FRaME
A review and evaluation of flood control areas
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to inform future guidance on the implementation of Flood Control Areas (FCAs). As a result this document should not be considered a definitive statement on best practice.
Samenvatting

Om een effectieve uitvoering van de FRaME demonstratie projecten mogelijk te maken is een aantal evaluatie studies uitgevoerd om relevante ervaringen omtrent de toepassing van noodoverloopgebieden in estuaria te verzamelen. Een van deze studies, uitgevoerd door Black and Veatch, WL|Delft Hydraulics en Resource Analysis, richtte zich op de evaluatie van de werking van noodoverloopgebieden.

Na een initiele quick scan fase, werden projecten in Nederland, België, Engeland en Frankrijk geselecteerd voor meer gedetailleerde analyse. Het succes dan wel het falen op het gebied van planning, ontwerp en gebruik van elk van deze projecten werd geanalyseerd. De analyses werden uitgevoerd aan de hand van zogenaamde Key Performance Indicators, aan de hand waarvan elke site werd bestudeerd.

Lessen die konden worden getrokken uit elk project afzonderlijk of meer in het algemeen, werden geformuleerd ten behoeve van een nog op te stellen leidraad voor het gebruik van noodoverloopgebieden in estuaria.
Abstract

To inform the delivery of the FRaME demonstration projects, reviews have been commissioned to collect relevant international experience of Flood Control Area (FCA) implementation. One of these studies, undertaken by Black and Veatch, WL|Delft Hydraulics and Resource Analysis, focuses on the review and evaluation of flood control areas.

From an initial quick scan phase, sites in the Netherlands, United Kingdom, Belgium and France were selected for more detailed analysis.

The success or otherwise of the planning, design, implementation and operation of a specific flood control area in each site has been reviewed. The analysis was conducted through the establishment of Key Performance Indicators, against which each site was assessed.

Lessons that have been learnt relating to each site and more generally, have been identified and these will be used to support the preparation of an FCA best practice manual.
Contents

Non technical summary ...........................................................................................................v

1 Introduction .......................................................................................................................1
   1.1 Introduction to the FRaME project .................................................................1
   1.2 Study objectives ..........................................................................................1
   1.3 Approach to work .........................................................................................2
       1.3.1 The quick scan phase ...................................................................2
       1.3.2 The main review phase ..................................................................3
   1.4 Report structure ...........................................................................................4

2 Outline of analysis framework .........................................................................................5
   2.1 Case analysis: the ‘frame of reference’ method ..............................................5
       2.1.1 Management objectives ..................................................................6
       2.1.2 Decision process ............................................................................6
   2.2 Summarising effectiveness: Key Performance Indicators ..................................8

3 The Dutch river branches: Aakvlaai ..........................................................................11
   3.1 Summary of Key Performance Indicators .....................................................11
   3.2 General case description .............................................................................11
   3.3 FCA analysis: Aakvlaai .............................................................................14
       3.3.1 Objectives of depoldering the Aakvlaai area ..................................14
       3.3.2 The problem ..................................................................................15
       3.3.3 The project ....................................................................................16
       3.3.4 Evaluation of operational success ....................................................19
   3.4 General conclusions .....................................................................................20
   3.5 Lessons learned ..........................................................................................21
   3.6 Acknowledgements .....................................................................................22
4 The Scheldt estuary: Tielrodebroek ......................................................... 23
  4.1 Summary of Key Performance Indicators ........................................ 23
  4.2 General case description ............................................................... 23
  4.3 FCA analysis: Tielrodebroek .......................................................... 27
    4.3.1 Objectives of the Tielrodebroek FCA ....................................... 28
    4.3.2 The problem ........................................................................ 29
    4.3.3 The project .......................................................................... 30
    4.3.4 Evaluation of operational success ....................................... 31
  4.4 General conclusions .................................................................. 31
  4.5 Lessons learned ....................................................................... 32
  4.6 Acknowledgements .................................................................. 33

5 Baie des Veys: The Marshes of Cotentin and Bessin ....................... 35
  5.1 Summary of Key Performance Indicators ....................................... 35
  5.2 General case description ............................................................. 35
  5.3 FCA analysis: The Marshes of Cotentin and Bessin ...................... 38
    5.3.1 Objectives for the Marshes of Cotentin and Bessin ............... 38
    5.3.2 The problem .................................................................. 38
    5.3.3 The project .................................................................. 39
  5.4 General conclusion ................................................................. 41
  5.5 Lessons learned .................................................................. 41
  5.6 Acknowledgements .................................................................. 42

6 Humber: Paull Holme Strays ............................................................... 43
  6.1 Summary of Key Performance Indicators ....................................... 43
  6.2 General description .................................................................. 43
  6.3 FCA analysis: Paull Holme Strays ............................................... 46
    6.3.1 Objectives of managed re-alignment at Paull Holme Strays .... 46
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.3.2</td>
<td>The problem</td>
<td>48</td>
</tr>
<tr>
<td>6.3.3</td>
<td>The project</td>
<td>48</td>
</tr>
<tr>
<td>6.3.4</td>
<td>Evaluation of operational success</td>
<td>50</td>
</tr>
<tr>
<td>6.4</td>
<td>General conclusions</td>
<td>51</td>
</tr>
<tr>
<td>6.5</td>
<td>Lessons learned</td>
<td>52</td>
</tr>
<tr>
<td>6.6</td>
<td>Acknowledgements</td>
<td>53</td>
</tr>
<tr>
<td>7</td>
<td>Norfolk Broads: Broadland Flood Alleviation Project</td>
<td>55</td>
</tr>
<tr>
<td>7.1</td>
<td>Summary Of Key Performance Indicators</td>
<td>55</td>
</tr>
<tr>
<td>7.2</td>
<td>General Case Description</td>
<td>55</td>
</tr>
<tr>
<td>7.3</td>
<td>FCA analysis: Broadland Flood Alleviation Project</td>
<td>58</td>
</tr>
<tr>
<td>7.3.1</td>
<td>Objectives of the Broadland Flood Alleviation Project</td>
<td>59</td>
</tr>
<tr>
<td>7.3.2</td>
<td>The problem</td>
<td>60</td>
</tr>
<tr>
<td>7.3.3</td>
<td>The project</td>
<td>62</td>
</tr>
<tr>
<td>7.3.4</td>
<td>Evaluation of operational success</td>
<td>64</td>
</tr>
<tr>
<td>7.4</td>
<td>General conclusions</td>
<td>64</td>
</tr>
<tr>
<td>7.5</td>
<td>Lessons learned</td>
<td>64</td>
</tr>
<tr>
<td>7.6</td>
<td>Acknowledgements</td>
<td>65</td>
</tr>
<tr>
<td>8</td>
<td>Main review conclusions</td>
<td>67</td>
</tr>
<tr>
<td>8.1</td>
<td>Introduction</td>
<td>67</td>
</tr>
<tr>
<td>8.2</td>
<td>Inter-comparison of cases study sites</td>
<td>67</td>
</tr>
<tr>
<td>8.3</td>
<td>Recommendations for the planning, design and implementation of FCAs</td>
<td>68</td>
</tr>
<tr>
<td>8.3.1</td>
<td>Introduction</td>
<td>68</td>
</tr>
<tr>
<td>8.3.2</td>
<td>Recommendations relating to the planning phase</td>
<td>69</td>
</tr>
<tr>
<td>8.3.3</td>
<td>Recommendations relating to the design phase</td>
<td>70</td>
</tr>
<tr>
<td>8.3.4</td>
<td>Recommendations relating to the implementation phase</td>
<td>71</td>
</tr>
<tr>
<td>9</td>
<td>Literature references</td>
<td>73</td>
</tr>
</tbody>
</table>
Non technical summary

FRaME is an international project financed under the EU Interreg IIIb programme. It aims to promote flood control areas (FCAs) as a means to reduce flood risk in estuaries. To help inform the delivery of a range of demonstration projects, reviews have been commissioned to collect relevant international experience of FCA implementation and thereby aid the preparation of a best practice manual.

One of these studies, undertaken by Black and Veatch, WL|Delft Hydraulics, and Resource Analysis focuses on the review and evaluation of flood control areas.

An FCA, for the purposes of this report, is defined as a piece of land that is intentionally flooded in a controlled manner, in order to prevent uncontrolled flooding at an uncertain location (or locations) and with an uncertain severity.

To achieve the review objectives an initial quick scan was undertaken and, based on that, a more focused main review of a smaller number of potentially useful sites. This report describes the results of the main review and evaluation phase.

From the initial quick scan phase, the following locations were selected for more detailed analysis from a long-list of over 100 sites:
• the Dutch River Branches;
• the Scheldt Estuary;
• the Baie des Veys estuary (the Marshes of Cotentin and Bessin);
• the Humber Estuary; and
• the Norfolk Broads.

The success or otherwise of the planning, design, implementation and operation of a specific flood control area in each of these estuaries has been assessed; based on literature review and selective interviews with site managers. The analysis was conducted in a rigorous manner through the establishment of a 'Frame of Reference' which led to the development of a series of Key Performance Indicators (KPIs) against which each site was assessed.

The case from the Dutch River Branches (Aakvlaai) is designed to continuously cope with river floods, as the main flood risk comes from river discharges, with the tidal waters playing only a minor role in this area. The effectiveness of Aakvlaai lies in its ability to act as a floodplain while at the same time diverting a significant part of the river discharge to existing river channels of greater capacity.

On the Scheldt, the Tielenrodebroek case is designed to operate only for a matter of hours, dealing with the critical peak in water levels during high tides. Unlike Aakvlaai, the main flood risk comes from storm surges at sea. The large tidal range results in the critical water levels lasting only for a few hours. This short duration enables storage of the excess water, thus lowering critical water levels on the Scheldt.

For the Marshes of Contentin and Bessin the management challenge is selecting a water level management strategy that optimally satisfies all the interests present in the system. The ability to automatically operate sluices in a large area enables a sophisticated water management system that takes into account the water needs of different interests throughout the year. This case provides an illustration of controlled flooding, in which the reduction of flood damage is only an element.

The Paull Holme Strays case, located in the Humber Estuary, was constructed as a cost-effective replacement of existing (failing) defences and also to provide compensation for nature losses due to flood defence strengthening elsewhere in...
the estuary. This project illustrates that any flood control measure should always be considered in the context of the whole estuary system.

The Haddiscoe example from the Norfolk Broads provides an interesting illustration of the construction of additional floodplain by managed realignment, through a public-private partnership. As such, this site is innovative on an organisational rather than a technical level.

Besides their different characteristics, the cases are also in different stages of implementation: Tielrodebroek has been operational since the early 1980’s, Aakvlaai was completed in 2001, the water management system in the marshes of Cotentin and Bessin came into operation in 2002, the Paull Holme Strays works were finished only very recently in 2003 and the Haddiscoe site as of January 2004 is still partly in the planning phase.

Site-specific lessons are discussed in the chapter relating to each case. However, more general recommendations emerge from an overview of all the projects. These have been sub-divided in the main report into those relating to planning, design and implementation, and comprise:

- [when considering FCAs] It is important to gather contextual information on the relevant physical, economic and administrative aspects of the [estuary] system
- Once the system boundaries are clear it is important to agree on the [FCA’s] strategic objectives and the associated operational objectives
- Consider a wide range of potential [FCA] solutions but adopt a pragmatic approach to their reduction to a short-list
- Give serious consideration to the multiple objectives of an FCA [to aid successful progression through the approvals process]
- Establish a ‘fit for purpose’ [FCA] implementation plan early on in the process that deals with local issues
- FCAs are only likely to be successful for flood risk reduction in certain [upper tidal] locations within estuaries
- When dealing with flood risk it is important to agree upon a number of technical performance criteria against which the effectiveness of an FCA can be evaluated
- Once the performance criteria have been established (see above) it is important to arrange the necessary measurement and monitoring activities that enable quantification
- Make use of existing guidance relevant to the design of FCAs
- Once a decision is made to proceed with the realisation of a certain [FCA] measure it is important to make a detailed implementation plan
- The success of an FCA is rarely guaranteed and ongoing monitoring activities based around the performance criteria should be undertaken.
I Introduction

1.1 Introduction to the FRaME project

FRaME is an international project financed under Interreg IIIb. It aims to assess the effectiveness of flood control areas (FCAs) as means to reduce flood risk in estuaries. An FCA, in this report, is defined as a piece of land that is intentionally flooded, in a controlled manner, in order to prevent uncontrolled flooding at an uncertain location (or locations) and with an uncertain severity. This type of solution is well-known along rivers, but not so common in estuarine environments. One could argue that this is logical as the influence of the sea is too large for such solutions to work. However, several effective examples are available especially in upper tidal situations.

To further investigate the circumstances under which FCAs might be effective, the FRaME project has selected a total of five demonstration sites for the implementation of these solutions:

- Zuiderklip – Biesbosch (NL);
- The Northern Fringe of Goeree Overvlakkee – Haringvliet (NL);
- Alkborough flats – Humber estuary (UK);
- Kruibeke-Basel-Rupelmonde – Scheldt estuary (NL/B); and
- IJzer – IJzer estuary (B)

To allow for optimal learning and knowledge development the sites have been chosen to highlight different aspects of interest to the FRaME project. On three of the sites, activities focus on flood management, planning and engineering and on two of the sites activities focus on alternative sustainable land uses.

To realise effective demonstration projects, two parallel studies alongside FCAs have been commissioned to collect existing relevant international experience. The studies, coordinated by three working groups (WGs), focus on the review and evaluation of:

- flood control areas (WG 1);
- new and innovative land uses (WG 2); and
- communication aspects (WG 3).

Furthermore, studies have recently been commissioned by the FRaME project in the topics of the Birds and Habitats Directives, and economics. This report presents the results of the FCA study.

1.2 Study objectives

The objectives of the review and evaluation study are the following:

- to identify the success and failure of various approaches to planning, design and implementation,
- to generate ideas for ‘best practice’, and
- to feed these ideas into the development of a decision making methodology.
1.3 Approach to work

To achieve the above objectives each of the review studies first performed a broad initial quick scan and, based on that, a more focused main review of a smaller number of potentially useful sites. This report describes the results of the main review and evaluation phase of the FRaME project ‘review and evaluation of flood control areas’ (WG 1). The next sub section briefly describes the quick scan phase that preceded this main review in order to provide some background information.

1.3.1 The quick scan phase

The purpose of the quick scan was to obtain a comprehensive overview of relevant experience with flood control areas, land use and communication issues in the EU and in North America. In order to achieve such a comprehensive overview of experiences, an initial long list of potential sites would be drafted based on maps (see Figure 1.1). The resulting long list would contain a relatively large number of estuaries (order 100 – 110).

Based on expert judgement by the consultants, this long list was then reduced to a medium list of 28 ‘potentially interesting’ sites. These sites was then distributed among the consultants (Black and Veatch & WL|Delft Hydraulics and Soresma & Halcrow), according to indicated preferences and the nature of the available contacts, for more detailed investigation through brief interviews with the key contacts for each site. Figure 1.1 provides an illustration of the sites that were on the long list (the red dots). The black dots represent the sites that were on the medium list and that where targeted during the quick scan.

After interviewing the contacts for each site on the medium list, evaluation of the gathered information per site helped the drafting of a shortlist of sites to be carried forward to the main review. The main selection criteria for a site to be carried forward were related to the presence of flood control areas and the availability of persons and supporting information for purpose of analysis.

Figure 1.1. Geographic overview of the quick scan results (Source: Van Koningsveld et al. (2003))
Although not all sites on the long list were eventually investigated, Figure 1.1 clearly indicates that the approach resulted in a broad scan of experience along the European and North American coasts (black dots). The collaboration between Black and Veatch & WL|Delft Hydraulics and Soresma & Halcrow minimised overlap during the interviews while at the same time it has increased the number of sites that could be addressed. As a result, the limited time available for the quick scan was used efficiently to gather as much information as possible.

1.3.2 The main review phase

From the quick scan phase, that was reported in the Quick scan report (Van Koningsveld et al., 2003), ten potential sites for the main review emerged. The FRaME partners selected, from these ten, the following sites to be addressed in the main review:

- the Dutch River Branches;
- the Scheldt Estuary;
- the Baie des Veys estuary (the Marshes of Cotentin and Bessin);
- the Humber Estuary; and
- the Norfolk Broads.

