DESIGN OF EARTH SPILLWAYS

Wisconsin Supplement to engineering Standard for Pond should be followed for the required design storm criteria.

The following tables and charts were developed from information in Technical Release 39 dated May 1968, and issued by the Washington Design Unit. The layout configurations in tables 2 and 3 have been revised from that previously shown in Technical Release 2.

The tables are based on an inlet channel length of 100 feet, 3:1 side slopes, and the configuration as shown in the table. Correction factors, when necessary, are given below the table when the length of the inlet channel is either closer to 50 feet or 150 feet. Manning's roughness coefficient of 0.040 was used for all cases.

The bottom slope of the inlet channel must fit the conditions given for the particular table used. The bottom slope of the outlet channel must fall between the minimum and maximum values given in the table to keep the exit velocities within the limits of 7 feet per second.

V_c values given in the tables are for Hp flow and do not include velocities encountered during freeboard flows. It should also be noted that the V_c and Q_c values are for the average bottom width as shown in the tables.

<u>Example No. 1</u>

Drainage area = 80 acres
Height of dam < 20 feet
Storage (Ac. Ft.) < 50
Principal Spillway Design = 10-year, 24-hour
Emergency Spillway Design = 25-year, 24-hour

Q_{25} = 125 cfs

Examination of the site indicates that a level inlet section-type emergency spillway would fit best. (Refer to figure 1, table 1, chart 1).

<u>From table 1</u>

Hp	=	1.0 ft.	Hp	=	1.5 ft.
Bottom Width	=	90 ft.	Bottom Width	=	40 ft.
Q	=	134 cfs	Q	=	135 cfs

<u>From chart 1</u>

Hp	=	1.0 ft.	Hp	=	1.5 ft.
Q	=	125 cfs	Q	=	125 cfs
Bottom Width	=	83 ft.	Bottom Width	=	37 ft.

A minimum of 1.0-foot freeboard to be added to Hp to get elevation of settled fill.

When Hp = 1.0 ft., the slope of the exit channel shall be between 4 percent and 15 percent. When Hp = 1.5 ft., the slope of the exit channel shall be between 3.5 percent and 10 percent.

Example No. 2

Drainage area = 250 acres
Height of dam = 22 feet
Storage (Ac. Ft.) <50
Principal spillway Design = 10-year, 24-hour
Emergency Spillway Design = 50-year, 24-hour

Q_{50} = 310 cfs

Examination of the site indicates that a sloping inlet channel emergency spillway would fit best. Refer to Figure 2, table 2, and chart 2).

From table 2

Hp	=	1.5 ft.	Hp	=	2.0 ft.
Bottom Width	=	80 ft.	Bottom Width	=	50 ft.
Q	=	320 cfs	Q	=	340 cfs

From chart 2

Hp	=	1.5 ft.	Hp	=	2.0 ft.
Q	=	310 cfs	Q	=	310 cfs
Bottom Width	=	76 ft.	Bottom Width	=	45 ft.

A minimum of 1.0-foot freeboard to be added to Hp to get elevation of settled fill.

When Hp = 1.5 feet, the slope of the exit channel shall be between 3.5 percent and 8 percent. When Hp = 2.0 feet, the slope of the exit channel shall be between 3 percent and 5 percent.

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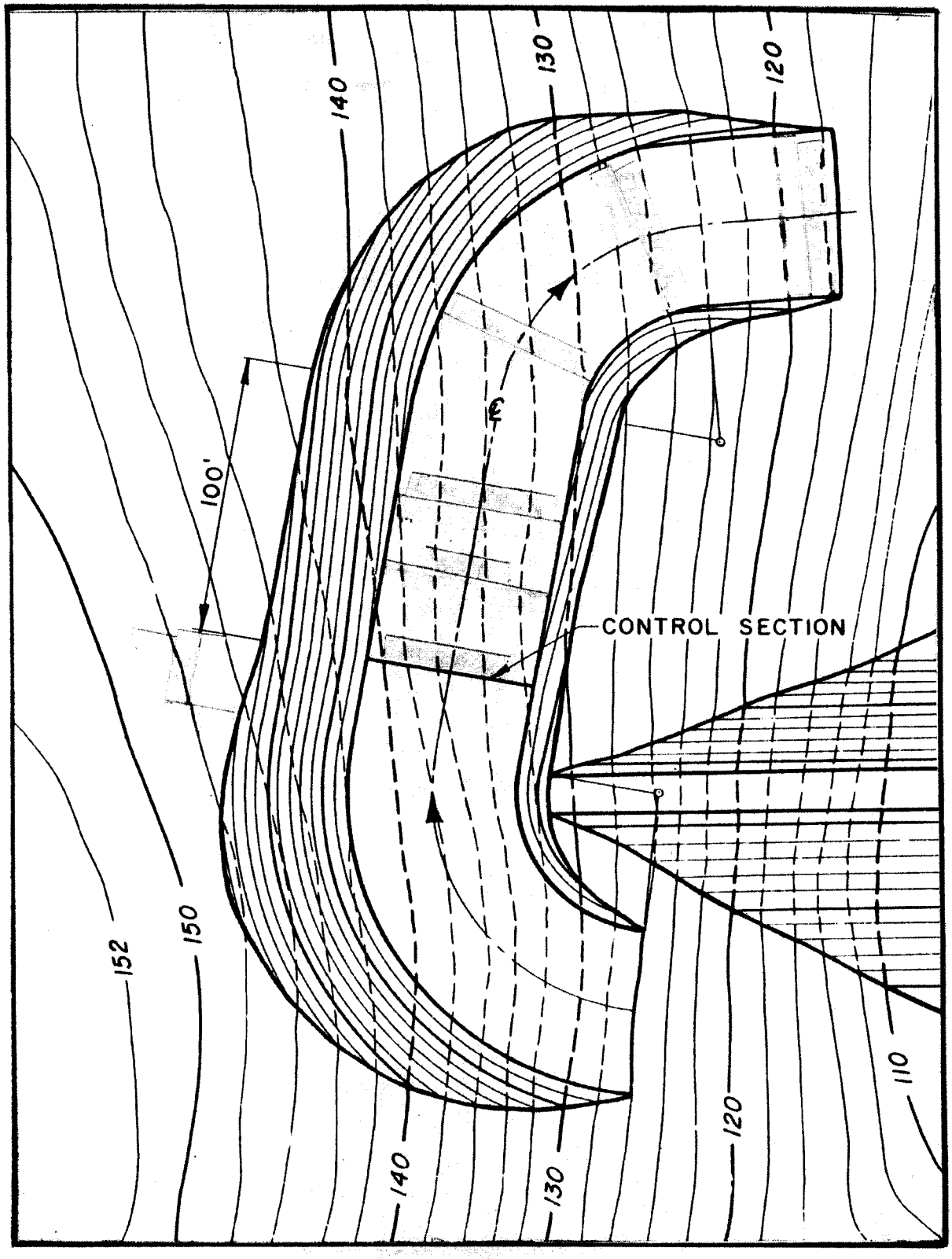
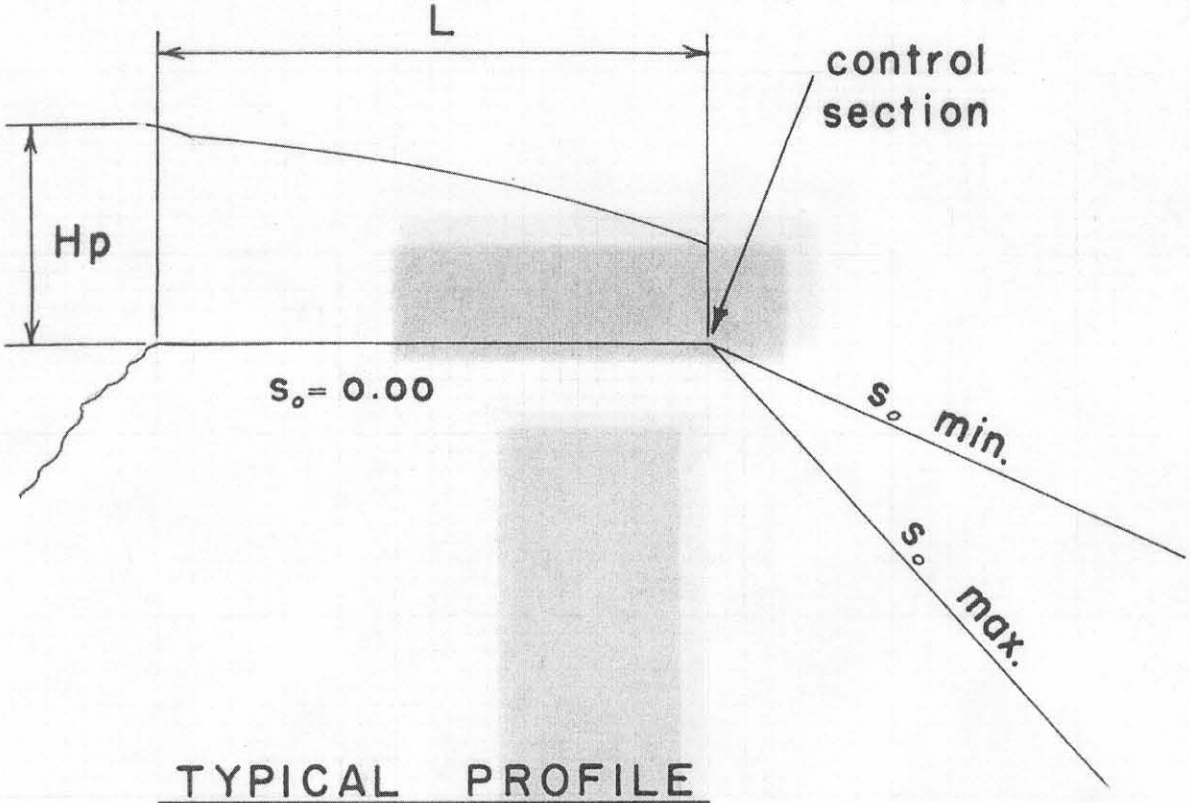
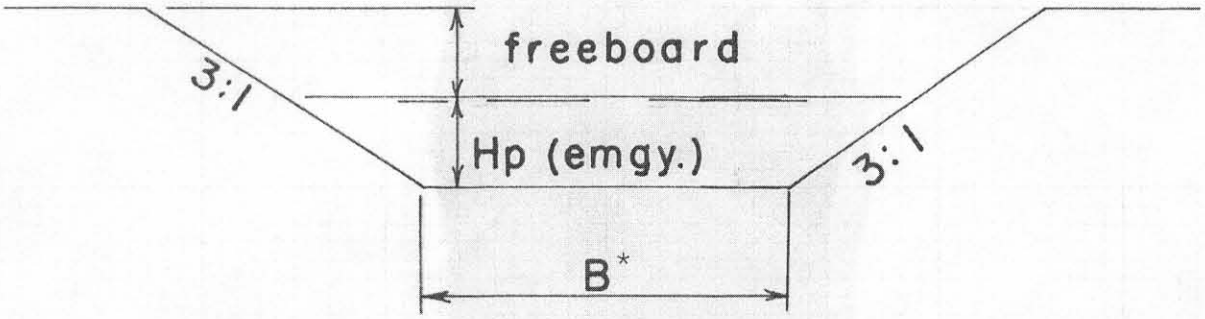
FIGURE 1





