Practising Adaptive IWRM (Integrated Water Resources Management) in South Africa

Report to the
Water Research Commission

by

CG Palmer and V Munnik
Rhodes University

in collaboration with
D du Toit[2], KH Rogers[3], S Pollard[2], N Hamer[1], M Weaver[1], H Retief[1], A Sahula[1], JH O'Keeffe[1]

[1]Rhodes University, [2]AWARD, [3]University of the Witwatersrand

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Water Research Commission
Private Bag X03
GEZINA 0031

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The publication of this report emanates from a project titled *Water Resources Management in South Africa: Towards Practising a New Paradigm* (WRC Project No. K5/2248).

In addition to this report, 9 accessible Adaptive IWRM: "How to…." handbooks have been produced. They are also available as individual publications (WRC Reports SP 116/18-124/18) that can be ordered or downloaded from the addresses mentioned above.

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EXECUTIVE SUMMARY

Urgent necessity for the project

Integrated Water Resource Management (IWRM) has largely failed in South Africa since it was first embedded in law (National Water Act (NWA), No 36 of 1998) and policy (the first democratic National Water Policy, 1997). It is most specifically the practice of **integration** that is so difficult. We still work persistently in silos. The core goals for IWRM in South Africa, stated in the NWA, of equity, sustainability and efficient use, have therefore frequently not been met.

However, since the 1990s, a literature emerged, that indicated practical integration, and progress towards the core goals **could** be achieved using a set of "new" concepts. This set of concepts was sufficiently different from the traditional linear and top-down approach to IWRM, to be called "a new paradigm" for IWRM by the WRC. Early WRC research and practice in the South African National Parks (SANParks) and the Inkomati-Usuthu Catchment Management Agency (IUCMA) was promising and guided this project.

The challenge was to demonstrate that the practice of new concepts will result in effective IWRM.

Outcome Recommendation:
Adopt **Adaptive** IWRM practice, based on **Adaptive IWRM** principles

This demonstration was required in a wider range of case studies, addressing specific intractable problems, to provide **confidence** that new practice could be encouraged and actioned nationally in South Africa.

The success of the research can and should strongly influence the content and direction of new legislation and the next National Water Resource Strategy.

Failure of strong uptake will mean retention of old practices that have resulted in over-allocation and over-use of water; deterioration of water resource health, instream flows and water quality; human health issues related to microbial and other pollution; eutrophication; and water insecurity.

This project recommends the use of the term **Adaptive IWRM** to signify the new approach and practice. The results provide clear, positive evidence that investment in further research into, and related practice of, Adaptive IWRM is essential. The project is referred to in the text as TPNP: towards practising a new paradigm. The new practice is Adaptive IWRM.

OBJECTIVES AND AIMS

AIM 1: To conduct a workshop in which (i) the project philosophy, conceptual framework, methodologies and processes are discussed and a shared understanding achieved with the WRC and within the project team; and (ii) transdisciplinary practice is initiated.

AIM 2: To co-ordinate the development of component case study research plans that demonstrate integration of focus areas (resource protection, eutrophication, and microbial pollution); attention to bio-physical and institutional scale; community engagement in a "water for dignity" process; and the use of integrative, systemic methodologies.

AIM 3: To clearly link the theoretical, conceptual framework to a specific set of methodologies across the case studies, so as to lay a foundation for the development of robust

transdisciplinary scholarship and practice, and to explore a richer understanding of "integration".

AIM 4: To develop a set of guiding principles for the practice of Adaptive IWRM in South Africa.

AIM 5: To undertake relevant research in three place-based case study areas in respect of each case focus area: (1) household water security; (2) using the Green Drop Programme to address eutrophication and microbial pollution, and (3) water resource protection.

AIM 6: To produce a set of practical handbooks for “new paradigm” or Adaptive IWRM practice.

AIM 7: To have proposed and selectively practiced the "new paradigm" of water resource management in South Africa.

AIM 8: To have contributed to the scholarship and practice of transdisciplinarity, particularly in the linked development of concept, theory, and method.

METHODOLOGY

The project methodology (Figure ES-1) is framed by theory and concepts:

- The overarching theory is General Critical Complexity – which requires an understanding of the characteristics and functioning of complex systems.
- The primary concept is that the bio-physical landscape of the catchment, together with all the social elements associated with the catchment, comprises a complex social-ecological system (CSES).
- Given this single social-ecological system, a transdisciplinary approach is required. In transdisciplinary research, integrating the use of the most appropriate methods for particular the knowledge areas, is still being explored.
- The project used case studies to demonstrate “proof of concept”.
- This project provides examples of using a mixed method approach to transdisciplinary research.
- The philosophy of Critical Realism is a useful reference at it encompasses knowledge of causal relationships beyond the empiricism of the scientific method.
- In addition, Cultural Historical Activity Theory and the concept of expansive learning allow for the investigation of relationality and social learning which is essential in understanding social mechanisms in in a CSES.

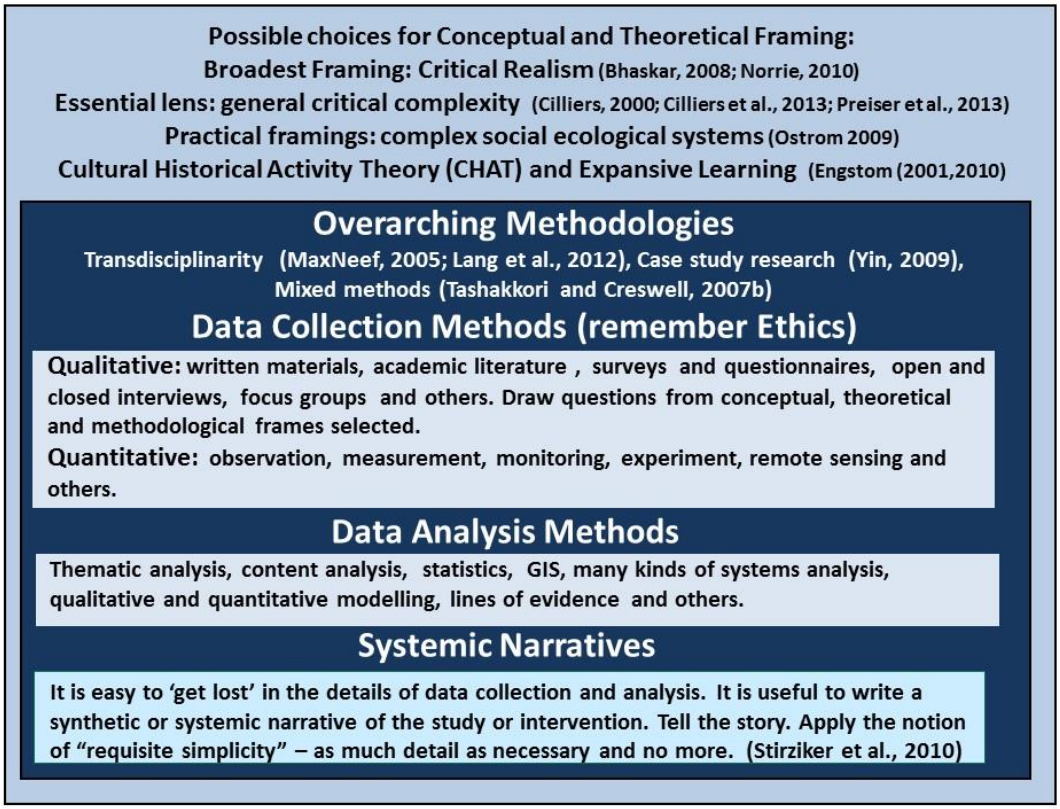

Figure ES-1: An illustration of the relationship between the theories, concepts, approaches, methodology and methods used. Different selections were made in different case studies. (References: in the full report).

Data gathering and Data analysis

The data gathering (a), and related data analysis (b) methods used, were:

1. a) Critical literature review, paying particular attention to the interface between disciplines and knowledges. b) Critical analysis.
2. a) Case study selection and b) mixed methods analysis.
3. a) Identification of the i) elements, and ii) the relationship between elements of the relevant complex social-ecological system, paying particular attention to feedbacks, scale, context, and non-linearity. b) Systemic analysis.
4. a) Quantitative data gathering: the conventional scientific method was used, with considered, replicated, quantitative measuring and data gathering. This method was applied in all the biophysical aspects of the project, and for quantitative modelling. There were also quantitative components in interviews. b) Statistical analysis, modelling, input into systemic narratives.
5. a) Qualitative data gathering involved designing and undertaking structured, semi-structured and in-depth, open and closed, interviews and focus groups; reflections; and workshop processes which yield text: written or verbal recording that were transcribed. b) Thematic analysis, conceptual modelling.
6. a) Systemic narratives connected analysed data and drew on the multiple lines of evidence and causal insights.

Data collection was conducted in terms of required ethical clearance from Rhodes University.

RESULTS AND DISCUSSION

AIM 1: The first step was to develop a conceptual framing as part of addressing Aim 1. The initiating workshop resulted in "fish bone" conceptual framing (Figure ES-2).

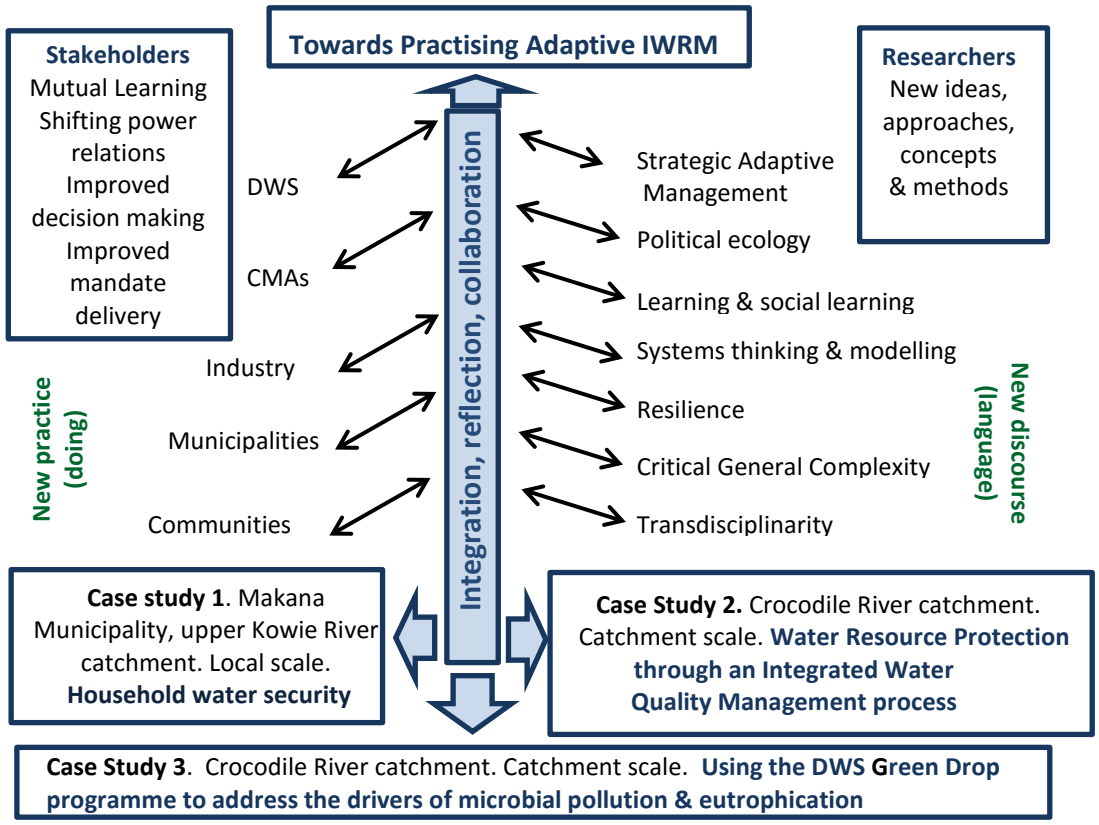

Figure ES-2: Project Conceptual Framing: Engaged, action research, undertaken with an understanding that people in catchments comprise complex social-ecological systems (CSES), using appropriate complexity- and systems-based approaches and methods, in case studies, resulting in examples of practical Adaptive Integrated Water Resource Management (Adaptive IWRM). New practice emerged from new ideas, affecting both stakeholders and researchers, and was driven by reflection, integration and collaboration. (DWS – Department of Water and Sanitation, CMAs – Catchment management agencies)

This conceptual framing evolved during the TPNP to the final form in Figure ES-2. The structure remained consistent while case study formulations and the suite of concepts shifted adaptively. The framing drew on the full range of theories, approaches and methods used to address the TPNP aims.

Engaged, participatory action research was used in all the case studies. The project process envisaged case study research providing practical spaces to explore knowledge sharing between: i) the new academic discourses in strategic adaptive management (SAM), political ecology, learning and social learning, systems thinking and modelling, resilience, general, critical complexity, and transdisciplinary, and ii) the practical knowledge in communities, industry, and local, provincial and national levels of government. The conscious development of integrating skills, reflection and collaborative initiatives were planned to mediate co-learning and knowledge sharing. The intention was to increase mutual learning, shifting power relations, improved decision making and improved mandate delivery in the practical Adaptive IWRM domains.

Social and other learning processes require attention to including reflexive opportunities, and explicit interrogation of, for example, the questions (i) was there a change in understanding of

participants, (ii) was this change shared and understood within a broad social context or community of practice, and (iii) did the learning take place through social interaction?

Several integrating systemic approaches were practised in the case studies, including systems thinking, soft system modelling, and system dynamics modelling. Strategic Adaptive Management (SAM) is a systemic, inclusive process that is particularly attentive to developing a rich understanding of context (social, technical, economic, environmental and political); a shared articulation of values and the co-development of a vision of a shared future. The use of SAM was taken further by paying specific attention to ensuring stakeholders participating in any of the research processes (planning, data collection and analysis, and knowledge sharing) were able to participate fairly. This required attention to the context of knowledge sharing, making use of translation where appropriate, as well as demonstrating an inclusive and invitational attitude in explicitly inclusive processes. All of these were part of paying attention to epistemic justice – the fairness and equity of participation. An awareness of the political ecology of the case studies supported SAM practice, because the role of politics is increasingly clear in any drive towards equity and sustainability.

The "fishbone" model proved to be valuable and effective in guiding the research.

AIMS 2 and 5: The case study methodology and methods were followed as presented. Since scale has such a strong role influencing social-ecological systems, three aspects of scale were consciously included: i) bio-physical, ii) governance and ii) relational scales. Aims 2 and 5 both deal with the case studies and the results are summarised here together.

1. **Case Study 1 Makana Municipality:** The case study was engaged at the local government (Makana), sub-catchment scale (Upper Kowie River catchment), in the Eastern Cape. This case study was built on and extended previous work in the Lower Sundays River Valley Municipality, to the Makana Municipality – another local municipality in the Sarah Baartman District Municipality. Students supported by the project have extended the water governance work across the Eastern Cape and their data and insights fed back into the case study. The focus was on water governance in the local government and the local sub-catchment overlapping area. The work was linked strongly to community and citizen science. We coined the term "water for dignity" and facilitated the emergence of a civil society organisation that took on that name. Research started with a system description, using historical contextual analyses and household surveys by Water for Dignity citizen-researchers. Although the case study was initiated with the idea of investigating microbial pollution (identified initially as a research focus), household water security emerged as the main issue for citizens. By then, case study 2 was evidently addressing water quality and water resource protection research foci, so the household water security focus was retained.

   The Makana case study has accelerated local water institutional development with the establishment of the first South African Water, Sanitation and Catchment Management Forum. The combined forum is actively co-hosted by the local Municipality and the DWS. The forum, called the "Makana Water Forum" by participants, is actively developing a local catchment management strategy (CMS) for the Upper Kowie River Catchment, to contribute to the overall CMS of the Mzimvubu-Tsitsikamma proto-CMA (MT-CMA). To date more than 85 stakeholders, widely and deeply representative of local interests have actively participated in the Makana Water Forum. This ground-breaking and exemplary research is already

extending to the Tsitsa River Catchment with the support of the DWS (M-T CMA) and the DEA.

Case Studies 2 and 3 Crocodile River sub-catchment in the Inkomati River catchment: The Crocodile River catchment proved to be the most fruitful case study site and serviced two TPNP research foci: i) water quality issues that lead to, among other things, microbial pollution and eutrophication and ii) water resource protection. The research was undertaken at the Catchment Management Agency (CMA) governance scale, at the biophysical catchment scale and included explicit attention to relational scales. A dti-NRF-THRIP project, provided additional resources for case study 2, and additional WRC funding for an associated project enabled greater depth of study in the Green Drop Campaign. The case studies are reported as i) case study 2: water quality issues and resource protection; and ii) case study 3: using the Green Drop Campaign to address microbial pollution and eutrophication. These case studies identified but did not address directly the role of non-point sources of nutrients – which would also require both social and technical interventions.

Case Study 2 addressed the Adaptive IWRM challenge of *building a co-operative integrated water quality monitoring process for the Crocodile River catchment*, to progress solutions to deteriorating water quality as a threat to water resource protection. The research used Adaptive IWRM processes to build stakeholder capacity to co-operatively change behaviour and collectively improve water quality. This resulted in improvements in IUCMA monitoring of ecological Reserve indicators – indicating resource protection in action. The case study brought many large industries together (including sugar, pulp and paper, and mining industries), with local government, water service providers, water managers, and regulators. Stakeholders met three times a year for two years, and then handed stakeholder engagement to the Crocodile Forum.

The Inkomati-Usuthu Catchment Management Agency (IUCMA) made case study 2 part of their business plan for Water Quality, in the process of operationalising their Catchment Management Strategy. The IUCMA practices Strategic Adaptive Management (SAM), and is arguably the best-functioning CMA in South Africa. The water quality-quantity model WQSAM, applied during the TPNP project for the first time, has been installed at the IUCMA, personnel were trained, and implementation is expected in 2018. The application of WQSAM is being further developed and applied in the Olifants River catchment.

Case Study 3 grew out of the recognition that conventional research into microbial pollution and eutrophication was not going to result in sufficient in-stream change. Three Crocodile River Catchment local municipalities engaged actively in seven workshops. Municipal staff shared their experience that wastewater treatment works (WWTW) are not a municipal priority. Funds were redirected away from WWTW, maintenance was neglected, works operated beyond their design capabilities, there were procurement difficulties, debt interrupted supplies of treatment chemicals, and Green Drop training was inadequate. The many inter-related problems, with feedbacks – like lack of funds and training demotivating operators – indicate that the effective operation of WWTW is a "wicked problem". It is not likely be resolved by additional scientific understanding but rather by concerted engagement within DWS, and between national and local government. Politically-based changes are required, the research using political ecology approaches need to be further developed and applied.

Case study 3 achieved part of the goal of the TPNP "to work with stakeholders to enable mutual learning, shift power relations, improve decision making and improve mandate delivery". Stake holders were actively engaged, the dysfunctional power relations were identified, but an improvement in mandate delivery will need a shift in the power relations. That will require focussed research and practice effort.

The Crocodile River Catchment can be used as a model Adaptive IWRM catchment; lessons learned can guide a National Water Resource Strategy. This was exemplary Adaptive IWRM practice: 1) there was sustained high-level stakeholder engagement and collaboration with active industry input; 2) the Green Drop Programme was identified as a key intervention point for eutrophication and microbial pollution, and the deep intractability of the problem was made explicit. Multiple problems and their exacerbating feedbacks mean progress absolutely requires politically-based interventions; 3) application of the WQSAM model was trialled and the model was installed at the IUCMA; and 4) this case study research made strategic input into the 2017 DWS Water Quality Policy and Strategy, finding traction at the highest levels of the Department and can make serious input into the next National Water Resource Strategy.

Direct influence on DWS IWRM practice and policy

The central arrow in Figure ES-2 indicates a process of reflection, integration and collaboration that leads to the implementation of Adaptive IWRM. Concurrently with the case study work, the TPNP project team worked actively with IWRM practitioners, especially within government (primarily DWS but also DEA), so that the new paradigm practice happened during the TPNP project rather than being simply reported for the first time in this report. The many consultations with the DWS and other stakeholders are listed in the Impact Table (Chapter 8). This core engagement process drew in a wide range of stakeholders and was fuelled by the discourse or conversation about new ideas and methods interacting with the practical case study experience.

AIM 3: The development of cross linkages supported i) practical integration and ii) the scholarship of integration was developed during the case studies. The two core principles for practical integration are iteration and the use of the TD practice principles (text box below). A central TPNP finding, based on an understanding of complex systems, is that **principles are more useful that rules** or prescriptive guides. Principles can be applied flexibly in context specific circumstances and are both strong and flexible.

The SAM process guides iterative participatory processes and the conscious reflexive use of TD practice principles. Practising SAM reduces tension as people discover non-linear processes are usual and expected. Expecting the unexpected increases social and practical resilience and encourages adaptation. Of the practice principles in the text box below, the one that recurs most often is dealing with discontinuities. Most IWRM processes in South Africa are characterised by: changes of plan; changes of attendance, challenges with permission to travel, challenges with transport and other logistical issues **and** sequentially different attendees staff members, or representatives during a set of engagements that are designed to achieve a purpose. Accepting discontinuities as an inevitable reality is the first stage of adaptation; followed by making time allowances for reiteration of progress at the start of each meeting. If practising TD principles becomes a routine practice, discontinuity loses its acute frustration factor and becomes an opportunity for deepening learning. If this is explained up-front, group frustration levels also drop. The Adaptive Planning Process, which is the first step of SAM has proved to be a most valuable

step for learning integration practice through planning among differing people with a shared future, for example in a catchment. SAM is particularly useful in integrating impacts and opportunities offered by the social, technical, environmental, economic and political characteristics, guide by agreed values.

Principles of transdisciplinary (TD) practice from Palmer et al. (2013):

- Tolerate and even welcome discomfort and unresolved tensions, they are often gateways to knowledge and trust.
- Be sensitive to "aha" moments or insights and note that irritation and conflict often signal moments of insight and a learning opportunity.
- Engage with balanced generosity; listen and share.
- Practice tolerance, build integrity and mutual trust.
- Be sensitive to "arrivals" of both people and ideas.
- Create and use reflective opportunities.
- ***Manage discontinuities (people come and go, and arrangements change suddenly).***
- Sustain enquiry (keep going when it is tough).
- Be conscious that everyone involved in the process is a whole, multi-dimensional person, with the potential to engage with their whole self and many ways of knowing.

Two core principles for the scholarship of integration are 1) pay attention to clarity in the framing philosophy, theories and concepts and 2) pay attention to the appropriate selection of methodology and methods aligned with the philosophy, theories and concepts. We recommend the development of a conceptual and methodological framing diagram for each Adaptive IWRM project and intervention.

AIM 4: The following Adaptive IWRM guiding principles for IWR were developed in response to current practices that are not proving to be helpful: these principles were co-developed by participants at the 2014 TPNP "mirroring" workshop.

Principles for practising Adaptive IWRM in South Africa: to transcend current practices, to transform, and to shape the future	
PRINCIPLE:	**ADRESSES:**
From the National Water Act: equity, sustainability and efficiency	Discrimination, unfairness, and wastefulness
Courage – transformation is revolutionary and radical	Current paralysis in the status quo
Consciously accept, understand and act in terms of the implications of complex social-ecological systems: - trust longer, winding journeys - watch out for and accept emergence - we can't know everything – all our knowledge is provisional so humility is essential - requisite simplicity - relationality and relationships are key drivers	Pitfalls of mistaken "efficiency" and arrogant knowledge

Foreground practice and learning by doing, changed behaviour arises from awareness and knowledge transfer	"Listen to me and do what I tell you"
Foreground the social	Habits of science only, and science superiority
Pay attention to context	Habits of stereotyping and seeking recipes that can be broadly applied
Use values and principles to guide contextual decision-making	Beliefs that stereotyped roles and recipes can be broadly applied
Pay vigilant attention to emancipatory and transformative potential	Convictions that "the rules work and can be revised"
Pay attention to power relations	The powerful are happy with the status quo – they created it and benefit from it
Build on existing strengths and opportunities	Paralysis by enormity and tangledness* of problems
Cultivate consciousness and recognise "traps" of old practice – good facilitation can be helpful	That it is easier to ignore the implications of complexity and change
Work towards shared understanding	Starting with conflict
Work on challenges that bring people together	Paralysis by enormity and tangledness* of problems
Create a vision of a shared future (learn to be adept at moving between the challenges of the present and what will embody that future)	Paralysis by enormity and tangledness* of current problems
Recognise the power of citizen science and participatory governance	Acceptance that real participation is too hard and too expensive
Pay attention to learning opportunities: work-based learning for change; social learning where tensions create learning chances, and learning for capability (doing the task), rather than competency (understanding the task)	Changed behaviour arises from awareness and knowledge transfer
Engage and co-learn	Avoid engagement where you announce and impart what is always only partial knowledge. Avoid just ticking "stakeholder engagement" box.
* The metaphor we have come to use is that of the "knot": – When one tries to untangle a piece of fishing line picked up on the beach, tugging in one place often tightens another, and then there is the seaweed, or fishing hooks that have become entangled. At first a lot of energy goes into loosening. In Adaptive IWRM the best we can often aspire to, is the conscious recognition of new options that arise as "knotty" problem areas are loosened, mindful of the future knots that will necessarily emerge. However, the team work, confidence and ability to take action, to monitor consequences and adjust direction become empowering ways of operating.	

AIM 5: Reported together with **AIM 2**.

AIM 6: Nine accessible Adaptive IWRM: "How to…." handbooks have been produced. **They have been tested with potential users** and will be used extensively by civil society, staff and stakeholders in catchment management forums and agencies (CMFs and CMAs) and by local municipalities.

1. How to think and act in ways that make Adaptive IWRM practically possible
2. How to think about water for people and people for water: Some, for all, forever
3. How to establish and run a Catchment Management Forum (CMF)
4. How to manage Water Quality and Water Quantity together

5. How to engage with the challenges facing Water and Sanitation Services (WSS) in small municipalities.
6. How to run a Green Drop campaign in a Catchment Management Forum
7. How to engage with coal mines through a Catchment Management Forum
8. How to use Strategic Adaptive Management (SAM) and the Adaptive Planning Process (APP) to build a shared catchment future
9. How to understand Environmental Water Quality in Water Resource Management

AIM 7: The "new paradigm" has been termed **Adaptive IWRM** and was practiced in the case studies of this project, in collaboration with the DWS, and has also been actively taken up and used by the DEA, Chief Directorate for NRM, in the Mzimvubu (specifically the Tsitsa) River catchment.

AIM 8: The frontiers of scholarship are most often to be found in the best doctoral thesis of the day. In the course of the TPNP three doctoral students graduated with exceptional international referees' reports, one with no corrections, and one with the comment "exemplary transdisciplinary research". The theses are listed in the impact table (Chapter 8) and are available online from the Rhodes University library. The master's theses are also innovative and contribute to the practice of Adaptive IWRM. The graduation of eight students is a strong contribution to "the linked development of concept, theory and method" in transdisciplinary research. We also developed a post-graduate "transdisciplinary research" short course for Rhodes University Centre for Post Graduate Support, using Adaptive IWRM as one of the exemplary fields of study.

CONCLUSION and RECOMMENDATIONS

Conclusion: Adaptive IWRM **IS** ground breaking: hard, slow, and **EFFECTIVE** and **IS** the way to achieve the balanced protection and use of water resources for the equitable and sustainable benefit of those who live in South Africa.

Recommendations:
Immediate uptake by DWS: The DWS accepted Adaptive IWRM concepts in the 2017 Water Quality Management Policy and Strategy (WQMP&S); other immediate actions and applications are:

- formally adopt and promote the term **ADAPTIVE IWRM,**
- actively ensure the revised single water law is consistent with Adaptive IWRM,
- actively promote the "How to…" series,
- use Adaptive IWRM in the Olifants River IWQMP,
- use Adaptive IWRM in the Master Plan for Water and Sanitation,
- check for consistency between the WQMP&S and the monitoring and evaluation framework,
- actively support SAM-based stakeholder engagement in catchments, while governance and institutional arrangements are evolving.

Longer term uptake by DWS:

- invest in embedding SAM in DWS water resource management and water service delivery (this will need purposeful, systematic and systemic action).

Uptake by the WRC:

- formally adopt the term **ADAPTIVE IWRM**,
- actively promote the "How to…" series,
- actively support building an Adaptive IWRM community of practice,
- actively promote the practice of engaged, transdisciplinary, action research where it is needed,
- address the research questions
    - How do we use SAM to catalyse effective IWQM at the catchment level while governance and institutional arrangements are evolving?
    - What is the political ecology of the Green Drop incentive programme and how to identify windows of opportunity in a fractured governance landscape?
    - Household water security is key to reduced public protect. Use TPNP evidence of the importance of social networks to address the question: How can household water storage be supported to complement piped water delivery is urban and rural areas?
- recognise the WRC's global reputation is founded on the **practical application** of research to the benefit of people,
- recognise the power and necessity of **integration** to address water issues in both service delivery and resource management,
- recognise and reaffirm that water services (and the national economy) are **dependent** on the hydrological cycle and water resource protection,
- foster **transdisciplinary** research – which **includes** strong, well developed disciplinary research and judicious inter- and multi-disciplinary research,
- plan systemic adaptive research **programmes** (for example, explicitly LINK the "light houses") and manage **peer review** systemically (for example, make greater use of the global standards of peer-reviewed literature for **scholarly merit**, and mechanisms like programmatic colloquia for peer reviewed **impacts** on policy and practice,
- recognise key "windows of opportunity":
    - the new legislation, combining Water Resources and Water Services, is being drafted. Liaise with Department of Water and Sanitation (DWS) to ensure a systemic approach where integration and synthesis are used. (There are specialist practitioners in these skills who have been associated with the WRC).
    - recognise student and **young water professionals** are hungry for the Adaptive IWRM approach.
    - identify linked WRC projects, add "adaptive catalyst" funds, and assign a small Adaptive IWRM specialist team to work with project leaders to increase the likelihood of added values from interactions and feedbacks.
    - Promote and invest in 'meta-research' that works across projects.

FINAL NOTE: Adaptive IWRM research and practice is "tortoise work"

The literature on engaged action research as a catalyst in adaptive complex social-ecological systems is clear that:

- this research praxis requires "a certain slowness"
- outcomes and responses also emerge slowly and through time
- pathways of uptake and change are unpredictable.

HOWEVER:
This approach offers the most promising pathway of substantive progress in engaging with the most difficult social-ecological problems facing humanity.

From the TPNP we suggest: long term, substantive research investment in at least two catchment management governance entities, like CMAs, to support ongoing and developmental praxis IN Adaptive IWRM. It would be worthwhile to invest in at least a decade-long programme.

POST SCRIPT Reference Group member, Dr Chris Dickens, Head Regional Office (South Africa), IMWI: *"Agreed. Maybe it is worth addressing some deeper issues like how do you sustain progress and momentum in the face of such required slow pace?*
I see this a lot with transboundary River Basin Organisation creation. It takes forever and there is often some randomness involved in a first champion pushing things for a few years, then nothing for a few years, then a new champion coming in to drive the process trying to pick up pre-gap-period. I can't help but wonder if there may be ways to orient this toward a more cohesive process." Adaptive IWRM processes?

ACKNOWLEDGEMENTS

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The Inkomati-Usuthu Catchment Management Agency (IUCMA) was a fantastically supportive practitioner-partner. We hope your future use of the project products is fruitful.

The "Water for Dignity" team were tireless civil society researchers. They substantively shaped the content of this report and raise serious questions about how we value citizen science contributions. We thank Mr M Lipile, Mrs N Lipile, Mrs X Nzwana, and Mr S Saki. We thank the Khulumani Support Group and particularly Dr Marjorie Jobson, for their human rights and social justice leadership and example, and for their active participation in the Makana case study.

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Margaret Wolff worked way beyond any reasonable expectation, to edit and correct drafts, as well as taking forward in her own research the thinking and scholarship of expansive learning. Thank you, Margaret, for unstinting hard work, support and care.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AIWRM	Adaptive Integrated Water Resource Management
APP	Adaptive Planning Process
AWARD	Association for Water and Rural Development
CAS	Complex Adaptive Systems
CGDSC	Crocodile Green Drop Support Campaign
CHAT	Cultural Historical Activity Theory
CMA	Catchment Management Agencies
CMF	Catchment Management Forum
CMS	Catchment Management Strategy
COGTA	Cooperative Governance and Traditional Affairs
CoP	Community of Practice
CR	Critical Realism
CRC	Crocodile River Catchment
CROC OC	Crocodile River Operating Committee
CSES	Complex social-ecological systems
CSG	Core Stakeholder Group
CSIR	Council for Scientific and Industrial Research
DAD	Decide, Announce, Defend
DEA	Department of Environmental Affairs
DSS	Decision Support System
DTI	Department of Trade and Industry
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EWR	Environmental Water Requirement
GSG	General Stakeholder Group
IDP	Integrated Development Plan
INR	Institute for Natural Resources
IUCMA	Inkomati-Usuthu Catchment Management Agency
IWQM	Integrated Water Quality Management
IWQMP	Integrated Water Quality Management Process/Plan
IWQMS	Integrated Water Quality Management Strategy
IWR	Institute for Water Research
IWRM	Integrated Water Resource Management
KSG	Khulumani Support Group
KWfD	Khulumani Water for Dignity
LSRV	Lower Sundays River Valley
MLM	Makana Local Municipality
NRF	National Research Foundation
NRM	Natural Resource Management
NWA	National Water Act
OCMA	Olifants Catchment Management Agency
RDDA	Research, Develop, Disseminate, Adopt
RQOs	Resource Quality Objectives
SALGA	South African Local Government Association

SAM	Strategic Adaptive Management
SANParks	South African National Parks
SAVE	Save the Vaal Environment
SCOWSAS	Standing Committee on Water Supply and Sanitation
SES	Social Ecological System
TD	Transdisciplinarity
THRIP	Technology for Human Resource and Industry Programme
TNP	Towards a New Paradigm
ToR	Terms of Reference
TPNP	Towards Practising a New Paradigm
TRC	Truth and Reconciliation Commission
UCEWQ	Unilever Centre for Environmental Water Quality
UEIP	uMngeni Ecological Infrastructure Programme
UJ	University of Johannesburg
UKZN	University of KwaZulu-Natal
V-STEEP	Values – Social, Technical, Economic, Environmental, and Political
VEJA	Vaal Environmental Justice Alliance
VPL	Ventilated Pit Latrine
WESSA	Wildlife and Environment Society of South Africa
WfD	Water for Dignity
WQSAM	Water Quality Systems Assessment Model
WRC	Water Research Commission
WReMP	Water Resources Modelling Platform
WRM	Water Resource Management
WSS	Water and Sanitation Services
WTW	Water Treatment Works
WUA	Water User Association
WWTW	WasteWater Treatment Works

LIST OF APPENDICES

CHAPTER 1: GENERAL INTRODUCTION

From the initiation of the project, there was an explicit acceptance that this project was to address **integrated** water resource management (IWRM). Early in the project it was agreed that the philosophy, kinds of thinking, approaches and methods that provide the motivation for, and appreciation of, "integrated" in IWRM are not "new". These integrative concepts are still actively developing, especially in respect of social analysis (for example Fabinyi et al., 2014), and they will be reiterated and explained in this report, because while not new, they are not widely known or deeply appreciated. Discussion about these concepts led the project team and reference group to the insight that what would be new is research that critically explores how integrative principles, methods, thinking and approaches can be **practically** applied, in South Africa, towards more effective IWRM.

This recognition was the first of the adaptive steps in the project management that influenced a change of focus, framing, approach and actions of the project team. As a result, the project name was changed from: Water Resources Management: towards a new paradigm; to *Water Resources Management: towards **practising** a new paradigm.* We have subsequently called the "new paradigm": **ADAPTIVE IWRM**.

A definition of Adaptive IWRM:

***Using adaptive, systemic, processes and an understanding of complex social-ecological systems* to coordinate conservation, manage and develop water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems.**

This definition is based on the Global Water Partnership (2000) definition of IWRM (Agarwal et al., 2000), with specific Adaptive IWRM additions shown in italics.

The revised focus was therefore to use the literature that underpins the integrative thinking of the last two decades (critical general complexity, transdisciplinarity, complex social-ecological systems (CSES), systems thinking, adaptive systems, strategic adaptive management, resilience, social learning, expansive learning, and political ecology) to plan and undertake research that would provide examples of how **practices** emerging from the set of this relatively recent thinking provide confidence for the hard task of effective Adaptive IWRM.

The notion of undertaking water resource management in an integrated manner is internationally contested. As early as 1975, Hynes (1975) wrote about "the stream and it valley", and the implications of water being embedded in the landscape, began to be recognised Flader and Callicott, 1992). One implication is that water management needs to take account of the many elements and processes that comprise aquatic bio-physical systems, people's use of these systems, and therefore water resource management. The idea of "integration" found international traction with the Global Water Partnership:

> "Integrated water resources management (IWRM) is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems." (Agarwal et al., 2000)

The challenge of connecting across the elements of water resources management is considerable. Biswas (2008) launched a trenchant criticism of IWRM, based on his view of the implementation impracticability. This view has been supported by Mehta et al. (2014), especially in an African context, while Medema et al. (2008) offered a comparative view, acknowledging successes and failures. Woodhouse and Muller (2017) have suggested that South African IWRM:

> "remains a scene of contestation between local and global criteria and developmental and environmental goals. But, in the face of challenges of complexity and diversity and the emerging understanding of network governance, emerging practitioner-oriented guidance is focusing on general principles and explicitly avoiding normative approaches."

Woodhouse and Muller (2017) might have taken 'normative' to mean prescriptive, rather than ethical. However, in this TPNP project, we have taken both a **principled** and **normative** (in the ethical sense) position, accepting the foundational principles of South African National Water Act: equity, sustainability and efficiency. We agree with South Africans Swilling and Annecke (2012) that sustainability emerges from social and environmental justice. We therefore present this work as the strong "practitioner-oriented guidance …. focusing on general principles" (Chapter 2), suggested by Woodhouse and Muller (2017).

Since the Global Water Partnership 2000 definition of IWRM (Agarwal et al., 2000), the IWRM literature has progressed considerable and the arguments for refinement nuanced. Giordano and Shah (2014) offer a cogent review. We suggest that the addition of "Adaptive" to the IWRM moniker covers most of the arguments for nuance. However, it must be noted the IWRM as term does retain the specifically **water** focus whereas in all we present here emphasises that water is one of the connecting elements within a complex social-ecological system. We have retained the term IWRM because of its international currency, but we do agree with a nuanced and inclusive perspective – as indicated by **Adaptive** IWRM. At this point, South African water governance and associated institutional arrangements are fluid and will be supported by retention of a familiar term.

Therefore, in this report we provide (1) practitioners' experience and perspectives on what knowledges, discourses and practices are needed to advance the implementation of Adaptive IWRM in South Africa (Chapters 3-7); and (2) a scholarly view of the philosophical conceptual and methodological basis of Adaptive IWRM (Section 1.2). The reader will find the text moves between academic and practical styles. This next section provides an academic grounding for Adaptive IWRM.

1.1 Adaptive IWRM conceptual framing

The first objective in the WRC solicited call was "to develop and test fundamental international emerging concepts and approaches to water resources management and adapt them to our South African context". We present this in two steps 1) we propose a founding ontology, 2) we envisage the ontology supported by consistent epistemologies; where **ontology** is an understanding of the nature of reality: *what is*; and **epistemologies** are: *the way/s in which we know what is*.

Ontology

General, Critical Complexity

Our ontology is that the elements of the social and bio-physical world – the elements that comprise reality – interact in ways that conform to the understanding elucidated by general, critical complexity theory (Cilliers, 2000, 2001; Cilliers et al., 2013, Audouin et al., 2013). The living and non-living elements interact in recognisable, systemic, ways, that together comprise complex systems, and these complex systems can be recognised at multiple spatial and temporal scales, from cells to a global community (Nicolescu, 2000; Bruggeman et al., 2007). Cilliers (2000, 2001) provides a clear

introduction to general complexity thinking, and identifies the following characteristics of complex systems: they comprise many interacting elements, they are characterised by non-linear processes; there are feedbacks between components and processes; scale (e.g. temporal, spatial) influences processes and feedbacks; small changes can lead to large effects (e.g. spatially and temporally) and vice versa; the system propagates emergent properties; context is critical in a consideration in understanding any complex system and therefore narratives and records of history are important. These characteristics differentiate complex systems from complicated systems which, though intricate, are predictable in the relationship/s between elements.

The recognition of complexity fundamentally shapes any approach to understanding and influencing humans in relation to the rest of the bio-physical world. It provides a solid foundation for challenging the primacy of positivist, reductionist epistemologies, allowing for a more inclusive and broader set of ways to know. The consequences of engaging with this wider range of ways to understand reality is to move away from relying primarily on insights from linear cause and effect relationships, and the consequent confidence in top-down, linear management and decision-making processes. **The recognition of a complexity-based ontology is the new paradigm "game changer" in approaching water resources and their management – the response is Adaptive IWRM.**

Epistemologies

There are many formalised ways of understanding and knowing about reality that are consistent with complex systems ontology. We have selected a core set that have been used internationally to advance the understandings of people in relation to bio-physical world (for example, IWRM). In the course of this project other epistemologies were also used.

Complex social-ecological systems (CSES)

Having accepted that the nature of the world is systemic complexity, it is logical to understand humans – and societies – embedded in the bio-physical world as complex social-ecological systems (CSES) (Biggs and Rogers, 2003; Carpenter and Folke, 2006; Folke, 2006, Pollard and Du Toit, 2011). Consequently, it is necessary to take explicit account of the characteristics of complex systems when engaging with water resource issues. As the narrative of the new paradigm progresses we will give examples of insights into each of the complex system characteristics – and the implications for water resource management practice.

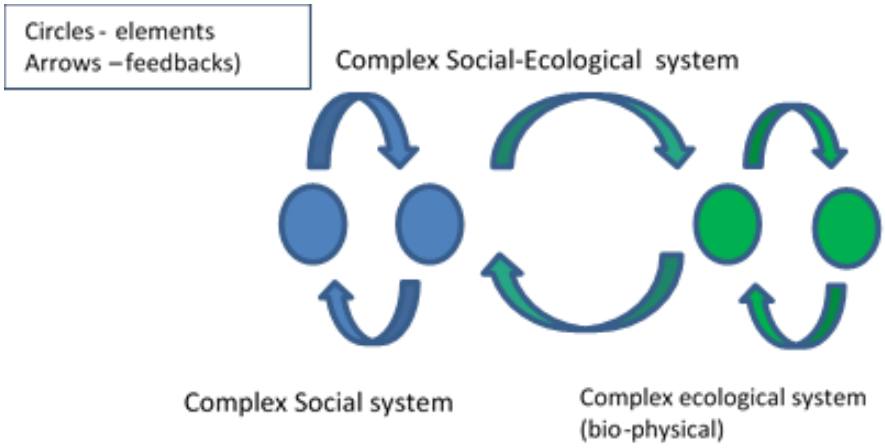

Figure 1-1: A diagram illustrating that complex social-ecological systems (CSESs) include interactions and feedbacks between the elements of complex social systems and complex ecological systems. (Adapted from a presentation by R. Biggs, Stellenbosch, 2016)

At present, Water Resource Management (WRM) largely relies on strong assumptions of linearity and direct causal relationships. Evidence-based management mainly relies on the use of traditional

reductionist scientific approaches. Even much modelling (which may well be complicated) does not include elements of complexity. This response to understanding the world has served us reasonably well, as there are circumstances when failing to acknowledge complexity does not appear to matter much (consequences are often externalised to environmental costs which may take some time to become evident). There are also many examples of linear causal relationships within complex systems. But we are approaching thresholds of water availability and quality, and the powerful influence of society, both in causing degradation and in experiencing shortage (e.g. public protests at lack of service delivery) is impacting on WRM processes. It is time to face the challenge posed by the inherent characteristic of complexity when dealing with water and "people on the planet" (Rogers et al., 2013). It is time to action the transition to **integrated** water resource management (IWRM) **practice: Adaptive IWRM**.

Transdisciplinarity (TD)
Nicolescu (2000) discusses the inevitable link between complexity and TD and Swilling and Annecke (2012) place this connection in the specifically South African context of linked social and ecological justice, where knowledge is power, exercised in a context where natural resources, and the benefits of natural resources, are unequally distributed and accessed.

When IWRM practice is viewed in the context of CSESs, it becomes obvious that a wide range of skills and knowledge sources are needed: multi-, inter- and particularly transdisciplinary teams and processes. When working in CSESs, is especially important to acknowledge that knowledge resides in all people involved and that the co-creation of new knowledge and knowledge exchange are more powerful approaches than knowledge transfer (for example, Rogers et al., 2013). TD is particularly appropriate in respect of Adaptive IWRM. Firstly, it is explicitly "problem focused", so creative energy is applied to solutions, resolutions and the loosening of "wicked" (sensu Rittel and Weber, 1973) problems. Wicked problems arise directly from the nature of complex systems because not all the consequences of particular responses and actions can be envisaged, so whenever action is taken, unintended consequences arise, sometimes of alarming proportions.

The metaphor we have come to use is that of the "knot" – which refers also to the notion of “tangledness” in the Principles for Adaptive IWRM (Chapter 2). When one tries to untangle a piece of fishing line picked up on the beach, tugging in one place often tightens another, and then there is the seaweed, or fishing hooks that have become entangled. At first a lot of energy goes into loosening the knot. In Adaptive IWRM the best we can often aspire to, is the conscious recognition of new options that arise as "knotty" problem areas are loosened, mindful of the future knots that will necessarily emerge. However, the team work, confidence and ability to take action, to monitor consequences and adjust direction become empowering ways of operating.

Max-Neef (2005) uses a TD understanding (epistemology) to organise discipline-based ways of knowing into a hierarchy, where the foundation layer provides the capacity to address an empirical domain, and to describe what exists, the "what is" of the system (using for example physics, mathematics, ecology, geology, politics, economics). This supports the capacity for pragmatic action, framing the next level – what we are capable of doing (e.g. policy, risk analysis, engineering, agriculture, industry, commerce). This in turn supports normative considerations of what we want to do using, for example, adaptive management, planning, scenario development, design, politics, and law. Finally, the practices that overarch (and underpin) everything else, guiding how, why, and if, we do what we want to do, use values, ethics and philosophy. In the context of the South Africa, the early democracy water law reform process was based on an acknowledgement of values, and of the fundamental importance of a principled, and ethical basis for drafting of policy, law and practice

(Asmal and Hadland, 2011). There is much to learn from reflecting on that process. We use the Max-Neef layers to structure each of the case studies.

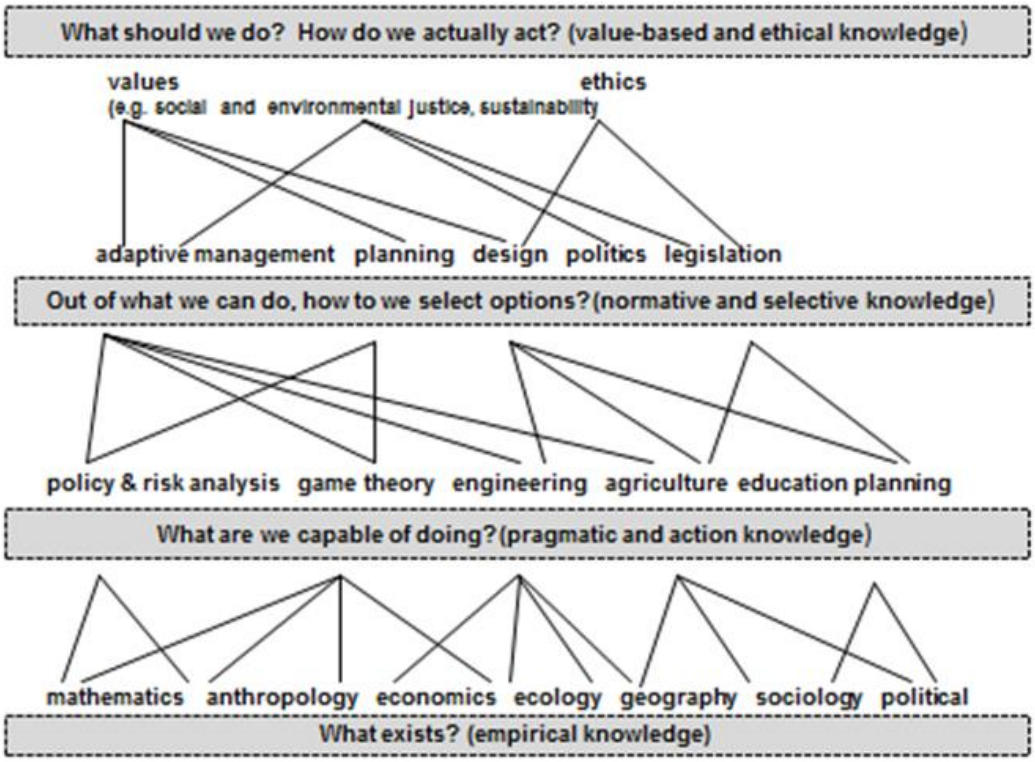

Figure 1-2: A diagram adapted from the layered concept of transdisciplinarity Max-Neef (2005).

