DESIGN GUIDE

FOR

RIPRAP-LINED FLOOD CONTROL CHANNELS

Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA)

December, 1983

Riprap-Lined Flood Control Channels are to be designed with the standards outlined herein. These standards represent compromises among many considerations including first cost, right-of-way, safety and maintenance. When compliance is not possible, alternate design concepts may be proposed.

The City of Albuquerque plans to use this guide. All or portions of this or a modified version of the Design Guide may be incorporated into the Development Process Manual.

Comments and suggested changes are encouraged.

Most, if not all, references are available at AMAFCA.

DESIGN GUIDE

FOR

RIPRAP-LINED FLOOD CONTROL CHANNELS

I. GENERAL

A. The criteria included herein are intended to provide standards for the design and construction of dumped riprap-lined channels in the Albuquerque Metropolitan Area. Alternates to these standards may be proposed where unique or special conditions are encountered.

B. Arroyo beds and banks in the Albuquerque area are generally unstable, and are highly erodable even at low and moderate flows. This instability results in a scour-and-fill regimen of arroyo floors, with scours tending to outpace fill, and bank sloughing a common occurrence.

C. Riprap may be a suitable means of stabilizing arroyos or channels, particularly where velocities are low (5 fps or less), adequate right-of-way is available, and a compromise between concrete lining and a "natural" arroyo is desired.

D. Riprap-lined channels are most appropriate where "natural" scour-and-fill takes place, i.e., the bed is maintained in a dynamically stable manner. The design objective is to establish an "equilibrium channel slope," wherein the channel's sediment transporting capacity is equal to the incoming sediment supply. Accordingly, the design will involve the selection of bed width, sideslopes, grade, bank protection, and if necessary, grade-control and/or energy-dissipating structures. (Reference 2D, pp. 1-2)

E. Where "clean" (sediment-free) water is to be conveyed, riprapping of only the channel banks may not be sufficient (e.g., immediately below a dam, or where runoff is from a developed area). In this case, the channel must be designed for no sediment movement, that is, both the sides and bottom of the channel must be lined. The increased cost of full lining might make concrete lining more economical.

F. This design guide is intended to provide general guidance. The references listed will provide specific design criteria and methods.

II. DESIGN MEMORANDUM

A. AMAFCA Design Contracts normally call for submission of a Design Memorandum, for approval, before proceeding to preliminary design. The purpose of the Design Memorandum is to describe design assumptions and concepts, and serve as a future reference. Properly used, the Design Memorandum can avert false starts and wasted effort.

B. The following are among items which should be addressed in the Design Memorandum:

1. Description of the project.
2. Flow rates and hydrology on which they are based. Acceptable methods are described in Volume 2, Albuquerque Development Process Manual. (Reference 1C)
3. Proposed channel section(s), "n" values, water velocities, grade control or other structures, and profiles of channel invert for each reach.
4. Profiles of hydraulic grade line.
5. Soil investigations.
6. Determination of equilibrium slope for the channel, for each reach, for 25%, 50% and 100% of design flow (Q_{100}).

7. Upstream collection, downstream energy dissipation, and other channel transitions.

8. Bridges or other traffic crossing structures.

9. Analysis of channel junctions and inlets through proposed range of flows.

10. Maintenance access.

11. Relationship to upstream and downstream facilities, both in existence and planned.

12. Any unusual feature of the project.

13. Proposed deviations from this Guide or the DPM, and justification therefore.

14. Right of way available, to be dedicated, or reverted.

15. Cost estimate.

III. DESIGN STORMS

A. The design flow shall be for the 100-year frequency storm unless otherwise specified by the City or AMAFCA.

B. Analysis shall also be made for 25% and 50% of design flow.

IV. DESIGN PROCEDURE AND GUIDELINES

A. Channels

1. Where channels are designed for dynamic equilibrium (incoming sediment), the principal design criteria shall be that contained in References 2A and 2B.

2. When designing for a "clean" water condition, tractive force analysis, involving computation of Shear Ratio is more appropriate. (Shear Ratio is the ratio between fluid shear exerted on a sediment particle and that particle's resistance to displacement).

This type of analysis is documented in Chow, 1959, and Henderson, 1966, (References 2C and 2D, respectively). A methodology for this procedure is presented in Reference 2E.

3. Bottom width - 10 feet minimum.

4. Riprap slopes shall not be steeper than 1.0 V to 2.0 H east of the Rio Grande, and 1.0 V to 2.5 H west of the Rio Grande. Flatter slopes are preferred.

5. Freeboard shall be 2 feet unless analysis indicates the need for more (e.g., vicinity of side channel inlets, curves, transitions, or antidune analysis). Riprap may be deleted from the top 50% of the freeboard provided such deletion is supported by analysis.

B. Riprap Lining

1. The principal design guides for riprap lining shall be References 2A and 3A which are based on the dynamic equilibrium principle (i.e., only the channel sides are lined). Copies are available from AMAFCA.

2. Other design guides are listed in the references. Among those appropriate is Reference 3B, which outlines a procedure for fully-lined trapezoidal channels carrying less than 1000 cfs.

3. Riprap rock shall meet the following criteria:

   a. Specific gravity of 2.65 (165 pounds per cubic foot), as determined by ASTM C 127. If available rock does not meet this density, size and depth of riprap shall be increased according to the following table:

Specific Gravity	Percent increase in size and depth
2.65	1.00
2.60	1.05
2.50	1.15
2.40	1.25

   Slabs and oblong pieces are not permitted. Broken concrete may be used, if approved by Public Authority.

b. Los Angeles abrasion wear of not more than 40 percent as determined by AASHTO T96.

c. Soundness loss of not more than 21 percent, as determined by AASHTO T104.

d. Freeze thaw loss of not more than 10 percent after 12 cycles, per AASHTO T103, Procedure A.

4. Minimum depth of riprap - 12 inches.

5. Riprap shall be placed to its full design thickness (depth) in one operation.

6. Toe of riprap slopes shall extend a minimum of 3 feet (vertically) below channel invert; more if analysis deems necessary. Suggested methods of toe protection are at Figure 1.

7. Suggested methods of termination of riprap lining are shown in Figure 2.

8. Riprap slopes shall have a filter blanket to prevent bank material from filtering through the riprap cover. Filter blankets shall be the granular type, and designed using procedures in Simons & Li (References 2A, 2B, 3A) or FHWA HEC-11 (Reference 3B). Field samples of arroyo bed material are necessary for proper design; however, some data is currently available (Reference 1A). The contribution of tributary sources should be considered.

9. If a two-layer filter blanket is indicated, it should be compared, functionally and economically, to thickening of a single layer filter. Normally, AMAFCA will require only one filter blanket; however, this blanket must be sufficiently thick. The filter blanket should be extended above and around riprap to provide erosion protection. (Figure 3)

10. The subgrade under the filter blanket shall be of suitable material, and the top 12 inches compacted to 90% Modified Proctor before placing the filter.

