Annex 1
Procurement guidelines for tender preparation, evaluation and award of contract

INTRODUCTION

All procurement (and planning) must conform to the three pillars of Integrity, Transparency and Accountability. These apply to all activities before construction, the actual construction (especially if consultants and contractors are to be used) and to the subsequent operation and maintenance of the structure and any related infrastructure such as an irrigation scheme.

Procurement rules exist in most countries and for all international financing agencies and these must be followed. These rules should encourage true and open competition in tendering and contract award, open meetings and equitable and fair distribution of information, effective monitoring and auditing of all processes and implementation activities.

As part of the preparation work, and before any tender is advertised, the procuring agency requires a realistic estimate (based on a good quality design and costing process) of the cost of the structure with a breakdown of significant cost items. To prepare such an estimate, an engineer (**The Engineer**) should be selected and be appointed to not only carry out this preliminary work but continue to supervize the contractor and ensure all works are carried out according to the design and to the highest quality possible.

This estimate must be kept strictly confidential and there should be no links between personnel having this knowledge and the bidders. Should the subsequent bidding result in bids received that vary greatly from this estimate, questions should be raised on the validity of the bids. Underestimates from bidders could lead to poor contract performance and the need for changes and variations as the contract proceeds and overestimates may suggest over pricing, cartel links or other unrealistic bidding.

Decision-making criteria at all stages must be clear, justifiable and objective (with a written record where needed) with no room for discretion at any time, especially in the evaluation and comparison of the bids.

Prequalification of bidders for significantly expensive contracts or a series of small contracts[18] is recommended, but avoiding the possibility of establishing cartels. This prequalification should be based on professional competence (staff and equipment), relevant experience, financial capability and integrity. Any contractor or consultant that has recent, relevant convictions or has been disbarred for irregu-

18 Awarding contracts for a number of small dams in one area, or for one project as one overall contract, may result in economies of scale in mobilization, the use of plant and equipment and in supervision.

lar, financial activities, or failure to complete contracts, should not be allowed to prequalify.

PREPARATION WORK

The preparation of tender and contract documents, including all survey and design work needed to prepare quantities and guideline costings, should take place in good time. If funds are to be sourced from international lending agencies or donors, their guidelines will have to be followed and examples of advertisements and documents from such organizations should be obtained at the beginning of this process.

Preparation may require the application for land and water rights, environmental impact assessments plus any needed compensation or resettlement plans. These must be completed before the dam construction can be approved and allowed to proceed.

In many places, construction can only take place in the dry season when river levels are low, access to the site easier and moisture control for compaction possible. Thus, the design and tender process should take place in the rainy season and be timed to be completed by the beginning of the next dry season in time for mobilization of plant and equipment as the ground begins to dry out. Clearing access roads, felling and removing trees and stripping foundation areas is often best begun before the ground has completely dried out. The end of one rainy season and the start of the subsequent dry season are the best times for this.

ADVERTISEMENT OF THE TENDER

Always include a site visit in any tender advertisement and award procedure.

The tender advertisement period has to take into account the need for approval (usually at the advertisement and award stages) from the lender or donor, the need to adhere to local or national government regulations and bureaucratic procedures, whether it will be advertised internationally, regionally or nationally and the scope of works. A tender for one small dam could be advertised nationally and potential tenderers given 6 to 8 weeks to respond, including site visits and collection of documents. Thus, the tender period for this, including advertisement and evaluation could be around 12 weeks.

A series of dams being funded by one or more donors may require international advertisement with time for potential bidders to collect documents, make site visits and prepare timetables and bids (in their home countries). Such a tender may require up to 20 weeks to complete with further time required for the winning bidder to mobilize.

The more complicated the works and the size and number of dams to be built, the longer the tender process will take. Guidelines to assist in the preparation of tender and contract documents, and in the award of a contract for a simple project involving only one or two small dams, are given below:

The evaluation modalities (see details hereafter) – or any modified equivalents – are to be attached to every tender document to permit bidders to understand the proposed evaluation process.

Always keep written records of significant events and always advise bidders in writing of any matter that could have legal implications. Any specific information given to any tenderer that is not in the documents should be passed on, in writing, to all other tenderers.

THE EVALUATION MODALITIES

Two options exist for tender, and the choice has to be indicated in the tender document.

In the first option, the technical and financial offer are combined and presented in a single envelope. The second option, called staged tender, involves a two envelope system in which the technical proposal (first envelope) is evaluated and bids ranked before the financial offer (second envelope) is opened. It ensures that price does not influence the technical evaluation of the bid. This approach should be preferred, in particular in the case of complex contracts. Where a two envelope tendering process is used, it should be indicated in the tender document that tenderers are to place the technical and financial components of their tenders in separate, clearly marked, envelopes. These envelopes are to be placed inside a single envelope and normal procedures apply for the lodging of the tender.

A points system should be adopted, based on criteria that can be adjusted according to country, individual dam sites, scope of work and other factors. All tenderers must be made aware of the evaluation procedure to be followed and whether there are any special conditions involved. The following point system can be used as a guide:

Technical bid: 50 points
Experience – 20 Points maximum
This is calculated according to the personal evaluation of each team member and considers the following: any experience (good or bad) with the contractor, experience of the contractor in the area and in similar works.

Equipment and Staff – 10 Points maximum
Again individual team member evaluation is used. Factors such as numbers and age of equipment, suitability of equipment for the works involved, experience of staff (including operators and supervisors) and support the contractor has in country (including provision of fuel supplies, site accommodation, mechanical backup and so on) should be considered. Where labour intensive works are being promoted this category could be given more points (20 perhaps and the experience category reduced to 10) and those contractors offering to follow such procedures given the highest number of points.

Work Programme – 10 Points maximum
Highest points are given to contractors who can complete the works within the already decided project time frame or before the next rainy season begins.

Location of Contractor – 10 Points maximum
Based on mobilization distance rather than physical location of the contractor, this is also determined at the judgment of each team member. As a guide, highest (i.e. 10) points should be given to contractors located within the local area, then say 8 points for provincial locations, 4 points for nationally based contractors and 2 or less for contractors mobilizing from outside the country.

Financial bid: 50 points
Cost - 50 Points maximum
The lowest priced bid receives 50 points and other bids receive points based on 50 minus 1 point for every 2 percent difference from the lowest bid price. Any bids more than 100 percent higher than the lowest bid receive no points.

The evaluation
An evaluation team of at least three people should be established. At least one person should have an engineering background (The Engineer is best selected for this) and be able to advise other team members on technical issues if they arise. Inclusion of a local (dam committee) person may also prove useful. A team of more than six may, however, be too cumbersome and thus inappropriate.

Team members should avoid fraternization and other close contact with bidders at this time.

The following steps are to be followed:

Step 1: RECEPTION OF THE BIDS

Following advertisement of the tender, ensure that every tenderer who pays the required, non-refundable, fee[19] receives the documents, design drawings, quantities (but no guideline costs), any Community Agreement, the date of the site visit and details on where the tender documents are to be delivered, the deadline for delivery and the location and time of tender opening.

If the deadline is changed, all potential tenderers must be advised either personally (if few in number) or by advertisement in the media.

Bids received should be noted in a diary and the bidder and staff member sign to confirm date and time received. Any bids delivered in unsealed envelopes should be rejected and the bidder advised in writing that his/her fee is forfeited and that s/he cannot re-bid. All other bids are to be kept in a secure and inaccessible location until the time of tender opening.

The site visit should be formally recorded in the same diary and any bidder unable to make the visit should be excluded from the process and his/her bid returned unopened.

Step 2: OPENING OF THE BIDS

The responsible officer opening the bids should first advise all those present of the procedure he/she will follow. Brief details on the evaluation process (already provided in the documents and based on the guidelines above should be given to assure potential bidders that the evaluation is to be fair and equitable.

At tender opening, one staff member should be given the responsibility for opening the bids received. A secretary will be required to note persons attending and any comments (especially objections) made. The minutes – brief and noting points only – should be filed for future reference.

19 Accept cash or bank certified cheques only.

Step 3: REVIEW OF THE DOCUMENTATION

As each bid is opened, the responsible staff member may name the bidder but then must check that the bid is complete and conforms to the advertised conditions. If for any reason it is not complete (for example the site visit certificate is missing), the bid should be rejected and the bid price not disclosed. The whole document has to be returned to the bidder with a covering letter stating why it had been rejected. There is no appeal on this matter.

Minor omissions or errors can be accepted. Small arithmetic errors should be corrected and the revised figure used in the evaluation. If significantly large errors that may affect the bid price are noted, and at the discretion of the evaluation team, the bid should be rejected.

Unrealistic bids with either costs shown at levels impossible to achieve or for bidders who show that they are completely inexperienced or have completely inappropriate equipment, can also be rejected at this stage.

If the bidders have not been prequalified some investigation at this stage (this process should be noted in the bidding documents and/or tender advertisement) into the integrity of the bidder should be carried out. Any bidder with recent[20] criminal convictions relating to fraud, bribery or corruption or with serious, proved cases of contract malpractice or failure, should be excluded at this time. The bid should not be evaluated. As above, the bid should be returned to the bidder with a covering letter and all other bidders informed of the decision.

Step 4: TECHNICAL EVALUATION

Once the bids are declared valid, the actual points evaluation procedure can begin.

Tenders should initially be assessed, in accordance with the evaluation methodology being utilized, against non-price criteria, that is, on their technical merits. The evaluation team should not have access to the tender price at this stage. The assessment of the non-price criteria is to be documented before moving onto the next stage of the evaluation.

Step 5: FINANCIAL ASSESSMENT

Once tenders have been assessed against the technical criteria, a financial evaluation of the prices tendered (or quoted) can then be undertaken. The results of the financial assessment are to be documented before moving onto the next stage of the evaluation.

Step 6: ASSESSMENT OF 'BEST COMBINED OFFER'

Having separately assessed tenders against technical and financial criteria, a comparison of 'technical worth' and 'price', is undertaken in accordance with the criteria established in the tender document, to determine which tender represents the best combined offer. This stage will establish the final ranking of the tenders.

20 In the last five years or any other agreed period.

AWARDING THE CONTRACT

Once the final ranking has been established, the contractor with the highest total should be awarded the contract.