We draw on two aligned definitions of TD:

> "Transdisciplinarity is a reflexive, integrative, method-driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge." (Lang et al., 2012)

> "Transdisciplinary is a reflexive research approach that addresses societal problems by means of interdisciplinary collaboration as well as the collaboration between research and extra-scientific actors; its aim is to enable mutual learning processes between science and society; integration is the main cognitive challenge of the research process." (Jahn et al., 2012)

Adaptive IWRM therefore seeks to build and learn to benefit from well-functioning TD research and practice teams, deliberately exploring boundary areas currently separated into silos (for example water resource management and water service delivery or water quantity and quality).

Resilience

Resilience thinking and practice (Folke, 2006; Pollard et al., 2008; Biggs et al., 2012) provides a conceptual framework and guides for application (Resilience Alliance 2010) that are founded on the recognition of feedbacks. Resilience is a system characteristic observed as the capacity of a system to experience stresses, to change, and yet to retain key structure, function and process identity. Where these recognisable features change there is deemed to have been a change of state. The process of large magnitude change is understood as a transition past a threshold (Walker et al.,

2004; O'Brien et al., 2009). Increasingly the ecological parts of a CSES are seen as providing their related societies with valued goods and services. When use of the ecosystem threatens to move ecological processes through thresholds into a new state which perhaps offers fewer services, it seems important to recognise approaching thresholds and adapt. In Adaptive IWRM this means paying attention to water-use stressors such as abstraction and waste disposal.

The recognition of resilience traps, thresholds and changes of state are critical in the practical unfolding of this project. For example, eutrophication is itself a "change of state" phenomenon, as is the shift from a perennial to a seasonal or ephemeral river. Poverty is a resilience trap that drives water and health issues arising from microbial pollution. Fabinyi et al. (2014) refer to "rigidity traps" as being especially characteristic of the social aspects of a CSES. Rigidity traps resist transformation (in a positive direction), so, while transformation may be necessary, it is resisted through current power structures. This provides a social interpretation of the conservation phase and its rigidity. The idea of "thresholds of probable concern" (Rogers and Biggs, 2000; Rogers, 2006), as well as monitoring and knowledge feedback will both be used in the context of strategic adaptive management (SAM) (Rogers and Luton, 2011).

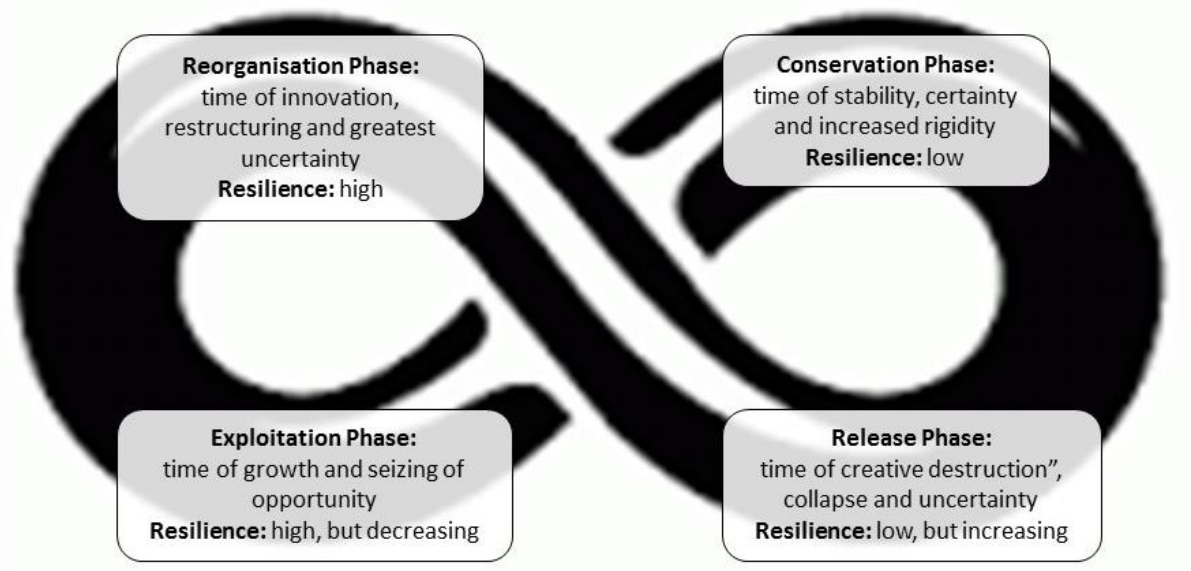

Figure 1-3: Resilience: a generalised diagram of the cycle of regenerating change (Walker et al., 2004). Such cycles can be linked and nested at different scales (Gunderson and Holling, 2001), and each phase is characterised by thresholds of change. (Note the infinity symbol, lemniscate, is used).

Processes of change also occur at different spatial and temporal scales. As we seek to ***act*** in ways aligned with Adaptive IWRM thinking, it is useful to recognise that uptake of new ideas and practices depend on the context and circumstances. Becoming alert to sensing contextual change alerts practitioners to "widows of opportunity". (Figure 1-4).

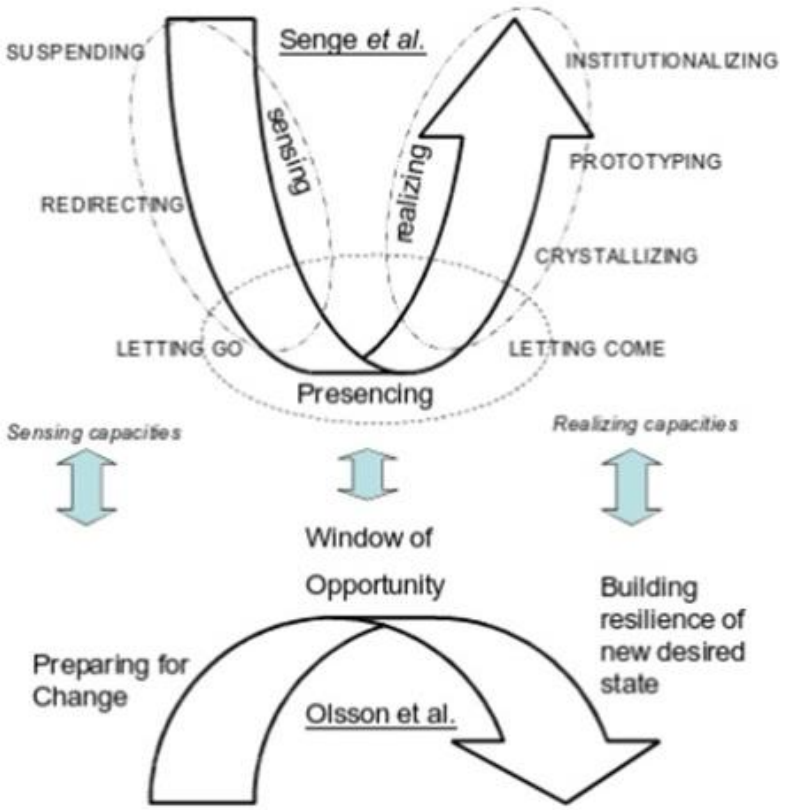

Figure 1-4: Resilience may be conferred by the capacity to recognise and take advantage of a "window of opportunity". (Biggs et al., 2008, and drawing on Senge et al., 2005 and Olsson et al., 2004).

Adaptive IWRM pays attention to the resilience of CSESs; using monitoring to identify trajectories of change towards thresholds and potential changes of state in systems; and seeks to expand learning about how to respond to recognised thresholds.

Social learning

Building on complexity, CSESs, transdisciplinarity and resilience, leads directly to social learning, which, in CSESs, is strongly associated with stakeholder participation (Ison et al., 2004, 2007, 2010; Pahl-Wostl et al., 2007) and is defined as having taken place by Reed et al. (2010) if: (1) there is a change in understanding of learners; (2) this change is shared and understood within a broad social context or community of practice and (3) the learning has taken place through social interaction. In terms of symbols, there is a clear parallel in resilience and social learning in the symbolic use of a lemniscate, or the infinity symbol (Figure 1-5) (Wals et al., 2009). The symbol provides a rich image of a continual process of input and feed-back driven change, within an infinite system. A process of alertness to current situations, response to change, and learning from actions is necessary. Learning relies on reflection on situations, actions and responses – and attentiveness to wide range sources (Figure 1-6).

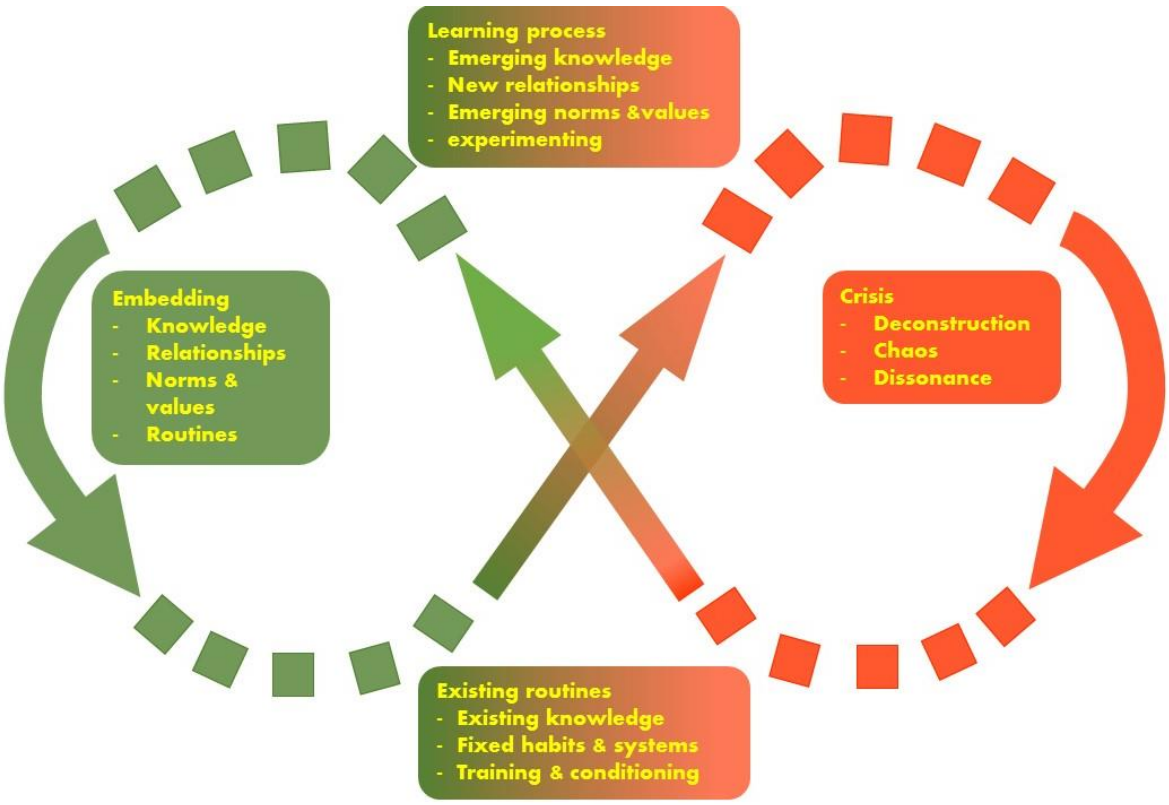

Figure 1-5: A social learning system (Wals et al., 2009, based on Hurst, 1995). (Note: infinity symbol, a lemniscate, used again, as in the resilience diagram Figure 1-3).

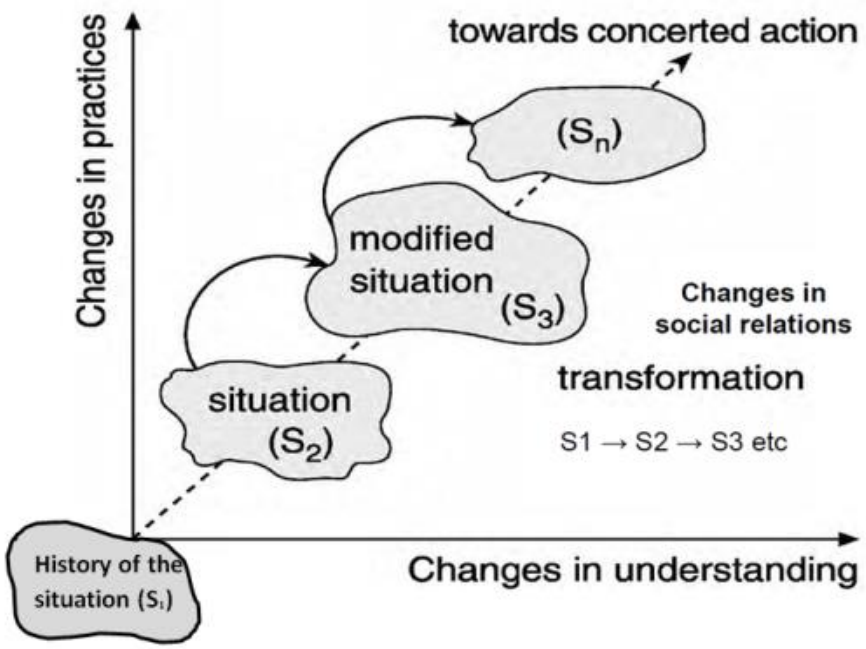

Figure 1-6: A diagram adapted from Ison (2010) illustrating how the start of a project system has a history, and that transformational change as the system progresses through time can be tracked by noting and analysing changes in practice (doing) concurrently with changes in understanding. Both the doing and the understanding drive each other along a trajectory of learning and concerted action.

Acting in ways aligned with Adaptive IWRM will therefore include reflection within the research team, and among the emerging community of practice that will arise in the case study locations. Adaptive IWRM will become a responsive learning arena.

Strategic Adaptive Management (SAM)

In the South African transition towards Adaptive IWRM, SAM has a solid history (Roux and Foxcroft, 2011) and is probably the best gateway to bring in new practices consistent with the fuller range of Adaptive IWRM concepts. The important characteristic of SAM is the centrality of the role of **feedback** – and responses to feedback information (while being attentive to emergence). This provides a consistency with the intrinsic characteristics of complex systems. In SAM, monitoring and response superseded forward planning with immovable goals and preconceived outcomes. Strategic adaptive management, as applied by South African National Parks (Roux et al., 2006; Roux and Foxcroft, 2011), included thresholds of probable concern which triggered specific management responses – preceding the resilience notion of thresholds of change at the system scale (Pollard et al., 2008).

Strategic adaptive management (Rogers and Luton, 2011; Kingsford and Biggs, 2012) (Figure 1-7) emerges from the broad adaptive management literature. Rogers (Rogers and Luton, 2011) importantly prefaced adaptive management processes with a detailed exposition of adaptive planning. Even more recently researchers and practitioners have recognised the utility – indeed necessity – of linking in adaptive governance, and adaptive monitoring and evaluation (Figure 1-8).

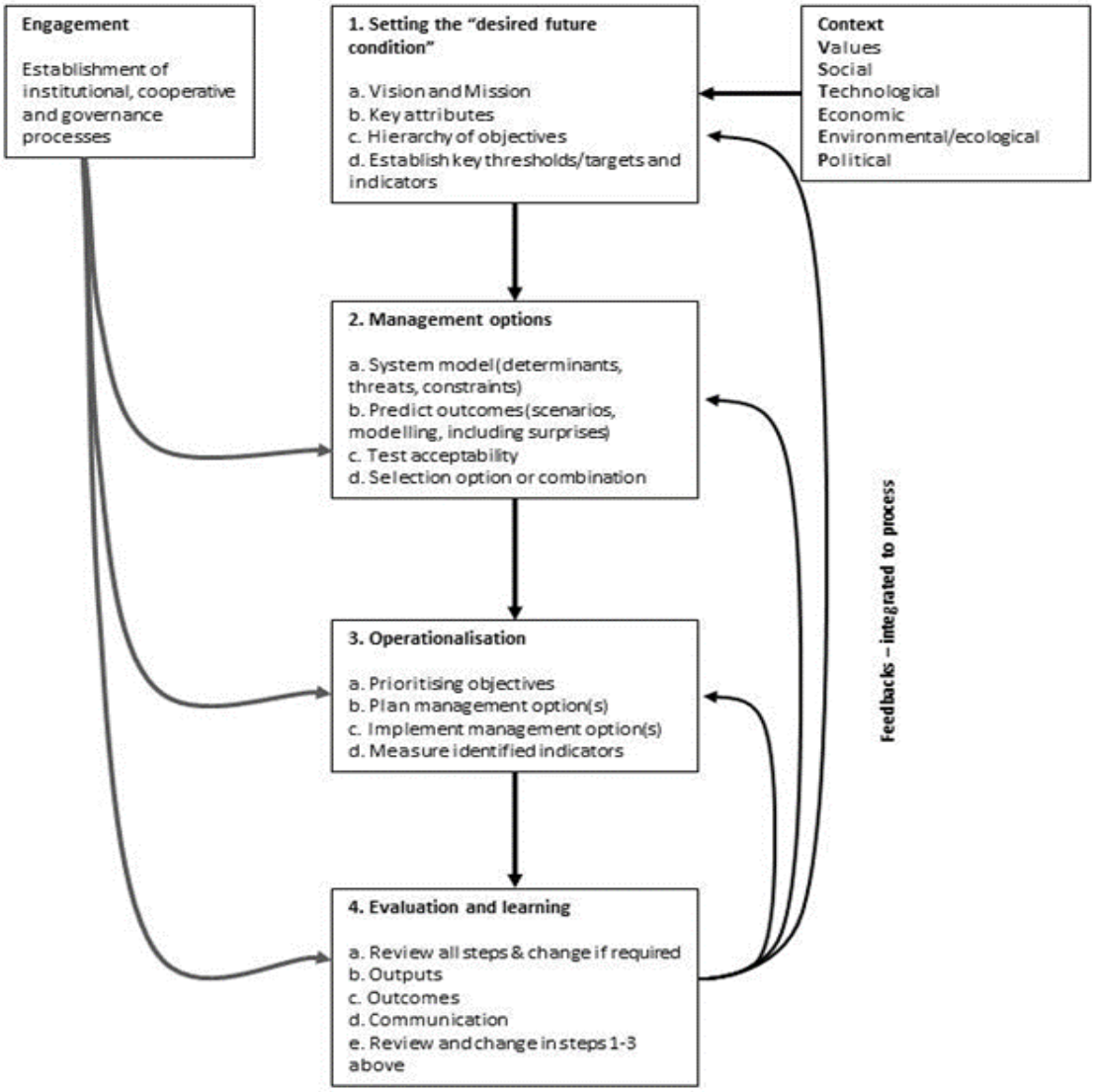

Figure 1-7: A diagram of the strategic adaptive management process (adapted from Kingsford and Biggs (2012) based on Rogers and Luton (2011).

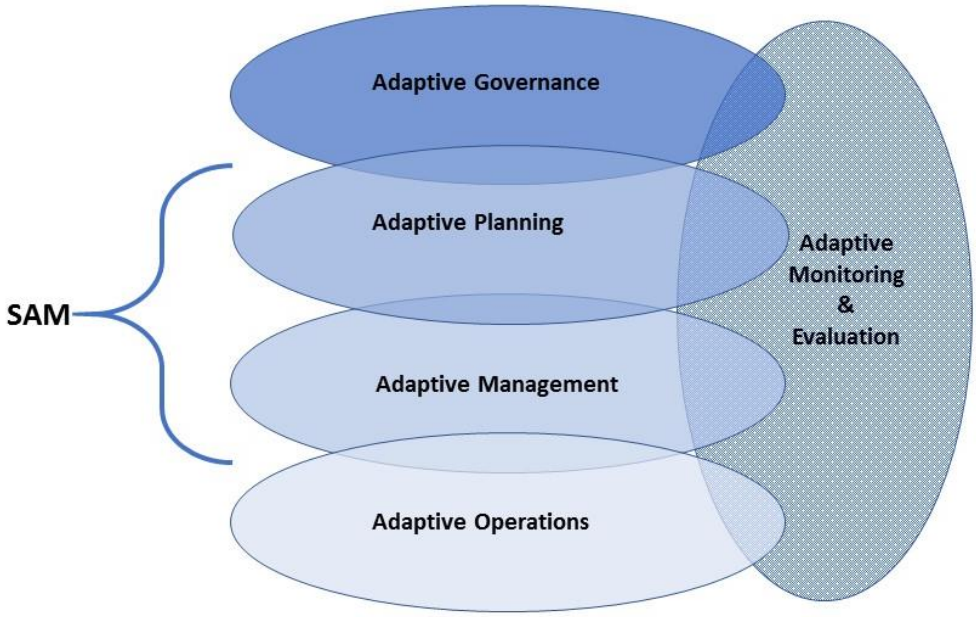

Figure 1-8: A diagram of the strategic adaptive management process (SAM), (Rogers and Luton, 2011). Kingsford and Biggs (2012), nested within adaptive governance, adaptive operations and adaptive monitoring and evaluation. (Adapted from (Novellie et al., 2016).

Adaptive IWRM practice will include doing SAM and LEARNING BY DOING.

Political ecology

The V-STEEP analysis (used to take account of any context in terms of the influence of values and social, technical, environmental, economic and political factors), is a key step in SAM. Integrated water resource management has long been the domain of engineers, more recently of ecologists and latterly social scientists and economists have come into play. Increasingly we must take account of politics. In this research, we have used political ecology (Greenberg and Park, 1994) because political ecology places an understanding of a biophysical reality – with all its complexity – into a political reality (a particular perspective on a complex social system). Political ecology allows a discursive analysis of particular issues, for example water (Johnston, 2003), within a political discourse. Applications of political ecology to IWRM have come from Chile (Budds, 2004) and Mexico (Delgado-Ramos, 2015). In South Africa, Hallowes and Munnik (2016) present a trenchant view of the coal mining political ecology, with its water connectivity.

Political ecology provides a useful Adaptive IWRM approach within IWRM, particularly in the V-STEEP analysis within SAM. Political ecology is particularly useful for practitioners coming from disciplines unused to taking account of politics.

As the social side of CSES's comes more firmly under the spotlight, new challenges open up. Fabinyi et al. (2014) recognise 1) there is more diversity within groupings such as communities, or even institutions than previously acknowledged, leading to added complexity; 2) power issues are important and 3) CSES thinking needs to probe the consequences of its focus on biophysical, because stakeholders' interest may not be focused on the biophysical, but rather on broader political issues (this is illustrated in the Makana (Chapter 4) and Green Drop (Chapter 6) case studies).

Science and citizen science

There is no doubt that natural science remains important to natural resource management and Adaptive IWRM. However, how science is done comes into question in Adaptive IWRM. To make informed decisions, stakeholders need to find ways of participating in science (Graham, 2012; Graham et al., 2015; Graham et al., 2016). This may include understanding how science works, how scientific agendas are set, and practising science as citizen's science (Weaver et al., in review). Science becomes both more controversial and more relevant in this paradigm (Weaver et al., in review).

Collectively, this thinking could be called "post normal science" (Gallopin et al., 2001; Rogers, 2008), and emerges from the recognition that conventional science which has served, and continues to serve humanity so well, has real limitations. The world as we know it includes phenomena that are not amenable to reductionist, deductive approaches, top-down linear management, or easily known cause and effect relationships.

1.2 The Adaptive IWRM project framing

The first step of the adaptive planning process in SAM is agreeing on a "shared rationality" – a shared view of reality (Figure 1-9 and 1-10). The rationality of Adaptive IWRM is (1) every human being lives in a catchment: a piece of land on which rain falls (or fog, dew or snow). (2) all elements of the human and biophysical world make up a connected whole, (3) humans compartmentalise for convenience, gaining manageability and losing linkages; and (4) pathways – whether they be personal or professional are always circuitous, never an absolutely straight line (this is a function of the uncertainly inherent in a complex adaptive world.). In this project we were consciously, reflexively alert to the reality and implications of this shared rationality,

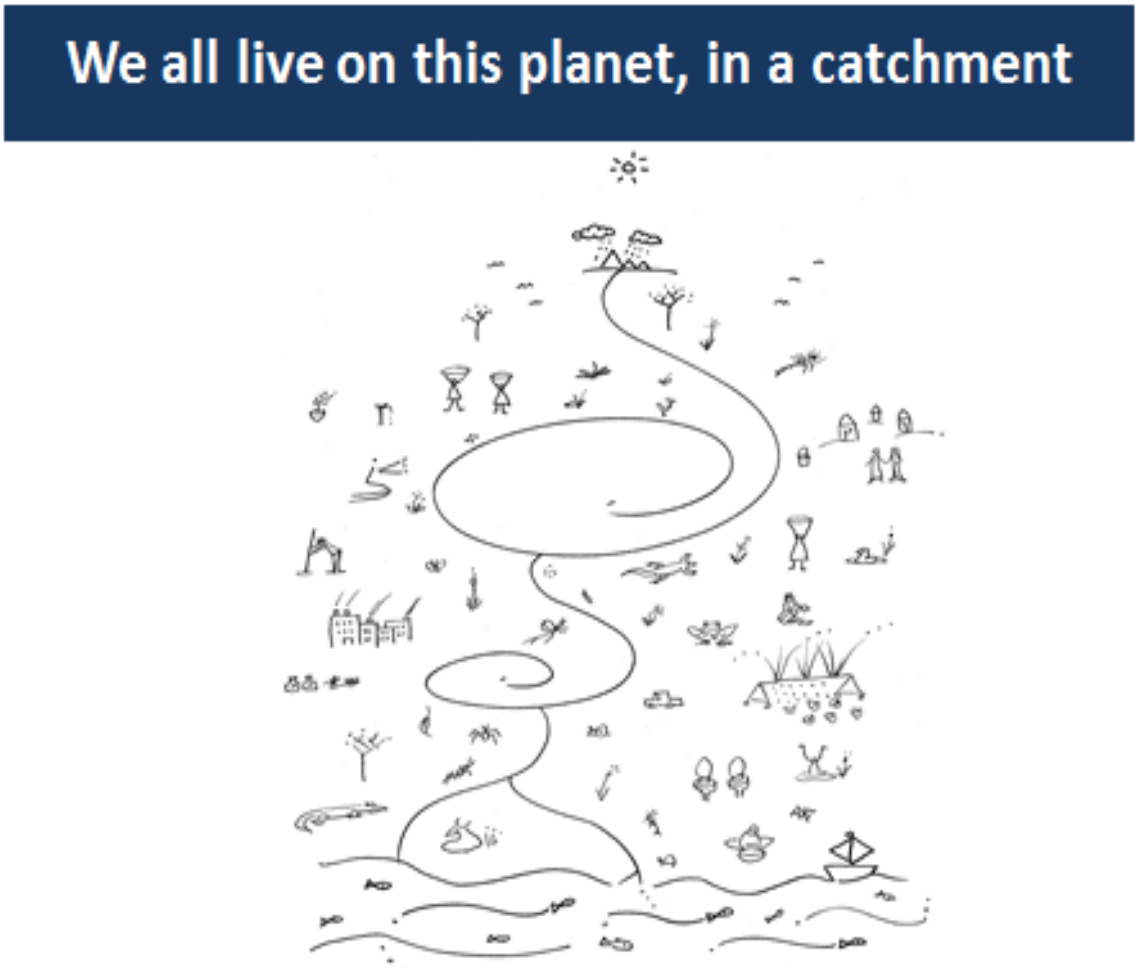

Figure 1-9: The diagram illustrated a catchment with many elements, the river, rising in the mountains and flowing to the sea, the animals and plants, the sun driving the hydrological cycle, people using the river and other ecological infrastructure for many – often competing – uses.

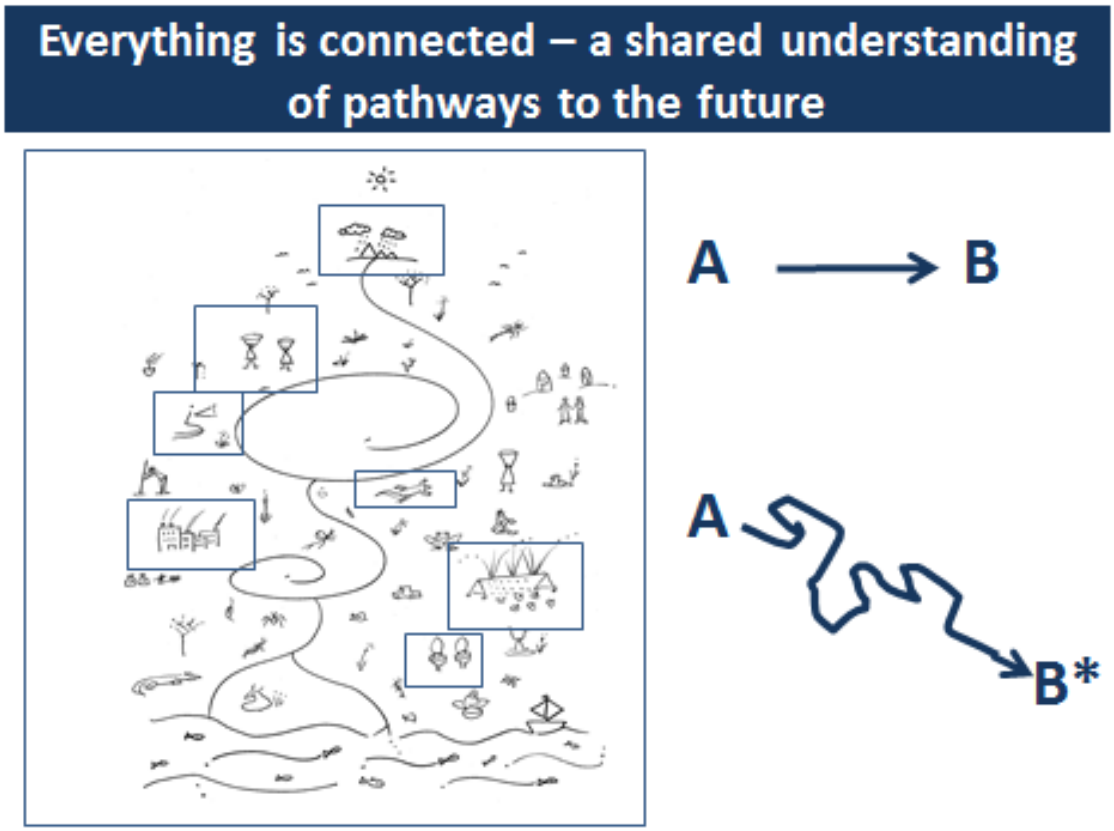

Figure 1-10: Some of the convenient compartments: agriculture, industry, domestic use (rural and urban) – water supply and waste disposal, spiritual and cultural uses; habitat for plants and animals. The circuitous pathway to setting an objective "B', moving and adapting, keeping focussed on "B" and reaching a goal close to, but not exactly B – but rather B*.

The driver for this project call was the widespread recognition that the 1998 National Water Act (NWA) was visionary and internationally acclaimed (as is the South African Constitution) but ***it is hard to make it work in the real world***. It was, and is, vitally important for the "national project" that the cynicism arising from disappointment should not deter the work needed to reap the benefits of the vision: "Some for all forever" (Palmer et al., 2004).

The NWA was drafted at the start of the democracy in South Africa and aims to ensure that the protection and use of water resources will fairly benefit current and future generations of people living in South Africa. Critical innovations in the NWA were:

- de-linking land ownership and rights to use water – with a move to an administrative management of water use (for abstraction and discharge) by licence; and
- provisions to allow water resource use (source directed controls) to be balanced with water law protection (resource directed measures). These legal provisions were translated into implementation strategies in 2004, and updated in 2013 (DWAF, 2004; DWS, 2013).

Many water-related issues have been evident in the first 20 years of democracy, including the time it has taken to move to an administrative system of water-use licensing (required because land-ownership was no longer the basis of deciding water use); and in the huge challenge of providing water services to all people living in South Africa after decades of discriminatory apartheid practices.

In the face of long delays, public protests have erupted, sometimes violently and destructively (Figure 1-11).

Figure 1-11: The offices of the Sundays River Valley Municipality in Kirkwood, Eastern Cape, were destroyed by arson as part of public water protests. Photo 23/09/2014. Source: Facebook (no citation/acknowledgement available). (Clifford-Holmes et al., 2015).

The problems that have become apparent as the great human challenges on our current times, include poverty and the huge differences between rich and poor (Ferguson, 2007); climate change and escalating environmental degradation (Meadows and Hoffman, 2003; Ison, 2010); the concentration of human populations in cities and the challenges of both urban and rural service provision (McIntyre and Gilson, 2002); and critically, global limits to freshwater (Rockstrom et al., 2009).

These kinds of problem have been characterised. They do not have a single cause, the multiple causes are inter-related, there are feedbacks between drivers of change, they are not amenable to simple interventions, any intervention has unknown outcomes – some positive, some negative. They have been called “wicked problems” (Rittel and Webber, 1973; Stirzaker et al., 2010).

Why do such problems emerge? When there is a surplus of resources (biophysical and human), the consequences of intense resource-use can be “externalised” – that is the consequences do not affect the user who may remain unconscious of them. Think of human waste disposed on the landscape or in rivers by small populations early in the history of humanity. As resource-use becomes more extensive and intensive, consequences begin to interact and feedback to the user. Think of the difficulties associated with sanitation provision and human waste disposal in South Africa today.

The first project activity was to develop a conceptual framing as part of addressing Aim 1: “*to conduct a workshop in which (i) the project philosophy, conceptual framework, methodologies and processes are discussed and a shared understanding achieved with the WRC and within the project team; and (ii) transdisciplinary practice is initiated.*” The workshop was facilitated by Professors Tally Palmer and Kevin Rogers, and the “fish bone” conceptual framing emerged (Figure 1-12). This conceptual framing changes as the project progresses and is presented here in its final form (within the project).

This conceptual framing (Figure 1-12), draws on a range of theories, approaches and methods to address the TPNP aims.

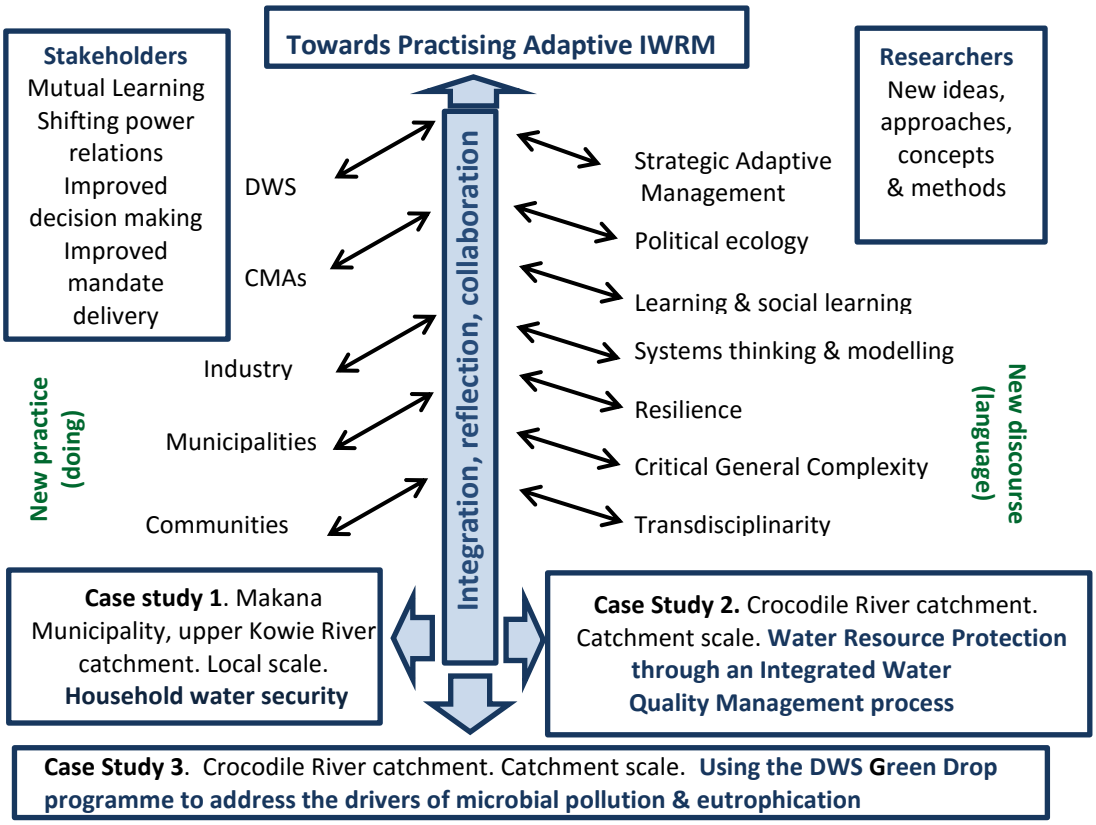

Figure 1-12: Project Conceptual Framing: Engaged, action research, undertaken with an understanding that people in catchments comprise complex social-ecological systems (CSES), using appropriate complexity- and systems-based approaches and methods, in case studies, resulting in examples of practical Adaptive Integrated Water Resource Management (IWRM). New practice emerged from new ideas, affecting both stakeholders and researchers, and was driven by reflection, integration and collaboration. (DWS – Department of Water and Sanitation, CMAs – Catchment management agencies)

Engaged research and participatory action research methods were used in all the case studies to address research questions relating to stakeholders. Qualitative methods included the use of questionnaires, and structured, semi-structured and depth interviews. Specific attention was paid to ensuring stakeholders participating in any of the research processes (planning, data collection and analysis, and knowledge sharing) were able to participate fairly. This required attention to the context of knowledge sharing, making use of translation where appropriate, as well as demonstrating an inclusive and invitational attitude in explicitly inclusive processes. All of these were part of paying attention to epistemic justice – the fairness and equity of participation.

Social and other learning processes require attention to including reflexive opportunities, and explicitly interrogates the questions (i) was there a change in understanding of participants, (ii) was this change is shared and understood within a broad social context or community of practice, and (iii) did the learning take place through social interaction? Cultural History Activity Theory (CHAT) guided qualitative methods for tracking and identifying expansive learning and was used particularly in case studies 1 and 2. The theory defines elements of social activity systems; the subject/s are identified in relation to the objective and outcomes of the activity. Engagement with subject/s explores the tools used in the activity, the rules (both formal and informal) controlling the activity, views of the community of practice, especially peers, and the division of labour – those with whom the subject/s work in the activity system. This choice of CHAT is consistent with critical complexity

theory which emphasises the role of history in understanding a present context. During data analysis, the researcher is particularly attentive to recognising tensions, as these are theorised as the most likely focal points for new learning and behavioural change

A range of systemic approaches were used, including systems thinking, soft system modelling, and system dynamics modelling in all the case studies. Strategic Adaptive Management is a systemic, inclusive process that is particularly attentive to developing a rich understanding of context (social, technical, economic, environmental and political); a shared articulation of values and the co-development of a vision of a shared future. The political ecology literature can be used to support SAM practice, which was used in all the case studies because the role of politics is increasingly clear in any drive towards equity and sustainability.

The project terms of reference required a case study methodology, and a case study development process. Since scale has such a strong role influencing social-ecological systems, both the governance, and bio-physical special scale of each of the case studies is describes, and a range of scales was selected.

Case Study 1 Makana Municipality: At the local government, sub-catchment scale (Upper Kowie River catchment), in the Eastern Cape, this case study extended previous work in the Lower Sundays River Valley Municipality, to Makana Local Municipality – another local municipality in the Sarah Baartman District Municipality. The focus was on local government governance, linked strongly to community and citizen science, where we recognised the importance of "water for dignity". Research started with historical contextual analyses and household surveys by citizen-researchers, engaged with local government. Although the case study was initiated with the idea of investigating microbial pollution, household water security emerged as the main issue for citizens. By then Case study 2 was evidently addressing water quality issues, so the household water security focus was retained. ***The case study has catalysed local water institutional development: the establishment of a Water Sanitation and Catchment Management Forum co-hosted by the Municipality and DWS. The forum is actively working on a local catchment management strategy to contribute to the proto-CMA. An industry-partnered initiative to expand household water tanks for household water security is underway.***

Case Study 2 Crocodile River sub-catchment in the Inkomati River catchment: At the Catchment Management Agency (CMA) – catchment scale, an independently funded (dti-NRF-THRIP) project provided additional resources for the TPNP. Case Study 2 addressed the Adaptive IWRM challenge of building a co-operative integrated water quality monitoring process for the Crocodile River catchment, thus addressing the water quality issues of eutrophication and microbial pollution specified in the terms of reference. The case study brought industries in the Crocodile River catchment together, with local government, water service providers, water managers and regulators. In a three-year process of working towards collaboratively improving water quality in the Crocodile River, the project contributed to national water quality policy development, the installation of the novel new WQSAM model into the IUCMA, and collaboration toward improved water quality in the catchment.

The Inkomati-Usuthu Catchment Management Agency made this project part of their business plan for water quality as part of operationalising their Catchment Management Strategy (which was designed in collaboration with team member Professor Kevin Rogers from the University of the Witwatersrand). The IUCMA had embedded the results in the most developed example of water resources governance in South Africa and has the opportunity to influence the development of a CMA in the Olifants River Catchment. IWR-UCEWQ post-doctoral researcher, Dr Paul Mensah, led

the case study from April to October 2013, after which Dr Victor Munnik took over. Two Masters' students graduated, and their theses contribute to this report. The students and a research assistant were accommodated by the IUCMA and included in daily water quality activities. The assistant was later employed by the CMA.

The case study therefore embodied TPNP approaches, in that researchers and water resource managers ware institutionally engaged in co-operative activities to improve in-stream water quality. In this case study, the recognition emerged that conventional research into microbial pollution and eutrophication was not going to affect the kind of instream changes needed. The project team motivated additional resources (in the form of a WRC contract grant at the request of the DWS Green Drop Unit in head office) and initiated research-driven Green Drop campaign to see if the DWS Green Drop programme would be a more effective intervention to address both microbial pollution and eutrophication than conventional fundament research. The Green Drop campaign revealed exactly why the constant input of nutrients into aquatic environments rom wastewater treatment works is so hard to address. It is indeed a "wicked problem" that is not likely be resolved by additional scientific understanding but rather by concerted engagement within DWS, and between national and local government. A political ecology approach is most likely to be constructive.

The case study identified the problem but did not directly address non-point sources of nutrients – which would also require both social and technical interventions.

The Crocodile River catchment case study provided the most comprehensive examples of TPNP practice in all aspects required. (1) Water quality and aquatic resource protection: this case study research has had foundational, and strategic input into the 2017 National Water Quality policy and strategy, finding traction at the highest levels of DWS; (2) the Green Drop Programme was identified as a key intervention point for eutrophication and microbial pollution, and the deep intractability of the problem was made explicit. Progress absolutely requires politically-based action; (3) the case study showcased industry IWQM process co-operation, highlighted in a study of the sugar industry; and 4) novel and original research developed in other WRC projects was applied, and soft-ware installed in the IUCMA to integrate water quality and water quantity data for Adaptive IWRM ready to be implemented with implementation dates agreed. *This case study research clearly demonstrated practical use of TPNP approaches to both water resource protection and water quality issues, as well as having a direct national policy impact.*

Case Study 3 Olifants River Catchment: At the broadest biophysical scale, within an international catchment, with regional institutional co-operation, the Association of Water and Rural Development (AWARD) have been running a large USAID-funded project. The project name is RESILIM-O – towards improving resilience in the Olifants River catchment, as part of the Limpopo River Basin. The first stage of the project has been completed, with progress towards building a co-operative, systems-based understanding of the Olifants River basin across South Africa and Mozambique. Participants demonstrate learning and are acting to increase the resource protection and climate change resilience in the Limpopo Basin System. Currently the focus in on building civil society and catchment-based local capacity for Adaptive IWRM understanding and action. IWR-UCEWQ researchers have been members of the AWARD team, and RESILIM-O has an explicit aim to build water resource protection approaches. As the case study partnership progressed it was clear that the RESILIM-O and TPNP initiatives found traction at different rates, and that the USAID-funded results had to be reported first in RESILIM-O. **While this case-study collaboration was fruitful, with considerable co-learning, and clear evidence of the efficacy of TPNP approaches, the reporting into the TNPNP is in summary form from RESILIM-O. There is a related TPNP impact**

that combines case studies 2 and 3: the DWS is currently using the Crocodile River catchment pilot development of the water-quality-quantity integration software, with additional development by RESILIM-, into a Departmental IQWM project in the Olifants River catchment.

1.3 Direct influence on DWS IWRM practice and policy

The central arrow in Figure 1-12 indicates a process of engagement directly in IWRM in the DWS, and with linked NRM with the DEA. (Section 1.5 and Chapter 3, Section 3.8). Concurrently with the Case Study work, the project team worked actively with IWRM practitioners, especially within government so that the new paradigm practice (Adaptive IWRM), was co-created during the project rather than being simply reported for the first time in this report. The core engagement process, drew in a wide range of stakeholders and fuelled by a discourse or conversation about new ideas and methods (see Impact Table).

1.4 Key adaptions in this research project

Six major adaptations were made during this research project:

1. Title change: The project team and reference group recognised that the Adaptive IWRM was 'new' in terms of practice rather than concept, as the theories and concepts were already well established. The title of this project was therefore formally changed by the WRC, to "*Integrated Water Resources Management: Towards **Practising** a New Paradigm" (TPNP)*, with a clear focus on **Adaptive IWRM**.

2. The eutrophication and microbial pollution themes shifted and were addressed through supporting the DWS Green Drop approach, requiring a shift in project team members. Initially, it seemed that specialist scientific expertise in eutrophication and microbial was required. However, it became clear that the excellent scientists who joined the team were not easily adept at transdisciplinary complexity-based thinking and action-research, and that early outcomes were too conventional and were not sufficiently advancing practice. These team members stopped working on this project after contributing to early project deliverables.

   At the same time progress on the Crocodile River Case study was good – and it emerged that stakeholders there, in municipalities and industries had developed a clear focus on supporting the DWS Green Drop Programme as the way to systemically address both eutrophication and microbial pollution. For this reason, the Green Drop Campaign is reported as a distinct case study of this project.

3. Handbooks for practitioners: At the second reference group meeting a concern was expressed that the deliverables as they were described in the contract, and as drafted by the WRC, would not provide usable products in practice. The project team responded with the idea of producing a series of handbooks each of which would address an aspect of "how to…." act in ways aligned to new paradigm thinking, in particularly difficult areas of Adaptive IWRM. As a result, nine "How to…." handbooks are products of the project.

4. Adding the theme *Household Water Security*: The Makana case study was the most deeply stakeholder-led case study. The community members who were project research partners elicited from the wider community that household water security was the most urgent local water concern. Since the project team has recent experience in that field (Molony, 2014; Clifford-Holmes, 2013; Clifford-Holmes, 2015, 2016) the TPNP included addressing household water security as one of the areas on impact.

5. New research partners emerged and were profoundly influenced by the adaptive perspective: The DEA in collaboration with DWS, initiated a project to restore ecological infrastructure and support rural livelihoods in the Tsitsa River catchment, upstream of the proposed Ntabelanga and Laleni Dams (Fabricius et al., 2016). **The TPNP project team recognised the DEA was undertaking a very large project that would benefit from Adaptive IWRM thinking and practice.** TPNP resources were used to run three complex social-ecological systems workshops each at different levels of DEA management and operations: (i) Senior management (Director General, Deputy Director General, Chief Directorate, Directorate); (ii) provincial management and (iii) provincial operations. Through this, the Chief Directorate for Natural Resource Management (DEA: NRM) has formally taken on complexity-based transdisciplinary understanding of complex social-ecological systems as 'the way they work'. **This is the area of most active national governmental uptake impact of the TPNP in South Africa.** DEA terms Adaptive IWRM, Adaptive NRM. In that process, the TPNP project team has worked to broker a closer relationship between DEA and DWS. We are hoping that both Departments will take on Water, Sanitation and Catchment forums as their institutional arrangement for local participation in natural resource (including water) management. This has proved to be a circuitous pathway and a challenging goal – however laudable.

6. Further changes in project team: The final adaptation was a response to the retirement of Prof Kevin Rogers who led the process that produced the "fishbone" model (Figure 1-2), which is his strong legacy in the project. He remained an active mentor throughout but moved out of active participation. The reality of the USAID-funded RESILIM-O project partnership emerged and it became clear that results and intellectual property had to be reported separately. The RESILIM-O project also operates in terms of 'Adaptive IWRM thinking and practice', and researchers have shared generously across the two projects. In this report, however, the RESILIM-O results are reported as "Adaptive IWRM learnings in RESILIM-O", with thanks to Drs Harry Biggs and Sharon Pollard. RESILIM-O researchers are co-authors of the handbook: How to think in ways that make Adaptive IWRM practically possible". RESILIM-O was planned as the major TPNP vehicle to progress practice in resource protection. As this changed, the Crocodile River Case study then contributed the main advances in resource protection practice.

It is useful here to summarise a section that is part of Chapter 2, as it both completes Chapter 1 and has a place in Chapter 2. The section supports the wisdom and assertion of Cilliers (2006) that "a certain slowness" is essential:

Successful Adaptive IWRM needs to be developed in a sequence because some feedbacks take time to become evident, and the foundation stages must be in place for them to be recognised.

The most uniform finding across our studies was that it took considerably longer (two to three times longer) than expected to introduce these ideas at a level that was viable for meaningful implementation.

Although social learning processes contributed to the longer time frames, it seemed that, if the social learning component was skimped on, there was little chance of transformative outcomes that had a chance of persistence. A common feature was that although managers (or other 'practically minded' people) often wanted quick action, the project tended to produce only temporary results if the conceptual orientation steps were left out. Some conceptual steps appeared to be helpful if placed before others, even if this was unclear at the start of these initiatives.