C. Grade Control and Drop Structures

1. Principal design guides include the following:

   a. For steep channels with high flows, a baffled chute is appropriate, accommodating flows up to 300 cfs per foot of width (Reference 4E). (Figure 4)

   b. For steep channels and flows up to 500 cfs, the riprap-lined inclined drop structure, as developed by NMSU (Reference 4A), should be appropriate (Figure 5) NOTE: AMAFCA plans to install and test an inclined drop structure designed for flows greater than 500 cfs. If successful, this type of structure may be permitted for higher flows.

   c. For mild channels, appropriate structures include the following:

      (1) Type C vertical drops of concrete (References 4B, 4C, and 4D). (Figure 6)

      (2) Box-inlet drop spillway of concrete (References 4C and 4J). (Figure 7)

      (3) Gabion drops (Reference 4N). (Figure 8)

      (4) Rock-lined transitions and cascades (References 4C, 4H and 4I). (Figure 9)

      (5) Sloping drop structure or vertical drop structure of the "Denver" type (Reference 4K). (Figure 10)

      (6) Drops of other materials (e.g., sheet piling, timbers) for which little information, if any, is available.

2. Structures which do not appear appropriate include impact basins and hydraulic jump spillways. Discussions of several types of structures are in References 4C and 1E.

3. The designer should be aware of constraints associated with each type of structure.

4. No single vertical drop shall exceed 3 feet. Drop structures in excess of 3 feet will normally be stepped, and fences provided, for safety reasons.

5. The crest wall of drop structures shall be level and rigid, to distribute flow evenly.

6. Erosion and scour must be analyzed and planned for, especially downstream of any structure. (See References 2A, 4L and 4M.)

V. DRAINAGE WAY

A. Right-of-Way

Sufficient right-of-way (fee simple or easement) shall be provided to accommodate the channel along with the necessary channel appurtences. Temporary construction easements may be required.

B. Maintenance Road

1. Width - 12 feet.

2. Provided on at least one side of the channel, preferably on the uphill side.

3. Sloped away from the channel, with drainage collected at designated channel inlets.

4. Sediment catch basin, inlets, and rundowns may be incorporated into the maintenance road.

5. If needed, establish turnouts to allow passage of two, 5-ton trucks at 1/2 mile intervals. Provide turnarounds at dead ends.

6. Ingress and egress shall be provided from public right-of-way to the channel maintenance road. A gate will normally be required.

7. Consider the need for barriers, barricades and delineators.

C. Channel Access

1. Provide ramps as necessary for vehicle access to the entire channel, from the maintenance road.

2. Maximum length of channel between ramps - one-half mile.

3. Ramps shall not have slopes greater than 15%.

4. Ramps shall not enter the channel at angles greater than 15^{o} from a line parallel to the channel centerline.

5. The maintenance road shall be offset around the ramp to provide for continuity of the road.

6. The downhill direction of the ramp shall be oriented downstream.

7. Channel capacity shall not be reduced, nor shall hydraulic problems be included.

I. EARTHWORK

A. The following shall be compacted to at least 90% of maximum density as determined by ASTM D-1557 (Modified Proctor):

1. The 12 inches of subgrade immediately beneath the riprap and filter lining.

2. Maintenance road.

3. All embankment material.

VII. INLETS

Local and exterior drainage shall be allowed to enter the channel through designed inlets only. Inlets may consist of the following types:

A. Surface Inlet (Figures 11a and 11b)

1. Surface-type inlets shall be constructed of reinforced concrete whenever possible.
2. The floor of the inlet shall have a minimum thickness of 6 inches.
3. Stem walls shall be high enough to contain the flow, and extend at least 12" below the filter blanket.
4. The upstream end of the surface inlet shall be provided with a concrete cutoff wall having a minimum depth of three feet and the downstream end of the inlet shall be provided with a splash apron, scour protection, and/or cutoff wall, as appropriate. (See Figure 11a.)
5. Side slopes of a surface inlet, if made a part of the maintenance road, should be constructed at slopes no greater than 1 vertical to 10 horizontal to allow vehicular passage across the inlet. (See Figure 11b.)
6. Drainage ditches or swales immediately upstream of a surface inlet shall be provided with erosion protection.
7. Surface inlets shall enter the channel at a maximum of 90° to the channel centerline, i.e., they may not point upstream.

B. Pipe and Box Culvert Inlets to the Channel

1. Criteria governing angle of entrance and depth are in Paragraph 18.h.; Reference 2F.
2. Culvert inlets should have energy dissipators, aprons, or other features to blend flows and/or protect the channel. See References 4E, 5A thru 5C. Scour should be considered (References 4L and 4M).

C. Side Channels

1. Side channels shall be designed to match main channel flow characteristics as closely as feasible. Design and construction shall be similar to the main channel.

2. Additional information is provided in Reference 2F, Paragraphs 18 (d) and (e).

VIII. STREET CROSSINGS

A. Street crossings or other structures over a channel should conform to the channel cross-section. If not possible, transitions should be designed to minimize hydraulic disturbance.

B. Rundowns from the street shall be incorporated in the design, and should be of the surface-type, if possible.

C. Minimum height of channel opening should be 4 feet.

D. Where the crossing structure involves concrete channel lining, the upstream and downstream ends of the lining shall have 3-foot deep cutoff walls extending the full width of the concrete lining, and scour/erosion protection as necessary.

