International Levee Handbook - Scoping Report

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- Scoping Report

A report developed by an international working group consisting of organisations from Germany, France, Ireland, the Netherlands, the United Kingdom and the United States of America.

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Abstract

Levees to defend against flooding remain a critical part of flood risk management. The effects of ongoing climate and socio-economic change have been exemplified by the serious disasters in recent years in USA (Hurricanes Katrina and Rita) and France (Tempête Xynthia) where extensive property damage and loss of life occurred following levee failures or overflowing. An international team from France USA and UK/Ireland supported by Netherlands and Germany have identified the need for a new comprehensive guidance handbook , ruling out lesser options such as bibliographies or gap filling guidance. The new 1000 page expert and practitioner written handbook will enable mutual lesson-learning between the participating countries in the project consortium. This scoping report explains the detailed background and basis for proceeding. It also gives a detailed contents list explaining the contents of the proposed chapters. Guidance for levee owners/managers will cover operation, maintenance, condition assessment and emergency preparedness and management; guidance for designers will cover site characterisation and data requirements, physical processes and design tools, and practical design and construction aspects. The work is expected to take three years to publication and be completed in 2013.

Front cover photograph is from the FLOOD*site* project (courtesy BeeldbankVenW.nl, Rijkswaterstaat)

Executive summary

Over the last decade, coastal flooding resulting from storms such as Hurricane Katrina in New Orleans and Tempête Xynthia on the Atlantic coast of France has caused loss of life and destruction of property on a devastating scale. Critical flood defences have failed under the impact of the storm surges leading to tragic losses of life and the devastation of large areas. Failure of coastal and river levees (also called dikes, digues or flood defence embankments) during these storms was a major factor in the scale of the tragedy in both New Orleans and in France, just as it had been in the North Sea floods of 1953, which so badly affected the Netherlands and the United Kingdom. Inland levees have also been severely tested by exceptional rainfall events in recent years, for example those in the UK in 2007 and those in USA, France and central Europe in 2010. However, despite their critical importance in mitigating flood risk, interest and investment in levees has tended to be lower than in other critical water retaining infrastructure such as dams. In particular, in many countries, levees have lacked the legal and technical framework necessary to promote an appropriate level of performance.

Many levees have been built up and extended over decades or sometimes centuries. Few were originally designed or constructed to modern standards and records of their construction and historical performance rarely exist. Despite their apparent simplicity, levees can be surprisingly complex structures. They have generally been constructed by placing locally won fill material onto alluvial flood plains (with all their inherent natural variability). Unlike engineered structures built using concrete or steel, levees can be irregular in the standard and nature of their construction and can deteriorate markedly over time if they are not well maintained. Further, levees are generally long linear structures which are part of an overall levee system; such systems should be considered as chains which are only as strong as the weakest link. Evidence-based assessment, good design, effective adaptation and good inspection and maintenance are therefore vital if levees (particularly those representing the weakest parts of levee systems) are to perform well on the infrequent occasions when they are loaded in storm or flood events. It should be noted that levees may stand for much of their lives without being loaded to their design capacity. This can create a false sense of security in the level of protection they will provide.

Hurricane Katrina was described as a wake-up call for those involved in the field of flood defence. It was seen as a portent of how an increasing frequency of extreme events brought about by climate change could have a devastating effect on poorly maintained levees. Discussions held at international conferences as well as at the national level in Europe and America after the event indicated that these problems were not confined to the Mississippi Delta. Many similarities were identified elsewhere across the United States of America and in many European countries.

In September 2008, organisations from six countries (France, Germany, Ireland, Netherlands, United Kingdom, and United States of America) confirmed a desire in principle to participate in an international project in order to learn from one another's experiences and to produce, between them, a document setting out good practice for the operation, assessment, maintenance, monitoring, design and construction of levees – the International levee handbook (ILH). Discussions between various responsible bodies during 2009 further developed this proposal and the conclusions of these collaborations are now summarised in this scoping study report.

The main purpose of the scoping study has been to establish whether there is a logical case for producing an international handbook rather than developing piecemeal guidance on a national basis and, if so, to set out the proposed contents of that document and identify the methods by which the handbook would be developed. Following discussions held in workshops and telephone conferences, it has been concluded that an international handbook is the preferred way forward for three reasons. Firstly, it has been found that none of the nations involved in the workshops currently have a comprehensive manual for the design, operation and maintenance of levees; existing guidance is either broad in scope but lacking detail or detailed but limited in coverage. The great majority of the participants in the workshops have consistently expressed the need for comprehensive 'whole life' guidance. Secondly, the extreme climatic events that can cause the failure of large strategic levees are, by their very nature, unusual and infrequent. For this reason, relatively few will be recorded during any practitioner's lifetime; a pooling of knowledge is therefore vital. Finally, given the devastating impact (in terms of loss of life and damage and repair costs) of storms such as Hurricane Katrina and the storm Xynthia and the total length of critical levees in the participating nations, it is considered that there is a significant risk of another disaster of similar proportions unless action is taken to improve performance.

In addition to examining the case for the ILH, the detailed objectives of this scoping study have been:

- to establish an agreed business case for the production of the ILH
- to confirm the function, target audience, scope and specification for the document to be produced subsequently, including an outline contents list, the form of the final paper and electronic documents
- to produce a conceptual framework setting out the broad rationale for the assessment, design and management processes
- to develop and agree both national and international project team structures and membership, including both practitioners and researchers and ensuring that an appropriate mix of hydraulic, geotechnical, operations and maintenance, design, and construction expertise is drawn together
- to develop, agree and ratify a collaboration agreement between partner countries; the purpose of the agreement being to address how the costs of the overall project management, editing, translating and publishing will be met.

The business case developed during the study ruled out doing nothing or adopting other project options such as bibliographies and gap-filling guidance. These are seen as failing to overcome the piecemeal and poorly integrated geotechnical and hydraulic practice. Much of the existing guidance currently used for the design and operation of levees was originally produced for dams or other infrastructure such as road or rail embankments; there is a pronounced lack of published information that relates specifically to levees. Even in the Netherlands where comprehensive design guidance is published, it mainly relates to Dutch soil types and is not applicable elsewhere in the world where ground conditions can be very different. Further, the existing published guidance does not deliver the necessary level of whole life cycle and systems thinking or the benefits of best practice sharing amongst international partners.

A number of key recommendations have emerged from the recent international collaboration for incorporation into the specification and work plan for the ILH. These are as follows:

- The ILH should be written to be a 'decision support' document as distinct from a prescriptive 'decision-making' code of practice. However, the technical guidance provided by the document should be sufficiently comprehensive to establish minimum standards of good practice. The ILH should be written for two target audiences; the levee owner (or manager) and the levee designer.

- The ILH will be available in both printed and electronic form and, having examined the options, an optimum size of 1000 pages is proposed. An associated contents list for the document has been prepared covering:
  - conceptual thinking and frameworks and descriptions of the from and function of levees
  - guidance aimed mainly at levee owners and managers on operation, maintenance, condition assessment and emergency preparedness and management
  - guidance aimed mainly at designers on site characterisation and data requirements, physical processes and design tools, and practical design and construction aspects.

- The ILH should be written by a project core team of experts and practitioners from the full range of relevant disciplines and drawn from the partner countries. The team should work in an integrated manner both within and across chapter a process which should be supported by conceptual frameworks prepared in draft form during the scoping phase The ILH should adopt a consistent style and lexicon; it will include a glossary of terms and definitions to avoid problems of translation or interpretation.

- An international review should be undertaken using experts from other countries who will also be invited to make contributions of technical material or case studies.

- The overall project to produce the ILH should follow an agreed set of processes and be managed by a technical editorial team supported by an executive steering board drawn from the national backing groups of the partner countries. Management support should be provided by CIRIA (UK) who will also prepare the resulting document for final publication. A project website should be used to support management, document exchange/control and external communications and publicity. To support these arrangements, a draft collaboration agreement has been prepared for signature by representatives from the partner countries.

Finally, the scoping study established that the likely cost of the project inclusive of both paid and in-kind (or unpaid) contributions is likely to be of the order of US$3m. The majority of this cost will be shared approximately equally between the lead partners (currently France, UK/Ireland and USA) with smaller contributions from other partners (Netherlands, Germany). The anticipated time to completion and publication of the ILH is expected to be about 3 years. Participating organisations will obtain the resulting ILH at a fraction of the total project costs were the project to be carried out at a national level and with the benefits of international collaboration. Whilst the cost and time inputs remain significant, they are extremely small in comparison with the costs associated with another major levee system failure arising from the lack of existing comprehensive guidance.

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1 Background to the project

Levees are raised, predominantly earth, structures (sometimes called flood defence embankments or dikes) whose primary objective is to provide protection against fluvial and coastal flood events along coasts, rivers and artificial waterways that are not reshaped under normal conditions by the action of waves and currents.

Levees form part of flood defence systems that may also include flood walls, pumping stations, gates closure structures, natural features etc.

Billions of US$/€/£ are spent around the world every year on the maintenance, repair, improvement (e.g. strengthening and/or raising) or construction of levees. Careful planning and judgement is needed for the effective use and siting of levees. Many flood defence systems have been abandoned or moved in the past to better accommodate their relevant flood or storm protection function. Many flood defence systems have been abandoned or moved in the past due to changes in flood or storm protection policies.

Some have questioned whether investment in levees remains worthwhile and whether the construction and maintenance of such structures should be continued. Gilbert F. White discussed in his 1945 dissertation Human Adjustments to Floods (White, G.F. 1945), written in an era when natural systems were deemed to be manageable by human intervention, that flood losses were generally the result of human actions that put people and property at risk and to resolve this problem a broad series of 'adjustments' was needed, not just levee construction.

The EC Floods Directive (EC 2007) favours long-term planning and long term planning to reduce the risks associated with flooding. Other recent national flood management policies, such as the UK Government's *Making Space for Water,* the Netherlands and German Governments' programme *Room for the Rhine and* the French Government's *Grenelle de l'environnement* have emphasised the need to embrace a portfolio of responses or adjustments for both coastal and river flood risk management. They recognise that responding only with flood defence measures (including levees) is neither acceptable environmentally, socially or economically, nor is the approach sustainable in the long term. Hence long term planning measures to improve use of available spaces for human activities, but also to accommodate flooding should be an integral part of the response. However, the various national authorities and agencies recognise that levees will continue to form a significant part of their nation's overall flood risk management strategy for the foreseeable future. This also opens new opportunities for combining flood protection with other functions and creating win-win-situations for safe, liveable and attractive areas.

Indeed, even when looking at the long term benefits of adopting a portfolio of approaches, the UK study *Foresight Future Flooding* (UK Government 2004) suggested that annual expenditure on flood and coastal defences in the UK would need to be doubled in real terms by the 2080's to take account of effects such as sea level rise, increased storminess, and socio-economic factors including population growth.

In a similar way, a commitment has been made to improve levee safety in the USA following the devastation of Hurricanes Katrina and Rita (2005). The American Society of Civil Engineers released a report card (grading A-F), rating all infrastructure in the USA. Based on this report, levees were given a failing grade indicating the extremely poor condition of that infrastructure. Subsequent to these events a National Committee on Levee Safety was established by the USA Congress to recommend a path forward for the Nation. The National

Committee on Levee Safety recommended the establishment of a *National Levee Safety Programme* with focused efforts to improve the overall condition of levees and manage those systems in a risk based framework.

In the Netherlands, the second Delta Commission (DC 2008) has identified a significant shortfall in the safety standards of the Dutch dikes and a need for a multi billion Euro expenditure programme to meet the challenges of climate change. Therefore risk reducing measures are needed by means of lowering the probability of flooding and reducing the effects for the hinterland by appropriate planning and the development of new concepts.

Thus, in most cases the principal challenge for flood management authorities is to determine how best to manage and upgrade their flood defence systems and associated levees in order to manage the increasing flood risk whilst obtaining best value from investment in their existing levees. In many cases, there is no alternative than to build on existing alignments.

A particular challenge in strengthening and /or raising existing levees is dealing with the uncertainty of their internal and foundation conditions. Many have been extended or raised over the years, often in a piecemeal manner or in response to performance problems. The design and construction records are often poor or non-existent and when analysed to modern standards, the levees are often found to have low factors of safety, particularly for the extreme events that they should be capable of resisting. In addition, many have deteriorated over the years since construction as a result of settlement, cracking, animal infestation and the like.

High quality assessment and design guidance is therefore essential to ensure that such levees are constructed or improved to be appropriately resilient for future extreme events without incurring excessive cost.

Recent experiences have emphasised the importance of designing and implementing appropriate monitoring and maintenance strategies for levees. The need for a strong asset management approach (whole life / holistic) are critical to long term performance of flood defences. These experiences in this regard are:

1. After the levee failures in France during the major floods of the Rhône river, it became clear that levees must be correctly monitored and maintained following a similar approach which had been adopted for dams since the 1970s. This led to changes in French law and, now there is a classification for dikes and levees comparable to those for dams and an expert group called *technical point of support for hydraulic structures* (PATOUH) has been created to help authorities guaranteeing the safety of these works. Recent guidance *Surveillance, Maintenance and Diagnosis of Flood Protection Dikes* (P Royet et al 2007) stresses the need for an integrated management of deteriorating dikes.
2. After the serious floods of the Oder (summer 1997) and the Elbe (Summer 2002) many analysis and research activities were launched to improve the knowledge and understanding of the behaviour of flood protection works. On the basis of many reports, the German Standard DIN 19712 *Flood protection Works along flowing Waters* (DIN 2010) and the Guideline 507 *Dikes along flowing Waters* (German Association for Water, Wastewater and Waste 2007) were updated.
3. In the Netherlands, several guidelines, manuals and technical reports referred to in the “Relevant Publications” in Appendix C of this report are available for the design, periodical safety check and management of soil structures.
4. *The Framework for Action* (Defra 2004) resulting from a UK study on *Reducing the risks of embankment failure under extreme conditions* recommended production of a full design guide, especially because of the lack of proper understanding of how levees perform and design standards. A related interim *Good Practice Guide for Management of Flood Embankments* (Defra 2007) supports the need for integrated guidance for levees across

the engineering disciplines (hydraulics, geotechnics, geology and structures) and the adoption of risk and performance management principles and approaches.

5. The extensive breaching of levees in New Orleans USA during Hurricane Katrina has led to a number of state and federal activities in the USA including a significant *Levee Safety Programme*.

2 Introduction and objectives of the scoping study

In September 2008, organisations from six countries (France, Germany, Ireland, Netherlands, United Kingdom, and United States of America) expressed a desire in principle to participate in an international project in order to learn from one another's experiences and to share the effort to produce good practice guidance – the International Levee Handbook (ILH). Past experience suggests that considerable confidence is gained in individual countries by being able to refer to authoritative guidance from an international team, which has discussed and resolved differences in practice and identified necessary improvements. National and public organisations as well as key industrial stakeholders will gain considerably from the experience, and participation will facilitate subsequent uptake and implementation by their organisations and associated contractors.

To start the international project, a scoping study has been undertaken including the following activities.

2.1 Objectives of the scoping study

The objectives for the scoping study were to:

- establish an agreed business case for the production of the ILH
- confirm the function, target audience, scope and specification for the document to be produced subsequently, including an outline contents list, the form of the final paper and electronic documents
- produce conceptual frameworks setting out the broad rationale for the assessment / design / management process
- develop and agree national and international project team structure and membership, including both practitioners and researchers. Ensure an appropriate mix of hydraulic, geotechnical, operations and maintenance, design, and construction expertise is drawn together
- develop, agree and ratify a collaboration agreement between partner countries. The agreement will address costs of overall project management, editing and publishing of the document in English and also the translation into French. Subsequent translation into other languages will be dealt with separately
- facilitate the process of securing funding for the main phases of the project.

The final product from the scoping study is this scoping report, which explores the following sections:

- background, introduction and objectives of the scoping study and the ILH
- the need for the ILH, including overview of benefits, value of collaboration, country statements
- the objectives of the ILH
- options assessment, including options considered and option preferred
- summary of the preferred approach
- proposed content and frameworks to be included in the ILH
- information on form and layout, considering editorial aspects

- the method of delivering the ILH, including management of the project and risks identified
- project programme
- dissemination and communication
- key conclusions and recommendations.

2.2 Programme of activities

2.2.1 International meetings and workshops

A number of international meetings have taken place:

1. First international meeting held in Oxford, UK, 29 September 2008. A formal project proposal confirming the scope and specification and also an outline contents list for the proposed project were produced following this first international meeting.
2. Second international meeting, Wallingford, Oxfordshire, UK, 12-13 May 2009. The outline contents list was expanded following a number of workshops at the meeting. Also a conceptual framework setting out the broad rationale for the assessment / design / management process was developed. Besides these, a number of project management related documents were explored, including the project programme and work plan, a methodology document, a communications plan and a proposal to set up a website for the project.
3. Third international meeting, New Orleans, Louisiana, USA, 26-29 October 2009. Key outputs from the discussions at this meeting included: a revised outline contents list and conceptual framework to support the scoping report; first agreements on the form of a collaboration agreement amongst the nations involved; exploration of costs of overall project management, editing and publishing of the ILH in English and also a probable translation into French. Agreements were reached on definitions of a levee and flood defence system and on the title of the final product ("International Levee Handbook"). The meeting focussed on firming up the function and scope of the Handbook as well as confirming the programme, work plan and method of international collaboration and included an initial debate to identify chapter leaders and chapter teams. Furthermore, it was agreed that a solid business case for the ILH project would be required to convince funders and those outside the project promoters already involved.

2.2.2 International conference calls

Besides the listed international meetings, a number of international conference calls have taken place on the below listed dates. The conference calls were held to allow for country updates and ensure any possible concerns would be addressed as efficiently as possible.

- 23 April 2009
- 11 September 2009
- 15 December 2009
- 23 February 2010
- 21 April 2010
- 25 May 2010.

2.2.3 National backing group meetings

Each nation has also held a number of national backing group meetings to ensure the best possible backing groups have been formed, to prepare for international meetings, to review and comment on material developed, such as the contents list, the conceptual framework and the project management related documents and also to facilitate securing the funds required to undertake the project.[1]

For more information on project team structure see Chapter 9 and Appendix D of this report.

[1] At the time of writing this report, the Netherlands and Germany did not have formal national backing groups formed.

3 The need for and benefits of the International levee handbook

3.1 Introduction and overview of benefits

It is clear that existing guidance on the assessment, design, construction, and maintenance of levees is variable in detail and scattered through numerous and often obscure documents. Whilst guidance on some issues (such as how to undertake a levee inspection) can be obtained from existing best practice documents and the technical literature, other issues (such as the integration of the geotechnical and hydraulic aspects of design) require synthesis and the production of new or additional guidance. It is particularly important to explain to both asset owners/managers and designers alike that engineering judgement, experience and knowledge of local conditions all contribute to effective design and management practice.

New guidance can be partly drawn from recent and ongoing research in the EU / USA and partly from collation of previously published and unpublished best practice. Even though the legal and professional framework will vary from country to country, a single, comprehensive and self-contained handbook will make dissemination and wider uptake of consistent standards and approach easier and more effective. The ILH will provide the reader with an overview of the approaches in the different existing national and international codes and standards, filling any gaps in guidance whilst avoiding being over-prescriptive. The ILH should therefore be regarded as a 'decision support' document for a competent engineer, as distinct from a prescriptive 'decision-making' code of practice.

A corollary of the need for comprehensive and guiding document is the need to avoid the danger of fragmented guidance which might actually make the present situation worse. For example, in Europe Eurocode 7: Geotechnical Design has been issued for use and will be compulsory as the only code of practice for use in the engineering design of structures for government funded projects within the EU after 2010. However, whilst it sets out the principles for geotechnical design, it provides little specific guidance on the design of embankments and levees. During the next revision of Eurocode 7, this issue may be addressed (but it will still focus on principle rather than detail). Without proper input from those experienced in the design of levees, (e.g. in the form of guidance notes or design manuals), the resulting code could be confusing or possibly even contradictory. The ILH will therefore offer a consistent framework available to all countries for understanding, designing and managing levees, taking account of their different geometries and strengths (and their associated uncertainties), whilst still allowing country specific factors to be adopted by users.

