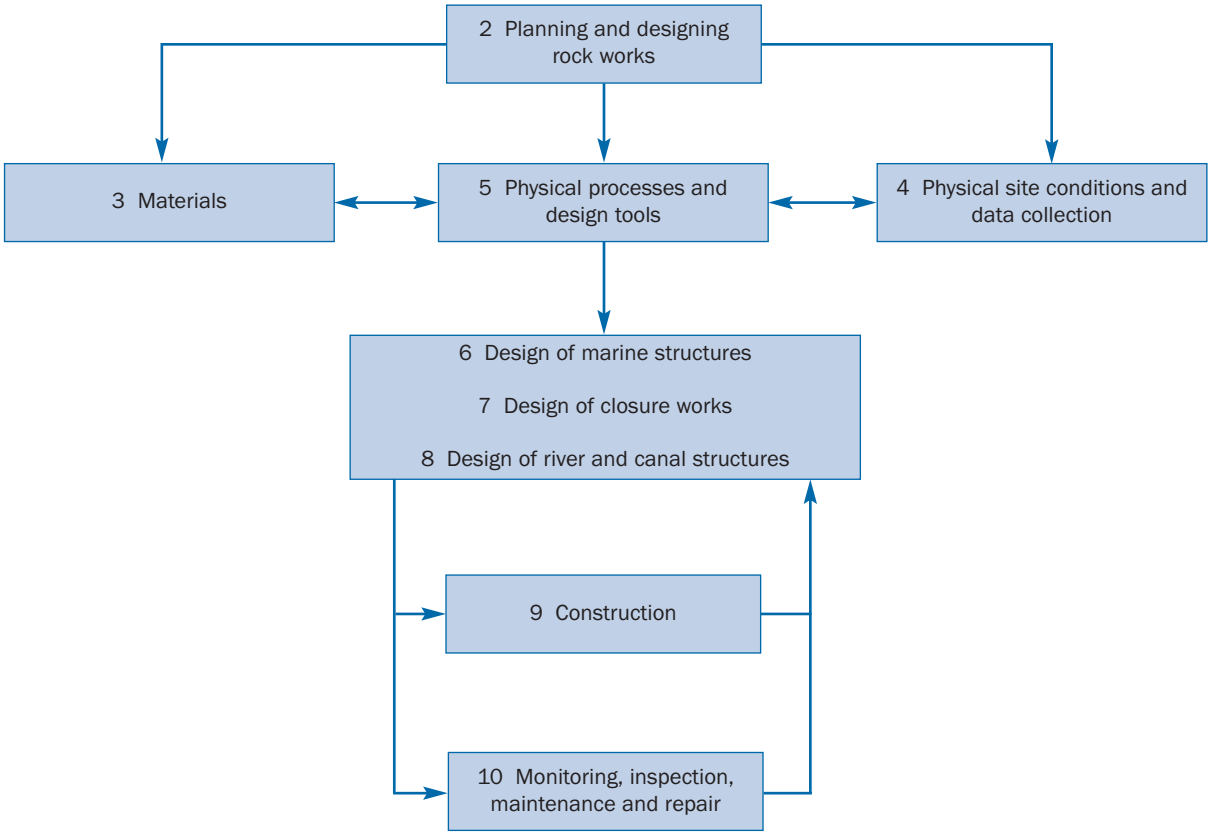
1 Introduction

CHAPTER 1 CONTENTS

1 Introduction

This flow chart shows the links between the technical chapters that follow this introductory chapter. It is repeated at the start of each chapter and expanded to show more detail of the contents of the relevant chapter. Use it in conjunction with the contents page and the index to navigate the manual.



1.1 USE OF ROCK

Rock is a commonly used construction material in the hydraulic environment. It is used in the marine and fluvial environments to provide protection against scour and erosion and to limit wave overtopping and flooding.

Rock is quarried to produce armourstone, defined as coarse aggregate used in hydraulic structures and other civil engineering works. This may be produced in masses ranging from approximately 1 kg up to 20–30 tonnes. Rock may be employed as an armouring material, as a filter or underlayer, or as a fill material.

Where armourstone of sufficient size or quality is not available then artificial units (generally of concrete) may be used. Gabion boxes or mattresses filled with smaller armourstone are another alternative. Other materials, such as industrial by-products, may also be used instead of quarried rock.