If, for exceptional reasons, a decision is made that does not award the contract to the highest evaluated bidder, other bidders must be formally advised of the reasons why and given a period (10-14 days) in which to object but not change their bids. All objections then have to be looked at and a final decision made. Because this can lead to delays and legal issues it is best not to make decisions that award contracts to bidders other than the highest evaluated.
Lastly, once a decision has been made to award the contract, the potential contractor can be contacted and the contract awarded. It is recommended that the winning bidder should not be negotiated with to either reduce the price (i.e. if above the budget for the dam or project or if all bids are considered unacceptably high in part or whole) or to improve on the bid to include items considered deficient. It is not unethical to do so as long as it is done for the interest of the cost effectiveness and in a open and transparent way.

If the award of contract fails, or is stopped for any reason, the second highest bidder can be brought in. Do not however negotiate with two bidders at any one time in an attempt to play off one against the other. This is extremely unethical and unprofessional.

Once the contract has been awarded, the other, unsuccessful bidders should be formally advised of the award but not of the final price. The actual evaluation is confidential and information therein is only released if a losing bidder should complain and arbitration has to take place. The award decision should be published with a list of all the bidders, major elements of the evaluation process detailed and specific reasons why the award has been made to the winning contractor.

A sample evaluation sheet is provided below (refer to **Table A1**).

Table A1 – Sample evaluation points table

Project .....
Name of dam/spillway .....
Date .....

	Bid price	Price (50 max)	Experience (20 max)	Staff/equipment (10 max)	Work programme (10 max)	Location (10 max)	Total points (100 max)
Names of bidders	Lowest	50	Calculate	Calculate	Calculate	Calculate	Add from calculations in columns to the left
	Next lowest and so on	Calculate	“”	“”	“”	“”	
		“”	“”	“”	“”	“”	
		“”	“”	“”	“”	“”	

CONTRACT SUPERVISION

Continuous monitoring and auditing is required to supervise any contract. This can be carried out by the dam owner, government agencies or consultants appointed to supervise a contract being funded by an international financing agency. For all but the former, the supervisor must in turn be monitored and audited to ensure compliance with the contract and to encourage cost effectiveness and to avoid corruption. The World Bank establishes a panel of experts for every large dam contract and

these personnel are fully independent and are able to carry out regular (and irregular) monitoring and auditing activities throughout the duration of the contract.

Particular attention should be paid to contract variations. Any variation should be scrutinized both individually and in aggregate, and once a financial ceiling is reached (based on the contract price and usually in the range of 10-15 percent) the independent outside experts should be called in. Any proven case of variation in response to bribery and corruption should cause the immediate cancellation of the contract (without any penalty payment to the contractor) and dismissal and prosecution of any supervision personnel involved.

For all contracts, an effective dispute resolution organization/entity is required. As with the panel of experts, this should be independent and suitably qualified to resolve disputes impartially and in the interest of fairness and integrity. This may be a government agency or could be based in the private sector. Details of such an agency should be clearly stated in all tender and contract documents.

PAYMENTS

The sequence of payments to the contractor will have been outlined in the tender and contract documents. Usually these will have been negotiated at contract signing and any variations allowed outlined in the tender documents.

Advance payment:
Most dam contracts will require an advance payment being made to the contractor for **mobilization** (establishing a site complete with offices, power, communications and water supplies, clearing the dam site, establishing stockpiles of materials, moving equipment and staff to site and related initial activities). This would be recorded as an advance payment and can comprise between 10 and 25 percent of the total contract amount. It can either be made as a lump sum payment or can be proportionally recovered as routine payments are made to the contractor as the works proceed.

Routine progress payments:
Routine payments can be agreed at contract signing and can take the form of a monthly payment based on estimated amounts of work completed or can be based on proportion of the dam being completed. Either way, the payment requests have to be submitted by the contractor and then checked and approved by the Engineer supervising the works.

All approved payments should be scrutinized and cleared; then paid quickly. Many contractors do not have the financial resources to cater for lengthy delays in routine payments and, where private sector contractors are working for public sector clients such as government ministries, effective and transparent ways and means of ensuring quick payments to the contractors should be established before the project starts.

Variation payments:
In all but the simplest contracts, a sum for unexpected works or for variations to the design should be catered for. Usually listed in the Bill of Quantities as **Contingencies**, this can be calculated at around 5 to 15 percent of the total contract sum.

Again all such payments should be initially approved by the engineer, scrutinized once the works have been done and then paid quickly to the contractor. Note the comment above on this.

Final payments:
At the end of construction, the works should be inspected and signed off by the engineer. The contractor can then demobilize and leave the site. Usually, the final payment is withheld for a period agreed in the contract – one year is satisfactory and will give the dam a chance to fill and be used before the contractor's liability is removed. During this period, the dam should be closely monitored and checked. Defects should be noted and rectified at his/her expense.

If the contractor is unable or unwilling to do this work, the retained sum can be used to pay another contractor to do the work required.

Once the liability period is over, the engineer certifies the dam as good, and the contractor can be paid the balance owed.

FINAL INSPECTION AND MEASUREMENT

This is an important activity and can be carried out by the engineer to ensure the completed dam has been built to the design and to the highest standard possible. This activity can be carried out jointly by the engineer and the contractor to ensure there are no disputed findings but the engineer is the overall responsible officer.

The final inspection is best completed before the contractor demobilizes to ensure that any outstanding work noted can be completed without delay. As built drawings should be produced and kept on record.

The maintenance and safety programme can then be instigated.

Annex 2
Cost Benefit Analysis

The example below is from a project for an 11 m high dam and associated private irrigation scheme costed for Zambia in 2008.

Table A2: Cost Summary Table

Bill	Activity	Unit Rate	Quantity	Cost US$	Amount US$
1	Site investigation work	Sum	–	–	12 000.00
2	Engineer's Fees: design and supervision	Sum	–	–	17 000.00
3	Mobilization	Sum	–	–	7 500.00
4	Clearing site:				
	Embankment area	ha	5	2 000	10 000.00
	Reservoir	ha	40	500	20 000.00
5	Cut-off/Core:				
	Excavation	m^3	750	5.5	4 125.00
	Backfilling	m^3	750	7.0	5 250.00
6	Embankment	m^3	22 000	3.5	77 000.00
7	Training banks	m^3	1 400	6.0	8 400.00
8	Spillway	m^3	770	6.0	4 620.00
9	Finishing works	hours	240	10	2 400.00
10	Other dam work including settlement works after construction	Sum	–	–	5 000.00
Subtotal Dam				**A**	**173 295.00**
11	Irrigation scheme (one centre-pivot)	ha	35		42 000.00
12	Miscellaneous (access road/power line)	Sum	–		30 000.00
Subtotal Irrigation Scheme				**B**	**72 000.00**
Subtotal Overall Project				A+B	245 295.00
Contingencies				10%	24 560.00
Grand total				**US$**	**269 845.00**

First prepare the cost table as shown in **Table A2, Section 6.6**.

INITIAL ANALYSIS[21]:

The total estimated cost of the bulk water infrastructure (dam, irrigation scheme, associated infrastructure such as provision of access roads and power lines and the supervision by a qualified engineer is US$ 270 000 for a end result of 35 ha irrigated. Thus, the per ha cost for the scheme in capital funding is US$7 715 about the median range for irrigation development in Zambia in 2008.

21 The FAO *Rural Invest* toolkit provides an accurate and transparent methodology for formulating, costing and evaluating small-to medium-scale investments using custom developed software. Both income generating and non-income generating can be considered. Further information can be found at www.fao.org/tc/tci/ruralinvest_en.asp

Table A3: Proposed time schedule for the works

Bill	Activity	April	May	June	July	Aug	Sep	Oct	Nov
1	Site investigation								
2	Engineer: design supervision								
3	Mobilization								
4	Clearing site								
5	Cutoff/Core								
6	Embankment								
7	Training banks								
8	Spillway								
9	Finishing								
10	Other								
11	Irrigation scheme								
12	Roads/Power lines								

Notes:
Schedule based on a dry season period April-November.
Site investigation could occur the year before.
The spillway must be in place and operational before the rainy season begins.
The irrigation scheme works could begin the following year while the dam is filling.
The irrigation scheme comprises two electric powered pumps, pipeline, fittings and a centre-pivot irrigator for a total of 35 ha.
Reservoir area clearing is usually trees and large shrubs only. Topsoil can be stripped in areas that will be used as borrow pits.

The per hectare cost is a useful way of comparing dam sites where irrigation is involved and can be done for just the cost of the dam alone or for the combined costs of the dam and its attendant irrigation scheme.

Second comparisons can be made on the cost of the dam for the amount of water stored – in this case the capacity of the dam (which determined the area that could be irrigated – for wheat in the dry season) was estimated at 280 000 m^3. Thus, the cost for the water stored was US$1.47/$m^3$ taking into account the cost of the dam above plus a 10 percent contingency. Where more than one dam site exists this is a useful means of comparison for economic reasons.

FURTHER ANALYSIS:

For assessing economic viability the costs and benefits can be estimated (and again comparisons made between sites and schemes to evaluate the highest potential sites to be developed). In this example, wheat was the dry season crop to be grown on the 235 ha irrigation scheme. Zambia wheat prices in 2008 were US$450/t and wheat yields from irrigation schemes in Zambia consistently average 6 t/ha. Thus, for 35 ha, yields would total 210 t and bring in a return of US$94 500 per season based on 2008 prices. The rainy season crops were planned as a mix of maize and soya beans which would yield 8 t/ha for maize and 2 tons/ha for soya bean. Farm gate selling prices in 2008 were US$220/t for maize and US$300/t for soya beans.

Table A4: Return to Farming Activities (One Farming Year – April to April)

Crop	Yield (35 ha)	Area farmed	Farm gate price US$	Production	Total received US$
Wheat	6 t/ha	35 ha	450/t	210 t	94 500.00
Maize	8 t/ha	15 ha	220/t	120 t	26 400.00
Soya	2 t/ha	20 ha	300/t	40 t	12 000.00
Total					132 900.00

Thus, a rough estimate can be made of the return the irrigator will receive for one farming year for the 35 ha

Average input costs per farming year were US$750/ha for fertilizer, other inputs including land preparation and harvesting and US$300/ha for irrigation pumping costs (both dry season and supplemental). Thus, the overall input costs were US$1 150/ha for 35 ha, totalling US$40 250 for the farming year. It would seem therefore, without a comprehensive cost benefit analysis, that the construction of the dam and irrigation scheme are economic with annual 'profits' on the 35 ha exceeding US$90 000, enough to contribute to operation and maintenance costs and to pay off the capital cost of the dam and scheme in 3-4 years.

