO DIFFERENCE BETWEEN ONTOLOGIES

Different ways can be used to consider how the ontologies can add to modelling, I will discuss them here.

When showing the example of the levee modelling (as a lateral structure or as a point), stakeholders will see a different type of modelling of their ontologies. They will realise that both ontologies can be modelled in a different ways. It can be proven that the difference in results, when comparing the ontologies on pre-defined indicators, is significant, or insignificant. If it is not sensitive, stakeholders can agree that it actually does not matter how the dykes are modelled. Then, it can be decided to research the wetland absorption by modelling a 1D/2D the wetland absorption or a 3D wetland. This process can be continued until each of the ontologies is checked to see whether they would cause a significant difference in the outcomes on the KPI's. When the sensitivity is significant, it can be decided to do monitoring of the breaches of dykes, and thus guide future data gathering. If not, then it does not seem to be relevant to deal further with the ontological difference, and then we can use the outcomes. This gives us pragmatic ontologies. Even though various ontologies can occur simultaneously, policies can be formulated, and by showing this clearly, stakeholders can feel attached and included in the process.

Furthermore, as suggested previously, it can be verified if an ontology also can be 'true' in another's ontology, and thus will be considered as 'true' by these stakeholders as well. If this can be done by gathering more data is debated. The proponents of data gathering suggest (expert workshop, 2019) that by gathering more data, more understanding can be given of one's own ontology or insights can be made of another's ontology. For example, the ontology of the collapse of the dykes can be evaluated by collecting a sample of data of failed dykes. By using satellite data, the area flooded of the dykes can be found. Furthermore, with a remotely sensed algorithm and by intersecting this with google earth, the location of dykes can be found (expert workshop). Some suggested that uncertainty analysis/ scenario based analysis would be a much more suitable way to analyze such a system with data scarcity (expert workshop). While others argue that collecting data is not the issue of the ontology: the data scarcity issue can never be solved (expert workshop, 2019). So many details are present, which we can never all investigate. Also, Mol (2002) shows that in the hospital data was never really an issue. Still data was measured based on a certain ontology, and thus proved the previous only. I argue that by discussing ontologies, the debate can improve regarding what data should be gathered. We

must accept that we can never understand all ontologies, and by simply gathering more data, we will construct more ontologies. However, by discussing ontologies openly, decisions can be made to what data is necessary to give a scientific foundation to the various ontologies. In this way, it can guide future research. Therefore, choices have to be made regarding what to measure.

As, we discussed in the previous paragraphs, the perspective/ontology also matters on modelling that take place (van Nooyen, Coenders, expert workshop, 2019). Therefore, discussing ontologies openly with modellers will aim to make them aware of their own biases, and stimulate them to be critical on their own ontology and what they find of others.

Furthermore, by considering ontologies, behaviour and actions of actors could be better understood and included in modelling (expert workshop, 2019). This increased understanding of the ontologies of agents could be used to show these ontologies in agent-based modelling.

VALUE: UNDERSTAND ONE'S OWN ONTOLOGY

Furthermore, the suggestion is made by Hrachowitz (2019) that by investigating ontologies, one's own ontology will be better understood (expert discussion, 2019). Hrachowitz (2019) suggests that our individual ontologies are only covering one limited part of reality, due to epistemic (lack of information/knowledge), random and deliberate uncertainties. This can be found in three ways:

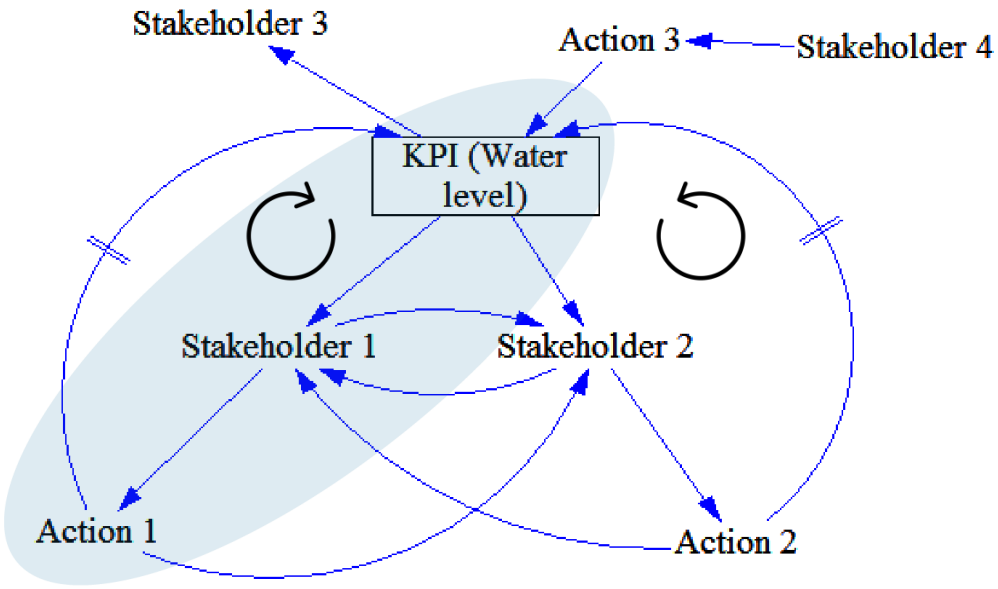
1. We are not aware that other ontologies exist or we consider other ontologies as less relevant, as for example the ontologies of the local women considered by many actors.
2. We are aware of it but cannot quantify other ontologies due to a lack of information. For example, a lack of information regarding the functioning and location of dykes or a limited process understanding.
3. We can strategically block other ontologies, so we give more weight to our own ontologies. For example, the social activist highlights that the gated communities dykes are blocking water and thus influencing the hydraulic stability of the Delta.

As Hrachowitz (2019) mentions:

> *"By implicitly stating that "my ontology" = "objective and full reality" (for the above reasons), we then each of us use different models of that incomplete reality, which in turn all produce different outputs, making us believe that we are dealing with "multiple realities" (in our case "multiple deltas."*

We are able to separate two levels: The first level is the level of the variable of interest (e.g. the water level). Hrachowitz (2019) suggests that we can assume that we have this variable is one single, objective reality and can be measured independently *(see considerations below for other thoughts).* If we have a poor understanding of our own ontologies, then we will misrepresent the variable of interest, and this will lead us to wrong conclusions (Hrachowitz, 2019). Furthermore, other ontologies can also act on 'our water level'. If actors do not consider the ontologies of others, they may miss the feedback effect; other agents may have on 'their water level'. This feedback can take place with a delay. Furthermore, by observing the actions of other stakeholders, or just by hearing their ontology or reading it in the newspaper, it will also stimulate us to think or act differently. Furthermore, by considering multiple ontologies, the effect of these feedbacks on stakeholders who do not act on the water system but endure the consequences of changes in water level can be considered (example abused women) (expert discussion). This process is shown in figure 13 for the ontology of stakeholder 1.

The second level relates the impact and/or different priorities of individual stakeholders. Depending on its priorities, the stakeholder will also consider the variables of interest differently. For example, a local woman considers a rise in water level as a threat, while environmentalists see it as a condition to sustain wetlands. Therfore, Hrachowitz (2019) argues that by separating between the two levels, it can be shown that on the first level problems arise because we do not fully describe reality and on the second level since not one objective best solution can be found. I will describe my considerations to these ideas below.



FI GURE 13 REPRESNETATION OF IDEA UNDERSTANDING OF OWN ONTOLOGY STAKEHOLDER 1

My considerations feedback

As Carolan (2004) suggests, the previous sections show that different enactments of the Delta are interdependent. However, if the various ontologies influence each other, and have feedback, this would also be highly important to consider when modelling. Thus, by structuring the different ontologies, and evaluating their feedbacks, new ontologies can be structured to define modelling.