Standard solutions do not generally exist in this field of engineering. To develop a robust, site-specific rock-based solution for a project it is necessary to consider a wide range of issues including materials, environmental conditions, construction methodology, maintenance regime and health and safety for construction personnel and the general public.

1.2 BACKGROUND TO THE MANUAL

In 1991 CIRIA/CUR published the original *Manual on the use of rock in coastal and shoreline engineering*, commonly referred to as "The Rock Manual". This was followed in 1995 by the *Manual on the use of rock in hydraulic engineering* by CUR. Two French reference books were produced during the late 1980s: *Le dimensionnement des digues à talus* (EDF-LNH, 1987) and *Les Enrochements* (LCPC, 1989). Since these books were published there have been many advances in the understanding of rock as a material and of the design and behaviour of rock structures in the hydraulic environment. This new edition of *The Rock Manual* presents current good practice for the design and construction of rock structures. Where appropriate, it presents new or emerging technologies that have not, at the time of writing, become standard practice, to allow the reader to be fully aware of, and make best use of, the latest research findings. Section 1.5 defines the scope of this updated manual and includes a list of changes from the earlier versions.

The manual has been updated by a principally British, Dutch and French team and has benefited from extensive international review to ensure that it provides guidance on current good practice worldwide. The manual collates available research data and technical information together with practical experience gained by practitioners. In doing this, care has been taken to indicate current limitations in the design processes and the extent to which empirical methods and engineering judgement are involved.

A full list of acknowledgements to the organisations and individuals who have contributed to the updating of *The Rock Manual* is provided at the beginning of this manual.

1.3 STRUCTURE OF THE MANUAL

1.3.1 Chapters

1 **Introduction** explains the philosophy behind the manual, the key features of the update and the structure of the contents.

2 **Planning and designing rock works** discusses key considerations for a rock project in the hydraulic environment. This chapter is an important first point of reference in the manual, as it provides an *aide memoire* of issues that should be addressed. Readers are encouraged to read this chapter before proceeding with other chapters. The contents have been kept concise and focused to aid usability.

3 **Materials** discusses the range of issues with regard to armourstone and other material selection, including concrete armour units. The chapter considers source evaluation, properties, performance prediction, quarry yields and quarry operations. It describes the various testing methods to determine rock and armourstone properties. It cross-references to the European armourstone specification EN 13383.

4 **Physical site conditions and data collection** describes how to derive hydraulic, geotechnical and ice conditions and summarises data collection. Designers can use this chapter as the starting point for design, but it is also relevant to contractors and suppliers who need information on environmental conditions for construction operations.

5 **Physical processes and design tools** presents design methods for rock structures in both marine and fluvial environments. It covers hydraulic performance, structural stability and geotechnical behaviour. The hydraulic and geotechnical parameters derived in Chapter 4 and the material characteristics derived from Chapter 3 are the key inputs to this chapter.

6 **Design of marine structures.** See below.

7 **Design of closure works.** See below.

8 **Design of river and canal structures.** See below.

Chapters 6, 7 and 8 provide practical guidance for the design of different types of structure. These chapters take the outputs from the design methods in Chapter 5 and provide guidance for the geometry (plan layout, cross-section) and structure details taking into account the constraints that exist, such as buildability and access (discussed in Chapter 9), availability of resources (discussed in Chapter 3) and maintenance (discussed in Chapter 10). In particular, Chapters 6–8 cover plan layout, geometry of cross-sections, structural details (toe, crest etc), transitions and joints, design-related construction, cost and maintenance considerations, and repair and upgrading of existing structures. Selection of appropriate design conditions is also covered in these chapters.

9 **Construction** covers commonly used equipment and transport, site and location considerations (including site preparation), quality control in rock structures (including placing and packing, survey and measurement techniques), health and safety, and risks. Some methods of construction are described for the most common hydraulic structures using rock.

10 **Monitoring, inspection, maintenance and repair** discusses monitoring techniques, appraisal of structure performance, and repair and construction methods.