TYPICAL PROFILE



TYPICAL CROSS SECTION

* BOTTOM WIDTH ENTIRE LENGTH

TABLE 1

EARTH SPILLWAY DESIGN - LEVEL INLET CHANNEL
3:1 Side Slopes, Based on Technical Release No. 39

L=100 Ft.	Hp=1.0 Ft.	Hp=1.5 Ft.	Hp=2.0 Ft.	Hp=2.5 Ft.*	Hp=3.0 Ft.*
"n" value	0.040	0.040	0.040	0.040	0.040
q_c in c.f.s.	1.5	3.3	5.6	8.4	11.6
v_c in ft/sec.	3.6	4.7	5.6	6.4	7.2
s_o min.	4%	3.5%	3%	3%	3%
s_o max. 1/	15%	10%	5%	3%	3%
Bottom Width in Feet			Q in C.F.S.		
10	17	40	72	118	172
20	31	72	128	200	288
30	46	104	183	285	404
40	61	135	238	370	520
50	75	170	290	454	630
60	90	200	350	540	740
70	105	234	405	625	860
80	120	265	455	710	970
90	134	295	512	790	1080
100	150	325	571	870	1215

Note: Hp value does not include freeboard, except where it pertains to freeboard hydrograph discharge.
If L=50' instead of 100', subtract 0.1' from Hp value.
If L=150' instead of 100', add 0.2' to Hp value.
Minimum slope of exit channel based on 25% of Q value and "n" = 0.040.
1/ S_o max. applies only to Hp (emergency).
Maximum slope of exit channel based on an "n" value = 0.040 and a velocity of 7.0 Ft/sec., not to exceed 15% slope.
If dikes are needed along exit channel to contain flow, a height equal to Hp would be adequate.
Exit channel should be kept straight for 100 ft. if possible.
Curves showing above discharges versus bottom are given in chart 1.
* This column must be used with caution because of high V_c.

