FDM 13-5-1 Introduction

August 8, 1997

1.1 Introduction

Field surveys are routine and are intended to give the designer a clear picture of existing conditions at any location where water comes to and/or leaves a proposed project.

This procedure contains a general description of the field survey data required for the hydraulic design of small culverts, large culverts, and bridges. For a more detailed description of drainage survey requirements and procedures, the structural hydraulic engineer, roadway drainage engineer and survey chief are referred to FDM 9-55-1 through FDM 9-55-15 of this manual.

FDM 13-5-5 Survey Data

August 8, 1997

5.1 Drainage Cross Section for Small Culverts

Show clearly the traverse and stream profile. With this information the designer can:

1. Determine if reduction in water elevation is practical.
2. Determine if realignment or relocation can better serve the overall design.
3. Proportion the structure dimensions.

Show topography and elevations of existing ditches and natural streams in detail. Usually, infall information is necessary only for 100 to 300 feet or a sufficient distance upstream to indicate the degree of channelization and direction of flow.

Information on the outfall portion should extend far enough to determine the direction and degree of channelization, the rate of fall in water surface, and the effect of channelization on downstream structures and development, etc. Any apparent constriction in outfall portions should be noted, located, and cross-sectioned.

If ditch or channel work is desired, topography will be necessary downstream to a point at which damage to adjacent property need no longer be considered.

The field party will have to exercise its own judgment in many cases where the slope along a line being considered as an outfall is very flat. Use of such an outfall is in most cases a matter of economics.

5.2 Drainage Surveys for Large Culverts and Bridges

The meander of both banks of a stream for sufficient distance upstream and downstream to determine the approximate extent of any probable channel relocation should be shown in the field survey. This ordinarily can be shown within 500 to 1,000 feet laterally from the structure site.

Any major overflow channels should also be indicated within approximately the same limits or within the limits that these channels leave and return to the main channel. Meandering channels close to and approximately parallel to the project center line should be located carefully and cross-sectioned.

If the proposed project follows an existing fill that crosses a floodplain, cross sections should extend laterally far enough to provide a record of natural ground profiles right and left of the project. Any washouts or significant swales, runs, or sloughs should be noted clearly in the topography.

For bridges it is necessary to obtain certain existing high-water elevation data. If reliable data are not available, that fact should be noted by the field party.

Record, if available, the extreme high water within the proposed, or existing structure location and give the approximate date of occurrence. If other high waters can be dated, supply as many as practical, showing dates of occurrence.

If possible, determine a "normal" high-water elevation or one that can be expected to recur about every two to three years. Record a normal water elevation that would be expected to prevail through seasons of average rainfall. High-water locations within one-quarter mile are also of value.

5.3 Preliminary Field Review

A field review of the proposed structure site is important to the designer in terms of a physical determination of structure size and the legal responsibility of the Department of Transportation. Information gathered from this review should include existing and past flood conditions, special controls on flood rates, proposed changes to existing conditions, and possible tail-water controls. Prior to the field review a preliminary flow rate and structure size should be determined from an office review of the soil types, land usage, and from as-built plans.

5.3.1 Preliminary Flow Rate

After the drainage pattern and the drainage areas have been outlined on a contour map, a preliminary peak flow rate should be calculated to give the engineer an idea of the proposed size of the structure (see FDM 13-10-5 for methods of computing peak flow rates). Comparing this preliminary work-up with existing conditions or structures may point out the accuracy of the work-up. The determination of the preliminary flow rate will require that a field review be made of the drainage areas with regard to land usage. It should be noted whether the land is wooded, fallow, plowed and planted with crops, or urban development containing a high percentage of roof areas, paved parking lots, grass lawns, etc. All of these factors will affect the flow rate computations, especially with the use of the Rational Method (Q = CIA).

1. Soil Types: Soil characteristics of the various drainage areas for the project should be considered prior to a field review. The engineer must be aware of the runoff characteristics of the soils, the capabilities of the soil to resist erosion, locations where soil erosion may be a problem, and locations where channel banks may need riprap for protection against erosion. This information may be obtained from consultation with the region soils engineer or from soils maps. Design engineers should also obtain their own firsthand knowledge of the various soils throughout the region.

