



Adaptive Water Governance: Responding to Flood and Drought Events in the Dutch Vecht Basin

Master Thesis of Elise Holubek



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Colophon

Document type: Master's Thesis
Title: Adaptive Water Governance: Responding to Flood and Drought events in the Dutch Vecht Basin
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Preface

I am proud to present my master's thesis, *Adaptive Water Governance: Responding to Flood and Drought Events in the Dutch Vecht Basin*, concluding my Master's in Civil Engineering and Management at the University of Twente. During my studies, I developed a deep interest in climate change and wanted to contribute to this important field. I greatly enjoyed exploring flood and drought response, combining theoretical knowledge with practical applications.

Throughout this journey, I had the opportunity to speak with many people from diverse backgrounds and gained valuable insights into their perspectives on these challenges, which I found both inspiring and enjoyable. I sincerely thank all interviewees who generously shared their thoughts and experiences. I was also fortunate to conduct my research at Water Authority Vechtstromen, with special thanks to Lisette van der Giessen, my external supervisor, for her continuous guidance and for always listening to my ideas with enthusiasm. I am equally grateful to my university supervisors, Joanne Vinke-de Kruijf and Anicia Touraine Andersson, for making time for me and providing valuable feedback throughout the process.

Last but not least, I would like to express my gratitude to my friends and family for their unwavering support and the fun we shared throughout my entire studies.

I hope you enjoy reading this work and gain insights that inspire further learning and action toward a more sustainable future.

Elise Holubek

Enschede, October 2025

Abstract

Floods and droughts are increasing in frequency and severity in the Dutch Vecht basin as a result of climate change. The water governance system, which includes the political, social, economic, and administrative systems that regulate water management and services, must cope with both excess water during floods and water scarcity during droughts. Actors are the individuals who participate in these water governance processes, taking on specific roles with responsibilities that shape their actions and interactions, which together form their responses to flood and drought events. Knowledge, understood as information that is given meaning, is actively used by actors to guide these responses.

Since these events involve high uncertainty, with variable conditions and incomplete knowledge, a flexible response approach is required. Adaptive governance provides such an approach, understood as the ability of actors, networks, and institutions to evolve, adapt, or transform in situations of change through a range of interactions and actions to achieve a desired state. This study explores how actors in the Dutch part of the Vecht basin adapt their roles and use knowledge during flood and drought responses and identifies opportunities to strengthen adaptive governance.

In this study, adaptive governance is approached from a *response-oriented* perspective, emphasizing its role in disaster risk management. This focus results in an analysis of *short-term event-based* adaptive governance. To operationalize this concept, the Management & Transition Framework (MTF) was adapted by selecting specific elements relevant to short-term responses to flood and drought events. This includes the element *action arena*, which refers to the flood and drought response system, and the *action situation*, which encompasses the response of actors to the event. In this context, the translation from the *action arena* to the *action situation* is examined to understand how the response system functions in practice. Actor role adaptation is analysed through the MTF elements of *actor* and *role*. Knowledge utilization is explored with the following elements: *knowledge*, which refers to the available knowledge in the broader system, and *situated knowledge*, which is held by actors and can be transferred to the broader body of *knowledge*.

A qualitative research design was applied, focusing on two case studies: the flood around Christmas 2023 and the drought of summer 2022 in the Dutch Vecht basin. Data on these case studies were collected through 18 semi-structured in-depth interviews complemented with a document analysis. Data were analysed thematically using codes derived from the MTF, focusing on the elements *action arena*, *action situation*, *actor*, *role*, *knowledge*, and *situated knowledge*. These elements interact, and through the thematic analysis, the resulting processes were synthesized into key themes encompassing challenges for both the flood and drought case studies. These results and the follow-up recommendations were validated through a dialogue session with the interview participants.

The findings show that floods and droughts differ in their dynamics. Floods are rapid and visible events that trigger established crisis structures, whereas droughts are slow-onset, creeping crises with less perceptible impacts and varied interpretations, complicating coordination. Therefore, floods and droughts are analysed separately, as the hazards differ in terms of duration, origin, and required response strategies.

Consequently, four key themes were identified for flood response in 2023: differences in crisis escalation due to flood risk perceptions; weak embedding of relevant informal roles in the crisis organization; limited reliability and undefined responsibilities of FEWS; and static knowledge tools restrict timely and relevant knowledge. For drought response, three themes emerged: absence of well-established drought response system at water authority Vechtstromen (WVS); undefined roles and authority in Regional Drought Meetings (RDO's); and different drought definitions creating perception–response gaps.

To conclude, in flood response, actors in the Dutch Vecht basin demonstrate adaptability by adjusting their roles to rapidly evolving situations. The *action arena* is generally stable, structured around formal crisis plans, but the adoption of crisis *roles* is influenced by actors' *mental models*, an MTF element initially excluded from the conceptual framework, particularly referring to an actor's perception of flood risk. *Actors* combine formal crisis roles with informal roles, drawing on pre-established and informal networks as well as their own *situated knowledge* to enhance decision-making. Additionally, certain informal operational *roles* contribute valuable *situated knowledge* during response actions, even though these actors do not hold formal crisis responsibilities. Not all relevant knowledge is fully integrated, and mismatches between available knowledge and actual needs constrain adaptability.

Furthermore, for drought response, the *action arena* is less stable because formal *roles* are unclear, leading *actors* to operate primarily from informal roles. This allows flexibility but also creates uncertainty, as responsibilities are vague. The slow-onset nature of drought and differences in actors' *mental models* limit the effective use of *knowledge*, as actors must first sufficiently interpret the hazard before applying and generating the relevant knowledge.

Overall, adaptive governance in the Dutch Vecht basin is driven by actors' mental models and the alignment of knowledge with needs. Strengthening adaptability requires clarifying roles and knowledge requirements, and fostering a shared understanding of risks and responsibilities.

Based on these insights, the research offers the following recommendations for practitioners: (1) Engage involved organizations in the Vecht basin in scenario-thinking to clarify roles and responsibilities for flood and drought response; (2) Develop a dynamic, real-time knowledge tool to provide tailored, actionable knowledge for internal and external organizations; (3) Revise flood crisis plans to specify responsibilities, including water level monitoring and integration of informal operational roles; (4) Define the desired drought response system at WVS through internal discussions to clarify roles of the Drought Team, crisis organization, and RDO. Together, these measures can enhance adaptive governance for flood and drought response in the Dutch Vecht basin.

Table of Contents

Colophon	iii
Preface.....	iv
Abstract	v
List of Figures	x
List of Tables.....	xi
List of Abbreviations.....	xii
List of Translations	xiii
1. Introduction	1
1.1 Context	1
1.2 State-of-the-art	2
1.3 Problem Statement	2
1.4 Research Objective & Research Question.....	3
1.5 Scope	4
1.6 Outline of the Thesis	5
2. Theory.....	6
2.1 From Natural Events to Human Crises.....	6
2.2 Adaptive Governance as a Response.....	9
2.3 Operationalizing Short-term Event-based Adaptive Governance.....	11
3. Methodology	15
3.1 Research Approach	15
3.2 Case Studies	16
3.2.1 Flood Event – Winter 2023	18
3.2.2 Drought Event – Summer 2022.....	18
3.3 Data Collection	19
3.4 Data Analysis	21
3.5 Data Validation.....	25
4. Results	27
4.1 Comparison of Floods and Droughts	27
4.2 Flood Events	27
4.2.1 Differences in Crisis Escalation due to Flood Risk Perceptions	28

4.2.2	Weak Embedding of Relevant Informal Roles in the Crisis Organization	37
4.2.3	Limited Reliability and Undefined Responsibilities of FEWS	45
4.2.4	Static Knowledge Tools Restrict Timely and Relevant Knowledge	47
4.3	Drought Events	50
4.3.1	Absence of Well-established Drought Response System at WVS	50
4.3.2	Undefined Roles and Authority in Regional Drought Meetings	55
4.3.3	Different Drought Definitions creating Perception–Response Gaps	57
4.4	Opportunities for Improvements	60
5.	Discussion	62
5.1	Reflection on Key Findings	62
5.2	Reflection on Application of Management & Transition Framework	63
5.3	Reflection on Research Methods	65
6.	Conclusion & Recommendations	68
6.1	Conclusion	68
6.1.1	Contrasting Dynamics: Floods and Droughts	68
6.1.2	Key Findings for Flood Events	69
6.1.3	Key Findings for Drought Events	69
6.1.4	Overall Conclusion: Mindset and Knowledge drive Adaptive Governance	70
6.2	Recommendations for Practitioners	70
	Bibliography	73
	Appendix	77
	Appendix A – Elements of Management and Transition Framework (MTF)	77
	Appendix B – Data Collection	79
	Appendix C – Data Collection Goals for Interviews & Document Analysis	81
	Appendix D – Interview Protocol	86
	Appendix E – Coding Tree of the Thematic Analysis	92
	Appendix F – Details on Dialogue Session (Validation Step)	93
	Appendix G – Description GRIP Crisis Teams	96
	Appendix H – Description WVS Crisis Teams	98
	Appendix I – Responsibilities of Organizations in Flood Response System	100
	Appendix J – Description Actor’s Formal Roles Safety Region IJsselmeer	103

Appendix K – Details on TPI’s & Water Allocation Hierarchy.....	104
Appendix L – Responsibilities of Organizations in RDO-TK.....	106
Appendix M – Safety Regions in the Netherlands.....	107
Appendix N – RWS Regions in the Netherlands	108
Appendix O – Water Authorities in the Netherlands.....	109
Appendix P – RDO Regions in the Netherlands	110

List of Figures

Figure 1 - Relationship between various types of droughts, based on Wilhite (2000) & Bressers et al. (2016)	7
Figure 2 – Basin-wide disaster risk management phases, based on Van Ginneken (2023).....	8
Figure 3 - Interconnections between risk, event, disaster and crisis	9
Figure 4 – Conceptual framework based on the Management and Transition Framework (MTF)	14
Figure 5 – Visualization of the research approach	16
Figure 6a - The main rivers in the Vecht basin (Klein & Van der Vat, 2024, p. 31) & Figure 6b – Municipalities along the rivers in the Vecht basin (Hoebergen, 2021).....	17
Figure 7 - Data analysis of MTF elements.....	23
Figure 8 - GRIP phases & crisis teams [I-S1; D-V4; D-S1; D-N1; D-N2; D-N3].....	29
Figure 9 - Crisis organization of WVS translated from GRIP [D-V3; D-V4; D-S1; D-N1; D-N2; D-N3]	30
Figure 10 - Flood response system in the Vecht basin (authors interpretation based on document and thematic analysis)	32
Figure 11 - Timeline flood event 2023 from WVS perspective [I-V1; I-V4; I-H1; I-V9; I-S1; D-V1; D-H1]	35
Figure 12 - WVS actor's formal roles in crisis teams (authors interpretation based on document and thematic analysis).....	39
Figure 13 - Safety Region IJsselland ROT actors formal roles [I-S1; D-V4; D-S1].....	41
Figure 14 - Network Analysis of Flood Event 2023 in Vecht basin (authors interpretation based on document and thematic analysis).....	42
Figure 15 - Timeline drought event 2022 from perspective WVS [I-V3; I-V4; I-V7; D-V2]	53
Figure 16 – Structure Regional Drought Meeting Twentekanalen (RDO-TK) (authors interpretation based on document and thematic analysis)	56
Figure 17 - Coding tree based on MTF elements and interview questions.....	92
Figure 18 - Safety Region IJsselland actor's formal roles in crisis teams: responsibility and authority [I-S1; D-V4; D-S1]	103
Figure 19 - Safety regions in the Netherlands. Retrieved from Rijksoverheid, Veiligheidsregio's, https://www.rijksoverheid.nl/onderwerpen/veiligheidsregios-en-crisisbeheersing/veiligheidsregios	107
Figure 20 - RWS regions in the Netherlands. Retrieved from Rijkswaterstaat, https://www.rijkswaterstaat.nl/over-ons/onze-organisatie/groot-onderhoud	108
Figure 21 – Water authorities in the Netherlands. Retrieved from Unie van Waterschappen, https://unievannwaterschappen.nl/publicaties/waterschapskaart/	109
Figure 22 - Water authorities in the Netherlands. Retrieved from 'Landelijk draaiboek watervdeling en droogte' [D-V23]	110

List of Tables

Table 1 - Description of MTF elements used in conceptual framework.....	13
Table 2 - Organizations with relevant actors in Vecht basin suitable for data collection (interviewed organizations in bold).....	19
Table 3 - Number of interviews per organization	21
Table 4 - Description of data collected for MTF elements from conceptual framework	22
Table 5 - Color coding for drought risk from 'Landelijk draaiboek waterverdeling en droogte' [D-V23]	59
Table 6 - Elements of MTF. Highlighted elements included within the conceptual framework.	77
Table 7 - Data collection overview documents	79
Table 8 - Data collection overview interviews	80
Table 9 - Data collection goals and questions of interviews and document analysis based on MTF elements (continued on next pages)	81
Table 10 - Overview of Interview Questions and Guideline Duration	87
Table 11 - Results of voting during dialogue session	93
Table 12 - Color coding for flood risk from 'National Crisisplan Highwater and Floods' [D-N1].....	102
Table 13 - National Water Allocation Hierarchy [D-V23]	105

List of Abbreviations

<i>Abbreviation</i>	<i>English</i>	<i>Dutch</i>
ACW	Action Center Water	Actiecentrum Water
CoPi	On-site Command Post	Commando Plaats Incident
FEWS	Flood Forecasting & Early Warning System	Flood Forecasting & Early Warning System
GBT	Municipal Governance Team	Gemeentelijk Beleidsteam
GDO	Coordinated Drought Meeting	Gecoördineerd Droogte Overleg
GRIP	Coordinated Regional Incident Management Procedure	Gecoördineerde Regionale Incidentbestrijdingsprocedure
HOvJ	Chief Public Prosecutor	Hoofdofficier van Justitie
HWC	Highwater Coordinator	Hoogwatercoördinator
ICO	Information Coordinator	Informatiecoördinator
ICW	Information Center Watersystem	Informatiecentrum Watersysteem
IM	Information Manager	Informatiemanager
KNMI	Royal Netherlands Meteorological Institute	Koninklijk Nederlands Meteorologisch Instituut
LC	Leader CoPi	Leider CoPi
LCMS	National Crisis Management System	Landelijk Crisis Management Systeem
LCO	National Flood Risk Coordination Committee	Landelijke Coördinatiecommissie Overstromingsdreiging
LCW	National Coordination Committee Water Distribution	Landelijke Coördinatiecommissie Waterverdeling
LTO	Dutch Federation of Agriculture and Horticulture	Land- en Tuinbouw Organisatie Nederland
NAP	Normal Amsterdam Water Level	Normaal Amsterdams Peil
OL	Operational Leader	Operationeel Leider
OvD	Officer on Duty	Officier van Dienst
PBC	Water Level Coordinator	Peilbeheercoördinator
RBT	Regional Governance Team	Regionaal Beleidsteam
RDO	Regional Drought Meetings	Regionale Droogte Overleg
RDO-TK	Regional Drought Meeting Twentekanalen	Regionaal Droogte Overleg Twentekanalen
ROT	Regional Operational Team	Regionaal Operationeel Team
RWS-NN	Rijkswaterstaat Northern Netherlands	Rijkswaterstaat Noord-Nederland
RWS-ON	Rijkswaterstaat Eastern Netherlands	Rijkswaterstaat Oost-Nederland
TPI	Temporary pump installations	Tijdelijke pomp installaties
Vz Vr	Chair Safety Region	Voorzitter Veiligheidsregio
WAT	Water Action Team	Water Actie Team
WBT	Water Authority Governance Team	Waterschap Beleid Team
WDOD	Water Authority Drents Overijsselse Delta	Waterschap Drents Overijsselse Delta
WMCN	Water Management Center Netherlands	Watermanagementcentrum Nederland
WOT	Water Authority Operational Team	Waterschap Operationeel Team
WRIJ	Water Authority Rijn and IJssel	Waterschap Rijn en IJssel
WVS	Water Authority Vechtstromen	Waterschap Vechtstromen

List of Translations

<i>English</i>	<i>Dutch</i>
Action Center Water	Actiecentrum Water
Chair RDO	Voorzitter RDO
Chair Water Authority	Watergraaf
Chair WBT	Voorzitter WBT
Communication Advisor	Communicatie Adviseur
Coordinated Drought Meeting	Gecoördineerd droogte overleg
Crisis Control Advisor	Adviseur Crisisbeheersing
Crisis organization	Crisis organisatie
Daily management	Beheer organisatie
Drought Team	Droogteteam
Duty Officer for Population Care	Officier van Dienst Bevolkingszorg
Field Manager	Gebiedsbeheerder
Field Workers	Veldmedewerkers
Fieldteam	Veldteam
Head of ACW	Hoofd ACW
Head of Field	Hoofd Veld
Highwater Coordinator	Hoogwatercoördinator
Hydrology Advisor	Strategisch Specialist Hydrologie
Information Center Watersystem	Informatiecentrum Watersysteem
Information Overview Water System	Informatiebeeld Watersysteem
Member Executive Board	Lid Dagelijks Bestuur
Municipal Secretary	Gemeentesecretaris
National Crisis Management System	Landelijk Crisis Management Systeem
National Water Overview	Landelijk Waterbeeld
Policy Officer for Water and Rivers	Beleidsmedewerker Water en Rivieren
Regional Drought Meeting	Regionale Droogte-Overleg
Regular Organization Advisor	Adviseur Reguliere Organisatie
Safety Region	Veiligheidsregio
Senior	Senior
Tactical Water Level Manager	Tactisch Peilbeheerder
Temporary pump installations	Tijdelijke pomp installaties
Upscaling	Opschaling
Warning Notification	Waarschuwingsbericht
Water abstraction ban	Onttrekkingsverbod
Water Agreements	Waterakkoorden
Water allocation hierarchy	Verdringingsreeks
Water authorities	Waterschappen
Water Authority Operational Team	Waterschap Operationeel Team
Water Authority Governance Team	Waterschap Beleid Team
Water Level Coordinator	Peilbeheercoördinator

Water Safety and Flood Risk Advisor	Strategisch Adviseur Waterveiligheid Wateroverlast
Water System Advisor	Adviseur Watersysteem
Water System Coordinator	Coordinator Watersysteem

1. Introduction

1.1 Context

Climate change is having a global impact, leading to an increase in the frequency and intensity of extreme weather events. These include high-temperature extremes, which may cause more severe and prolonged droughts, as well as heavy rainfall events, that can result in devastating floods (Copernicus Climate Change Service, 2025). In 2024, Europe experienced an estimated €18.2 billion in losses due to natural disasters, with flooding accounting for 85% of the total. At least 335 lives were lost as a result of storms and floods, and around 413,000 people were affected. In addition, the continent faced lower-than-average rainfall and endured its driest summer in the 12-year drought index record. More lakes had below-average water levels compared to the summer of 2023, and summer-average river flows were notably or exceptionally low in 35% of rivers across Europe (Copernicus Climate Change Service, 2025).

As a result of these impacts, European societies have become increasingly aware of climate risks, prompting a rise in adaptation measures. Flooding is identified as the climate risk most urgently requiring action (Copernicus Climate Change Service, 2025). The summer of 2021 brought catastrophic flooding to parts of Belgium, Germany, and the Netherlands. Caused by two days of extreme rainfall, the floods led to more than 200 fatalities and extensive infrastructural damage. In contrast, the summers of 2018-2020 and 2022 were marked by exceptionally low rainfall and high temperatures, leading to widespread droughts causing low river flows disrupting shipping and energy production, while also harming agriculture and ecosystems (Bartholomeus et al., 2023).

These extreme weather events underline how vulnerable these regions are to climate change impacts (Blankesteyn & Pot, 2024). Furthermore, they show that floods and droughts do not respect national borders, making transboundary collaboration essential. To manage these extreme weather events effectively, governance systems, defined as the combination of rules, processes and instruments structuring interactions between actors to realize collective goals, must be structured in a way that enables them to withstand and respond to these shocks (Bressers et al., 2016; Blankesteyn & Pot, 2024).

Flood and drought events are difficult to manage by actors within governance systems, due to the uncertainty surrounding their timing, location, intensity, and duration. To effectively respond to these unpredictable and high-risk events, governance systems must adopt adaptive approaches, which promote flexibility and learning (Hurlbert, 2018). Adaptive governance has been identified as essential for managing risk and uncertainties during periods of abrupt change (Pahl-Wostl et al., 2010). In this context, improving the understanding of extreme weather risks is crucial for developing effective approaches to manage these risks. To advance this goal, the research is conducted in collaboration with the Joint Cooperation Programme on Applied Research to Accelerate Transboundary Regional Adaptation to Climate Extremes (JCAR ATRACE), which aims to enhance understanding of these risks and strengthen transboundary resilience (JCAR ATRACE, sd).

1.2 State-of-the-art

According to Fournier et al. (2016), adaptive governance is increasingly recognized as an essential component in managing the uncertainties of extreme weather events within complex socio-ecological systems. However, there has been limited research performed into the extent to which existing governance structures reflect desirable forms of adaptive governance. Furthermore, Hurlbert & Gupta (2016) highlight a knowledge gap concerning how governance systems effectively operationalize adaptive governance and how policy responses are framed in relation to risk.

Building on this, literature has also pointed out that the connection between adaptive governance and disaster risk management has not yet been fully explored (Djalante et al., 2011; Aoki, 2016; Janssen & Van der Voort, 2020). While adaptive governance has mainly been developed in the fields of environmental and climate change studies, often with a focus on long-term processes, disasters offer the opportunity to study short-term event-based adaptive governance (Aoki, 2016; Janssen & Van der Voort, 2020).

Therefore, this research aims to contribute to the assessment of adaptive governance within the response to disasters. To achieve this, the study brings together literature on *adaptive governance* and *disaster risk management*, with a particular focus on event-based contexts.

1.3 Problem Statement

Climate change will lead to an increased frequency and risk of extreme weather events, including floods and droughts. These events are already being felt across Europe and pose serious risks for water management, agriculture, ecosystems, and society (Hurlbert & Gupta, 2016; Bartholomeus et al., 2023).

The transboundary Vecht basin provides a clear example of these challenges. Over the past 15 years, the area has experienced multiple flood events caused by high-intensity rainfall, most recently in December 2023 (Klein & Van der Vat, 2024). This event led to significant disruption in several areas, with roads, bike paths, and meadows being flooded (Waterschap Vechtstromen, 2023). In addition to floods, the Vecht basin also faced drought events, most notably in 2018-2020 and in 2022 (Klein & Van der Vat, 2024). The droughts caused low water levels and dry soil affecting agriculture, nature and drinking water supply (Waterschap Vechtstromen, 2019). Together, floods and droughts illustrate the basin's vulnerability to climate extremes.

Responding to flood and drought events in the Vecht basin is challenging, because the increasing impacts of climate change interact with a complex governance context. First off, the rivers in the Vecht basin flow across both the Netherlands and Germany, requiring cross-border coordination between the two countries. Additionally, within the Dutch region, responsibilities for flood and drought response are shared among multiple actors, including water authorities, safety regions, municipalities, and provinces (Klein & Van der Vat, 2024). Effective response therefore requires strong coordination and collaboration across both national and regional borders.

Such complexity highlights the importance of governance systems that can adapt to changing conditions. Adaptive governance is regarded in the literature as the preferred approach for governing social-ecological systems during periods of abrupt change, due to its ability to manage the uncertainty and unpredictability of extreme weather events (Pahl-Wostl et al., 2010; Fournier et al., 2016; Raadgever & Hegger, 2018). Yet, a major challenge lies in the limited understanding of how adaptive the actors' responses are during flood and drought events. Strengthening adaptive governance requires insight into the current state: who is involved, how they interact, and which actions are taken. There is thus a demand for basin-wide governance assessments (Klein & Van der Vat, 2024). Therefore, this research examines how actors in the Dutch Vecht basin respond to flood and drought events.

1.4 Research Objective & Research Question

In the Dutch Vecht basin, the water governance system refers to the political, social, economic, and administrative systems that regulate the management of water resources and the provision of water services (Pahl-Wostl, 2009, p. 355). During floods, the system faces excess water, while during droughts it must cope with water scarcity.

Actors, who are individuals participating in water governance processes (Pahl-Wostl et al., 2010), respond to these events. These responses consist of actions and interactions among actors, which are shaped by the specific roles with responsibilities each actor assumes (Jiménez et al., 2020; Pahl-Wostl et al., 2010). Knowledge, defined as information given meaning, is actively used to guide these actions and interactions (Vinke-De Kruijf et al., 2013).

Flood and drought events involve a high level of uncertainty, with variable conditions and incomplete knowledge (Hurlbert, 2018), requiring a flexible approach to manage these challenges. Adaptive governance provides such an approach, understood as the ability of actors, networks, and institutions to evolve, adapt, or transform in situations of change through a range of interactions and actions to achieve a desired state (Munene et al., 2018; Jiménez et al., 2020).

Building on this perspective, the objective of this research is to improve understanding of how actors in the Dutch Vecht basin adapt their roles and use knowledge during flood and drought events, and to identify ways to strengthen adaptive governance under increasing climate variability.

To fulfil the research objective, the following research question has been formulated:

How do actors in the Dutch Vecht basin water governance system adapt their roles and utilize knowledge during flood and drought events, and how can responses be improved to strengthen adaptive governance?

The research question has three components: first, which roles are assigned to actors and how these roles are adapted in practice. Second, what knowledge is used in responses and how effectively it informs decision-making. Third, how these insights can guide recommendations to strengthen adaptive governance, particularly by improving actors' roles and the use of knowledge within the water governance system.

1.5 Scope

The study area comprises a transboundary river basin, including both natural rivers and managed waterways. Its transboundary nature requires cross-border coordination across multiple authorities, which may span countries as well as municipal, provincial, water authority or safety region boundaries.

The study area is prone to floods and droughts. For floods, the study concentrates on *fluvial* flooding, which occurs when rivers or lakes exceed their capacity (Yang & Liu, 2020; Klein & Van der Vat, 2024). Other flood types, such as *pluvial* floods, referring to overwhelmed drainage systems, do occur in the study area but are not the focus of this research, while *tidal* floods from storm surges are excluded, as the study area does not include coastal areas (Raadgever & Hegger, 2018; Klein & Van der Vat, 2024). For droughts, the research focuses on *meteorological*, *agricultural* and *hydrological* droughts, which relate to deficits in precipitation, soil moisture, and (sub)surface water (Klein & Van der Vat, 2024; Bressers et al., 2016). Other types, such as *mega* droughts or *socioeconomic* droughts, are excluded as they are less commonly referenced when defining drought (Bressers et al., 2016; Klein & Van der Vat, 2024).

Flood and drought events provide a window to observe adaptive governance within a relatively short time span and to learn about its principles in action (Janssen & Van der Voort, 2020). Moreover, short-term adaptive governance often requires fast decision-making (Janssen & Van der Voort, 2020), which in the Netherlands may involve the activation of the crisis chain. In this study, governance encompasses the *politics*, *polity*, and *policy* dimensions, with emphasis on the *politics* dimension, as it focuses on decision-making and interactions among actors (Pahl-Wostl, 2015).

To operationalize adaptive governance, the Management and Transition Framework (MTF) is used as a conceptual foundation for this research (Pahl-Wostl et al., 2010). The MTF can be applied to analyse transition of multi-level governance regimes towards more adaptive systems and can serve as a tool for conducting a process analysis of an entire water governance system (Pahl-Wostl et al., 2010). However, in this study, the MTF is used as a reference framework and not applied in its entirety, as the research does not aim to fully analyse the transition of the governance system of the study area. The complete governance system through the lens of MTF includes all policy sectors, while this research solely focuses on the actors, roles and interactions in flood and drought response. Furthermore, the temporal scope of this research focuses on the period surrounding a specific event, as opposed to the longer timeframe used in full transition studies.

Thus, this study focuses on the response of actors to flood and drought events, relating to the *emergency* phase within disaster risk management. Other phases, such as *prevention*, *protection*, and *recovery*, are beyond the scope of this research (Rana et al., 2021; Wilhite, 2000; Van Ginneken, 2023). In terms of the MTF elements, the *emergency* phase corresponds to the policy sector of flood and drought response, called the *action arena*, encompassing the interactions between *actors*, referred to as *action situations*. In this *action situation*, actors adopt *roles* and (*situated*) *knowledge* is applied (Pahl-Wostl et al., 2010).



Other components of the water governance system, such as *institutions* and *paradigms*, are related to the *action arena* but not directly included in the conceptual framework of this study. While these elements may influence actor decisions, changes in institutional structures or underlying paradigms are beyond the scope of this study. These elements fall outside the conceptual framework, which is further detailed in Chapter 2.

1.6 Outline of the Thesis

The remainder of the master thesis elaborates further on the research. Chapter 2 introduces and explains the key concepts related to disaster risk management and adaptive governance, leading up to the conceptual framework based on the Management and Transition Framework (MTF). Chapter 3 outlines the research methodology, including an introduction of the case studies, the data collection approach for these cases, and the application of the conceptual framework for data analysis. This is followed by Chapter 4, showcasing the results of the research. Chapter 5 provides a discussion of these results, finalized by Chapter 6 which concludes the research and presents recommendations.

2. Theory

This chapter elaborates on the key theoretical concepts relevant to this study and introduces the conceptual framework applied in the research. It begins by explaining how natural events such as floods and droughts can escalate into human crises, thereby drawing in actors from the field of disaster risk management. The subsequent section discusses adaptive governance as a response mechanism to such events, focusing on its role during the emergency phase. Finally, the chapter synthesizes these concepts into a conceptual framework through which adaptive governance can be operationalized and analysed as a response to flood and drought events.

2.1 From Natural Events to Human Crises

To strengthen actor's responses to floods and droughts, it is important to first examine the impact of these events. Climate change is expected to increase both the frequency and the risk of extreme weather, leading to more frequent and severe flood and drought events (Hurlbert & Gupta, 2016; Bartholomeus et al., 2023). In this research, an *event* refers to a general occurrence taking place within a socio-ecological system, regardless of its consequences. *Socio-ecological systems* refer to the complex adaptive systems constituted by interactions between diverse people and elements of diverse ecosystems (Schlüter et al., 2019).

Within socio-ecological systems, *climate risk* provides a useful framework for understanding the impacts of climate change and strategies to mitigate consequences for present and future generations (IPCC, 2022). IPCC (2022) and Raadgever & Hegger (2018) define climate risk as a combination of calculable and social components: risk can arise from the dynamic interactions among climate-related *hazards*, the *exposure* and *vulnerability* of affected socio-ecological systems.

First off, *hazards* refer to the potential occurrence of an event with the potential to result in harm, e.g. loss of life, injury, environmental resources (IPCC, 2022). Secondly, *exposure* can be defined as the presence of people, livelihoods, ecosystems, services, resources, infrastructure, and assets in areas that could be adversely affected (IPCC, 2022). Last but not least, *vulnerability* can be defined as the degree to which a socio-ecological system in a specific region is susceptible to, and unable to cope with, adverse effects of events (Raadgever & Hegger, 2018).

When the *hazard* manifests, it materializes as an *event*. If this event interacts with *exposure* and *vulnerability*, and its consequences are significant, it is regarded as a *disaster*. While floods and droughts occur as natural events, they are classified as disasters only when their impacts are substantial, such as causing loss of life or major economic damage (Wilhite, 2000; Pahl-Wostl, 2015). Pahl-Wostl (2015) divides disasters into five categories: geophysical disasters (e.g. earthquakes and volcanic eruptions), meteorological disasters (e.g. hurricanes), hydrological disaster (e.g. floods), climatological disasters (e.g. droughts and wildfires) and biological disasters (e.g. pandemics).

Hydrological disasters encompass different kinds of hazards caused by the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater (Pahl-Wostl, 2015). *Floods* fall within this category. Two types of flood events can be differentiated in the study area: *pluvial* floods and *fluvial* floods (Yang & Liu, 2020). First off, *pluvial* floods refer to the event when rainfall falling on an area exceeds ground infiltration and/or storm drain capacity (Yang & Liu, 2020). The second type, *fluvial* floods, encompasses events when excessive amount of rainfall exceeds the capacity of a river (Yang & Liu, 2020).

Climatological disasters encompass different kinds of hazards caused by long-lived/meso-to-macro scale processes ranging from intra-seasonal to multi-decadal climate variability (Pahl-Wostl, 2015). *Droughts* fall within this category. The following three definitions of drought are considered for this study (Bressers et al., 2016):

1. *Meteorological* drought, referring to precipitation deficits caused by a long period of no or very little rainfall.
2. *Agricultural* drought, referring to a soil moisture deficit affecting crops.
3. *Hydrological* drought, characterized by river flows that are below average.

The relationship between these types of droughts is shown in Figure 1, aligning with the findings of the scoping study of the Vecht: when a meteorological drought has ended, the soil moisture content recovers first followed by the groundwater levels and surface water bodies (Klein & Van der Vat, 2024).