"Feedback of other ontologies should be considered while modelling"

My consideration separation levels of interest

Several considerations can be made regarding the argument of the water level, that can be measured independently. Carolan (2014) shows in his analysis of the Klamath Basin that multiple ontologies can be formulated regarding methods. He argues that several tests can be used, such as pH, nutrient tests, oxygen tests, water temperate, explaining that under the right conditions, methods make realities. He argues that testing water quality is then actually testing for oxygen levels. Also, Moll (2002) shows that different measurement devices all aim to measure her disease, give different results, and thus creating another reality. Her actors value the measurement devices differently. Ertsen (personal conversation, 2019) mentions that measuring in Celsius or Kelvin, if increasing the temperature with 1%, will give different outcomes. Again, ontologies are created in practice. If we take this idea back to the water level, my question arises: can we measure water level really so objectively? I present several arguments:

a) Does it not matter how many times per day we are measuring? If we measure once a day, we will miss the entire tidal effect, while if we measure every minute, we will get a lot of high varying water levels (especially due to the wind). Can we say with such scarce data anything about the water level? Also, will stakeholders, in their understanding of the Delta, not propose a certain measurement to prove their ontology.
b) Also, what I saw in the Paraná Delta, different organisations relate their own measurements in relation to their own local levels (approximately 9 different reference levels can be found in the Delta, some are connected to each other, others not). When I discussed the water levels in my workshops, participants mentioned that my data were false, but only later, I realized they were used to another local reference level and thus another reality.
c) Furthermore, the water level can be measured by visual inspection or by using sensors/transmitters/GPS etc. All these methods have their own uncertainties. Do they also not produce a certain ontology?
d) Moreover, what is a change in water level? During the day, sometimes the level can vary up to 7 meters. Is a change, a change in average water level (of a day, a month a year) or change in the peak level, what if one change contradicts the other?

Hrachowitz (2019) highlights that these considerations will have value, but in practice will give little different disagreement if the stakeholders can agree about what actually to measure. I argue we cannot say that no different ontologies of the water level can be produced in practice if we really can find an independent variable in the Paraná Delta Based on this discourse, but I suggest to treat the separation of variables as a 'pragmatic ontology', I believe that in both levels multiple ontologies can be found, but in the first level fewer ontologies will be present. Therefore, it is useful to take this separation into account.

"Separating ontologies in various levels is a 'pragmatic ontology'"

VALUE: OBJECTIVES

In the expert workshops, some participants suggested that thinking about ontologies might actually overcomplicate things, while the aim of modelling is to make reality less complex. Therefore, the need would be to understand first the goal for the model. Definition of specific objectives was argued to be the first step for modelling. In the case of multiple stakeholders, with multiple objectives, we should not engage in this over-complication by means of ontologies. Others suggested, by allowing models and thus modellers to make choices, we can have a better understanding of the ontologies of reality. It will help us to study parts of the ontology we do not understand. In this way, different models can be made describing the various objectives. While, Curran (2019, personal conversation) suggested, if the goals and indicators for the Delta are not yet understood, understanding of different perspectives in a delta would be an essential step. Therefore, the aim would not be to develop a plan already but to understand the main goal. Curran (2019, personal conversation) argues that a first step would be to develop indicators, which can be scored late by means of modelling, or if possible, by expert judgement. By using a multi-criteria decision method, weights can be attributed to these indicators by decision makers. On the other hand, as Ersten (2019, personal conversation) suggests that planning and modelling can help to define goals at later stages. This discussing shows that multiple ways exist regarding the connection between ontologies and objectives. However, this does not seem to a major issue for ADM, even though the framework suggests that objectives should be defined upfront (Haasnoot et al., 2013), it is an adaptive framework and objectives could be situated in the beginning, followed by plans and modelling and a redefinition of the objectives. This requires a flexible, ADM approach.

GIVING VALUE TO ENGINEERS

Still, the concept did not seem easy to grasp and implement for WM experts (Coenders, van Nooyen, expert workshop, 2019). It seems a bit outside the comfort zone; it increases uncertainty, while the aim of modelling often is to decrease uncertainty (Coenders, expert workshop, 2019). Therefore, the suggestion was made not to emphasize the idea by using the word 'realities', but to focus on 'the creation of multiple ontologies in practice' (expert workshop, 2019). A pragmatic way to deal with ontologies seemed to facilitate the implementation of multiple ontologies in modelling (van Nooyen, 2019, personal conversation). Coenders (2019, personal conversation) suggested to place ontological thinking in the ethical discussion on engineering; she argued that it is important to create awareness that data and facts are also only samples, measured in a certain way. By discussing the idea with engineers, they could be made aware of the different ontologies.