Key benefits of the ILH include:

- using and influencing the ILH will provide infilling information in those areas where the participating countries' own guides and manuals are lacking
- promoting and synthesising good practice on assessment, management, design and construction will enable better understanding and learning from others
- establishing a baseline of good practice and standards in area will address gaps where information does not presently exist
- permitting the setting up or improvement of regulation procedures for levees will enable improved (or more consistent) risk-based condition and performance of levees to be achieved
- improving outcome levee performance will result in reduction of flood risk

- providing guidance will support countries which have a lower level of technical expertise and may be a greater risk of major flood events
- streamlining technical decision making process will be particularly useful where fast decisions are required from within a possibly multi-national team in disaster recovery situations.

A full list of all the benefits anticipated to arise from the production of the ILH identified during the scoping phase is included in Appendix A.

3.2 Value of collaboration

Organisations from six countries (France, Germany, Ireland, Netherlands, United Kingdom and United States of America) have expressed a desire in principle to participate in an international project. This interest has arisen from a desire to learn from one another's experiences and to share the effort to produce good practice guidance described in Chapter 2 of this report. Past experience suggests that considerable confidence is gained in individual countries by being able to refer to authoritative guidance from an international team which has discussed and resolved differences in practice and identified necessary improvements.

The endorsement and participation of national and public organisations as well as private sector firms and academia is key to the project. Participating partners will gain considerably from the experience and participation will facilitate subsequent uptake and implementation by their organisations and associated contractors, including facilitating subsequent training programmes.

The benefits of international collaboration also include sharing costs associated with producing the ILH, enabling organisations to participate in the project at a fraction of the total project costs.

3.3 Country statements, needs and benefits

3.3.1 France

In France, there is a huge patrimony of existing levees (around 10.000 km), old, generally poorly maintained, and even worse with many levees without a proper management organization. On the other hand, since the early 1990s, recent events (floods and levee failures) have led French society to be more aware of this problem. French national administration has improved the regulation related to levees, mainly the owners' obligations, and the state control. Locally, authorities have here and there started to organize managing organizations, with a few exemplary cases. There is no national technical guidance; all is based on common best practice, which is so far not vey well developed for flood protection levees (unlike dams and canals). A lot of research is going on the levee subject, but generally acknowledged guidance is so far limited to assessment of existing levees condition, so this Handbook will definitely be more than useful to all stakeholders. It will make every stakeholder aware that designing and building a levee with local perspective is not enough. A levee is part of a system, at different scales, up to the whole catchment scale, and should be designed according to all these scales perspectives. Also, building a levee is not enough, it has to be taken care of maintained and checked.

3.3.2 Germany

By taking part in the project, the participants from Germany will have the opportunity to contribute to the planned ILH for embankments and sea dikes with respect to design, construction, and maintenance. It will offer a unique chance to incorporate guidance which has be summarised in the current German Standards *DIN 19712 (DIN 2010)*, *Guideline 507*

(DWA 2007) and the Guidelines of the German Port Technology Association (HTG) as well as others. These documents represent the present best practice in Germany including the experiences from the large floods in German river basins during the last decade and previous storm surges along the coasts. On the other hand, the German participants will have the opportunity to share the experience of other countries which will help to check and further enhance the German standards concerning completeness, gaps, or different approaches. The concerted efforts could also bring up items from which suggestions for the harmonising of national guidelines could be derived. This might be of great importance to achieve the same degree of flood protection for the hinterland at border crossing levees and sea dikes.

3.3.3 Netherlands

Deltares has participated in the scoping phase and will stay involved in the next phase as a technological institute, but not on behalf of the Netherlands. By participating in the development of the ILH, Deltares sees itself investing in international cooperation and the exchange of knowledge and sees particular importance in contributing to guidance in the ILH on safety philosophy and preparing for climate change. In terms of public bodies, the Dutch Ministry of Public Works and Water Management (Rijkswaterstaat) will contribute by making available in English existing Dutch guidelines and technical reports. In addition it is hoped that STOWA (the Dutch organisation representing the local water boards responsible for levee management) will contribute both in terms of involvement of personnel and also with some additional funding.

3.3.4 UK/Ireland

The need for development of guidance for levees in the UK has been recognised since the *ICE Presidential Commission report* (ICE 2001) and the need for guidance was set out in the national project on *Reducing the risks of embankment failure under extreme conditions Defra Project FD2411* (Defra 2004). The need for a guidance document that focuses on the performance of flood defence embankments is strongly supported by practitioners. By contributing to the project, the participants from the UK and Ireland will have the opportunity to influence and contribute to what is likely to become a major international point of reference for design, construction and management of flood embankments and to learn from best practice in other countries Using the ILH will ensure that operating authorities in flood and coastal risk management (FCRM) and the practitioners in the wider FCRM industry will make engineering and asset management decisions based on the best available and internationally accepted evidence. This will produce efficiency gains (making future asset management less costly) and performance gains (doing things that make assets perform better). A key benefit is in establishing a baseline of good practice which does not presently exist by bringing together the approaches of the UK, Ireland and other lead nations. This baseline will make it relatively easy for UK authorities to develop improved internal assessment and design processes for flood embankments and thus allow measured steps to be made towards the introduction of appropriate risk-based certification of embankments.

Without this project, the UK and Ireland will miss an opportunity to build on an emerging partnership to ensure UK and Irish embankment design, construction and management decisions are based on internationally accepted best practice.

3.3.5 USA

Management and design of levees in the USA is complex because of the size of the country and the number of federal and state organisations involved. However, momentum for support for the ILH to build as a result of a workshop in New Orleans held at the end of October 2009 hosted by the US Army Corps of Engineers (USACE) and supported by the Department of Homeland Security. At the workshop, a draft contents list (largely prepared in Europe) was presented and discussed; the senior USACE staff involved in the workshop decided to report the ILH initiative to the National Committee on Levee Safety. The issues raised in the contents list matched so many of the issues already identified by the Committee that the ILH received strong endorsement. This is enabling both USACE and other US federal and state organisations as well as professional organisations to get involved and contribute and for appropriate funding streams to be identified.

3.4 Resulting business case for International levee handbook

Given the foregoing discussion it is clear that there is a good emerging business case for proceeding with the ILH. Examining typical business options the following is clear.

Doing nothing is not acceptable. As already stated, existing guidance on the assessment, design, construction, and maintenance of levees is variable in detail and scattered through numerous and often obscure documents. This situation continues to encourage and perpetrate engineering practice which at best is variable and inconsistent and at worst is poor and liable to lead to levee failure.

Doing the minimum might represent simply drawing together a bibliography of existing guidance from the plethora available with some signposting as to where to look to tackled specific issues. This might be quick and easy to achieve but would fail to deliver the degree of integration of between geotechnical and hydraulic practice and in whole life cycle and systems thinking. This lack of integration has been identified as leading to variable, inconsistent and even poor management and design practice, exacerbated by piecemeal development and raising of levees. Furthermore, previously acceptable management and design practice may no longer deliver adequate levee performance in the future as climate and land use change.

Doing something more than the minimum might be best envisaged as adding to the minimum signposting guidance, some additional guidance which might plug the gaps in what is currently available. However, the different participating countries would identify different aspects on which they would like to focus and thus would tend to create guidance that was country specific. Thus the benefits identified in the country statements above of international collaboration (such as sharing where a country is strong and learning from others where it is weak) would be lost.

The full ILH resolves the problems associated with the above lesser options and, despite its cost and resource implications, is the only identified way of delivering the required integrated guidance. The integrated and international ILH team will set the necessary international baseline of good practice and will help future management and design to adapt to socio-economic, climate and related ground condition changes. Detailed options for different aspects of the ILH are discussed in more detail in Chapter 5.

4 Objectives of the International levee handbook

Arising from the needs discussed in the previous section, the following objectives for the ILH have been confirmed during the scoping study.

Principal objective:

- to provide a comprehensive and definitive guide to set out good practice in the evaluation, design, implementation, maintenance and management of levees (including guidance on site investigation).

Specific objectives:

- to present a rational approach to the classification, evaluation and management, design, repair, upgrading and construction of levees for fluvial and coastal floods
- to distil principles, processes and conclusions from existing guidance, recent research and practical experience on the use of levees for flood defence
- to develop a generic and non prescriptive conceptual framework, which should connect the overlaps and bridge the differences between countries, and adopt risk management approaches and principles for flood risk safety
- to identify any areas where new collaborative research might beneficially be promoted over the subsequent 5 years
- to provide a mechanism for the rapid integration and dissemination of new knowledge and practice as existing and future initiatives are completed.

Particular issues and principles to be addressed by or contained within the ILH were identified during the scoping stage. Issues of equal interest to both to levee owners/managers to designers included:

- description and classification of the different structures and component types and their design, construction and management issues and also distinctions between old and new levees
- integrating management process and design, including hydraulic and geotechnical engineering
- dealing with existing and proposed national, Federal/EU and international laws and codes of practice affecting the design, construction, maintenance and improvement of levees.

Issues of more interest to levee owners/managers were:

- operation and maintenance protocols
- management and repair of deterioration processes such as settlement, cracking, vegetation growth, animal infestation etc
- emergency action prior to and during floods (including breach closure)
- practices and principles of stakeholder engagement for engineers, levee owners etc
- the importance of understanding the historical development of the levee and managing both historical and contemporary data.

Issues of more interest to designers were:

- description of failure modes/processes, both hydraulic, morphological and geotechnical, including their interaction with ground conditions and the need for associated best practice in site investigation and seismic design
- design methodologies for dealing with the various applied hydraulic loads (wave, scour, overtopping, piezometric pressures, currents etc) and other loads associated with the different types of levee
- environmental context, including geological, geomorphological and climatological factors
- resilience in extreme events beyond the design standard
- integration of the flood management function of levees with their other functional uses, including amenity, environmental and transportation
- construction considerations, including use of novel materials and systems
- quality control and quality assurance.

Issues of more interest to levee owners/managers and designers were:

- current practice and innovative ways of repairing, upgrading (including raising) levees
- evaluation, inspection, analysis and assessment of levees, including novel technologies for levee and leakage monitoring.

5 Options assessment for International levee handbook

This section summarises the information gathered and relevant findings resulting from the programme of activities described in Chapter 2 of this report.

Throughout the meetings and workshops undertaken in the scoping study, representatives from the participating nations raised various queries on how the ILH would work, who would be the target audience and what it should contain. A balanced group of experienced practitioners and well-informed 'industry' professionals considered the options and addressed these queries.

5.1 Options considered

The main queries that were raised and options that were considered during the scoping study are grouped below:

5.1.1 Type of guidance

Options were considered by the participating nations as to whether the ILH should override other existing national guidance or compliment it. Queries were also raised by the group on how to deal with the varying approaches and principles on levee design and management that exist in various nations and which ones would be included in the ILH.

At the very beginning of the study, it was agreed by all that it is not the intention of the ILH to replace existing guidance, but instead to provide some high level guidance and a generic framework to connect the overlaps and bridge the differences between countries. It was agreed that the ILH would provide the reader with an overview of the approaches in the different existing national and international codes and standards, filling any gaps in guidance whilst avoiding being over-prescriptive. It was agreed that the advantages and disadvantages of design and management methods used in various countries would be explained, but not prescribed. Minimum standards would be developed with the benefit of experience from participating and other international review partners.

In summary, it was agreed by all that the ILH would be regarded as a 'decision support' document as distinct from a prescriptive 'decision-making' code of practice.

5.1.2 Content and size

Options were considered by the participating nations as to what the ILH should contain and how large it should be. The group was originally concerned at the start of the study that it may become a detailed textbook on levee design, too large to be of any practical assistance. On the other hand, it was also agreed that merely producing a short document that provided 'signposts' to existing national documents would not achieve the desired degree of integrated international understanding.

As the study progressed, the international group agreed the following:

- only best practice would be referred to in the ILH
- existing guidance and links to web pages would be referred to where this is considered appropriate
- where considered appropriate to include more detail, these would be included in appendices

- case studies highlighting techniques and methods for designing and managing levees in various countries would be highlighted within appropriate chapters alongside the text
- practical limits would be agreed for chapter lengths and it was agreed to control the size of the ILH to around a 1000 page limit.

5.1.3 Target audience

The group considered the various types of audience, who may be interested in the ILH and what level of technical ability these audiences may have to understand at what level the ILH should be pitched. It was agreed by all that the ILH would be written for two target audiences:

1. The levee owner and manager, who may have limited technical knowledge, and the ILH would therefore seek to provide sufficient background information to enable them to understand the key issues and general procedures for levee management.
2. The levee designer, for whom the ILH would seek to provide sufficient technical details to enable them to design improvements and new works.

Levee constructors would be heavily involved in the production of the ILH, but primarily to ensure that information on construction aspects was included to advise the levee manager or designer how to carry out maintenance, improvements or new construction works; the ILH would not be aimed at providing detailed guidance to constructor teams.

Queries were also raised by the group as to whether the ILH could be considered "international" and could be used by third world countries with only 6 countries participating.

It was agreed by all that an international review by other countries would be undertaken and representatives from such countries as India, China, Korea and Japan would be invited to review various sections and chapters. There would be no limit to the number of reviewers. In addition, experts from other countries not included in the Project core team will be invited to write sections of the ILH.

5.1.4 Terminology to be used

A key point of the discussions between the participating nations throughout the scoping study, including at the international meetings, was the achievement of agreed definitions., It was noted that terminology and words could mean different things in different countries; for example 'inward face' and 'outward face' have opposite meanings in the UK and Netherlands and in. the USA the word 'defence' is used instead of 'protection'. It was therefore agreed by all that common definitions of key terms would be agreed and defined in the ILH. As a first step, and to help more clearly define the scope of the ILH, at the workshop in New Orleans, Louisiana, US, 26-29 October 2009, the following definitions were agreed:

> ***Levees*** *are raised, predominantly earth, structures (sometimes called embankments or dykes) whose primary objective is to provide protection against fluvial and coastal flood events along coasts, rivers and artificial waterways that are not reshaped under normal conditions by the action of waves and currents.*
>
> *Levees form part of* ***flood defence systems*** *that may also include flood walls, pumping stations, gates closure structures, natural features etc.*

In addition, at the New Orleans workshop, several organisations expressed concern that the term 'Manual' used at the start of the scoping study conferred an unintended degree of prescription. It was agreed to call the document a Handbook rather than a Manual so as to convey better the concept of a comprehensive but non-prescriptive reference document.

5.2 Preferred option

Through discussions and agreements with the participating countries, the scoping study has provided firmer facts and information. Various options for delivering the ILH have been considered as described above and these have been developed to provide the preferred option for taking the ILH forward.

The preferred option agreed by all is summarised below:

- the ILH would be regarded as a 'decision support' document as distinct from a prescriptive 'decision-making' code of practice
- in order to control the size of the ILH, a practical limit of up to 1000 pages would be specified. To maintain this, only best practice would be included, existing guidance and links to web pages would be referred to where this is considered appropriate, and details would be included in appendices where appropriate
- the ILH would be written for two target audiences, the levee owner/manager and the levee designer, and that various chapters within the ILH would be targeted at these specific groups and pitched at the appropriate technical level. (Information on construction aspects would be included, but primarily to advise the levee manager or designer how to carry out maintenance, improvements or new construction works; the ILH would not be aimed at providing detailed guidance to constructor teams)
- an international review by other countries would be undertaken and experts from other countries not included in the project core team will be invited to write sections of the ILH
- a common understanding of words would be agreed and defined in the ILH.

In addition to the notes in this section, further details are given in the following sections of this report on how the preferred option was developed such as the proposed contents of the ILH in Chapter 7 and the form and layout in Chapter 8 of the scoping report. Also, a work plan and methodology have been developed based on other previously successful international projects.

As discussed in Chapter 3 of this report, the benefits of developing the ILH was agreed by all participating countries during the scoping study. It was agreed, it would be beneficial to have a internationally recognised handbook on levees alongside all the other national guidance and mandatory documentation because:

- existing guidance on the assessment, design, construction, and maintenance of levees is variable in detail and scattered through numerous and often obscure documents; and
- a single, comprehensive and self-contained handbook would make dissemination and wider uptake of consistent standards and approaches easier and more effective.

In order to obtain a wider opinion on the options for producing the ILH, as part of the scoping study, consultants/designers, contractors/constructors and client organisations (both levee owners and managers) have been consulted about practical experiences and industry needs. For example, a questionnaire circulated amongst engineering consultants working for the Environment Agency in England and Wales identified many areas where current practice could be improved. In particular, it was found that a lack of common guidance has led to inconsistent approaches to the assessment and design of levees. There is an over-reliance on personal experience in decision-making and a frustration that asset owners often do not appreciate the complexities of their earthen structures. Many responses supported the need for establishing best practice for site ground investigation and identified the benefits of having a standard specification for construction of levees. There was particularly strong support for risk-based assessments of designs coupled with a certification scheme for levees that a handbook could support (designers in the UK are familiar with this approach as it is widely used for infrastructure embankments already). Overall, there was strong support of a levee handbook as long as it provided guidance on principles and examples of good practice, but was not prescriptive and did not inhibit innovation.

There was a broad consensus by all members of the participating nations at the start of the scoping study about what the perceived issues were and that this was a viable project. As the scoping study progressed, it was agreed that the ILH was a challenging but desirable and attainable goal and therefore the project to deliver it should be supported.

6 Summary of preferred approach

The ILH will be written to assist a technically competent practitioner with a broad (but not necessarily expert) knowledge of the field of application to arrive at the best approach for a particular asset or asset system. In this context, the objective of the ILH will be to provide information to support decisions made rather than to direct which decisions are made. The ILH will also seek to provide an intelligent client (i.e. a client with a technical background, but no particular specialist knowledge) with sufficient background information to understand the key issues and general procedures likely to be followed by an experienced practitioner.

The ILH will be written to address two major viewpoints:

1. That of the manager of the operating authority's physical assets who has the overall task of owning, maintaining, upgrading, adding to and disposing of its stock of flood or coastal defence.
2. That of the designer who will tend to focus on the need for, design of and implementation of improvements and new works.

In addition, the ILH will provide some useful information for contractors/constructors (or other organisations) that may be advising the manager or designer, carrying out maintenance, or carrying out new construction work on construction issues.

The ILH will take a risk, performance and systems based approach. Any asset will have a primary function of flood management or coast protection to which performance objectives or standards will apply. All assets will also have various secondary functions – eg environmental, amenity, health and safety, access – which can impose significant performance requirements.

In drafting the ILH, the author teams will consider the various management interventions that will be needed to achieve the performance requirements of the asset over its whole life cycle. Therefore the ILH will address the assessment of existing assets (possibly for new or changed performance requirements), their adaptation or replacement, and their operation and maintenance, as well as new design and removal.

The author teams will recognise that management interventions range from major construction projects carried out by external contractors through to routine maintenance by the involved authorities' own work force.

The intervention and the ongoing process of operation and maintenance will contribute to an appropriate archive of asset data (including costs), which establishes the essential operational feedback. The overall process is sometimes referred to as the "management cycle of a levee" (see Figure 1).