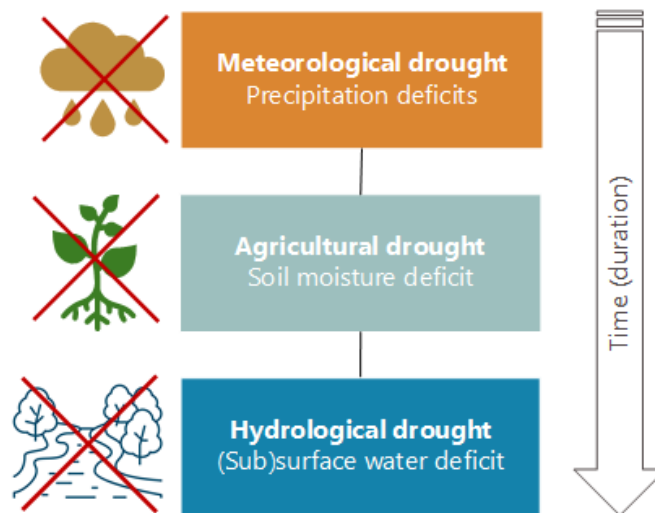


Figure 1 - Relationship between various types of droughts, based on Wilhite (2000) & Bressers et al. (2016)

Droughts have a number of characteristics which makes it distinct from other hazards. First off, drought is called a creeping crisis, since the effects of drought often accumulate slowly over a considerable period of time and the effects may persist for years even after the event has ended. Droughts usually require two to three months to establish and can then continue for months or even years. Therefore, the start and end of a drought is difficult to predict (Wilhite, 2000). Unlike floods, which typically develop abruptly in a short time period and have a relatively short-term

effect (Yang & Liu, 2020). Secondly, the impacts of drought are spread over a larger geographical area than damages resulting from other hazards. Thirdly, there are no precise and universally accepted definitions which identify whether a drought materialises and the corresponding severity degrees (Wilhite, 2000).

To manage the risk of potential disasters, disaster risk management is implemented. *Disaster risk management* can be defined as the management of resources and responsibilities for dealing with all humanitarian aspects of emergencies (Raadgever & Hegger, 2018). Disaster risk management involves multiple phases, each with a specific goal aimed at managing different aspects of the disaster (Rana et al., 2021). In the context of this study, an example of four phases for basin-wide assessments, as adopted by JCAR ATRACE, is illustrated in Figure 2: *protection, prevention, emergency and recovery*.



Figure 2 – Basin-wide disaster risk management phases, based on Van Ginneken (2023)

The *prevention* phase involves pre-disaster activities aimed at decreasing the potential consequences by reducing exposure of people and property (Raadgever & Hegger, 2018). The *protection* phase also occurs before a disaster but focuses on decreasing the likelihood of floods and droughts by reducing the hazards themselves (Raadgever & Hegger, 2018). The *emergency* phase encompasses response activities directly before or during a disaster to protect lives and limit damage (Rana et al., 2021; Wilhite, 2000). The *recovery* phase follows, encompassing post-disaster activities aiming to restore critical systems and return affected areas to normal functioning (Wilhite, 2000).

Beyond the aforementioned phases, fostering *awareness* among communities is a crucial component in disaster risk management, both for floods and droughts (Yang & Liu, 2020). The quality of risk perception is based on sufficient knowledge of the risk factors, the methods concerning protection against disasters and procedures of solving the developed events. An increase in risk awareness can increase the level of resilience against disasters (Titko & Ristvej, 2020). In the Netherlands, the individual flood risk awareness of citizens is relatively low compared to other countries in Europe and very little information is provided to citizens regarding flood risks and possible measures (Raadgever & Hegger, 2018).

Within the emergency phase of disaster risk management, actors respond to the occurrence of an event in order to manage the risk and thus avoid the disaster or limit the impact of a potential disaster. Actors may interpret an event as a *crisis* when they perceive it as a situation in which their social system faces a serious threat to its fundamental structures or core values, requiring critical decision-making under conditions of time pressure and uncertainty (Wolbers et al., 2021). However, not all events are perceived as a crisis, and definitions of crisis can vary. Therefore, whether an event is regarded as a crisis depends on the risk perception of the individuals or organizations involved and may vary between different parties (Fakru'l-Razi & Mat Said, 2003). The interconnections between the concepts *risk*, *event*, *disaster*, and *crisis* are visualized in Figure 3.

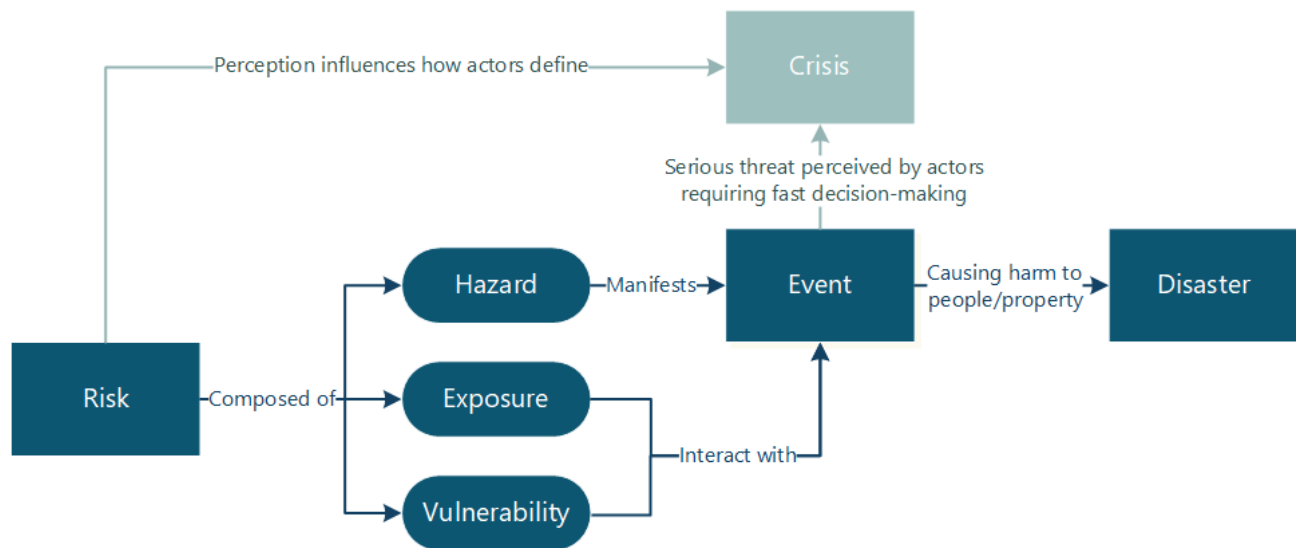


Figure 3 - Interconnections between risk, event, disaster and crisis

2.2 Adaptive Governance as a Response

As natural events escalate into human crises, effective responses depend on the ability of actors to manage the risks of these events. *Adaptive governance* has been identified in the literature as a useful concept for addressing such risks and uncertainties in the context of climate change (Munene et al., 2018; Fournier et al., 2016; Pahl-Wostl et al., 2010). Understanding how adaptive governance operates in practice requires first examining the broader concept of governance, particularly in relation to water resources.

To manage the risk of flood and drought events effectively, governance systems must be structured in a way that enables them to withstand and respond to these events (Bressers et al., 2016). In the literature, a broad range of definitions is given for the concept of *governance*. Pahl-Wostl (2015) provides a classification of different typologies of governance according to its function being primarily *politics*, *polity* or *policy*.

First off, in the *politics* dimension, emphasis lies on the process of policy making within actor networks (Pahl-Wostl, 2015). The second dimension, *polity*, refers to governance as a set of institutions: a system of rules shaping the actions of actors (Pahl-Wostl, 2015). Thirdly, the *policy*

dimension defines governance as modes of political steering, referring to governance instruments (Pahl-Wostl, 2015). In practice, however, these distinctions are often impractical due to governance complexity, making an all-encompassing concept more suitable (Pahl-Wostl, 2009; Pahl-Wostl, 2015). Blankesteyn & Pot (2024) provide such a definition, describing governance as the combination of rules, processes, and instruments that structure interactions between public and/or private actors to realize collective goals (Blankesteyn & Pot, 2024, p. 14).

A specific form of governance is *water governance*. Following the requirement of an all-encompassing definition embracing the full complexity of regulatory processes and their interaction, Pahl-Wostl (2009) defines water governance as the range of political, social, economic and administrative systems that are in place to regulate development and management of water resources and provisions of water services at different levels of society (Pahl-Wostl, 2009, p. 355). This encompasses water-related crises, such as droughts or floods, that may have severe impacts across scales and sectors (Pahl-Wostl & Knieper, 2023).

External factors such as climate change can pressure governance systems to adapt, introducing *adaptive governance* (Munene et al., 2018; Fournier et al., 2016; Pahl-Wostl et al., 2010). The literature presents multiple definitions for adaptive governance, which for this study are conceptualized through three perspectives: as a *response*, a *learning process*, and as a *system*.

The *response-oriented* perspective is most relevant here, framing adaptive governance as an adaptive response to sudden shocks, such as the occurrence of a flood or drought event. It operates when a change is occurring with respect to a resource, knowledge is incomplete, and science is uncertain (Hurlbert, 2018). The response includes interactions between actors, networks, organizations, and institutions working towards a desired state for the socio-ecological system (Munene et al., 2018). Jiménez et al. (2020) provide such a definition for adaptive governance: “The ability to evolve, adapt or transform in a situation of change, through a range of interaction and actions that occurs between different actors in a social-ecological system in order to meet a desired state” (Jiménez et al., 2020, p. 2).

Originally, however, adaptive governance emerged from climate change and natural resource management, where it emphasizes continuous learning and the long-term evolution within social-ecological systems (Aoki, 2016; Janssen & Van der Voort, 2020). From this perspective, adaptive governance is linked to managing ecosystems as a whole and focuses on gradual adaptation over time (Aoki, 2016), connecting directly to the *learning process*. From this perspective, adaptive governance is viewed as a continuous process in which governance systems enhance their adaptive capacity. Adaptive capacity is the ability to alter processes and adapt structures in response to current or anticipated changes, helping resolve multi-level governance challenges arising from socio-economic changes, such as natural events (Pahl-Wostl, 2015; Hurlbert, 2018).

Although not the focus of this study, the *system* perspective frames adaptive governance as a non-dynamic end-state supporting adaptation. Hurlbert & Gupta (2016) define it as “a range of political, social, economic, and administrative systems that develop, manage and distribute a resource in a manner that promotes resilience through collaborative, flexible, and learning-based issue management across different scales” (Hurlbert & Gupta, 2016, p. 341).

2.3 Operationalizing Short-term Event-based Adaptive Governance

This section synthesizes the theoretical concepts introduced earlier and translates them into a framework through which adaptive governance can be operationalized. Building on the three perspectives of adaptive governance, the section develops a conceptual framework, adapted from the Management and Transition Framework (MTF) (Pahl-Wostl et al., 2010), to analyse how actors, their roles, and their use of knowledge shape responses to flood and drought events.

In Section 2.1, it was explained how natural events such as floods and droughts can develop into human crises. Once a hazard manifests as an event, its interaction with exposure and vulnerability may lead to significant impacts on life and property, thereby constituting a disaster (Wilhite, 2000; Pahl-Wostl, 2015; IPCC, 2022). If an actor perceives the risk of the event as a significant threat requiring fast decision-making, the event may be regarded as a crisis (Wolbers et al., 2021). The risks associated with these events can be mitigated through disaster risk management (Raadgever & Hegger, 2018). In Section 2.2, the concept of adaptive governance is introduced to address such risks. In such, adaptive governance is applied as an approach for disaster risk management within the emergency phase. Accordingly, this study adopts a *response-oriented* perspective on adaptive governance, examining how actors within water governance systems respond during flood and drought events through interactions and actions in order to avoid the disaster or mitigate the potential impacts (Aoki, 2016; Janssen & Van der Voort, 2020). Janssen and Van der Voort (2020) identify three key challenges for this short-term event-based adaptive governance in disaster risk management: time (responding quickly without compromising decisions), centralization (allocating decision-making appropriately across levels), and stability (adapting while maintaining control).

To operationalize short-term event-based adaptive governance, a conceptual framework is developed based on the Management and Transition Framework (MTF). While the complete MTF will not be applied, it provides the basis for this research's conceptual framework. The MTF is an interdisciplinary conceptual and methodological framework that supports understanding of governance regimes and transition processes toward more adaptive management, integrating a set of elements to capture the complexity of water governance (Pahl-Wostl et al., 2010). Whereas the MTF generally addresses long-term adaptive governance from a *learning-process* perspective, this study focuses on *short-term event-based* adaptive governance. Therefore, the framework is adapted by selecting specific elements to translate the long-term transition perspective into an event-based, response-oriented approach.

In this research, adaptive governance refers to the response of actors, encompassing both their actions and the interactions between them (Jiménez et al., 2020; Munene et al., 2018). For this study, two core MTF elements are therefore particularly relevant: the *action arena* and the *action situation*. The *action arena* represents a specific political arena focused on a societal function within the water governance system. In this study, there are two action arenas considered: flood and drought response. Additionally, the action arenas comprise *action situations*, capturing interactions of individual *actors* who negotiate about a specific problem as well as aggregated interactions among collective actors (Pahl-Wostl et al., 2010).

Within the *action situation*, actors are assigned specific *roles* with responsibilities that shape both their actions and their interactions in the response (Pahl-Wostl et al., 2010). The *action situation* therefore reflects the dynamics of the emergency phase, where actors must respond under time pressure, make decisions across different levels of governance, and apply response mechanisms in practice. In this way, the *action situation* provides a lens to examine the key challenges of short-term event-based adaptive governance identified by Janssen and Van der Voort (2020).

Furthermore, according to Vinke-De Kruijf et al. (2013), the transfer of knowledge can play an important role in reducing disaster risks in the water governance context. Knowledge can be understood as information that individuals have processed and interpreted, thereby giving it meaning. In this sense, knowledge goes beyond information by transforming raw data into something meaningful and applicable (Vinke-De Kruijf et al., 2013). Knowledge is not static but can be transferred between actors through interactive processes of sharing and acquisition, enabling its practical application (Vinke-De Kruijf et al., 2013). Therefore, knowledge elements from the MTF are also included in this research. Within the *action situation*, actors draw on *situated knowledge* and apply this within knowledge transfers or decision making. *Situated knowledge* contributes to the broader body of *knowledge*, which exists independently of individual actors, and in turn influences both the actions and interactions of actors within the *action situation* (Pahl-Wostl et al., 2010).

The conceptual framework for this study therefore encompasses the green elements of the MTF shown in Figure 4, including the *action arena*, *action situation*, *actor*, *role*, *knowledge*, and *situated knowledge*. Definitions of these elements in the context of this research are provided in Table 1, while definitions of the complete set of MTF elements are given in Appendix A. Using this framework facilitates the analysis of actor roles and knowledge utilization in water governance system in response to flood and drought events.

Table 1 - Description of MTF elements used in conceptual framework

<i>MTF element</i>	<i>Definition (Pahl-Wostl et al., 2010; Pahl-Wostl et al., 2016)</i>	<i>Within study context</i>
Action arena	An issue specific political arena focused on a societal function.	Two action arenas are considered for the water governance system of the Dutch Vecht basin: 'flood response system' & 'drought response system'.
Action situation	A structured social interaction context that leads to specific outcomes. 'Action situation' is the regime element where 'actors' take certain 'roles' which entitles them to perform certain actions.	The action situations include the response of actors to flood/drought events in the Dutch Vecht basin, encompassing actions such as knowledge transfers, data transfers, and decision-making.
Actor	An individual or collective participant populating an 'action arena'.	The actors involved within the flood/drought response in the Dutch Vecht basin.
Role	'Roles' belong to the relation 'actor' – 'action situation' and not to the 'actor'. 'Roles' entitles 'actors' to perform certain actions.	The roles describe the assigned responsibilities of an actor involved within flood/drought response in the Dutch Vecht basin.
Knowledge	Meaningful information and experience. 'Knowledge' is used in an 'action situation'.	Knowledge encompasses information that has been given meaning which is used in the decision making within flood/drought response in the Dutch Vecht basin.
Situated knowledge	Personal information used by an 'actor' in an 'action situation'.	Situated knowledge is context-specific knowledge on flood/drought response which an actor holds and draws upon during a knowledge transfer/decision-making.

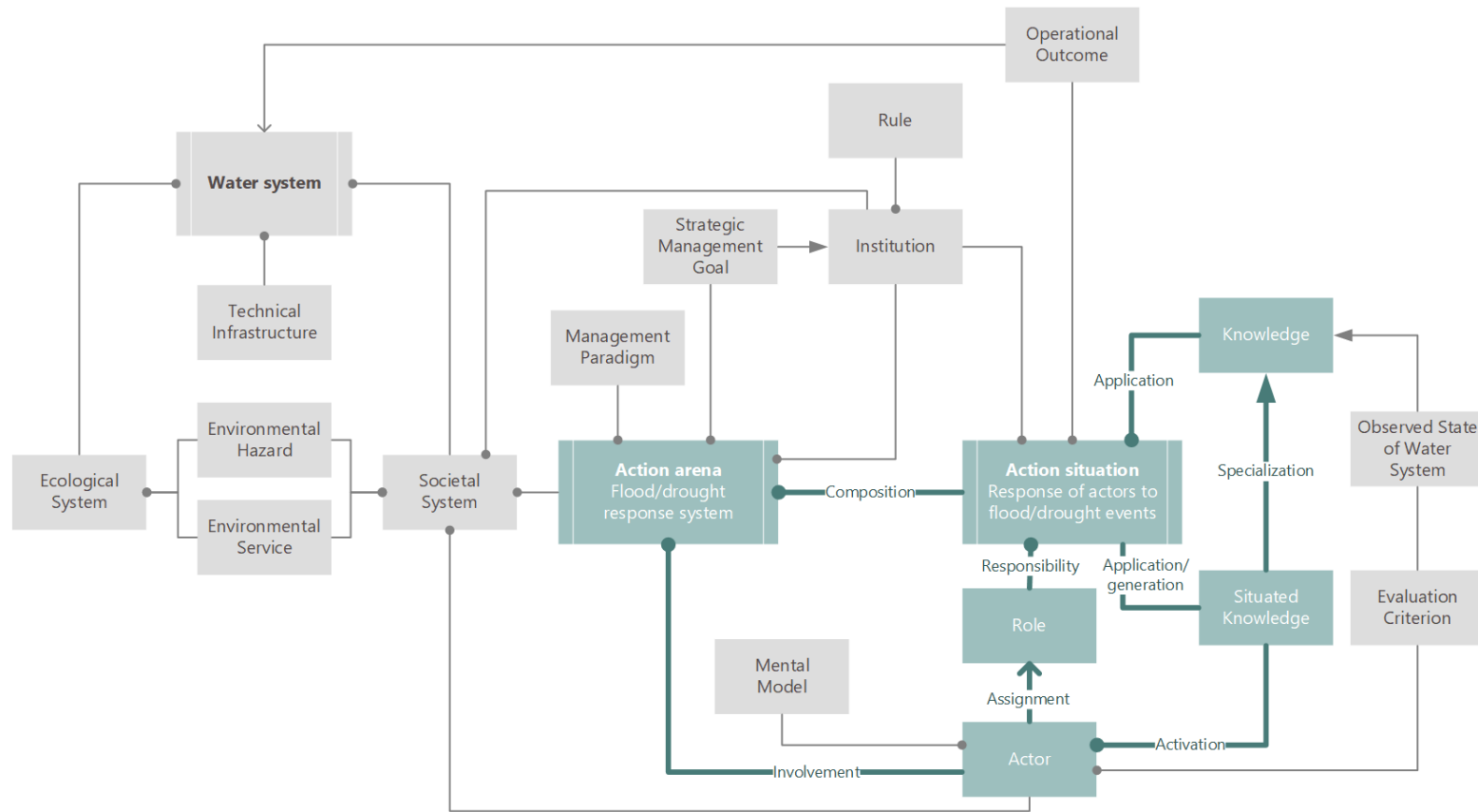


Figure 4 – Conceptual framework based on the Management and Transition Framework (MTF)

3. Methodology

To answer the research question, a research methodology has been developed. This chapter presents the research methodology. It begins with a discussion of the research approach, followed by a description of the case studies, data collection methods, data analysis procedures and validation method.

3.1 Research Approach

This study encompasses qualitative case study research. Qualitative research is particularly well-suited to exploring the textures of human experiences and perspectives, capturing contextual details that quantitative research often overlooks. It provides a unique lens for examining and interpreting the complexities of social phenomena (Lim, 2025). This approach aligns with the research aim: to understand how actors in the Vecht basin adapt their roles and utilize knowledge during flood and drought events. This includes considering different perspectives, social interactions, and the context of the selected case studies.

One case study was selected for a flood event and one for a drought. Although these are different types of disasters, the response system is managed by the same actors within the same water governance system and is based on a similar crisis framework. Therefore, it is possible to relate the two cases to one another in terms of how actors adapt their roles and utilize knowledge. Additional case studies for each disaster type were not selected due to time constraint and limited availability of recent case studies.

To collect data for the case studies, a combination of semi-structured in-depth interviews with actors and document analysis have been performed. This is followed by a thematic analysis, in which the data has been analysed using the conceptual framework presented in the previous chapter as a basis. Based on this data analysis, recommendations for possible improvements have been formulated. Finally, a validation step was conducted through a dialogue session with the actors to discuss the results and recommendations. The research approach is visualized in Figure 5 below.

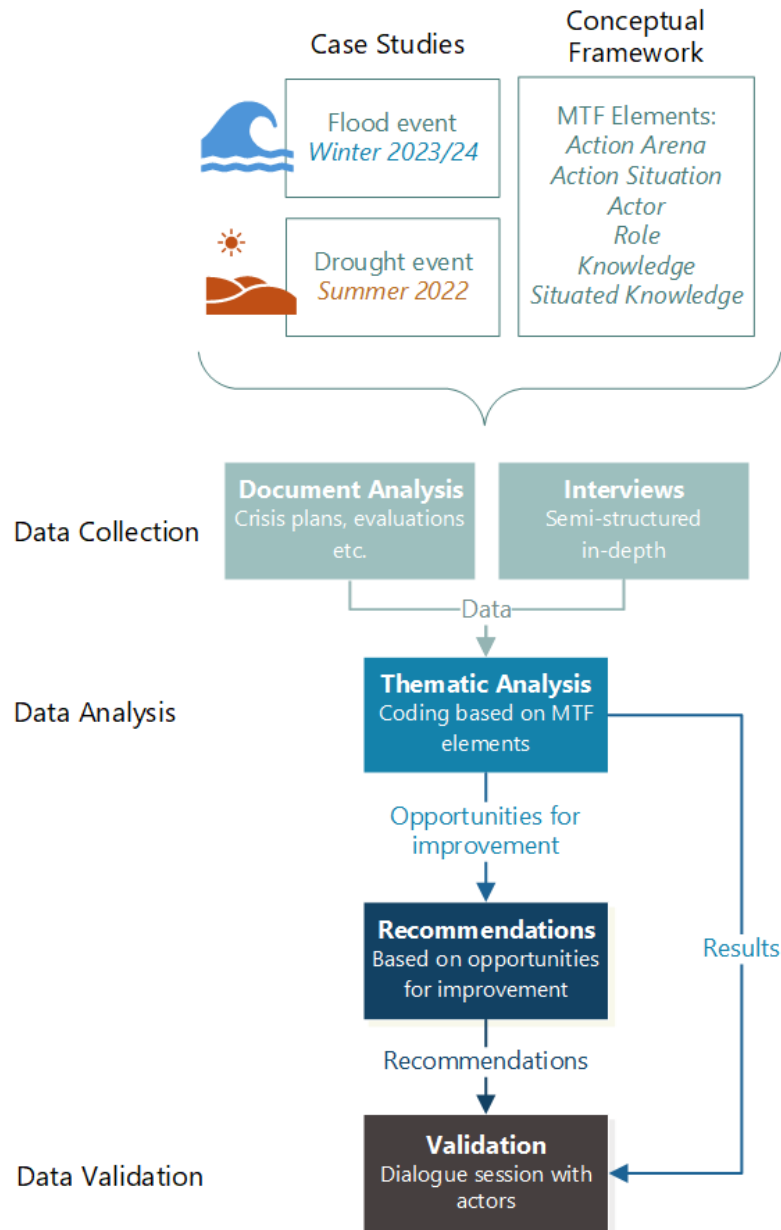


Figure 5 – Visualization of the research approach

3.2 Case Studies

The Dutch side of the Vecht basin has been selected as the study area. The transboundary Vecht basin encompasses several transboundary regional rivers, which flow from north-western Germany into the north-east of the Netherlands (Klein & Van der Vat, 2024). This study focusses specifically on the Dutch portion of the basin, however the interaction with actors from the German part are taken into consideration in this research. A map illustrating the Vecht basin and its main waterways is provided in Figure 6a, where the Dutch border is marked to outline the study area. The waterways relevant for this research include the Vecht, Regge, Dinkel and the Twentekanalen. Additionally, in Figure 6b, municipalities located along the main waterways are shown.

What makes the Vecht basin particularly interesting is that it is a transboundary basin, not only crossing national borders but also spanning multiple organizational boundaries, making it a complex setting of multi-actor governance. First of all, the Vecht basin is jointly governed by the Netherlands and Germany, and it is the largest of the three main cross-border basins, compared to the Berkel and the Oude IJssel, with an area of 4,393 km² (Klein & Van der Vat, 2024). Despite this division across national boundaries, floods and droughts affect both countries simultaneously, making cross-border coordination essential.

Additionally, within the Dutch part of the basin, water governance is shared between two water authorities: water authority Vechtstromen (WVS) and water authority Drents Overijsselse Delta (WDOD). During crises, these authorities can receive support from the safety regions, which are responsible for crisis response within their jurisdiction. Other relevant actors include municipalities located along the main waterways (see Figure 6b), the provinces, and Rijkswaterstaat (RWS). Consequently, many actors from different organizations operate within the same basin, leading to frequent interactions, making this an especially relevant and dynamic study area. From this point forward, any reference to the Vecht basin refers to the Dutch side.

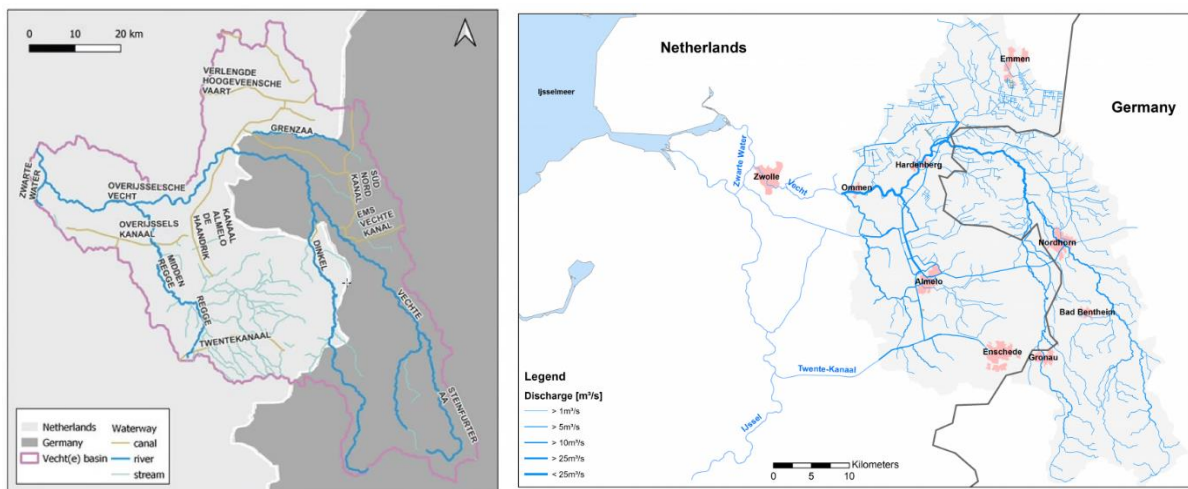


Figure 6a - The main rivers in the Vecht basin (Klein & Van der Vat, 2024, p. 31) & Figure 6b – Municipalities along the rivers in the Vecht basin (Hoebergen, 2021)

The selection of case studies is based on the following criteria: the chosen flood and drought events must have been considered crises for WVS, meaning that the crisis organization was activated and specific crisis roles were assigned. Furthermore, the events must be no older than five years to increase the likelihood that actors involved in crisis response are still employed within the relevant organizations and can still recall the events clearly. This also helps to minimize the impact of recollection bias, whereby interviewees may have difficulty accurately recalling details, which could unintentionally lead to the misrepresentation of information due to incomplete or insufficient memory (Von Soest, 2023). In addition, the selected cases must have well-documented evaluations. Based on these criteria, one flood event and one drought event in the Vecht basin have been selected as case studies: flood event of winter 2023 and drought event of summer 2022.

3.2.1 Flood Event – Winter 2023

Over the past century, the Vecht basin has experienced multiple flood events, particularly in the years 1960, 1998, 2010 and 2023. The most recent event, which occurred in *winter 2023*, was caused by a high-intensity rainfall event that led to widespread flooding in the eastern Netherlands (Klein & Van der Vat, 2024). The flood event of winter 2023 is selected as a case study not only because of its recent occurrence and significant impacts but also due to the unique context in which it occurred. The event took place during the Christmas holiday period, posing additional challenges related to the availability and capacity of the actors involved.

Between 18th of December 2023 and 3rd of January 2024, an accumulated precipitation between 100 and 200 mm was recorded in the Vecht basin (Klein & Van der Vat, 2024). As a result, rivers overflowed, causing flooding of roads, bicycle paths and meadows (Waterschap Vechtstromen, 2023). The river Vecht reached a record water level of 13.14 meters above NAP, exceeding the previous peak recorded in 1998 by 70 centimetres (Vechtstromen, 2023). The high water levels even resulted in the exceedance of measurement ranges, which in turn affected the accuracy and reliability of knowledge provision such as water level forecasts (Klein & Van der Vat, 2024).

3.2.2 Drought Event – Summer 2022

The region of the Vecht basin has experienced severe droughts in 1921, 1959-1960, 1976, 1996, 2003, 2018, 2019, 2020 and 2022 (Klein & Van der Vat, 2024). The most recent drought, in the summer of 2022, is selected as a case study not only to ensure that the event can still be accurately recalled but also because the repeated droughts in 2018, 2019, and 2020 may have provided actors with opportunities to learn from previous experiences. This repetition could have contributed to the establishment and improvement of response strategies, making the 2022 drought particularly relevant. Additionally, due to the consecutive years of drought, the impacts in 2022 may have been amplified (Vechtstromen, 2023).

The year 2022 was a significant dry year for the Netherlands. Precipitation levels were already limited early in spring, particularly in March. Additionally, the months of May, July and August experienced exceptionally dry conditions (Hendriks & Mens, 2024). The maximum national precipitation deficit was reached by late August with a peak of 318 millimetres, twice as much as normal (Ministry of IWM, 2023). The summer period was followed by a relatively wet season in autumn (Hendriks & Mens, 2024). The extensive drought led to a nationwide demand for water that exceeded the available supply (Ministry of IWM, 2023). The drought of summer 2022 affected the river systems of the Vecht basin, with meteorological drought resulting from a precipitation deficit, agricultural drought associated with dry soils, and hydrological drought linked to low water levels. This led to loss in biodiversity and irreversible damage to nature (Klein & Van der Vat, 2024; Natuurmonumenten, 2022).

3.3 Data Collection

To answer the research question, data are collected on the actor's roles and knowledge utilization during the flood event of 2023 and drought event of 2022. This research specifically focuses on actors operating within flood and drought response in the Vecht basin.

In the Netherlands, the management of floods and droughts is primarily the responsibility of water authorities and Rijkswaterstaat (RWS), forming the regular water management chain. When a crisis occurs, management shifts to crisis structures led by regional water authorities and safety regions (in Dutch: *veiligheidsregio*'s). Provinces and municipalities may also be involved during flood and/or drought events and required during response efforts (Klein & Van der Vat, 2024). For this study, relevant actors are drawn from these organizations, therefore employing a purposive sampling method. Table 2 shows which specific organizations are active in the Vecht basin. Municipalities were selected based on proximity to main waterways (see Figure 6b) and involvement in the 2023 flood. A small part of the basin falls under Gelderland province and the North- and East Gelderland safety region, but these are excluded due to limited involvement.

To identify the relevant actors and obtain contact information, 12 exploratory interviews were initially conducted with various actors from the water authority Vechtstromen. Insights from these discussions guided the selection of actors from the relevant organizations. Table 2 presents the interviewed organizations in bold.