Annex 3
Fish Production in Farm Dams

DAMS AND FISH PRODUCTION

The majority of small earth dams are constructed for water conservation, irrigation and animal watering, domestic water supplies and other purposes. Dams are rarely constructed for fish farming but can be used for this purpose in conjunction with other uses.

If fish farming is considered at the design stage of the dam, benefits in production and yield can be achieved at little extra expense in the overall cost of the dam. Dams with a likelihood of significant through flow, or those with steep sides and depths greater than 3-5 m, cannot be considered as suitable for significant fish production.

CONSTRUCTION CONSIDERATIONS

The site for the reservoir should be stripped as much as possible of vegetation to avoid a build up of carbon dioxide and methane in the water after first filling – this is also desirable to reduce the production of greenhouse gases[22] and minimize the effects of the decomposition of organic matter on oxygen levels in the water – when rotting vegetation in the water would provide a hostile environment for any fish. This removal of existing vegetation is advisable – especially in cooler areas where the breakdown of the plant material can take a long time – when regular flows are released from the dam (for example for hydroelectric power generation) as polluted water would then be introduced into the downstream watercourse.

In areas of highly acidic soils (as is common in central and southern Africa) liming the reservoir area with up to 2 t/ha (or the recommended rate for normal crop production) broadcast and then worked into the topsoil before first filling can be useful to reduce acidity and encourage more alkaline water (pH 7.0 to 8.5 is the ideal range) to be stored. Fish production is enhanced in alkaline waters but this would have to be considered carefully where the reservoir water was primarily for irrigation or domestic use where a neutral pH of 7.0 or lower is recommended.

Rocky areas within the confines of the reservoir can be left to provide shelter for fish and insects and for breeding purposes. If desirable one or two such areas can be built up to create islands in the full reservoir and these will encourage bird life as well as provide extra shallow areas for fish breeding and feeding. For larger dams, where netting may occur, rocky areas on the reservoir floor may have to be removed to prevent snagging and damage to nets.

In all cases the dams should not be stocked with fish until at least 3-4 months after first fillin. This will allow the water to ‘mature’ and develop a stable ecosystem that can support fish and other wildlife.

22 It was estimated in 2000 that dam reservoirs contributed up to 7 percent of the world’s greenhouse gases.

RESERVOIR SIZE AND DEPTH CONSIDERATIONS

➔ Large dams with 10 ha or more of reservoir surface area:
Where such dams have significant through flows, or are mostly of depths greater than 5 m, the potential for fish production will be limited. Other factors, including turbidity, water temperature, variations in pH and low oxygen content waters may also affect production.

Generally areas of depth 3-5 m are ideal for fish production.

➔ Medium dams with 3-10 ha reservoir surface area:
The constraints to through flow and depth above apply, but generally these dams are well-suited to fish production. Should significant areas of the reservoir provide for shallow water, it may be economic to consider liming the reservoir soil before filling and fertilizing the water, 14-21 days after liming has been completed,[23] to encourage plankton and algae growth and for supplementary feeding of the fish. Fertilizer can take the form of inorganic material (dissolved in water and applied at time of higher water temperatures) or manure. For the latter it is often advantageous to establish piggeries or similar near the dam and apply manure at a rate of up to 100 kg/ha a day – either initially worked into the soil on the dry reservoir bed or placed in small quantities at regular intervals in the shallow water.

Fertilizing/manuring of the water should be done at regular intervals in quantities that do not pollute the water. Fresh manure will be eaten by fish and any remaining portion will induce the growth of minute plant and animal organisms.

Fertilizing should not be done at times of high through flows or at times of low water levels. Care to maintain good vegetation control is also linked. Excessive growth of weeds will lead to lower fish populations, smaller fish, use nutrients that otherwise may produce plankton, interfere with swimming and boating and also encourage water-borne diseases such as malaria and bilharzias. It is important to balance vegetation growth in a dam reservoir so shelter is provided for smaller fish, insects and other small animals, the water is oxygenated and decaying plant life provides an important source of fertilizer without having excessive vegetation and the subsequent adverse affects on the water. Occasionally, manual clearing of weeds may be required to ensure plant growth is not too excessive.

➔ Small dams less than 3 ha reservoir surface area:
These structures include seasonal dams and larger fish ponds and are the most effective sources of fish production, especially if they have extensive areas of water between 3 and 5 m deep.

The treatments suggested above including fertilizer or manure and liming combined with good management and supplementary feeding can achieve high yields of fish production. These dams are more suited to fish farming rather than fish stocking and should be managed accordingly.

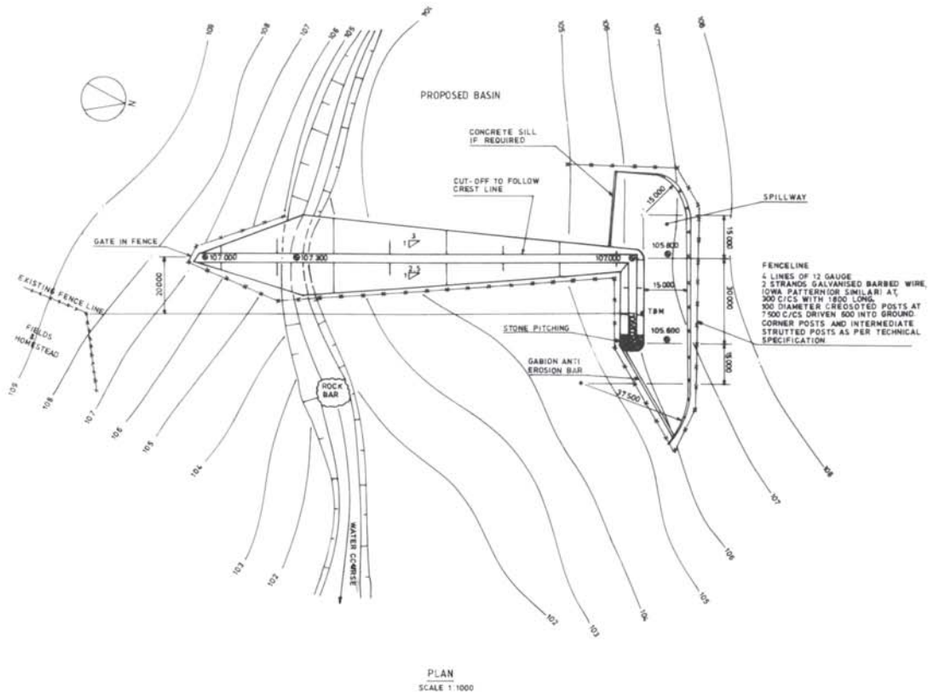
23 This is not acceptable for dams that provide domestic water supplies.

For developing fish farming in all dams, a good start is to refer to the Simple methods for aquaculture (FAO, 2006), which includes manuals for management and farming techniques for freshwater fish culture.

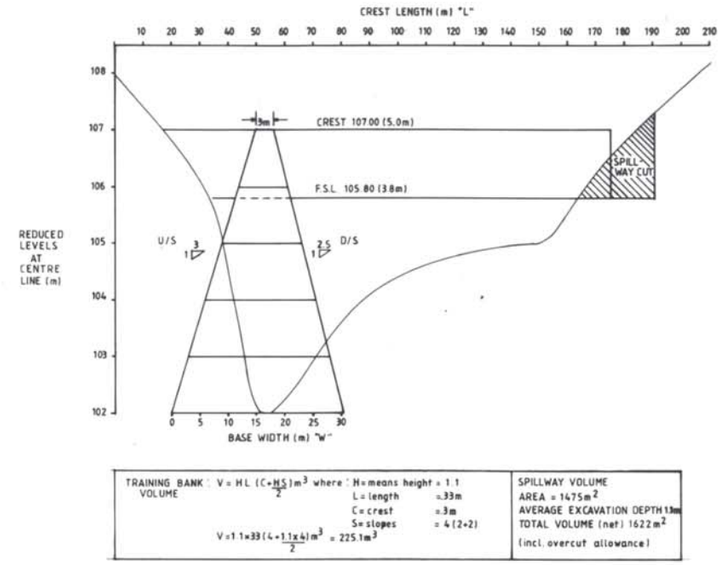
Annex 4

Examples of standard drawings

DRAWING 1: DAM DRAWING (I)



PLAN
SCALE 1:1000

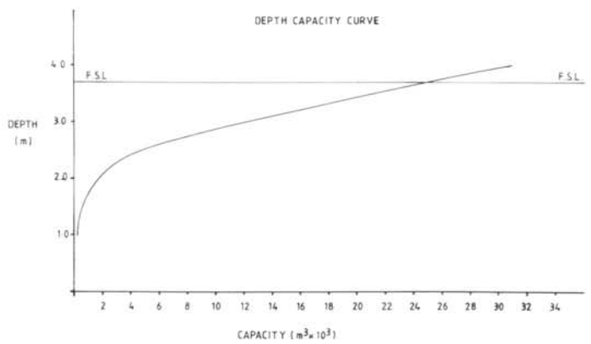


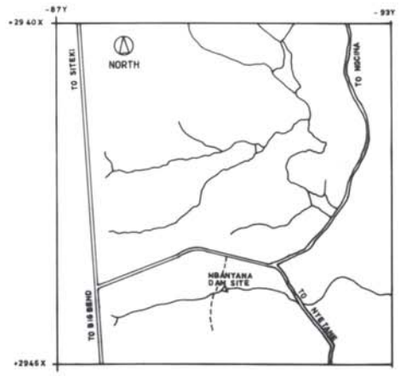
TRAINING BANK VOLUME	SPILLWAY VOLUME
$V = H.L\ (C + \frac{H.S}{2})m^3$ where: H = means height = 1.1; L = length = 33m; C = crest = 3m; S = slopes = 4 (2+2)	AREA = 1475 m^2
$V = 1.1 \times 33 (4 + \frac{1.1 \times 4}{2})m^3 = 225.1 m^3$	AVERAGE EXCAVATION DEPTH 1.1m
	TOTAL VOLUME (net) 1622 m^2
	(incl. overcut allowance)

TYPICAL VALLEY CROSS-SECTION AND EARTHWORKS VOL. DETAILS

AREA OF CROSS SECTION W×H = m^2	LENGTH OF LONGITUD SECTION L = m	VOLUME W×H×L = m^3
6.0	150	900.0
11.4	123	1402.2
16.9	63	1064.7
22.4	34	761.6
27.7	16	443.2

EMBANKMENT VOL.	4571.7 m^3
TRAINING BANK VOL.	225.1 m^3
TOTAL VOL (net)	4796.8 m^3
SETTLEMENT ALLOW 5%	239.8 m^3
FINAL VOL (gross)	5036.6 m^3
(spillway excluded)	





KILOMETRES
0 1 2 3
PWD 20 (PART OF SHEET)

LOCATION PLAN

NOTES
1. SPILLWAY 15m WIDE AND 1.20m DEEP.
2. EMBANKMENT CREST HEIGHT 5.0m NET (REF. SETTLEMENT ALLOWANCE)
3. EMBANKMENT SLOPES :- 3.0 : 1 UPSTREAM 2.5 : 1 DOWNSTREAM.
4. TRAINING BANK SLOPES :- 2.0 : 1 BOTH SIDES
5. SETTLEMENT ALLOWANCE 5%
6. ALL DIMENSIONS IN MILLIMETRES.
7. REDUCED LEVELS FROM ARBITARY DATUM.