I believe that placing ontological thinking into the ethical domain of engineering would be valuable. It imposes the modeller to reflect on its own values, beliefs, assumptions and the ontologies of others. Of course, modelling ontologies is much more than ethics; it also relates to the craftsmanship of modelling, which should not be forgotten. In her own research, Coenders (2019, personal conversation) also faces critique regarding which type of assumptions were taken. Furthermore, often, the discussion can be found regarding definitions, also found by van Nooyen (2019, personal conversation). Van Nooyen (2019, personal conversation) highlights that for academics, it does not matter to discover this together, but in commercial projects, less time will be available to discover this.

The claim that more than 'one reality exists' seemed to be a profound topic of debate among the experts and in literature. As Carolan (2004) argues, the objects change through translation, but the structure of reality does not. However, a counter-argument could be made that when the reality is created in practice, we do not need to discuss the structure of reality. Since practices are plural, then the realities they enact will be as well (Mol, 2002). In the expert workshop, some found that only one delta exists; these different versions of reality seem to confuse and overcomplicate things. It is more an issue with how to communicate the results. Others mentioned that multiple ontologies are created in practice. Other experts argued that by investigating all ontologies, we are able to understand 'the entire reality'. While another respondent mentioned that we could never know the absolute truth, even knowing all ontologies does not mean we will understand the entire system (expert discussion). In general, it seemed for the experts that the discussion of if one reality exists outside quantum mechanics is not real. Therefore, it was suggested not to discuss reality but only speak of ontologies (Van Nooyen, expert discussion, 2019, personal conversation). I propose that leaving the debate of the existence of one reality outside this discussion since it does not interfere with the discussion of this article. Therefore, there is no need to solve this discussion here.

8. CONCLUSION AND FUTURE DIRECTIONS

8.1 WHAT HAVE I SHOWN?

In this research, I have made the following discoveries:

(1) Several observations can be made when applying ADM in the Paraná Delta, which can be explained by a multiple co-existing deltas.
(2) Valuing multiple ontologies in the Paraná Delta can assist ADM.
(3) Ontologies can be a way to bring insights to the modelling of a delta (for ADM).

In my journey to model Adaptive delta planning in the Paraná Delta, I found several observations by doing a multi-method action research: difficulty with describing the system, dealing with a broad range of uncertainties, formulating and quantifying objectives, dealing with a variety of actors, dealing with a complex system, and finally the complexity of the method itself. In order to explain these observations, I turned towards the fields of philosophy and anthropology (Carolan, 2004; Mol, 2002), and formulated a new idea: the co-existence of a multiple ontologies in the Paraná Delta. By applying this idea on the Paraná Delta, I was able to find multiple ontologies, which were changing in time, space and per actor. Ontology in practice comes with objects that coexist side by side, mutually include or exclude each other, interfere or have tensions. I could formulate different objects/agents as dykes, water, rivers, developers, local women and local men. I also found many objectives of these agents, sometimes overlapping, sometimes conflicting. Adding to Mol's (2002) suggestion, not only multiple Deltas' could be formulated in one space and time, but I discovered ontologies that were part of a process of change and development. As Carolan (2004) suggests, if it is multiple, then it is also political. The ontologies in practices will lead to real actions, developments and actions, since decisions need to be made regarding delta planning. As he mentions:

> *"The issue of ontological politics will consequently become progressively salient for socio-environmental scholars as the method becomes the medium through which we experience and help to make 'real' environmental problems"* (Carolan , 2004, p. 517)

He suggests that ontological politics will help to ground these environmental debates further and study how the multiplicity becomes coordinated into coherent, comprehensible systems. I aimed to give guidance to these ontological politics, by structuring ontologies in a pragmatic way. Different than Mol's (2002, p. 157) I presented a visual table of structured ontologies, in order to be able to compare on fixed points of comparison as KPI's, agents and events. Furthermore, I translated these ontologies into modelling terms, to support modelling, and discussed this with experts.