Table 2 - Organizations with relevant actors in Vecht basin suitable for data collection (interviewed organizations in **bold**)

Organization	Active within Vecht basin
Water authorities	- Water authority Vechtstromen (WVS) - Water authority Drents Overijsselse Delta (WDOD)
Rijkswaterstaat (RWS)	- Rijkswaterstaat Eastern Netherlands (RWS-ON) - Rijkswaterstaat Northern Netherlands (RWS-NN)
Safety regions	- IJsselland - Twente - Drenthe
Provinces	- Overijssel - Drenthe
Municipalities	- Hardenberg - Zwolle - Ommen - Dalfsen

To gather the relevant data, a combination of document analysis and semi-structured in-depth interviews have been used. This combination of methods is recommended for research within the socio-ecological context (Biggs et al., 2021).

A *document analysis* was conducted alongside semi-structured, in-depth interviews. The purpose was to provide contextual understanding of the research, particularly regarding the *action arena*, such as crisis plans outlining the involved actors and their roles, and the *action situation*, including evaluation reports detailing timelines and descriptions of the selected flood and drought events. Additional documents included internal memos on the events, operational protocols, and Water Agreements (Dutch: *Waterakkoorden*). This helps to better interpret the findings from the interviews and to cross-check the interview data with the documented data.

In total 34 documents were analysed. This primarily includes documents from the water authority Vechtstromen, as this is also the organization where the research is conducted. Additional documents were obtained from other organizations, including other water authorities, municipalities, provinces, and safety regions. An overview of the documents used, along with their assigned reference codes, is provided in Appendix B. Additionally, the specific collection goals per MTF element for the document analysis are outlined in Appendix C.

Furthermore, interviews were conducted as a means of gathering information from actors who are part of the socio-ecological system of interest, allowing researchers to learn directly from their experiences through conversation. Interviews do not only serve as a method for data collection but also contribute to building a deeper understanding of the system. For this research, interviews are a well-suited approach to generate insights on social-relational dimensions, such as collaboration and coordination among actors (Biggs et al., 2021).

Collecting data by means of interviews require interpretation by the researcher. In this context, positionality is important: it refers to the researcher's perspective and how their social, cultural, and political position can influence the research process, outcomes, and findings (Holmes, 2020). Reflexivity, referring to the practice of reflecting on one's own role in the research, is therefore essential for identifying potential biases and understanding how the researcher may influence the study (Holmes, 2020). To support reflexive analysis and provide a structured perspective, the research was guided through the theoretical lens of adaptive governance, which helped frame the interpretation of findings. Additionally, language also plays a role in interpretation, as meanings are socially and individually constructed and can vary between people (Holmes, 2020). To reduce bias, interview quotes were translated and sent back to interviewees for validation.

The specific type of interviews that have been conducted are *semi-structured in-depth interviews*. This method generates qualitative data through extensive individual interviews with guiding questions as a basis. Semi-structured interviews offer greater flexibility than structured interviews, enabling respondents to elaborate on their experiences while still adhering to a predefined set of guiding questions (Biggs et al., 2021). In total, 18 semi-structured in-depth interviews were conducted, with at least one actor from each relevant organizational body presented in Table 2. This number is considered sufficient based on the principle of saturation, which occurs when additional data no longer yield new insights (Hennink & Kaiser, 2022). Saturation is generally reached between 9 and 17 interviews (Hennink & Kaiser, 2022), and in this study, key themes as presented in the results consistently recurred, suggesting that saturation was achieved at 18.

It should be noted that multiple organizations were covered, including actors from different governance levels. Most interviews were held with WVS representatives from various levels, as the research was carried out within their organization, enabling an organization-wide analysis. A total of 13 interviews were conducted at WVS across operational, tactical, and strategic levels, ensuring that saturation was definitively reached for that organization. For other organizations, only one or two representatives were consulted. While individual statements cannot be generalized to all similar actors, municipalities indicated that other involved municipalities had comparable experiences, and provinces provided overviews of how each province approaches flood response. Overall, the sample size is considered adequate to capture the main insights across the basin.

An overview of the distribution of interviews is provided in Table 3. A detailed description of the interviewed actors, including their role titles and the assigned reference codes, can be found in Appendix B.

Table 3 - Number of interviews per organization

<i>Organization</i>	<i>Number of interviews</i>	<i>Number of participants</i>
WVS	13	16
WDOD	1	1
RWS-ON	1	1
Safety region IJssel	1	1
Municipality of Hardenberg	1	2
Province of Overijssel	1	1

The interviews lasted between 60 and 90 minutes and were conducted with either one or, in some cases, two participants. Both the flood and drought events were discussed during each interview. The interview questions were designed to collect relevant data for each MTF element, as presented in Appendix C. The complete interview protocol is provided in Appendix D.

3.4 Data Analysis

To process the data collected with the interviews, a *thematic analysis* was conducted. Thematic analysis is a valuable explanatory tool in qualitative research, used to derive insights about participants' experiences and perspectives through the lens of a conceptual or theoretical framework (Lochmiller, 2021). In this study, the analysis is guided by the concept adaptive governance operationalized through elements of Management and Transition Framework (MTF). A description of the data collected for each MTF element is provided in Table 4.

Table 4 - Description of data collected for MTF elements from conceptual framework

MTF element	Qualitative description of...
Action arena	The organizational structure of flood and drought response within the Vecht basin
Action situation	The interactions between actors, including the actors involved, the type of situated knowledge/information shared, the timing and nature (formal/informal) of the interaction
Actor	Each actor, including their job title, their role and situated knowledge
Role	Each actor's responsibilities, both within daily management and during flood/drought events and the corresponding degree of flexibility
Knowledge	The knowledge used in the action situations, including the accessibility and distribution channels, actors who use it and how/why, the information it is based on, and the applied experience from actors
Situated knowledge	The situated knowledge of an actor, including the usage in decision-making and knowledge transfers, the information it is based on, and the actor's applied experience

The thematic analysis involves examining how patterns identified within the data correspond to specific MTF elements. Each MTF element is associated with a set of predefined codes, which connect the researcher's analysis to the collected data. These individual codes provide structure and clarity, enabling the analyst to evaluate different perspectives, experiences, and recollections (Lochmiller, 2021).

The set of codes used for the thematic analysis was defined in advance and derived directly from the MTF elements, which also formed the basis for the interview questions (see Appendix C). The resulting coding tree is presented in Appendix E. The coding of the interview data was conducted using ATLAS.ti.

The thematic analysis resulted in key themes for flood and drought, identified across multiple interviews, each addressing specific challenges in flood and drought response. Each theme is linked to specific MTF elements represented in the coding tree. In both the research question and the conceptual framework, a distinction is made between actors' roles and knowledge utilization. Both aspects have been further examined in relation to the *action arena* and the *action situation*. Their connections to the relevant MTF elements are visualized in Figure 7, with an explanation provided below.

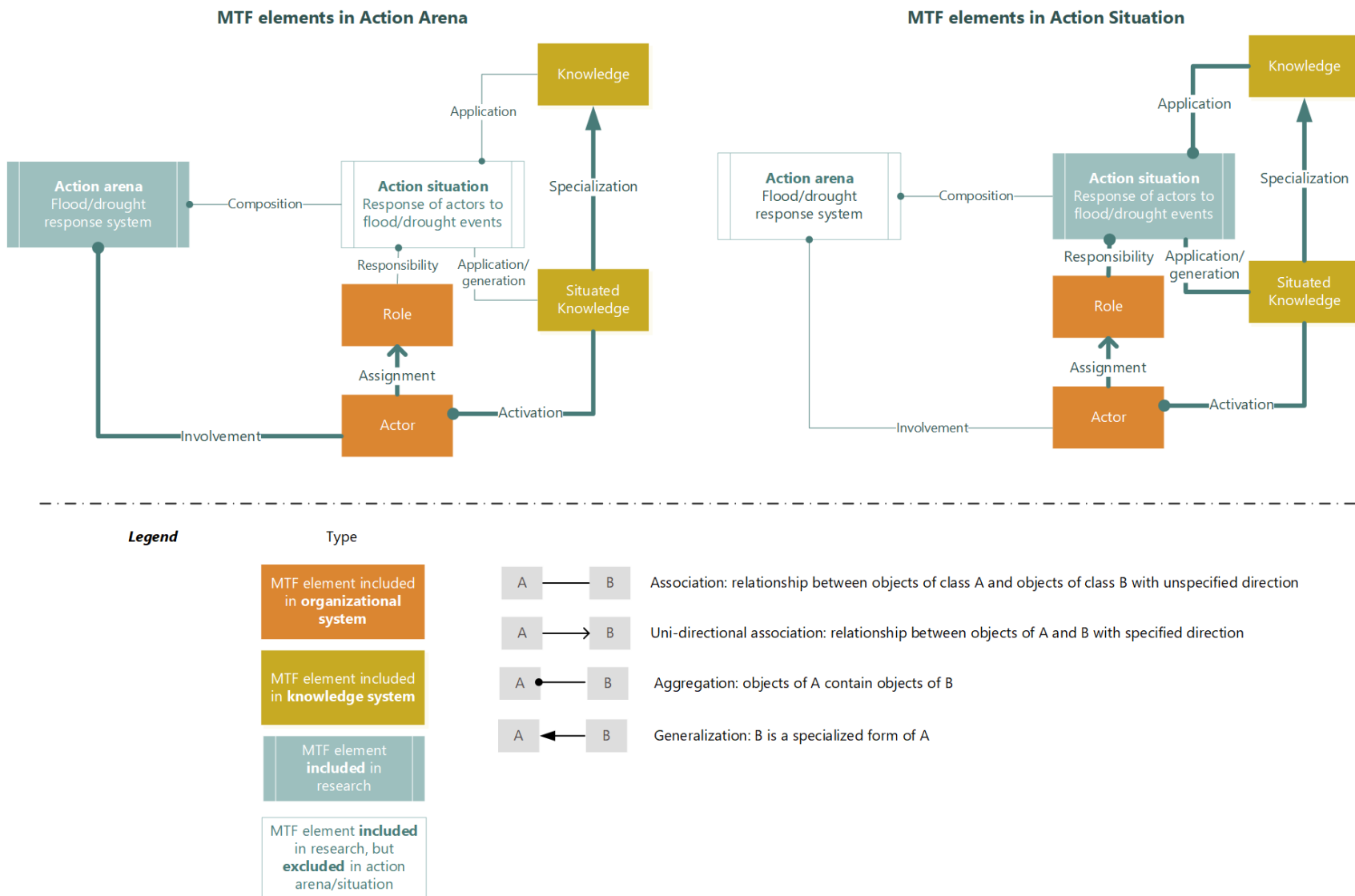


Figure 7 - Data analysis of MTF elements

First off, the *action arena*, in this case the flood/drought response system, is partly described through two MTF elements: the involved *actors* and their assigned *roles*, collectively referred to as the organizational system. Everything within the *action arena* is formally established and documented, for instance in crisis plans, Water Agreements (Dutch: *Waterakkoorden*), and operating procedures. The *actors* are predefined in these official documents, meaning that when a flood or drought occurs, they are entitled to participate and carry out their assigned *roles*. These roles include specific responsibilities, which are also formally recorded in such documents. An example is the actor with the daily management role of Water System Advisor at WVS, who, during flood events, is assigned the coordinating role of Highwater Coordinator, with the associated responsibilities formally documented in crisis plans.

In addition to the organizational system, knowledge tools and platforms are available to help actors perform their roles. This constitutes the knowledge system, which consists of both MTF element *knowledge* and *situated knowledge*. Actors can draw on their *situated knowledge*, which in theory refers to the expertise they should possess, for example, a Hydrology Advisor who is expected to have sufficient knowledge of hydrological processes to provide advice in their advisory role in crisis teams. *Situated knowledge* is connected to the broader body of *knowledge*, allowing for two-way knowledge transfers: it can both contribute to and draw from this broader knowledge base. The broader body of *knowledge* comprises tools and resources available to generate data for knowledge and aid in knowledge provision during flood and drought response, such as water level forecasting tools.

With this foundation established, the concept of the *action situation* comes into focus. The *action arena* is composed of multiple *action situations*. Within each *action situation*, the response system described in the *action arena* is activated, resulting in the actors' response to flood or drought events. In practice, this means that the scenarios described in formal documents such as crisis plans are enacted in real time. The case studies serve as the context in which these *action situations* take place. Within *action situations*, *actors* interact and perform their *roles*.

Together, the *actors* and *roles* constitute the organizational system in practice. While the *action arena* shows which role is formally assigned to each actor, the *action situation* allows for analysis of whether actors actually adopt these roles in practice. This includes examining whether actors perform their assigned responsibilities during the event, take on additional responsibilities, or exercise flexibility in adapting their role to the situation. It can also be analysed whether additional actors, who are not officially documented in the *action arena*, also become involved in the response and play a relevant role.

Additionally, the use of the knowledge system is examined in the *action situation*. This includes analysing which *situated knowledge* actors activate in practice, how and why they apply it (e.g., for decision-making or knowledge transfer), and whether new *situated knowledge* is generated or required *situated knowledge* is missing as situations unfold. For the broader body of *knowledge*, this involves identifying which knowledge tools are applied, how the knowledge is used, and what actions it informs. For example, water level forecasts may be applied to guide decisions, and the

analysis investigates what knowledge is retrieved, how it is applied, and which actions result. This helps identify which knowledge is considered critical during the response, and whether it is available in a timely, accurate, and accessible manner, but also whether required knowledge is missing.

Based on this analysis, themes are derived that focus on specific MTF elements and their interrelations as described above. These themes highlight opportunities for improvement, focusing on strengthening actor roles, optimizing knowledge utilization, and improving the translation from *action arena* to *action situation*. This also incorporates the three challenges of short-term event-based adaptive governance described by Janssen & Van der Voort (2020): the timing of decisions and actions, the suitability of the governance level at which actions are taken, and the balance between stability and flexibility in actors' assigned roles in practice. These opportunities for improvement form the basis for the recommendations to enhance adaptive governance.

In addition to the thematic analysis, a visual network analysis (VNA) was used as a tool to present the data. The VNA provides innovative tools for qualitatively analysing social situations by constructing, analysing, and interpreting visual networks based on interview data (Decuypere, 2019). It is used to interpret the *action situation* and map the interactions between actors. The VNA is constructed through conceptual mapping in the program Microsoft Visio.

3.5 Data Validation

Based on the data analysis, key themes describing challenges in flood/drought response were identified, which led to the formulation of recommendations for practitioners. These findings and recommendations were subsequently validated through a dialogue session at the water authority Vechtstromen (WVS). The session had two main objectives. Firstly, to confirm the key themes by presenting and discussing them with the participants to ensure they recognized and agreed with the findings. Secondly, to refine the recommendations and discuss their priority and feasibility from the participants' perspectives. The participants comprised a group of eight actors involved in the (exploratory) interviews:

1. WVS Highwater Coordinator / Water System Advisor [I-V7]
2. WVS Senior Vecht [I-V11]
3. WVS Regional Manager Regge [I-V12]
4. WVS Crisis Control Advisor [I-V4]
5. WVS Strategic Advisor #1 [exploratory interview]
6. WVS Strategic Advisor #2 [exploratory interview]
7. WVS Theme Leader Water Quality [exploratory interview]
8. WVS Water System Advisor [exploratory interview]

Further details on how the dialogue session was organized can be found in Appendix F. The session confirmed the key themes, which participants identified as the most prominent challenges in flood and drought response. The session also contributed to refining and recognizing the recommendations for practitioners.



Overall, participants agreed with all recommendations and regarded them as important. However, there was some discussion regarding their feasibility and prioritization, which differed across actors. These aspects are examined in detail in the results (Chapter 4) and the presentation of the recommendations (Chapter 6) and may impact on the implementation of the recommendations. The participants also provided additional input regarding recommendations for further research. While this study focuses on short-term event-based adaptive governance, participants emphasized the importance of long-term adaptive governance from a learning perspective. They noted that evaluation points from flood and drought events are often not addressed or resolved at WVS, which limits the long-term learning process from one event to the next.

4. Results

This chapter presents the results of the research. It begins with a reflection on the comparison between floods and droughts. Subsequently, the chapter examines floods and droughts separately, highlighting the key themes that reflect the main challenges in flood and drought response. The chapter concludes by outlining potential opportunities for improvement in terms of actors' roles and knowledge utilization

4.1 Comparison of Floods and Droughts

For this study, one flood and one drought event were used as case studies, revealing substantial differences in their nature and impacts. Prior the flood event of 2023, forecasts clearly indicated that high water levels were expected. Such measurements were acknowledged and routinely monitored by water authorities and Rijkswaterstaat regions. The increasing water levels were also visually observable, leading to a perceived potential crisis relatively quickly. From the perspective of water authority Vechtstromen (WVS), the official crisis lasted 14 days. The impacts of the flood were also directly felt, such as flooded basements or power outages. Near the end of these two weeks, the threat subsided, which could also be directly observed through lowering water levels, marking the end of the flood event [I-V2; I-V3; I-V4; I-V5; I-V6; I-V7; I-V8; I-V9; I-V11; I-V12; I-V13].

In contrast, the 2022 drought event did not have a clearly defined start or end. From the perspective of WVS, the drought period lasted around eight months, but it was not considered a crisis throughout this period. Drought develops gradually, unlike floods, which occur rapidly. This slow progression allows for a more proactive response, embedded within daily operations rather than requiring rapid decision-making through crisis structures. However, unlike floods, there are no precise variables or forecasts to determine the start of a drought, partly because the definition of drought is not uniform across actors. Additionally, drought is not directly visually perceivable, and its consequences are not felt immediately [I-V3; I-V4; I-V5; I-V6; I-V7; I-V8; I-V9; I-V13].

Therefore, while floods are generally considered acute crises, droughts are considered creeping crises and therefore represent long-term challenges. Although both events occurred in the same study area with a similar water governance system, the perception and handling of these events differ significantly, which in turn affects the response strategies. For this reason, floods and droughts are discussed separately in the following sections of the results.

4.2 Flood Events

For flood events, four key themes related to challenges in flood response and linked to MTF elements were identified through the thematic analysis. Each of these themes is elaborated on in this section. Each theme description follows the same structure: first, a description of the relevant aspects of the *action arena*, followed by an analysis of the *action situation* based on the 2023 flood case study, and finally, an interpretation of the implications of the findings. The four key themes are organized as follows: the first two mostly focus on the organizational system, while the last two relate to the knowledge system. These themes are:

- Differences in crisis escalation due to flood risk perceptions
- Weak embedding of relevant informal roles in the crisis organization
- Limited reliability and undefined responsibilities of FEWS
- Static knowledge tools restrict timely and relevant knowledge

4.2.1 Differences in Crisis Escalation due to Flood Risk Perceptions

The first theme examines the relationship between *action arena* and *action situation*, specifically focusing on when and how the *action arena* is translated into the *action situation*. In this context, the *action arena* refers to the crisis plans, and whether these plans are put into practice varies across the study area. This variation is influenced by an MTF element not originally included in the conceptual framework: *mental models*, which reflect actors' perceptions of flood risk.

Within the Vecht basin, several organizations are responsible for flood response. The most relevant organizations have developed crisis plans to respond to flood events, all of which share the same foundation: Coordinated Regional Incident Management Procedure (GRIP). However, during flood event 2023, differences in how organizations applied this escalation system, particularly in their reasoning for scaling up, led to gaps in basin-wide coordination. The root cause lies in differing perceptions of flood risk, which include the perceived *hazard*, *vulnerability*, and *exposure*. In particular, differences in how *exposure* was perceived over time and how *vulnerability* was assessed by each organization emerged as key factors in shaping the application of the escalation system.

To elaborate on this, the first section provides an introduction to the crisis escalation system in the Vecht basin for flood response. In order to highlight how the escalation system is applied in practice, the second section presents a timeline of the 2023 flood. Finally, the third section discusses the functioning of the escalation system in the Vecht basin and examines the role of flood risk perceptions in this context.

4.2.1.1 Action Arena - Crisis Escalation System in the Vecht basin

In order to understand how the crisis escalation system in the Vecht basin operates, this section first briefly explains the foundation of the system, which is the GRIP framework. Next, it describes the escalation system used by water authorities, which is adapted from GRIP. Finally, it discusses the rules for upscaling among the other relevant organizations within the Vecht basin.

The crisis escalation system in the Vecht basin is based on the Coordinated Regional Incident Management Procedure (GRIP), which provides a standardized framework for scaling and coordinating crisis response. Developed by the Ministry of Justice and Security, which is responsible for crisis control policy in the Netherlands, this system ensures an organized and consistent approach to managing crises. When an event occurs that is perceived to exceed the capacity of municipalities and/or water authorities to manage, the safety region activates the GRIP escalation system. This system is used to coordinate the crisis response within the area under the safety regions authority. GRIP organizes the crisis response into five phases, depending on the severity and scale of the crisis. These GRIP phases are described in Figure 8 [D-N1; D-N2].

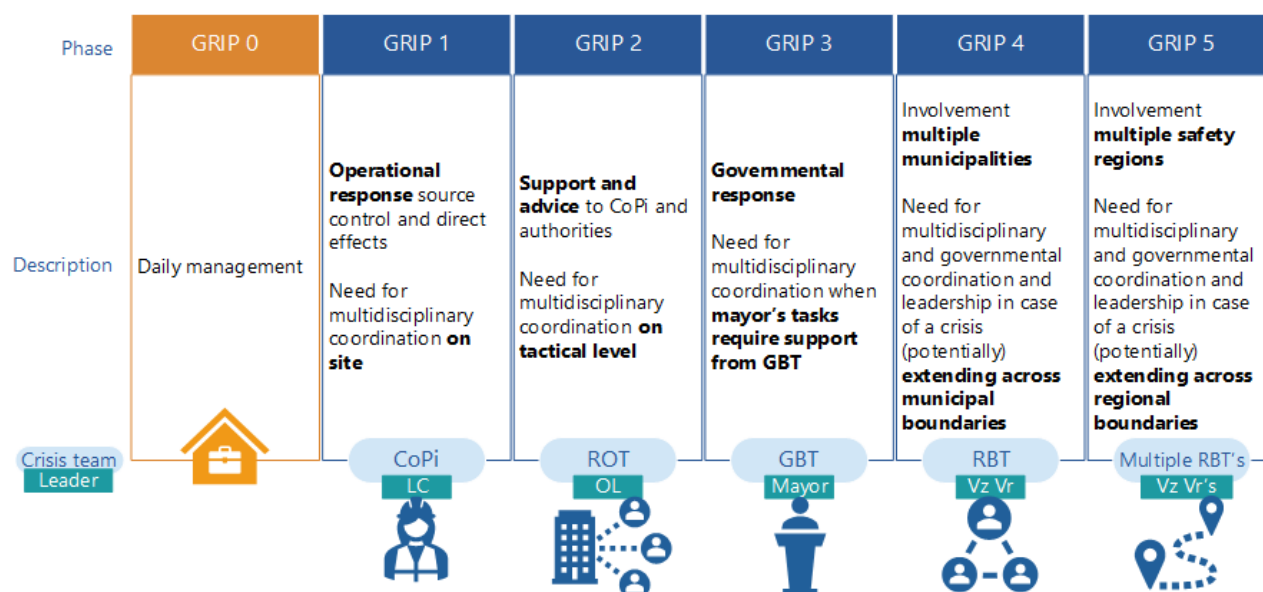


Figure 8 - GRIP phases & crisis teams [I-S1; D-V4; D-S1; D-N1; D-N2; D-N3]

The activation process of the GRIP phases is not necessarily sequential. The transition from regular organization to crisis organization, or from a lower to a higher GRIP level, is called upscaling. Conversely, returning to regular organization or a lower GRIP level is known as downscaling. Furthermore, as visualized in Figure 8, each GRIP phase corresponds to the activation of specific crisis team, which may operate simultaneously. The GRIP phases and corresponding teams are as follows [I-V4; I-V6; I-V7; I-S1; D-S1; D-V3; D-V4; D-N1; D-N2; D-N3]:

- **GRIP 0 – No crisis team:** Municipalities and/or water authorities manage incidents independently and safety region support is not required.
- **GRIP 1 – On-site Command Post (CoPi):** Crisis managed on-site with operational services, coordinated by the Leader CoPi (LC).
- **GRIP 2 – Regional Operational Team (ROT):** Activated when crises extend beyond the incident site. Led by the Operational Leader (OL) to coordinate across municipalities and water authorities.
- **GRIP 3 – Municipal Governance Team (GBT):** Mayor activates GBT for governance-level escalation.
- **GRIP 4 – Regional Governance Team (RBT):** Crisis affects multiple municipalities. Led by the Chair Safety Region (Vz Vr), while the OL continues ROT coordination.
- **GRIP 5 – Multiple RBT's:** In transboundary crises, multiple RBTs are involved, with one Vz Vr designated as coordinating chair.

Actors within crisis teams operate at three levels: operational, tactical, and strategic. The operational level focuses on direct field actions, such as managing or repairing infrastructure (e.g. CoPi). The tactical level coordinates these efforts, translating strategic objectives into practical execution and providing advice when needed (e.g. ROT). The strategic level involves policy-makers, such as mayors, who set overall priorities and make decisions requiring specific authority (e.g. GBT/RBT). A detailed explanation of each GRIP crisis team is given in Appendix G [I-S1; D-V4; D-S1].

In the context of flood response, the water authorities play the most prominent role in protecting the Vecht basin against flooding. When flood risk arises, the water authorities activate their crisis organization via the escalation system. Below is an outline of how water authority Vechtstromen (WVS) has structured its escalation system, based on the GRIP [D-V4; D-D1; D-N1; D-N5].

The crisis plan of WVS adapts the GRIP escalation system for application within the water authority context, as illustrated in Figure 9. GRIP levels are referred to as Phases, with no distinction between GRIP 4 and 5 due to the focus on water authority boundaries [I-D1; D-D1; D-V3; D-V4].

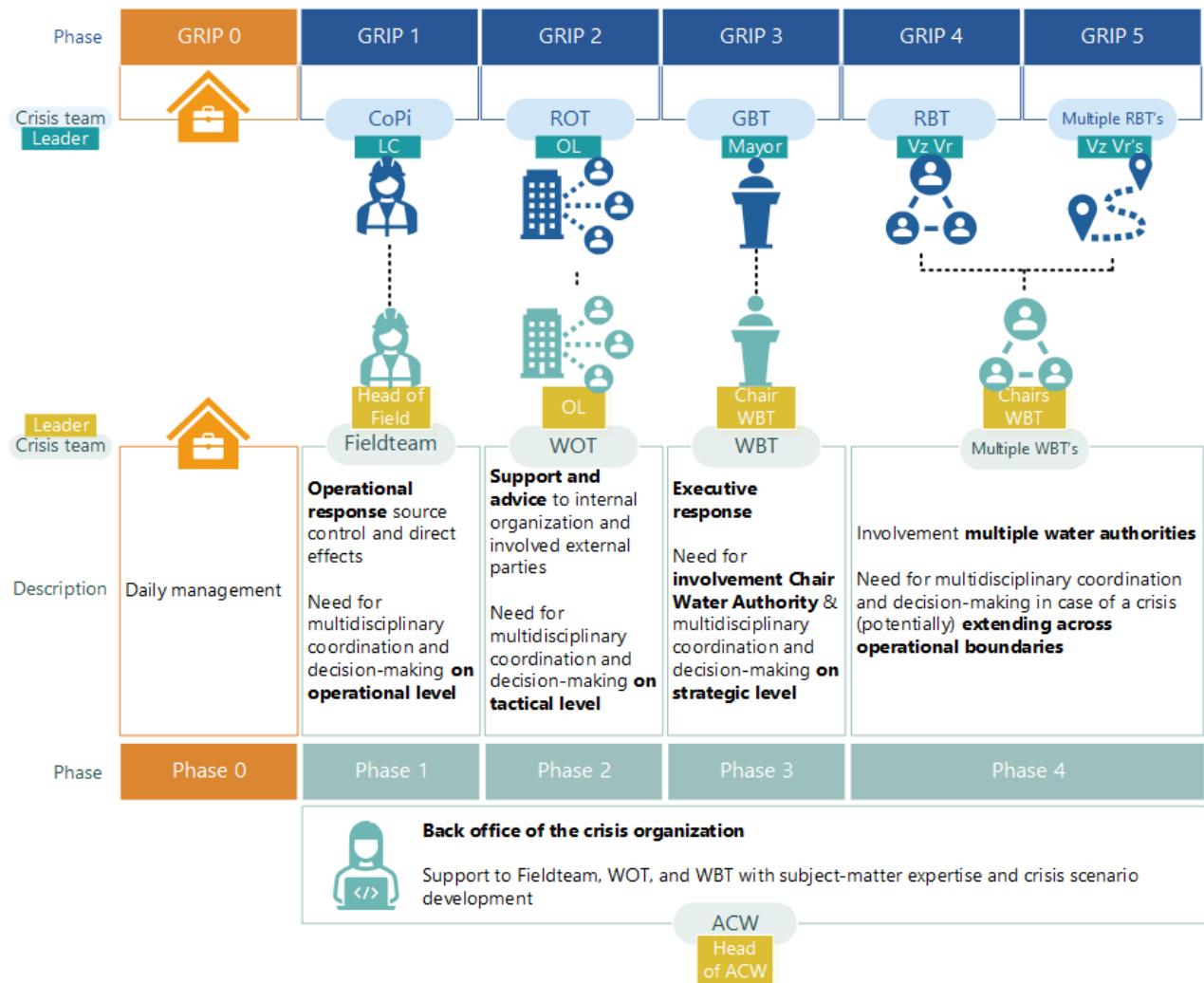


Figure 9 - Crisis organization of WVS translated from GRIP [D-V3; D-V4; D-S1; D-N1; D-N2; D-N3]

The Phases and corresponding teams at WVS are as follows:

- **Phase 0 – No crisis team:** Incidents managed within daily management, no crisis activation required.
- **Phase 1 – Fieldteam:** Local incidents handled on-site by Head of Field. Operational coordination only.
- **Phase 2 – Water Authority Operational Team (WOT):** Tactical team led by Operational Leader (OL). The WOT coordinates response and creates situational picture.
- **Phase 3 – Water Authority Governance Team (WBT):** Strategic team led by Chair WBT (in Dutch: *Watergraaf*). WBT sets overall crisis strategy.
- **Phase 4 – Multiple WBTs:** Activated when crisis extends beyond WVS jurisdiction. Multiple WBT's coordinate joint decisions.
- **Phases 1 to 4 – Action Center Water (ACW):** Back office supporting Fieldteam, WOT, and WBT with expertise and scenario development.

The same escalation system is applied at water authority Drents Overijsselse Delta (WDOD), with a similar foundation based on GRIP. Details on both the teams and Phases of WVS and WDOD are provided in Appendix H. For both WDOD and WVS, decision-making for upscaling in flood response typically rely on two key factors: the contextual circumstances and forecasted water levels [I-V2; I-V4; I-D1; D-V3; D-V4].

First off, context plays a major role in determining whether to scale up. Phase 1 is activated in response to a localized incident, Phase 2 when the flood risk affects more than one location, Phase 3 when public safety is at risk, and Phase 4 when a high-risk flood impacts the territory of multiple water authorities. Other contextual factors may also influence the decision, such as media pressure or requests from the communications department to activate the crisis organization. Additionally, upscaling gives crisis team leaders certain authorization. For example, the ability to authorize expenditures up until a certain budget without immediate accountability. This enables faster decision-making and can also be a reason to initiate a higher crisis phase [I-V2; I-V4; I-V5; I-V6; I-V13; I-D1; D-V3; D-V4; D-D1].

Secondly, critical water levels serve as important guidelines for considering the activation of the crisis organization. This assessment primarily relies on the Flood Forecasting & Early Warning System (FEWS), which assists in quantitating flood risk. Forecasted water levels from FEWS are compared with real-time field measurements collected through the monitoring network. As a result, the decision to scale up is based on a combination of expert judgment from the field and the interpretation of data [I-V2; I-V6; I-V10; I-V11; I-D1; D-D1].

In addition to the water authorities, several organizations are involved in the flood response system of the Vecht basin, as shown in Figure 10. The flood response system operates at three governance levels: local, regional, and national. At the local level, water authorities and municipalities handle on-the-ground response. The regional level connects national strategy with local action and involves safety regions, Rijkswaterstaat (RWS) regions, and provinces. At the national level, the Water Management Center Netherlands (WMCN) coordinates and provides guidance.

Since the study area borders Germany, the system also has a transboundary dimension: decisions by German water authorities directly affect downstream flood dynamics in the Netherlands. The detailed responsibilities of the organizations are given in Appendix I. In practice, most flood events in the Vecht basin are managed jointly by WVS, WDOD, the safety regions, and the involved municipalities.