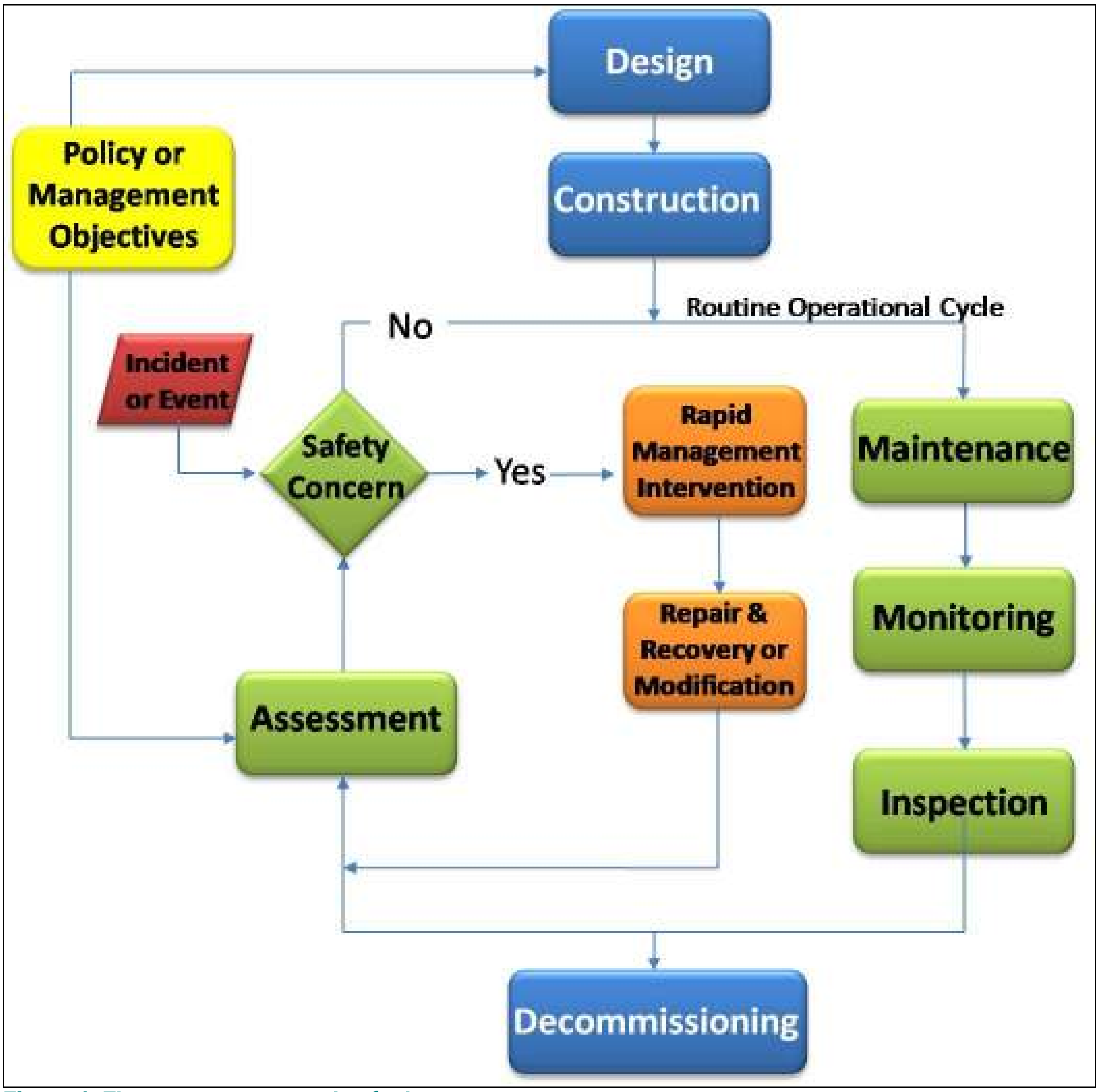

Figure 1: The management cycle of a levee

To promote a wide uptake of the handbook after it has been produced, it was deemed necessary to utilise the right mix of skills (particularly hydraulic and geotechnical engineering, operations and maintenance, design and construction) in writing the report. A significant effort has therefore been made during the scoping study to ensure that leading experts from each participating nation are involved in the project.

Producing an international manual of this scope and scale is a significant undertaking. This will involve each country leading on the production of certain chapters, plus considerable pan-nation collaboration in terms of contributing to, and commenting on the ILH as a whole. Each participating nation will have developed its own budget and will be responsible for securing funds required. However, it is estimated at least $3m will be required to set up, develop, edit and publish the ILH. This figure does not take into the account the significant amounts of contributions in kind which will be offered towards the project by participating organisations.

For detailed information on costs, the following organisations can be contacted in the participating nations:

- France: CETMEF
- Germany: TU Dresden[2]
- Netherlands: DELTARES[3]
- UK / Ireland: CIRIA
- USA: USACE.

[2] TU Dresden is acting as the coordinating organisation and not as a contractual partner from Germnay at the time of writing this scoping report.
[3] DELTARES is acting as the coordinating organisation and not as a contractual partner from The Netherlands at the time of writing this scoping report.

7 Proposed contents and frameworks to be included in the International levee handbook

7.1 The proposed contents list

An outline contents list for the ILH was produced following the first international meeting in Oxford, UK, 29 September 2008. This has been expanded following subsequent international and national meetings and includes comments from the national backing groups from participant countries. The list has undergone much iteration including changes to the order of chapters and sections and what issues should and should not be included. The final agreed contents list is included in Appendix B with discussion on some of the key principles shown below:

- a glossary of terms and abbreviations will be included
- an executive summary aimed at policy managers and strategists will be included, together with a statement that the governance infrastructure must provide adequate authority (e.g. laws, policy, regulations) or direction for the engineer/planning body
- case histories will not be presented in a separate chapter, but in text boxes in a relevant form within the body of the document. These will cover things that have gone well and things that have gone badly from large to small scale and will demonstrate the tiered risk-based approach to flood risk management (including examples of construction, maintenance practice and usage)
- usable information at the operational end, i.e. key points, should be summarised for ease of use at the end of the chapter
- the project may well identify some gaps in knowledge, which need to be filled by further research. This will be the subject of a separate short report and will not be included within the main document to avoid unnecessary detail
- recent and ongoing research will be referred to in the text within the relevant chapters.

7.2 A summary of chapters

A summary of the contents of each chapter, who the most relevant users of the chapter are and how each chapter links to other chapters are included in this section:

CHAPTER 1: INTRODUCTION

This chapter will clearly define the handbook's structure including the scope, i.e. what is and what is not addressed. It will establish the need for the ILH and explain how it builds on and differs from existing manuals and guidance. To address the issues that were discussed in the scoping study, a definition of a levee and the context of the levee within a scheme and strategy for a region will be included in this chapter.

All chapters will be linked to this one as relevant to the user.

This chapter will be relevant to all users to enable them to determine which of the ILH's sections are relevant for their requirements.

CHAPTER 2: CONCEPTUAL FRAMEWORKS

This chapter will provide two conceptual frameworks; firstly, a generic management framework on flood defence systems, which will connect the overlaps and bridge the differences between countries. This will put levees in context with other parts of the flood defence system. Secondly, it will also include a flow diagram showing the framework for the life cycle management of a levee, which will be used as a route map to guide the user through the ILH.

All chapters will be linked to this one as relevant to the user.

This chapter will be relevant to all users in order that they can determine which chapters are relevant for their requirements. It will be most relevant to levee owners and managers as well as decision makers (funders and/or local/national authorities) and will therefore be pitched to this level.

CHAPTER 3: FORM AND FUNCTION OF LEVEES

This chapter will include a description and diagrams of the main different types of levees and how they function with regard to flood risk. It will discuss the influence of other structures associated with levees and the multi-functionality of levees. A section will be included on failure modes and how these are connected to certain types of levees.

All chapters will be linked to this one, but of most relevance is Chapter 9 on *Design*.

This chapter will be useful to all users of the handbook.

CHAPTER 4: OPERATION AND MAINTENANCE

This chapter will address work that does not require detailed design. It will discuss the role of maintenance in the face of deterioration and climate change including best practice and innovative methods. It will highlight the competing goals of flood protection, environmental and social issues. There will be a significant section on vegetation control and management.

This chapter will have links to Chapter 6 on *Emergency preparedness and management*, Chapter 5 on *Condition assessment of levees* and Chapter 9 on *Design*.

The key users for this chapter will be staff from operational authorities and levee owners and managers. Consultants and designers should be familiar with this chapter to allow them to incorporate whole life management processes into their designs.

CHAPTER 5: CONDITION ASSESSMENT OF LEVEES; INSPECTION, INVESTIGATION AND MONITORING

This chapter will include best practice procedures for diagnosis and condition assessment of levee structures in order to allow consistent and appropriate levels of reporting, including visual inspection, investigations and risk assessment. The first sections will provide a tiered approach to investigation of levee condition including inspection techniques and different types of investigations. Another section will provide recommendations to provide a levee system risk assessment. The next section will deal with monitoring common issues including appropriate tools, instrumentation and survey methods as well as state of the art methods of monitoring. The last section will deal with geographical information systems (GIS) to support levee management.

This chapter will have links to Chapter 4 on Operation and maintenance, Chapter 6 on *Emergency preparedness and management*, Chapter 7 *Site characterisation and data requirements*, Chapter 8 on *Physical processes and tools for levee design* and Chapter 9 on *Design*.

The key users for this chapter will be staff from operational authorities and levee owners and managers. Consultants and designers should be familiar with this chapter to allow them to incorporate whole life management processes into their designs and undertake condition assessments of existing levees before designing repairs or improvements.

CHAPTER 6: EMERGENCY PREPAREDNESS AND MANAGEMENT

This chapter will provide a section on guidance on breach modelling with emphasis on the limitations and uses of methods and preparing and implementing emergency action plans. It will include guidance on event management, including methods for emergency breach repairs, post flood cleanup and data collection.

This chapter will have links to Chapter 4 on *Operation and maintenance* and Chapter 5 on *Condition assessment of levees*.

The key users for this chapter will be levee owners and managers, staff from operational authorities and emergency responders.

CHAPTER 7: SITE CHARACTERISATION AND DATA REQUIREMENTS

This chapter will begin with detailing site investigation methods and how these are critical for establishing appropriate boundary conditions and properties for design. It will cover desk study procedures, intrusive and non-intrusive techniques for sampling and field investigation as well as relevant laboratory testing techniques and approaches to data interpretation that are suited to levees and the ground on which levees are built. This will be followed with a section on recommendations for minimum or target levels of protection to provide flexible standards. It will establish the design loading criteria including environmental and social criteria for both coastal and fluvial levees. A section on the effects of climate change will feature in this chapter.

This chapter will have links to Chapter 5 on *Condition assessment of levees*, Chapter 8 on *Physical processes and tools for levee design* and Chapter 9 on *Design*.

The key users for this chapter will be consultants and designers, and contractors/constructors. In addition, this chapter will be useful for staff from operational authorities and levee owners and managers.

CHAPTER 8: PHYSICAL PROCESSES AND TOOLS FOR LEVEE DESIGN

This chapter will demonstrate the need for a holistic approach to the design of levees that embraces both geotechnical and hydraulic engineering disciplines. It will set out the physical processes that control the performance of levees and indicate which analytical engineering methods and techniques best represent these characteristics. Amongst other things, the chapter will identify common failure modes and deterioration processes. It will give examples of typical engineering calculations for both the assessment of existing structures and the design of completely new levees. Case histories will be included to illustrate projects where best practice has been applied. The chapter will also include a summary of sophisticated geotechnical and hydraulic modelling techniques

This chapter will have links to Chapter 7 on *Site characterisation and data requirements* and Chapter 9 on *Design*.

The key users for this chapter will be consultants and designers.

CHAPTER 9: DESIGN

This chapter will highlight the need for early specialist input from a variety of disciplines and a balance between engineering, environmental and social factors. Sections will be included for design of remedial and improvement works, new levees and removal of levees including sections on planning and options appraisal. The chapter will provide recommendations on methods for taking levees out of service including realignment options. The chapter will highlight the potential impacts on adjacent sections, e.g. increased flood levels, and how to deal with these. Specific design details with examples will be featured.

Key points will include “expedition planning” to deal with long-term climate change, access requirements (for the land owner, maintaining authority and for public right of way), non-structural alternatives, communication and collaboration, consideration of whole life management, best practice vegetation design, sustainability, environmental and social issues.

Other design manuals and codes will be referenced. It is anticipated that Chapter 8 will set out the engineering principles and procedures that govern or characterise how levees perform. This chapter will demonstrate how these techniques can be used for design purposes and will provide both guidance and examples of best practice..

This chapter will have links to Chapter 3 on *Form and function of levees*, Chapter 4 on *Operation and maintenance*, Chapter 5 on *Condition assessment of levees*, Chapter 7 on *Site characterisation and data requirements*, Chapter 8 on *Physical processes and tools for levee design* and Chapter 10 on *Construction*.

The key users for this chapter will be consultants and designers including contractors/constructors involved in design and build projects.

CHAPTER 10: CONSTRUCTION

This chapter will describe how construction practices and standards have changed over time. It will include economic best practice, planning (in particular access of plant to site), designing for ease of construction, sourcing of suitable earthworks materials, sustainable and innovative construction practices for decommissioning, maintenance, remedial, improvement and new works. It will highlight common problems and risks faced on different sites, including the need for a good knowledge of foundations, how soil variability can be addressed, dealing with a flood event during construction, programme constraints, environmental issues as well as the need for good quality control, monitoring and record keeping practices. A section will also be included on availability and selection of equipment and plant in particular for earthworks.

This chapter will have links to Chapter 9 on *Design*.

The key users for this chapter will be consultants and designers to ensure their designs have buildability and can be implemented by the use of best practice and sustainable construction methods. Contractors/constructors (or other organisations that may be either advising the manager/designer or carrying out maintenance/new construction work) should be familiar with this chapter to ensure they are using best practice and that their methodology takes account on the constraints peculiar to levee works.

CHAPTER 11: REFERENCES

The current list of relevant publications to be reviewed and included in this chapter is held by CIRIA and is being updated as the project progresses. The list in Appendix C currently reflects what is in the CIRIA database.

7.3 Chapter leaders and teams

A draft table indicating chapter leaders was developed at the international workshop, held in New Orleans, Louisiana, US, 26-29 October 2009 and have been updated following a number of telephone conference calls, the latest taking place 25 May 2010.

Chapter	Chapter Title	Chapter Lead
1	Introduction	
2	Conceptual frameworks	UK/Ireland, Netherlands
3	Form and function of levees	France
4	Operation and maintenance	USA
5	Condition assessment of levees	France
6	Emergency preparedness and management	USA
7	Site characterisation & data requirements	UK/Ireland
8	Physical processes and tools for levee design	France
9	Design	UK/Ireland
10	Construction	Netherlands (to be confirmed)
11	References	

Table 1: Draft table of chapter leaders

This table will be confirmed as part of milestone 1: Contents list, chapter outline of the main project (see Section 9.2).

8 Form and layout

The presentation of the ILH will include making good use of figures (including boxed examples, flow diagrams, lists of points to be considered, etc) and case studies to illustrate the desired content. The ILH may also include a tool box of methods and approaches setting out why one option could be chosen over another.

8.1 Form and layout – editorial

English will be the primary language used; therefore the ILH needs to have a consistent quality of English. In addition, non native English speakers will read the ILH. Consequently, a consistent style that is easy to understand and that provides clear and concise information is key. This is a challenge for all authors, even the native English-speaking authors not to over-complicate sentence construction and/or use difficult vocabulary.

Considering this, the editorial format and layout of the ILH should follow guidelines set out by CIRIA: the *CIRIA Style Guide: Preparing work for publication*. The CIRIA style guide outlines CIRIA standards on what to consider when planning for a publication. This includes written style, requirements for illustrations, permissions and permission letters, detailed guidance on punctuations, editorial style, quote marks, italics, classifications and keywords as well as layout, including text styles. The Style Guide furthermore sets out a number of examples pages for guidance. The CIRIA style guide is supported by dictionary. Copies of the CIRIA style guide and the dictionary are available upon request from CIRIA.

To support chapter leaders and teams a guidance pack will be prepared offering:

- scoping report, including the contents list
- CIRIA guidance on preparing work for publication and dictionary
- work-plan and programme
- comments log
- project contact details.

The guidance pack will also include:

- guidance on the use of the project website, including access and file naming protocols
- templates, including chapter draft templates, letters, review forms, case studies, equations, line drawings, boxes and tables.

The ILH will upon completion of the final draft undergo an external technical review for quality control purposes. The ILH will also be edited by a professional editor prior to publication. This will be co-ordinated by CIRIA and will include a 'plain English' check to ensure consistent quality of English and that the ILH is understandable to the non native English speaker. The ILH will subsequently be translated into French. Translation into other languages will be dealt with separately.

To increase the uptake of the ILH an interactive/hyperlinked electronic document will be produced. This will be complemented by a hard copy which will be available for sale. Innovative ideas and formats for the interactive electronic and hard versions, which facilitate increased uptake of the ILH while bearing in mind the characteristics of the target audience, will be explored.

8.2 Length

The ILH will be a substantial document (A4 portrait in size) with some chapters longer than others. Some will be 50 pages and some up to 250 pages with a total of between 800 and 1000 pages.

Chapter	Chapter Title	Estimated chapter length (pages)
1	Introduction	15
2	Conceptual frameworks	30
3	Form and function of levees	100
4	Operation and maintenance	60
5	Condition assessment of levees	115
6	Emergency preparedness and management	70
7	Site characterisation & data requirements	120
8	Physical processes and tools for levee design	170
9	Design	185
10	Construction	120
11	References	20

Table 2: Estimated chapter length

Average word count per page has been estimated to approximate 300 words.

9 Method of delivery

9.1 Project team structure

The project team structure to be adopted for the development of the ILH includes three levels as demonstrated in Figure 2: Project organisation.

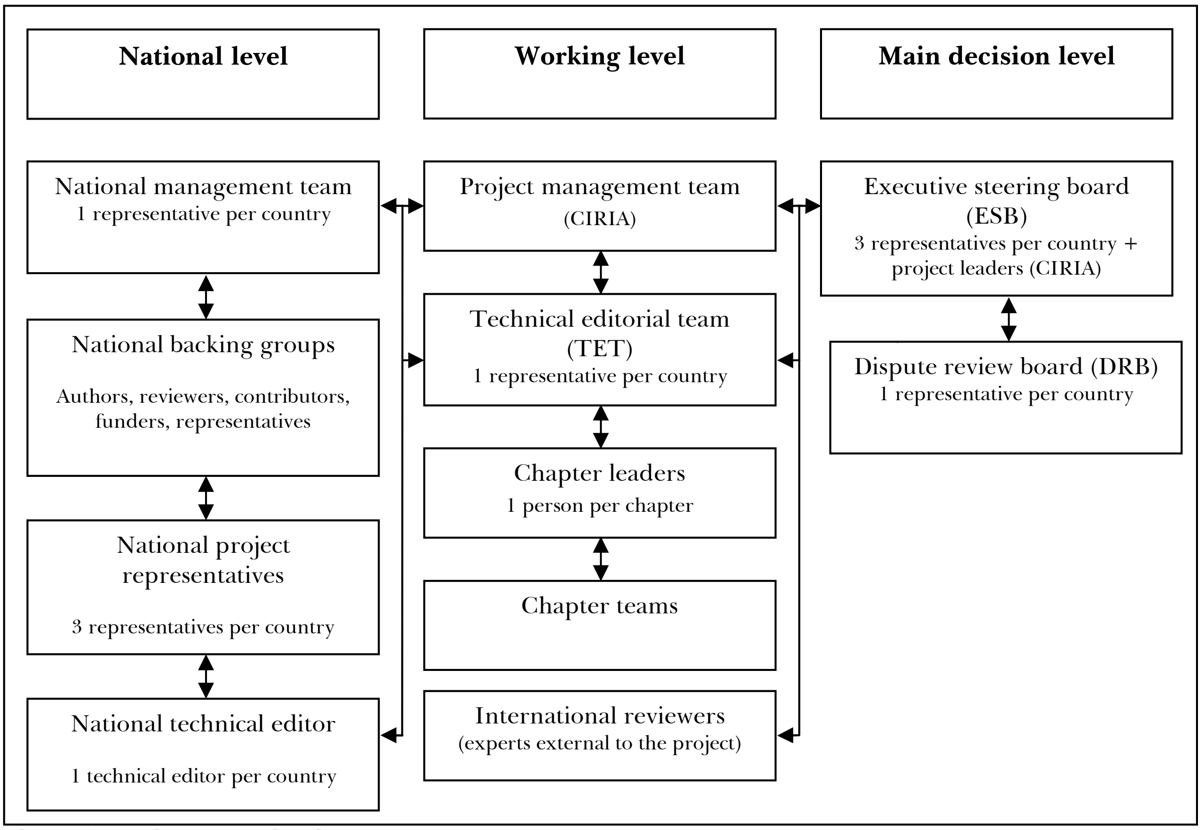

Figure 2: Project organisation

See Appendix D for outlined information on the national level, the working level and the main decision level and their associated roles of responsibilities.