Comparing ontologies based on the structured analysis, proved to be useful. By considering a structured comparison of ontologies in a delta, insights can be given into the perception of modellers by stimulating a debate, empowering stakeholders, and assisting in definition issues. Furthermore, in situations of data scarcity in which ontologies steer the academic discourse, more insights can be made on the functioning of the Delta and motivations behind specific outcomes. Moreover, ontologies can aid modelling by investigating if one's ontology also fits in another's ontology and by this guiding future research and measurements. Also, if ontologies are proven to have insignificant impacts on the model outcomes, it can be decided to have a 'pragmatic' approach by the stakeholders. But, in this way stakeholders still will feel included. Likewise, by considering other ontologies, more insight can be given into one's own ontology. Finally, by considering ontologies, objectives will be made more explicit in a re-iterative way during the ADM planning.

Considering ontologies for ADM is valuable because ontologies are an explanation for the issues encountered when applying ADM in the Paraná Delta. I argue that ontologies are an explanation for the confusions and the tensions in the given case. The first step in ADM is the system definition; by describing the various ontologies, stakeholders could feel more attached to the framework. It may lower the risks of blocking the ADM process since stakeholders will feel higher ownership of the issues. Moreover, the difficulty for stakeholders to select actions might be explained by the fact that stakeholders have different ontologies than ADM experts, and thus prefer another type of actions. Furthermore, more insights can be given when describing ontologies regarding the different objectives of the multiple stakeholders.

However, given the current 1D model HEC-RAS model, a full comparison of ontologies was not possible due to the complex dynamics in the Delta, and the multiple system understandings and the relations the ontologies propose. Only parts of the ontologies could be illustrated by means of the current model, or the ontology could be modelled as an illustration. Therefore, in order to compare ontologies, or to entirely demonstrate the ontology, a model needs to be set up specifically for comparing ontologies. The value of such a comparison would be to stimulate further debate by giving quantitative 'evidence' of the ontologies. In this way can be discovered whether ithe ontologies actually considerably vary. Also, by structuring and discussing ontologies stakeholders and decision makers can be assisted in the ADM process. The eventual aim is that even as stakeholders maintain their own ontology, they would still be able to agree upon common grounds for a plan formation. I argue that if stakeholders are aware of ontological differences, less confusion will be present in the ADM process, and thus, a more stable base can be created for ADM planning. Future debates and research should guide us on how to deal with these pragmatic ontologies, regarding modelling for ontological comparison.

8.2 FUTURE WORK

I would like to suggest several steps, for modellers to go further on the work provided in this thesis to support the modelling of an ADM plan. I will explain the steps I would do myself. Firstly, I would analyse the feedback effect the ontologies have on each other. Then, I would design a modelling environment, in which the various ontologies can be compared. A structure as Murphy et al. (2017) proposes to be able to change many things on the model could be of value, by comparing a 2D hydrodynamic model with wetlands and system dynamics with GIS files representing future land use could be valuable. By investigating the different formulations of polders, for example, I would check what the influence is on the water level at various locations. It can be determined if the given variable varies significantly, or if the various ontologies do not seem to matter in practice. In this way, I would first model and compare certain aspects of the ontologies, thereby enhancing the modelling environment.

Furthermore, I would immediately relate the ontologies to the stakeholders in the Paraná Delta. By discussing the various ontologies, the various ontologies can be made clearer for the stakeholders and decision makers. Together, the stakeholders can debate on which sensitive locations the models should be compared and which ontologies are desired for comparison. This could inform further data gathering, if necessary. Discussion of the results with stakeholders can clarify if the stakeholders have more understanding of each other ontologies, and decision makers can become more aware of the multiplicity. This can help decision makers find pragmatic ontologies to go further. Furthermore, by doing this approach, objective formulation of the ADM model or plan can be formulated and reiterated throughout the process. It can be studied if Pareto optimization forms a way to support objective formulation. The aim eventually is that even though stakeholders maintain their own ontology, they would be able to agree upon common grounds for a plan formation.

Moreover, a study regarding the structural changes in a delta, which will have a feedback effect on later times steps, - for instance in order to model ontologies of change,- could be highly relevant for ADM.

Regarding the understanding of the theory of multiple ontologies water modelling, more studies and debates are required. The differentiation between two levels, as Hrachowitz (2019) should be further investigated in order to have pragmatic implications. Also, the suggestion to include these ideas to the discussion of engineering ethics is relevant in future studies.