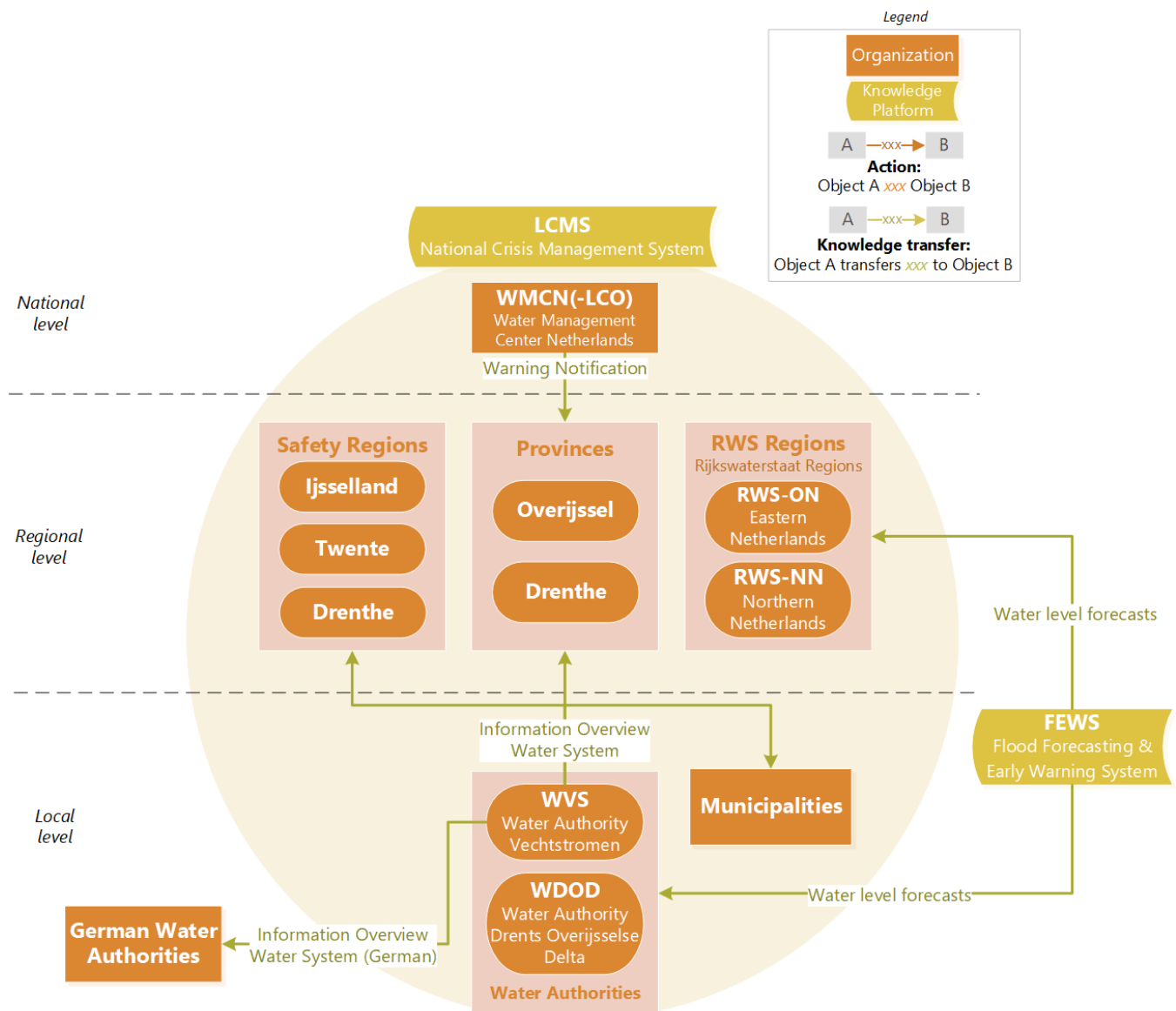


Figure 10 - Flood response system in the Vecht basin (authors interpretation based on document and thematic analysis)

For safety regions, whether a flood event is classified as a ‘crisis’, and thereby activating the GRIP escalation system, depends on the severity of the potential threat. A threat implies that there is actual disruption such that people may be in danger, or that significant economic damage is likely. A clear example of such a threat is a dike breach, where the safety of inhabitants in the flood area may be at risk. However, the occurrence of flood risk does not necessarily mean lives are at risk, and thus does not automatically require GRIP activation [I-V4; I-S1; D-N1; D-S1].

Furthermore, similar to water authorities, municipalities have crisis plans based on the GRIP escalation system. Municipalities in the Vecht basin follow contextual guidelines for scaling up flood response, with decisions always shaped by how other involved organizations perceive the flood risk.

In GRIP 1 and GRIP 2, municipalities coordinate the local response in collaboration with emergency services. Emergency services perceive flood risk according to their own expertise. For example, the fire brigade may provide sandbags if water levels rise, while the police intervene when security measures are needed in vulnerable areas. When a strategic response is required, escalation to GRIP 3 occurs, and the mayor assumes leadership, taking urgent measures such as ordering evacuation of retention areas. This is in collaboration with water authorities. If the flood risk affects multiple municipalities, GRIP 4 is activated, and coordination shifts to the Chair Safety Region (Vz Vr), thus depending on the flood risk perception of safety regions [I-H1; I-V4; I-V6; I-V7; I-S1; D-S1].

4.2.1.2 Action Situation - Crisis Escalation during Flood Event 2023

In order to understand how the escalation system in the Vecht basin is applied in practice, a timeline of flood event 2023 is given from the perspective of WVS (Figure 11). The green, yellow, and red colors indicate when each Phase was activated. The crisis teams are also shown as active during specific days, potentially linked to notable events.

The timeline illustrates when WVS identified the event as a crisis, primarily driven by contextual factors. Early warnings emerged in October during a presentation on the 1998 flood event at WVS. The precipitation patterns in 1998 were similar to those observed at the end of 2023, suggesting a potential repetition of such a flood event. The first concrete signals of flood risk appeared in the week before Christmas, with wet conditions and heavy rainfall expected. The crisis organization at WVS was then activated because the Christmas holiday was approaching, making it essential to call a crisis in time to manage preparedness and response. Early flood warnings were distributed internally and externally to prepare for potential challenges, as staffing capacity could be limited during the holiday period [I-V2; I-V4; I-V6; I-V12].

In contrast to the water authorities, the safety regions and affected municipalities did not activate their crisis organizations. However, two notable events occurred that nearly led to upscaling. The first event concerned the usage of the retention area Heemsermarskamp in Hardenberg. This area fills automatically with excess water once a critical water level is reached. These water levels are monitored by WVS. The retention area needs preparation, such as movement of objects and animals, for which a preparation period of 24-36 hours is required. This is the responsibility of the municipality of Hardenberg, receiving a warning from WVS when critical levels are almost reached. During the 2023 flood, the retention area was eventually prepared, but under severe time pressure due to communication issues (see Section 4.2.2) [I-V2; I-V10; I-H1; D-H1].



The second notable event concerned the North and South Meene (NZ Meene) retention areas. These are large retention areas that are only used in case of emergency and also fall under the jurisdiction of the municipality of Hardenberg. In this case, the WBT decided that these retention areas were not needed. If they had been, authority would have transferred to the Mayor to decide on the use of NZ Meene, forcing an immediate escalation by the municipality from GRIP 0 to GRIP 3. When these problems spread across multiple municipalities, which would be likely at that point, GRIP 4 can be triggered and automatically requires the safety region to be actively involved as well, who was initially also not scaled up [I-V5; I-V11; I-H1; D-V1].

TIMELINE OF WATER AUTHORITY VECHTSTROMEN (WVS) FLOOD EVENT CHRISTMAS 2023

Activation crisis organization	DATE	Fieldteam Active	WOT meeting	WBT meeting	Notable events (involving Fieldteam/WBT)
	OCTOBER				First warning flood risk during presentation highwater 1998
	18-12				First signals flood risk: Very wet conditions, additional rainfall expected
	19-12				
	20-12				Internal briefing session potential activation crisis organization
Upscaling Phase 2	21-12		1st WOT		Issuing flood risk warnings to safety regions and municipalities
	22-12		2nd WOT		Risk assessment meeting together with municipalities and WDOD at Safety Region IJsselland
	23-12		3rd/4th WOT		Regge river overflowing its banks, Fire brigade reports sandbag requests from Hardenberg residents
	24-12		5th/6th WOT		
	25-12	Fieldteam	7th/8th WOT		Power outage at Nijverdal wastewater treatment plant
Upscaling Phase 3	26-12		9th/10th WOT	1st WBT	Water inflow into retention area Heemsermarspark
	27-12		11th/12th WOT	2nd WBT	WBT decision: no preparation of retention area NZ Meene, 2nd meeting Safety Region IJsselland
	28-12		13th WOT		
	29-12		14th WOT		
Downscaling Phase 2	30-12		15th WOT		
	31-12				
	01-01				
	02-01		16th WOT		
	03-01	Fieldteam	17th WOT		Weir malfunction at Stroothuizerweg
	04-01		18th WOT		
Downscaling Phase 0	05-01		19th WOT		
	06-01				

Figure 11 - Timeline flood event 2023 from WVS perspective [I-V1; I-V4; I-H1; I-V9; I-S1; D-V1; D-H1]

4.2.1.3 Implications on the Functioning of Escalation System

Despite the fact that the relevant organizations in the Vecht basin all base their crisis organization on the GRIP system, reasoning for (not) scaling up varied during flood 2023 due to the differences in flood risk perceptions. Water authorities responded consistently, activating their crisis organizations based on a shared understanding of flood risk. Municipalities and safety regions, however, worked from different risk perspectives. Although all actors faced a similar *hazard*, reflected in comparable water level forecasts, their interpretation of *exposure* and *vulnerability* differed, resulting in divergent responses.

Safety region IJsselland did not consider the flood risk severe enough to pose a threat to people or cause significant economic damage. Consequently, no escalation was initiated and responsibility was placed by the municipalities. The safety regions' perception of risk was primarily shaped by *vulnerability*, reflecting the assessment that the municipalities were able to sufficiently cope with the *hazard* and therefore were not susceptible to significant harm:

"During the 2023 event, there was no GRIP escalation, as there was no immediate threat. A large number of municipalities took protective measures, where necessary in coordination with the safety region. [...] They [municipalities] also have a municipal crisis team that coordinated these actions internally." [I-S1]

In the municipality of Hardenberg, the crisis organization was not activated, based on the risk perception of the safety region, emergency services and water authorities: the *hazard* was acknowledged, but the municipality's *vulnerability* was not deemed significant enough to initiate additional crisis measures:

"There was insufficient reason [to escalate to GRIP 1, 2, or 3] so no escalation took place. [...] The fire brigade indicated that it would focus on emergency dispatch calls and saw no reason to scale up, and the police said, 'We do not have much to do here.' [...] From the water authority's perspective, the situation was not significant enough to require municipal involvement at the strategic level, so it kind of stalled." [I-H1]

Even though the estimated flood risk was initially not deemed a crisis requiring formal escalation, Hardenberg's perception changes as *exposure* became apparent. Early on, the municipality did not perceive any directly visible threat to people or critical areas. However, when sandbag requests arose and the potential use of the retention area Heemsermarspark became relevant, the municipality recognized that the manifested *hazard* could directly affect residents:

"But then [when fire brigade reports sandbag requests] I felt, okay, this is indeed a kind of crisis, in the sense that people are going to get their feet wet." [I-H1]

This illustrates how the perception of *exposure* evolved: initially, the *hazard* existed abstractly, but the risk became real once the water reached people and key infrastructure. The municipality's response shifted accordingly, highlighting the critical role of perceived *exposure* in shaping risk perception.

Additionally, the large differences in upscaling nearly triggered a sudden escalation from GRIP 0 to GRIP 3/4 for the NZ Meene retention area. This can be problematic because it leaves little time for decision-makers to build up the crisis organization and to respond effectively. Municipal decision-makers, especially mayors, are in this way formally involved only once the situation has already become critical. Mayors from different municipalities expressed a desire for earlier and better coordination with water authorities to allow more proactive flood response [I-V4; I-H1].

To conclude, the 2023 flood event revealed a fragmented escalation process in the Vecht basin. A lack of coordination in crisis upscaling can hinder collaboration between organizations, as they may not align in their priorities or in the interpretation of emerging risks. Additionally, organizations are not always scaled up simultaneously, leaving key communication channels unused. This issue is explored further in the next section.

4.2.2 Weak Embedding of Relevant Informal Roles in the Crisis Organization

The second theme examines *actor* involvement and *role* development during flood response. For *actors* formally incorporated in crisis plans within the *action arena*, the *roles* assigned on paper generally correspond well with how they are enacted in practice within the *action situation*. In contrast, this section mostly focuses on *actors* who are not formally part of the *action arena* but nevertheless hold a relevant *role* in the *action situation*, and how these informal *roles* remain weakly embedded within the formal structures. Furthermore, the section highlights the importance of the *situated knowledge* contributed by these *actors*.

Within the flood response system, two types of roles can be distinguished: formal and informal. Formal roles are assigned to actors who are part of a crisis team within a scaled-up organization. Informal roles, by contrast, refer to actors who are not included in an activated crisis team but still contribute to flood response through daily management tasks. In the Vecht basin, formal roles are executed effectively in practice. However, informal roles also play a very important part in flood response. Field workers provide crucial situated knowledge but are not formally embedded in the crisis organization. Furthermore, when the crisis organization is not activated, pre-defined formal roles remain inactive, increasing reliance on informal connections.

In this section, the formal roles within the crisis teams of the water authorities and safety regions are first briefly outlined. This is followed by a network analysis of the 2023 flood event, examining how formal roles were enacted in practice and identifying which informal roles also played a relevant part in the flood response. The section concludes with a discussion of the overall functioning of the response system based on the assigned roles.

4.2.2.1 Action Arena - Description Formal Roles

To analyse the functioning of assigned roles, this section begins by examining the formal roles of actors as defined in crisis plans. First, the formal role division of the water authorities is considered, as they hold primary responsibilities for flood response and have key actors assigned to these roles. Next, the safety region is discussed, as it can also play an important coordinating role in flood response through interaction with the other organizations.



Figure 5 shows the basic composition of the crisis teams of water authority Vechtstromen (WVS), with the description of the responsibility and authority of each role. Additional actors working at WVS may be added as needed, for example, to provide specialized advice. The roles of Highwater Coordinator (HWC) and Water Level Coordinator (PBC) apply only in situations of flood risk, and not in cases of drought or other crises [I-V7; D-V3; D-V4]. For water authority Drents Overijsselse Delta (WDOD), the basic composition of crisis teams is largely similar, although certain roles can differ in terms of exact responsibilities and authorities [I-D1; D-D1]

The crisis roles are filled in by employees of which most have on-call duty (in Dutch: *piketdienst*) from WVS. These individuals have to give priority to their crisis responsibilities over their regular responsibilities once the crisis organization is activated. In practice, individuals within the crisis organization often hold dual crisis roles, meaning one person may perform two crisis roles simultaneously and be part of multiple crisis teams. A common example is the combination of Head of ACW and Operational Leader (OL), and Water Systems Advisor and HWC. In contrast, for crisis roles appearing across multiple teams, such as ICO and Communication Advisors, the same person is not necessarily assigned to be within all teams due to time and capacity constraints. Furthermore, roles such as OL may rotate depending on who has on-call duty, meaning the specific individuals involved may vary [I-V1; I-V2; I-V4; I-V6; I-V7; I-V13; D-V3; D-V4].

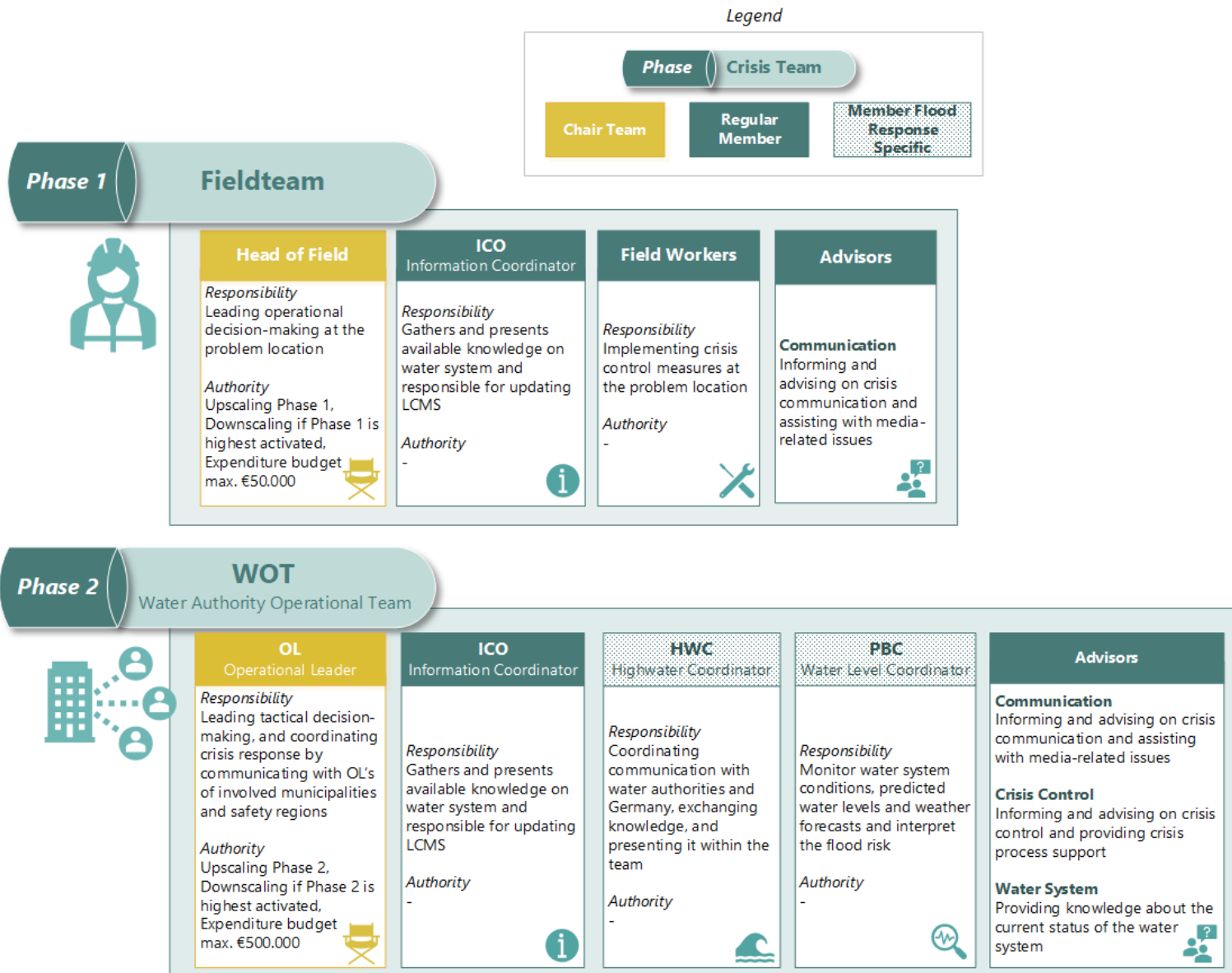


Figure 12 - WVS actor's formal roles in crisis teams (authors interpretation based on document and thematic analysis)

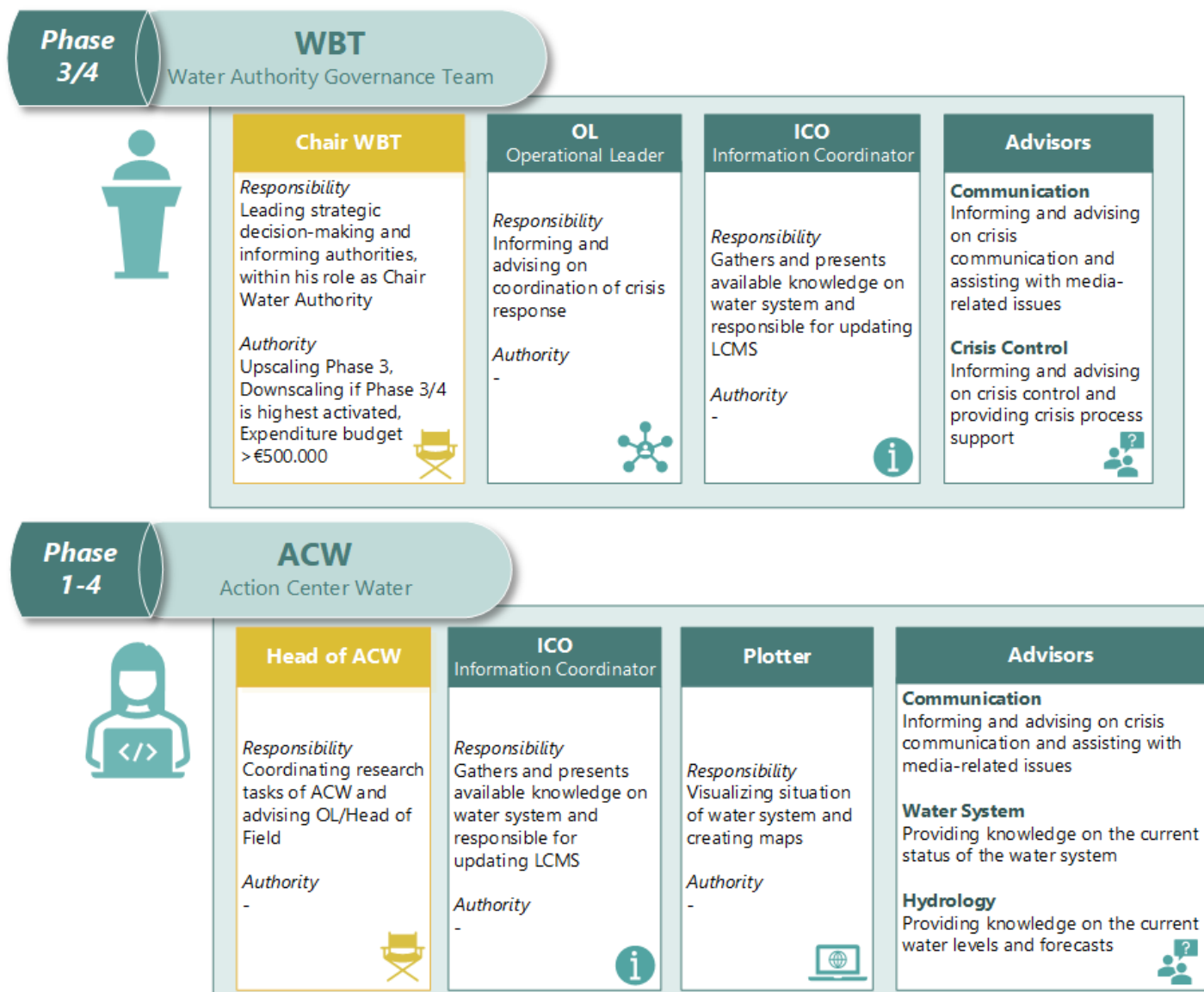


Figure 12 (continued)

Furthermore, all safety regions base their crisis teams on GRIP, but the exact composition may differ. For flood response specifically, the crisis team which is typically most involved is ROT (see Figure 13). Appendix J shows the complete basic composition of the crisis organization safety region IJsselland. In the early stages of flood risk, typically the ROT may meet informally during a ‘potential’ GRIP phase. An on-call duty Operational Leader (OL) is always available and can be activated if necessary. Although the OL does not yet hold formal responsibility during this ‘potential’ GRIP 2 phase, it allows for early communication with water authorities and municipalities within the region. This communication occurs through established formal channels, such as between the OL and the mayors [I-S1; D-V4; D-S1; D-N1; D-N2; D-N3].

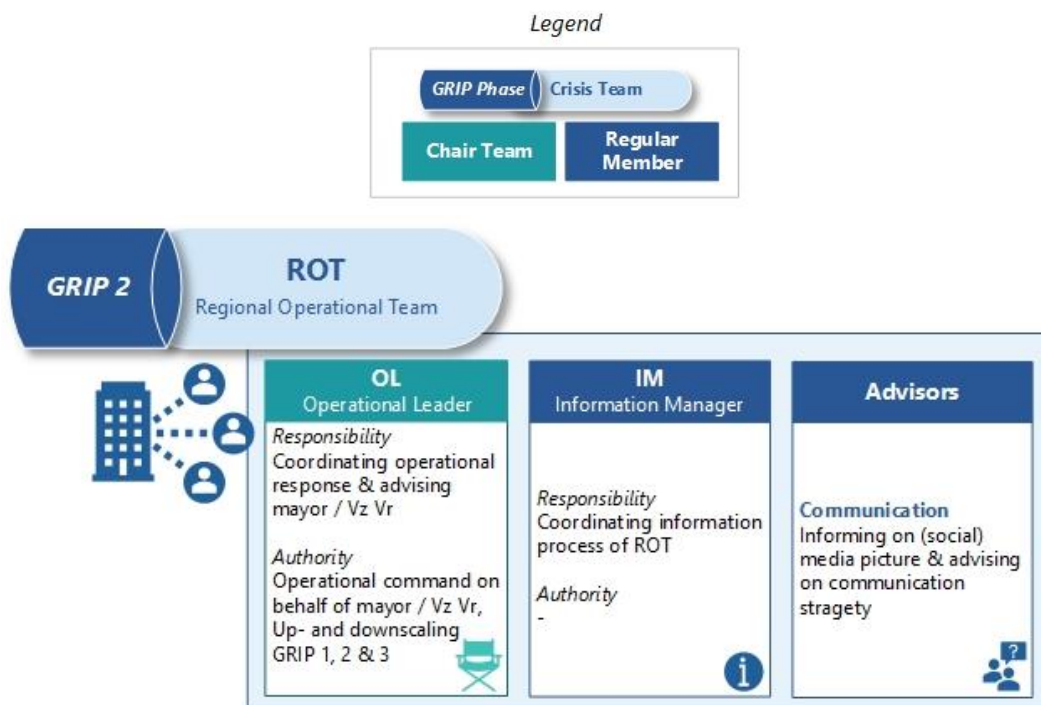


Figure 13 - Safety Region IJsselland ROT actors formal roles [I-S1; D-V4; D-S1]

4.2.2.2 Action Situation - Network Analysis of Flood Event 2023

To gain insights into how actors carried out their formal roles in practice, their interactions, and any responsibilities assumed through informal roles, a network analysis was conducted. The relevant interactions between the actors in the Vecht basin during flood event 2023 have been mapped out in Figure 14. Actors with formal roles are shown in green, while informal roles are shown in orange. Formal interactions (green) follow official crisis organization channels, whereas informal interactions (orange) depend on pre-existing relationships. A distinction was made between different types of interactions between actors, such as collaborative and informative exchanges. In addition, the figure illustrates the flows of knowledge transfer between organizations. The network analysis is categorized into the three levels actors enact on: operational, tactical, and strategic.

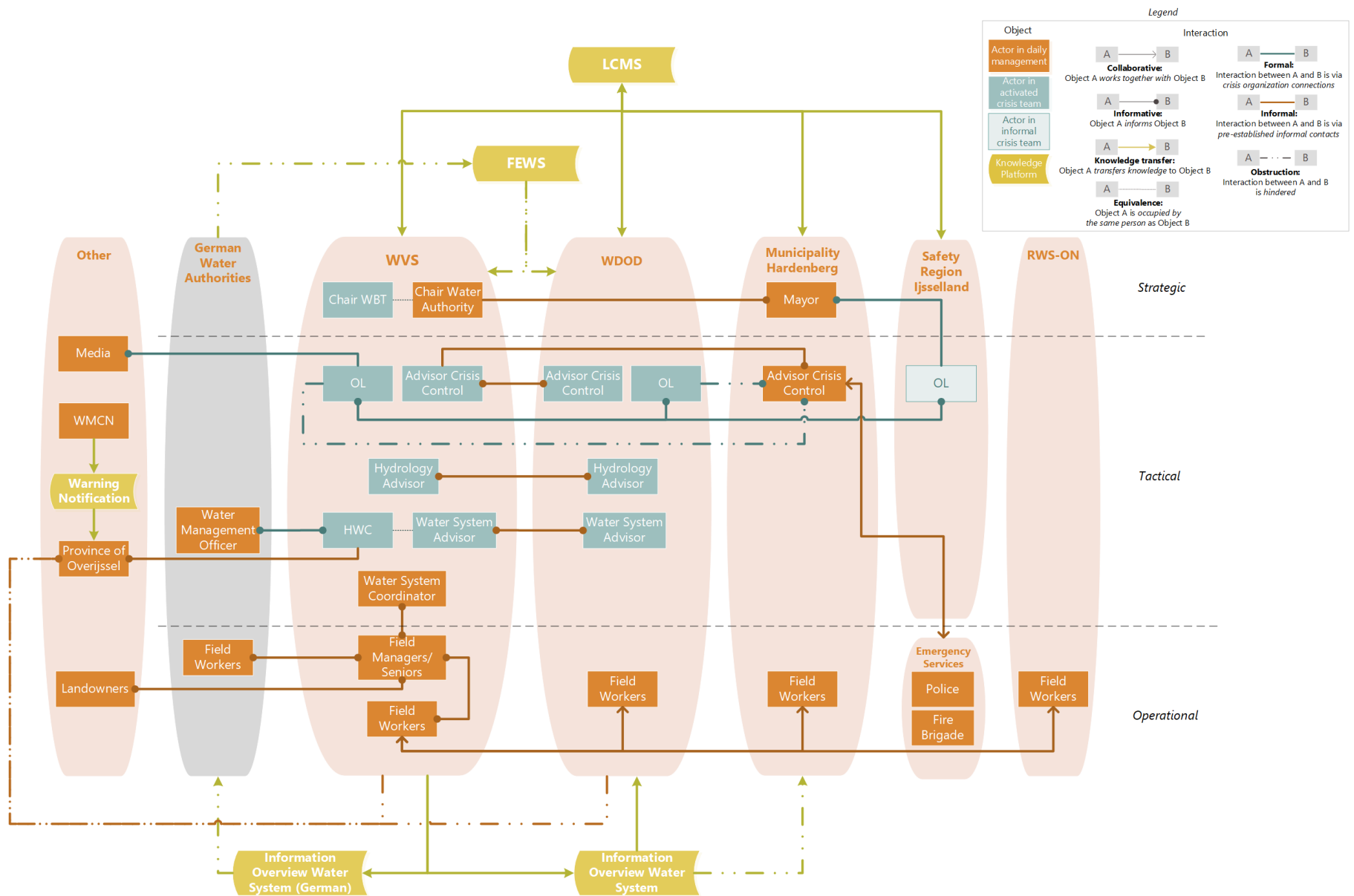


Figure 14 - Network Analysis of Flood Event 2023 in Vecht basin (authors interpretation based on document and thematic analysis)

Formal Roles combined with Formal Networks

With regards to the responsibilities assigned to formal crisis roles, most WVS decision-making occurred at the tactical level via WOT, with crisis team members also handling external communication. Both WVS and WDOD scaled up, activating their crisis teams, while safety region IJsselland did not formally scale up. Instead, an informal ROT was activated, with the Operational Leader (OL) participating only to share information at the start of the flood event with other organizations, without assuming the advisory role to the mayor or the coordination role that a formal activation would entail. Crisis lines between formal OL's were used for informative purposes. Additionally, The OL WVS represented the organization to the media [I-V4; I-V6; I-V7; I-D1; I-S1].

Communication between Hardenberg and safety region IJsselland was limited, since both organizations were not (formally) scaled up. As Hardenberg's OL was not activated, communication primarily went through the Crisis Control Advisor, who received early flood warnings from the WVS Crisis Control Advisor. Thus, coordination with WVS and WDOD had to occur outside formal OL network, leading to delays in contacting the right people and obtaining operational information. These informal routes complicated timely responses to emerging issues, such as retention area management [I-V4; I-H1; D-H1].

Formal Roles combined with Informal Networks

Certain actors holding formal roles utilized their informal networks to facilitate coordination with external actors. Between WVS and WDOD, pre-established contacts enabled rapid communication, such as among Hydrology Advisors, who quickly shared updates on the water system. The Highwater Coordinator (HWC), having in this case a double role as Water System Advisor, maintained contact with familiar WDOD colleagues and had daily contact with German water authorities to coordinate flood response. Separately, the HWC provided initial flood warnings to familiar colleagues at the Province of Overijssel, but no further planned communication was in place. When the province experienced issues such as basement flooding and sought to contact WVS and WDOD, existing agreements and contact information were outdated, making it difficult to reach the right people [I-V2; I-V7; I-D1; I-R1; I-O1].

In comparison to the tactical level, formal strategic-level interactions in the Vecht basin were limited. For WVS flood response, the strategic level only became formally involved when the WBT was activated in Phase 3, engaging the Chair WBT. Nevertheless, some informal strategic interactions occurred: the Chair Water Authority, in his daily management role, kept the mayor informed about the Heemsermarskamp retention area. The mayor of Hardenberg was not officially involved, as the municipality remained at GRIP 0, and no formal channels connected them to the flood response with exception of flood risk warnings sent by the informal OL of the Safety Region [I-V5; I-H1; I-S1].

