CHAPTER 8
CHANNELS

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8.1 INTRODUCTION

8.1.1 <u>Definitions</u>

Open channels are a natural or manmade conveyance for water in which:

- The water surface is exposed to the atmosphere; and
- The gravity force component in the direction of motion is the driving force.

The designer of transportation facilities encounters various types of open channels including:

- Stream;
- Roadside; and
- Irrigation.

The principles of open channel flow hydraulics are applicable to all drainage facilities including culverts. While the principles of open channel flow are the same regardless of the channel type, stream channels and artificial channels (primarily roadside channels) will be treated separately in this chapter as needed.

Photo 8.1

Photo 8.2

Photo 8.3

Photo 8.4

8.1.2 Significance

Channel analysis is important for the design of drainage systems. A well done channel analysis should show the following:

- Potential flooding caused by changes in water surface profiles;
- Disturbance of the river system upstream or downstream of the highway right-of-way;
- Changes in lateral flow distributions;
- Changes in velocity or direction of flow;
- Need for conveyance and disposal of excess runoff; and
- Need for channel lining to prevent erosion.

8.1.3 Purpose

Hydraulic design associated with natural channels and roadway ditches is a process that selects and evaluates alternatives according to established criteria. These criteria are the standards established by CDOT to ensure that a highway facility meets its intended purpose without endangering the structural integrity of the facility itself and without undue adverse effects on the environment or the public welfare.

The purpose of this chapter is to:

- Establish and specify CDOT design criteria;
- Review design philosophy; and
- Outline channel design procedures.

8.2 DESIGN CRITERIA

The following criteria apply to natural as well as manmade channels:

- Embankment encroachment in any stream channel or floodplain should be avoided.
- If encroachment into a floodplain cannot be avoided, the hydraulic effects of floodplain encroachments shall be evaluated over a fall range of frequency based peak discharges for the two-year, design flood and 100-year recurrence intervals on any major highway facility.
- If relocation of a stream channel is unavoidable, the cross-sectional shape, meander, pattern, roughness, sediment transport, and slope shall conform to the existing conditions insofar as practicable. Some means of energy dissipation or grade control may be necessary when existing conditions cannot be duplicated.
- Streambank stabilization (see Chapter 17 – Bank Protection) shall be provided, when appropriate, as a result of any stream disturbance such as encroachment and shall include both upstream and downstream banks as well as the local site.
- Bends should have radii equal to the natural bends in the vicinity. The minimum radius for subcritical flow should be three times the water surface width.
- Channel side slopes shall not exceed the angle of repose of the soil and/or lining and shall be 2:1 or flatter in the case of rock-riprap lining. Vegetated channels side slopes shall be 4:1 or flatter.
- Flexible linings shall be designed according to the method of allowable tractive force and follow HEC-15 criteria.
- The design discharge for permanent roadside ditch linings shall have a 10year frequency while temporary linings shall be designed for the two-year frequency flow.
- Channel freeboard shall follow the same requirements set forth in Chapter 10 for bridges. A minimum of 1 foot of freeboard should be provided for all open channels designed.
- The use of rigid type channel linings such as concrete and asphalt is not recommended. However, because of right of way or entity agreements their use may be unavoidable. All rigid linings shall be designed or reviewed by the Hydraulic section.
- Trickle channel or low flow channels shall be designed based on the *Urban Drainage and Flood Control District Criteria Manual*.

8.3 HYDRAULIC ANALYSIS

8.3.1 General

The hydraulic analysis of a channel determines the depth and velocity at which a given discharge will flow in a channel of known geometry, roughness and slope. The depth and velocity of flow are necessary for the design or analysis of channel linings and highway drainage structures.

Good channel design consists of the proper selection of capacity, freeboard, alignment, erosion resistance and aesthetics. The ideal channel is the stable natural channel developed by nature over many years of time. Modification of such natural channels should be minimized. Improperly designed manmade channels, including roadway ditches, can be a source of considerable maintenance. If a natural channel needs to be relocated, the designer should try to recreate the natural water course slope and path as near as possible.