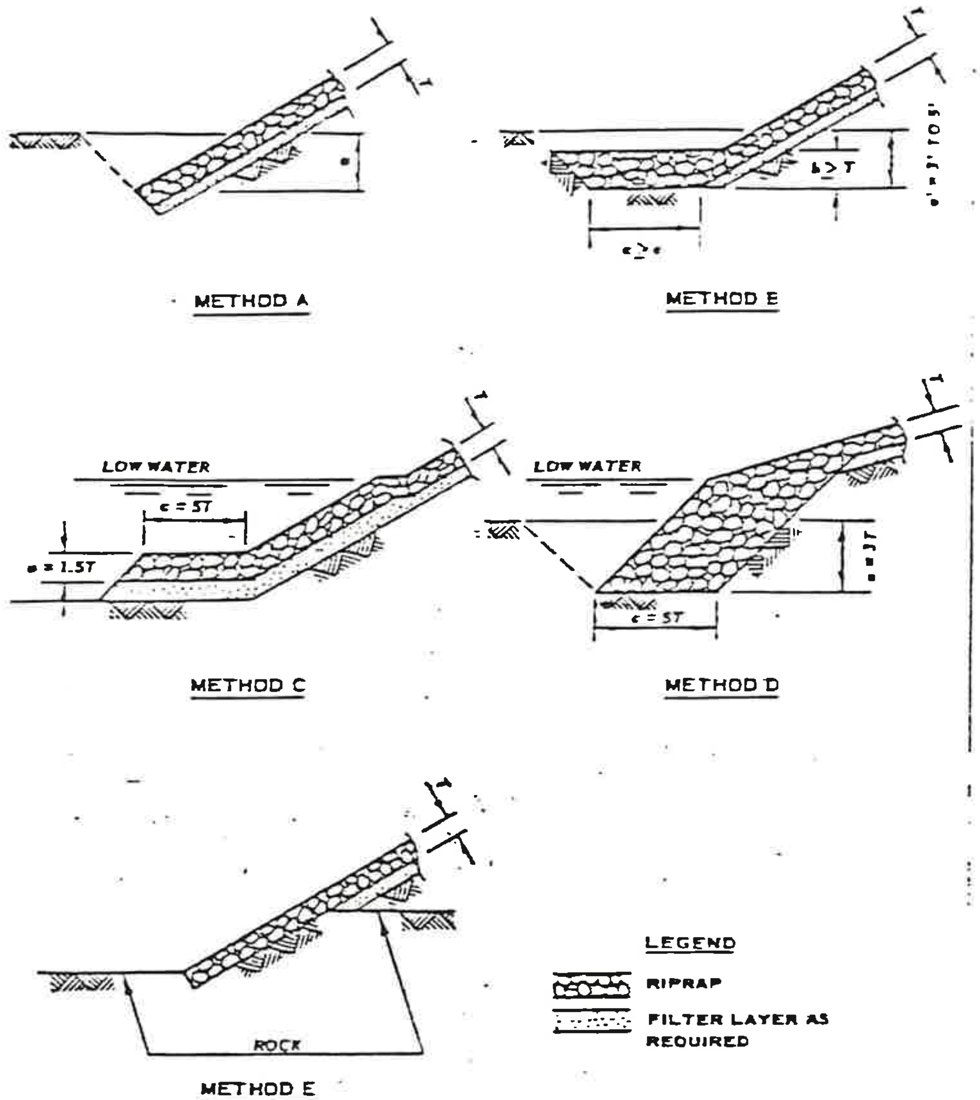


Fig. 1 - Methods of toe protection by trenching and thickened toe (U.S. Army Corps of Engineers, 1970).

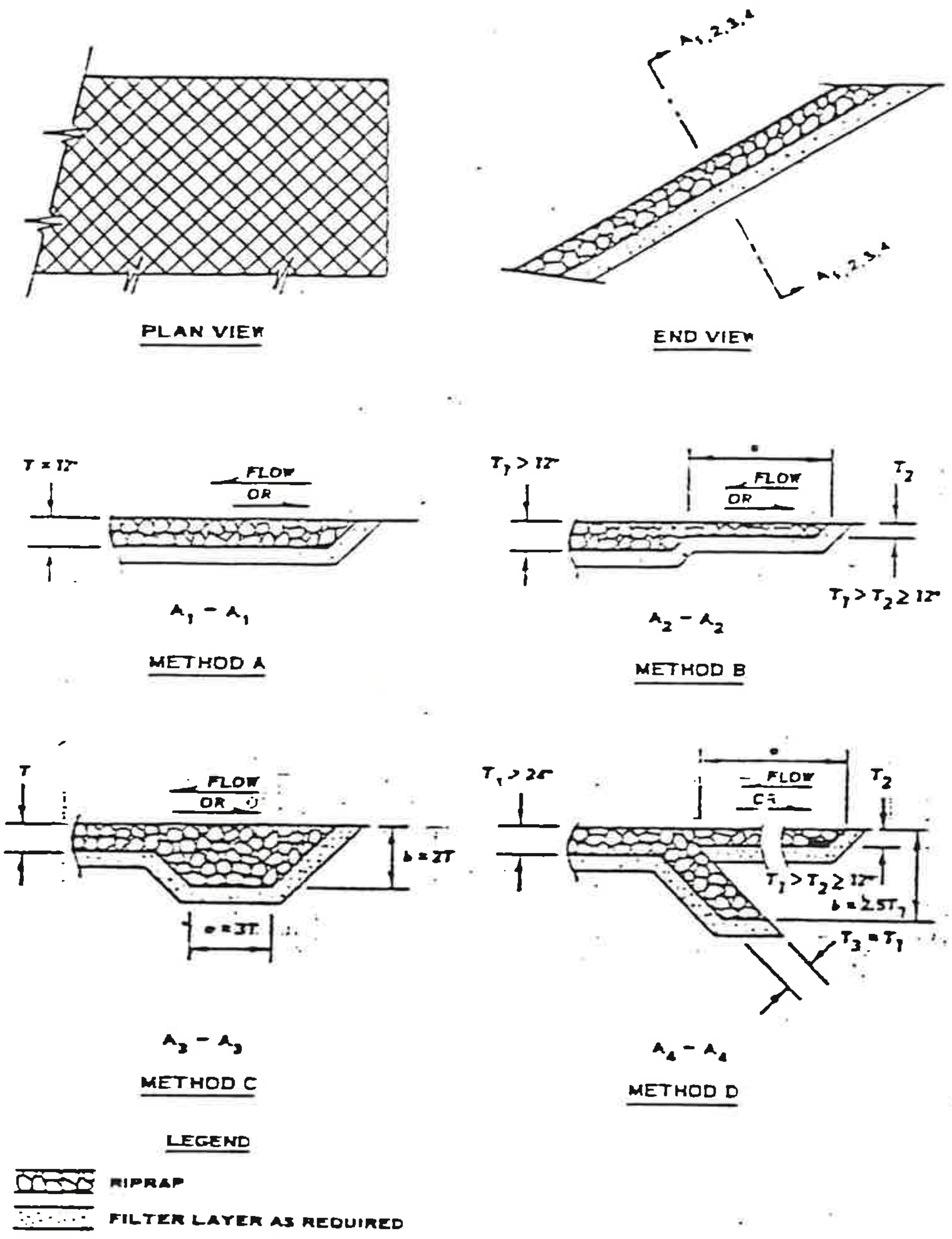
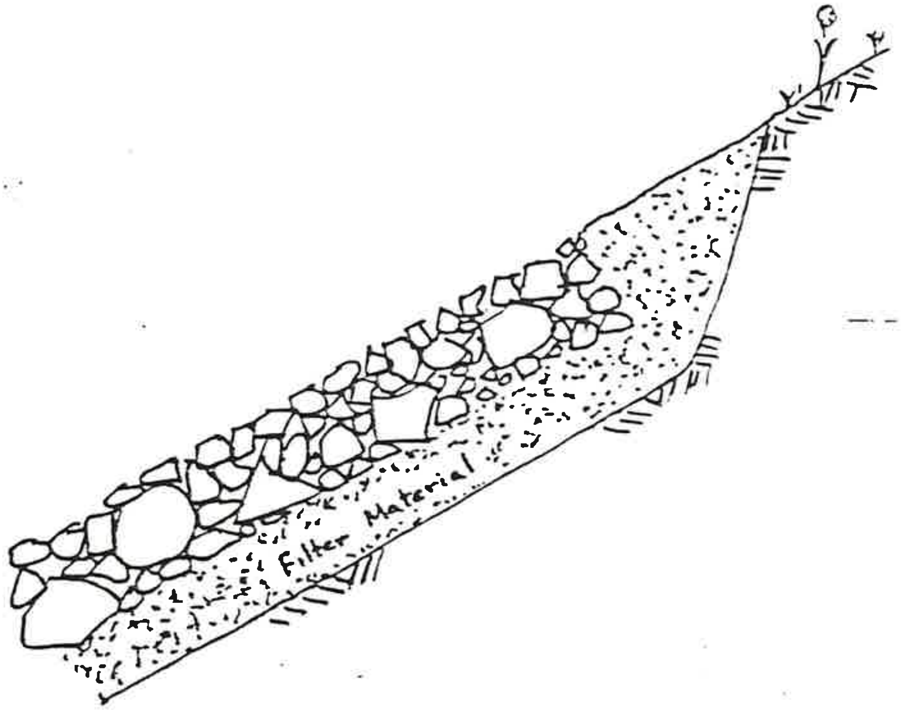
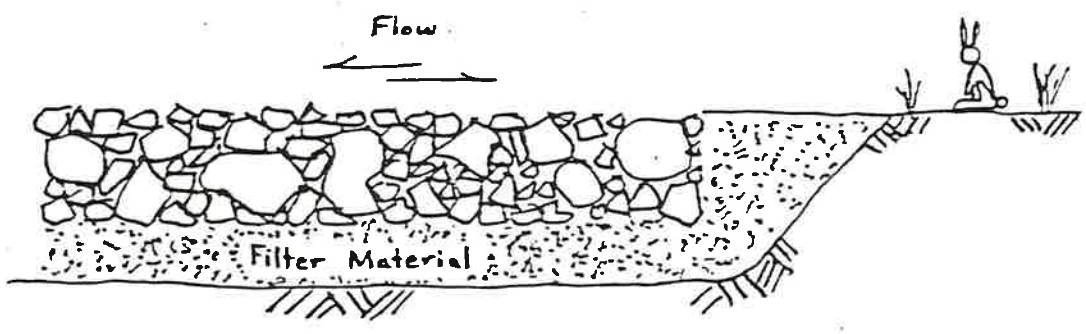