Responsibilities and Contributions of Informal Roles

Aside from two brief activations of the Fieldteam, no actors with formal crisis roles were active at the operational level. Instead, most flood response operations were carried out by actors assuming informal roles within daily management. Field managers oversee water operations in their area, act as contact points for landowners, and coordinate fieldwork such as weir control and mowing, carried out by field workers. Each area is divided into zones led by seniors, who supervise tasks and report to the field manager. The critical importance of these informal operational roles meant that field managers were available for duty 24/7 during the flood event, taking responsibility for the continuous flood response of their areas [I-V8; I-V11; I-V12; I-R1; I-H1].

The link between the field at operational level and the tactical level runs through the Water System Coordinator, the main contact for field managers informally appointed for this task during flood event 2023. Externally, field workers from WVS, WDOD, RWS-ON, and the Municipality of Hardenberg cooperate through their informal roles. Field managers also maintain established ties with field workers from the German authorities, sharing updates on flood developments of the transboundary Dinkel. In addition to field workers, emergency services were actively involved on the operational level in collaboration with the municipality, with the police responsible for security at Heemsermarskamp and the fire brigade handling sandbag distribution [I-V8; I-V11; I-V12; I-R1; I-H1].

4.2.2.3 Implications on the Functioning of Assigned Roles

There is no significant difference between the formal roles outlined in crisis plans and their implementation in practice. Within WVS, actors clearly understand and are motivated to fulfill their assigned roles, even when contextual factors, such as the Christmas period, could pose a challenge. This demonstrates a high degree of flexibility when responding to a flood event:

“What I find a very strong point in a scaled-up situation is that a real spirit develops of rolling up your sleeves and working together: Let’s go for it together. I think that is fantastic. [...] People are really at their strongest in that context, and it is wonderful to see. So I am very pleased with that. It underlines that we are not doing a bad job at all; there is a strong level of professionalism.” [I-V7]

While interactions between actors in formal roles generally function well, particularly at the tactical level, informal roles also play an important part in the Vecht basin, especially field workers, field managers and seniors. Their situated knowledge and direct implementation of flood risk measures at the operational level are highly valuable:

“In the field, it is always different. From a model, you can see that the water level is high and that it is rising significantly in a certain area. But you still need to go on-site to check things in person. [...] There are so many details, but all of that is knowledge that, I would say, regular people do not possess.” [I-V11]

Because these informal roles in the field are not officially recognized or included in crisis organizations, there is a risk that their valuable knowledge and experience could be lost:

“When you look at flood events, as we said earlier, the field workers coordinate very well among themselves. But what happens if one of them is hit by a tram and is unavailable? How would that work then?” [I-R1]

Furthermore, when a crisis organization is not activated and therefore formal crisis roles are not assigned, there is a stronger reliance on informal, pre-existing connections between people. While these connections can help with quick coordination, they are not always reliable. In Hardenberg, the crisis organization was not activated, leaving crisis connections between Operational Leaders (OL's) unused. Communication instead flowed through daily management roles, which reduced the perceived urgency and relied on informal contacts that were not always established beforehand. Therefore, municipalities risked missing critical links with water authorities, leaving municipal decision-makers feeling uninformed:

“I can also imagine that they [WVS] may not have given it [problems at Hardenberg] their full priority because they were dealing with a much larger area than Hardenberg and probably had even more urgent problems elsewhere. On the other hand, we were not scaled up, and if we had been, we would have had an operational leader. Those lines of communication run more naturally in that case than when a Duty Officer for Population Care or someone from the municipality calls.” [I-H1]

In the current crisis organization, the informal roles that actors take on are highly relevant but weakly embedded, which can make the overall flood response in the Vecht basin less robust.

4.2.3 Limited Reliability and Undefined Responsibilities of FEWS

This key theme focuses on knowledge utilization, specifically on data-generation tools that contribute to the broader body of *knowledge*. While these tools are assigned for use in the *action arena*, their performance during the *action situation* does not fully meet expectations. This gap is linked to the absence of clearly assigned responsibility for their operation within the *role* definitions of the *action arena*.

The data-generation tool in question is FEWS, a crucial flood forecasting system in the Vecht basin, relying on data from Dutch and German water level monitoring networks measuring the current water levels. However, the monitoring network is not always fully reliable, and responsibilities for maintaining and ensuring the functioning of these measuring points are unclear, which can limit timely and accurate flood forecasts.

To address this, first a brief overview of FEWS is provided, followed by its application during the 2023 flood event. Finally, the implications of FEWS functioning on forecasting during flood events are discussed.

4.2.3.1 Action Arena - Description Flood Forecasting & Early Warning System (FEWS)

Flood Forecasting & Early Warning System (FEWS) is a forecasting and decision-support system developed by Deltares, used by WVS, WDOD and RWS regions in the Vecht basin (visualized in Figure 14). FEWS integrates data from multiple sources, including rainfall measurements, river discharge data, and current water levels from both Dutch and German water level monitoring networks. Although Dutch authorities cannot directly verify the German monitoring data, this information is publicly available online and incorporated into FEWS calculations. FEWS uses various international weather and climate models to forecast rainfall and river behavior, producing water level forecasts for rivers like the Vecht, Dinkel, and Regge [I-V1; I-V2; I-V7; I-V10; I-D1].

4.2.3.2 Action Situation - Role FEWS during Flood Event 2023

During the 2023 flood event, FEWS was actively used by WVS and WDOD to anticipate high water levels for their own decision-making as well as external warnings, and to activate the crisis organization in a timely manner. However, this knowledge tool was briefly disrupted as visualized in Figure 14, when a German monitoring point, needed to calculate Regge discharge, was damaged by high water. As this measuring point fell outside the jurisdiction of both WDOD and WVS, it was not directly clear who was responsible for the maintenance of this measuring point. The HWC could therefore not directly identify the correct German contact person, delaying the fixture and impacting the accuracy of forecasts until the German counterpart resolved the issue [I-V1; I-V2; I-V7].

4.2.3.3 Implications on the Functioning of the Forecasting

FEWS is a key source of data for knowledge generation in the Vecht basin, helping to manage floods proactively. Its effectiveness, however, relies on the reliability of the water level monitoring network:

“We can still make progress in generating the right data in the moment itself. Our models and decision-support systems receive data from measuring points outside, and sometimes some of these points are out of order. It then takes a while before they are repaired, and we are somewhat blind in the meantime.” [I-V6]

Challenges include not only equipment failures but also the lack of an actor with an assigned responsibility for monitoring and maintaining the measuring points during flood events:

“At the moment, we don’t really have anyone responsible for the management of measuring points and for monitoring whether those points are still functioning properly and measuring what they are supposed to measure. From my own perspective as PBC, I keep track of the measuring points that are important to me. [...] But this responsibility is not clearly assigned to any group.” [I-V2]

The situation gets even more complicated because some measurement points are located in Germany, which added extra time at the transboundary level to resolve issues. Consequently, responsibility must be assigned not only on the WVS side but also by the German authorities to ensure effective collaboration:

“If you have a phone list, so you know who picks up the phone [from the German water authorities], even at Christmas, just in case. Of course, measurement points can fail if it gets extreme, and then you want a line where someone actually answers. I think that is enough. You can, for my part, meet once a year for coffee, so you also maintain the relationship. That will take you a long way, I think.”

[I-V7]

Without formally integrating FEWS into the crisis organization by assigning clear responsibilities, repairing or addressing failures can take a long time, as no one is officially accountable for fixing issues or ensuring alternative data sources are available.

4.2.4 Static Knowledge Tools Restrict Timely and Relevant Knowledge

The final key theme identified for flood response relates to knowledge utilization. Individual *actors* possess *situated knowledge*, but during flood response this knowledge is often incomplete for specific actors. To compensate, these *actors* attempt to draw on the broader body of *knowledge* to fill these gaps. However, the broader body of *knowledge* itself does not contain all the knowledge required, leaving critical actor-specific knowledge missing during the *action situation*. Moreover, what actors choose to transfer from their *situated knowledge* to the broader body of *knowledge* is guided by their perception of what is important, rather than by what other actors need to know. This process is also influenced by the actors' *mental models*, thus their interpretation of the situation.

WVS plays an important role in knowledge provision in the Vecht basin during flood events, sharing updates on the state of the water system. It uses the National Crisis Management System (LCMS) and also distributes the *Information Overview Water System*. However, both tools are static and often fail to provide timely, relevant knowledge, creating a need for real-time, dynamic systems with direct access to live data and forecasts to support flood response actions.

To further elaborate on this, first the knowledge tools LCMS and *Information Overview Water System* are briefly explained. Then, how these knowledge tools were applied during flood 2023, followed by implications on functioning of these knowledge tools.

4.2.4.1 Action Arena - Description Knowledge Provision Tools

To assess whether the knowledge provision in the Vecht basin meets the needs, the knowledge tools themselves must first be explained. Therefore, this section first discusses LCMS, followed by the *Information Overview Water System*.

National Crisis Management System (LCMS)

The National Crisis Management System (LCMS) is an online database accessible to multiple organizations, allowing them to share knowledge and/or data, such as expected water levels and their operational interpretation, to create a comprehensive and up-to-date picture of the water system. These organizations in the Vecht basin are highlighted within the yellow circle in Figure 10: WMCN(-LCO), safety regions, RWS regions, water authorities, provinces, and municipalities.

However, for provinces and municipalities, whether they have access to or use LCMS can vary depending on their regional and local setup. They often gain access to LCMS through their respective safety regions. Additionally, other involved entities such as electricity companies, drinking water providers, police, and emergency medical services may also receive access to LCMS via the safety regions [I-V1; I-V4; I-V9; I-D1; I-H1; I-S1; D-O1; D-N1].

Information Overview Water System

Furthermore, within Phase 0, WVS prepares and shares a weekly document called the *Information Overview Water System* with relevant actors. This overview summarizes the current status of WVS's water system, including surface and groundwater levels and weather forecasts. When flood risk occurs and the crisis organization is activated, the *Information Overview Water System* is produced more frequently and used as a key input for decision-making.

Externally, the *Information Overview Water System* is distributed via email to involved actors such as provinces, municipalities, safety regions, and environmental organizations. At present, German authorities are not included in the standard distribution list. However, they receive a tailored version of the document via email, specifically prepared for them. This German version of the *Information Overview Water System* includes relevant data on the Dinkel catchment and forecasted conditions near the border. [I-V2; I-V6; I-V7; I-V10; I-V13].

4.2.4.2 Action Situation - Role Knowledge Provision Tools during Flood Event 2023

The application of knowledge tools during flood event 2023 is visualized in the network analysis of Figure 14. During the flood response, LCMS was used for crisis communication by, among others, WDOD, WVS, safety region IJsselland, and the Municipality of Hardenberg (via the safety region). WVS shared the *Information Overview Water System* with external organizations as planned, however emails to Municipality of Hardenberg and the German version to the German water authorities were sent to incorrect addresses and not received [I-V1; I-V4; I-V7; I-H1; I-O1; D-H1].

4.2.4.3 Implications on the Functioning of Knowledge Provision Tools

Both LCMS and the *Information Overview Water System* are currently static knowledge tools that require manual updates and written input. While LCMS primarily functions as a platform for crisis knowledge exchange between organizations in the Vecht basin, it does not guarantee that all required knowledge is available at any given moment. What is accessible in LCMS depends entirely on what actors choose to document, rather than on what other parties specifically need to know. For example, the knowledge shared was primarily related to general system conditions rather than to location-specific details:

“So they [safety region IJsselland] used it [LCMS] for all the safety information reports and tried to interpret them. It [LCMS] was activated back then, yes. And that was done in consultation with the water authority. But yeah, I checked and there were like three lines about the Vecht or something. That was the broader perspective, so to speak” [I-H1]

In addition to LCMS, WVS distributes the *Information Overview Water System* as another form of knowledge provision, also shared with municipalities. However, there are both accessibility issues and content-related challenges. Some municipalities did not receive the knowledge due to incorrect email addresses and the content itself was too technical or insufficiently tailored to their needs:

“The Information Overview Water System we receive, I cannot interpret it. I am not an expert when it comes to that, so I do not know what to make from it. And it is also very important for the municipality to start thinking in scenarios: what is coming our way in the next one, two, or three days? So you also have to link a forecast to this.” [I-H1]

The need to adapt knowledge tools is not limited to municipalities, it is also recognized within WVS itself. For example, the case of the retention area of Heemsermarskamp highlights the inefficiencies of manual knowledge processing. Both the Hardenberg side and WVS expressed frustration about not having direct access to relevant measurements:

“At that moment, we [ACW at WVS] had to manually check every minute to see, okay, when will it [Heemsermarskamp] actually overflow there? What water levels can we expect? All of this was still being done manually.” [I-V2]

This illustrates a broader, basin-wide need for automated, real-time knowledge on the water system. Instead of relying on individuals to manually update or interpret knowledge, actors across organizations want direct access to live data and forecasts:

“In general, and it also applies to low water levels, I do believe that ultimately, together, and by ‘together’ I mean all water managers, so both Rijkswaterstaat as the main manager of the primary water system, as well as the regional managers, we would greatly benefit from having a comprehensive network of measurement stations that provide real-time, up-to-date information. [...] And during flood events, you really want to know: where is a lot of water coming from right now, and at what speed?” [I-R1]

On a transboundary level, the Vecht basin currently uses a tailored version of the *Information Overview Water System* to share knowledge with German water authorities. However, the added value of this approach has been questioned due to both the time investment required and the limited usefulness of the knowledge:

“I think we should really evaluate that at some point: does it make sense? Because it actually took quite a lot of time to make those overviews specifically for Germany on a daily basis, while, in reality, we did not really benefit from it. [...] I think if we just had our measurement points online, just like the Germans do, you can actually work perfectly well with that information.” [I-V7]

To conclude, current knowledge transfer tools like LCMS and the *Information Overview Water System* are static, time-consuming, and often fail to provide timely and relevant knowledge. Actors across the Vecht basin, including municipalities, WVS, and RWS, express a clear need for dynamic, real-time systems that deliver the knowledge they actually require.

4.3 Drought Events

For drought events, three themes were identified, analysed following the same structure as floods. The first two themes are on the organizational system, and the third on the knowledge system:

- Absence of well-established drought response system at WVS
- Undefined roles and authority in regional drought meetings
- Different drought definitions creating perception–response gaps

4.3.1 Absence of Well-established Drought Response System at WVS

The first key theme focuses on how the *action arena*, as defined by crisis plans and formal procedures, translates into the *action situation*. The formal description of the drought response system in the *action arena* does not fully align with what occurs in practice in the *action situation*. Instead, an informal response system emerges, with other *actors* assuming undefined informal *roles*. Moreover, it remains unclear when and how the transition from the *action arena* to the *action situation* occurs, and how *actors* with formal *roles* interact with or integrate into the existing informal response system.

Water Authority Vechtstroom (WVS) manages drought primarily within daily management through the Drought Team, activating the crisis organization only when necessary. While both the Drought Team and crisis organization function effectively on their own, they are not yet fully integrated, creating challenges in coordination and communication. As a result, the drought response system at WVS remains fragmented and therefore not yet well-established.

To elaborate, first the drought response system of WVS is explained, covering both daily management and the crisis organization. Next, the application of this system during the 2022 drought event is described through a timeline. Finally, the implications of this event for the functioning and effectiveness of WVS's drought response system are discussed.

4.3.1.1 Action Arena - WVS Drought Response System

WVS views drought not as an acute crisis, but as a long-term challenge. This perspective was shaped significantly by the extreme drought event in 2018. That year, WVS activated its formal crisis organization for several months to deal with the drought, a duration that was experienced as too long and impractical. However, drought develops gradually slowly, in contrast to flooding which occurs rapidly. This long development time allows for a more proactive response, embedded within daily operations rather than relying on rapid decision-making through crisis structures [I-V3; I-V4; I-V5; I-V6; I-V7; I-V8; I-V9; I-V13].

Based on the lessons learned in 2018, WVS decided to treat drought as part of its daily management. To support this approach, the Drought Team was established in 2019. Although not part of the formal crisis structure, the Drought Team coordinates WVS's response during drought events. The formal crisis organization is only involved when the situation escalates beyond what can be managed within standard procedures. In this way, the drought response system at WVS consists of two layers: the informal Drought Team in daily management and the formal crisis organization [I-V3; I-V4; I-V5; I-V6; I-V7; I-V8; I-V9; I-V13].

Daily Management (Drought Team)

The Drought Team at WVS brings together a multidisciplinary group of people from across the organization. Participants include Water System Advisors, Communication Advisors, Water System Coordinator, and representatives from corporate office (in Dutch: *bedrijfsbureau*), enforcement (in Dutch: *handhaving*) and the department Strategy and Environment. If needed, other experts from within the organization can also be involved, such as legal advisors or technical specialists. The nature of the Drought Team be seen as a combination of the ACW and WOT from the formal crisis organization, as it partly serves to provide expertise on drought management while also facilitating tactical-level decision-making [I-V3; I-V4; I-V5; I-V6; I-V7; I-V8; I-V9; I-V13].

The Drought Team meets regularly through the Coordinated Drought Meeting (GDO). During periods of drought, these meetings are typically held weekly. Key topics of the GDO typically include the current status of surface and groundwater levels, trends in water quality, appliance of regional Water Allocation Hierarchy (in Dutch: *verdringingsreeks*) and operational issues such as fish passage management or the placement of TPI's [I-V3; I-V4; I-V5; I-V6; I-V7; I-V8; I-V9; I-V13].

In addition to internal coordination, the GDO serves as an important link to the regional level. The WVS representative who participates in Regional Drought Meeting Twentekanalen (RDO-TK) also takes part in the GDO, sharing insights and agreements discussed in RDO-TK. This ensures a two-way knowledge transfer, keeping WVS aligned with the regional level. RDO's are discussed in more detail in Section 4.3.2 [I-V3; I-V4; I-V5; I-V6; I-V7; I-V8; I-V9; I-V13].

Crisis Organization

While drought is primarily managed within daily management through the Drought Team, the formal crisis organization of WVS can also be activated during drought events when necessary. However, there are no predefined thresholds or formal indicators for scaling up to crisis organization. Drought develops gradually, and scaling up depends largely on contextual factors rather than quantitative triggers. Key considerations that may lead to the activation of the crisis organization include:

- Decisions or technical challenges related to Temporary Pump Installation 3 (TPI 3) at Eefde (further details in Appendix K)
- Implementation of the Water Allocation Hierarchy (in Dutch: *verdringingsreeks*) (further details in Appendix K)
- Coordinated upscaling within RDO-TK
- Scaling-up decision made individually by other water authorities or the National Committee Water Distribution (LCW)
- Increased societal or political pressure due to media attention
- A very difficult or problematic situation involving many people which cannot be solved within daily operations

In such cases, the crisis organization enables faster decision-making, with designated crisis roles granted authority to make higher order decisions, such as the installation of TPI 3. Furthermore, activating the crisis organization sends a clear signal to the outside world that WVS takes drought issues seriously [I-V3; I-V4; I-V5; I-V6; I-V7; I-V8; I-V9; I-V13].

There is, however, an intermediate phase between daily management and an activated crisis organization, marked by the activation of a ‘potential’ crisis phase, which focuses on knowledge exchange and coordination but does not allow for formal decision-making. By initiating a ‘potential’ phase, the associated crisis team can be activated informally, allowing actors to assume their crisis roles and gather or share knowledge without formal authority [I-V4; I-V5].

4.3.1.2 Action Situation - Drought Response during Drought Event 2022

To understand how the Drought Team and the crisis organization operate alongside one another, the timeline of the 2022 drought event from the perspective of water authority Vechtstromen (WVS) is presented in Figure 15. It presents both the upscaling process of National Committee Water Distribution (LCW) and WVS, along with information on the context, decision-making processes, and the drought measures taken.

As can be seen in Figure 15, the starting point of the drought period is linked to the RDO-TK start-up meeting which took place in late March/early April, when drought issues were already emerging and discussed. On May 19, the first clear signals of a drought appeared with water quality problems caused by rising temperatures and limited precipitation. This triggered the start of Coordinated Drought Meetings (GDO’s) at WVS, following the approach of previous drought years, and eventually led to withdrawal bans as a drought measure. The drought period in the timeline ends when all withdrawal bans were lifted [I-V3; I-V4; I-V7; D-V2].

Most of the drought period was managed within daily management. Nevertheless, Phase 2 of the crisis organization was activated twice: first for decision-making on the use of TPI 3, and later when TPI 3 risked failure due to extremely low water levels in the IJssel. A failure of TPI 3 would have severely reduced inflow to the Twentekanalen from the IJssel, triggering significant water shortages in water supply areas of WVS, therefore requiring the implementation of the Water Allocation Hierarchy. This is a ranking of water uses by priority during supply shortages (see Appendix K). Since the rules and practicalities of the hierarchy were not entirely clear, an informal WBT meeting was held to discuss the potential issue with the Chair Water Authority included, who serves as informal Chair WBT. A few days later, multiple WBT Chairs from different water authorities held an informal meeting to discuss the drought situation and the possibility of joint upscaling. Although no joint scaling followed, an informal WBT was brought together for this moment [I-V3; I-V4; I-V7; D-V2; D-V5].

TIMELINE OF WATER AUTHORITY VECHTSTROMEN (WVS)

DROUGHT EVENT 2022

Activation crisis organization LCW/WVS	DATE	Context	Decision-making Process	Drought measures
	END OF MARCH / START OF APRIL		First meeting RDO-TK	
	19-05	Problem water quality		
	25-05		Start Coordinated Drought Meetings (GDO)	
	20-06	Low water levels IJssel		
	22-06	Groundwater levels and discharge below average		
	27-06			Withdrawal ban for urban ponds
	12-07		RDO-TK: Usage TPI 1 & 2 at Eefde	
LCW Phase 1	13-07	Potential water shortage		
	14-07	Aadorp sluice issues, Almelo de Haandrik waterlevel below target, TPI not yet operational		
	20-07			TPI 1 operational at Eefde
WVS Phase 2	22-07	Water supply at risk (Eefde)	RDO-TK/WOT: Usage TPI 3 at Eefde	
	23-07			TPI 2 operational at Eefde
	27-07	Reduced discharge of Dinkel at Stokkenspiek		TPI 3 operational at Eefde
WVS Phase 0	01-08			
LCW Phase 2	03-08	Actual water shortage		
	12-08	Water supply issues at Aadorp sluice, water level problems at Stieltjeskanaal		Groundwater withdrawal ban at sensitive ecosystems Vecht
	13-08	Water supply issues at Holthe sluice		
WVS Phase 2	15-08	Risk of TPI 3 failure due to low water levels IJssel		Preparation for withdrawal ban sprinkler and surface irrigation
	16-08		Informal WBT (intern): Discussion decision-making TPI 3 & potential use Water Allocation Hierarchy	
	22-08	Increase water levels IJssel	Informal meeting between WBT's (extern): Discussion on potential joint upscaling for drought	
WVS Phase 0	08-09	Daily water management		
LCW Phase 1	21-09			
LCW Phase 0	28-09			
	01-11			Withdrawal bans lifted

Figure 15 - Timeline drought event 2022 from perspective WVS [I-V3; I-V4; I-V7; D-V2]

4.3.1.3 Implications on the Functioning of WVS Drought Response System

Thus, the drought event of 2022 has been managed by WVS mainly through daily management via the Drought Team, with the crisis organization only activated due to the risks of losing water supply to the Twentekanal. This drought response structure is generally accepted within WVS, as prolonged upscaling is deemed impractical. However, the Drought Team is informal, while crisis teams are formal, creating a dilemma: informally managing drought without urgency of a crisis, or scaling up but potentially sidelining Drought Team.

“It is actually quite a dilemma, because that is precisely the advantage of a crisis organization: everyone works according to protocols, drops their other tasks, and focuses entirely on the crisis organization. Those people in the Drought Team have to do their regular work more or less on the side, and they have no formal status. So I do not even know if other water boards have a drought team that they can contact. [...] But on the other hand, if you scale up to the crisis organization, you effectively sideline the entire Drought Team, because it is uncertain whether they will have a role in such a crisis team, like a WOT or WBT.” [I-V9]

Another consequence of not activating the crisis organization is that formal communication channels remain inactive, which can be regarded as a problem:

“And I noticed back in 2022 that, yes, especially from other parties, it was sometimes experienced as difficult that we were not scaled up, and therefore they could not, for example, easily contact the Operational Leader to ask, “How are things going on your side?” because that role was not active with us.” [I-V3]

On the other hand, other interviewees argued that inactive crisis lines are less of a problem and that the focus should be on informal connections and preparation within daily management.

Furthermore, the shift from daily management to crisis organization is not clearly defined and occurs reactively only when a problem is too large to handle within daily management:

“There [drought event 2018] we were fortunately already scaled up, and those teams were all doing their work, keeping the usual logs and using LCMS and so on. If you still have to get all of that up and running at the moment, [...] I think in that situation you would run into some startup problems, causing delays that you cannot afford at such a moment” [I-V7]

To conclude, opinions on the effectiveness of the drought response system of WVS differ. The Drought Team and the crisis organization have their advantages and function effectively on their own, but they are not fully integrated. This lack of alignment results in a fragmented drought response system. The main challenge lies in adapting the current approach to improve coordination and create a shared purpose among all actors to ensure cohesive drought response.

4.3.2 Undefined Roles and Authority in Regional Drought Meetings

The second key theme focuses on *role* definitions in the *action arena* compared to how they are adopted and played out by *actors* in the *action situation*. In practice, the *action situation* reveals vagueness and gaps in *roles* that are not clearly defined in the *action arena*, making it difficult to determine which responsibilities are assigned to the *actors*.

On a regional level, drought response coordination takes place via Regional Drought Meetings (RDO's), making it an essential element in decision-making in the Vecht basin. However, undefined roles and authority for WVS representatives create gaps in coordination with the crisis organization.

To elaborate on this, first the concept of RDO is explained, followed by its role during the 2022 drought event in the Vecht basin. Finally, a discussion addresses the functioning and challenges of RDO.

4.3.2.1 Action Arena - Regional Drought Meetings (RDO's)

The Regional Drought Meetings (RDO's) form the regional platform for coordination, knowledge sharing, and joint decision-making within drought response. There are six RDO's across the Netherlands, each covering a specific region (see Appendix P) [I-R1; D-V8; D-V23].

In the Vecht basin, the most relevant RDO is Regional Drought Meeting Twentekanalen (RDO-TK). This RDO is particularly important as it covers the sluice complex at Eefde, where drought conditions can disrupt water distribution to the eastern Netherlands. RDO-TK consists of members from RWS regions, provinces, water authorities and drinking water sector (non-voting member), and has a connection to the national level via the National Committee Water Distribution (LCW), as visualized in Figure 16. An elaboration of each involved organization in RDO-TK is included in Appendix L [I-R1; D-V8; D-V23].

RDO-TK typically meets at least twice per year but can meet more frequently during periods of drought. The meetings focus on evaluating current and expected water availability and aligning regional needs for water distribution. Additionally, when deemed necessary, RDO-TK can decide to scale up, meaning that all members activate their own crisis organizations. Within RDO-TK, joint decision-making is primarily required for two specific hydrological drought measures: Temporary Pump Installations (TPI's) and Water Allocation Hierarchy (in Dutch: *verdringingsreeks*). These themes are discussed in detail in Appendix K [I-V2; I-V3; I-V7; I-V8; I-D1; I-O1; I-R1; D-V8; D-V23].

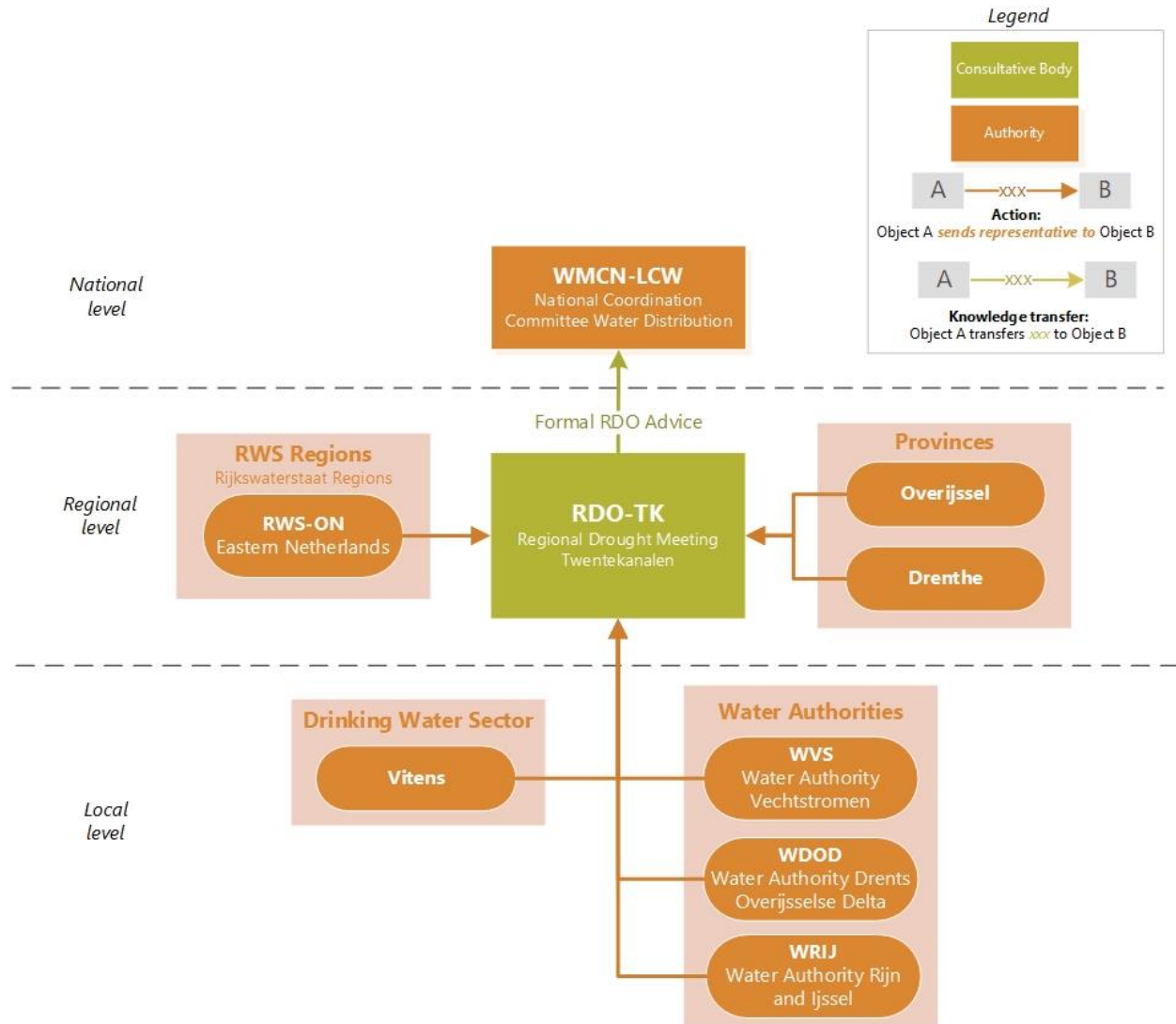


Figure 16 – Structure Regional Drought Meeting Twentekanalen (RDO-TK) (authors interpretation based on document and thematic analysis)

4.3.2.2 Action Situation - Role RDO in Drought Event 2022

During the drought event in 2022, as shown in the timeline in Figure 15, the startup meeting of RDO-TK also served as the meeting where emerging drought problems were discussed. Additionally, the timeline shows that collective decisions were made in RDO-TK regarding the placement of TPI 1, 2, and 3. In addition to decision-making, RDO-TK also serves as a platform for external collaboration in the Vecht basin. This also facilitated informal contacts via WhatsApp or calls, reducing the need for multiple RDO meetings to discuss issues. Formal crisis networks did not play a major role in this drought event in comparison to flood response [I-V2; I-V4; I-V12; I-R1; I-D1].

4.3.2.3 Implications on the Functioning of RDO

In 2022, key decisions such as the placement of TPI-3 were made within RDO-TK, which had direct implications for WVS operations. This emphasizes that RDO-TK is a critical element of the drought response system in the Vecht basin. Additionally, although Drought Team and RDO are well-connected, the connection of RDO the crisis organization is lacking, requiring further attention:

“It is important to have the appropriate representation in national and regional consultation bodies regarding drought and floods. An example of this is the RDO’s. Before the event, this body is responsible for preparing for drought, while during the event makes decisions regarding the drought. This requires different authorities and mandates.” [I-V4]

Thus, the role and required authority of a WVS representative in RDO-TK are not yet formally defined, which may lead to gaps in coordination and integration with the crisis organization.