2. As-Built Plans: If the project consists of reconstruction of an existing highway, the as-built plans of the highway can be used as a guide for the sizing of the proposed structures and the determination of drainage patterns. As-built plans should be used during the field review to aid in the determination of the drainage patterns and drainage areas.

5.3.2 Existing and Past Flood Conditions

After the information noted above has been accumulated and reviewed, the design engineer is prepared for a field trip to review the existing hydrology and hydraulics of the drainage patterns and drainage areas. The field trip is required to allow the engineer to become aware of the effects caused by the new highway on the existing drainage patterns. The things to look for in the field may not be easily discernible, since time has a way of healing and disguising flood damage. The following information should be gathered:

1. High-Water Elevations for Channels: Existing stream channels (when there is a definite channel) show flooding effects in various ways. The effects can be shown by different degrees of erosion in the stream bank or the stream bottom. Sometimes scouring can occur during low-frequency storms as well high-frequency storms. The degree of scouring will depend upon the type of soil material that exists in the stream bottom and sides. Other indications that may be evident are high-water marks shown as mud lines on concrete surfaces or rock faces along stream embankments and debris that has been deposited along the channel slopes. These high-water marks are only to be used as indications that serve to confirm or validate design flow rate computations.

2. Personal Interviews: Another method of determining previous flooding problems is by personal interview of area residents. This information may not be 100 percent correct, because some people's recollections become exaggerated over time. It has been found that information obtained from interviews of local residents is helpful and can be used as an indication of high-water elevations in conjunction with the proper computations and field observations.

3. Approximate Flow in Channels: When high-water elevations are determined in a channel, a rough approximation of the flow rate can later be determined by estimating an average velocity that is compatible with the type and slope of the channel and then multiplying this velocity by the estimated waterway area determined from rough field measurements.

4. High Water Elevations for Existing Structures: High-water elevations determined for an existing drainage structure will enable the engineer to calculate a more definite flow rate that might have existed at that structure. The information needed for an existing structure is the approximate depth of the headwater, the approximate depth of the tail water, the slope of the existing structure, and the type and size of the structure. This information can then be analyzed through the use of FDM 13-15-10 and FDM 13-20-1.

5. Deposition and Scour at Existing Structures: Signs of flooding at existing culverts are scour marks around the inlets of the structures. Scour marks around the outlets of structures are not as indicative of

flood conditions, since normal flows through a structure can cause scour and erosion at the outlet. Deposition of stream load, which will consist of sand, gravel, or other debris, can occur within the upper portions of a drainage structure that does not have any significant outlet control. Deposition and scour marks are indications of possible build-up of headwater at the inlet, which shows that a culvert may be too small.

6. Debris and Velocity: The size and weight of deposited material is also a general indication of the velocity of the stream during maximum flow conditions. As the stream channel grade steepens and as the flow rate increases, the velocity will be faster and the heavier debris is more easily moved by the flowing water. By observing these general characteristics of a stream and culvert, the engineer can make a better determination of the past velocity and flow rate to confirm the design flow rate.

5.3.3 Special Controls on Flow Rates in Drainage Areas

Special conditions should be considered during the field review that will affect the time of concentration and the flow rate for a stream channel or structure. These special controls are existing swamps, ponded areas, flood control dams, reservoirs, and lakes. These all have the effect of increasing the time of concentration, which reduces the flow rate and the size of the structure at the point under consideration. If the control is high in the headwaters of the drainage area, its effects can usually be ignored, since the delay in the time of concentration will not be as great as the effect would be if the control were immediately upstream of the point of highway crossing. However, if the storage feature is close to the point of crossing, a special analysis will have to be performed to determine the proper flow rate. This analysis, referred to as flood routing for reservoirs and ponding areas, is discussed in FDM 13-10-10. In some cases storage basins, which have a retarding effect on the flow of a stream, can reduce the size of a required structure appreciably.

When reviewing a drainage area that does contain a flow rate control system, consideration will have to be given to the future existence of this flow control feature. For example, if the feature is a city reservoir, a large natural lake, or a permanent flood control system, it is very doubtful that the effect from the feature will be altered in any way in the near future that will require a larger pipe structure for the highway crossing. However, if there is a swamp area or natural low spots in the surrounding terrain that tend to hold water during high-water stages, these features can very easily become obliterated as commercial and urban development progresses in the area. If the latter situation prevails, it is best to consider designing the culvert size under the highway to accommodate the flow rate that is uninhibited by the existing storage areas. This would be more practical than designing a small pipe, with the possibility of having to increase the culvert capacity at a greater cost in the future.