Fig. 2 - Methods of ending riprap lining (U.S. Army Corps of Engineers, 1970).



On Slopes



On Bottom

Figure 3. - Extending Filter to Provide Erosion Protection.

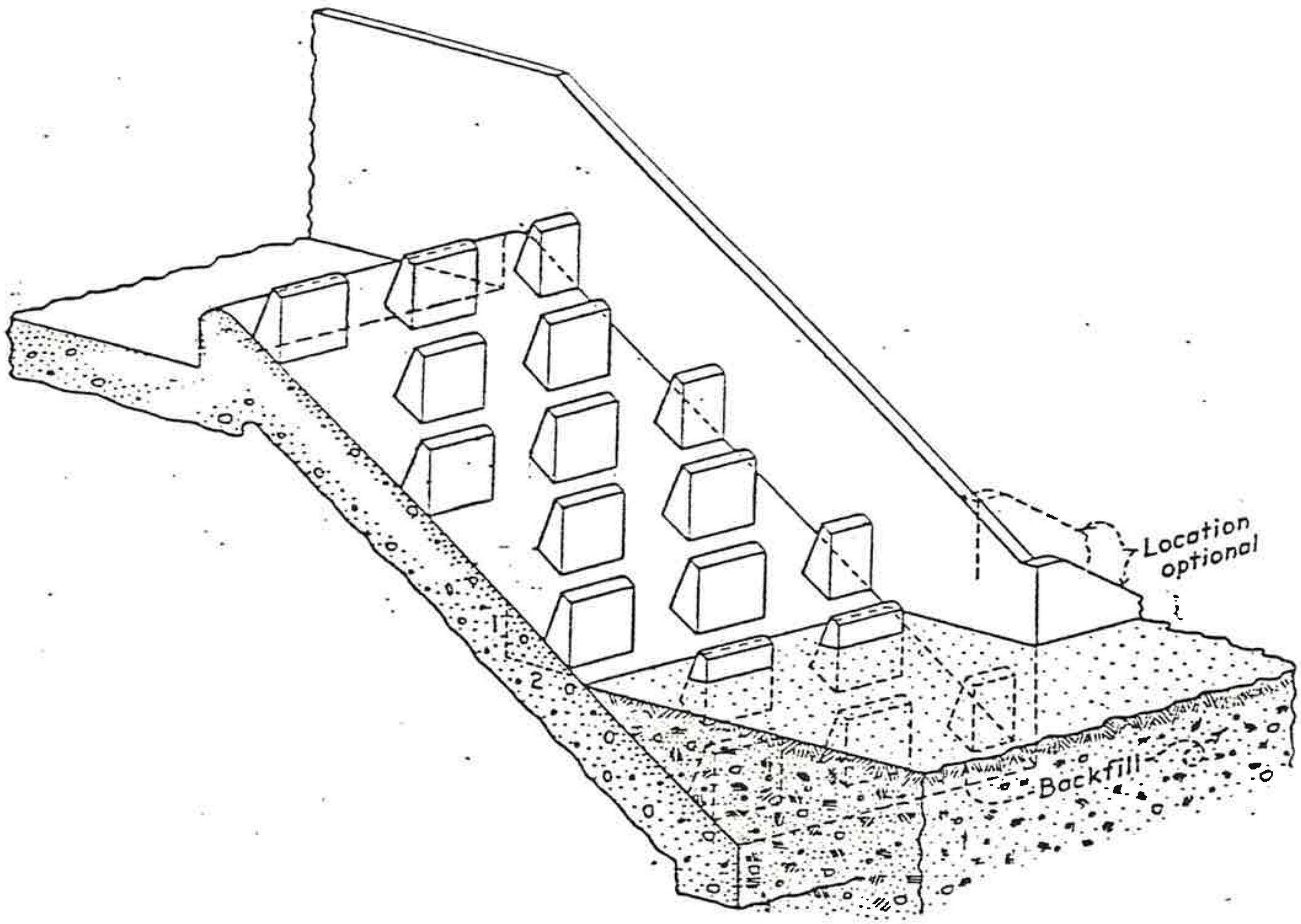


Fig. 4 - General sketch of the baffled chute as developed by the USBR (Peterka, 1963).