Two methods are commonly used in hydraulic analysis of open channels. The single-section method is a simple application of Manning's Equation to determine tailwater rating curves for culverts, or to analyze other situations in which uniform or nearly uniform flow conditions exist. The step-backwater method is used to compute the complete water surface profile in a stream reach to evaluate the unrestricted water surface elevations for bridge hydraulic design, or to analyze other gradually varied flow problems.

The single-section method will generally yield less reliable results because it requires more judgment and assumptions than the step-backwater method. In many situations, however, the single-section method is all that is justified, e.g., standard roadway ditches, culverts and storm drain outfalls. Design analysis of both natural and man-made channels proceeds according to the basic principles of open channel flow (Chow, 1970; Henderson, 1966) and fluid mechanics --continuity, momentum, and energy. Natural channels display a much wider range of roughness values than manmade channels.

8.3.2 Single-Section Analysis

The single-section analysis method (slope-area method) is simply a solution of Manning's Equation for the normal depth of flow given the discharge and cross-section properties including geometry, slope and roughness. It implicitly assumes the existence of steady, uniform flow; however, uniform flow rarely exists in either artificial or stream channels. Nevertheless, the single-section method is often used to design man-made channels for uniform flow as a first approximation, and to develop a stage-discharge rating curve in a stream channel for tailwater determination at a culvert or storm drain outlet.

Alluvial channels present a more difficult problem in establishing stage-discharge relations by the single-section method because the bed itself is deformable and may generate bed forms such as ripples and dunes in lower regime flows. These bed forms are highly variable with the addition of form resistance, and selection of a value of Manning's n is not straight forward. In irrigation ditches it is also difficult to predict a normal depth because of the flat bed slope. In irrigation ditches, measured water surfaces are required for calibration of calculated water surfaces.

There may be locations where a stage-discharge relationship has already been measured in a channel. These usually exist at gaging stations on streams monitored by the USGS. Measured stage-discharge curves will generally yield more accurate estimates of water surface elevation and should take precedence over the analytical methods described above.

For a given channel geometry, slope, roughness, and discharge Q, a unique value of depth occurs in steady uniform flow. It is called the normal depth. The normal depth is used to design manmade channels in steady, uniform flow and is computed from Manning's equation:

$$Q = (1.486 / n)\ A\ R^{2/3} S^{1/2} \qquad (8.1)$$

where Q = discharge, cfs; n = Manning's roughness coefficient ; A = cross-sectional area of flow, ft^2 ;
R = hydraulic radius = A/P, ft; P = wetted perimeter, ft; S = channel slope, ft/ft.

Figure 8-1 can be used to solve Manning's equation for the depth of flow in trapezoidal channels or circular pipes using the following procedure:

a. Given data are: Q, S, n and channel dimensions.

b. Compute $A\ R^{2/3} = Q\ n\ / 1.49\ S^{1/2}$

c. Compute $AR^{2/3}/b^{8/3}$ for trapezoidal channels or $A\ R^{2/3} / d^{8/3}$ for circular pipes

d. Enter Figure 8-1 with the result of step c and read up to the appropriate curve.

e. Read across to the depth ratio and compute the depth, y.

The selection of Manning's n is generally based on observation; however, considerable experience is essential in selecting appropriate n values. The range of n values for various types of channels and floodplains are given in Table 8-1.