For each of these sites definite flood control projects were selected to be evaluated during the main review. To achieve the objectives, mentioned in Section 1.2, the following activities have been undertaken:

**Gathering of information**

Each case analysis started with a review of relevant documentation followed by interviews with participants in each project in order to gather the information required to assess strengths and weaknesses. Site visits have been undertaken where possible.

**Analysis of this information**

Once the necessary information was gathered a detailed analysis of this information was performed. To determine the success and failure of approaches, evaluation against the objectives of a project is crucial. To ensure comparability of results across all five cases, the analysis of each project was structured according to the basic *frame of reference* (see also Chapter 2) determining:

- each project’s strategic and operational objectives, and
- the basis for the decisions made to achieve those objectives, including
  - the system description;
  - the decision procedure;
  - the applied intervention (FCA); and
  - the effectiveness of this solution in achieving the objectives.

The frame of reference structure was chosen to ensure that each case analysis would describe the (1) implemented measures, (2) the extent to which these measures achieved the predefined objectives and (3) the circumstances that helped or inhibited success.

**Preparing case descriptions**

The information derived in the previous steps was then collected in convenient case descriptions (Chapters 3 to 7). The descriptions together form a catalogue containing concise descriptions of each project’s approach to the planning, design, implementation and operation of FCAs.
and a list of ‘best practice’ suggestions per project. The resulting catalogue thus forms an important input for the best practice manual that is to be developed in later stages of the FRaME project.

**Overall analysis**

What is ‘good practice’ in one project might be less effective when different circumstances apply. So the main review phase concludes with an overview of lessons learned to feed into the planning and design of the FRaME demonstration projects (Chapter 8).

### 1.4 Report structure

This report aims to provide a catalogue of FCA case descriptions. Each case is analysed in a similar way, using the frame of reference approach, enabling inter-comparison of cases. To summarize the working of a particular case, Key Performance Indicators (KPIs) are analysed per project. The frame of reference methodology and the selected KPIs are described in brief in the next chapter. Chapters 3 to 7 contain the FCA case descriptions. Each description starts with a KPI summary table. The background information for each KPI helps to identify which factors contributed to or impeded successful operation of a given FCA. This, more detailed, information comprises the main part of each case description. Based on the detailed information, ‘best practice’ suggestions derived from each case are formulated at the end of each case description. Chapter 8, the final chapter, draws overall conclusions based on an inter-comparison of case descriptions.
2 Outline of analysis framework

2.1 Case analysis: the ‘frame of reference’ method

The aim of the work under WG 1 is to identify projects where FCAs have been implemented and evaluate the effectiveness of the suggested solutions. Most project evaluations start with data collection; much like the FRaME project. To enable a useful extraction of ‘lessons learned’, it is important to analyse each project according to a suitable framework; an important lesson learned *inter alia* from the EU ICZM demonstration projects. The University of Twente, in close cooperation with WL|Delft Hydraulics and the Dutch National Institute for Coastal and Marine Management (RIKZ), initiated the development of a framework that would help efficient identification of those elements that are most likely to be of interest in project evaluation studies.

The resulting methodology was called the ‘frame of reference’-methodology (Van Koningsveld, 2003). In short this methodology aims to explicitly link the management objectives at hand and the technical (and administrative) solutions that aim to achieve those objectives. Van Koningsveld and Mulder (2003) applied this methodology, in their evaluation of Dutch coastal policy. Their analysis revealed a set of basic elements that proved to be generically useful in efficient structuring of policy evaluations.

As basic elements Van Koningsveld and Mulder (2003) identify the explicit definitions of both strategic and operational objectives applied in a 4-step decision recipe of (1) a quantitative state concept, (2) a benchmarking procedure, (3) a design procedure for measures or intervention and (4) an evaluation procedure (see Figure 2.1). Analysis of all these elements results in a clear summarising ‘picture’ of the problem at hand and the way it is now handled. This quality forms one of the most interesting

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**Figure 2.1: The basic frame of reference**

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characteristics of the basic frame of reference, viz. its effectiveness in facilitating discussions on policy development, implementation and evaluation between managers and specialists (Van Koningsveld et al., 2004). The next section provides a brief description of each of the elements from the basic frame of reference.

2.1.1 Management objectives

To determine success and failure of an approach, the evaluation against the objectives of a project is crucial.

**Strategic objective**

Strategic objectives provide the long term context for policy and management. They express the vision of the interdependencies of the natural and the socio-economic system and of the role of man therein. Strategic objectives tend to vary slowly. Nonetheless they have a profound impact on the kind of policy and management that is required and acceptable.

**Operational objective**

The operational objective expresses our vision on how to handle the interactions between the natural and the socio-economic system. As such it is a concrete implementation of the strategic objective. Operational objectives are assumed to be related to the status of values and interests in the area under analysis. As such the operational objective should include an explicit indication regarding the temporal and spatial scales involved. It may take more than one operational objective to cover the strategic objective.

2.1.2 Decision process

From the strategic and operational objectives follows our vision on potential and acceptable human interventions. A fully developed decision process for intervention coherently addresses the following elements:

1. **Quantitative state concept**

To enable objective and reproducible decision making, a quantitative concept needs to be developed that describes the state of the system or certain aspects thereof in an appropriate form. The appropriate form is determined by the strategic and operational objective as well as by the next steps in the decision process. Practical effectiveness is closely linked with knowledge of the system’s behaviour.

2. **Benchmarking procedure**

A benchmarking procedure is necessary, so that we can systematically and objectively determine when to intervene in the system. Intervention is required when a discrepancy arises between the current system state and a desired or reference system state. Implicit differences in the desired
system state often trigger heated discussions on what is in the interest of the management objectives and what is not. To help useful discussions, the current as well as the (implicitly) desired state should be made explicit, preferably expressed in terms of the quantitative state concept chosen in the previous step. This element of the decision process often relies on measured or predicted trends in state descriptions, costs and benefits.

3. Intervention procedure

An intervention procedure specifies how we should manipulate (part of) the system in order to bring it to a desired state. It specifies not only the type of intervention but also the method to determine its design. Knowledge of the system, in particular regarding physical processes, plays a crucial role in this element. The design procedure should use the quantitative state concept as one of its primary building blocks. Furthermore it should at least ease significant manipulation of the system’s current state towards its desired state identified in the previous step.

4. Evaluation

The decision process and the effects of its application should be evaluated. This evaluation should take place in the development stage (expected effects), as well as after some period of application (actual effects). First of all, one needs to assess whether or not the operational objective is being sufficiently achieved. If this is not the case, the decision process may have to be changed. If the operational objective is satisfactorily achieved, it is still necessary to evaluate the management efforts, but now against the wider perspective offered in the strategic objective. This may trigger modifications in the decision process, but it may also result in an adaptation of the current operational objective, or the formulation of a new one.

A simple example of the outlook of a ‘frame of reference’ in the analysis of FCAs could be:

![Diagram showing a potential frame of reference for the analysis of FCAs]

**Figure 2.2:** A potential frame of reference for the analysis of FCAs

- **Strategic management objective:**
  “Sustainable preservation of functions and values in and around some given estuary”

- **Operational management objective:**
  “Maintainance of favourable physical conditions for functions and values present”

- **System description:**
  How are ‘favourable conditions’ to be defined given current presence of functions and values?
  *E.g. in terms of flood risk*

- **Decision process:**
  What is the actual state of the physical conditions?
  *E.g. risk: 1/1500 per year*
  What is their desired state in this context?
  *E.g. norm: 1/2000 per year*

- **Intervention:**
  When intervention is needed (previous step)? How to design and implement a FCA to meet the project objectives?
  *E.g. x cm waterlevel reduction under design conditions FCA*

- **Evaluation:**
  Was the operational objective achieved?
  Was the strategic objective achieved?
2.2 Summarising effectiveness: Key Performance Indicators

The FCA reviews the cases according to the frame of reference methodology. The analysis follows the following steps:

As a first step we start with an inventory of the strategic and operational objectives that were formulated for the FCA under consideration. Clearly establishing the objectives of a FCA is crucial in order to enable a useful evaluation of its success. As key performance indicators (KPIs) we identify whether or not objectives have been formulated.

KPIs: Objectives
- A clear strategic objective is developed
- A clear operational objective aimed at realising the strategic objective is developed

To enable a fruitful analysis that yields useful best practice suggestions we are not just interested in the presence of objectives, we also look at their actual implications. To look into that, as a second step we investigate how the flood control problem was ‘framed’ for a particular FCA. To enable a rational design of the FCA, generally information regarding storage capacity, water levels, discharges etc. is needed. As key performance indicators (KPIs) we identify whether or not such state indicators have been formulated, and to what extent these are quantified using monitoring, measurements and modelling.

KPIs: Quantitative state description
- A clear state definition following from the operational objective is developed
- A functional monitoring network is in place to quantify the state definition
- A functional measurement network has been in place for some time enabling historic analysis of data
- A functional modelling system is in place that helps to predict changes in the values of the state definition if necessary

It is clear that these KPIs support a rapid overview of the presence of some essential elements of the project. However, the real information is in the actual state definitions themselves. Based on for example the water levels in the main channel, as defined in the previous step, a rational decision regarding the operation of the FCA can be made.

As a third step we analyse the decision procedure that is used to operate the FCA. In some cases an active operation may be required, in most of the cases; however, the FCA will be operated passively for example through the installation of a weir. In either case a desired and a current state of the system should be defined in order to evaluate performance. As key performance indicators (KPIs) we identify whether or not a decision procedure is present and if a clear image of the desired and current state of the system exists.
KPIs: Decision procedure
• A clear decision procedure using the state definition is developed
• A clear definition of the desired state of flood risk is developed
• A clear definition of the current state of flood risk is developed

Once it is clear that based on current water levels a piece of land needs to be flooded in order to maintain a previously determined state of flood risk, an intervention in the river-system is needed. As a fourth step we describe the hydraulic intervention that is present in a given FCA. The intervention may be active or passive in nature but should always have the desired effect on the state of the system, for example expressed in terms of flood risk reduction. Furthermore, the operation and maintenance of an FCA could require a clear timing and definition of responsibilities. As key performance indicators (KPIs) we identify whether or not an intervention procedure is present, whether or not it has an effect on the state of flood risk and whether or not timing and responsibilities are sufficiently clear.

KPIs: Intervention procedure
• A clear intervention procedure based on the decision procedure is developed
• The intervention scheme has effect on the current state of flood risk
• The intervention scheme contains a description of the timing and responsibilities during the operations

Once all these elements have been made clear, we can evaluate the success of that FCA. This success is closely related to the measure by which it has been successful in achieving its objectives. As a fifth, and final, step we therefore assess the extent to which a given FCA has been successful in achieving its objectives.

KPIs: Evaluation
• The FCA strategy succeeds in achieving its operational objectives
• The FCA strategy succeeds in achieving its strategic objectives.
3 The Dutch river branches: Aakvlaai

3.1 Summary of Key Performance Indicators

<table>
<thead>
<tr>
<th>KPIs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic objective</td>
<td>“The main objectives are strengthening of the ecological structure (by zoning of recreation and nature) and creating more room for the river.”</td>
</tr>
<tr>
<td>Operational objective</td>
<td>“Lowering of the design high-water levels on the Meuse, enough to warrant the extra cost of the required hydraulic works”</td>
</tr>
<tr>
<td>State description</td>
<td>The state of river is well described. Indicators, models as well as all necessary quantitative information are available.</td>
</tr>
<tr>
<td>Decision procedure</td>
<td>A (passive) decision procedure is developed.</td>
</tr>
<tr>
<td>Intervention procedure</td>
<td>An intervention is designed. The river dike is lowered along a length of 1.3 km to a height of 2.00 m+NAP so that Aakvlaai automatically participates in the discharge when needed. A new landward dike is constructed and a direct connection with the surrounding waters is created. The effectiveness of Aakvlaai comes from diverting a significant part of the river discharge from the Bergsche Maas to the Spijkerboor.</td>
</tr>
<tr>
<td>Evaluation operational objective</td>
<td>Computer models have shown that the FCA reduces water levels on the river by 8 cm. Based on this, it is assumed that the intervention will be sufficiently effective.</td>
</tr>
<tr>
<td>Evaluation strategic objective</td>
<td>The objectives are partially achieved. The nature recreation objective has been achieved, although the vegetation in the area has yet to fully develop. The project is too young (app. 2 years) to make statistically significant statements regarding Aakvlaai’s effectiveness as a flood control area.</td>
</tr>
</tbody>
</table>

3.2 General case description

The Aakvlaai project is located southeast of the Biesbosch national park (see Figure 3.1b), that itself is located approximately 30 km southeast of Rotterdam (see Figure 3.1a). The Biesbosch is divided up into various parts. Several polders, used for agriculture, are responsible for a fragmentation of the nature reserve area. Planners aim to reintroduce natural conditions into these polders in order to create one large nature area. A larger area offers greater opportunities for species of plants and animals that have long since disappeared.

For six polders, together constituting an area of 2500 hectares, nature development plans have been prepared. Landowners were bought out, after which the area was to be restored to a landscape consisting of a multi channel system with sloping banks and islands in between, that was common there in earlier days.

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1 This description has made use of the report “Voorbeelden boek. Parels van vernieuwend waterbeheer” Ministerie van Verkeer en Waterstaat et al. (2001), and “Room for the Rhine branches in the Netherlands; What the research has taught us” Silva et al. (2001).
The Aakvlaai area (see Figure 3.1b), which mainly consisted of farmland that had been reclaimed relatively recently, is actually located just outside of the Biesbosch. It is not so much the Aakvlaai area itself as the partly-surrounding Biesbosch area that triggered the shift in its land use. With the finalisation in the early 1970’s of the nearby Haringvliet sluices, that were built in the context of the Delta project, the level difference between ebb and flood in the Biesbosch area was strongly reduced (from 1.8 m to 0.4 m). With the milder tidal regime, the area remained navigable throughout the tidal cycle and water recreation started to flourish. The recreation activities had a negative impact on the environment and a decision was made in 1975 to close of some of the most valuable creeks for water recreation. The active recreation lobby did not accept this closure of the heart of the Biesbosch area. The pressure resulted in a promise to compensate this loss with the creation of the so called ‘Miniature Biesbosch’, with an area of 150 hectares, in the polders located in the south east corner of the Biesbosch. The project received the name of the local creek: the Aakvlaai.

From 1984 onwards, considerable public controversy preceded the designation of the Biesbosch as national park in 1987. As part of the Aakvlaai project the function of the area had to be changed from agriculture to nature recreation. The local inhabitants and municipality strongly opposed what they considered to be the pointless creation of a new recreational area on their lands. Between 1984 and 1998, four exhaustive participation procedures were undertaken, on practically each occasion running to the highest level of appeal.

At the very end of all the procedures yet another development emerged. Triggered by the high water events of 1993 and 1995 along the Meuse, a project was started to create more ‘room for the river’. The high water events had shown that flood risks are high along significant stretches of the Dutch rivers. Due to climate change, sea level rise and subsidence, high water events were, and in fact are, expected to occur ever more frequently in the future. The resulting flood risks are exacerbated by bottlenecks,
caused by villages and towns colonizing the river’s floodplains. To be prepared for the expected increase in unfavourable hydraulic conditions a national project was started to create more ‘room for the river’. The additional room is needed to lower the peak water levels on the river itself and thus to at least maintain the current level of flood risk despite an increased design discharge. The room for the river approach has been adopted alongside the other potential solution, viz. raising the dikes. Throughout the 1990’s it was felt that, with an expected increase in peak water levels in the order of tens of centimetres, the latter approach alone could not be sustained.

The Biesbosch area lies in the Dutch delta area where the largest rivers of the Netherlands find their way to the sea. Although, as a result of the Delta works the tidal range in the Biesbosch area had been significantly reduced, flooding is still a real issue. The main threat is now not so much the sea as the fresh water from the rivers that flow through the area. From this perspective the Public Works department wanted to participate in the Aakvlaai project because they saw the opportunity to use the area as an additional floodplain. This initiative was embraced by the initiative to turn Aakvlaai into a recreation area, under the precondition that the original plans could not be changed significantly. Study showed that the initiatives could be integrated with almost no modifications to the original plans and in 1999 the work began.