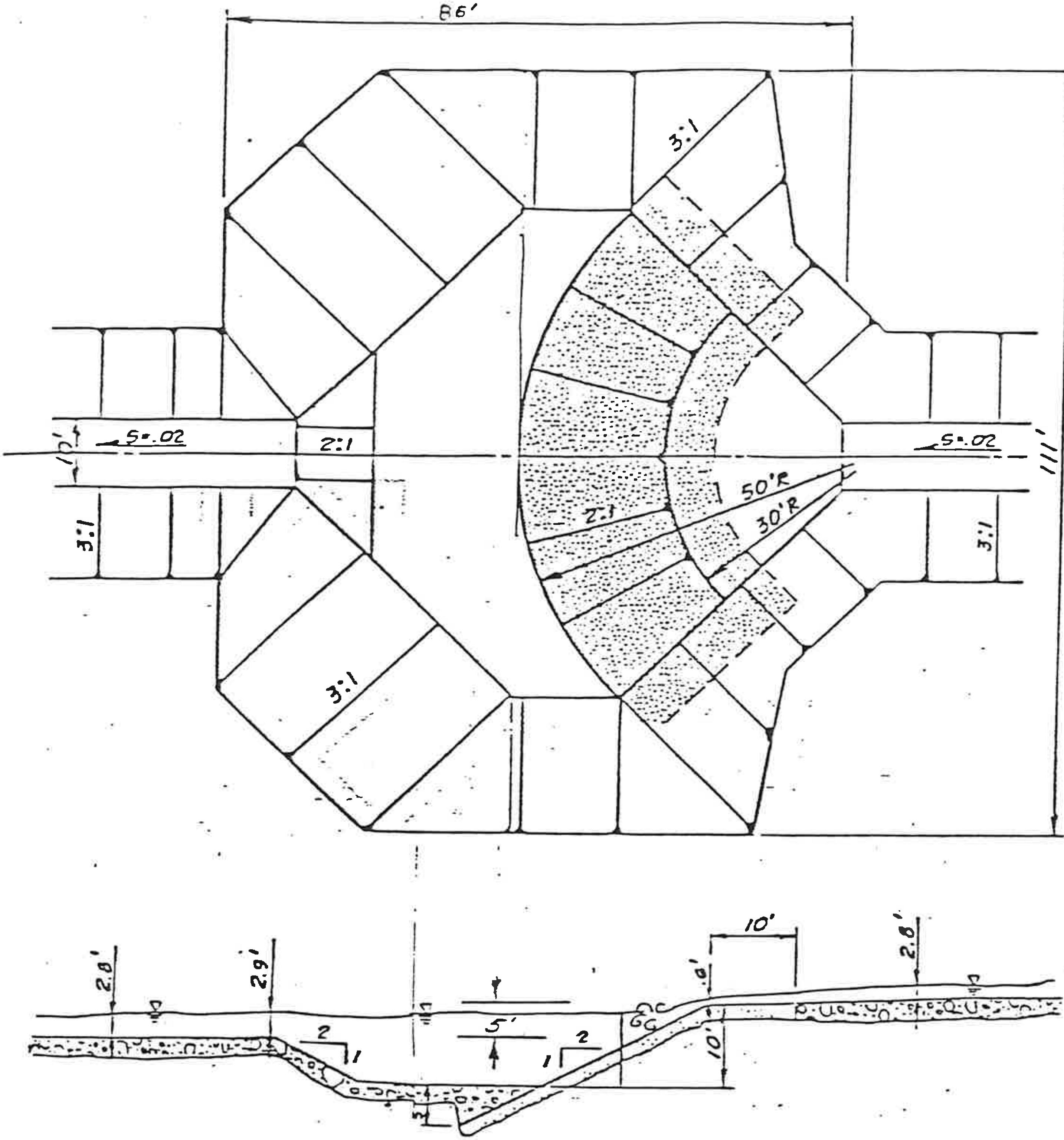
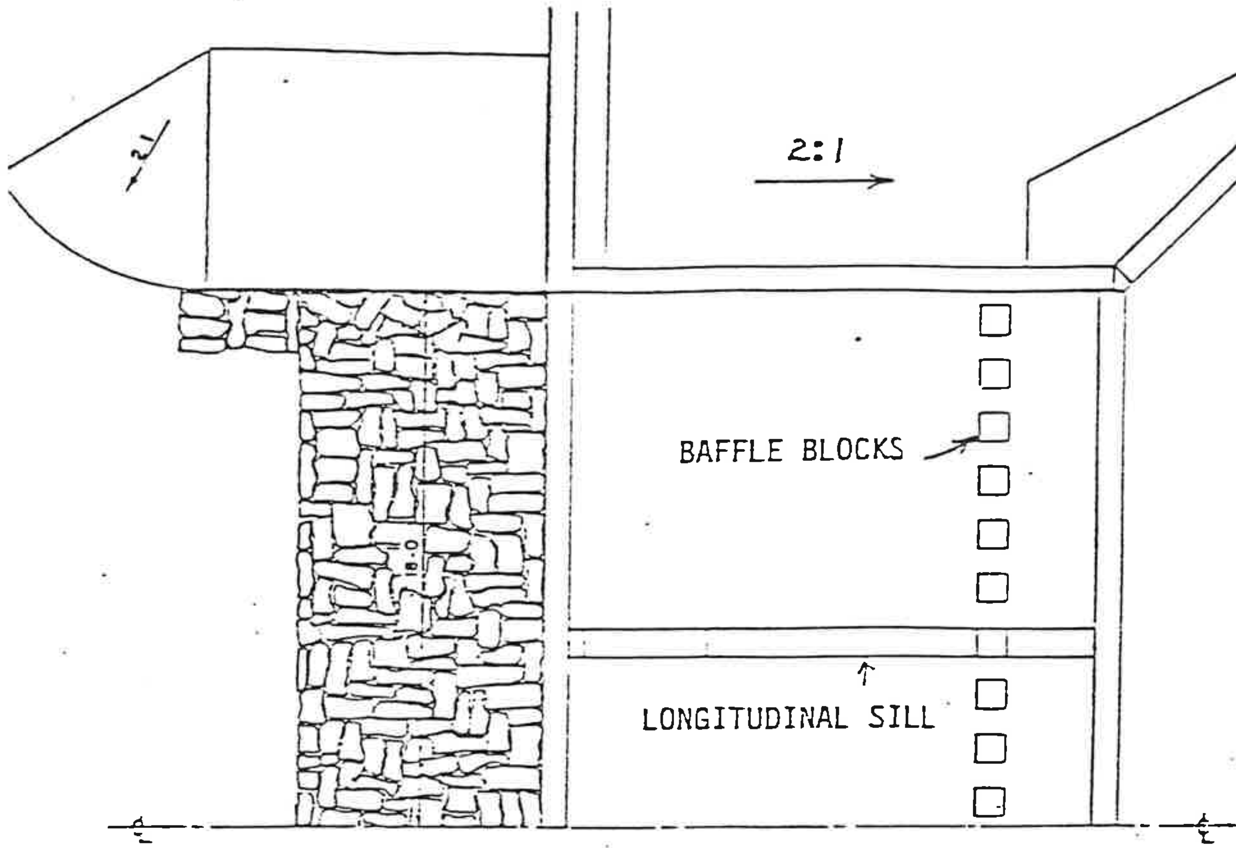
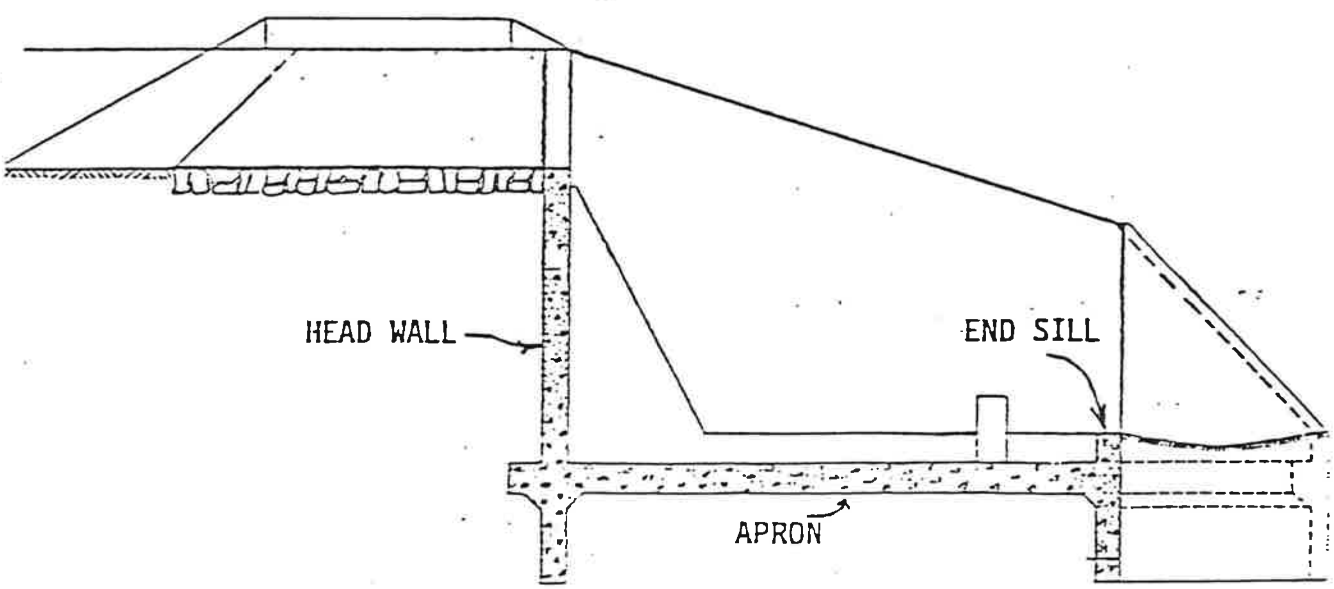


