DESIGN FREQUENCY

Or now that I have flow rates, which one do I pick to size the structure….

MnDOT Guidance

Road Classification	Size	Design Frequency
Entrance Culvert	15″ Minimum	10 year event
All Centerline Pipes	≤ 48″ Minimum Varies[1]	50 year event

Minimum Pipe Sizes

Type of Roadway	Minimum Size
Trunk Highway Centerline	24″
CSAH Centerline	18″
Local Road Centerline	18″
Ramps, Loops and Rest Areas	18″
Side Culverts	15″
Entrances	15″

MnDOT Guidance

Road Classification	Size	Design Frequency
Entrance Culvert	15″ Minimum	10 year event
All Centerline Pipes	≤ 48″ Minimum Varies[1]	50 year event
All Centerline Pipes	> 48″	Use Risk Assessment to Determine the Design Frequency

Risk Assessment

- *"Design of Encroachments on Flood Plains Using Risk Analysis"* HEC 17, Published April 1981
- Encouraged the abolishment of arbitrary design frequencies for all classes of roads
- Utilized the Least Total Expected Cost (LTEC) design process
- LTEC design requires considerable expenditure of resources
- Risk Assessment Form was developed to identify high risk projects that would require an LTEC design
- HEC 17 has been superseded by policy but we still need a risk based procedure that considers regulation constraints.

Selection of Alternative Designs

- 1^{st} Step- Start with a minimum overtopping Flood Frequency based on ADT

Projected ADT	Minimum OT Flood
0-10	2 year
11-49	5 year
50-399	10 year
400-1499	25 year
≥ 1500	50 year

Remember: The design flood can not overtop the roadway

Next Steps and Considerations

- Analyze the in-place condition
- Consider limitations imposed by roadway geometrics
- Clearance for ice and debris
- Navigation considerations
- Flood plain ordinances
- Flood damage potential
- Velocity through the structure
- Environmental concerns

3/21/2012

RISK ASSESSMENT FOR ENCROACHMENT DESIGN Date:

District:__________ County:__________ Vicinity of:__________

DATA REQUIREMENTS Sec.__ T __ R

1. Location of Crossing: Roadway: ________________ C.S.___ M.P.__________
2. Name of Stream: __________ Bridge No. Old: __________ New: __________
3. Current ADT: ________________; Projected ADT: __________
4. Practicable detour available Yes___ No ___

If no is checked, please explain: ___

If there is no practicable detour available, then the use of the road must be analyzed. Considerations such as emergency vehicle access, emergency supply and evacuation route, and the need for school bus, milk and mail routes should be studied. Factors to consider for this analysis include design frequency, depth, duration, and frequency of inundation if appropriate, and available funding.

5. Hydraulic Data: (Fill in as appropriate)
   Approximate Flowline Elevation

Q_2 = __________ HW_2 Elevation__________ TW_2 Elevation__________
Q_5 = __________ HW_5 Elevation__________ TW_5 Elevation__________
Q_{10} = __________ HW_{10} Elevation__________ TW_{10} Elevation__________
Q_{25} = __________ HW_{25} Elevation__________ TW_{25} Elevation__________
Q_{50} = __________ HW_{50} Elevation __________ TW_{50} Elevation__________
Q_{100} = __________ HW_{100} Elevation__________ TW_{100} Elevation__________

Circle Design Frequency:

Reasons for selecting Design Frequency: ____________________

3/21/2012

6. Magnitude and Frequency of the smaller of "Overtopping" or "500 yr." (Greatest) flood: _______

7. Low member elevation____

8. Minimum roadway overflow elevation if appropriate______

9. Elevation of high risk property, i.e. residences ________________________________

Other buildings ____

10. Horizontal location of overflow:

At structure ______________(See 12); Not at structure ______________________________

11. Type of proposed structure:

Bridge ________(See 12); Culvert(s)___________________________________

12. If the proposed structure is a bridge with the sag point located on the bridge and there is ice and debris potential, strong consideration should be given to using Q_{50} as design discharge with 3' of clearance between the 50 year tailwater stage and low member.