Lessons learned:

- Patience and perseverance are required if we are to move to even reasonably effective developmental Adaptive IWRM. ***(This is probably the single most important truth to grasp and internalise!)***.

- The most important of all the concepts involved is the complex social-ecological systems (CSES), and we recommend that is included early in the process. For instance, transdisciplinarity initiatives worked better once CSES thinking was included. Strategic Adaptive Management (SAM) is useful as a 'practical management tool' with which to get going, the SAM procedures are built on an understanding of CSES's in their early steps (Figure 1-7).

- 'Rushing in' prematurely with the management actions proved less effective than we thought. However, SAM philosophy is very firm about taking emergency action when necessary, but only for genuine emergencies and, at the same time, to carry out the emergency action with sufficient time for the intermediate- and the longer-term processes to be established. Even the emergency process follows (a very short set of) the SAM steps. This apparent paradox is explained by the overlapping feedbacks expected in SAM.

- The iterative (cycling repeatedly through steps) nature of SAM, and many of the other guiding ideas, such as social learning, depends on each step feeding back to the step before, so that the next time round it can be done more effectively for the particular situation (learning by doing).

- Although this sounds philosophically sensible, it often turns out to be quite foreign to western-trained scientific-technical people and requires explicit attention and practice. In the early stages, people tend to wrongly self-assess themselves as 'obviously practising effective feedbacks' – **whereas explicit attention to feedbacks, and adjustments in practice, is fairly rare, and hard to establish as a habit.** Resist thinking that the cycling back to repeat and check is a waste of time. It is a VERY important step!

- Check and self-examine carefully whether you really have adequate feedbacks – if you don't, your process does not qualify as adaptive (for an excellent layout of feedbacks, see Pollard and Du Toit, 2011).

CHAPTER 2: PRINCIPLED PRAGMATISM IN THE PRACTICE OF ADAPTIVE IWRM

2.1 A set of guiding principles for the practice of Adaptive IWRM in South Africa.

Principled pragmatism is an approach that finds creative ways to deal with the challenges of practising Adaptive IWRM because it refuses to abandon the underlying principles of the approach on the basis that they are 'too difficult to practise'. One of the early TPNP activities was a "mirroring" workshop (the term taken from Engström's 2001 notion of mirroring in expansive learning). The workshop was attended by a group of researchers from other South African research groups, the project research manager, and members of the DWS, engaged with Adaptive IWRM thinking and practice. The outcome was the generation of a set on principles for Adaptive IWRM (Table 2-1), that were used subsequently in the case study research, and are recommended for widespread practice:

Table 2-1: Principles for practising Adaptive IWRM in South Africa: to transcend current practices, to transform, and to shape the future

PRINCIPLE:	**ADRESSES:**
From the National Water Act: equity, sustainability and efficiency	Discrimination, unfairness, and wastefulness
Courage – transformation is revolutionary and radical	Current paralysis in the *status quo*
Consciously accept, understand and act in terms of the implications of complex social-ecological systems: • trust longer, winding journeys • watch out for and accept emergence • we can't know everything – all our knowledge is provisional so humility is essential • requisite simplicity • relationality and relationships are key drivers	Pitfalls of mistaken "efficiency" and arrogant knowledge
Foreground practice and learning by doing, changed behaviour arises from awareness and knowledge transfer	"Listen to me and do what I tell you"
Foreground the social	Habits of science only, and science superiority
Pay attention to context	Habits of stereotyping and seeking recipes that can be broadly applied
Use values and principles to guide contextual decision-making	Beliefs that stereotyped roles and recipes can be broadly applied
Pay vigilant attention to emancipatory and transformative potential	Convictions that: "the rules work and cannot be revised"
Pay attention to power relations	The powerful are happy with the status quo: they created it and benefit from it.
Build on existing strengths and opportunities	Paralysis by enormity and tangledness* of problems
Cultivate consciousness and recognise "traps" of old practice – good facilitation can be helpful	That it is easier to ignore the implications of complexity and change
Work towards shared understanding	Starting with conflict
Work on challenges that bring people together	Paralysis by enormity and tangledness* of problems
Create a vision of a shared future (learn to be adept at moving between the challenges of the present and what will embody that future	Paralysis by enormity and tangledness* of current problems
Recognise the power of citizen science and participatory governance	Acceptance that real participation is too hard and too expensive

Pay attention to learning opportunities: work-based learning for change; social learning where tensions create learning chances, and learning for capability (doing the task), rather than competency (understanding the task)	Changed behaviour arises from awareness and knowledge transfer
Engage and co-learn	Avoid engagement where you announce and impart what is always only partial knowledge. Avoid just ticking “stakeholder engagement” box.
Contributed by participants at the TPNP Mirroring Workshop (Grahamstown, August 2014).	
* The metaphor we have come to use is that of the "knot”: – When one tries to untangle a piece of fishing line picked up on the beach, tugging in one place often tightens another, and then there is the seaweed, or fishing hooks that have become entangled. At first a lot of energy goes into loosening. In Adaptive IWRM the best we can often aspire to, is the conscious recognition of new options that arise as "knotty" problem areas are loosened, mindful of the future knots that will necessarily emerge. However, the team work, confidence and ability to take action, to monitor consequences and adjust direction become empowering ways of operating.	

Each of these principles is explained further:

Principle 1: Encourage ‘learning by doing’ and ‘doing in order to learn’
In the past, we thought situations changed because we learned new things. We thought solutions were simple and that people became aware of new knowledge and then learned new ways of acting. We thought solutions could be achieved by a ‘transfer of knowledge’.

Now we understand that change happens slowly, and in small steps. We need to share what we know with others who know different things, and with people who know things in different ways. As we respond and personally change, we become part of the transformation ‘learning by doing’ spiral. This kind of learning builds long and trusting partnerships between stakeholders. Managers and implementing agencies should join in with this learning, and work **with** their stakeholders, only using enforcement when co-operation fails (Roux et al., 2006).

Principle 2: Make social issues a priority
Physical and environmental scientists, and engineers, have dominated the water management scene and must now unlearn many of their traditional ways of seeing and doing things in order to enrich their work with insights and approaches developed in the social sciences.

It is really important to co-learn and co-develop knowledge across science, social science and the humanities (like art, dance, creative writing), in order to co-create knowledge with stakeholders, in particular water users, by paying attention to their life worlds.

Principle 3: Pay attention to the social context in which you apply your decision-making
Assigning rules and ‘recipes’ for doing things usually backfires because different ways of doing will achieve change towards a desired future, depending on contexts and circumstances.

Principle 4: Use values and principles to guide contextual decision-making
Because context is so important and so variable, practice and decision-making need to be guided by sets of principles and values that are developed among stakeholders. This provides the opportunity to adapt decisions and practice within the specific context. Rules, recipes and directives seldom support lasting implementation.

Principle 5: Make sure that decision-making promotes social and environmental justice
Change will only come if stakeholders see new opportunities to move toward a better future.

Rules are not actually easy to implement or change – and relying on rules without paying attention to justice produces for social unrest.

Principle 6: Pay attention to power relations and give voice to the voiceless
In general, the powerful are happy with the way things are, and will use distraction to prevent change, while the less powerful will lose even more of their voice.

Create opportunities for the less powerful to speak and be heard. Listen.

Principle 7: Stakeholder-centred facilitation is critical
Make stakeholder input the central theme of any engagement. Do not do superficial meaningless 'stakeholder engagement' in order to 'tick the box' of policy requirement. Do not do what is known as a DAD (Decide, Announce, Defend) or even RDDA (Research, Develop, Disseminate, Adopt).

These approaches come from using outside experts to find a solution to a problem that they think the stakeholders have.

Make decisions and propose solutions based on how the stakeholders see the issues and, on their capacity, to solve them. Do not overvalue how the visitor, outsider, or 'specialist' sees the problem – or the solution. They only know one part of it.

Always build on existing strengths and opportunities before proposing something completely new.

Principle 8: Cooperatively cultivate a shared consciousness of the issues at hand
Talk through the context and the problem together – sharing different ways of seeing and knowing. Use these open, trusting conversations to build a shared understanding of the challenges. Often stakeholders begin an engagement expecting conflict and become disheartened and paralysed when the problem seems too huge and tangled to make progress.

This kind of shared communication encourages institutions like Catchment Management Forums to thrive.

Principle 9: Work towards a future that stakeholders desire
Conflict and paralysis disappear when the focus is on the future, even if it is uncertain. Decide to take possible steps towards the future you desire, rather than getting lost in the mess and conflict of the present.

Principle 10: Persevere with stakeholder-based co-learning and look for ways that are as simple as possible, while taking account of everything that is important.
This is also known as 'social learning'. Citizen science is a valuable learning tool that can lead to untangling the enormous size of a problem and overcoming apathy. Build confidence in the stakeholder group by learning for capability (how to do and act), rather than competency (how to know and understand).

Often specialists 'know and understand' and communicate in ways that become overwhelming for many other people.

The research outcome is supported by, and is consistent with, principles recommended in the literature in the context of natural resource management. The notion of principle instead of recipes

or rules is fundamentally aligned with a complexity-based understanding which emphasises the importance of context. Principles hold in different contexts, where rules and recipes do not.

2.2 Further examples of principles

The critical contribution of this research is the recognition that a different way of working (practising) emerges from the realisation of the reality of CSESs, and that that way of thinking moves beyond reductionists science while preserving some of science's best traits in the form of a robust science (Rogers et al., 2013).

Having accepted the reality of CSESs we recognise that each circumstance through time and across space is unique, with a unique context and history. However, for practical purposes, we have to have some generalisations to work with. The TPNP emphasises the importance of principles, rather than 'recipes' and 'specific guides'.

The difference between a recipe or set of rules, and a set of principles is that principles are generalisations that last and can be applied in different circumstances. Context and history drive the specific way in which the principle will take its form.

The South African National Water Act (NWA) (No. 36 of 1998) was drafted with the main aim of ending the discriminatory and unsustainable water use practices of the Apartheid era. It was founded on the need to develop a system of Adaptive IWRM that ensures equity, sustainability and efficiency in the process of balancing water resource protection and use.

The NWA is progressive. The Act is based on a set of principles developed after a national stakeholder engagement programme and was finalised in the National Water Policy of 1997. Sadly, in the years following the early democratic hopefulness, a state close to paralysis has developed (Schreiner and Hassan, 2011; Woodhouse and Muller, 2017). There is slow and circuitous action in implementing the NWA, with a range of negative feedback loops tightening into an intractable "knot". This is especially clear in the slow pace of formation of CMAs and CMFs and in threats to Water User Associations (WUAs) (Schreiner, 2013), all of which are necessary for governance of Adaptive IWRM practice at the local, participatory, level to function.

The kind of national transformation required by the NWA is revolutionary and radical; it takes a great deal of courage to overcome the barriers. In fact, it requires re-wiring of how our brains work (Rogers et al., 2013), because, in this democracy, we have to change our thinking from the old, 'top-down' approach to policy implementation to a new thinking in which dialogue among diverse stakeholders is vital. This is the path to deepening democracy.

The CSES understanding means we shift from a focus mainly on water itself to a focus on all the inter-related social and ecological aspects water in the context of a catchment. Internalising the characteristics of complex systems (Figure 1-11) helps in changing "habits of mind" (Rogers et al., 2013). Table 2-2 summarises a comparison of these new habits with the old.

Table 2-2: An 'old' (reductionist/positivist) approach compared with a 'new' (complexity-based) approach (Rogers et al., 2013).

Whose reality is real?	
The reductionist habit	**The emerging complexity-based pathway**
Cause and effect are linear and traceable.	Non-linear feedback is a mass of interconnecting interactions; causes are often not traceable.
A system is divisible into parts that can be studied or resolved independently.	The interactions between parts are as, or more, important than the parts themselves.
Parts can be categorised into like types to reduce complicatedness through generalisation.	The variability between parts is of more interest than values above the average and generalisations.
The parts and the system can be fully understood if we have the right information.	Neither parts nor the whole system can be fully understood and therefore the world is full of surprises (and disappointments).
We can isolate and complete (finish) individual tasks, decisions, solutions.	The outcome of any one task affects others. There is no definitive end to a task, or solution to a problem. Therefore, we work towards a direction, value, or vision decided by a relevant group of people – stakeholders.
Given the 'right' information we can 'get it right' and tell people what to do; and – we can also 'reverse' or 'correct' something if we get it wrong.	There can be no right or wrong framing of a problem or solution. We judge outcomes in terms of values. A new state can be 'good enough' – rather than right or wrong. Often consequences cannot be reversed.
Stakeholders can expect someone to 'get it right' and to solve their individual and group problems.	Stakeholders must be part of the process, and we can only loosen/tweak the problem knot so as to reveal new perspectives and options.
This thinking is at least 300 years old – but no more. It became a habit with the industrial revolution, where uniformity of task and outcome were paramount.	This way of thinking is nearly 100 years old, and is not a habit because values determine outcomes, and values change.

The new style of CSES thinking also requires a change in styles of leadership, management and decision making. We need to move from bureaucratic hierarchies and rules for action to a style of "generative leadership", in organisations that are becoming "learning organisations" (Table 2-3)

Table 2-3: Principles of leadership (Roux et al., 2006).

	Conventional Bureaucracies	**Learning Organisations**
Leadership style	Primarily command and control, resulting in instructions and paper shuffling.	Primarily co-ordinate and facilitate – where knowledge grows (a leader may be a designer, teacher, steward).
Structure	Functional hierarchies. Vertical communication. Work **for** one boss (line manager).	Dynamic teams, horizontal dialogue, work across boundaries.
Culture	Planning at the top, doing at the bottom. 'This is our empire' syndrome with internal defensiveness /protection. Observe and criticise mistakes. Rather make no decision than the wrong one.	Driven by common vision and collaborative goal setting. Enthusiastic sharing across internal and external boundaries. Learn and adapt through experiment and critical reflection that leads to new knowledge and better decisions.

	View uncertainty, complexity and change as threats. We do not have capacity; Government must provide.	Treat uncertainty, complexity and change as opportunities for learning and improvement. We have the vision and courage to innovate.

Principles for Adaptive IWRM engagement … HOW to ACT (Palmer et al., 2007, 2015)

- Tolerate and even welcome discomfort and unresolved tensions; they are often gateways to knowledge and trust.
- Be sensitive to "Aha!" moments or insights.
- Note that irritation and conflict often signal moments of insight and a learning opportunity.
- Engage with balanced generosity; listen and share.
- Practice tolerance, build integrity and mutual trust.
- Be sensitive to 'arrivals' of both people and ideas.
- Create and use reflective opportunities.
- Manage discontinuities (people come and go, and arrangements change suddenly).
- Sustain enquiry (keep going when it is tough).
- Be conscious that everyone involved in the process is a whole, multi-dimensional person, with the potential to engage with their whole self and many ways of knowing.

ARE YOU BEHAVING LIKE THIS?
FOUR PRACTICAL WAYS THAT SHOW YOU ARE 'ON TRACK'

The South African National Parks have explicitly taken on CSES thinking and practice SAM (Rogers and Luton, 2011; Kingsford and Biggs, 2012). From their experience, and that of TPNP research team members we share four practical checks that indicate you are on track with practising new-paradigm, developmental Adaptive IWRM. If you are not thinking and acting at least partly like this, you will probably have difficulty putting developmental Adaptive IWRM into practice.

1. Each problem needs to be addressed with enough of the right tools by teams and/or staff that include some people who can use them

Experience indicates that if we are going to put developmental Adaptive IWRM into practice meaningfully, we need to use the set of potential ideas in our 'toolbox' (see "Fishbone", Figure 1-12). Just as different people use different tools to find their way – a compass, a map, a GPS, asking people – and everyone will most likely get to the destination eventually, those who use more than one tool will possibly do better.

We have noticed that wherever practice has shifted towards effective developmental Adaptive IWRM, the new paradigm tools – and different combinations of these tools – are being used. You do not have to use ***all*** the ideas and methods – choose the ones that will serve you best.

Lessons Learned:
It seems that using just a selection of the new ideas and practices can shift a situation toward a desired future. For example, the RESILIM-O project focuses on CSESs, resilience and social learning, whereas the Towards Practising a New Paradigm (TPNP) project produced the "fishbone"

model – and focused mainly on CSESs and transdisciplinarity. Each project or study will select appropriate tools. In Adaptive IWRM, understanding a catchment as a CSES is essential.
We found that people understand most of the "fishbone" ideas (Figure 1-12) relatively easily when they are working on a particular project or at a particular site, because the various ideas/tools overlap. Often different words are used for a similar idea – so look out for these. Common meaning usually emerges in shared conversations. While it is good to have an open mind about the value of a variety of ideas, we think it is more practical and effective to assemble a team where at least some members have a deep knowledge of the practice associated with particular ideas. We have found that some specialists, with important knowledge to share, simply cannot work flexibly and adaptively, and cannot place their knowledge into systemic engaged processes. Often, they feel they are 'wasting time'. Then it is better for team members who can work in a complexity-based way to access their knowledge and bring it into the systemic understanding.

So, you must decide how many (and which combination) of tools you want to develop for your purpose. You may land up choosing a combination of three or four approaches where you place your main focus, and these might be determined by available expertise, or your history, as well as obviously being suitable for your particular purpose. We recommend at least two fairly different ones, to help cover the range of challenges you will face. There is more below about a likely sequence of applying the ideas, which works well.

The reason this point of 'some useful tools and some people who know how to use them' is so important, is that often developers or practitioners waste time searching for the perfect solution, or the perfect team, or get stuck in frictions between the different approaches.

A critical success factor is having at least a few 'people thinking like this', with competencies across two or more concepts or ideas, in your immediate community or project team, working at your particular scale.

But, in addition, it is true over and over again that there are always individuals present with hidden ability in these skills, and they can be relatively easily skilled, often simply by being present and working with experienced and enthusiastic people.

Growing these 'new champions' has certainly proved possible and often surprisingly effective.
(Biggs, pers comm., 2015)

2. Encourage everyone to become comfortable with the inevitable messiness and patchiness

We grow up in a world that values perfection and often (consciously or subconsciously) emphasising the belief that is it possible to 'roll out' initiatives comprehensively across the country. In our experience this is not true, because of the contextual individuality of sites and circumstances. 'Success' in a complex world seems more related to taking account of context than to the perfection of any application.

This does not exclude striving towards excellence, and some standardisation of some factors across sites. It does mean that excellence should include defining unique contexts, and exploring which aspects are similar across sites and which are unique. We need to find sensible mixes.
Our findings showed that emphasising uniqueness and context was motivating, because local residents or managers tended to take pride in reflecting on what makes their situation special. Taking

careful account of context can mean participants 'reinvent their own wheel'. This redundancy – or repetition – is often a strength and contributes to system resilience.

Lessons Learned:

- Because it is difficult to actually set establish new ways of thinking and act in ways which will enable developmental Adaptive IWRM, and because of the importance of site-to-site differences, it is reasonable to expect that the spread of such initiatives will be patchy across the country. The examples of success may be rather rare but they are 'windows of opportunity or narratives of hope'.

- Although careful preparation and thought might suggest where new paradigm ideas and practice might easily be launched and thrive, there is always the element of chance. There will be surprises and disappointments. Respond to positive surprises with opportunistic energy and imagination, and to disappointments with perseverance – and imagination. **Do not let apparent early 'failures' demotivate you.**

- There is a recommended sequence for establishing the new practices – but you need to use your selection of 'thinking and acting' tools to think on your feet, and your persistence, flexibility and innovation will become critical success factors. The recommended sequence is called Strategic Adaptive Management – SAM. (See the "How to use Strategic Adaptive (SAM) and the Adaptive Planning Process (APP) to build a shared catchment future" handbook – Appendix 1h).

- It is clear that smaller municipalities in more rural settings, as well as large metros, struggle with water service delivery. Detailed engagement with two small Eastern Cape municipalities – Makana and the Sundays River Valley revealed really different 'blockages' to improving household water security.

- Makana has been mired in the political processes of leadership, and Sundays River Valley cannot 'ring-fence' water-related income and expenditure. The Sundays River Valley Municipality is also missing a crucial service level agreement with the local Water User Association. Both municipalities face severe limitations with aging and inadequate infrastructure. Both have begun to respond to new paradigm thinking. Both municipalities are beginning to engage with new paradigm practice.

3. The recognition that a developmental sequence of events or actions is necessary – because some feedbacks are only slowly effective and the foundation stages must be in place for them to be recognised

The most uniform finding across our studies was that it took considerably longer (two to three times longer) than expected to introduce these ideas at a level that was viable for meaningful implementation. This supports the wisdom of Cilliers' (2006) "a certain slowness".

Although social learning processes contributed to the longer time frames, it seemed that, if the social learning component was skimped on, there was little chance of transformative outcomes that had a chance of persistence. A common feature was that although managers (or other 'practically minded' people) often wanted quick action, the project tended to produce only temporary results if the conceptual orientation steps were left out. Some conceptual steps appeared to be helpful if placed before others, even if this was unclear at the start of these initiatives.

The recommended sequence of steps follows Strategic Adaptive Management (SAM), and is illustrated in Figure 1-7.

Lessons learned:

- Patience and perseverance are required if we are to move to even reasonably effective developmental Adaptive IWRM. ***(This is probably the single most important truth to grasp and internalise!)***.

- The most important of all the concepts involved is the complex social-ecological systems (CSES), and we recommend that is included early in the process. For instance, transdisciplinarity initiatives worked better once CSES was included. And although SAM is attractive as a 'practical management tool' with which to get going, SAM procedures are built on an understanding of CSES's in their early steps.

- 'Rushing in' prematurely with the management actions proved less effective than we thought. However, SAM philosophy is very firm about taking emergency action when necessary, but only for genuine emergencies and, at the same time, to carry out the emergency action with sufficient time for the intermediate- and the longer-term processes to be established. Even the emergency process follows (a very short set) of the SAM steps. This apparent paradox is explained by the overlapping feedbacks expected in SAM.

- The iterative (cycling repeatedly through steps) nature of SAM, and many of the other guiding ideas, such as social learning, depends on each step feeding back to the step before, so that the next time round it can be done more effectively for the particular situation (learning by doing).

- Although this sounds philosophically sensible, it often turns out to be quite foreign to western-trained scientific-technical people, and requires explicit attention and practice. In the early stages, people tend to wrongly self-assess themselves as 'obviously practising effective feedbacks' – **whereas explicit attention to feedbacks, and adjustments in practice, is fairly rare, and hard to establish as a habit.** Resist thinking that the cycling back to repeat and check is a waste of time. It is a VERY important step!

- Check and self-examine carefully whether you really have adequate feedbacks – if you don't, your process does not qualify as adaptive (for an excellent layout of feedbacks, see Pollard and Du Toit, 2011)

4. Making time to be pro-actively adaptive

A common context for organisations is that they hear about developmental Adaptive IWRM, or adaptive management, realise it has ***real potential*** for their situation, but then find themselves ***too busy and involved in 'business as usual'*** give it a fair try (and remember how long it takes). This barrier of finding time is made worse by the uncertainty of a new way of thinking and working.

An example comes from river and general environmental management in the Kruger Park. (Biggs and Rogers, 2003)

At the beginning, there was a long period when there seemed to be no time for an entry point. Senior officials deferred any crises or issues which seemed to require adaptive handling, to other people (for example 'external' scientists who had been part of the Kruger National Park Rivers Research Programme).

But…developmental Adaptive IWRM cannot be practiced through a third-party organisation, especially if internal people simply have not developed the capacity to practice the new approach or change their behaviour and emphasis. In this example, the new paradigm skills were not internalised in the implementing agency.

In SANParks, some external coaching and encouragement was essential, but it was only when a group of key internal officials realised that developmental Adaptive IWRM/SAM would never get started as long as they saw the current work overload as the priority – and new practice as something that would have to wait till an opportunity after that.

What they did then, was to ***re-orientate their own system*** to practically allow enough of the less important issues in the business-as-usual bundle to slide (with some obvious repercussions they anticipated) to free up time to begin the more proactive adaptive planning and management.

This had the predicted outcome – it helped, sometimes quickly and sometimes more slowly – reduce the large number of crisis-type situations, and once that pattern became clearer, it generally motivated staff in the organisation, and the proactive cycle grew.

Of course, there had to also be institutionalisation measures to assist this. After a while, senior management formalised the reporting and subsequent tracking of key thresholds into their regular science-management meetings. Management thus began to use adaptive cycles and feedbacks.

Crises never disappeared – in fact they keep arising partly because of non-adaptively-handled issues coming from other scales (e.g. head office) or from neighbours not using adaptive approaches. But at least a slice of the work over which there was more direct influence became more adaptively handled, and crisis management became less overwhelming.

Some further progress is currently being made, or is more likely to be made, as developmental Adaptive IWRM at different scales starts slowly aligning and certainly as CMAs (such as evidenced by the IUCMA) become operational.

REITERATING "HABITS OF MIND" (Rogers et al., 2013): DEEPENING PRINCIPLED, PRAGMATIC PRACTICE

If you think the principles presented up to this point have become habits for you, this next section gives you a new mix and additions to, your useful habits. They will help to deepen your practice of developmental Adaptive IWRM. (This section is based on Rogers et al., 2013)

Reminder: The TPNP way of thinking really is important if you want to change habits and move to practising developmental Adaptive IWRM. Once you really understand that principles are more useful than rules, that catchments really do operate as complex social-ecological systems – and that

therefore scale, feedbacks, and the interaction between elements are system drivers, then you are on the road to practising Adaptive IWRM. Also, because there is low predictability you must accept messiness and patchiness and still persevere towards your vision or goal – THEN the way you work will change and your practical actions will be more fruitful.

Remember: don't just rush into 'problem solving'. Assess the problem situation, act on the really urgent immediate crises, and AT THE SAME TIME start using the SAM steps and do them over and over adaptively.

Realise: a habit of mind is a pattern of behaviour that leads to productive actions. Habits of mind are seldom used in isolation but in clusters that together make up pattern of behaviour. When people are confused by dilemmas, or come face-to-face with uncertainties, their response is determined by their habits of mind.

So – try to become and remain aware of your habits of mind – and check that they support this new practice.

We offer you three broad frames of mind that each contain a set of habits of mind that are critical to leading participative planning and decision making in CSESs:

- openness,
- situational awareness, and
- respect the 'wait' or 'act' alternatives

Openness (see Text Box 1)

Change requires openness. This is difficult if your usual habit is reductionist and 'top down'. Openness includes being willing to accept diversity. People know and communicate different things in different ways. Personal and institutional openness means accepting things that do not make immediate sense to you, understanding that chance may make things unexpectedly easy – or difficult. It is helpful to hold your own strong opinions 'lightly'; do not take yourself or your opinions too seriously.

Text Box 1:

- *Habits of mind that promote patterns of **openness** in behaviour*
- Hold your strong opinions lightly and encourage others to do the same.
- Do not take yourself or your opinions too seriously.
- Be prepared to identify and accept surprises, chances, and unexpected understandings.
- Meet every person with equal respect, listen for their specific needs, knowledge, and ways of knowing.
- Be open to options that include aspects that seem to be opposite.
- Do not reject things that are not precisely clear, or that seem to include opposites.
- Seek out and respect all the various characteristics of other people, and different circumstances.
- Accept everyone you meet and work with as co-learners – not as either experts or people in competition with you.
- Encourage co-operation and consensus: **the best way to get what you need is to help others get what they need.**

(Rogers et al., 2013)

Situational Awareness (see Text Box 2)

One of the critical differences between complexity-based and reduction-based thinking is the importance of context and scale in complex systems. Issues, characteristics and interactions are different, with different outcomes in the wide range of contexts, and at different time and spatial scales. In addition – the values people hold deeply influence the ways they respond and make decisions. We use the acronym V-STEEP (Values – Social, Technical, Economic, Environmental, and Political) (Rogers and Luton, 2011) to guide aspects of the system that need attention from us when we start to work in a new context. Exploring each of these aspects builds our awareness of the specific context. As we work we pay attention to V-STEEP components and interactions, returning to them repeatedly through time. Practising V-STEEP awareness is a practical tool for navigating complex systems.

Text Box 2:

- *Habits of mind that promote patterns of **situational awareness** in behaviour*
- Watch out for and decide when a change is sufficient to require re-negotiation or review.
- Remember that understanding the ***relationships*** between the parts of the system may be more important than understanding the nature of each element.
- Watch out for and embrace people and processes, then help with change.
- Specify the time and space aspects of your system.
- Be aware of the history of your system and consider how the past influences the present and the future.
- Work with other stakeholders to discover the values that will drive decision in your system.
- Scan through the principles in this handbook and decide which one you will adopt in your system.
- Reflect often: formally, informally, individually, and collectively.

(Rogers et al., 2013)

A Healthy Respect for the 'Wait' or 'Act' alternative (see Text Box 3)

Leadership and decision-making in a complex system needs you to balance risks associated with practicing restraint and taking action. On the one hand, if the context requires it, you need to hold back and leave space for new ideas and opportunities to emerge. Remember the metaphor of the knot – it takes time (as well as trust and opportunity) to loosen the tangled problem knot. There is a strong need for a necessary slowness (Cilliers, 2006).

On the other hand, you need the courage to take action in a middle of uncertainty because, in a complex system, the consequences of our actions are never entirely predictable. Often it is necessary to act immediately and clearly – and then to watch and learn from the consequence.

How do you know what to do when?

There is no simple answer to this. Experience will help you begin to feel more confident of your decisions about when to wait and when to act. Go back to the principles of 'how to act' – as you practise these you will learn to recognise the moment for waiting and the moment for action.

You can trust yourself in the learning process because there is never an objectively 'right' decision. If you are working adaptively you will wait – or act – and then watch, communicate, listen and reflect on what happens as a result – and if the change is not in the direction of your values and the shared desired future for the system, there will always be another chance to adjust.

This pattern of working becomes adaptive leadership.

Text Box 3:
Habits of mind that promote patterns of a healthy respect for deciding on ***when to wait and when to act****.*

ACTING:

- Learn from experience when to act strongly even though there is tension, uncertainty and disagreement. Encourage courage – do not be afraid of intelligent mistakes.
- Avoid doing nothing in a vacuum. Waiting needs to active – watching for consequences. If fear is making you do nothing – then rather act.
- Have the courage to seize the 'just-do-it' moment.
- Accept that there is no one right place to start or end. Do so when it is sensible and useful.
- Have courage to take action from which you can learn. Even mistakes lead to learning.
- Push beyond discomfort – learning is uncomfortable.

WAITING:

- Avoid being too quick to make judgments and choices. Keep options on the table long past their apparent usefulness. Many will find context later in the process.
- Avoid overconfidence about being ready to take action in a data-driven 'predict and act' mode.
- Learn when to rest. Open and participatory engagement exposes vulnerabilities, requires humility, and takes energy.
- Going forward too fast leaves participants unsettled and vulnerable to defensive confusion.
- Provide participants plenty of time for questioning, healing and recovery from any discomfort.

(Rogers et al., 2013)

These three frames of mind are interdependent, with openness as the foundation and most critical one because it can enable or constrain the other two frames: adequate situational awareness is not possible without openness to a diversity of perspectives, because in a complex system, you simply cannot afford a one-sided perspective; knowing when to act and when to wait depends on your awareness of changing dynamics in the system, and it also requires openness to the unexpected.

The more specific habits of mind in the text boxes are more easily remembered and practiced when grouped under these frames, but they are not confined to use under one frame. As you become more practised in their use, it becomes easier to mix them. These lists of habits are a 'living list' that is continually refined as we learn by doing.

CHAPTER 3: OVERVIEW OF APPROACHES TO THE CASE STUDIES

3.1 Introduction

This chapter serves as a general introduction to the TPNP case studies, with feedback from the progress of the RESILIM-O project. We draw attention here, and note clearly, that each case is set in a different context and scale, and proceeded in different ways, as well as combining in use different discourses/practices and methodologies. To ensure a basis for comparability, each case study was required to use the Adaptive IWRM approach and methodologies, while not being required to record results in the same format. Case studies were designed to enable an exploration of scale effects – a core theoretical concept in complex social-ecological systems. We will be in a position to write a scholarly paper on a scale-comparison of practice-based Adaptive IWRM learning at different spatial and governance (institutional and social) scales, as a result of these findings.

Each case study includes:

1. **A contextual analysis that includes a description of the case study history, its original intentions and the issues it deals with, noting why Adaptive IWRM was required and why understanding context is crucial.**
2. **Explanation for case study selection, including expectations of how the case study would contribute to the overall aim of testing and/or identifying the interaction between new discourses and practices in Adaptive IWRM.**
3. **Record of participation.**
4. **Analysis and record of adaptation in the IWRM process, so as to recognise the reality of Adaptive IWRM. Emergence is a core concept in Adaptive IWRM thinking and practice. The case studies provide practitioners examples of recognising the emergence of new, sometimes surprising facts, perspectives and insights.**
5. **Conclusions to be drawn from the case study, including a record of adaptive research – how goals may have changed during the journey (while still achieving contractual project aims).**

Earlier chapters have argued that the suite of concepts underpinning what we have termed “Adaptive IWRM” do not in themselves constitute a “new paradigm” – but that **practising** those concepts does. The project title is therefore “Water Resources Management in South Africa: Towards Practising a New Paradigm”. A paradigm shift takes place when an older paradigm becomes so burdened with internal contradictions that it loses coherence, including the ability to explain the dynamics in its field of application, and finally its ability to guide interactions with realities and dynamics in its field (Kuhn, 1962).

In this project, we have argued that while the National Water Act (NWA) introduced many new ideas under the umbrella of IWRM, such as integration, subsidiarity, and water resource management that takes account of hydrological units such as catchments, implementation of the legislation was hindered by conventional thinking and practices, such as the application of positivist science without taking into account history, context, policy or practical effects (Rogers et al., 2013). There was a deep reliance on mono-disciplinarity, with a strong reliance on the practical field of engineering, and institutions were viewed as top-down, linear, line-function-based entities.

Complexity thinking was implied by IWRM, but not taken up in practice by the majority of practitioners (Pollard and Du Toit, 2011). However, a home grown South African version dealing with complexity, complex social-ecological systems (CSES), transdisciplinarity and strategic adaptive management

did emerge from work in Natural Resources Management (NRM) and IWRM (Cundill and Fabricius, 2009; Nkhata et al., 2008, 2012; Rogers and Luton, 2011; Kingsford and Biggs, 2012).

In order to find tangible evidence that would support – or refute – the practical emergence of such a new paradigm practice, as Adaptive IWRM, the TPNP project undertook a number of case studies to consciously test the practice of these new approaches in IWRM. The project also paid attention to the use of new paradigm discourses and practices within other, often closely related research projects and programmes in its environment. The aim was to interrogate the case studies and similarly engaged research to find evidence of the use of such ideas and practices, and to gauge what impact they make on practical, Adaptive IWRM. Because the project took place within a longer-run history of development and application of these ideas and practices; and among a broader cohort of researchers within the water sector and Natural Resources Management (NRM) more broadly, team members were also influenced by and learnt from other projects. Such related projects included the AWARD RESILIM-O project, as well as other WRC projects (Pollard et al., 2008; Rogers and Luton, 2011; Du Toit et al., 2012, 2013; UEIP, 2016; Munnik et al., in press). Researchers outside the TPNP core team were also brought into explorations of new paradigm developments, including on two formal occasions: the development of the Green Drop Campaign described in Chapter 6, and uptake of new paradigm ideas in the Natural Resource Management Chief-Directorate of the DEA.

The case study selection and final completion reflect adaptive responses to contextual change. The contract requires case studies to demonstrate what was called the “new paradigm” in terms of: 1) eutrophication, 2) microbial pollution and 3) water resource protection.

Contextual changes included: after 8 months of conventional experienced researchers engaging with eutrophication and microbial pollution there was no progress towards new paradigm thinking. Experience led the research team to the insight that we needed a higher-level intervention point and we selected the Green Drop Programme. It is a DWS institutionally supported programme, which, with increasing effectiveness can improve both eutrophication and microbial pollution impacts. The other case study aimed to address microbial pollution at the local level was the Makana case study. This study engaged fully with civil society in the co-learning and the co-creation of knowledge. Consultation by civil society research partners revealed household water security as their priority issues, and with the shift to Green Drop we took household water security on as an additional theme. The water resource protection theme was one of the core foci of the large USAID funded project – RESILIM-O – and that was the initial their case study. With time, it emerged that we would not be able to report USAID funded results in a WRC report – so this was downgraded to a record of RESILIM-O learnings in the Olifants River. AWARD works explicitly with Adaptive IWRM approaches. This also meant we lost the active and direct intellectual input of close AWARD collaborators Dr Sharon Pollard and Derick du Toit. At the same time Prof Kevin Rogers retired and was not in a position to maintain an active role in the project. He is a founder of SAM practice in South Africa, and a profound thinker and author in the field of what we call Adaptive IWRM. These were significant losses. Dr Victor Munnik stepped in as the second senior co-researcher in the TPNP project, bringing fresh perspectives and an extensive history of civil society engagement.

As a result, the following core case studies are reported, addressing the final themes:

1) **household water security** (Makana case study);
2) **water resource protection** (Crocodile River [Integrated Water Quality Management process] case study); and
3) exploration of the **Green Drop Programme** to address microbial pollution and eutrophication (Crocodile River [Green Drop] case study).

We also use recent, related projects to derive additional observed insights:

1) RESILIM-O (http://www.award.org.za/project/resilience-in-the-limpopo-basin)
2) Aligning and integrating biodiversity and environmental water quality into the mining development lifecycle. (Munnik et al., in press)
3) Principled, Pragmatic Revitalisation of Catchment Management Forums in South Africa (Munnik et al., 2015)

RESILIM-O offers perspectives on Adaptive IWRM at a transboundary scale, although institutional arrangements are only at a preliminary stage – with a proto-CMA in place. Two other WRC projects with close links to the TPNP are also considered as sources of learning: 1) Mining and Biodiversity focused on internalising biodiversity costs into decision making about coal mining, and centred on a CMF working group process, supported by transdisciplinary investigations (Burt et al., 2015; Munnik et al., 2015); and 2) a project on the revitalisation of CMFs, particularly a meeting of forums participants drawn from all over the country, called the Forum of Forums, which explicitly considered issues of knowledge creation and sharing in catchment forums and related spaces (Burt et al., 2015, Munnik et al., 2015).

In addition, two broader processes emerged out of the TPNP by invitation. 1) The DWS requested the TPNP team to support the development of Terms of Reference for the development of an Integrated Water Quality Management System (on national level) which was done through a WRC WAT-Indaba, as well as 2) a process with the Department of Environmental Affairs, Natural Resource Management unit/division after their decision to work within a Strategic Adaptive Management approach.

One of the core case studies (Crocodile River) is closely linked to an observed study – RESILIM-O. Work in the Crocodile River IWQM process including modelling and stakeholders' discussions, was directly applied in further work in the IUCMA to develop a dashboard of indicators in which water quantity and quality could be reconciled. These learnings were also taken into the support for the development of the new Olifants Catchment Management Agency (OCMA) and CMFs emerging in the process [RESILIM-O].

Scale matters

It was important for the project team to stratify case studies according to scale. The implications of smaller and larger scale differ in temporal, relational, biophysical and social domains. Constraints of one scale on another, or imposed from one scale to another, required clarification: for example, national legislation that constrains or limits local government. We describe social scales as being related interchangeably to social, institutional and governance dimensions. For example, power increases at higher scales (such as national policy decisions or international trade agreements) which can constrain decision making at lower/smaller scales. Project Aim 2 specifically required a scale-based approach.

The case studies were designed at spatial and institutional scales appropriate to the theme being addressed (Figure 1-2). The scale range was based on landscape units, **catchments,** with scale

related to hydrology: primary through quinary catchment scales. This is consistent with the Department of Water and Sanitation catchment units, and scales used in their Research Directed Measures Processes (DWAF, 2006, see Section 9.3). For example, the Ecological Category can be for any stretch of river, but would be expressed at the sub-quaternary or quinary scale. A Water Resource Class applies to all water users and is at the Integrated Unit of Analysis scale, which is even larger the quaternary catchments (DWAF, 2007).

The biophysical scale has the effect of focusing stakeholders' and institutional attention on an integrated biophysical system, its characteristics and its management (Fabinyi et al., 2014). The advantage of being explicit about bio-physical scales is to provide a material base for understanding, sharing and decision making. It underlines the importance of science, particularly ecosystems-based science. (The concept of complex social-ecological systems (CSES), Figure 1-1 is relevant.)

Research at smaller catchment scales, such as in the Makana (Chapter 4), (Crocodile (Chapter 5) and Carolina cases (Munnik et al., in press), facilitate the growth and use of local knowledge, and build familiarity and trust between the stakeholders involved. A literature scan indicated that practice outcomes are mainly reported at the "smaller" catchment scale (Table 3-1). The qualitative descriptors: i) Transboundary, ii) Large, iii) Smaller and iv) Areas of river contained in Municipal boundaries; are used in Table 3-1 because the area size of primary to quinary catchments depends on the size/area of the primary catchment. The role of catchment scale to Adaptive IWRM practice seems to be related as much to land area and distances between people as it is to the biophysical order of the river and its catchment area. A formal literature review and confirmation of where Adaptive IWRM practice has most commonly been pioneered, together with analytical work on underlying reasons and process drivers, would be fruitful basic research to underpin the selection of Adaptive IWRM implementation at difference scales.

Table 3-1: A scan of > 50 relevant research papers (see List of References, References 9.2) indicated practical experience in Adaptive IWRM is most common at a "smaller catchment" scale.

SCALE ⟶ **TPNP Concepts** (see fishbone diagram, Figure 1-12) ↓	**Transboundary basins/catchments** (across two or more countries) e.g. Inkomati, Limpopo Rivers.	**Large catchments in one country** e.g. Vaal, Orange, Olifants Rivers	**Smaller catchments** e.g. Sabie, Crocodile, Sundays, Berg Rivers	**Areas within a catchment under Local government** e.g. Sundays River, Makana, Mbombela Municipalities
Complex social-ecological systems (CSES) approach	⓫	O	⓫	x
Strategic Adaptive Management (SAM)	⓫	O	⓫	⓫
Transdisciplinary approaches	X	O	⓫	⓫
Social Learning	X	O	⓫	⓫
Systemic thinking – seeing links and interconnected functions as well as elements	⓫	O	⓫	⓫
Citizen science	X	O	⓫	⓫
Political ecology	X	O	⓫	⓫
Resilience thinking	⓫	X	⓫	X

Institutions involved in IWRM in South Africa are typically divided between those which follow a hydrological or catchment logic, such as Catchment Management Agencies (CMAs) with responsibilities for the nine Water Management Areas of South Africa (Figure 3-1), and those that do not, such as district and local municipalities, and provincial government departments which are crucial to the "integration", or "adaptive" part of Adaptive IWRM. Hydrologically based institutions usually receive more attention in IWRM analysis than non-hydrological ones. However, tensions and analytical distortions can arise as a result.

Table 3-2: Contributions to the Crocodile River Adaptive IWQM process

ORGANISATION	PARTICIPANT	POSITION	CONTRIBUTION (ZAR)/year over two years
DELTA EMD (mining)	Baijnath, Praveen	Chief Executive Officer	
	Carroll, Irene	SHEQ Manager	
	Naiker, Collin	Operations Manager	
	Seymore, Johan	Financial Director	75,000
MMC	Barnard, John	Improvement Specialist	
	Fourie, Walter	Environmental Superintendent	20,000
Samancor Chrome	Booysen, Heather	Group Environmental and Community Superintendent	
SAPPI PPE	Dreyer, Nic	Technical Manager	
	Engelbrecht, SW	General Manager	
SAPPI	Roothman, Duane	Regional Manager	40,000 (1 year)
SAPPI KRAFT	Smith, OB	Risk Manager: Ngodwana Mill	
Sappi Ngodwana	Olivier, Benjamin	WQ	
	Ackermann	Risk and environmental Specialist	
Sappi Forest	Van Tonder, Andre		
	Van Hoeve, Renee		
SEMBCORP	Oosthuizen, Yolanda	Scientific Services Manager	
	Haroon, Aneesa		
	Van Aardt, Marius	CEO	
Assmang Chrome	McLeod, Ashley	Senior General Manager	20,000
	Pida, Tswelopele		
	Schoeman, Pieter		
	Schoeman, Joe	SHEQ Manager	
SANParks	Peterson, Robin		
IUCMA	Selepe, Marcus	Manager: Water Utilization	
	Guedu-Ababio, Thomas	COO/CEO	
	Jackson, Brian	Specialist Manager: River Systems Operations & Data management	30,000
Crocodile River Major IB	Van Rooy, Dawie	Chairperson	
	Putter, Ronelle		
TSB	Van Rooy, Dawie	Director: Sugar	100,000
	Cronje, Pieter		
	Vermeulen, Clinton		
	Botha, Marianne	Secretary to D. van Rooy	
	Slabbert, Martin	General Manager cane supply	
TSB, Coca-Cola Sabco	Beyers, Greg	Consultant	
Coca-Cola Sabco	Claassen, Teresa	SHEQ Manager	80,000
Elands WUA	Bowers, Justine	Chairperson	
	van Noordwyk, Nick		
Mbombela Municipality	Seloane, Bertha	Manager in Water and Sanitation	
	Marota, Peter	Senior Engineering Technician	
Suidkaap Farmers Association	Shabangu, Abei Pillay	Chairperson	

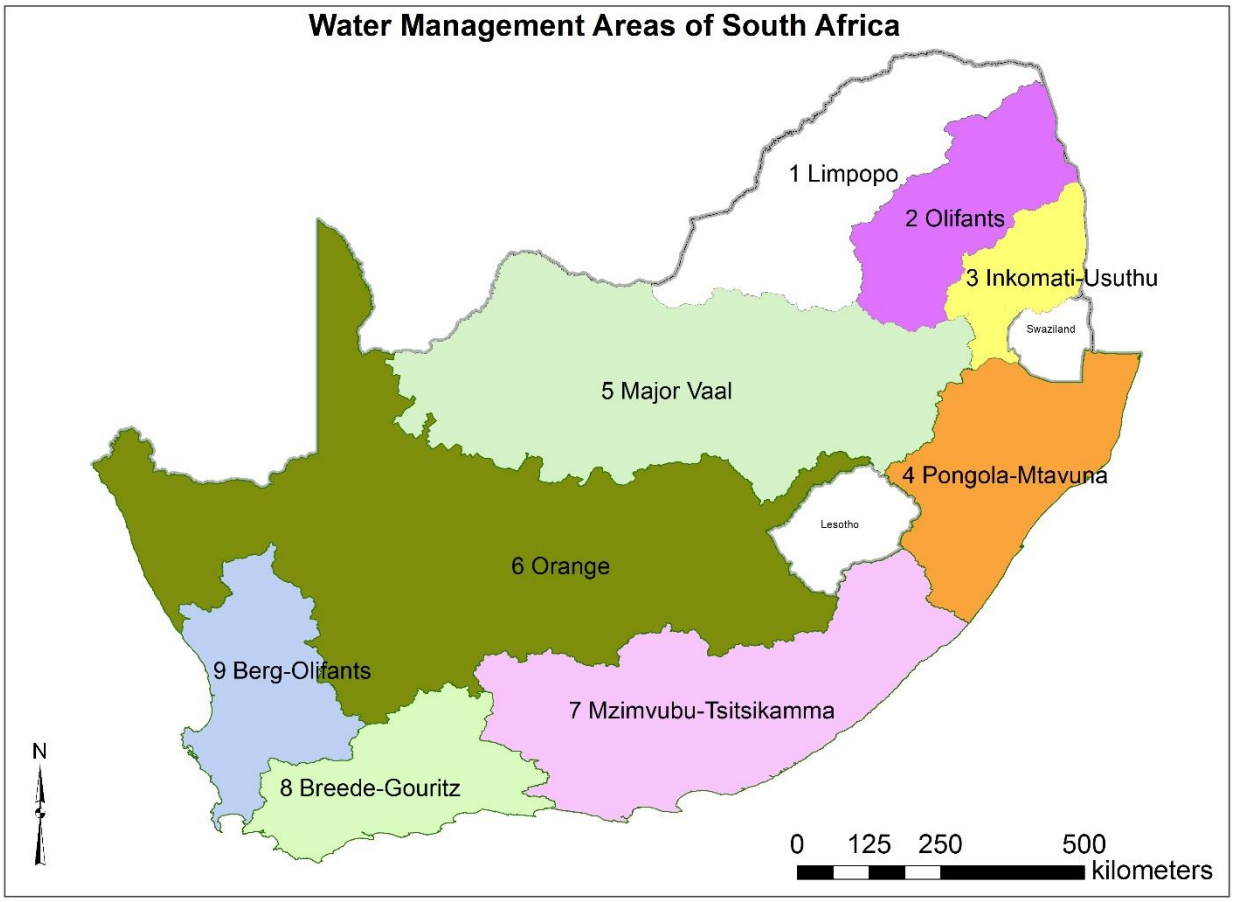

Figure 3-1: Nine water management areas of South Africa 9 (modified from Bailey and Pitman, 2016).

The two main qualitatively different types of scales – biophysical and institutional may overlap and are the result of a history of water sector's advocacy in the early 1990s (for example the Standing Committee on Water Supply and Sanitation (SCOWSAS) process, Schreiner and Hassan, 2011), aimed at organising water governance along hydrological lines.

The NWA principles (DWAF 1997) promoted the bio-physical logic, which drove the acceptance of CMAs, but the refusal to align local political boundaries to catchments led to current functional consequences of non-aligned political and CMA boundaries.

