REACTIVE VERSUS ANTICIPATIVE ADAPTIVE MANAGEMENT OF DELTAS

The Sacramento-San Joaquin Delta and the Rhine-Meuse Delta compared

*T.J. Vlieg, M. Zandvoort**

In this paper Californian Adaptive Management (AM) and Dutch Adaptive Delta Management (ADM) are compared. The concepts are introduced in a policy context to deal with prevailing types of uncertainty in water management in the Californian Sacramento-San Joaquin Delta and the Dutch Rhine-Meuse Delta respectively. While having the same objective, we show that adaptive management in these Deltas differs considerably, because the concepts address different uncertainties. Californian AM is primarily applied to ecosystem management while Dutch ADM is primarily developed for flood risk management and fresh water supply purposes. Californian AM is based on modeling the performance of different actions. It emphasizes that, once management actions are selected, formal and continuous learning is required to deal with uncertain effects and effectiveness of management actions. Thus it *reacts* on present states in a continuous fashion as adequately and flexible as possible. In contrary Dutch ADM *anticipates* on possible futures through projections of climate change and socio-economic circumstances. Different sets of measures to avoid or postpone projected problems are developed. In ADM uncertainty in projections is recognized, and possible rejection of projections over time is acknowledged. For climatic and socio-economic circumstances ADM aims to ensure that alternative adaptation pathways can still be opted. We argue that good Delta management should be based on long term projections, as in Dutch ADM, and scientific learning from implemented actions, as in Californian AM. A hybrid of both concepts can thus be created in order to strengthen adaptive management practice in the face of future uncertainty.

In the coming centuries climate change, land subsidence and population growth are changes that will have a major influence on Deltas worldwide. The extent and impact of these changes on human safety, food security, ecosystems and financial capital in the Sacramento San-Joaquin Delta and the Rhine-Meuse Delta are uncertain[1, 2]. In light of exceeding uncertainty, adaptive management has gained interest in California's Sacramento-San Joaquin Delta and the Dutch Rhine-Meuse Delta. In these Deltas, major interest exists in appropriate management of water as a resource and transport medium, and as threat regarding drought and flooding. For example, two thirds of California's population (approximately 25 million people) and millions of acres of irrigated agriculture depend on water diverted from the Sacramento-San Joaquin Delta. The Rhine-Meuse Delta holds the world's fourth largest port, in the city of Rotterdam, and gives home to over 1,5 million residents. Both Deltas are densely populated and are

* **T.J. Vlieg**, Cataly Partners B.V., tjallingvlieg@gmail.com,
M. Zandvoort, Wageningen UR, Landscape Architecture Group, mark.zandvoort@wur.nl

highly used for agriculture, shipping, housing, industry, and recreation. To a large extent, these developments have come at costs of nature. The reason that adaptive management has gained interest, is that it claims to enable management in unpredictable and highly complex situations[3]. However, as is illustrated in this article the manner in which it enables these situations to be managed, differs per case. In the Californian Sacramento-San Joaquin Delta Adaptive Management (AM) is an approach that is associated with ecosystem management[1]. Recently, the concept is also introduced for the purpose of flood risk management and fresh water supply. Parallel to this introduction, Adaptive Delta Management (ADM) is formulated in the Netherlands to inform long term strategizing in the Delta Program. Both AM and ADM are still in development[1, 4, 5]. By conducting a comparative case study between Californian AM and Dutch ADM, transferable insights are derived[6], and arguments to combine both concepts in order to strengthen adaptive management practice are presented.

The history of two Adaptive Management concepts

As Smit et al.[7] describe, *ways to adapt* depend on *to what to adapt.* Californian AM and Dutch ADM are ways of adapting that have been shaped to address the uncertainties that come with their system of interest. Studying the system of interest can thus provide insight in why Californian AM and Dutch ADM are defined and implemented the way they are. In the following section we therefore describe the background of Californian AM and Dutch ADM, and explain their current definition and key elements.