1. BACKWATER DAMAGE - Major flood damage in this context refers to shopping centers, hospitals, chemical plants, power plants, housing developments, etc.	LTEC DESIGN
1a. Is the overtopping flood greater than the 100 yr. flood?	
Yes ___(Go to l b.); No ___(Go to 1 e.)	
1b. Is the overtopping flood greater than the "greatest" flood (500 yr. Frequency)?	
Yes ___(Go to l d.); No ___(Go to 1 c.)	
1c. Is there major flood damage potential for the overtopping flood?	
No ___(Go to l e.)	YES (Go to l e.)
1d. Is there major flood damage potential for the greatest flood (500 year frequency)?	
No ___(Go to l e.)	YES (Go to l e.)
1e. Will there be flood damage potential to residence(s) or other buildings during a 100 yr. flood?	
Yes ___(Go to l f.); No ___(Go to 2)	
1f. Could this flood damage occur even if the roadway crossing wasn't there?	
Yes ___(Go to l g.); No ___(Go to 1 h.)	
1g. Could this flood damage be significantly increased by the backwater caused by the proposed crossing?	
Yes ___(Go to l h.); No ___(Go to 2)	
1h. Could the stream crossing be designed in such a manner so as to minimize this potential flood damage?	
Yes ___(Go to 1i.); No ___(Go to 2)	
1i. Does the value of the building(s) and/or its contents have sufficient value to justify further evaluation of risk and potential flood damage?	YES (Go to 2)
No ___(Go to 2)	

2. TRAFFIC RELATED LOSSES

2a. Is the overtopping flood greater than the "greatest" flood (500 yr. frequency)?

Yes ___(Go to 3); No ___(Go to 2 b.)

2b. Does the ADT exceed 50 vehicles per day?

Yes ___(Go to 2 c.); No ___(Go to 3)

2c. Would the (duration of road closure in days) multiplied by the (length of detour minus the length of normal route in miles) exceed 20?

Yes ___(Go to 2 d.); No ___(Go to 3)

2d. Does the annual risk cost for traffic related costs exceed 10% of the annual capital costs?

No ___(Go to 3) (See figures A and B for assistance)

YES (Go to 3)

3. ROADWAY AND/OR STRUCTURE REPAIR COSTS

3a. Is the overtopping flood less than a 100 year frequency flood?

Yes ___(Go to 3 b.); No ___(Go to 3 i.)

3b. Compare the Tailwater (TW) elevation with the roadway sag point elevation for the overtopping flood. Check the appropriate category.

___When TW is above the sag point (Go to 4)

__When TW is between 0 and 0.5' below sag point (Go to 3 c.)

__When TW is between 0.5' and 1.0' below sag point (Go to 3 d.)

__When TW is 1.0' and 2.0' below sag point (Go to 3 e.)

__When TW is more than 2.0' below sag point (Go to 3 g.)

3c. Does the embankment have a good erosion resistant vegetative cover?

Yes ___(Go to 3 i.); No ___(Go to 3 d.)

3d. Is the shoulder constructed from erosion resistant material such as paved, coarse gravel, or clay type soil?

Yes ___(Go to 3 i.); No ___(Go to 3 e.)

3e. Will the duration of overtopping for the 25-year flood exceed 1 hour?

Yes ___(Go to 3 f.); No ___(Go to 3 i.)

3f. Is the embankment constructed from erosion resistant material such as a clay type soil?

Yes ___(Go to 3 i.); No ___(Go to 3 g.)

3g. Is the overtopping flood less than a 25-year frequency flood?

Yes ___(Go to 3 h.); No ___(Go to 3 i.)

3h. Will the cost of protecting the roadway and/or embankment from severe damage caused by overtopping exceed the cost of providing additional culvert or bridge capacity?

No ___(Go to 3 i.);

YES (Go to 3 i.)

3i. Is there damage potential to the structure caused by scour, ice, debris or other means during the lesser of the overtopping flood or the 100 year flood?

Yes ___(Go to 3 j.); No ___(Go to 4)

3j. Will the cost of protecting the structure from damage exceed the cost of providing additional culvert or bridge water capacity?

No ___(Go to 4);

YES (Go to 4)

3/21/2012

4. Will the capital cost of the structure exceed $1,000,000?

No ___(Go to 5);

YES (Go to 5)

5. In your opinion, are there any other factors that you feel should require further study through a risk analysis?

No ___(Go to 6);

YES (Indicate)

6. If there are no √'s in the LTEC Design column on the right, proceed with the design, selecting the lowest acceptable grade line and the smallest waterway opening consistent with the constraints imposed on the project. The risk assessment has demonstrated that potential flood damage costs, traffic related costs, roadway and/or structure repair costs are minor and therefore disregarded for this project.

One or more √'s in the LTEC Design column indicates further analysis in the category checked may be required utilizing the LTEC design process or justification (below) why it is not required.