This gives rises to a complex system of multiple interacting boundaries. These boundaries are moreover porous and dynamic. This alerts the researcher to the possibility that the development of catchment institutions such as CMAs and CMFs may be in tension with the agendas of actors more invested in political scales (at both provincial and local scales).

Scale effects are also relational and are experienced by participants involved in Adaptive IWRM at different levels. "Critical Realism" is a philosophy and theory that provides a framing and conceptual tool to deal with relational scale in practice. Critical realism views human interactions in four planes (Bhaskar, 2008). Firstly 1) fundamental to all human life is interaction with nature, as a source of life's necessities. But the human that interacts with nature in an activity system (Engeström, 2000) can be best understood in three additional planes or dimensions: 2) individual stratified personality (Bhaskar et al., 2010) which is interested in how the person thinks, feels and acts as a result of a personal history or biography (the realities of hearts and minds); 3) that of face-to-face interaction, where the scale is small enough for knowledge to be shared and trust to be built. In some sense, face-to-face interactions are always part of situations, and 4) there is also the experience of

“institutional realities”, as when people, e.g. participants in a CMF, play a role to some extent defined by the organisations they represent.

Encounters with structure – with institutions – can be viewed on a scale from local realities, through scales of local/district government (a mixture of face to face and institutional logics), and provincial and national scales, on to scales that include large historical movements (colonialism, apartheid, post-apartheid democratic, e.g. constitution, shaping a stratified historical reality) and global discourses/practices (e.g. Adaptive IWRM in the water sector, biodiversity, sustainable development, human rights).

Because of this multi-faceted interest in scale and its many effects, the research team paid attention to specific scales at which case studies took place.

Exploring new discourses, methods and practices

Another requirement for the case studies was to find one or more practitioners to be involved and willing to work explicitly with the ideas and practices of Adaptive IWRM. In the three core case studies, this commitment was explicit and shared with participants in action research processes.

1) The Makana Case partner was the civil society group “Water for Dignity” (Weaver et al., 2017).
2) In the Crocodile River study, we worked with the IUCMA, and a set of industry partners contributed financially to the research (Table 3-2). The most engaged industry partner was the sugar Industry and one master’s student (Sahula, 2014) focused on their needs.
3) In the Green Drop case study, the active partners were the municipalities of Mbombela, Emakhazeni, Umjindi, Bushbuckridge, Nkomazi and Thaba Chweu.

In all case studies attention was paid to social learning, (Figure 1-2) and in particular expansive learning as presented in Cultural Historical Activity Theory (CHAT) (Engeström, 2000). The CHAT approach was introduced to research participants, from a theoretical perspective before the field research, during the research (for example at the start of each interview) as well as in a mirroring back process where social learning by participants was reflected back to them to ensure a reliable record. The use of CHAT enabled an “expansive learning” process (Engeström, 1987), aimed at identifying tensions in the activity system and using the energy of the tensions to spark learning and movement to a better-functioning system (Engeström, 1987) The RESILIM-O programme (http://www.award.org.za/project/resilience-in-the-limpopo-basin) is also explicitly committed to exploring the “new” discourses in practice and documenting and sharing the results.

The TPNP research team acknowledged that case studies worked with different combinations of theories and practices within the Adaptive IWRM practice approach. The combinations emerged both from theory and interesting combinations of team members’ intellectual biographies. The case studies thus link in different ways to the basic toolbox of theories, methods and general approaches (Figure 1-2) that make up what has emerged as Adaptive IWRM practice. The different ways in which theories and practices were integrated depended on emerging needs within the case study (for example the direction of household water security taken in the Makana case study); and also, team composition (three lead researchers left the project, each with sound reasons, and one, extremely fortuitously, joined the project). Adaptive responses to these circumstances indicate the open-ended nature of the emerging paradigm practice and its toolbox.

We take on our own advice in the TPNP handbook "How to think and act in ways that make Adaptive IWRM practically possible" (Appendix 1a): "***Each problem needs to be addressed with enough of the right tools by teams and/or staff that include some people who can use them"***.

A brief narrative of the approach and Adaptive IWRM learning value, of each core case study and observed study is given now in Sections 3.2-3.8. These serve as introductions to Chapters 4-7).

3.2 Makana Municipality: adapting to stakeholder priorities

Makana Municipality was chosen as the focus for one case study partly because it is the local municipality of Grahamstown, where the project institutional home, Rhodes University is located. (Note: many case study participants refer to the university as the University Currently Known as Rhodes [UCKAR]). There is already considerable water- and local government-related knowledge of the area, as well as of neighbouring local municipalities in the same district municipality – Sarah Baartman (Clifford-Holmes et al., 2014, 2015, 2016). The Makana case study focused on household water scarcity, in relation to governance issues at the local and district municipal scale, within the biophysical quaternary catchment scale. These scales overlap but the areas do not completely coincide. It is true of most case studies that the political area of jurisdiction and the hydrological area do not exactly coincide – see for example the Green Drop study in Chapter 7. The Makana case study provided insights into the role of civil society in citizen science, and engagement with local government, governance and institutional arrangements (Clifford-Holmes et al., 2014). Like all CSES's Makana is a product of its history (Mullins, 2011; Weaver et al., 2017) culminating in present water crises. The case study brought active citizen participation, and the sharing of knowledge between researchers and social justice activists. It brought considerable insight into grassroots issues and experiences, as well as perspectives on water justice, into the project.

Foundational knowledge was developed earlier in lower Sundays River catchment, with the Sundays River Valley Municipality (SRVM) (Clifford-Holmes et al., 2014, 2015, 2016), which focused particularly on water supply management and used systemic analysis to identify positive and negative feedback loops (Appendix 1e).

The Makana case study focused on civil society research partners (Water for Dignity), and the delicate task of working with a local municipality under strain from many demands, and with limited capacity to respond. It also showed how the local is embedded in bigger scales, and criss-crossed by actors from other, much bigger scales. Because of its history as a small but strategic city, Grahamstown also contains local actors who function on a national scale, particularly the university and the High Court. The university is dependent on the municipality as a water service provider, and acts at a scale and in a power position very different to that of the Makana citizens and the activist members of Water for Dignity.

3.3 Crocodile River Catchment (Mpumalanga): an integrated, stakeholder-driven approach to water quality

The second case study took place at the "smaller" catchment scale, in a secondary catchment, and institutionally with the first, and arguably the most advanced Catchment Managing Agency (CMA) in South Africa, the Inkomati-Usuthu CMA. The TPNP theme addressed was water resource protection, and the approach was founded on engagement with stakeholders, who were primarily industries along the Crocodile River. The resource protection focus was the practical application of new technology allowing the concurrent setting of integrated water quality and water quantity RDM goals (DWAF, 2006). It involved the development of an Integrated Water Quality Management (IWQM) process. The crucial project advance was the first practical application (Retief, 2014) of a model which enabled the integration of water quantity and water quality (Slaughter et al., 2012, 2017). The

project was characterised by strong and effective stakeholder involvement – and materially influenced the development of the Water Quality Management Policy and Strategy (DWS, 2017). The specialised study into the sugar industry as an example of a downstream water user in the catchment used both the WQSAM model and CHAT interviews in a novel and innovative transdisciplinary MSc (Sahula, 2014). The IUCMA is party to strict international agreements on cross-border water quantity and quality with Swaziland and Mozambique as to water quantity and quality on the shared Crocodile/Nkomati River and this case study will be of value in that process.

The Crocodile River catchment as a case study is relevant not only for its own water quality challenges, but also because:

1. It provides an example of addressing water quality issues at a workable scale (that is, simpler than, for example, the Upper Vaal River or the Olifants River catchments), while still including the complexity of multiple users including forestry, mining and beneficiation, farming (commercial, large scale and emerging/land reform farmers) and municipal WWTWs, as well as sensitive tourism and dense urban and rural populations.
2. It is in the care of one of only two functioning CMAs in the country.
3. It is well researched, good data are available, and its RDM river classification process was under way at the time of the research.
4. Stakeholders were keen participants, with a growing sense of their interdependence.
5. The Inkomati River catchment (the primary catchment) has international flow and water quality obligations to Mozambique.
6. It can serve as a living laboratory to develop principles and processes that assist with resolving water quality and linked quantity issues, that may useful for other challenged rivers and catchments. This research project comes out of a long history of engagement with the Crocodile catchment (Palmer et al., 2013), and support for the Inkomati-Usuthu CMA (Rogers and Luton, 2011). We will use the findings and learnings of this research to support the IUCMA further, as well as emerging CMAs in the Olifants (Limpopo basin) and in the rest of the country.
7. The research can contribute to a South African practice of new paradigm thinking: Adaptive IWRM, and specifically to understanding and managing water quality and quantity together in the context of adaptive integrated water resource management (AIWRM).

3.4 Green Drop Campaign: an integrated approach to the challenges of microbial pollution and eutrophication

The addition of this case study was driven by the insight – discussed in the project overview in Chapter 1 – that the research need was not for more detailed understanding of microbial contamination and eutrophication, but a more political or systems understanding of the management of WWTW by local government, and how a nascent catchment management system could deal with the problem, as well as the urgency of the matter for participants in the Crocodile River IWQM process. The work was deepened and extended, motivated by the initial TPNP work, in WRC Report K5/1098 (Munnik and Barnes, 2016)

The case study investigated interactions on two scales: 1) the face to face relational scale in a developing Community of Practice (CoP) in a working group of a CMF (the Crocodile River Forum), and 2) as well as the institutional scale of local governments who had WWTW along the Crocodile River and its tributaries. Given that the framework for the case study was the Department of Water and Sanitation's Green Drop incentive scheme, a national level was also involved.

The campaign brought together a range of stakeholders in an attempt to deal with a frustrating lack of improvement in dealing with dysfunctional WWTW, a top issue for the Crocodile River CMF, and

the Crocodile River case study. The crucial transdisciplinary innovation was the use of a political ecology (Budds, 2004; Delgado-Ramos, 2015) lens to understand better the power dynamics that determine the dysfunctionality. This was combined with systemic thinking, and facilitation for building a community of practice, in which expansive social learning was enabled. It also built social trust and developed the social instrument of a CMF working group for tackling specific water quality issues.

While pollution from WWTW is a top priority nationally (Dr Marlene van der Merwe Botha, DWS, personal communication, October 2013), in terms of both eutrophication and microbial pollution, there is a clear disconnect between this view of the national importance of dysfunctional WWTWs, and the lack of importance ascribed, in practice, to these issues by especially local government politicians and officials.

At the heart of the issue is the tension between the constitutional right of local government to provide and earn income from water services, including WWTWs, and the impact that dysfunctional WWTWs have on the broader environment, as these water resources belong to all who live in South Africa. This is a political tension. However, most interventions to solve the WWTW problem have focused on training and capacity building, emergency interventions and inspections and technical and infra-structural interventions. They have not addressed the political tension. This is exactly the intellectual-political challenge that the Crocodile Green Drop Support Campaign (CGDSC) took on, on the assumption that a principled and pragmatic Adaptive IWRM would need to deal with political and power issues. In this way, it answers to the question of "Why it is necessary to pursue a social-political understanding of bacteriological contamination and eutrophication in a transdisciplinary setting?"

3.5 Lessons from RESILIM-O (Resilience in the Limpopo Basin: the Olifants River Catchment)

The programme entitled "Water resources protection in the Olifants Catchment" is conducted under the RESILIM-O Programme: The programme is a co-operative agreement with a number of research partners, civil society originations, and government departments aimed at building resilience in two countries which the Olifants River traverses: South Africa and Mozambique. Initiated in December 2012, the programme addresses the reduction in the vulnerability of people and ecosystems through improved transboundary governance and management of natural resources. The programme is grounded in a grassroots approach to understanding the systemic causes of vulnerability, including climate vulnerability, and promoting new ways of thinking and acting to promote integrated water and biodiversity management. The TPNP was a research partner in RESILIM-O and there was mutual knowledge exchange between the two.

The programme deals head on with the challenge of integration, recognising the complexity it has to deal with. As AWARD comments: "If the key challenge is the achievement of a more integrated region for an improved quality of life for southern Africans, there will need to be an explicit attempt at the integration process. The integration of policy alone is not adequate. A number of practical, 'on-the-ground' interventions are required so that the higher order, regional integration is possible. This means that there needs to be a synthesis and harmonisation of daily institutional practices. This is particularly challenging given the legacy and the diverse nature of the region and its institutions."
Social learning is also a core issue: "We recognise that learning has a role to play in moving systems towards more resilient, stable and sustainable states. In a sense, such an exploration would look at the internal capacity or capability of social systems to learn and respond to contextual events and changes. The resilience, and hence sustainability of a system, is not an individual property, but a property of an entire system. Working at the catchment level is therefore an imperative in dealing with capacity building."

Key components of the Olifants new paradigm practice include the implementation of the Environmental Water Requirement (EWR), development of Resource Quality Objectives (RQOs) collaboratively with various sectors (especially mining, industry, agriculture and local government) so as to build understanding and capacity (in other words, action research); water demand assessments – through bringing together information from different sources, e.g. plans; Water Quality assessments and mitigation procedures, with land use assessments, assessments of discharge activities,' developing mitigation measures together with stakeholders, in the context of climate change predictions… and livelihoods vulnerability, exploring the linkages between human health and river health, how the river supports ecosystems and the services they provide… Water governance, sectoral priorities and social processes, Institutional capacity development, pro-poor planning, a specific learning and sharing strategy.

The RESILIM-O capacity development will be implemented over the course of the project. Towards the end of the project, activities will focus on capturing lessons learnt through implementation. These will:

1. Facilitate active stakeholder participation in local, national, and regional policy dialogues on transboundary management of the Limpopo.
2. Facilitate and support involvement of local NGOs and communities in management of sub-catchment.
3. Provide training in integrated water resource management for sub-catchment water management authorities and stakeholders.
4. Build capacity within governments, communities, and other stakeholders to formulate, develop, and implement natural resource management and climate change adaptation strategies that mitigate threats to biodiversity (water demand management, watershed maintenance and restoration, community-based forest management, livelihood diversification).

The RESILIM O programme, like AWARD itself, is very explicit about working with the discourses and practices identified in the TPNP, including complexity, systems approach, resilience, CHAT, political ecology, SAM and V-STEEP. The RESILIM team, internal to AWARD as well as many of the associated researchers, include people steeped in new paradigm thinking and practice, as well as some of the pioneers of this approach (Harry Biggs, Kevin Rogers, Sharon Pollard and Derick du Toit).

3.6 Revitalisation of Catchment Forums

This research project (WRC K5/2411) (Munnik and Price, 2015) was designed to accompany the Department of Water and Sanitation (DWS) revitalisation of Catchment Management Forums, which is taking place as part of the rollout of catchment management agencies, currently in progress. The revitalisation of CMFs is based on a 2014 draft policy (Mahashe, 2014) within the DWS which envisions the CMF role as acting as a communication channel between catchment residents and local government, municipality, other user-based institutions, and the CMA. The DWS proposals included that CMFs should become appropriate vehicles to foster cooperative governance between the CMA, local government and other stakeholder interest groups in the interest of integrated management to support Adaptive IWRM (Burt et al., 2015). Such activities could include monitoring, river clean-ups, catchment care and land care that could be voluntary or that could compensate participants within a public works format. Emergence of strong CMFs would give meaning and reality to the NWA and the National Water Resource Strategy 2 (DWS, 2013).

The current state of catchment management forums (CMFs) reflects many of the challenges of participation in Adaptive IWRM governance including racialised differences in who is able to participate, and therefore a questionable democratic practice within them, as well as a lack of official response to issues brought before the forums.

As part of this project a “Forum of Forums” met for two days in November 2015. Participants were drawn from both forum participants and organisations who were currently not in forums but preparing to enter them. Members of the TPNP research team participated in and supported the meeting.

Historical redress, equity and voice were prominent discussions. Exclusion through the use of English (excluding non-English speakers) as well as scientific language (excluding non-scientists) was a prominent issue. But exclusion was more basic, as logistic support, venue choice, chairing, minute taking and communication were identified as crucial supports for or obstacles to participation. Excluded groups that received specific attention included emerging farmers and spiritual leaders as water users. The Forum of Forums resolved to meet again, beyond the lifespan of the research project, in order to support the existing and emerging CMFs, which could be regarded as an outcome of action research.

An important argument – for the TPNP – that emerged out of this gathering of current and prospective CMF participants was for a **principled pragmatism**. Principled pragmatism means being pragmatic in terms of what can be done with available resources and within real contexts, while at the same time taking care not to breach principles which are fundamental to the achievement of social justice and sustainability within Adaptive IWRM. Examples that emerged from the Forum of Forums are:

1. Pragmatism should not shirk difficulties where principles are at stake, for example the high transaction costs for the participation of people from rural areas, where transport and communication systems are not well-developed, because this would be to repeat exclusion and sabotage the purpose. In this case, principle should outweigh pragmatism. It would of course be easier and cheaper to bring together the usual participants, but that would be hopeless in dealing with historical redress and inequity.
2. A simple, straightforward, easily translatable use of language has the advantage not only of inclusivity, that is, removing the intimidatory (symbolic violence) aspects of expertise; it can also encourage simplicity, clarity and sincerity. For example, in many CMFs circumspect and cautious explanations of the source of a water quality problem are given, according to which the participant must be familiar with a map, a sampling point, know that a certain mine or industry is located above that point, and that “high salts” or “high oxygen demand” indicate variously on-going non-compliance or a spill. Principled, pragmatic communication would mean pointing out the polluter and explaining the mechanism and results of the pollution clearly.
3. Principled pragmatism gives weight to a history of injustice, but also moves briskly into the present and its challenges. It does not split history from current challenges but understands the linkages and is prepared to deal with both.
4. Principled pragmatism subscribes to a principle of dialogue in “a parliament of knowledges”. It forms coalitions, which in itself can be a process producing dialogue, clearing misconceptions and suspicions, and establishing reasoned through, shared expectations. It builds a discursive democracy.
5. Principled pragmatism must be practical, and performatively consistent. What we argue in theory and determine in policy, should be lived out in practice.

3.7 Internalising the costs of biodiversity into mining decision making

Finally, a sister project (Munnik et al., in press) also developed the practice of CMF participation, and provided opportunities to test Adaptive IWRM processes. This project sought to address the contested arena of mining in relation to water resource and biodiversity protection by integrating and making accessible the multiple laws governing mining (and especially coal mining) practice. The clear understanding of the legally expected practice was then tested against actual mining practice – and the mining activity system evaluated using CHAT. At the same time, the condition of wetlands affected by Acid Mine Drainage (AMD) was investigated – and evidence of both AMD impact, and ecological recovery was presented. The ecological study, and apparent reasonable health of the affected wetland was moderated by a view that the wetland had been "reset" when an AMD event mobilised metal ions, and that there were now again being immobilised in the sediments, making the wetland vulnerable to another AMD event. In addition, the current method for delineating wetland was shown to be of limited use in indicating threat to the ecological health of the wetland as interruptions to the horizontal water flow would not be detected until the wetland was no longer functional and restoration impossible. These insights came from a hydro-pedology study. A resource economics perspective was added and the danger of simply monetising wetland value was raised. Mines refused access to key data, and the impunity with which some national government departments act was noted. Throughout the research process an AMD action group, part of the Upper Komati CMF was engaged, and tools developed to enable them to act in relation to the law in monitoring and mining activities – enabling the CMF to alert the CMA to unlawful processes.

The intended institutional outcome of the project was to form a network of government, private enterprise stakeholders and other stakeholders including civil society who had worked together – within an adaptive management framework – to develop and practice new ways of evaluating the benefits of a variety of water uses including water for mining and water for the conservation of aquatic ecosystems, and especially wetlands, and take this into account when land use decisions are made. This network – in the form of the multi-stakeholder Upper Komati Forum open working group – collaborated in identifying aspects of the current authorisation and enforcement practices that overlap, are inconvenient and/or ineffective. It developed an alternative 10 step process of decision making can be integrated with water resource protection processes of classification, reserve determinations and setting resource quality objectives (RQOs) and other environmental management processes such environmental impact assessment and environmental management plans.

The project was supported by a strong transdisciplinary (TD) approach, but the practice of concurrent knowledge exchange was only partially achieved, with some of the studies continuing in relative isolation. The project was successful in applying the understanding of catchments as complex social-ecological systems and a need for engaged transdisciplinary action research (Swilling and Annecke, 2012), to address the challenge of balancing water resource protection and water resource use. The project highlighted the need processes of water use licensing to **integrate** the needs of the mining industry as a water user (considering abstraction, waste disposal and landscape transformation) with the needs of wetland ecological health and ecosystem service delivery.

The focus on a CMF process as the fundamental institutional mechanism for building a network of locally engaged water users to collaborate in balancing water resource protection with water resource use by mines was questioned by the WRC – which was dubious of CMF effectiveness. A view was strongly expressed that conventional approaches with top-down networking, particularly starting with DWS had been anticipated. However, the project had explicitly committed to testing the TPNP-based Adaptive IWRM approach. Certainly, the Upper Komati CMF, including regulators (CMA and DWS national staff responsible for AMD), was an engaged and positive collaborator. It

seems important to communicate better the value and innovation of Adaptive IWRM approaches to the WRC.

3.8 Uptake by the Department of Environmental Affairs: Natural Resource Management

In South Africa, terrestrial natural resource protection is primarily the mandate of the Department of Environment Affairs (DEA), while the protection of aquatic natural resources is primarily the mandate of the Department of Water and Sanitation (DWS). Yet a catchment is an integrated whole where land and water are inextricably linked and people living in the catchment depend on the combined ecosystem services for livelihoods and well-being. In many instances, failure of natural resource protection can be traced to inadequate intra-governmental cooperation and co-ordination. This is especially true when the resource use Departments like the Department of Agriculture Fisheries and Forestry, and the Department of Mineral Resources are involved (Munnik et al., in press).

The Tsitsa River Catchment – a tributary of the Mzimvubu River, provides a case where the DEA and DWS are co-operating closely. The Mzimvubu is one of the last free flowing large rivers in South Africa, and the DWS is planning to build a large dam – the Ntabelanga Dam on the Tsitsa River (as well as a smaller hydro-power dam – the Laleni dam), and the DEA motivated to invest heavily (R465m over 10 years) in Natural Resource Management to contribute to soil erosion reduction, because the soils in the upper catchment are highly erodible, threatening the water storage life and capacity of the Ntabelanga dam. The planned NRM interventions were: alien vegetation clearing, physical soil erosion reduction (gabions in dongas and smaller scale surface flow reduction structure using geotextiles. A research budget was also included. The TPNP project leader saw this as a TPNP opportunity to work across the land-water resource boundary in line with TPNP principles. The TPNP approach was motivated to DEA, and TPNP resources were used to host a workshop for DEA senior management, proposing (Deputy Director General, Chief Directors and Directors) to illustrate the opportunities and implications of managing the operations and research to support the Ntabelanga-Laleni Ecological Infrastructure Project (NLEIP), using the TPNP approach.

Concept note submitted to the DEA for a senior management TPNP workshop

Ntabelanga-Laleni Catchment: working towards fairness and livelihoods within an environmentally healthy catchment

A concept note concerning an Ntabelanga Integrated Research Workshop: 4-5 March 2015

The Centre for Environmental Water Quality, within the Institute for Water Research at Rhodes University has been working in catchments, at different scales, with the widest range of participants, towards "social and ecological justice". That means working towards goal of human **and** ecological health and well-being. This means we work from a value proposition that:

- accepts that people live within a complex social and ecological (environmental) context – **everyone** lives in a catchment;
- ecosystems (or ecological infra-structure) provide people with services on which human health and well-being depends – both directly and indirectly;
- the many components, linkages, feedbacks, and non-linear processes comprising any set of people living a catchment – with natural landscapes and both rural and urban areas make the goal of achieving both human **and** ecological health very difficult; and therefore:
- that we have to do the hard work of **working across** the widest range of knowledge and skills, **WITH** the people living in, invested in, dependent on, and responsible for managing the various aspects of the catchment.

We call this approach "transdisciplinary and complexity-based action-research and practice":

> *"All research undertaken by UCEWQ staff and students is founded on the understanding that humans living on earth comprise complex social-ecological systems. It is the characteristics of complex systems that give rise to most of the intractable problems that arise in water resource management. Therefore, key foundation approaches to water research that seeks to shift and loosen problem issues, include complexity thinking (because the systems are by their nature complex) and transdisciplinarity (because it offers methods for concurrent knowledge development and sharing across disciplinary boundaries, and among communities, researchers and practitioners)."* IWR Annual Report 2012

There are particular skills and methods that are helpful in managing a transdisciplinary, engaged, research and practice programme. The NLEIP aims to engage exactly with the challenges characteristic of complex social-ecological system. The project is taking place in a context where much other work is taking place, there is a strong, diverse, operational component as well as a research component, and a wide range of catchment residents and people with connections to the catchment. At the end of the day we are hoping for a more intact landscape, a dam that does not fill up with sediment, and catchment residents who have more secure livelihoods and a better experience of wellbeing.

UCEWQ IWR has a Water Research Commission project, running from 2013-2016, *called IWRM in South Africa: Towards a New Paradigm (TNP)* – where the "new paradigm" is the implementation of "transdisciplinary and complexity-based action-research and practice". The TNP has a budget in 2015 to run a "mirroring" workshop, where we seek to learn and share across projects beyond the TNP case studies. We propose to use this workshop to upskill Ntabelanga research and practice managers and participants in "transdisciplinary and complexity-based action-research and practice" – and to collectively plan an integrated approach to the whole Ntabelanga project, so as to assist the project to achieve its challenging goals.

We propose that the workshop be hosted at Rhodes University, in the Environmental Learning and Research Centre 4-5 March. It will be facilitated by Prof Tally Palmer (Project leader TNP, and possible participant in the Ntabelanga Project). The workshop costs including tea and meals will be covered by the TNP project. The travel and accommodation costs of out of town participants will be covered by the DEA. UCEWQ-IWR will circulate starter documents and a programme by 20 February. A draft programme will be circulated to the DEA project leaders by 26 January and finalised in time to be circulated with the programme 20 February.

The WRC hosted one of their prestigious “Water Dialogues” in November 2015 to communicate the progress and aspirations of the TNP project. The programme and notes of the TNP Water Dialogue form a motivating appendix to this concept note.
22 January 2015

Professor CG (Tally) Palmer
Director, Unilever Centre for Environmental Water Quality
Institute for water Research, Rhodes University

As a result, Professor Christo Fabricius (NMMU and Stockholm Resilience Centre) and Dr Harry Biggs (retired Resilience Strategy Specialist, South African National Park, SAM theorist and practitioner) were retained as consultants to build a TPNP-based project. (Fabricius, Biggs and Powell, 2016).

NOTE: The NLEIP project was initiated, with the TPNP project leader securing partner funding from the Department of Science and Technology (DST) to develop catchment (land and water) governance research that would ensure local sustainability of resource protection measures. The DST and other NRF funding has allowed for continued Adaptive IWRM research to support the development of the Mzimvubu to Tsitsikamma proto-CMA Catchment Management Strategy and the emergence of CMFs.

In July 2016 the NLEIP MAREP (Management, Research and Planning) meeting was held in Grahamstown, with TPNP project leader, Prof Tally Palmer, a guest speaker, presenting “An introduction to social-ecological systems thinking and complexity theory. The MAREP programme title: **Social-Ecological Systems (SES) Management, Research and Planning Forum is indicative of TPNP influence.**

An outcome of the MAREP meeting was the formal adoption of complex social-ecological systems as the framing for ALL the NRM Chief Directorate activities.

The MAREP meeting included operations managers from all the provinces. Their response to the participatory face of CSES concepts was enthusiastic and in in some cases emotional. There was an evident urgency to make participation and stakeholder engagement real. The TPNP then motivated to run a further workshop on CSES practice with operational practitioners in the Northern Cape, Eastern Cape and KwaZulu-Natal provinces.

Concept note for a DEA-NRM operational practitioners CSES training workshop

How do you practically use the idea of complex social-ecological systems (CSES)?

A training workshop for DEA CSES practitioners 15-16 February 2017

Researchers in the Institute for Water Research at Rhodes University have been working in catchments (landscapes), at different scales, with the widest range of participants, towards "social and ecological justice". That means working towards goal of human **and** ecological health and well-being. This means we:

- accept that people live within a complex social and ecological (environmental) context (**everyone** lives in a catchment/landscape);
- ecosystems (or ecological infra-structure) provide people with services on which human health and well-being depends – both directly and indirectly;
- the many components, linkages, feedbacks, and non-linear processes comprising any set of people living a catchment – with natural landscapes and both rural and urban areas make the goal of achieving both human **and** ecological health very difficult; and therefore:
- we have to do the hard work of **working across** the widest range of knowledge and skills, **WITH** the people living in, invested in, dependent on, and responsible for managing the various aspects of the catchment.

We call this approach "transdisciplinary and complexity-based action-research and practice":

> *All research undertaken by UCEWQ staff and students is founded on the understanding that humans living on earth comprise complex social-ecological systems. It is the characteristics of complex systems that give rise to most of the intractable problems that arise in water resource management. Therefore, key foundation approaches to water research that seeks to shift and loosen problem issues, include complexity thinking (because the systems are by their nature complex) and transdisciplinarity (because it offers methods for concurrent knowledge development and sharing across disciplinary boundaries, and among communities, researchers and practitioners).* IWR Annual Report 2012

There are particular skills and methods that are helpful in managing a transdisciplinary, engaged, research and practice programme. The DEA NRM programme accepted CSES thinking as the basis for its practice at their 2016 MAREP meeting. Now we need to make sure that DEA on-the-ground staff both understand the concepts and know how to apply them practically in their daily work.

The goal is to address the question: How do DEA staff work to ensure that investments in NRM also have social benefit and livelihood outcomes for the people living in the landscapes where they work?

Professor CG (Tally) Palmer
Director, Institute for Water Research, Rhodes University

With the NLEIP progressing through another five years at least, there is the potential to deepen the DEA-DWS partnership and to enable Adaptive IWRM to become the embossed NRM practice in the Eastern Cape.

Note: The WRC has funded a "Green Village" research project within the NLEIP area.

3.9 Conclusion

Together the three core case studies, and the three shared and observed case studies provided opportunities to meet a core requirement in this research, namely to demonstrate how the concepts of complexity, systems thinking, social-ecological systems, transdisciplinary, resilience, social learning and strategic adaptive management – plus concepts that emerged during the research journey – contribute practically to equitable and sustainable integrated water resource management.

The next three chapters present the three core case studies as narrative accounts of the research, referencing more formal publication of the results. The chapter following them (Chapter 7) draws together the insights from the three core case studies, plus other cases that the project team participated in, or was able to observe. The case studies exemplify a collaborative effort in which discoveries and insights emerged and were shared in practice, in numerous workshops and encounters, and therefore cannot be said to belong to a few people only. However, we are mindful of the hard work of other researchers and have endeavoured to acknowledge their contributions – and the contributions of many participants in these studies.

CHAPTER 4: THE MAKANA HOUSEHOLD WATER SECURITY CASE STUDY

This chapter is supported by one published and three submitted research papers (Weaver et al., 2016, Weaver et al. Parts I and II, submitted; Hamer et al., submitted. They are not reproduced here to avoid issues of plagiarism. They are the substantive record of the detailed research findings. Until publication, confidential drafts are available from IWR, PO Box 94, Grahamstown. 6140.

4.1 Introduction

This case study took place at the local municipality institutional scale, within the quaternary catchment of the Upper Kowie River. The case study engaged with civil society research partners, local residents, and the local municipality, which was clearly under strain from many demands, and with limited capacity to respond (Weaver et al., 2017). The research was supported by previous research into challenges, dysfunctionality and privilege in the Sunday's River Valley Local Municipality, with insights drawn from systems analysis and modelling, including feedback loops (Clifford-Holmes et al., 2014, 2015, 2016).

The Makana case study shows how the local is embedded in bigger scales, and criss-crossed by actors from other, much bigger scales. Because of its history as a strategic small city, Grahamstown also contains local actors who function on a national scale, particularly Rhodes University, as well as national scale schools, churches and courts. The university is dependent on the municipality as a water service provider, but exercises power very different to that of the Makana Local Municipality residents, especially those of Grahamstown East who are the most underprivileged and alienated water users in Grahamstown (Figure 4-1). Engagement with the local residential community in Grahamstown East was initiated through a partnership between an NGO – the Khulumani Support Group (KSG), and the TPNP research team from the Institute for Water Research at Rhodes University. As a result, a civil society activist group, "Water for Dignity" (WfD) was formed, and members became civil society researchers practising citizen science (Weaver et al., submitted).

The (KSG) is a membership-based organisation of more than 100,000 victims and survivors of Apartheid-related gross human rights violations in South Africa (its membership was counted and verified in early 2016). Started by survivors testifying at the Truth and Reconciliation Commission (TRC), the KSG has become a globally recognised movement spear-heading healing and memory, the struggle for reparations, and active citizenship in countries transitioning out of conflict. (http://www.khulumani.net/khulumani/about-us.html, accessed 6 Feb 2017). After a meeting between KSG Director Dr Marjorie Jobson, and the TPNP project leader Professor Tally Palmer it was agreed that water remained a current injustice in South Africa and that "Water for Dignity" would become a KSG theme. The KSGs involvement in this research project not only provides a direct window into the enduring injustices after apartheid, but also shows a keen grassroots intellectual energy and local knowledge of water service provision.

The short account above of the actors involved, confirms the fundamental starting point in this research, that the Grahamstown water supply as a complex social-ecological system (CSES) with a history of service provision and infrastructure decisions (Mullins, 2011; Weaver et al., 2017, Weaver et al., submitted). When this history is probed, it reveals neglect and frustration which predate the present democratic dispensation, apartheid and segregation, and is rooted in the colonial era in which the origin of the current challenges – some would call it a crisis – can be recognised. Clifford-Holmes (2015) provides a strong coherent history of access to water in South Africa and in particular the Eastern Cape. This case study therefore echoes the other local government case study (the Green Drop case study, Chapter 6) in requiring a political ecology approach. In this study, the emphasis will be on the responses, initiatives and limitations of a civil society organisation, working

in close concert with a part of the university, the Institute for Water Research, in a difficult and dynamic situation.

The university is first a place of learning, so that this case study is somewhat exceptional in the on-going and close contact between the civil society activists and university students and academics, which created opportunities for both sets of actors together to probe issues of the politics of knowledge (although in the case study it was not named as such). Rhodes University is unusual in having four loci of engaged, participatory CSES research: the Institute for Water Research (Palmer et al., 2015, the Environmental Learning Research Centre (Lotz-Sisitka et al., 2016), the Department of Environmental Science (Cundill et al., 2014) and the newly formed Centre for Epistemic Justice and Engaged Research (Paphitis, in press). The TPNP team's research focus is encapsulated by the TPNP project: complex social-ecological systems, learning from practice, transdisciplinarity, community participation, and from civil society ideas about a politically aware knowledge practice, quoting authors like Paolo Freire who wrote "Pedagogy of the Oppressed" (Freire, 1970). **We suggest that this research practice produces a remarkable fusion of social justice concerns with a scientific and academic co-learning by students and academics.**

The Makana case study focuses on governance at the local and district municipal institutional scale, and at the quaternary catchment biophysical scale. It was designed to investigate the Cacadu (now Sarah Baartman) District Municipality, which surrounds (but does not include) Nelson Mandela Bay Metro, and includes the following Eastern Cape Municipalities: Baviaans, Ikwezi, Camdeboo, Blue Crane Route, Makana (which includes Grahamstown as its urban core), and the coastal municipalities of Kou-Kama, Kouga, Sundays River Valley and Ndlambe.

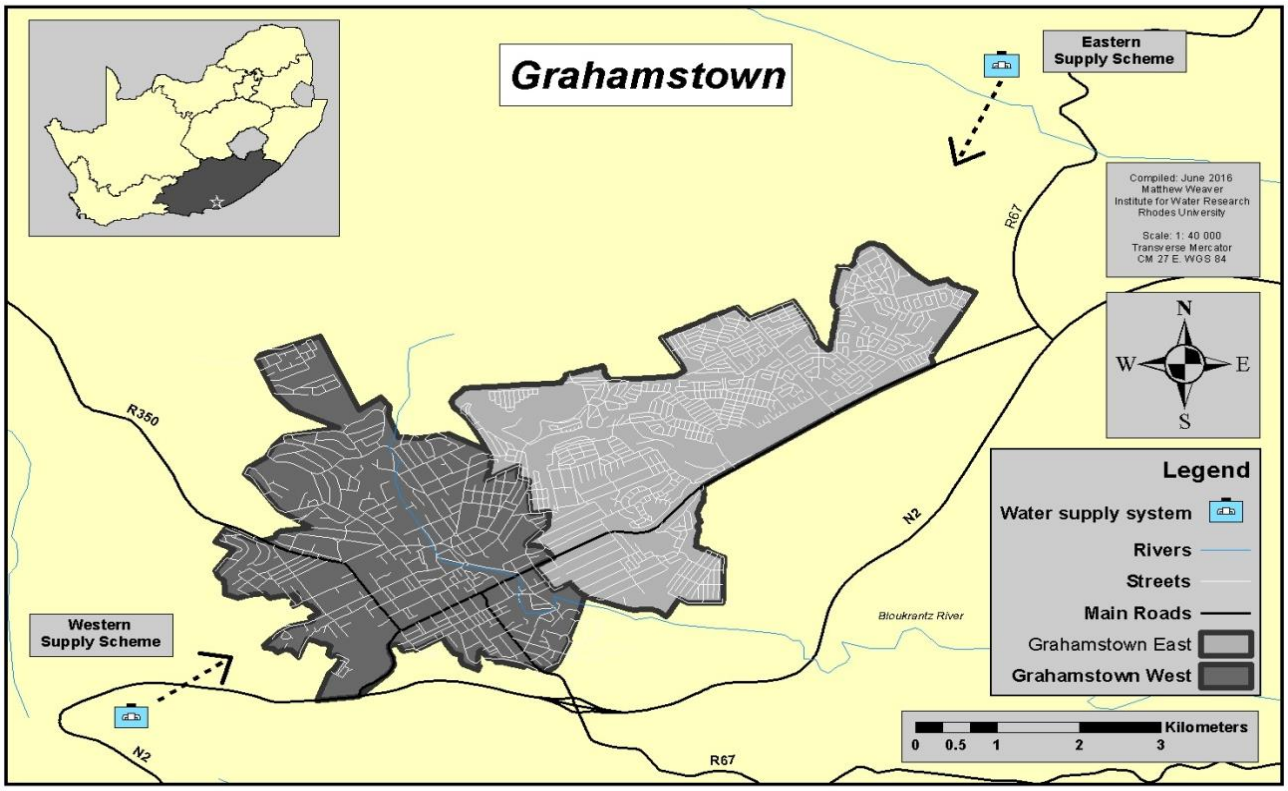

Figure 4-1: Map of Grahamstown, the location of the Makana Case Study. Depicted are the two recognised areas Grahamstown West receiving water from the western supply system and the former township, Grahamstown East, receiving water from the Orange/Fish River inter-basin transfer scheme via the eastern water supply system (Weaver et al., 2017).

The research process developed between 2011 and 2014 for the Lower Sundays River Valley (LSRV), and Sundays River Valley Municipality (Clifford-Holmes et al., 2016), was extended to the Makana Local Municipality (Weaver et al., 2017; Weaver et al., submitted), focusing particularly on water supply. The case study worked with citizen researchers, and other stakeholders to find a way towards a more sustainable approach to addressing local water supply issues. It aimed to provide insights local government governance and institutional arrangements. The case study focused on building an understanding about Adaptive IWRM based on what people think and experience, and not making assumptions about how to solve problems in advance. This work built on previous insights into district municipality and neighbouring Sunday's River, drawn from modelling, feedback loops, municipal dysfunctionality and failure. In the LSRV, the municipality exhibited reactive responses, were not responsive to service delivery failures and protest, and ultimately experienced the torching of municipal buildings (Clifford-Holmes, 2015)

4.2 The process of action research

4.2.1 Understanding the infrastructure and history

The project comprised two processes: interaction or attempted interactions with the municipality of Makana, and layered, iterative processes of learning by probing Makana's history, including its water infrastructure history, Makana residents' current experiences of water provision, as well as a number of initiatives aimed at immediate improvements of the situation, which, in themselves, were processes of learning and discovery.

Makana municipality was a central player in the case study, because it is legally responsible for water services. These responsibilities were researched in various parts of water legislation and policy by the WfD team with the support of TPNP research team members. The research reflected the fiercely held belief by the social activists that they needed to equip themselves with knowledge in order to be politically and socially effective. The team identified a number of problems in the municipality's provision of water services which corresponded to the everyday experience of many residents in a Grahamstown East suburb, Vukani. WfD activities included:

1. Citizen Report Cards: household surveys exploring water service delivery experiences of Grahamstown East residents;
2. Community Water Forums: water related neighbourhood-based communication hubs serving as information pathways between the MLM and Grahamstown East residents;
3. Emergency Water: installation of water storage infrastructure (5000L street tanks and 210L barrels) on streets and households to serve as an emergency water supply during instances of water supply shortfall; and
4. School Water Forums: awareness raising and encouraging best practices relating to hygiene, water conservation and catchment health.

(Weaver et al., 2017; Weaver et al., submitted, Hamer et al., submitted). (Note: the Hamer et al. paper is co-authored by the civil society researchers.)

In its first year, the project defined the priority issues around water services in the Makana Local Municipality, through a process of observation, document analysis, and stakeholder interviews at a number of levels. The Water for Dignity research involved provided access to a diversity of stakeholders in Grahamstown East, and the project team held meetings and interviews with other stakeholders, including Rhodes University management, its water task team, municipal officials, Re-Solve consulting engineers (engineering firm assisting the municipality), Amatola Water (regional water board who at the time were in negotiations about assisting the municipality), retired municipal staff, and other relevant initiatives such as the Kowie Catchment Campaign (local civil society

organisation), and the MobiSam (a Rhodes University, Computer Science civic communication project). An analysis of municipal records, newspaper articles and readers' letters, and a review of recent literature were undertaken.

What emerged from the preliminary analysis is a suite of historical, social, technical, economic, hydrological, and political issues that together build a contextual understanding of a complex and multi-variate set of circumstances which the municipality alone, in its present form, is ill-equipped to resolve without additional assistance. In making these issues public, the research team felt it was important to be clear about the purpose and scope of this statement: *Grahamstown East, and specifically the suburb of Vukani-resident's water supply experiences in Makana.* This was not to apportion blame, or to minimise the fact that, in many cases, and for much of time, these municipal services were being provided acceptably. The lack of water service delivery to a proportion of the population, and temporary failures of supply for several weeks in a year, was understandably foregrounded and emphasised by many of the stakeholders, because of the inconvenience, frustration and suffering that these failures caused. In Grahamstown West, the failure of the water supply to the university for a week or more at a time, caused tremendous difficulties for the students and for the university management. The long-term inadequacy of water services to a proportion of the residents of Grahamstown East causes ongoing suffering to those affected.

What were the difficulties and problems for Makana's water services provision?
There were hydrological and climatic factors. Grahamstown sits in a semi-arid and highly variable climatic region, with an average rainfall of around 600 mm per year, and is prone to droughts. The historical rainfall record shows that through the record, every month in the year has at one time recorded the highest, and lowest, rainfall in a year. The local rivers are small and unreliable. The augmentation of Grahamstown's water supply by the Great Fish River scheme, which provides water via an inter-basin transfer from the Orange River, since the 1990s, has greatly reduced the risk of water shortages. However, the Fish River water carries high loads of suspended sediment and dissolved salts, which create treatment problems. The Fish River has an old marine geology and the water tastes somewhat brackish. Here biophysical factors exacerbate social factors – Grahamstown West is supplied from local dams collecting water from rivers flowing over a quartzite geology – delivering tasty drinking water in comparison to the more salt water supplied to Grahamstown East – from the Fish River.

There were historical factors. Growing populations since the colonial founding of Grahamstown in the early 1800s consistently required the area's authorities to find and exploit additional water supplies. Recent increases in the population of Grahamstown East, and the expansion of Rhodes University (the largest single user of water in the municipality), are just the latest strains on the municipal capacity to provide infrastructure, water supply and sanitation. The municipality has a history of responding to service needs once they have developed into crises and does not appear to have ever engaged in extensive forward planning to avert shortages and supply shortfalls.

Aging infrastructure was a factor. Much of the piping and pump capacity from Grahamstown West's local supply (from Settler's and Howieson's Poort dams) is over 60 years old. Spare parts are hard to come by, and pumps have to be transported to and from Johannesburg for repair. Much of the town's piping system is also old, and has been installed in an *ad hoc* fashion, without adequate mapping. The result is that there was no detailed system diagram in 2014, and one had to be commissioned. A complicated system of pipes and valves was therefore not understood, and pressure differences caused further damage to infra-structure and water leaks. Many of the water meters were initially hard to find. All of this hampered routine maintenance and repairs. At the same time, there was a growing need for water supply pipes and sewerage infrastructure to Grahamstown

East. Despite more secure water supply available for Grahamstown East from the Fish River, potable water supply was interrupted because of the capacity, and maintenance of the water treatment works.

Another complex problem was related to wastewater treatment. There were large, visible leaks of untreated sewage in sections of Grahamstown East. According to Re-Solve, the consulting engineers that assisted the municipality, the repair of these leaks, while removing the health, smell and aesthetic problems caused by surface flow of untreated sewage, would significantly increase the problems of the two wastewater treatment works (WWTW) which were already grossly overloaded, and would not be able to cope with the significant increase in the volume of untreated effluent delivered to them.

There were also social and economic issues. Apart from the constant population growth which has meant that the municipal authority is consistently playing catch-up with water service provision, Makana had to deal with a situation typical for many authorities in South Africa: A fast-growing community of formerly disadvantaged black people, for whom the municipality has a priority responsibility to provide adequate water services, often from a base of no, or rudimentary existing services. A large proportion of this community was, and is, unable to pay for the installation or maintenance of these services, because of unemployment (estimated at 40% in Grahamstown East). The much smaller privileged community in Grahamstown West (about 10%) has always had access to adequate modern water facilities, and a corresponding intolerance when these facilities are not fully serviced. This community provides the large majority of municipal funding (Rhodes University alone provides 64% of Makana's GDP). Municipal priorities are consequently schizophrenic, with priority needs that are not adequately funded, but priority demands that seem less serious, but have the economic muscle.

An example of the University's involvement with the Municipality could be seen in a circular from the Rhodes Vice-Chancellor outlining a series of funding difficulties: "In September 2012 the University discovered a discrepancy in its municipal electricity account. ..... The Municipality undertook to investigate the discrepancy and to revert to the University; the discrepancy, however, remains unresolved and a matter of dispute." In October 2013: "Makana Municipality approached the University and indicated that it was experiencing a cash-flow problem ..... and would therefore not be able to meet its staff salary and wage obligations due for payment on that day ..... The University agreed to make a once-off advance payment of R 3.0 million to the Municipality for municipal services." This shows the University as powerful actor but also dependent on the municipality for its water supply. That this structural situation had an impact on the research project was shown when members of the research team published in the local press an alternative point of view to that of the University as an institution.

There was a lack of capacity. The municipality had a critical lack of technically qualified staff (Table 1). There was only one qualified engineer employed, considered adequate for a municipality of Makana's size. The other difficulties listed here were undoubtedly factors in the inability of the municipality to hire and retain staff, particularly technically qualified staff that are employable elsewhere.

Table 4-1: Makana Local Municipality Annual Municipal Strategic Self-Assessment 2014 (Source: Office of the Administrator, 2015, p.4). Low vulnerability (75-100%), moderate vulnerability (60-75%), high vulnerability (50-60%), extreme vulnerability (0-50%). (Source: Office of the Administrator, 2015)

Indicator Description	Score
Management Skill Level (Technical)	35%
Staff Skill Levels (Technical)	40%
Infrastructure Assets Management	10%
Operation and Maintenance (O & M) of Assets	40%
Financial Management	30%
Revenue collection	15%

Communication was an issue. Municipal staff were consistently criticised for poor communications at many levels. Probably because of under-staffing, but also in response to constant criticism, it seemed that the communications division of the municipality were unable and/or unwilling to set up regular and open communication channels with stakeholders. This resulted in a lack of response to reported failures, and a lack of information about impending service outages. This behaviour was a major cause of frustration for stakeholders, who were unable to plan for outages, or to be clear where and for how long these would last. According to Re-Solve, there were a number of initiatives in process which would materially improve service delivery, but these are not being adequately publicised or communicated to citizens. An example was that there is a widespread perception that water leakage is still a major cause of water wastage in Makana, but in fact, most of the major leaks had already been repaired, although the research team observed that since then, new leaks emerged. [But things change: recently, in February 2017, the municipality made a concerted effort to regularly inform residents of service delivery disruptions and management responses. However, this service was only available to residents with access to internet or smart phones]. The involvement of the University project MobiSAM, a mobile phone-based water communication project became extremely important. The TPNP researchers connected MobiSAM and the Municipality.

There were and are undoubtedly major political issues, both between different parties vying for power within Makana council, and within the ruling ANC party. Parties and individuals used the water crisis as a vehicle for political “point scoring”, and there were allegations of corruption, hiding of information, and the appointment of highly paid jobs on the basis of political affiliation rather than competence. Makana Municipality was place under administration 6 October 2014-July 2016, and to date (September 2017) has only had acting Municipal Managers.
The research team judged that it would be very difficult (and probably unwise) for the project team to engage in these controversial issues, which would, at the very least, harm the image of the project as an “honest broker” aiming to develop ways of assisting all stakeholders.