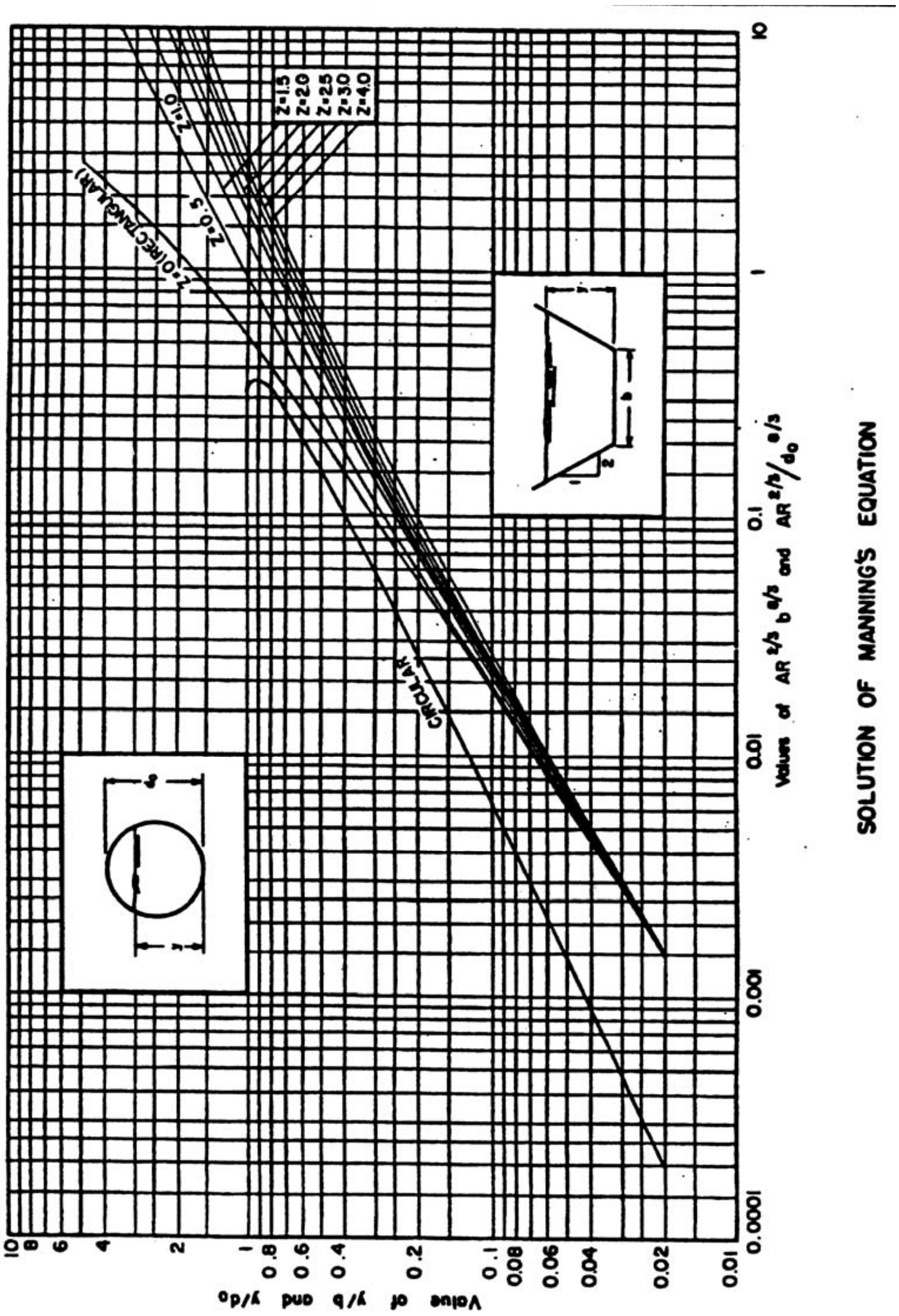

Figure 8.1 Trapezoidal Channel Capacity Chart

Table 8.1 Values of Roughness Coefficient n (Uniform Flow)

Type of Channel and Description	Minimum	Normal	Maximum
EXCAVATED OR DREDGED			
a. Earth, straight and uniform	0.016	0.018	0.020
1. Clean, recently completed	0.018	0.022	0.025
2. Clean, after weathering	0.022	0.025	0.030
3. Gravel, uniform section	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense Weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom, rubble sides	0.025	0.030	0.035
5. Stony bottom, weedy sides	0.025	0.035	0.045
6. Cobble bottom, clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
NATURAL STREAMS			
1. Minor streams (top width at flood stage < 100 ft)			
a. Streams on Plain			
(1) Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
(2) Same as above, but more stones and weeds	0.030	0.035	0.040
(3) Clean, winding, some pools	0.033	0.040	0.045
(4) Same as above, but some weeds and some stones	0.035	0.045	0.050
(5) Same as above, lower stages more ineffective slopes and sections	0.040	0.048	0.055