JUSTIFICATION: ______________________

Form is signed by a Professional Engineer Licensed in the State of Minnesota

3/21/2012

3/21/2012

DESIGN FREQUENCY

Design frequency should be selected commensurate with cost of the facility, amount of traffic, potential flood hazard to property, expected level of service, political considerations, and budgetary constraints as well as the magnitude and risk associated with damages from larger flood events. When long highway routes having no practical detour, where many sites are subject to independent flood events, it may be necessary to increase the design frequency at each site to avoid frequent route interruptions from floods. Consideration should be given to what frequency flood was used to design other structures along a highway corridor.

It is not economically feasible to design highway structures for the maximum runoff that a watershed is capable of producing. Therefore, a design frequency must be established. The design frequency for a given flood is defined as the reciprocal of the probability that a flood flow will be exceeded in a given year. The frequency is analogous to the recurrence interval. A 50-year recurrence interval means that every year there is a 2% chance that a 50-year flood will occur at a given point, and it could conceivably occur in several consecutive years. Over a long period of time, the 50-year flood will be equaled or exceeded on the average of once every fifty years.

While drainage structures are designed to operate for a given design frequency, performance should be checked for the review frequency. After sizing a drainage facility to pass a peak flood or the hydrograph corresponding to the design frequency, it may be necessary to review this proposed facility considering a larger discharge to insure that there are no unexpected flood hazards inherent in the proposed facility(ies). Potential impacts to consider include possible flood damage due to high embankments where overtopping is not practical and backups due to the presence of noise walls. The flood damage potential due to bridges and major culverts (greater than 48") should be reviewed for the 100 year frequency. The scour potential for bridge substructures should be reviewed for the 500 year frequency or overtopping event.

Design Frequency Policy
The design frequency used to design a hydraulic structure is determined by the type, size, and location of the structure. Design frequency for inlets and storm sewers is based on the allowable spread on the roadway. Minor culverts (48" or less in diameter) shall be designed using a 50 year frequency. Major culverts (larger than 48" in diameter) and bridges require completion of a Risk Assessment Form (Appendix A) to determine the appropriate design frequency.

Bridges and Centerline Culverts

For all bridges over waterways, and for major centerline culverts (larger than 48"), a risk assessment shall be completed. Instead of arbitrary design frequencies, the risk assessment procedure takes into consideration capital costs and risks, and other economic, engineering, social, and environmental concerns. The risk assessment is based on the:

- the overtopping flood or the base flood, whichever is greater , or
- the greatest flood which must flow through the highway drainage structure where overtopping is not practicable. This is considered to be a 500-year frequency flood. If flood frequency data is not available, use 1.7 x 100 year flood.

Table 3.1 gives the guidelines for the recommended minimum overtopping flood criteria which should be used for a risk assessment. The risk assessment procedure is difficult to apply to small culverts. Consequently, a formal risk assessment or analysis will ordinarily not be required for minor culverts (48 in. diameter or less) unless there is significant flood damage potential. The design frequency for minor centerline culverts shall be a minimum of 50 year frequency. A copy of the risk assessment form and other information is provided in Appendix A.

Table 3.1 Minimum Overtopping Flood Frequency for Risk Assessment

PROJECTED ADT	MINIMUM OVERTOPPING FLOOD FREQUENCY
0 - 10	2 year
11 - 49	5 year
50 - 399	10 year
400 - 1499	25 year
1500 and up	50 year

Entrance Culverts

Entrance culverts shall be a minimum of 15" in diameter. They should be designed for a 10 year frequency and an overtopping area should be provided.

Risk Assessment:

When designing structures, the following is guidance from our Drainage Manual:

Road Classification	Size	Design Frequency
Entrance Culvert	15” minimum	10 year event
All Centerline Pipes	≤ 48” minimum varies[1]	50 year event
All Centerline Pipes	> 48”	Use Risk Assessment to determine Frequency

[1]Minimum Pipe Sizes:

Type of Road	Minimum Size
Trunk Highway Centerline	24”
CSAH Centerline	18”
Local Roads Centerline	18”
Ramps, Loops and Rest Areas	18”
Side Culverts	15”
Entrances	15”

For the first attempt at sizing the pipe, consider the following guidelines:

Projected ADT	Minimum Overtopping Flood Frequency
0-10	2 year
11-49	5 year
50-399	10 year
400-1499	25 year
1500 and up	50 year

Consider the risk this design creates and adjust as appropriate. The table above will give you the minimum design flood to be used. Remember, by definition the design flood can not overtop the roadway. Use the Risk Assessment Form to document the risk considerations. Redesign, if necessary.