Figure 3.2: Outlook on the Aakvlaai area
3.3  FCA analysis: Aakvlaai

3.3.1  Objectives of depoldering the Aakvlaai area

**Strategic objective**

The project Aakvlaai is part of the ‘room for the river’ project to implement flood-prevention policy in the heavily inhabited regions along the Rhine and Meuse. The project looked specifically at the agricultural Allardspolder where land had been acquired to set up a ‘miniature Biesbosch’. In short, the strategic objectives of depoldering the Aakvlaai area were the following:

1: strengthening the ecological structure through zoning of recreation and nature, and
2: reduction of flood risk by creating ‘room for the river’

The Aakvlaai polder, situated in the Brabantse Biesbosch, has been appointed as a recreation development area. The Aakvlaai area will be developed into a nature recreation area in order to compensate for creeks that have been closed for recreation in the past. All ecological effects shall be implemented in accordance with the Nature Policy Plan. The project is not subject to the Bird and Habitat Directives.

To create additional room for the river, the Aakvlaai polder will be used as a flood plain in order to reduce peak water levels in case of high water events. The required measures are not to interfere with the original plans that were developed for the recreation objective. As part of the FCA review of the FRaME project, this report will primarily focus on this second element of the strategic objective.

**Operational objective**

The main reason to create additional room for the river lies in the desire to safely handle the expected future increase in the design high water levels on the river and in the design relative sea level. These increased water levels can be handled by raising the dikes as well as by taking the peak of the high water wave. The latter can be achieved by creating extra storage and expanding the discharge capacity at strategic points in the river. As a result, creating additional storage capacity in itself, although obviously important, is generally not considered to be a valid operational management objective. Instead the focus is on lowering design high water levels at specific locations in the river.

At the time that the potential of the Aakvlaai project as an FCA was under investigation, studies like “Integrale Verkenning Benedenrivieren” (IVB) were still in progress. As a result no (explicit) quantitative operational target with respect to peak water level reduction was identified. Implicitly, however, it was clear that with the expected future conditions, water levels in the vicinity of the Aakvlaai project had to be reduced by centimetres, rather than millimetres.
3.3.2 The problem

As stated above, Dutch water managers work with so-called design high water levels (in Dutch: Maatgevend Hoog Water - MHW). In the lower river region, these design water levels are calculated based on the normative peak discharge, the river geometry, sea water levels, design flood frequency and the probability of failure of barriers. Approximately 7000 model calculations (taking into account 9 different river discharges, 6 storm surge levels, 16 wind directions, 5 wind speeds, 2 barrier scenarios (2 open or 2 closed barriers) and 2 river states (Meuse and Rhine dominance)) yield design high water levels throughout the entire lower river region (Min V&W, 2001). For the Aakvlaai region, the design standard is for a discharge occurring once in every 2000 years to be safely conveyed to the sea. The calculations yield a design high water level of 3.00 m+NAP (NAP is the Dutch ordnance level) on the Bergsche Maas at the location of the Aakvlaai project. From the operational objective it was learned that the main goal of the Aakvlaai project was to lower the design water levels by a significant amount (in the order of centimetres). At Aakvlaai this was to be achieved by a local alteration of the river geometry, or in other words through the creation of a flood control area.

It is known that high water waves travelling down rivers can cause peak water levels that last from hours to sometimes days. As a result, if the peak itself is to be stored an appropriate storage capacity would be needed to cause any significant peak reduction. Given the local circumstances, the storage capacity provided by an area of the modest size of Aakvlaai (150 ha) is not large enough to cause a significant peak water level reduction (compared with for example Tielrodebroek - Chapter 4).

Consequently rather than storing the peak itself, the area will be involved in the rivers discharge capacity. This way the area works as a peak stage reducer as long as the high water event lasts. However, Aakvlaai will not only work as floodplain. Its location and interior design diverts part of the river discharge from the Bergsche Maas to the Spijkerboor (see Figure 3.3a). This causes Aakvlaai to be particularly effective as an FCA. To achieve the required peak reduction of the high water wave it is necessary to initiate the flooding early. As a result the area is flooded at lower, more frequently occurring, water levels. However, if the flooding is initiated too soon, the area would flood so frequently that the recreational interests would be harmed; and a compromise therefore has to be reached. To enable rational decision making in this respect the project benefits from regular measurements that have been carried out by the Public Works department for a number of years, and the availability of numerical models that enable prediction of water levels throughout the river.

Besides meeting the flood control objectives, the water in the Aakvlaai area also has to suit certain recreational and environmental purposes. The creek system that was dug inside Aakvlaai had to be carefully designed to serve the recreational objectives (maintain a minimal navigable depth) as well as environmental objectives (prevent occurrence of blue algae, stimulate conditions for desired ecotypes, etc.). However, detailed analysis of this particular subject is outside the scope of the FCA review.
3.3.3 The project

Before the construction of the Aakvlaai project, the main goal for the lower river area was to reduce the design high water levels with respect to the expected increase of design water levels in the future. To reduce the water levels, and the consequent pressures on dikes, the Aakvlaai area would basically be turned into a floodplain of the (Bergsche) Maas. The decision on whether or not this was a valid option depended on the expected reduction in the design water levels. Based on modelling work the introduction of the Aakvlaai area as a flood control area was expected to result in a local reduction in the indicative peak water level of 8 cm. This was considered to be more than enough to warrant the extra cost of creating the hydraulic works needed for flood control.

The operational objective did not provide a quantitative statement regarding a minimum required reduction. The reason for this, as mentioned earlier, was that the ‘room for the river’ initiatives were in a relatively early stage. Despite the lack of a clearly defined minimum effect, Public Works department workers could still evaluate the merit of the calculated 8 cm peak reduction. Basically this evaluation followed from a comparison with other (similar) areas and their estimated effectiveness. Calculations showed, for example, that the Zuiderklip area, with a surface of 400 hectares, would result in a peak level reduction of 4 cm. The Noordwaard area, with its surface of 600 hectares was expected to result in a local peak reduction of 10 cm.

The remarkable effectiveness of Aakvlaai is caused by the diversion of a significant part of the river discharge from the Bergsche Maas to the Spijkerboor (see Figure 3.3a). Although at the time studies like IVB, were still in progress, the river area that included Aakvlaai was expected to have to cope with an increase in the indicative peak water level of in the order of 40 cm by the year 2015. The fact that 20 per cent of this increase was expected to be covered by the relatively small Aakvlaai area, provided more than enough justification to go ahead with the implementation.

The chosen idea for peak level reduction was to involve the entire Aakvlaai in the river discharge. For this purpose a spillway was to be constructed along the Bergsche Maas, so that the Aakvlaai area would automatically participate in the river discharge when certain water levels were reached. To ensure effectiveness of the measure, the river water entering the area would have to be able to exit at the other end. This was achieved by means of an opening in the dike along the Spijkerboor. To implement the above idea several actions had to be undertaken:

- *Construction of a new dike further inland to protect the hinterland.*

In order to enable discharge through the Aakvlaai polder, the original dike ring basically had to be breached. To protect the hinterland, a new dike was constructed first along the north eastern border of Aakvlaai (see Figure 3.3). It should be noted, however, that this relocating of the dike was also needed in the original plan that only took the recreation objective into consideration. Therefore the original plan did not have to be altered in this respect.
The new dike is 3.5 kilometres long and constructed using soil that was dug from the interior of the Aakvlaai area. In fact the entire project was constructed with a neutral soil balance, meaning that no soil was to be ‘imported’ to or ‘exported’ from the area. This neutral soil balance approach was adopted to circumvent time consuming procedures needed for acquiring the necessary permits.

- **Construction of the interior of Aakvlaai.**
  To ease the creation of the desired nature recreation environment, a system of creeks has been dug inside Aakvlaai. The creeks create a system of channels, islands and quays (Figure 3.3a shows the original plan; Figure 3.3b shows how the plan has been put into practice). The fact that Aakvlaai was to be used as a ‘nature recreation area’ implied the need for a relatively detailed design. Elements like quays and miniature beaches would not have been introduced if the area only had a ‘nature conservation’ function. In fact other nature conservation development projects in the Biesbosch, like Noordwaard and Zuiderklip, have been designed in a much coarser manner. There, only the basic system of creeks will be dug out, after which nature is free to take its course.

  Because Aakvlaai has a specific recreational function the design had to meet more strict requirements, for example the creeks needed to be kept open and at sufficient depth, etc. A key element of this interior design of Aakvlaai is the open connection with the surrounding waters. The open connection allows boats to enter the area and introduces a tidal range into the area that helps to create and maintain certain natural values. The introduction of a tidal influence into Aakvlaai, in itself, however, does not contribute to a reduction of the high water levels.

- **Lowering of the dike to an overflow dike**
  To ease Aakvlaai’s participation in the river discharge, the dike along the (Bergsche) Maas was lowered over a length of 1.3 km to create a spillway. The lowering of the dike from the original 3.40 m+NAP to the current 2.00 m+NAP ensures that the area contributes to the river’s discharge capacity in case of high water.

  The choice for 2.00 m+NAP has been made rather arbitrarily. Nonetheless some rules of thumb may be applied. A level of 2.00 m+NAP is associated
with a flooding frequency of once every two years. These high water events were expected to occur mainly in the early spring and late autumn seasons. This is more or less outside the recreation season, which minimizes conflicts between the two main functions of Aakvlaai, viz. nature recreation and room for the river. Reduction of the crest level to for example 1.80 m+NAP would greatly increase the flooding frequency and thus the inconvenience for tourists. From the recreational objectives this would be very undesirable. An increase of the crest level, on the other hand, to for example 2.50 m+NAP would reduce the flooding frequency to about once every 25 years. On top of that it would significantly reduce the effectiveness of Aakvlaai’s discharge capacity. Through the open connection, the water levels in the river and inside Aakvlaai are more or less the same. So rather than by storage, the area derives its effectiveness from its discharge capacity, which is basically determined by the area above the crest level of the spillway. In summary a lower crest will be harmful to the recreation objectives whereas a higher crest level will adversely affect the flood control objectives. As a result the selected 2.00 m+NAP, although somewhat arbitrary, is close to optimal.

The length of the spillway is determined by the following considerations. In cases of high water, a short length of the spillway would result in very high flow velocities over the crest of the dike. To prevent the need for (visually unattractive) hard defence works along the crest, the length of the overflow was increased. Calculations showed that a length of 1.3 km would reduce the flow velocities at the crest to below 1 m/s. Besides a longer crest, the slopes at either side of the crest were reduced to the shallowest possible. This was done to create a so-called hydraulically smooth overflow (low turbulence). The low flow velocities and the shallow slopes enabled the use of grass on the spillway, which greatly reduced the cost of the intervention. A natural overflow was also to be preferred from the nature recreation objectives.

• Creating an open connection between Aakvlaai and the Spijkerboor
In June 2001, the dike along the Spijkerboor was opened to create an open connection between the nature and recreation area Aakvlaai and the surrounding waters. As a result the Biesbosch area had now increased by an area of 150 hectares. The opening had a width of approximately 100 m at the normal water levels. This width was enough to satisfy the requirements derived from the nature and the recreation objectives.

From the flood control objectives, however, again some alterations were made in the original plan. Just as in the case of the overflow dike, the flow velocities through the open connection with the Spijkerboor would rise to unacceptable levels in case of a high water event. The water slowly entering Aakvlaai over the broad and smooth spillway would have to be rushed through the relatively small opening on the opposite side. To counter this problem it was decided to make the opening with the Spijkerboor a stepped construction. To prevent major changes to the original plan the opening at normal water levels remained approximately 100 m. To maintain acceptable flow velocities through the mouth, the opening was broadened at higher levels, albeit in steps. In this manner the width of the open connection was approximately 300 m at water levels of 2.00 m+NAP and higher. This approach reduced flow velocities to below 1
m/s for all conditions, which again limited the need for hard protection works to the minimum.

- **Apply flood risk mitigating measures**
  Since the Aakvlaai area was now outside the dike ring, the area became flooded more regularly, as was to be expected. One restaurant that was to remain in the area, however, suffered from these flood events. As a final measure this restaurant was rebuilt on top of an artificial mound. A raised road was constructed to connect the mound with the dike ring so as to ensure its accessibility even during high water events.

### 3.3.4 Evaluation of operational success

#### Recreational objectives

The Aakvlaai project has met its primary recreation objective well. The area is used intensively for recreation. The quays attract a lot of boats (the small white dots in Figure 3.3b), the grass attracts campers and the miniature beaches are used intensively for swimming. The channel system was intentionally designed let the river water run in and out of the area. Active flow was to keep the navigational channels at a minimal depth. Furthermore the connection with the surrounding water was intentionally located at the western part of the area rather than the southeast. The reason for this was to prevent excessive settling of silt from the river water. So far the accessibility of Aakvlaai has been up to standards. However, despite the western entrance, silt does enter Aakvlaai. In particular the miniature beaches suffer from the siltation and maintenance of these beaches turns out to be not very cost efficient.

#### Environmental objectives

With respect to the environmental objectives the project also seems to be successful. After the construction of the channel system, nature basically has been left to take its course in the area. Vegetation has taken hold and the area has taken on its green appearance (see Figure 3.3b). The entrance and the connecting channels were designed in such a manner that the tidal influence would be felt in the entire area. Although part of the water in the creeks flows in and out, computer models had shown that the water in the southeast part of Aakvlaai would not be refreshed. There was some initial worry that during warm weather conditions this could result in toxic algal blooms. The summer of 2003, however, has been exceptionally warm and no problems of this nature have occurred.

#### Flood control objectives

Whether or not the area is really effective as a flood control area has not yet really been identified as no major high water events have occurred since its opening. Only on one occasion did Aakvlaai actually participate in the river discharge. With a water level of 2.11 m+NAP the area was involved in the discharge only slightly (see Figure 3.4a and b). With water levels inside only slightly lower than those outside, the flow velocities over the crest were small, as was predicted. To establish the effectiveness of the
area it was decided to monitor water levels and in particular flow velocities inside the area and through the inlets and outlets. The effectiveness of the designs, however, can only be tested usefully at circumstances close to the design conditions, for example 2.50 m+NAP and higher. As a result, so far no real quantitative performance indication can be given at this point although the first signs are positive.

![Figure 3.4: First high water event in Aakvlaai: February 23rd 2002 2.11 m+NAP (Source: H. Jagt).](image)

(a) Looking to the North over a drowned Aakvlaai towards restaurant De Steen on top of its dwelling mound

(b) Looking at the spill way: Aakvlaai on the left and the Bergsche Maas obscured by reeds on the right

### 3.4 General conclusions

After 25 years of planning Aakvlaai is now in use as a nature recreation area and a flood control area. The involvement of a wide range of disciplines in the technical design of Aakvlaai has resulted in an FCA that is effective in achieving the multiple objectives set out in the project. The carefully designed interior of the area has created physical conditions that are favourable to the predetermined ecotypes (water levels, submergence frequency), to the recreational requirements (water depth, flow velocities, water quality, refresh rates) as well as to the flood control requirements (flow velocities, flooding frequency, discharge capacity).

Although some people are of the opinion that a detailed design like Aakvlaai qualifies more as architecture than nature, the desired vegetation has started to develop. Over time the area is likely to take on an ever more natural appearance. During the exceptionally warm summer of 2003, the area was intensively enjoyed by many as a nature recreation area and no toxic algal blooms have occurred. The design until now has been tested once under flooding conditions during which the area behaved as was predicted. As such the Aakvlaai project is a fine example of a multi objective FCA.

Besides the technical design, the realisation process of Aakvlaai provides a clear illustration of the necessity to establish an effective communication between stakeholders throughout the decision making process. It became
equally clear, however, that compensation and communication are by no means a guarantee for a swift and smooth process.

3.5 Lessons learned

After interviewing some people that were involved in the Aakvlaai project it is possible to formulate some interesting lessons that can be drawn from their experience:

- It is always wise to make a soil flow plan. This plan should identify the soil types that are to be excavated and where the material is best reapplied. For example, dikes require different material than the miniature beaches, which in turn require different material than the small elevated areas, etc. In the case of Aakvlaai, working with a neutral soil balance proved to be particularly useful in preventing further delays through permit procedures.