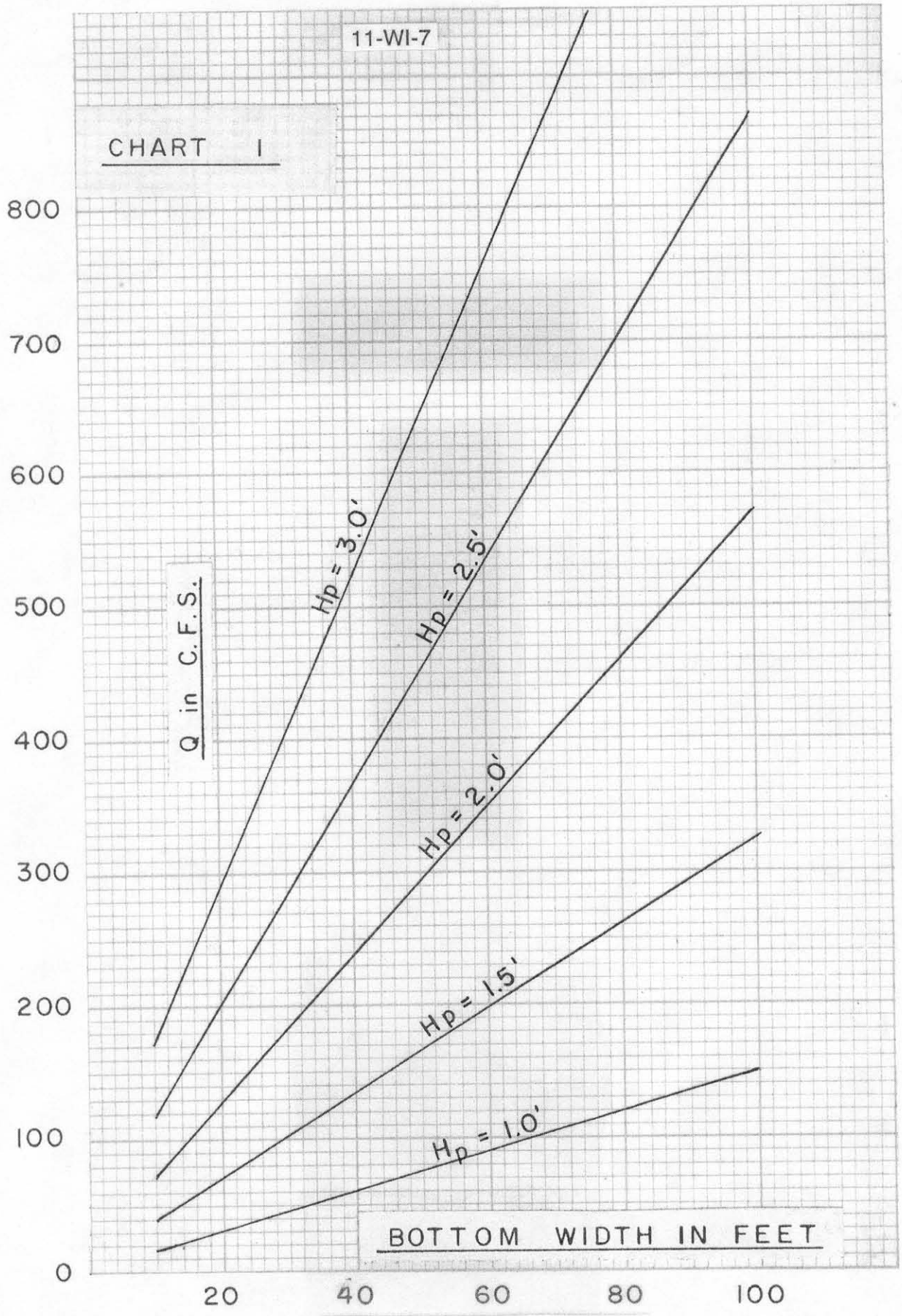
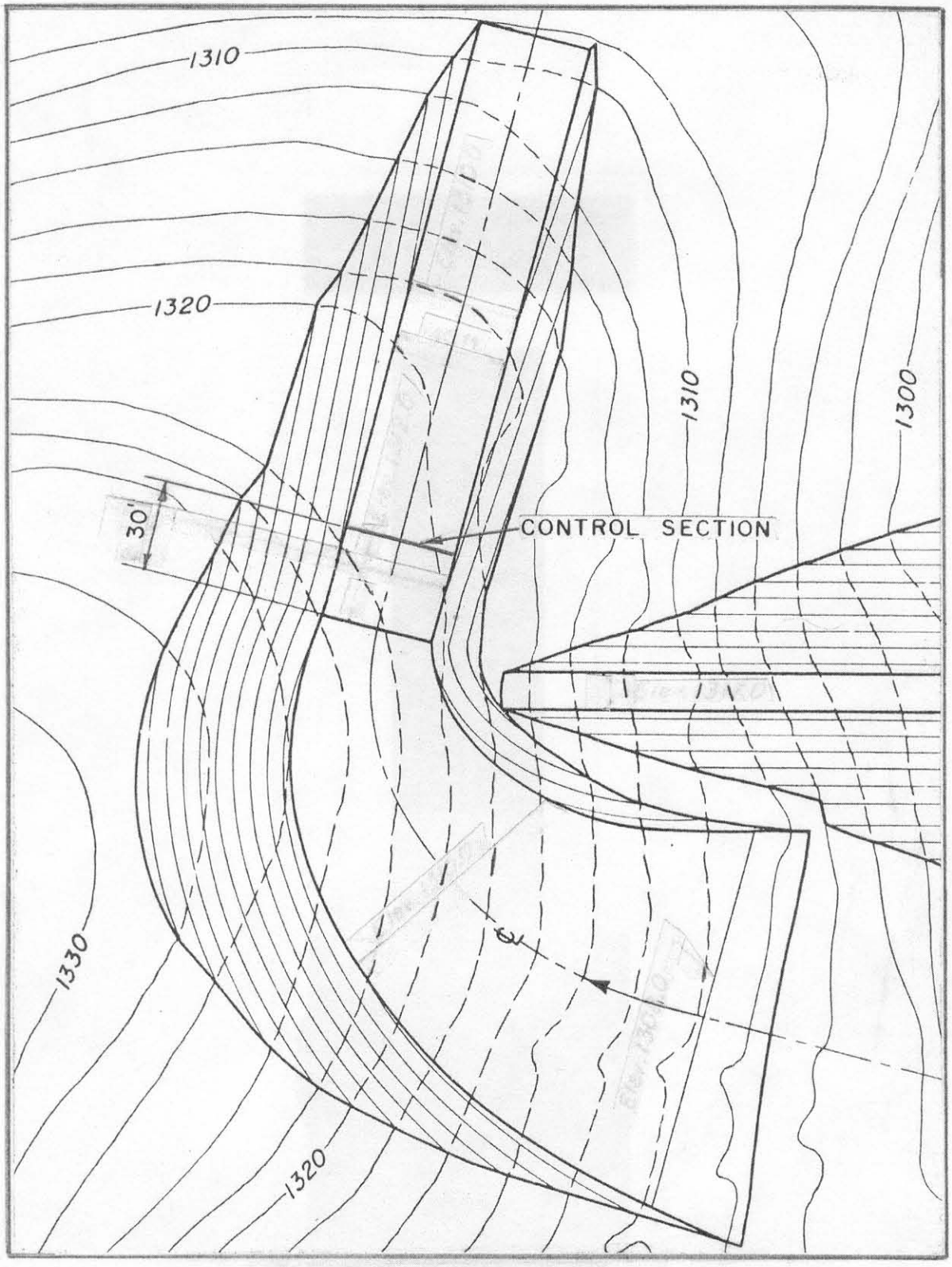
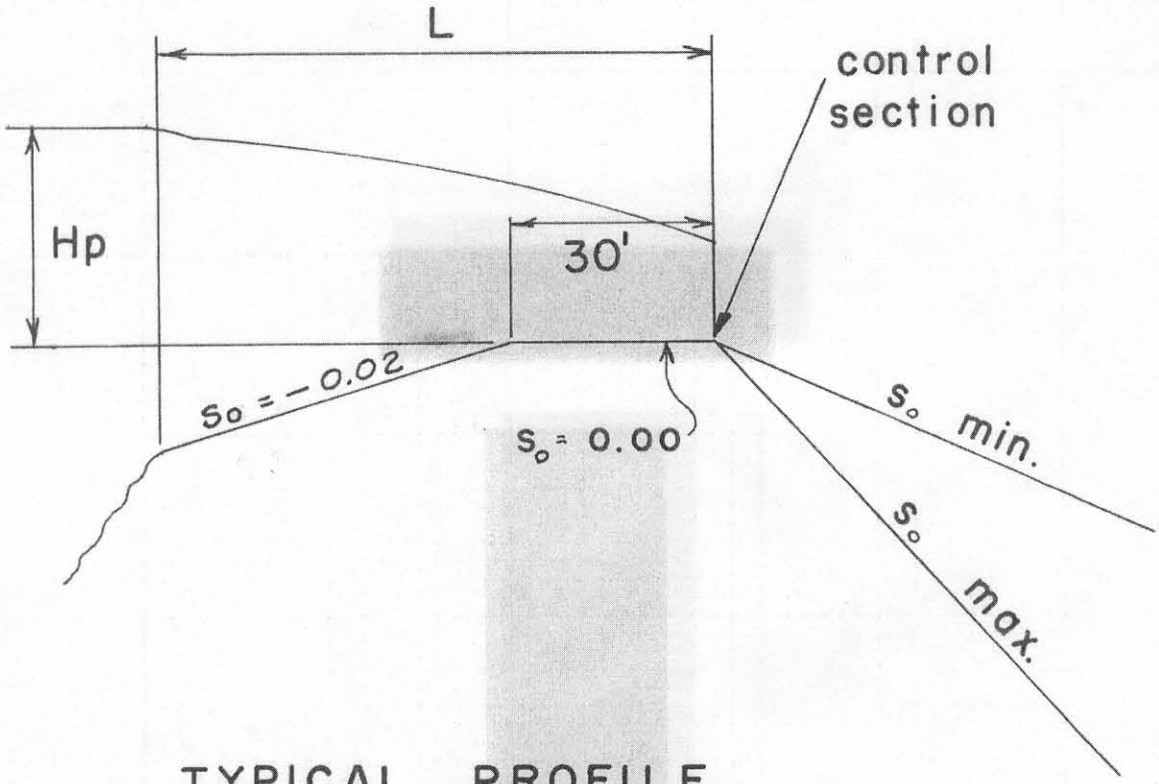
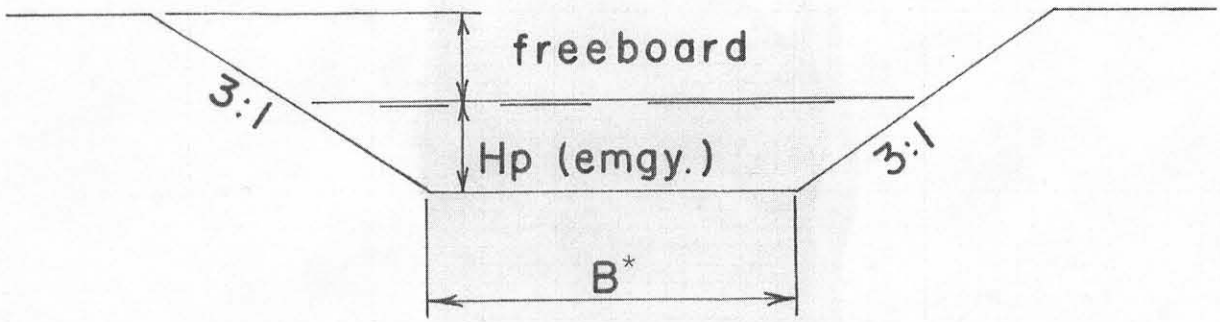