Other considerations are as follows:

1. Limitations imposed by roadway geometrics such as maximum or minimum grade lines, site distance, vertical curvature, etc.
2. Limitations imposed by inplace road grade.
3. Clearance requirements for ice and debris.
4. Overtopping frequency of the adjoining roadway. In particular, that section of roadway involving the same watershed under consideration.
5. Topographical features such as stream levees, elevation of the watershed divide and clearances for highways or railroads which are bridged.
6. Navigation clearance requirements.
7. Floodplain ordinances or other legislative mandates limiting allowable backwater or encroachment on the flood plain.
8. Channel stability considerations which would limit velocity or the amount of constriction.
9. Ecological considerations such as wetlands, sensitive environments or aquatic organism passage.
10. Social considerations including the importance of the facility as an emergency evacuation route in time of peril
11. Availability of funds to construct the facility. (This item may or may not be a consideration in a first appraisal but could ultimately govern the design selection).

THE DESIGN OF ENCROACHMENTS
ON FLOOD PLAINS
USING RISK ASSESSMENT AND/OR ANALYSIS

David V. Halvorson, P.E.
Hydraulics Engineer
Minnesota Department of Transportation

INTRODUCTION

The traditional concept of design frequency has been changed with the advent of FHPM 6.7.3.2 "Location and Hydraulic Design of Encroachments on Flood Plains". The FHPM does not specify a minimum design flood for any roads except Interstate Highways. The intent of the FHPM is to encourage the abolishment of arbitrary design frequencies such as the 50 year frequency for all classes of roads. Instead, the design selected for an encroachment should be supported by analyses of design alternatives with consideration given to capital costs and risks, and to other economic, engineering, social, and environmental concerns.

Consideration of capital costs and risks should include, as appropriate, a risk analysis or assessment which includes: (a) the overtopping flood or the base flood, whichever is greater, or (b) the greatest flood which must flow through the highway drainage structure(s) where overtopping is not practicable. The greatest flood used in the analysis is subject to state-of-the-art capability to estimate the exceedance probability.

The design of flood plain encroachments should include an evaluation of the inherent flood related risks to the highway facility and to the surrounding property. When this evaluation (risk assessment) indicates that the risk warrants additional study, a detailed analysis of alternative designs (risk analysis) is necessary in order to determine that design with the least total expected cost (LTEC) to the public. The LTEC design process is basically one of optimization, where economic and engineering analyses of alternative designs provide the basis for decision making.

All quantifiable losses are included in the risk analysis. These may include damage to structures, embankments, surrounding property, traffic related losses and scour or stream channel damage. The product of the risk analysis is the annual economic risk associated with each design strategy. The sum of the annual economic risk and the annual capital costs results in the total expected cost (TEC) for each design strategy. Comparison of the TEC's for all design strategies allows the designer to select the LTEC or optimum design.

The LTEC design process requires considerable expenditure of resources. Therefore, the level of analysis should be commensurate with the economic risks involved. On the bottom of the risk scale, encroachments which have little or no risk associated with them can be designed using appropriate hydraulic procedures. High risk encroachments which create large economic risks should be designed using the techniques described in "The Design of Encroachments on Flood Plains Using Risk Analysis" Hydraulic Engineering Circular No. 17. Copies of this circular can be obtained by writing to:

Mr. Philip Thompson
Hydraulics Branch, HNG-31
Federal Highway Administration
Washington, D.C. 20590

Mn/DOT has developed a risk assessment procedure which is an attempt to screen the projects and determine the level of analysis required. The procedure consists of a "data requirements" sheet and a questionnaire. All questions do not have to be answered. Start with the first question and follow directions from thereon.

The purpose of the questionnaire is to determine if a risk analysis is required. It is not a comprehensive design check list nor should it replace good engineering judgement.

SELECTION OF ALTERNATIVE DESIGNS

The first step in the selection process is to determine the range of practicable design alternatives. Frequently, there will be a number of constraints both engineering and non-engineering which may limit the available alternatives at a site. If the structure under consideration is a replacement structure, perhaps a good starting point is computing the hydraulic data for the inplace structure and performing a risk assessment on it. This will frequently, but not always, be the smallest structure which can be considered.