9.2 Management of the project

The production of the ILH will be undertaken in successive steps within the timescales agreed during the Scoping Study and outlined in this report. The programme is milestone-driven, with milestones based on clear project deliverables and co-ordinated with international workshops and meetings, linked to national backing groups reviewing these deliverables. Likely deliverable steps may well be:

- *Milestone 1: First draft outline of the ILH*. This should include the content, structure, format and substantive information of what will be included within each section and sub-sections of the final guidance. It is anticipated that the current 20 page contents list will be expanded to between 60 and 80 pages in length.

- *Milestone 2: First draft of chapter*. This milestone will consist of two parts: an interim delivery of draft chapters (milestone 2a) and a complete draft chapter delivery (milestone 2b). The chapters will be prepared by the chapter teams and coordinated by the chapter lead. The drafts should be based upon the agreed outline, with the interim draft having complete text, photos, case studies etc. to enable a full and thorough review by the national backing groups and technical peer reviewers. Each draft will be subject to executive steering board approval. It is anticipated that approximately 600 to 800 pages of the total 1000 pages would be drafted during this milestone.

- *Milestone 3: First full draft of ILH*. This first complete draft of the ILH will be prepared by the chapter teams and coordinated by the chapter lead. The drafts should be based upon the agreed outline, with the interim draft having complete text, photos, case studies etc. to enable a full and thorough review by the national backing groups and technical peer reviewers. Each draft will be subject to executive steering board approval. It is anticipated that all the 1000 pages would be drafted during this milestone.
- *Milestone 4: Final draft*. This will be prepared by an extended technical editorial team (i.e. likely to include technical editorial team and chapter leaders) based upon the final interim draft whilst taking account of all feedback received from the national backing groups and international reviewers. This draft will be complete and ready for handover to CIRIA for publishing, subject to executive steering board approval. No major changes would be expected to be made to this draft, other than editorial changes to improve style and English.
- *Milestone 5: English edit and publication*. This includes production of English paper and electronic versions of the ILH in the format agreed by the executive steering board and based on the technically complete document submitted by the technical editorial team at the end of milestone 4. Quality control of scientific and technical content will be addressed by the technical editorial team, the standard publishing measures applied by CIRIA's publishing team and (b) production of project closing reports, including any subsequent research recommendations.
- *Milestone 6A: Dissemination and implementation*. This will comprise: national and international launch events, involvement in one or more international conferences, training courses coordinated between the participating countries.
- *Milestone 6B: Translation into French*: The translation and production of a paper and electronic version will be based on the stabilised working document in English. It is anticipated that the French partners will take financial and publishing responsibility for this.

9.3 Project website

To facilitate the effective management of the project and production of the ILH, a collaborative project website is recommended. The proposed website will be for internal use (web-based project management tool for the project) as well as for external communication, promotion and dissemination. The aim of developing a web-based project management tool for the ILH would be to aid the project management, to facilitate co-working across countries, to ensure efficient and consistent communication as also to provide an effective dissemination tool.

External functions

- public website, with public registration / login
- a discussion forum for public users
- a frequently asked questions section for public users
- a news section for public users, including latest updates on the project
- a call for information from the public by the project team.

For internal use, a website may hold the following features

- a password protected team website
- a team registration/login plus control access by limited number of administrators
- a document library showing history of document uploads. This will besides drafted material hold templates, guidance for authors etc
- a page showing milestones/actions enabling the administrators to create/update/delete the project programme
- a storage system with sitemap showing links to all folders and uploaded files
- a discussion forum for team members
- a progress reporting tool
- an e-newsletter creation system enabling administrators to create email newsletters and publish those online plus send them to registered users (public and team)
- a frequently asked questions page
- a request for case studies and images page
- a meetings & events calendar
- an online project document editing system.
- a web conferencing/webinar system may be made available.

9.4 Memorandum of agreement amongst countries

To ensure a good contractual organisation of the project, a memorandum of agreement will be established between national representatives. These are:

- France: CETMEF
- Germany: TU Dresden[4]
- The Netherlands: DELTARES[5]
- UK/Ireland: CIRIA
- US: USACE

For detailed information on this collaborative agreement, please contact one of the national representatives.

9.5 Risk log

During a core group exercise at the international workshop held in New Orleans, Louisiana, US, 26-29 October 2009 potential risks were identified. These were grouped into three categories and are summarised below:

9.5.1 Technical / political

Risk	Mitigation
The risk that there is already sufficient knowledge on this topic and hence there will be a reduction in future research and development funding. In addition, the risk that a funder reduces or withdraws funds in any year due to high level policy changes de-	The needs and benefits providing a good business case for the ILH are described in the scoping report and can be provided to funders. Also, national backing groups can assist in making the case to funders.

[4] TU Dresden is not acting as a national representative on behalf of the Netherlands at the time of writing this report.

[5] DELTARES is not acting as a national representative on behalf of the Netherlands at the time of writing this report.

prioritising this project	
Risk	**Mitigation**
Resolving issues relating to different practices across countries in a way that is acceptable to all.	The ILH would provide the reader with an overview of the approaches in the different existing national and international codes and standards. The advantages and disadvantages of methods used in each country will be explained, but not prescribed.
Risk	**Mitigation**
Understanding links between the chapters.	Within the chapter including conceptual frameworks, a route map will be included, clearly defining the links.
Risk	**Mitigation**
The project team is large, which will be challenging to manage. There may be failure to get cross-country teams working together.	Appropriate people for each task will be identified at an early stage of the project. Clear definitions (and boundaries) of roles and responsibilities will be defined early on in the project.
Risk	**Mitigation**
The difficulty in managing different versions of documents after reviewing.	A tried and tested method of managing version control will be used on the project's website.

Table 3: Technical / political risks

9.5.2 Resourcing / programming

Risk	**Mitigation**
Being able to adequately determine chapter leads and writers.	Appropriate people for each task will be identified at an early stage of the project.
Risk	**Mitigation**
Maintaining the overall project schedule over the 4 year programme. Potential for personnel change.	With such a large pool of experts from within the project team and externally to call on, this is not foreseen as high risk.
Risk	**Mitigation**
Late comments and changes to documents, particularly at publishing stage.	CIRIA will manage strict target deadlines for changes and provide adequate time in the programme for consultation and review of sections.

Table 4: Resourcing / programming risks

9.5.3 Costs

Risk	**Mitigation**
Maintaining the overall project schedule. Underestimate of scope will result in cost creep.	A programme has been agreed based on experience of previous similar projects. The required activities, which such a project requires is well known and scoped out. Sufficient time has been included for each activity.

Table 5: Cost risks

10 Project programme and work plan

10.1 Programme

The project programme has been included in Appendix E.

10.2 Key milestones and dates

Milestones and dates are shown in Table 6.

Milestone 1: Contents list, chapter outline	
Agree chapter leaders and teams	APR 2010
Undertake literature review	MAY 2010
Identify existing standards, procedures and codes.	OCT 2010
Summarise and identify gaps	OCT 2010
Develop glossary	OCT 2010
Detailed contents list finalised	OCT 2010
Chapter outline finalised	OCT 2010
Design of end products decided(format of handbook)	OCT 2010
Milestone 2: Development of first draft of chapters	
First interim draft chapters developed, reviewed and signed off	JUN 2011
First of draft chapters developed, reviewed and signed off	DEC 2011
Milestone 3: Development of first full draft	
First full draft development, reviewed and signed off	JUN 2012
Milestone 4: Development of final draft	
Final draft completed, reviewed and signed off	DEC 2012
Milestone 5: English edit and publication	
English editing and publication of handbook	JUL 2013
Launch event, dissemination and implementation	JUL 2013
Milestone 6: Disseminate & implementation	
Translation/editing/publication of handbook into French (and other languages to be agreed)	APR 2014
Complete closure	APR 2014

Table 6: Key milestones and dates

10.3 Meetings

A proposed schedule of meetings is shown in Table 7 below.

Milestone	International workshops	National backing groups	Technical editorial team	Executive steering board
1	JUL 2010	AUG 2010	SEP 2010	SEP 2010
2	OCT 2010	APR 2011 OCT 2011	MAY 2011 NOV 2011	MAY 2011 NOV 2011
3	DEC 2011	MAY 2012	JUN 2012	JUN 2012
4	JUL 2012	OCT 2012	NOV 2012	NOV 2012

Table 7: Key meeting dates

10.4 Objectives of key meetings and groups within the project

10.4.1 International workshops

- ensure the previous milestone was completed as agreed and that chapter teams have received and acknowledged any feedback
- set out work programme for the milestone ahead
- facilitate internal liaison with chapter team
- facilitate transversal liaison between chapter leads and chapter teams.

10.4.2 National backing groups

- advise on the technical content and quality of drafts and to ensure the project fulfills their country's objectives
- the responsibilities include:
  - confirm objectives and technical scope of the work
  - help direct and advise executive steering board members
  - support the consultation process and help obtain key information
  - review draft outputs and advise on technical accuracy
  - assist in promotion of the ILH.

10.4.3 Technical editorial team

- meetings are held to ensure the technical accuracy and quality of materials developed
- act as central technical point of contact for chapter leads
- manage resolution of any content discrepancies that may arise
- review and comment on draft materials at end of each phase
- conduct complete technical review of all materials at end of project
- edit or amend writing styles and use of English language as required.

10.4.4 Executive steering board

- to ensure project is running to schedule and that all stated objectives are met
- agree a work programme and review project
- sign-off technical material, including chapter batches, first full draft and final draft
- resolve any technical disputes reported by the technical editorial team.

10.5 Consultation process

A number of consultations will be necessary. During milestone 2, 3 and 4, the national backing groups and other interested stakeholder will be consulted on the first draft of chapters, 1st full draft of handbook and the final draft of ILH. A comment log system will be adopted to ensure feedback is captured in time and author's responses are logged accordingly. CIRIA will coordinate any additional consultation as and when required.

Considering external consultation, it would be possible to invite technical contributions from across industry using, for example, flyers at key events. It would also be possible to consult with other stakeholders. In UK/Ireland, this will be undertaken by CIRIA.

10.6 Technical contents sign-off processes

For technical contents sign off the following process is suggested:

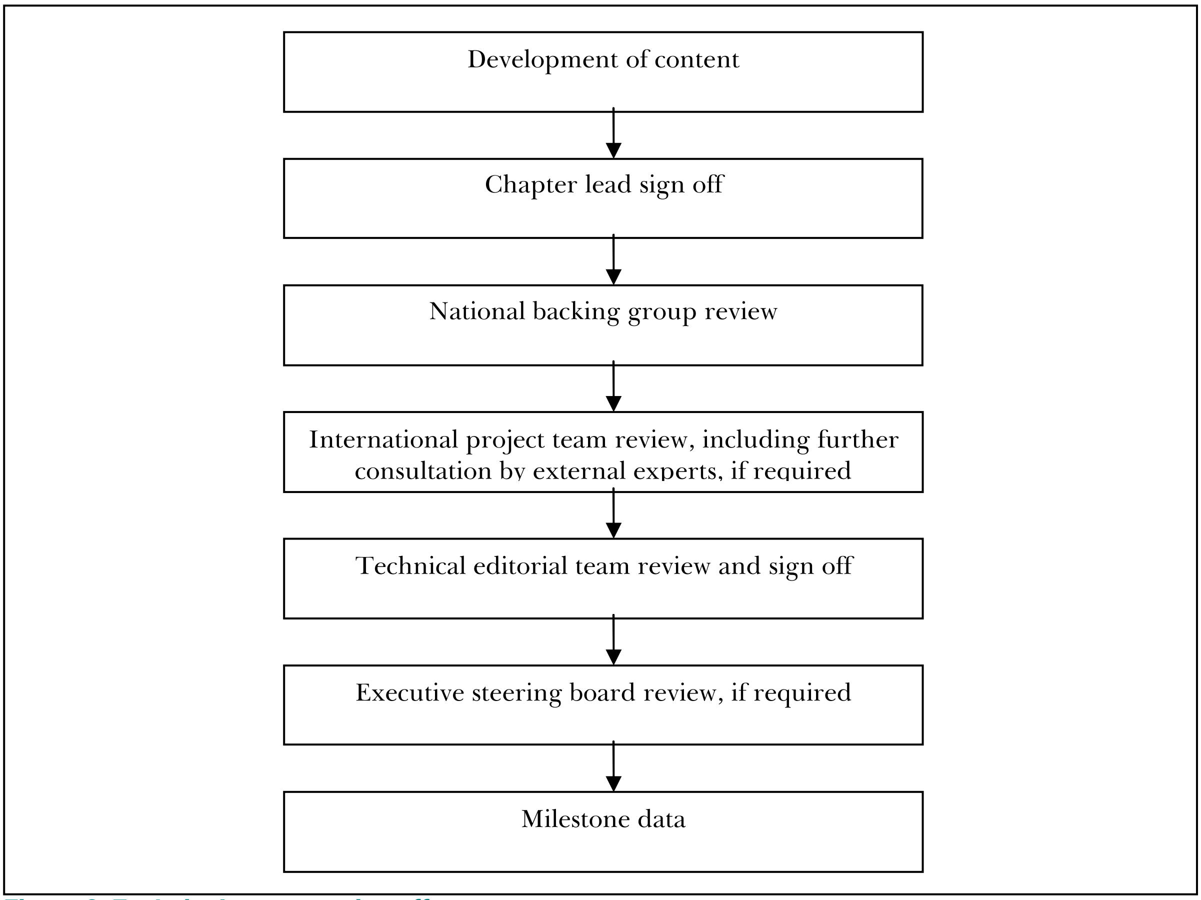

Figure 3: Technical contents sign-off process

Following the completed technical contents sign-off process of the final draft by the international project team, the technical editorial team and executive steering board, CIRIA will arrange and coordinate a technical review and edit of the final draft ILH. This will be conducted by an external expert identified by CIRIA representing the target audience. The identity of the technical reviewer will remain confidential to ensure the technical review will not be influenced by, for example, project funders and/or project steering group members.

The technical reviewer can review up to 70-100 pages per day depending on the quality of the draft and number of points of queries and points of clarification. Should any queries arise during the technical review; these will be relayed to technical editorial team. It would be expected that the technical editorial team and CIRIA will address all queries, amending the document as appropriate, before moving to the publishing stage of the project.

11 Dissemination and communications

11.1 Objectives

The objectives identified include:

- to develop a systematic approach to communicating the project to stakeholders is adopted
- to encourage effective communication from the technical community to the project team, including consultation of draft documents and the collection of case studies. To facilitate this, a dedicated project website is envisaged
- to develop regular project updates and make available appropriate information to the project team, funders and the industry at large
- to develop summaries and interim outputs offering end users the opportunity to identify further information for inclusion in the ILH
- to ensure an appropriate number of articles are included in relevant scientific journals in English and French (and other languages if applicable)
- to ensure an appropriate number of papers are included at international conferences as well as at specific national conferences organised in the country of the project partners
- to develop press releases near the publication date to improve dissemination
- to arrange launch event.

11.2 Joint communication actions

Encourage effective communication from the technical community to the project team

Effective communication from the technical community in the various nations to the project team will be facilitated by a dedicated project website. The administrators of the project will manage this process and ensure the project team is fully updated. Templates may be developed to facilitate the effective communication of the project.

Confirm regular project updates are developed

Project updates should be produced on a regular basis and should be available not just from the project website but also from the websites of all organisations involved. This will ensure funders, for example, are fully up to date on the project and also allow further involvement with wider stakeholders, should this be required. Furthermore, project updates will raise the profile of the project.

Develop summaries and interim outputs

End user summaries and interim outputs will help ensure end users have the opportunity to learn from the ongoing ILH development process and to identify further information for inclusion in the ILH. Interim outputs could include:

- early outlines of each chapter of the ILH
- case studies highlighting techniques/methods used for designing and managing levees in other countries
- lessons learnt from flood events in other countries
- draft minimum standards for the design and management of levees.

Articles in scientific journals
Journal articles will raise the profile of the project, reach out to wider stakeholders. Articles can also be used to attract specific information and could furthermore be an option to facilitate fundraising.

Papers at conferences
Papers at conferences will allow for the project to be showcased in front of peers. It will raise the profile of the project and also encourage dissemination of the Handbook when published. Conferences will furthermore offer an ideal opportunity to canvass further international case studies and/or relevant examples.

Develop press releases near the publication date
To ensure wider dissemination, higher level of sales and also to communicate activities such as the launch of the Handbook, up coming training courses and so on.

Arrange launch event
This event will be to launch the publication of the handbook. It could be an international conference / one day seminar with relevant speakers covering the chapters in the ILH. The ILH should be available for purchase at the launch – perhaps with a discount for delegates attending.

12 Conclusions and recommendations

The main purpose of the scoping study has been to establish whether there is a logical case for producing an international handbook rather than developing piecemeal guidance on a national basis and, if so, to set out the proposed contents of that document and identify the methods by which the handbook would be developed.

Following discussions held in workshops and telephone conferences, it has been concluded by the participants from six countries (France, Germany, Ireland, Netherlands, United Kingdom, and United States of America), who were involved in this study that an international handbook is the preferred way forward for three reasons. Firstly, it has been found that none of the nations involved in the workshops currently have a comprehensive manual for the design, operation and maintenance of levees; existing guidance is either broad in scope but lacking detail or detailed but limited in coverage. The great majority of the participants in the workshops have consistently expressed the need for comprehensive 'whole life' guidance. Secondly, the extreme climatic events that can cause the failure of large strategic levees are, by their very nature, unusual and infrequent. For this reason, relatively few will be recorded during any practitioner's lifetime; a pooling of knowledge is therefore vital. Finally, given the devastating impact (in terms of loss of life and damage and repair costs) of storms such as Hurricane Katrina and Tempête Xynthia and the total length of critical levees in the participating nations, it is considered that there is a significant risk of another disaster of similar proportions unless action is taken to improve performance.

The business case developed during the study ruled out doing nothing or adopting other project options such as bibliographies and gap-filling guidance. These are seen as failing to overcome the piecemeal and poorly integrated geotechnical and hydraulic practice. Much of the existing guidance currently used for the design and operation of levees was originally produced for dams or other infrastructure such as road or rail embankments; there is a pronounced lack of published information that relates specifically to levees. Even in the Netherlands where comprehensive design guidance is published, it mainly relates to Dutch soil types and is not applicable elsewhere in the world where ground conditions can be very different. Further, the existing published guidance does not deliver the necessary level of whole life cycle and systems thinking or the benefits of best practice sharing amongst international partners. By contrast an international handbook would address this gap by providing comprehensive guidance on the design, construction, maintenance and improvement of levees and describing the international state of the art on these matters.

During the scoping study, the participating nations undertook an assessment of the options with regard to the type of guidance, the size and layout, the content and the target audience that the ILH should be aiming towards. The recommended option agreed by all is summarised below:

The ILH would offer a consistent framework available to all countries for understanding, designing and managing levees, taking account of their different geometries and strengths (and their associated uncertainties), whilst still allowing country specific factors to be adopted by users.

The ILH would be regarded as a 'decision support' document as distinct from a prescriptive 'decision-making' code of practice. However, the technical guidance provided by the document should be sufficiently comprehensive to establish minimum standards of good practice. The ILH should be written for two target audiences; the levee owner (or manager) and the levee designer.

The ILH will be available in both printed and electronic form and, having examined the options, a practical limit of 1000 pages is proposed to be specified. To maintain this size limit, only best practice would be included, existing guidance and links to web pages would be referred to where this is considered appropriate, and details would be included in appendices where appropriate.