Table 8-1 Values of Roughness Coefficient n (Continued)

Type of Channel and Description		Minimum	Normal	Maximum
(6)	Same as 4, but more stones	0.045	0.050	0.060
(7)	Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
(8)	Very weedy reaches, deep pools, floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b.	Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
(1)	Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
(2)	Bottom: cobbles with	0.040	0.050	0.070
2. Flood Plains				
a.	Pasture, no brush			
(1)	Short grass	0.025	0.030	0.035
(2)	High grass	0.030	0.035	0.050
b.	Cultivated area			
(1)	No crop	0.020	0.030	0.040
(2)	Mature crops	0.025	0.035	0.050
c.	Brush			
(1)	Scattered brush, heavy weeds	0.035	0.050	0.070
(2)	Light brush and trees, in summer	0.040	0.060	0.080
(3)	Medium to dense brush, in summer	0.050	0.090	0.160
d.	Trees			
(1)	Dense Willows, summer, straight	1.110	0.150	0.200
(2)	Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
(3)	Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120

Table 8.1 Values of Roughness Coefficient n (Continued)

Type of Channel and Description	Minimum	Normal	Maximum
3. Major Streams (top width at flood stage >100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	.....	0.060
b. Irregular and rough section	0.035	.....	0.100

Manning's n is affected by many factors and its selection in natural channels depends heavily on engineering experience. Pictures of channels and flood plains for which the discharge has been measured and Manning's n has been calculated are useful (Arcement and Schneider, 1984; Barnes, 1978). For situations lying outside the engineer's experience, a more regimented approach is presented in Arcement and Schneider, 1984. Once the Manning's n values have been selected, it is recommended that they be verified with historical high-water marks and/or gaged streamflow data.

8.3.3 Step-Backwater Analysis

Step-backwater analysis is useful for determining unrestricted water surface profiles where a highway crossing is planned, and for analyzing how far upstream the water surface elevations are affected by a culvert or bridge. Because the calculations involved in this analysis are tedious and repetitive, it is recommended that computer programs such as WSPRO (FHWA/USGS), HEC-RAS or HEC-2 (Army Corps of Engineers) be used.

Water surface profile computation requires a beginning value of elevation or depth (boundary condition) and proceeds upstream for subcritical flow and downstream for supercritical flow. In the case of supercritical flow, critical depth is often the boundary condition at the control section, but in subcritical flow, uniform flow and normal depth may be the boundary condition. The starting depth in this case can either be found by the single-section method (slope-area method) or by computing the water surface profile upstream to the desired location for several starting depths and the same discharge. These profiles should converge toward the normal depth at the control section to establish one point on the stage-discharge relation. If the several profiles do not converge, then the stream reach may need to be extended downstream, or a shorter cross-section interval should be used, or the range of starting watersurface elevations should be adjusted. In any case, a plot of the convergence profiles can be a useful tool in such an analysis.

Given a long enough stream reach, the water surface profile computed by step-backwater will converge to normal depth at some point upstream for subcritical flow. Establishment of the upstream and downstream boundaries of the stream reach is required to define limits of survey data collection and subsequent analysis. Calculations must begin a sufficient distance downstream to assure accurate results at the structure site, and continued a sufficient distance upstream to accurately determine the impact of the structure on upstream water surface profiles.

8.3.4 Water and Sediment Routing

When a channel design is in an unstable environment, such as an alluvial stream or a degrading stream, sediment routing or stream routing should be considered. Stream routing effects can be simulated in HEC-2 and WSPRO by introducing factors such as increased roughness into the run. For sediment routing, the BRISTAR program is recommended.