1.3.2 Use of the manual

The following features are designed to assist readers in navigating the manual:

- **Diagram of general structure**. Figure 1.1 provides a flow chart of the structure and contents of the complete manual. It also suggests a relationship between the advice given and key phases of a typical project.
- **Diagram of content relevance to different users**. Table 1.1 presents an evaluation of the content from different users' perspectives to assist the reader in finding information relevant to his or her needs.
- **High-level contents list**. This is given for the complete manual at the start of the book.
- **Detailed contents list**. At the start of each chapter there is a contents list for that chapter only.
- **Structure of each chapter.** The front end of each chapter includes:
  - a detailed contents list for that chapter
  - an introductory box that describes what is included in the chapter
  - a flow chart to demonstrate how the chapter links with other chapters.
- **Where am I?** Each page tells the reader their current location in the manual. The chapter number is shown on the navigation bar running down the outer edge of right-hand pages, the chapter number and title are given on the left hand page header, while the section number and title are given on the right hand page header.
- **Index of key topics**. The index lists key topics by section number. A complete index of words is not included as most subjects should be easily locatable through the high-level contents list at the front of the book and the detailed chapter contents pages. The index is particularly useful for locating discussion of topics that span several chapters.
- **Electronic version**. The complete manual is available on the CD-Rom attached to the inside back cover of the book and on the web at the CIRIA and CETMEF websites <www.ciria.org/> <www.cetmef.equipement.gouv.fr/>. It incorporates a navigation facility permitting users to make rapid searches for words or phrases.

PROJECT PHASE	RELEVANT MANUAL CONTENT	Technical considerations (2.3)	Economic considerations (2.4)	Environmental considerations (2.5)	Social considerations (2.6)
Understanding the problem • Functional requirements • Performance criteria • Constraints: budget, access, materials, environment, maintenance	**Chapter 2: Planning and designing rock works** • Defining project requirements • Technical considerations • Economic considerations • Environmental considerations • Social considerations				
Information requirements Obtain all necessary site information: • Available materials • Hydraulic conditions such as waves, currents, water levels • Bathymetry and topography • Ice conditions • Ground conditions	**Chapter 3: Materials** • Quarried rock • Concrete • Recycled materials **Chapter 4: Physical site conditions and data collection** • Bathymetry • Water levels • Waves, currents • Ground conditions • Geotechnical properties of materials				
Developing solutions • Develop conceptual designs – *develop structure layouts and types* – *identify information requirements* – *review project feasibility* • Prepare preliminary designs – *perform required analytical studies and modelling* – *determine typical armourstone size and structure profile* – *assess alternatives against performance criteria and constraints* – *cost estimates* – *compare alternatives (technical, environmental and economic)* – *select preferred solution* • Produce detailed designs – *review possible failure mechanisms* – *calculate suitable armourstone gradings, design underlayers and filters* – *calculate structure dimensions* – *design toe and crest details* – *design transitions, end protection, drainage, services etc*	**Chapter 5: Physical processes and design tools** • Hydraulic interactions • Structure response to hydraulic loading • Geotechnical interactions • Geotechnical response **Chapter 6: Design of marine structures** **Chapter 7: Design of closure works** **Chapter 8: Design of river and canal structures** • Plan layout • Geometry of cross-sections • Structure details – toe, crest design • Transitions, joints • Design-related construction aspects • Cost aspects • Repair and upgrading • Design-related maintenance aspects				
Implementation • Armourstone production and control • Specifications • Construction	**Chapter 9: Construction** • Equipment and working conditions • Transport • Aspects of site and location • Placement, packing and tolerances • Survey, measurement and quality control • Construction risk, health and safety • Construction specification (**Appendix A1**)				
Operation • Monitoring • Maintenance • Decommissioning or removal	**Chapter 10: Monitoring, inspection, maintenance and repair** • Monitoring • Appraisal of structure performance • Repair and rehabilitation				

Note

Relevant section numbers are given in brackets.

Figure 1.1 *Structure of the manual and relationship to project phases*

1.4 TARGET READERSHIP AND EXPERIENCE

The target audience for the manual is wide and includes planners, developers, engineering consultants and designers, architects, building managers, facility managers, contractors, producers and suppliers, owners, staff from regulators, funders and educational institutions. The guidance is suitable for worldwide application.

The manual assumes that the reader has a level of technical knowledge typically corresponding to a minimum of:

a degree in civil engineering and two years' experience

or

equivalent qualification or experience.

The manual is appropriate for the non-specialist in that it provides the reader with an understanding of the principles and procedures involved. It is, however, emphasised that the manual itself cannot convert a non-trained person into a specialist and the guidance should not be used as a substitute for experience and judgement.