11-WI-7
CHART I
Q in C.F.S.
800
700
600
500
400
300
200
100
0
Hp = 3.0'
Hp = 2.5'
Hp = 2.0'
Hp = 1.5'
Hp = 1.0'
BOTTOM WIDTH IN FEET
20
40
60
80
100

FIGURE 2





TYPICAL PROFILE



TYPICAL CROSS SECTION

* BOTTOM WIDTH AT CONTROL SECTION AND FOR OUTLET CHANNEL

TABLE 2

EARTH SPILLWAY DESIGN - SLOPING INLET CHANNEL
3:1 Side Slopes, Based on Technical Release No. 39

L=100 Ft.	Hp=1.0 Ft.	Hp=1.5 Ft.	Hp=2.0 Ft.	Hp=2.5 Ft.*	Hp=3.0 Ft.*
"n" value	0.040	0.040	0.040	0.040	0.040
q_c in c.f.s.	1.9	3.9	6.4	9.3	12.7
v_c in ft/sec.	3.9	5.0	5.9	6.7	7.4
s_o min.	4%	3.5%	3%	3%	3%
s_o max. 1/	15%	8%	5%	3%	3%
Bottom Width in Feet			Q in C.F.S.		
10	22	49	85	134	196
20	41	87	147	225	320
30	60	126	211	320	450
40	79	165	276	414	573
50	98	203	340	505	700
60	117	242	400	600	825
70	135	281	465	690	955
80	155	320	530	790	1080
90	174	360	590	880	1210
100	192	398	650	970	1340

Note: Hp value does not include freeboard unless it pertains to freeboard hydrograph discharge.
Table based on L=100 ft. Change in Hp insignificant for range of L=50 to 150 ft.
If inlet channel slope is more than 2%, c.f.s. in above table are conservative.
If inlet channel slope is less than 2%, use table 1.
Minimum slope of exit channel based on 25% of Q value and "n" = 0.040
1/ S_o max. applies only to Hp (emergency).
Maximum slope of exit channel based on an "n" value = 0.040 and a velocity of 7.0 Ft./sec., not to exceed 15% slope.
If dikes are needed along exit channel to contain flow, a height equal to Hp would be adequate.
Exit channel should be kept straight for 100 ft. if possible.
Curves showing above discharges versus bottom width are given in chart 2.
*This column must be used with caution because of the high V_c.