Dutch ADM in the Rhine-Meuse Delta

The origin of Dutch ADM can be found in a search to deal with effects of climate change on the Dutch water system[2, 5]. A search that since 2009 is embedded in the Dutch Delta Program. The Delta Program primarily focuses on flood risk management and fresh water supply, while ecosystem management is also taken into account[2]. As a consequence, adaptation to the effects of climate change on the water system, and functions dependent thereon, is a key notion. In the Delta Program the ADM concept was first introduced in 2011. ADM integrates adaptation to climate change, and adaptivity to uncertainties concerning long term biophysical and socio-economic change in decision-making.

Regarding the background of the Delta Program, a transition from an emphasis on 'adaptation' to 'adaptive' strategies can be seen, also with respect to the development of ADM. The debate concerning adaptation to climate change started at the end of the 1990's. Pielke, for example, argues in 1998 that there are limitations to mitigation and he argues that a larger role has to be occupied by adaptation. He defines adaptation as: *'adjustments in individual, group and institutional behaviour in order to reduce society's vulnerabilities to climate, and thus reduce its impacts*[8]. From 2000 onwards the uncertainties surrounding climate change effects start to have a role. Grubler and Nakicenovic state that these uncertainties need to be taken into account, arguing for 'adaptive response strategies'[9]. Thus, instead of adapting to climate change effects (adaptation), an adaptive management scheme, having the capacity to adapt to current uncertainty about these effects is visible. As Van Rhee describes it: '*Adaptive Delta Management is an approach to take uncertainty about future development transparently into account in decision-making'*[5]. The Delta Program aims to manage uncertainty, because waiting is not an option. Thus, adaptive planning approaches become necessary in light of future uncertainties, ADM being an example hereof.

This transition is clearly visible in the goal of the Delta Program: "Adaptive management to adapt to climate and socio-economic change"[2]. Climate and socio-economic change entail the major interacting drivers that influence flood risk and fresh water supply, being the primary concerns wherefore ADM is developed. The objective of Dutch ADM is to anticipate different possible futures. This requires cooperatively developing cost-effective strategies, that fit a range of long term scenarios, while keeping as many as possible options open. Thus constructed sets of alternative strategies form a key element of ADM, and are referred to as adaptation pathways[10]. Therefore, in an ideal case, the ADM process starts with defining long term challenges found by assessing so called Adaptation Tipping Points (ATPs). ATPs are defined as: "*points where the magnitude of change due to climate change, or sea level rise is such that the current strategy will no longer be able to meet the objectives*"[11]. For example: an existing strategy based on (re)enforcing dikes is known to keep the Rhine-Meuse Delta safe up to a sea level rise of eighty centimeter. This is the ATP. In case of an assessment based on a worst case scenario for the Rhine-Meuse Delta with a projection of eighty centimeter sea level rise in 2060, 2060 is the moment of an ATP. The moment at which the tipping point might be reached differs per scenario, which is why assessing ATPs results in a range of possible futures[5, 10]. Through assessing the timing of ATPs the soonest and the latest moment at which adaptation pathways need to be initiated can be assessed, although the timing and initiation of a pathway is still hard to predict due to complexity of the system[12]. Once initial Adaptation Pathways are assessed Dutch ADM prescribes to combine them with plans and agendas of other parties, so-called mainstreaming[5]. Sharing agendas is intended to result in multi-purpose projects in which investments and efforts are combined. The different steps in an ADM assessment process are derived from the ADM guide in Table 1.

Dutch ADM explicitly recognizes uncertainty with regard to climate - and socio-economic change, which can be referred to as changing system circumstances.