The manual addresses the needs of a range of users who may refer to it in different ways depending on the stage they become involved in the project. Table 1.1 presents an evaluation of the content from the perspectives of different users to assist the reader in finding information relevant to their needs.

Table 1.1 *Relevance of chapters for different stakeholders and users*

Stakeholder/user	Chapter									
	1. Introduction	2. Planning and designing rock works	3. Materials	4. Physical site conditions and data collection	5. Physical processes and design tools	6. Design of marine structures	7. Design of closure works	8. Design of river and canal structures	9. Construction	10. Monitoring, inspection, maintenance and repair
Armourstone producer	●	◉	●	○	○	○	○	○	●	⊙
Supplier	●	◉	●	●	○	○	○	○	●	○
Transport agent	◉	⊙	◉	◉	○	○	○	○	●	◉
Contractor	●	●	●	●	⊙	◉	◉	◉	●	◉
Consulting engineer	●	●	●	●	●	●	●	●	●	◉
Structure owner	●	●	◉	●	◉	◉	◉	◉	●	●
Funding bodies	●	●	⊙	●	◉	◉	◉	◉	●	●
Regulatory bodies	●	●	⊙	●	○	○	○	○	●	●
Environmental organisation	●	●	◉	●	⊙	⊙	⊙	⊙	⊙	●
Rock-testing laboratory	⊙	○	●	○	○	○	○	○	○	◉
Geotechnical consultant	●	◉	●	◉	●	⊙	⊙	⊙	⊙	◉
Hydraulics consultant	●	◉	⊙	●	●	●	●	●	⊙	◉
Educational institution	●	●	●	●	●	●	●	●	●	●

Note

The relevance of material to each stakeholder or user group is indicated by the following symbols: ● high, ◉ medium-high, ⊙ medium-low, ○ low.

1.5 SCOPE

The manual provides guidance that starts from the stage in a project when it has been decided to construct a structure in a hydraulic environment using rock as the only material, or as the primary material where it is one of a combination of materials. Guidance is not provided on early feasibility studies.

Guidance on concrete armour units is given where these may be used as an alternative to armourstone. Only large concrete armour units are covered. This manual does not cover concrete revetment blocks.

Guidance on other alternative materials is provided only where these materials are used with, or in place of, quarried rock.

References to "the project" throughout the manual refer only to activities associated with the rock works.

1.5.1 Changes from earlier manuals

The updated manual includes the following new features:

- previous manuals completely reviewed, with updating and rewriting where appropriate
- scope extended (from the 1991 edition) to cover coastal, inland waterway and closure structures
- guidance on design and construction using concrete armour units
- an updated construction specification for rock structures
- cross-referencing to the new European armourstone specification EN 13383, which supersedes sections of the previous manuals
- cross-referencing to the new Eurocodes for geotechnical considerations
- updated guidance on wave climate description and representative wave parameters, including wave height distribution in shallow waters
- new research on block integrity and on packing and placement
- new research on predicting quarry yield and block size distributions
- new research on the performance of falling aprons
- updated guidance on wave overtopping, wave run-up and wave transmission
- new guidance on rear-side stability of rock structures
- new guidance on the stability of near-bed rockfill structures
- updated guidance on the stability of low-crested structures and the stability of rock-armoured slopes with shallow foreshores
- new guidance on design and construction of statically stable berm breakwaters
- new guidance on the structural response to ice loads
- a new section on design of rock protection works in ports
- a completely revised chapter on monitoring, maintenance, inspection and repair.

The following changes or omissions from the earlier versions have been made in this update:

- gravel beaches have been omitted, as these are covered in other texts on beach design
- detailed guidance on scour is omitted, as this subject is covered in other reference texts and manuals
- appendices on rock measurement, hydraulic and geotechnical data collection have been omitted

- the appendix on structure monitoring techniques has been omitted, as this subject is now covered in Chapter 10.

1.5.2 Structure types considered

This manual provides guidance on the use of rock in a range of hydraulic structures. The various structures in scope, and their key functions, are summarised in Table 1.2. A range of structures is shown in Figures 1.2 to 1.18.