- One should carefully design the interior of an FCA to suit the needs that can be derived from its land use objectives. A comparison between Aakvlaai and the nearby Noordwaard, shows, for instance, how a ‘nature conservation’ area warrants a much coarser design than a ‘nature recreation’ area.

- The construction of miniature beaches should be avoided near the spillway as the beaches may disappear in flood events. When the surrounding water contains silt it may be wise not to include miniature beaches at all, as under those circumstances they are expensive and difficult to maintain.

- Small elevated areas, used for example for grazing cattle, in between channels and islands were considered to be a useful addition to the landscape. Such areas may therefore be applied when digging of additional creeks is not feasible or unwanted.

- Once creek excavation starts, the reduced weight may cause the remaining soils to rise. When for example a navigable depth is an important issue, this effect should be monitored and countered when necessary. Obviously the importance of this phenomenon varies with the uses identified in the objectives.

- Design the creek system in such a manner that the water flow requirements in the entire area are met. The hydraulic resistance of channels, for example, needs to be taken into account to evenly distribute the flows. In case of a tidal range the channel system should be wide enough so as to allow the tide to penetrate the entire area. Furthermore the occurrence of ‘dead’ areas should be avoided.

- Through in and outflow, the water in the system is partially refreshed. However, generally some area that is not refreshed will remain. This area should be monitored for the occurrence of environmentally unwanted conditions (anoxia, algal blooms).

- When the soil within the FCA is excavated the possibility of ground failure should be considered. Pressure caused by the higher water levels in the river may cause the up-welling of ground water in the new floodplain. When the pressure is too large the soil could break and river water may cause piping underneath the dike. This could have adverse effects on the stability of the dike.

- If the FCA is to be excavated to create creeks, precautions should be implemented so that the creeks cannot migrate towards the foot
of the dikes and cause instability. Internal creeks may be allowed to migrate.

- The Aakvlaai project has suffered serious delays which has led to a significant increase in cost. A risk analysis should be undertaken at the beginning of each project. This risk analysis should involve an assessment of all things that could go wrong so as to provide a realistic estimation of budget regarding time as well as money.
- The effectiveness of Aakvlaai in reducing the indicative high water levels is mainly due to its positive effect on the amount of water that is discharged through the Spijkerboor area instead of through the Maas. Without this effect on the discharge distribution over the two branches, Aakvlaai would have been much less effective.

3.6 Acknowledgements

For the information regarding the Aakvlaai project, the FCA review team acknowledges the support by Romke van Willenswaard (DLG Tilburg) and Henk Jagt (Public Works department - Rijkswaterstaat).
4 The Scheldt estuary: Tielrodebroek

4.1 Summary of Key Performance Indicators

<table>
<thead>
<tr>
<th>KPIs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic objective</td>
<td>“The main objectives are to guarantee protection from flooding, access to the ports along the Scheldt and naturalness of the physical and ecological system.”</td>
</tr>
<tr>
<td>Operational objective</td>
<td>“Increase safety levels to a level of once in 10,000 years”</td>
</tr>
<tr>
<td>State description</td>
<td>The state of the estuary is well described. Indicators, models as well as all necessary quantitative information is available.</td>
</tr>
<tr>
<td>Decision procedure</td>
<td>A (passive) decision procedure is developed. During a storm surge, the Tielrodebroek FCA will automatically store excess water if water levels in the Zeeschelde exceed the level of 6.80 m+TAW.</td>
</tr>
<tr>
<td>Intervention procedure</td>
<td>An intervention is designed. A new ring dike has been constructed. The river dike along the Zeeschelde has been lowered to 6.80 m+TAW so that the FCA automatically comes into operation when water levels exceed that value.</td>
</tr>
<tr>
<td>Evaluation operational objective</td>
<td>The construction of Tielrodebroek FCA contributes to achieving the operational objective, but is just one of a range of measures undertaken.</td>
</tr>
<tr>
<td>Evaluation strategic objective</td>
<td>The construction of Tielrodebroek FCA contributes to achieving the strategic objective, but is just one of a range of measures undertaken.</td>
</tr>
</tbody>
</table>

4.2 General case description

The Tielrodebroek flood control area (FCA) forms an integral part of a larger project for increasing the safety against flooding in the Scheldt estuary. Before describing the Tielrodebroek FCA in detail, a description is given of the Scheldt estuary context.

The Scheldt rises 100 m above sea level in Northern France to the north of St. Quentin and has a river basin of 21,000 km². It flows into the North Sea 350 km from its source and is joined en route by a number of tributaries, the largest being the Lys, the Dender and the Rupel. The Scheldt divides into four sections on Flemish and Dutch territory, i.e. the Upper Scheldt (upstream of Ghent on Flemish territory), the Upper Zeeschelde (from Ghent to Antwerp), the Lower Zeeschelde (from Antwerp to the Belgo-Dutch border) and the Westerschelde. The Zeeschelde basin derives its name from the Zeeschelde (Upper Zeeschelde and Lower Zeeschelde), and comprises the Zeeschelde and all openly connected tributaries. The Scheldt river catchment and sub-catchments are presented in Figures 4.1 and 4.2.

2 This description has made use of the report ‘Updating the SIGMAPLAN, Waterways and Maritime Affairs Administration, Flanders, 2001’
Where the river mouth meets the North Sea, via the Westerschelde, the tidal action reaches far inland in the form of an elongated wave. This tidal action is evident on the Zeeschelde (to Ghent), the Durme (to Lokeren), the Rupel, the Kleine Nete (to Grobbendonk), the Grote Nete (to Itegem), the
Dijle (to Haacht) and the Zenne (to Zemst). Thus, the Zeeschelde basin is characterised by a tidal action, which can be observed along the lower rivers and in the transitional area towards the upper rivers. Only in these transitional areas do upstream discharges affect water levels significantly. The Grote Nete is an example of just such a transitional area. Downstream of Rupelmonde, upstream discharges have only a negligible effect on the water levels of the Scheldt. Whereas, under normal circumstances, the tide rises and falls by 4 m on the Scheldt at Vlissingen, it can reach 5 to 6 m at Schelle. Further upstream resistance and friction losses take their toll, and the tidal difference drops to around 2 m at Ghent.

The Scheldt estuary is an economically important area especially due to its port activities. It is also a densely populated area (see Figure 4.3). Past floods resulting from storm surges in the Scheldt estuary have proven disastrous for the Flemish and Dutch populations. The North Sea tide can swell under the effects of a westerly to north westerly storm, causing a considerable rise of up to 3 m in the water level. When a westerly to north westerly storm combines with a rising tide this creates conditions known as a storm surge.

The Scheldt estuary has known several catastrophic storm surges in the years between 1350 and 1600. Large flood occurrences were the Saint Elisabeth flood of 1430, the Saint Felix flood of 1530 and the All Saints flood of 1570. A more recent event was the flood in February 1953. Stirred up by a heavy north westerly storm the Belgian and Dutch coastal waters rose to a height that had never been witnessed before. The water thrust into the estuary and broke through the dykes in several places. The Dutch Delta region suffered most and more than 1,800 people lost their lives. In Flanders there were “only” 6 victims, but the damage was wide-scale. The waters of the Scheldt reached the highest level ever recorded in Antwerp, 7.77 m+TAW, (reference level). After the heavy floods of February 1953 the Dutch Government decided to draw up and implement the DELTAPLAN.
Amongst other measures this involved sealing all the tidal inlets to the Delta with the exception of the Nieuwe Waterweg (New Waterway) and the Westerschelde and raising the dykes.

In January 1976 yet another heavy, north westerly storm stirred the waters again. In Antwerp the water level was recorded at 7.31 m+TAW. There were floods in numerous places along the Zeeschelde basin. In response, the SIGMAPLAN was drawn up and implemented by the Belgian Government.

The SIGMAPLAN was initiated in 1977 and is designed to protect the Zeeschelde basin (Figure 4.4) against storm surges from the North Sea. It involves three complementary measures:

- Heightening and improving of 512 km of dykes
- Laying out flood control areas and partitioning dykes
- Constructing a storm surge barrier at Oosterweel (Antwerp)

The Zeeschelde basin was to be given the same level of protection as the Westerschelde received under the Dutch DELTAPLAN. This implies turning a tide with a HWL of 8.97 m+TAW (reference level in 1977) at Antwerp. Such a tide has a 1 per cent chance of occurring per century, or once per 10,000 year.

<table>
<thead>
<tr>
<th>no.</th>
<th>Name</th>
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<th>Area (ha)</th>
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<tbody>
<tr>
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<td>Zeeschelde</td>
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<td>5.</td>
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<td>Berlare/Wichelen</td>
<td>Zeeschelde</td>
<td>84</td>
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<td>6.</td>
<td>Bergenmeersen</td>
<td>Wichelen</td>
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<td>Waasmunster</td>
<td>Durme</td>
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<td>8.</td>
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<td>Durme</td>
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<td>9.</td>
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<td>Lier</td>
<td>Beneden-Nete</td>
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<td>Lier</td>
<td>Beneden-Nete</td>
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<td>12.</td>
<td>Polder van Lier</td>
<td>Lier</td>
<td>Beneden-Nete</td>
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</table>

Table 4.1. Operational FCAs in the SIGMAPLAN

In 2001 an update of the SIGMAPLAN was initiated. By that time the option of the storm surge barrier had been discarded and about 79 per cent of the envisaged dyke elevation and improvement works had been carried out. Of
the 13 FCAs that were planned in 1977 (see Table 4.1 and Figure 4.5), 12 are already in use, covering a total area of around 533 ha.

Preparations for the 13th FCA, Kruibeke-Bazel-Rupelmonde (KBR), on the Zeeschelde have been finalised and the area is now being implemented. KBR is one of the demonstration sites in the FRaME project. It is the last large FCA that was originally planned in the SIGMAPLAN and covers an area of around 600 ha.

![Figure 4.5: Flood control areas in the Zeeschelde basin catchment (source: Meire et. al. 1995)](image)

The updated SIGMAPLAN revealed new insights to increase safety in the Zeeschelde basin, i.e. by optimising the catchment capacity of the valley areas. In this way, a higher level of safety can be achieved, there will be a smaller need for hard infrastructure and more land will come available for natural development. Instead of the storm surge barrier at Oosterweel extra FCAs will be developed, particularly in the upstream area of the estuary, and combined with other measures, such as partitioning.

### 4.3 FCA analysis: Tielrodebroek

Tielrodebroek was the first FCA to be established under the SIGMAPLAN and is now the largest operational FCA. It was established in the 1980’s and is not very well documented. Except for a few hydrodynamic studies there is hardly any documentation about its design and implementation. Yet, a first survey of the FCAs in the Zeeschelde basin, and the consultation of the responsible authorities in Flanders, has strengthened the viewpoint that Tielrodebroek should be included in this review on FCAs.
Key personnel involved in the design and implementation of Tielrodebroek has been interviewed to acquire the type of information that can help to generate best-practice material.

The Tielrodebroek FCA (Figure 4.6) was initiated in 1979. It is located adjacent to the Zeeschelde and Durme rivers and has an area of 93 ha. The land use of the area has not changed since implementation of the FCA and no area was purchased or purchased compulsorily. The area is mainly covered with grassland (especially for hay), with some smaller areas of corn fields and poplar trees. Until the 1960’s Tielrodebroek was flooded yearly, during the winter time. With the ringdike in place, the polder board has decided to irrigate the area again for several weeks each winter. As soon as the news of a coming storm surge arrives the irrigation is stopped to give the FCA its maximum overflow capacity.

4.3.1 Objectives of the Tielrodebroek FCA

Strategic objectives

The strategic objectives for the construction of Tielrodebroek follow from the original SIGMAPLAN from 1977. While the original SIGMAPLAN mainly aimed at protection from flooding, other values were of interest as well, although at the time this was not explicitly included. In 2001 the so called Long-Term Vision for the Scheldt Estuary was finalised. This combined Dutch-Flemish vision explicitly states objectives for the next 30 years and focuses on the three major functions of the estuary:

- protection against flooding
- access to the ports along the Scheldt
- naturalness of the physical and ecological system.

The desired situation for 2030 for ‘safety against flooding’ is that protection against the flooding of land adjacent to the Scheldt estuary remains a priority factor to be maximised in line with social development and
feasibility. This priority factor will include the retention of the natural estuarine system and adequate access to the ports on the Scheldt. The safety level will be improved to the maximum possible, on the understanding that absolute safety cannot be guaranteed.

**Operational objectives**

The objective of the original SIGMAPLAN is to achieve a safety against flooding which is measured as turning a tide with a HWL of 8.97 m+TAW. (reference level) at Antwerp. Such a tide has a 1 per cent chance of occurring per century, or 1/10,000 per year. The updated SIGMAPLAN calls for a new approach to safety, one in which different levels of protection are envisaged against flooding. The basic assumption is that flooding can not be avoided at all times. The idea is that water management infrastructure can be lighter in areas where the effects of flooding are less serious. The updated SIGMAPLAN states that when the required tools are available, it is justified move away from an overall protection of the river basin based on a given chance occurrence (for example 1/10,000).

Calculations that were carried out for the updated SIGMAPLAN revealed that the establishment of extra FCAs (instead of the storm surge barrier) would lead to a safety level of 1/4,000 per year. This is the same safety level that exists for the Dutch part of the Scheldt estuary (Westerschelde). It is assumed here that about 4,000 ha of extra space in the Zeeschelde basin can be found for the river through 'depoldering' and the creation of FCAs. A number of studies were carried out to investigate a range of measures. One of those measures is the construction of a connection between the Westerschelde and Oosterschelde, the so called Overschelde. Exploratory calculations reveal that this would give a safety level comparable with that of the original SIGMAPLAN, i.e. protection against a storm surge with less than a 1/10,000 chance per year of occurring.

**4.3.2 The problem**

The establishment of FCAs will contribute to the objective of increasing safety levels. The FCAs operate by deliberately keeping the river embankments lower, a quantity of water from a storm tide wave can be allowed to flow over at points where these areas have a large catchment capacity. It is designed to store excess water during storm surges and the main effect here would be to curtail the height of the storm surge upstream. Tielrodebroek is one of the FCAs that contributes towards achieving the objectives of the original as well as the revised SIGMAPLAN.

Extra storage capacity is needed when the water level in the Scheldt river exceeds 6.80 m. TAW. The Scheldt dike has been lowered to this same height, so it will start overflowing as soon as the water level in the river exceeds 6.80 m. TAW. The working of this FCA does not require an active decision to be taken, it will come into operation when the design water levels have been reached (see Figure 4.7).
4.3.3 The project

The construction of Tielrodebroek FCA took place in two phases starting from 1979. The total design and implementation of the project took about 4 years. The first phase consisted of the strengthening (and widening) of the dike along the Durme River together with construction of a new ring dike with a height of 8.00 m. TAW (see Figure 4.8).

This ring dike basically creates the actual flood control area and protects the area behind the FCA. The second phase consisted of constructing the last 10-20 per cent of the ring dike and broadening and lowering of the Zeeschelde dike. The height of the dike was decreased by 50 cm. to 6.80 m+TAW. In addition the slope on the landward side was altered roughly from 1:2 to 1:4 and on the river side roughly from 1:2 to 1:3. The river side of the dike is vegetated (bushy vegetation) and the landward side of the slope is covered with paving asphalt (porous concrete asphalt) as shown in Figure 4.9.
The material for the construction of the ring dike was taken from an available stock of sand in the area (around 80,000 m$^3$), from dredging in the Durme river (also around 80,000 m$^3$) and clay material from a quarry.

Two identical discharge structures were built to drain water from the FCA after the water level in the river has dropped. The two discharge constructions are constructed in a stretch of dike of approximately 950 m. The height of this stretch has been increased to 8.35 m TAW so that water does not overflow the dike at this point (and possibly cause damage to the discharge structures).

### 4.3.4 Evaluation of operational success

The FCA is designed to store excess water during storm surge conditions. If water levels in the Zeeschelde reach a certain level, the FCA will come into operation. This implies that the FCA may be used to store water 5 times in one year and not at all in the next. The last storm surge situation when Tielrodebroek was filled was in 1996. In 1990 there were 7 consecutive storm surges in which the FCA was flooded twice a day. During all these situations the overflow dike has never fully ‘drowned’, i.e. the dike has always stayed visible.