Then, a study related to the communication of ontologies for engineers and governmental officials is suggested. By making choices in the communication of the ideas, and thus presenting the concepts of a pragmatic ontology, the concepts discussed in this article can be valuable for more stakeholders than just for a limited specific scientific public

8.3 TOWARDS A FRAMEWORK OF UNDERSTANDING

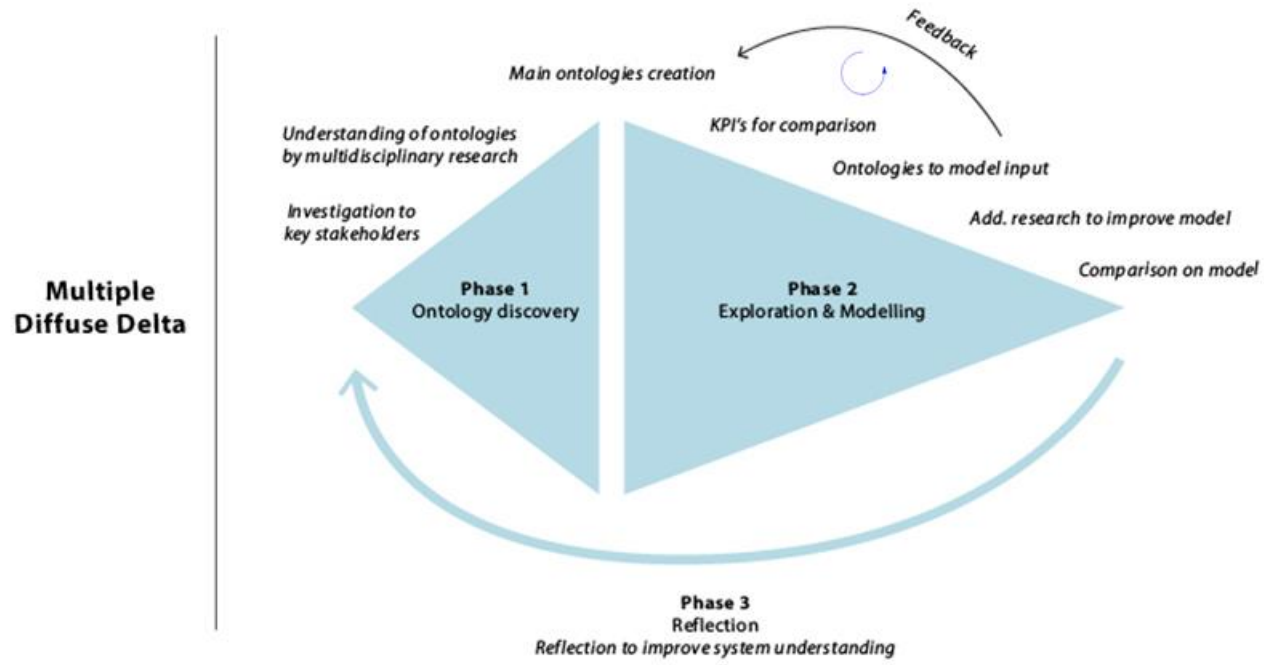
As I have shown in the previous paragraphs, ADM only considers one fixed system. However, I have shown that pragmatic ontologies deal with the multiple-existence of ontologies in the Paraná Delta. I posit that a framework addressing the multiple ontological environments, by applying engineering principles, can stimulate understanding, debate and policy for ADM on the Paraná Delta. The framework consists of the following phases: Construction of ontologies, modelling the ontologies and reflection. I could not test the framework, but the framework is set-up based on my experience and designed in a co-session with a science-communication expert. Its purpose is to guide future researchers working on ontologies and modelling for Delta's through the steps I aimed to obtain. Van Nooyen (2019, personal communication) suggested that such a framework could guide researchers to discuss the different ontologies. In figure 15, the entire framework is presented.

9. ACKNOWLEDGEMENT

I would like to acknowledge Deltares and the TU Delft for the funding of this research and all the scientific support. Furthermore, INA and specifically Martin Sabarots for providing the HEC-RAS model, and data of the water system. INTA for supporting me in the workshops and measurmeents. Dr. Maurits Ertsen for thorough supervision and opening my eyes for ontological thinking. Alex Curran for the support in understanding HEC-RAS. Finally, all supervisors and experts involved in this research for giving me scientific input.