4.3.3 Different Drought Definitions creating Perception–Response Gaps

Unlike the previous themes, which focus on the translation from the *action arena* to the *action situation*, this theme emphasizes actors’ *mental models*, an MTF element not originally included in the conceptual framework. *Mental models* encompass actor’s subjective notions about parts of reality, in this context referring to drought risk perception. This element was subsequently incorporated in the analysis for drought response because clear differences emerged in how actors perceived drought and how an appropriate response should look like. These divergent perceptions, combined with limitations in the overall available *knowledge* on drought, contributed to inconsistencies in the responses observed during the *action situation*.

These inconsistencies are shaped by the regional and typological variation of drought. Differences in definitions shape how actors perceive severity and guide organizational responses. This is a problem, because if perceptions of drought *hazards* differ greatly, the responses may vary just as much, potentially leading to actions that do not match the local conditions or the actual severity of the situation.

To elaborate, the definitions of drought as perceived by different organizations are explained first to illustrate their underlying *mental models*. This is followed by a discussion of the implications these differences have for the functioning of drought response measures.

4.3.3.1 Mental Models: Definitions Drought per Organization

To understand the differences in risk perceptions between organizations, the perspectives of each organization must first be examined. In this section, three different organizations are discussed and elaborated on their definitions of drought: water authorities on local level, National Coordination Committee Water Distribution (LCW) on national level, and drought represented by the media.

Water Authorities WVS & WDOD

The water authorities are responsible for implementing drought measures in their jurisdiction area, guided by their assessment of drought severity. WVS defines drought across three categories: *meteorological*, *agricultural* and *hydrological* drought. Each type offers a different perspective and requires its own monitoring approach. *Meteorological drought* is tracked using the precipitation deficit, calculated with data from KNMI weather stations and adapted to the WVS region. Although it does not immediately indicate drought-related problems, meteorological drought often serves as an early warning and can be a signal to start with Coordinated Drought Meetings (GDO). *Agricultural drought* is assessed more qualitatively, through input from stakeholders such as Dutch Federation of Agriculture and Horticulture (LTO).

WVS is able to take the most direct action in response to *hydrological drought*. This type of drought is monitored primarily through groundwater levels, which serve as a key indicator of remaining supply, along with water inflows. Monitoring is supported by a network of over 300 groundwater measurement points across the region. WDOD defines and monitors drought in a similar manner [I-V3; I-V9; I-V13; I-D1].

National Coordination Committee Water Distribution (LCW)

The National Coordination Committee Water Distribution (LCW) is the national-level governance body, authorized to activate the national Water Allocation Hierarchy based on their perception on drought problematics. The LCW uses color coding (see Table 5) to provide an overview of the drought's severity. Additional indicators used by the LCW to determine when to scale up include river discharge levels, which reflect *hydrological drought* as a concern [I-V2; I-V7; I-R1; I-O1; D-V8; D-V23].

The LCW considers drought a problem when there is a potential or actual water shortage, meaning that water demand exceeds the available supply of suitable quality. To manage an actual shortage, the LCW is authorized to apply the national Water Allocation Hierarchy. Furthermore, the LCW regards drought as a (potential) crisis only at level 3 (code red), a situation that occurs once every 10 to 20 years. At this level, the water shortage is significantly greater than normal, has major societal impacts, and requires measures beyond regular water management [I-V2; I-V7; I-R1; I-O1; D-V8; D-V23].

Table 5 - Color coding for drought risk from 'Landelijk draaiboek waterverdeling en droogte' [D-V23]

Green Code: Level 0 Sufficient water is available to meet water demand according to existing Water Agreements (in Dutch: <i>Waterakkoorden</i>) There are no or limited issues related to drought. RWS, water authorities, and provinces carry out regular tasks and prepare for potential water shortages.
Yellow Code: Level 1 There is a potential water shortage. Water authorities, RWS, and provinces take measures to meet water demand.
Orange Code: Level 2 There is an actual water shortage. Water Agreements and other arrangements can no longer be fulfilled. Not all societal sectors can be fully served. Choices must be made based on the official Water Allocation Hierarchy (in Dutch: <i>verdringingsreeks</i>).
Red Code: Level 3 There is a (potential) national crisis. This includes a (potential) national water shortage with major societal impacts and possible related political and administrative sensitivities. Exceptional measures must be taken.

Media

Although the media do not hold formal decision-making authority in the drought response system of the Vecht basin, they can influence decisions by shaping societal perceptions of drought. This, in turn, places pressure on WVS to demonstrate accountability and visible action as the authority responsible for water supply, which may lead to the activation of the crisis organization. Media coverage of droughts often does not distinguish between different types of drought, generally using the term 'drought' without specifying whether it is *meteorological*, *hydrological*, or *agricultural* [I-V3; I-V4; I-V5; I-V7; I-V12; I-V13].

For example, NOS in 2022 mostly referred to 'drought' while discussing *meteorological* drought conditions. On 13 May 2022, days before WVS noted that water quality issues arose (see timeline Figure 15), NOS reported:

"Parts of the Netherlands are once again facing drought. In many areas, it has not rained for weeks, and March was also dry. The number of measures to combat the drought is increasing, such as raising the water level in the IJsselmeer for water extraction. But what is the situation in the Netherlands exactly? The so-called precipitation deficit (precipitation minus evaporation) is calculated from April 1 until the end of September. [...] A precipitation deficit cannot be eliminated with just a few heavy showers. When a lot of rain falls at once, much of it is discharged through the rivers, a factor not included in the calculation of the precipitation deficit, as described above."

(NOS, 2022)

As can be seen in the quote, the term 'drought' is first used to refer to *meteorological* drought, then shifts to mention a measure addressing *hydrological* drought. Later, the discussion of the precipitation deficit again refers to *meteorological* drought, followed by a note on river discharges, which once more points to *hydrological* drought.

4.3.3.2 Implications on the Functioning of Response Measures

Differences in definitions of drought lead to varying perspectives on the problem, influencing which measures are taken. Water authorities focus on local conditions, LCW defines drought nationally, and the media often combines multiple definitions under one term. Media coverage can amplify these differences by shaping public and political perceptions. For example, the NOS report on 13 May 2022 highlighted the occurrence of an extremely dry year, while from WVS's viewpoint the drought was not yet problematic since there were no immediate water supply issues yet. Different definitions of drought across different locations are also tied to distinct associated problems, which may require different responses, as one interviewee explains:

“We [WVS] sometimes have, in our area, situations where in Twente not a single drop falls, while in Drenthe there have been several heavy showers. It [drought] is actually a very diffuse term, that can even apply nationwide. At some point, people say, ‘oh, it is extremely dry,’ and we would think, well, it is dry, but there is no problem. You stick your spade into the ground and after five centimeters you still find wet soil. Whereas there are also places, for example on those higher sandy soils, also in Twente, where all the water that falls flows away if you do not retain it. Yes, there it was indeed dry again.” [I-V13]

Additionally, aside from differences in perspectives on what drought means, there is also the challenge of quantifying drought to decide which measures to take. While water authorities have monitoring tools in place, it remains a complex issue:

“We [WVS] know exactly how many centimeters of water are allowed to be on a piece of land and when we have done well or not. But for drought, we do not know that. We can only look at groundwater levels, more or less. And we listen to the landowners when they feel that their nature areas are starting to dry out. [...] We cannot yet quantify drought well enough to connect it to our measures, and I find that very difficult.” [I-V9]

Besides the aforementioned organizations, other actors, such as farmers experiencing *agricultural* drought, may hold different views, adding even more complexity to the differences in drought definitions. To conclude, these regional and drought-type variations shape how drought is perceived, influencing whether it is considered a significant problem and determining what measures are deemed necessary. With respect to *mental models* of drought risk perception, this finding indicates a limited understanding of the drought *hazard* and a lack of alignment in its interpretation across actors.

4.4 Opportunities for Improvements

Based on the findings from the interviews and the dialogue session, several opportunities for improvement emerged regarding actor's roles and knowledge utilization to strengthen adaptive governance through the lens of MTF elements.

For flood response, improvements in the translation from the *action arena* to the *action situation* could be achieved by acknowledging the influence of actors' *mental models* on the activation of crisis plans and therefore the adoption of crisis *roles*. A basin-wide discussion among organizations could help align perspectives on flood risk and clarify mutual expectations, explicitly including scenario-based thinking. Within WVS, formally recognizing *actors* who are not currently part of the *action arena* but play relevant *roles* in flood response would ensure that their *situated knowledge* is preserved and effectively utilized. The dialogue session underlined this need, stressing clearer documentation of responsibilities and better integration of informal roles, for example through a formal liaison between operational and tactical levels [I-V4; I-V11; I-V12; I-H1; I-O1; I-R1; I-S1].

In terms of knowledge utilization, data-generation tools such as FEWS currently do not perform in the *action situation* as intended in the *action arena*. Aligning the *action arena* with practice could involve assigning responsibilities for the water level monitoring system and designating alternative sources in case FEWS is unavailable. For knowledge provision tools from WVS to external organizations, such as LCMS and the *Information Overview Water System*, the *situated knowledge* that actors contribute to these tools is not always aligned with the needs of receiving actors. Addressing this requires clarifying *mental models* to understand how different actors perceive the flood event and what knowledge is relevant to whom. This could be supported by transforming the static tools into dynamic systems that provide actionable, actor-specific knowledge, a need highlighted by multiple interviewees. The dialogue session pointed to opportunities for such a dynamic knowledge tool. A comparable system successfully providing tailored water level warnings, including corresponding recommended actions, was developed in the past but lost due to merging of water authorities. This shows that such approaches can indeed be developed. Building on this experience, and drawing on recent pilots based on Artificial Intelligence, participants saw to develop tools that better translate the documented information and available data into usable knowledge across organizations [I-V2; I-V4; I-V6; I-V7; I-D1; I-H1; I-R1; I-O1].

For drought response, the translation from the *action arena* to the *action situation* is currently vague, with unclear purposes, actor roles, and responsibilities. Internally, WVS should define which *actors* are involved and their respective *roles*, integrating both formal and informal response systems to ensure a coherent response. Externally, discussions with other organizations are recommended, similar to flood response, to clarify roles, responsibilities, and expectations, incorporating scenario-based thinking to improve preparedness and coordination. Additionally, differences in actors' *mental models*, in this case the perceptions of drought hazards, shaped by varying definitions and local conditions should be addressed in these discussions to align understanding and support more consistent responses. Once the purpose of drought response is aligned across the Vecht basin and within the organizations themselves, the next step is to identify the knowledge required to effectively fulfill this purpose. The dialogue session reinforced these findings, with participants explicitly agreeing that defining drought and identifying the appropriate response remain the central challenges, especially under external pressures from national authorities (LCW) and the media [I-V4; I-V5; I-V7; I-V8; I-V9; I-O1; I-R1].

5. Discussion

In this discussion, key findings are reflected upon, the application of the Management & Transition Framework (MTF) is considered, and the research methods are evaluated, including six recommendations for further research.

5.1 Reflection on Key Findings

This study examines the adaptation of actors' roles and the use of knowledge in response to flood and drought events, highlighting how actors perceive risks differently and how this affects whether they classify an event as a crisis. Risk is defined as a combination of *hazard*, *exposure*, and *vulnerability* (IPCC, 2022; Raadgever & Hegger, 2018), and the findings support this definition, as differences in these dimensions are notable and lead to different risk perceptions.

In the case of floods, the *hazard* was seen consistently throughout the Vecht basin because actors relied on the same forecasting knowledge tools, such as FEWS. Despite this, perceptions of *vulnerability* and *exposure* varied. The safety region, for example, considered municipalities less *vulnerable* than the municipalities considered themselves. *Exposure* only became apparent when the effects were directly visible, such as flooded basements or usage of retention areas. This aligns with findings on low flood risk awareness in the Netherlands (Raadgever & Hegger, 2018), as actors often underestimated potential consequences, overlooking that significant damage can occur even without dike breaches or casualties.

Droughts, however, present a different situation. The *hazard* is harder to define, and distinctions between *meteorological*, *agricultural*, and *hydrological* drought (Bressers et al., 2016) were recognized by some interviewees, particularly hydrology experts, but not by others. Several could not define drought at all, highlighting the uncertainty in identifying the *hazard*. *Vulnerability* is difficult to determine because it depends on how people and systems can cope with drought, but this is challenging when it is unclear what the specific hazard is and thus the impacts are. *Exposure* is also not easy to observe, since impacts develop slowly and it is not immediately clear which people, crops, or infrastructure are at risk. Together, these factors make assessing risk more complex. As a result, risk perception of drought is unclear and variable, complicating both recognition of the *hazard* and planning of appropriate responses.

The terminology of disasters further illustrates these challenges. Following Wilhite (2000) and Pahl-Wostl (2015), a *disaster* is defined as an event with significant consequences for human life or finances. The flood of 2023 challenges this definition. Although no lives were lost and overall water damage was limited, consequences for specific individuals, such as flooded basements or power outages, could still be serious. This raises the question of what counts as significant consequences and who decides when an event qualifies as a disaster.

Although this study classifies the event as a *fluvial flood*, meaning rainfall exceeds river capacity (Yang & Liu, 2020), practitioners described it as a 'high-water event' (in Dutch: *hoogwater situatie*) rather than a flood. In Dutch, a flood translates to 'overstroming', which the interviewees seem to

define as the inundation of normally dry land. Interviewees at water authorities did not consider the usage of retention areas to be a flood, as these areas are designed to hold excess water. However, for municipalities or affected residents, these same events might feel like a flood, highlighting how risk perception can differ depending on perspective. By contrast, ‘hoogwater situatie’ refers to exceptionally high water levels that do not lead to damaging flooding. This suggests that practitioners reserve the term *flood event* for severe events with widespread damage, effectively equating it with a *disaster*.

Droughts remain a contrasting case. Literature characterizes them as creeping crises, with impacts that accumulate slowly over time (Wilhite, 2000). In line with this, interviewees from water authority Vechtstromen did not see drought as a crisis requiring fast decision-making, but as a long-term challenge. This aligns with the definition of crisis proposed by Wolbers et al. (2021), which emphasizes situations requiring critical decision-making under conditions of time pressure and uncertainty, that droughts generally did not meet. Nevertheless, water authority Vechtstromen partially used its crisis organization during the drought of 2022. This raises the question of whether drought should be managed within the same crisis structures as floods, as the nature of the hazard and its consequences are fundamentally different. The unclear definition of drought complicates the issue further, reflecting the lack of widely accepted definitions and severity thresholds (Wilhite, 2000).

Comparison of the flood event of 2023 in the Vecht basin with the Limburg flood of 2021 (Waterschap Limburg, 2022) help place the findings for flood response in context. Both events required activation of the GRIP system and coordination among water authorities, Rijkswaterstaat, municipalities, and safety regions. In these cases, similar challenges emerged. These included unclear understanding of roles, responsibilities, and terminology among organizations, which led to difficulties in communication and collaboration. Additionally, limited access to reliable knowledge and real-time data, and the need for scenario-based insights into which areas would be affected and the potential consequences further challenged effective response. These similarities suggest that the challenges observed in the Vecht basin may also arise in other basins with similar response structures. At the same time, important differences were evident. In Limburg, crisis roles were unclear, whereas in Vechtstromen they were well established. This difference can be explained by the stage of crisis planning: Limburg was still embedding a revised plan, while Vechtstromen’s plan was already practiced and familiar. These findings indicate that clear and practiced crisis structures strongly influence how effective the flood responses are.

5.2 Reflection on Application of Management & Transition Framework

In this research, adaptive governance is defined from a *response-oriented* perspective, examining how actors within water governance systems respond during flood and drought events through interactions and actions in order to avoid the disaster or mitigate the potential impacts (Aoki, 2016; Janssen & Van der Voort, 2020). This study demonstrates that the Management & Transition Framework (MTF) can be applied to analyse short-term event-based adaptive governance.

The MTF, originally designed for long-term governance transitions (Pahl-Wostl et al., 2010), was adapted in this study for short-term, response-focused analysis. The *action arena* represents the response system, while the *action situation* captures the dynamic context in which interactions occur during a specific event. This structure allows the framework to show how the response system functions and which factors shape interactions, linking the theoretical elements of the MTF directly to practical governance dynamics.

The MTF elements provide a way to analyse adaptive governance in short-term event responses by linking what is formally arranged in the *action arena* with what unfolds in the *action situation*. For actor roles, this allows examination of how responsibilities defined in crisis plans translate into practice: whether *actors* adopt their assigned *roles*, whether they adapt them in response to circumstances, and whether additional *actors* with informal *roles* emerge as relevant despite not being formally included. This highlights the degree to which governance systems balance stability with flexibility.

For knowledge utilization, the MTF distinguishes between the broader body of *knowledge* and the *situated knowledge* held by actors. This makes it possible to assess how knowledge tools, such as forecasting tools, are intended to function on paper compared to how they are used in practice to generate knowledge, and whether they provide a good fit for decision-making during events. At the same time, it highlights how *actors* activate their *situated knowledge*, transfer it to others, or draw upon the broader body of *knowledge* to acquire knowledge they initially lack. By tracing these exchanges, the framework identifies where gaps or misalignments arise between knowledge provision and actual needs. In this way, it captures both the formal design of the knowledge system and the dynamics of its use in practice.

Although the MTF element *mental models* is not formally included in the conceptual framework within this study, it influences responses to floods and droughts significantly. *Mental models* reflect an actor's risk perception, shaping critical decisions such as when a flood is considered a crisis and when to activate the crisis organization. In drought situations, *mental models* similarly affect how the problem is perceived. Incorporating *mental models* in future applications would allow the framework to capture these perceptual influences more effectively.

The interview data were analysed thematically using the codes from the object tree (Appendix E), with each code linked to a specific MTF element. In many cases, double-coding occurred, for example when an *actor* and their use of *situated knowledge* were closely intertwined with the responsibilities of their *role*. Such overlaps show that the MTF elements are not isolated, but work together as part of a process. Looking at these connections provides richer insights than analyzing individual elements alone. Therefore, future applications should prioritize coding the processes between elements, as this approach better captures the dynamics of adaptive governance and helps key themes emerge more clearly.

Furthermore, the MTF was analysed separately for flood and drought response systems. This approach is appropriate, as the two hazards differ in nature and therefore require distinct response systems. However, conducting the analyses simultaneously allowed for a comparison of how actors perceive the event in terms of risk and handling them. To illustrate, for floods, actors are generally confident in their roles and knowledge usage, and the *action arena* is well-established. In contrast, drought response is characterized by greater uncertainty and less clearly defined roles and knowledge use. This comparison is particularly valuable because both response systems are still based on the same foundation, namely the GRIP system. Thus, while it is recommended to analyse floods and droughts separately, performing the analyses simultaneously provides valuable insights into the differences in how the *action arena* is structured and translated into the *action situation*.

Overall, the MTF proves useful for analysing short-term event-based adaptive governance. Linking actor roles and knowledge utilization to MTF elements clarifies governance dynamics, highlights both formal and informal contributions, and identifies gaps in knowledge or responsibility. Including *mental models* and focusing on inter-element processes in future applications would further strengthen the framework's analytical power within adaptive governance research.

5.3 Reflection on Research Methods

In this research, several limitations were identified, which directly inform six recommendations for further research.

First off, this study examines flood and drought separately because their nature differs, resulting in distinct responses. However, both occur within the same water system. By treating them separately, the influence of drought on flood response, and vice versa, is not fully accounted for. For example, certain flood measures might either reinforce or limit drought measures. Understanding these interactions is important for adaptive governance, as it can reveal how responses to one hazard influence the system's ability to adapt to another. This leads to the following recommendation for research:

1. **Study the interaction between flood and drought response measures:** analyse how response measures for floods and droughts affect each other within the same water system to identify synergies and conflicts and support more integrated, adaptive governance.

Secondly, this research focused on a specific form of adaptive governance, namely from a short-term event-based perspective. It did not, however, consider the long-term learning process, such as learning from one event to the next. Water authority Vechtstromen (WVS), as well as other organizations within the Vecht basin, conduct evaluations of each event that include learning points. During interviews, it emerged that these evaluation points are often not fully addressed in practice, and in the dialogue session, the need to act on these evaluation points was specifically emphasized. Studying this process could provide insights into how learning can be applied more effectively in practice, leading to the following recommendation for future research:

- 2. Analysis of adaptive governance as a learning process:** examine how organizations within the Vecht basin capture and apply lessons from past flood and drought events to improve future responses.

Thirdly, although this study focused on the transboundary Vecht basin, only the Dutch side was examined. In practice, however, the floods and droughts analysed in the case studies also affected the German side, making collaboration essential. To gain a more complete picture of response dynamics, a similar analysis on the German side is needed to identify differences and similarities in practices and to draw lessons for improving transboundary collaboration. Moreover, it would be valuable to incorporate into the analysis existing transboundary initiatives, such as the Transboundary Platform for Regional Water Management (GPRW), Drought Strategies in Water Management (DIWA) and the SpongeWorks project on nature-based water retention, as these may shape future responses and provide insights into evolving collaboration mechanisms (GPRW, sd; Interreg, sd; spongeworks, sd). This leads to the following recommendation for future research:

- 3. Comparison with Germany:** analyse short-term event-based adaptive governance on the German side of the Vecht basin to explore cross-border practices and lessons for collaboration.

Furthermore, the study focuses exclusively on the Vecht basin, meaning the results are context-specific and may not fully apply to other regions, as different river basins may face distinct challenges and involve different actors, which can influence governance dynamics. However, since crisis control in the Netherlands is largely based on the same GRIP escalation system, some lessons, particularly for floods, may still be transferable, as demonstrated by the comparison with the Limburg flood event of 2021. Therefore, the following recommendations for future research are provided:

- 4. Comparison across basins:** study other basins and cases to see if similar themes exist and to identify transferable lessons for flood and drought response.

In addition, a limitation of this research is that it focused only on drought response at WVS, while drought is a diffuse phenomenon with impacts that vary across geographical scales. This includes a gap in understanding drought, as noted by interviewees: what constitutes a drought, what are its consequences, and how can they be measured. The discussion also raised questions about whether drought should be considered a crisis and whether crisis response structures are sufficient to address it. These aspects highlight areas where further investigation could enhance understanding and practice. This leads to the following recommendation:

- 5. Developing strategies for decision-making in drought response:** study the drought response of other organizations, both within the Netherlands as internationally, to gain insights for adapting drought response at WVS.



Last but not least, a limitation of this research is that it did not fully explore potential solutions, as the study primarily focused on identifying knowledge gaps rather than evaluating or developing specific tools to fill this gap. During interviews and the dialogue session, interviewees highlighted a need for dynamic knowledge tools that can provide timely, relevant, and actionable information. Options involving Artificial Intelligence were discussed during the dialogue session, but further exploration of such solutions was beyond the scope of this research. Developing a dynamic knowledge system could improve knowledge transfer, support decision-making, and enhance coordination across organizations, leading to the following recommendation for research:

- 6. Developing a dynamic knowledge provision tool:** study knowledge needs from the organizations in the Vecht basin to design a system that provides tailored and actionable knowledge, supporting both flood and drought response, including cross-border cooperation.

6. Conclusion & Recommendations

6.1 Conclusion

The main research question addressed in this research was:

How do actors in the Dutch Vecht basin water governance system adapt their roles and utilize knowledge during flood and drought events, and how can responses be improved to strengthen adaptive governance?

In this study, *adaptive governance* is approached from a *response-oriented* perspective, emphasizing its role in disaster risk management. This focus results in an analysis of *short-term event-based* adaptive governance. To operationalize this concept, the Management & Transition Framework (MTF) was adapted by selecting specific elements relevant to short-term responses to flood and drought events. In this context, the translation from the *action arena* to the *action situation* is examined to understand how the response system functions in practice during the case studies, while actor role adaptation is analysed through the MTF elements of *actor* and *role*, and knowledge utilization is explored via the elements of *knowledge* and *situated knowledge*. These elements interact, and through a thematic analysis, the resulting processes were synthesized into key themes for both the flood and drought case studies. Floods and droughts are analysed separately, as the hazards differ in terms of duration, origin, and required response strategies.

To answer the research question, conclusions are drawn from the interactions between the MTF elements, highlighting the main findings regarding how actors in the Vecht basin adapt their roles and utilize knowledge in response to flood and drought events. This conclusion is structured to first address the contrasting dynamics of floods and droughts, then present the key findings for each hazard, and concludes with an overall synthesis across events.

6.1.1 Contrasting Dynamics: Floods and Droughts

In general, floods and droughts differ in their temporal dynamics, perceptibility, and impacts, which shapes how they are perceived and managed. Floods are acute, rapidly developing events with clearly observable indicators such as rising water levels. For such hazards, existing crisis structures in the Vecht basin including short-term decision-making protocols are appropriate for the response.

Droughts, by contrast, are slow-onset, creeping crises that develop gradually and whose impacts are not immediately visible. Additionally, the definition of drought varies across actors, and its effects differ per geographical area. Because of these characteristics, droughts require careful consideration regarding how and when responses are activated, as they do not clearly fit traditional crisis definitions. These differences between floods and droughts have important implications for response coordination and recognizing these contrasting dynamics is crucial for strengthening adaptive governance and tailoring strategies to the specific characteristics of each hazard.

6.1.2 Key Findings for Flood Events

For flood events, *actors* in the Vecht basin demonstrate adaptability in their *roles*, adjusting to the demands of rapidly developing situations. The *action arena* is generally stable, structured around existing crisis plans that clearly define formal crisis *roles* for *actors* across the Vecht basin, providing a uniform basis for response. However, the assignment of crisis roles is strongly influenced by actors' *mental models*, particularly their perception of flood risk. When actors underestimate the severity of a situation, crisis roles may not be assigned, disrupting the uniform basis for response across the basin and leaving key responsibilities unfulfilled.

When the crisis response system is activated, the translation from the *action arena* to the *action situation* reveals a balance between the stability of the crisis plans and the adaptability of actor *roles*. Actors at the tactical and strategic levels demonstrate flexibility by combining their formal crisis roles with informal roles. In doing so, they draw upon established crisis networks as well as informal networks developed prior to the event, and utilize *situated knowledge* gained from their informal roles to enhance decision-making in their crisis roles.

Moreover, certain informal roles relevant to flood response exist outside the defined *action arena*. Although these actors do not hold formal crisis responsibilities, their *situated knowledge* at the operational level proves highly valuable during response actions. However, this knowledge is not fully integrated into the broader body of *knowledge*, putting it at risk of being overlooked or lost.

Regarding knowledge utilization, the findings indicate that not all actors possess the *situated knowledge* needed to respond effectively to floods and therefore rely on other knowledge sources. Currently, there is a mismatch between the knowledge provided and the knowledge needs across the Vecht basin, both in terms of content and accessibility, which constrains the system's adaptability.

In conclusion, the flood response system demonstrates clear potential for adaptive governance, achieving a balance between stability and flexibility in role adaptation. Nevertheless, this potential is constrained by two key limitations: the influence of *mental models* on the adoption of crisis roles and the incomplete alignment between available knowledge and the knowledge required for effective response. Addressing these limitations, by enhancing awareness of flood risk via scenario-thinking and better integrating operational-level knowledge into the broader system, could further strengthen adaptive governance. Building on past experience and recent AI-based pilots, developing dynamic tools to translate documented information and data into actionable knowledge could further strengthen response and coordination.

6.1.3 Key Findings for Drought Events

For drought events, *actors* in the Vecht basin demonstrate a high degree of flexibility in their *roles*, but the *action arena* is less stable compared to floods. The rules, procedures, and formal crisis roles for drought response are not clearly defined, and within the *action situation*, actors typically act from informal roles. This provides freedom of movement and potential for adaptivity, but also creates uncertainty, as responsibilities remain vague and inconsistent, revealing a lack of balance

between stability and adaptability. Differences in actors' *mental models*, particularly regarding how drought is defined, further shape role adoption, as varying perceptions of the hazard influence when and how actors assume responsibilities.

Knowledge utilization in drought response is similarly constrained. Many actors, except those directly involved in drought-related fields, lack sufficient *situated knowledge*, and the creeping, slow-onset nature of drought makes it difficult to determine what knowledge is relevant and when it should be applied. The broader body of *knowledge* therefore now plays a limited role, as actors must first understand drought itself before identifying the knowledge needed for effective response. Differences in *situated knowledge* across actors, combined with unclear *roles*, further challenge coordination.

To improve adaptive governance, several steps are recommended. Internally, water authority Vechtstromen (WVS) should clearly define which *actors* are involved and their respective *roles*, integrating both formal and informal systems to ensure coherent responses. Externally, discussions with other organizations are needed to clarify roles, responsibilities, and expectations, incorporating scenario-based thinking to improve preparedness. Aligning *mental models* across actors, particularly regarding the definition and perception of drought, will support more consistent responses and inform the knowledge required to effectively fulfill response objectives

6.1.4 Overall Conclusion: Mindset and Knowledge drive Adaptive Governance

Adaptive governance in the Vecht basin is driven first by actors' *mental models*, which shape how *roles* are assumed and how *knowledge* is utilized. Current knowledge use is often misaligned with what actors actually need, creating opportunities to transform information into actionable, context-specific knowledge that better support decision-making. By aligning *mental models* and clarifying knowledge needs, actors can adapt their roles more effectively, use knowledge more strategically, and coordinate responses across organizations. Strengthening adaptive governance therefore requires not only clear roles and accessible knowledge, but foremost a shared understanding of risks, responsibilities, and knowledge requirements.

6.2 Recommendations for Practitioners

Based on the opportunities for improvements from the findings and the outputs of the dialogue session, four recommendations have been formulated for practitioners. All recommendations are written from the perspective of the water authority Vechtstromen (WVS). Implementation of the recommendations should follow a logical sequence. Developing the dynamic knowledge tool (Req. #2) first requires a basin-wide scenario analysis (Rec. #1) to determine which knowledge provision is needed. Similarly, the updating of crisis plans (Rec. #3) and revision of drought response system (Rec. #4) should also build on insights from scenario-thinking (Rec. #1) to define the required responses.

1. Engage water authorities, RWS regions, provinces, safety regions, and municipalities in scenario-thinking on flood and drought response to clarify roles, responsibilities, and expectations.

Organizations in the Vecht basin often have different perceptions of flood risk and definitions of drought, which can misalign responses and hinder collaboration. It is recommended that water authorities engage with RWS regions, provinces, safety regions, and municipalities to clarify roles and responsibilities. Scenario-thinking could be used as a tool to guide these discussions, helping actors explore potential situations and align perspectives. For flood response, discussions should focus on aligning the GRIP escalation system and adapting escalation procedures to ensure coordinated action. For drought response, the focus should be on defining a shared vision, including when drought is considered a problem and clarifying mutual expectations between water authorities and other organizations. Additionally, each organization's knowledge needs should be identified, with mechanisms to provide timely, actionable information in line with Recommendation #2.

2. Develop a dynamic knowledge provision tool with real-time data to provide tailored and actionable knowledge to internal teams and external organizations.

Currently, WVS relies on static knowledge provision tools, which limit the timeliness and relevance of knowledge. A real-time tool, such as an online dashboard, would provide up-to-date information accessible to both internal and external actors. The tool should include an interpretation layer that translates information into clear actions, ensuring that all actors not only have timely information but also know how to act on it effectively. For municipalities, this includes information on water levels in retention areas including guidance on actions for specific scenarios with critical water levels. For WVS, the tool should automate monitoring and provide real-time insights instead of relying on manual observation. In addition, the tool should support flood response by making relevant knowledge easily accessible to all actors, including those in Germany.

3. Revise flood response crisis plans to clearly define responsibilities, including both the upkeep of the water level monitoring system and the integration of the informal roles at the operational level.

Findings indicate that the FEWS knowledge tool is currently unreliable, which can be improved by assigning clear responsibility for the upkeep of the monitoring system within the crisis organization. This includes specifying which measuring points are functional, which are broken, how to fix them or how to arrange an alternative knowledge source, who to contact for issues, and who is accountable for each task. Additionally, the results reveal a weak embedding of relevant informal roles in flood response, particularly among field workers, field managers, and seniors. To preserve their situated knowledge and ensure effective communication between the tactical and operational levels during crises, it is recommended to revise the crisis plans to formally recognize these roles, document their knowledge and actions for operational use, and appoint a designated liaison.

4. Define the desired drought response system by clarifying and reaching consensus on the roles and responsibilities of the Drought Team, the crisis organization, and the involvement of the RDO, by holding internal discussions at WVS.

Unlike flood response, there is no consensus on drought response at WVS. In the current drought response system, the integration between the Drought Team/RDO and the crisis organization is lacking. It is important to discuss how daily management roles integrate with crisis roles, including when to (informally) activate the WOT earlier to ensure a smooth transition, or whether an alternative response strategy should be considered. The advantages of involving operational leaders (OL's), such as their established connections with formal crisis networks, should be considered, including how they can link effectively with the RDO. Additionally, the role of the RDO representative should be defined, specifying the authority of this person, which decisions they are allowed to make, and which decisions remain with the WOT or the Drought Team. All of these aspects should be clearly documented in an updated drought crisis plan to ensure coordinated decision-making, responsibilities across all actors in WVS.