Steps in the Adaptive Delta Management cycle
1 Identify goals and current/future problems based on Delta scenarios and ATPs
2 Specify the different main approaches into adaptation pathways, including:
• If desired so assess alternative main approaches ('leading principles');
• Compose adaptation pathways;
• Point out time spans for which measures are effective;
• Make an inquiry of moments to change pathways, possible lock-ins and lock-outs
3 Combine adaptation pathways with regional ambitions and plans of other parties, including:
• Inquiry of other's agendas;
• Determine opportunities (e.g. cost saving, multipurpose, limit nuisance from work activities by simultaneous operations);
• Define optimal sequence of measures;
• Assess indicators (for monitoring), that can trigger changing course;
• Formulate promising strategies;
4 Assess promising strategies and propose preferred strategy based on a value assessment of pathways or measures that are part of it. This allows for comparing different pathways, and for the assessment of no-regrets and urgent decisions.

Table 1:
The Dutch ADM process steps
(translated from Van Rhee 2012)

The actual execution of adaptation pathways relies amongst others on whether projections of this change in circumstances are confirmed over time. ADM thus says that the chosen pathway should be re-evaluated over time and (*ex ante* uncertain) course must be changed[10]. ADM not only prescribes to map out alternative adaptation pathways, but also includes the assessment of the *potential to change* between pathways. Hereby the concept intends to enhance flexibility so that actions can be properly timed, over- or underinvestment is avoided and path dependency is acknowledged at the onset of the decision-making process.

Californian AM in the Sacramento-San Joaquin Delta

The concept of adaptive management in the Sacramento-San Joaquin Delta has a different origin. It goes back to the seminal work of C.S. Holling, who emphasized that knowledge of systems functioning is "*small when compared to that of our ignorance*"[3]. The focus of adaptive management, as Holling described it, is on ecosystems and natural resources. Uncertainty about what humans know, and what is unknowable about natural dynamics and long term stability of ecological systems has driven the development of AM in this field[3]. An essential idea behind the concept is that effects of human interventions on natural dynamics and system stability are uncertain and in need of (informed) adjustments. This is acknowledged by the Delta Stewardship Council, and Californian AM reflects this[1, 6]. Walters describes that the central tenet in AM is continuous learning[13]. Continuous learning has to be done by monitoring, thereby gaining data and knowledge to adjust management of a system in order to keep it balanced. Thus, in origin Californian AM has been shaped to address the uncertainties of concern in managing ecosystems.

The Delta Stewardship Council, responsible for the Delta Plan of the Sacramento-San Joaquin Delta, states that *'adaptive management is useful in that it provides flexibility and feedback to manage natural resources in the face of often considerable uncertainty'*[1]. Since 2013 the Delta Reform Act requires that state or local government actions are consistent with the Delta Plan. Adaptive Management thereby became a legal requirement for certain actions in the Sacramento-San Joaquin Delta. The Delta Plan states that "*Ecosystem restoration and water management covered actions must include adequate provisions, appropriate to the scope of the covered action, to assure continued implementation of adaptive management*"[1]. This entails that Californian AM is introduced for purposes besides ecosystem restoration, including fresh water supply and flood risk management. The case of the Sacramento-San Joaquin Delta shows that human interventions in ecosystems, but also other uncertainties, like impacts of climate change, are increasingly acknowledged as drivers of change[14]. Basic assumptions underpinning flood-, water- and conservation management have to be reconsidered when taking into account adaptation to climate change.

The most dominant principle in Californian AM is the necessity of continuous and deliberate learning. Key drivers underlying this necessity are the recognition of uncertainty in Delta systems, and uncertainty concerning the effects and effectiveness of management actions[1]. The Californian AM process in Figure 1 allows for dealing with these uncertainties. The process prescribes to select and implement actions based on modeling their performance. Californian AM recognizes the level of uncertainty concerning modeled outcomes to be so high, that without continuous monitoring, evaluation and adaptation of management actions, proper management of socio-ecological systems cannot be done. One of the Californians interviewed for this study, expressed this recognition of uncertainty: *'I think it's naive to think if one fashions a management plan, to*