The ILH would be written for two target audiences; the levee owner and manager and the levee designer. Through various chapters within the ILH, these two specific groups would be targeted at the appropriate technical level.

An associated contents list for the document has been prepared covering:

- *conceptual thinking and frameworks and descriptions of the form and function of levees*
- *guidance aimed mainly at levee owners and managers on operation, maintenance, condition assessment and emergency preparedness and management*
- *guidance aimed mainly at designers on site characterisation and data requirements, physical processes and design tools, and practical design and construction aspects.*

The ILH should adopt a consistent style and lexicon; it will include a glossary of terms and definitions to avoid problems of translation or interpretation.

To promote a wide uptake of the ILH after it has been produced, it is recommended to utilise the right mix of skills (particularly hydraulic and geotechnical engineering, operations and maintenance, design and construction) in writing the report. A significant effort has therefore been made during the scoping study to ensure that leading experts from each participating nation are involved in the project. The team should work in an integrated manner both within and across chapter a process which should be supported by conceptual frameworks prepared in draft form during the scoping phase. An international review should be undertaken using experts from other countries who will also be invited to make contributions of technical material or case studies

The overall project to produce the ILH should follow an agreed set of processes and be managed by a technical editorial team supported by an executive steering board drawn from the national backing groups of the partner countries. Management support should be provided by CIRIA (UK) who will also prepare the resulting document for final publication. A project website should be used to support management, document exchange/control and external communications and publicity. To support these arrangements, a draft collaboration agreement has been prepared for signature by representatives from the partner countries and addresses issues such as costs of overall project management, editing and publishing of the document in English and also the translation into French.

Finally, the scoping study established that the likely cost of the project inclusive of both paid and in-kind (or unpaid) contributions is likely to be of the order of US$3m. The majority of this cost will be shared approximately equally between the lead partners (currently France, UK/Ireland and USA) with smaller contributions from other partners (Netherlands, Germany). The anticipated time to completion and publication of the ILH is expected to be about 3 years. Participating organisations will obtain the resulting ILH at a fraction of the total project costs compared to the project being carried out at a national level and with the benefits of international collaboration. Whilst the cost and time inputs remain significant, these are extremely small in comparison with the costs associated with another major levee system failure arising from the lack of existing comprehensive guidance.

This scoping report has demonstrated that an ILH is achievable and that the proposed programme and method of delivery has been reasonably optimised.

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A Summary of benefits of the International levee handbook

GENERAL
First "state of the art" for levees.
It could state what we don't know as well as what we do.
JUSTIFICATION FOR LEVEE SAFETY PROGRAMMES
Brings more support to justify investment.
Validates investment programming by integrating international procedures.
Provides more cost effective designs and therefore savings in the investment programmes.
Need to protect critical infrastructure.
IMPROVED RISK MANAGEMENT OF LEVEES
Avoidance of disasters through using best practice.
Brings more realistic understanding of risks.
Provides improved reliability of structures.
Improved ability to manage aging assets with risks associated with these.
A DOCUMENT FOR ALL STAKEHOLDERS
Benefit to levee owners, managers, designers, operators, policy makers, enforcement authorities.
Provides a forum of stakeholders.
SHARING INTERNATIONAL KNOWLEDGE
Existing guidance is scattered through many documents - improvement by collation of this in one document.
Demonstrates pro-active intervention of the participating nations in setting out realistic approaches.
Everyone gains from other countries' knowledge and experience.
Sharing best/good practices.
Demonstrates that one person's issues are not unique and therefore more believable.
Provides links to all the nations current guidance.
Sharing innovative ideas/approaches.
Many hands make light work!
With international collaboration comes a more authoritative document.
Consolidates international knowledge.
Not having to reinvent the wheel.
Learning lessons from things that went wrong.
Identifies commonalities and differences between approaches undertaken by nations.
DEVELOPING NATIONAL BEST PRACTICE
Involvement in project will help rapid uptake of best practice.
Assist countries to push their regulation boundaries.
LEGISLATION
Could be used in a legal action to prove best practice was applied.
Avoids unrealistic EC legislation being developed.
RESEARCH & DEVELOPMENT
Maximises research and development investment by knowing what has been done, is being done and what are the gaps in knowledge.
Promotes international collaboration on research and development (potential to share research and development resources).
Underpins national and international research and development.

ENVIRONMENTAL IMPROVEMENTS
Provides a guide for the whole life management of reservoirs.
Improved sustainability.
Effects of climate change included.
USE AS A TRAINING TOOL
Helps to avoid ill-informed practices of below average managers and consultants.
Tool to train new professionals, levee managers, control authorities, etc.
It is likely that university lecturers will use the document and thus the underlying principles and conceptual framework will be fed into the next generation of engineers.
IMPROVED DESIGN PROCESSES/PROCEDURES
Sets a minimum standard of design.
Sets a standard against which a design can be judged.
Provides common standards and design approaches.
Sets out a collective, authoritative understanding of the science and appropriate processes and procedures.

B The expanded contents list for the International levee handbook

1. INTRODUCTION

Main points: This chapter will clearly define the handbook's structure including the scope, i.e. what is and what is not addressed. It will establish the need for the ILH and explain how it builds on and differs from existing manuals and guidance. To address the issues that were discussed in the Scoping Study, a definition of a levee and the context of the levee within a scheme and strategy for a region will be included in this Chapter.

Chapter links: As appropriate to the user.

Target user: This chapter will be relevant to all users to enable them to determine which of the ILH's sections are relevant for their requirements. Potential users include planners, developers, levee owners and managers, operational authorities and regulators, funders, consultants and designers, architects, contractors/constructors, building managers, producers and suppliers, emergency responders and educational institutions.

1.1Scope

i) Define that the ILH is a collation of best practice on levee design/management and not a prescriptive handbook and explain how the handbook should be used with other national codes.

ii) Emphasize that the prevailing approach is from a risk-based or risk-informed perspective.

iii) State that the guide represents the current state of the art internationally.

iv) Include a list of participating countries and organisations.

v) Set out likely target audience and include a flow chart showing which sections are relevant to which audiences.

vi) Define the ILH's structure including the scope, i.e. what is in it and what is not addressed (such as management of existing as well as new structures).

vii) Provide the definition of a levee, i.e. narrow the topic to levees for flood protection; and the significant element of the structure should be the earth embankment; as well as the definition for a flood defence system

1.2 Identifying the need

i) Establish the need for an ILH and why an international handbook is better than a national one.

ii) Explain how the ILH builds on and differs from existing manuals.

iii) Highlight importance of flood defences during extreme events.

iv) Indicate potential consequences of failure and give examples of extreme worldwide floods (e.g. UK/NL, 1953, Katrina).

v) Highlight that levees are only a small part of the whole flood defence system. Set the scene of the need for flood defence systems before getting into the detail of levees.

vi) Present national approaches of flood protection.

vii) Include limitations of levees, i.e. levels of protection, and the need to increase public awareness of this.

viii) Include the need for a balance between engineering, environmental and social factors.

ix) Touch on the effects of climate change.

x) Include the importance of human resources, the critical mass and competences, training and continuous professional development and communication of knowledge.

2. CONCEPTUAL FRAMEWORKS

Main points: This chapter will provide two conceptual frameworks; firstly, a generic framework on flood defence systems, which will connect the overlaps and bridge the differences between countries. This will put levees in context with other parts of the flood defence system. Secondly, it will also include a flow diagram showing the framework for the life cycle management of a levee, which will be used as a route map to guide the user through the ILH.

Chapter links: As appropriate to the user.

Target user: This chapter will be relevant to all users in order that they can determine which of the chapters are relevant for their requirements. It will be most relevant to levee owners and managers as well as decision makers (funders and/or local/national authorities) and will therefore be pitched to this level.

2.1 Levees and the flood defence system – generic framework

i) The generic framework, which refers to the flood defence system as a whole should connect the overlaps and bridge the differences between countries.

ii) Include a Source-Pathway-Receptor Framework for flood risk management (Figure B1).

iii) Define risk and application of risk management. [Risk = Probability (strength; loads) x Effect (damage; causalities; habitat)]. Avoid too extensive a discussion of flood risk management (FRM), but note importance of FRM systems evaluation in setting standard of protection of defences.

iv) Promote a tiered approach to both management and design, related to level of risk adopting risk management principles and approaches. This should note that the tiers can relate to either the consequence of failure, or the likelihood of failure (related to complexity of design which is the basis of categorisation in the Highways Agency Design manual HD22/08) or some combination.

v) Include a description of different levels and phases of risk management, i.e. hazard identification, risk analysis, risk reduction (residual risk), etc.

vi) Include a section on the protected area of a system. This could include some methodology for hazard inventory and vulnerability assessment. Also indications about economic analysis (cost/avoided damage analysis).

vii) Include a flood defence system failure framework covering both levee body, foundation and associated structures (c.f. key table from FD2411 and reproduced as Table B1), understanding a levee as a system. Note that failure can come from poor design, poor construction or poor maintenance. Make a distinction between causes (borer, erosion, defects), mechanisms (overtopping, breach) and effects (flooding). Cross reference to the failure modes section in the Chapters 3 and 8.

viii) Highlight the importance of focusing on the entire flood defence system (and supporting infrastructure such as flood gates, pumping systems and spillways/pumps for extreme events) when repairing/designing a flood mitigation system.

ix) Put levees in context with other parts of flood defence system. Flood risk management is the holistic approach to reducing flood risk- levees, dams, flood plain management, and non-structural alternatives. Levees are just one component of the holistic flood risk management approach.

x) Include a levee safety philosophy including a conceptual framework for flood risk safety levels/standards, reliability assessment methodologies (including concept of fragility curves), links to US and EU codes, etc.

xi) As well as diagrams, include a series of statements of principle, e.g. levees have various functions, failure may be by excessive overtopping (due to exceeding design criteria), internal erosion or breach, risk is a function of…, as part of the decision, whether and where to construct a levee, should be considered.

xii) Explain roles and responsibilities of the various participants/stakeholders in levee design and management (owner/manager, designer, environmental regulator, etc). Explain that these roles will be taken into account in the way the manual is written. Give examples from various nations of how these roles are arranged in practice. Explain that interests of stakeholders may be conflicting and may require resolution on a case by case basis.

xiii) Introduce issue of uncertainty.

2.2 Life cycle management framework of a levee

i) The second framework refers to a levee and its life cycle.

ii) A suggestion for adapting Figure B2 would be to include three scaled cycles: Largest = National cycle framework; Middle = Catchment cycle framework; and Small = Levee or local cycle framework. This could be used as a route map to guide the user through the ILH (and placed in Chapter 1).

iii) Include how this relates to higher policy.

iv) Include the link between 'levee safety philosophy', 'functional objectives' and 'performance objectives'.

v) The definition of 'functional objectives' can include change in design requirement, change in policy or safety philosophy, adaption to climate change, etc.

vi) Note that it is possible to enter the asset management cycle from a number of different positions dependent on functional objectives.

vii) Include project and facilities planning, design, construction, O&M, inspections and monitoring, emergency response and decommissioning of levees in the framework.

viii) Include current concepts of asset management for infrastructure.

ix) Introduce issue of data management, including hierarchies, uncertainty. Note differences between data which is measured, calculated/assumed, measured during actual performance (including extreme events). Mention meta-data.

3. FORM AND FUNCTION OF LEVEES

Main points: This chapter will include a description and diagrams of the main different types of levees and how they function with regard to flood risk. It will discuss the influence of other structures associated with levees and the multi-functionality of levees. A section will be included on failure modes and how these are connected to certain types of levees.

Chapter links: All chapters will be linked to this one, but of most relevance is Chapter 9 on *Design*.

Target user: This chapter will be useful to all users of the handbook.

3.1 Functions of levees

i) Note that the primary function depends upon the stakeholder. It can be to provide flood protection, but it also can be to convey traffic. Hence a multi-function approach is essential.

ii) Differentiate between levees that are functioning as permanently wet (storing water) or dry and those with varying loads.

iii) Discuss the combination of flood management with other functions.

iv) Function of the flood protection system should be the goal rather than a project. Being function centric allows the project to change if surrounding conditions change.

v) Discuss the use of other infrastructure embankments that have a flood defence function, e.g. road and rail, but which have not been designed as such and have hydraulic 'transparency'. Experience shows that both of these bodies are reluctant to have their infrastructure used as a formal flood embankment without the provision of protective measures.

vi) Discuss the function of allowing land to be used as flood storage and importance of not using this subsequently for development.

vii) Include environmental/ecological functions – recreation, access and habitat areas etc.

viii) Other functions include water conveyance and navigation.

ix) Note the importance of access as a function for construction, inspection, maintenance. (This will influence form.)

3.2 Form of levees

i) Include a description and diagrams of the main different types and subtypes of levees with typical plan and cross-sections (including composite structures) and how they function.
   - Include coastal structures, (shingle, sand and silt structures, but not rockfill), together with their weak points for access and outlets.
   - It would not include breakwaters, groynes and seawalls (without an earth component).
   - As well as the body & foundation of a levee, include the foreshore. Include the issues (not prediction) of sediment transport (deposition & erosion) and impact on the system.
   - Include canals with banks.
   - It would not include dams or other structures covered by other legislation such as the Reservoirs Act.

ii) It would not include 'unintentional' embankments such as dredging tailings, which have not been designed as a water retaining structure, but these should be mentioned.

iii) Discuss fluvial versus coastal levees (i.e. their similarities and differences).

iv) Include the historical context of levees' layers and sections over the years.

3.3 Structures associated with levees

i) Discuss the combination of earth structures with other water-retaining structures (e.g. sheet pilings, walls, gateways, innovative constructions, etc).

ii) Discuss use of spillways as an integral part of a levee other types of structure penetrations.

iii) Discuss the influence of non-water retaining objects (e.g. buildings, trees, pipelines, manholes, etc) on levees.

3.4 Overview of failure modes

i) Include as feedback on experience and connecting failure modes to some types of levees, cross-referencing to the 'local condition' (that would put the levee at risk, e.g. peat) and to the 'situations/scenario' (e.g. during upgrading or flooding).

ii) Provide an overview of all failure modes - environmental-natural hazards, eliminate change, man-made hazards (activist/terrorist).

iii) Define what a failure is. Overtopping is considered a design exceedance not a failure.

iv) Ensure link to FLOODsite failure modes work and check gaps in knowledge from T4, T6 and T7.

4. OPERATION AND MAINTENANCE

Main points: This chapter will address work that does not require detailed design. It will discuss the role of maintenance in the face of deterioration and climate change including best practice and innovative methods. It will highlight the competing goals of flood protection, environmental and social issues. There will be a significant section on vegetation control and management.

Chapter links: Chapter 6 on *Emergency management*, Chapter 5 on *Condition assessment of levees* and Chapter 9 on *Design*.

Target user: The key users for this chapter will be staff from operational authorities and levee owners and managers. Consultants and designers should be familiar with this chapter to allow them to incorporate whole life management processes into their designs.

4.1 Routine and preventative maintenance

i) Include best practice (safe & easy) and examples of methods and frequency of maintaining levees. (Note link to form/frequency of inspection discussed in Chapter 5.)

ii) Distinguish between and note that any non-routine, significant repairs or remedial works should be undertaken by professional designers and contractors/constructors.

iii) Highlight the importance of record keeping by a levee manager (linked to Chapter 5 Section 7) and how to format and what data should be collected. Also how it should be stored to promote and optimise asset management, including performance under extreme loads (floods etc) to provide lessons learnt and opportunities to improve.

iv) Types and ways to control vermin. Cross-reference to Design Chapter on preventative design.

v) Discuss the role of maintenance in the face of deterioration, climate change, etc.

vi) Discuss conduit/culvert periodic inspection, testing and replacement/lining - methods (video taping) and frequency.

vii) Maintenance/operation of gates, valves, etc.

viii) Maintenance of seepage remediation measures such as "relief wells", collector drains, which require periodic inspection, testing to determine efficiency and rehabilitation to ensure efficiency remains within design requirements.

ix) Competing goals of flood protection, environmental, and social issues need to have a resolution process established. Coordination and collaboration with environmental laws, habitat protection and restoration.

x) Prevention of encroachments on land for access. Give examples and discuss issues of permits for emcroachment.

xi) Discuss the need to maintain maintenance flexibility to reflect resource limits and consequences of failure.

xii) Discuss sediment issues.

xiii) Note that adequate funding for operations and maintenance is a problem world wide and risk may need to be considered in some circumstances.

xiv) Funding levels and mechanisms with examples from countries.

4.2 Vegetation control and management

i) Management of existing vegetation on levees including trees/shrubs (removal of root balls).

ii) Vegetation gestation and management with details on roots, surface protection and soil moisture and where on the levee to plant (distance from toe).

iii) Include case studies and innovative management examples.

iv) Operational management such as when and how to cut the grass.

v) Impacts from invasive species.

4.3 Operation

i) Distinguish operational activities as compared to maintenance within the management of a levee and the flood defence system.
ii) Provide examples of operations regarding flood management, e.g. closing flood gates.
iii) Security issues (e.g. vandalism, damage due to unauthorised access with vehicles etc).

5. CONDITION ASSESSMENT OF LEVEES; INSPECTION, INVESTIGATION AND MONITORING

Main points: This chapter will include best practice procedures for diagnosis and condition assessment of levee structures in order to allow consistent and appropriate levels of reporting, including visual inspection, investigations and risk assessment. The first sections will provide a tiered approach to investigation of levee condition including inspection techniques and different types of investigations. Another section will provide recommendations to provide a levee system risk assessment. The next section will deal with monitoring common issues including appropriate tools, instrumentation and survey methods as well as state of the art methods of monitoring. The last section will deal with geographical information systems (GIS) to support levee management.

Chapter links: Chapter 4 on *Operation and maintenance*, Chapter 6 on *Emergency management,* Chapter 7 *Site characterisation and data requirements*, Chapter 8 on *Physical processes and tools for levee design* and Chapter 9 on *Design.*

Target user: The key users for this chapter will be staff from operational authorities and levee owners and managers. Consultants and designers should be familiar with this chapter to allow them to incorporate whole life management processes into their designs and undertake condition assessments of existing levees before designing repairs or improvements.

5.1 Levee assessment

i) Include best practice procedures for condition assessment and diagnosis of the data collected including asset mapping and assigning condition grades and tools to determine these.
ii) Provide simple guidance for non-technical inspection staff, e.g. explain why you see what you see.
iii) Link with failure modes and refer to sections in Chapters 3 and 8 on these. Also, link with reliability analysis and quantitative assessment tools and GIS expression of the results.
iv) Discuss the issues of degradation and deterioration of levee grade / performance.
v) Assessment (or diagnosis) as a conclusive multi-criteria analysis.
vi) Don't use the word "certification" in the ILH.

5.2 Risk assessment

i) Promote the adoption of risk management principles and approaches.
ii) Include how to undertake a "risk assessment" to assist with the selection of the most appropriate techniques for inspection, investigation and monitoring.
iii) Analysis functions and failure modes of levees (FMEA).
iv) Analysis of functional and failure scenarios for levees (Event Tree Analysis, Fault Tree Analysis).
v) Provide the reliability of the levee system against different hazards, including floods (Qualitative approach; Quantitative Probability Approach).
vi) Provide risk assessment: FN curve for levees.

5.3 Diagnosis Methodology

i) Present the general assessment methodology, which is definitely multi disciplinar, and based on a failure modes analysis and a functional analysis of the levee system.
ii) Explain that a diagnosis/assessment can have different objectives, at different times in a levee lifecycle. Present this life cycle and the different types of assessment that have to be made all along.
iii) An assessment, according to its objective can be based or more or less data, and require more or less specific inspection and/or investigation.

iv) Briefly present the most complete assessment methodology ("diagnosis"), which includes an analysis of loadings, site constraints and the levee system (will be detailed in 5.6).