Figure 5 .- Configuration 3 riprap lined inclined drop. All dimensions in prototype units. Design discharge is 500-cfs. (From Reference 4A)



HALF PLAN



SECTION ON CENTERLINE

Fig. 6 - General sketch of the Type C vertical drop spillway as developed by (SCS, undated).

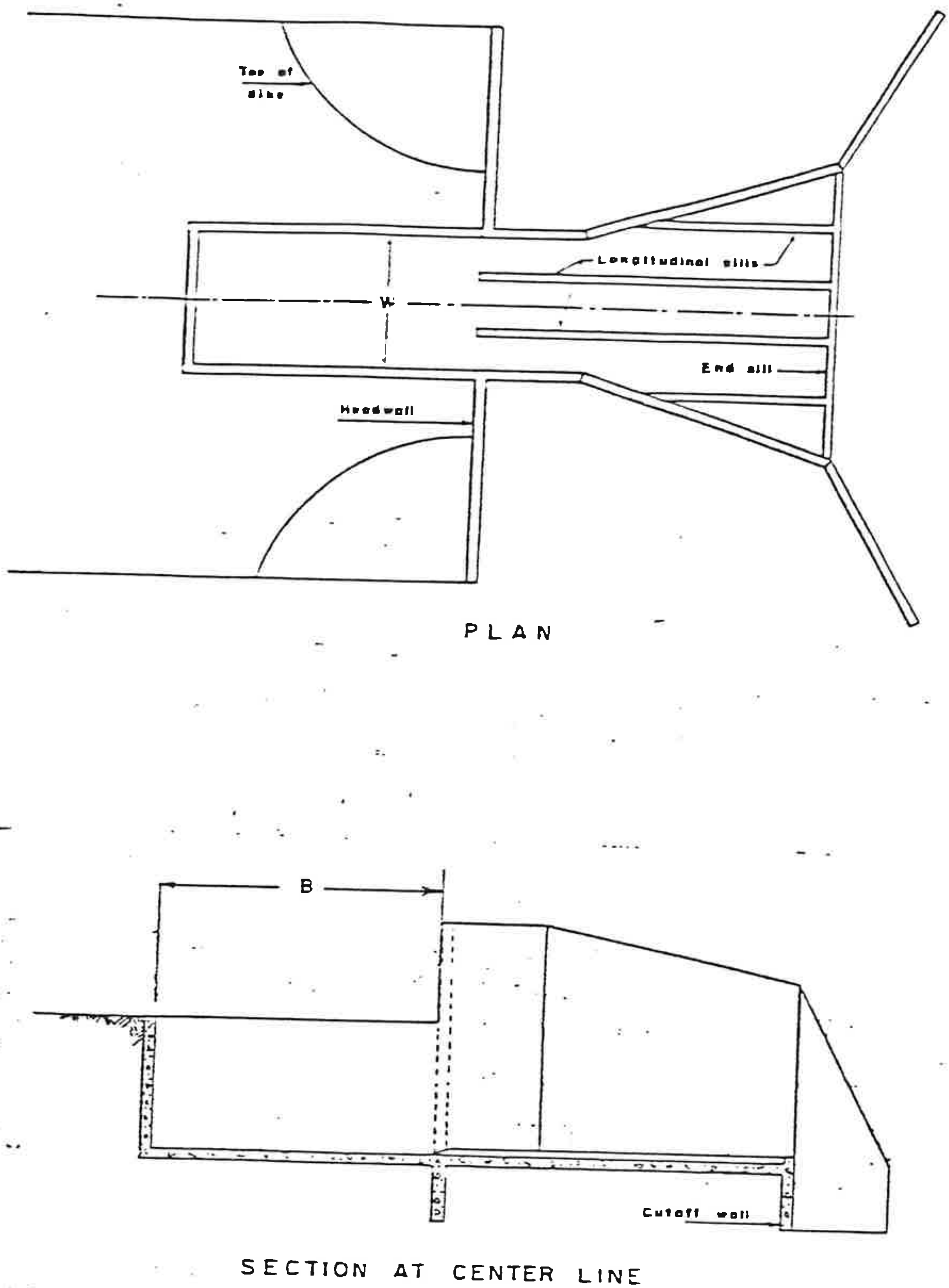


Fig. 7 - General sketch of the box-inlet drop spillway as developed by the SCS (Blaisdaell and Donnelly, 1966).

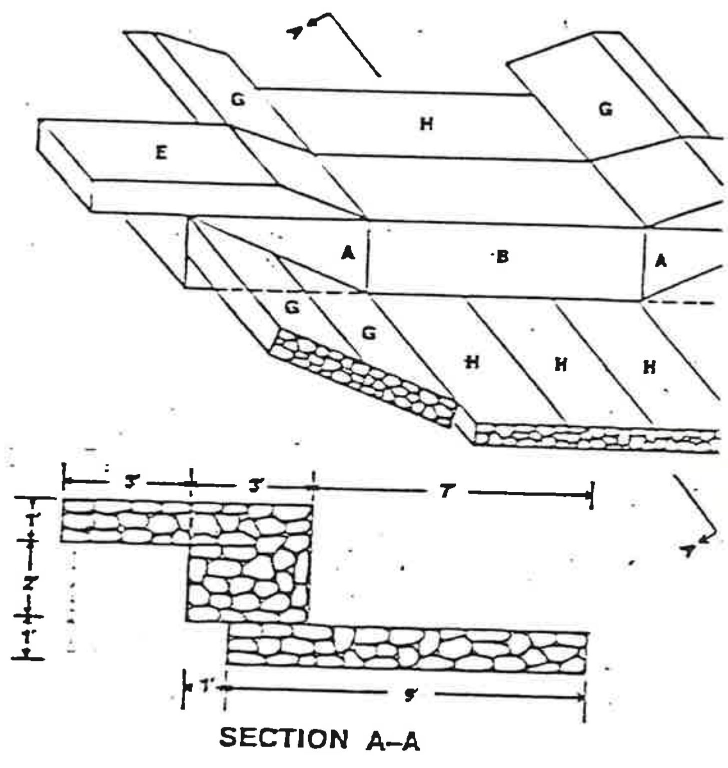


Fig. 8 - Small vertical drop, and local scour protectio
(Bekaert, undated).