In order to assist the engineer in selecting a design frequency and insure some degree of uniformity around the state, Mn/DOT has established guidelines for selecting a minimum design frequency which is tied to the projected average daily traffic (ADT) of the roadway under consideration. This minimum design frequency is not absolute but perhaps a good starting place. Remember, by definition the design flood can not overtop the roadway. The minimum design frequency - ADT guidelines as well as a number of other constraints which may limit the design are as follows: (See next page)

GUIDELINES/CONSTRAINTS WHICH MAY LIMIT SELECTION OF DESIGN FREQUENCY

1. Recommended minimum overtopping flood criteria:

Projected ADT	<u>Minimum</u> Overtopping Flood Frequency
0-10	2 yr.
11-49	5 yr.
50-399	10 yr.
400-1499	25 yr.
1500 and up	50 yr.

2. Limitations imposed by roadway geometrics such as maximum or minimum grade lines, site distance, vertical curvature, etc.

3. Limitations imposed by inplace road grade.

4. Clearance requirements for ice and debris.

5. Overtopping frequency of the adjoining roadway. In particular, that section of roadway involving the same watershed under consideration.

6. Topographical features such as stream levees, elevation of the watershed divide, and clearances for highways or railroads which are bridged.

7. Navigation clearance requirements.

8. Flood plain ordinances or other legislative mandates limiting allowable backwater or encroachment on the flood plain.

9. Channel stability considerations which would limit velocity or the amount of constriction.

10. Ecological considerations such as may exist with wetlands or in other sensitive environments.

11. Geological or geomorphic conditions or constraints including subsurface conditions.

12. Social considerations including the importance of the facility as an emergency evacuation route in time of peril.

13. Availability of funds to construct the facility. (This item may or may not be a consideration in a first appraisal but could ultimately govern the design selection).

RISK ASSESSMENT FOR ENCROACHMENT DESIGN

Date: 2/6/2012

District: ______ County: ____________________ Vicinity of: ____________________

DATA REQUIREMENTS

1. Location of Crossing: ____________ C.S. ____________ M.P. ____________

   Sec. ________ T ____________ R ____________

2. Name of Stream: ____________________ Bridge No. Old: ____________ New: ________

3. Current ADT: ____________________ Projected ADT: ____________________

4. Practicable detour available ☐ Yes ☐ No

If no is checked, please explain: ____

If there is no practicable detour available, then the use of the road must be analyzed. Considerations such as emergency vehicle access, emergency supply and evacuation route, and the need for school bus, milk and mail routes should be studied. Factors to consider for this analysis include design frequency, depth, duration, and frequency of inundation if appropriate, and available funding.

5. Hydraulic Data: (Fill in as appropriate)

   Elevation Datum: ______

Q_2 =	________	cfs	HW_2 Elevation	________	ft	TW_2 Elevation	________	ft
Q_5 =	________	cfs	HW_5 Elevation	________	ft	TW_5 Elevation	________	ft
Q_{10} =	________	cfs	HW_{10} Elevation	________	ft	TW_{10} Elevation	________	ft
Q_{25} =	________	cfs	HW_{25} Elevation	________	ft	TW_{25} Elevation	________	ft
Q_{50} =	________	cfs	HW_{50} Elevation	________	ft	TW_{50} Elevation	________	ft
Q_{100} =	________	cfs	HW_{100} Elevation	________	ft	TW_{100} Elevation	________	ft
Q_{500} =		cfs	HW_{500} Elevation		ft	TW_{500} Elevation		ft

Approximate Flowline Elevation: ________ Ft

Design Frequency Event: ☐ 100-yr ☐ 50-yr ☐ 25-yr ☐ 10-yr

Reasons for selecting Design Frequency: ____

6. Magnitude and Frequency of the smaller of "Overtopping" or "500 yr." (Greatest) flood: ____________

7. Low member elevation: ____

8. Minimum roadway overflow elevation if appropriate: ____________________________

9. Elevation of high risk property, i.e. residences: ____________________________

   Other buildings ____

10. Horizontal location of overflow:

    ☐ At Structure (See 12) ☐ Not At Structure:

11. Type of proposed structure:

    ☐ Bridge (See 12) ☐ Culvert(s)

12	If the proposed structure is a bridge with the sag point located on the bridge and there is ice and debris potential, strong consideration should be given to using Q_{50} as design discharge with 3' of clearance between the 50 year tailwater stage and low member.