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Appendix

Appendix A – Elements of Management and Transition Framework (MTF)

Table 6 - Elements of MTF. Highlighted elements included within the conceptual framework.

MTF element	Definition (Pahl-Wostl et al., 2010; Pahl-Wostl et al., 2016)	Within study context
Action arena	An issue specific political arena focused on a societal function.	Two action arenas are considered for the water governance system of the Vecht basin: 'flood response system' & 'drought response system'.
Action situation	A structured social interaction context that leads to specific outcomes. 'Action situation' is the regime element where 'actors' take certain 'roles' which entitles them to perform certain actions.	The action situations include the response of actors to flood/drought events in the Vecht basin, encompassing actions such as knowledge transfers, data transfers, and decision-making.
Actor	An individual or collective participant populating an 'action arena'.	The actors involved within the flood/drought response in the Vecht basin.
Role	'Roles' are based on a shared understanding of their meaning and function. 'Roles' belong to the relation 'actor' – 'action situation' and not to the 'actor' in general. 'Roles' entitles 'actors' to perform certain actions.	The roles describe the assigned responsibilities of an actor involved within flood/drought response in the Vecht basin.
Knowledge	Meaningful information and experience. 'Knowledge' is used in an 'action situation'.	Knowledge encompasses data that has been given meaning which is used in the decision making within flood/drought response in the Vecht basin.
Situated knowledge	Personal information used by an 'actor' in an 'action situation'.	Situated knowledge is context-specific knowledge on flood/drought response which an actor holds and draws upon during a knowledge transfer and decision-making.
Evaluation criterion	Criteria an actor uses to evaluate the personal satisfaction with the water system.	Degree of adaptive capacity.
Mental model	An actor's subjective notions about parts of reality.	Flood/drought risk perception.
Operational outcome	Concrete, physical, measurable effects of water management.	Structural and non-structural measures in flood/drought response.

Observed state of water system	How a water system state is perceived and assessed.	The system performance of adaptive governance.
Rule	Rules, norms and codes regulate human behaviour.	Rules that are in place related to flood/drought response.
Institution	Set of rules, decision-making procedures, and programs that define social practices, assign roles to participants in these practices, and guide interactions among the occupants of individual roles.	Institutions shape the interactions of the flood/drought response.
Environmental hazard	Sporadic natural events with fatal impacts	Floods & drought event.
Management paradigm	Dominating frame of the water management issues in a group of actors.	Resistance-focused mindset for flood.
Strategic management goal	General goals in an action arena	Ensure water supply and safety.
Environmental service	The role of ecological system to serve as resource for human beings	Provision of water (general).
Ecological system	Abiotic and biotic components of the water system	The (ground)water bodies in the Vecht basin.
Water system	All environmental and human components	The Vecht basin.
Societal system	The societal context in which the action arenas related to water management are embedded and influenced by	The people living within the Vecht basin.
Technical infrastructure	The infrastructure of relevance for water management issue under concern	Structural measures for flood/drought response.

Appendix B – Data Collection

Table 7 - Data collection overview documents

Documents	
Water Authority Vechtstromen (WVS)	
Code	Document title
[D-V1]	Procesevaluatie Hoogwater Kerst 2023 (12 april 2024)
[D-V2]	Interne evaluatie droogte 2022 (10 maart 2023)
[D-V3]	Calamiteitenbestrijdingsplan Waterkwantiteit (mei 2023)
[D-V4]	Crisisplan Waterschap Vechtstromen 2022-2025 (21 mei 2024)
[D-V5]	Waterbeheerprogramma 2022-2027
[D-V6]	Waterakkoord Twentekanal en Overijsselse Vecht 2025 (14 nov. 2024)
[D-V7]	Jaarverslag LCMS Hoogwater Kerst 2023
[D-V8]	Draaiboek Regionaal Droogte Overleg Twentekanal en Overijsselse Vecht 2025 (11 maart 2025)
[D-V9]	Draaiboek Hoogwater Waterakkoord Meppelerdiep - Overijsselse Vecht (26 mei 2020)
[D-V10]	Draaiboek Hoogwater Noord (juni 2024)
[D-V11]	Memo 'Communicatie regionale verdringingsreeks' (6 aug. 2018)
[D-V12]	Successen en aandachtspunten waterbeheer 2022
[D-V13]	Terugblik op de droogte van 2022 (29 sept. 2022)
[D-V14]	Crisiscommunicatieplan (3 maart 2015)
[D-V15]	Brief 'Klimaat & Droogte' (29 nov. 2022)
[D-V16]	Brief 'Droogte-aanpak 2022' (2 juni 2022)
[D-V17]	Brief 'Hoogwatersituatie Kerst 2023' (1 febr. 2024)
[D-V18]	Brief 'Hoogwater 2023-2024' (16 mei 2024)
[D-V19]	Brief 'Evaluatie hoogwater 2023-2024' (25 maart 2025)
[D-V20]	Memo 'Droogte-aanpak 2022' (16 mei 2022)
[D-V21]	Memo 'Voorbereiding PEILdag 28 september' (27 sept. 2022)
[D-V22]	Netwerkanalyse hoogwater kerst 2023
[D-V23]	Landelijk draaiboek waterverdeling en droogte (30 maart 2021)
Water Authority Drents Overijsselse Delta (WDOD)	
[D-D1]	Crisisplan Waterschap Drents Overijsselse Delta (19 april 2021)
[D-D2]	Brief 'Watertekort 2022; maatregelen in wateraanvoergebied Ankersmit en Eefde' (11 aug. 2022)
Municipality of Hardenberg	
[D-H1]	Memo 'Evaluatie wateroverlast kerst 2023 (9 febr. 2024)
Province of Overijssel	
[D-O1]	Betrokkenheid provincies bij watercrises
[D-O2]	Waarschuwingbericht sector IJssel en Vecht (5 dec. 2024)
Safety Region IJsselland	
[D-S1]	Crisisplan Veiligheidsregio IJsselland 2023-2026 (29 nov. 2022)
National level	
[D-N1]	Landelijk Crisisplan Hoogwater en Overstromingen (25 nov. 2020)
[D-N2]	Nationaal Handboek Crisisbeheersing (december 2022)

[D-N3]	Website Rijksoverheid ‘Veiligheidsregio’s’ https://www.rijksoverheid.nl/onderwerpen/veiligheidsregios-en-crisisbeheersing/veiligheidsregios
[D-N4]	Website Rijkswaterstaat ‘Organisatiestructuur’ https://www.rijkswaterstaat.nl/over-ons/onze-organisatie/organisatiestructuur
[D-N5]	Website Rijksoverheid ‘Waterschappen’ https://www.rijksoverheid.nl/onderwerpen/waterschappen

Table 8 - Data collection overview interviews

Interviews	
Water Authority Vechtstromen (WVS)	
<i>Code</i>	<i>Job Title Interviewee</i>
[I-V1]	Information Coordinator (ICO)
[I-V2]	Water Level Coordinator (PBC) / Tactical Water Level Manager (1)
[I-V3]	Water Level Coordinator (PBC) / Tactical Water Level Manager (2)
[I-V4]	Crisis Control Advisor
[I-V5]	Dike Reeve / Chair WBT
[I-V6]	Operational Leader (OL) / Head of ACW
[I-V7]	Highwater Coordinator (HWC) / Water System Advisor
[I-V8]	Water Systems Coordinator / Water System Advisor
[I-V9]	Member Executive Board
[I-V10]	Hydrologist
[I-V11]	Regional Manager & Senior Vecht
[I-V12]	Regional Manager Regge & Dinkel
[I-V13]	Communication Advisor
Water Authority Drents Overijsselse Delta (WDOD)	
[I-D1]	Hydrology Advisor
Municipality of Hardenberg	
[I-H1]	Duty Officer for Population Care / Policy Officer for Water and Rivers
Province of Overijssel	
[I-O1]	Water Safety and Flood Risk Advisor
Rijkswaterstaat Eastern Netherlands (RWS-ON)	
[I-R1]	Chair RDO
Safety Region IJsselland	
[I-S1]	Operational Leader (OL)

Appendix C – Data Collection Goals for Interviews & Document Analysis

Table 9 - Data collection goals and questions of interviews and document analysis based on MTF elements (continued on next pages)

Element of MTF	Official definition	Reference to definition	Plain language explanation/definition	Element within context study	Type of information - MTF specific	Questions interview	Questions document analysis
Action arena	An issue specific political arena focused on a societal function.	Pahl-Wostl et al. (2010): Analyzing complex water governance regimes: the Management and Transition Framework	The 'action arena' specifies a policy sector of the governance system.	Two action arena's are considered for the water governance system of the Vecht basin (Vechtstroomgebied): 'flood response' & 'drought response'.	Qualitative description of the organizational structure of flood and drought response within the Vecht basin.	AA1 - Authority AA1.1 - Which decisions were you authorized to make in the organizational structure of the response to [event]? AA2 - Effectiveness organizational structure AA2.1 - Are there existing protocols or organizational structures that should be redesigned to manage [event] more effectively (e.g. responsibilities or meetings formalized in protocols, adjustments in crisis plans)	AA3 - Organizational structure AA3.1 - Which organizations and governance levels are formally involved in the response to [event] within the Vecht basin? AA3.2 - What strategic plans or protocols govern the response to [event] and which coordination structures are present? AA3.3 - What recommendations do the evaluation reports of [event] provide regarding changes to organizational structures and protocols?

Action situation	A structured social interaction context that leads to specific outcomes (e.g. 'knowledge'). 'Action situation' is the regime element where 'actors' take certain 'roles' which entitles them to perform certain actions.	Pahl-Wostl et al. (2010): Analyzing complex water governance regimes: the Management and Transition Framework	The 'action situations' comprise the dynamic interactions among involved 'actors' within the 'action arena'.	The action situations include knowledge transfer and data transfer between actors involved in flood/drought response in the Vecht basin.	Qualitative description of the interactions between actors, including the actors involved, the type of situated knowledge/data shared, the timing and nature (formal/informal) of the interaction.	AS1 - Problem context AS1.1 - At what point was [event] considered a situation requiring extra attention? AS1.2 - By who/how were you informed on the [event]? AS1.3 - What were the causes that led to [event] becoming a problem situation? AS1.4 - How did [event] differ from previous events? AS2 - Actions AS2.1 - At which moment did daily management shift to crisis control/extra measures within daily management? AS2.2 - Who were involved in this decision? AS2.3 - Is it clear to you when and why actions for managing [event] were taken, and do you think this happened at the right moment? AS3 - Interactions in practice AS3.1 - Which actors did you actively collaborate with during [event]? AS3.2 - What was the purpose of the interaction? AS3.3 - At which moment during [event] did you interact with these actors? AS3.4 - How did you communicate with these actors (e.g. calling, mail)? AS3.5 - Was the interaction on a formal or informal basis? AS3.6 - How frequent did you interact with these actors during [event]? AS3.7 - Do you miss certain lines of contact with people or organizations before/during [event] and when/why? AS3.8 - Are there any technical, organizational, or communication barriers that limit effective collaboration or the exchange of knowledge/data?	AS4 - Interactions in documentation AS4.1 - Which actors involved in the response to [event] interact with one another and what is the purpose of this interaction? AS4.2 - How are interactions between actors structured, e.g. through (in)formal meetings, platforms, etc? AS4.3 - What decisions were taken during [event], by which actor(s) and when in time? AS4.4 - What recommendations do the evaluation reports of [event] provide regarding changes to (in)formal interactions between actors?
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Actor	An individual or collective participant populating an 'action arena'.	Pahl-Wostl et al. (2010): Analyzing complex water governance regimes: the Management and Transition Framework	'Actors' are individuals or organizations who participate in the 'action situations' of the 'action arena'.	The actors involved within the flood/drought response in the Vecht basin include individuals/teams from the water authority Vechtstromen, WDOD, RWS regions, municipalities, provinces, safety regions and, if relevant, other external parties.	Qualitative description of each actor, including their job title, their role and situated knowledge .	A1 - Job title A1.1 - What was your official job title during daily management A1.2 - What was your official job title in the crisis team? A2 - Identification of actors A2.1 - Do you have any relevant documents or know of contact persons who you believe could be valuable for my research, and whom I could potentially approach for an interview? A3 - Missing actors A3.1 - Are there any actors who were not involved in the response to [event] but should have been?	A4 - Involved actors A4.1 - Which actors are involved during the response to [event]? A4.2 - What recommendations do the evaluation reports of [events] provide regarding changes with respect to involved actors?
Role	'Roles' are based on a shared understanding of their meaning and function. 'Roles' belong to the relation 'actor' – 'action situation' and not to the 'actor' in general. 'Roles' entitles 'actors' to perform certain actions.	Pahl-Wostl et al. (2010): Analyzing complex water governance regimes: the Management and Transition Framework	The 'role' of an 'actor' describes their assigned responsibilities.	The roles describe the assigned responsibilities of an actor involved within flood/drought response in the Vecht basin.	Qualitative description of each actor's responsibilities, both under normal circumstances and during flood/drought events and the corresponding degree of flexibility.	R1 - Responsibilities daily management R1.1 - Can you describe your function in the organization and the associated responsibilities? R2 - Responsibilities and flexibility during event R2.1 - What responsibilities did you have during [event]? R2.2 - How flexible was your role compared to your regular responsibilities while adapting to the changing situation? R2.3 - Who or what determined when your responsibilities should be adjusted? R2.4 - Were the responsibilities concerning [event] formally defined (e.g., in protocols) or informal? R2.5 - Do you feel that the (in)formal nature of the responsibilities helped or hindered effective response during [event]?	R3 - Assigned roles in documentation 3.1 - What is the formal description of an actor's role with regards to responsibilities, both in daily management and during crisis control? 3.2 - What recommendations do the evaluation reports of [event] provide regarding changes to assigned roles of actors?

Knowledge	Meaningful information and experience. 'Knowledge' is used in an 'action situation'.	Pahl-Wostl et al. (2010): Analyzing complex water governance regimes: the Management and Transition Framework	'Knowledge' encompasses data that has been given meaning which is used in 'action situations'.	Knowledge encompasses data that has been given meaning which is used in the decision making within flood/drought response in the Vecht basin.	Qualitative description of the knowledge used in the action situations, including the accessibility and distribution channels, actors who use it and how/why, the data it is based on, and the applied experience from actors.	K1 - Used knowledge K1.1 - Which type of knowledge was used for the decision-making during [event] and for what purpose? K1.2 - What data is the knowledge based on? K1.3 - How was the reliability of this data assessed? K1.4 - To what extent did local experience and judgement play a role alongside objective measurements? K1.5 - Did other organizations use the same knowledge for decision-making, or did they make decisions based on its own sources? K1.6 - Should certain types of knowledge, such as local experience or real-time data, play a bigger role in future decision-making during [event]? K2 - Knowledge accessibility K2.1 - Through which medium was the knowledge shared (e.g verbal or digital platform)? K2.2 - Which actors had access to or made use of the knowledge? K2.3 - Would you prefer that certain knowledge or data be made available in a different, faster, or more centralized way?	K3 - Knowledge in documentation K3.1 - Which knowledge is used in decision-making during [event]? K3.2 - What recommendations do the evaluation reports of [event] provide regarding changes to the accessibility/reliability of knowledge?
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<u>Situated knowledge</u>	Personal information used by an 'actor' in an 'action situation'.	Pahl-Wostl et al. (2016): Introduction to the MTF total system database (V11C)	'Situated knowledge' is context-specific 'knowledge' which an actor holds and draws upon when engaging in 'action situations'.	Situated knowledge is context-specific knowledge on flood/drought response which an actor holds and draws upon during a knowledge transfer and decision-making.	Qualitative description of the situated knowledge of an actor, including the usage in decision-making and knowledge transfers, the data it is based on, and the actor's applied experience.	SK1 - Situated knowledge in decision-making SK1.1 - What knowledge did you use during decision-making during [event], and for what purpose? SK1.2 - Is your knowledge primarily based on data-analysis and/or experience from practice? SK1.3 - Do you think the current protocols or organizational structures allow enough space for your knowledge to influence decisions? SK2 - Situated knowledge in knowledge transfer SK2.1 - What specific knowledge and data did you share with which actors during [event]? SK2.2 - Through which medium was this knowledge and data shared (e.g., digitally or verbally)? SK2.3 - Do you feel that your knowledge was shared effectively with other actors during [event], and what would help to improve this (e.g. platforms, structured collaboration)?	SK3 - Situated knowledge in documentation SK3.1 - What recommendations do the evaluation reports of [event] provide regarding the efficiency in sharing and using situated knowledge?
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Appendix D – Interview Protocol

Information Letter

Dear Mr./Ms. [name]

My name is Elise Holubek, and I am a Master's student in Civil Engineering & Management at the University of Twente. For my graduation project, I am conducting research on governance structures and knowledge exchange during flood and drought events in the Dutch part of the Vecht Basin. This research is supervised by Lisette van der Giessen (Vechtstromen), Joanne Vinke-de Kruijf (UT), and Anicia Touraine-Andersson (UT).

In this research, I focus on the governance of flood and drought, particularly two recent cases: the flood event in the winter of 2023/2024 and the drought in the summer of 2022. I examine who was involved and when, how flexible roles and responsibilities were, what knowledge was shared, when and how an event is perceived as a crisis, and how responsibilities may have shifted.

I am looking for information about these events and people who are willing to participate in an interview of approximately 60–90 minutes. The interview data will help map responsibilities and knowledge exchange between different parties. This contributes to understanding knowledge exchange during such situations and identifying possible areas for improvement.

Via [contact person Vechtstromen], your name was mentioned as someone who might have valuable experience in this field from [organization]. If you are open to a conversation, I would be happy to schedule a suitable time. Your participation will remain anonymous. If you are interested, I can share the research results with you afterward.

Thank you very much for your time and consideration. I look forward to hearing from you.

Sincerely,

Elise Holubek

Structure Interview

1. Introduction (5–10 minutes)
 - Example text:
My name is Elise Holubek, a Master's student in Civil Engineering at the University of Twente. For my graduation research with water authority Vechtstromen, I am studying how parties collaborate and exchange knowledge during the flood event (2023–2024) and drought (2022) in the Dutch part of the Vecht Basin. I would like to better understand who was involved, when, and how, and how roles and knowledge were shared. The aim is to identify any needs or ideas for improvement. The consent form explains how your data will be used. Is it okay if I record this interview so I can process it carefully later?
2. Start recording (max 1 minute)
3. Repeat consent confirmation (for recording)
4. Interview Questions (approx. 75 minutes)
 - General questions will be asked in each interview. If the interviewee was involved in the flood event of 2023, the “flood” questions will be asked. The same applies to the drought of 2022. If they were only involved in one of the two events, a 60-minute interview is planned.
5. Closing (approx. 5 minutes)

Table 10 - Overview of Interview Questions and Guideline Duration

#	Event	Onderwerp	Code Excel sheet	Time (min.)
1	General	Actor / role	A1 – Job title R1 – Responsibilities daily management	3
2	Drought	Action situation	AS1 – Problem context	5
3	Drought	Action arena / action situation	AA2 – Effectiveness organizational structure AS2 – Actions	5
4	Drought	Action arena / actor / role	AA1 – Authority A1 – Job title R2 – Responsibilities and flexibility during event	7
5	Drought	Action situation / actor	AS3 – Interactions in practice A3 – Missing actors SK2 – Situated knowledge in knowledge transfer	10
6	Drought	Knowledge / situated knowledge	K1 – Used knowledge K2 – Knowledge accessibility SK1 – Situated knowledge in decision-making	10
2	Flood	Action situation	AS1 – Problem context	5

3	Flood	Action arena / action situation	AA2 – Effectiveness organizational structure AS2 – Actions	5
4	Flood	Action arena / actor / role	AA1 – Authority A1 – Job title R2 – Responsibilities and flexibility during event	7
5	Flood	Action situation / actor	AS3 – Interactions in practice A3 – Missing actors SK2 – Situated knowledge in knowledge transfer	10
6	Flood	Knowledge / situated knowledge	K1 – Used knowledge K2 – Knowledge accessibility SK1 – Situated knowledge in decision-making	10
7	General	Actor	A2 – Identification of actors	3

Interview Questions

The word [event] should be filled in with the relevant situation (flood 2023/drought 2022).

1. What is your function within the organization, and what are your responsibilities?
 - i. What is your job title in daily management?
 - a. *How long have you been working at the organization (in this role)?*
- *Specifically in 2022/2023?*
 - b. *With which other roles in the organization do you collaborate?*
 - c. *With which other organizations do you collaborate, and how frequently?*
 - d. *Do you primarily contribute to routine processes or to projects?*
2. Could you tell me more about [event]? At what point was [event] considered a situation requiring extra attention?
 - i. How and by whom were you informed about [event]?
 - ii. What were the causes that made [event] a problematic situation?
 - iii. To what extent does [event] differ from previous events?
3. Can you indicate when daily management shifted to crisis escalation / additional measures for [event]?
 - i. Who were involved in making this decision?
 - ii. Was it clear to you when and why this action was taken? Do you think it happened at the right moment?
 - iii. Are there existing protocols or organizational structures that should be redesigned to manage [event] more effectively (e.g., responsibilities formalized in protocols, crisis plan adjustments)?

4. What were your responsibilities during [event]?
 - i. What was your job title within the crisis organization?
 - ii. What decisions were you authorized to make in the response to [event]?
 - iii. How flexible was your role compared to your regular responsibilities while adapting to the changing situation?
 - iv. Who or what determined the adjustment of your responsibilities?
 - a. *Was this change self-initiated or assigned directly?*
 - b. *Did you take on responsibilities or authorities that differed from normal?*
 - v. Were your responsibilities concerning [event] formally defined (e.g., written in protocols) or informal?
 - vi. Do you feel the (in)formal nature of responsibilities helped or hindered effective action during [event]?
 - a. *To what extent were responsibilities clear and flexible enough to respond effectively?*
5. With which parties did you actively collaborate during [event]?
 - i. What was the purpose of the interaction (e.g., seeking/giving advice, coordination)?
 - ii. At what moments during [event] did you interact with them?
 - iii. How did you communicate with these actors (e.g., phone, email)?
 - iv. Was this contact on an formal or informal basis?
 - a. *Was knowledge/data shared based on formal agreements/protocols?*
 - v. How frequent did you have contact with these actors during [event]?
 - vi. What knowledge and data did you share with these parties?
 - vii. Through which medium did you share this knowledge and data (oral/written)?
 - viii. Do you think your knowledge was effectively shared with other actors during [event], and what could help improve this (e.g., platforms, structured collaboration)?
 - ix. Do you miss certain lines of contact with people or organizations before/during [event]? When and why?
 - x. Are there technical, organizational, or communication barriers that limit effective collaboration or the exchange of knowledge/data?
 - xi. Were there parties not involved in [event] that should have been?

6. What knowledge was used to make decisions during [event], and for what purpose (e.g., escalation, extra measures)?
 - i. What data (e.g., measurements) is the knowledge based on?
 - a. *Are fixed thresholds, scenarios, or evaluation frameworks used?*
 - b. *What sources is the data based on (e.g., KNMI)?*
 - ii. How was the reliability of this data assessed?
 - iii. To what extent did local experience or intuition play a role alongside objective data?
 - iv. Did other organizations use the same knowledge for decision-making, or do they rely on their own sources?
 - a. *(e.g., Germany, WDOD, Vechtstromen, municipalities, national level)*
 - v. Should certain types of knowledge, such as local experience or real-time data, play a bigger role in future decision-making for [event]?
 - vi. Through what medium is this knowledge shared (e.g., digital platform, verbal communication)?
 - vii. Which actors have access to or make use of this knowledge?
 - viii. Would you prefer certain knowledge or data to be available in a different, faster, or more centralized way?
 - a. *Was all required knowledge and data available at the right time, or was something missing?*
7. Do you have relevant documents or know of contacts who could be valuable for my research and whom I could approach for an interview?
 - i. *Water authorities*
 - ii. *Safety regions*
 - iii. *Municipalities*
 - iv. *Provinces*
 - v. *Other organizations*

Consent Form (Dutch)

Toestemming dataverzameling en -gebruik

Hartelijk dank voor uw bereidheid om deel te nemen aan het interview over samenwerking en het delen van kennis en informatie tijdens droogte en hoogwater in het Nederlandse deel van het Vechtstroomgebied. Hierbij is bijzondere aandacht voor de extreme situaties die zich voordeden in de zomer van 2022 (droogte) en de winter van 2023/2024 (hoogwater)

Het doel van dit interview is:

1. Inzicht krijgen in het ontstaan van en de eigenschappen van de droogte en/of hoogwater.
2. Inzicht krijgen in de rollen en verantwoordelijkheden van betrokken partijen (governance) tijdens hoogwater en droogte en de flexibiliteit hiervan.
3. Inzicht krijgen in wie met wie contact heeft en welke kennis en informatie wanneer met wie wordt gedeeld.
4. Signaleren van mogelijke verbeterpunten in de governance en uitwisseling van kennis en informatie tussen betrokken partijen en flexibiliteit van rollen tijdens dergelijke crises.

Dit interview is onderdeel van de masterafstudeeropdracht van Elise Holubek, student Civiele Techniek & Management aan de Universiteit Twente, onder begeleiding van Joanne Vinke-de Kruijf (Universiteit Twente), Anicia Touraine Andersson (Universiteit Twente) en Lisette van der Giessen (Waterschap Vechtstromen). Met dit document leggen we de omgang met onderzoeksdata uit en vragen uw **toestemming** voor dataverzameling en -gebruik.

Uw bijdrage bestaat uit de deelname aan dit interview op xxx 2025. Uw deelname is vrijwillig. Het interview dient als dataverzameling voor een **wetenschappelijke publicatie**, waar de data wordt verkregen door middel van audio-opnamen en aantekeningen. Alle gegevens die worden verzameld, bewaard en gebruikt tijdens het onderzoek, worden op een beveiligde manier opgeslagen en zijn alleen toegankelijk voor het onderzoeksteam. Ook na afloop blijven de gegevens vertrouwelijk en op een veilige manier opgeslagen, conform de daarvoor geldende richtlijnen voor wetenschappelijk onderzoek aan Universiteit Twente (zie [GDPR](#)).

Indien u meer over het onderzoek, workshop of datagebruik wilt weten, kunt u contact opnemen met Elise Holubek (e.d.holubek@student.utwente.nl).

Toestemmingsverklaring

Door dit formulier te ondertekenen verklaar ik het volgende. Ik heb de informatie gelezen, ik begrijp wat het doel van het onderzoek is en ik sta toe dat er onderzoeksdata van mij zullen worden verzameld. Het onderzoek is duidelijk aan mij uitgelegd en ik kreeg de gelegenheid vragen te stellen.

1.	Ik begrijp dat deelname aan dit onderzoek geheel vrijwillig is.	Ja ☐
2.	Ik geef toestemming dat de data gebruikt zullen worden in publicaties.	Ja ☐ / nee ☐
3.	Ik begrijp dat rollen en functies van de organisatie benoemd kunnen worden in de publicatie, ondanks de anonimisering van de data.	Ja ☐
4.	Ik geef toestemming voor het opslaan en het gebruik van de onderzoeksgegevens die tijdens het interview worden verzameld, voor publicaties door het onderzoeksteam.	Ja ☐ / nee ☐
5.	Ik geef toestemming dat mijn gegevens in overeenstemming met het GDPR zullen worden behandeld, opgeslagen en gebruikt in wetenschappelijke publicaties.	Ja ☐ / nee ☐

Naam van de deelnemer:

Handtekening van de deelnemer:

Datum:

Appendix E – Coding Tree of the Thematic Analysis

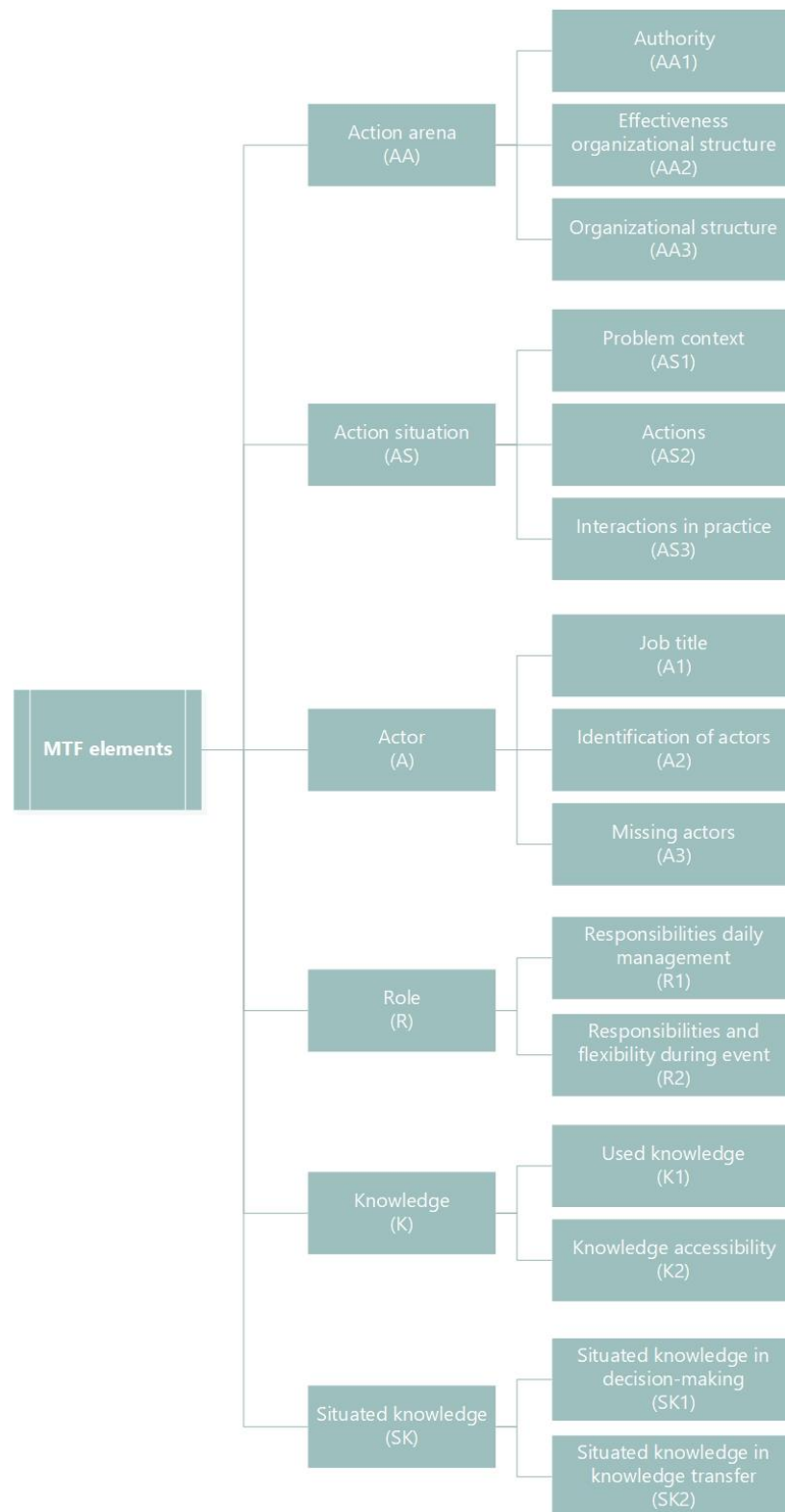


Figure 17 - Coding tree based on MTF elements and interview questions

Appendix F – Details on Dialogue Session (Validation Step)

When: 08-09-2025, 10.30-12.00

Where: office water authority Vechtstromen, Almelo

Invited actors: all interviewees, 34 in total (coded interviews + exploratory interviews)

Actors present and their role: 8 in total

9. WVS Highwater Coordinator / Water System Advisor [I-V7]
10. WVS Senior Vecht [I-V11]
11. WVS Regional Manager Regge [I-V12]
12. WVS Crisis Control Advisor [I-V4]
13. WVS Strategic Advisor #1 [exploratory interview]
14. WVS Strategic Advisor #2 [exploratory interview]
15. WVS Theme Leader Water Quality [exploratory interview]
16. WVS Water System Advisor [exploratory interview]

Timetable:

- 5-10 minutes walk-in
- 15-20 minutes presentation
- 45-55 minutes discussion recommendations
- 10-15 minutes voting and closing

Voting results for recommendation priorities

Table 11 - Results of voting during dialogue session

<i>Recommendation</i>	<i># votes for top two priorities*</i>	<i># votes for top one priority</i>
Revision crisis plans flood response: informal roles and FEWS	4	2
Development dynamic knowledge tool	5	3
Internal discussion drought response system	3	0
Scenario-thinking engagement external organizations in Vecht basin	3	3

* One actor voted once instead of twice

Summary of Dialogue Session

The recommendations were discussed during a dialogue session at water authority Vechtstromen with several interviewees. Overall, the participants agreed with all four recommendations and considered them important. However, discussions focused on their implementation order and practical feasibility:

Interrelation and sequence

While all recommendations were valued, participants emphasized that implementation should follow a logical order. For example, developing the dynamic knowledge tool first requires a basin-wide scenario analysis to determine which knowledge provision is needed. Similarly, the updating of crisis plans and revision of drought response system should also build on insights from scenario-thinking to define the required responses.