DRAWING 1

DESIGNED			
DRAWN			
DESIGN CHECK			
DRAWING CHECK			
APPROVED			

DRG. No.	REFERENCE DRAWINGS

No.	DATE	REVISION	MADE	CHKD.

No.	DATE	REVISION	MADE	CHKD.

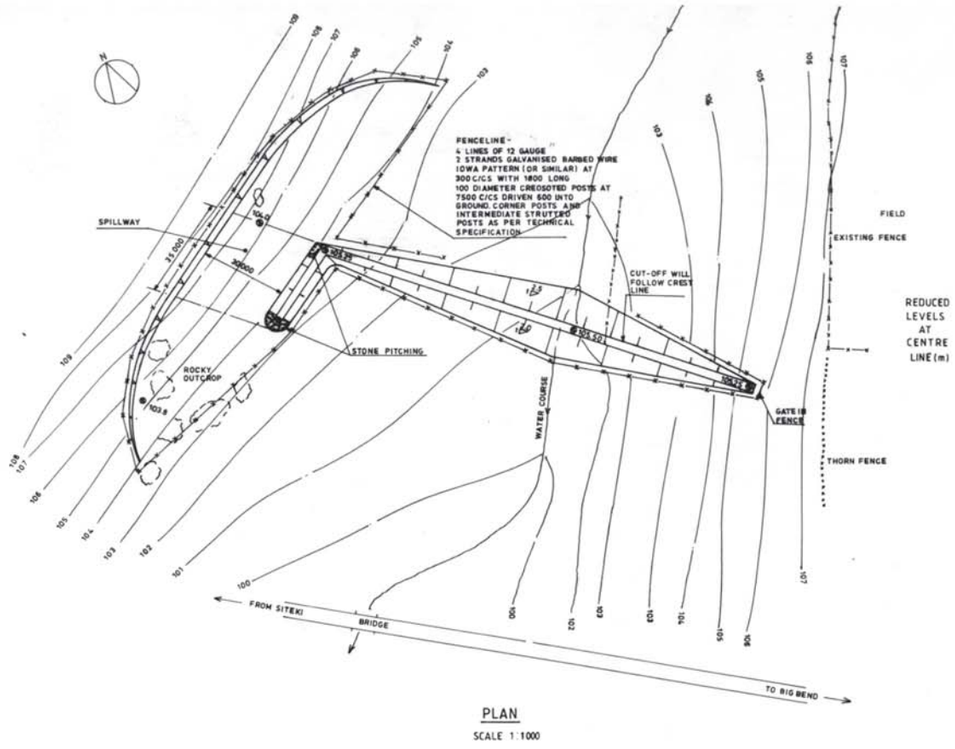
SCALE
UNLESS OTHERWISE SHOWN

DAM DRAWING (I)

MANUAL ON SMALL EARTH DAMS
A GUIDE TO SITING, DESIGN AND CONSTRUCTION

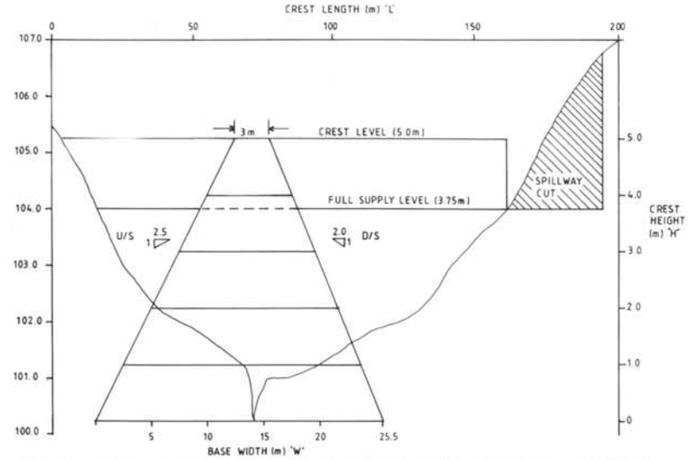
DESIGNED BY			
DRAWN BY			
CHECKED BY			

DRAWING 2: DAM DRAWING (II)



PLAN

SCALE 1:1000

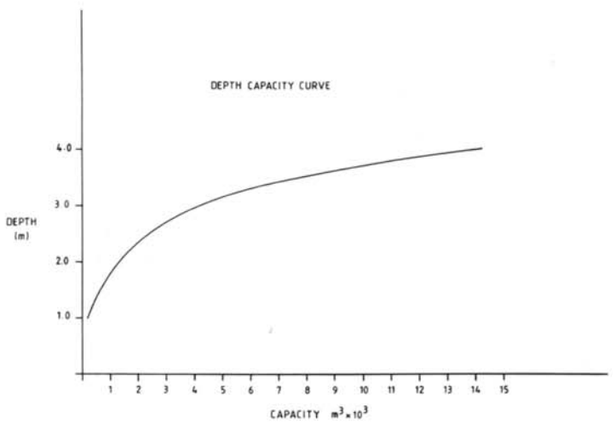


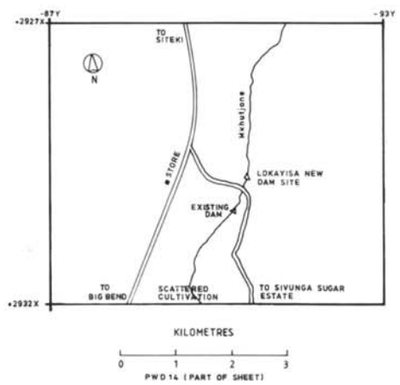
TRAINING BANK VOLUME	SPILLWAY VOLUME
$V = \frac{HL(C+HS)}{2} m^3$ where: H = mean height (m) = 1.25; L = length = 33; C = crest width (w) = 3; S = slopes = 4 (2+2)	AREA = 7700 m^2
$V = \frac{1.25 \times 33 (3 + \frac{1.25 \times 4}{2})}{2} = 226.875 m^3$	AVERAGE EXCAVATION DEPTH = 1.4m
	VOLUME TO BE EXCAVATED = 10 780.00 m^2
	(no overcut allowance - rock assumed)

TYPICAL VALLEY CROSS-SECTION AND EARTHWORKS VOLUME DETAILS

AREA OF CROSS SECTION W x H = m^2	LENGTH OF LONG SECTION L = m	VOLUME W x H x L = m^3
5.2	152	790.4
9.9	138	1366.2
14.4	110	1584.0
18.0	56	1058.4
23.5	4	94.0

EMBANKMENT VOLUME : 4 893.0 m^3
TRAINING BANK VOLUME : 226.9 m^3
TOTAL VOLUME (net) : 5 119.9 m^3
SETTLEMENT ALLOW 5% : 256.0 m^3
FINAL VOLUME (gross) : 5 375.9 m^3
(spillway excluded)





LOCATION MAP

NOTES

1 SPILLWAY 30m WIDE AND 1.25m DEEP
2 EMBANKMENT CREST HEIGHT 5.0m NET (REF SETTLEMENT ALLOWANCE)
3 EMBANKMENT SLOPES :- 2.5 : 1 UPSTREAM, 2.0 : 1 DOWNSTREAM
4 TRAINING BANK SIDE SLOPES :- 2.0 : 1 BOTH SIDES
5 SETTLEMENT ALLOWANCE 5%
6 ALL DIMENSIONS IN MILLIMETRES.
7 REDUCED LEVELS FROM ARBITARY DATUM

DRAWING 2

				DRG. No.	REFERENCE DRAWINGS	No.	DATE	REVISION	MADE	CHKD.	No.	DATE	REVISION	MADE	CHKD.
DESIGNED															
DRAWN															
DESIGN CHECK															
DRAWING CHECK															
APPROVED															

SCALE
UNLESS OTHERWISE SHOWN

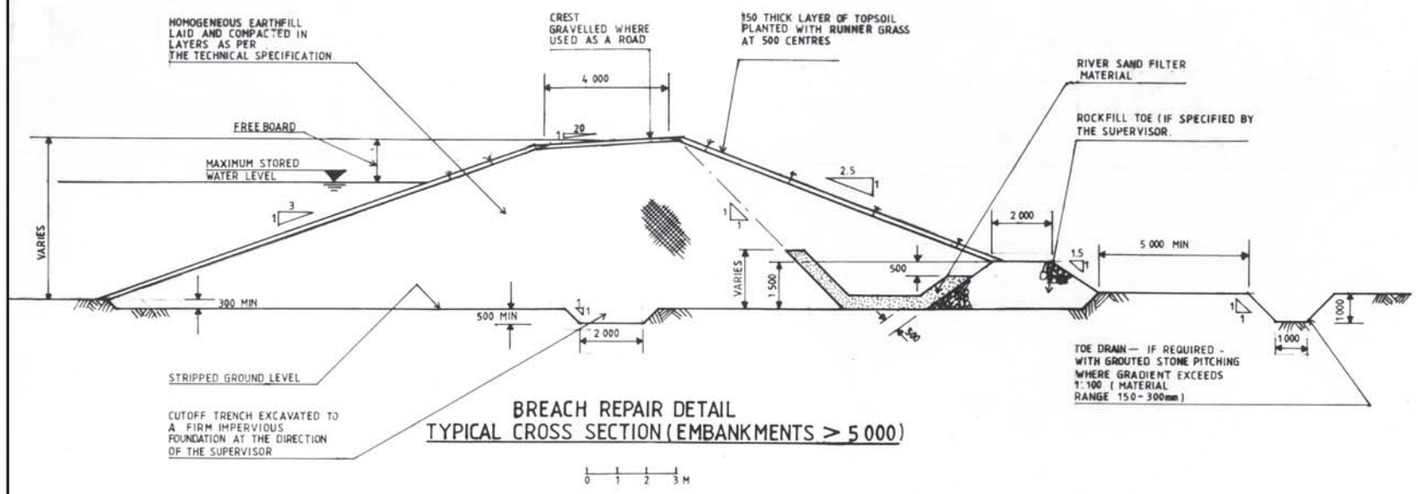
DAM DRAWING (II)