8.4 DESIGN PROCEDURE

8.4.1 General

The design procedure for all types of channels has some common elements as well as some substantial differences. This section will outline a design procedure for assessing natural or manmade channel and a design procedure for assessing roadside channels.

8.4.2 Natural Stream Channel

The analysis of a channel in most cases is in conjunction with the design of a highway structure such as a culvert or bridge or with the alignment or widening of a highway. In general, the objective is to convey the water along or under the highway in such a manner that will not cause damage to the highway, stream, or adjacent property. An assessment of the existing channel is usually necessary to determine the potential for problems that might result from a proposed action. The level of detail of studies should be commensurate with the risk associated with the design and with the environmental sensitivity of the stream and adjoining floodplain.

The following step-by-step procedure can be used to design most new channels:

Step one

Assemble site data and project file.

A. Data collection (see Chapter 6, Data Collection).

B. Studies by other agencies (e.g. floodplain studies).

C. Environmental constraints such as:

- Floodway width and elevation;
- Fish habitat and migration;
- Commitments in environmental review documents;
- Animal passage; and
- Erosion control.

D. Design criteria (see section 8.2).

Step two

Determine the project scope.

A. Determine level of assessment.

B. Determine type of hydraulic analysis.

- Qualitative assessment;
- Single-section analysis; and
- Step-backwater analysis.

C. Field survey information (see *Survey Manual*).

Step three

Evaluate hydrologic variables.

A. Compute discharges for selected frequencies; and

B. Consult Chapter 7, Hydrology.

Step four

Perform hydraulic analysis by:

A. Single-section analysis (see 8.3.2);

B. Step-backwater analysis (see 8.3.3); and

C. Calibrate with known high water.

Step five

Perform stability analysis considering:

A. Geomorphic factors;

B. Hydraulic factors; and

C. Stream response to change.

Step six

Design countermeasures.

A. Criteria for selection:
- Public safety;
- Erosion mechanism;
- Stream characteristics;
- Construction and maintenance requirements;
- Vandalism considerations; and
- Cost.

B. Types of countermeasures:
- Meander migration countermeasures;
- Bank stabilization (Chapter 17 -- Bank Protection);
- Bend control countermeasures;
- Channel braiding countermeasures;
- Degradation countermeasures; and
- Aggradation countermeasures.

8.4.3 <u>Roadside Channels</u>

A roadside channel is defined as an open channel usually paralleling the highway embankment and within the limits of the highway right of way. It is normally trapezoidal or V-shaped in cross-section and lined with grass or a special protective lining.

The primary function of roadside channels is to collect surface runoff from the highway and areas that drain onto the right of way and convey the accumulated runoff to acceptable outlet points.