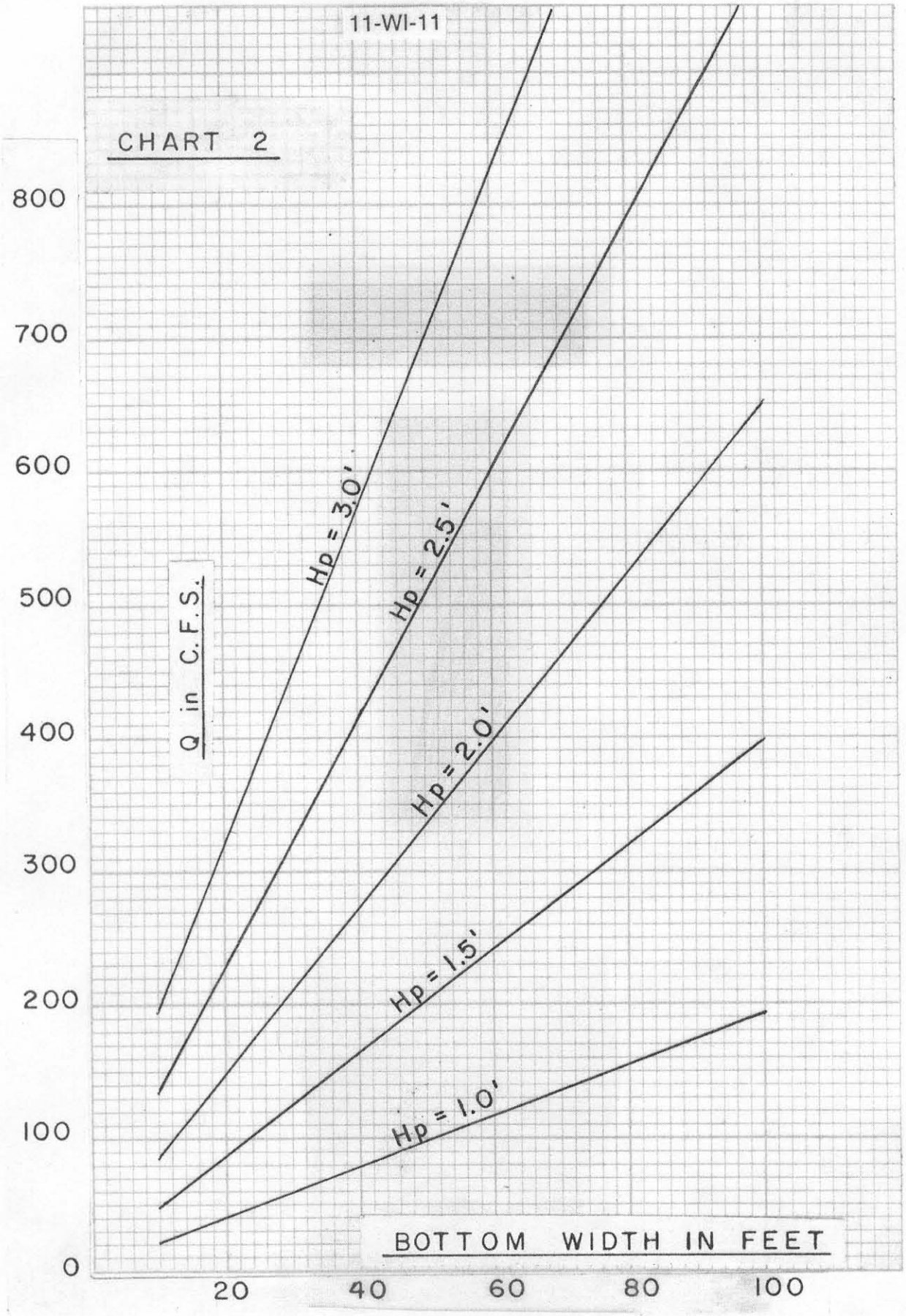
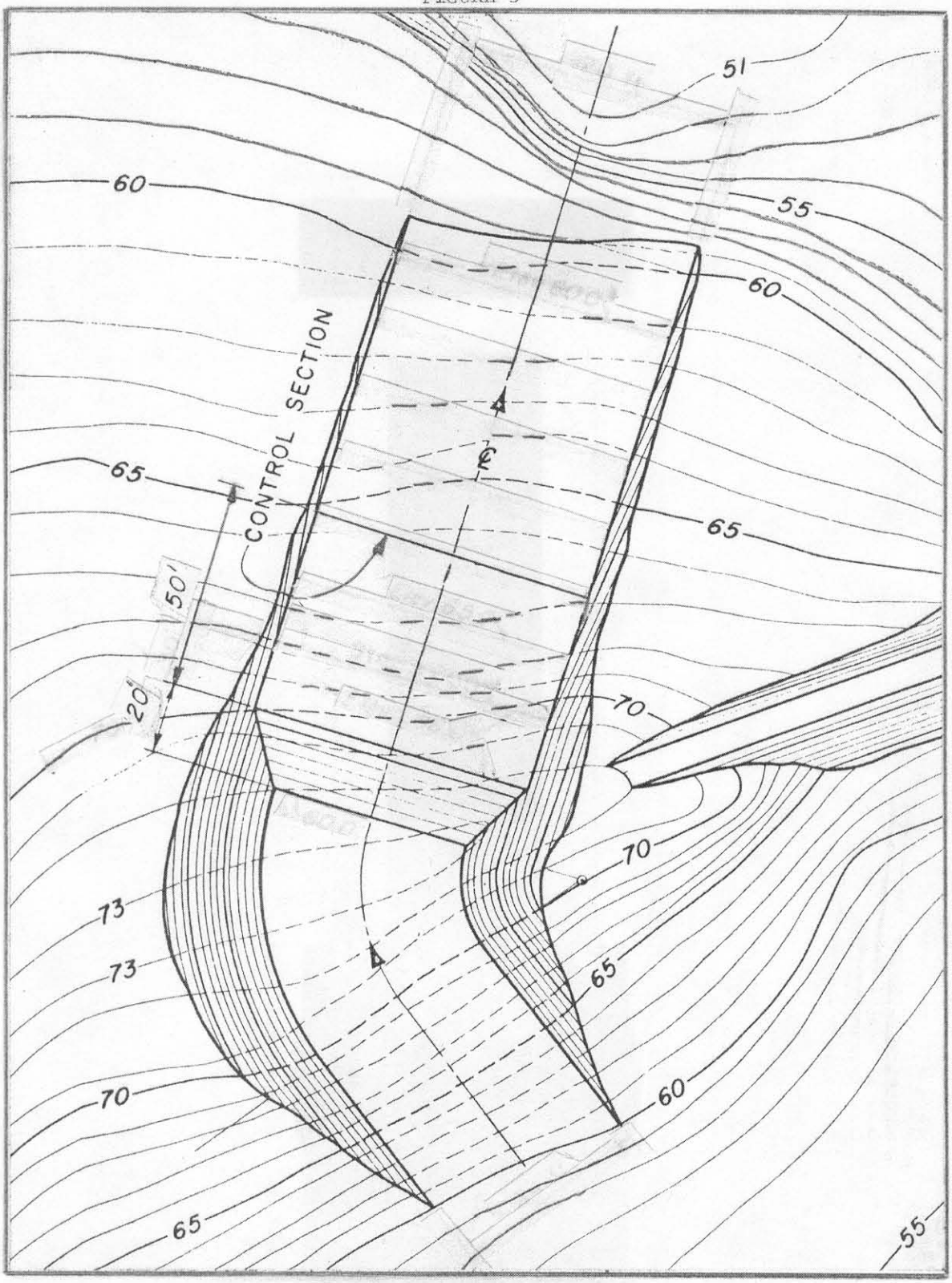
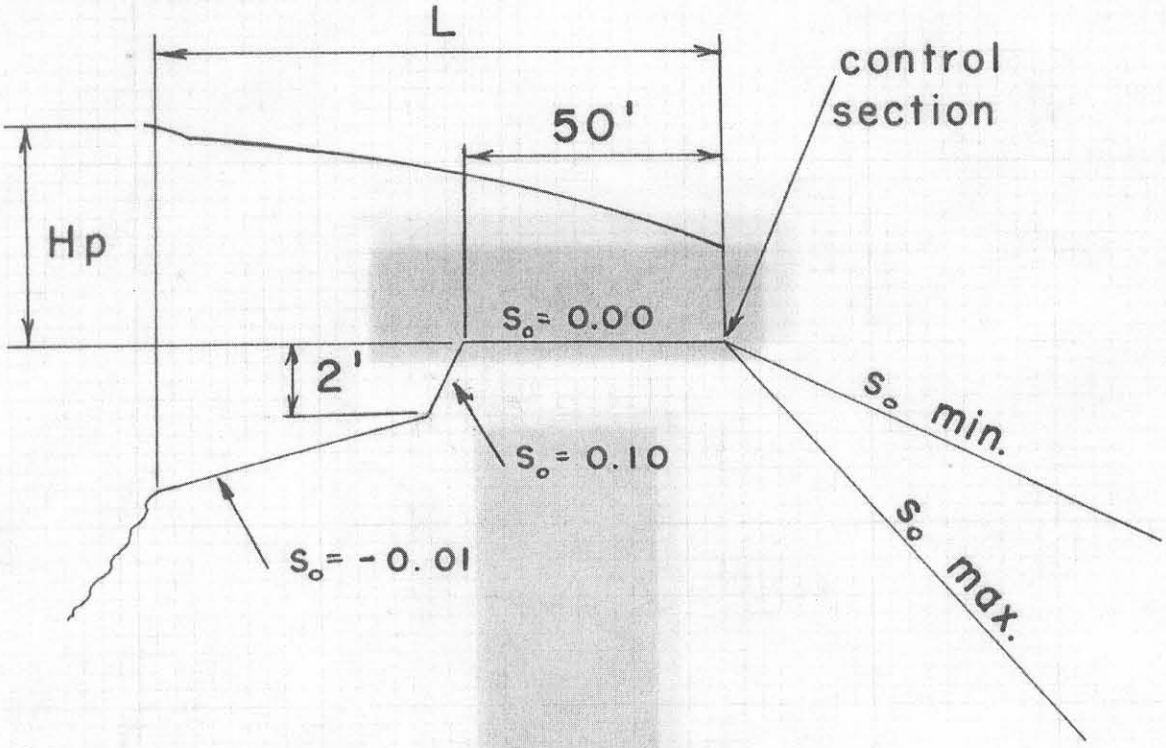
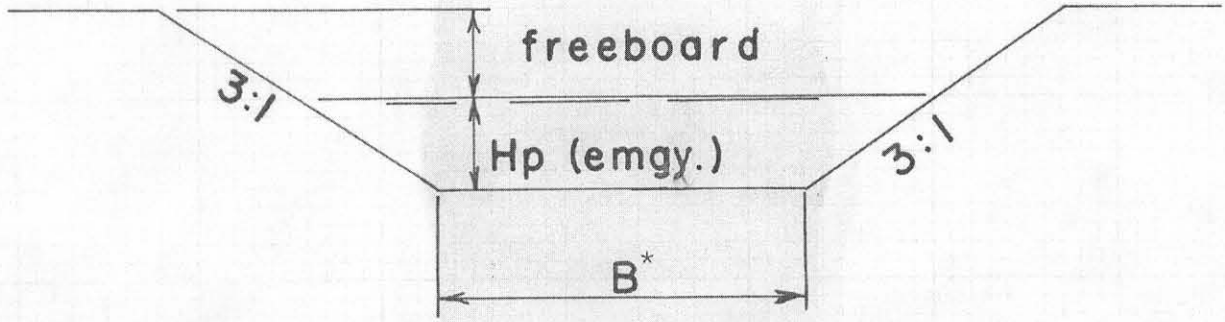