	LTEC Design
1. BACKWATER DAMAGE - Major flood damage in this context refers to shopping centers, hospitals, chemical plants, power plants, housing developments, etc.	
1a. Is the overtopping flood greater than the 100 yr. flood? ☐ Yes (Go to 1b) ☐ No (Go to 1e)	
1b. Is the overtopping flood greater than the "greatest" flood (500 yr. Frequency)? ☐ Yes (Go to 1d) ☐ No (Go to 1c)	
1c. Is there major flood damage potential for the overtopping flood? ☐ No (Go to 1e)	☐ Yes (Go to 1e)
1d. Is there major flood damage potential for the greatest flood (500 year frequency)? ☐ No (Go to 1e)	☐ Yes (Go to 1e)
1e. Will there be flood damage potential to residence(s) or other buildings during a 100 yr. flood? ☐ Yes (Go to 1f) ☐ No (Go to 2)	
1f. Could this flood damage occur even if the roadway crossing wasn't there? ☐ Yes (Go to 1g) ☐ No (Go to 1h)	
1g. Could this flood damage be significantly increased by the backwater caused by the proposed crossing? ☐ Yes (Go to 1h) ☐ No (Go to 2)	
1h. Could the stream crossing be designed in such a manner so as to minimize this potential flood damage? ☐ Yes (Go to 1i) ☐ No (Go to 2)	
1i. Does the value of the building(s) and/or its contents have sufficient value to justify further evaluation of risk and potential flood damage? ☐ No (Go to 2)	☐ Yes (Go to 2)
2. TRAFFIC RELATED LOSSES	
2a. Is the overtopping flood greater than the "greatest" flood (500 yr. frequency)? ☐ Yes (Go to 3) ☐ No (Go to 2b)	
2b. Does the ADT exceed 50 vehicles per day? ☐ Yes (Go to 2c) ☐ No (Go to 3)	
2c. Would the (duration of road closure in days) multiplied by the (length of detour minus the length of normal route in miles) exceed 20? ☐ Yes (Go to 2d) ☐ No (Go to 3)	
2d. Does the annual risk cost for traffic related costs exceed 10% of the annual capital costs? ☐ No (Go to 3) (See figures A and B – Appendix A(2) - for Assistance)	☐ Yes (Go to 3)

3. ROADWAY AND/OR STRUCTURE REPAIR COSTS

3a. Is the overtopping flood less than a 100 year frequency flood?

☐ Yes (Go to 3b) ☐ No (Go to 3i)

3b. Compare the Tailwater (TW) elevation with the roadway sag point elevation for the overtopping flood. Check the appropriate category.

☐ When TW is above the sag point (Go to 4)

☐ TW is between 0 and 0.5' below sag point (Go to 3c)

☐ TW is between 0.5' and 1.0' below sag point (Go to 3d)

☐ When TW is 1.0' and 2.0' below sag point (Go to 3e)

☐ When TW is more than 2.0' below sag point (Go to 3g)

3c. Does the embankment have a good erosion resistant vegetative cover?

☐ Yes (Go to 3i) ☐ No (Go to 3d)

3d. Is the shoulder constructed from erosion resistant material such as paved, coarse gravel, or clay type soil?

☐ Yes (Go to 3i) ☐ No (Go to 3e)

3e. Will the duration of overtopping for the 25-year flood exceed 1 hour?

☐ Yes (Go to 3f) ☐ No (Go to 3i)

3f. Is the embankment constructed from erosion resistant material such as a clay type soil?

☐ Yes (Go to 3i) ☐ No (Go to 3g)

3g. Is the overtopping flood less than a 25-year frequency flood?

☐ Yes (Go to 3h) ☐ No (Go to 3i)

3h. Will the cost of protecting the roadway and/or embankment from severe damage caused by overtopping exceed the cost of providing additional culvert or bridge capacity?

☐ No (Go to 3i); ☐ Yes (Go to 3i)

3i. Is there damage potential to the structure caused by scour, ice, debris or other means during the lesser of the overtopping flood or the 100 year flood?

☐ Yes (Go to 3j) ☐ No (Go to 4)

3j. Will the cost of protecting the structure from damage exceed the cost of providing additional culvert or bridge water capacity?

☐ No (Go to 4); protecting abutments from scour by riprap. ☐ Yes (Go to 4)

---

4. Will the capital cost of the structure exceed $1,000,000?

☐ No (Go to 5); ☐ Yes (Go to 5)

5. In your opinion, are there any other factors that you feel should require further study through a risk analysis?

☐ No (Go to 6); ☐ Yes (Indicate)

6. If there are no √'s in the LTEC Design column on the right, proceed with the design, selecting the lowest acceptable grade line and the smallest waterway opening consistent with the constraints imposed on the project. The risk assessment has demonstrated that potential flood damage costs, traffic related costs, roadway and/or structure repair costs are minor and therefore disregarded for this project.