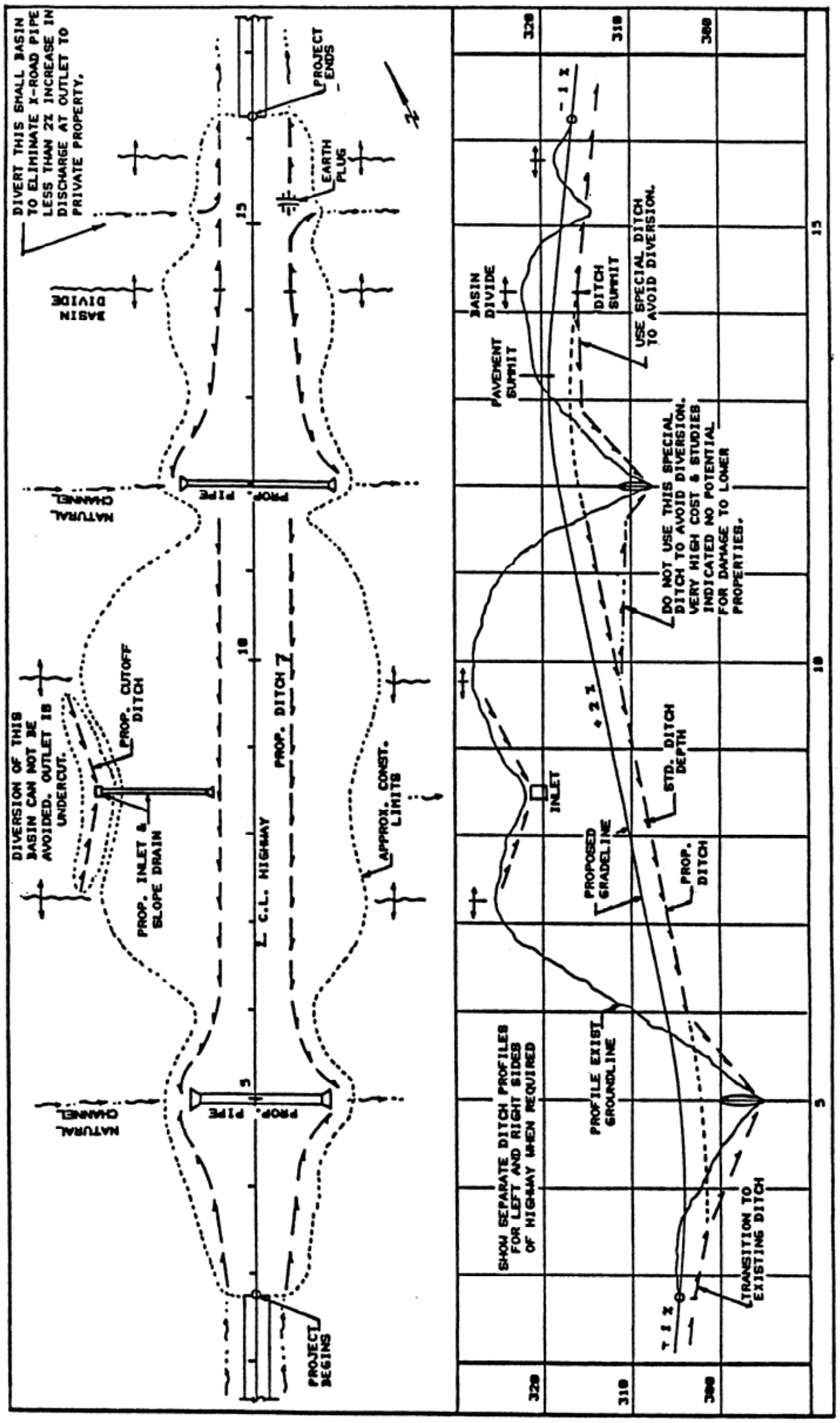

Figure 8.2 Roadway Plan and Profile

A secondary function of a roadside channel is to drain subsurface water from the base of the roadway to prevent saturation and loss of support for the pavement or to provide a positive outlet for subsurface drainage systems such as pipe underdrains and edge drains.

The alignment, cross-section and grade of roadside channels are usually constrained to a large extent by the geometric and safety standards applicable to the project. These channels should accommodate the design runoff in a manner that assures the safety of motorists and minimizes future maintenance, damage to adjacent properties, and adverse environmental or aesthetic effects. Erosion protection is important for these types of ditches.

Step-by-step Procedure

Each project is unique, but the following six basic design steps are normally applicable:

Step one

Establish a roadside plan.

A. Collect available site data.

B. Obtain or prepare existing and proposed plan-profile layout including highway, culverts and bridges.

C. Determine and plot on the plan the locations of natural basin divides and roadside channel outlets. An example of a roadside channel plan/profile is shown in Figure 8.2.

D. Perform the layout of the proposed roadside channels to minimize diversion flow lengths.

Step two

Obtain or establish cross-section data.

A. Identify features that may restrict cross-section design:
- Right-of-way limits;
- Trees or environmentally sensitive areas;
- Utilities; and
- Existing drainage facilities.

B. Provide channel depth adequate to drain the subbase and minimize freezethaw effects.

C. Choose channel side slopes based on geometric design criteria including:
- Safety;
- Economics;
- Soil types;
- Aesthetics; and
- Access.

D. Establish bottom width of trapezoidal channel.

Step three

Determine initial channel grades.