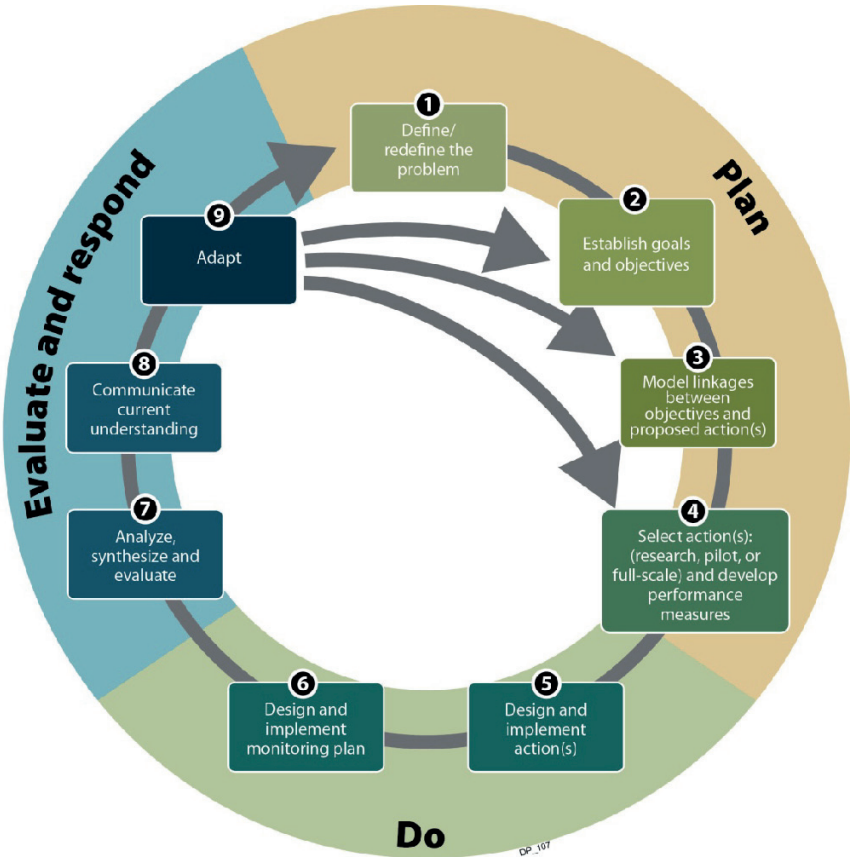

Figure 1:

The three phase nine step Californian Adaptive Management cycle

(DCS, 2013)

think that you can then go in there and apply it to a situation, particularly a complex situation, and expect it to work right away.' As the Californian AM process shows, evaluating performance requires monitoring plans, suitable indicators, data management and integration of knowledge. Thus, despite considerable uncertainty, the iterative AM process allows for short term actions by safeguarding adaptation of management actions in an instant fashion.

A positive example of how Californian AM is intended, is the Kissimmee River Restoration Project in South-Florida. In the Kissimmee River Restoration Project a canal was backfilled and river channels were reconnected and recarved. The measures' effects on the situation were modeled and a monitoring plan with measurable performance indicators (amongst others number of wading birds; wetland vegetation coverage) was put in place. Monitoring and evaluating progress indicated that the project is on track to achieve its ecological restoration goals[15].

Results of a comparison

In general both adaptive management concepts aim at adequate and informed policy-making in complex Delta systems that are exposed to different types and levels of uncertainty. In both cases adequate responses to change and creating flexibility in the management scheme plays an important role. The main difference between Californian AM and Dutch ADM is that they address different types of uncertainty, which is caused by differences in the system of interest. Californian AM puts uncertainty about the effects and effectiveness of management actions central, whereas Dutch ADM stresses uncertainty with regard to changing system circumstances. This leads to Californian AM being reactive and Dutch ADM being anticipative. Dutch ADM typically prescribes the mainstreaming of local and regional agenda's into their adaptation pathways. In Figure 2 the main differences and similarities between both concepts are presented.