MANUAL ON SMALL EARTH DAMS
A GUIDE TO SITING, DESIGN AND CONSTRUCTION

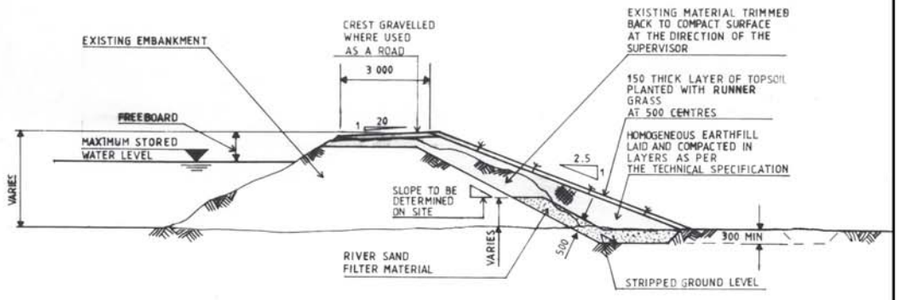
DESIGNED BY			
DRAWN BY			
CHECKED BY			

DRAWING 3: EMBANKMENT REPAIR

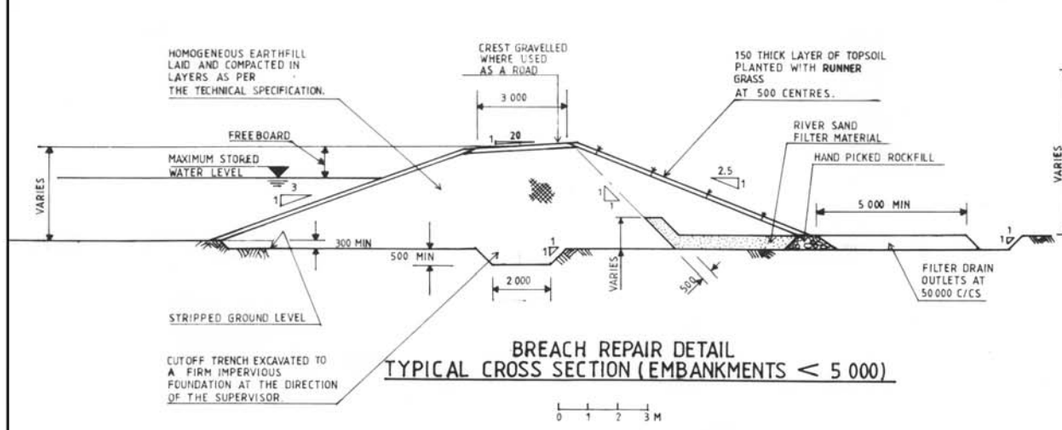
CONSTRUCTION DRAWING



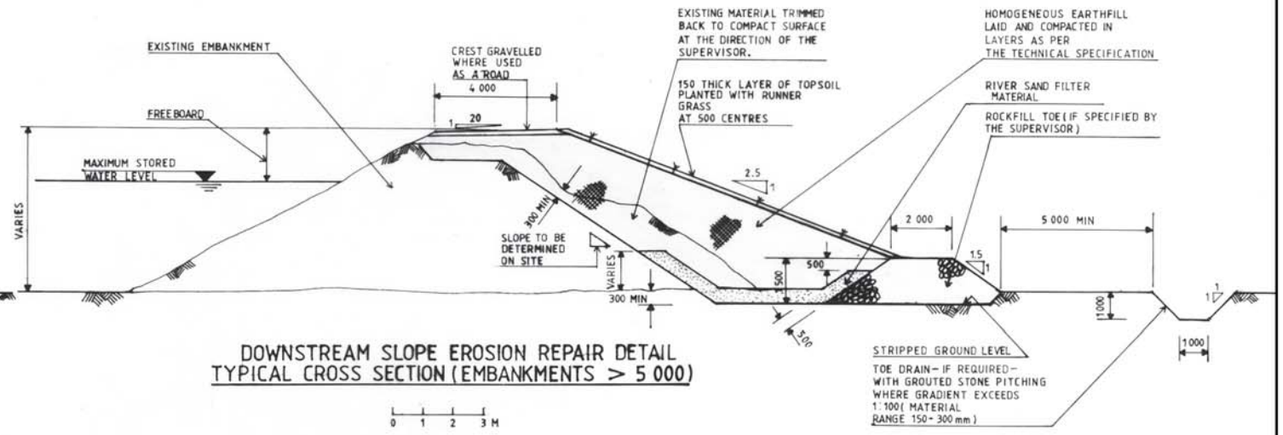
BREACH REPAIR DETAIL
TYPICAL CROSS SECTION (EMBANKMENTS > 5 000)



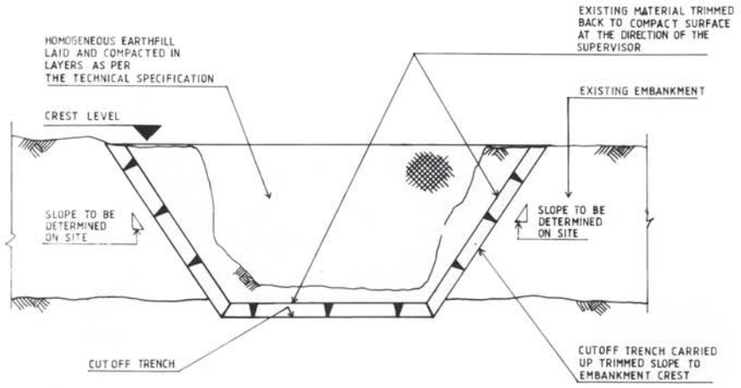
DOWNSTREAM SLOPE EROSION REPAIR DETAIL
TYPICAL CROSS SECTION (EMBANKMENTS < 5 000)



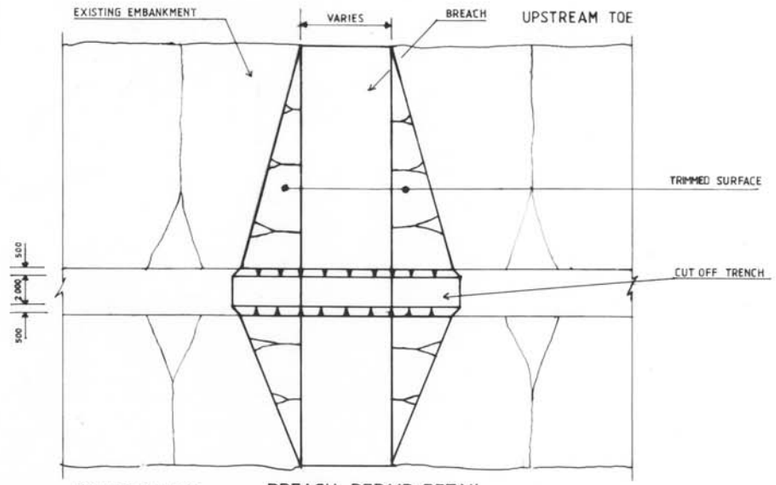
BREACH REPAIR DETAIL
TYPICAL CROSS SECTION (EMBANKMENTS < 5 000)



DOWNSTREAM SLOPE EROSION REPAIR DETAIL
TYPICAL CROSS SECTION (EMBANKMENTS > 5 000)



BREACH REPAIR DETAIL
TYPICAL SECTION THROUGH BREACH



BREACH REPAIR DETAIL
PLAN OF BREACH

NOTES

(1) DIMENSIONS IN MILLIMETRES
(2) DO NOT SCALE - USE FIGURED DIMENSIONS ONLY
(3) FILTER MATERIAL GRADINGS TO BE SPECIFIED AFTER OPENING OF EARTHFILL BORROW AREAS.
(4) ROCKFILL TOE MATERIAL GRADINGS TO BE SPECIFIED AFTER OPENING OF EARTHFILL BORROW AREAS.

DRAWING 3

DESIGNED		
DRAWN		
DESIGN CHECK		
DRAWING CHECK		
APPROVED		

DRG. No.	REFERENCE DRAWINGS

No.	DATE	REVISION	MADE	CHKD.

No.	DATE	REVISION	MADE	CHKD.