11-WI-11
CHART 2
Q in C.F.S.
800
700
600
500
400
300
200
100
0
Hp = 3.0'
Hp = 2.5'
Hp = 2.0'
Hp = 1.5'
Hp = 1.0'
BOTTOM WIDTH IN FEET
20
40
60
80
100

FIGURE 3





TYPICAL PROFILE



TYPICAL CROSS SECTION

* BOTTOM WIDTH AT CONTROL SECTION AND FOR OUTLET CHANNEL

TABLE 3

EARTH SPILLWAY DESIGN - INLET CHANNEL NO. 3
3:1 Side Slopes, Based on Technical Release No. 39

L=100 Ft.	Hp=1.0 Ft.	Hp=1.5 Ft.	Hp=2.0 Ft.	Hp=2.5 Ft.*	Hp=3.0 Ft.*
"n" value	0.040	0.040	0.040	0.040	0.040
q_c in c.f.s.	1.8	3.8	6.4	9.3	12.7
v_c in ft/sec.	3.9	5.0	5.9	6.7	7.4
s_o min.	4%	3.5%	3%	3%	3%
s_o max. 1/	15%	8%	4%	3%	3%
Bottom Width in Feet			Q in C. F. S.		
10	21	47	85	136	195
20	39	85	147	230	320
30	57	122	210	320	445
40	75	160	275	415	570
50	93	197	340	510	695
60	112	237	400	605	820
70	130	273	465	696	945
80	147	311	530	790	1080
90	166	350	592	885	1200
100	183	385	654	980	1325

Note: Hp value does not include freeboard unless it pertains to freeboard hydrograph discharge.
Table based on L=100 ft. Change in Hp insignificant for range of L=50 to 200 ft.
Minimum slope of exit channel based on 25% of Q value and "n" = 0.040.
1/ S_o max. applies only to Hp (emergency).
Maximum slope of exit channel based on an "n" value = 0.040 and a velocity of 7.0 Ft./sec., not to exceed 15% slope.
If dikes are needed along exit channel to contain flow, a height equal to Hp would be adequate.
Exit channel should be kept straight for 100 ft. if possible.
Curves showing above discharge versus bottom width are given in chart 3.
*This column must be used with caution because of the high V_c.

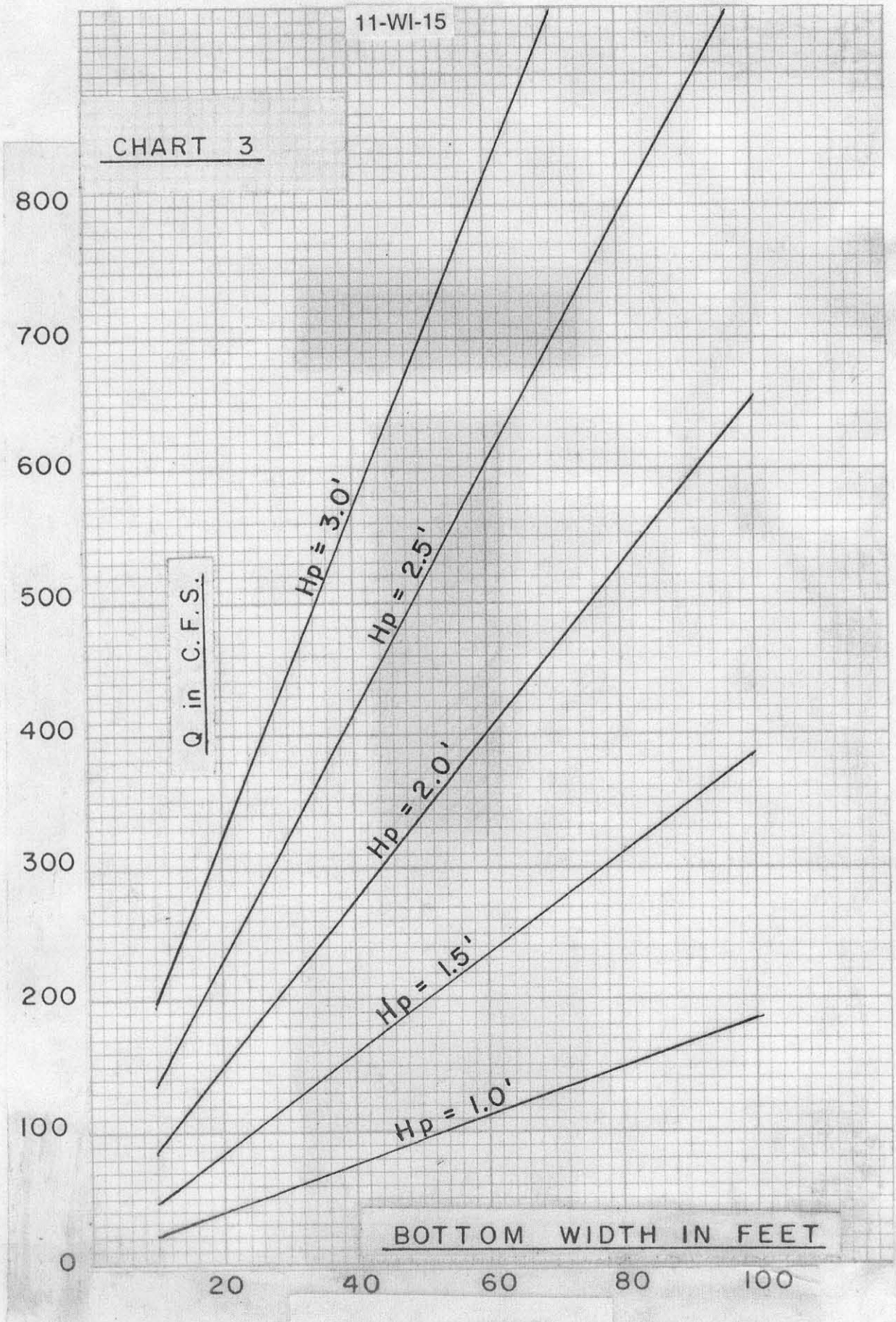


CHART 3
Q in C.F.S.
800
700
600
500
400
300
200
100
0
Hp = 3.0'
Hp = 2.5'
Hp = 2.0'
Hp = 1.5'
Hp = 1.0'
BOTTOM WIDTH IN FEET
20
40
60
80
100