The FCA works as intended and has been used for the storage of excess water during storm surge situations (see Figure 4.10). There have been some design problems with the embankment slope-covering material. The landward side of the slope was initially covered with nylon mats. In the first winter after the FCA was constructed the dike overflowed and the nylon mats were unable to withstand the water forces. Immediately after the incident, the nylon mats were replaced by a heavier form of covering, namely paving asphalt. This material is elastic and able to resist the water forces which flows into the FCA with a speed of around 5 m/s. It is also perfect for covering with clay material and grass.

### 4.4 General conclusions

The Tielrodebroek FCA was constructed in a time when no environmental impact assessments or even construction permits were required. There was no public participation at all. The municipality of Temse and the local polderboard, both in favour of the FCA, had been kept informed about the plans. It was also a time when large budgets were available for these types of project. Still, those involved in design and implementation of the project feel that considerable effort was made to blend the FCA into the landscape.
In general, the FCA works as designed and has been used for the storage of excess water during storm surge situations. It has thereby contributed towards achieving the objectives of SIGMAPLAN. If the FCA were to be implemented today more detailed studies would be undertaken to assess the (environmental) effects of construction of the FCA. In addition, more attention would be paid to processes for public participation.

4.5 Lessons learned

After interviewing some people that were involved in the Tielrodebroek project it is possible to formulate some interesting lessons that can be drawn from their experience.

- In the context of the Scheldt there are three important criteria that, from a hydraulic point of view, determine whether a certain area is suitable for flood control. First of all it is important that the area that is available for flooding is of sufficient size. Next, the depth of the area is an important factor determining the available storage capacity. Last but certainly not least an important factor is the length of the overflow weir (see also the illustration in Figure 4.11). Selecting FCAs in a Scheldt like environment these aspects should be considered carefully.

![Figure 4.11: Length of the overflow compared to the entire storage area, an important FCA design criterion.](image)

- Designing a FCA one should not forget to put sluices in the ring dike itself to enable the drainage of water from the hinterland behind the dike into the FCA, if the circumstances require this. For Tielrodebroek three of such sluices were constructed.
- Depending on the size and orientation of the FCA, the potential generation of wind waves inside the FCA should be taken into account in designing (ring)dike protection measures.
- A careful inventory of available construction materials can give a significant reduction in the construction cost. A large part of the material for the construction of the ring dike was taken from an available stock of sand in the area (around 80,000 m$^3$), from dredging in the Durme River (also around 80,000 m$^3$) and clay material from a nearby brick factory.
- Until the 1960’s the area was irrigated in winter time. With the ring dike retaining the flooding waters, the polder board reintroduced a period of several weeks each winter to irrigate the area. In fact the
current conditions are rather similar to the ones before, the ring dike only establishes a much more secure protection for the people living around the Tielrodebroek area. As a result the nearby people were actually quite happy with the new situation and there was hardly any opposition to the FCA.

- It is important to make a careful analysis of the material that is to be used to cover embankment slopes. The nylon mats used at first in this case were unable to withstand the water forces at some locations and had very harmful effects on the sheep grazing the slopes on others. The nylon mats had to be replaced by a heavier form of covering, namely paving asphalt. This material is elastic, which is convenient as it automatically adapts to settling of the underlying ground. It is also perfect for covering with clay material and grass, which is ideal for landscape aesthetics.

4.6 Acknowledgements

The assistance of ir. W. Dauwe (Waterways and Maritime Affairs Administration, Sea Scheldt, Flanders) and ir. E. Taverniers (Waterways and Maritime Affairs Administration, Maritime Scheldt, Flanders) for this case study is gratefully acknowledged.
5 Baie des Veys: The Marshes of Cotentin and Bessin

5.1 Summary of Key Performance Indicators

<table>
<thead>
<tr>
<th>KPIs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategic objective</strong></td>
<td>“The objectives are to assure the sustainable conservation of the marshes and permit a balanced development of the different uses on these marshes.”</td>
</tr>
<tr>
<td><strong>Operational objective</strong></td>
<td>“Raising the water level in the rivers during the summer without causing damage to agriculture.”</td>
</tr>
<tr>
<td><strong>State description</strong></td>
<td>The state of the marshes is well described. Necessary quantitative and qualitative information is available, or being gained in 2003</td>
</tr>
<tr>
<td><strong>Decision procedure</strong></td>
<td>An (active) decision procedure is developed. A study of the water use in the area was commissioned with input and participation of all the users and managers of the marshes. They agreed on a minimum water level during the summer and a period of inundation during winter to be maintained through a system of sluices.</td>
</tr>
<tr>
<td><strong>Intervention procedure</strong></td>
<td>An intervention is designed. A computer model of the catchment area, which will receive measurements from a monitoring network in the field, predicts the discharge for the next 6 to 12h in the river and controls sluice operation. The regulation of the water level by these sluices will be automated. The model will be built when there is enough information.</td>
</tr>
<tr>
<td><strong>Evaluation operational objective</strong></td>
<td>Operational objective will be achieved It is possible to raise the water level during the summer by 20 cm and regulate inundation during winter.</td>
</tr>
<tr>
<td><strong>Evaluation strategic objective</strong></td>
<td>Strategic objective is achieved: The raising of water levels during the summer and controlled inundations in winter has created win-win situations. It has a positive effect on the ecology of the marshes and on navigation. It has no significant negative effect on agriculture. The improved ecological quality of the marshes also has positive effects on fishery and hunting possibilities.</td>
</tr>
</tbody>
</table>

5.2 General case description

The Regional Natural Park of the marshes of Contentin and Bessin is situated 250 km west of Paris in the Manche (Cotentin peninsula) and Calvados departments, in the Basse-Normandie region. These two departments meet in the Baie des Veys. The total surface of the park is about 145,000 ha and it contains 144 communities with 64,400 inhabitants.

The marshes cover the river valleys of the Taute, Douve, Aure and Vire. This almost uninterrupted stretch of marsh is the largest in north and northwestern France. It opens out into the sea at the Baie des Veys. The marshes are subject to regular winter flooding. The Cotentin peat bogs cover 15 – 16,000 ha, making them the largest peat reserve in France. They host a mosaic of biotopes like meadows, heath, small woods, and waterlogged areas. These huge expanses hold such a wealth and variety of original plant and animal species that they have achieved recognition at European and international level.
Figure 5.1:  
(a) Orientation of the marshes of Cotentin and Bessin (source: www.parcs-naturels-regionaux.tm.fr)  
(b) Sign of the Regional Natural Park (source: www.parcs-naturels-regionaux.tm.fr)

About 15,500 ha are protected by the EU Wild Birds Directive and 32,500 ha by the international Ramsar convention. These wetlands are exceptional because of the lack of disturbance during the breeding season. The mosaic of biotopes encourages many bird species to nest. For migratory birds, the Marshes of Cotentin play a prime role due to their position on the migration routes. Main migratory species are ducks, waders and several seabird species. Many others are breeding in the peat heathlands, reedbeds or marshes. The site hosts many species that are rare or endangered in France. It is also rich in fish (predominantly pike and eel), on which some bird populations depend for feeding. Common seal also occur in this wetland. About 29,000 ha of the area is protected by the EU Habitats Directive. Many habitats have maintained much of the ecological integrity they inherited from centuries of balancing between a natural environment and human activities. Vegetation at the site is mainly herbaceous.

The site is subject to a very marked oceanic climate with typical slight temperature differences, prevailing westerly winds and frequent rainfall. Due to their shallow gradient, the rivers have a low discharge capacity compared to the amount of water captured by the catchment. This effect is enlarged by the fact that outflow is dependent on the tides. The hydrological regime inherited from two centuries of management and water control has led to alternating flooding in winter and drying out in spring and summer. A system of sluice gates downstream prevents salt water from flowing upstream to the marshes. Peat is still the major soil component, although it can be concealed under surface mineral strata. The nature and thickness of peat surface formations differ greatly, and cause a variety of local conditions.

The land of the site is under private and local community ownership, while the rivers and offshore waters are state-owned. Lands are used for multi-crop and livestock farming activities. Both the wet meadows in the marshes and the small woods and pasture plots higher up are used. The marshes are prime hunting grounds. Hunters have taken over large tracts of reserve land and have acquired the necessary technical and regulatory tools for
rational management of the "waterfowl resource". Fishing associations are tackling the problem of maintaining fish stocks and developing spawning grounds. Since 1991 tourism has increased. On the rivers Douve and Taute tourists can discover and explore the marshes by boat (50 places). Canoes can also be rented.

Figure 5.2: a) Catchment area of the marshes of Cotentin and Bessin (source: Objectif 2008, Parc national regional des Marais du Cotentin et du Bessin) 
b) Picture of the marshes of Cotentin and Bessin (source: www.parcs-naturels-regionaux.tm.fr)

Agricultural changes in the early 1990s caused the marshes to be in danger of becoming completely abandoned, leading to progressive overgrowth by rank vegetation, scrub and, ultimately, woodland. This would in turn lead to the disappearance of the flora and fauna that are presently of great significance. In 1991 the Government created the "Le parc natural régional des Marais du Contentin et du Bessin".

By creating this park the intention is to combine nature and landscape conservation with economic development of the region. The park is a syndicate with representatives of the two regional departments and the local communities. The working of the park is financed by the French state and the local communities contribute an annual fee per inhabitant. There are 5 workgroups in the park reflecting the different topics and projects in the park. The main topics are: environment and water, spatial planning, local development and conservation of the cultural heritage. The park is also guided by a scientific advisory committee. This committee provides know-how to solve the local management problems.
5.3 FCA analysis: The Marshes of Cotentin and Bessin

5.3.1 Objectives for the Marshes of Cotentin and Bessin

**Strategic Objective**

Different stakeholders use the marshes, some uses are historic like agriculture and hunting and some are quite new like tourism and nature preservation. Water management and especially the water level play a crucial role in the conservation of the marshes. Every stakeholder has his own desired water level. The strategic objective of the Natural Regional Park is to find a suitable management of the water level for all users of the marshes such as farmers, fishermen, hunters, conservationists and tourists. This water level management should assure the sustainable conservation of the marshes and permit a balanced development of other use like farming, fishery, hunting, navigation and tourism.

**Operational Objective**

An analysis of the yearly use of water and related water level of all these stakeholders (as stated above) showed that the strategic objective could be achieved by raising the water level in the rivers during the summer and an assured inundation during the winter.

5.3.2 The problem

The table in Figure 5.3 presents the conflicts related to the water level management of the marshes.

The farmers want a low water level in the spring when the cattle start grazing on the marshes. They also want a low water level in summer so they can collect enough high quality hay for cattle feed in the winter. However, they want a sufficient water level in the ditches in order to keep a retain soil moisture rate in the ground and therefore to get good grass growth. The fishermen want inundation from February until April for a good reproduction of several fish species. They also need enough water in the ditches during summer. On the other hand the marshes should be easily accessible by car because the fisherman handle heavy gear. The hunters want a shallow depth of water from November until March creating a wetland attracting migratory birds. They do not want complete inundation in winter because they want to attract birds on the small ponds especially created for hunting. Moreover, hunters shooting waders like snipe, need to walk in the marshes. For tourists the needs are different. During the summer there should be enough water for the boats but not too much so the boats can pass under bridges. The view on a winter landscape with inundations is famous and very attractive for tourists. For the protection and the conservation of the marshes, the water level should be medium in every season, but especially in the summer.
The conflicts related to the water level management of the marshes:

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<tr>
<td>Tourists</td>
<td>✔️</td>
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<td>✔️</td>
<td>✔️</td>
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<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

Figure 5.3: Table of the conflicts related to the water level management of the marshes (source: Paquereau Valérie, Le Parc naturel régional des marais du Cotentin et du Bessin: médiateur dans les conflits d’usages liés à l’eau)

The table shows that spring and summer are the period with the greatest differences in the demands between the users.

There is only one water manager in the marshes, “les syndicates de marais”, with one association per valley. These associations were created in the nineteenth or twentieth century according to a law of 1865. This law presents the will of the state to drain marshes to gain agriculture land. The association gains taxes from the landowners, which mainly are farmers. With these funds it takes care of the water management and the maintenance of sluices etc. Until recently the syndicates of the marshes have been regulating the water level in favour of agriculture. They kept a very low water level, to ensure storage capacity in spring and summer when there is a risk of heavy rainfall caused by thunderstorms. This was done for two reasons: inundation during summer could lead to a lot of damage to the hay and detailed water management serving all users was not possible by merely controlling the sluices by hand. Moreover is the outflow of the sluices is also dependent on the tide level. The sluices only open when the sea level is lower than the level of the fresh water behind the sluices. This is the only influence of the tides on the water management of the marshes.

5.3.3 The project

The regional natural Park searched for solutions. In 1995 a water commission was installed. This commission has the objective to enhance the communication between the different users and managers of the
marshes. All stakeholders are represented in this commission. They have annual meetings.

The water commission agreed in 1998 on several points:
- Flooding due to heavy rainfall during the period of October until April, is a natural phenomenon that cannot be controlled
- Flooding during winter presents a number of agricultural and biological assets, (improving the ecological quality of the marshes)
- Flooding in the lowest region between the 15th of December and the 15th of February serves a good ecological condition of the marshes, without damaging agriculture
- Maintaining water in the ditches in summer is useful for the drinking of the cattle, delimitation of the land-parcels and plays an important biological role in the hydrological working of the soil.

A water agreement was signed between the Park and the "syndicat de la Douve". The "syndicat de la Douve" has to assure:
- inundations in the marshes between the 15th of December and the 15th of February even when there is not enough rainfall in the winter
- a minimum water level in the river during the summer (0.20 NGF)

The park finances technical solutions for "les syndicats des marais" to create a more detailed water management to serve all use. The Park assists and finances automated control of the sluices on the Douve (see Figure 5.4-5.5). This project is the result of a long partnership between the Park and the syndicates of the marshes. The Park is responsible for the field monitoring network and the syndicate is responsible for the working of the automated sluices. The network was established in the summer of 2002. The model will be built when there is enough data and knowledge on the catchment area. This will result in a better (i.e. higher) water level in the river and the ditches, which has a positive effect on the ecology of the marshes and on navigation. It will have no significant negative effect on agriculture. An improved ecological quality of the marshes also has positive effects on fishery and hunting possibilities.

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**Figure 5.4:** Principle of the automated working of the sluices (source: Bilan d' activité 2002, du Parc naturel régional des Marais du Cotentin et du Bessin)
5.4 General conclusion

The objective of the regional national park of the marshes of Contenin and Bessin is to maintain the characteristics and the value of the marshes. This environment is recognised on an international and national level. There are several conflicts in the regulation of the water level especially between historic uses like farming and hunting and new uses like nature conservation and tourism. The park served as mediator between these parties. By organising a communication platform between all the relevant stakeholders, win-win situations were created and agreements on the regulation of the water level in the area were reached. This resulted in a higher water level (inundation) during summer and regulated inundation during winter. A new water management of the marshes was implemented by the introduction of new techniques.

5.5 Lessons learned

After interviewing stakeholders and reviewing reports on the multi-use of the marshes, some interesting lessons can be drawn from the experience.

- Create a communication platform where all users are represented. Use a mediator and treat all users equally. Show to all users that the Park is able to carry out definite projects with each of them.
- There will always be prejudiced people even after completing an elaborate communication process.
- The effect of consultation on conventions and agreements however is unsure. The outcome is dependent on the will to cooperate from every stakeholder. This problem can be solved by creating a global
water management plan (Schéma d' Aménagement et de Gestion des Eaux, SAGE). This is a planning tool of with legal implications.

• Create pilot studies and experiments to demonstrate and test new water management techniques and create new partnerships between users.

• Common approaches for nature preservation like buying land from farmers are not suitable in larger areas (say greater than one thousand ha). This would be far too expensive for the state.