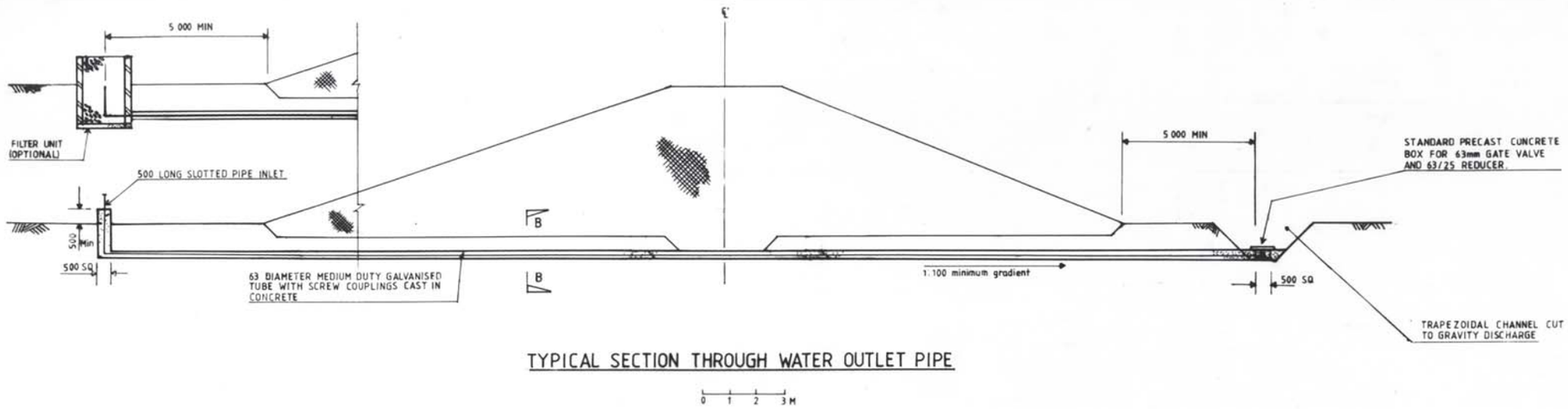
SCALE
UNLESS OTHERWISE SHOWN

EMBANKMENT REPAIR

MANUAL ON SMALL EARTH DAMS
A GUIDE TO SITING, DESIGN AND CONSTRUCTION

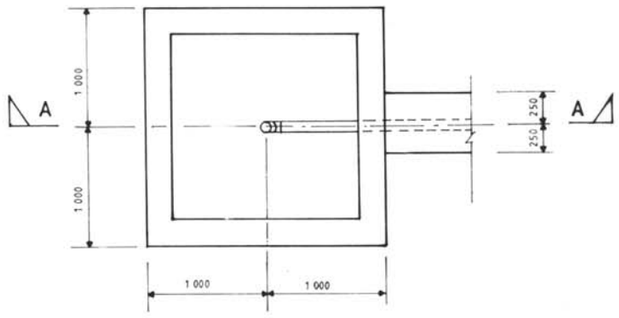
DESIGNED BY		
DRAWN BY		
CHECKED BY		

DRAWING 4: OUTLET PIPE AND ANCILLARY STRUCTURES



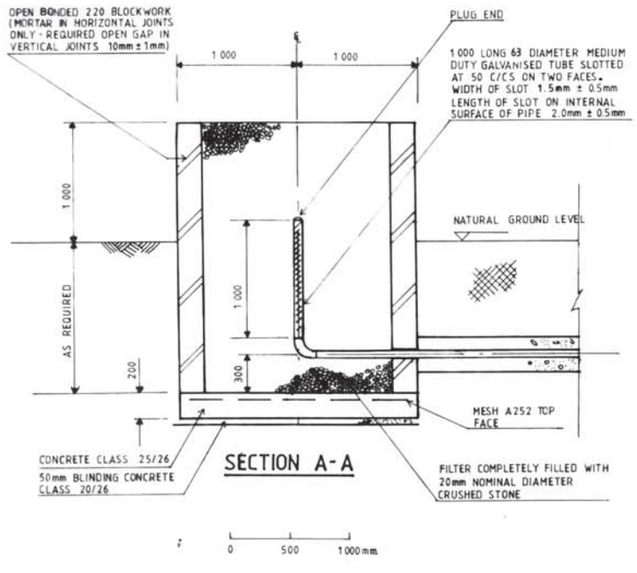
TYPICAL SECTION THROUGH WATER OUTLET PIPE

0 1 2 3M



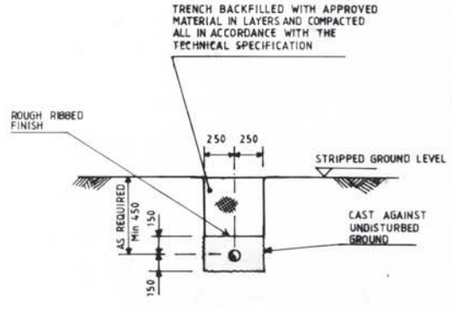
PLAN ON FILTER UNIT

0 500 1 000mm



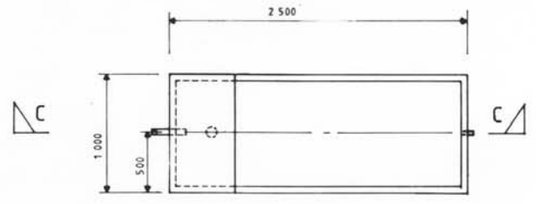
SECTION A-A

0 500 1 000mm



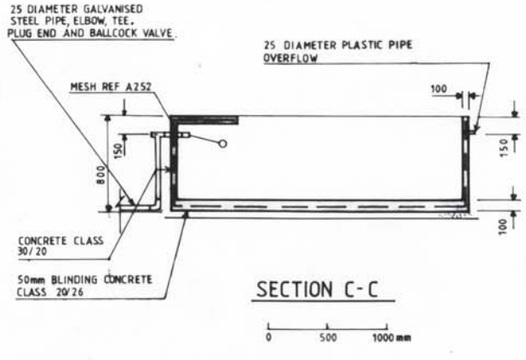
SECTION B-B

0 500 1 000mm



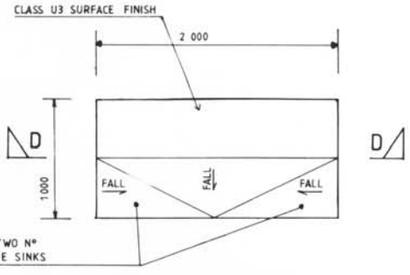
PLAN ON CATTLE TROUGH

0 500 1 000mm



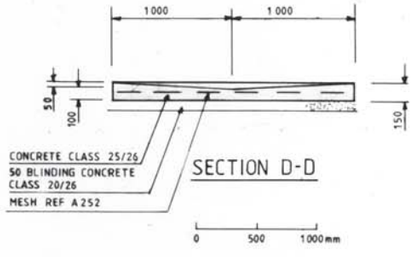
SECTION C-C

0 500 1000 mm



PLAN ON WASH SLAB

0 500 1 000mm



SECTION D-D

0 500 1 000mm

CONSTRUCTION DRAWING

NOTES

(1) ALL REINFORCEMENT ON THIS DRAWING IS DETAILED IN ACCORDANCE WITH BSCP 110 (1972 AS FOLLOWS:

(2) BAR CALLING UP SYSTEM

NO. IN GROUP | DIAMETER MM | SPACING M

37 - T 16 07 - 250 - T

MATERIAL TYPE | MARK NUMBER | POSITION

(3) COVER TO REINFORCEMENT TO BE 50 MM. UNLESS STATED OTHERWISE.

(4) BENDING TO BE IN ACCORDANCE WITH BS 4466.

(5) MATERIAL TYPE

REINFORCING STEEL SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF BS 4449 AND BS 44 THE MATERIAL TYPE IS SHOWN ON THE DRAWING AS FOLLOWS:-

R = MILD STEEL BARS GRADE 250

T = TYPE 2 DEFORMED BARS GRADE 460/425

X = TYPE 1 SQUARE TWISTED COLD WORKED BARS GRADE 460/425

(6) IN THE EVENT OF NON-AVAILABILITY OF BAR SIZE SHOWN, THE STEEL AREA, LAP AND ANCHORAGE LENGTHS AT ANY CROSS SECTION MAY BE AMENDED SUBJECT TO THE APPROVAL OF THE ENGINEER.

(7) GENERAL ABBREVIATIONS

N.F NEAR FACE, F.F. FAR FACE, E.F. EACH FACE
B. BOTTOM, T. TOP
A.B.R. ALTERNATE BARS REVERSED
ALT. ALTERNATE, E.W. EACH WAY
STGD. STAGGERED

(8) DIMENSIONS IN MILLIMETRES

(9) DO NOT SCALE - USE FIGURED DIMENSIONS ONLY

DESIGNED			DRG. No.	REFERENCE DRAWINGS	No.	DATE	REVISION	MADE	CHKD.	No.	DATE	REVISION	MADE	CHKD.	SCALE UNLESS OTHERWISE SHOWN
DRAWN															
DESIGN CHECK															
DRAWING CHECK															
APPROVED															

DRAWING 4

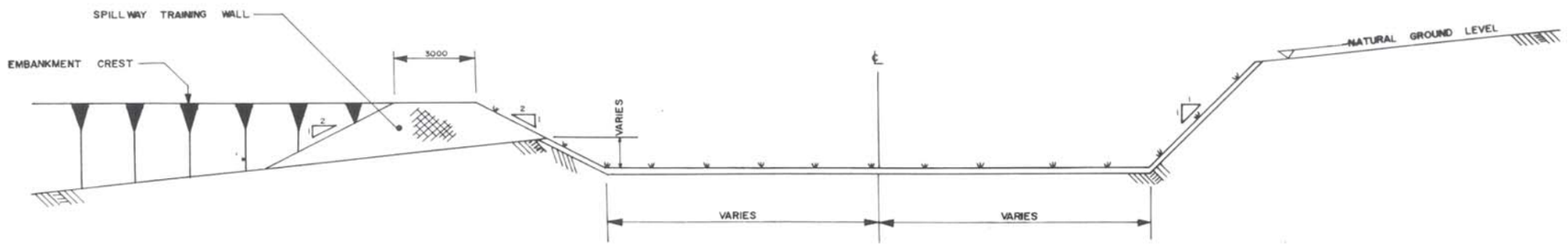
OUTLET PIPE AND ANCILLARY STRUCTURES

MANUAL ON SMALL EARTH DAMS
A GUIDE TO SITING, DESIGN AND CONSTRUCTION

DESIGNED BY			
DRAWN BY			
CHECKED BY			

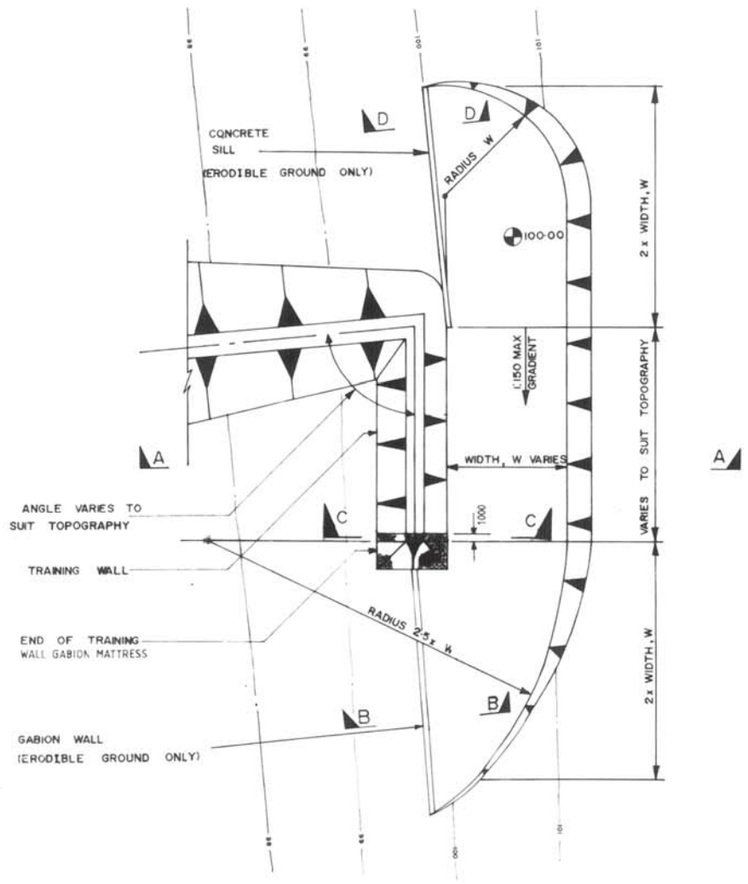
DRAWING 5: SPILLWAY DETAILS (I)