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DAM BREACH STUDY INFORMATION

There are a large number of dams of various sizes in Wisconsin and many of these dams are becoming older and are in need of repair. Zoning restrictions may not exist downstream of many dams. Buildings are being constructed downstream of some dams, which may result in changes in hazard classification. Due to these situations and others, it is often necessary to perform a dam breach study.

It is important to consider the need for a dam breach analysis on any embankment when a new dam (or embankment) is planned, or needs to be repaired. Most dams will not require this analysis due to the small volume of water storage or lack of development downstream from the structure.

A dam breach analysis is required when the Wisconsin Department of Natural Resources (DNR), Chapter NR 333, "Dam Design and Construction Standards" applies to a dam. This Wisconsin Supplement to the Engineering Field Manual Includes some information about Chapter NR 333 and a checklist of information required to do a dam breach study.

NR 333 IS NOT APPLICABLE TO DAMS WITH:[1]

1. A storage capacity[2] of 15 acre-feet or less.

2. A structural height[3] of 6 feet or less.

3. A structural height of more than 6 feet but less than 25 feet and a maximum storage capacity of less than 50 acre-feet.

[1] NR 333 can apply to even these dams, however, if DNR determines that the dam is likely to endanger life, health or property if it is not designed, constructed or reconstructed in accordance with NR 333.

[2] Storage Capacity - the volume of water in acre-feet capable of being stored behind the dam at the maximum water surface elevation before overtopping would occur.

[3] Structural Height - the difference in elevation, in feet, between the lowest elevation of the dam before overtopping and the lowest elevation of the natural streambed at the downstream toe of the dam. Overtopping means the flow of water over parts of a dam which are not part of its spillway system.

Reference: Department of Natural Resources, Chapter NR 333, "Dam Design and Construction Standards"

WHEN NR 333 IS APPLICABLE, THE FOLLOWING NEEDS TO BE DONE:

1. A dam breach analysis is required to determine the hydraulic shadow of the dam (100-year dam breach boundary downstream of the dam).

2. A dam hazard rating is to be determined.

3. A 100-year floodplain is to be determined assuming that the dam does not exist. This requires water surface profile modelling using a model such as WSP2 or HEC-2.

4. A stability analysis may be required for the dam.

5. The above information, along with plans and specifications for construction/reconstruction of the dam and a cost estimate for the construction/reconstruction, is to be sent to DNR by the landowner. DNR's approval is then required prior to construction of a new dam or reconstruction of an existing dam.

CHECKLIST OF INFORMATION REQUIRED FOR DAM BREACH STUDIES:

A. A complete copy of the "As-Built" construction plans including the following information is required. If not available, provide the following information:

1. Cross Section of the embankment at its greatest fill height, including the following:
   a. Elevations of:
      i. Upstream toe of dam
      ii. Downstream toe of dam
      iii. Top of dam
      iv. Top of any upstream or downstream berms
   b. Widths of :
      i. Top of the dam
      ii. Any upstream or downstream berms
   c. Side slopes:
      i. Upstream side slope
      ii. Downstream side slope

2. Principal spillway dimensions required:
   a. Riser dimensions:
      i. Diameter or length and width
      ii. Height
      iii. Crest elevation
   b. Hooded inlet invert elevation at the inlet
   c. Conduit dimensions:
      i. Diameter
      ii. Length
      iii. Invert elevation at the outlet
   d. Conduit material (eg. PVC, CMP or RCP)

3. Emergency spillway dimensions required:
   a. Approach section information:
      i. Length
      ii. Slope
   b. Level section information:
      i. Elevation
      ii. Length
      iii. Bottom width
      iv. Side slopes
   c. Exit section information:
      i. Length
      ii. Slope

4. Minimum elevation of the top of dam (better yet a profile along the top of the dam).

5. Original valley cross section at the dam before construction.

6. Hydrology data required:
   a. Runoff curve number (along with how it was derived)
   b. Drainage area boundary (or at least the location of the dam so that we can delineate the drainage area)
   c. Stage-storage data for the pool to the top of dam as a minimum, including sediment pool and impounded water (need total volume).

B. Surveyed cross section data required downstream of the dam:

1. Locate the cross sections on a map.

2. Give the stationing of the cross sections starting at the centerline of the dam and working downstream.

3. Space the cross sections about 500 to 1000 feet apart.

4. The maximum end elevations for each cross section should be higher than the estimated dam breach elevation at that cross section.

5. Survey a cross section at any tributary.

6. Survey the elevations of any houses possibly within the dam breach boundary.

7. At each cross section, include the following (to determine Manning's "n" values):
   a. Describe the material that makes up the streambed (eg. silt, fine sand, gravel, cobbles).
   b. Describe the material or cover on the streambanks.
   c. Describe the cover in the left and right floodplains separately (eg. woods, brush, crop, pasture, row crop - parallel to the channel or row crop - perpendicular to the channel).

8. Include the following data for any roads crossing the downstream channel:
   a. Culvert information
      i. A profile along the top of the road
      ii. Culvert diameter or width and height
      iii. Conduit length
      iv. Upstream invert elevation
      v. Downstream invert elevation
      vi. Inlet type (ie., projecting, headwall, etc.)
      vii. Culvert material
   b. Bridge information
      i. A profile along the top of the road (include the start and end stations of the bridge opening)
      ii. Plan and cross section sketches of bridge opening (see attached examples)

iii. Dimensions of bridge deck
    a. Length
    b. Width
    c. Thickness
iv. Pier information
    a. Number
    b. Width
    c. Elevation at bottom of pier(s)
    d. Type (ie., circular, rectangular, etc.)
v. Angle of wingwall with road, if applicable
vi. Handrail dimensions