The management process as described in the formal Delta planning documents reflects these main differences and similarities. Californian AM has a formal and structured learning process to assess the effectiveness and effects of management actions. Californian AM is explicit about monitoring, and it elaborates on monitoring the effects and effectiveness of actions. In Dutch ADM the importance of a learning process is not explicitly recognized, and monitoring is more implicit. Effective implementation of ADM, however, requires the drivers of Delta scenarios to be monitored. Another major difference between the processes is that contrary to Dutch ADM, Californian AM is not explicit about connecting the short term with the long term through adaptation pathways and monitoring changing system circumstances. Additionally Californian AM does not stress the importance of combining projects of different parties, called mainstreaming in Dutch ADM.

The differences with respect to uncertainties that

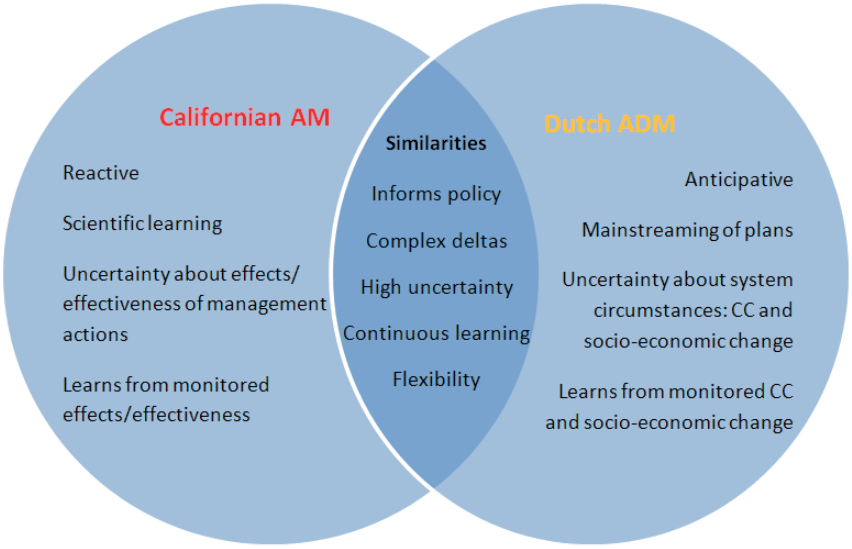

Figure 2:
Main differences and similarities between Californian AM and Dutch ADM

are addressed, can largely be explained by the different background of the concepts. Dutch ADM finds its origin in climate adaptation and has been developed accordingly. Dealing with uncertainty about climate change, together with socio-economic change, are key notions for achieving the goals of the Dutch Delta Program. The origin of Californian AM is in ecosystem management, and historically the concept has developed to cope with the unpredictability of the interaction between human actions and the ecosystem. This is a logic development, considering that ecological restoration is a main goal of the Delta Plan. However, for Dutch ADM as well as Californian AM, the comparison indicates that these two concepts are no longer fit for their current purposes.

Discussion

This study has unraveled important differences and similarities between Californian AM and Dutch ADM. The two concepts differ to a large extent. ***Learning by doing*** and ***management as experiment*** are typologies of Californian AM in the Sacramento-San Joaquin Delta. The Californian AM process allows Delta managers to decrease the high levels of uncertainty with regard to the effects and effectiveness of management actions. Californian AM is intended to result in reactive and flexible management. Dutch ADM could best be referred to as ***anticipative (strategic) planning***. It is anticipative because ADM actively tries to set up sets of alternative measures that fit a range of long term scenarios. In Dutch ADM adjustments should be made based on monitoring system circumstances, while it could be challenging to measure change and act upon accordingly. This is not dealt with in the formal documents.