CONSTRUCTION DRAWING



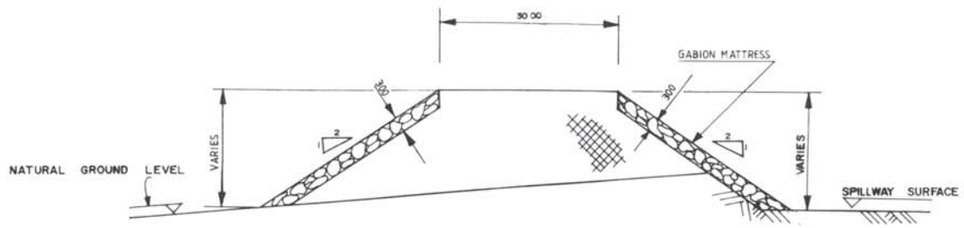
SECTION A-A

0 1 2 3 4 5 METRES



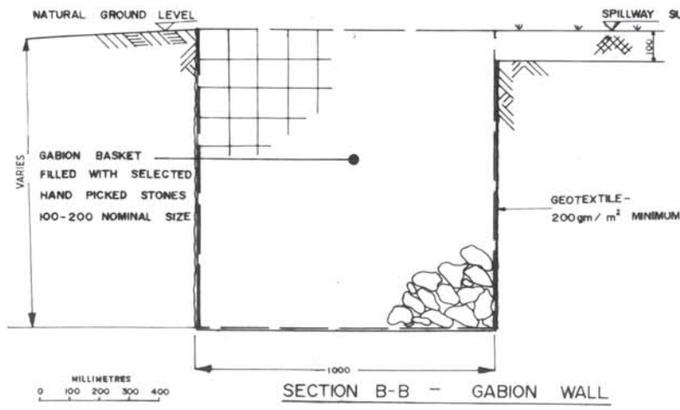
TYPICAL SPILLWAY ARRANGEMENT – PLAN

METRES 0 5 10 15 20



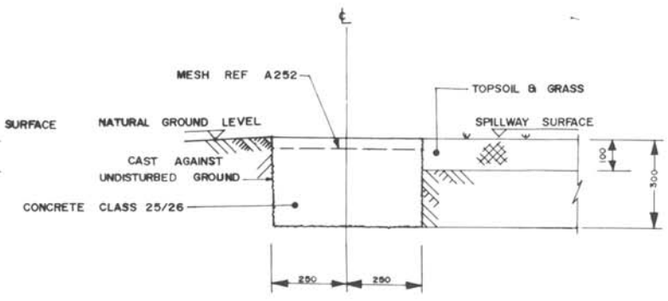
SECTION C-C

METRES 0 1 2 3



MILLIMETRES 0 100 200 300 400

SECTION B-B – GABION WALL



SECTION D-D

CONCRETE SILL

MILLIMETRES 0 100 200 300 400

NOTES

(1) ALL REINFORCEMENT ON THIS DRAWING IS DETAILED IN ACCORDANCE WITH BSCP 110 (1972) AS FOLLOWS:

(2) BAR CALLING UP SYSTEM

NO. IN GROUP | DIAMETER MM | SPACING MM

37 – T | 16 | 07 – 250 – T

MATERIAL TYPE | MARK NUMBER | POSITION

(3) COVER TO REINFORCEMENT TO BE 40 MM. UNLESS STATED OTHERWISE.

(4) BENDING TO BE IN ACCORDANCE WITH BS 4466.

(5) MATERIAL TYPE

REINFORCING STEEL SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF BS 4449 AND BS 4461. THE MATERIAL TYPE IS SHOWN ON THE DRAWINGS AS FOLLOWS:-

R = MILD STEEL BARS GRADE 250

T = TYPE 2 DEFORMED BARS GRADE 460/425

X = TYPE 1 SQUARE TWISTED COLD WORKED BARS GRADE 460/425

(6) IN THE EVENT OF NON-AVAILABILITY OF BAR SIZES SHOWN, THE STEEL AREA, LAP AND ANCHORAGE LENGTHS AT ANY CROSS SECTION MAY BE AMENDED SUBJECT TO THE APPROVAL OF THE ENGINEER.

(7) GENERAL ABBREVIATIONS

N.F NEAR FACE, F.F. FAR FACE, E.F. EACH FACE, B. BOTTOM, T. TOP
A.B.R. ALTERNATE BARS REVERSED
ALT. ALTERNATE, E.W. EACH WAY,
STGD. STAGGERED

(8) DIMENSIONS IN MILLIMETRES.
(9) ELEVATION IN METRES ABOVE ARBITARY DATUM.
(10) DO NOT SCALE – USE FIGURED DIMENSIONS.
(11) GABION BASKETS TO BE CONSTRUCTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.

DRAWING 5

DESIGNED		
DRAWN		
DESIGN CHECK		
DRAWING CHECK		
APPROVED		

DRG. No.	REFERENCE DRAWINGS

No.	DATE	REVISION	MADE	CHKD.

No.	DATE	REVISION	MADE	CHKD.

SCALE UNLESS OTHERWISE SHOWN

SPILLWAY DETAILS (I)

MANUAL ON SMALL EARTH DAMS
A GUIDE TO SITING, DESIGN AND CONSTRUCTION

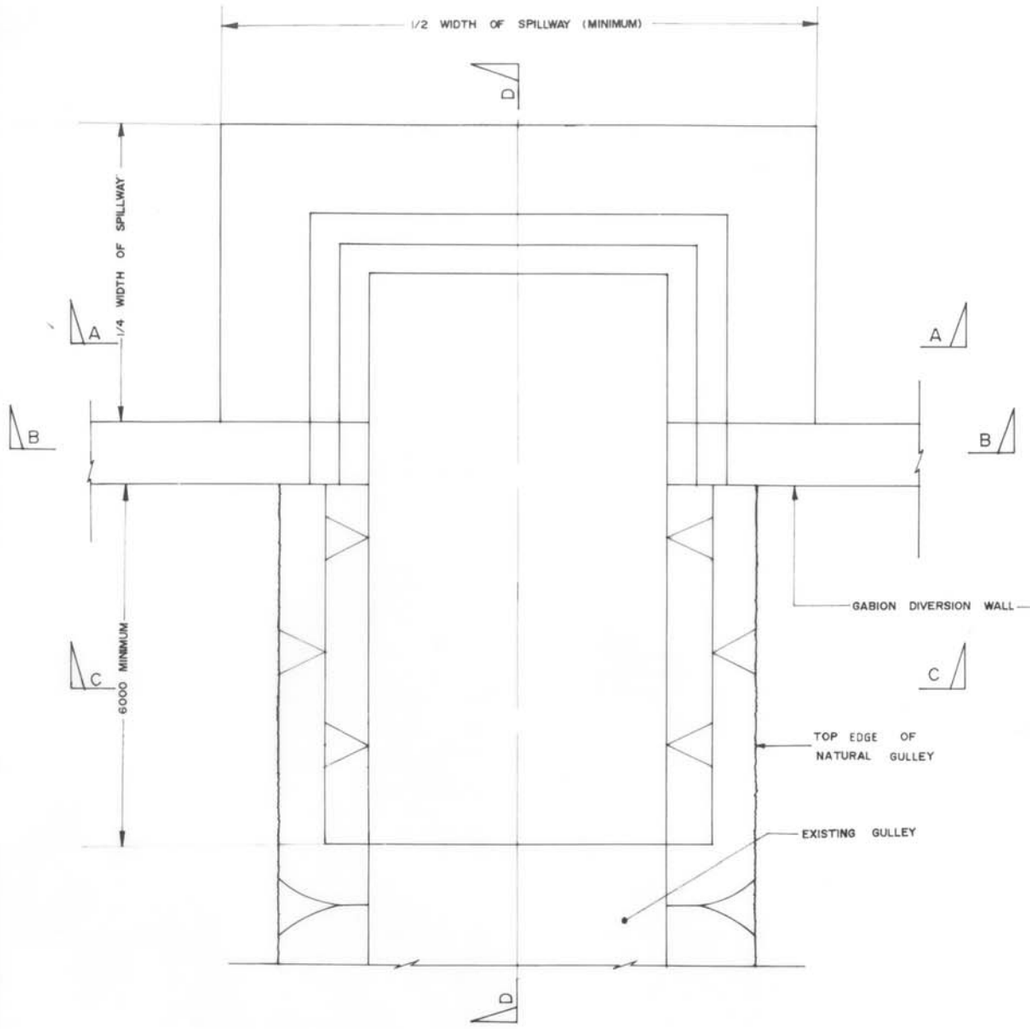
DESIGNED BY		
DRAWN BY		
CHECKED BY		

DRAWING 6: SPILLWAY DETAILS (II)