Table 1.2 *Rock structure types covered by the manual*

	Structure type	Description	Functions
Chapter 6	Breakwater (Figures 1.2, 1.3 and 1.4)	Usually rubble (rock) mound structure projecting into the sea, comprising gradations of stone, armoured with large armourstone or concrete armour units	Shelters vessels and structures from waves and currents Prevents siltation of navigation channel Prevents thermal mixing (eg cooling water intakes)
	Rock protection to port structures (Figure 1.5)	Usually rock protection at the toe of a vertical wall or beneath a piled deck	Provides protection against propeller wash and ship-induced waves
	Revetment (Figure 1.6)	Protective structure normally placed on embankment or profiled fill material, often to form a seawall	Protects coast against erosion Protects low-lying areas against flooding
	Seawall (toe) (Figure 1.7)	Rock berm at toe of structure, often applied to existing structures experiencing scour problems	Prevents undermining of seawall
	Groynes and artificial headlands (Figure 1.8)	Rock mound structure generally constructed on a beach perpendicular to the shore	Intercepts and traps beach material
	Detached or reef breakwater (Figure 1.9)	Rock mound structure generally constructed parallel to, but not connected to, shore	Intercepts and stabilises beach material
	Sill or berm	Rock mound structure generally constructed parallel to shore at toe of beach	Traps or holds beach material in elevated position
	Rock protection to pipelines and cables (Figure 1.10)	Rock bund on sea bed or rockfill in trench	Maintains stability of pipeline Provides protection against impact, eg from anchors, fishing gear
	Scour protection of slender structures such as monopiles	Rock protection around base of structure	Prevents undermining of structure
	Scour protection for large (eg concrete gravity) structures	Rock protection at toe of structure	Prevents undermining of structure
Chapter 7	Rockfill closure dams (Figure 1.11)	Closure dam composed of loose rock, usually dumped in place, characterised by high flows during the final stages of the closure	Stops water flow and in some cases acts as a temporary dam (cofferdam) protecting a site where a dam or other major structure is to be built in a construction dock
	Estuary closure (Figure 1.12)	Dam at a location where water levels and currents are determined mainly by the tide; in most cases the closure dam is incorporated in the final estuary dam	Possible functions are flood control, land reclamation, creation of a freshwater reservoir, creation of a tidal energy basin, or providing a road or rail connection
	River closure	River structure involving a closure dam or cover dam either to divert the discharge or to store it temporarily	Diversion of rivers (temporary or permanent), eg for river control, temporary works, irrigation, or water level control for navigation
	Rock protection of reservoir dams (Figure 1.13)	Dam to create a reservoir, often involving a rock protection to dam face, on downstream slope or in filter drains and possibly a rockfill dam	The rock protection prevents erosion of dam core material that may also be partly constructed from rock (rockfill dam)
	Rock protection to barriers, sills, weirs, barrages, diversion dams, spillways (Figure 1.14)	Generally low structures relative to water level designed for through-flow or overflow for a large proportion of the time	Rock is used to provide protection to areas downstream of these structures, for armouring and bed protection and for filter layers

Table 1.2 *Rock structure types covered by the manual (contd)*

	Structure type	Description	Functions
Chapter 8	Bank protection (Figures 1.15 and 1.16)	Rock or gabion revetment to protect riverbank	Prevents bank erosion Controls river development, preventing outflanking of adjacent structures
	Spur-dikes (Figure 1.17)	Bund protected by rock, generally perpendicular to riverbank	Controls river channel position Constricts low-water channel to control water depth Diverts flow from riverbank
	Longitudinal dikes (also called guide banks or guide bunds) (Figure 1.18)	Bund protected with rock, generally orientated along same axis as river	Prevents bank erosion Controls river flow and development, preventing outflanking of adjacent structures
	Bed protection	Rock or gabion armouring to river bed	Prevents bed scour, including vessel-induced scour
	Fish passes	Rock-armoured channel	Provides open passage to enable fish to pass a river control structure. Rock provides scour/erosion protection
	Bridge scour protection	Rock berm or bed protection around base of bridge piers	Prevents scour of river bed around bridge piers

1.5.2.1 *Marine structures*

Marine structures using rock are shown in the following figures. Design guidance for these structure types is given in Chapter 6.