5.6 Acknowledgements

The assistance of Valérie Paquereau and Jean-Baptiste Wetton of Parc naturel régional des Marais du Cotentin et du Bessin for this case study is gratefully acknowledged.
6 Humber: Paull Holme Strays

6.1 Summary of Key Performance Indicators

<table>
<thead>
<tr>
<th>KPIs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic objective</td>
<td>The main strategic objective is to provide improved flood defence to the east of Hull’s seaboard associated with the Humber Urgent Works flood defence programme.</td>
</tr>
<tr>
<td>Operational objective</td>
<td>The operational objective is cost effective flood control. The FCA will provide an adequate defence line by managed realignment inland of an existing seawall which no longer meets current design criteria for flood defence. This will provide additional intertidal habitat in the Humber needed for mitigation of other flood defence works.</td>
</tr>
<tr>
<td>Current condition</td>
<td>The estuary flood risks are well known. Quantitative studies and ecological information are available.</td>
</tr>
<tr>
<td>Decision procedure</td>
<td>A decision was made to adopt the managed re-alignment as a preliminary to the Humber Estuary Shoreline Management Plan.</td>
</tr>
<tr>
<td>Intervention procedure</td>
<td>An intervention has been designed. The existing bank has been breached in two places after re-alignment of the defence line about 500m inland. The current gravity drain has been replaced by a pumped system.</td>
</tr>
<tr>
<td>Evaluation of operational objective</td>
<td>Operational objective has been achieved in terms of flood defence improvement by the raised and realigned seawall. The position of the FCA in the estuary means that it will have minimal effect on water levels in the estuary. The intervention should be effective in creating 75 ha of intertidal habitat.</td>
</tr>
<tr>
<td>Evaluation of strategic objective</td>
<td>The physical actions needed to achieve the objectives are in place. The project is too young (the work was completed in September 2003) to make a definitive statement on the project’s effectiveness as a FCA.</td>
</tr>
</tbody>
</table>

6.2 General description

The Paull Holme Strays project is located in the middle part of the Humber Estuary, the location of which is shown in Figure 6.1.

The Humber estuary is on the north eastern seaboard of England (see inset in Figure 6.1). The estuary has the largest catchment area of any river system in England, covering a fifth of the country and drains the Rivers Trent, Ouse, Don and their tributaries. The estuarial plain is some 1,500 km² in extent and is an economically important industrial and port area. Tidal defences constructed in the past protect the developments on the coast and have successfully claimed land for agriculture from coastal marshes. The defences have a total linear length of 235 km of mostly earth/clay embankments but near population centres and port areas concrete and piled structures have been built. Much of the intertidal area has national and international protection under conservation law.

The condition of the defences has been of concern for some time: their effectiveness is threatened by rising sea levels due to global warming and isostatic tilting of the eastern seaboard, as well as by localised effects of sediment movements eroding the foreshores in places. The Environment Agency (EA) and its predecessor the National Rivers Authority began flood...
defence reviews in 1995. In 1997 EA published its interim findings\(^3\), followed in 2000 by the Humber Estuary Shoreline Management Plan (HESMP)\(^4\). This set out the vision for managing sustainable flood defences in the estuary for the next 50 years.

Through the 1990’s, studies culminating in the HESMP took place and it was soon recognised there was a need for some urgent remedial coastal protection works before the final strategy for the flood defences as a whole could be agreed. A number of key areas were identified in a long list of candidates for the Urgent Works programme\(^1\), and from these sites a shorter list of Urgent Work sites was prepared. Paull Holme Strays is Urgent Works Site 1.

Flood defence at this site could have been improved by bank raising, but this would have damaged the important nearby conservation areas. A better option was considered to be managed re-alignment. Thereby the works, whilst achieving the requisite flood control, would also provide a substantial area of additional intertidal habitat\(^5\). This additional intertidal habitat was needed to order to comply with the Habitats Regulations with regard to habitat compensation for other projects in the Urgent Works Programme.

![Figure 6.1: Site location and layout](image)

Physical features of project area

The site was originally known as Thorngumbald. However, the project has now been re-named as Paull Holme Strays as it is within Paull Parish area and Paull Holme is the historic settlement nearest to the coast. The site is

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\(^3\) EA, 1997 *Humber Estuary Management Strategy*.

\(^4\) EA, 2000 *Humber Estuary Shoreline Management Plan*.

\(^5\) Halcrow, 2001 *Humber Estuary Tidal Defences, Engineers Report, Urgent Works 1, Paull to Little Humber*. 


about 10 km southeast of Hull; its northern extremity is a little north of the pair of historic Thorngumbald Lighthouses, and it then extends some 2.5 km to Little Humber in the south.

The existing coastal wall was built in the 1970’s, behind which are reclaimed saltings and the remains of the soke dyke and old borrow pits forming freshwater wetlands from an older previous seawall. The current embankment itself is now fringed with a small strip of saltmarsh averaging about 10m wide, although in places this saltmarsh strip is absent. There is then an extensive intertidal mudflat offshore that joins, in the south, the more extensive Paull Holme Sands sandflat.

The intertidal area seaward of the defences form part of the Humber Flats and Marshes Special Protection Area (SPA), designated as an internationally important site for bird populations under the EU Wild Birds Directive (see below).

The area behind the 1970’s seawall was a mix of arable land with areas of pasture, and some wetland areas associated with the old soke dike and previous borrow pits. There are gas pipelines coming ashore near Thorngumbald Lighthouse which run inland to a major gas distribution station. The seawall carries a public footpath and the area, particularly around the rock protection at Thorngumbald Lighthouse, is regularly used by seafish anglers and is the access point for shellfish collection from the intertidal area. The seawall is regularly used by bird watchers, and there are also visitors to heritage sites such as the World War 2 fortifications at Paull and the lighthouses.

The existing seawall no longer gives adequate flood protection as its current level is at the 1 in 10 year flood level, and would be expected to be overtopped every year (the 1 in 1 year level) in 50 years time. As scour of the embankment might now occur on any high tide that coincided with rough wave action, the defence was estimated as potentially failing within 3 years.

Socio-economic and natural environment issues

The strategic importance of the gas supply system and the urbanised areas of Hull to the north and west of the site provide a convincing case for the scheme. Inundation could affect 150 square kilometres, 6,500 houses and a large chemical complex. Consequently, the project has a high benefit to cost ratio using standard UK Government economic assessment procedures, and also scores above the level to qualify for funding under the Government’s prioritisation system. The adoption of managed realignment at this site allows substantial savings in the costs of other projects in the Urgent Works programme, by removing the need for these other sites to provide habitat compensation. These savings exceed the slightly greater financial cost of managed realignment at Paull Holme Strays over a simple on-the-line improvement.

The major potentially negative socio-economic impacts of the project are the need to buy the land from landowners, who would lose their income from it. It is understood that no single landowner using the affected land

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6 Halcrow, 2000  Environmental Statement for Paull Holme Strays
has had his business rendered unviable as a result of the project, and the purchase price for the land has been agreed at values above the statutory minimum.

The positive socio–economics of flood protection are of overriding value to the wider population and are shared by the local population. The local population, who are likely to be subject to temporary construction period impacts, were however initially concerned over these impacts, but the adoption of the managed realignment option, together with provision of a temporary construction access road, was welcomed and no objections were sustained. The scheme is seen as being to their advantage in minimising construction traffic and associated impacts. Purchase of the land also gave EA the mineral rights so that borrow areas could be developed within parts of the new future intertidal area and fill for the new embankment has not had to be moved along local roads. In addition to these advantages, the area of habitat gained through managed realignment, the improved access to the coast’s heritage features, and the visitors’ car parking area are recognised as likely to lead to economic benefits from increased visitors and cultural tourism.

The shoreline that will be affected is ecologically an integral part of the Humber Flats and Marshes SPA complex, that regularly supports more than 20,000 waterfowl with four waders species present in internationally important numbers and three further species in nationally important numbers. The adoption of a realigned seawall, instead of rebuilding the existing wall on line, means that the ecologically damaging work of excavation and re-instatement of the seawall which otherwise would have been within the tidal zone and the SPA, can instead be undertaken in the dry. This helps to minimise the interaction with the Habitats Regulations and reduced the engineering costs. As described earlier, managed realignment provides considerable benefit to this coast area by increasing the intertidal area by some 75 ha, which provides habitat compensation for other works in the Urgent Works Programme, and a significant contribution to mitigation associated with the HESMP.

6.3 FCA analysis: Paull Holme Strays

6.3.1 Objectives of managed re-alignment at Paull Holme Strays

Strategic objective

The primary objective of the project is improvement in flood defences in Urgent Works Zone 1; part of a package of Urgent Works in the Humber. The Environment Agency is committed to improving the environment and additionally has responsibilities under the EU Habitats and Wild Birds Directives. As implemented in the UK, these require that habitat loss in designated areas is compensated for by replacement with similar habitat as close to the original as possible. The EA therefore needs to consider the

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7 DEFRA/EA, 2000 Managed Realignment Review (PRP FD2008)
creation of suitable intertidal habitat in the middle estuary in order to compensate for intertidal habitats lost in the commissioning of the Urgent Work Programme.

The Paull Holme Strays site is considered as a key site in the Urgent Works programme as without it there is an imminent risk of flooding from tidal scour. Overtopping of the existing bank would lead to inundation of 150 km² by about 1.5m depth of water of an area stretching from the eastern suburbs of Hull south to Thorngumbald. This also includes a high risk of severing a key regional gas supply system serving the whole of the industrial NE of England. In addition local populations would be particularly affected, with loss of seven residences, two lighthouses providing navigation lights with the estuary, and salinisation of a considerable area of arable land. Damages by such inundation were estimated to be greater than £370m.

There is also a need to 'create' additional intertidal habitat in the estuary to replace that lost, or in danger of being lost, due to coastal squeeze and in further Urgent Works. Paull Holme Strays is able to provide about 75 ha of intertidal area, which although not legally within the SPA area will be contiguous with it and which given a successful habitat creation, could in the future, be added to the SPA area on a future boundaries revision.

**Operational objective**

The main reason to develop the project is to improve the level of flood protection in the middle estuary. The options for the project have been examined following Government economic assessment protocols, and the preferred scheme will improve the protection to Urgent Works Flood Risk Zone 1 by setting back the seawall some 500m. As part of the project it is also necessary to locally strengthen the gas pipeline installations against scour and to provide a pumping station for the existing Thorngumbald Drain. The saltmarsh that will develop within the new intertidal area will in time assist in protecting of the seawall from extreme tidal activity thus creating the equivalent of “additional room for the estuary’s wave action regime”.

It should be noted that Paull Holme Strays is too near to the mouth of the estuary and of insufficient tidal volume to reduce significantly the flood levels within the estuary. Any FCA gain from the project in terms of water level reduction would be at best no more than a few millimetres, and would thus be un-measurable in times of high fluvial discharge and high tidal state. The scheme should therefore be discounted for this particular FCA function.

Additional intertidal habitat created at Paull Holme Strays will thereby allow other projects in the Urgent Works Programme to proceed because these schemes do not readily provide compensatory habitats to make up for those lost by their construction.

The operational objectives can therefore be summarised as to:
- provide an economically sustainable flood defence in the vicinity of Paull Holme Strays;
- compensate for habitat loss arising as a direct result of works at this location;
• provide habitat compensation for habitat loss arising from other projects under the Urgent Works Programme.

6.3.2 The problem

As noted above, the existing seawall from Thorngumbald Lighthouse to Little Humber was judged by Environment Agency staff in 1997 to be at imminent risk of failing. Inundation would put at risk gas supply to domestic and industrial users in much of the NE of England as well as having local effects. Managed re-alignment is regarded as preferable to the simplest improvement option, that of raising the existing bank along the present line. On line raising would have been technically difficult and English Nature (UK Government conservation advisors) considered that in their view it would be unsustainable. A managed realignment scheme can be built with minimal physical impact to the conservation area though there could be minor short term adverse impacts from construction activities on the local residents. Further, an improvement option alone will not provide the additional intertidal habitat that the Environment Agency would need in order to comply with the requirements of EU Directives with regard to the Urgent Works programme.

The project design also considers the effects on the gas pipeline which now crosses the arable land and which could be adversely affected by scour from creeks expected to form in the newly created intertidal zone after the new seawall has been built. In order to reduce risk of scour to the pipeline, the Thorngumbald Drain which had previously discharged from a tidal sluice on the seawall known as Thorngumbald Clough, has a new discharge culvert to the estuary. The Clough structure has been demolished and the freshwater flows now impeded by the new inland embankment are pumped over the new embankment.

Recreational use of the present area, and the needs for the future shoreline have to be considered. The public have been fully involved in the project from its inception through an Environmental Steering Group (ESG). The ESG is composed of design engineers, regulators and local authorities, specialist environment advisers, and EA staff. Its role is to ensure the continued involvement of key consultees through the implementation phase and as the site developed. Through the ESG the public have been involved in the decision making process. They were consulted from the beginning on key features of the scheme, particularly relating to recreational use as well as the role of the scheme in the overall flood defences for the estuary.

6.3.3 The project

The project involves the provision of a new seawall on high ground some 500m inland from the existing sea wall in the north, tapering to 250m inland in the south. The Thorngumbald Drain, which carries surface runoff and field drainage is retained, but flows now enter it after being pumped by a new pumping station over the new embankment.

The wall was breached in two places, the breaching being in September 2003. The main breach was at the northern end, being 150m long, and the southern breach was 50m.
The levels of the land between the new and old seawalls and thereby their new estuarine habitat type will be allowed to develop naturally, and there is therefore no certainty what proportion or type of mudflat and saltmarsh communities will establish and when. A detailed physical, botanical and ornithological monitoring of the newly created intertidal area is to be undertaken. The ESG will keep under review, with the aid of an Environmental Action Plan (EAP), the developing habitat. An attempt to quantify the expected habitats has been made for the EAP and these initial estimates will be used in the habitat audits to measure the success of the project. Further interventions to assist in suitable habitats becoming established remain a possibility.

A car park is provided as well as bird viewing facilities with educational information about the conservation importance of the area, its archaeological features and the wider biodiversity. The existing sea wall was breached in two places in late September 2003 as seen in the aerial photographs, Figures 6.2 and 6.3.

![Figure 6.2: Overview of Paull Holme Strays](image1)

![Figure 6.3: Gas Pipeline scour protection for Paull Holme Strays](image2)
6.3.4 Evaluation of operational success

Flood control aspects

The level of the new embankment will be 6.4m AOD which provides a 1 in 200 year level of protection. Difficulties with planning approvals associated with land purchase and EU Directives meant that the project’s original three year construction programme had to be revised. However, the consultants, Arup Water and Halcrow, together with the contractor, Edmund Nuttall were able to meet the desired completion date for 2003.

The construction of the realigned seawall was completed in 2003 and the final cost of the scheme was £7.1m (approximately 10m Euros). The source of the fill used in the new embankment was partially from excavation of the new soke drain behind the re-aligned seawall and from the three borrow pit areas in front of the new seawall.

The only bulk materials needed to be brought onto the site were rock armouring from 4.3m AOD to the top of the northern end of the embankment to improve the protection for the existing bank at the Thorngumbald Lighthouses, and Armourflex mattresses. These were used elsewhere near the toe of the embankment and as scour protection over the gas pipelines.

A Traffic Management Plan which was agreed with local residents and local authorities was effective in reducing construction period traffic noise, dirt and dust nuisance and local congestion. Residential areas were avoided and all incoming vehicular traffic remained on metalled roads thus reducing dust and mud propagation.

Habitat creation objectives

The project, through the realignment of the seawall, restores to the intertidal area the previous habitats that had been cut off from the estuary almost half a century ago in some areas and longer in others. The engineering actions do not include direct provision of specific areas of particular intertidal habitats. Instead the present mix of arable and pasture land in front of the new seawall will be subject to natural forces from tidal inundation, and allowed to revert to whatever intertidal habitat is thus formed.

The Environmental Action Plan\(^8\) includes a number of Appendices detailing monitoring of the developing habitats and biota to be undertaken. This allows the Environmental Steering Group (ESG) to determine if the compensatory habitat has been delivered. If the habitat development is not adequate, other interventions may be required.

In the case of terrestrial and freshwater habitats, several specific new habitats have been created. This work was, in large part, undertaken to mitigate the loss of original habitats and features on the site, all of which have been lost to the new intertidal areas. However, some enhancements

\(^8\) Halcrow 2002 Environmental Action Plan Appendix A Habitat Creation and Management Plan.
have been provided by EA as part of its national policy to improve the environment.