5.4 Inspections

i) Include comparison of different countries' legislation for inspecting levees and discuss frequencies related to low/medium/high risk systems.
ii) Distinguish between routine inspections made by operator staff and complete inspections made by contractors.
iii) Include a description of an initial inspectection followed by routine inspections.
iv) Communication is a key component of any flood defence system. Public, politicians, and practicing engineers all need to understand the project function, its limitations, and why inspection criteria etc. are vital.
v) Include best practice procedures for visual inspection and surveillance of levee structures and provide an example of a good existing inspection programme.
vi) Discuss how to ensure consistent and appropriate levels of inspection and reporting.
vii) Training and communication for operational staff to ensure consistency.
viii) Make recommendations for qualification of inspectors.
ix) Include procedures for emergency/event inspections including health and safety issues.
x) Note it can be easier to see defects during a flood event.
xi) Post flood inspections and reporting.

5.5 Investigation

i) Describe the tiered approaches to investigation of levee condition (desk study, visual, non-intrusive, then intrusive). This links to codes such as Eurocode, including review of best practice approaches to ground investigation.
ii) Discuss use of geophysics to complement LiDAR and aerial photos to identify the locations of infilled creeks (with weaker material) and localised near surface deposits of permeable material.
iii) Discuss when it is necessary to undertake intrusive investigation.
iv) Discuss the importance of site investigation and refer to the details in Chapter 7.1.
v) Note that monitoring interpretation for condition assessment and to establish design parameters, (which are detailed in Chapter 7), could be significantly different.
vi) Discuss the need for historical research of technical information.

5.6 Instrumentation and performance monitoring

i) Describe options for automated monitoring of marginal 'at risk' structures.
ii) Include particular recommendations for monitoring common issues such as seepage, settlement, desiccations, cracking, instability, etc; including available inspection tools, survey methods (e.g. LiDAR) and instrumentation (e.g. piezometers).
iii) This section should also include walking the levee.
iv) Include state of the art, new, cost effective and best practice methods of monitoring including:
    - Geophysics techniques (what really works, what to use when and tiered systems).
    - 'Willowstick' technology to identify seepage paths. (Note that willowstick should not directly be mentioned as this is a product from a commercial vendor).
    - Innovative mapping techniques.

- Optic fibre, interferometry and infra-red photos.

v) Include how to analyse the data collected and how to move from passive monitoring to active intervention, i.e. provide a decision tree and tiered approach to intervention.

vi) Include the importance of data records and register keeping for traceability.

vii) Databases – who are they for? Ease of access versus security. Keep audit trail of changes.

5.7 Record keeping and documentation

i) GIS as a tool for managing (storing, retrieving and enhancing the value of) all existing and future data related to levee management, mainly produced during the assessment/inspection/investigation processes.

ii) Data is localised spatially, but also has a time localisation (a date or a time span).

iii) Provide a spatial decision support system aiding levee managers in condition assessment.

iv) Provide a decision-making aids for levee managers taking into account a risk analysis on a levee system scale.

v) Data spatialisation and methods suited to the great length of levees in operation.

6. EMERGENCY PREPAREDNESS AND MANAGEMENT

Main points: This chapter will provide a section on guidance on breach modelling with emphasis on the limitations and uses of methods and preparing and implementing emergency action plans. It will include guidance on event management, including methods for emergency breach repairs, post flood cleanup and data collection.

Chapter links: Chapter 4 on *Operation and maintenance* and Chapter 5 on *Condition assessment of levees*.

Target user: The key users for this chapter will be levee owners and managers, staff from operational authorities and emergency responders.

6.1 Emergency planning - breach modelling & inundation mapping

i) Provide guidance on breach modelling including stability analysis, breach prediction (rate, size and location), reliability analysis and note that each provides specific and different levels of results.
ii) Breach modelling must take into account a coupled approach between hydraulic and geotechnic parameters, in order to compute breach dimensions
iii) Provide guidance on how to relate accuracy of modelling results to end use and be clear on limitations of methods and when to use or not to use these.
iv) Link with work in FLOODsite, DSIG, USACE/USBR projects.
v) How to anticipate the place where a breach has the highest probability to occur?
vi) Take them into account multiple breaches and the influence of a breach on the foundation of the other defences.

6.2 Readiness and preparedness - emergency action plans

i) List example “events” and how a levee typically fails and the responsible stakeholder for which these are classified as an emergency.
ii) Note that there any many emergency events that occur long before breaching occurs.
iii) Provide information on how to prepare an emergency action plan that are compatible for all users including typical emergency scenarios with pre-flood, flood and post-flood actions.
iv) Who keeps what data and where? What should be available in an emergency (e.g. levees leaking badly).
v) Emphasize that emergency action plans must be periodically exercised and involve all the parties who would be expected to respond in an incident.
vi) Discuss the exchange of information between all involved authorities.
vii) Discuss how to communicate and improve public awareness/knowledge – shared responsibility – residual risk – levee watch programme.
viii) Safe havens for operational staff.
ix) Include case histories and lessons learnt from events. Review data and analyse levees that have failed.
x) Provide examples of methodologies for learning lessons from flood events, (e.g. the "retour d'experience" or "REX" in France).

6.3 Event and breach management

i) Include definition of emergency works versus urgent works, i.e. is their time to plan the work?
ii) Consider advance measures in preparation for a flood, flood fighting, and post flood cleanup such as removal of temporary embankments so they are not adopted as levees.
iii) Floodfight resources to be stockpiled (availability of supplies that can be stockpiled such as sand, gravel, etc), floodfight training and agreements for mutual assistance.

iv) Include signs of failure, processes to failure and how to prevent these including:
- H&S issues for work on levees during flooding and best practice for repairing breaches under the influences of tidal, wind and flow rates.
- Tools available for breach repairs in different settings (availability and mobility of equipment, limited access, roads blocked, support not available).
- The need for back up systems when levee design is exceeded i.e. pumps (diesel vs. electrical - power supply reliability).

v) Methodologies to do breach and emergency repairs during a flood and after it has passed, e.g. typical breach closure/blockage and opening (fuse-plug) techniques (e.g. methods for construction of sand-bag walls). How to handle sand boils, seepage, potential overtopping. EA Guidance: Emergency Response for Flood Embankments 2009. NRA Guidance: Sealing of breaches 1994.

vi) Consider some materials need to be air-lifted in due to limited access so should be light weight and simple for installation by a small crew.

vii) Include the process for collection of data on performance during and immediately after a flood event. Typically there are only inspections during a flood for emergency purposes, not for documenting actual performance.

viii) Highlight the need for expanded geo-referenced data base links to geotechnical, hydraulic, inspection, performance, design and construction information. In order to make the right decision during emergency situations all relevant information needs to be readily available.

7. SITE CHARACTERISATION AND DATA REQUIREMENTS

Main points: This chapter will begin with detailing site investigation methods and how these are critical for establishing appropriate boundary conditions and properties for design. It will cover desk study procedures, intrusive and non-intrusive techniques for sampling and field investigation as well as relevant laboratory testing techniques and approaches to data interpretation that are suited to levees and the ground on which levees are built. This will be followed with a section on recommendations for minimum or target levels of protection to provide flexible standards. It will establish the design loading criteria including environmental and social criteria for both coastal and fluvial levees. A section on the effects of climate change will feature in this chapter.

Chapter links: Chapter 5 on *Condition assessment of levees*, Chapter 8 on *Physical processes and tools for levee design* and Chapter 9 on *Design*.

Target user: The key users for this chapter will be consultants and designers, and contractors/constructors. In addition, this chapter will be useful for staff from operational authorities and levee owners and managers.

7.1 Site investigations

i) Detail site investigation methods including geotechnical, morphological, hydrogeological and investigations.

ii) Include discussion on how to undertake a desk study, intrusive investigation techniques, in situ testing (including pumping trials), use of laboratory testing, geophysical methods, installation of borehole instrumentation

iii) Discuss best practice reporting procedures (consider adapting HA standard HD22/08 Managing Geotechnical Risk for levees).

iv) Highlight the need for separate site characterisation reports (or chapters) to be produced for each of geotechnical conditions, hydrogeology, wave climate, flood levels. The content and form of these is likely to vary significantly between countries (e.g. see variation in required contents of geotechnical interpretative reports from Highways Agency, Environment Agency, Association of Geotechnical Specialists, etc).

v) Explain that site investigation is critical for establishing appropriate boundary conditions and properties for the design model.

vi) Floodplains are geologically complex environments. Suitable investigation and appropriate engineering geological interpretation are critical for the development of suitable ground models which envelope the geological uncertainty.

vii) Good assessment of the mass permeability of the founding soils is required for efficient design. This is difficult to measure. A range of techniques should be considered including published correlations, empirical guidance, head tests in boreholes and the laboratory and larger scale pumping trials.

viii) Include guidance on methods of obtaining ground investigation data adjacent to, or over, water, which may be essential for appropriate ground characterisation.

7.2 Loads on coastal and river levees

i) Discuss the evaluation of loadings on levees and how to combine the loads, e.g. for coastal defences, discuss the combination of sea level, waves and surge.

ii) Give information for both coastal and fluvial loadings.

iii) Include information on estuarine levees.

iv) Include offshore - onshore transition of loadings and how the foreshore affects loadings.

v) Include dynamic aspects such as hydrographs.

vi) Lateral movement of river bank i.e. erosion can be an important load on an embankment and is a key issue in planning and design that should be highlighted.

vii) Evaluating changing requirements due to climate change, land use change etc with regard to loads, strengths.

7.3 Specific loads and design criteria

i) Define the words: "protection level", "design situations", "design criteria" and "performance".

ii) Detail the failure modes before going into the design aspects to focus the mind of the reader on what we are aiming to achieve and why.

iii) Establish the design/analysis loading criteria such as design flood/ storm, maximum water level, critical gradient of soil and fill, water velocity, dealing with sill effect, uncertainty and contingencies.

iv) Distinguish between standards of protection (and freeboard) depending on risk and consequence of failure and size of levee.
- Flood protection level = no water passes the levee.
- Failure protection level = Levee breaches.
- Intermediate protection levels = Limited damage from overtopping, spilling, seepage.

v) Discuss the selection of the target level of protection, but do not prescribe, i.e. there will not be an 'international standard'. What are, in each country, the different standards of protection?

vi) Prevent "withering of communities". Provide flexible standards so that people are not priced out of communities.

vii) Include physical constraints within the design criterion. These can be grouped as:
- External (forces and physical site constraints)
- Internal (piping, fissuring etc)
- Sub surface (below OGL). Issues relating to ground conditions. Under seepage, localised weak ground etc.

viii) Include environmental and social boundary conditions and constraints, e.g. good ecological status, SSSI, protected species etc. These affect (constrain) operation, design and may have their own management plan to promote particular habitats etc.

ix) Include all kind of contingencies such as breakdown of gates, obstruction of spillways, local heightening of head.

x) Explain importance of assessing seismic load.

xi) Consider human impact on levees such as horse-riding and pedestrians and traffic induced loads.

xii) Discuss the 'no water' load, i.e. long drying out conditions causing desiccation.

xiii) Discuss how vegetation may affect loading, e.g. saltmarsh.

7.4 Effects of climate change

i) Discuss the influence of climate change on the strength of levees, the safety levels, the flood risk, loading and the functions in the protected areas.

ii) Consider the short-term flexibility versus long-term robustness/sustainability, adaptation strategies (including 'real options') and turning points in policy, techniques, costs and functions.

iii) Discuss likely changes to ground conditions.

iv) Consider the effects and uncertainties of climate change on embankments soil state & vegetation state.

8. PHYSICAL PROCESSESS AND TOOLS FOR LEVEE DESIGN

Main points: This chapter will demonstrate the need for a holistic approach to the design of levees that embraces both geotechnical and hydraulic engineering disciplines. It will set out the physical processes that control the performance of levees and indicate which analytical engineering methods and techniques best represent these characteristics. Amongst other things, the chapter will identify common failure modes and deterioration processes. It will give examples of typical engineering calculations for both the assessment of existing structures and the design of completely new levees. Case histories will be included to illustrate projects where best practice has been applied. The chapter will also include a summary of sophisticated geotechnical and hydraulic modelling techniques.

Chapter links: Chapter 5 on Condition assessment of levees, Chapter 7 on *Site characterisation and data requirements* and Chapter 9 on *Design*.

Target user: The key users for this chapter will be consultants and designers.

8.1 Analysis and design approaches

i) Demonstrate the need to address both geotechnical and hydraulic disciplines. The two are inextricably linked, and in most practices, once design hydrographs are established the levee design would be undertaken by a geotechnical engineer. They would undertake assessment of permeability, flow paths and hydraulic gradients.

ii) Note the commonalities between coastal and river levees in the design methodology.

iii) Describe SLS (serviceability limit state) and ULS (ultimate limit state) performance criteria.

iv) Discuss other 'limit states' required to reflect the real world, i.e. to maintain, repair and rebuild levees.

v) Describe both the deterministic design approach (including safety factors per failure mode - strength, loadings, modelling) and the probabilistic analysis approach (including ways of generating fragility curves).

vi) Note that it is impossible to have a fully probabilistic approach to design.

vii) Check whether the designed levee retains the design event and check under design loading, whether it meets the design assumptions/criteria (specifically for seepage).

viii) Describe methods/techniques for investigating the reliability of existing levees and predicting long term performance including:
- Give guidance on how to identify, and assess strength/resilience of, weak points.
- Discuss how to take account of the uncertainties/variabilities of some of the characteristics.
- How to give an existing levee a return period for protection.

ix) Discuss the distinction between new and existing levee with regard to dealing with uncertainties.

x) Consideration of safety factors due to uncertainties and areas of limited knowledge, e.g. should they be higher than THC STD 1.2 to allow for degradation? Uncertainty in water level is a key uncertainty and its link to “freeboard” and hence crest level needs to be highlighted as it is ultimately a key design decision.

8.2 Analysis of failure modes and associated physical processes

i) Introduce functional analysis of levee systems as well as levees themselves and also of their components as a way to assess failure resistance and understand complex failure mechanisms.

ii) Where river banks/coastal shelves are in reasonable proximity to levees, the global stability of the entire slope system must be considered.

iii) Explain how flood defences perform during extreme events, including slope failure of the landward face and basal sliding failure of levee during flood events.

iv) List failure mechanisms and remedies to each and the degree of resistance to each including:
  - That overtopping and overflow can initiate erosion due to localised factors such as paths, bushes, fence posts and junctions of hard structures and rutting of the crest and poaching by animals.
  - Seepage, internal erosion and piping in the levee body, foundation and adjacent to appurtenant works, e.g. culverts.
  - Failure can occur due to inappropriate foundation materials.
  - Uplift of confining layers
  - Slope stability of the front face and impingement of river erosion on set-back levees.
  - Information on burrowing animals.
  - Rapid drawdown failures of riverward face.
  - The threat from wind, blowing over a tree and pulling out a root ball in the bank.
  - Note that culverts through levees can be in poor condition, leaking and collapsed.
  - Unapproved utilities installed through a levee (not only through the fill but in a longitudinal direction too).
  - Effects of "navigation" on process of erosion.
  - Flow concentration due to bridge piers.
  - Deterioration and settlement.
  - Fissuring/cracking.
  - Seismic failure modes, including liquefaction and sliding. Note in some parts of the world these may dominate).
  - "Combined" failure modes (external erosion, slope instability, breach, etc).
  - Kinetic? Approach.
  - Specifically for peat soils and levees, uplift and lateral displacement of the levee body (see paper from Van Baars).

8.3 Hydraulic design tools for performance of coastal and river levees

i) Highlight the key differences between coastal and river structures regarding overtopping and overflowing.

ii) Give information, equations etc for both fluvial and coastal structures identifying, for example, differences in approaches for steady water levels versus waves for both geotechnical and hydraulic analysis.

iii) Note the need to understand performance under a range of loadings and to design for a range of loads, e.g. water levels, and to understand/select extreme values such as climate extremes (e.g. freezing conditions, hot conditions, etc).

iv) Include description of the system and system risk models.

v) Suggest appropriate software/tools/models for different aspects of levee analysis (benchmark software) for flood stage, wind and wave, erosion, internal drainage, seepage and spillway sections.

vi) Seepage modelling is part of the design. In terms of breach development seepage induced failures are more likely than slope stability failures. Include guidance on the use of steady state or transient seepage analysis. This should recognise a number of factors including:
  a) Duration of flood events.
  b) “Usual” groundwater conditions – e.g. is the flood likely to occur when soils are partially or fully saturated.

c) Consequence of failure – relying on transient effects carries a higher risk.

vii) Discuss the inclusion of grouting and cut-off walls for remediation of levees where under-seepage is creating foundation pipes.

viii) Note that models have limitations.

ix) Include a description of physical modelling.

x) Consider including an appendix to detail models and equations, leaving other points for main text.

xi) Include tools associated with 'real-time observational methods'.

8.4 Geotechnical design tools and effects of water

i) Note that the determination of geotechnical parameters is an inexact science. However, the approach to determine these should be rigorous, based on science and requires appropriate interpretation by an experienced geotechnical engineer.

ii) Provide guidance on fill material parameters for a range of typical values for permeability, strength, erodibility, compressibility and resistance to internal erosion and note that foundation soil permeability is critical.

iii) Provide information on weak soils (including uplift mechanism and settlement/subsidence), fill materials and natural soils.

iv) Care should be used when referring to "poor quality" materials.

v) Discuss the problems (and their resolution) of existing embankments/levees for which there may be poor or no construction or maintenance records.

vi) Investigations of the compaction characteristics of fill (e.g. dynamic penetration tests).

vii) Geotechnical analysis to include seepage, underseepage, slope stability, embankment zoning, filters, drainage, sources of borrow and foundation treatments.

viii) Slope stability modelling is part of the design. Up until recently slope stability analysis was undertaken using a simple circular method and/or noncircular method. More modern versions of programs (e.g. Slope/w) include a slip surface optimisation routine which reports a lower factor of safety then the simple methods. Experience shows that this is often about 10% lower and leads to the possible conclusion that the FoS of embankments constructed comparatively recently may be less than envisaged by the designer. Issues such as these should be included within the discussions of software.

ix) Include text to cover sites where the river bank stability is in question and there is often a lack of GI at the toe of the river bank slope – due to access difficulties. This problem is compounded by the potential for ground conditions to vary at the toe of river bank slopes due to scour or historical changes in the position of the river channel. This can lead to incorrect assumptions at the toe of the slope, which could potentially lead to incorrect analysis. The importance of obtaining this data or dealing with the risks where it is not available should be emphasised.

x) Guidance should be included on the use of drained and undrained strength parameters depending on the soil type and loading situation e.g. what should be used for rapid drawdown case?

xi) Include that back analysis is a useful tool for understanding slope behaviour and parameters, but it is worth noting that parameters from back analysis should be treated with caution and must consider current state of levee (saturated/unsaturated, effective or undrained strengths) and past flood loading compared with the design flood condition.

9. DESIGN

Main points: This chapter will highlight the need for early specialist input from a variety of disciplines and a balance between engineering, environmental and social factors. Sections will be included for design of remedial and improvement works, new levees and removal of levees including sections on planning and options appraisal. The chapter will provide recommendations on methods for taking levees out of service including realignment options. The chapter will highlight the potential impacts on adjacent sections, e.g. increased flood levels, and how to deal with these. Specific design details with examples will be featured.

Key points will include "expedition planning" to deal with long-term climate change, access requirements (for the land owner, maintaining authority and for public right of way), non-structural alternatives, communication and collaboration, consideration of whole life management, best practice vegetation design, sustainability, environmental and social issues. Other design manuals and codes will be referenced. It is anticipated that Chapter 8 will set out the engineering principles and procedures that govern or characterise how levees perform. This chapter will demonstrate how these techniques can be used for design purposes and will provide both guidance and examples of best practice.

Chapter links: Chapter 3 on *Form & function of levees*, Chapter 4 on *Operation and maintenance*, Chapter 5 on *Condition assessment of levees*, Chapter 7 on *Site characterisation and data requirements*, Chapter 8 on *Physical processes and tools for levee design* and Chapter 10 on *Construction*.

Target user: The key users for this chapter will be consultants and designers including contractors/constructors involved in design and build projects.