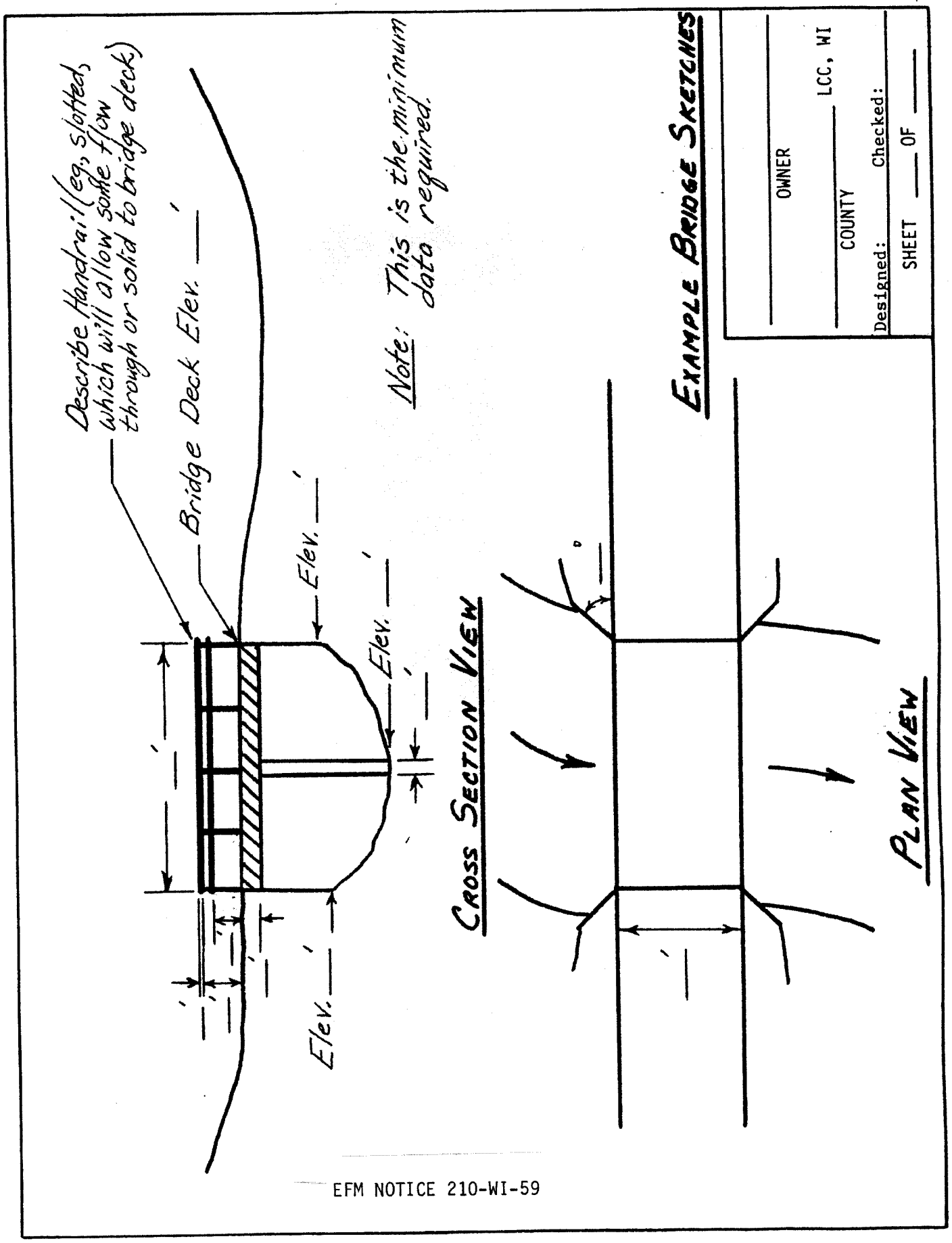
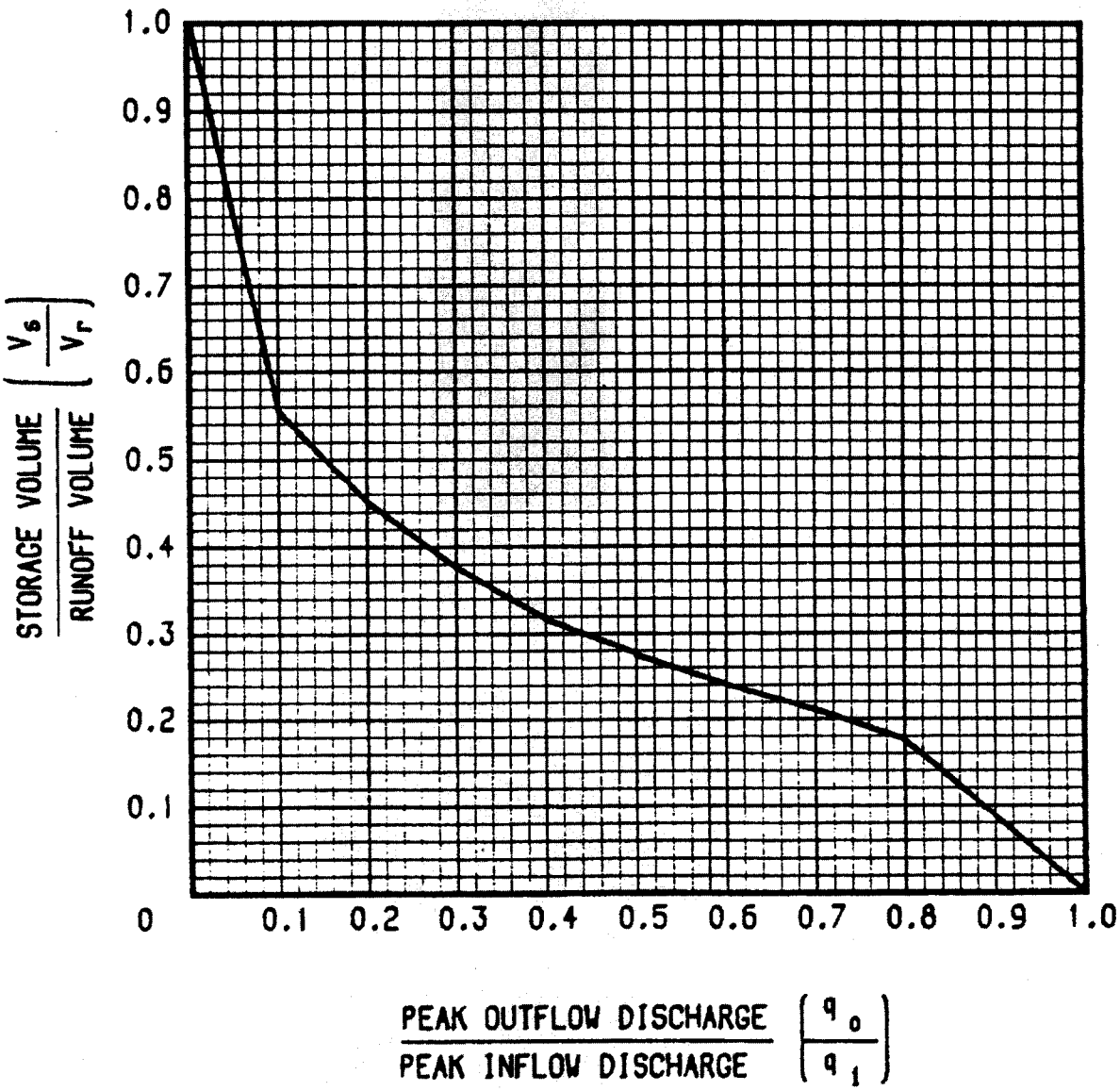

Describe Handrail (eg., slotted, which will allow some flow through or solid to bridge deck)
Bridge Deck Elev. ___'
Note: This is the minimum data required.
Elev. ___'
Elev. ___'
Elev. ___'
Cross Section View
Example Bridge Sketches
Plan View
OWNER
COUNTY
LCC, WI
Designed:
Checked:
SHEET ___ OF ___

Figure WI-1

APPROXIMATE DETENTION BASIN ROUTING
FOR TYPE II STORMS