At the time of writing it is too soon after the creation of the breach to comment on the success of the habitat creation. However, there were encouraging signs even in the winter of 2002/3 when the borrow pits, at that time temporary freshwater habitats, attracted large numbers of over wintering waders and water fowl, and even some breeding avocets in spring 2003. EA are cautiously optimistic that the targets set in the EAP, which require appropriate species colonisation and stabilisation in the new intertidal areas, will be met in due course. Realistic time scales in terms of periods of decades or more are being considered.

The new embankment has been provided with a footpath along the whole of the new embankment. A number of information boards are to be fixed around the site to point out particular features both man-made and natural. The car park serves visitors to the site, and is sited in the centre of the site, adjacent to one of the newly constructed freshwater ponds. Regular visitors to the lighthouses such as dog walkers and fishermen from Paull village can park in the existing village car park at Paull and approach the embankment from the north as well as using the new car park. At the present time, though access to the new shore has not been denied, access by the public has not been eased in order to allow the coastal vegetation to develop naturally. Along the northern edge, where the High Water line runs up a natural slope, the new coast line will be the only place within the Humber estuary where the estuary waters are not constrained by man-made slopes and great interest in being taken in this part of the coast.

6.4 General conclusions

The flood control objectives have yet to be actually tested but the flood defence embankment has now been put in place and the older embankment was breached in October 2003. The habitat gains that were a major though secondary strategic objective are now developing, although it may be some years before the more slowly establishing vegetative elements can be proven to have stabilised. In discussion with EA staff for this review, and taking into account the earlier published discussions regarding managed realignment schemes, the following conclusions can be drawn.

- The development of an overall strategy for the Humber site in which key objectives could be set and agreed with a range of stakeholders allowed early decisions to be made with regard to priority flood defence projects such as Paull Holme Strays.
- There is a need in the case of large projects which impinge upon the lives or expectations of a wide range of residents, and commercial and regulatory interests; to ensure that there is effective communication between stakeholders throughout the decision making process, in order to avoid delay to that process.
- Interaction between project development staff, regulators and key individual stakeholders needs to be maintained throughout the planning, construction and operational periods. In Paull Holme Strays an Environmental Steering Group has proved particularly effective.
• The advantage of including the contractor as well as the consultant in the Environmental Steering Group was clearly demonstrated by the speed with which alternative but agreed and satisfactory means of working were developed in Group meetings.

• There were delays in implementing the Paull Holme Strays project that were felt to be due to the EU Directives. However, in general the pace of decision-making reflected the lack of experience with the proper interpretation of the complex legislation implementing the Directives in the UK, rather than any fault or characteristic of the legislation itself.

• Technical difficulties with the engineering of the embankment and with the need for scour studies to adequately protect the shallow gas pipelines also caused some delay to the programme but satisfactory conclusions were drawn from the studies and delays were kept to a minimum consistent with safety.

6.5 Lessons learned

The Paull Holme Strays FCA project is still too young for final conclusions to be drawn and it is too soon to compile a full listing of experiences that could be applied to planning FCAs elsewhere. However the following pointers can be made, from the initial experiences and from comments made at a meeting held to discuss this project and other managed realignment projects in 20035.

After interviewing some people that were involved in the project it is possible to formulate some interesting lessons that can be drawn from their experience.

• There is a need to clearly emphasise the beneficial impacts of a scheme to the local community as early as possible, as some of these may not be as readily apparent to residents as the more normal adverse impacts due to construction related impacts of development. This is necessary to avoid the ‘Fear the worst syndrome’.

• At Paull Holme Strays there was a comprehensive public participation and communication strategy using the Environmental Steering Group. This was found particularly useful in engaging the public and authorities in discussions on environmental quality issues, conservation and on heritage and recreational interests. In addition this provided the opportunity to explain the proposed means of meeting the other objectives of the project, and where needed, getting early agreement to a different way forward. Despite the time and complexity, the consultation procedure needs to be done thoroughly and should not be rushed, and in this case achieved its aims.

• Habitat changes and ecological responses are key to successful design of a project so that competent assessments of its likely impacts on designated conservation areas can be agreed with the appropriate authorities.

• Time was lost as a result of “technical hurdles” for example, in obtaining the necessary planning approvals and the time involved in detailed consideration of some options that might have been recognised earlier to be unworkable. However, many felt that the
learning experience associated with this work was valuable. There was a feeling that at Paull Holme Strays there was some reluctance to move fast in case untoward precedents were created when dealing with new legislation such as under the Habitats Directive.

6.6 Acknowledgements

For the information regarding the Paull Holmes Strays project, the FCA review team acknowledges the assistance of Keith Slaney and Chris Owens of the EA. The figures and photographs in this chapter are copyright of the Environment Agency, and the underlying maps are copyright of the Crown and reproduced under licence to the Environment Agency.
7 Norfolk Broads: Broadland Flood Alleviation Project

7.1 Summary Of Key Performance Indicators

<table>
<thead>
<tr>
<th>Key Performance Indicators for the Broadland Flood Alleviation Project</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategic objective</strong></td>
<td>Implementation of sustainable flood defence improvements in Broadland aiming to ensure that navigation, recreational and wildlife interests are all fully protected. Secondary objectives are contained in the method of working i.e. environmentally sound practices which would lead to increase of nature areas or at least compensation for nature areas lost.</td>
</tr>
<tr>
<td><strong>Operational objective</strong></td>
<td>Operational objectives are developed.</td>
</tr>
<tr>
<td>• Improve and maintain the quality of existing flood defences as they were in 1995.</td>
<td></td>
</tr>
<tr>
<td>• Provide flood defences for the first time to undefended riverside communities</td>
<td></td>
</tr>
<tr>
<td>• Reduce the risk of existing flood defences breaching during flood surges</td>
<td></td>
</tr>
<tr>
<td>• Provide 24 hour emergency response</td>
<td></td>
</tr>
<tr>
<td><strong>State description</strong></td>
<td>Overall hydrodynamic model is available</td>
</tr>
<tr>
<td>State description Haddiscoe/Halvergate available (the only two areas as yet)</td>
<td></td>
</tr>
<tr>
<td><strong>Decision procedure</strong></td>
<td>A decision procedure is in place for consultation of stakeholders. For landowners another procedure is available through the Broadland Authority</td>
</tr>
<tr>
<td><strong>Intervention procedure</strong></td>
<td>A public consultation and participation procedure, aimed at reaching a broad agreement on project implementation, is in place. A monitoring procedure was initiated and yearly reporting will take place, also consultation was undertaken on Strategic Environmental Assessment</td>
</tr>
<tr>
<td><strong>Evaluation operational objective</strong></td>
<td>The measures have been undertaken recently at Haddiscoe and Halvergate and floods have not occurred since that would allow assessment of effectiveness.</td>
</tr>
<tr>
<td><strong>Evaluation strategic objective</strong></td>
<td>The project has not progressed far enough for evaluation</td>
</tr>
</tbody>
</table>

7.2 General Case Description

Situated in East Anglia, Broadland is one of the finest wetland areas in Britain. It includes both open water, the Broads themselves, and the low-lying marshland surrounding the tidal reaches of the River Yare, the Waveney and the Bure. These rivers reach the sea at Great Yarmouth. Figure 7.1 gives an overview.

For many centuries, the rivers of Broadland played an important role in transporting goods and raw materials for trade and industry. Today, Broadland is still busy,
although in a different way. The rivers remain a major inland navigation waterway which, together with the Broads, provides access to 200km of navigable waters. Recreation and tourism have become very important, with thousands of visitors each year. In response, the boat hire industry now makes an important contribution to the local economy (Environment Agency, 2001). Of the remaining land, fifty percent of the land is used by traditional farmers.

From the Broads, 6000 hectares are formally designated for nature conservation. The international designations are Special Area of Conservation (SAC) under the Habitats Directive; Special Protection Area under the Birds Directive; and Ramsar Sites under the Ramsar Convention (BESL, 2003).

The main features of the ‘natural’ environment of the Broads include amongst others:

- **River and broads.** These form the main aquatic habitat in Broadland. Their nature conservation value is closely linked to water quality and quantity. Good water quality is important for many rare wetland species including aquatic plants, otter and bittern.

- **Salt marshes and mudflats.** These are found mainly on the edge of Breydon Water and the lower reaches of the Bure and Yare/Waveney confluence. They provide feeding and roosting areas for tens of thousands of ducks, geese and wading birds during the winter months.

- **Ronds.** These are low-lying areas of land between the front face of the floodbank and the water’s edge. Depending how frequently they are flooded, ronds support a variety of vegetation communities including salt marsh and reedbed. Ronds have a high wildlife value as they provide habitat for breeding and wintering birds, small mammals, rare plant species and invertebrates.

- **Floodbanks.** These are the main line of flood defence and their normal vegetation is rough grass but they can support several rare plant species such as marsh mallow and Biodiversity Action Species (BFAP, 2001c).

Now some 240 kilometres of flood banks protect approximately 21300 hectares of Broadland; containing more than 1700 properties of which more than 100 are residential. Most of the original material used to construct these flood banks was silty clay and many of these dikes have deteriorated over time. Combined with changes to river channels, they are now susceptible to seepage and in danger of being undermined and/or subjected to breaching.

Many flood banks have also settled since they were built or last improved and are at risk of being overtopped by even small tidal surges. Settlement will continue over time and the effects of sea level rise (SLR) will further...
affect the dikes. Actual SLR is anticipated to be 6mm per annum at Great Yarmouth. Soil settlement (compaction) and SLR work out to be the same as an average total subsidence of about 25 mm/year. In some parts of Broadland the existing defences are also threatened due to erosion of riverbanks caused by wind and waves, boat wash, normal river flows and the action of the tide. Although many areas have been protected by steel or timber sheet piles, much of this was installed over the last 40 years or so and now needs replacing (BFAP, 2001b).

In the past, several flood defence options were considered to protect the Broadlands. They are listed below:

- Doing nothing;
- Substantially raising the standard of existing defences;
- Building a Bure Barrier;
- Building a Yare Barrier;
- Constructing formal washlands.

These options were last considered by the Environmental Agency in the 1990s but were not carried forward. This was either because they did not meet the Government’s cost-benefit criteria for flood defence, or they met with strong opposition from local interests, or both.

After carefully considering all the options outlined above, in 1995 the Environment Agency agreed a programme of works to improve flood defences in the Broadlands by sustaining and renewing the condition of the existing defences through floodbank strengthening and erosion protection, but without raising the long-term level of protection that these defences provide. This means flood banks will be strengthened to protect against breaching but will not be raised, except for compensation of soil settlement and actual SLR.

In the late 1990s the Environment Agency started to investigate how its strategy could be delivered as a Public Private Partnership under the Private Finance Initiative. In May 2001 BESL (Broadland Environmental Services Limited), a consortium of two private companies: Edmund Nuttall Ltd. and Halcrow Group Ltd, was awarded a 20-year contract by the Environment Agency to

![Figure 7.3: Erosion protection Works Acle Boat Dyke](image)

![Figure 7.4: Erosion protection Works Acle Boat Dyke](image)
improve and maintain flood defences in Broadland: the Broadland Flood Alleviation Project. The first phase will be running 2001-2006, which means that experience is still relatively limited.

### 7.3 FCA analysis: Broadland Flood Alleviation Project

The Broadland Flood Alleviation Project (BFAP) is a long-term project to provide a range of flood defence improvements, maintenance and emergency response services within the tidal areas of the Rivers Yare, Bure, Waveney and their tributaries. Broadland Environmental Services Limited (BESL) has been appointed by the Environment Agency to deliver these services and, in partnership with the Agency, it is now developing a 20-year program of sustainable and cost-effective flood defences for the Project area.

As the project is situated in the Broads Authority area (a National Parc type of organisation) the BFAP is given to work according to strict environmental guidelines which are summarized in the Strategic Environmental Assessment, in the form of 36 Strategic Environmental Objectives. This ensures environmentally sound practices are used by the Contractor BESL. These practices represent a catalogue of the integrated way of working initiated by the Environment Agency in partnership with BESL (Halcrow, 2003).

Within the contract, the methods for putting the aforementioned work into place have already been identified. The solutions available to BESL are (see Figure 7.5 for a visualisation):

![Figure 7.5: Floodbank Strengthening and Floodbank Setback options](image-url)
• **Floodbank Strengthening** - This will be used where there is still a good band of rond (a strip of land) between the river and the floodbank. This method involves strengthening the existing flood banks in their present locations by putting material on the back slope. The crest (top of the floodbank) will also be raised to the agreed 1995 level. The increase in height will be up to an average of approximately 30-40 cm, depending on their topographic elevation at present compared to 1995 standards, and their location in the river system (BFAP, 2001b).

• **Floodbank Setback** – This method will usually be used where the river is already hard up against the floodbank and flood defence is protected by erosion protection, such as piling or sheeting. This solution involves laying a new clay floodbank *inland* from the river’s edge, set back far enough from the existing line of flood defence so that a new rond can be created and natural vegetation established. For the dike soil from the rond is used. The existing erosion protection will then be removed once the new floodbank is in place and the new rond has been established. The process takes three years (BFAP, 2001b).

• **Floodbank Erosion Protection** – This method will be used in various locations to stabilise the flood banks and the edges of the rond. Several types of erosion protection can be used depending on local circumstances. These include asphalt matting, coir (coconut husk) rolls or matting, alder poles and reed based products. In a few places, new sheet metal piling will be needed (BFAP, 2001b).

• **Works to improve the situation of undefended communities** – Although much of Broadland now has some form of flood defence, not all areas do. There are several hundreds of properties including boatyards and riverside chalets that are subject to periodic flooding. In some places there are no defences at all or, where they exist, these defences are set well back from the river’s edge. These areas can generally be divided into distinct settlements, commonly referred to as ‘Undefended Communities’ (BFAP, 2001d).

• **Testing of other options, such as informal washlands** – The washland option currently is not used much as locations for this particular solution are not frequently available, nor is it likely to be used through the project.

### 7.3.1 Objectives of the Broadland Flood Alleviation Project

**Strategic objective**

The Broadland project aims to meet rigorous environmental standards in a way that is cost effective and technically feasible. It is also a project that is subject to extensive public participation in a manner that identifies and incorporates the views and opinions of its stakeholders wherever possible and appropriate. Overall, it is intended that the progressive implementation of the project will maintain and improve the Broadland environment for the benefit of local communities both now and into the future. The Project will implement flood defence improvements in Broadland whilst also aiming to ensure that navigation, recreational and wildlife interests are all fully protected. However it cannot do this entirely on its own. BESL must also consult widely with a range of stakeholders to ensure that the programme
as a whole is sustainable both economically and environmentally and has continuing public support.

**Operational objective**

The following operational objectives may be identified:

- Improve and maintain the quality of existing flood defences as they were in 1995;
- Provide flood defences for the first time to undefended riverside communities
- Reduce the risk of existing flood defences being breached during tidal surges
- Provide 24 hour emergency response

The main aim of BESL’s work is to strengthen existing flood defences and restore them to a height that existed in 1995 (a level defined by the Environment Agency) and make additional allowances for sea level rise and future settlement of the flood banks. The Broadland Flood Alleviation Project will not prevent all future flooding as land that flooded in 1995 will still be subject to periodic flooding at the end of the Project.

### 7.3.2 The problem

The flood control options in the Broadland Project are defined as follows:

- Floodbank strengthening;
- Floodbank setback;
- Floodbank erosion protection;
- Protection of undefended communities;
- Testing other options, such as washlands.

The project started in 2001 and is now in year 2. A computer model of the Broadland river system has been developed by BFAP (Halcrow) using detailed, current survey information of river channel shape, bank height etc., as well as predictions of sea-level rise. This “hydraulic model” will be used to determine what effect, if any, a particular scheme of works might have on water levels, flows and the frequency of flooding in any other part of the Project area. It is an important tool to help BESL decide exactly what to do, and where and how their programme of works should be phased. At this moment the model is being calibrated.

While carrying out these operational objectives, a wide range of secondary objectives are aimed at, amongst others enhancement of biodiversity, increase in nature creation areas, all in accordance with the Strategic Environmental Assessment (SEA) (Halcrow, 2003). Through the integrated way of working, a whole range of actions are taken and/or will be taken which will provide compensation for valuable areas lost due to the reconstruction works.