Figure 1.2

Rubble mound breakwater (courtesy Brien Wegner, USACE)

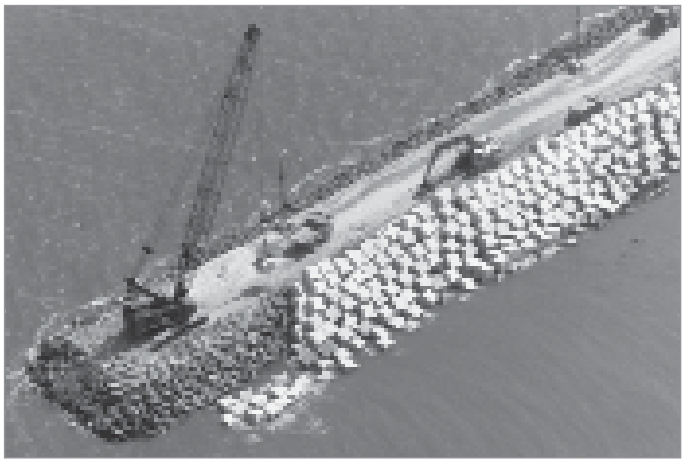


Figure 1.3

Construction of breakwater using concrete armour units (courtesy CUR)

Figure 1.4 *Breakwater – eventually to contain reclamation (courtesy Edmund Nuttall)*

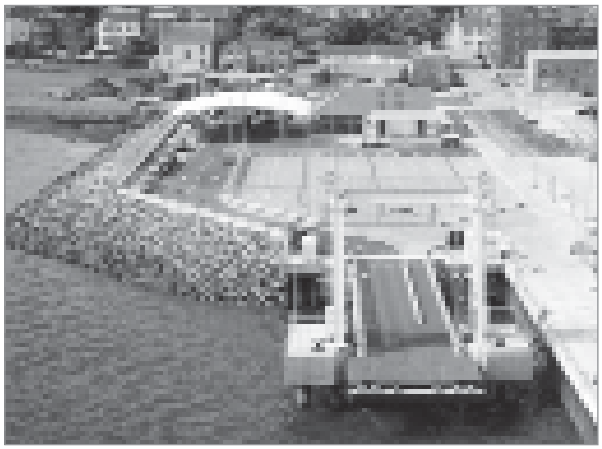


Figure 1.5 *Rock protection to port structures (courtesy Edmund Nuttall)*

Figure 1.6 *Rock revetment (courtesy HR Wallingford)*

Figure 1.7 *Scour protection to seawall (courtesy Clive Orbell-Durrant)*

Figure 1.8 *Groynes and artificial headlands (courtesy Halcrow)*

Figure 1.9 *Detached or reef breakwater (courtesy Clive Orbell-Durrant)*

Figure 1.10
Rock protection to pipelines – using a fall-pipe dumping vessel (after CUR 1995, courtesy Van Oord nv)

1.5.2.2 Closure works

Various types of closure works using rock are shown in the following figures. Design guidance for these structure types is given in Chapter 7.

Figure 1.11
Rockfill closure dam under construction (courtesy KARICO)

Figure 1.12
Sea dike (courtesy KOWACO)

Figure 1.13 *Reservoir dam (courtesy KOWACO)*

Figure 1.14 *Weir with rock glacis (courtesy Andrew Pepper)*

1.5.2.3 River and canal structures

River and canal structures using rock are shown in the following figures. Design guidance for these structure types is given in Chapter 8.

Figure 1.15 *Rock revetment being constructed on geotextile (courtesy Mott MacDonald)*

Figure 1.16 *Rock protection to outfall structure on bank (courtesy Charlie Rickard)*

Figure 1.17 *Spur-dikes (after CUR 1995)*

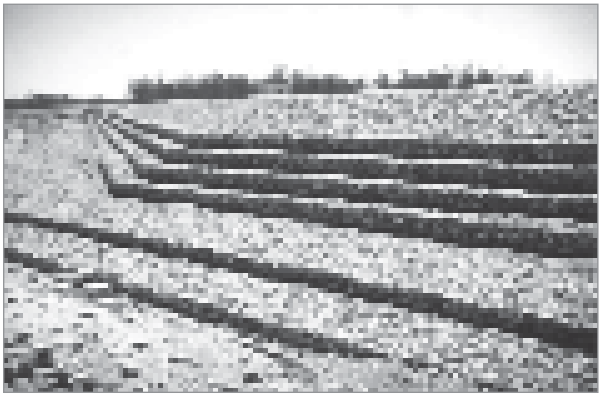


Figure 1.18 *Gabion guide bank (courtesy Mott MacDonald)*

1.6 REFERENCES

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