   One or more √'s in the LTEC Design column indicates further analysis in the category checked may be required utilizing the LTEC design process or justification (below) why it is not required.

JUSTIFICATION:

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of Minnesota:

Signature: ______________________________

Registration Number: ____________________ Date: ______________

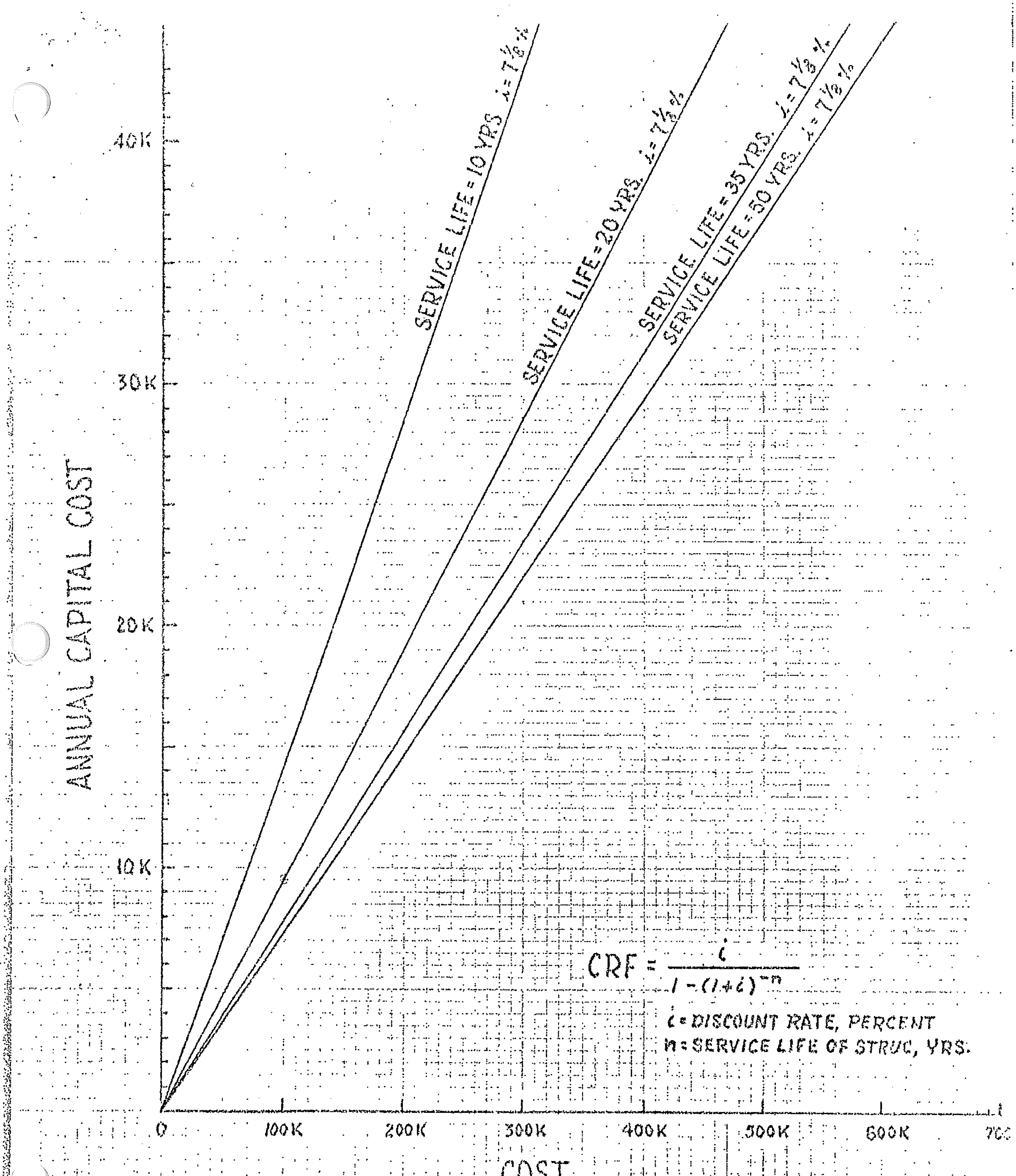