At this stage of the research, complexity thinking proved an absolute prerequisite for engaging with this situation. The research team observed that at present, most stakeholders in Grahamstown were clinging to a comfortable assumption that there was one major cause for the problems in Makana’s water service delivery, and that, if this could be rectified, all would be well. The multiple, concurrent and interdependent major causes included the need to:

- replace the aging infrastructure
- consider replacing the council members or municipal staff
- hire consultants to re-plan the water services
- organise a monitoring and maintenance programme

- access substantial additional funding.

These assumptions were well-illustrated in an October 11th 2013 editorial in the local weekly newspaper Grocott's Mail, which asserted that "we (the newspaper) have been trying to get to the root of the water problems in Makana ....". The project team responded in a letter published in Grocott's October 25th issue: "The first thing to realise is that there isn't one "root", there is a tangled network of roots, and they go very deep, and in lots of wiggly directions ...."

It became clear during this initial phase of the project that a primary task of the project team was to communicate with stakeholders that the Makana water services situation is made up of a complex web of issues, which will all need addressing at different time and spatial scales, for which there is no "quick fix"; and that solutions require a change of mind-set. We paraphrase the late John F. Kennedy "Ask not what your municipality can do for you – ask what you can do for your municipality". The present predilection of most citizens to complain and criticise, needs to change to one of trying to help with solutions. In this regard, the Water Dignity programme has adopted as its mission "to change from just complaining, to becoming part of the solution".

The research project was careful to take note of concurrent initiatives that were operating to improve Makana's water services. Because of protests and adverse national publicity, a Presidential task team was sent in late September 2014 to assess the situation, and to plan remedial measures. It appeared that additional funding (R3.5 million) had been provided to Makana Municipality.

The Makana Local Municipality had already been relying on the regional water board, Amatola Water, to manage its bulk water supply since the 3rd October 2013. Under this five-year support agreement, Amatola Water would be responsible for bulk water supplies to Makana, including delivery to the water treatment reservoirs and ensuring compliance with water quality guidelines. Makana would still be responsible for distribution of water throughout the network, as well as wastewater treatment. A capacity-building plan was built into the agreement, so that Makana would be better able to effectively take over the five-year period. However, the municipality owns the smaller dams (Settlers and Howieson's Poort) which means they are not supported by the DWs regional office in technical issues or monitoring.

Rhodes University had appointed an internal task team in 2013 to investigate their short-, medium-, and long-term responses to improve water security on campus. Their terms of reference, in order of priority, was to address the following issues: drinking water; sanitation; dining halls; ablutions; laundry, life science and chemistry buildings; the health centre. The plan included a crisis management system to ensure a three-day emergency supply of water, utilising either rainwater harvesting and/or existing groundwater, which was being used for irrigation of grounds and gardens. The plan also addressed ways in which university expertise and resources can be used to assist the municipality. There was no plan to render the university independent of municipal services, although a water tanker was bought, and back up plans put in place for outages, such as using JoJo tanks (popular name for plastic rainwater harvesting tanks) filled by tanker and an intermediate reservoir on campus.

Response by the research project after the diagnostic phase

From this preliminary analysis, it was clear that the TPNP project should aim to cooperate with, and assist the municipality, Amatola Water, and the university with their planning and implementation where those institutions indicated openness to assistance. All of these organisations, as well as the Presidential task team, were at an early stage in planning, and the project team was sensitive and careful to respond appropriately as plans developed. The priority was to develop close relationships

and to build trust with these organisations, so that they felt comfortable to communicate their plans to the research team openly, and to include the research team in their implementation. (NOTE: By 2016 the IWR had contributed to a Terms of Reference for a local water forum, it was formed by the Municipality and the Mzimvubu-Tsitsikamma proto-CMA and has met regularly for a year. The CMA noted the positive contribution of the forum in a state of acute drought and critically low dam levels.)

The Water for Dignity team continued to be the main contact with stakeholders in Vukani, Grahamstown East. Their planned activities continued to concentrate on developing citizen report records, leading water awareness activities and capturing the experiences of Grahamstown East residents. These included: a survey of water-related health problems in school; the initiation of ward-based water forums, providing residents with a meeting place to express opinions; organising “water walks” to publicise environmental issues in urban streams and wetlands; and a media scrapbook to capture publicity on water issues (Hamer et al., submitted). A post-graduate student, Matthew Weaver, researching the role of civil society in grass-roots water resource management, assisted Water for Dignity in organisation, recording, and analysis of their data and results (Weaver et al., 2017, Weaver et al., submitted, Hamer et al., submitted).

At the core of the TPNP project was the need to reflect on and use emerging data to develop new ways of thinking about water management, that can accommodate the complexity and multiple dimensions, at different temporal and spatial scales, that must underpin any successful implementation of Adaptive IWRM. This initial stage of the Makana case study already provided significant insights into the nature of this complexity. The development of systems heuristics (Figure 4-2) was an example of a method with which the project team achieved a better understanding this complexity; as was a record of the history of the Grahamstown water system.

History of Grahamstown water system

Early 1800s-1850 (Small reservoirs, wells, furrows and iron pipes)
For an adequate water supply for the initial settlement, sluices were built running from the hill to the south, and collected in a tank built in 1818 (Maki, 2008). Each household could draw its water in accordance to a timetable. There were also two wells, but collection was time consuming. The Mfengu women saw an opportunity to get paid to carry the water for the white townspeople (Maki, 2008). From as early as the 1820s the water supply became a problem as the population gradually increased. From here on history follows a general trend of the demand for water outweighing the supply.

Successive councils dealt with water problems as they arose and consequently were seldom ahead of the race to supply adequate water to the population. When a decision needed to be made, it was often the cheaper alternative which was chosen or at least the decision was postponed until all the cheaper alternatives were explored (Maki, 2008). In the 1940s when the furrows fell apart and got clogged with refuse, polluting the water, iron pipes were installed and a town reservoir was built. Poor planning resulted in a number of problems from the beginning, the small dams were badly constructed and the pipes got damaged from being placed too close to the surface.

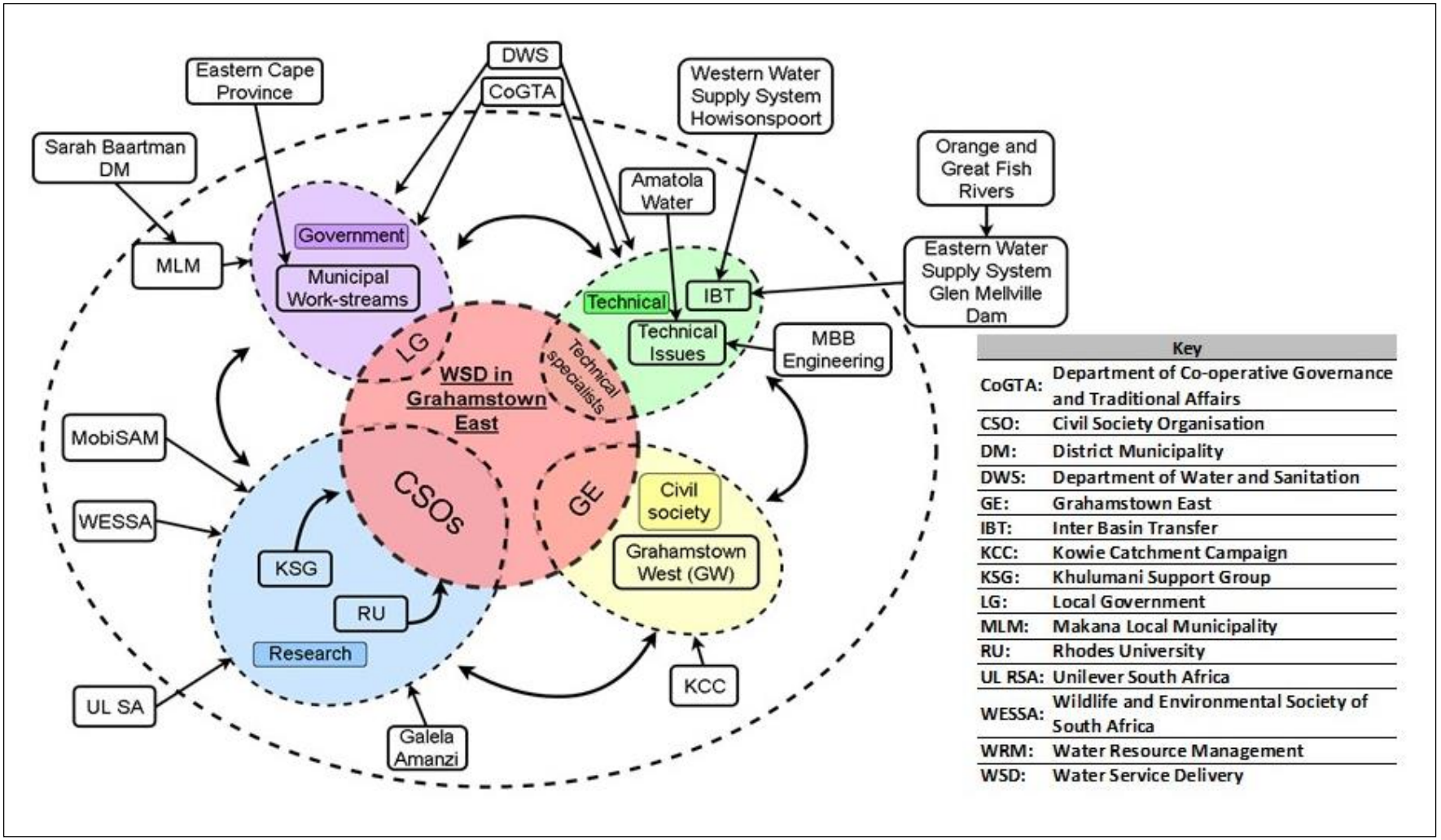

Figure 4-2: Systems heuristic of the MLM CSES, depicting an overview of actors and their relationships (arrows) when engaging in the common interest of water service delivery in Grahamstown East. Oval rings are the four identified sub-systems. The central ring indicates a key focal area of the Makana Case Study – Water for Dignity's engagement in WSD issues in Grahamstown East. The outer ring bounds the system of interest within and the environment without (Weaver et al., 2016).

1850-1900 (small dams: Grey, Douglas and Hamilton Dam)
The previous lack of management and maintenance of water infrastructure saw the establishment of a more focused water governance and management with the appointment of a 'Supervisor of Water' in 1950 who controlled when the water was turned on and monitored the reservoirs and watering points (Mullins, 2011). Successive droughts emphasised the need for greater storage capacity to supply the town and the military who were threatening to pull out due to the lack of water. A city engineer was appointed to supervise public works which led to the gradual construction of three dams (Grey, Douglas and Hamilton dam). Once again poor engineering and lack of maintenance of the dams rendered them ineffective at times.

Up until 1877 little effort went into supplying water to "the Location" (Grahamstown East) which relied on collecting water from Grahamstown West. Due to severe water shortages, five springs were opened, two more wells were dug, and a municipal tank was installed. The quality of the water from the springs was dubious as all of them were situated close to harmful contaminants such as refuse and night soil dumps, carcass burial grounds and a gas works. The Location was heavily over-crowded, with inadequate housing, no adequate pure water resulting in a high death rate as well as no suitable sewage disposal system (Maki, 2008).

1900-1950 (Milner (1898) and Jamison Dam, Water Purification Plant, Sewage Works and Water supply developed for Grahamstown East)
Around the turn of the century saw impounding of the Coldstream River in the Slaaikraal Valley, west of Grahamstown, through Milner (1898) and Jamison (1905) dams. The council, after much internal dispute, placed a tank in every Location in Grahamstown East, greatly improving water availability albeit not sufficient to claim that they had supplied water for all (Mullins, 2011).

Within a couple of years however the reservoirs were polluted resulting in outbreaks of disease. This highlighted the need for a water purification plant, which took almost a decade of council dispute before it was eventually completed in 1914. Severe droughts and the unreliability of existing reservoirs resulted in a water crisis in Grahamstown once more. Temporary schemes to alleviate the stress were attempted by the council, reopening of old wells, instillation of a rainwater harvesting tank and even tapping into the borehole pipe that fed the power plant but these efforts provided little relief. Thus, began the construction of the Howieson's Poort dam in the hills south of Grahamstown. Completed in 1931 the dam provided sufficient water for the implementation of the much-demanded water-borne sewage scheme. The location still relied on the bucket system as digging of own latrines was unsuccessful due to unsuitable subsoil (conversion to water-borne sewage only began in 2007).

The construction of the first sewage treatment works was completed and ready, by 1937 most of the city was connected. Neglect of the treatment sewage system, due to the lack of employment of an engineer's assistant to oversee it, resulted in a total blockage in 1943 (Mafuta et al., 2011).

The council came under increasing pressure and criticism regarding the deplorable state of the location, being described as "...one vast latrine...an utter disregard of human values..." (quoted in Mafuta et al., 2011). In 1938 a new water supply was laid for Grahamstown East and 53 stand pipes were able to bring water closer to people's homes.

1950-2000: Settlers Dam (previously Kariega Dam), Settlers Dam wall raised, Orange/Fish inter-basin transfer.
From the 1950s to today Grahamstown has been plagued with droughts resulting in extremely low water levels required for crisis measures to be taken. The completion of the Kariega Dam scheme (Settlers Dam) in 1962 saw the last feasible harnessing of local water sources. In 1981 the Settlers

Dam wall was raised by 2.3 m, increasing the capacity by a third. Yet demand still outweighed supply and Grahamstown had to look further afield to augment its supply.

The biggest breakthrough in water supply to Grahamstown was the Orange/Fish inter-basin transfer in the 1970s which moved water through an 83km pipeline to the Great Brak River, a tributary of the Great Fish. The aim was to provide the seasonal Great Fish River with a constant supply of water to support year-round irrigation to farmers in the middle Fish River Catchment. Grahamstown was at first hesitant to tap into the system due to cost implications. With water shortages ever increasing with the compounding effect of a decade long drought in the 1980s the Grahamstown Council was left with no alternatives for water supply. A tunnel was constructed in 1991 to transfer some of this Orange River Water from a weir on the Great Fish River and into the Glen Melville Dam on the Ecca River north east of Grahamstown. Water from the Glen Melville dam passes through the onsite James Kleinhans Water Treatment Works from where it is pumped up to Botha's Hill Reservoir on the hill north of Grahamstown East. Two thirds of Grahamstown's current water supply, primarily to Grahamstown East, is from this scheme.

Present Water Supply and Wastewater Treatment

Water Supply

Grahamstown's water supply systems are divided into two distribution zones, Grahamstown East and West. The East servicing 79% of Grahamstown: 3000 Ml/d from the Orange/Fish River inter-basin scheme is diverted into the Glen Melville Dam which then gets treated on site at the James Kleinhans water treatment works (WTW) with a capacity processing 10 Ml/d. Water is then pumped over 9km to three reservoirs in the east and two, the intermediate and low-level reservoir, in the west with a total storage capacity of 22.5 Ml/d. The West servicing 21% of Grahamstown: Water is drawn from a number of dams impounding nearby catchments. Settlers and Howieson's Poort Dams supply the majority and the remainder is supplied from Jamison and Milner Dam. Raw water is pumped to Waainek WTW which can process nine Ml/d but realistically only produces 5.1 Ml/d. This is partly due to it supplying a reservoir with the capacity of only 2.25 Ml/d (Desai et al., 2012). This system is also vulnerable in periods of drought and relies on east system for supplementation during shortages (Desai et al., 2012).

Grahamstown's total demand for water in 2013 was 21 Ml/d exceeding the 15.1 Ml/d combined capacity of the two WTW. At the James Kleinhans WTW, by 2015 demand increased to 1.77 Ml/d, with a higher summer demand and the 10% water lost through the treatment process (Stemele Bosch Africa, 2011). Therefore, during peak hours, the James Kleinhans WTW can only supply 70% of the demand (Desai et al., 2012).

Inadequate water pressure at high lying areas is no new issue to Grahamstown, citizens have been complaining about it since 1906 (Mullins, 2011). The topographical design of Grahamstown is such that housing is distributed between **500 and 690 m** above sea level (Clifford-Holmes, 2015). This creates challenges in the supply of water to different suburbs, but this problem is tackled through a number of strategically placed reservoirs and pumps at different elevations (Waainek is strategically crucial). Suburbs at a higher elevation experience far more shortages than mid and lower areas, where the water pressure is greater. (It is these elevation differences that require valves all over the city). A main pipeline connects the East and West supply network together but there is only sufficient pressure to augment the supply of water to the West intermediate and low-level suburbs. Thus, when the Waainek reservoir falls below 80% capacity, often during droughts, the higher lying regions in the West go without water (pers. com Engineering and Technical Services Director Mr ET Myalato).

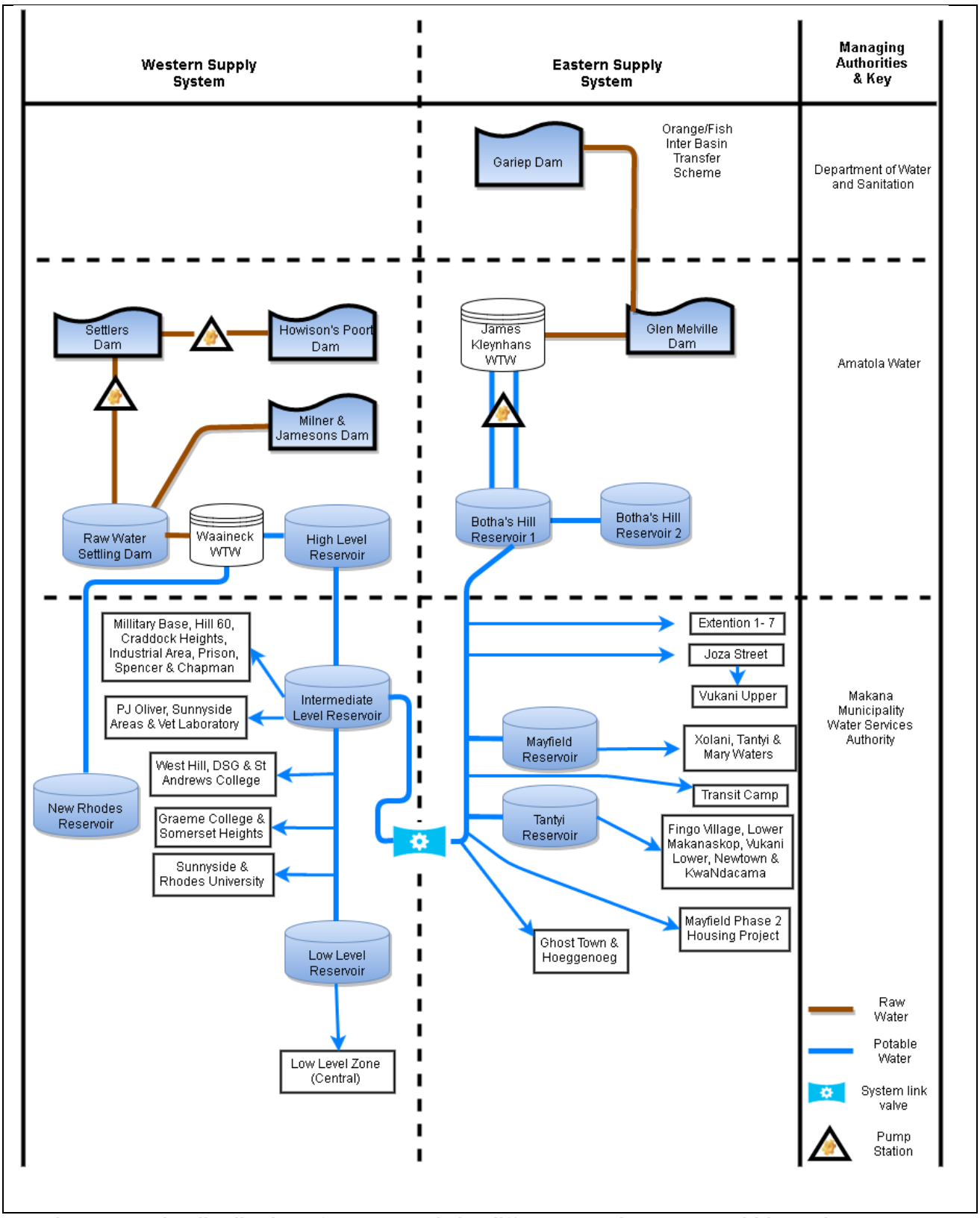

Figure 4-3: The distribution of water supply by different supply systems within Grahamstown (Source: Matthew Weaver)

Grahamstown has faced several serious water shortages over the past decade mostly due to failure of the aged, poorly maintained infrastructure compounded by low reservoir levels. This was felt by both Grahamstown West and East however most severely by the higher lying areas. The Makana Municipality came under huge pressure and criticism from the public and the media for its failure to provide water. Poor communication between the municipality and the public about the state and

progress of Grahamstown's water supply led to increasing friction and protests. Despite water shortages, water reticulation improved from 2001 census to the 2011 census; piped water inside of dwellings improved from 23% to 50%; fewer people relied on collecting water further than 200 m from their dwellings (2%) and from dams or stagnant water in pools and small peri-urban wetlands (Makana IDP 2013/2014).

Sanitation

The local topography has resulted in Grahamstown being divided into northern and southern drainage areas, each serviced by a wastewater treatment works. Mayfield WWTW, an activated sludge and aerobic digestion system, services the northern drainage area and the Belmont Valley WWTW services the southern drainage area using biological filtration and anaerobic digestion as a purification method (Green Drop 2012). A small quantity of sewage (100 000 l/d) is treated at the Belmont Valley WWTW by the Environmental Biotechnology Unit (Rhodes University), using an innovative treatment process called the Integrated Algal Pond System (Mambo et al., 2014.

Table 4-2: Sanitation infrastructure in Makana from census 2001 to 2011 (adapted from Makana IDP 2013/2014).

BASIC SERVICE / INFRASTRUCTURE	MAKANA AREA (STATSSA 2001)	% 2001	MAKANA AREA (STATSSA 2011)	% 2011	GROWTH % p.a.
Total number of households	17813		21389		
Flush toilets	5849	32.8%	15370	71.9%	16.3
Flush septic tank	494	2.8%	548	2.6%	1.1
Chemical	30	0.2%	27	0.1%	-1.0
VIP	1429	8.0%	1349	6.3%	-0.6
Pit latrines	2521	14.2%	2086	9.8%	-1.7
Bucket latrine	5412	30.4%	774	3.6%	-8.6
None	2078	11.7%	837	3.9%	-6.0

The 2001 census revealed that 55% of households in Makana had sanitation systems below the minimum RDP level of a ventilated pit latrine (VPL); 34% had flush toilets connected to sewerage, 30% of still relied on the bucket system, 14% had pit latrines without ventilation and 12% had no sanitation access in their household (Census, 2001). There was a vast improvement by the next census in 2011 where 72% of households had flush toilets connected to sewerage, 3.6% bucket system, 9.8% pit latrines and 3.9% had no sanitation access within their dwelling (Makana IDP 2013/2014). The Belmont Valley WWTW was operating at 103% of its design capacity and Mayfield WWTW at 64% of its design capacity with poor effluent compliance (Green Drop 2011) and more recent estimates indicate Belmont Valley WWTW may be operating at as much as 133% of its design capacity (Clifford-Holmes, 2015).

There was a housing backlog of 14 026 houses in the Makana area (Makana IDP 2013/2014). These proposed housing projects were designed to have piped water in the dwelling be connected to waterborne sewerage systems (Makana IDP 2013/2014), putting additional pressure on the stressed water supply and over capacity WWTW.

The water master plan outlined in the Makana Municipality Integrated Development Plan 2013/2014 details a number of projects that have been proposed and implemented to address the water and sanitation problems facing Grahamstown, including: construction of a 4 Ml reservoir beside Botha's Hill reservoir; construction of a bulk water supply at James Kleinhans water treatment works; laying

of a bulk water pipe from Settlers Dam connecting to the Howieson's Poort/Waainek pipe; extensive pump and purification infrastructure upgrades and repairs. The sanitation projects aim to eradicate sanitation backlogs in formal areas and provide alternative sanitation system in rural areas involving; upgrading Belmont Valley WWTW and conversion of ventilation improved pit toilets to waterborne sanitation.

This research showed transdisciplinarity at work in considering the implications of history, water supply engineering, political decisions, issues of health and water quality were involved in this account. The challenges of the present required not only working with complexity but paying attention to human interactions and political tactics.

Response by the civil society research partner

Water for Dignity (WfD) engaged communities in Grahamstown East on the issues of water services, water quality and water management. The group emerged in April 2013 and participant observation continued between March 2014 and July 2015. They built their own capacity in a number of research and learning settings: internally, as part of the research project team, and in interaction with university academics in a regular transdisciplinary seminar. They made sure that they understood the responsibilities of local government through a study and discussion of water policy and legislation. They undertook a report card data collection exercise, in which community members were asked about their experiences and perceptions of water services in Grahamstown. The results were analysed with support from academics (Weaver et al., submitted, Hamer et al., submitted). The WfD team developed their own principled approach to citizen's science and practiced it in monitoring of the Matyana River. The organisation reached out to schools in the area, raising awareness of the link between water quality and health issues and hosting school water forum days that included assessing the state of school sanitation, cleaning, painting and basic repairs of washbasins. Interested learners established School Water Forums to continue the monitoring of the state of hygiene at schools.

Water for Dignity attempted a number of times to engage with the local municipality, in order to establish a discussion forum (Community Water Forum), but they were not successful in obtaining municipal participation. (The local water forum emerged later in 2016, see Appendix 1a, for a consideration of the time needed for 'new paradigm" practices to emerge as transformative actions.). Working with local government was frustrating. (See principles for engagement in Section 2.2 – and note the principles:

- Manage discontinuities (people come and go, and arrangements change suddenly).
- Sustain enquiry (keep going when it is tough).

Twice invitations through the right channels, laboriously negotiated, were not distributed. In the end, there was no proper process with the municipality and activists withdrew, fearing that their legitimacy with the community would be undermined if they continued working with the unresponsive municipality. This frustration played out at other levels, under the Administrator, work streams were established to enable better communication between the municipality and local stakeholders. There were promising moments from the workstreams, but ultimately, they were dropped and few agreed actions were actually followed up. A high-level University-Municipality crisis Imbizo was held, with the Vice Chancellor and mayor in attendance. Once again agreed upon commitments were dropped and the whole initiative fell flat. In this instance, the University also showed little willingness to continue pushing for the agreed initiative formally. The TPNP has continued to engage – and the new Water forum is an encouraging result.

Community activists

Community activists The WfD team embarked on activities that fitted into their existing social justice agendas. The IWR and WfD developed a Report Card questionnaire. The research was conducted door to door. Conducting the surveys came naturally because for one, the WfD members were in solidarity with community members in water service injustices. The IWR project partners contributed with their experience in conducting rigorous scientific research in terms of methodology and data management and analysis. The IWR conducted data collection, management and analysis Learning Workshops to build the researcher capacity of WfD members. However, the KSG (acting as the WfD team) already had the intention to expand their own knowledge in terms of legislation, what their rights were, what the obligations of the municipality were, as well as the scientific knowledge they needed for monitoring the river.

The WfD team embraced his principles of Paolo Freire's Education for Liberation (Freire, 1970): "where we learn together by doing and then reflecting on the outcomes of our actions. We embody a spirit of vigilance that infuses all our actions while we stay alert to the possible abuse and misuse of power." The core elements of this approach are:

1. We need to become skilled in understanding power and voice so that we become effective communicators about issues and concerns.
2. We need to recognise that the achievement of social change and greater social justice is a political process in which the people struggle to assert their rights, to challenge injustice and to change their position in society. Every advance takes a struggle. All social change requires struggle. Struggle is taken forward in different ways. While the national struggle for liberation involved *ukuzabalaza* or 'collective political acts to address political and social concerns', the struggle for water justice is a different struggle by people who are involved also in day-to-day struggles within difficult socio-economic circumstances – *ukusokola*, while also working for *ukuqhankqalaza* – the struggle to realise the meeting of peoples' needs within the present system.
3. Solutions come out of the construction of democratic space in which everyone's voice is heard.
4. Social change emerges from spaces where we engage regularly and rigorously with each other towards achieving long-term change.
5. The basis for such collective thinking and planning is respect for and acknowledgement of peoples' existing knowledge and experience. When we draw on this experience and knowledge, we can often find new information and new learning possibilities.
6. New knowledge comes out of practising cycles of action or doing and then reflecting on the impact of the action.
7. There are many tools we could draw on for this work including making maps, producing images using videos and photographs, and using theatre and role-plays.
8. Practising self-management, autonomy and self-organisation is very helpful in building capacities along with a continuous focus on the power dynamics inherent in every situation.

Engaging with the municipality and other institutions

The WfD team continued its efforts to engage with the municipality. It drew up a document to explain the work of WfD and shared it with stakeholders who had requested information. Members visited Ward Committee persons tasked with reporting on water and sanitation issues in each of Makana's 14 wards and invited them to a monthly Community Water Forum. The then Director for Water Infrastructure, Mr Myalato, was approached to introduce Water for Dignity, its purpose and its project activities and to discuss the launching of a proposed monthly Community Water Forum in Grahamstown East. A date was agreed for the launch of the Community Water Forum and Mr Myalato requested a formal invitation that he would have photocopied and distributed to the fourteen

ward councillors from Grahamstown East. They were asked to invite their ward committee members who are tasked with water and sanitation issues for their wards. The formal letter of invitation was drafted by Water for Dignity and hand-delivered to the office of the Director for Infrastructure, as requested.

Rhodes University's Department of Community Engagement provided a letter to enable WfD to be allocated a community hall for the meeting free of charge. However, the first Community Water Forum in July 2013 was attended only by the WfD team and members of the IWR and associated university-based initiatives including the Environmental Learning and Research Centre. It emerged that the invitation to the Community Water Forum had not been distributed to the ward councillors.

Another date was set for the following month – 14 August 2013 and this time the request from the Municipality to WfD was to write the letter to the Speaker of the Municipality so that she would extend the invitation to all the councillors to attend this forum. The speaker, Ms Madinda, had been ill and the formal invitation was never distributed to the ward councillors. One ward committee member then came forward to make himself available to support the Water for Dignity initiative to set up community water forums.

At this point, a decision was taken to draft a registration form for interested citizens to become part of the local community water forum, rather than trying to rely on engaging ward committee members. There has been quite significant uptake on this registration amongst residents who want to play a meaningful role in helping to make plans to solve the town's water challenges.

The activists also acted on their own. They decided to monitor the Matyana River from north to south once a month. They acquired mini SASS equipment for use on the Matyana River. The WfD team will be trained in its use and constructed checklist for monthly water walks. The first walk took place on October 26 2013 in an activity driven by IWR and involving school learners. The activity stimulated huge interest in learning about monitoring water quality and pollution. The WfD team have been equipped with a camera by IWR and have taken photographs to document water and sanitation issues that need attention. The WfD team have produced several Power Point presentations to highlight what they have witnessed on their walks and survey activities.

The WfD team decided to monitor the incidence of diarrhoea amongst learners at township schools as a measure of possible microbial water pollution and on-site inspections of state of school sanitation. A record sheet for visits to Grahamstown East's 23 schools was developed and a process of monthly visits was initiated. The purpose of this activity was explained to the School Governing Body Task Team for Grahamstown East's schools. The target was set at ensuring that each school had one functioning toilet accompanied by one hand washing station. The team was introduced to the Tippy Tap as a hand washing solution for schools. The schools that attended the ECO-SCHOOLS outreach on 24 October were introduced to the Tippy Tap. There are plans to hold a function in January 2014 with 2 representatives from every school attending to learn to make the Tippy Tap and to launch a School Water Forum in each school through the participation of learners. The schools indicated that they report their diarrhoea statistics to the District Health Office.

The team then visited the District Health Office to introduce Water for Dignity. The officials were enthusiastic about the possibility of the incidence of diarrhoea being reduced through the participatory activities being introduced by WfD and asked to be invited to events. They informed the team that permission would be needed from the Provincial Health Department to allow them to release the diarrhoea statistics that the team were requesting. A formal letter was written to the

Provincial Department of Health's Communications Division to request monthly diarrhoea statistics from Grahamstown's clinics as an indicator of water microbial pollution.

Note: by first engaging with the interested of the community researchers – an interest in local microbial pollution also emerged.

State of water services

The WfD undertook research into the state of water services in Makana, as seen by residents of Vukani, Grahamstown East. The report card survey was constructed and reviewed by IWR staff. It was refined through drawing on a student Masters' project conducted in the Sundays River catchment (Molony, 2014). Three team members conduct house-to-house surveys in the designated areas.

A review of 90 completed citizen report cards reflected the following issues and concerns related to water service provision in Makana Municipality:

- Inadequate or absent communication from the Municipality to local residents.
- Instances of water destined for filling water storage tanks, being sold by officials.
- Frustration and anger on the part of citizens.
- A lack of collaboration and cooperation in solving water challenges in the town.
- Old malfunctioning water infrastructure.
- Challenges regarding water quality.
- Demand exceeds supply in the town.
- A lack of citizen participation and engagement.
- Illegal disconnection of water to properties in Grahamstown East.
- A lack of a sense of shared responsibility for water.

The Water for Dignity citizen report cards point to the difficulties the municipality experienced in providing for the water requirements of residents of Grahamstown East. Beyond this, is the lack of communication between the Municipality and the communities it is meant to serve. Calls to the municipality are unanswered and the surveys reveal that the Municipality often does not report back to citizens. This results in a breakdown in trust and a denial of access to the right to water.

An interim solution was proposed by WfD was the installation of JoJo tanks in Makana Municipality to provide for the 'One Street, One Tank' campaign of Water for Dignity and to link it to ward-based Community Water Forums. There was a design available to ensure that the manufactured tanks would be safe from pollution and from vandalism. The plan included the linking of fire hydrants to the tanks. Meetings were held with the Manager of the Makana Community Works towards creating employment opportunities. Another focus was the collection of rain water from the roofs of each house in Grahamstown. Unilever South Africa funded the purchase of tanks and the building of tank supports. Amongst the challenges facing the community during the many water outages is that the 5,000 litre JoJo tanks that had been installed mainly at community centres, the community forum did not effectively prevent vandalism and it was decided not to install more street tanks after the first two. An additional concern was that the database used by the municipality for sending out accounts for water usage was extremely outdated. Most households also do not know how to monitor their water meters.

The WfD team did not keep their insights to themselves. Some of the many issues identified through the community survey process were captured in a research presented at the Rhodes Water Week.

Water for Dignity facilitated access to community members for the Carte Blanche documentary on Makana Municipality's Water Woes.

A peoples' water science (citizen science*)

Early on in the project, WfD expressed its commitment to a people's science, where the knowledge generated by communities, whether or not in partnership with academia, serves the interests of communities immediately and concretely. They said:

> "We expect respect for the expertise of people regarding the reality of their lives, and respect for the knowledge they have had passed onto them from our ancestors and from those around them. Khulumani believes that all people deserve the basic dignity of having their wisdom honoured. We believe that people are aware of the impact of water stress in their lives, and are able to provide data to academics that would be meaningful."

The TPNP researchers confirm that peoples' analytic outcomes were useful and were deepened and developed in the course of this project. People were happy to share what they knew and to learn how water systems work biophysically and societally. Broad-based participation was important during the entire scientific process, contributing to democratising concepts like hydrology, climatology and water resource management, so that people can contest, create, debate and discuss in order to participate meaningfully in future water resource management.

The WfD group anticipated that knowledge would lead to controversy. They proposed that the project "should first focus on building the capacity of communities that struggle with access to water to establish common understandings and demands before building broad-based community meetings, so that powerful interests cannot dominate meetings from the start." They also undertook to take care to ensure that women's views are well-represented, because women are often the most likely to be involved in the sourcing of water, as well as its distribution within the household, their input will be critical.

Learning from the case study

The Makana case study highlighted the challenges of scale, with multiple scales of intervention, within the context of a dysfunctional municipality, leading to fractured opportunities for systemic change. The systemic approach of the case has provided a realistic point of departure. Technical responses alone to Adaptive IWRM challenges have not been successful in resolving the challenges faced in the Makana Local Municipality. Recurring technical issues have continued to pose problems, even under the stewardship of the local Water Board, Amatola Water. Additional external expertise may assist but it will still take a long time to lay new infrastructure. Given the economic context, repairing of infrastructure will likely continue in an *ad hoc* manner.

The TPNP project team's persistent, and consistent, engagement with WfD and the municipality over time, connected to the multiple water related processes, ultimately yielded results in terms of the establishment of a Water, Sanitation and Catchment Management Forum, formally hosted jointly by the municipality and the Mzimvubu-Tsitsikamma proto-CMA. The establishment of this forum has been facilitated through the active engagement and facilitation of the TPNP researchers, is the first forum in South Africa where service delivery and catchment management have been integrated. The Department of Water and Sanitation and local officials have recognised the importance of a holistic response, which engages across scales, responding to concerns of citizens. The emergence of this forum in late 2016 indicates the time-frames for Adaptive IWRM approaches to bear fruit, remembering engagement with the municipality was initiated in 2011.

The case clearly demonstrated the value of developing research partnerships with community partners, though it is important to recognise that this is a relatively slow and long-term process. In particular, an appreciation of the fragility of the socio-economic context and the implications for conducting this work needs to be recognised. In the Makana case an outbreak of Xenophobic violence in August 2015 tragically brought to the fore, community tensions over high levels of violent crime and was a powerful reminder to the research team that such systemic issues cannot be ignored when considering ostensibly unrelated issues such as Adaptive IWRM. This was not a conducive context to continue some aspects of social engagement. University research partners need to be flexible, alert to, and generous with support in attending to community needs.

Experiences from the case study highlighted the importance of strong community-based research partnerships to foster water related learning and active citizenship in communities. The research also highlighted how the small size and member turnover has a negative impact on the effectiveness, resilience and sustainability of a civil society group such as WfD. A less positive longer-term outcome was that with the end of TPNP funding WfD was no longer able to function. Three years of intensive support and training, and real evidence of learning (Weaver submitted), was not enough to enable WfD members to secure further funding to keep the civil society organisation (CSO) going. One member of WfD is a member now of the East Cape Water Caucus, a larger CSO, and the IWR is alert to further funding possibilities.

The emergence of the Upper Kowie Water, Sanitation and Catchment Management Forum, formally hosted jointly by the municipality and the Mzimvubu-Tsitsikamma proto-CMA is the most tangible outcome of the Adaptive IWRM practice. It also serves to emphasise the importance and values of the work on CMFs – a feature of all the TPNP case studies.

Note from project leader, Professor Tally Palmer:
"I collaborated meaningfully at a national government level from 1995 to 2004 (Palmer, 1999) – when there was traction with and access to the national water Department and Ministry. In 2017 this has changed. I am of the firm opinion this is the time to work at the grass-roots level, so to contribute effectively to, and learn from, a strong, informed, participatory, civil society. I believe that in the water sector, Catchment, Water and Sanitation Forums are the most vibrant and hopeful institutional vehicles of water equity, justice, and transformation."

CHAPTER 5: THE CROCODILE RIVER WATER QUALITY AND RESOURCE PROTECTION CASE STUDY

This chapter is supported by two MSc theses, Retief (2014) and Sahula 2014) Some parts of the thesis texts are quoted, but they are not reproduced here to avoid issues of plagiarism when they are submitted for publication. They are the substantive record of the detailed research findings, and the theses are available from the Rhodes University library.

5.1 Introduction

This case study addresses the question of how to ensure resource protection in a catchment used heavily for industry, mining and irrigated agriculture, that services a large population, has 17 wastewater treatment works and flows through the Kruger National Park before flowing into Mozambique – with international obligations for flow and water quality. In addressing this question of resource protection, we confronted a persistent problem facing both Resource Directed Measures (RDM) – classification, Reserve determination, setting Resource Quality Objectives) (DWA 2013), and SDC controls – including licenses to control use so that the goals are met ((DWA 2013). To date, both RDM goals and licencing have addressed flow and water quality separately, despite their being directly causally linked. Organisms in an aquatic ecosystem, such as a river, respond to concentration. However, **concentration** data do not indicate **how much**, or the **load**, of a pollutant that is contributed by a stream over a given time (Figure 5-1). Industry stakeholders expressly communicated their urgent need for load and concentration data on the IUCMA website.

The relationship between these is: flow x concentration = load
Note: the units for each factor need to be checked

Concentrations are used to set ROQs, loads are used to manage the amount of pollutant in a system. Licences should specify both load and concentration. Load will require flow data. Unless flow and water quality are integrated, the likelihood of resource protection (RDM and SDC) measures successfully ensuring a balance between resource protection and water resource use, is low.

In this project, we not only demonstrated the practice of a new model, that is designed as being accessible for use by CMAs, that combines flow and concentration data – we also collaboratively installed the model in the IUCMA data management system, and we are currently working to move from installation to implementation. (Again, note time frames to implementation).

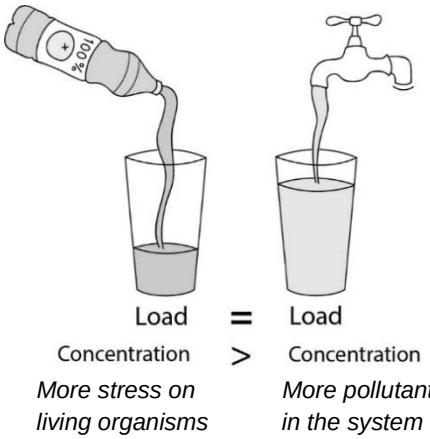

Figure 5-1: Orange Cordial example: If we pour only cordial into a glass, there will be a 100% concentration of cordial and it will taste extremely sweet (because of the high concentration). If we add water to the glass, the concentration decreases and, therefore, its sweetness.

The Crocodile case study research team gathered together a working group of participating industrial stakeholders, the Crocodile River Forum and the Inkomati-Usuthu Catchment Management Agency

(IUCMA), which met quarterly over two years, and twice in the final third year (2013-2015). We also reported regularly directly to individual stakeholders and to the Crocodile River Forum. Co-operation among the working group participants was driven by the recognition of deteriorating water quality in the river. We aimed to address water resource protection by developing a co-operative adaptive Integrated Water Quality Management (IWQM) process, based on integrating quality and quantity, as a prototype for application first in the other Inkomati Basin Catchments and then more widely. By 2017 the model that integrated water quality and quantity was being further developed, with mobile phone apps in the Olifants River. The student who graduated after the case study, Hugo Retief, was employed by AWARD and has continued with the work of a practical implementation of integrating water quality and quantity. (Again, note time frames for development and implementation).

The case study work was founded on a previous collaboration between IWR and AWARD (Palmer et al., 2013), where all of the Crocodile River stakeholder had already worked together and with the researchers. This early work had shown that there was a sense of apprehension about the future of the river, and how water scarcity would impact on the industries. It also produced a provisional list of priority issues:

- the performance of wastewater treatment works (WWTW);
- disposal by irrigation of pulp and paper effluent;
- nutrient enrichment (agriculture and WWTW);
- accelerated sediment production (forestry);
- dissolved manganese and iron (mining and beneficiation);
- the need to identify and integrate diverse monitoring programmes and data;
- the need to harmonise various water quality standards used by diverse industries;
- the need to identify accredited analytical laboratories and to develop protocols for a trajectory towards a high level of reliability and accuracy of water quality data.

Using these questions as the starting point and building on the foundational of trust build during the 2011-2012 engaged research, was critical to the buy-in of stakeholders into the Crocodile case study.

In summary: the research took place at the “smaller” catchment scale, with arguably the most advanced catchment institution in South Africa, the IUCMA, tackling the issue of water resource protection through engagement of stakeholders (primarily industries along the Crocodile River). It involved

- the development of an IWQM process based on a model which enabled the integration of water quality into water quality issues, which included a design and training for the IUCMA in integrating water quality into their Crocodile Operations model,
- a systemic inquiry into the catchment’s water quality activity system, following the Cultural Historical Activity Theory (CHAT) methodology,
- a rigorous process of stakeholder participation,
- a specialised study into the sugar industry as example of a downstream water user in the catchment, and
- the deployment of a number of new discourses and practices.

5.2 Context, partners and outcomes

The Crocodile River has played an important role in the commercial and industrial development of the Lowveld of Mpumalanga. Over geological time, the Crocodile, with its tributary the Elands River, had carved a valley which provided a route from the inland South Africa (Mpumalanga, before then the Eastern Transvaal) for a road and then a railway outlet for the Boer Republics to the Mozambican

port of Maputo (then Delagoa Bay and after that Lourenco Marques). In the 1960s/70s the area along the river industrialised with the wood and paper industry SAPPI, sugar growing and milling, and several other industries. The Crocodile River is part of the Inkomati River (also called Ncomati) catchment, which is an international catchment. The IUCMA's management of the South African Water Management Area is subject to, and has strict agreements with Swaziland and Mozambique, water quantity and quality of the shared river system.

The Crocodile River Catchment (CRC), like many South African catchments, is over-allocated and experiencing increasing pollution of source water (IUCMA 2013 Catchment Management Strategy, Du Toit et al., 2012). The poor water quality is becoming a critical risk in terms of costs and productivity to many industries in the catchment. As a prelude to this project, Du Toit et al., (2013) undertook a Water Research Commission (WRC) project that evaluated compliance with environmental water quality criteria in the catchment. They reported lack of compliance and deterioration of water quality. Most water stakeholders were involved in the WRC project and collectively indicated the urgent need to develop and implement an IWQM process for the catchment. The Inkomati-Usuthu Catchment Management Agency (IUCMA) is responsible for water quality management in the CRC but was unable to implement and enforce compliance without stakeholders' collective commitment.

The call from the stakeholders for the development and implementation of an IWQM process was well received by the IUCMA. Unilever Centre for Environmental Water Quality (UCEWQ) of the Institute for Water Research (IWR), Rhodes University in collaboration with the Association for Water and Rural Development (AWARD) won a Technology for Human Resource and Industry Programme (THRIP) project to partner the IUCMA and stakeholders to develop and implement the IWQM process. The stakeholders include IUCMA, MMC, Delta EMD, Assmang Chrome, TSB, Coca-Cola Sabco and Elands Water Users Association (Table 3-2). These were called core stakeholder group (CSG) members because they provided funds for the project. General stakeholder group members (GSG) are significant water users (both abstraction and discharge) in the catchment, willing to become involved but not making any direct funding contribution (e.g. Mbombela Water Service Provider). The IUCMA is both a CSG member and host of the project. The IUCMA welcomed TPNP research students into their offices, provided them with full logistical support, including transport, and also included them as members of their water quality team. This provided invaluable experience to the both the students from this project now occupy significant positions in water protection.

The IUCMA expected the IWQM process to reduce costs of enforcement, support water quality compliance, ultimately to improve source water quality and thus, decrease industrial risks. The plan was to operationalise WQSAM, and integrate it into the flow models used by the Crocodile River Operating Committee or CROC OC.

The results that actually emerged were:

- a practical example of effective stakeholder engagement, meeting the Figure 1-12 criteria of mutual learning, shifting power relations, Improved decision making, Improved mandate delivery; through an active partnership between industry, local and national government, water managers and regulators;
- the first practical application of the water quantity-quality integration model, WQSAM (Hughes and Slaughter, 2016; Slaughter et al., 2012, 2015);
- recognition that the downstream industry user, the sugar industry was less of an impact that expected with the sugar field acting like an "industrial wetland, removing excess nutrients (Sahula, 2014);

- use of IWQM process by IUCMA in annual milestone reporting, an in implementing their Catchment Management strategy;
- use of TPNP approaches and the IWQM process as a model for the new Water Quality Management policy and Strategy (DWS, 2017);
- the recognition of the need for a focussed Green Drop Campaign (Munnik and Barnes, 2016) see Chapter 6;
- recognition that insufficient trust was built to agree on collective action by other industries;
- water quality data sharing among stakeholders and with the TPNP team;
- recognition of different level of uptake: one industry insisted they did not contribute pollution despite using the ecosystem services of a clean water supply from one river, the ion adsorption capacity of a parcel of land and polluting another river;
- installation of the water quantity-quality integration model;
- a much longer pathway to IUCMA implementation of the water quantity-quality integration model than expected;
- uptake of the model for the Olifants River catchment;
- the IUCMA communicated in 2106 that after the project water quality performance along the river had improved as a result not of rules, but better understanding of the river through this TPNP social learning process (Jackson, personal communication 2016), and
- the demonstration of practical application underpinned by theoretical and conceptual depth.

This illustrates an important argument in the TPNP approach to transdisciplinarity: the core disciplines contributing to a transdisciplinary approach must themselves be strong in their own disciplinary terms, but then need to be able to communicate and simplify as needed in the decision-making system. An early positive response was when industries who were paying to participate decided that other actors in the catchment should participate for free, because they are needed both for their inputs and for the implementation of the results of the process.