**Floodbank Strengthening and Erosion Protection**

Options 1 and 3 are implemented at sites where urgent measures were needed and where not enough space is available to use other, more environmentally friendly measures. With the project entering its second year the progress is more than expected. In two larger areas, by end-2003,
14 km of flood defences have been reinforced and improved with good stakeholder participation. By using the SEA, the current cases are demonstrating their use for flood control while at the same time taking care of and incorporating a host of environmentally sound practices. The actual length of floodbank protecting land against flooding is some 280 km, but not all needs to be reinforced and/or installed with hard measures (piling and/or sheeting; environmentally friendly materials are preferred). The favourable weather has contributed significantly to the current level of progress.

**Washlands**
A washland is defined as “land periodically flooded by a stream” (Concise Oxford Dictionary), but as a flood defence measure it is defined as “an area of land adjoining a river of stream that floods from the positive act of directing floodwaters onto it”.

Washlands are considered as viable options, but there are no firm plans for implementing them in this project yet. Several reasons can be indicated:

- At present, from modelling simulations, no suitable or ‘promising’ sites can be identified which will contribute to a substantial decrease of the flood water level. These areas will function at peak tidal levels only, but this is still not welcomed by landowners as they consider the use of their land as a washland will restrict their movements too much.

- If certain locations could be transferred to washlands, the discussion starts regarding the landownership. Based on the goals of the project (extensive public participation) and the fact that the ‘body’ (Broadland Environmental Services Ltd) does not have the power to enforce sale of land, the possible sale of land is based on voluntary agreements with landowners. This contrasts with the ‘normal’ situation where the Environment Agency can compel landowners to sell their land.

- In the past, several sites in the area were identified as potential washlands (in inception or design phases of previous projects) but were never implemented as such. In the *Flood Alleviation Strategy for Broadland, Haddiscoe Island Washland Outline Design Project* (1992) the use of washlands was considered in conjunction with other engineering options (such as bank strengthening and barriers). However, this option was not taken forward as a preferred option for more detailed appraisal due to high costs and concerns over the Bure barrier which was an integral part of the Haddiscoe Island washland. Bank strengthening was considered the most cost-effective option for the whole of Broadland (Risk & Policy Analysts Limited, 2001).

**Floodbank Setback (managed realignment, managed retreat)**
This option comes closest to Flood Control Areas (FCA) as defined within the FRaME project. Figure 7.5 explains this option in detail. Two adjacent sites, Halvergate Marshes and Haddiscoe Island, are now under construction or are already partly implemented. One of these two sites is discussed below. It is noted that the site is an amalgam of different measures as can be expected: in terms of linear metres, floodbank strengthening comes first, floodbank setback is a close second; whilst piling comes third by some margin. Figure 7.6. gives an overview of the area concerned, showing the detailed custom-built improvements that are proposed.
7.3.3 The project

The Haddiscoe Island site involves 2500m of floodbank strengthening and 1800m of floodbank setback. Nearby, a further 3304m of floodbank strengthening, 2471m of floodbank setback and 290m of piling is proposed.

A round of public consultation over the planning of the work was held early 2003. The general conclusion from the public consultation was that the floodbank setback was an urgent issue, and priorities had to be applied. Compensation was to be found for the loss of some 16 ha of marsh grazing land and navigation was to be maintained under some conditions. With two sites running, the arrangement provides pilot experience to the project. The project is executed in a phased manner (Figure 7.7).

Figure 7.6: Halvergate Marshes and Haddiscoe Island areas: flood alleviation proposals in phase 1. Some small changes were applied to this design while executing. Figure courtesy BFAP, underlying map is Crown Copyright.
According to BFAP, the flood defence improvements will be undertaken over several years. The exact programme of implementation will depend on floodbank stability, and settlement rate and the establishment of natural vegetation that will provide the appropriate level of erosion protection on the setback banks before the actual extraction of the piling takes place.

Nonetheless, the anticipated detailed programming of the construction works is outlined below. Construction works are of course dependent upon environmental constraints, resources and weather conditions. The programme will start in the summer season of 2003, and continue during the summer season of 2004, with a few minor exceptions.

The extraction of piles will take place when the natural erosion protection has established satisfactorily and will be at least one growing season after reprofiling of the rond takes place. Success of regeneration will be monitored to ensure success.
7.3.4 Evaluation of operational success

Given the start of the project was only 2003, a limited amount of progress has been made. This also means that it is yet too early to evaluate success. However, some first impressions are given.

- The improvement of flood defences is given shape after due public consultation.
- A phased approach is taken, while addressing hot spots first. So far FCAs are minimal in surface coverage. Reasons for the lack of implementation have been summarised, and will be of interest elsewhere.

Moreover, some areas, are expected to flood even when the project is complete, and hence will act as FCAs at the highest tides. The reason for this is that a certain amount of natural dynamics is needed to maintain Broadland landscape characteristics, including biodiversity and that this type of flooding would not be harmful to the area.

7.4 General conclusions

Although it is a little too early to come to firm conclusions as there has been relatively little FCA implementation in this case, the general impression is that the FCA approach as promoted in this project is a workable one.

Legal and budgetary considerations aside (see below), the public-private partnership can provide an adequate working environment to tackle the complicated issues of an integrated flood defence strategy.

The process of stakeholder involvement is crucial to successful implementation.

7.5 Lessons learned

After interviewing some people that were involved in the project it is possible to formulate some interesting lessons that can be drawn from their experience.

- In the case of the Broadlands, a Strategic Environmental Assessment (SEA) has proven to be a viable means to structure the project’s legal and societal framework, on the national as well as international level.
- In order for a public-private partnership to be successful several conditions need to be satisfied. Some of the crucial ones are that the PPP needs to be empowered with full legislative authority (for example for land purchase), it should have a budget available to make the correct technical (preparations for) decisions and it needs to be supported by an appropriate framework under which the partnership is established (in case of the Broadlands: the MoU Broads Authority-Environment Agency (Anonymous, 2003)).
- The FCA idea should be handled in such a way that is compatible with the natural dynamics which are responsible for generating the
high quality habitats for which the Broads are known, while at the same time improving the safety situation of its inhabitants.

- Up to now FCAs have been rarely applied in estuaries. Reasons could be found in land owners not wanting to give up the current land use of their property for some more risky type of land use. Lack of space in general, or lack of opportunities to generate compensation elsewhere could be reasons behind such landowner reluctance.
- Public consultation has been an essential part of the process taking place in the Broadlands and it should remain high on the agenda during the execution of the project.

7.6 Acknowledgements

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8 Main review conclusions

8.1 Introduction

When it comes to the planning, design and implementation of FCAs, a lot can be learned from analogous examples. FCAs have proven to work along rivers and a number of interesting examples may be found, for example, in:

- Hungary – The successful operation of 11 FCAs on 14 occasions has triggered the consideration of additional areas (30 locations in the study area);
- France – Along the middle Loire there are 35 dike rings, 33 of which are ‘open dikes’ with inlets that allow controlled flooding thus preventing major damage to the dike itself (Équipe Pluridisciplinaire Plan Loire Grandeur Nature, 1998);
- Germany – When water levels in the Elbe were monitored during the operation of an FCA, the water levels were proved to drop measurably; and
- Poland – Recent floods have shown that unintentional as well as forced dike breaches can cause a significant water level reduction further downstream.

However, when it comes to analogies in estuaries there is little FCA-specific literature readily available in a consolidated form. Although useful lessons may still be learned from river based FCAs, this report provides a number of interesting example cases in tidal rivers and estuaries.

This chapter summarises the findings of the review and evaluation of the five case studies. What is ‘good practice’ in one project might be less effective when different circumstances apply. Nonetheless, some general lessons that can be drawn from the case study sites have been identified and are discussed below. These can then feed into the planning, design and implementation of the FRaME demonstration projects.

8.2 Inter-comparison of cases study sites

Comparison of the five Main Review cases shows a diversity of findings. These are summarised in brief:

- **Aakvlaai** is designed for continuous operation, to cope with river floods, which when compared to storm surges are relatively slow. The main flood risk comes from river discharges, with the tidal waters playing only a minor role in this area. The effectiveness of Aakvlaai lies in its ability to act as a floodplain while at the same time diverting a significant part of the river discharge from the Bergsche Maas to the Spijkerboor.
- **Tielrodebroek** is designed to operate only for a matter of hours, taking the critical peak of the wave during high tides. Contrary to Aakvlaai, the main flood risk comes from storm surges at sea. The large tidal range results in the critical water levels lasting only for a
few hours. This short duration enables storage of the excess water, thus lowering critical water levels on the Scheldt.

- **For the Marshes of Contentin and Bessin** the management challenge is selecting a water level management strategy that optimally satisfies all the interests present in the system. The ability to automatically operate sluices in a large area enables a sophisticated water management system that takes into account the water needs of different interests throughout the year. This case provides an illustration of controlled flooding, in which the reduction of flood damage is only an element.

- The **Paull Holme Strays** site, located in the Humber estuary, was constructed as a cost-effective replacement of existing (failing) defences and also provided compensation for nature losses due to flood defence strengthening elsewhere in the system. This project illustrates that any flood control measure should always be considered in the context of the whole estuary system.

- The Haddiscoe example from the **Norfolk Broads** provides an interesting illustration of the construction of additional floodplain by managed realignment, through a public-private partnership. As such, this site is innovative on an organisational rather than a technical level.

Besides their different characteristics, the cases are also in different stages of implementation: Tielrodebroek has been operational since the early 1980’s, Aakvlaai was completed in 2001, the water management system in the marshes of Cotentin and Bessin came into operation in 2002, the Paull Holme Strays works were finished only very recently in 2003 and the Haddiscoe site is still partly in the planning phase.

Site-specific lessons are discussed in the relevant chapters and are not repeated here.

### 8.3 Recommendations for the planning, design and implementation of FCAs

#### 8.3.1 Introduction

The recommendations arising from this study have been subdivided to ensure that they are readily accessible for use in the FRaME demonstration projects. The sub-division is based on the three main phases of project implementation, i.e.

*Planning* – this is the first assessment of the problem to be addressed with simplified diagnostic tools and preliminary identification of the measures that can be taken to tackle the issues identified.

*Design* – this can be considered an extension of the planning phase. It comprises more detailed analysis of the problems and development of measures to address them, with the help of more sophisticated predictive tools to assess short and long term effects of the proposed measures.
Implementation - This comprises two main sub-stages: construction and operation. The construction of the proposed measures and related enabling mechanisms often relies on expert knowledge for successful implementation. Operation is the management phase where predictive tools may be used, together with real time monitoring as a support system for decision making.

The ‘basic’ frame of reference, as described in Section 2.1, provides a useful tool in support of decision making in each of these phases as it coherently addresses a number of elements that are crucial in each of these phases.

Note: the primary purpose of this component of the FRaME project is the examination of general technical issues associated with the implementation of FCAs. Whilst this inevitably touches on land-use and communication issues, these latter aspects are examined in more detail in separate components of the FRaME project. Furthermore, information on detailed technical issues can be found within the FRaME literature review report.

8.3.2 Recommendations relating to the planning phase

Recommendation: It is important to gather contextual information on the relevant physical, economic and administrative aspects of the system

Given the nature of flood risk, an individual flood control area can rarely be considered in isolation from the tidal river system within which it is located. It is therefore vital to take a broad approach to the assessment of flood risk and the FCA under consideration. This will help ensure that the FCA is sited appropriately and its influence on flood risk is properly understood.

Recommendation: Once the system boundaries are clear it is important to agree on the strategic objectives and the associated operational objectives

The strategic objectives relate to long-term fundamental issues across an entire estuary; whilst operational objectives refer to the goals of individual measures or projects and thereby enable the attainment of the strategic objectives.

The establishment of clear project objectives at the outset is essential in order that successful FCAs are developed. Once the objectives are established, it is possible to formulate the potential alternative measures that may be taken and test the degree to which each alternative satisfies the strategic and operational objectives.

Recommendation: Consider a wide range of potential solutions but adopt a pragmatic approach to their reduction to a short-list

It is common practice in the implementation of FCAs to first consider a wide range of possible solutions, and then gradually reduce this range of options down to a preferred approach. There is considerable guidance on site selection process emerging in the UK and elsewhere, primarily in relation to
the identification of ‘managed realignment’ sites. Further information is provided in the FRaME Literature Review report.

It is recommended that the appropriate use of ‘expert judgement’ is made, in order that many of the alternatives can be rapidly eliminated without excessive time or cost. The range of practicable solutions will also be determined by the regulations and policies applicable at a local, national and European level; and options should be screened against these as early as possible in order that non-compliant options can be quickly eliminated.

**Recommendation: give serious consideration to the multiple objectives of an FCA**

The review of case studies suggests that successfully implemented FCAs deliver a range of objectives. This is a reflection of the fact that FCAs operate within a wider environment, and stakeholders have an expectation that their interests will not be prejudiced by a given project. A theme emerging from the case study review is that flood control often provides the economic justification for implementing an FCA, but measures to improve recreation or the natural environment are also required to ensure successful progression of the project through consenting processes.

**Recommendation: Establish a ‘fit for purpose’ implementation plan early on in the process that deals with local issues**

Allied to the above, the construction of a given FCA may be seriously delayed when stakeholders oppose the proposed changes in land use. What is an appropriate strategy depends on the problem at hand, the envisaged solution and the stakeholders involved but the earlier these are addressed in the planning phase the better. This particular report does not deal with land use or communication issues, but the interested reader is referred to the FRaME Land Use and Communication reviews.

**8.3.3 Recommendations relating to the design phase**

**Recommendation: FCAs are only likely to be successful for flood risk reduction in certain locations within estuaries.**

Review of the case studies supports the view that FCAs are unlikely to be successful for flood risk reduction when positioned in outer estuary locations. They are more likely to be successfully applied in inner estuary locations where they can provide a flood-water storage function and/or enhance river width during flood events.

**Recommendation: When dealing with flood risk it is important to agree upon a number of technical performance criteria against which the effectiveness of an FCA can be evaluated.**

Usually some of these quantitative criteria have already been defined at a higher level. This is commonly the case for reference levels (for example relative to N.A.P. in the Dutch case or T.A.W. in the Belgian case) and safety standards (for example in the Delta plan for the Dutch case and in the Sigma plan for the Belgian case). Others may need to be defined specifically for each case. The crest level of an overflow weir, for example,
needs to be tailored for each overflow area. These performance criteria are likely to form part of the operational objectives.

**Recommendation: once the performance criteria have been established (see above) it is important to arrange the necessary measurement and monitoring activities that enable quantification.**

Whether or not a certain scheme will work and to what extent, is usually not something that is easily established based on expert judgement. In many cases computer models are available that allow for the testing of the effects of different options on the water levels on the river. Computer models are also often critical to gaining approvals; by lending credibility to the expert judgements and potentially identifying issues that judgement alone would have missed. However, in order for these models to produce accurate results it is important to provide appropriate input information. More detailed contextual information than that gathered during the initial planning phases will probably be required.

**Recommendation: make use of existing guidance relevant to the design of FCAs**

Considerable effort has been spent in recent years on the implementation and monitoring of demonstration sites, and the development of guidance documents that have at least some bearing on the implementation of FCAs. These are summarised in the FRaME Literature Review report.

### 8.3.4 Recommendations relating to the implementation phase

**Recommendation: once a decision is made to proceed with the realisation of a certain measure it is important to make a detailed implementation plan**

Usually the construction of FCAs involves a number of standard measures that need to be carried out, and such projects are often not unduly challenging in terms of their design. However, many projects still encounter difficulty at the implementation stage and careful planning can save considerable time and money. Reusing soil that is dug out in the area itself for the construction of new dikes, for instance, may significantly reduce construction costs. The communication and land issues are critical and generally will need to have been dealt with at the planning stage (see above), but ongoing consultation will almost certainly be required.

**Recommendation: the success of an FCA is rarely guaranteed and ongoing monitoring activities based around the performance criteria should be undertaken**

Even adopting the best available technology and expertise during the planning and design phases is unlikely to remove altogether the uncertainty over the success of the scheme. In recognition of this, a useful approach is to accept a degree of uncertainty during the planning and design phases, but make sufficient provision for monitoring during operation such that remedial measures can be taken if the FCA fails to meet the performance criteria.
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