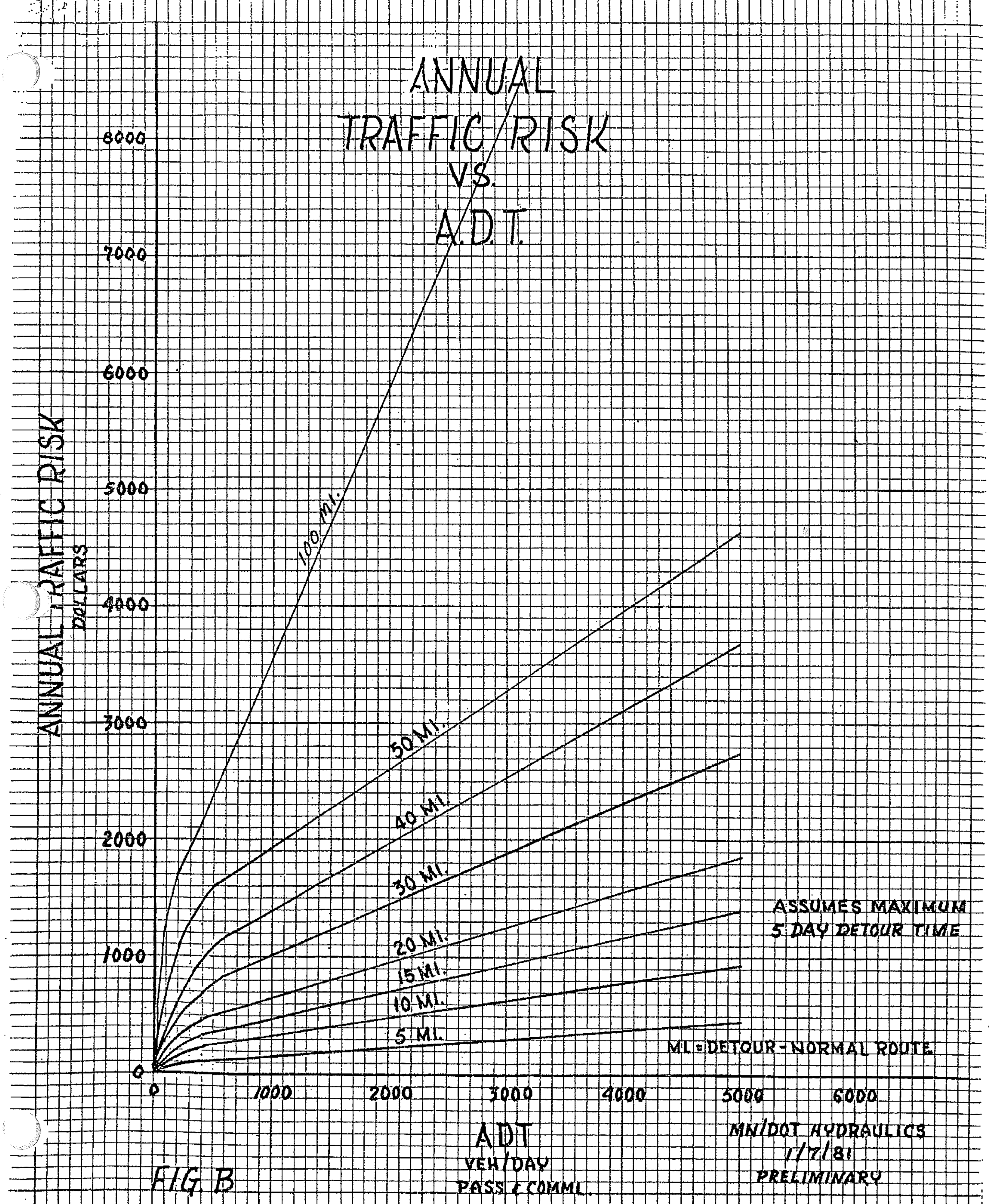


FIG. A

MN/DOT
HYDRAULICS 12/23/80


ANNUAL
TRAFFIC RISK
VS.
A.D.T.
ANNUAL TRAFFIC RISK
DOLLARS
8000
7000
6000
5000
4000
3000
2000
1000
0
100 MI.
50 MI.
40 MI.
30 MI.
20 MI.
15 MI.
10 MI.
5 MI.
ASSUMES MAXIMUM
5 DAY DETOUR TIME
MI. = DETOUR - NORMAL ROUTE
0
1000
2000
3000
4000
5000
6000
ADT
VEH/DAY
PASS & COMML.
MN/DOT HYDRAULICS
1/7/81
PRELIMINARY
FIG. B