Riprap Gradient Control Structure

A riprap gradient control structure is a riprap structure consisting of a prismatic channel with a converging inlet transition at the upstream end and a diverging outlet transition at the downstream end of the prismatic channel. The riprap structure should have an essentially straight alignment as shown in Figure 9.

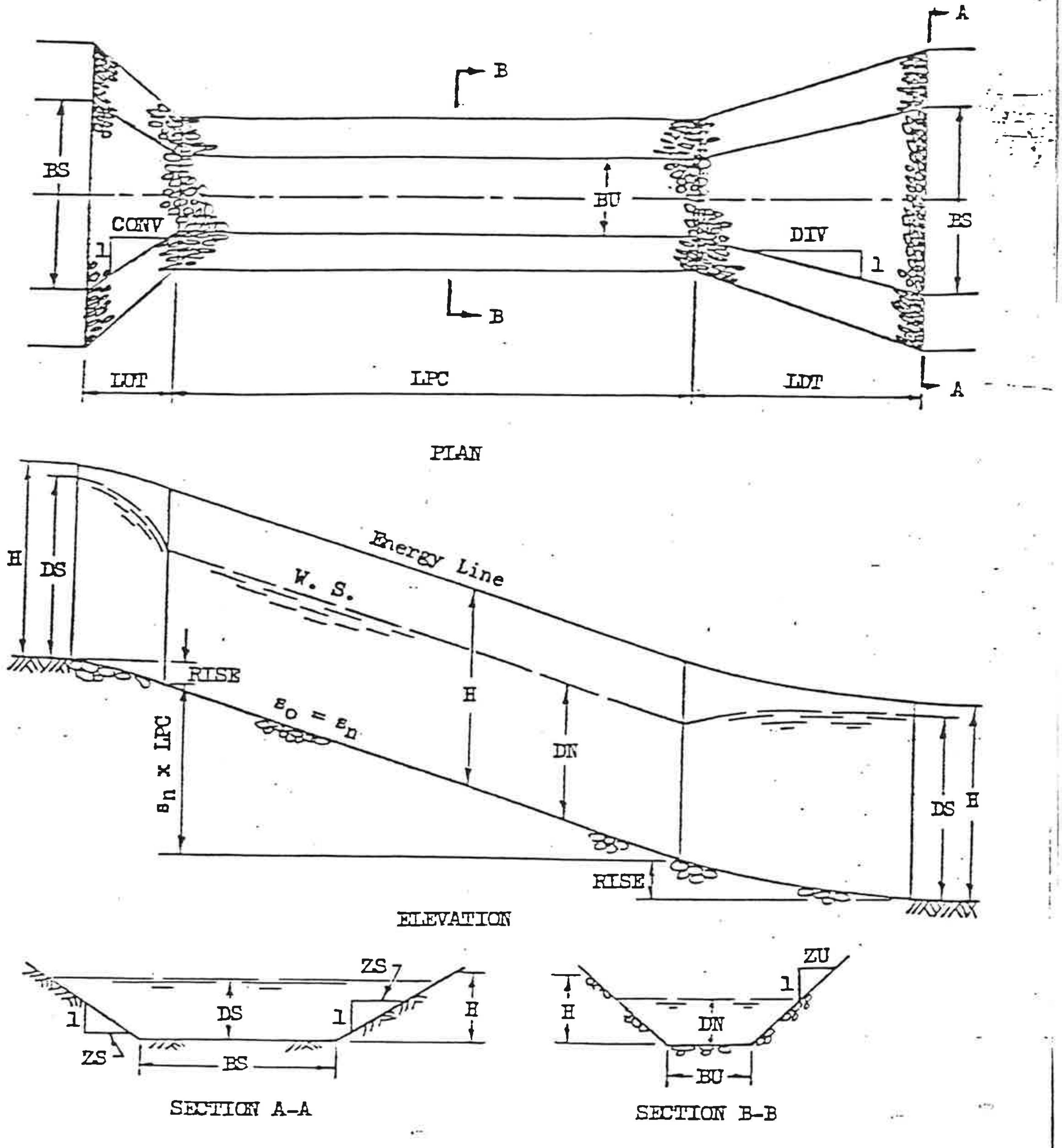


Figure 9 Riprap gradient control structure
(From Reference 4H)