In both cases, the Sacramento-San Joaquin Delta and the Rhine-Meuse Delta, managers apply a type of adaptive management that fits only certain purposes. In the Sacramento-San Joaquin Delta a type of adaptive management is applied that fits ecosystem management, but that is currently proposed for purposes besides ecosystem management, including fresh water supply and flood risk management. In the Netherlands a type of adaptive management is applied that fits flood risk management and fresh water supply. Interesting is that the concept is presented as an integrated approach that, besides flood risk management and fresh water supply, will allow for ecological improvement of the Rhine-Meuse Delta. Thus in both Deltas planners present adaptive management as an integrated approach applicable to their Delta in general. We gave arguments why this is not the case and showed that the original application needs to be 'adapted' according to the system of interest. As a consequence both concepts require rethinking, we provide four lessons that can be distilled from our comparison.

First, the Dutch ADM guideline does not elaborate on how or what to monitor to assess adaptation tipping points. Possibly this makes ADM in its management scheme not as anticipative as it claims to be. Comparing it to Californian AM reveals that a good monitoring plan could enhance the claim that it anticipates changing system circumstances. The ADM guideline could be extended by including general guidelines for a monitoring plan in order to assess adaptation tipping points.

Second, to fit the purpose of ecosystem management, Dutch ADM should incorporate scientific learning by monitoring the effects and effectiveness of management actions. Dutch Delta planners could learn from the Sacramento-San Joaquin Delta case, which forms a good example of continuous scientific learning. The tailoring of this monitoring however, should be thought trough carefully for the system of interest. More research is necessary to see into the possibilities of monitoring climate- and socio-economic change, and acting to monitoring results. Both parts could be challenging tasks for the Delta managers.

Third, with respect to Californian AM the change of scope from ecosystems to a larger climate and socio-economic system, asks for adjustments according to the

change in system focus. In its current form Californian AM does not prescribe in which way anticipation on changes in climate and socio-economic circumstances are included. Dealing with these uncertainties becomes increasingly important in ecosystem management, as well as in the recent focus on fresh water supply and flood risk management. Also more emphasis should be given to assessing in advance under what system circumstances strategies might have to be adjusted, and by which means. Being able to adapt Californian AM to the changed system's focus, for example by means of scenario analysis specified for the Sacramento-San Joaquin Delta, is a necessity. Dutch ADM forms a good example of how to explicitly integrate these aspects.

Fourth, Californian AM could be complemented with searching for coupling opportunities. Dutch ADM can function as an example, because it enables assessing the potential for multi-purpose projects in which investments and efforts are combined. The growing amount of literature on mainstreaming and integration could also provide useful additions for Californian AM.

In the long run good Delta management should be based on long term projections, as in Dutch ADM, and scientific learning from implemented actions, as in Californian AM. In the end concepts like Adaptive Management are never finished, if only because the situations they are developed for continuously change. As described by one of the Dutch interviewees: *'To create a palette of understandings of Adaptive Management is of great value, because it may lead our Delta managers to do things differently'*. Comparing AM practice in different Delta's is a first step to create such a palette of understanding.