Feasibility dynamic knowledge tool

Opinions varied on the feasibility of developing the dynamic knowledge tool. Some participants noted that the development of similar tools had failed in the past, while others highlighted opportunities offered by artificial intelligence (AI). For example, WDOD has tested an AI-based system that provides tailored and actionable information from crisis plans. A comparable tool called GDH was developed in 2005 to provide water level warnings and recommend appropriate actions, but this was lost following the merger of water authorities. Concerns were raised about over-reliance on technology, but participants agreed that the tool could be valuable if used to complement, rather than replace, critical thinking and field knowledge.

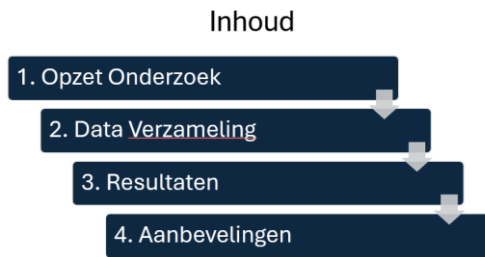
Feasibility incorporating informal roles

Participants agreed on the need to incorporate informal operational roles into revised flood response plans, but the implementation approach remains unclear. They highlighted inadequate communication and knowledge transfer between the operational and tactical levels as a main problem and emphasized the importance of establishing a formal connection, such as appointing a liaison from the operational field. Additionally, participants stressed the need for clear documentation of responsibilities and related actions at the basin-wide level.

Challenges of drought response

The participants highlighted the challenge of defining drought and determining the appropriate response, especially under pressures from national authorities (LCW) and the media. Despite this, the revision of drought plans was rated as the least important among the recommendations, likely because it is the most difficult to initiate.

PowerPoint slides



1. Opzet Onderzoek

• Onderzoeksvraag:

Hoe passen actoren in het Vechtstroomgebied hun **rollen** en **kennis** toe bij droogte en hoogwater, en hoe kunnen responsen **adaptiever** worden gemaakt?

• Scope: Nederlandse deel van het Vechtstroomgebied



2. Data Verzameling

Case Studies
• Hoogwater Kient 2023/24 • Droogte 2022
Interviews
• 18 interviews • WVS • WOCOD • Gemeente Harderberg • Provincie Overijssel • Rijkswaterstaat ON • Veiligheidsregio IJsselland
Documenten
• Crisisplannen • Evaluaties • Etc.

4

3. Resultaten - Hoogwater

1. Verschillen in **activatie crisisorganisatie** door uiteenlopende **risicopercepties** van hoogwater
 2. **Zwakke verankering** van **relevante informele rollen** in de crisisorganisatie
 3. **Beperkte betrouwbaarheid** en **onduidelijke verantwoordelijkheden** bij het beheren van het **meetpuntenstelsel** van FEWS
 4. **Statische kennisinstrumenten** beperken tijdige en relevante kennis
- 5

4. Aanbevelingen

1. Herzie de **crisisplannen** voor hoogwaterrespons om **verantwoordelijkheden** duidelijk vast te leggen, inclusief zowel het onderhoud van het **meetnetstelsel** als de integratie van **informele rollen** op operationeel niveau
 2. Ontwikkel een **dynamisch kennisvoorzieningsinstrument** met real-time data om interne teams en externe organisaties van **op maat gemaakte en bruikbare kennis** te voorzien
 3. Organiseer een **interne discussie** over het gewenste **droogteresponsstelsel** bij WVS om de **rollen en verantwoordelijkheden** van het Droogteteam, de crisisorganisatie en de betrokkenheid van de RDO te verduidelijken, en **consensus** te bereiken over hoe het stelsel zou moeten functioneren.
 4. Betrek waterschappen, RWS-regio's, provincies, veiligheidsregio's en gemeenten bij **scenario-denken** over hoogwater- en droogterespons om **rollen, verantwoordelijkheden en verwachtingen** te verduidelijken.
- 7

3. Resultaten - Droogte

1. Afwezigheid van een **goed ingebed en duidelijk droogteresponsstelsel** bij WVS

2. **Onduidelijke rollen en bevoegdheden** in regionale droogteoverleggen (**RDO**)

3. **Verschillende definities** van droogte zorgen voor kloof tussen **perceptie en respons**

4. Aanbevelingen

Welke **twee aanbevelingen** hebben de hoogste noodzaak om als eerste opgepakt te worden?

1. Crisisplannen hoogwaterrespons: informele rollen en FEWS
 2. Dynamisch kennisvoorzieningsinstrument
 3. Interne discussie droogteresponsstelsel voor consensus
 4. Verduidelijking verantwoordelijkheden/verwachtingen bij externe organisaties
- 8

Appendix G – Description GRIP Crisis Teams

Up to and including GRIP 3, the crisis teams can operate simultaneously alongside one another. For example, if GRIP 3 is initiated, CoPi, ROT and GBT may all be activated and working in a coordinated manner. However, once upscaling occurs from GRIP 3 to GRIP 4, the GBT is phased out and replaced by the RBT within the crisis organization.

While all safety regions structure their crisis control plans around the GRIP system, the composition of each specific crisis team may vary slightly. The role of the crisis team leaders (LC, OL, Mayor and Vz Vr) remain consistent across all safety regions. A short description of each crisis team in relation to the GRIP phases is given below [I-S1; D-V4; D-S1; D-N1; D-N2; D-N3].

GRIP 0 – No crisis team

At **GRIP 0**, municipalities and/or water authorities manage incidents independently within daily management. The safety region is not required to activate the crisis organization with the GRIP escalation system to deliver support.

GRIP 1 – On-site Command Post (CoPi)

At **GRIP 1**, the crisis can be managed at the incident location itself, with the help of operational services such as police or fire brigade, coordinated by the On-site Command Post (**CoPi**) under the leadership of the Leader CoPi (**LC**) [I-S1; D-S1].

GRIP 2 – Regional Operational Team (ROT)

From **GRIP 2** onwards, the crisis extends beyond the incident site, and additional support and substantive advice are needed for the CoPi. At this point, the Regional Operational Team (**ROT**) is activated and operates from the designated office location, where the Operational Leader (**OL**) takes on an active coordinating role. This includes direct contact with other OLs from municipalities and water authorities, especially when those crisis roles are also activated. The OL ensures alignment of actions across organizational boundaries during a crisis [I-V4; -V6; I-V7; I-S1; D-S1; D-V3; D-V4].

GRIP 3 – Municipal Governance Team (GBT)

If the crisis escalates further, the mayor, who holds responsibility for the safety of the population within the municipality, may need to respond directly. This leads to the activation of **GRIP 3**, during which the Municipal Governance Team (**GBT**) is formed and chaired by the **mayor**, marking a shift toward a governance-level escalation [I-S1; D-S1].

GRIP 4 – Regional Governance Team (RBT)

When the crisis affects multiple municipalities within the same safety region, **GRIP 4** is activated. The Chair Safety Region (**Vz Vr**) then takes over leadership of the Regional Governance Team (**RBT**). While the OL continues to lead the ROT, final decision-making and accountability rest with the Vz Vr during GRIP 4 [I-S1; D-S1].



GRIP 5 – Multiple RBTs

In the case of **GRIP 5**, multiple Regional Governance Teams (**RBTs**) from different safety regions are involved due to the transboundary nature of the crisis. One Chair Safety Region (**Vz Vr**) is then designated to act as coordinating chair [I-S1; D-S1].

Appendix H – Description WVS Crisis Teams

Phase 0 – No crisis team

During **Phase 0**, the water authority can handle everything within its daily management, without the need to scale up to the crisis organization.

Phase 1 - Fieldteam

In **Phase 1**, the CoPi is translated as the **Fieldteam** and is led by the **Head of Field** at the operational level. Similar to the GRIP structure, Phase 1 involves a localized incident, such as a local power failure caused by highwater. The Fieldteam functions as an operational service, coordinating field actions in response to these incidents. Since the issue is site-specific and manageable at the location, no tactical-level involvement is required. In the context of flood response, the impact area of flood risk is typically broader than a single local incident. As a result, the situation is often immediately scaled up to Phase 2. Nevertheless, the Fieldteam may still be deployed to handle localized incidents. Furthermore, it is important to note that the Fieldteam serves as a crisis response team and does not handle day-to-day field operations. Daily field management remains the responsibility of the field managers, who are not formally part of the crisis organization [I-V6; I-V12; I-V13; D-V3; D-V4].

Phase 2 – Water Authority Operational Team (WOT)

In **Phase 2**, the ROT is translated into Water Authority Operational Team (**WOT**), also led by the Operational Leader (**OL**). WOT serves as the decision-making body at the tactical level and is responsible for managing the effects of the crisis. WOT brings together multiple disciplines within WVS to create a shared situational picture of the water system and initiates coordinated response actions. While the Fieldteam operates directly in the field, WOT is based at the main office of WVS and holds official WOT meetings, typically twice a day, once Phase 2 has been initiated. Additionally, an informal Phase 2, called a ‘potential’ Phase 2, may be activated at the first signs of flood risk to initiate early knowledge transfers and facilitate a smoother transition from daily management to crisis organization [I-V2; I-V8; I-V13; D-V3; D-V4].

Phase 3 – Water Authority Governance Team (WBT)

When flood risk poses a serious threat that disrupts public safety within WVS’s jurisdiction, **Phase 3** is initiated. In Phase 3, the Water Authority Governance Team (**WBT**) is activated, operating at the strategic level and involving policymakers. The WBT is chaired by the Chair Water Authority (Dutch: Watergraaf), who holds the crisis role of **Chair WBT** and leads the team. WBT serves as the ultimate decision-making body within the crisis organization, determining the overall strategy for managing crisis response and representing WVS from a strategic perspective. Formally, the Chair Water Authority becomes involved only in Phase 3. However, to engage the Chair earlier, a ‘potential’ Phase 3 may be initiated, allowing an informal WBT to convene. In this informal WBT, led by the Chair Water Authority acting as the informal Chair WBT, knowledge exchange can take place. No official decisions can be made during this informal meeting. If decision-making is required, a formal WBT must be established [I-V4; I-V5; I-V13; D-V3; D-V4].

Phase 4 – Multiple WBT's

Scaling up from Phase 3 to **Phase 4** occurs when the flood risk, which disrupts public safety, extends beyond the jurisdiction area of WVS. In Phase 4, **multiple WBTs** and their **Chairs WBT** from different water authorities meet to make joint decisions concerning the broader affected area [D-V3; D-V4; D-D1]

Phase 1, 2, 3, 4 – Action Center Water (ACW)

In addition to the three main crisis teams, WVS also established the Action Center Water (**ACW**), active in **Phase 1 up until Phase 4**. The ACW functions as the back office of the crisis organization, coordinated by the **Head of ACW**. It supports the Fieldteam, WOT and WBT by providing subject-matter expertise and developing crisis scenarios. The ACW is a network of experts, such as hydrologists and GIS specialists, who are mobilized as needed. Typically, ACW meetings follow immediately after WOT meetings, allowing actions and questions raised in the WOT to be directly translated into tasks within the ACW [I-V8; I-V13; D-V3; D-V4].

WDOD Crisis Teams

The same escalation system as WVS is applied at WDOD, with a similar foundation based on GRIP. A key difference is the setup of the Action Center Water (ACW), a physical space at WDOD where an entire floor is dedicated to crisis control. In addition to ACW, the Water Action Team (WAT) is established during flood response. The ACW is the physical location, while the WAT refers to the meeting associated with it. Both ACW and WAT are involved in all Phases of the crisis [I-D1; D-D1].

Appendix I – Responsibilities of Organizations in Flood Response System

Water Authorities

The water authorities are public authorities responsible for water management within a defined region, each represented by a Chair Water Authority (Dutch: Watergraaf). There are 21 water authorities in total across the Netherlands (see Appendix O). In the context of flood response, they are responsible for protecting their area against (potential) flooding. This involves both an operational role, such as monitoring hydraulic structures during flood events and implementing flood risk management measures, as well as a knowledge-sharing role. As part of their knowledge-sharing role, water authorities are expected to issue warnings and/or advice to relevant stakeholders, ranging from local actors, such as municipalities and neighboring water authorities, to regional and national parties, including RWS regions, provinces, and WMCN. Communication with these partners may take place through LCMS. Two water authorities operate within the Vecht basin: Waterschap Vechtstromen (WVS) and Waterschap Drents Overijsselse Delta (WDOD) [D-V4; D-D1; D-N1; D-N5].

Municipalities

When flood risk arises in the Vecht basin, municipalities may also be affected at the local level. While they are not directly responsible for flood risk management, they can face threats to public safety and damage to property. Like water authorities, they have crisis plans based on the GRIP escalation system to ensure coordination with the safety region and water authorities via the established connections between operational leaders (OL's) [I-H1; I-V4; I-V6; I-V7; I-S1; D-S1].

In the Vecht basin, municipal involvement varies depending on the flood event's impact and geographical features. For example, municipality of Hardenberg has several retention areas within their jurisdiction, like Heemsermarspark, Noord-Meene, and Zuid-Meene, that help control excess water. These areas may fill automatically or require preparation, with the mayor deciding on activation and evacuation in coordination with water authorities [I-V4; I-V5; I-V6; I-H1].

Safety Regions

In general, crises are managed by safety regions. The Netherlands is divided into 25 safety regions, as shown in the map of Appendix M. The safety regions are responsible for preparing for disasters through the development of a regional crisis plan, as well as for coordinating and delivering operation assistance during crises. The regional crisis plans are based on GRIP escalation system [D-S1; D-N1; D-N2; D-N3].

If local flood risk in the Vecht basin becomes severe enough that municipalities and/or water authorities need additional support, the safety regions step in. The safety regions covering the Vecht basin are IJsselland, Twente, and Drenthe. A very small part of North- and East Gelderland is also within the study area but is excluded due to its limited size. Safety regions assist water authorities and municipalities with operational tasks such as evacuations and damage repair. They also play a key role in coordination and knowledge sharing, for example, by providing municipalities access to knowledge systems like LCMS [I-V4; I-S1; D-N1; D-S1].

Rijkswaterstaat Regions (RWS Regions)

Not all hydraulic structures within the jurisdiction of water authorities are managed by the water authorities themselves, some fall under the jurisdiction of Rijkswaterstaat (RWS) regions. RWS is a government agency responsible for flood protection, organized into seven regional departments called RWS regions (see Appendix N). Within the Vecht basin, two RWS regions are active: Rijkswaterstaat Eastern Netherlands (RWS-ON) and Rijkswaterstaat Northern Netherlands (RWS-NN) [I-R1; D-N1; D-N4].

At the operational level, RWS field workers coordinate informally with water authorities WDOD and WVS, especially regarding the management of hydraulic structures when flood risk occurs. These collaborations do not require activating the formal crisis organization. At the tactical level, RWS regions focus on flood risk management by monitoring water levels, providing forecasts, and supporting water authorities and municipalities with situational awareness. They also monitor broader developments that may affect areas beyond the Vecht basin. For example, RWS-ON tracks inflows from the Twente canals influencing the IJssel and IJsselmeer. To do this, they use the same knowledge systems as water authorities, such as the water level monitoring network incorporated in FEWS. Despite these involvements, RWS involvement does not directly influence formal flood response decisions within the Vecht basin [I-V10; I-V11; I-V12; I-D1; I-R1; D-N4].

Provinces

Similar to RWS regions, provinces may be responsible for the operation of certain hydraulic structures, such as locks and sluices. The Vecht basin mainly falls within the provinces of Overijssel and Drenthe, with a small part of Gelderland which is excluded from this analysis due to its limited size [I-O1; D-N2].

Provinces do not have dedicated crisis teams, but they are involved in flood response at three levels. At the operational level, they manage hydraulic structures under their authority, including during flood risk situations. At the strategic level, they monitor the situation through *Warning Notifications* from WMCN about rising water levels and potential exceedances, informing field workers like sluice operators. At the highest administrative level, provinces may take on a crisis role if the Ministry of Justice and Security activates the national GRIP escalation system, although this is rare for flood events [I-O1; D-O1; D-O2; D-N2].

Overall, provinces play a limited and mostly indirect role in flood response. They lack a formal mandate within the Vecht basin's flood response system and are not formally integrated into the crisis teams of WDOD and WVS [I-O1; D-O1].

Water Management Center Netherlands (WMCN)

If required, local and regional organizations in the Vecht basin can make use of support on flood risk management from a national level. The Water Management Center Netherlands (WMCN) is a partnership of Rijkswaterstaat, KNMI, the water authorities, and the Ministry of Defence. Its role is to provide daily knowledge on the Dutch water system to safety regions, RWS regions, provinces, and water authorities. When flood risk is expected, WMCN can issue *Warning Notifications* or scale up to the National Flood Risk Coordination Committee (WMCN-LCO) [I-O1; D-N1].

WMCN-LCO is activated in case of high flood risk and uses a four-stage color code to indicate the perceived risk of the crisis situation (see Table 12). An orange code, or multiple yellow codes across regions, triggers the activation of LCO. These codes help regional and local organizations assess flood risk levels and consider appropriate actions. However, water authorities WVS and WDOD rely on their own local monitoring and crisis escalation system, which assess flood risk at a finer scale. In the Vecht basin, provinces rely more on WMCN(-LCO) at the national level because they are not directly connected to the local GRIP system used collectively by water authorities, municipalities and safety regions [I-V8; I-D1; I-O1; D-N1].

Table 12 - Color coding for flood risk from 'National Crisisplan Highwater and Floods' [D-N1]

Green Code Daily water management.
Yellow Code Water levels are (expected to be) elevated in some areas. Water managers take standard measures. Functions that use or are located near water, such as shipping and activities in floodplains or other outer dike areas, may be limited.
Orange Code The threat of highwater is (expected to) increase. Water managers take further measures. If necessary, large-scale measures are prepared. Use of and access to water may be restricted. Minor damage and water-related disruptions may occur.
Red Code A severe and exceptional situation in the water system is (expected). Large-scale emergency measures may be taken. Damage may occur. National safety may be at risk.

German Water Authorities

Flood risks can extend beyond national boundaries. Due to the transboundary nature of the Vecht basin, which spans both German and Dutch territory, effective flood response requires cross-border collaboration. In Germany, a different crisis response system is in place, which is not aligned with the crisis structure used in the Netherlands. When flood risk occurs, communication is maintained via the appointed Highwater Coordinator (HWC) at WVS, who serves as the single formal contact point for the German counterparts. The HWC reports directly to the WOT in WVS [I-V2; I-V4; I-V7; I-V10; D-V3; D-V4].

Appendix J – Description Actor's Formal Roles Safety Region IJsselland

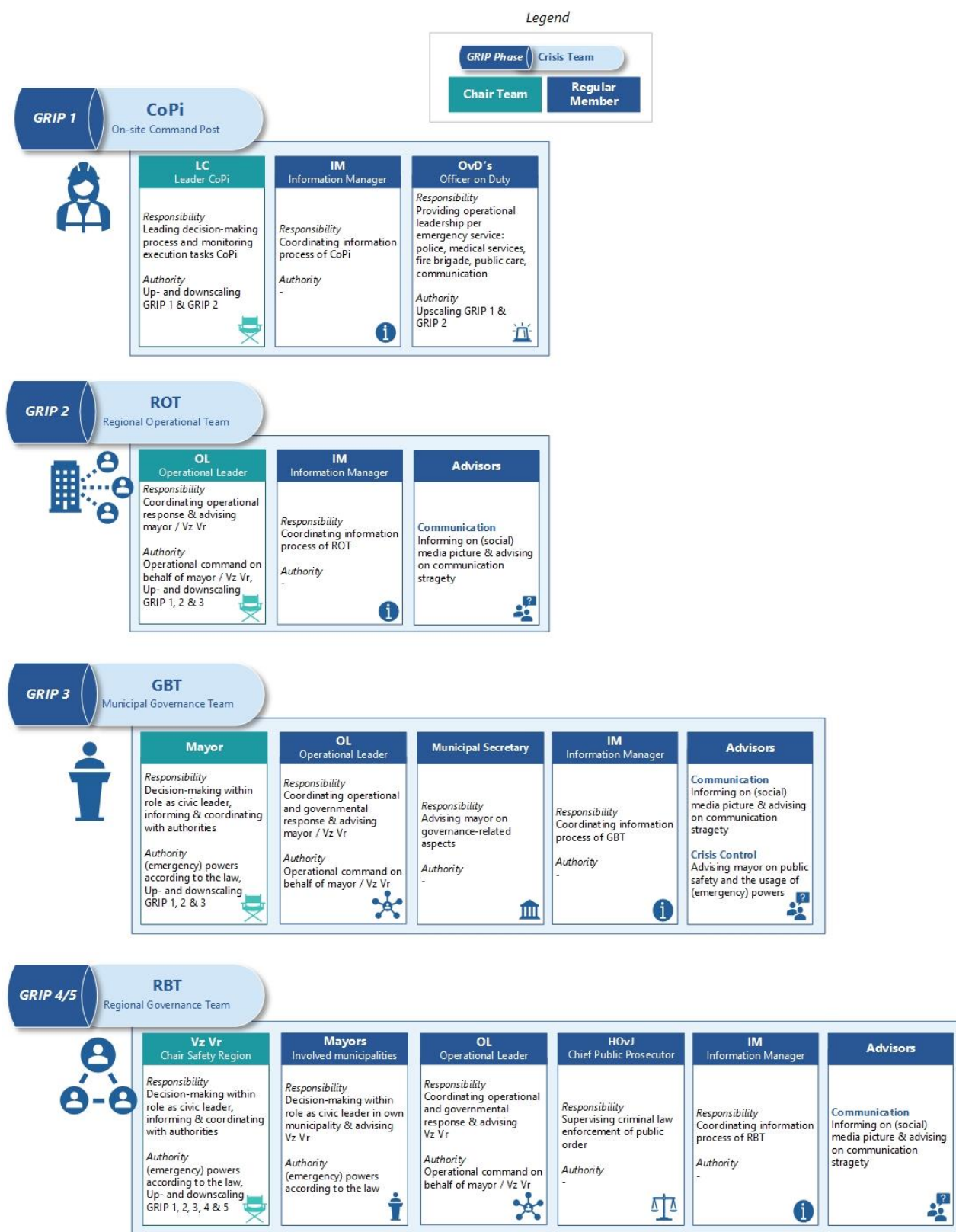


Figure 18 - Safety Region IJsselland actor's formal roles in crisis teams: responsibility and authority [I-S1; D-V4; D-S1]

Appendix K – Details on TPI's & Water Allocation Hierarchy

Temporary Pump Installations (TPI's)

Temporary Pump Installations (TPI's) are emergency pumping systems used to maintain water levels in the Twentekanalen during periods of hydrological drought. They become necessary when the water level in the IJssel drops below NAP +3.00 m near sluice complex Eefde, significantly reducing the functionality of the regular pumping stations. In such cases, TPI's are installed to ensure continued water supply to the eastern Netherlands. There are three TPI configurations, TPI 1, TPI 2, and TPI 3, brought into operation sequentially depending on the severity of the drought. TPI 1 and 2 are considered standard emergency measures and are used more frequently, with approval from all representatives decided within RDO-TK [I-V2; I-V3; I-V4; I-R1; D-V8].

TPI 3, however, involves significantly higher costs and logistical complexity. Because of this, the installation of TPI 3 requires formal approval from a higher level within the organizations represented in Regional Drought Meeting Twentekanalen (RDO-TK), including consultation at the tactical or strategic level [I-V2; I-V3; I-V4; I-R1; D-V8].

Water Allocation Hierarchy

The Water Allocation Hierarchy (Dutch: verdringingsreeks) is a legally established system that prioritizes the distribution of available surface water during hydrological droughts. It guides authorities on which water uses are most important when there is a water shortage. The *national* Water Allocation Hierarchy (see Table 13), coordinated by the National Committee Water Distribution (LCW), has four main categories, with essential functions like safety and drinking water at the top two categories. Categories 3 and 4, covering economic and environmental uses, can be further specified regionally through provincial regulations. Within RDO-TK, these regional priorities are discussed and agreed upon. If LCW scales up and enforces the *national* Water Allocation Hierarchy to reduce water use at Eefde, RDO-TK must comply. However, RDOs can apply the *regional* Hierarchy independently, even without national activation by LCW. While RDO-TK is not required to scale up when the national or regional Water Allocation Hierarchy is activated, it is customary [I-V3; I-V4; I-V7; I-V8; I-D1; I-R1; D-V8; D-V11; D-V23].

Table 13 - National Water Allocation Hierarchy [D-V23]

Category 1	Category 2	Category 3	Category 4
Safety and prevention of irreversible damage 7. Stability of flood defences 8. Prevention of subsidence and settlement 9. Nature, insofar as it concerns irreversible damage	Utility services (regarding supply security) 10. Drinking water supply 11. Energy supply	Small-scale high-quality use 12. Temporary irrigation of capital-intensive crops 13. Processing of industrial process water	Other interests (economic considerations, including nature) 14. Shipping 15. Agriculture 16. Nature (no irreversible damage) 17. Industry 18. Water recreation 19. Inland fisheries 20. Drinking water supply (other than cat. 2) 21. Energy supply (other than cat. 3) 22. Other interests
<i>Has priority over</i> →	<i>Has priority over</i> →	<i>Has priority over</i> →	

Appendix L – Responsibilities of Organizations in RDO-TK

Water Authorities

In the context of drought response, it is the responsibility of water authorities to ensure water quantity: to maintain a sufficient amount of water to fulfill the water demand. This responsibility can be challenged during water shortages, which occur when water demand exceeds supply. A water shortage can be a result of a drought event. Water authorities are structured to address this locally, either through crisis organization and/or within daily management, and they also operate at the regional level by participating in Regional Drought Meetings (RDO's) [D-V4; D-V8; D-N5]. Two water authorities present in RDO-TK operate within the Vecht basin: Water Authority Vechtstromen (WVS) and Water Authority Drents Overijsselse Delta (WDOD). While Water Authority Rijn en IJssel (WRIJ) also participates in RDO Twentekanalen (RDO-TK), it is not addressed here, as it lies outside the geographical scope. However, it is important to note that there is some level of cooperation with WRIJ, for example through RDO-TK. [D-V4; D-V8; D-N5].

RWS Regions

In RDO-TK, Rijkswaterstaat Eastern Netherlands (RWS-ON) plays an important role as the chair member. The sluice complex at Eefde, managed by RWS-ON, is one of the key topics for joint decision-making within RDO-TK. This responsibility makes RWS-ON a relevant actor in drought response in the Vecht basin [I-V2; I-V3; I-V7; I-V8; I-D1; I-R1; I-O1; D-V8].

Provinces

The two provinces who are taking part in RDO-TK in the Vecht basin are Overijssel and Drenthe. Their primary role is external, through participation in RDO-TK, but internally they may coordinate on potential impacts of drought measures, such as the application of the Water Allocation Hierarchy. Operationally, their role is limited: while they manage a small number of sluice complexes, such as Overijssel's management of the sluice at Almelo-De Haandrik, most drought response actions are carried out by the water authorities [I-O1; I-R1; D-V8; D-V23].

Drinking Water Sector

In the Vecht basin, drinking water company Vitens participates in the RDO-TK mainly to ensure that their water intake points continue to operate reliably. Since Vitens participates mainly to represent its interests rather than to make decisions, its role in drought response within the Vecht basin is limited. Nevertheless, Vitens remains an important organization to consider when implementing drought measures, as drinking water supply holds a high priority in the Water Allocation Hierarchy [I-R1; I-D1; D-V8; D-V23].

National Coordination Committee Water Distribution (WMCN-LCW)

The RDO-TK is also connected with the national level via the Water Management Center Netherlands (WMCN). In addition to its role in flood response, WMCN also includes a dedicated department for drought response: the National Committee Water Distribution (LCW). The key role of the LCW is to provide updates to water authorities and provinces on drought developments. The LCW issues national warnings about the severity of drought [I-V2; I-V7; I-R1; I-O1; D-V8; D-V23; D-N1].

Appendix M – Safety Regions in the Netherlands



Figure 19 - Safety regions in the Netherlands. Retrieved from Rijksoverheid, Veiligheidsregio's, <https://www.rijksoverheid.nl/onderwerpen/veiligheidsregios-en-crisisbeheersing/veiligheidsregios>

Appendix N – RWS Regions in the Netherlands



Figure 20 - RWS regions in the Netherlands. Retrieved from Rijkswaterstaat, <https://www.rijkswaterstaat.nl/over-ons/onze-organisatie/groot-onderhoud>

Appendix O – Water Authorities in the Netherlands

UNIE VAN WATERSCHAPPEN

LEGENDA

1. Waterschap Aa en Maas
2. Waterschap Amstel, Gooi en Vecht
3. Waterschap Brabantse Delta
4. Hoogheemraadschap van Delfland
5. Waterschap De Dommel
6. Waterschap Drents Overijsselse Delta
7. Wetterskip Fryslân
8. Hoogheemraadschap Hollands Noorderkwartier
9. Waterschap Hollandse Delta
10. Waterschap Hunze en Aa's
11. Waterschap Limburg
12. Waterschap Noorderzijlvest
13. Waterschap Rijn en IJssel
14. Hoogheemraadschap van Rijnland
15. Waterschap Rivierenland
16. Waterschap Scheldestromen
17. Hoogheemraadschap van Schieland en de Krimpenerwaard
18. Hoogheemraadschap De Stichtse Rijnlanden
19. Waterschap Vallei en Veluwe
20. Waterschap Vechtstromen
21. Waterschap Zuiderzeeland

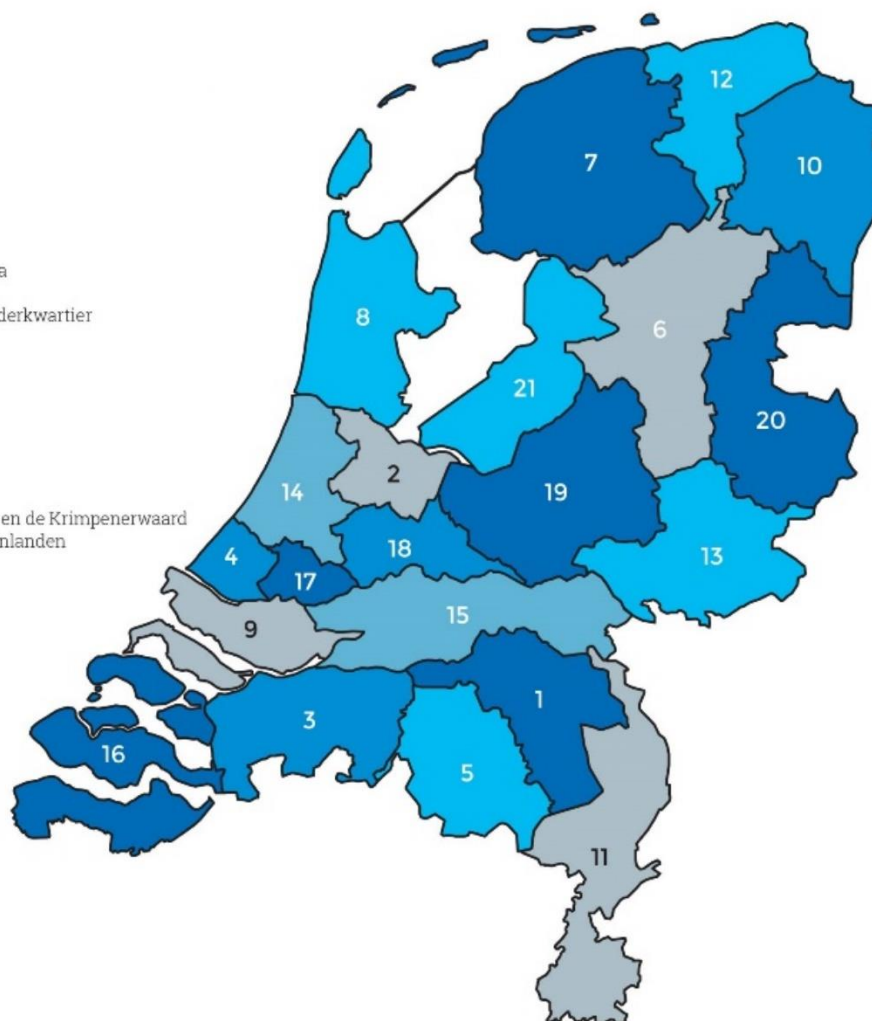


Figure 21 – Water authorities in the Netherlands. Retrieved from Unie van Waterschappen, <https://unievanwaterschappen.nl/publicaties/waterschapskaart/>

Appendix P – RDO Regions in the Netherlands



Figure 22 - Water authorities in the Netherlands. Retrieved from 'Landelijk draaiboek waterverdeling en droogte' [D-V23]