A. Plot initial grades on plan-profile layout. Give special attention to where the roadway transitions from a cut to a fill section. (Slopes in roadside ditch in cuts are usually controlled by highway grades.)

B. Provide minimum grade of 0.3% to minimize ponding and sediment accumulation.

C. Consider influence of type of lining on grade.

D. Where possible, avoid features which may influence or restrict grade such as utility locations.

Step four

Check flow capacities and adjust as necessary.

A. Compute the design discharge at the downstream end of a channel segment (see Chapter 7, Hydrology).

B. Set preliminary values of channel size, roughness coefficient, and slope.

C. Determine maximum allowable depth of channel including freeboard.

D. Check flow capacity using Manning's equation and single-section analysis.

E. If capacity is inadequate, possible adjustments are as follows:
- increase bottom width;
- make channel side slopes flatter;
- make channel slope steeper;
- provide smoother channel lining; and
- install drop inlets and a parallel storm drain pipe beneath the channel to supplement channel capacity.

F. Provide smooth transitions at changes in channel cross-sections.

Step five

Use HEC-15 to determine channel lining/protection needed.

Step six

Analyze outlet points and downstream effects.

A. Identify any adverse impacts to downstream properties that may result from one of the following at the channel outlet:
- Increase in discharge;
- Increase in velocity of flow;
- Confinement of sheet flow;
- Change in outlet water quality; or
- Diversion of flow from another watershed.

B. Mitigate any adverse impacts identified in step A. above. Possibilities include:
- Enlarge outlet channel and/or install control structures to provide detention of increased runoff in channel;
- Install velocity control structures;
- Increase capacity and/or improve lining of downstream channel;
- Install sedimentation/infiltration basins;
- Install sophisticated weirs or other outlet devices to redistribute concentrated channel flow; and
- Eliminate diversions which result in downstream damage that cannot be mitigated in a less-expensive fashion.

8.4.4 Design Considerations

To obtain the optimum roadside channel system design, it may be necessary to make several trials of the previous procedure before a final design is achieved.

More details on channel lining design may be found in HEC-15 including consideration of channel bends, steep slopes, and composite linings.

8.5 STREAM MORPHOLOGY

8.5.1 Introduction

The form assumed by a natural stream, which includes its cross-sectional shape as well as its platform, is a function of many variables for which cause-and-effect relationships are difficult to establish. The stream may be graded or in equilibrium with respect to long time periods, which means that on the average it discharges the same amount of sediment that it receives although there may be short-term adjustments in its bedforms in response to flood flows. On the other hand, the stream reach of interest may be aggrading or degrading as a result of deposition or scour in the reach, respectively. The platform of the stream may be straight, braided, or meandering. These complexities of stream morphology can be assessed by inspecting aerial photographs and topographic maps for changes in slope, width, depth, meander form, and bank erosion with time.

A qualitative assessment of the river response to proposed highway facilities is possible through a thorough knowledge of river mechanics and accumulation of engineering experience.

The natural stream channel will assume a geomorphological form that will be compatible with the sediment load and discharge history that it has experienced over time. To the extent that a highway structure disturbs this delicate balance by encroaching on the natural channel, the consequences of flooding, erosion, and deposition can be significant and widespread. The hydraulic analysis of a proposed highway structure should include a consideration of the extent of these consequences and the effect of channel instability in the structure.

8.5.2 Levels of Assessment

The analysis and design of a stream channel will usually require an assessment of the existing channel and the potential for problems as a result of the proposed action. The detail of studies necessary should be commensurate with the risk associated with the action and with the environmental sensitivity of the stream. Observation is the best means of identifying potential locations for channel bank erosion and subsequent channel stabilization. Analytical methods for the evaluation of channel stability can be classified as either hydraulic or geomorphic, and it is important to recognize that these analytical tools should only be used to substantiate the erosion potential indicated through observation. A brief description of the three levels of assessment is as follows.