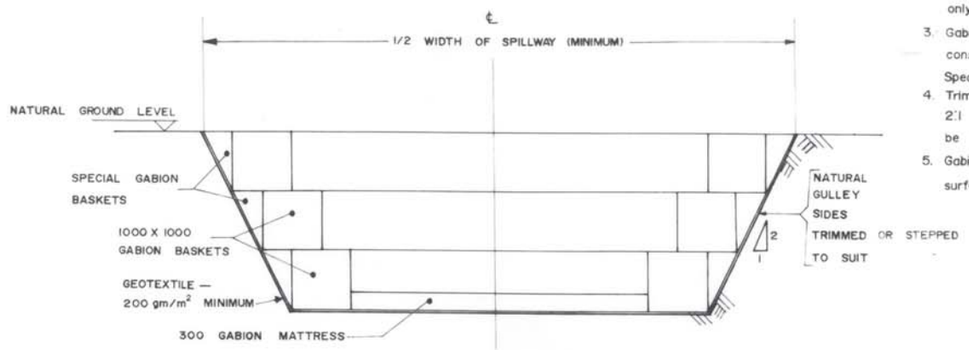
TENDER DRAWING

NOTES

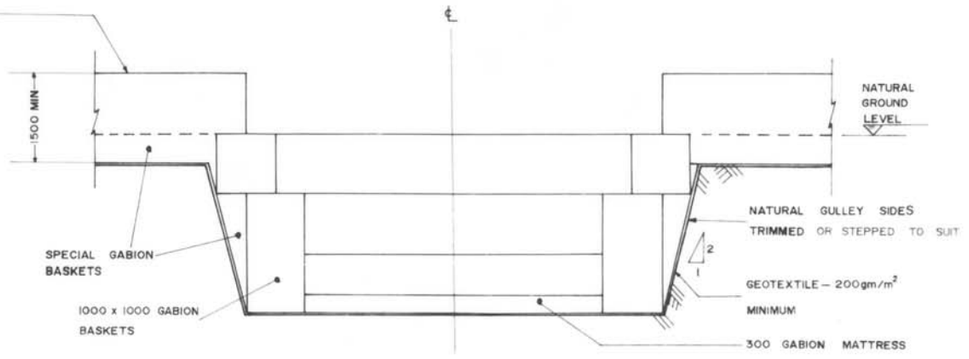
1. Dimensions in millimetres
2. Do not scale – use figured dimensions only.
3. Gabion baskets and mattresses to be constructed as detailed in the Technical Specification.
4. Trimmed gulley face slopes shown as 2:1 approximate only – actual slope to be determined on site.
5. Gabions to be laid against excavated surfaces only – not against fill.



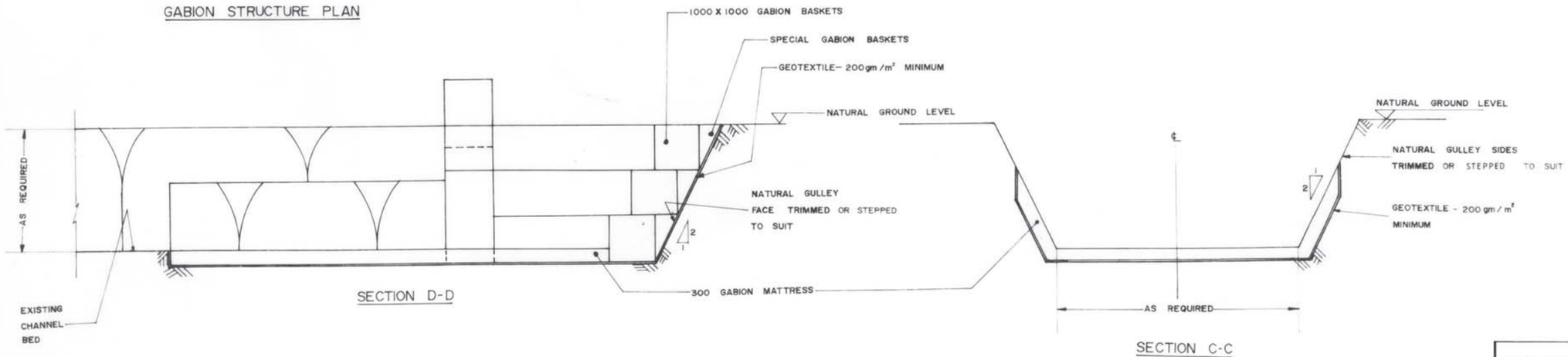
GABION STRUCTURE PLAN



SECTION A-A



SECTION B-B



SECTION D-D

SECTION C-C

DRAWING 6	DESIGNED			DRG. No.	REFERENCE DRAWINGS	No.	DATE	REVISION	MADE	CHKD.	No.	DATE	REVISION	MADE	CHKD.
	DRAWN														
	DESIGN CHECK														
	DRAWING CHECK														
	APPROVED														

SCALE
UNLESS OTHERWISE SHOWN

SPILLWAY DETAILS (II)

MANUAL ON SMALL EARTH DAMS
A GUIDE TO SITING, DESIGN AND CONSTRUCTION

DESIGNED BY		
DRAWN BY		
CHECKED BY		

FAO TECHNICAL PAPERS

FAO IRRIGATION AND DRAINAGE PAPERS

1 Irrigation practice and water management, 1972 (Ar* E* F* S*)
1 Rev.1 Irrigation practice and water management, 1984 (I)
2 Irrigation canal lining, 1971 (New edition, 1977, available in E, F and S in the FAO Land and Water Development Series, No. 1)
3 Design criteria for basin irrigation systems, 1971 (I*)
4 Village irrigation programmes - a new approach in water economy, 1971 (F I*)
5 Automated irrigation, 1971 (E* F* S*)
6 Drainage of heavy soils, 1971 (E* F* S*)
7 Salinity seminar, Baghdad, 1971 (F I*)
8 Water and the environment, 1971 (E* F* S*)
9 Drainage materials, 1972 (E* F* S*)
10 Integrated farm water management, 1971 (E* F* S*)
11 Planning methodology seminar, Bucharest, 1972 (E* F*)
12 Farm water management seminar, Manila, 1972 (I*)
13 Water use seminar, Damascus, 1972 (F* I*)
14 Trickle irrigation, 1973 (E* F* S*)
15 Drainage machinery, 1973 (F* I*)
16 Drainage of salty soils, 1973 (C* E* F* S*)
17 Man's influence on the hydrological cycle, 1973 (E* F* S*)
18 Groundwater seminar, Granada, 1973 (E* F S*)
19 Mathematical models in hydrology, 1973 (I)
20/1 Water laws in Moslem countries - Vol. 1, 1973 (F* I*)
20/2 Water laws in Moslem countries - Vol. 2, 1978 (F I)
21 Groundwater models, 1973 (I)
22 Water for agriculture - index, 1973 (E/F/S*)
23 Simulation methods in water development, 1974 (E* F* S*)
24 Crop water requirements, (rev.) 1977 (C* E F S)
25 Effective rainfall, 1974 (C* E* F* S*)
26/1 Small hydraulic structures – Vol. 1, 1975 (E* F* S*)
26/2 Small hydraulic structures – Vol. 2, 1975 (E* F* S*)
27 Agro-meteorological field stations, 1976 (E* F* S*)
28 Drainage testing, 1976 (E* F* S*)
29 Water quality for agriculture, 1976 (E* F* S*)
29 Rev.1 Water quality for agriculture, 1985 (C** E* F* S*)
30 Self help wells, 1977 (I)*
31 Groundwater pollution, 1979 (C* E* S)
32 Deterministic models in hydrology, 1979 (I)*
33 Yield response to water, 1979 (C* E F S)
34 Corrosion and encrustation in water wells, 1980 (I)
35 Mechanized sprinkler irrigation, 1982 (C E* F S*)
36 Localized irrigation, 1980 (Ar C E* F S*)
37 Arid zone hydrology, 1981 (C I)
38 Drainage design factors, 1980 (Ar C E F S)
39 Lysimeters, 1982 (C E* F* S*)
40 Organization, operation and maintenance of irrigation schemes, 1982 (C E* F S*)
41 Environmental management for vector control in rice fields, 1984 (E* F* S*)
42 Consultation on irrigation in Africa, 1987 (F I)
43 Water lifting devices, 1986 (F I)
44 Design and optimization of irrigation distribution networks, 1988 (F I)
45 Guidelines for designing and evaluating surface irrigation systems, 1989 (I)
46 CROPWAT – a computer program for irrigation planning and management, 1992 (E F* S*)
47 Wastewater treatment and use in agriculture, 1992 (I)
48 The use of saline waters for crop production, 1993 (I)
49 CLIMWAT for CROPWAT, 1993 (I)
50 Le pompage éolien, 1994 (F)
51 Prospects for the drainage of clay soils, 1995 (I)
52 Reforming water resources policy, 1995 (I)
53 Environmental impact assessment of irrigation and drainage projects, 1995 (I)
54 Crues et apports, 1996 (F)
55 Control of water pollution from agriculture, 1996 (E* S)
56 Crop evapotranspiration, 2006 (E S)
57 Soil salinity assessment, 1999 (I)
58 Transfer of irrigation management services: guidelines, 1999 (E F R S)
59 Performance analysis of on-demand pressurized irrigation systems, 2000 (I)
60 Rev.1 Materials for subsurface land drainage systems, 2005 (E)
61 Agricultural drainage water management in arid and semi-arid areas, 2002 (I)
62 Guidelines and computer programs for the planning and design of land drainage systems, 2007 (I)
63 Modernizing Irrigation Management – the MASSCOTE approach. Mapping System and Services for Canal Operation Techniques, 2007 (I)
64 Manual on small earth dams. A guide to siting, design and construction, 2010 (E)

Ar – Arabic
C – Chinese
E – English
F – French
P – Portuguese
R – Russian
S – Spanish
Multil – Multilingual
* Out of print
** In preparation

64

FAO IRRIGATION AND DRAINAGE PAPER

Manual on small earth dams

A guide to siting, design and construction

This publication aims to fill a void of practical guidelines for the construction of small earth dams. It presents readers with sound, reliable and practical source material to improve dam siting and design capacity in rural areas, to introduce a beneficiary and gender sensitive approach and to enhance safety and competence in construction. A section also provides convenient guidance on costing, drafting tenders and awarding contracts.

The manual is primarily aimed at technicians and others with knowledge of engineering and basic irrigation systems and processes to apply the concepts, techniques and methods proposed, using simple and straightforward design and construction procedures.

ISBN 978-92-5-106547-1 ISSN 0254-5284

9 789251 065471

I1531E/1/04.10/2000