5.3 Crocodile River Water Quality Activity System

The research team laid the foundation for the stakeholder process through an analysis of the water quality activity system of the Crocodile Catchment – as seen and experienced by the participants. The team used the theory and method of Cultural Historical Activity Theory (CHAT) to do this. Activity theory holds that knowledge and learning emerge out of practice (Figures 1-2, and 1-6), which is an appropriate perspective for the building of an IWQM process. A prominent thinker in this tradition, Yrjö Engeström (2001) suggested the following five principles for CHAT:

1. The prime unit of analysis is an “activity system”: a group of people who select tools from a range of tools in common, whose actions have objectives in common, and which can be understood in its network relation to other activity systems.
2. Activity systems are multi-voiced and are a nexus of many points of view, traditions, and interests. The multi-voicedness of the activity systems is a source of both tension and innovation.
3. Activity systems take shape and are developed over long periods. An activity system should be analysed in terms of its history, objectives, and outcomes, as well as in terms of the origins and development of conceptual tools that have shaped it over time.
4. Contradictions between and within activity systems are potential sources of change and development. Activity systems are also seen as open-ended learning systems that can adopt new elements from outside, which can create contradictions.
5. Activity systems have the potential for expansive transformations, which occur through relatively long cycles of qualitative transformation. Expansive transformations happen when

the object and motive of an activity have been reconceptualised to embrace a much wider horizon of possibilities than originally imagined.

The first round of data collection interviews using the Activity System method took place in October and November 2013, and the results, after analysis, were presented to stakeholders in a mirroring back workshop on 6 December 2013. This workshop provided the opportunity for participants to engage in this way with the results of the interviews in order to begin to develop the IWQM process.

5.4 The activity system analysis

For the purposes of the water quality CHAT research, the Rhodes team (Tally Palmer) designed a heuristic (Figure 5-2) based on 1997 National Water Policy and 1998 National Water Act, in the form of a table listing the likely categories of water quality management actions that are provided for in law and policy. This part of the model is divided into the actions of Water Resource Protection (undertaken by regulators) and actions undertaken by Water Resource Users. The triangle below the table is an adapted activity system model (Jonassen and Rohrer-Murphy (1999) on which the questions for the interviews were based. The questions were developed as guidelines, and that the interviews were open-ended.

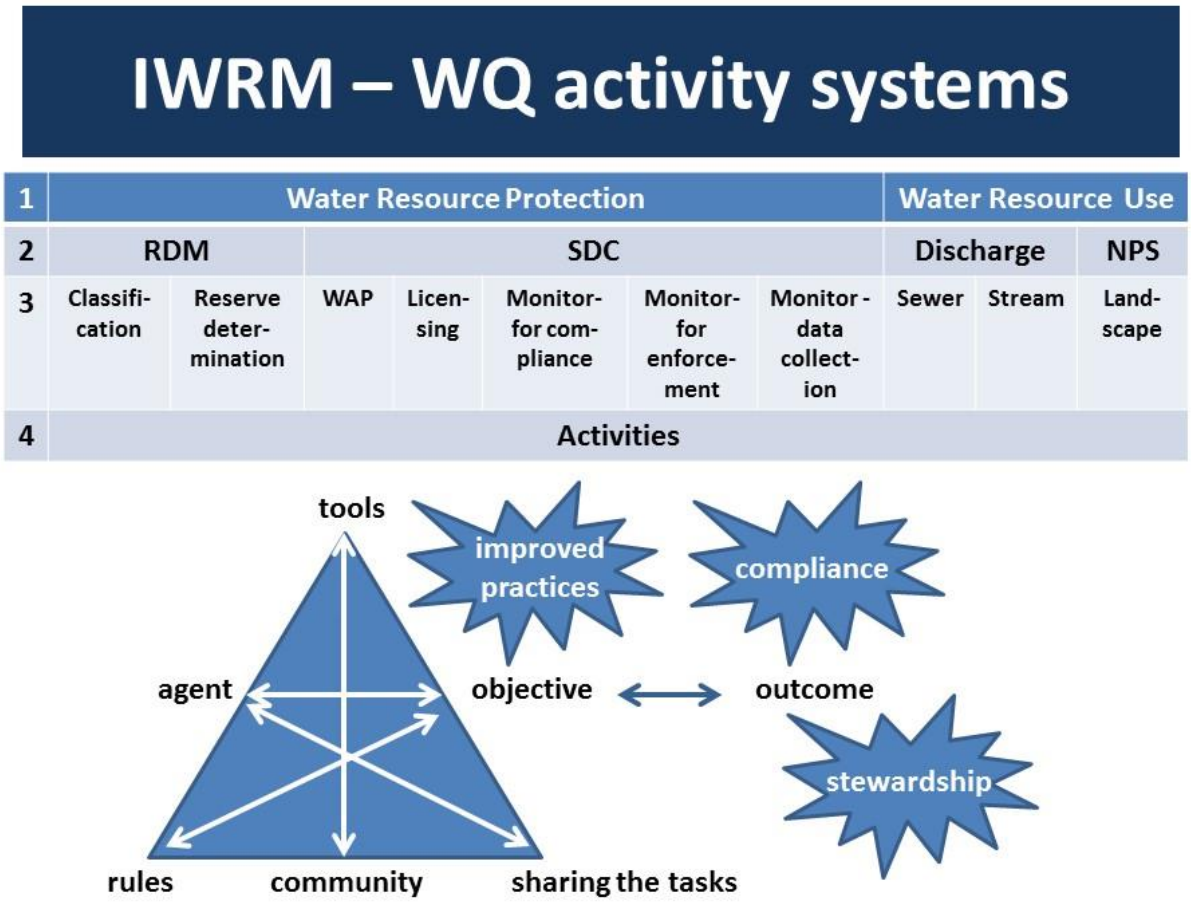

Figure 5-2: A representation of a range of water quality management activities provided for in South Africa law and policy (the table), and a diagram of an activity system modified from Jonassen and Rohrer-Murphy (1999).

The Agent

The agent is the person who is involved in the activity of management the water quality impacts on behalf of the company. The questions are about the person in a position as a professional, what influences have shaped him/her, including training and work experiences.

1. What your responsibilities are for water quality in your company (or institution)?
2. How did you end up in this job? Did you choose it and were you specifically trained for it?
3. Is it easy or is it quite difficult? Do you enjoy it?
4. Is water quality an important issue for your company? Does it receive a lot of attention?

Objective

The objective (traditionally termed the object) is “the intention that motivates the activity” (Jonassen and Rohrer-Murphy, 1999: 63), in other words the outcome that the agent wants to achieve as a result of his or her activities. In the structured nature of the Crocodile Water Quality Activity System, this is closely aligned with the agent’s job description, but also includes other outcomes that s/he may be pursuing.

1. What is the objective of your work?
2. What would it look like if you have achieved the outcomes you are responsible for?

Tools

The concept of tools may be confusing at first. This is how it is defined in the literature (Jonassen and Rohrer-Murphy, 1999: 63):

> "Tools can be anything used in the transformation process (physical, such as hammers or computers or mental, such as models or heuristics). The use of culture-specific tools shapes the way people act and think. ... tools mediate or alter the nature of human activity and, when internalized, influence humans' mental development. Kaptelinin (1996) argues that all "human experience is shaped by the tools and sign systems we use" (1996: 10). Just as activity can be understood by comprehending the tools and signs that mediate it, the nature of a tool can be understood only in the context of human activity-by looking at the way that people use it, the needs it serves, and the history of its development. Tools are changed by the ways in which they have been used. In other words, tools are a reflection of their historical development-they change the process and are changed by the process."

In the context of an emerging system of water quality management in South Africa, it is important to give close attention to the available tools – such as laws, policies, protocols and guidelines, computers models, and data systems, as well as physical hardware such as monitoring equipment, and components of factories – how they are being used, and whether they need to be changed.

1. What are the tools that you have to do your job with? That could be anything, from the pipes, pumps and treatment dams, to the protocols and procedures that help you achieve your objectives. These are all the aspects of the production process that influence your work.
2. What is the basic production process? What water impacts does it have that you have to cope with? How do you deal with them?
3. What sort of procedures, protocols and paper work is there?
4. Can you tell us about changes that have happened, or that you accept to happen in the production process or the treatment processes?
5. Which tools work well for you, and which would you like to change?

Sharing tasks (division of labour)

"The division of labour prescribes the task specialization... by individual members of groups within the community or organisation." (Jonassen and Rohrer-Murphy, 1999: 64).

1. Who are the people or the team that shares tasks with you – the people inside your company or institution that work with you, including your managers and the people that you manage?
2. What do they need to do to achieve the objective of good water quality effluent from your works? How are they doing?
3. How does your position relate to the people in the hierarchy above you/? How do they enable your job? Are there pressures they transmit to you? What opportunities do they provide to you, and how do they support you?

Community of practice, or peers

Most people involved in water resource use and management are part of some type of community of practice – that is colleagues or fellow professionals outside your company that you may share experiences, and learnings with, and who influence your values. Many companies and professionals are increasingly interested in sustainability and environmental quality, and want to show that to their customers too.

This research chose to use the definition of "community", in the form of community of practice, due to the importance of the emerging community of practice in the Crocodile River Catchment. More

conventionally, the question of “community” would be interpreted as “people and institutions that benefit from your work”.

1. Do you have fellow professionals that you meet with, or discuss with? Do you belong to a professional society, have access to trade or professional publications? Or do you basically work on your own in this respect?
2. As you are part of this IWQM process, have you found that to be an interesting place to discuss these issues?
3. In your contact with your fellow professionals, what are the water quality topics that are most discussed? Are you concerned about the state of water quality in the Crocodile River Catchment, and what do you think could be done about it?

Rules of the game

There are both formal and informal rules that determine what is acceptable (or required) and not acceptable in a given activity system. In a developing context like the South African water quality system, these rules may be changing fast, or different sets of rules may co-exist. The core definition of rules is:

“Team members have negotiated roles based on skills, preferences, or availability. Formal and informal rules evolve to guide their activity. Their assignment to those activities defines the division of labour, which is also mediated by rules and social negotiation... Any work community negotiates the rules, customs, and division of labour that mediate its activity. Different communities negotiate different rules and customs. (Jonassen and Rohrer-Murphy, 1999: 66). Rules may be “rules in form” – what is recorded in writing, in official documents like laws policies and codes of practice; “rules in use” are the protocols actually flowed in practice and are very often handed down through time “this is how we do it”. This is the point at which history play a crucial role in understanding a human activity system.

1. What are the formal rules and procedure for the job you are doing? Where do they come from?
2. And what are the informal ones, the ones that make sure that the job actually gets done?
3. Do you think these rules have been changing, or are changing now?

The past and the future in the present

The past and the future are very much present in the present. Not only is the present shaped by what happened in the past, it is also actively involved in shaping how the future unfolds. Many aspects of an activity system would not be comprehensible without knowledge of the past activities and the plans for the future of the actors involved.

1. What has shaped your job, what are the important turning points you remember or you have heard about for your company (or institution)?
2. How long has your company been here? How are things going – for example, have you been affected by the recession?
3. What are your expectations and concerns about the future?
4. What does the future of water quality in the catchment look like to you?

Mirroring back the results of the interviews

The aim of using activity system theory is not the simple gathering and analysis of information by researchers who are "outsiders", but rather it is to encourage the analysis of information by the stakeholders themselves, in order for an understanding of the activity system to emerge from stakeholders actively involved in it. In this way, knowledge is not separated from practice, rather there is an active feedback between an emerging understanding of the system as a whole, and the activities or practices of the stakeholders within it.

The role of the researchers is to gather information, mirror it back. This means reporting – or reflecting back – to participants what the researcher heard and recorded, to make sure the record reflects the intention of the participant. The process of mirroring back creates the spaces in which stakeholders can engage with the information and each other. In order to achieve this, the meeting on 6 December was devoted to an interactive mirroring workshop, with professional design and facilitation.

The mirroring back process enabled participants to engage with the perspectives that emerged from the CHAT research. In particular, the workshop worked with "disturbances" or tensions, because these are regarded as points of growth, learning and pathways to possible improvements. They indicate places where an energy for change has accumulated:

> "Activity systems are in constant movement and internally contradictory. Their systemic contradictions, manifested in disturbances and mundane innovations, offer possibilities for expansive developmental transformations. Such transformations proceed through stepwise cycles of expansive learning which begin with actions of questioning the existing standard practice, then proceed to actions of analysing its contradictions and modelling a vision for its zone of proximal development, then to actions of examining and implementing the new model in practice." (Engeström, 2000: 960).

In order to protect the confidentiality of the interviews, the results were anonymised for presentation. It is important to engage with the ***content*** that emerges, and not the ***positions*** of the water users. The mirroring process, in two groups, produced the following responses to three crucial questions. The responses are reproduced as they came from the workshop. The first question was: ***What struck you the most about what was mirrored back?***

Group 1 was struck by the emergence of an evident community of practice in the catchment. They noted that there are consistent issues in the catchment that have been raised in other catchment platforms as well. This has positive and negative connotations to it. The positive side being that there has been progression towards improvement. The results of the research showed that there is fragmentation between institutions, institutions are working in isolation when there should be collaboration. There were also upstream tensions that the group were not aware existed that were presented. Group 2 noted that there was commonality of issues that came out in the results and that there are no new arguments in the catchment. The main question that arose was: are these issues real or are they developed on assumptions or inner perspectives instead of facts? The group identified that some of the results that were presented might have been raised because the person interviewed may be ill-informed.

Question 2 was: ***Can you identify the areas with most potential for change?*** Group 1 identified that there was potential for change in the power struggle between the then DWA and the IUCMA. Appropriate delegation of powers by the then Minister of Water Affairs, and DWA appropriately handing over functions to IUCMA could help resolve many problems because this has held back IUCMA. (DWA not DWS – Department of Water and Sanitation.) Secondly, if municipalities used

their budgets appropriately and dealt with their WWTWs with allocated funds, they would become excellent regulators as their eyes and ears are everywhere. The group used the phrase: “Naughty people becoming the prefects”. The second group identified that there is potential for change in making sure that there is clear communication in the catchment. There was also potential for change in finding how to get all stakeholders into a single communication space. Scientists are often very quick to provide technical answers to problems and not focus on social perspectives. There is potential for change when people engage the issues and practices, but don’t target the person.

Question 3 asked: **What did you notice that was missing from the results that were mirrored back?** Group 1 responded that groundwater was not mentioned in any of the results, the focus is on surface water. The focus is also on the effect of water quality on humans and no focus is given to ecosystems. Co-operative governance was not addressed. The importance of managing water quality for the contribution made to Mozambique downstream of the catchment was also missing.
Group 2 noted the absence of key role players. “The surfacing of underlying issues is also missing.” They missed a discussion of differentiating between support and blame, and suggested “Raising the white flag, and inviting co-operation instead of accusation.” Also absent was perception management to provide the clarification of issues with factual information.

There are indeed missing actors in the discussions. The industries who are contributed funding to the project were core participants. Actors such as municipalities were invited to participate without a cash contribution as their input was identified as being vital in a previous phase of the project (Du Toit et al., 2012). Local government is critical for understanding and dealing with the water quality system. A major absence among the industries is in the forestry sector, which absorbs an estimated 40 to 50% of rainfall before it reaches the rivers, thus appreciably reducing the dilution capacity available in the system. SAPPI attended several meetings but would not contribute funding until the last months of the project. The regional DWA office was not represented, and civil society organisations were only represented through the Crocodile Forum.

An emerging catchment ethos, and a system of inter-dependencies and links became evident through the CHAT process. Two types of actors were identified (1) system maintaining actors: the IUCMA, DWA, the Crocodile Forum and (2) actors directly influencing (and being influenced by) water quality. The function of the first group is to build, strengthen and maintain the overall system. They hold the system together, due to their social authority rest s in governance functions of allocation, regulation and representivity (in the case of the civil society inclusive Crocodile Forum). However, there was a tension at the heart of the system, in the form of a slow or delayed process of delegation of functions from the DWA national and regional offices to the IUCMA. This tension escalated and resulted in the loss of an experienced member of the IUCMA staff. Specific instances include that the IUCMA was often not part of the process of setting water use license requirements but had to monitor and enforce them.

Other actors in the system remarked that the IUCMA’s regulatory (monitoring and enforcement) performance was superior to that of regional DWA, and that they find them responsive and much easier to communicate with than the national Department. They ascribe that to the “focus” in the IUCMA. It is also national policy that mandates and budgets need to move from DWA to CMAs. The CMAs are emerging governance systems and this hobbling of their capacity needs to be addressed, as it generates disability at the heart of the system.

The Crocodile Forum is another actor with an overall catchment management role. It draws together all the actors in the catchment and although participation fluctuates, and the forum does not have authority to enforce compliance it plays a critical role in co-learning and communication in the

catchment water quality activity system. The forum relies on persuasion and the actions of other agencies to encourage compliance and best practice. It thus has complex relationships with the range of players in the catchment, who are part of it. The character of the forum depends on participants, and actors are able to avoid its influence through non-attendance. There is a current initiative from the DWA to improve the status, effectiveness of and support for catchment forums in line with the new National Water Resource Strategy (DWA 2013, personal communication, Matome Mahasha, DWA who is leading this initiative).

Civil society actors are an in-between category as they represent both water users, especially rural communities, and also act as direct user-custodians of water resources and ecosystems.

The second set of actors directly impact on water quality. These actors are arranged along the river from upstream to downstream, and along its tributaries. This means that physically the impacts are linear from upstream to downstream. However, socially the actors are able to influence each other through the emerging catchment management system in proportion to the effort they put into catchment management. It is noticeable that one of the most vulnerable actors to water quality problems is located downstream – the sugar industry. They also have the most sophisticated internal water management system, a satellite-and-computer aided surveillance system of exactly how much water is being used, is in the soil and in the sugar plants at any one time. They are also very active in catchment management processes: at the Crocodile Forum and with the TPNP case study. The conclusion can be drawn that vulnerable actors will put more effort into developing and driving catchment processes on the principle that they need to improve the whole system to improve their situation. It was also noticeable that the industry with access to an excellent water quality source not in the Crocodile River system, and who discharge into the Crocodile River system was the least engaged.

5.5 Sugar industry as a catchment citizen

The stakeholder process was deepened by a study for a master's degree by IWR student Asiphe Sahula, titled "*An exploration and critical assessment of the development of an integrated, participative, water quality management process for the Crocodile River Catchment, focusing on the Sugar industry*". (Sahula, 2014). The thesis combined biophysical and CHAT methodologies to understand the sugar industry as a downstream water user, sensitive to water quality, and also investigated the activity system of emerging sugar cane farmers in schemes based on land reform:

> "The South African Sugar Industry is described as one of the world's leading cost-competitive producers of high quality sugar (SASA, 2012). The industry is very diverse, producing raw and refined sugar, syrups, specialised sugars and a range of by-products as well as co-products for both local and export markets from 15 mills. The mills are supplied with sugar cane grown by approximately 29 130 registered sugarcane growers farming in KwaZulu-Natal, Mpumalanga and the Eastern Cape Province (Maloa, 2001; SASA, 2012).
>
> "There are currently 14 sugar milling companies that are located in South Africa and they include: Illovo Sugar (owns four mills), Tongaat Hulett Sugar (owns four mills), TSB sugar (owns three mills), Gledhow Sugar (owns one mill), UCL Company (owns one mill) and Umfolozi Sugar (owns one mill) 96(SASA, 2012). Only two of these mills are located in Mpumalanga province, all the others are located in KwaZulu-Natal. This study will thus focus on the TSB Malelane Mill that is located in the study area in the Crocodile River Catchment.

“The Malelane mill abstracts raw/source water from the Crocodile River, at a point just upstream of the Crocodile River Bridge entrance to the Kruger National Park. Water use patterns of the mill are influenced by the seasonality of the crushing process which depends on the availability and storage of sugarcane. VWG Consulting (2007) adds that the mill also has a water treatment works that treats a portion of the source water to portable water and distributes portable as well as source water to other users.”

“This study consists of two components, namely: Biophysical Component and a Social Component. The Biophysical component involves the analysis of in-stream water quality data, historical monitoring data (including observed values for the identified parameters of concern available from the following website:
http://www.dwaf.gov.za/iwqs/report.aspx), flow data and rainfall data. Data from TSB’s LIMS (Lab Info Management System) programme will also be obtained to access the water quality needs and impact of the processing of sugar at the mill. A Microsoft excel database has been set up to synthesise the data and produce flow duration curves.

“The Social component involved the understanding the interface between the sugar industry and the in-stream water quality in the Crocodile River Catchment through the analysis of the water quality activity system. The analysis of the management system of the mill as well as examining agricultural practices in the sugar cane fields. This will include documenting how management practices in the sugar industry can be modified to improve impacts that the sugar industry has on the water quality of the Crocodile Catchment. This component was achieved using the theory and method of Cultural historical activity systems (CHAT) by interviewing key individuals at the sugar mill and the cane growers.

“This study has explored the development of an IWQM process for the Crocodile River Catchment with a technical and social-based understanding of the sugar industry. However, also important is examining how the information provided in this thesis can be used to contribute to the implementation of the IWQM process once it is established. There are various options that can be taken by the sugar industry as a way forward to moving towards applying the information made available by this research and these options are listed below:

“The water quality analysis shows that the Kaap River contributes a negative effect in the Crocodile River main stem in terms of TDS, pH and alkalinity, posing a very high-water quality risk for irrigation water for sugar production and water used for processing sugarcane. The poor water quality from the Kaap River is attributed to extensive mining in the catchment area of the river. The social component results that were produced though CHAT work, highlighting the CMA as an overarching institution or rule-producing activity system has made it clear that the elucidation of water quality description emerged as a stakeholder need. Even though the pollution contribution of WWTWs in the Lower Crocodile River Catchment has been known, the negative contributions from the Kaap River, compared with Mbombela, was not explicit and this shifts the relationship between the sugar industry and the IUCMA and indicates focus areas for IUCMA. This information is now available for the sugar industry to address and this may be done in various ways. Such as making the information available to the IUCMA and nominating the institution to facilitate a discussion between the mines and the affected downstream water users. The IUCMA can also do a further detailed investigation of whether the mines in the catchment area of Kaap River comply in terms of their license conditions and if they do not comply,

what actions need to be taken. This information may already be available at the IUCMA; however, it may have not been made available by the IUCMA to the sugar industry.

"The water quality analysis also shows that the Hectorspruit WWTW contributes high concentrations of TDS and TAL into the Crocodile River in terms of the general effluent discharge limit and this is influenced by the performance and management of this WWTW. This aspect can be addressed through a subsidiary project that was developed as part of the larger project to address the performance of WWTWs in the Crocodile River Catchment and the project is known as the Green Drop Support Campaign. Hectorspruit WWTW can be added to the priority WWTWs in the catchment that needs assistance in terms of their performance in waste management. The sugar industry can participate in the discussion to assist as an affected party.

"The IUCMA Compliance and Enforcement Division can participate in the above discussions to assist with any relevant information in terms of the measures that can be put in place to reduce TDS, pH and alkalinity loads from mining activities and WWTWs.

"The biomonitoring results… show that for a catchment that has an extensive agricultural land use in terms of sugarcane and citrus production, the Crocodile River is unexpectedly not in a potentially adverse or chronic state in terms of aquatic health. From this one can deduce that there are no acute pesticide impacts from the agricultural land use in the catchment (though chronic effects cannot be discounted). This is a positive result and it means that pesticide use is strictly controlled in the sugar and citrus industry in the Crocodile River Catchment. It is very important for the sugar industry to maintain this pesticide management.

"Another major aspect that came out from the social component of the research is the need for an explicit platform for communication of water quality issues that the sugar industry faces. This was influenced by the difficulty of access to information about the water quality issues specific to the sugar, and other industries. This study is a crucial step towards making this information available for discussion at existing communication platforms in the Crocodile River Catchment and can influence the IUCMA to accelerate plans to develop a web-based water quality reporting platform. The lack of monitoring tools such as flow meters and soil moisture meters were also a contradiction identified within the sugar industry and the sugar industry can be involved in facilitating ways of subsidising the provision of such tools. More generally, the study has demonstrated the value of integrated, engaged, transdisciplinary research in progressing realistic natural resource sustainability across landscapes." (Sahula, 2014).

5.6 Applying the WQSAM model which Integrates water quantity and quality

The development of an IWQM process was supported by Mr Hugo Retief's MSc Water Resource Science, under the title "*Investigating integrated catchment management scenarios using a "simple" water quality and quantity model: A case study of the Crocodile River Catchment, South Africa*". (Retief, 2014):

"The Crocodile River Catchment [CRC] has been experiencing a decline in water quality as a result of the point source input of a cocktail of pollutants, which are discharged from industrial and municipal wastewater treatment plants, as well as from diffuse source runoff and return flows from the extensive areas of irrigated agriculture and mining sites (Deksissa et al., 2004). The decline in water quality has profound implications on a range

of stakeholders across the catchment. The major implication is the financial repercussions incurred by stakeholders particularly that rely on high water quality for production as they must face the increase in costs of treating water extracted from the Crocodile River. Even more importantly the Crocodile River flows out of the catchment into a bordering country, Mozambique, and South Africa is governed by international treaties to regulate the quantity and quality of rivers leaving South Africa (Palmer et al., 2013).

[The aim of the study was] understanding the relationship between surface water flow and water quality to be able to determine compliance (or non-compliance) of water users within the catchment. Therefore, this research will attempt to understand the relationship between quantity and quality of surface water in the Crocodile River Catchment (CRC) with the use of the Water Quality Systems Assessment Model (WQSAM) model. This research will contribute to a larger project with the aim of building a co-operative, implemented and integrated water quality management process (IWQM process) in the CRC.

[The study presented a major effort at integrating and consolidating] "all data (rainfall, land use maps, catchment characteristics and observed daily flows), required for disaggregating simulated monthly incremental flows an output from the Water Resources Modelling Platform (WReMP) to daily simulated incremental flows (Hughes and Slaughter, 2015, 2016). Other data consolidated include all observed water quality measurements for monitoring stations across the Crocodile River Catchment such as air temperature datasets used for water temperature modelling (Palmer et al., 2013). Many challenges have been encountered throughout the process of consolidating data; these include gaps in all the observed data sets obtained as well as the variations in data set format. A number of methods were implemented to identify gaps as well as to streamline processing of all datasets in the required format. Due to the number of ungauged catchments within the CRC, seven of the CRC quaternary catchments and one from the Buffalo River Catchment were disaggregated for and will be used in the development of a regionalisation model to disaggregate for ungauged catchments"

The study was successful in addressing the challenge that

> "… in practice, the implementation and success of IWRM policies has been hampered by the lack of availability of integrative decision support tools, especially within the context of limited resources and observed data. This is true for the Crocodile River Catchment (CRC), located within the Mpumalanga Province of South Africa. The catchment has been experiencing a decline in water quality as a result of the point source input of a cocktail of pollutants, which are discharged from industrial and municipal wastewater treatment plants, as well as diffuse source runoff and return flows from the extensive areas of irrigated agriculture and mining sites. The decline in water quality has profound implications for a range of stakeholders across the catchment including increased treatment costs and reduced crop yields.
>
> The combination of deteriorating water quality and the lack of understanding of the relationships between water quantity and quality for determining compliance/non-compliance in the CRC have resulted in collaboration between stakeholders, willing to work in a participatory and transparent manner to create an Integrated Water Quality Management Plan

(IWQM[Plan]). This project aimed to model water quality, (combined water quality and quantity), to facilitate the IWQM[Plan] aiding in the understanding of the relationship between water quantity and quality in the CRC. A relatively simple water quality model (WQSAM) was used that receives inputs from established water quantity systems models and was designed to be a water quality decision support tool for South African catchments.

The model was applied to the CRC, achieving acceptable simulations of total dissolved solids (used as a surrogate for salinity) and nutrients (including orthophosphates, nitrates +Nitrites and ammonium) for historical conditions. Validation results revealed that there is little consistency within the catchment, attributed to the non-stationary nature of water quality at many of the sites in the CRC.

The analyses of the results using a number of representations including seasonal load distributions, load duration curves and load flow plots, confirmed that the WQSAM model was able to capture the variability of relationships between water quantity and quality, provided that simulated hydrology was sufficiently accurate. The outputs produced by WQSAM was seen as useful for the CRC, with the Inkomati-Usuthu Catchment Management Agency (IUCMA) planning to operationalise the model in 2015. The ability of WQSAM to simulate water quality in data scarce catchments, with constituents that are appropriate for the needs of water resource management within South Africa, is highly beneficial." (Retief, 2014)

At the end of his study, Hugo Retief concluded that:
"stakeholders see value in WQSAM not only as tool for simulating future water quality scenarios-based in hydrological changes simulated by the WReMP model but also as a decision support system. As a WQDSS, WQSAM can provide reliable analyses of observed and simulated water quality in the form of concentration and load frequency curves, a process which would otherwise be time consuming. WQSAM could therefore provide stakeholders and the IUCMA with the capabilities of in-house analysis for effective compliance monitoring in accordance with the RQOs... In addition, the issue of the current discharge licences being a fixed concentration limit regardless of seasonality was highlighted by the environmental control officer. The control environmental officer recommended that the WQSAM model could be used for creating an understanding of assimilation capacities of rivers and assigning dynamic load targets to ensure RQOs are met, with an emphasis on controlling WWTW discharges." (Retief, 2014:107)

The Rhodes University team provided training to the IUCMA in using this model, but due to time and staffing issues, it was not completed. It is foreseen that training will resume after staffing issues (there needs to be a modeller in the water quality unit for this to work). In the meantime, the researcher, Hugo Retief, after qualifying, was employed by AWARD to continue developing a similar model for the Olifants catchment." (Retief, 2014).

5.7 Working on an IWQM process together

The IWQM process was the main topic of ongoing work in the Crocodile case study meetings that took place in early 2014. These meetings were supported by a consultation process with DWA and the IUCMA on the nature of and requirements for developing an IWQM process. During this consultation, it was resolved that it was possible for a specialised group of stakeholders, such as the

industries and other participants in this project, to develop the IWQM process as an additional chapter to the IUCMA CMS.

However, the IWQM process needed to be in line with the Catchment Management Strategy, not only in content but also in process,that is being conducted in transparent fashion with full knowledge of the Crocodile Forum as a space in which catchment stakeholders participate. Consultation with the DWA concluded that the development of the IWQM process for the Crocodile River would be a pioneering effort. However, there was one example (in the Upper Vaal) of developing a similar plan, plus a number of DWA guidelines. The DWA guidelines specify that it is completely acceptable (in fact would be welcomed) to develop a theme specific (in this case, industry and big user water quality challenges) strategy, that is confined to a smaller geographic area than the whole Inkomati (now including Usuthu) catchment, namely, a strategy specifically for the Crocodile River.

The DWA input was taken into account in the consultations with the IUCMA, and then presented to the stakeholders in a meeting on 23 May 2014. This meeting agreed to proceed with the development of the IWQM process. The IUCMA decided to proceed with work on this immediately, while taking into account that the River Classification project would only report on its proposals in November 2014.

An outline for the process was developed in terms of DWA's 2003 guidelines, which prescribe a four-step process:

1. What are the goals for water quality management?
2. How must water quality loads change to achieve the goals?
3. How will this be managed in the Crocodile catchment?
4. How, where and by whom will this be implemented?

The 23 May 2014 Crocodile case study meeting agreed to undertake the first two steps. The understanding of, and agreement on, goals for water quality management will be strongly influenced by the new Resource Quality Objectives (of which a first draft was expected in November 2014). The required changes in water quality loads will need to be spelled out very clearly and persuasively through the use of the quantity/quality model developed by Rhodes, as this is needed by THRIP participants to persuade their principals of new investments that will be needed to make the implementation of the IWQM process possible. The Core Stakeholders Group had met regularly, for a total of eight meetings on a quarterly basis, with the last meeting taking place on 27 February 2015. By February 2015, the process of multi-stakeholder meetings came to a halt. Participants indicated that they would prefer to go back to the Crocodile Forum meetings to deal with the issues raised in the research project. DWA and the IUCMA require, as does water policy in general, that the development of the IWQM process should be transparent and consultative. The case study project regularly reported to the Crocodile Forum, which is an open access Catchment Forum run by civil society, and in which most if not all of the stakeholders participate regularly. This process will continue, but the detailed proposals in the IWQM Plan will be presented only when there is more certainty about them.

The IUCMA had embarked on a process to develop the plan, possibly as a chapter in the new Catchment Management Strategy, which would have to be written (or rewritten) after the inclusion of a new area, the Usuthu catchment, into its WMA.

The WQSAM model was embedded on the IUCMA server, and training started for the migration of the water quality-quantity model to the IUCMA real-time management system. An important aspect

of the operationalisation is the development of a “dashboard” which would allow stakeholders to graphically see the water quality conditions in the Crocodile River on display.

The DWS and WRC then requested the research team to take the lead in organising an indaba in which the Terms of Reference for a new national Integrated Water Quality Management Strategy could be agreed upon. This happened, and the strategy (prepared by the consultant firm Pegasys) released a version for consultation in February 2017. The draft strategy acknowledges the importance of complexity and interdisciplinarity in dealing successfully with water quality challenges.

5.8 Conclusions

This project achieved the development of an Integrated Water Quality Management process based on a model which enabled the integration of water quality into water quality issues, which included a design and training for the IUCMA in integrating water quality into their Crocodile Operations model. It conducted a systemic inquiry into the catchment’s water quality activity system, following the Cultural Historical Activity Theory (CHAT) methodology. If followed a process of stakeholder participation. A specialised study into the sugar industry as example of a downstream water user in the catchment highlighted the detail, as well as biophysical and social aspects of the sugar industry’s interaction with water quality. This was achieved by using the transdisciplinary approach.

The need for robust science in decision making was accentuated in this process. Some industry stakeholders, while very much in support of the development of the water quality plan, insisted that “the scientific knowledge base” would have to be very robust, before they can take it into real time negotiations with their respective principals. The reason is that the measures alluded to above, may involve new expenditure, in some cases substantial.

To argue for such expenditure would absolutely have to be backed up by “solid science”. The modellers in the team are able to meet these requirements – that is in fact the purpose of their work – but it is important for this scientific information to be carefully validated and presented in forms that are immediately useful to these anticipated intra-industry discussions and “negotiations”. It is also of course necessary for the environmental managers, participating in the process, to be armed with information about the advantages, including an enhanced ability to manage water risk in their companies, to be effective in discussions within their own workplaces.

The work around developing the IWQM process has shown that science has an important role to play in decision making, and that scientific knowledge is co-constructed, both in the sense that it brings together local and “expert” knowledges,that in fact these two create each other and flow into each other (see Brian Wynne, 1996). Crocodile case study meetings were characterised by a negotiation over knowledge in this way. **The case study confirms one of the foundational principles in the TNP approach, namely mutual learning – not only of the social systems, but also of the science.**

It also pointed to the important role that environmental managers in industry and municipalities can play in sharing their knowledge in catchment forums. Industries were initially reluctant to provide data, and protective memorandums of understanding had to be negotiated.

The CHAT research, analysis and mirroring back was useful in developing an understanding of the shared water quality activity system which is starting to encompass the whole catchment. From this position, it is reasonable to assume that the attention will shift from the tools to manage the catchment together, rather than only the tools to manage the impacts of individual industries. This

echoes the principle in Strategic Adaptive Management to envision a different future, rather than be stuck in an unsatisfactory present.

The WQSAM model and its results were extensively discussed in the meetings. The WQSAM model provides an understanding of water quality and quantity and is able to take seasonality into account. During the dry winter months, the dilution capacity of the Crocodile River is being exceeded and steps will need to be taken – both in terms of industry investment as well as regulation by IUCMA – to deal with this emerging challenge. It was the shared development of a new tool which was then ready to be put into practice.

The two-day meeting to develop a Terms of Reference for a national Integrated Water Quality Management Strategy provided an ideal opportunity for many of the learnings in this project – that came to a somewhat unsatisfactory end – to be discussed and interrogated by national water quality specialists. **The outcome can be seen in the emphasis that the new WQM Policy and strategy (DWS 2017) places on complexity and transdisciplinarity.**

CHAPTER 6: THE GREEN DROP SUPPORT CAMPAIGN CASE STUDY

This chapter is supported by Munnik and Barnes (2016) which reports on a separate study that provided additional funding to deepen and extend the work initiated by the TPNP on Green Drop as a mechanism to address microbial pollution and eutrophication.

6.1 Introduction

This case study deals with bacteriological contamination and eutrophication as a result of dysfunctional Wastewater Treatment Words (WWTW). Drawing on Bhaskar (2008), the case study investigates social interactions at the face to face level of relationships between individuals, at two institutional scales in a developing Community of Practice (CoP), firstly in a working group of a Catchment Management Forum (the Crocodile Forum), and secondly with four local government municipalities within the Crocodile River catchment.

Most observers would agree that dysfunctional Wastewater Treatment Works (WWTW) in SA are a typical wicked problem (Rittel and Webber, 1973) that defies easy understanding or easy solution, because of the nature of complex systems with multiple concurrent issues, causalities and feedbacks (Cilliers et al., 2013).

Pollution from WWTW is a top priority nationally (Dr Marlene van der Merwe Botha, personal communication, October 2013; DWS, 2017), as well as for stakeholders in the Crocodile River catchment (Palmer et al., 2013). It is an important focus area for the Integrated Water Quality Management (IWQM) process in the Inkomati-Usuthu Catchment, in terms of both eutrophication and microbial pollution. However, there is a clear disconnect between this view of the **national importance** of dysfunctional WWTWs, and the **lack of importance ascribed, in practice**, to these issues by especially local government politicians and officials. At the heart of the issue is the tension between the constitutional right of local government to provide and earn income from water services, including WWTWs, and the impact that dysfunctional WWTWs have on water resources, the mandate of DWS; and held in public trust (Sax, 1970) by the government, for the people who live in South Africa (NWA, No 36 of 1998). This is a **political** tension. However, most interventions to solve the WWTW problem have focused on **technical**, infra-structural interventions, training and capacity building, emergency interventions and inspections. They have not addressed this political tension. This is exactly the intellectual-political challenge that the Crocodile Green Drop Support Campaign (CGDSC) took on. The campaign recognised that a principled and pragmatic Adaptive IWRM would be needed to deal with political and power issues. **In this way, it addresses the question of "Why it is necessary to pursue a social-political understanding of bacteriological contamination and eutrophication in a transdisciplinary setting?"**

An important aspect of the TPNP is to identify new intellectual resources to deal, in a holistic and transdisciplinary, with the complex issues in water resource protection and Adaptive IWRM generally, and to deal with this complexity in a way that leads to workable, pragmatic solutions to current challenges. The starting point is to see the problems as occurring within a social-ecological system.

The Resilience dictionary (www.Stockholmresilience.org/21/research/what-is-resilience/resilience-dictionary.html) defines a social ecological system (SES) in the following way:

> "Social-ecological systems are linked systems of people and nature. The term emphasises that humans be seen as part of, not apart from, nature – that the delineation between social and ecological systems is artificial and arbitrary… The term… was coined by Fikret Berkes and Carl Folke in 1998."

In this TPNP report, *social ecological systems thinking* is used explicitly as embedded in *general complexity thinking* and the term: **complex social-ecological system** (CSES) is used.

In the case of dysfunctional WWTW, the social part is strongly political, and we have therefore used a version of political ecology (Greenberg and Park, 1994) within a framework provided by critical realism (Norrie, 2010), to deal with the politics and complexity of the WWTW problem within a transdisciplinary space. Political ecology is:

> "…a historical outgrowth of the central questions asked by the social sciences about the relations between human society, viewed in its bio-cultural-political complexity, and a significantly humanized nature. It develops the common ground where various disciplines intersect." (1994:1). Two major streams of work have most influenced political ecology: "…political economy, with its insistence on the need to link the distribution of power with productive activity and ecological analysis, with its broader vision of bio-environmental analysis" (Greenberg and Park, 1994).

A third and growing stream in political ecology is an interest in discursive power, or how issues are represented, and how power arises from the way they are represented (Ferguson, 1990; Escobar, 1995; Leff, 2012). These newer approaches in political ecology emphasise how the way we think and talk about social and material reality, influences the way that reality changes and gets changed. This is important in terms of both a transition to sustainability and to social justice (Swilling and Annecke, 2012), which both require radically new forms of thinking.

Political ecology provides the tools to engage directly with the political mechanisms that lead to the failure of municipal WWTW, and to investigate and propose alternative policy options to deal with the problem. In this case, critical realism (Bhaskar, 2008), was adopted as a philosophical-theoretical framework that:

- allows work across disciplines and scales to be integrated,
- within a critical perspective on knowledge production, but
- with a realist ontology, which results in practical discovery of causal mechanisms, and
- that opens possibilities for using a theory of change approach through participatory action and generative research.

It is ideally suited to an approach of principled pragmatism, which calls for the simplification of Integrated Water Resource Management within the means available to developing countries like South Africa (Munnik and Price, 2015).

6.2 Critical Realist thinking in the Crocodile Green Drop Support Campaign (CGDSC)

This section will explain how the critical realism thinking allowed us to develop a sharpened and action-oriented approach to seeing WWTWs, and the natural and social landscape in which their challenges are situated, as a **social political system**.

A hallmark of critical realism is relational thinking, which provides for the possibility that entities can be part of each other, overlap, have internal splits, and transform over time. For example, people are clearly part of nature, but a people-nature divide may be a useful concept without which, for example we could not describe an "Anthropocene" (Lewis and Maslin, 2015). The CSES concept allows movement within, between and through social and ecological elements and systemic connections (Figure 1-1). Recognition of the social, the ecological and their systemic connections are particularly useful in this case study where local government is a crucial actor, and is part of a bigger whole, the

catchment. But local government itself is made up of smaller units, for example we could identify a division between frontline staff at the WWTW as separated by a "glass ceiling" (in the words of the frontline staff in the CGDSC process) from the powerful "management triangle" consisting of the municipal manager, services manager and financial manager, who controlled the resources the WWTW needed to function. **As a result of the dialogues in the CGDSC (see below), the "us and them" line between frustrated residents and WWTW frontline staff shifted, so that a new understanding and incipient solidarity emerged in which the frontline staff could be directly supported.**

Critical realism also provides two interesting ways of thinking through complex systems, that of a laminated reality (Figure 6-1) and the more general approach of an "open totality" or constellation. Many traditions have grappled with the problem of complexity. The Resilience Dictionary (www.Stockholmresilience.org/21/research/what-is-resilience/resilience-dictionary.html), for example, states that

> "Complex Adaptive Systems (CAS) include companies, the weather, our immune systems, the economy, ecosystems, single cells and brains. In these CAS, simple rules of cause and effect do not apply, they are complex, unpredictable and constantly adapting to their environments. Hence, they are far from being machines that you can take apart and investigate the parts to understand the whole."

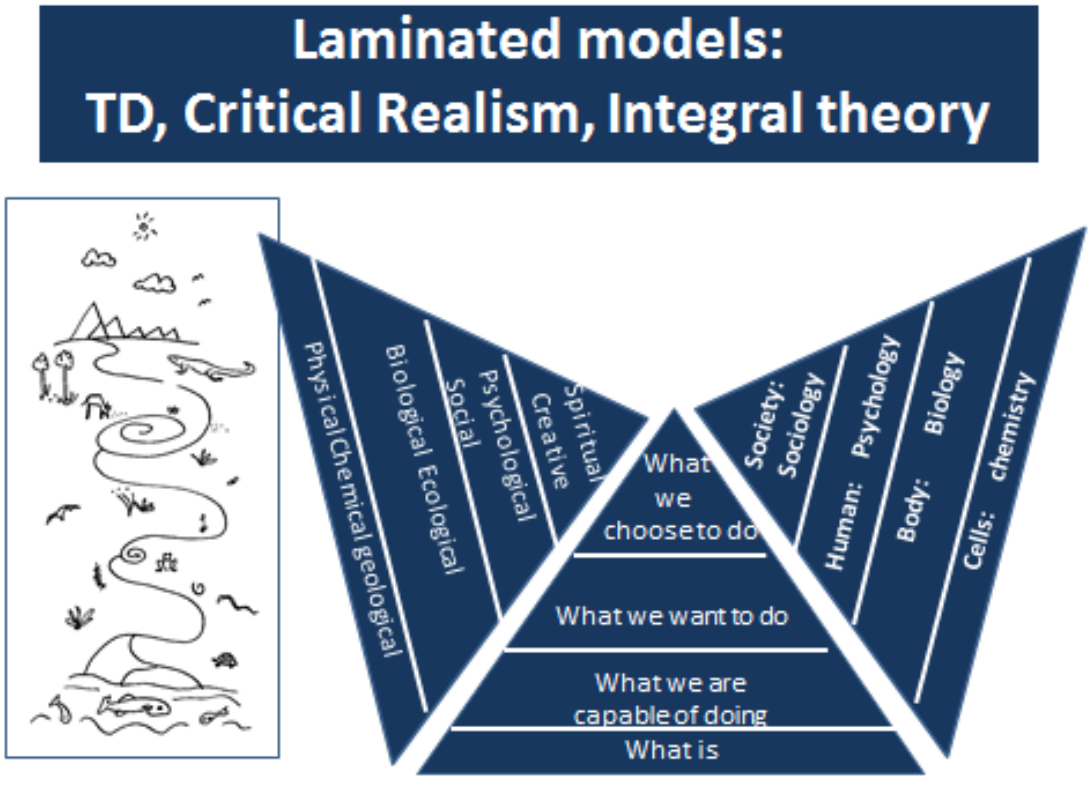

Figure 6-1: There are at least three theoretical traditions that suggest a "laminated" (Bhaskar, 2008) view of reality, where each layer is entirely dependent on, and emerges from, the existence of the lower levels and together they make an integrated whole. These are – left triangle: critical realism (Bhaskar, 2008); central triangle: transdisciplinarity (Max-Neef, 2005); and right triangle: integral theory (Wilber, 2007).

The "open totality" approach in critical realism allows for a complex system to be thought of as a dynamic, constantly changing whole, with "splits" (that is parts in contradiction or active contestation to each other), but still "hanging together". These are not systems that are determined from a central

point or by a single logic. An application of this logic is the recognition of a constellation of interests around, for example, a catchment management forum, which include not only the stakeholders and the organisations or constituencies they may represent, but also the capacities of those linked-in institutions to act. An example is the potential of a Department of Water and Sanitation (DWS) regulator to learn about a problem situation (such as sand mining) in a forum meeting, and then acting to pay attention to the issue as a regulator. This logic of "borrowing power" (Betzold, 2010) from participants in catchment management is crucial to the CGDSC as well as a principled, pragmatic Adaptive IWRM relying on contributions from all "catchment citizens".

Critical realism offers a structured approach to the knowledges – or explanations – which are relevant at different scales of a complex reality (Munnik and Burt, 2013) and used in Du Toit et al. (2013) to understand what influences collective action at the level of (1) the psychology of individuals, (2) individual material circumstances on a biographical level, (3) human face-to-face interaction, (4) the structure and culture of society, (5) a national society as a whole, for example the emerging project of democracy in South Africa, (6) geohistorical trajectories, including "a degrading environment, a closed catchment, changing rainfall patterns, apartheid and colonialism, land use practices" and (7) global trends such climate change, the internet, and the ideas and practice of Adaptive Integrated Water Resource Management. At each level, different knowledges and logics may apply, and can be differentiated, but in the end, they need to be understood together to allow for practical action, and to allow for recognising emergence between levels – because there is, for critical realism, a single reality beyond the various understandings of that reality.

Possibly the most fundamental concept in critical realism is the distinction between

1. what is **real** – the underlying mechanism that results in consequences, for example gravity that results in objects falling to the earth when not held up;
2. what is **actual** – what actually happens, for example a bridge is subject to real gravity, but does not actually collapse as long as it is strong enough to resist gravity. Note that in that situation the **actual** appears to contradict or obscure the **real**; and
3. finally, the **empirical** is which is observed and recorded by people. When a tree falls unseen in a forest, for a critical realist it really falls! (Therefore, the realm of the empirical is often smaller than that of the real, a crucial part of the critical realist critique of scientific reductionism which privileges observations over understanding of causative mechanisms.)

Critical realism sees the positivist insistence on only the empirical – that for which we have direct observation evidence – as unnecessarily limiting in terms of generating useful, and often needed explanations, for example of the type that support the precautionary principle in environmental management. In critical realism the main task of science (natural and social, according to their different research objects) is to discover real mechanisms through their consequences and use an understanding of their conditions of possibility (what must be the case for them to happen), in order to invent, or experiment with – for example through action research – theories of change that lead to interventions to solve the problem. These interventions create knowledge by testing whether and how reality responds to actions based on our understanding of it.

In the critical realism view, ideas that people hold and act on, are real, because they have real consequences. For this reason, social learning is a powerful concept, capable of leading to change. In social learning, knowledge is co-created, with people involved in daily practice, as opposed to a transfer of abstract knowledge to individuals who are learning in a "classroom" situation (Lave and Wenger, 1991). Learning feeds back directly into practice.

What follows is a short overview of the CGDSC and what it did, before discussing four areas of insight and/or discovery, learning, and emergence to be discussed in this paper/contribution:

1. Discovering drivers of WWTW dysfunctionality in Crocodile in a social learning environment;
2. Understanding interest, mandate and power constellations around WWTW;
3. Political trajectories to deal with dysfunctional WWTWs, and a return to the science of microbial contamination and eutrophication in a transdisciplinary setting: question setting and political communication, and
4. Working with emergent properties of a Catchment Management Forum working group for collective action on WWTW.