9.1 Introduction and principles of levee design

i) Emphasise the complexity of structures (location and role) and need for early specialist input (e.g. Geotechnical Adviser as per EC7).
ii) List useful disciplines to have on a project, e.g. geotechnics, hydraulics, geomorphology, historians, biologists, forestry, sociologists and economics.
iii) Include the need for a balance between engineering, environmental and social factors.
iv) Include that interventions vary from maintenance to renewals to new levees to removal, required as a result of deterioration or the need for adaptation.
v) Include a list of key principles to cover during design.
vi) Discuss planning a life expectancy objective for a levee.
vii) Distinguish between what is established, well-proven guidance and provisional, interim guidance.
viii) Refer to other well used guidance or codes e.g. the Rock Manual, so as not to repeat these, but consider what to do about guides that are not free in the public domain.
ix) Include how the ILH complies with the different national CoPs and legislation and distinguish between common areas and those unique to particular countries.
x) Include how to design levees to EC7, i.e. using partial factors and appropriate design approaches (1, 2 or 3) in different countries.

9.2 Options appraisal and constraints

i) Provide assistance for decision making on whether to demolish, replace, investigate and/or refurbish. Note that completely new works are required in some cases.
ii) Describe a screening type analysis; integrating data, parameters and performance descriptors to assess risk.
iii) Discuss the impacts of decision making on the downstream hydrograph and geomorphology.
iv) Explain the scale at which a protection strategy has to be taken ("whole system"), and the "lifetime" of a project.

v) Explain what the costs/benefits analysis is and how it can be used to help the decision making for a protection strategy. Include the need to insert life safety into the cost benefit ratio when evaluating protection levels.

vi) Include a decision model for choosing the 'optimum' solutions, e.g. a decision assessment table for different types of measures. Measures 1, 2 and 3 versus criterion (safety, cost, etc).

vii) Consider the global picture, i.e. whether to insure, protect or abandon property.

viii) Consider whole life costs - economics; social / amenity / recreation; environmental etc.

ix) Discuss the methods for prioritisation of remedial/upgrading works, e.g. risks based approach to prioritising investment; and describe the link between condition assessment and investment referring to Chapter 5.

x) Consider constraints - environmental, property etc and the need to provide accessibility for maintenance.

xi) Discuss the option of managed retreat and who should pay. Making room for the river, i.e. using set back of levees such as putting parklands in front of levee.

xii) Discuss the design of alignment, ensuring the river is free to meander naturally.

xiii) Consider ground conditions when selecting possible alignments. At this stage it could comprise a review of geological maps, existing geotechnical data (BGS boreholes), aerial photographs and Lidar data. When considering raising and existing embankment the maintenance history of the defence will highlight any problem sections where poor ground condition may be present.

xiv) Consideration of non-structural alternatives.

9.3 Decommissioning

i) Decommissioning is one possible scenario, but includes discussion on what happens when you "stop" maintenance and accept the increased risk.

ii) This option requires detailed planning and design.

iii) This should recommend a forensic dissection of the embankment to assess its internal structure and level of fissuring. This would help with the development of an understanding of the internal structure of adjacent sections of embankment which are to remain in service.

iv) Guidance on the logistics of how the fill can be used in the construction of new retreated embankments should be included.

v) Discussion on how decommissioning of levees is managed in different countries.

vi) Opportunities for environmental restoration.

9.4 Remedial works design

i) Include design of remedial works including levees close to failing.

ii) Include geotechnical remedies such as clay core inclusion, fissuring repair, etc.

iii) Include novel practices for extending life of structures.

iv) Give an example of sheet piling through the centre of an embankment.

v) Suggest how to proceed when design is lacking, but a quick design must be done, e.g. communicate increased risk and suggest remedial measures.

vi) Include maintaining coastal levees affected by littoral drift.

9.5 Improvements works design

i) Include design of improvement works including generic approaches and methods to increasing level of protection such as levee raising and the use of innovative, lightweight materials, which are required for increasing the height of existing levees incorporating rigid structures.

ii) Include a tiered approach to consideration of environmental and social issues.

iii) Include details on ‘green’ levees for protected species and fish, e.g. rock protection on inner face, which promotes diversity.

iv) Multi-function approach – consider recreation.
v) Discuss community stakeholder engagement.
vi) Use of temporary demountables and sand bags to increase height of levees.

9.6 Planning and design of new levees including anticipating the effects of climate change

i) Consideration of whether a levee or a composite structure is the better solution.
ii) Expedition planning to deal with long-term change and making best use of foundation strength gain over time through consolidation.
iii) Resilience and adaptation to climate change (impact on hydraulics and functions, drought impact, short-term flexibility versus long-term sustainability, no-regret measures, turning points in policy etc). Include information on how to plan for the future and the need for adaptable designs for changing conditions.
iv) Highlight that engineering (specifically geotechnical) input is required at the planning stage to avoid inappropriate schemes.
v) Include how to avoid planning pitfalls and how to handle the planning process.
vi) Integrate with local/regional development plans.
vii) Discuss how to deal with protected land.
viii) Consensus building or agreement of competing interest needs to be accomplished at the front end, prior to design including the requirement for multi-function structures.
ix) Provide guidance on design for secondary users such as for recreation and environment.
x) Discuss how the installation of trees can reduce velocity or wave affects with supported maintenance and funding.
xi) Discuss how to deal with the variety of levee owners and the potential for weak spots with small private owners.
xii) Include a sub-section on sociological aspects in the design of new levees including:
  a) Social behaviour, understanding and awareness.
  b) How to overcome public perception that they are safe from flooding if they live behind a levee.
  c) How to educate the public as to the need for defence and how to compel communities to buy flood insurance.
xiii) Discuss risk communication/threat communication.
xiv) Provide key analysis methods (all relevant models and equations) for use in design and appraisal. These methods would cover all relevant performance requirements and failure modes, (the latter following the conceptual framework). Cross-reference to Chapter 8.
xv) Include the need to agree and clearly define future maintenance commitments & procedures with the owner/operator.
xvi) Identification of a no-development corridor on levee alignment to facilitate credible future raising, flood fighting and maintenance, etc. including appropriate land acquisition.
xvii) Consider that the land use behind the levee may change, i.e. agricultural land may become urban area. Variable levee design/O&M based on the land use behind them is a dangerous approach.
xviii) Include the two stage design, i.e. crest level at the system scale, then geotechnical/structural design at the levee scale.
xix) Discuss the need to use locally sourced material for cost & environmental reasons and therefore, how to design levees with this constraint.
xx) Cross-reference to morphological movement of river bed and shoreline erosion in the Site Characteristics Chapter.
xxi) Consider use of mobile, temporary flood defences.

xxii) Discuss where design stops and the interaction with construction, cross-referencing to the Construction Chapter and particularly the Sustainable Construction section.

xxiii) Highlight the need for early contractor involvement to prevent constructability issues.

9.7 Design details

i) Include structure specific issues with separate sections, as required, for fluvial and coastal structures.

ii) Discuss designing levees in mountainous rivers with fast flow and changes in bed.

iii) Detail use of proper drainage materials. Don't use CMP or other short life materials or up and cover levee rather than through.

iv) Discuss directional drilling beneath levees or placement of utility crossings over levees.

v) Describe how to appraise, design or detail:

- Specific levee types.
- Toe and crest structures and details/freeboard allowance.
- Slope protection methods (not just grass) with consideration of transitions to berms.
- Outfalls and utilities in structures.
- Steps and ramps.
- Transition details (including problems related to interfaces between soils and hard structures and how to resist piping).
- Provide typical sections (bad as well as effective examples of cross-sections & details).
- Include the do and don'ts of composite structures, e.g. I-walls, crest walls, etc.
- Describe the design of safety spillways (plus fuse-plugs) including consideration of whether damage should be allowed and the constraints, e.g. design to accommodate overtopping to buy time or channel into less sensitive areas.

vi) Describe how to use poor quality material dictated by site, i.e. how to treat, extract, compact, etc the material. (Broadlands has an example of an embankment which was constructed using a site mixed combination of peat and gravel. This has preformed well and withstood an over topping event!!

vii) Discuss smart specification of the soil to reduce erodibility.

viii) Discuss the provision of additional sacrificial fill.

ix) Describe how to design for seepage, piping, sand-boils etc.

x) Include a section on foundation design.

xi) Discuss soil improvement as well as some mixing. Include the latest research on bacterial fixing of silicon or calcium to increase strengths. Note that such systems may significantly improve the strength of granular materials, but it is unlikely to result in beneficial reductions in permeability.

xii) Advocate options/details for designs giving ecological benefits/soft engineering options – e.g. set back and reed planting of berms to break up wave action, alluvial woodland etc –users should see the river system as a whole.

xiii) Include questions, constraints and methods for solving problems, lessons learnt and case histories.

xiv) Include a design procedure for the design of a simple clay embankment. Three cases; over hard ground, over soft ground and where under seepage could occur.

xv) Include use of geosynthetics.

9.8 Vegetation design

i) Provide best practice for what to plant on coastal levees (dunes) and fluvial levees.

ii) Include how to design a levee to provide resistance to external erosion and how to assess resistance of existing levees such as grass-cover strength and maintenance plus impact of trafficking, animals and overtopping (reference CIRIA 116).
iii) Conflicts of interest regarding vegetation, e.g. aesthetics versus levee performance.
iv) Log jam resistance and log jam impact on flood and water level.
v) Long term management including opportunities for habitat creation & recreation.

10. CONSTRUCTION

Main points: This chapter will describe how construction practices and standards have changed over time. It will include economic best practice, planning (in particular access of plant to site), designing for ease of construction, sourcing of suitable earthworks materials, sustainable and innovative construction practices for decommissioning, maintenance, remedial, improvement and new works. It will highlight common problems and risks faced on different sites, including the need for a good knowledge of foundations, how soil variability can be addressed, dealing with a flood event during construction, programme constraints, environmental issues as well as the need for good quality control, monitoring and record keeping practices. A section will also be included on availability and selection of equipment and plant in particular for earthworks.

Chapter links: Chapter 9 on *Design*

Target user: The key users for this chapter will be consultants and designers to ensure their designs have buildability and can be implemented by the use of best practice and sustainable construction methods. Contractors (or other organisations that may be either advising the manager/designer or carrying out maintenance/new construction work) should be familiar with this chapter to ensure they are using best practice and that their methodology takes account on the constraints peculiar to levee works.

10.1 Project preparation

i) Provide information on contracting and bidding processes.
ii) Describe the changes in construction practices and standards over time, i.e. what to expect on older structures.
iii) Highlight the way to manage with acceptance of works, e.g. verify functional level and other key points with the contractor.
iv) Highlight the need for thorough planning and programming (scheduling) of the work, and the benefits of early involvement of the construction organisation.
v) Highlight the constraints of access to the works, e.g. agreement of access with landowners, long linear site area, ability to get to the element of work, consideration of use of specialist/floating equipment, etc.
vi) Highlight the importance of programme (schedule?) considerations, e.g. seasonal restrictions on earthworks, flora and fauna constraints such as breeding/spawning seasons, spring/neap tides, seasonal weather, seasonal flood storage considerations, etc.

10.2 Sustainable construction

i) Include sustainable construction procedures and practical requirements related to work teams, contract size, client, etc.
ii) Include the use of alternative sustainable construction materials, e.g. used tyres, PFA and crushed concrete.
iii) Include the advantages and disadvantages of different options e.g. include the total costs of options including environmental impacts such as haulage through towns.

10.3 Site preparation

i) Location of storage and welfare facilities.
ii) Establishment of access to the work area and/or consideration double-handling of materials.
iii) Site won or imported materials.
iv) Environmental considerations, e.g. protection to trees and hedges, identification and protection/translocation of protected species, arrangement for avoiding

potential pollution of water courses – interception of runoff/settlement ponds/etc, use of bio-degradable oils, bunded tanks, etc.

v) Provide information on soil remediation and improvement techniques for contractors.

10.4 Construction risk and safety

i) Highlight construction issues in both rivers, estuaries and on the coast, e.g. assessment of construction flood and cofferdam, flood/storm warning.

ii) Flag up the need for diligence during construction such that if site operatives note that locally the construction feel different of is behaving differently then this should be raised with the Engineer. It could be an indication of locally poorer ground conditions not identified by the GI or non-invasive techniques.

iii) Include typical problems and solutions, e.g. suggest approaches and details for dealing with difficult ground such as large thicknesses of soft soil and permeable layers and also singular points e.g. access ramp and interface between fill and concrete or rocks.

iv) Describe treatment of nonconformity by the contractor e.g. forgetting of geotextile between existing soil and gravel drain weighting, relief wells, draining or supporting layer.

v) Highlight the need for good knowledge of foundations and site investigation.

vi) Describe how variability can be addressed, e.g. in soil type on site.

vii) Include options for preventing pedestrian or livestock erosion such as mesh reinforced grass.

viii) Discuss issues with archaeological sites, SSSIs, nesting birds, etc and EIA requirements.

ix) Provide construction risks and H&S issues e.g. the importance of segregation of pedestrians from construction equipment.

x) Include health and safety guidance including PPE, access/retreat, lifebelts, buoy ropes, safety boat etc.

xi) Health and safety guidance such as under the UK's CDM Regulations.

10.5 Equipment in particular for all earthworks

i) Emphasise the importance of appropriate equipment selection for the particular circumstances of the site and access arrangements, (e.g an oversized excavator of dump truck could damage the formation or initiate an earthworks failure on soft ground) and having properly trained/competent operatives.

ii) Environmental considerations: bio-degradable oils, bunded diesel tanks, noise suppression, etc.

iii) Excavators; 360°, size, low ground pressure, long reach, GPS controlled, etc.

iv) Haulage Equipment; Road vehicles need high quality access, articulate dump trucks, 4WD dumpers, etc.

v) Spreading equipment; dozers large and small, 360° excavator, etc.

vi) Compaction equipment; bulk earthworks/ around structures, towed rollers, self propelled rollers, remote controlled rollers, smooth/sheep's foot/ grid rollers.

vii) Floating equipment; marine equipment such as barges, conventional equipment on pontoons, jack up or spud leg pontoons.

viii) Other equipment; craneage, piling rigs, piling hammers, etc.

10.6 Works methods

i) Include best practice construction procedures for decommissioning, maintenance, remedial, improvement and new works

ii) Provide examples of innovative construction practices.

iii) Discuss the need to make sure that the practices presented for site investigation, construction, etc. are realistic for general application and not just "special" projects.

iv) Define procedure of approval for fill (local or not) before compaction.
v) Provide information on the control of compaction rate, water content and its variation during construction of embankment.
vi) Provide ecological advice about sowing and plantations as well as guarantees about it.
vii) Reinstatement considerations, such as leaving a construction access road in place, or simply topsoiling/seeding over it, to facilitate future inspection/maintenance.
viii) Note the requirement for reinstatement of working faces in case of flood warning as a construction constraint.
ix) Note that backfill around structures can be a potential weakness, if not done well.
x) Note that levee construction is not quite a "standard" muckshift operation, as special care is needed for conditioning of fill and protection of exposed surfaces to ensure embankment is water retaining.

10.7 Quality control and monitoring

i) Include typical specifications on fill material or specification requirements including making best use of locally available fill material and/or measures to improve available material.
ii) Describe monitoring and control procedures during construction.
iii) Discuss the importance of local knowledge and experience of monitoring assets.
iv) Discuss soil testing methods.

10.8 Survey techniques and record keeping

i) Conventional or GPS.
ii) Highlight the need to ensure all as built drawings are kept in the future plus geotechnical information and a construction report.

11. REFERENCES

i) List of all documents cited in the handbook.

ii) Note CIRIA Style Guide – Havard system.

iii) The current list of relevant publications to be reviewed and included in this section is held by CIRIA and is being updated as the project progresses.

This is revision 10 of the expanded contents list of the ILH, prepared by Tracey Williamson (United Kingdom) incorporating comments from the comments logs from country leads in France, US and UK/Ireland received during March, April and May 2010.