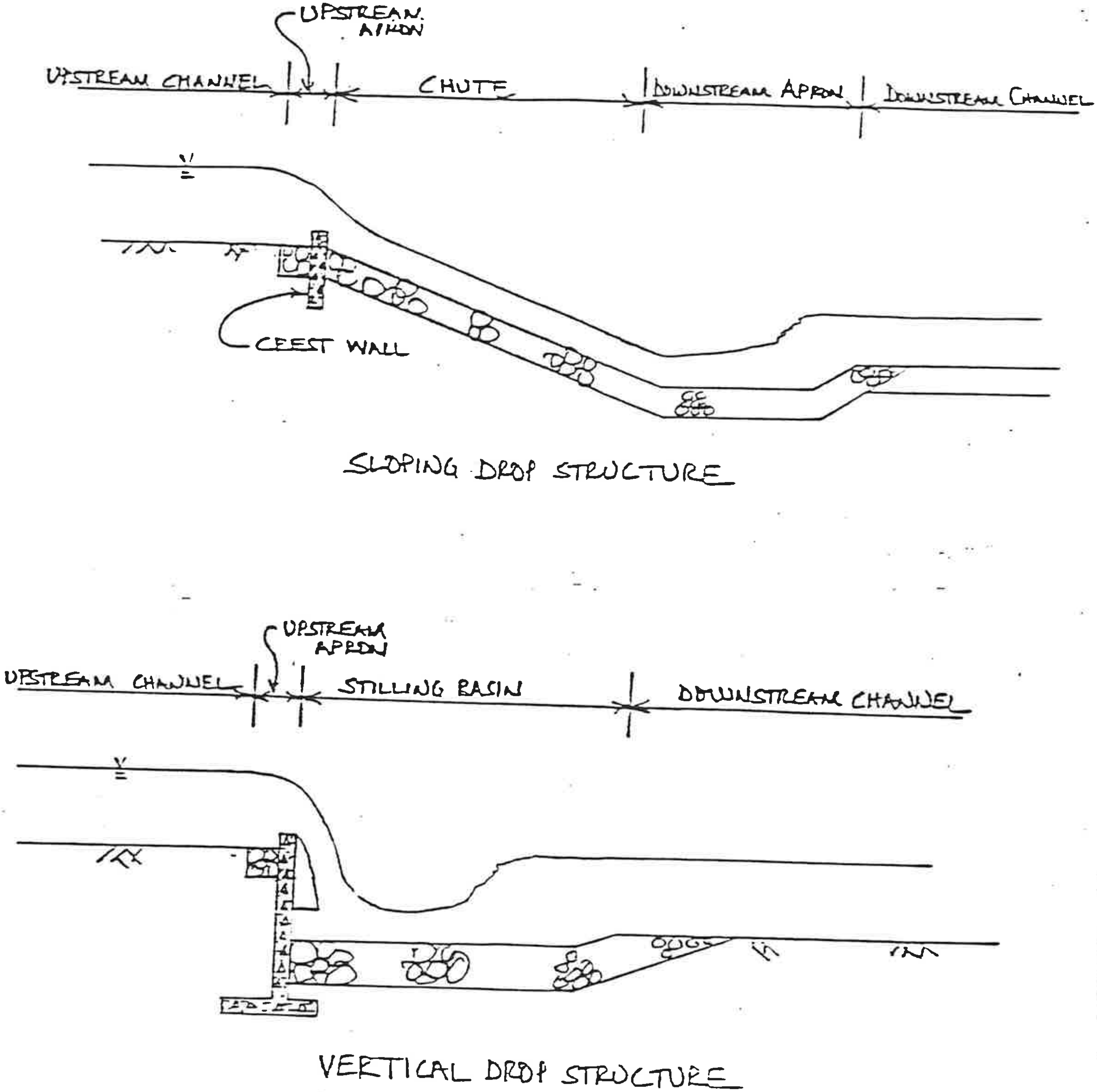
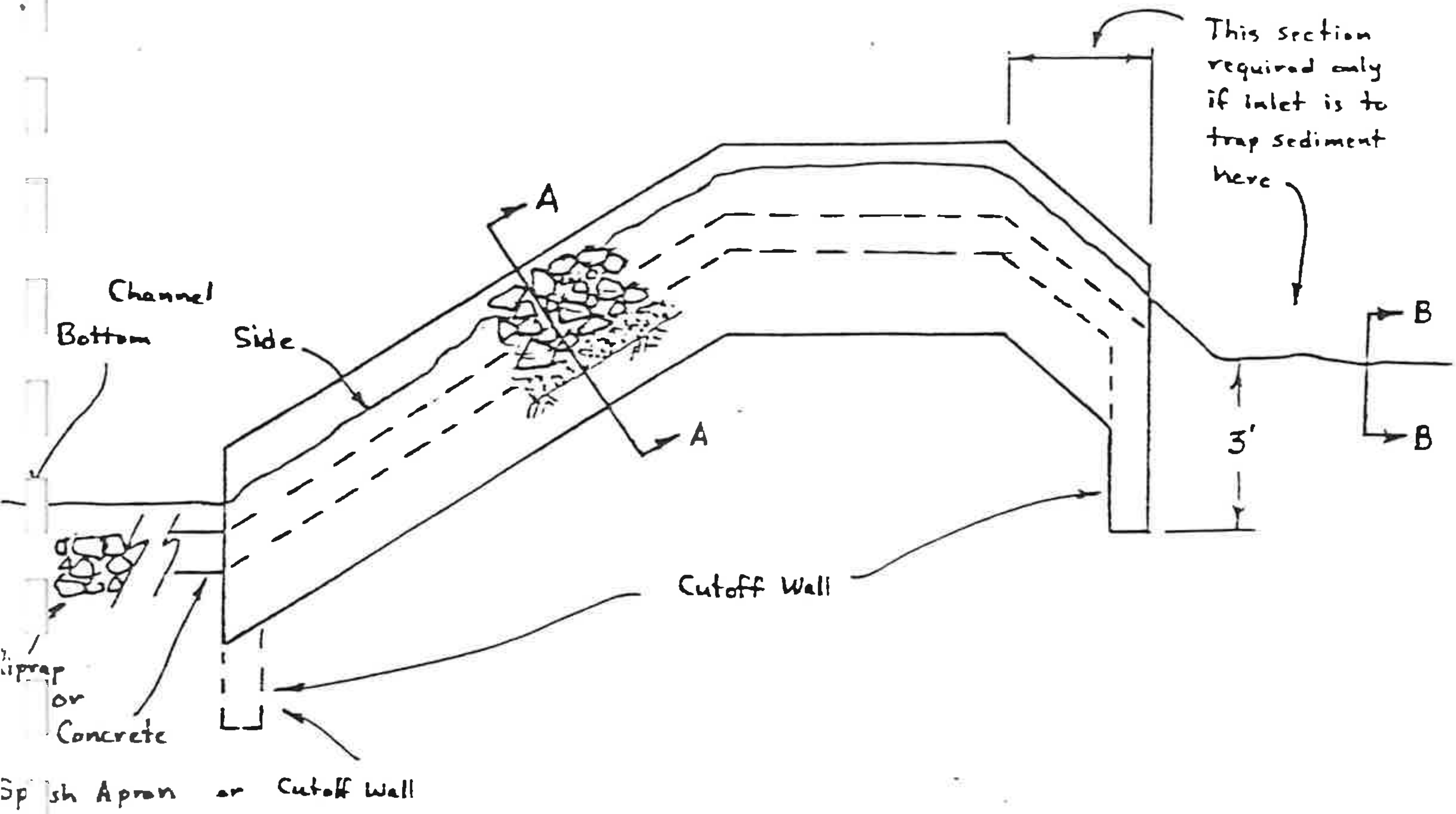
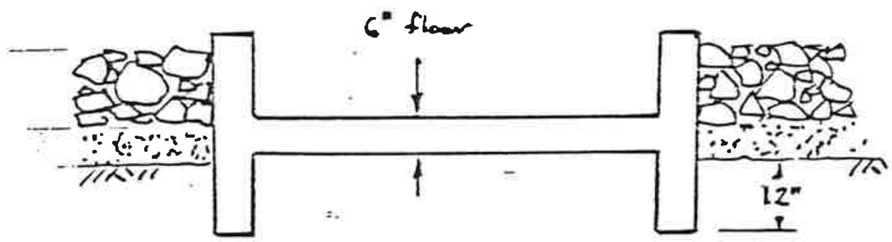


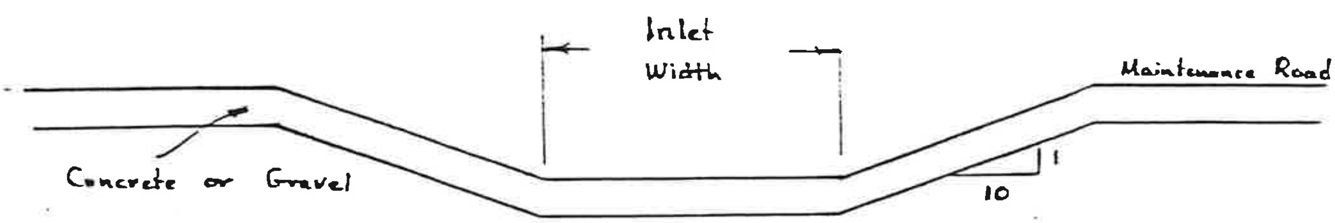
Figure 10. - General Bed Profiles of Riprap Drop Structures
(Adapted from Reference 4K)





Section A-A

Figure 11a. - Concrete Surface Inlet



Section B-B

Figure 11b. - Maintenance Road Drop Inlet Section

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