6.3 The Crocodile River Forum Green Drop Support Campaign

In the Crocodile River catchment, there are 17 wastewater treatment works (WWTW), and they are widely spread out (Figure 6-2). They belong to four local municipalities (Figure 6-3):

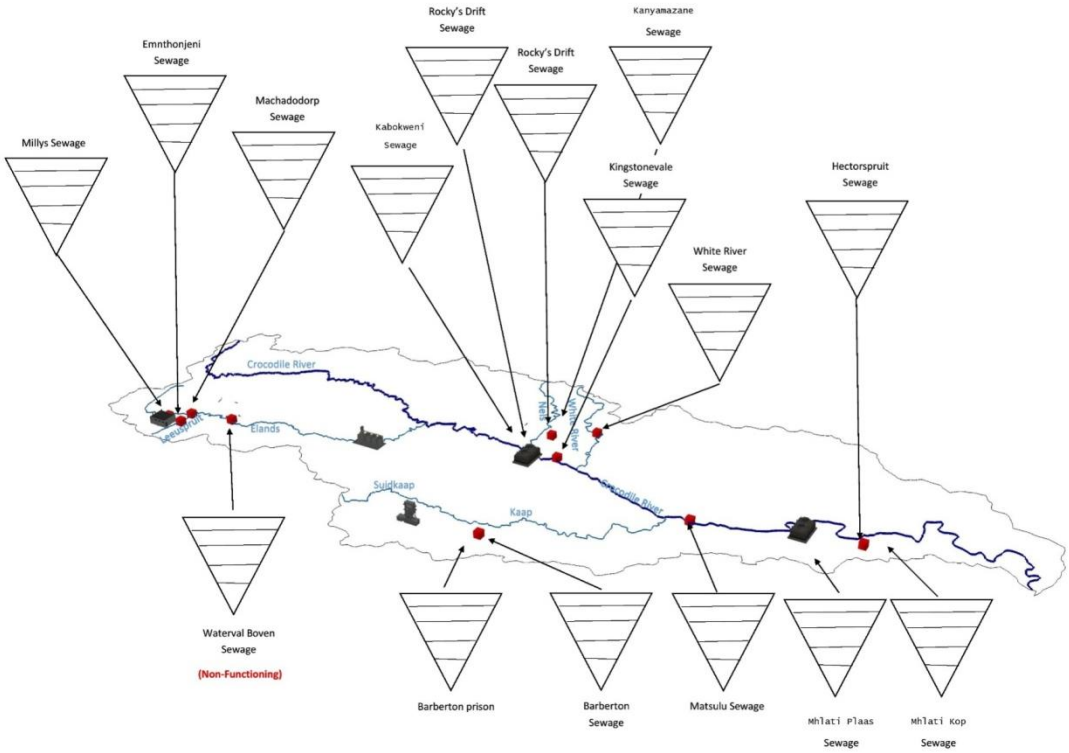

Figure 6-2: Wastewater treatment works along the Crocodile River (graphic by Hugo Retief).

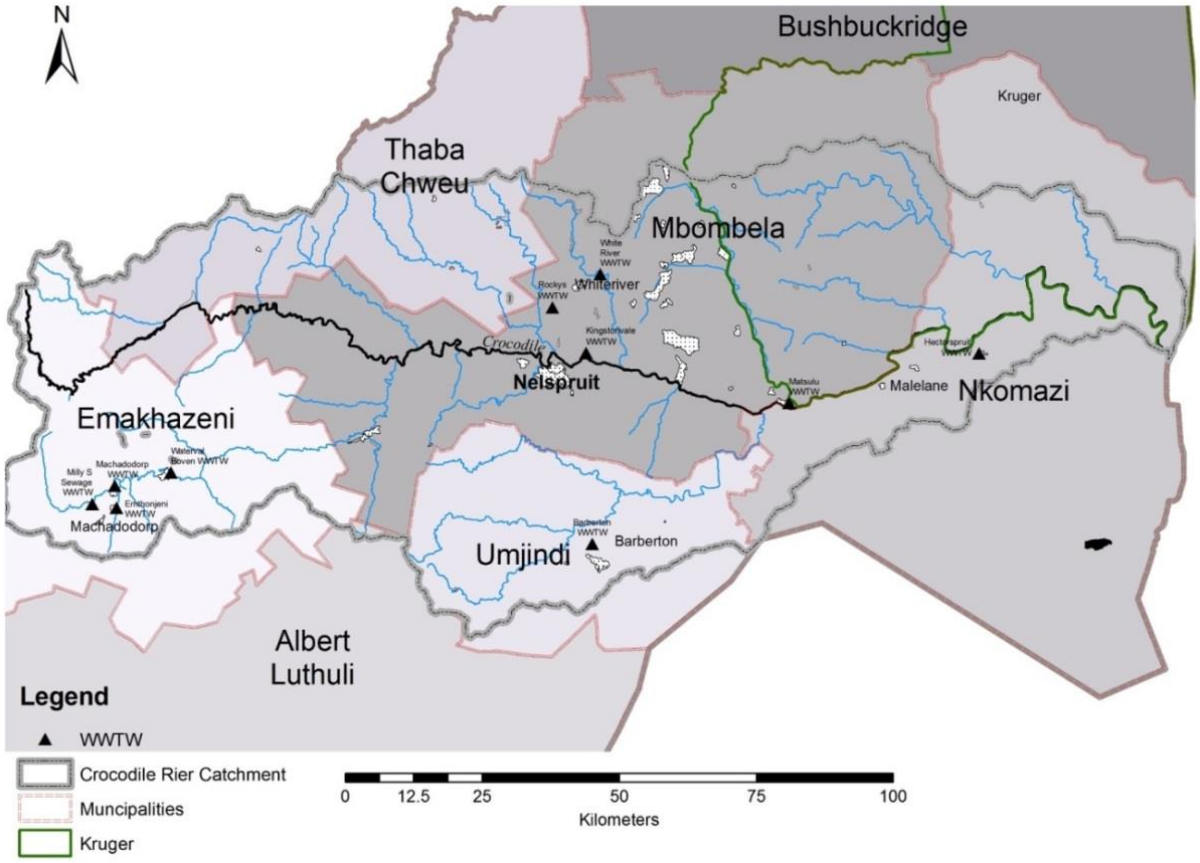

Figure 6-3: Municipalities along the Crocodile River.

In early 2014, the Crocodile (East) Catchment Management Forum (Crocodile Forum) agreed to form the Crocodile Green Drop Support Campaign as a working group, in response to a proposal by the TPNP project team emanating from information gathered in interviews with stakeholders in the Crocodile River case study in November 2013. Based on these interviews, a theory of change was developed to tackle the problem of dysfunctional WWTW, namely that as a result of a Green Drop support campaign:

1. WWTWs will achieve a higher profile locally, in public and with the municipality (councillors and officials). This will prevent the current practice of reallocating WWTW budgets to other priorities midyear, and inappropriate and inadequate procurement practices.
2. Civil society will adopt a supportive attitude towards WWTW, on the basis of an in depth understanding of their context and functioning. Staff responsible for WWTWs will not be under general attack by civil society and other catchment stakeholders; instead efforts will be focused on identifying the bottle necks in achieving a better Green Drop score, within the Green Drop programme.
3. While there is clear support from national and regional DWS, and a focus by the IUCMA, the working group with broad stakeholder support needs to receive and orient the support into productive channels.

This three-fold theory of change relied implicitly on a theory of local government practice. However, this theory was not made explicit, nor was it directly pursued in the form of research into local government, for example through qualitative interviews, surveys, or analysis of budgets and expenditure. Such a conventional approach may have yielded little (due to the sensitivity of the questions being asked) and may have had the result of local government closing down access.

Instead, an action research located within the bigger constellation of actors surrounding the problem, and anxious to resolve it, was pursued.

At the heart of the CGDSC was an attempt to bring the **insights and energies of actors outside of local government, into collaboration with local governments** to improve their WWTW performance. This was a response to the current dynamics around WWTW: while segments of civil society, business and various national departments are intensely concerned about the risks of dysfunctional WWTW, the local governments responsible for them seemed to be resolutely out of step. However, the risk to the health of citizens affected by microbial pollution in rivers (aggravated in some instances by deficient drinking water treatment systems, see Bloemhof discussion below) and the ongoing degradation of ecosystems (Le Roux et al., 2012) were the concern of actors outside of local government. The contradiction was that local government is guaranteed a strong degree of autonomy in how it takes responsibility for this particular water service. The DWS Green Drop scheme is itself the result of this arrangement – it is an incentive scheme, rather than a compliance regime, although it does not replace the compliance regime. Moreover, this was – at the time of the research – complicated further by political reluctance to release information about local government performance (see Sipho Kings, Mail and Guardian 7 Aug 2015 as an example). Such strong control over information flows was another reason to plunge directly into action research.

Nevertheless, as the research was undertaken, it was clear that the situation was dire, not only in the Crocodile catchment, but in Mpumalanga as a whole. In the previous inspection of 2013, only 2 WWTW in Mpumalanga as a whole were awarded Green Drop Certificates while 41 systems had a score lower than 30%, according to the Executive Summary of the 2013 report (DWA, 2013).

Apart from dealing with an immediate problem, the intention of the CGDSC was also to experiment with what a working group of a Catchment Management Forum (CMF) is able to achieve, and how it can do so. (Note: This experience provided the learning-base to form and use the Upper Komati Forum, AMD group, to address issues of mining and Biodiversity in the X11B quaternary catchment around the town of Carolina (Munnik et al., in press)). This CGDSC research therefore also intended to make a practical contribution to the development of robust and capable CMFs through action research (in the form of an experiment) into the institutional form of a CMF working group, that could be used more broadly. The revitalisation of CMFs was at the time part of the roll-out of CMAs country wide (Mahasha, 2014; Munnik et al., 2015), so the understanding of the role of working groups was an important investment in the creation of new instruments to address complex problems.

The CGDSC followed seven steps, developed in an earlier, similar campaign in the Rietspruit Forum in the Upper Vaal (Munnik, 2010). While the steps are generic, they require detailed attention to the specific context in which the campaign is undertaken:

Step 1	Check (with stakeholders/actors) the need for the campaign: Are dysfunctional WWTW an important problem? For whom? Check the institutional feasibility: What elements are present in the context, what types of civil society, water sector, local government and other actors? Specifically, what is the catchment management set-up? Are there forums and possibly a CMA?
Step 2	Establish a mandated, representative (across class, race, geographical spread, interest groups, etc.) group. Agree on campaign objectives and working group rules and approach. Build capacity, especially knowledge of WWTW, the Green Drop criteria, and a language in which the working group can discuss and understand the issues. (Good materials are available, starting with the WRC publications, e.g. Boyd and Mbelu, 2009).
Step 3	Involve the operators. Share and understand their challenges. Get to know and understand the specific WWTW and their issues in detail.
Step 4	Test current performance against the Green Drop criteria. How is the Green Drop process going, which criteria were met, and which were not met, and why? Understand the WWTW/local government interface: what is the nature of municipal support (or lack of support) for WWTW?
Step 5	Develop solutions and implement them. Use a wide range of tactics, including close engagement with local government, small circle engagement in problem areas, also publicity and engaging allies and other sources of influence. This is the wrestle phase.
Step 6	Acknowledge and publicise success. Analyse the reasons for success. Consider how to make the situation sustainable (e.g. does it need ongoing monitoring from the catchment or does each WWTW need a citizens' committee – like landfill committees – and regular reporting?). Is there need for a standing Green Drop support group? Is it possible to fold the work of the working group back into the sub catchment forum?
Step 7	Link with and support other sub catchment forums and other institutions dealing with the same issues. For example, neighbouring sub catchment forums in the Upper Vaal, or other active or challenged forums dealing with dysfunctional WWTWs. Feed experiences into broader CMA policy and implementation, and into local government policy. Draw out the lessons for sector collaboration and DWS's role as a regulator, including the role of citizens' monitoring.

The first CGDSC dialogue took place in January 2014, with the seventh in February 2015. The campaign participants met roughly every two months (sometimes more often, other times less). Attendance grew with each meeting. It involved most relevant stakeholders: TSB Sugar, White River Irrigation Board, manganese mines and industries, Mbombela frontline staff, the Sembcorp WWTW operator, IUCMA water quality team and Green Drop staff, Crocodile Forum chair, DWS, South Kaap Farmers Association, university researchers, the four municipalities all in campaign, with senior managers from two out of the four. An exception was the Mpumalanga Water Caucus, a civil society formation, which did not regularly attend because they consider the Blue Drop "more relevant to the communities where many people still don't have clean drinking water" (December Ndlovu, informal communication May 2014).

The municipalities own the WWTW and play a crucial role in the impact of sewage disposal. The specific approach the campaign followed was to work from the ground up, by first inviting the frontline staff. The theory (developed in Rietspruit in 2009/10, Munnik (2010) was that the frontline staff (1) were interested in their jobs and could do them well under different circumstances (2) needed help from the broader community including national structures and (3) good relationships between frontline staff, civil society and other water users would lead to solutions, instead of the current hostility.

In the first meeting, the CGDSC working group responded by agreeing on the following approach or principles, after broad discussions:

1. Understand each individual WWTW and its challenges. Understand Green Drop requirements in relation to the individual works.
2. Know and support the frontline staff.
3. Collective empowerment at process controllers' level so that they can support each other
4. Develop healthy challenges between municipalities
5. Understand the dynamics in the municipalities and get ward councillors on board
6. Work with the willing, attract the unwilling, look for sticks for the unwilling – in Berg River, farmers were affected economically and made a strong lobby group. Patience with local government may run out. Media can be used as a stick (Name and Shame).
7. Use tools from regulations, and pressure from central government
8. Approach rapid response unit for financial needs
9. Encourage industry and civil society to adopt a neighbouring wastewater treatment works

The co-creation of these principles (see Chapter 2 on the role of principles) reflected that participants were drawing on local knowledge, not only of the WWTW but also the political nature of local government. They were acting as catchment citizens, with an awareness of the resources they themselves brought into the group, as well as the resources available in the "catchment constellation". It became clear early on that the IUCMA (where the meetings took place) formed a crucial support for this constellation. The IUCMA also compiled, as a result of its regular inspections in the area, a comprehensive report on WWTW (IUCMA, 2014).

Creating a safe space in which to discuss the real obstacles to Green Drop improvements was gradually achieved as more municipal staff joined in the discussion and became more frank and open about their experiences. Influenced by the Chatham House Rules, which create a safe space by protecting the confidentiality of participants' contributions, the minutes were kept without references to the names. Initially there was certain nervousness from municipal employees, but this disappeared over time as the group identity grew stronger. This underlines the importance of creating a culture of social learning, reflection and the building of social trust within a logic of active catchment citizenship.

6.4 Discovering drivers of WWTW dysfunctionality in the Crocodile River catchment in a social learning environment

Through dialogues, sharing information and then in small group discussions where participants drew diagrams of the "flow of work" within municipalities, the main problem became clear: a disconnect between the WWTWs and frontline staff and local government's top triangle: municipal manager, technical manager, finance manager. Staff would be given responsibility for Green Drop performance, then not get budget or support, then do badly, and then be held responsible for the results by top management. This was very frustrating, not productive, and was generally the case among all the municipalities, although to varying degrees.

This mirrored the experience in the Upper Vaal, where the core finding had been that the municipality did not take proper care of their WWTW and their staff. This was not only an intellectual discovery, but a trigger for growing solidarity and understanding between WWTW frontline staff and civil society counterparts who until then had taken a generally accusatory attitude. **It was crucial to take a relational perspective**, and not see the local government as a whole as a problem. It was also important to recognise that the dynamic inside local government was not a personal one. This became clear when a municipal manager, who joined the dialogues at a later stage, made a frank contribution in which he explained that municipal managers are overworked ("their in-trays are overflowing"), and that the politicians they answer to have far more interest in interventions that are visible to their constituents, such as health clinics, roads and street lights, than in WWTW.

Both of these contrasting insights depended on local knowledge, the courage to speak out in an expectation to be heard in a sympathetic atmosphere, and the ability to realise that the agendas of local government may, in a way that is rational to them, be in contradiction to what the working group wanted to hear. It required, in critical realism terms, a "perspective switch" in order to understand the other side of the argument.

In response, the CGDSC working group proposed two approaches:

1. To create four local teams to interact with each of the four local municipalities.
2. To involve national departments, with regulatory, fiduciary or other responsibilities that may enable or entitle them to intervene in the situation, "from the top".

6.5 Understanding interest, mandate and power constellations around WWTW

While the first resolution had a local character, and was within the capabilities of the participants, the second resolution reflected a desire among participants to reach for some "top down" force to persuade the local government to take the WWTW issue more seriously. They wanted to "borrow the power" of the relevant national government departments. Of course, it also revealed an awareness that the consequences of dysfunctional WWTW also fell – or should fall – within the mandates of several national government departments. In response, and in co-operation with AWARD, the TPNP team undertook a number of interviews with national government departments which revealed the following institutional and political landscape:

- Treasury was reluctant to intervene, and not well placed since it pays attention to mainly money flows. The quality of the effluent and other technical parameters is not visible to these officials. However, they have taken a keen interest in Green Drop developments, from a "value for money" perspective, and might consider participating in a limited pilot project (in one or two municipalities) to see whether focused attention could motivate better performance at municipal level.

- Cooperative governance and traditional affairs (COGTA) had undertaken a "back to basics" programme, which did hold the promise to motivate better performance of WWTW. However, it was noticeable in interviews with MISA, a supporting agency within COGTA that interventions in municipalities could only happen when welcomed by the municipalities. This hesitant approach seemed to characterise the national constellation around municipal WWTW.

- Department of Water and Sanitation (DWS) arguably had the most responsibility and opportunity to intervene. In theory, the Green Drop scheme does not replace the day-to-day compliance monitoring, and could itself trigger pre-directives, and court action (against

poorest non-performing municipalities). In practice, this is limited by the number of officials on the ground, and the fact that Green Drop competes with other tasks on their agenda. However, DWS officials pointed out that a number of directives have been issued against municipalities and do have results. In addition, DWS had embarked on a (MuSSA) programme, in which municipalities self-report in a number of risk areas, including wastewater treatment (interview Alistair Wensley, 2015).

The overriding picture that emerged from interviews was that all the national departments were bound by the constitutional autonomy of local government, which (1) is an equal sphere of government and (2) has the right (or is designed) to earn income from providing water and electricity services, which it defends jealously. Policy change that would change this situation would be difficult to achieve. In theory, there are two strategic scenarios within these limits: (1) the full use of DWS and other government department powers and (2) raising the political visibility of WWTW failure in order to achieve a priority or parity with other local government concerns, through making the consequences clear.

The full use of DWS powers are currently blocked by a number of obstacles at regional level. These are unlikely to disappear until the (new) Catchment Management Agencies are in full swing, and operate with full water quality teams – like the IUCMA. Delegation of powers will remain an issue. **This research recommends that the issue of WWTW be carefully watched in the emergence of seven new CMAs, and they be given the ability to deal with it. However, a national workshop bringing together a network of officials concerned with the issue, could assist in encouraging exchange of information and raise the possibility of developing a coordinated response.** This idea was mooted by the research team in some interviews, and positively received.

6.6 Potential political trajectories

The fact remains that on-going risk and degradation is also the business of actors other than local government. There is a constellation of interests and mandates around dysfunctional WWTW – although they are not currently all connected and working together. At the moment, local government is uniquely privileged in this constellation, although not capable and motivated to deal with the consequences of its neglect of WWTW.

A first potential policy response is to decide that it is mistaken to assume that local governments are capable of taking responsibility for WWTW, and that the responsibility should be moved to other actors, such as water boards. This has in fact happened in Bushbuckridge within in the IUCMA area and, on a temporary basis, in the Upper Vaal. In an interview with the South African Local Government Association (SALGA) the research team was warned that such a trajectory would invite stiff resistance from organised local government, although the possibility of outsourcing the operation and maintenance (with some profit for local government built in) already exists (William Moraka, pers comm., 2014). The broader political problem is whether local government has more responsibilities than it has a budget and capacity.

A second response is to sharpen the possibilities for intervention and make that a concerted and co-ordinated effort by national government. A third is a more long-term building of citizens' power via catchment management agencies (and catchment forums), to hold local government to account, and also to support them.

Both of these trajectories rely on increasing public awareness and pressure on this issue. It requires raising the visibility of the WWTW issue by making the consequences clear. It would rely on

expanded research, synthesis of existing research, and communicating the results not only to local and national government, but also to the public at large. The issues are of real concern and provide the reasons why dysfunctional WWTW are in the spotlight in the first place. Issues can be organised in three main areas:

1. Diarrhoea is a leading cause of child death between the ages of 1 and 5. Contaminated drinking water is an important cause of diarrhoea (Basson, 2009; NEPAD, 2013).
2. The impact of eutrophication on ecosystems: repeated oxygen depletion events, for example, lead to the impoverishment of ecosystem function and integrity, also reducing the ability of the river to self-purify.
3. Economic impacts: impacts of the above on health (costs to the public purse and to suffering families), to livelihoods, and threats to products marketing nationally and internationally.

The most immediate area of concern is the impact and cost of bacteriological contamination on people's health, particularly direct river water users, including poor people with no access to treated water, farmers who use raw water for productive uses, fisher-folk, children who swim in rivers, and traditional healers (who use river water for immersion and use river water for mixing medicines (see a case study in the Upper Vaal: citizens' monitoring of the current National Water Resource Strategy 2, Wilson et al., 2016)).

Diarrhoea is the third biggest killer in South Africa (Basson, 2009) and children in particular are vulnerable to it. According to a recent NEPAD report, diarrhoea is a major cause of mortality for children under 5 years, claiming between 65 and 70 children's lives per 1000 births, per year (NEPAD, 2013:48).

A study in the Upper Olifants catchment – the neighbouring catchment to the Inkomati – found that "extreme levels of faecal pollution could in most instances be traced back to inadequate wastewater treatment" (Le Roux et al., 2012: 6587). Research done on microbial water quality risks concluded that:

> "…The data show that an individual consuming 100 ml of untreated water from such a water source (i.e. highly contaminated with faecal pollutants) could expect to have up to a 26% chance of falling ill" (from any of the seven pathogens that were monitored in this study). It further notes... "Important water-borne pathogens as they may be, these organisms are but a fraction of the total potential pathogen pool expected to occur in poor quality waters, and the true risk water users face would in fact be much higher. Using E coli as an indicator for pathogens, the risk of infection at some sites was calculated to be in the region of 80% based on a single exposure event…" (Le Roux et al., 2012: 6586).

The authors concluded that "…large gains can be achieved by ensuring the proper functioning of a few WWTW within the Upper Olifants River catchment".

Bacteriological contamination is purified by the workings of healthy aquatic ecosystems. The irony is that on-going eutrophication weakens river ecosystems, and their ability to deal with bacteriological contamination. This is the second area of impacts. Eutrophication damages river ecosystems through algal blooms (and other growth stimulated by an excessive supply of the nutrients phosphate and nitrogen), which often results in deoxygenation, and the death of fish and invertebrates. There is less active life that can deal with the bacteriological contamination. International research (Zheng and Paul, 2007:7) pointed out that

> "Eutrophication, as one of the main causes of stream impairment in the United States, imposes severe threats to ecosystem structure and function. The direct impact of nutrient

enrichment is to increase autotrophic production and change species assemblages including proliferation of filamentous algae. Nutrient enrichment also accelerates litter breakdown rates by bacteria and fungi. The dramatic changes at lower trophic levels may also lead to "trophic cascading". As nutrient concentrations increase and destabilize the primary producer assemblage and water chemistry, macro-invertebrates and fish may shift from sensitive species to more tolerant, often non-native species. Changes in the food web may also cause changes in ecosystem function and further alter stream physical habitat and water chemistry, e.g. decreasing dissolved oxygen."

Other effects include reduced light penetration, changes in available habitat, long term oxygen depletion, extremely high or low pH levels (increasing toxicity to fish and other organisms), while low pH can make heavy metals in stream sediments available, toxin released by cyanobacteria, and a decrease in macrophyte richness.

Thirdly, there are economics impacts of dysfunctional WWTW. Improvements in the Berg River catchment in the Western Cape resulted from a response to economic threats, namely the rejection of fruit by export markets. But there are other costs as well, including health costs borne by the state and by families exposed to contamination.

A practical recommendation is therefore to focus on research into relevant river stretches, with popular participation and support from a Green Drop Support Campaign (replicated along the lines described in this section), in order to determine whether it should and could be a municipal priority. This could take the form of delineating, with the help, for example, of the equivalent of the IUCMA Water Quality team, of a river stretch directly following a WWTW, and determining the impact of its dysfunctionality. This could be supported by a social component, in which the water uses and other water interactions are documented. Visibility could then be achieved by the erection of warning signs downstream from dysfunctional WWTW.

The functionality of WWTW is, in the final analysis, not only a local government issue, to be assigned priority amongst competing priorities for local government who, it can be argued, has inherent limitations in according it proper importance. It is also a national issue as it affects people's health, and the health of water resources and ecosystems. It is urgent for the conceptualisation of WWTW dysfunctionality to be seen beyond the realm of local government.

In the meantime, the political response by affected people is not far from the surface, as evidenced by events in Ukhahlamba, Delmas, Biesiesvlei, Sannieshof and Bloemhof reported in the public media. Observation of the public sphere during this project (that is by media and civil society groups) has shown widespread and growing concern. There is also growing awareness of the politically disruptive potential of the issue, for example the close attention of opposition councillors in Nkomazi local municipality, and the Bloemhof case of suspected vandalism with a political motive (Tempelhof and Ginster, personal communication July 2015). Wastewater infrastructure, the works as well as the sewerage lines, are vulnerable.

6.7 Politics and science

An underlying question for this chapter was "Why it is necessary to pursue a social-political understanding of bacteriological contamination and eutrophication in a transdisciplinary setting?" The answer is not an exclusion of natural science, but an argument for a new relationship between science and social-science that plays to the strengths of each discipline (Stott and Sullivan, 2000).
The political ecological analysis in this section concludes that a scientific approach to microbial contamination and eutrophication from dysfunctional WWTW has an important role to play. However,

the analysis has also shown that this will need to happen in a transdisciplinary setting, in which the process of formulating research questions is guided by, among others, the **need for politically effective communication**. There is an urgent **need for a science that would make consequences and impacts clear** to the different groups dispersed in the constellation around WWTW as well as concentrated in emergent CMF working group or similar organisations. Such science would point out clearly – and even dramatically – (1) the health risks, the health consequences of dysfunctional WWTW, for how long these persist along the river, what dangers (Le Roux et al., 2012), and (2) the ecological consequences such as ecosystem degradation, as well as relating them very clearly to social consequences in a register that is understandable to and motivating for the power groups identified above. Such research would also integrate insights from broader social analysis, for example that the problem is not limited to dysfunctional WWTW, but also sewers and pump stations, as well as informal settlements without services.

6.8 Working with emergent properties of a Catchment Management Forum working group

In addition to dealing with an immediate problem, the intention in this action research was also to experiment with what a working group of a CMF able to achieve, and how it could do so. This research thus intended to also make a practical contribution to the development of robust and able CMFs by developing the practice and concept of CMF working groups. The revitalisation of CMFs is currently part of the roll-out of CMAs country wide (Mahasha, 2014; Munnik et al., 2015), so the understanding of the role of working groups is an important investment in the creation of new instruments to address complex problems.

The CGDSC as a working group experience, could be widely replicated to build the ability of catchment forums to deal with issues of WWTW and water quality. This may however depend on the stage of maturity of the forum. The expectation is that new forums and new CMAs will be formed, but they may be caught up in initialising activities, such as devising a catchment management strategy. The CGDSC is replicable as a way of building participation in catchment management, so that participants can experience the CMFs as forums where things can be achieved, but then there must be results. Achieving these results does not depend on the campaigns only.

Replication is closely bound up with the sustainability question. If the practice of the Green Drop support campaigns should spread as working groups of forums, these working groups can support each other, and this practice can become a norm, rather than a pioneering effort. An effect of upscaling would be to place catchment citizens in a position where they can form effective alliances for collective action with other actors in catchment management. Such an approach, characterised by active catchment citizens collaborating with responsible authorities, could also be integrated into the thinking of the regulator and the rest of the sector.

Research into the future replicability of the campaign (Munnik, 2015) has revealed the existence of extensive resources in the catchment management centred constellation around WWTW. Such resources include:

1. Reliable monitoring information, ideally triangulated by different institutions, such as Rand Water, DWS and local municipalities in the Rietspruit who brought their own monitoring data to the forum working group, where it could be compared by citizens.
2. Existing knowledge, in the form of research so that the issues are clearly defined. In the Crocodile catchment, the impacts on water quality are known and can be substantiated. IUCMA 2014 report was crucial contribution, in terms of information, authority and indicating

seriousness in approach. Knowledge should be used to develop a theory of change, and there needs to be agreement on the principles of the approach in the campaign.

3. Knowledgeable participants, often found in CMA or Water Board, universities and researchers, volunteer consultants and industry's environmental managers.
4. The ability to provide capacity building to civil society participants. The capacity building was specific in the Rietspruit, and dispersed, generalised and ongoing in IUCMA area.
5. The Crocodile experience showed that there is ample knowledge within municipal staff themselves. They are more frustrated with support from senior managers and access to resources than under capacitated, although it is granted that training of some staff is needed. In the Crocodile, Silulumanzi (Sembcorp) had professional staff on the ground who joined the campaign. In the Rietspruit, there were consultants and environmental managers in industry who were willing to act in the public interest.
6. Organised civil society with legitimacy, with constituencies in the different segments of society, along class and racial lines. In the Rietspruit case, the Vaal Environmental Justice Alliance (VEJA) was a prominent, if not driving force, and both the Mvula Trust and WESSA participated. The disillusioned Save the Vaal Environment (SAVE), which follows a strongly legal, confrontational strategy, did not agree to participate in the Rietspruit campaign. In the Crocodile, the Mpumalanga Water Caucus had limited participation, because, as one participant explained "the Blue Drop is more relevant to us than the Green Drop because many of our people do not have safe drinking water". This aspect needs further attention as it indicates that civil society, like the majority of voters at local government level, does not view the water cycle as a whole. VEJA, on the other hand, had as one of its founding issues the water quality concerns from industrial pollution in the Vaal.
7. As a working group of an established CMF, the campaign enjoyed legitimacy and accountability through the need to report back regularly.
8. Some openness from local government to co-operate, interest or enthusiasm from local WWTW staff, and space for them to participate. It was clear that working with local government on these issues was tricky. The campaigns-built solidarity from the ground up with willing parties, rather than starting from the top where there could be a lack of interest or defensiveness. However, the aim remains to win over the upper echelons of local government through real assistance, encouragement and acknowledgement of any success. The GDSC is designed to allow local government top structures to achieve, to look good, and is not meant as an attack on them. Interaction between local government staff across different municipalities should be encouraged and supported, and some of this happened in the Green Drop space. It needs to be acknowledged that this interaction also happens in other forums, including with support from DWS, SALGA, WISA and other programmes such as the Dutch-South African Kingfisher programme. The GDSC would do best to find out what these opportunities are and participate in them and support them.
9. The ability to facilitate working group meetings to deal with lack of trust, fears of professional repercussions (for WWTW staff but also for consultants) within local government power structures and replacing old patterns of blame and confrontation with new patterns of collaboration, listening, building trust and sharing resources. Facilitation needs to be based on social learning or community of practice principles, which include listening skills, facilitation that involve people, small group work instead of lectures and very importantly Chatham House rules providing for safe space, and anonymity in reporting in the minutes that are distributed.
10. The ability of the working group to make wise decisions about how to handle publicity. In neither the Rietspruit nor Crocodile campaigns did the campaign use the media. It is in contradiction with the "safe space" and trust building principles, and premature publicity would threaten these. The consensus within the groups – after discussion – was to hold back

until success, or utter failure, is achieved. This was not easy to achieve in the Rietspruit, as it meant civil society had to refrain from using one of its strongest “weapons” (compare point 6, above). At the same time, publicity should not be given to hollow successes, as this will compromise civil society constituencies.

11. Visiting the works physically can raise the profile, because a root cause of WWTW neglect is their lack of visibility. In the Crocodile catchment, it was learnt that spatial spread in a rural area may pose logistical challenges for this, thus a system of “local committees” was proposed.
12. Explore the possibility of creating local structures – subgroups focused on each municipality – within the working group. This has not been tested in full yet.
13. National help and intervention can be very helpful. This includes financial, information and training, as well as strengthening the profile of the campaign.
14. It remains to be tested whether a GDSC in a more resource scarce environment could succeed through different means.
15. Finally, the Green Drop scheme – which is a dynamic, evolving one – in is crucially important in providing a framework which is both technically sound and politically acceptable to all participants. This cannot be underestimated as providing the basis for the campaign. Therefore, the continued investment of government in the Green Drop scheme is important.

6.9 Conclusions

In conclusion, the Crocodile Green Drop Support Campaign demonstrates a number of elements delineated in the central conceptual framing of the TPNP (Figure 1-12): the CGDSC, as a working group of the Crocodile Catchment Forum, is rooted in **stakeholder engagement**. From its start in January 2014, its method was **mutual learning** in a series of dialogues to develop understanding and social capital for collective action (Du Toit et al., 2013) in an approach where the aim was, as the diagram puts it, **“to work with stakeholders to enable mutual learning, shift power relations, improve decision making and improve mandate delivery”.**

Its practice, through seven dialogues and two working sessions, progressively involved all stakeholders – communities, municipalities, industry, catchment management agency, the Departments of Water and Sanitation (DWS) as well as Cooperative Governance and Traditional Affairs (COGTA), in both national and provincial offices, into a single, safe space for social learning, that was approached as a Community of Practice Munnik et al., 2015). The involvement of these **stakeholders** is central to TPNP, as can be seen on the left side of the diagram under “New Practice”.

Moreover, the CGDSC brought new ideas, approaches, concepts and practices to Adaptive IWRM. It was based on **social learning** in which practice and knowledge creation are closely related. The working group was seen representative of, and as a leading part of, a **CSES** from which new ideas and actions could emerge as a result of this approach. A core assumption was that such capacity for collective action, drawing on the inherent but often unrealised strength of a catchment management approach, in which **“catchment citizens”** work together in the public interest, and within a long-term sustainability framework, could lead to a shift in power and a resolution of tensions between political and ecological imperatives by combining the two.

Perhaps the most innovative approach was in the practice of **political ecology,** and the clear demonstration that improvement in WWTW management and effluent quality (Green Drop indicators) depends on political intervention, change and transformation, as much as in technical and infrastructural interventions.

CHAPTER 7: LEARNING FROM PRACTICE: LESSONS FROM THE CASE STUDIES

7.1 Introduction

The purpose of this final chapter is to draw together the evidence presented in previous chapters to demonstrate how the concepts of complexity, systems thinking, complex social-ecological systems, transdisciplinary, resilience, social learning, political ecology and strategic adaptive management – plus concepts that emerged during the research journey like critical realism, contribute practically to equitable and sustainable adaptive integrated water resource management.

This chapter starts by showing how the various discourses and practices in the "new paradigm", that we have termed Adaptive IWRM, are closely interlinked and mutually supportive:
While there is a central core of theories and methods, the paradigm used in this report is an open constellation that uses different combinations of transdisciplinary approaches according to what is needed, what fits, what team members or participants know.
In this research journey, a number of knowledges, concepts and practices were added as the team explored the case studies: citizens science, including political ecology and principled pragmatism.

The chapter then draws together the experiences and insights from different case studies and observations around each of these practices and discourses.

Finally, the chapter discusses some practical contributions of this new way of thinking and working have made to Adaptive IWRM, and argues for further results that could be seen to emerge in this research, but may need further research and practical support. It ends with policy and research recommendations.

7.2 Discourses and practices in the new paradigm are closely interlinked and mutually supportive

The experiences and insights of practical work in IWRM show clearly that Adaptive IWRM is much more about managing people and institutions who use water, and in the process impact on water, than about managing the water itself. It is from this basic fact that the need emerges to engage with the social side of the use and governance of water. However, water services provision and water resources management depend also on science and engineering knowledges to function. Practitioners therefore soon discover – if it is not already clear to them – that the social side can only be understood as closely linked to a material, biophysical and technical side, in other words, as part of complex social-ecological systems.

Maybe most fundamentally, researchers have discovered that a deepening understanding of complex social-ecological systems leads to an entirely different conception of what the work of the engaged researcher is, and how, as a result, the engaged researcher interacts with research participants, approaches institutions, and uses technical and bio-physical knowledge and data. This gives rise to new attitudes, such as humility (acknowledging the provisionality of everything we think we know) in the face of complexity (Palmer et al., 2015); and a recognition of the need for new skills: 1) processes of facilitation, and re-orientation in service of the co-creation of knowledge; 2) a practical approach that is as interested in changes or improvements in situations that are being researched, 3) recognition that the intellectual (understandings) and practical knowledges that are generated in this encounter interact towards transformation (Figure 1-6). Case study examples of this interaction include:

- Makana household water security (case study 1): The Water for Dignity (WfD) civil society organisation practiced Appreciative Inquiry reflection and learning, which changed the WfD

engagement practice with their water stakeholder community, such that WfD could be tracked through a transformative process into a community of practice (Chapter 4).
- Crocodile River water quality and resource protection (case study 2): The practise of regular stakeholder meetings with a high participatory commitment, interacted with an increased understanding of the water quality linked from upstream to downstream in the catchment, with the transformative outcome of the IUCMA recording better compliance with the Ecological Reserve (Chapter 5).
- The Green Drop Support Campaign (case study 3): The practices of the Green Drop Campaign engagement, and their increase in mutual understanding led to the transformative realisation that political engagement was required for technical interventions to be successful. This point of the intersection of practice and understanding transformation is an early stage of the transformative journey – it is the "preparing for change" stage of Figure 1-5. Further transformation requires political figures and Green Drop practitioners to move together into the stage of "presence" (Figure 1-5), in order to transform further into effective Green Drop practice (Chapter 6).

It can be said that experience and insight into CSESs can lead to profound changes in researchers, the nature of research and the practice of IWRM. Behind these changes, we can recognise the receding of the figure of the scientist/researcher as independent, objective, distanced from what she or he studies, and not implicated in the consequences of the research. It adds to, and nuances, the positivist and reductionist scientist, encouraging the emergence of a **scientist engaged in the challenges of the world: sustainability, justice and transformation**.

Again, this approach does not mean that the scientific approach – the search for evidence, for the best explanation, and openness to peer review and criticism – has disappeared. Quite the opposite. Researchers working in transdisciplinary teams are opened to critique and correction not only from colleagues in their home disciplines, but from researchers in other disciplines, as well as from participants. This is exactly the reason for the word "critical" in critical realism.

Robust natural science is required

The links between natural science and ecological sustainability are close. This science has authority and needs to be as robust as possible (as seen in the Crocodile River IWQM Process, Chapter 5).

Complex-social ecological systems (CSESs) are complex, but at the same time they are amenable to **systemic thinking**. This means that researchers can keep the advantages and power of modelling in Adaptive IWRM (and the Crocodile River IWQM experience shows both power and how to work with modelling), as long as they are seen as partial representations, in other words, as epistemology, a work of the mind, not the same as reality, but a best approximation for now), and as long as they respond to and are adapted for local conditions. When such science is understood (or at a minimum trusted) and accepted by stakeholders, it can be an important and clear motivation for using the science, managing with science.

The other example of modelling is demonstrated in Appendix 1e the handbook *"How to engage with the challenges facing Water and Sanitation Services (WSS) in small municipalities*". A big discovery is that complex problems emerge from complex social-ecological systems (CSES), because everything seems to be connected to everything else. In order to work with these challenges, researchers and practitioners need to come to grips with **complexity** thinking, which leads to many insights, including that they:

- comprise many interacting components.
- are characterised by non-linear processes,

- there are feedbacks between components and processes,
- small change can lead to large effects, and large efforts to small outcomes;
- context is a critical consideration in understanding any complex system and therefore narratives and records of history are important (Cilliers, 2002, 2001).

This means that the practice of natural science needs to be reformulated as complexity science.

The social science side of complex social-ecological systems

The social science side of CSES is in an active state of development. Some writers, e.g. Fabinyi et al. (2014), argue that the study of CSES is still marked by its functionalist origins, which is understandable because it grew mainly from natural science practice and management literature. Fabinyi et al. (2014) identify "three main biases":

1. the tendency to assume that within an SES, people's knowledge, values, and livelihoods are concerned primarily with the environment;
2. the tendency to aggregate or homogenise social complexity and thereby assume that people's interests, expectations, and experiences are the same; and
3. the value-laden use of resilience within the social arena.

On the first point, this research project has certainly recognised that the "social scale" (described in Chapter 4, for example) focuses attention on political and social-economic agendas that often are much more focused on livelihoods in which water use is not the centre of attention, and water resources receive even less attention. Both the Makana case study and the Crocodile River Green Drop Support Campaign worked across a divide where political factors not explicitly linked to water resources seemed to be a far more powerful influence on people's behaviour. This is a significant challenge for IWRM thinking which works in a linear, somewhat simplistic manner from a biophysical understanding to stakeholder engagement. Certainly, at present there is little theoretical underpinning of stakeholder engagement processes in relation to water, while, for example the Resource Directed Measures methods are strongly underpinned by biophysical theory. Hence the move to Adaptive IWRM.

It is difficult to do research in South Africa and not be struck by the segmentation of society, and its social complexity. As a result of a lively politics and public sphere, there are not many South African researchers who think that South Africans' experiences, expectations and interests are the same. However, in terms of social theory, some researchers still use over-simplified concepts which can lead to blind spots about the nature of agency, power and exclusion, and conflicting agendas within groups – and as a result, be misleading guide to action/intervention. Two of the methods – V-STEEP analysis and Cultural Historical Activity Theory, used as a framework for qualitative research and process work within systems – also work against a tendency of homogenising members of communities, be they geographical separations or different communities of interest.

However, the Adaptive IWRM approach does suggest that through processes of social trust building, building mutual understanding and growing communities of practice in the catchment management system, collective action can be brought about. **It is hardwired in the South African approach to [Adaptive] IWRM that transformation, based on collective action, is necessary** (Schreiner, 2013). Collective action also can lead to a shared ethics that is maintained through peer pressure in shared spaces such as catchment management forums. There should be a distinction made between the use of the word "normative" to indicate a Northern-centred imposition of the principles and even practices of IWRM, regardless of local context, as against "normative" that means ethical and is founded on the idea that catchment management needs to happen in the public interest (including the principles of equity and sustainability) and therefore has a clear ethical or normative

component (see Woodhouse and Muller, 2017, for an unqualified rejection of “normative IWRM” – in the sense of imposed framings).

The complexity of systems is closely related to their resilience – the ability of a system to bounce back, to absorb disturbance, to cope, but also the insight that systems are dynamic, respond (have attractors, can move from one state to another, be resilient rather than stable. The biophysical aspect of this is, that the diversity in systems supports their resilience (for example in the case of wetlands in the biodiversity and coal mining study). Socially, a resilience orientation brings out the need for the participation of people in management of natural resources, ecosystems, water resources, although resilience and transformation could be understood as opposites in a social science perspective.

Resilience thinking provides the grounding for strategic adaptive management (SAM), where a shared understanding is reached of what is required to move to a shared future in a catchment. SAM also uses the concept of “requisite simplicity” Stirzaker et al. (2010), that works well as part of principled pragmatism – finding the “sweet spot where we integrate the many aspects to be considered and find the **best possible, from the widest range of perspectives, taking into account priority values**. This concept is echoed in a demand by participants in the Forum of Forums that communication in catchment management forums should be based on “simplicity and sincerity”, and that the need for simplicity would force sincerity. Resilience analysis not only gives attention to feedback loops, but stresses history, how current systems, structures and conditions developed, often through using the technique of developing timelines (Biggs et al., 2012). Adding time depth to the analysis, allows patterns and form them, underlying dynamics and mechanisms to emerge.

This attention to history is also crucial to Cultural Historical Activity Theory (CHAT) analysis that also shares a systems orientation. In the TPNP case studies, where CHAT was explicitly used, the application led to expansive social learning on how to improve systems by paying attention to points of tension.

Together these insights, and the experience of using these approaches, make a convincing case for transdisciplinary **work**. Transdisciplinary work combines different disciplines – fields of knowledge, knowledge/practices – as well as different kinds of knowledges beyond academic or expert knowledge. It also means engaging with local knowledge, indigenous knowledge, as well as ways of understanding that are more spiritual. Transdisciplinary work needs to deal with life worlds, and practice cognitive justice. How researchers can approach these life worlds and complex problems in them, is beautifully shown in Max-Neef’s (2005) diagram, Figure 1-3. Another theory – or more correctly a philosophy of science – that supports and brings together disciplines into transdisciplinarity is critical realism.

New ways of working with CSES

The realisation and understanding of the ontological given of CSES also leads to **new ways of working** with CSES, such as a necessary slowness, humility, inclusiveness and necessitates working with stakeholders’ and their own knowledge. Cognitive justice is a crucial part of participation, as it allows the fullness of participants and stakeholders’ life worlds to enter into the processes of knowledge creation and decision making.

These insights lead to a new way of seeing participation as an opportunity for **social learning**, which encourages and supports the co-creation of new knowledge and practices. It also encourages a close and mutual enrichment between thinking and practice, discourse and doing. So, we are working with concepts that enrich practice, but are also tested and transformed in practice.

Finally, the nature of the issues encountered, also implies that we need draw in very specific fields of knowledge, that need to contribute the insights developed through the application of their core disciplines. For our purposes, water resource science (e.g. hydrology, water quality, aquatic ecology, ecosystem health) remains the **foundation** layer (the "What is" of the Max-Neef (2005) transdisciplinary model), the bio-physical basis. A biophysical understanding is entirely necessary to understand the interactions of people within catchments. Complexity makes modelling – as long as the provisionality of the model is acknowledged, a particularly useful approach. An example of this is the substantive potential of the WQSAM model to increase management capacity of CMAs, and the self-regulatory responses of industries (Retief, 2014). Thus, good natural science – understanding biophysical factors, indicators, causal mechanisms in ecosystem functioning remains crucial. However, **science in the Adaptive IWRM view is no longer an isolated, privileged activity, but an active participant in a dialogue with other knowledges and agendas.** Some experiences in this project showed that strategies for building alliances between different knowledges to tackle a focused problem, become necessary. An example is when during the research into bacterial contamination as a result of dysfunctional WWTW, it became clear that more expansive work on the impacts of rivers contaminated by dysfunctional WWTW, is needed from a health perspective, in a format that will draw the attention of decision makers at local government level. In this case a political-ecology perspective is required to catalyse political responses necessary for change.

7.3 Experiences and insights from different case studies and observations

Examples of implementation exhaustion related to current IWRM practice

The case studies indicate that practitioners and regulators have become exhausted through trying to apply all the idealised principles and approaches of IWRM in a context where there are obstacles not foreseen for practical Adaptive IWRM in South Africa, for example: 1) the practical and logistical difficulties of people's participation when they cannot afford transport to venues; 2) where democratic practices are new – for example where local governments can ignore WWTW problems even if they are reported at CMF meetings – because they don't see water resources protection as a priority, and their constituents do not see or express it as a priority (even though if affects them); and 3) where the establishment of CMAs has been repeatedly delayed, and functional CMAs demotivated by a lack of devolution of powers. (Note – another focus point for a political ecology approach.). The exhaustion is exacerbated by non-adaptive practices that do not facilitate and enable Adaptive IWRM.

Therefore, by expanding how we think about things, how we act as researchers, managers and citizens we can co-learn to practice practising Adaptive IWRM slowly, steadily and determinedly. We can revitalise IWRM practice into a practical reality, attainable through a clear, shared vision of the future, taking adaptive steps towards that future, using and respecting the widest range of knowledge. In this way, we can also revitalise the underlying ideals of transformation, equity, sustainability – social and environmental justice – that have been expressed at hoped-for outcomes of Adaptive IWRM in South Africa.

The TPNP has worked at a pioneering transition between old and new Adaptive IWRM practice and ideas. Disillusionment and exhaustion are indicators of a need for "Narratives of hope" (WRC Dialogue 2014, Appendix 4) – that will emerge with further and deeper Adaptive IWRM research.

The case studies provide examples where Adaptive IWRM practice is not supported by traditional approaches, where technical and engineering solutions alone are simply not enough. It is important that social issues, including governance but extending to an understanding of power issues as well

as challenges in interpersonal interaction, need to inform problem solving on cases like dysfunctional WWTW (Green Drop in Crocodile River catchment) and service delivery (Makana local municipality and Water for Dignity).

The Green Drop study was very clear that technical interventions, even training of staff, has not been successful in changing the performance of dysfunctional WWTW along the Crocodile River. The issue, as it was confirmed in participatory action research, lay in the first place in a mismatch between priorities for the local government and a range of water resource users. The local government/s had other priorities that were more important for them, but which had the mandate to operate WWTW; while role players including local citizens, regulators in the CMA and the national departments of water, local government and even the treasury, for whom clean water released into the environment is a priority; do not have the mandate or power to intervene. The heart of the problem is a power constellation, and this had to be understood and acted on through a social understanding, in fact an understanding of the political ecology. Secondary issues came out of an understanding of the historical, social context of the municipality and its relationship to privileged citizens, who would complain, and in many cases, alienate potential allies within local government who were all criticised as equally responsible and to blame.

In the Crocodile River, IWQM process new technology, **combined with socially mediated** interactions and knowledge building, breached scepticism and allowed the value of integrated water quality-quantity modelling to be appreciated.