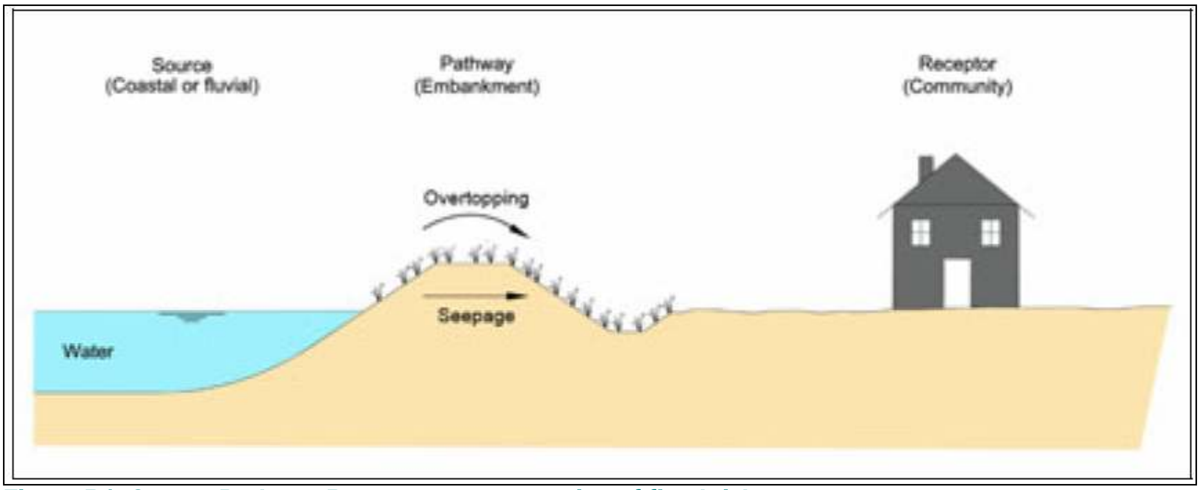

Figure B1: Source-Pathway-Receptor representation of flood risk management

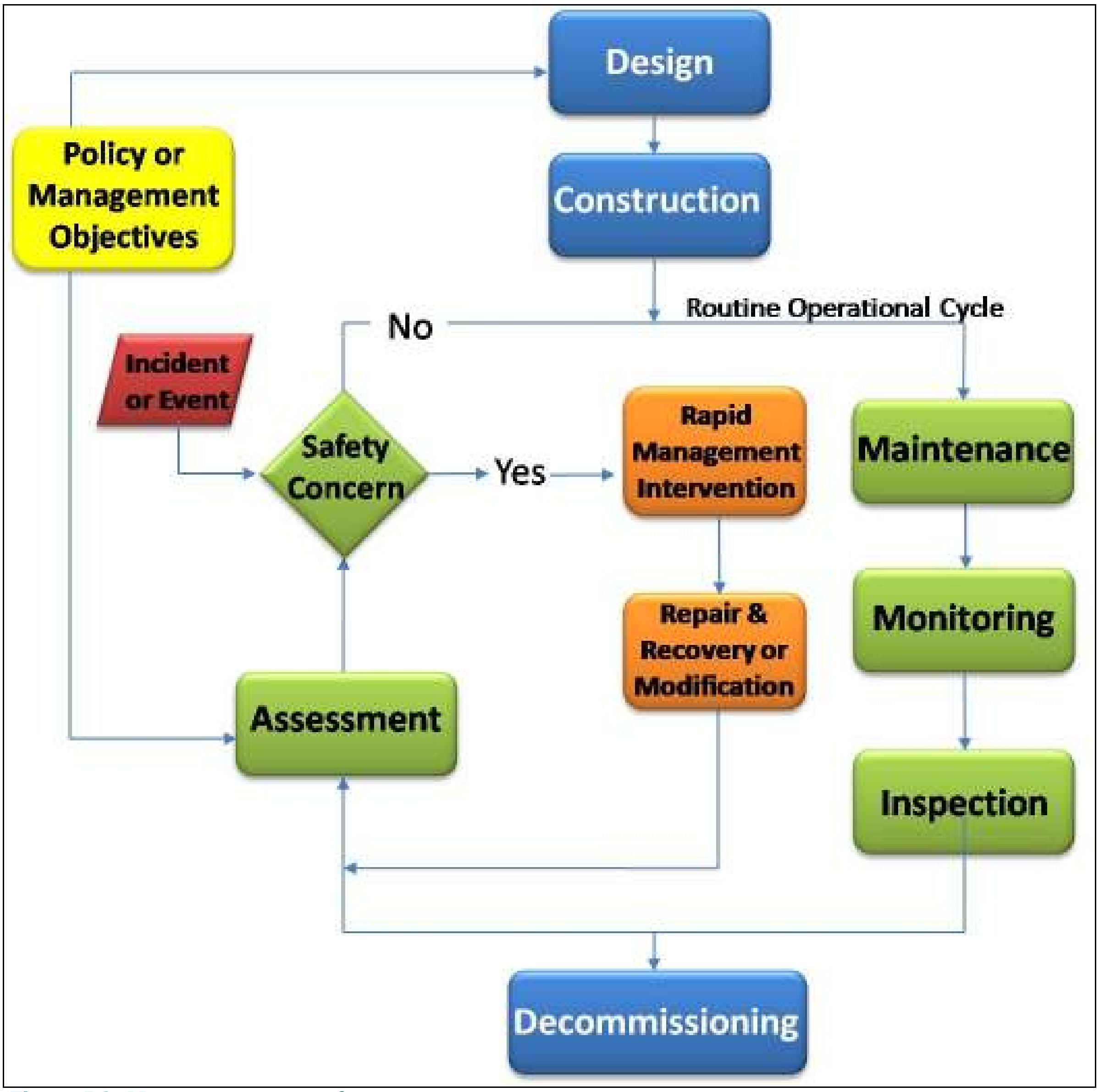

Figure B2: Management cycle for levees

Element	Hazard	Field observations	Risk	Geotechnical process	Ground conditions to consider / investigate
Founding strata	Settlement	Low crest levels	Low crest levels leading to overtopping	Consolidation of underlying strata (including dissipation of excess pore pressures) or embankment fill material	Consolidation and compression characteristics of underlying soils. Secondary consolidation and creep of soils and fill. Differences in horizontal and vertical permeability of foundation material
	Deep rotational failure	Tension cracks on embankment crest. Settlement of part of crest. Lateral displacement of embankment toe. Heave of ground in front of toe	Catastrophic failure of embankment	Shear failure during construction or embankment raising	Shear strength of fill and foundation soils, in particular undrained shear strength of clays. Possible longer term gain in strength due to consolidation
	Translational sliding	Distortion of embankment crest leading to bulging along outward face	Catastrophic failure of embankment	Lateral hydraulic force exceeds shear resistance of founding strata along base of embankment or desiccation of organic fill leading to a reduction in dead weight	Shear strength of soft clays and organic soils directly beneath the embankment. Desiccation of peat and organic fills leading to a reduction in dead-weight
	Seepage and piping	Seepage or ponding of water in front of embankment	Seepage causing internal erosion and piping	Under-flow of flood water leading to erosion and slope instability	Presence of highly permeable strata beneath embankment either leading to excessive seepage
	Uplift pressures	Heave of embankment toe	High pore pressures causing instability	Build up of uplift pressures in confined permeable strata due to hydraulic continuity with flood or high water load on inward face	Presence of highly permeable strata beneath embankment leading to build up of pore pressures due to confinement
Embankment structure	Shallow slope instability	Shallow translational slumping or slippage of embankment side slopes. Possible tension cracks on embankment crest, settlement of crest, lateral displacement of embankment toe or heave of ground in front of toe	Damage to outward and inward faces of embankment leading to a loss of integrity or a reduced resistance to seepage or overtopping	Instability during rapid drawdown after flood or high water load on inward face. Longer term slippage of slopes due to pore pressure equalisation, reduction in soil suction or progressive failure. Erosion of toe along outward face due to river migration	Compaction of fill material in relation to moisture content. Build up of pore pressures after lengthy period of high water load resulting in saturation of fill material or leading to uplift. Swelling of over-consolidated clay fill leading to shallow slips. Repeated shrinkage and swelling of clay fills leading to progressive failure. Reduction in soil suction pressures in partially saturated soils following infiltration of rain and/or high water load
	Internal seepage and erosion	Cracking within embankment body. Visible seepage on outward face of embankment, particularly during "bank full" conditions. Sediment in water. Animal burrows. Local variations in growth of vegetation	Washout of embankment fill material leading to local settlement, preferential seepage paths, piping and eventually breach	Excessive seepage caused by desiccation and fine fissuring. Excessive seepage due to highly permeable fill material. Loss of embankment material through burrowing or washout of fines	Shrinkage of medium and highly plastic clay leading to fine fissuring. Excessive seepage through coarse-grained fill leading to piping at critical hydraulic gradients
	Erosion of inward face and toe	Bare soil, loss of material visible Undercutting at base of slope	Increased risk of seepage or instability	Erosion of inward face and toe due to river / coastal migration or wave erosion	Shear strength and grading of embankment material. Geomorphological assessment of long term river or coastal migration
	Erosion of outward face	Bare soil, loss of vegetation	Reduced resistance to overtopping	Erosion of outward face due to over flow	Selection of suitable topography, topsoil and vegetation. Possible use of geotextiles

Table B1: Geotechnical factors affecting the performance of flood embankments from Defra (2003)

C Relevant Publications

This Appendix provides a list of publications to be reviewed and included in the references chapter of the Handbook. The list is held by CIRIA and is being continually updated as new publications are suggested.

Germany

- DIN 19712 German Standard “Flood protection Works along flowing Waters” Draft 2010

- Guideline 507 “Dikes along flowing Waters” of the German Association for Water, Wastewater and Waste, Draft Feb. 2007

- EAK (2002): Empfehlungen für Küstenschutzwerke (Recommendations for Coast Protection Works). Die Küste. Archiv für Forschung und Technik an der Nord- und Ostsee, Heft 65, Boyens & Co., 589 S.

- Guideline 246 “Freeboard at Dams” of the German Association for Water, Wastewater and Waste, 1997

- Guideline for the continuous Dam Inspection (VV WSV 2301) 1981

- Code of Practice “Stability of Dams at federal Inland Waterways” (MSD)

- EAU (2004)
  Empfehlungen des Arbeitsausschusses „Ufereinfassungen“, Häfen und Wasserstraßen, (EAU 2004), Hafenbautechnische Gesellschaft und Deutsche Gesellschaft für Geotechnik (DGGT), 10. Auflage, Ernst & Sohn Verlag, Berlin 2004

- EAK (2002)
  Empfehlungen für Küstenschutzwerke (Recommendations for Coast Protection Works). Die Küste. Archiv für Forschung und Technik an der Nord- und Ostsee, Heft 65, Boyens & Co., 589 S.

- Probst, B. (2004)
  Konstruktive Gestaltung von Seedeichen in Deutschland - Ausführungsbeispiele. HTG, *Jahrbuch der hafenbautechnischen Gesellschaft*, Bd. 54, S. 171-178.

France

- National research project on internal erosion (ERINOH)
- Pilot studies on LIDAR for levees (Cemagref /CNR/Symadrem)
- ANR research : application of geophysics to levee assessment CRITERRE)
- ANR research : Use of optical fiber for monitoring internal flows inside hydraulic works (Hydrodetect)
- Regional project : DIGSURE project (levee performance indicators, vulnerability assessment, GIS)
- MEEDDAT project : use of simplified visual indicators and comparative techniques for coastal levees monitoring

- ANR research : Impact of climate change on coastal defence structures and reinforcement approaches
- Technical guides on levee reinforcements (flood protection levees and canals)
- Guide on safety weirs on levees
- Typology and inventory of French coastal structures
- Guides for the new technical elements of the french hydraulic works regulation
- Guidance was produced in 2000: Surveillance maintenance and diagnosis of flood protection dikes – a practical handbook for operators and owners. translated to English in 2007
- Internal erosion of dams and their foundations. Fell & JJ Fry. Publ Taylor and Francis. 2007. ISBN 978-0-415-43724-0
- Patrice Mériaux and Paul Royet. 2007. *Surveillance, Maintenance and Diagnosis of Flood Protection Dikes - A Practical Handbook for Owners and Operators*, Cemagref Editions, available from http://www.quae.com/en/livre/?GCOI=27380100011370

The Netherlands

- Working together with water, a living land builds for its future, Findings of the Delta commission 2008. http://www.deltacommissie.com/doc/deltareport_full.pdf
- Current TAW/ENW- guidelines and technical reports**:**
- Guideline for safety assessment Dunes as water-retaining structure, 1984
- Fundamentals report sandy coast, 1995
- report sea and lake dikes, 1999
- Technical report water-retaining soil structures, 2001
- Addendum to Technical report water-retaining soil structures, 2007
- Technical report for safety assessment of Boezem dikes, 1993
- Guideline methodology for options dike and bank revetment. Part I and II. 1988
- Technical report dune erosion, 2008
- Guideline for Construction and management of Pipelines (Liquid) in and en near water- retaining structures, 1971
- Guideline for Construction and management and maintenance of structures and strange objects, 1976
- Technical report cofferdams and diaphragm walls, 2004
- Guideline for application of asphalt in hydraulic engineering, 1984 (now an annex to Technical report asphalt for water retaining)
- Guideline for concrete revetments, 1984 (*CUR 119, no longer available)*
- Technical report clay for dikes, 1996
- Technical report erodibility of grass as revetment, 1998
- Technical report asphalt for water retaining, 2002
- Technical report stone pitching, 2003
- Technical report wave run-up and wave-overtopping for dikes, 2002
- Technical report design loads for River area[6]), 2007
- Technical report sand boils (piping), 1999
- Technical report water pressures in dikes, 2004
- Technical report existing strength of dikes, 2009 (*replaces Research study for* existing strength of River dikes)
- Guideline for soil investigation in and near dikes, 1988
- Technical report geotechnical classification of peat, 1994

[6] This technical report is published together with Guideline Rivers (2007)

- Technical report environmental quality, 2007

Guidelines for design of river dikes:
- Part 1: Upper River area, 1985
- Part 2: Lower River area + appendices, 1989

Guideline committee Boertien:
- Guideline vision- development, 1994
- Guideline inventory and judgment of LNC-aspects (Landscape, Nature and Culture), 1994
- Guideline policy analysis, 1994
- Guideline constructural design + annexes, 1994
- Guideline environmental design, 1994
- Guideline sea and lake dikes, 1999
- Guideline Sandy coast, 2002
- Guideline Structures, 2003
- Guideline rivers, 2007
- Addendum I to Guideline rivers, 2008
- Pipe line systems (*NEN 3650*):2003
  - Part 1: General (*NEN 3650-1*)
  - Part 2: Steel (*NEN 3650-2)*
  - Part 3: synthetic material *(NEN 3650-3, design standard*)
  - Part 4: Concrete *(NEN 3650-4, , design standard*)
  - Part 5: Cast iron (*NEN 3650, , design standard*)
- Additional demands for pipe Lines in crossings with important government structures (*NEN 3651*), 2003
- Subsoil pipe lines. Basis for strength calculation, 1996 (*NPR 3659*)
  - Addition (*NEN 3659/A1,* 2003
- Safety assessment of asphalt revetments (V&W), 2005
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D Project team structure

The key components of the arrangements are listed below.

National level

National project representatives. It is suggested each country nominate three national project representatives. In the UK/Ireland, for example, these would be the project management lead, the technical lead and the national backing group chair. The national project representatives will sit on the executive steering board.

National technical editor. It is suggested each country nominate a technical editor. In the UK/IRL, for example, this would most likely be the technical lead. The national technical editor will sit on the technical editorial board.

National backing groups. Each country will have a large team of experts and user representatives covering all disciplines[7]. The national backing groups will guide the project to ensure that the project outputs are independent, robust and of the technical quality required. The national backing group members will incorporate an appropriate mixture of project funders, representatives of stakeholders and experts in technical areas relevant to the project. The responsibilities would include:

- confirm objectives and technical scope of the work
- contribute to directing the project via nominated representatives
- support the consultation process and help obtain key information
- review draft outputs and advise on technical accuracy
- assist in promotion of the handbook.

National management team. Each country should nominate a management team to coordinate the project management. In the UK/Ireland, for example, CIRIA will take on this task. Each country will address separately whether particular contributors should be paid or whether to rely on voluntary/supported input. Input and review by experts from other countries not entering into the formal collaboration agreement should be encouraged.

Working level

Project management team. It is proposed that CIRIA will act as the overall the project management coordinator of the ILH.

Project publisher. It is proposed that CIRIA will have the responsibility for publishing the final document in 'plain English'. This would include carrying out a full English language edit as well as the final quality controls, publication and printing process. CIRIA has an impressive record of production of previous engineering and environmental guidance documents. The cost of the publishing, including the plain English edit will be shared amongst all nations involved in the project. CETMEF will play a similar role for the translation, editing and publication of the manual into French.

Technical editorial team will be formed, allowing one representative per country to sit on the board.. The technical editorial team's role is to ensure the technical accuracy and quality of materials developed. The responsibilities of the technical editorial team will include:

- act as central technical point of contact for chapter leads
- manage resolution of any content discrepancies that may arise

[7] At the time of writing this report, the Netherlands and Germany did not have a formal national backing group formed.

- review and comment on draft materials at end of each phase
- conduct complete technical review of all materials at end of project
- edit or amend writing styles and use of English language as required
- report to the executive steering board (see below)
- national technical editorial team members will liaise with national colleagues should difficulties / disputes arise.

Chapter leads. One chapter leader will be identified for each chapter. The chapter leader may be assisted by a co-leader should chapters be particularly large chapters or should chapters cover a wide range of technical aspects. Expertise will come from more than one source or from more than one country involved, however the chapter lead will hold the responsibility to coordinate inputs of technical information. The chapter leader shall use a chapter team as support and incorporate views from the various country representatives.

Chapter teams. Chapter teams will be formed to support the chapter lead. They will meet as required, most probably at least once a year during the drafting stages of the project.

International reviewers. A number of international reviewers may be used to ensure the technical content of the project is up required standards and also to ensure a fully international status of the published manual. International reviewers will be expected to offer their time as contribution in kind. This could either be on a chapter per chapter basis or for a review of the entire handbook.

Main decision level

Executive steering board, which would include representatives from each of the participating nations (France, Germany, Netherlands, UK/Ireland and USA). The executive steering board's role would be to ensure:

- the country teams are integrated, work to schedule and meet all stated objectives
- agree a work programme
- meet regularly to review progress
- sign-off technical material
- resolve any technical disputes reported by the technical editorial team.

In case of disputes, a dispute resolution board will be consulted. The dispute review board is composed of appropriate experts considering the dispute. The technical experts nominated should not be directly involved in the project. Should any serious disputes occur or should a party wish to pull out, the project will still be completed with supporting recommendations from the dispute resolution board on how to ensure project completion is the best possible way.

E Programme

Main work tasks				Year	2010												2011											
				Month																								
	Milestone deliverables	Start date	End date	Duration	Jar	Fet	Ma	Ap	Ma	Jur	Jul	Au	Sej	Oct	No	De	Jar	Fet	Ma	Ap	Ma	Jur	Jul	Au	Sej	Oct	No	De
1 Contents list, chapter outline and design																												
(i)	Agree chapter leaders and agree detailed roles and responsibilities for each chapter	May-10	May-10	1																								
(ii)	Undertake literature review, identify existing standards, procedures and codes. Summarise and identify gaps.	Jun-10	Jul-10	2																								
(iii)	International workshop to review and comment on chapter outline	Jul-10	Ju1-10	1																								
(iv)	Finalise chapter content outlines	Jul-10	Aug-10	2																								
(v)	Decide on the design of end products	Aug-10	Aug-10	1																								
(vi)	National backing group meeting	Sep-10	Sep-10	1																								
(vii)	Technical editorial team meeting	Sep-10	Sep-10	1																								
(viii)	Executive steering board meeting	Sep-10	Sep-10	1																								
(ix)	End of milestone 1	Sep-10	Sep-10	1																								

Main work tasks				Year	2010												2011											
				Month																								
	Milestone deliverables	Start date	End date	Duration	Jar	Fet	Ma	Ap	Ma	Jur	Jul	Au	Sej	Oct	No	De	Jar	Fet	Ma	Ap	Ma	Jur	Jul	Au	Sej	Oct	No	De
2 Development of first draft of chapters																												
(i)	International workshop to review and comment on first draft of chapters	Oct-10	Oct-10	1																								
(ii)	Develop of first interim draft of chapter content	Oct-10	Feb-11	5																								
(iii)	Review period of first interim draft of chapter content	Mar-11	Apr-11	2																								
(iv)	National backing group meeting to review first interim draft of chapters	Apr-11	Apr-11	1																								
(v)	Technical editorial team meeting to review first interim draft of chapters	May-11	May-11	1																								
(vi)	Executive steering board meeting to sign off first interim draft of chapters (M2A)	May-11	May-11	1																								
(vii)	Develop first draft of chapter content	Jun-11	Sep-11	4																								
(viii)	Review period of first draft of chapter content	Sep-11	Oct-11	2																								
(ix)	National backing group meeting to review first draft of chapter content	Oct-11	Oct-11	1																								
(x)	Technical editorial team meeting to review first draft of chapter content	Nov-11	Nov-11	1																								
(xi)	Executive steering board meeting to sign off first draft of chapter content	Nov-11	Nov-11	1																								
(xii)	End of milestone 2	Nov-11	Nov-11	1																								

		Main work tasks / Milestone deliverables	Start date	End date	Year / Month / Duration	2011	2012
3		**Development of first full draft of manual**					
	-1	International workshop to review first full draft	Dec-11	Dec-11	1		
	(ii)	Develop first full draft of manual	Dec-11	Apr-12	5		
	(iii)	Review of first full draft	Apr-12	May-12	2		
	(iv)	National backing group meeting to review first full draft	May-12	May-12	1		
	(v)	Technical editorial team meeting to review first full draft	Jun-12	Jun-12	1		
	(vi)	Executive steering board meeting to sign off first full draft	Jun-12	Jun-12	1		
	(vii)	End of milestone 3	Jun-12	Jun-12	1		

		Main work tasks / Milestone deliverables	Start date	End date	Year / Month / Duration	2012	2013
4		**Development of final draft**					
	-1	International workshop - formal content sign off	Jul-12	Jul-12	1		
	(ii)	Develop final full draft of manual	Jul-12	Sep-12	2		
	(iii)	Review of final full draft	Sep-12	Oct-12	2		
	(iv)	National backing group meeting	Oct-12	Oct-10	1		
	(v)	Technical editorial team meeting - content sign off	Nov-12	Nov-12	1		
	(vi)	Executive steering board meeting to resolve any final issues	Nov-12	Nov-12	1		
	(vii)	Incorporation of final comments and delivery of final draft for editing	Dec-12	Dec-12	2		
	(ix)	End of milestone 4	Dec-12	Dec-12	1		

		Main work tasks / Milestone deliverables	Start date	End date	Year / Month / Duration	2012	2013
5		**English edit and publication**					
	(i)	English edit and layout	Dec-12	Jun-13	6		
	(ii)	Development of science reports and presentations	May-13	May-13	3		
	(iii)	Publication of electronic and hard copy manual in English	Jul-13	Jul-13	1		
	(iv)	Launch event	Jul-13	Jul-13	1		
	(v)	End of milestone 5	Jul-13	Jul-13	1		

		Main work tasks / Milestone deliverables	Start date	End date	Year / Month / Duration	2013	2014
6		**Dissemination and implementation**					
	(i)	Dissemination and implementation	Jul-13	Jul-14	12		
	(ii)	Translation, editing and publication of manual in French	Jul-13	Jul-14	5		
	(iii)	Project closure	Jul-14	Jul-14	1		
	(iv)	End of milestone 6	Jul-14	Jul-14	1		

Project funders and lead organisations

France

Germany

Netherlands

United Kingdom / Ireland

United States of America