Level One

Qualitative assessments are made involving the application of geomorphic concepts to identify potential problems and alternative solutions. Data needed may include historic information, current site conditions, aerial photographs, old maps and survey notes, bridge design files, maintenance records, and interviews with long-time residents and maintenance personnel.

Level Two

Quantitative analysis is combined with a more detailed qualitative assessment of geomorphic factors. This generally includes water surface profile and scour calculations. This level of analysis will be adequate for most locations if the problems are resolved and relationships between different factors affecting stability are adequately explained. Data needed will include level One data in addition to the information needed to establish the hydrology and hydraulics of the stream.

Level Three

Complex quantitative analysis is based on detailed mathematical modeling and possibly physical hydraulic modeling. Level Three analysis is necessary only for high-risk locations, extraordinarily complex problems, and possibly after-the-fact analysis where losses and liability costs are high. This level of analysis may require professionals experienced with mathematical modeling techniques for sediment routing and/or physical modeling. Data needed will require level One and Two data as well as field data on bed load and suspended load transport rates and properties of bed and bank materials such as size, shape, gradation, fall velocity, cohesion, density, and angle of repose.

8.5.3 Factors That Affect Stream Stability

Factors that affect stream stability and, potentially, bridge and highway stability at stream crossings, can be classified as geomorphic factors and hydraulic factors.

I. Geomorphic factors including:

- Stream size;
- Valley setting;
- Natural levees;
- Sinuosity;
- Width variability;
- Bar development;
- Flow variability;
- Flood plains;
- Apparent incision;
- Channel boundaries;
- Degree of braiding; and
- Degree of anabranching.

II. Hydraulic factors such as:

- Magnitude, frequency and duration of floods;
- Bed configuration;
- Resistance to flow; and
- Water surface profiles.

Rapid and unexpected changes may occur in streams in response to man's activities in the watershed such as alteration of vegetative cover. Changes in perviousness can alter the hydrology of a stream, sediment yield, and channel geometry. Channelization, stream channel straightening, stream levees and dikes, bridges and culverts, reservoirs, and changes in land use can have major effects on stream flow, sediment transport, and channel geometry and location. Knowing that man's activities can influence stream stability can help the designer anticipate some of the problems that can occur.

Natural disturbances such as floods, drought, earthquakes, landslides, volcanoes, and forest fires can also cause large changes in sediment load and thus major changes in the stream channel. Although difficult to plan for such disturbances, it is important to recognize that when natural disturbances do occur, it is likely that changes will also occur to the stream channel.

8.5.4 Stream Response to Change

The major complicating factors in river mechanics are:

- The large number of interrelated variables that can simultaneously respond to natural or imposed changes in a stream system; and
- The continual evolution of stream channel patterns, channel geometry, bars, and forms of bed roughness with changing water and sediment discharge.

To better understand the responses of a stream to the actions of man and nature, the Hydraulics Engineer should consult the following FHWA publications (see reference section):

- Highways in the River Environment
- Countermeasures for Hydraulic Problems at Bridges
- Stream Stability at Highway Structures, HEC-20

8.6 STREAM CLASSIFICATION SCHEME

An expert system for stream classification was developed as part of the NCHRP Project No. 15-11, BRI-STARS (Molinas, 1986 and 1990). The purpose of the stream classification system is to assist the users in assessing stream stability and in choosing the appropriate sediment transport equation.

The methods utilized in the expert system are predicated on bed material, sediment size, and stream channel slope. Stream morphology and related channel patterns are directly influenced by the width, depth, velocity, discharge, slope, roughness of channel material, sediment load, and sediment size. Changes in any of these variables can result in altered channel patterns.

As stream morphology is a result of these mutually adjustable variables, those most directly measurable were incorporated into criteria for stream classification. These criteria were selected for use in the expert system as it is a detailed analysis of hundreds of streams over many hydrophysiographic regions and from portions of other existing classification schemes. Stream channel patterns are classified based upon bed material size, channel gradients, and channel entrenchment and confinement. For further information on typical classifications of channels that are prevalent in Colorado, refer to the BRISTAR Expert System Classification and Highways in the River Environment.

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