1 DSC. 2013. Final Delta Plan. Delta Stewardship Council, California, USA. Citation I: p. 43. Citation II: p. 53.
2 Ministerie Infrastructuur en Milieu. 2012. Deltaprogramma 2013.Den Haag.
3 Holling, C.S. 1978. Adaptive environmental assessment and management. Chisester, UK: Wiley.
4 Brugge, Van der. R., Roosjens, R., Morselt, T., Jeuken, A. 2012. Case Study: Adaptief Deltamanagement. Water Governance 2, 35-40. See also Vlieg, T.J. 2012.
5 Van Rhee, G. 2012. Handreiking adaptief deltamanagement. Definitief concept. Stratelligence, Leiden. Citation: p. vii.
6 Vlieg, T.J. 2012. Comparing Adaptive Management for flood management in the Sacramento-San Joaquin Delta and the Southwestern Delta. Master Thesis Report, Wageningen University, Wageningen.
7 Smit, B., I. Burton, R.J.T. Klein, J. Wandel. 2000. An anatomy of adaptation to climate change and variability. Climatic Change 45, pp. 223-251.
8 Pielke, R.A. 1998. Rethinking the role of adaptation in climate policy. Global Environmental Change 8(2), p. 159.
9 Grubler, A., N. Nakicenovic. 2001. Identifying dangers in an uncertain climate. Nature 412, p. 15.
10 Haasnoot, M., Middelkoop, H., Offermans, A., Van Beek, E. & Van Deursen, W.P.A. 2012. Exploring pathways for sustainable water management in river deltas in a changing environment. Climatic Change 115(3-4), 795-819., see also Van Rhee 2012.
11 Kwadijk, J.C.J., M. Haasnoot, J.P.M. Mulder, M.M.C. Hoogvliet, A.B.M. Jeuken, R.A.A. Krogt, N.G.C. Oostrom, H.A. Schelfhout, E.H. van Velzen, H. van Waveren, M.J.M. de Wit. 2010. Using adaptation tipping points to prepare for climate change and sea level rise: a case study in the Netherlands. Wiley Interdisciplinary Reviews: Climate Change 1(5), pp. 729-740.: p. 731
12 Van der Vlist, M.J., Ligthart, S.S.H., Zandvoort, M. Forthcoming. Replacement of hydraulic structures in light of tipping points. Journal of Water and Climate Change
13 Walters, C. 1986. Adaptive management of renewable resources. New York, USA: Macmillan and Co. See also Holling 1987.
14 Cloern, J.E., N. Knowles, L.R. Brown, D. Cayan, M.D. Dettinger, T.L. Morgan, D.H. Schoellhamer, M.T. Stacey, M. Van der Wegen, R.W.Wagner, A.D. Jassby. 2011. Protected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change. PLoS ONE 6(9), e24465.
15 Toth, L. A., S. L. Melvin, D. A. Arrington, J. Chamberlain. 1998. Hydrologic manipulations of the channelized Kissimmee river – Implications for restoration. Bioscience 48: 757-764. See also DSC 2013.

Additional literature and all references are available upon request.

SAMENVATTING

In dit artikel zijn het Californische Adaptief Management (AM) enerzijds en het Nederlandse Adaptief Delta Management (ADM) anderzijds vergeleken. Beide concepten zijn in een beleidscontext geïntroduceerd om met verschillende typen onzekerheid in watermanagement om te gaan, respectievelijk in de context van de Sacramento-San Joaquin Delta en de Rijn-Maas Delta. Alhoewel de onderliggende doelen gelijk zijn, laten we zien dat de concepten in hun operationalisatie verschillen, doordat ze verschillende onzekerheden adresseren. Californische AM wordt toegepast op ecosysteem management terwijl het Nederlandse ADM ontwikkeld is voor risicobeheer van overstromingen en het managen van zoet water. Californische AM is daarbij gebaseerd op het in kaart brengen van de effecten en effectiviteit van verschillende beheersmaatregelen, waarbij de nadruk ligt op formele en continue leerprocessen zodra maatregelen zijn geselecteerd. In het concept wordt dus continue zo adequaat en flexibel mogelijk gereageerd op huidige ontwikkelingen. Daarentegen tracht ADM te anticiperen op mogelijke toekomstige ontwikkelingen door middel van het in kaart brengen van klimaatverandering en sociaaleconomische verandering. Pakketten van maatregelen worden vervolgens ontwikkeld om geprojecteerde problemen te vermijden of uit te stellen. ADM erkend onzekerheid ten aanzien van delta scenario's en stelt daarom dat voortschrijdend inzicht ertoe kan leiden dat huidige scenario's verworpen dienen te worden. ADM streeft ernaar alternatieve adaptatiepaden voor handen te hebben in dergelijke situaties. Wij stellen dat goed delta beheer dient te anticiperen op mogelijke toekomsten, als in ADM, en continue zal moeten leren van geïmplementeerde maatregelen, zoals in Californische AM. Een dergelijke hybride van de bestudeerde concepten kan het omgaan met onzekerheid in delta's versterken.