FIGURE 14 MEASUREMENT FIXED POINT

'THE KITE FRAMEWORK'



Phase 1: Ontology discovery

In the first phase of the framework the aim is to create and understand different of the Delta, or in general situations 'the cartoon' as mentioned by Murphy (2012). In order to construct these ontologies, first the main actors/ stakeholders (Latour&Strum, 1986; Murphy et al., 2012, (Enserink et al., 2010; Hermans, 2006), Enserink et al., 2010, Ertsen et al., 2014; Ertsen, 2016) are analysed, in order to understand whose ontologies to describe. By organizing a variety activities with these selected stakeholders as interviews, focus groups, workshops, other interactive exercises, or by analyzing literature, or newspaper articles/social media information can be formed in order to construct the multiple ontologies. These ideas can be re-discussed with the stakeholders. By means of description in narratives, the different ontologies can be presented, and in order to compare these ontologies in a structured way in a comparison table is set-up.

Phase 2: Model exploration

In the second phase is investigated how the ontologies can be translated into modelling to support ADM. For the different ontologies is highlighted what are the main Key performance indicators (KPI's). Than the ontologies are translated I terms of model input. By viewing the feedback is present between the different ontologies, the ontologies will be adjusted. It is investigated how current models can be used, or what information is needed to step-up new models, or adapt models to be able to represent the several ontologies. If possible, the different ontologies are modelled and compared by means of model output.

Phase 3: Reflection

A reflection is made if an improved understanding can be made of the Paraná Delta by the modelling of the different ontologies, and if policies can be formulated. Maybe, it would mean that additional research is necessarily, or new type of models have to be formulated. It can be reflected if it is possible to implement certain policies, even though such a multiple ontological environment is present. Expert judgement could provide a great value here. Different ways forward for research or policy formulation are suggested.

FIGURE 15 THE KITE FRAMEWORK

|Reflection on personal development

FIGURE 16 MEASUREMENT OF RIVER PROFILE AFTER A DYKE BREACH

Now that I am closing off the 1 year and 3 months of the two theses, I can look back on the process and reflect on my personal development over this period. It was a challenging, learnful, but enjoyable experience. Would I do it again? Yes! Would I do it differently, definitely! All over, I am grateful for having the experience of these two theses both on an intellectual and personal level. From the beginning it was my intention to do research which would form a bridge between engineering and the real social world. However, bringing these ideas into a research project proved not always to be easy. I realized that not everybody both in Argentina and in the Netherlands got enthusiastic about my aim to connect society and engineering so strongly. Like one supervisor said:

> *"Why would you go to the field and talk with all these people if you can calculate everything behind your computer?"*

And in reality, of course, this gave some issues. The practical situation was completely opposite from what I initially expected in Argentina, since no foundation for my research seemed to be present. There was not a network of stakeholders available which I could approach, not a set of data available of the dykes. This meant that I had to start from scratch.

I started to talk to people I considered of interest for my research, invited myself to workshops on the Delta, wrote, texted, called so many people in the field as possible before I could start the actual work. Many people were kind, talked about their water issues, giving me many insights on what to research. After my conversations with so many organizations, and also with adaptive delta management experts, I realized I could organize a series of workshops myself (together with an Argentinean student I had met at the end of her studies). Furthermore, together with the water institute of Argentina, I set up a modelling campaign. I decided to adjust my research in order to get an overlap and find data that could be useful for both of us, so we could have a fruitful cooperation. The whole time I was looking to find people with similar interests, to set up cooperations, and into making my research a success. Back in the Netherlands, finally really knowing what I wanted to do, I started to approach funds and looked at original ways to use my money.

But after this initial set-up phase I had to remain creative, social and focused in Argentina... During one day of measurements, when I could not reach my measurement area, I could luckily borrow a canoe to still be able to reach