7.4 Case studies that specifically draw on new discourses to develop new practices

Complex social-ecological system

All of the case studies start from the premise of a catchment as a complex social-ecological system (CSES) (Figure 1-1). Each of the case studies used this as the embossed guide to practice – actively inter-relating the social and biophysical. RESILIM-O researchers declared that there is a clear need for integration rivers/catchment systems to integrate across local, district, provincial and national boundaries management of catchments (for water yield, water quality/resource protection, for resilience). Researchers and practitioners need to see these as integrated systems, where elements affect each other. In some cases, integration, will take extra work, since institutional and natural (hydrological or catchment) systems do not coincide. There is a need to work within both realities.

The Crocodile Green Drop brought together municipalities with WWTW along the Crocodile River across municipal boundaries, while the Crocodile IWQM process drew a range of stakeholders into a more common and dynamic relationship with each other, and with water quality and quantity.
Systems have feedbacks, and systems analysis can consciously work with these feedbacks. For example, reducing vulnerability (to climate change) depends on water resources protection. In Makana, for example (following research in Sunday's River, where there was extensive use of systemic analysis, e.g. identifying actors and processes, and identifying feedback loops in schematics/diagrams that are readable to all participants) systemic connections and effects can be clearly illustrated by this method. These feedback loops are also used extensively in AWARD's projects, including RESILIM-O.

Scale

A specific aspect of complexity is the influence of scale on processes and outcomes. Hydrological scale has been prominent in these studies, as it is the basis in IWRM, of monitoring and scientific model building. Catchment Management Strategy information is organised according to catchments and divided up into smaller catchments. This gives a coherence to the scientific information and

enables citizens to imagine rivers and other water resources as a system (for example through the use of maps of the catchment, and regular CMF meetings, participants develop a container for scientific information, such as water quality monitoring information, as could be seen clearly in the Crocodile River IWQM process as well as the Green Drop).

Institutional scale – with its issues of powers, responsibilities, political systems, etc. does not match hydrological boundaries, but does also exhibit scale effects (e.g. a provincial government can intervene when a local government fails in its duties – although that can be affected by other political dynamics which may not be related to services and not be easy to see, explain and engage with).

Relational scale – has highlighted the dynamics of interpersonal through to institutional relationships. At the individual level, the individual is "internally stratified", there is an emotional, psychological, ethical, etc. life within each of us, closely connected to our biography, but also shaped by individual imprints of what happened to us, our sense of self in society, our values, our symbolic capital (Bourdieu, 1992), language skills, knowledge of science and policy, and sense of power from networks and connections. All of these determine how we feel, see and act in the world and with others.

This broad sense of self determines, for example, how people respond in face-to-face interactions (which is a scale a community of practice setting, e.g. in a catchment working group (Green Drop working group, e.g. racial issues, gender issues, facilitation style) – directly linked to the first level of institutions, e.g. forums, local government.

But local government goes beyond the face-to-face scale and starts the (alienating) process of social structures and systems (which are agents acting through rule-bound individuals). Many social structures (but perhaps not the family) are for the individual in some ways "too big and complex to take in and understand" without specialised study, like a municipality [the notion of specialised study is important] or "vastly too big" like national political system and dynamics, global production and financial systems (the impact of sugar production and market conditions globally, e.g. in Brazil). In the Crocodile IWQM process, researchers learnt that the positions of industry representatives could be influenced by dynamics internal to their companies, for example budget flows and orientation towards sustainability investments, and corporate take-overs and buy-outs.

The components of the TPNP project worked with a number of different ideas of scale, both of nested ecosystems, and of social systems and institutions (especially government units) moving from local to provincial to national scale. A deep engagement with a comparative scale analysis of the TPNP case studies and other studies from the literature would a fruitful direction of research – and understanding the complexity of scale effects will assist in recognising the likely effectiveness of interventions.

Critical realism

Critical realism, an underpinning, foundational philosophy of natural and social science together, is sensitive to a "stratified" or "layered" world, in which emergence plays an important role (Figure 6-1). This is both in the sense that more complex phenomena emerge from simpler ones (e.g. life from chemistry or language from speech-able anatomy) but cannot be reduced to them, and in the sense of new phenomena "emerging". Emerging phenomena cannot be anticipated (they are surprises) but can be understood in the light of the dynamics that give rise to them. **Working with complexity in research, researchers can be open and attentive to the phenomenon of emergence** – for example, the Green Drop project emerged because it was a priority issue for Crocodile River

industries who recognised that they were individually and collectively vulnerable to WWTW effluent; and Green Drop was also take on by the TPNP team as an inherently integrated practical response to the serious issues of eutrophication and microbial pollution. (An example of inherent integration more familiar to natural scientists, is bio-monitoring – where the presence, absence, and abundance of particular organisms reflects their integrated responses to stressors that include water quality, flow and habitat change (Graham and Dickens, 2002.)

Critical realism also pays attention to interaction with nature, an aspect that is often neglected in social research (Bhaskar, 2010; Norrie, 2010). The Anthropocene (Lewis and Maslin, 2015) is characterised as a time when humanity, as a single species, has an identifiable influence on all the components of the planet. People transform the natural world in so many ways, including extracting materials, returning waste; creating new and more fertile soil through permaculture, or reducing the fertility of the soil through inadequate rehabilitation after mining (Munnik et al. in press).

Transdisciplinarity

Complex social-ecological systems need to be approached in a transdisciplinary way (Swilling and Annecke, 2012). "The essence of the RESILIM-Olifants Programme is that systemic, multidisciplinary approaches need to be prioritised so that practical interventions can be designed out of sound and comprehensive scientific evidence but at the same time draw on a variety of discourses notably climate change, ecosystems services linked to livelihood security, socio-ecological systems and their drivers as well as institutional functioning and governance." (http://www.award.org.za/project/resilience-in-the-limpopo-basin)

Participants in the Forum of Forums declared that they expect – and demand from – government officials that they should use their knowledge to explain clearly what the causes of pollution are, what the consequences are, and what will happen to polluters. They see knowledge support from officials as part of the officials' job (Munnik et al., 2017).

Expert and local knowledges very often confirm and support each other. In the project dealing with internalisation of biodiversity costs into mining decisions making (Munnik et al., in press), the specialised discipline of hydropedology confirmed local knowledge of hydro-connectivity. There was an experience-in-practice recognition of the connections between rivers, wetlands and springs, determined by the local layered sandstone geology. Mining operations puncture the impermeable layers, and then rehabilitation methods are employed that do not rebuild layered impermeability and rivers and wetlands are slowly starved of replenishing water. The role of expert disciplines working together with local knowledge can work in a complementary way (an approach to citizen science).

RESILIM-O used a resilience analysis that combines method from SAM (V-STEEP), as well as a transdisciplinary, participatory review process by specialists including social scientists, ecologists, climate change specialists, educationalists, agriculturalists, and medical practitioners; the majority of whom had worked in, or were familiar with, the local catchment area. This process of specialist involvement was designed to develop and test systems representations of the catchment, to discuss and evaluate thresholds and state changes, and to use these to develop and debate scenarios. The specialists were also asked to reflect on whether the approach generated a systemic understanding of resilience in such catchments and could meaningfully enhance management decisions and practice amongst a variety of stakeholders and levels. The key concerns of this project include the opinions of the participants. We see again the functioning of expertise, of all types of disciplines, to deepen and validate citizens' knowledge and participation – not to ignore or override them.

Application of Cultural Historical Activity Theory (CHAT)

It is not always easy to translate philosophical intentions for transdisciplinary work into a field methodology that enables the gathering of data, as well as qualitative insights into the dynamics of a system, into a shared methodology. The majority of TPNP case- and observed studies discovered the usefulness of CHAT as a tool that could do exactly that. The recognition of human "activity systems", as guided by CHAT, allowed transdisciplinary researchers in the component studies to create a shared framework for designing questions for interviews, as well as for subsequent analysis and discussion by research participants.

Cultural Historical Activity Theory relates consciousness and activity, revealing systemic connections and tensions. CHAT is a good method to support systemic analysis, as was shown in the sugar industry case study where activity systems of the overall sugar production, could be differentiated from sugar out-growers who had been drawn into the sugar system as a result of land reform (Sahula, 2014).

The CHAT field research approach (see explanation in Chapter 5) sees the individual agent interacting directly with nature (transforming nature to support human life), with tools to reach an objective (material and conceptual – this research focuses on conceptual tools), working with others (teams inside the organisation as well as with peers or in some form of a community of practice), according to rules that are both formal and informal. This shows why CHAT is so applicable to Adaptive IWRM.

Cultural Historical Activity Theory also bridges the space between the individual's agency and social structures (relational scales), perhaps the most important and puzzling question in social sciences. In South Africa, the opportunity is to ask how change happens, how transformation comes about, and how that strengthens the overall system and its resources. CHAT is a dynamic system that can lead to expansive learning. In the Crocodile integrated water quality management strategy (IWQMS), CHAT research was mirrored back to participants to start a process of reflection on tension points in the system, which sped up discussions of exactly those tensions.

The requirement in CHAT for paying attention to how the present developed from the past, was an active and rewarding principle in the cases. This may be because South Africa's history is still so strongly influential in the present: for example, 1) in Makana, the neglect of services to poorer section of Grahamstown; 2) in the Crocodile IWQM process the historically strong position of the Irrigation Boards; and 3) in the Crocodile Green Drop a historical backlog of services to councillor's priority constituents that pushed WWTW issues into a lower if not invisible priority.

Social learning

Social learning played a crucial role in all of the projects. In some it was explicit, such as in Makana, where a learning approach was explicitly articulated and formulated by the Water for Dignity activists. The RESILIM-O programme approach investigated learning within complex systems and pointed out the importance of diversity coupled with engagement in which there is free flow of information and mutual learning – thus laying down an approach which builds social trust, allows and encourages all voices to speak, and to listen, consonant with the principle of cognitive justice and dialogue, which were also explored in the Forum of Forums research.

Skills in and practice in communities of practice, can be made explicit, so that social learning in these forums is encouraged. The concept of a community of practice proved very interesting for researchers in the Green Drop and Makana case studies, as a way of describing the emergence of social trust between participants, and the process of building a shared understanding of the catchment, its biophysical but also its vital social, economic, political and technological attributes, and a sense of a desired shared future. To capture these processes – and consciously work with them – a modified form of the community of practice arose (Weaver et al., 2017; Munnik and Barnes, 2016).

Political ecology

Political ecology emerged as a framing approach in the Crocodile Green Drop case study. It was also used, to some extent, in analysing power relationships in the RESILIM-O project. Respondents to a list of questions sent by the TPNP researchers project to RESILIM-O staff to capture learning, argued that political ecology, with its recognition of the importance of power and its effects, including how resources are allocated, had become an inherent way of looking at the world in terms of Adaptive IWRM. The Makana study revealed a well-developed politics of knowledge in the practice of civil society.

Fields of knowledge themselves get transformed through exposure to practice, and political ecology is an interesting example. Originally emanating from critical theory, it is a social science approach (Frankfurt School) that critiques present reality through the lens of power against an idea of how it should or could be (which fits in well with the transformation dynamic inherent in SA Adaptive IWRM and constitution, as well as political history, aimed at equality and sustainability, social and environmental justice). In its encounter, e.g. with local government politics of WWTW it was (1) able to explain the power dynamics and (2) challenged to take into account the logic of stakeholder processes and the need to act in specific ways (e.g. work with municipality rather than just heap critique and criticism on them), to understand dynamics, in order to shift a balance of forces. This is an innovation in the field of political ecology. Another lesson political ecology could learn from CSES is to take the ecology part more seriously, as in the Green Drop study again, much time was spent to understand eco-systems as well as the engineering of water infrastructure.

It remains true that the South African transformation project, and Adaptive IWRM as part of that, needs to deal with power issues, there is no way around it. How did this project deal with power issues?

1. Through the community of practice within social learning: spelling out issues, building social trust, respecting view-points and persons, reducing conflict and aggression
2. Understand political dynamics, for example: 1) rights and obligations: who has what duty and what power; 2) what are the interests and motivators of politicians (relationship with their constituencies), e.g. at local level people affected by river water quality may not know or may not care (Green Drop) so bringing out that knowledge enriches the political system and

enables (or motivates) the local government political system as a whole to deal with the issue and 3) recognise historical power imbalance consequences that pervade the present.

3. Building capacity of citizens to understand and engage **is** building capacity for sustainability, over longer term as well as for a well-developed participatory democracy (Buhlungu, 2007 and Booysen, 2008).

Citizen science

This concept was first added to the TPNP by the Makana case study, in its engagement with a local civil society group – Water for Dignity – part of a national social movement, the Khulumani Support Group. Water for Dignity gave the citizen science concept a broad definition. Yes, they said, understanding water science and engineering, what the infrastructure system is, what water quality is, and how to test it is important, but it is also important to understand the law, what policy is, the rights and obligations around the provision of water, and the role of the local municipality within it. **Citizen science was understood as empowering people as citizens.**

Strategic Adaptive Management: Building social trust and participation

Strategic Adaptive Management had already been established as an approach to IWRM and NRM in parts of the Kruger Park (Cilliers et al., 2013) – whose officials were important stakeholders in the Crocodile IWQM process and Green Drop – but also historical in the development of new paradigm thinking (Rogers et al., 2000, 2013). SAM had also been the foundation of the approach for the IUCMA catchment management strategy development (Rogers and Luton, 2011). The SAM process has many practical advantages: it is holistic an inclusive, asking questions during stakeholder processes that elicit consideration for ALL participants of values involved in the social, technological, economic, environmental and political (STEEP) domains. By treating these questions as necessary, participants are encouraged to delve into these sometimes-difficult questions.

Strategic Adaptive Management was central to the approach of AWARD in RESILIM O. In terms of stakeholder relations in for example catchment forms, SAM was crucial for moving from a "stuckness" in conflicts, to what path is necessary to achieve a desired future. When focusing on a desired future, stakeholders move past current conflicts and into a shared future vision. SAM takes participants into an imagined shared future – so that paths to that shared future can be envisaged. The notion of a shared future encouraged trust: "**the best way to get what you need is to help others get what they need**" (Chapter 2)**.**

All the case studies, but perhaps particularly Green Drop and Makana required trust building, so as to shift from hostile criticism to more understanding, in relationship with local governments. Appreciative Inquiry (Cooperrider, 1995) was used in Makana to achieve this. However, in Makana, while this helped, it did not ultimately change the inability or unwillingness of local municipality to respond, to the point where Water for dignity was concerned that further direct engagement with local government would undermine their credibility in the community (because there were no discernible outcomes from the engagement with the municipality). In the Crocodile Green Drop, by contrast, the working group first also followed the engagement and understanding rather than criticism route and built up very good relationships and understanding. But the situation did not change. The Green Drop Campaign reached out to what was understood to be more influential national departments, who had mandates and programmes to intervene – DWS, COGTA, Treasury… and discovered a reluctance to intervene. Indeed, influence of politics is under-estimated.

Maybe building of understanding, trust, networking, etc. is a first step and behavioural changes take longer than we expect?

7.5 Practical contributions and the emergence of Adaptive IWRM

While some outcomes of this new way of working may take long to bear fruit, there were a number of important instances in which it did have positive, practical outcomes within 5 years of initiating the project:

- In the IUCMA: 1) as a result of work done on integrating water quantity and quality, the CROC OC created new rules integrating water quality and quantity; 2) WQSAM was installed and is ready to be implemented 3) implementation training is underway; 4) the understanding built up during the IQWM process however improved water users' compliance with water quality requirements, (IUCMA pers. comm. Brian Jackson). This shows that participation in the multi-stakeholder IWQM process had an influence of individual environmental manger behaviour.
- In the Green Drop Campaign: 1) working in the TPNP way resulted in attitudes between people changing drastically; 2) relationships and attitudes between opponents became much friendlier, in fact co-operative; there was a clear exchange of knowledge, in the Green Drop Campaign. This was caused by, and in turn strengthened, the exchange of information about dysfunctional WWTW and their causes and helped the working group in their seven meetings to build up a shared understanding of what the problems were.
- In Makana, a different attitude from university and other critics towards local government emerged, as a result of encounters between individuals from very different backgrounds and perspectives in the project. There was also new behaviour from industry managers as they had started talking to each other and other stakeholders in Crocodile River.
- In the Green Drop Campaign, there was direct positive change in at least one municipality (Nkomazi). One industry participating in the campaign decided to donate land to Nkomazi municipality to allow it to upgrade an inadequate WWTW. The industry representative and the local government manager had discovered during a working group meeting that both could benefit from working together. Other participants were highly encouraging and appreciative, which lent support to the initiative and made sure it would not go unrecognised.
- A major and potentially long-lasting influence from the TPNP came about as a result of networking and involving decision makers in TPNP sharing workshops. The research leader, Prof Palmer, was invited to host a workshop to develop the Terms of Reference for a new national Integrated Water Quality Management Policy and Strategy, a national policy (DWS 2017). The documents maybe the first formal policy documents in South Africa to explicitly acknowledge complexity and social ecological systems.

7.6 Systems-based Adaptive Management

Enables an adaptive response to changing circumstances and achievements based on effective on-going monitoring and evaluation

The managing of a **complex social-ecological** system requires an adaptive management approach. Successful implementation of this strategy will be based on the ability of the state, particularly at the catchment level, to implement a deliberate, systems-based, adaptive management approach. This approach must be inclusive, **bringing together state, private sector and civil society players on a regular basis to review and adapt plans and actions.**

Adaptive management enables the refinement of strategies and plans and the refocusing of financial and human resource allocation once certain actions have been implemented or certain milestones achieved, **when the expected results from implemented actions are not achieved or when new information becomes available that informs improved approaches.**

Adaptive management will be based on the premise that actions should be appropriate to solving particular problems within their particular local contexts through:

- creating a decision-making environment that encourages **experimentation and courageous decisions;**
- enabling active, on-going, **experiential and experimental learning amongst all stakeholders** and an iterative feedback of lessons learned into the development of new solutions; and
- engaging a wide range of stakeholders to ensure that the necessary buy-in, partnerships and suite of actions are developed so that the programme is sustainable, legitimate, relevant and implementable.

This approach needs to be supported by an effective monitoring and evaluation system, particularly at the **catchment level where the most substantial implementation of the strategy will take place.** This system needs to be structured around a broader programmatic monitoring and evaluation that would include a reflection of impact within water resources themselves. Since this strategy is an integral part of the NWRS this will need to be aligned with approaches to monitor, report and evaluate progress for the NWRS.

It is essential that these systems become more efficient to enable more robust decision making and more effective responses to catchment level requirements.
In addition, it is critical that effective M&E in other relevant organs of state, including departments of agriculture, environment, minerals, health, and local government support the **adaptive management approach.**

Systems-based adaptive management is an imperative for managing water quality, supported by information and knowledge networks that provide the evidence base for decision-making." DWS 2017

CHAPTER 8: SUMMARY CONCLUSIONS AND RECOMMENDATIONS FOR POLICY AND RESEARCH

8.1 Adopt the term Adaptive IWRM

After a long process of wrestling with "new paradigm" and "practising a new paradigm" we recommend the adoption of the term Adaptive IWRM, with a definition based on the globally accepted Global Water Partnership 2000 definition (Agarwal et al., 2000).

Adaptive IWRM:
***Using adaptive, systemic, processes and an understanding of complex social-ecological systems* to coordinate conservation, manage and develop water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems.**

8.2 Adding value: the benefits of understanding the implications of Adaptive IWRM

The Towards Practising a New Paradigm (TPNP) provides **magnifying lenses, insights, and "narratives of hope"** through clear indicators that a solid, sustained investment in Adaptive IWRM is worthwhile.

Three TPNP outcomes provide enough evidence for the Water Research Commission (WRC) to select Adaptive IWRM and the TPNP approach as an immediate priority, and strongly supported research thrust, with specific projects:

- **Water resource protection** was moved forward by adding value to **Integrated Water Quality Management (IWQM)**: This value is expressed by the term **Adaptive IWRM,** signifying a radical change in the manner of IWRM. The TPNP provided clear evidence that sustained, positive stakeholder engagement and the application of new technology CAN be rolled out by all Catchment Management Agencies (CMAs).

The TPNP shaped **national policy and strategy**: There IS a sustained thread of IWQM in complex social-ecological systems in the new IWQM policy and strategy.

The next research question is:
How do we use Strategic Adaptive Management to catalyse effective IWQM in ALL the CMAs?

- **Green Drop** is the most likely pathway to improvements in eutrophication and microbial pollution. Wastewater treatment works (WWTW) effectiveness is primarily a **political issue.** Invest in **political ecology research** within Adaptive IWRM. This in a distinct advance from the current sole focus on technical solutions.

The next research question is:
"What is the political ecology of the Green Drop and how to identify windows of opportunity in a fractured governance landscape?"

- **Household water security** is a key to reduced public protest. Insights into household water security followed the Sundays River research (Hamer et al., submitted) and gathered household level data, engaged local citizen researchers, and responded to

local issues at the local scale. In Makana this showed that for people who have piped water but experience interruption, and in-house tanks of ±250 l capacity is there preferred option. There is an opportunity to use public-private partnerships to stimulate the supply of in-house tanks to such households.

The next research question is:
Use TPNP evidence of the importance of social networks to address the question: How can household water storage be supported to complement piped water delivery is urban and rural areas?

8.3 Systemic, adaptive research planning and management

The WRC's global reputation is founded on the practical application of research to the benefit of people. The TPNP provides the following recommendation at a critical moment in the Anthropocene:

- Recognise the power and necessity of **integration** to address water issues in both service delivery and resource management.

- Recognise and reaffirm that water services (and the national economy) are **dependent** on the hydrological cycle and water resource protection

- Foster **transdisciplinary** research – which **includes** strong, well developed disciplinary research and judicious inter- and multi-disciplinary research

    - Plan systemic adaptive research **programmes** (for example, explicitly LINK the "light houses") and manage **peer review** systemically (for example, make greater use of the global standards of peer-reviewed literature for **scholarly merit**, and mechanisms like programmatic colloquia for peer reviewed **impacts** on policy and practice.

    - Recognise key "windows of opportunity" (*sensu* Olsson et al., 2004).

For example: a **new Water Act**, combining Water Resources and Water Services, is being drafted. Liaise with Department of Water and Sanitation (DWS) to ensure a **systemic approach** where integration and synthesis are used. (There are specialist practitioners in these skills who have been associated with the WRC.) Unfortunately, the project team was not included in the legal revision process despite regular updates of the Chief Directorate Policy and Strategy.

    - Recognise that students and **young water professionals** are hungry for the Adaptive IWRM approach.

    - Identify sets of linked WRC projects, add "adaptive catalyst" funds, and assign a small Adaptive IWRM specialist team to work with project leaders to increase the likelihood of added values from interactions and feedbacks.

    - Promote and invest in 'meta-research' that works across projects.

8.4 To ensure radical progress in addressing three TPNP themes

Green Drop

- Recognise that the **extensive and entrenched** problems of microbial pollution and eutrophication, are unlikely to be shifted by additional scientific research into microbial, algal and nutrient processes.

- Recognise that in South Africa, the DWS **Green Drop Programme** is the most likely intervention to mitigate the effects of microbial pollution, by improving wastewater treatment works (WWTW) management.

- Recognise that WWTW management and effective Green Drop campaigns require, in order of priority:
    - catalytic **political ecology** research
    - an understanding of the **local government "wicked problem"** (*sensu* Clifford-Holmes et al., 2016).
    - technical expertise. Write a policy brief on ring-fencing local government WWT up-grades and maintenance funds.

Water Resource Protection

- support an Adaptive IWRM co-learning process with DWS
- use the Ntabelanga-Laleni dams project to build a deep catchment management partnership with the Department of Environmental Affairs.

Household water security

- Recognise the importance of, and interactions between, **primary and secondary water scarcity** as drivers of household water security.
- Support research that contributes to integrated governance approaches to household water security involving DWS, COGTA and the local municipality/metro both 1) city and 2) small town (B3) municipality scales.

8.5 Catchment governance a central role for Catchment Management Forums (CMFs)

- An unplanned outcome of the TPNP is clear evidence of the **value of CMFs** in implementing practical **participatory** water governance. Catchment Management Forums offer the best process and structure to ensure investment in engaged complexity-based research does not disappear with the project but is left in the capability developed in local people to advocate for and practice sustainable Adaptive IWRM.

FINAL NOTE: This is "tortoise work".

The literature on engaged research as a catalyst in adaptive complex social-ecological systems is clear that:

- this research praxis requires "a certain slowness" (Cilliers, 2000, 2001)
- outcomes and responses also emerge slowly and through time
- pathways of uptake and change are unpredictable.

HOWEVER:

This approach seems to offer the most promising pathway of substantive progress in engaging with the most difficult social-ecological problems facing humanity.

From the TPNP we suggest: long term, substantive research investment in at least two CMAs to support ongoing and developmental praxis IN Adaptive IWRM. It would be worthwhile to invest in at least a decade-long programme.

POSTSCRIPT:

A comment from Reference Group member Dr Chris Dickens,
Head of Regional Office (South Africa) at the International Water Management Institute (IWMI):

"Agreed. Maybe it is worth addressing some deeper issues like how do you sustain progress and momentum in the face of such required slow pace?

I see this [slowness] a lot with transboundary RBO [River Basin Organisation] creation. It takes forever and there is often some randomness involved in a first champion pushing things for a few years, then nothing for a few years, then a new champion coming in to drive the process trying to pick up pre-gap-period. I can't help but wonder if there may be ways to orient this toward a more cohesive process."

8.6 Impact Table

Year of Graduation	Student Name	Degree	Race	Gender
2015	Ntombekhaya Mgaba	Honours	Black	Female
2015	Asiphe Sahula	Masters	Black	Female
2015	Hugo Retief	Masters	White	Male
2015	Jai Clifford-Holmes	PhD	White	Male
2015	Helen Fox	PhD	White	Female
2016	Chloe Karstadt	Honours	White	Female
2016	Martyn De Jong	Honours	White	Male
2017	Athina Copteros	PhD	White	Female
Currently registered				
	Sinako Mtakati	Honours	Black	Female
	Caleena De Carvallos	Honours	White	Female
	Tia Keighley	Masters	White	Female
	Gareth Thomson	Masters	White	Male
	Mateboho Rahletla	Masters	Black	Female
	Qawekazi Mkatali	Masters	Black	Female
	Margaret Wolff	Masters	White	Female
	Notiswa Libala	PhD	Black	Female
	Matthew Weaver	PhD	White	Male
Date	**Activity – Workshop/Dialogues/Meetings**	**Aim**	**Participants/Influence**	**Outcome**
28 March 2014	**Appreciative Inquiry (AI) workshop I, for Makana case study team** Appreciative enquiry in an inclusive, creative methodology that invites active participation, learning and commitment to action. The annual AI workshops were identified as catalytic points in the Water for Dignity learning journey of civil society water activism.	Team building for collective action: *Introduction to Appreciative Inquiry theory and approach *Develop an understanding of participants learning of the AI process and its application in the Makana Case Study *Elicit personal commitments inspired from the workshop that to be taken forward and followed up upon at subsequent AI sessions	Water for Dignity civil society participant researchers and water activists; TPNP researchers and post-graduate students, Facilitator: Dr Sue Southwood, Centre for Higher Education and Research Learning, Rhodes University.	Participants recorded learning, an understanding of an increase in individual and group agency; clear immediate goals for action in the Makana Case study. Evidence of the importance of a central reflexive process, as illustrated for the whole TPNP in the “Fishbone” diagram, Figure 1-1.

4-6 Aug 2014	**Mirroring Workshop – Grahamstown** The term Mirroring comes from the writing on expansive learning by Engeström and colleagues (2000, 2001). Mirroring is a process of sharing knowledge, reflecting back the shared knowledge, and using AI iteration to co-develop knowledge throughout the project. In this activity, the TPNP team identified other research teams across South Africa that were using at least some of the core Adaptive IWRM concepts and engaged in a co-learning process that generated the core principles for Adaptive IWRM that guided the TPNP, especially case-study practice.	The aim of the work-session was to share knowledge, and then to mirror to each other what we have experienced and learned in listening to each other. Then we will join in a process of expanding our understanding of the range of thinking and approaches that can take Adaptive IWRM forward practically, in ways that explicitly include the integration	Teams from: UCT – Berg River project; Umgeni River – early members of UEIP WESSA, INR, and Ground Truth; CSIR Governance research group, TPNP research team. Facilitator: Prof Tally Palmer	A co-developed set of core principles for Adaptive IWRM. Publication in preparation.
13 Nov 2014	**WRC Water Dialogue – 13th November 2014** WRC Water Dialogues bring a wide range of water practitioners and researcher together to engage about cutting edge issues. In this dialogue, all the mirroring workshop teams presented dual perspectives of the projects. Each team had a researcher and a participatory partner speaking. The TPNP team presented learnings in municipalities. TPNP co-funder, Unilever South Africa, presented an industry	In this Water Currents Policy Dialogue, we: *Shared the stories that show-case a hopeful way forward, at different scales of Adaptive IWRM (Local, Provincial, National and Transboundary); *Discussed how innovative Adaptive IWRM ideas and practices enable transformation “towards a new paradigm"; surfacing questions about barriers and pathways; and *Encouraged active commitment to	See attached registration registers (Appendix 3) Including representatives from DWS, Aurecon, UJ, Golder Associates, Sundays River Valley Municipality, IUCMA, CSIR, COGTA, AWARD, UKZN, Unilever, Bergrivier Municipality, WRC	A “Water dialogue brochure, entitled Narratives of Hope” was produced and circulated to all Dialogue participants (Appendix 4); Active demonstration in the water sector of “engaged participatory research, based on an understanding of catchments as complex adaptive systems, and using transdisciplinary approaches.

	perspective on how corporate South Africa could participate in water stewardship, and contribute to IWRM. This was misunderstood by the WRC as a corporate sales pitch, a conflict that highlighted the real gaps between research and practice. This gap was identified and a new level of understanding was brokered.	transformed practice by participants."		
4-5 Feb 2015	**WRC WAT-Indaba:** Invited participants (Appendix 3), Requested by DWS Water Quality Planning Director, Mr Pieter Viljoen. Water Quality Specialist input to guide the TOR for the development of the National Integrated Water Quality Management Policy and Strategy. Organised and co-funded in collaboration with AWARD (the Association for Water and Rural Development) and the WRC.	The DWS requested assistance in bringing together water quality specialists around the innovative thinking and practice of Adaptive IWRM.	41 delegates, and broad national representation of water quality specialists. See attached attendance registers (Appendix 3) Facilitators: Prof Tally Palmer and Dr Victor Munnik.	A Dialogue workshop report, with recommendations, was provided to DWS, Planning, Water Quality. The resulting Terms of Reference for drafting the policy and strategy was based on the outcomes of the Dialogue. The final **National IWQM Policy and Strategy** explicitly include the concept of catchments a complex social-ecological systems and the approach of Adaptive IWRM
23 Feb 2015	**Appreciative Inquiry (AI) workshop II, for Makana case study team** Appreciative Inquiry in an inclusive, creative methodology that invites active participation, learning and commitment to action. The annual AI workshops were identified as catalytic points in the Water for Dignity learning journey of civil society water activism.	This workshop aimed to build on the outcomes of the 2014 AI work-session, and to use AI to envision and enable positive actions in 2015.	"Water for Dignity" civil society participant researchers and water activists; TPNP researchers and post-graduate students, Khulumani Support Group. Facilitator: Prof Tally Palmer, TPNP	The AI workshop outcomes were described by the Water for Dignity team as of central importance to their learning and practice. Their activities were guided by the agreed AI workshop agreements.

4-5 March 2015	**TPNP strategic research and practice approach workshop for DEA Senior Management:** *Creating integrated research and action plans for DEA NRM initiatives – working towards research and rehabilitation activities that catalyse transformation towards environmental and social justice.* The Ntabelanga-Laleni dam development project of the DWS, in the Tsitsa River Catchment, provided a landmark opportunity for collaboration. The DWS provided funds to DEA for landscape restoration and supporting research to advance natural resource management (including IWRM) so as to optimise the storage capacity of the dams. This was followed by two more Adaptive IWRM//NRM workshops for 1) DEA NRM managers and 2) operational practitioners.	Aim: to initiate an understanding of the value of the Adaptive IWRM approach across DEA and DWS. The TPNP motivated complex social-ecological systems and strategic adaptive management approach to DEA, and as a result conducted three workshop/presentation events for DEA at different management levels.	The two-day workshop was attended by more than 40 delegates, including a Deputy Director General, Chief Directors, Directors and additional staff of the DEA. The subsequent events deepened and extended Adaptive IWRM/NRM practice in the DEA. See attached attendance registers (Appendix 3)	Workshop materials and notes were provided for all delegates. The Adaptive IWRM suite of concepts was accepted by DEA and went on to be the frame for all the research in the Tsitsa River catchment, and the CSES approach was later adopted formally as the basis for all DEA Natural Resource Management activities.
13 March 2015	Makana Water and Sanitation Indaba, TPNP Makana Case Study team members participated actively in the Indaba, and the subsequent work streams.	In Indaba aimed to provide an overview of the challenges the municipality was facing regarding water resource management and supply in the Makana Municipality, as well as detailing the response from Provincial and National Government departments.	Stakeholder in the Makana Municipality were exposed to Adaptive IWRM thinking and practice.	TPNL researchers attended water work-stream meetings and began to make trusted connections within the municipality
28 July 2015	**Appreciative Inquiry (AI) workshop III, for Makana case study team**	Aimed to: *Explore alternative funding opportunities, e.g. Rotary funding	“Water for Dignity” civil society participant researchers and water activists; TPNP researchers	Case study work plan including activities, people responsible and time frames

		*Discuss project involving Unilever, emergency water and the low rinse washing powder *Develop effective mechanisms to improve sustainability and accountability of Water for Dignity work *Discuss and clearly define rules/principles for working for Water for Dignity	and post-graduate students, Khulumani Support Group. Facilitator: Prof Tally Palmer, TPNP	
10 Sept 2015	**Feedback workshop in the Sundays River Valley Municipality (SRVM)**: learning for Makana Case study The SRVM research provided the primary basis for Adaptive IWRM work in municipalities, and specifically in the Makana Municipality case study.	The aim was to "mirror" results back to the communities who contributed to the research. This is one aspect of ethical Adaptive IWRM research,	Presentations were made by post graduate students and supervisors, the Dialogue Brochure was distributed, and a summary isiXhosa document was distributed.	Feedback to contributing communities.
12-13 October 2015	WRC "Forum of Forums" workshop, organised by TPNP team member Dr Victor Munnik. TPNP team members participated actively and funded the travel of key Eastern Cape delegates.	To communicate and exchange knowledge on the contribution CMFs can make as the main DWS participatory water governance mechanism.	National DWS, TPNP and civil society. See attached attendance registers (Appendix 3)	TPNP research began to focus more on CMFs as the main participatory water governance mechanism. The East Cape Water Caucus delegates supported by TPNP became core participants in the last phase of the Makana Case study.
21 Jan 2016 4 Feb 2016	**CMF workshops** Mthatha (River catchments: Mthatha, Mzimvubu (near Matatiele), Tsitsa, Mzimvubu mouth (Port St John's))	The TPNP team facilitated workshops that introduced participants to the concept of catchments as CSES and engaged in a knowledge exchange and knowledge	The DWS proto-MT CMA identified participants and arranged for participation. Proto-CMA staff attend and participated. See attached	A record of the concerns and planned actions of participants living in the each of the selected river catchments.

11 Feb 2016 16 Feb 2016 19 Feb 2016	Alice (River catchments: Upper Tyume, Upper Kowie, Buffalo) Kirkwood, Lower Sundays River Valley (River catchments: Sundays) Patensie (River catchments: Gamtoos, Krom) Kareedouw (River catchments: Krom, Gourits) The TPNP research team contacted the emerging WMA7 proto-Mzimvubu to Tsitsikamma CMA. The Adaptive IWRM approach was explained, and we motivated to initiate work to establish CMFs in selected catchments of rivers that run in parallel along the WMA. Using the Forum of Forums results that CMF have a greater chance of sustainability if there is an anchor institution that will work support them, we recommended 5 CMF "starter" workshops. These were hosted and organised by DWS, with the time commitment of the TPNP team covered by the TPNP project. This CMF establishment work was linked in to the DEA Ntabelanga dam research – where a CMF was initiated in Maclear for the Tsitsa river Catchment. At same time, the DEA/DST funded a project in	building process with participants. Concepts relating to water policy, legislation, strategy, management and governance were introduced. Participants' interests, concerns and planned actions within their catchment area were recorded.	attendance registers (Appendix 3) Workshop/s facilitator: Prof Tally Palmer	After five CMF starter workshops, and after related CMF work in the Crocodile River case study, we produced the "How to establish and run a Catchment Management Forum" handbook

	participatory water governance in the Tsitsa River catchment.			
10-11 May 2016	**Post graduate Transdisciplinary (TD) research methods short course Rhodes University** Transdisciplinarity (TD) is a core Adaptive IWRM concept and practice. All TPNP students used a TD approach. The TPNP team were competitively awarded internal university research funding to develop and two-day short course on Transdisciplinary research It was envisaged that through the workshop, TD practice may develop as a common thread across innovative Postgraduate research practice at Rhodes University. Prof Tally Palmer established the RU TD research group in 2011, motivated by the growing need to conduct research that addresses the global challenges of complex, or "wicked" problems, that cannot be addressed by separated disciplinary approaches.	The main aim of the workshop was to introduce the concept of transdisciplinarity (TD) to Rhodes University Postgraduate students.	28 post-graduate students participated, from Faculties of Humanities, Science, Commerce, and Education and Psychology, Music, Chemistry, Biotechnology, Environmental Science, and Human Kinetics and Ergonomics Departments, Rhodes Business School, Institute for Water Research, Public Service Accountability Monitor. The course was presented by TPNP researchers, post-graduate students, and colleagues in the Department of Environmental Science. See attached attendance registers (Appendix 3)	Documented TD research course content. A group of post graduate students trained at an introductory level.
22 August 2016	**WRC Water Currents: Policy Series** **Towards Practising a New Paradigm for IWRM: URGENT ISSUES: 1) WWTW, Green Drop, microbial pollution and eutrophication, and 2) Household water security**	In this Water Currents Policy Dialogue,we aimed to : *share the complexity and systems approach; *engage with participants from a multi-stakeholder Green Drop Support	This focussed dialogue was attended mainly by DWS delegates, and by water sector practitioners that could take up the challenge of household water tanks for household water security.	Understanding of the link between effective Green Drop implementation and the control of microbial pollution and eutrophication was deepened in a group of water practitioners.

		Campaign and the DWS Green Drop programme; and *engage with researchers and pratitiones in exploring how to innovatively augment household water supply to increase reliabiltiy.	See attached attendance registers (Appendix 3)	
27 October 2016	**Upper Kowie River Water, Sanitation and Catchment Management Forum** In 2016 the DWS minister issued a directive to municipalities to establish Water and Sanitation forums. In the Upper Kowie Catchment this Water and Sanitation forum was combined with the CMF to form a Water, Sanitation and Catchment Management Forum.	To link participatory water governance across the catchment and municipalities in the establishment of a joint WS and CMF.	The Makana Municipality and DWS proto-MT CMA jointly commit to the Upper Kowie WS and CMF. See attached attendance registers (Appendix 3)	An agreed Terms of Reference for a combined WS and CMF was developed and implemented. The proto-CMA Acting CEO, and lead CMA CMS implementer commended the forum for their role in participating in the water supply crisis in the Makana Municipality as the drought deepened.
	Conferences/Presentations			
October 2013	CG Palmer *Water for people and people for water.* National Sustainability Week Conference. Sandton City, Johannesburg, South Africa.			
25-29 May 2014	CG Palmer CG *Integrated Water Resource Management: Implementing the National Water Act.* Session Keynote, WISA Biennial National Water Conference, Mbombela			
22-26 June 2014	CG Palmer, AV Munnik and D du Toit (2014) *Building a co-operative water quality management process in the Crocodile River catchment.* Paper presented at the South African Society of Aquatic Sciences (SASAQS) 2014 conference. Black Mountain Leisure and Conference Hotel, Free State, South Africa			
22-26 June 2014	CG Palmer, S Pollard, D du Toit, JH O'Keeffe, KH Rogers, M Jobson, C van Ginkel, N Griffin, AV Munnik, N Hamer, M Weaver, A Sahula, DCH Retief, M Lipile, S Saki, N Lipile and X Nzwana *Towards a new paradigm for integrated water resource management: An integrated research programme.* Paper presented at the South African Society of Aquatic Sciences (SASAQS) conference. Black Mountain Leisure and Conference Hotel, Free State, South Africa			
22-26 June 2014	CG Palmer and K Rogers *Catalysing support to towards a new paradigm process.* Paper presented at the South African Society of Aquatic Sciences (SASAQS) conference. Black Mountain Leisure and Conference Hotel, Free State			

14-17 September 2014.	CG Palmer, AV Munnik, D du Toit, N Griffin, H Retief, A Slaughter and P Mensah *Transdisciplinary research on a guideline-based, integrated water quality management process, towards improving the social-ecological health of the Crocodile River*. SETAC Asia-Pacific, Adelaide, Australia
November 2014	CG Palmer, S Mantel and C Knowles *Gendered perspectives on water resource management, service delivery, governance and indigenous knowledge* Conference: Water Gender and Development. East London
December 2014	CG Palmer, JH Slinger, H Lotz-Sisitka, KH Rogers, C de Wet, N Hamer, S Pollard, D du Toit and J Clifford-Holmes *Transformative water research practice – a response to the multiple stressors of global change.* National Research Foundation Global Change conference, Port Elizabeth, December 2014.
4-6 May 2015	Water for Dignity presented a session at the Rhodes University Community Engaged Learning Symposium.
8-12 March 2015	CG Palmer, D du Toit, A Slaughter, H Retief, A Sahula and AV Munnik *Diverse sense-making in a co-operative integrated water quality management process in the Crocodile River, towards improved social-ecological health*. Savannah Network Meeting Skukuza
8-10 July 2015	CG Palmer *Water: a blue driver of a green economy.* Keynote: Conference of the Journal of Development and a Green Economy, Durban July 2015.
28 Sept-2 Oct 2015	CG Palmer *Action research practice in post-apartheid South African catchments, taking a complex social-ecological system approach.* Conference on Complex Systems, Phoenix, Arizona.
13-17 March 2016	CG Palmer *Transdisciplinary action research on Integrated Water Resource Management: implications for the river catchments within the Kruger National Park.* Savanna Science Network Meeting, Skukuza, Kruger National Park
3-5 May 2016	CG Palmer *Community engagement in catchments as complex social-ecological systems*. 2nd Annual Community Engaged Learning Symposium, Grahamstown, 3-5 May 2016
18 May 2016	Durban CG Palmer presentation WISA conference
26-30 June 2016	CG Palmer and ON Odume *Transdisciplinary approaches to loosening intractable environmental water quality problems in South Africa.* Southern African Society of Aquatic Scientists conference, Skukuza, Kruger National Park
19-22 September 2016	CG Palmer and MG Wolff *Engaged Action Research as a catalyst of co-learning in catchments (watersheds): complex adaptive social ecological systems*. Conference on Complexity Systems, Amsterdam, The Netherlands
October 2016	Mr Nick Hamer attended the Citizen Engagement in Local Water Governance symposium. The symposium was an opportunity for civil society activists to share their experiences of participating in participatory action research.
	Publications
2013	CG Palmer CG (2013) Editorial. July Proceeding of the Institution of Civil Engineers 166:355-356 (AR2013)
2015	CG Palmer, R Biggs and G Cumming (2015) *Applied research for enhancing human well-being and environmental stewardship: using complexity thinking in southern Africa.* Ecology and Society 20 (1), Special feature – guest editorial
2016	JK Clifford-Holmes, CG Palmer, CJ de Wet and JH Slinger (2016) *Operational manifestations of institutional dysfunction in post-apartheid South Africa.* Water Policy 18, 998-1014

2017	Hamer, N.G., Lipile, L., Lipile, M., O'Keeffe, J., Molony, L., Nzwana, X., Shackleton, S., Weaver, M. and Palmer, C.G. (submitted) *Community experiences of second order water scarcity: two case studies provide different insights and perspectives.*
2017	Weaver, M. O'Keeffe, J., Hamer N. and Palmer C. (2017). *Water service delivery challenges in a small South African municipality: Identifying and exploring key elements and relationships in a complex social-ecological system.* Water SA, 43(3).
2017	Weaver MJT, O'Keeffe J, Hamer N and Palmer CG (under review, Geoforum). *Exploring a civil society organisation response to water service delivery issues in the context of South Africa as a developmental state. Part 1: Emergence and practice.*
2017	Weaver MJT, O'Keeffe J, Hamer N and Palmer CG (under review, Geoforum). *Exploring a civil society organisation response to water service delivery issues in the context of South Africa as a developmental state. Part 2: Knowledge building, learning and active citizenship.*
	Activity – Seminars
September 2013	CG Palmer: Transdisciplinary research practice within social ecological systems. Invited seminars in the School of Environmental Science, and the Institute for Sustainable Futures University of Technology, UTS Sydney, Australia. September 2013
18-20 June 2014	Conference: "Postdoctoral Fellowships on Resources, their Dynamics, and Sustainability – Capacity Development in Comparative and Integrated Approaches" CG Palmer part of the review panel for the junior and senior fellowship applications.
16-22 March 2015	Prof Palmer was invited to the Volkswagen Foundation to offer a course in Madagascar on transdisciplinary research to African Post-Doctoral researchers

- Prof Tally Palmer was invited to give guest seminars and post-graduate coaching at the University of Technology, Sydney in the School of Environmental Sciences and the Institute for Sustainable Futures on TD research theory and practice, and UCEWQ was visited by Prof Grant Hose (Macquarie University, Sydney) an eminent ecotoxicologist
- Rhodes University has generative partnerships with the Departments of Management, Economics, Environmental Science, Geography and the Environmental Learning Research Centre.

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9.2 List of references for Table 3-1, Chapter 3

Concept:

i) Complex Social-Ecological Systems (CSES) Approach

— Transboundary basins/catchments (across two or more countries), e.g. Inkomati, Limpopo Rivers.

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ii) Strategic Adaptive Management

- Transboundary basins/catchments (across two or more countries), e.g. Inkomati, Limpopo Rivers.

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iii) Transdisciplinary Approaches

— Transboundary basins/catchments (across two or more countries), e.g. Inkomati, Limpopo Rivers.

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iv) Social learning

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v) Systemic Thinking-seeing links and interconnected functions as well as elements

— Large catchments in one country, e.g. Vaal, Orange, Olifants Rivers.

Hipel, K.W., Fang, L. and Wang, L. (2013). Fair water resources allocation with application to the south Saskatchewan River Basin. *Canadian Water Resources Journal, 38(1)*, 47-60.
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vi) Citizen Science

- Transboundary basins/catchments (across two or more countries), e.g. Inkomati, Limpopo Rivers.

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vii) Political Ecology and Governance

— Transboundary basins/catchments (across two or more countries), e.g. Inkomati, Limpopo Rivers.

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viii) Resilience Thinking

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— Areas within a catchment under Local government, e.g. Sundays River, Makana, Mbombela Municipalities.

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9.3 RDM methodology documents

DWAF (2006) This list was taken from the DWS website but the whole documents do not seem to be available on the website. They are most easily available from RDM practitioners.

1.1 *Inception Report
1.2 *National and International Literature Survey and Contextual Review
1.3 Appendix E: Project Document. Glossary of terminology often used in the Resource Directed Management of Water Quality
1.4 Volume 1: Policy Document Series
1.4.1 Volume 1.1: Summary Policy
1.4.2 Volume 1.2: Policy
1.5 Volume 2: Strategy Document Series
1.5.1 Volume 2.1: Summary Strategy
1.5.2 Volume 2.2: Strategy
1.5.3 Volume 3: Institutional Arrangements
1.6 1st Edition Management Instruments Series (Prototype Protocol)
1.6.1 Appendix B: Project Document. Conceptual Review for water licence application from a Resource Directed Management of Water Quality (RDMWQ) perspective
1.6.2 **Guidelines on Catchment Visioning for the Resource Directed Management of Water Quality
1.6.3.1 **Guideline for determining Resource Water Quality Objectives (RWQOs), water quality stress and allocatable water quality
1.6.3.2 **Guideline on the conversion of the South African Water Quality Guidelines to fitness-for-use categories
1.6.3.3 **Guideline for converting Resource Water Quality Objectives (RWQOs) to individual end-of-pipe standards
1.6.3.4 Appendix D: Project Document. ACWUA Decision-making support system for Resource Directed Management of Water Quality (RDMWQ)
1.6.4 **Decision-support instrument for the Assessment of Considerations for Water Use Applications (ACWUA)
1.6.5 **Guideline on pro-forma licence conditions for the Resource Directed Management of Water Quality
1.7 Volume 4: 2nd Edition Management Instruments Series
1.7.1 Volume 4.1: Guideline for Catchment Visioning for the Resource Directed Management of Water Quality
1.7.2 Volume 4.2: Guideline for determining Resource Water Quality Objectives (RWQOs), Allocatable Water Quality and Stress of the Water Resource
1.7.2.1 Volume 4.2.1: Users' Guide. Resource Water Quality Objectives (RWQOs) Model (Version 4.0)
1.7.3 Volume 4.3: Guideline on Monitoring and Auditing for Resource Directed Management of Water Quality
1.7.4 Appendix A: Project Document: Philosophy of Sustainable Development
1.7.5 Appendix C: Project Document: Guidelines for Setting Licence Conditions for Resource Directed Management of Water
Quality (RDMWQ)
1.7.6 Introduction