5.3.4 General Guides

During the field review, special consideration should be given to the effects of the proposed drainage patterns on any future flood conditions upstream or downstream. The following guides should be followed when designing a drainage system for a highway:

1. Every effort is to be made in the design of a highway to perpetuate the drainage pattern that existed prior to the construction of the highway project. Collection and diversion of flows should be avoided whenever possible.
2. When existing drainage patterns are disturbed by a highway project (by collection, diversion, elimination of ponding areas, or an increase in stream velocities), provisions are to be made to return the drainage pattern downstream of the highway to approximately the conditions existing prior to the highway project. Whenever possible, the natural drainage pattern is to be reestablished within the highway right-of-way.
3. Drainage easements (usually permanent easements) may be purchased from private property owners. This should be done only in special situations (refer to FDM 13-1-5).
4. Under special circumstances, overflow sections may be considered.

The purpose of all highway drainage design is to plan for the removal of water from the highway, prevent surface runoff from reaching the highway, and pass existing streams under the highway economically while disturbing the surrounding environment as little as possible.

5.4 Changes in Existing Flow Conditions

The proposed highway alignment can force changes of existing flow conditions in various ways. The first is the collection and concentration of water through a structure under the proposed highway. This water would normally flow in an overland sheet pattern. The second is the change of depth of floodwaters immediately above the proposed highway.

When the drainage area in the first case noted above has existing conditions that do not allow the accumulation of the runoff, the amount of water contained in the stream channel under flood conditions may not be excessive. However, if after the highway is constructed the water is concentrated through a single structure, the Department may be responsible for causing a flood condition that does not exist under present conditions. Therefore, a careful field review should be made of possible concentrations of water through a structure and a careful note of the provisions for a clear and definite outlet.

The second of the changes of flow conditions noted above can occur when an existing stream channel is inhibited by the proposed culvert and highway embankment. The stream channel under existing conditions would allow the water to flow unobstructed with an acceptable depth, but under the proposed conditions the water would be forced to develop a greater depth at the inlet of the structure. The engineer should be aware of the approximate depth of headwater required for the new conditions and review the drainage area in the field for possible locations of flood damage as a result of increased depth of floodwaters. A stream channel that is too shallow to contain an increased depth of water will allow the water to flow over its banks and cause flooding in another drainage area, flooding of buildings, or flooding onto or across a highway embankment.

5.5 Tail-Water Controls

The tail-water depth at the outlet of a structure may directly affect the headwater depth at the inlet of the structure. Tail-water depth, as defined for the purposes of designing culverts, is the depth of water at the outlet of a structure that will affect the flow of water through a structure. The depth of tail water other than that determined by the use of critical depth can normally be calculated by the use of Manning's equation, with either a field cross section of the existing channel or a new cross section of the proposed channel at the outlet end of the culvert.

There are conditions in the field that may give a variable effect on the tail water at the outlet of a structure other than that computed from Manning's equation. These conditions can be water surface variations in lakes controlled by power authorities or recreation authorities, barge canals, flood stages in large streams and rivers, etc. These variable restrictions on the tail water may force the culvert to act in inlet control when the tail-water surface is down to a low elevation or may force the culvert to act in outlet control when the tail water is at its maximum elevation. The maximum and minimum elevations of the tail water should be recorded during the field review. The culvert should then be designed for the condition that yields the largest culvert size. The engineer may be able to eliminate the effect of the variable tail water by placing the outlet of the culvert above the maximum high-water elevation of the control feature.

The field review should also include notations on features that will impose a fixed control on the tail water. This tail-water control may be from existing drainage structures downstream of the proposed structure. Information should be obtained to perform an analysis on the existing downstream structures to determine what effect it has on the proposed culvert.

5.6 Final Field Review

Sometimes all of the problems mentioned in the foregoing paragraphs are not immediately evident during a preliminary field review but may have to be determined by a more accurate field survey and by taking additional cross sections. After the preliminary field trip is completed and the follow-up design progresses, another field trip will have to be made to confirm that the structure designs proposed for each structure site are appropriate.