my destination. During an island festivity day (which I wanted to attend in order to be able to speak to local people), a strike took place, and I had to wait 6 hours in line for the public boat, and finally by hitchhiking I was able to attend the festivities for one hour. However, during that hour I got the most interesting insights, of how local women have difficulties living in the delta, and of the kind of difficult situations they were facing. I got robbed while I was in a meeting with my Argentinean supervisor. Also, I had to change houses multiple times, camped in an experimental station with local researchers, freezing in the cold. And then the Spanish language! First I spoke a very limited Spanish, but when I realized all my participatory work had to be in Spanish, I took every evening extra Spanish classes, and eventually, I was able to understand the Argentinean accent. Another problem was formed by the stakeholders that initially were supposed to come to my workshops. Due to a conflict outside my domain, they were not interested anymore in working with Dutch parties. Luckily, I went to do measurements and made field visits, where I could meet and talk to local people and with agriculture organizations. I encouraged them to participate in the workshops and they suggested other stakeholders to me. In the end, I was able to interview more than 50 people in Argentina, I organized 5 workshops where more than 50 people also attended, and I participated in different research activities and workshops speaking with many others.

Looking back, I can say that I'm proud of all the work I have done. The most important thing I have learned is that it is not possible to plan everything from the start to the end or to do risk analysis on all subjects: in the beginning when something went wrong, I used to reevaluate the problem more than a 100 times. Maybe I did it because I was afraid of what the supervisors in the Netherlands could say if they would evaluate to the non-technical components of the research. I have learned that sometimes I have to let it go, since I cannot do everything perfectly, I should not always be "an optimizer"; a "satisfier" could do as well. For all the things that turned out to be difficult, I discovered that I was creative enough to find solutions! I am also very happy with the results of the organization of my work: cooperation with people of all kind of different institutes, from different working cultures and nationalities in working situations. This was so inspiring, but at the same time quite tough as well. People reacted sometimes very directly, maybe even a bit rude or mean about my work, and these negative attitudes were quite shocking for me. Maybe some people did not appreciate my attitude to actively involve stakeholders, or did not appreciate my thinking about ontologies, or about modelling. I felt the need to adapt my research plan throughout the process.

I think I was so afraid to receive criticism on my scientific thinking, that I became too perfectionistic, trying to find proof of everything in literature which took quite some time during the last months of my studies. I realize that I should have trusted my sources and myself better from the beginning of the process. So at the end of the theses, I realize that if I start to approach new ideas, or different ideas, I can expect people to have different and critical opinions. I realize now that people will react differently and that it is up to me to make my ideas as clear as possible for them without fear for criticism. And I do realize now that criticism does not have to say anything about how they see me as a person. Or if they don't like me, I should still be proud of my own ideas, my way of thinking, and related to subjects of my research: being full of strength showing how I believe that engineering and the social world could be connected.

In sum, I believe this research has taught me to believe in my own strength, accept that things can go wrong, that I should not try to control everything, but that I should stay calm and think in possibilities while enjoying the research I am doing. I did my research in quite an experimental way in which engineering was connected to social studies and philosophy. This was what I intended to do from the beginning from my studies (Bachelor time in Leuven) and I found it not an easy project to do. I am happy that in the end of my studies I found in Dutch newspapers twice a top scientist, Prof. Louise Fresco, chairwoman of the University of Wageningen and Jan Mengelers, former chairman of the TU Eindhoven, saying that the study of technical engineer in the near future should cover for 20 percent social and liberal arts, and that the pure beta studies should not exist any longer. Both are stating that "the future engineer should be both an alpha, beta and gamma in one"(see: NRC[7] of FD[8]). I hope to take the valuable lessons from these very interesting studies with me to my next phase in life!

[7] https://www.nrc.nl/nieuws/2019/05/06/ena-niet-afschaffen-maar-verbeteren-a3959201
[8] https://fd.nl/economie-politiek/1301592/moderne-ingenieur-is-beta-alfa-en-gamma-ineen

|Appendices overview

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DATA FOR ONTOLOGIES

- Case description Paraná Delta
- Scoping mission
    - Report Scoping mission (group model building and actor mapping)
    - Main insights with literature
- Workshops comparison
    - EPA report
    - Data appendices
    - Method Appendices
    - Background literature review
- Workshop Deltares/INA

MODELLING & EXPERTS

- Experts
    - Expert meeting and interviews
- HEC-RAS and measurements
    - HEC-RAS set-up, change dykes, measurements + local interviews
    - Measurements files (together with existing data)
    - Shapes workshop campaign (what I measured)
    - climate series
    - Lujan Data
    - HEC-RAS model
- Results workshops
    - GIS workshops
    - Shape files

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